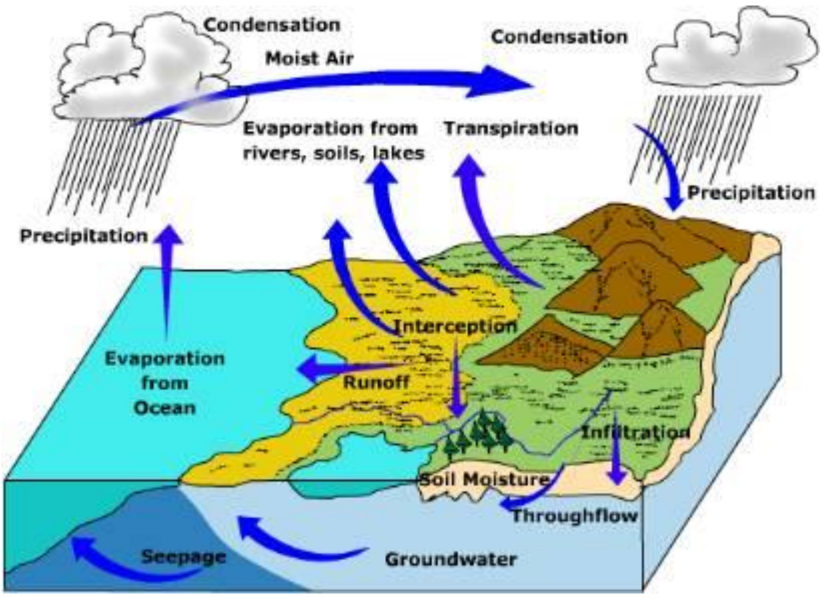
AGENDA AND AGENDA NOTES FOR THE 54th MEETING OF THE WORKING GROUP OF NIH

FEBRUARY 22-23, 2024
AT 1000 HRS



NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE-247667

AGENDA AND AGENDA NOTES FOR THE 54th MEETING OF THE WORKING GROUP OF NIH

AGENDA ITEMS

ITEM NO. 54.1 Opening Remarks by the Chairman

ITEM NO. 54.2 Confirmation of the minutes of 53rd meeting of the Working Group

The 53rd meeting of the Working Group was held during 16-17 March, 2023. The minutes of the meeting were circulated to all the members and invitees vide letter **No. RMOD/WG/NIH-10 dated 1st May, 2023.** No comments were received on the circulated minutes. A copy of the minutes of the 53rd Working Group is given in **Annexure-A (Page # 4).**

The Working Group may please confirm the minutes.

ITEM NO. 54.3 Action taken on the decisions/recommendations of the previous Working Group meeting

During the 53rd 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. 54.4 Presentation and discussion on the status and progress of the work programme for the year 2023-24.

The approved Work Programme of the six Divisions of the Institute for the year 2023-24 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:

During the present meeting, Division-wise progress and status of the work programme for the year 2023-24 shall be presented in detail. The Working Group may please consider the progress and status of the Work Programme for the year 2023-24.

	No. of Studies/Projects During the Year 2023-24					
Division	**New**		**Ongoing**		**Total**	
	Internally funded	Sponsored	Internally funded	Sponsored		Consultancy Projects
Center for Cryosphere & Climate Change Studies	-	-	7	1	**8**	**1**
Environmental Hydrology	2	-	3	5	**10**	**3**
Ground Water Hydrology	3	-	3	5	**11**	**-**
Hydrologic Investigation	4	-	2	2	**8**	**-**
Surface Water Hydrology	2	-	7	1	**10**	**-**
Water Resources System	2	-	3	6	**11**	**-**
Total	**13**	**-**	**25**	**20**	**58**	**3**

ITEM NO. 54.5 Presentation and finalization of the work programme for the year 2024-25.

The proposed Work Programme of the six Divisions of the Institute for the year 2024-25 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:

	No. of Studies/Projects During the Year 2024-25					
Division	**New**		**Ongoing**		**Total**	
	Internally funded	Sponsored	Internally funded	Sponsored		Consultancy Projects
Centre for Cyrosphere and Climate Change Studies	8	-	7	1	**16**	**1**
Environmental Hydrology	4	-	5	6	**15**	**2**
Ground Water Hydrology	6	2	4	2	**14**	**-**
Hydrologic Investigation	5	-	3	4	**12**	**-**
Surface Water Hydrology	5	-	6	1	**12**	**-**
Water Resources System	8	-	3	5	**16**	**-**
Total	**36**	**2**	**28**	**19**	**85**	**3**

The work programme has been categorized into three groups; (a) Internally funded studies, (b) Sponsored projects and (c) Consultancy Projects. During the present meeting, Division-wise proposed work programme for the year 2023-24 shall be presented.

ITEM NO. 54.6: Any Other Item with Permission of the Chair.

ANNEXURE – A

MINUTES OF THE 53rd MEETING OF WORKING GROUP

NATIONAL INSTITUTE OF HYDROLOGY, ROORKEE

Minutes of the 53rd Meeting of NIH Working Group
(16-17 March, 2023)

The 53rd meeting of NIH working group was held during 16-17 March, 2023 at Roorkee under the Chairmanship of Dr. Sudhir Kumar, Director (NIH). A list of participants of the meeting is given in Annexure-I.

ITEM NO. 53.1: OPENING REMARKS BY THE CHAIRMAN

The Chairman, WG, welcomed the WG members and the Scientists of NIH. He informed that the objective of this meeting is to review the progress of 2022-23 and to formulate the work program of 2023-24. Before initiating proceedings of the WG meeting, the Chairman 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.	Prof. A.P. Dimri	▪ To explore applicability of Geomatics & GNSS in various studies ▪ Try to prepare basin level atlas ▪ Suggestion for supervision of doctorate and Master Level Courses by Scientists and initiation of 2 week master student's program in the domain of hydrology and water resources
2.	Dr. Bhishm Kumar	▪ Develop a database and share it in the public domain ▪ Burning issues related to water should be emphasized while designing any research proposal ▪ R&D dissemination for Society
3.	Dr. Manoj P. Samuel	▪ Research should be executed in the interest of society and suggestion to develop Models/Mobile Apps for common people. ▪ Need of Commercial Wing for Business development related to water sector R&D activities ▪ Suggested collaboration of new NIH-RC, Jodhpur with CAZRI (Jodhpur) in R&D and other activities ▪ Suggestion for data base and data sharing
4.	Prof. Ramakar Jha	▪ While doing research, drone technology may be used in inaccessible areas ▪ Make efforts to patent the software developed by the Institute ▪ Re-employment of retired scientists in NIH to utilize their rich experience/knowledge for Institute's R&D activities
5.	Dr. Vijay Kumar	▪ Suggested for collaborative work with MOES in the area of Cryosphere/Glacier Studies as well as to increase collaboration with Intl. organizations. ▪ Creation and management of data base for further collaborative studies
6.	Sh. Sudhindra Mohan Sharma	▪ Suggestion for public centric R&D, develop public relations and translation of benefits to society and states ▪ Works for enhancing drinking water security as per mandate of the Ministry
7.	Dr. (Mrs.) Sadhana Malhotra	▪ Very enriching experience in NIH ▪ Dissemination of R&D Output/Press release of NIH Studies ▪ To assess impact of training programs
8.	Prof. K.K. Singh	▪ Data repository and sharing ▪ Separate Cell for Software Development in NIH ▪ Engagement of retired scientists

		▪ Research for the common man ▪ Suggestion for B. Tech/M. Tech. Internship Programs ▪ Need to rename WRS Division
9.	Prof. AK Saraf	▪ Appreciation for new NIH centre at Jodhpur ▪ Re-employment of NIH Scientists
10.	Dr. Prashant Rai	▪ Suggested more collaboration with CGWB in studies and to work in agricultural areas

After brief introduction about NIH activities, the Chairman asked the Member-Secretary to take up the agenda of this meeting.

ITEM No. 53.2: CONFIRMATION OF MINUTES OF 52nd MEETING OF WORKING GROUP

The 52nd meeting of the Working group was held during 12-13 April, 2022. The minutes of the meeting were circulated to all the members and invitees vide letter No. **RMOD/WG/NIH-10 dated 25th May, 2022**. The members confirmed the minutes of the 52nd Working Group meeting.

ITEM No. 53.3: ACTION TAKEN ON THE DECISIONS/RECOMMENDATIONS OF THE PREVIOUS WORKING GROUP MEETING

Er. Omkar Singh, Scientist G & Head (RMOD)/Member Secretary (WG) gave a brief account of the actions taken on the recommendations/ decisions of the 52nd working group meeting.

ITEM Nos. 53.4 & 53.5: PRESENTATION AND DISCUSSION ON THE STATUS AND PROGRESS OF THE WORK PROGRAMME FOR YEAR 2022-23 AND FINALIZATION OF THE WORK PROGRAMME FOR YEAR 2023-24

The Member-Secretary requested the respective Divisional Heads to present the progress of studies carried out during 2022-23 and also to present the proposed studies for F.Y. 2023-24. Accordingly, the progress of various studies and sponsored projects, and proposal for new studies and projects during 2023-24, were 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 below:

ENVIRONMENTAL HYDROLOGY DIVISION

The overview of the technical activities of Environmental Hydrology Division (EHD) was presented by Dr. R.P. Pandey, Scientist 'G' & Head. The Working Group was appraised about the scientific manpower, status of completed and ongoing studies, consultancy projects, publications, and technology transfer activities. Subsequently, the scientists of the Division were invited to present the completed studies, progress of ongoing internal studies and proposed new studies. The Comments/suggestions of Working Group members are summarized below.

Progress of Work Program for 2022-23

S. N.	Title of Project/Study	Recommendations/Comments
Internal Studies (Ongoing)		
1.	Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims using groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants	Dr. Bhishm Kumar suggested to involve state groundwater department in the study. Dr. Sharma noted for compliance.

2.	Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Dr. Bhishm Kumar (Ex. Scientist, NIH) suggested to correlate the Arsenic (As) in the GW with other relevant parameters. Dr. Sudhir Kumar, Director (NIH) suggested to collect and analyze sediments samples for trace metals particularly, Arsenic in Solani river.
3	Simulation of Non-Point Source Pollution Processes in Song River	There were no specific comments/suggestions.
Sponsored Projects (Ongoing)		
1.	Water Efficient Irrigation by Using SCADA System for Medium Irrigation Project (MIP) Shahnehar	PI has reported that further extension would be required from NHP to complete field observations.
2.	Anaerobic co-digestion of wastewater treatment plant sludge and organic fraction of municipal solid waste: Effect of thermal-chemical pretreatment on process performance and microbial community development	Dr. Bhishm Kumar (Ex. Scientist, NIH) and other working group members suggested to look after the economic benefits of the work.
Sponsored /Collaborative Projects (Ongoing)		
1.	SARASWATI 2.0 - Identifying best available technologies for decentralized wastewater treatment and resources recovery for India	PI reported that the study is in progress.
2.	Isotopic and geochemical approach to study vulnerable confined and unconfined drinking water aquifers in Varanasi and surrounding area, India	PI reported that this study is in progress in collaboration with other institutions
3.	Comprehensive characterization of variably processed sewage sludge in Ganga basin to classify its suitability for safe disposal	Co-PI reported that this study is in progress with IIT Roorkee
Internal Studies (New)		
1.	Hydrological Studies for the Conservation of Rewalsar Lake, H.P.	The queries raised by Prof. A. K. Saraf and Prof. Ramakar Jha related to methodology/data availability were replied by the PI. The WG agreed the objectives and scope of the study.
2.	Comprehensive evaluation of disinfection units of STPs in Ganga basin: Formation & Control of emerging oxidation precursors.	The WG appreciated the novelty of work to be taken up in this study. The WG agreed the objectives and scope of the study.

Recommended Work Programme for the Year 2023-24

S. N.	Title of Project/Study	Study Team	Duration	Funding (Rs. Lakh)
Internal Studies (Ongoing)				
1.	Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims using groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants	Dr. M. K. Sharma, Sc. F (PI) Dr. Suhas Khobragade, Sc. 'G' Dr. Rajesh Singh, Sc. 'D' RC Kakinada: Dr. YRS Rao, Sc.G CGWB-Hyderabad	2 Years (04/22-03-24)	NIH
2.	Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Dr. Rajesh Singh, Sc. D (PI); Dr. R. P. Pandey, Sc. G; Dr. Sumant Kumar, Sc. D; Dr. Pradeep Kumar, Sc. D; Dr. M. K. Sharma, Sc. F; Dr. V. K. Tyagi, Sc, D; Dr. Kalzang Chhoden, Sc. C	3 Years (07/21-06/24)	NIH

3.	Simulation of Non-Point Source Pollution Processes in Song River	Dr. Pradeep Kumar, Sc. D (PI) Dr. M.K. Sharma, Sc. F Dr. Rajesh Singh, Sc. D	4 Years (11/19-10/23)	NIH
Internal Studies (New)				
4.	Hydrological Studies for the Conservation of Rewalsar Lake (H.P.)	Dr. Kalzang Chhoden, Sc. C, (PI); Dr. Rajesh Singh, Sc. D; Dr. R. P. Pandey, Sc. G; Dr. Pradeep Kumar, Sc. D; Dr. Vinay Kumar Tyagi, Sc. D; Er. Omkar Singh, Sc. G; Dr. Shuhas Khobragade, Sc. G; Dr. D.S. Malik, Professor, GKU, Haridwar	3 Years (04/23-03/26	NIH
5.	Comprehensive evaluation of disinfection units of STPs in Ganga basin: Occurrence and control the formation of emerging oxidation precursors	Dr. Vinay Kumar Tyagi, Sc. D (PI); Dr. Rajesh Singh, Sc. D; Dr. Mukesh K. Sharma, Sc. F Dr. Pradeep Kumar, Sc. D; Er. J. P. Patra, Sc. D; Dr. Kalzang Chhoden, Sc. C; Dr. R.P.Pandey, Sc. G	3 Years (04/23-03/26)	NIH
Sponsored Projects (Ongoing)				
1.	Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (MIP) Shahnehar	Dr. R. P. Pandey, (PI) Er. J. P. Patra, Dr. Rajesh Singh Sh. N. K. Bhatnagar	3 Years (12/17-05/23). Further extension is needed to complete field based tasks	NHP (75.00)
2.	Anaerobic Co-digestion of Thermochemically Pretreated Organic Fraction of Municipal Solid Waste and Sewage Sludge: Effect on Process Performance and Microbial Community Development	Dr. Vinay Kumar Tyagi, Sc, ‘D’ (PI)	5 Years (2018-2023)	DBT (106.00)
Collaborative Projects (Ongoing)				
1.	Isotopic and geochemical approach to study vulnerable confined and unconfined drinking water aquifers in Varanasi and surrounding area, India	Dr. Rajesh Singh (PI) Dr. R.P. Pandey BHU, Varanasi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary	3 Years (07/21-06/24)	BHU
2.	Comprehensive characterization of variably processed sewage sludge in Ganga basin to classify its suitability for safe disposal	Dr. Vinay Kumar Tyagi, Sc, ‘D’ (Co-PI) Dr. A.A.Kazmi (PI, IITR)	02 Years (01/22-12/23)	CPCB-NMCG
3.	SARASWATI 2.0 - Identifying best available technologies for decentralized wastewater treatment and resources recovery for India	Dr. Vinay Kumar Tyagi, Sc, ‘D’ (Co-PI) Dr. A.A.Kazmi (PI, IITR)	4 Years (03/20-02/24)	DST

GROUNDWATER HYDROLOGY DIVISION

Dr. M. K. Goel, Sc. "G" and Head, Groundwater Hydrology Division (GHD) made a brief presentation about the present manpower of the division and attached Soil-Water laboratory, thrust areas of the division, work program and major achievements during the year 2022-23 and the proposed work program for 2023-24. It was informed that in addition to progress in various studies and sponsored projects, three software have been developed during the year and three new internal studies have been planned. Subsequently, detailed discussion on various studies were made by the respective Scientists (PIs) of various studies. The discussion on these studies is summarized below:

S. No.	Title of Project/Study	Recommendations/Comments
Internal Studies (Completed)		
1. NIH/GWH/NIH/20-22	Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System	Director desired to make a presentation for the CGWB and DoWR, RD & GR officials.
Internal Studies (Ongoing)		
1. NIH/GWH/NIH/22-25	Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin	No specific comments were made by the WG Members.
2. NIH/GWH/NIH/22-24	Conjunctive Management of Water Resources in IGNP Command	Dr. Dimri suggested to analyze the water-logged area before and after the introduction of IGNP. PI agreed to the suggestion.
3. NIH/GWH/NIH/22-24	Studying Groundwater Dynamics using Machine Learning and Numerical Modelling	No specific comments were received from the members.
Sponsored Projects (Completed)		
1. 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	Not Presented
2. NIH/GWH/PDS/17-21	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Not Presented
3. NIH/GWH/APN/22	Capacity Development Program on Site Suitability Mapping for MAR under Varying Climatic Conditions using Remote Sensing and Machine Learning based Hydrological Modelling Tools	PI presented the ***PraJal*** portal developed in the study. No specific comments were made by the WG Members.
Sponsored Projects (Ongoing)		
1. NIH/GWH/BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab -Groundwater resilience and adaptation to future changes in climate and water resource demands	Dr. S. M. Sharma advised to look the ownership of the installed piezometers in this project. PI noted.
2. NIH/GWH/CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi	Not Presented
3. 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	No specific comments were received from the members.

4. NIH/GWH/CCRBF/20-23	Expansion of Indo-German Competence Centre for Riverbank Filtration	The members appreciated for the efforts and no specific comments were offered.
5. NIH/GWH/DST/21-24	Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	Prof. Dimri and Dr. M. Samuel suggested to validate the results. PI replied for the queries.
Internal Studies (New)		
1. NIH/GWH/ 22-24	Hydrogeological and Isotopic investigation of groundwater in Himalayan Watershed of Kashmir, India	Dr. Bhishm Kumar supported the study & expressed need of isotope-based studies for Jammu & Kashmir. The WG agreed the proposal.
2. NIH/GWH/ 23-24	Development of Archive of Soil Hydraulic Characteristics	Dr. Bhishm Kumar and other members felt the need of such type of studies to disseminate outcomes for wider application/use/replication for other labs. The WG agreed the proposal.
3. NIH/GWH/ 23-25	Enhancement and application of NIH_WISDOM	There were no specific comments and WG agreed the proposal.

Finally, on the advice of the Director, Dr. M. K. Goel made a brief presentation about the NIH_ReSyP software developed at NIH for comprehensive reservoir-related analysis and its applications for the Upper Krishna basin. Dr. M. Samuel asked whether variable downstream channel capacity is being considered in the flood simulation module. It was informed that based on the observations from recent flooding in Kerala, variable downstream channel capacity option has been included. Dr. Bhishm Kumar suggested for its application and testing with some reservoir analysis for foreign reservoirs. He shared the contact details of Dr. Nachiappan who is working in Australia on reservoir-related aspects and may be helpful for such applications. The members appreciated for the efforts. The final proposed work program for the year 2023 – 24 is given below:

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2023-24

S. No.	Title of Project/Study	Project Team	Duration	Funding
Internal Studies (Ongoing)				
1. NIH/GWH/NIH/22-25	Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin	Sumant Kumar (PI), Surjeet Singh, Rajesh Singh, Gopal Krishan, S. S. Rawat, M. K. Sharma, N. Patidar, P. K. Mishra, M. K. Goel	3 years (04/22 – 03/25)	NIH
2. NIH/GWH/NIH/22-24	Conjunctive Management of Water Resources in IGNP Command	Nitesh Patidar (PI), M. K. Goel, Anupma Sharma, Surjeet Singh, Gopal Krishan, Sumant Kumar, Nidhi Kalyani	2 years (04/22 – 03/24)	NIH
3. NIH/GWH/NIH/22-24	Studying Groundwater Dynamics using Machine Learning and Numerical Modelling	Nidhi Kalyani (PI), Anupma Sharma, Nitesh Patidar, Sumant Kumar	2 years (04/22 – 03/24)	NIH
Sponsored Projects (Ongoing)				
1. NIH/GWH/BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab -Groundwater resilience and adaptation to future changes	Gopal Krishan (PI), S. Singh, C. P. Kumar (retd.), M. S. Rao; *BGS-UK:* Dr. Dan Lapworth,	5 years (12/17-11/22, ext. till Nov.	BGS: UK

	in climate and water resource demands (title modified by funding agency)	Dr. Alan MacDonald, Dr. Daren Goody	2024)	
2. 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, A. Sarkar, M. K. Sharma, L. N. Thakural, S. Kumar, P. K. Mishra, V. Singh, N. Patidar, N. Kalyani **Partners**: HIWRD, UPGWD, UYRB, CWC	4 years (04/18-01/24)	NHP
3. 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 (PI) Gopal Krishan, Nitesh Patidar, P. K. Mishra (**Lead:** CAZRI Jodhpur, **Partners**: NIH Roorkee, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur)	5 years (03/19 - 01/24)	DST
4. NIH/GWH/CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Co-coordinator)	3 years (07/20 – 06/23)	Federal M/o Edu. & Res., Germany
5. NIH/GWH/DST-SERB/21-24	Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	Gopal Krishan (PI), M. S. Rao	3 years (04/21 – 03/24)	DST-SERB
Internal Studies (New)				
1. NIH/GWH/ 22-24	Hydrogeological and Isotopic investigation of groundwater in Himalayan Watershed of Kashmir, India	Gopal Krishan (PI) M. S. Rao; *SKUAST-Srinagar* Rohitashv Kumar	1.5 years (09/22 – 03/24)	NIH
2. NIH/GWH/ 23-24	Development of Archive of Soil Hydraulic Characteristics	Surjeet Singh (PI); Nitesh Patidar; M. K. Goel; Anju Chaudhary; Anupma Sharma	1 year (04/23-03/24),	NIH
3 NIH/GWH/ 23-25	Enhancement and application of NIH_WISDOM	Nitesh Patidar (PI), D. S. Bisht, M. K. Goel, T. Thomas, Sunil Gurrapu, Anupma Sharma, Surjeet Singh	2 years (10/23 – 09/25)	NIH

HYDROLOGICAL INVESTIGATIONS DIVISION

Dr. Suhas Khobragade, 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, along with details about the publications by the Division and analytical work carried out at the Nuclear Hydrology Laboratory. The progress of each individual study for the year 2022-23 and the proposal for the new studies was presented by the respective P.I. of the study. Since Sh Hukam Singh, Sc. 'B' got retired the presentation of his completed study was made on his behalf by Dr. M. Someshwar Rao, Sc-F. Studies already presented under NHP were not presented. The comments/actions suggested by the working group for various studies are given below:

SN	Title of Project/Study	Recommendations/Comments
Internal Studies (Completed)		
1.	Assessment of dissolved radon concentration in groundwater of Uttarakhand	No specific comments/suggestions received
Internal Studies (Ongoing)		
1.	Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions Of India	Not presented
2.	Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions	No specific comments/suggestions received
Sponsored Projects (Completed)		
1.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	Not presented
2.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	Not presented
3.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	Not presented
4.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	Not presented
5.	Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS)	Not presented
6.	Web-GIS Based Spring Inventory for Vulnerability Assessment and Hydro-Geological Investigation of Selected Springs for Sustaining Local Water Demand in Ravi Catchment of Himachal Pradesh	Not presented
7.	Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River	Video Presentation
Sponsored Projects (Ongoing)		
1.	Leachate transport modelling for Gazipur landfill site for suggesting ameliorative measures	Not presented

2.	Changing the fate of the Hindon river by evaluating the impact of agriculture on the water balance: Developing a template for a cleaner Ganga river	No specific comments/suggestions received
Internal Studies (New)		
1.	Developing a Stable Isotopic Analysis System for analyzing the dissolved Nitrates in water	No specific comments/suggestions received
2.	Geo-Hydro-Chemical and Isotopic Aspects of Occurrence of Springs: A case study from the major settlement areas of Bhagirathi basin, Uttarakhand, India	No specific comments/suggestions received
3.	Feasibility of Open Sources Data for the Estimation of Runoff and Water Storage Capacity for Rainwater Harvesting Strategies	Dr. Praveen Thakur suggested to modify the title from feasibility to application since it is not a feasibility study. Sh. Sudhindra Mohan Sharma suggested to change the objectives as present objective are more like work elements
4.	Sedimentation and Water Quality Studies of Phulahar Lake, Pilibhit (U.P.)	No specific comments/suggestions received

Head (HID) also informed about the technology transfer activities organized by the Division during 2022-23.

Table : Details of training Courses/Workshops organised by the Division during 2022-23

S. N.	Topic	Duration	Coordinator	Venue	Partic-ipants
1.	Scientific Data Collection and Processing Techniques for Springshed Management and Rejuvenation	19-22.12.2022	Dr. S. M. Pingale & Dr. S. S. Rawat	IRI, Roorkee	24
2.	Springshed Management	13-15.12.2022	Dr. S. S. Rawat	DoLR, Kohima, Nagaland	47
3.	Scientific Data Collection and Techniques for Springshed Management and Rejuvenation	06-09.09.2022	Dr. S. S. Rawat	NEHARI, Guwahati	28
4.	Tools and Techniques for Springshed Management	03.09.2022	Dr. S. S. Rawat	Govt. Degree College, Udhampur (J&K)	80
5.	Groundwater contaminant transport monitoring & modelling	23 to 27.05.2022		Online Under NHP – PDS - 19	40
6.	Stakeholder Meeting Under DST-NWO Hindon Project	15th Feburary,2023	Ms. Anjali,	c-Ganga office, New Delhi.	10

RECOMMENDED WORK PROGRAMME OF FOR THE YEAR 2023-24

S. N.	Title of Project/Study	Study Team	Duration	Funding
Internal Studies (Ongoing)				
1.	Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions Of India	S.D.Khobragade (PI); Dr. Vishal Singh, Sudhir Kumar	3 years (04/22-03/25)	NIH
2.	Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions	Soban Singh Rawat, (PI); Sudhir Kumar, Santosh M. Pingale; P K Mishra; D. S. Bisht; Rajesh Singh	3 years (04/22-03/25)	NIH
Internal Studies (New)				
1.	Developing a Stable Isotopic Analysis System for analyzing the dissolved Nitrates in water	M. S. Rao(PI) Vishal Gupta	1 and ½ years (04/23-09/24)	NIH
2	Geo-Hydro-Chemical and Isotopic Aspects of Occurrence of Springs: A case study from the major settlement areas of Bhagirathi basin, Uttarakhand, India	Dr. Soban Singh Rawat, (PI); S. D. Khobragade; M K Sharma; M S Rao; S.M. Pingale; P. K. Mishra	3 years (04/23- 03/26)	NIH
3	Feasibility of Open Sources Data for the Estimation of Runoff and Water Storage Capacity for Rainwater Harvesting Strategies	S.M. Pingale (PI) Soban Singh Rawat, S. D. Khobragade Rajeev Gupta	2 Years (04/23- 03/25)	NIH
4	Sedimentation and Water Quality Studies of Phulahar Lake, Pilibhit (U.P.)	Rajeev Gupta (PI) S. D. Khobragade S.M. Pingale	2 Years (04/23- 03/25)	NIH
Sponsored Projects (Ongoing)				
1.	Leachate transport modelling for Gazipur landfill site for suggesting ameliorative measures	Anjali (PI) Sudhir Kumar, J. V. Tyagi M. K. Sharma Partner: CGWB (Delhi unit)	3½ years (11/19 – 06/23)	NHP-PDS
2.	Changing the fate of the Hindon river by evaluating the impact of agriculture on the water balance: Developing a template for a cleaner Ganga river	Sudhir Kumar, (Proj. Coordinator), M. K. Sharma, (PI), Suhas Khobragade, Anjali, Vishal Singh, SM Pingale, Nitesh Patidar, Surjeet Singh.	5 Years (04/22 – 03/27(	DST

SURFACE WATER HYDROLOGY DIVISION

Dr. A.K. Lohani, Sc G & Head, Surface Water Hydrology Division presented the various activities of the division. The number of research papers published in various journals, lectures delivered in various training courses and number of M.Tech./Ph.D. students guided/under guidance during the period were also reported. The concerned PI of the study presented the progress of his/ her completed and new internal studies during the working group meeting. Sponsored studies are not presented. The record of discussions for the respective study is given below:

Work Program for the Year 2022-23

S. N.	Title of Project/Study	Status and Recommendations/ Suggestions
Internal Studies (Completed)		
1.	Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan	Completed. No specific action suggested.
2.	Uncertainty in rating curves and discharge estimation	Completed. There were no specific comments from the members on the study.
3.	Application of unified-extreme-value (UEV) distribution for flood frequency: selected rivers of U.S.A	Completed. No specific action was suggested.
4.	Application of unified-extreme-value (UEV) distribution for flood frequency: Comparison of results using GEV distribution	Completed. No specific action was suggested.
Sponsored Projects (Completed)		
1.	Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh (NHP)	Completed. The study was reported.
Internal Studies (Ongoing)		
1.	Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Operation of Reservoirs	No specific action was suggested.
2.	Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model	No specific action was suggested.
3.	Hydrological Study to conserve the water resources of Bikaner, Rajasthan	No specific action was suggested.
4.	Review of design flood and dam break analysis of Khadakhai Dam in Odisha	No specific action was suggested.
5.	Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	The study was not presented.
6.	Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics	PI requested for provision of a resource person for the study as well as extension of the study by six months (up to April 30, 2024) and WG approved the extension. No other specific comments were received.
7.	Investigation of hydrodynamic approach of flood inundation mapping along with assessment of changes in river planforms using a cloud-based Google Earth Engine (GEE) computing platform	No specific action was suggested.

	in data-scarce Western Himalayan River basin	
Sponsored Projects (Ongoing)		
1.	Operational coastal flood management through short-to-medium range (real-time) flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate induced impacts	The study was not presented.
Internal studies (New)		
1.	Estimation of confidence intervals of index flow duration curves	PI presented the objectives and scope of the proposed study. There were no specific suggestions/comments from the members.
2.	Hydraulic force-inversion equation for exact modeling of hydraulic jumps in rectangular channels	PI presented the objectives and scope of the proposed study. No specific action was suggested.

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2023-24

S. N.	Title of Project/Study	Study Team	Duration	Funding
Internal studies (Ongoing)				
1.	Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Operation of Reservoirs	A. K. Lohani; R. K. Jaiswal J.P. Patra; P. C. Nayak Vishal Singh	2 Years (April 2022 – March 2024)	NIH
2.	Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model	P. C. Nayak; A. K. Lohani; J. P. Patra; Sunil Gurrapu; T. Thomas; Om Prakash; Jatin Malhotra	3 Year (July 2022 to June 2025)	NIH
3.	Hydrological Study to conserve the water resources of Bikaner, Rajasthan	L. N. Thakural; M. K. Sharma; R. K. Jaiswal; J. P. Patra; P. K. Mishra; Nitesh Patidar; N. K. Bhatnagar; Jatin Malhotra; Anil Kumar Chhangani	2 Year (July 2022 to June 2024)	NIH
4.	Review of design flood and dam break analysis of Khadakhai Dam in Odisha	J.P.Patra; A. K. Lohani; Pankaj Mani; P. C. Nayak; Sanjay Kumar	3 Year (April 2022 to March 2025)	NIH
5.	Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	Ashwini Ranade; P.K. Mishra Sunil Gurrapu	3 years (April 2022 to March 2025)	NIH
6.	Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics	Archana Sarkar; Jyoti Patil Rohit Sambare; Charu Pandey	2 Year (May 2022 to April 2024, after extn.)	NIH

7.	Investigation of hydrodynamic approach of flood inundation mapping along with assessment of changes in river planforms using a cloud-based Google Earth Engine (GEE) computing platform in data-scarce Western Himalayan River basin	R. V. Kale; A. K. Lohani J. P. Patra; D. Khurana	03 Years (September 2021- October 2024)	NIH
Sponsored Projects (Ongoing)				
1.	Operational coastal flood management through short-to-medium range (real-time) flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate induced impacts	B. Sahoo, (PI, IIT-Kgp) R. V. Kale, (Co-PI)	03 years (July, 2020 –June, 2023)	STARS (MHRD, GoI)
Internal studies (proposed)				
1.	Estimation of confidence intervals of index flow duration curves	Sanjay Kumar, Sunil Gurrapu; L. N. Thakural; J. P Patra	02 Years (April 2023 to March 2025)	NIH
2.	Hydraulic force-inversion equation for exact modeling of hydraulic jumps in rectangular channels	Sushil K. Singh	One Year (April 2023 to March 2024)	NIH

WATER RESOURCES SYSTEMS DIVISION

Dr. Sanjay K Jain (SKJ), Sc. G and Head, presented an overview of the division – scientific strength, the ongoing studies, sponsored & consultancy studies, technical publications and training courses organized. Dr. Jain informed that a Centre for Cryosphere and Climate Change has been established in the Division. Thereafter, PIs of the respective studies presented the progress and the details is given below:

SN	Title of Project/Study	Recommendations/ Suggestions
Internal Studies (Completed)		
1.	Seasonal characterization of Gangotri Glacier melt runoff and simulation of stream flow variation under different climate scenarios	No specific comments were received.
2.	Impacts of glacier and climate change on runoff for selected basins of Himalayan region	No specific comments were received.
Sponsored Projects (Completed)		
1.	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	Not Presented
Internal Studies (Ongoing)		
1.	Monitoring and Hydrological Modelling of Henvel watershed in Lesser Himalaya	No specific comments were received.
2.	Spatio-temporal Water Availability under Changing Climate and Land use Scenarios in Wainganga River Basin	No specific comments were received.
3.	Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin	Dr. Ramakar Jha suggested to consider different climatic zones of India for selection of GCMs. Dr. Sanjay K Jain suggested to further discuss with Prof. Dimri in this matter.

Sponsored/Collaborative Projects (Ongoing)		
1.	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya	Not presented.
2.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework	Not presented.
3.	Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework	Not presented.
4.	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram	Not presented.
5.	Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya	No specific comments were received in this collaborative study with IIRS.
6.	Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka	Not presented.
Internal Studies (New)		
1.	Monitoring and Modelling of Gangotri watershed (Bhojwasa) under different Climate Scenarios	Dr. A. P. Dimri suggested to undertake the Mass Balance of Glacier.
2.	Glacier recurrence survey, Instrumentation and Modeling to study the Batal Glacier in part of Western Himalaya, India	Dr. Dimri suggested to see the other sites in the nearby area before finalisation of the site.

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2023-2024

SN	Title of Project/Study	Study Team	Duration	Funding (Rs. Lakhs)
Internal Studies (Ongoing)				
1.	Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya	M K Nema; Sanjay K Jain; P K Mishra;	3 years (08/20-07/23)	NIH (10.22)
2.	Spatio-temporal Water Availability under Changing Climate and Landuse Scenarios in Wainganga River Basin	M K Nema; P K Mishra; Rahul Jaiswal	2 years (04/22-03/24)	NIH (9.72)
3.	Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin	Sunil Gurrapu; Nitesh Patidar; YRS Rao; R Venkata Raman; TVNAR Kumar	2 years (04/22-03/24)	NIH
Sponsored/Collaborative Projects (Ongoing)				
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; A K Lohani; Vishal Singh	3 years (11/19-11/22) Extended up to 09/23	NMHS-MoEF (143)
2.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.	P K Singh; P K Mishra;	2 years (08/20-07/22) Extended up to 06/23	NHP (14.50)
3.	Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework.	P K Mishra; P K Singh; Vishal Singh; P K Agarwal	2 years (04/21-06/23)	NHP (9.00)
4.	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram	Vishal Singh; M K Nema; P K Singh; Vanlalpekhlua Sailo (SDO from Mizoram); Lalruatkima (JE from Mizoram)	3 years (04/21-03/24)	NHP (25.00)
5.	Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya	M K Nema; Sanjay K Jain; P. K. Mishra; Praveen Thakur (IIRS)	3 years (04/22-03/25)	IIRS (30.91)
6.	Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka	P K Singh; Vishal Singh; Sanjay K Jain; Abhilash R.	3 years (04/22-03/25)	NHP (54.0)
Internal Studies (New)				

1.	Monitoring and Modelling of Gangotri (Bhojwasa) watershed under different Climate Scenarios	P K Mishra; Vishal Singh; Sunil Gurrapu; Manohar Arora; Sanjay K Jain; Jatin Malhotra	3 years (04/23-03/26)	NIH (57.0)
2.	Glacier recurrence survey, Instrumentation and Modeling to study the Batal Glacier in part of Western Himalaya, India	Vishal Singh; P K Mishra; Sunil Gurrapu; Sanjay K Jain; Manohar Arora; Jatin Malhotra	5 years (04/23-03/28)	NIH (71.0)

DETAILS OF TRAINING/ WORKSHOP DURING APRIL, 2022 - MARCH, 2023

SN	Title of Training Course/Workshop	Coordinators	Duration	Venue
1.	Twelve-day Training programme on "Water Resources Planning and Management" sponsored by META Nashik for the engineers of the Water Resource Department (WRD) of the Government of Maharashtra	Smt. D. Chalisgaonkar, Scientist G Er. P. K. Agarwal Scientist B	April 15-25, 2022	NIH, Roorkee
2.	Five-day Training on "National Hydrology Model" under the National Hydrology Project (NHP)	Dr. A. K. Lohani Scientist G Dr. S. K. Jain Scientist G	August 01-05, 2022	NIH, Roorkee
3.	Five-day online Training on "Hydrological Modeling using Soil and Water Assessment Tool (SWAT): Theory and Hands-on" sponsored by National Hydrology Project (NHP).	Dr. M. K. Nema Scientist D Dr. Vishal Singh Scientist D	August 22-26, 2022	NIH, Roorkee
4.	Five-day Training Course on "Application of Water Accounting Plus (WA+) Tool for Water Resources Management" under National Hydrology Project.	Dr. P. K. Mishra Scientist D Dr. P. K. Singh Scientist D	28 Nov. – 02 Dec., 2022	Kohima, Nagaland
5.	One-week Training Program on "Climate Change and Hydrological Impact Assessment"	Dr. Sunil Gurrapu Scientist C Dr. L N Thakural Scientist D	December 12-17, 2022	NIH, Roorkee
6.	Five-day Training Program on "Flood prone area mapping and modelling" for the Irrigation and Water Resources Dept., Govt. of Mizoram	Dr. Vishal Singh Scientist D	March 20 – 24, 2023	NIH, Roorkee

RESEARCH MANAGEMENT AND OUTREACH DIVISION (RMOD)

Er. Omkar Singh, Sc. G & Head, requested Dr. A. R. Senthil Kumar, Sc G to present the overview of the Division's activities and progress of studies during 2022-23. Dr. A. R. Senthil kumar presented tables showing the studies and outreach activities proposed for the F.Y. 2023-24. He also presented the progress of the studies/project along with the input of Er. Omkar Singh as given below:

SN	Title of Project/Study	Recommendations/Suggestions
Internal (Ongoing)		
1.	Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand Region, Central India	WG was informed a need for extension up to June 2023 as conveyed by the PI.
2	Establishing hydrological regime and ecohydrological functions of Jhilmil Jheel Wetland, Haridwar District	The study was not presented due to long leave of PI on medical ground.
3	Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat Region, Haryana	PI requested for extension of the study up to June 2023. There were no comments.
4.	Development of Water Security Plan for Healthcare Facilities: A Pilot Study for Swami Rama Himalayan University (SRHU-HIHT), Jolly Grant, Dehradun	Proposed to drop the study due to non-availability of requisite data/resource.
Sponsored (Ongoing)		
1.	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)-DST sponsored	Sponsored project was reported in WG meeting.

RECOMMENDED WORK PROGRAM FOR THE YEAR 2023-24 (RMOD)

S.N.	Title of Project/Study	Study Team	Duration	Funding (Rs. Lakh)
Internal Study (Ongoing)				
1.	Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand region	Jyoti Patil (PI) T Thomas (Co-PI), P K Mishra Rohit Sambare	Sep 2020- Jun 2023	NIH
2.	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade, N R Allaka; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Sep 2020- Aug 2023	NIH
3.	Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana	A R Senthil Kumar (PI), Omkar Singh (Co-PI) Rajesh Agarwal, N R Allaka Scientist from KVK/Agri Univ.	Sep 2020- Jun 2023	NIH
Sponsored Projects (Ongoing)				

1.	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	Omkar Singh (PI), Rajesh Singh (Co-PI), V.C. Goyal (Ex- PI), Jyoti P. Patil, Rohit Sambare, Rajesh Agarwal, NR Allaka and Project Staff-HQ (IC-EcoWS) **Partners:** NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand	Apr 2019-Mar 2024	DST-GoI (510)

Proposed Training/Webinar/Outreach Activities of RMOD (2023-24)

S.N.	Activity	Tentative Month	Place	Target Participants	Team
1.	5-days training on “Life Cycle Approach for Rejuvenation of Ponds and Lakes using Nature-Based Solutions” sponsored by NWM	May/ June 2023	Roorkee	R&D Institutes/ Univ./Govt. Organizations	J P Patil/AR Senthil Kumar, Omkar Singh, Rohit Sambhare, Rajesh Agarwal, NR Allaka
2.	Stakeholders workshop for Upper Dhasan Basin water resources assessment	May/June 2023	Bhopal	CWC, CGWB, State Govt. Dept., etc.	J P Patil, T Thomas, P K Mishra, Rohit Sambhare
3.	Five-day training program on “Hydrology of water bodies and their development under climatic uncertainty”	Jul/Aug 2023	Roorkee	Irrigation/PHE/ SWC departments	A. R. Senthil kumar, Jyoti Patil, Rohit Sambare, Santosh M Pingale, N R Allaka

Other Outreach Activities:

S.N.	Activity			
1.	Preparation of short videos on R&D findings of selected NIH studies			
2 .	Coordination & Organizing activities under Azadi Ka Amrit Mahotsav-Phase 2.0			
3 .	Any other Outreach activity (exhibition) as assigned			
4.	Outreach activity on “Water Conservation & Water Security” in Schools	Oct/Nov/ Dec. 23	Schools (2 nos.)	Team: A. R. Senthil kumar, Omkar Singh, Rajesh Agarwal, N R Allaka

Sh. Omkar Singh thanked the members for their valuable contributions during deliberations in the Working Group meeting. The meeting ended with vote of thanks to the Chair.

ANNEXURE-I

List of Working Group Members who attended the 53rd WG meeting

1.	Dr. Sudhir Kumar, Director, NIH	Chairman
2.	Dr. Vijay Kumar, Ministry of Earth Sciences, New Delhi	Member
3.	Dr. Prashant Rai, CGWB, Dehradun	Member
4.	Dr. Praveen Thakur, IIRS, Dehradun	Member
5.	Prof. A.K. Saraf, IIT, Roorkee	Member
6.	Dr. Manoj P. Samuel, CWRDM, Kozhikode	Member
7.	Dr. Bhishm Kumar, IAEA (Retd.), Roorkee	Member
8.	Prof. Ramakar Jha, NIT, Patna	Member
9.	Prof. A.P. Dimri, Indian Institute of Geomagnetism, Mumbai	Member
10.	Dr. (Mrs.) Sadhana Malhotra, Mindspace, Dehradun	Member
11.	Sh. Sudhindra Mohan Sharma, Ex-Nodal Officer, MoDWS, Indore	Member
12.	Prof. K.K. Singh, NIT, Kurukshetra	Member
13.	Dr. Sanjay K. Jain, Sc. G & Head WRS Division, NIH	Member
14.	Dr. M.K. Goel, Sc. G & Head GWH Division, NIH	Member
15.	Dr. A.K. Lohani, Sc. G & Head SWH Division, NIH	Member
16.	Dr. R.P. Pandey, Sc. G & Head EH Division, NIH	Member
17.	Dr. Suhas Khobragade, Sc. G & Head HI Division, NIH	Member
18.	Er. Omkar Singh, Sc. G & Head, RMO Division, NIH	Member-Secretary

Scientists from NIH

	EH Division		**SWH Division**
1.	Dr. M.K. Sharma, Sc. F	16.	Dr. S.K. Singh, Sc.F
2.	Dr. Rajesh Singh, Sc. D	17.	Dr. P.C. Nayak, Sc. F
3.	Dr. Pradeep Kumar, Sc. D	18.	Dr. Sanjay Kumar, Sc. F
4.	Dr. Vinay K. Tyagi, Sc. D	19.	Dr. Archana Sarkar, Sc. F
5.	Dr. Kalzang Chhoden, Sc. C	20.	Dr. L.N. Thakural, Sc. D
	GWH Division	21.	Dr. J.P. Patra, Sc. D
6.	Dr. Anupma Sharma, Sc. G	22.	Dr. R.V. Kale, Sc. D
7.	Dr. Surjeet Singh, Sc. F	23.	Sh. N.K. Bhatnagar, Sc. B
8.	Dr. Gopal Krishan, Sc. D	24.	Sh. Om Prakash, Sc. B
9.	Dr. Nitesh Patidar, Sc. C		**WRS Division**
10.	Ms. Nidhi Kalyani, Sc. B		
	HI Division	25.	Dr. Manohar Arora, Sc. F
11.	Dr. M.S. Rao, Sc. F	26.	Dr. P.K. Singh, Sc. D
12.	Dr. Soban S. Rawat, Sc. E	27.	Dr. Manish Nema, Sc. D
13.	Dr. Santosh M. Pingale, Sc. D	28.	Dr. P.K. Mishra, Sc. D
14.	Smt. Anjali, Sc. C	29.	Dr. Sunil Gurrapu, Sc. D
	RMO Division	30.	Dr. Vishal Singh, Sc. D
15.	Dr. A.R. Senthil Kumar, Sc. G		

In addition, Technical Staff have also participated during presentations of their respective Divisions.

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ANNEXURE – B
Division-wise Work Programme

CENTRE FOR CRYOSPHERE AND CLIMATE CHANGE STUIDES

Scientific Manpower

S N	Name	Designation
1	Dr. Surjeet Singh	Scientist G & Head
2	Dr. Soban Singh Rawat	Scientist F
3	Dr.(Smt) Ashwini A. Ranade	Scientist D
4	Dr. Sunil Gurrapu	Scientist D
5	Dr. Vishal Singh	Scientist D
6	Dr. Lavkush Kumar Patel	Scientist D
7	Dr. Deepak Singh Bisht	Scientist C
8	Dr. Akshaya Verma	Scientist C
9	Dr. Kuldeep Sharma	Scientist C
10	Shri Rajat Kumar	Scientist B
11	Shri Jatin Malhotra	PRA
12	Shri Madhusudan Thapliyal	SRA

APPROVED WORK PROGRAMME FOR THE YEAR 2023-2024

	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1. NIH/C4S/2022-2025/SSR-*1*	Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions	Soban Singh Rawat, **(**PI**)** Sudhir Kumar, Santosh M. Pingale, P K Mishra, DS Bisht, Rajesh Singh	3 years (04/22-03/25)	Ongoing
2. NIH/C4S/2023-2026/SSR-*2*	Geo-Hydro-Chemical and Isotopic Aspects of occurrence of Springs: A case study from the major settlement areas of Bhagirathi basin, Uttarakhand, India	S S Rawat (PI), Suhas Khobragade, M K Sharma, M S Rao, Santosh M. Pingale, P K Mishra	03 Years (04/23 -03/26)	Ongoing
3. NIH/C4S/2023-2028/VS	Real time monitoring of snow-glacier related parameters and Ensemble Hydrological Modeling (EHM) to study the Triloki Group of Glaciers and Khatling glaciers part of Western Himalaya, India under climate change scenarios	Vishal Singh (PI), Surjeet Singh, Sunil Gurrapu, Luvkush Patel, Akshay Verma, Madhusudan Thapliyal	05 Years (03/23-02/28)	Ongoing
4. NIH/C4S/2022-2024/SG	Climate Change Scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River Basin	Sunil Gurrapu (PI)	02 years (04/22-03/24)	Completed
5. NIH/C4S/2022-2025/AR	Investigation on occurrences of extreme rain events across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	Ashwini Ranade, PK Mishra, Sunil Gurrapu	03 years (04/22-03/25)	Ongoing
6. NIH/C4S/2021-2024/DSB-1	Early Signatures of 21st Century on Snow Cover Dynamics in Zanskar River Basin, Ladakh	DS Bisht (PI) & PG Jose	03 years (07/21-03/24) **(Extension needed up to 06/2024)**	Ongoing
7. NIH/C4S/2022-2024/DSB-2	Comparative Analysis of Fine Scale Satellite & Reanalysis Precipitation Products in Upper Ganga Basin using Multicriterion Decision-Making	DS Bisht (PI) & MK Goel	02 years (06/22-03/24) **(Extension needed up to 06/2024)**	Ongoing

	Project Title	Study Team	Duration	Status
8. NIH/C4S/2023-2026/LKP-1	Monitoring and Modelling of the Gangotri glacier catchment under different Climate Scenarios	Lavkush Kumar Patel (PI), Akshaya Verma, Vishal Singh, Kapil Kesharwani, Surjeet Singh, Jatin Malhotra	03 years (04/23-03/26)	Ongoing
SPONSORED PROJECTS:				
9. *SP/*C4S/2023-2028/SSR	Identification of Source and Causes of the gushing water in the premises of Jaypee Colony in the night of 02 January, 2023	SS Rawat (PI), Gopal Krishan, Rajesh Singh, SM Pingale, JP Patra	04 Month (01/23-04/23) **Sponsored by Uttarakhand State Disaster Management Authority (USDMA)**	Completed
10. *SP-54*	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar subbasins in the state of Mizoram (SP-54)	Vishal Singh	2.5 years (06/21-03/24) **Sponsored PDS under NHP**	Completed
11. SP65/2023-26/NIH(CHD)	Assessment of glacier-climate functional relationships across the Indian Himalayan region through long-term network observations	Vishal Singh, Lead Co-PI, NIH Roorkee	03 years (12/23-11/26) **Sponsored by NMHS-GBPNIHE**	Ongoing
CONSULTANCY PROJECTS:				
12. CS-257/2022-23/GWHD	System Studies for Proposed Farakka-Sundarban Link Project	Surjeet Singh (PI)	1.5 years (12/22-05/24) **Sponsored by NWDA**	Ongoing

PROPOSED WORK PROGRAMME FOR THE YEAR 2024-2025

	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1. NIH/C4S/2022-2025/SSR-*1*	Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions	Soban Singh Rawat **(PI),** Sudhir Kumar, SM Pingale, P K Mishra, DS Bisht, Rajesh Singh	3 years (04/22-03/25)	Ongoing
2. NIH/C4S/2023-2026/SSR-*2*	Geo-Hydro-Chemical and Isotopic Aspects of occurrence of Springs: A case study from the major settlement areas of Bhagirathi basin, Uttarakhand, India	SS Rawat (PI), Suhas Khobragade, MK Sharma, MS Rao, SM Pingale, PK Mishra	03 Years (04/23 - 03/26)	Ongoing
3. NIH/C4S/2023-2028/VS	Real time monitoring of snow-glacier related parameters and Ensemble Hydrological Modeling (EHM) to study the Triloki Group of Glaciers and Khatling glaciers part of Western Himalaya, India under climate change scenarios	Vishal Singh (PI), Surjeet Singh, Sunil Gurrapu, Luvkush Patel, Akshay Verma, Madhusudan Thapliyal	05 Years (03/23-02/28)	Ongoing
4. NIH/C4S/2022-2025/AR	Investigation on occurrences of extreme rain events across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	Ashwini Ranade (PI), PK Mishra, Sunil Gurrapu	03 years (04/22-03/25)	Ongoing
5. NIH/C4S/2021-2024/DSB-1	Early Signatures of 21st Century on Snow Cover Dynamics in Zanskar River Basin, Ladakh	DS Bisht (PI) & PG Jose	03 years (07/21-03/24) **(Extension needed up to 06/2024)**	Ongoing
6. NIH/C4S/2022-2024/DSB-2	Comparative Analysis of Fine Scale Satellite & Reanalysis Precipitation Products in Upper Ganga Basin using Multicriterion Decision-Making	DS Bisht (PI) & MK Goel	02 years (06/22-03/24) **(Extension needed up to 06/2024)**	Ongoing
7. NIH/C4S/2023-2026/LKP-1	Monitoring and Modelling of the Gangotri glacier catchment under different Climate Scenarios	Lavkush Kumar Patel (PI), Akshaya Verma, Vishal Singh, Kapil Kesharwani, Surjeet Singh, Jatin Malhotra	03 years (04/23-03/26)	Ongoing
8. NIH/C4S/2024-2026/SS	Inventory of Glaciers and Glacial Lakes in Indian Himalayan Region	Surjeet Singh (PI), Vishal Singh, Lavkush Kr Patel, Akshaya Verma, Madhusudan Thapliyal	02 years (04/24-03/26)	New

	Project Title	Study Team	Duration	Status
9. NIH/C4S/2024-2027/SG	Assessment of Hydrological Extremes and Impact on Future Water Availability in Pennar River Basin under Changing Climate	Sunil Gurrapu (PI), Surjeet Singh, Vishal Singh, YRS Rao, RV Ramana, Madhusudan Thapliyal, TVNAR Kumar, Chief Engineer, WRD, Govt. of AP	03 years (04/24-03/27)	New
10. NIH/C4S/2024-2027/LKP-2	Glacio-hydrological and GLOF investigations over the Triloki glacier, Bhaga basin, Western Himalaya	Lavkush Kumar Patel (PI), Akshay Verma, Vishal Singh, Surjeet Singh	03 years (03/24-03/27)	New
11. NIH/C4S/2024-2027/KS	WRF-based dynamical downscaling of CMIP6 climate projections over Himalaya and surrounding Region	Kuldeep Sharma (PI) Ashwini Ranade (Co-PI) Sahidul Islam (Co-PI) CDAC, Pune	03 years (04/24-03/27)	New
12. NIH/C4S/2024-2028/AV	Integrated long-term monitoring of Khatling Glacier, Bhilangana basin, Uttarakhand	Akshaya Verma (PI) Vishal Singh, Sunil Gurrapu, Lavkush Patel, Surjeet Singh	04 years (04/24-03/28)	New
13. NIH/C4S/2024-2026/DSB	A Spatially Explicit Assessment of CMIP6 General Circulation Models for the Indian Himalayan Region	Deepak Singh Bisht (PI) Nitesh Patidar, SS Rawat, Surjeet Singh	02 years (04/24-03/26)	New
14. NIH/C4S/2024-2026/RK	Climate change impacts on water resources availability and hydropower potential assessment in the Himalayan Satluj river basin (up to Kasol).	Rajat Kumar (PI), Vishal Singh, Surjeet Singh, Shakti Suryavanshi	02 years (04/24-03/26)	New
15. NIH/C4S/2024-2027/KK	Influence of Climate Change and Future Response of the Milam Glacier (Central Himalaya, India): Science – Practice - Policy	Kapil Kesarwani (PI), Surjeet Singh, Lavkush Kumar Patel, DS Bisht, Akshaya Verma, Madhusudan Thapliyal	03 years (04/24-03/27)	New
SPONSORED PROJECTS:				
16. SP65/2023-26/NIH(CHD)	Assessment of glacier-climate functional relationships across the Indian Himalayan region through long-term network observations	Vishal Singh, Lead Co-PI, NIH Roorkee	03 years (12/23-11/26) **Sponsored by NMHS-GBPNIHE**	Ongoing
CONSULTANCY PROJECTS:				
17. CS-257/2022-23/GWHD	System Studies for Proposed Farakka-Sundarban Link Project	Surjeet Singh (PI)	1.5 years (12/22-05/24) **Sponsored by NWDA**	Ongoing

ITEM NO. 54.2 ACTIONS TAKEN ON THE ADVICE / DECISIONS OF THE 53rd MEETING

The specific action taken on the advice/decision of the 53rd meeting of Working Group of NIH are as follows:

SN	Project	Status & Comments/ suggestions	Action Taken
INSTITUTE FUNDED R & D STUDIES			
1.	NA	NA	NA

ITEM NO. 54.3 PROGRESS OF THE WORK PROGRAM OF THE DIVISION FOR THE YEAR 2023-24 & 2024-25

As per the approved work program, the status of studies carried out in C4S during 2023-24 is given below:

Type of study/Project	***Completed during 2023-24***	***Continuing in 2024-25***	***Total***
Internal R & D Studies	01	07	08
Sponsored Projects	02	01	03
Consultancy Projects	0	01	01
New Studies	-	08	08
Total	03	17	20

Training Courses/Workshops organised by the Division during 2023-24: **10**

Details of Research Publications by the Division during 2023-24: **31**

	Published	**Accepted**	**Communicated**
Books/Book Chapter	4		
International Journals	10	1	
National Journals	**-**		
International Conferences	8		
National Conferences	8		

The progress of the various studies undertaken during 2023-24 is given below:

A. Internal R&D Studies

1.0 PROJECT CODE: NIH/C4S/2023-2028/VS

Title of the Study:	Real time monitoring of snow-glacier related parameters and Ensemble Hydrological Modeling (EHM) to study the Triloki Group of Glaciers and Khatling glaciers part of Western Himalaya, India under climate change scenarios.
Study Team:	Dr. Vishal Singh, Sc. D (PI) Dr. Surjeet Singh, Sc. G (Co-PI) Dr. Sunil Gurrapu, Sc. D (Co-PI) Dr. Luvkush Patel, Sc. D (Co-PI) Dr. Akshay Verma, Sc. C (Co-PI) Mr. Madhusudan Thapliyal, SRA (Co-PI)
Type of Study:	R&D
Funding Agency:	INTERNAL
Study Duration:	05 Years (2023 – 2028)
Budget:	

Objectives:

a) Monitoring, and Collection of hydro-meteorologial datasets for the Cyropsheric assessment and deriving data inputs for the comprehensive ensemble modeling of the selected snow-glacier induced Himalayan river basins.

b) Long-term change assessment in snow covers and glaciers (depth & area) using Satellite remote sensing and field based observations.

c) Re-construction of snow-water equivalent using real time snow cover datasets and field sampling/measurement of snow-density and snow-depth.

d) Development of an improved Ensemble Modelling Framework (under spatially-varying DDFs based Temperature Index Model) to address glacier changes (depth & area) and its impact on melt runoff under varying topographical & climatic conditions.

e) Projection of long-term snow covers, glacier areas and thickness in 21st century through modeling.

f) Analysing glacier and snow cover sensitivity to climate change and unraveling the effect of elevation and temperature gradient changes in snow-glacier dynamics and resultant melt runoff in 21st century using bias corrected and best fitted CMIP6 climate models.

Present state-of-art

A glacier survey in a physical model will be conducted to identify the most suitable glaciers for the analysis of glacier changes and its impact on river runoff and other watershed components. A feasibility report will be prepared as per the survey and the cryospheric, topographical and hydro-climatological characteristics of the glacier will be comprised. Then the instrumentation will be done in the glacier site for the analysis of different glacier parameters in the real time domain. The scientific instruments such as automatic weather station (AWS), automatic water level and velocity recorder, snow gauge and rain gauge (Depth and Sensitivity) will be procured and installed in the different sites for the measurements of hydro-meteorological variables to study snow and glaciers and resultant melt runoff. For glacio-hydrological analysis, the ensemble based modeling based framework will be developed utilizing the widely used modeling tools such as SPHY, SWAT and VIC etc. However, as the Himalayan glaciers are unique in nature and thus some modifications will be done by incorporating the effect of local parameters mainly to enhance the accuracy of the computed outcomes. Model calibration and validation will be done utilizing real time remote sensing data products and observed hydro-observational datasets. The snow and glacier melt runoff contribution in total discharge will be accounted and their fluctuations will be analyzed. The comparative seasonal and monthly snow cover and glacier change (area/volume/thickness) will be computed to highlight the variability in the glacier mass and other parameters. The geodetic mass balance of selected glacier will be done as mass balance methods as utilized previously utilizing the remote sensing, and field observation datasets. The effect of slope, aspect and elevations will also be incorporated to analyze their effects on glacial retreating and resultant runoff. As per the seasonal changes in precipitation and temperature at different altitudes within the glacier body and its catchment area will be studied and their relation to evapotranspiration (ET), soil moisture, surface temperature, radiation and surface albedo will be explored. Surface albedo and radiation have been recognized as important drivers to affect the snow cover and snow water equivalent. The snowpack cold content and albedo decrease when the intensity of shortwave radiation and temperature increases.

Study area:

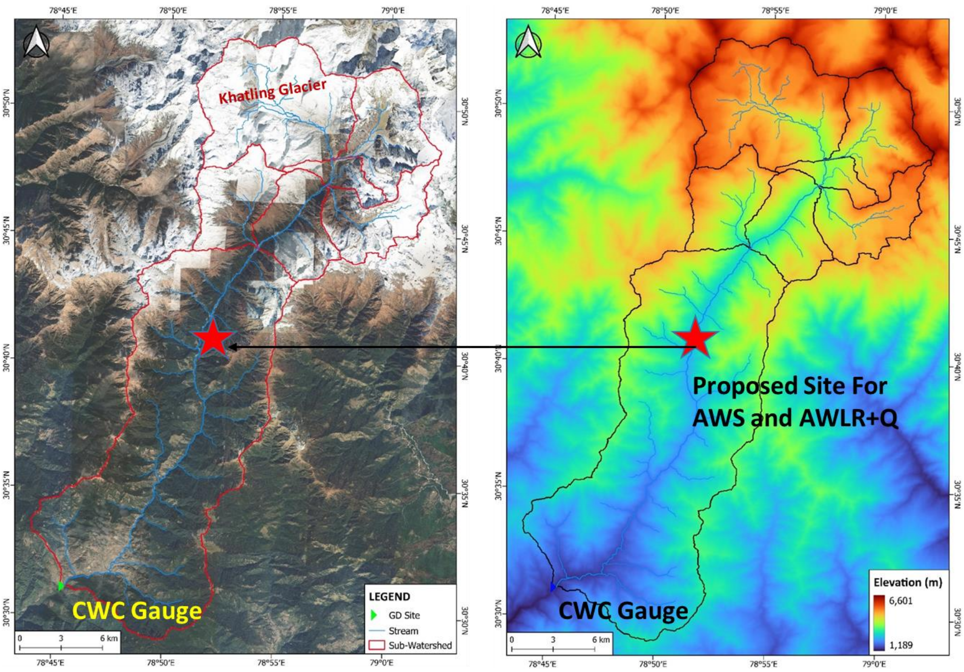


Figure 1: Upper Bhilangana River Basin (Highlighting Khatling Glacier).

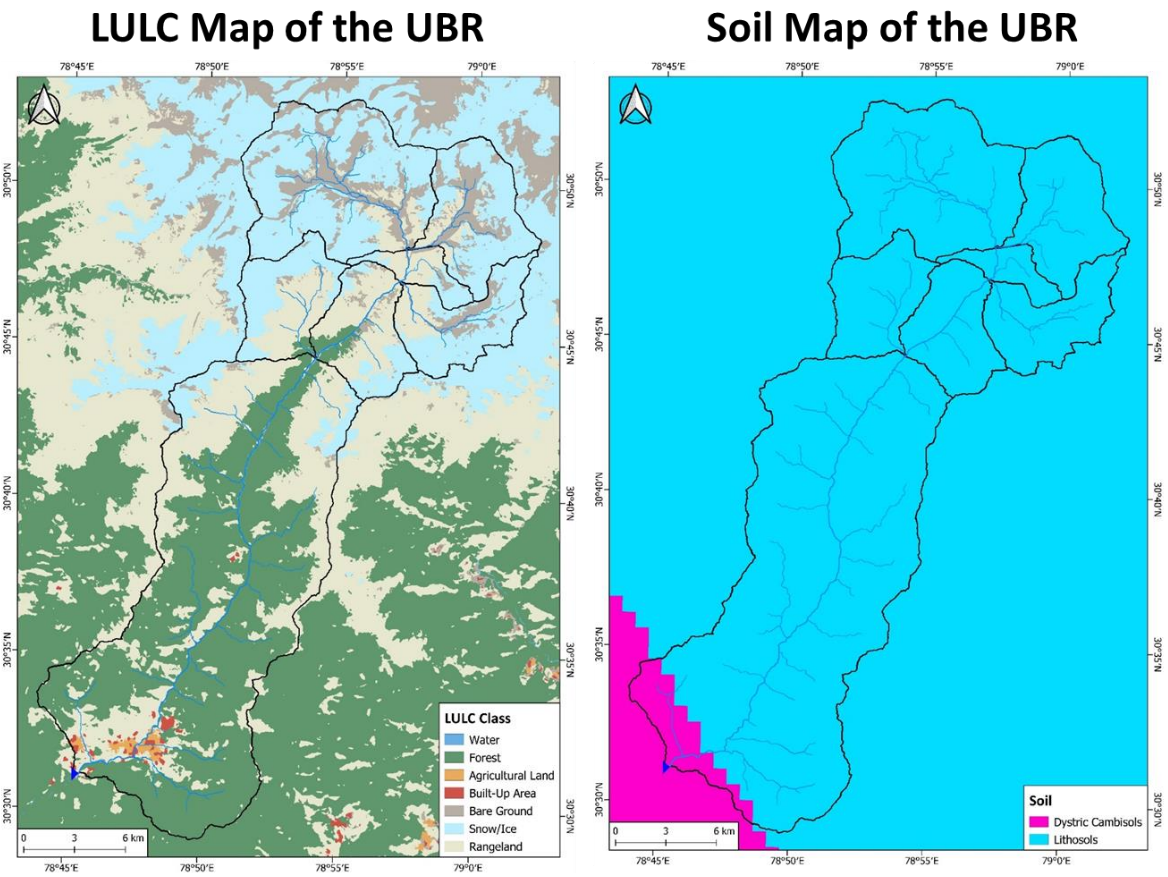


Figure 2: LULC and soil map of river Bhilangna basin.

Methodology:

1. Data Collection and Analysis:

Table 1: Details about the input datasets and their sources.

SI. N	DATASET NAME	SOURCES
1	Digital Elevation Model	SRTM/CARTOSAT - Freely Available
2	Landuse – Landcover Map	NRSC Decadal & ESRI - Freely Available
3	Soil map – FAO Global	Waterbase & HyHiDroSoil database - Freely Available
4	Soil map – High Resolution	HyHiDroSoil database – Freely Available
5	Satellite data – LISS4, LISS3	NRSC – (Taken from Bhuvan Portal)
6	Satellite data – Landsat, MODIS, Sentinel	Earth Explorer, NASA – Freely available
7	Precipitation data and other Meteorological datasets	IMD & IMDAA
8	Precipitation data and other Meteorological datasets	CHIRP, TRMM/GPM & Others
9	Observed discharge	CWC
10	Climate Models Data (CMIP5/CMIP6)	IPCC CMIP6 datasets

In the present study, meteorological variables, soil and runoff monitoring shall be done within the established experimental watershed. Modelling of runoff, soil moisture monitoring and modelling and comparison and validation of satellite soil moisture product with in-situ sensors are proposed. The methodology for these is described in the following sections.

2. Data assimilation and bias correction

For meteorological datasets, a high resolution gridded daily precipitation dataset (0.05º×0.05º) will be constructed for the historical time by assimilating IMD precipitation, TRMM based precipitation, GPM based precipitation and CHIRP precipitation datasets as per their availability. The bias correction will be done using advanced bias correction methods (such as Quantile mapping, Linear scaling etc.) (Singh and Xiaosheng, 2019).

3. Ensemble Hydrologic Modelling:

For the ensemble modeling, the Soil and Water Assessment Tool (SWAT), Spatial Process in Hydrology (SPHY) and Variable Infiltration Capacity (VIC) model, will be used for the estimation of snowmelt and glacier runoff over the selected Himalayan river basins.

4. Snow and Glacier runoff changes

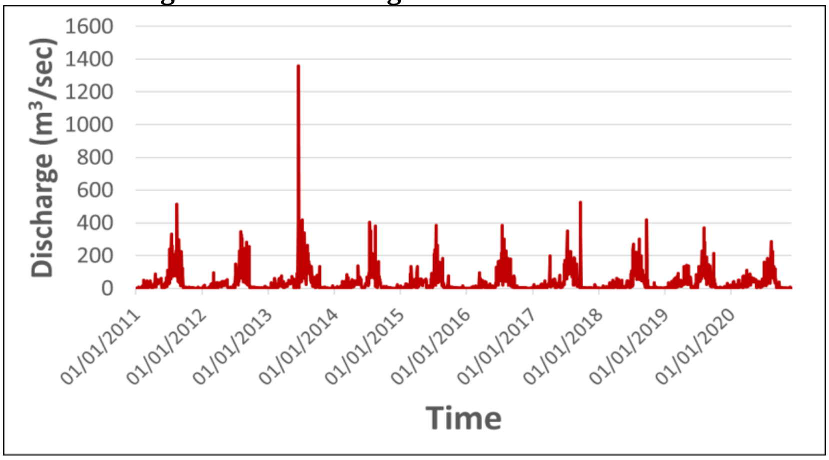
For snow-covered areas (SCAs) and glacier mapping, MODIS, LISS 3, LISS 4, and Sentinel satellite sensors data will be utilized. For snow cover extraction Normalized Difference Snow Index (NDSI) based on cloud removal technique will be utilized as previously used by various researchers. For the computation of snow and glacier melt a variable degree day factors based Temperature index model will be applied.

Achievement vis-à-vis Objectives

Progress of Work

A site visit near to Khatling Glacier (Bhilangna river basin) has been done in Oct, 2023 and a location is finalized (Near to Kharsoli Village) for the instrumentation (e.g. Rain Gauge & Water Level+Discharge)

Discharge simulation using SWAT at the outlet location.



Future work plan:

- Processing of hydro-meteorological datasets and climate model datasets.
- Precipitation trends and snow cover change assessment in the selected river basins.
- SWAT model based preliminary assessment of hydrological scenarios in the Triloki glaciers (part of Chandra-Bhaga basin) and Khatling glaciers (part of Bhilangna basin) situated in western Himalayan region.
- Instrumentation/procurement: the procurement of Drone, Spectroradiometer (1nos), AWS (2 nos.) and AWLR (2 nos.) are under process.
- A next site visit to **Triloki Glacier** is proposed in May/June 2024 to finalized the instrumentation location.

2.0 PROJECT CODE: NIH/C4S/2024-2026/SG

Title of the Study: Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin

Study Team:

NIH, Roorkee	DRC, Kakinada	WRD, Govt. of Andhra Pradesh
Dr. Sunil Gurrapu (**PI**), Sc. D Dr. Nitesh Patidar, Sc. C	Dr. Y R S Rao (**PI**), Sc. G Dr. R Venkata Ramana, Sc. E	Mr. T V N A R Kumar Chief Engineer, Hydrology Water Resources Dept.

Type of Study: R&D
Funding Agency: Internal
Study Duration: 2 years (04/2024 – 03/2026)
Budget:

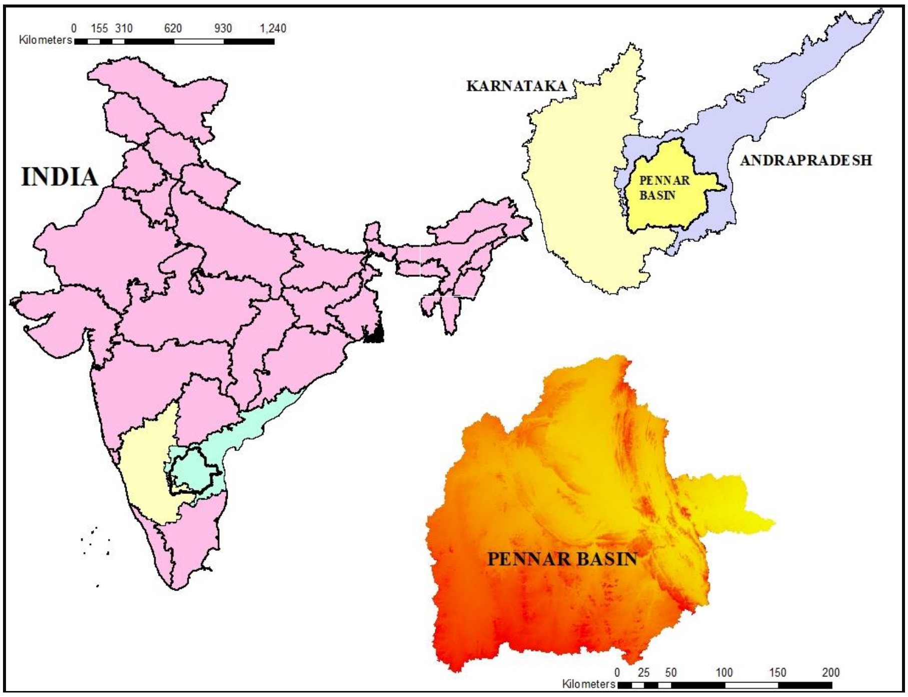
Objectives:

1. Analyse CMIP6 projected rainfall and temperature data for the state of Andhra Pradesh and generate multi-model scenarios of climate change.
2. Develop/calibrate and validate a hydrological model to simulate surface water and groundwater levels for the Pennar River Basin.
3. Generate hydrological scenarios (i.e. streamflow and groundwater levels) using CMIP6 projected climate.

Statement of the Problem:

It has been globally accepted that the changing climate is imposing significant alterations in the hydrological systems, which eventually is leading to the changes in the characteristics of hydrological extremes. In a most recent special issue on the impacts of climate on hydrological extremes, the focus was on the historically observed hydrological extremes and how these extremes are linked to the changing climate in several watersheds across the globe. Therefore, to evaluate the impacts of changing climate on the basin hydrology and/or hydrological extremes, the knowledge of complex interactions between climate and hydrological systems is vital. In addition to the changing climate, the hydrological dynamics of a basin are affected by the changes in catchment characteristics and river flow regime, caused by the land-use/land-cover changes from anthropogenic activities. In brief, the on-going changes in the global climate and the anthropogenic effects on regional/local climate would trigger imbalance in the hydrological systems and eventually result in disproportionate changes in the hydrological extremes. Several studies from the recent past indicate that the hydrological extremes would be more frequent and widespread in future due to extreme weather events perceived to be induced by climate change. Therefore, information on the impacts of climate change on the basin's hydrology and the basin's hydrological projections of the 21st century becomes a vital information for water managers, irrigation engineers, city planners, hydro-electric engineers etc. The proposed project aims to analyze the projected rainfall and temperature data from CMIP6 GCMs and generate multi-model climate change scenarios for the state of Andhra Pradesh. The second major objective of the project is to generate hydrological scenarios using a calibrated and validated hydrological model and evaluate the impacts of climate change on the hydrology and extreme hydrology of a selected watershed. The generated hydrological scenarios and the results from impact assessment will benefit water managers, irrigation and hydro-electric engineers, to plan and allocate water appropriately for its effective use and reduce negative impacts of floods and droughts.

Study area:



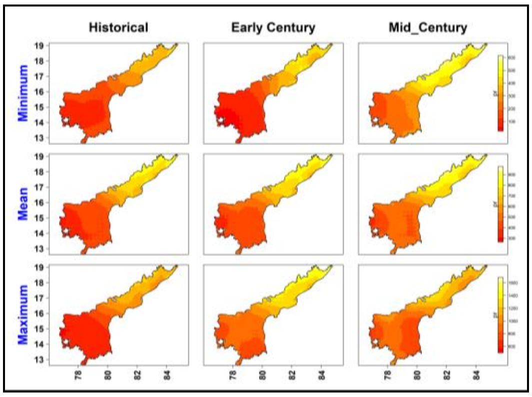
Location of the study area, the state of Andhra Pradesh and the Pennar River Basin.

Methodology:

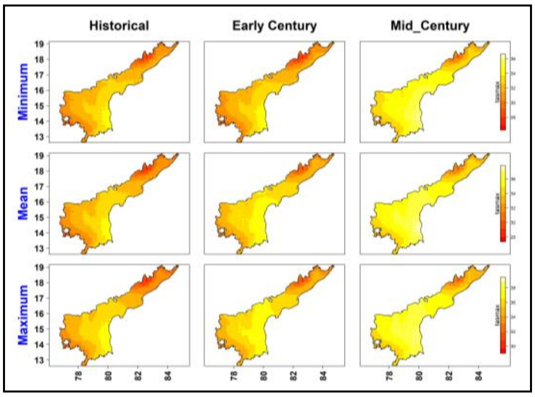
Achievement vis-à-vis Objectives

Progress of Work

The first objective of this study was to generate multi-model climate change scenarios for the state of Andhra Pradesh. To do so, the global climate scenarios derived from General Circulation Model (GCM) runs conducted under the coupled Model Intercomparison Project Phase 6, (CMIP6) were used. The climate scenarios generated under CMIP6 were downscaled, using Bias-correction Spatial Disaggregation (BCSD) method, to a common grid of 0.25 x 0.25 degrees by NASA and is made available through NASA Earth Exchange Global Daily Downscaled Projections, NEX-GDDP-CMIP6. These datasets are available for a total of 35 GCMs for 4 SSP scenarios (i.e. SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5) for the period 2015-2100, as well as the historical period 1950 – 2014. Of the existing 35 GCMs, 10 GCMs were selected based on the recommendations from the recently published climate change impact studies, and for 2 SSP scenarios, one likely (SSP2-4.5) and one unlikely (SSP3-7.0). These datasets are first bias corrected using delta-change approach with the gridded datasets of precipitation (0.25 x 0.25 degree) and temperature (1 x 1 degree) from IMD. The bias-corrected projections are later used to generate various change scenarios of precipitation and temperature based on multi-model statistics for the state of Andhra Pradesh.

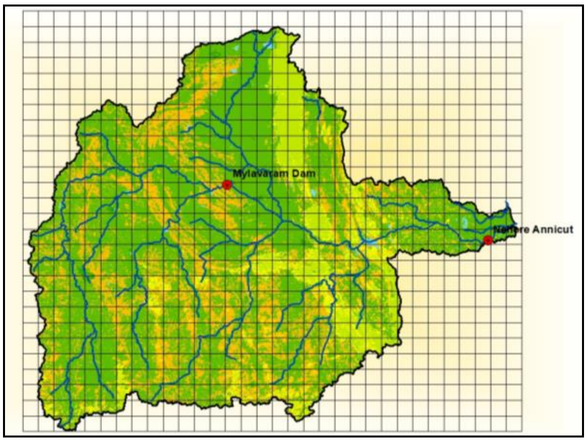


Multi-model (10 GCMs) maximum, mean and minimum of precipitation (pr) scenarios for the state of Andhra Pradesh

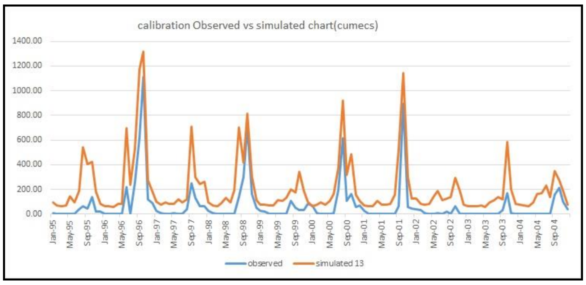


Multi-model (10 GCMs) maximum, mean and minimum of maximum temperature (tmax) scenarios for the state of Andhra Pradesh

To accomplish the second objective, a VIC model was developed for the Pennar River basin with a resolution of 5 km. Catchment characteristics for the basin were generated based on 30 m SRTM DEM, FAO soil map, and LULC information from Copernicus Global Land Service (CGLS). Gridded datasets of precipitation (0.25 x 0.25 degree) and temperature (1 x 1 degree) from IMD are used to run the model. In addition, wind speed dataset is required to force the VIC model, which is obtained from NASA POWER (Prediction of Worldwide Energy Resources), available at a 0.5 x 0.5-degree resolution. These datasets are further re-gridded to the resolution of the VIC model, i.e. 0.05 degree or ~ 5 km. Streamflow gauging station at Nellore Anicut and Chennur are selected for calibrating the VIC model. Historical streamflow data at Chennur station is available from IndiaWRIS and is currently used to calibrate the VIC model. Hydrological scenarios at Chennur are developed using calibrated and validated VIC hydrological model and the bias corrected projections of the 21st century. Gauging station at Nellore Anicut is located near the delta of Pennar River and is operated and maintained by the Water Resources Department (WRD), Andhra Pradesh. Observed streamflow dataset from this station is awaited and the model will be calibrated and validate at the exit of the Pennar River Basin. To accomplish the third objective, machine learning approach is adopted because of its ability to analyze complex datasets and make predictions or classifications based on patterns and relationships within the data. So, a random-forest-based model is developed to simulate the groundwater levels in the basin. Random forest models are data-driven and the data required for the analysis is obtained from Ground Water & Water Audit Department, WRD, Andhra Pradesh. These models are used to generate multi-model hydrological scenarios for the basin.



VIC model grid for the Pennar River Basin



Calibration plot of VIC model at Chennur Gauging Station

Future work plan:

3.0 PROJECT CODE: NIH/C4S/2022-2025/AR

Title of the Study:	Investigation on occurrences of extreme rain events across Northwest Himalaya in relation to global atmospheric thermal and circulation changes
Study Team:	Dr. Ashwini Ranade, Scientist 'D' (PI) Dr. P.K. Mishra, Scientist 'D' (Co-PI) Dr. Sunil Gurrapu, Scientist 'C' (Co-PI)
Type of Study:	R&D
Funding Agency:	Internal
Study Duration:	3 years (04/22-03/25)

Objectives:

- To document broad features and unique characteristics of the large-scale and isolated heavy rainstorms/snowstorms across Northwest Himalaya. (Completed)
- To generate in-depth information about the location, shape, size, and intensity of the various rain-producing weather systems that are formed over the northwest Himalaya during different seasons of a year. (completed)
- To investigate the relationship among global atmospheric thermal structure and general and monsoonal circulation features and seasonal extremes over the NW Himalaya. (Ongoing)
- To study the nature of mid/upper tropospheric tropical-extratropical interactions and different thermo-hydrodynamical processes causing isolated heavier rain/snow storms. (Ongoing)

Statement of the Problem:

Heavy rain events over the northwest Himalayan region are becoming ferocious in recent years causing catastrophic disasters. Colloquially termed as the cloudburst has a potential to downpour over a smaller region in very short duration. International disaster database (http://www.emdat.be) has reported the substantial increase in the extreme rain events over the western Himalayas in recent 30-40 years. It is one of the most studied but less understood phenomena so far. Under the influence of highly complex terrain and tropical-extratropical interactive atmosphere, the northwest part of Himalaya becomes more prone to such types of extreme events, especially during the monsoon season. There is a widespread belief that, in a recent global warming period, due to the intensification of the hydrological cycle, extreme rain events are increasing (Senior et al. 2002, IPCC 2007). The sixth assessment report (IPCC, 2021) projected that, extreme rainfall is projected to be intensified by 7% for each additional 1 ºC due to acceleration of hydrological cycle in warmer climate across the globe and become more frequent mostly in Africa and Asia. Since 2010, about 17 noticeable extreme events have been observed over Indian Himalayan region of Leh, Uttarakhand, Jammu and Kashmir and Himachal Pradesh, about 5 over subtropical Pakistan and 2 each over Nepal and China. Studies shows that, multiple visualizable factors operated in accord to produce extreme weather/rain events across subtropical Asia. Unprecedented interactions between deep westerly trough and cross-equatorial Indian Ocean south-westerlies as well as Pacific easterlies results in evolution of large and intense monsoon trough extending from Philippine through Indus basin. Arabian sea and Bay of Bengal provides the excessive moisture and numerous synoptic scales, mesoscale and microscale weather systems are evolved and interconnected in the anomalous monsoon trough along with topographical features results in increase in the severity of the events. Formation and intensification of troughs in the temperate westerlies is a short period phenomenon. Therefore, condensation and intense rainfall in subtropical mountainous terrain that involving confluence and convergence of huge air masses of contrasting characteristics are short lived.

Study area:

In this study, we propose a detailed systematic long-term analysis of various large-scale and isolated spatio-temporal extreme rain events over 3 states of the northwest Himalaya by using 0.25o x 0.25o Gridded daily rainfall observations (fig 1). The meteorological anomalies and physical processes causing most severe extremes are studied using ERA-5 reanalysis atmospheric parameters (temperature, pressure, geopotential height, precipitable water, wind, absolute vorticity, cloud cover, vertical velocity, freezing level, OLR etc.)

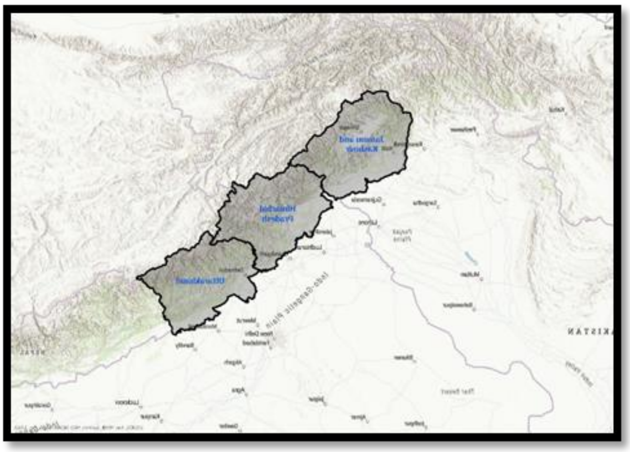


Fig 1. Study area: Northwest Himalaya

Progress of Work

1. **Analysis and Results**

1.1 Annual and seasonal rainfall characteristics across NW Himalaya

Daily gridded rainfall data over the three states (Uttarakhand: UK, Himachal Pradesh: HP and Jammu and Kashmir: JK) are area-averaged for the study period 1951-2021. The annual and seasonal (JJAS, OND, JF and MAM) rainfall are calculated. The mean annual rainfall of UK is 1444.7mm, HP is 1244.85mm and JK is 1125.8 mm. While mean monsoon rainfall of the three states UK, HP and JK are 1096.5mm, 746.78mm and 465mm respectively. The spatial distribution of mean annual and seasonal rainfall across the NWH region shows large spatial variation across NWH states. The maximum annual rainfall spatially varies between 1281.4 to 4668.8 mm while that of JF: 155.4-2311 mm; MAM: 244.9-15.4mm; JJAS: 453.8-4090mm and OND: 240.3-1101.5mm

Inter-annual variations in area-averages of annual and seasonal rainfall are studied using Mann-Kendall test for its trend detection. No significant long-term trend is observed in annual and monsoonal rainfall series of Uttarakhand, however, OND rainfall shows a significant decreasing long-term trend during 1951-2021. In the recent 20 years (2001-2021), OND rainfall of UK state has decreased significantly by 35% compared to the preceding 51 years record. Significant long-term decreasing trend is observed in annual rainfall of Himachal Pradesh during 1951-2021, however other seasonal rainfall series are homogeneous and random. In recent 20 years, annual rainfall of HP decreased by ~13%, monsoon by ~8.5%, OND by ~33%, JF by 17% and MAM by ~17% respectively. A significant long-term increasing trend is observed in JF rainfall of Jammu and Kashmir during 1951-2021, however annual and other seasonal rainfall series are homogeneous and random. In the recent 20 years, monsoon rainfall of JK increased by ~18% compare to the preceding period.

Spatial variation in long-term trends across the NWH states are studied by using Mann-Kendall test. Results show that, Annual rainfall of most parts of HP and some parts of UK is significantly decreased while that of J& K is significantly increased. Monsoon rainfall of most parts of the J&K and highly elevated parts of HP and UK is significantly increased while low elevated areas shows a significant decrease. Post-monsoon rainfall of UK is significantly decreased while winter rainfall of J&K shows a significant increase (fig 2)

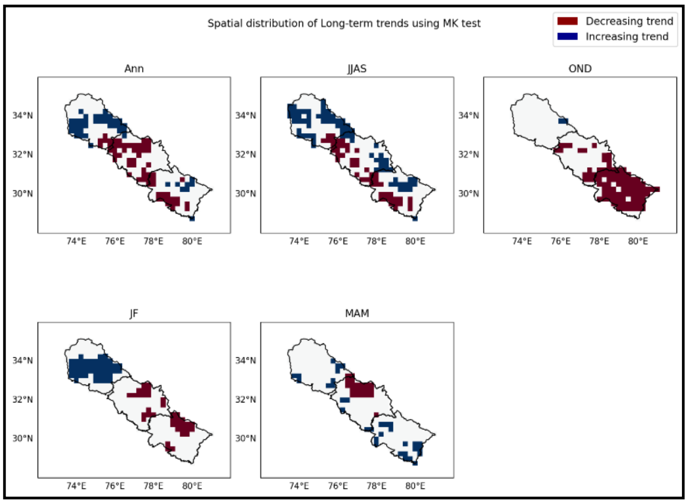


Fig 2 Spatial variation in long-term trend (tested using MK tests) in annual and seasonal rainfall across NW Himalaya during 1951-2021.

1.2 Identification of Large-scale ERE-RA and ERE-RW

The 1-to 10-day duration large-scale extreme rain events (EREs) are intended to quantify the severity of persisting intense rains over a particular area. An objective criterion has been developed to identify 1- to 25-day large-scale EREs concerning rainfall amount and rainwater (rainfall multiply by the area) for each year during 1951-2021 over NWH and three states. On daily basis, each grid is identified under wet condition if actual rainfall exceeds the daily mean monsoon rainfall (DMR) of the particular grid. The DMR is the daily mean rainfall during normal monsoon period over the grid taken as the threshold. On the grid scale, the DMR varies between less than 2mm/day to more than 18mm/day across NWH. The rainfall amount ERE-RA refers to annual maximum cumulative rainfall of wet grids for the duration 1- to 25-days. The ERE-RW refers to the total accumulated rainwater of wet grids for the duration of 1- to 25days. The procedure has been applied for each year of the period 1951–2021 to get the sequence of extreme rain events concerning rainfall amount (ERE-RA) and rainwater (ERE-RW) for 1–day to 25-days durations. The other parameters of the extremes like areal extent (AE) and date of start are also documented.

Climatological characteristics of ERE-RA and ERE-RW shows that, normally the rainfall amount of ERE-RA increases from 58.04 mm (±20.77) to 203.36mm (±36.54). Over UK it increases from 71.50mm (±31.70) to 148.14mm (±54.54); HP 57.05mm (±18.12) to 206.84mm (±42.47) and JK 58.58mm (±29.63) to 175.22mm (±46.26) respectively. The areal extent does not show much variations over the duration for all the three states. The percentage areal under wet condition is ~70% over UK and JK and ~57% over HP.

1.3 Long-term trends and recent changes in parameters of extremes

Inter-annual variations in parameters of EREs are studied using Mann-Kendall test. Results shows that, RA of large-scale 8- to 10-day ERE-RA of NWH show significant deceasing trend and rainwater of 1-day ERE-RW shows significant increasing trend tested using to Mann-Kendall test. Over UK, large-scale rainfall amount of ERE-RA does not any significant trend. Over JK, areal extent of ERE-RA of 1- to 6-days and rainwater of ERE-RW of 1- to 2-day shows significant increasing trend. Over HP rainfall amount of ERE-RA and rainwater of ERE-RW shows significant decrease for 3- to 10-days duration events (fig 3).

In recent 20 years over NWH, AE of 1- to 3-day ERE-RA and RW of 1-day ERE-RW has been increased significantly compare to preceding 51 years while no significant change is observed for rainfall amount. Over the UK state RA of 1- to 5-day ERE-RA and RW of 1- to 10-day ERE-RW has increased significantly. For HP state, significant decrease is observed for RA of 2- to 10-day ERE-RA and RW of 4- to 10-day ERE-RW. While over JK state, RA and AE of 1-day ERE-RA, AE of 4- to 7-day ERE-RA and RW of 1-day ERE-RW are increased significantly.

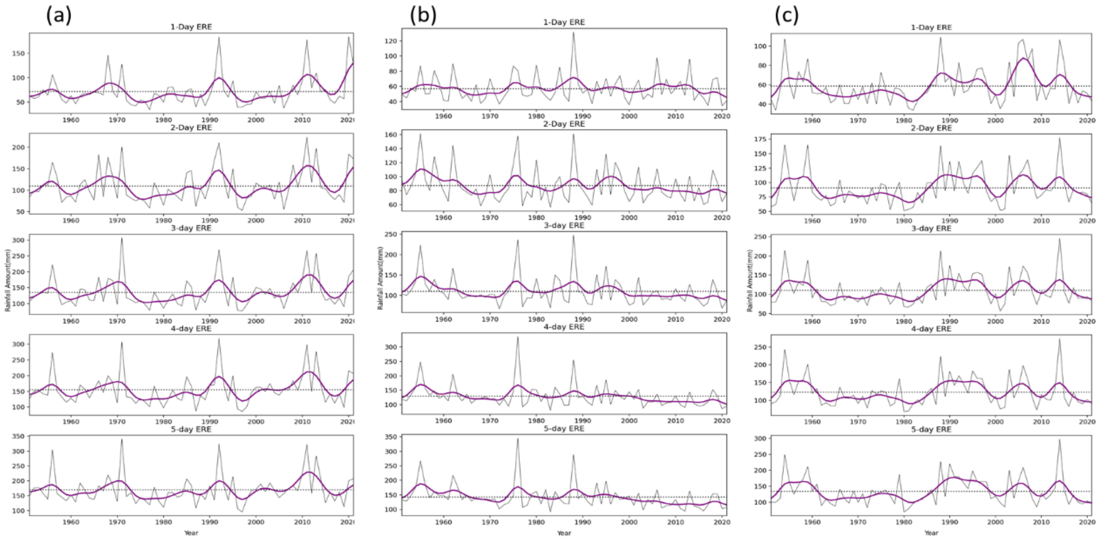


Fig.3 Interannual variations in rainfall amount of large-scale ERE-RA over a) UK b) HP and c) JK

1.4 Characteristics of Isolated Spatio-temporal EREs

Small-scale isolated extreme rain events exhibit large inter-annual spatial variability. To understand characteristics of these extremes an elaborate analysis of temporal and spatial variability of 0.25 deg grid scale EREs of 1- to 10-day duration has been carried out. The annual maximum rainfall series on grid scale for one day has been prepared during 1951-2021 by selecting year-wise highest rainfall amount for a particular grid. Similarly, annual maximum rainfall series for 2 to 10-day duration are also prepared.

The mean rainfall of 1-day ERE spatially varies from 50.3mm to 168.9mm across NWH states. For 10-day ERE, the rainfall varies from 121.23mm to 528.15mm. The spatial variation of highest experienced rainfall during the study period shows that, for 1-day ERE most extreme rainfall varies between 106mm and 762.9mm, while for 10-day most extreme ERE, the rainfall varies between 263mm to 1423mm. Most of the severe extreme rain events are observed to be occurred in Himachal Pradesh and Uttaranchal states.

1.5 Long-term trend in Isolated Spatio-temporal EREs

The spatial trend analysis using Mann-Kendal test show that the rainfall of 1-day ERE shows significant increase over major part of J&K and high elevated part of UK. However, most part of HP and some part of UK with lower elevation shows significant decrease in rainfall amount of long-period extremes ranging more than 2 days. Spatially coherent significant long-term trend is not seen in rainfall amount of 1- to 10-day ST-ERE across NWH.

1.6 Important Results:

1. The annual, monsoonal and other seasonal rainfall series of NWH are homogenous and random. No significant long-term trend is noticed in any of the series during 1951-2021. In recent 20 years (2001-2021), OND rainfall of NWH has decreased significantly by 25% compare to preceding 51 years record.
2. No significant long-term trend is observed in annual and monsoonal rainfall series of Uttarakhand, however OND rainfall shows significant decreasing long-term trend during 1951-2021. In recent 20 years, it has decreased significantly by 35%as compared to preceding 51 years record.
3. Significant decreasing long-term trend is observed in annual rainfall of Himachal Pradesh during 1951-2021, however other seasonal rainfall series are homogeneous and random. In recent 20 years, annual rainfall of HP decreased by ~13%, monsoon by ~8.5%, OND by ~33%, JF by 17% and MAM by ~17% respectively

4. Significant increasing long-term trend is observed in JF rainfall of Jammu and Kashmir during 1951-2021, however annual and other seasonal rainfall series are homogeneous and random. In recent 20 years, monsoon rainfall of JK increased by ~18% compare to preceding period.
5. Normally rainfall amount of large-scale ERE-RA of 1- to 10-day duration increases from 58mm to 203.36mm, over NWH, 71.5mm to 148.1mm over UK, 57mm to 206.8mm over HP and 58.5mm to 175.2mm over JK state.
6. During 1951-2021, over JK, AE of 1- to 6-days ERE-RA and RW of 1- to 2-day ERE-RW of shows significant increasing trend. Over HP, RA of 3- to 10-days ERE-RA and RW of 4-10 day ERE-RW shows significant decrease.
7. In recent 20 years compare to previous 51 years, RA of 1- to 5-day ERE-RA of UK increased by 10 to 23% while that of 1-day ERE-RA over JK by 16%. RA and AE of 2 -to 10-day ERE-RA over HP shows significant decrease by -10% -20 %.
8. In recent 20 years, the rainwater of 1-day ERE-RW over NWH increased significantly by 16%. Over UK the increase in RW of 1-10 day ERE varies from 14-34%. Over HP, the RW of 4-to 10-day ERE-RW shows decrease from 14-19%. Over JK state the RW of 1-day ERE-RW has increased significantly by 23%.

4.0 PROJECT CODE: NIH/C4S/2021-2024/DSB-1

Title of the Study:	Early Signatures of 21st Century on Snow Cover Dynamics in Zanskar River Basin, Ladakh.
Study Team:	Dr. DS Bisht, Scientist 'C' (PI) Dr. PG Jose, Scientist 'E' (Co-PI)
Type of Study:	R&D
Funding Agency:	Internal
Study Duration:	02 Years (2021 – 2024)

Objectives:

- To analyze the spatial distribution of snow cover extent in Zanskar River basin with respect to elevation, slope, and aspect
- To analyze the seasonal variability in snow cover extent in Zanskar River basin
- To investigate the impact of climate change on snow cover extent during 2001-2020

Study area: Zanskar River Basin, Ladakh

Methodology:

1. Spatial Analysis of Snow Cover Extent:

Analysis of snow cover extent in the Zanskar River basin, Ladakh, was conducted using remote sensing images obtained from MODIS datasets during 2001-2020. Topographic details derived from the SRTM DEM were integrated into the analysis to understand the relationship between snow cover extent and elevation, slope, and aspect.

2. Seasonal Variability Assessment:

The seasonal variability of snow cover extent was investigated across different hydrological years, as well as at monthly scale. Cloud cover data from MODIS images were used to filter out the imageries having cloudy pixels while analyzing the seasonal variability of snow cover.

3. Exploration of Climate-Cryosphere Linkages:

Given the limitations of IMD gridded data due to sparse weather observatory coverage in the Zanskar region, to explore climate-cryosphere linkages in the Zanskar River basin, air temperature data from ECMWF Reanalysis (ERA-5) was utilized. These products offer fine-scale climatic features over longer time periods, enhancing the robustness of the analysis. Trend and pattern of maximum, minimum and mean air temperature were studied employing non-parametric statistical tests.

Progress of Work

Sl. No	All Planned Activity as per original work plan	% Progress in the activity
1.	Literature Survey	100%
2.	Data collection & procurement	100%
3.	Data processing & analysis	80%
4.	Synthesis of report & publications	50%

Future work plan:

- Finalizing the climate data analysis.
- Report writing.

5.0 PROJECT CODE: NIH/C4S/2022-2024/DSB-2

Title of the Study:	Comparative Analysis of Fine Scale Satellite & Reanalysis Precipitation Products in Upper Ganga Basin using Multicriterion Decision-Making.
Study Team:	Dr. DS Bisht, Scientist 'C' (PI) Dr. MK Goel, Scientist 'G' (Co-PI)
Type of Study:	R&D
Funding Agency:	Internal
Study Duration:	02 Years (2022 – 2024)

Objectives:

- To perform statistical evaluation of fine scale satellite and reanalysis precipitation products in Upper Ganga Basin vis-à-vis station records.
- To carry-out performance ranking of fine scale satellite and reanalysis precipitation product in Upper Ganga Basin using Multicriterion Decision-Making and Group Decision-Making.

Methodology:

1. Data procurement and processing:

Fine-scale precipitation products were acquired from IMDAA and ERA5 reanalysis product and IMERG GPE estimates. Processed station precipitation data from 19 IMD stations and 11 CWC stations, as documented in a recently completed technical report by NMHS, were utilized.

2. Statistical evaluation:

Monthly statistical evaluation of different gridded products against station records were conducted using appropriate performance indicators i.e., Percent bias (Pbias), Pearson Correlation Coefficient (CC), Root-Mean-Squared-Error (RMSE), Nash-Sutcliff Efficiency (NSE). Analysis of light, moderate, and heavy precipitation events were performed based on threshold statistics, employing Probability of Detection and False Alarm Ratio.

3. Performance evaluation and rank integration:

Multi-Criteria Decision-Making (MCDM) techniques will be utilized in both deterministic and fuzzy scenarios to derive performance rankings. An entropy-based weight estimation technique will be employed to assess performance indicators. Additionally, the Group Decision-Making (GDM) technique will be applied to integrate ranks, yielding station-wise rankings for each gridded product.

Progress of Work

Sl. No	All Planned Activity as per original work plan	% Progress in the activity
1.	Literature Survey	100%
2.	Data processing & analysis	100%
3.	Statistical analysis and performance evaluation	70%
4.	Synthesis of report & publications	50%

Future work plan:

- Finalizing the statistical analysis
- Report writing.

6.0 PROJECT CODE: NIH/C4S/2022-2025/SSR-*1*

Title of the Study:	Ascertaining the Efficacy of use of state of the art technologies for Spring Mapping and Sustainability of Springs through Suitable Interventions
Study Team:	S S Rawat (P.I.), Sudhir Kumar, Santosh M. Pingale, P K Mishra, D. S. Bisht and Rajesh Singh
Collaborating agencies:	Central Ground Water Board (CGWB)
Type of Study:	Internal
Duration of Study:	03 Years (July 2022 to June 2025)

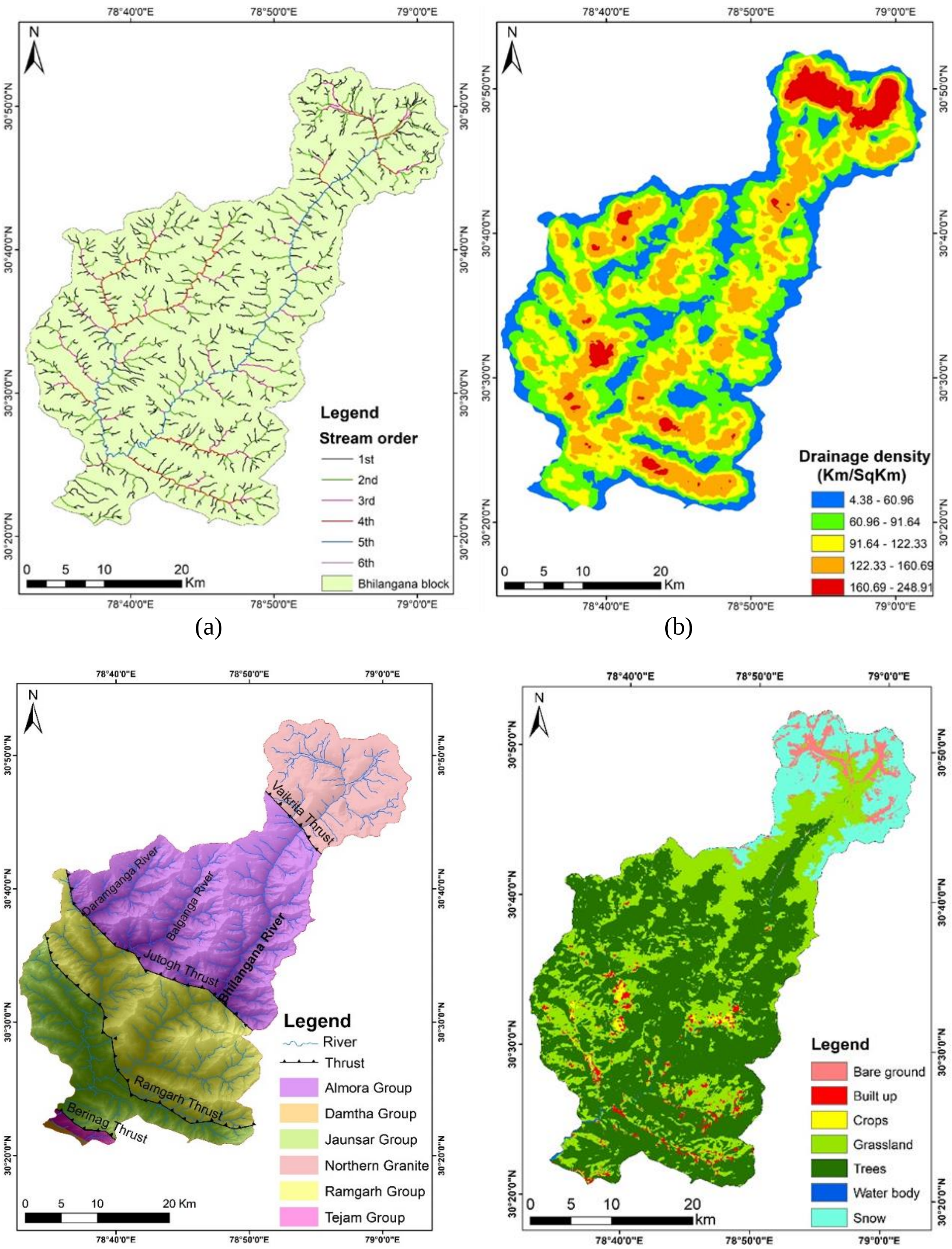
Study Area: The present study is being carried out in Bhilangana and Pratapnagar CD blocks of Tehri Garhwal district and Ukhimath CD block of Rudraprayag district of Uttarakhand state of India

Objectives:

i. To physically validate the springs identified by SOI using state of the art technologies in Bhilangana and Pratapnagar CD blocks of Tehri Garhwal district and Ukhimath CD block of Rudraprayag district,
ii. To create web-based spring database & its regular updation,
iii. To conduct water quality analysis of the surveyed springs to understand the qualitative status of the springs in the area,
iv. To identify the vulnerable springs which needs to be revived, and
v. To develop the capacity of local stakeholders and implementing agencies for effective development and management of springshed programme.

Progress:

i. Various thematic maps i.e., drainage, drainage density maps, geological map, Landuse Land cover map etc. were prepared using SRTM DEM (spatial resolution of 30 m), published data of CGWB and ESRI Sentinal-2 data (spatial resolution of 10m) (Fig.1).
ii. 06 field excursions were carried out by the project team during February to November, 2023 for verification of the spring locations given by SoI and mapping of other springs which could not be mapped by the SoI.
iii. A total of 134 springs were geotagged (Fig. 2) using KoBo Toolbox and 123 spring samples for detailed water quality and isotopic analysis were collected during the field visits. Measurement of physiochemical parameters i.e., pH, temperature, DO, ORP and EC were measured onsite. Details of the spring surveyed as per field investigations are given in Table 1
iv. In the total surveyed springs of Bhilangana block, 26.4% springs (23 no.) are safe, 31% springs (23 no.) are at low risk, 25 springs (29%) at moderate risk and 12 springs (14%) are at high risk as per WHO drinking water risk assessment guidelines. Therefore, springs of the Bhilangana block are needed to be monitored regularly for various geochemical and pathogens related aspects.



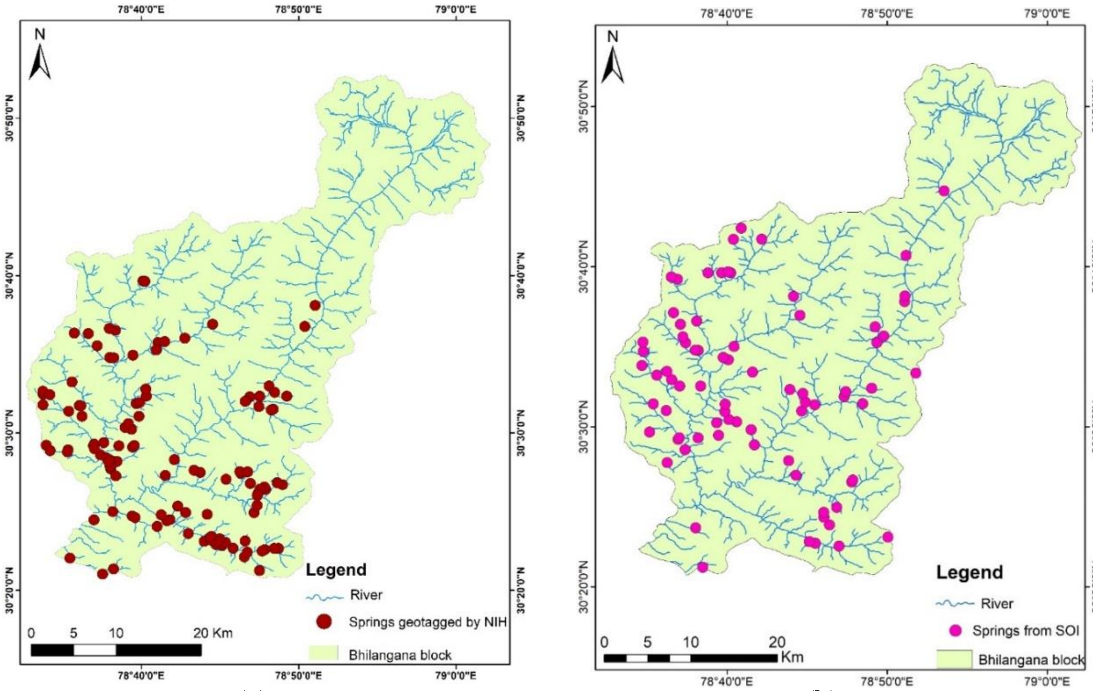
(c)
(d)

Figure 1: Various map such as (a) drainage; (b) drainage density; (c) geology, and (d) land use land cover map of Bhilangana block, Tehri Garhwal, Uttarakhand.

Table 1: Showing the details of spring data as per field investigations.

S No.	Dataset	No. of springs
2	Spring locations given by SOI	76
3	Spring locations geotagged by NIH	134
4	New springs identified	66

6	Springs found on SoI location	30 (±100m)
7	Springs in inaccessible regions	28
8	Springs not found at locations of SOI	12



(a) (b)

Figure 2: Maps showing the spring locations (a) geotagged by NIH and (b) given by SOI in Bhilangana block, Tehri Garhwal, Uttarakhand.

Future Plan:

i. Water quality of the surveyed springs will be analyze4d in detail for understanding the detailed qualitative status of the springs in the area.

ii. The collected data and analysed hydro-geo-chemical and isotopic data will be investigated to understand the occurrence of the springs in the area.

iii. This work will be extended for Pratapnagar CD blocks of Tehri Garhwal district and Ukhimath CD block of Rudraprayag district.

7.0 PROJECT CODE: NIH/C4S/2023-2026/*SSR-2*

Title of the Study: Geo-Hydro-Chemical and Isotopic aspects of occurrence of Springs: A Case Study from the major settlement areas of Bhagirathi Basin, Uttarakhand, India

Study Team: S S Rawat (P.I.), Suhas Khobragade, M K Sharma, Dr M S Rao, Dr. Santosh M. Pingale, P K Mishra,

Collaborating agencies: HNB Central University, Srinagar, Garhwal
Type of Study: Internal
Duration of Study: 03 Years (April 2023 to March 2026)

Study Area: The study focuses on the springs in the major settlements within the Bhagirathi Basin in Uttarakhand, India.

1. Objectives:

a) To characterize the identified springs based on their hydro-geochemical and isotopic characteristics.
b) To understand the geological control and its impact on the occurrence of springs
c) To carry out the vulnerability analysis of springs in the study area, and
d) To identify the major recharge sources of springs through isotopic analysis.

2. Progress in brief:

i. A comprehensive field survey was conducted, resulting in the identification and geotagging of 111 springs (Fig. 1). During this survey, meticulous records of on-site physiochemical parameters were maintained, and water samples were systematically collected. These samples undergo thorough laboratory analysis to delve into water quality and isotopic characteristics.
ii. As part of the study, various base maps, including a Geological map and a Land Use Land Cover map have been prepared. These maps serve as essential tools to better understand the geological context and land utilization patterns within the study area.
iii. An extensive classification of springs was undertaken, based on the characteristics of pH levels, electrical conductivity, discharge, Geology and Land Use Land Cover characteristics.
iv. The major ions were analyzed the concentrations of major ions in 25 samples, encompassing fluoride, chloride, nitrite, sulfate, bromide, nitrate, phosphate, lithium, sodium, ammonium, potassium, magnesium, and calcium.

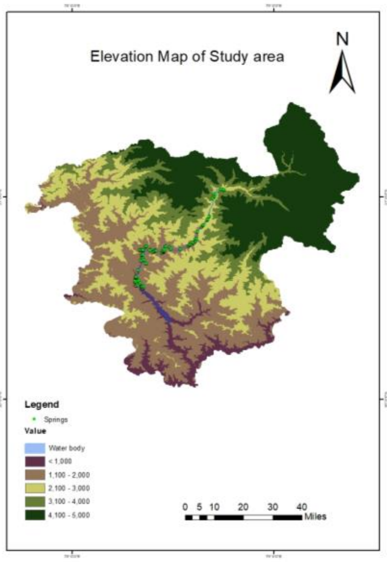


Fig. 1: Location Map of study Area.

v. Stable isotopic data, including $\delta^{18}O$, $\delta^{2}H$, and d-excess, were obtained for 17 spring samples, offering insights into water sources and evaporation effects.

vi. Springs B-SP-01, B-SP-02, B-SP-03, B-SP-04, B-SP-05, B-SP-06, B-SP-07, B-SP-08, B-SP-09, B-SP-10, B-SP-11, B-SP-13 are generally exhibit higher $\delta^{18}O$ and $\delta^{2}H$ values, suggesting a meteoric origin influenced by precipitation.

vii. Springs B-SP-14, B-SP-15, B-SP-16, B-SP-17 have lower $\delta^{18}O$ and $\delta^{2}H$ values compared to meteoric samples, along with higher d-excess values. This may indicate potential evaporation or modification of isotopic composition due to local processes.

viii. Springs B-SP-12 sample stands out with exceptionally high values for both δ18O and δ2H. Further investigation is needed to understand the specific geological or hydrological conditions contributing to this unique isotopic signature.

ix. Various rock types such as Gneiss, Quartzite, and Mica Schist were identified as contributors to the hydrochemical diversity observed in the springs.

Future Work:

i. To enhance the study's depth, additional isotopic studies and more detailed geological and geochemical investigations are needed. These would provide a comprehensive understanding of the geological controls influencing water composition.

ii. There is a need for integrated hydrogeological studies to map subsurface flow paths, identify recharge areas, and pinpoint potential contaminant sources affecting the springs.

iii. Acknowledging the crucial role of community participation, engaging with local communities to raise awareness about sustainable water management practices and mitigate anthropogenic impacts on water quality.

B. Sponsored R & D Studies

8.0 PROJECT CODE: *SP-54*

Title of the Study:	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar subbasins in the state of Mizoram
Study Team:	Dr. Vishal Singh
Type of Study:	Sponsored PDS under NHP
Funding Agency:	NHP
Study Duration:	2.5 Years
Budget:	Rs. 25.23 lakhs

Objectives:

The major objective of this study is to apply the advance modeling framework for Barak, Minor rivers draining into Bangladesh (MRD-BAN) and Minor rivers draining into Myanmar (MRD-MYA) subbasins in the state of Mizoram for water security plan. This will generate useful base data to help development of proper water management strategies and decision processes. The major objectives of the study are as follows:

a. To collect, prepare and evaluate various thematic datasets such as digital elevation model, land use/Land cover (LULC) map, soil map, population data (census) and hydro-meteorological data-sets such as precipitation, temperature, discharge etc.

b. Long-term Rainfall trend analysis based on rainfall frequencies and intensities to analyse the effect of climate change as per the standard guidelines.

c. Hydrological modelling, calibration and parameterization over Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar subbasins in the state of Mizoram for the assessment of watershed components (including surface and groundwater) and water availability using SWAT and SWATCUP models (Arnold et al., 2012).

d. Analyzing the effect of LULC changes on the hydrological scenarios such as water availability (or water yield) at sub-catchments scale and discharge at the outlets.

e. Analyzing the effect of climate changes on the hydrological systems, with possible thresholds for resilience under different conditions and combinations anticipated.

f. To setup WEAP model (Levite et al., 2003) for calculating water demand of Mizoram state subject to mid-term water availability (say up to 2050) to increase water use efficiency and maintaining the adequate water supply sustainable development.

g. To prepare the detailed report for study basins/sub-basins in Mizoram state as per the mid-term hydrological assessment with the guidelines of water security plan with particular reference to demand points (domestic, irrigation or others) identified by the Water Resources Department, Government of Mizoram.

h. To impart training on “hydrological modelling” to the state officials of Water Resources, Agricultural and other related Depts, as well as officers from other implementing agencies of the National Hydrology Project.

i. Selection of dam sites with suggested capacity to meet the growing demand of water in the state.

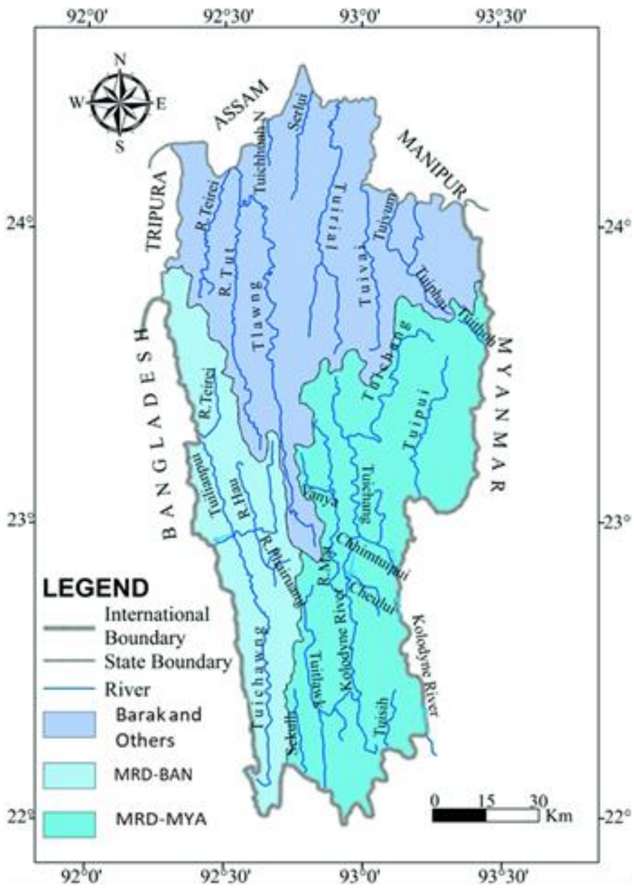


Figure 1: River basin map of the Mizoram showing river basins namely Barak and Other, Minor rivers draining into Bangladesh (MRD-BAN) and Minor rivers draining into Myanmar (MRD-MYA).

Progress of Work

The progress is given below:

Sr. no	All Planned Activity as per original work plan in approved PDS	Cumulative % Progress in the activity in this quarter	Comments / details of activities
1.	Hiring Manpower: JRF	100%	The JRF has been recruited.
2.	Nomination of Nodal-cum-Liasioning Officer from WRD Nagaland	100%	Chief Engineer cum Nodal Officer (NHP), WRD Nagaland has been approached to nominate a Nodal-cum-Liasioning Offier for smooth conduct of the study. SE K. Hamlet and AE Vanlalpekhlua Sailo have been nominated for the same.
3.	Collection and Processing of Thematic and Meteorological Datasets	100%	Done. A new Gridded Hybrid Rainfall datasets have been generated.
4.	Quality Check and Bias Correction of Hydro-meteorological datasets	100%	Done
5.	Development of SWAT model	100%	Model setup has been done. Model improvements, Calibration and Validation have been done and all watershed components

Sr. no	All Planned Activity as per original work plan in approved PDS	Cumulative % Progress in the activity in this quarter	Comments / details of activities
			have been generated for the historical and future times using CMIP6 climate model datasets
6.	Calibration and Validation	100%	A manual calibration has been done at 4 gauges as per the available observed Q and then the final results have been generated.
7.	Processing of Climate Model datasets	100%	For this study, the latest climate model datasets by Coupled Modelled Inter-comparison Projects (CMIP) under World Climate Research Programme (WCRP) named Coupled Modelled Inter-comparison Project Phase 6 (CMIP6) have been utilized. Initially 13 models, and each model includes five scenarios (historical, SSP1-2.6, SSP2-4.5, SSP3-7.0, and SSP5-8.5) were taken. After the Uncertainty Assessment of the Climate Models w.r.t. Observed Rainfall, four climate models viz. ACCESS ESM 1-5; BCC-CSM2-MR; EC-Earth3 and MRI-ESM2-0 considering three scenarios each (e.g. historical, SSP2-4.5, SSP5-8.5) have been selected for the final analysis. Bias correction of the selected model was done using Quantile Mapping method.
8.	Rainfall analysis	100%	For this purpose, the bias corrected climate model datasets were divided into two terms viz. near term (2020-2050) and far term (2060-2090) and for each category annual average and climate indices were calculated as per the guidelines of IPCC. Climate indices considered here are: Dry days: if rainfall is <2.5 mm/day Wet days: if rainfall is >2.5 mm/day Dry spell frequency: if rainfall is <2.5mm/day for a continuous 5 days Wet spell frequency: if rainfall is >2.5mm/day for a continuous 5 days Maximum 1-day precipitation per year (Rx1D): maximum precipitation in a day WDx95: Number of wet days with daily precipitation over a 95 percentile

Sr. no	All Planned Activity as per original work plan in approved PDS	Cumulative % Progress in the activity in this quarter	Comments / details of activities
9.	LULC Change Analysis	100%	Predicted LULC maps have been developed and their effects on hydrology has been analyzed using the SWAT model. LULC maps of different years viz. 2020, 2050 and 2090 have been generated and the effect of changes as notified in LULC has been analyzed on the hydrology of the region.
10.	Water Availability and Demand	100%	For the water availability and demand analysis WEAP model has been setup and simulation has been done. The water availability and demand under different LULC change conditions and Climate change conditions (through CMIP6 multi-model scenarios) have been done. The water availability and demand scenarios have been computed at Block and District level.
11.	Climate resilience analysis	50%	Using Budyko framework, the water demand and deficit areas are being analyzed at district and subbasin scale. The water availability surplus and deficit areas are computed.
12	Article and Report Writing	50%	One article based on rainfall data analysis, changes and trends are under review in water and climate journal. Second article and report writing works are under process.

9.0 PROJECT CODE: SP65/2023-26/NIH(CHD)

Title of the Study:	Assessment of glacier-climate functional relationships across the Indian Himalayan region through long-term network observations
Study Team:	Dr Vishal Singh, Scientist 'D' (Lead Co-PI, NIH Roorkee)
Type of Study:	SPONSERED RESEARCH PROJECT
Funding Agency:	GBPNIHE
Study Duration:	03 Years (2023 – 2026)

Objectives:

- Assessment of glacial dynamics, changes in the glacial morphometry and mass balance using space-based resources and field measurement
- Identifying changes in the glacier hydrodynamics and glacier melt-water chemistry using in-situ observations
- Investigating glacial mass balance as a response to changing climatic parameters using functional relationships through real-time and memory-based networks for understanding the glacial-climate functional relationships.

Methodology:

1. Data assimilation and bias correction

For meteorological datasets, a high resolution gridded daily precipitation dataset (0.05º×0.05º) will be constructed for the historical time by assimilating IMD precipitation, TRMM based precipitation, GPM based precipitation and CHIRP precipitation datasets as per their availability. The bias correction will be done using advanced bias correction methods (such as Quantile mapping, Linear scaling etc.) (Singh and Xiaosheng, 2019).

2. Integrated Hydrologic Modelling:

The Soil and Water Assessment Tool (SWAT) and SPHY model, will be used for the estimation of snowmelt and glacier runoff over the selected Himalayan River basin such i.e. Kali River basin, Uttarakhand, India.

3. Snow and Glacier runoff changes

For snow-covered areas (SCAs) and glacier mapping, MODIS, LISS 3, LISS 4, and Sentinel satellite sensors data will be utilized. For snow cover extraction Normalized Difference Snow Index (NDSI) based on cloud removal technique will be utilized as previously used by various researchers. For the computation of snow and glacier melt a variable degree day factors based Temperature index model will be applied.

4. Validation of Satellite-based Snow Covers with SPHY model derive Snow Covers and Model calibration

Various satellite-sensor based remote sensing products MODIS will be used to validate the SPHY derived snow covers. A detail calibration will be performed to calibrate/validate the SWAT derived stream flows at the available gauges.

Progress of Work

Quantifiable Deliverables (As per the sanction letter)	Monitoring indicators (As per the sanction letter)	Progress made against deliverables in terms of monitoring indicators	Attach the Annexure separately with other supportive documents i.e. PDF, Excel, JPG, TIFF, etc.
1	2	3	4
Glacier area, snow covered area, size and distribution	Glacier Mass balance analysis	Downloading and processing of glacier data for the Kali River basin	NA
Bias corrected meteorological datasets	Meteorological data processing	Processing & bias correction of time series data such as precipitation and temperature	NA
Hydrological water balance components	Hydrological analysis	Preparing data input layers to setup glacier snow hydrology model for the computation of water balance	NA

Work in Progress

Downloading of hydro-meteorological datasets and their pre-processing.

Downloading and processing of thematic datasets such DEM, LULC, Soil maps and other watershed parameters.

SPHY Model based simulation of various watershed components in the Kali river basin.

10.0 PROJECT CODE: *SP/*C4S/2023-2028/

Title of the Study:	Identification of source and causes of the Gushing Water in the premises of Jaypee Colony in the night of 02 January, 2023
Study Team:	Dr SS Rawat, Scientist-F Dr Gopal Krishan, Scientist-E Dr Rajesh Singh, Scientist-E Dr Santosh M Pingale, Scientist-D Dr JP Patra, Scientist-E
Collaborating agencies:	Uttarakhand State Disaster Management Authority (USDMA)
Type of Study:	USDMA sponsored
Duration of Study:	04 Months (January 2023 to April 2023)

Study Area: The study focuses on the subsidence area in the vicinity of Joshimath town of Chamoli district of Uttarakhand

1. Objectives:

i. To map drainage and springs in the study area
ii. To identify the sources of sub-surface water and seepage water

2. Methodology:

Delineation of Drainage Network of the Area

i. The drainage network of the region was delineated from the SOI toposheet no. 53N/10 (Fig. 1). Most of the streams originates from the NW-SE trending ridge Auli area and flows parallel to each other and joining the main river Alkananda almost *perpendicularly* and displays trellised drainage pattern. No drainage network was observed in Singhdhara, Manohar Bagh, Sunil Ward and JP Colony area in the toposheet (Fig. 1), which indicated the possibility of presence of subsurface channels, which normally dispose-off the water coming from the upper reaches (Auli areas).

ii. Mapping of Springs in the Joshimath Area

Total 16 nos. of springs have been identified in the vicinity of Joshimath during the field visits performed on 18 to 19 January, 2023. It was observed that most of the springs lie in the Western side of Joshimath i.e., Sunil Ward, Manohar Bagh, Singhdhar, Marwari and JP colony (Fig. 2). It is noticed that that most of the springs have been observed in the area of Subsidence (Fig. 2).

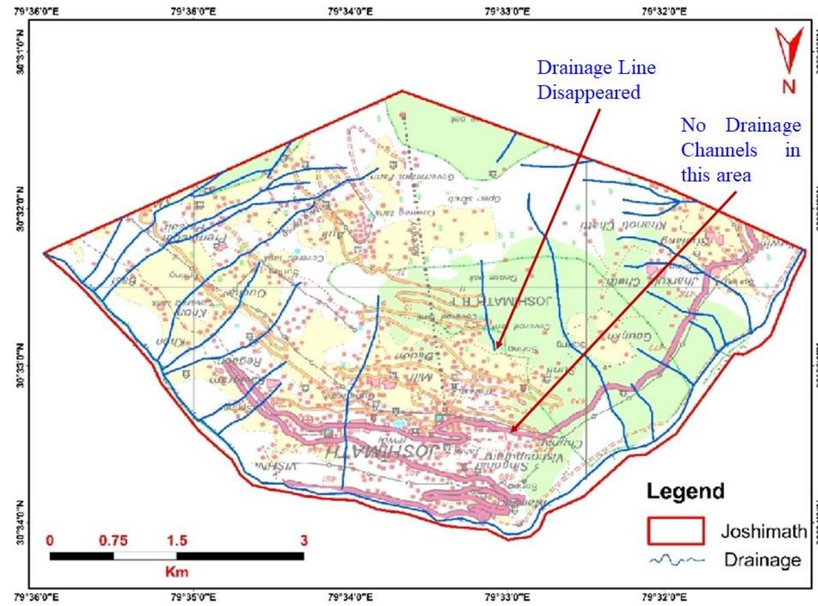


Fig. 1: Drainage network of the Joshimath area extracted from SoI toposheets

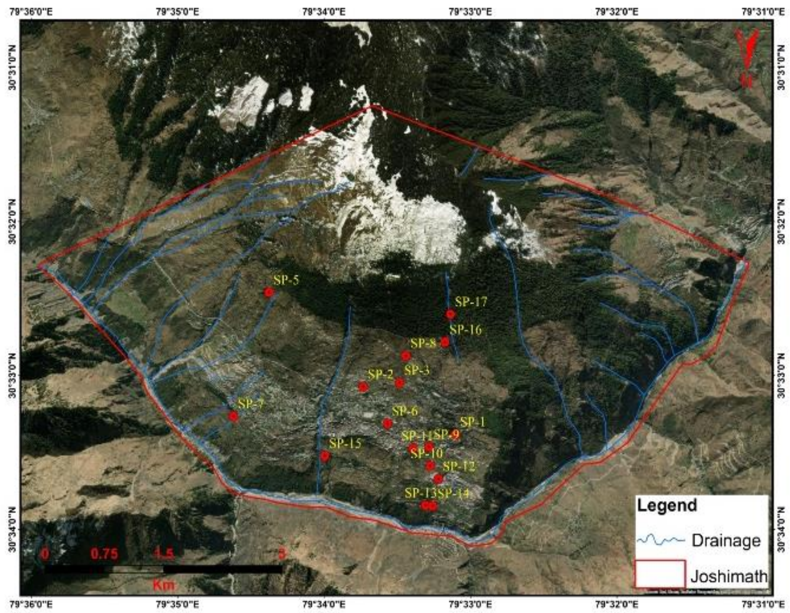


Fig. 2: Location of springs identified during field excursions

iii. Stable Isotope Analysis

A total of 40 samples (22 no. of samples collected from springs; 3 from hand pumps; 11 samples from drains; 5 samples from NTPC sites) were collected from Joshimath area in 3 field visits and analyzed for stable isotopes. Stable isotopes (δD and $\delta^{18}O$) in water were analyzed using GV-Isoprime Dual-Inlet Isotope Ratio Mass Spectrometer (DI-IRMS) with precision of measurement for δD is ± 1‰ and that for $\delta^{18}O$ is ± 0.1‰. The results of these samples are presented in Fig 3. Based on the analysis results, the recharge sources were identified.

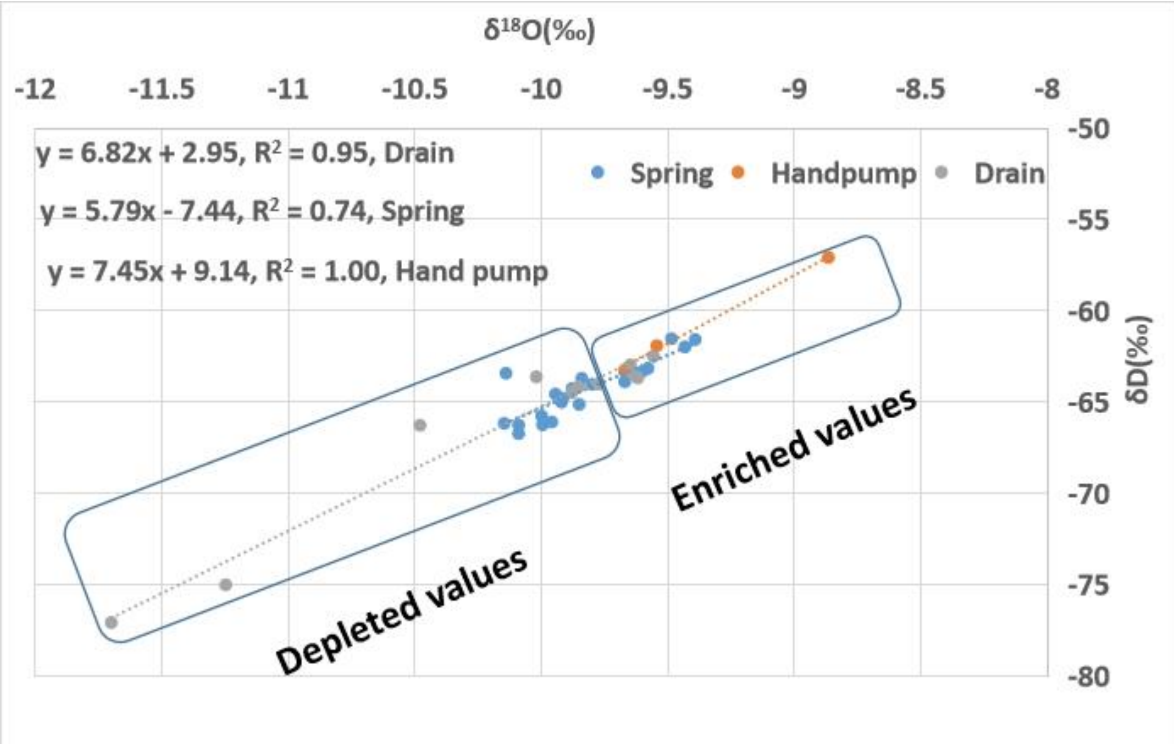


Fig. 3: $\delta^{18}O$ v/s δD for the samples collected during the field visit.

iv. Hierarchical Cluster Analysis (HCA) of Hydrochemical Data

To improve the understanding of the geochemical characteristics of the study area and to identify the source of the new spring that appeared near JP company, the hierarchical cluster analysis of 11 water quality parameters was performed using Ward's method. HCA analysis classified the water samples of the study area into five distinct groups, namely Cluster 1, 2,3 4, and 5 (Fig. 4). of water in the new spring appeared near JP company is in Cluster 1: Spring and is not linked to the water in the NTPC tunnel.

SITES	SITE NAME	SITES	SITE NAME
1	NTPC (inlet)	20	Above JPVL
2	NTPC (outlet)	21	Singhdhara Gopaldhar
3	JP company	22	JP Site
4	Below Jangal Gate	23	Marwari-1
5	Jyotirmath-53	24	Marwari-2
6	Near Swadeshi Dhaba	25	Kamed
7	Sunil Dhara (47)-2	26	Sunil Forest
8	JP Site	27	JP Nala
9	Marwari-1	28	Dawil/Dadon
10	JP Nala	29	Sunil Dhara (48)-3
11	Vishnuprayag	30	Parsari
12	Below Jangal Gate	31	Jogidhara
13	Dadon	32	Kamed
14	Sunil Dhara (46)-1	33	Kamed Nala-2
15	Manoti	34	Manoti
16	Jyotirmath-53	35	Mandir, Marwari
17	Near Swadeshi Dhaba	36	O Bend Petrol Pump
18	Sunil Dhara (47)-2	37	Sunil
19	Singhdhara		

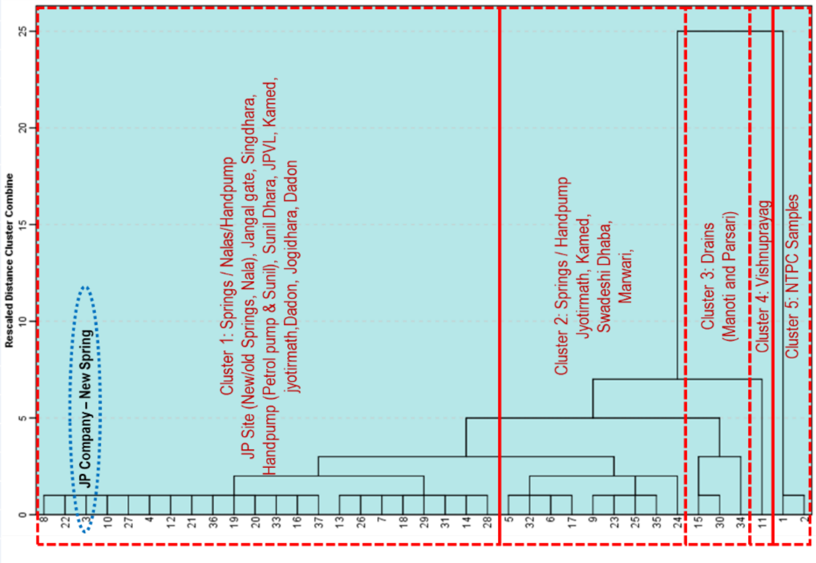


Fig. 4: Hierarchical Cluster Analysis (HCA) of Samples

3. Conclusion

Various spring, drainage network, areas of subsidence maps infer that land subsidence and subsurface water in the Joshimath area may have some connections. The Western part of the Joshimath has numerous springs which indicates good subsurface storage and transmitting capacities. Unfortunately, the topography (cascade of flat and steep terrain from top to bottom) and geological setting (presence of thick layers of galacio-fluvial and non-cohesive materials) of this part is in such a way which creates unfavorable condition for the development of permanent surface channels to dispose-off the water coming from upper reaches. Therefore, water moves in shallow subsurface channel (disappeared Channel shown in SoI toposheet) from upper reaches (after Sunil forest) to the lower reaches of the mountain and these channels also feed some springs in the area. The isotopic analysis also suggested that the origin of the gush water in Jaypee colony is from the upper reaches (Sunil forest and Auli area). Further, the gush water, local springs and drains fall in a similar cluster as per Hierarchical Cluster Analysis (HCA) of hydrochemical data. It also indicated the origin of springs and gush water in Jaypee colony is same i.e., from Sunil forest and Auli area. The isotopic and water quality signature of the samples taken from NTPC sites differs from the JP site as well as drains and springs in the nearby area of Joshimath. The bacteriological analysis also suggested that the gush water is fresh water and not contaminated by the local drains.

NEW STUDIES PROPOSED FOR THE YEAR 2024-25

11.0 PROJECT CODE: NIH/C4S/2024-2027/SG

Title of the Project:	Assessment of Hydrological Extremes and Impact on Future Water Availability in Pennar River Basin under Changing Climate.
Project Team:	Dr. Sunil Gurrapu, Sc. 'D' (PI), NIH Roorkee Dr. Surjeet Singh, Sc. 'G', NIH Roorkee Dr. Vishal Singh, Sc. 'D', NIH Roorkee Dr. Y R S Rao, Sc. 'G', DRC Kakinada Mr. R Venkata Ramana, Sc. 'E', DRC Kakinada Mr. Madhusudan Thapliyal, SRA, NIH Roorkee Mr. T V N A R Kumar, Chief Engineer, WRD, Govt. of AP
Type of Study:	Internal
Status:	New
Study Period:	1st April 2024 - 31st March 2027 (Three Years)

STATEMENT OF PROBLEM:
Historically observed changes in climate across the globe is altering the hydroclimatic and hydrological systems, which eventually is leading to the changes in the characteristics of hydrological extremes. In addition to the changing climate, the hydrological dynamics of a basin are affected by the changes in catchment characteristics and river flow regime, caused by the land-use/land-cover changes from anthropogenic activities. In brief, the on-going changes in the global climate and the anthropogenic effects on regional/local climate would trigger imbalance in the hydrological systems and eventually result in disproportionate changes in the hydrological extremes. For example, Pennar River basin witnessed extreme flooding during the years 2021 and 2022 leading to a destruction of various water resources infrastructure in the basin. This magnitude of flooding is unprecedented in the basin and in contrast the basin is frequently hit by drought because of the location in the rain shadow region of Eastern Ghats.

Pennar River Basin is located in the Peninsular India extends over the states of Andhra Pradesh (≈ 48,276 km^2) and Karnataka (≈ 6,937 km^2) with a total basin area of approximately 55,213 km^2. The basin lies between 13° 18´ to 15° 49´ N latitudes and 77° 1´ to 80° 10´ E longitudes, Figure 1. The river rises from the Chenna Kesava hills of the Nandi Ranges in Karnataka and flows about 597 km before draining in to the Bay of Bengal. The basin lies mostly in the rain shadow region of the Eastern Ghats, the zone of poor rainfall, and hence is frequently hit by drought. Drought is common during dry season (October – May) because of the scarce rainfall and can lead to water scarcity, reduced agricultural productivity and depletion groundwater resources. The annual mean rainfall received in the basin ranges between 400 mm (near Rayalaseema region) and 1200 mm (near coastal plains). Heavy rainfall in the upper reaches of the basin can lead to flash floods because of the steep terrain and results in inundation of low-lying areas. In addition, the rainfall and streamflow in the basin is shown to be significantly influenced by the large-scale climate phenomenon including Indian Ocean Dipole (IOD) and El Nino Southern Oscillation (ENSO). Moreover, the changing climate and the anthropogenic expansion in the basin are expected to further intensify hydrological extremes in the basin. Projections of climate in the 21st century indicate an increase in the frequency and intensity of precipitation events suggesting more frequent floods. These projections also indicate changes in precipitation patterns and increased evapotranspiration, which could intensify drought conditions in the basin.

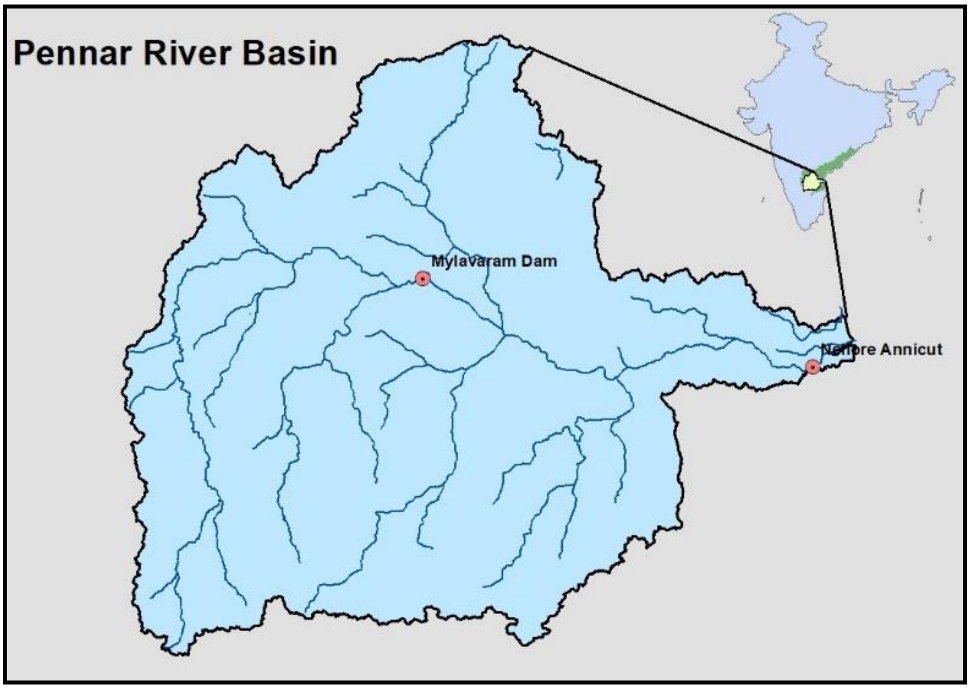


Figure 1. Location of the Pennar River Basin

The 2021 and 2022 floods have alerted the water resources department (WRD) of the Government of Andhra Pradesh to evaluate the impacts of climate change on the basin hydrology and hydrological extremes of Pennar River Basin. In response, we have taken up a study earlier on "Climate Change Scenarios for Andhra Pradesh and its Impact on streamflow and groundwater levels in Pennar River Basin" to generate multi-model climate change scenarios for the state of Andhra Pradesh and develop a VIC hydrological model for the Pennar River Basin. A VIC hydrological model at 0.05˚ resolution and hydrological scenarios were generated based on the projected climate from the 10 selected Global Climate Models (GCMs). In this study, in continuation with the previous study it is proposed to conduct a detailed assessment of hydrological extremes and the impact on future water availability in the Pennar River Basin under changing climate. Water availability assessment will be based on the hydrological scenarios generated by the VIC hydrological model developed for Pennar River Basin in the earlier study. Annual peak streamflow and the drought indices computed using projected precipitation and temperature datasets will be evaluated for the assessment of hydrological extremes.

OBJECTIVES:

1. Evaluation of historical records and model simulated hydrological scenarios to identify hydrological extremes in the basin and assess their characteristics viz. severity, frequency, duration, spatial extent, etc.
2. Use the suite of HEC tools for flood hazard assessment and flood inundation mapping based on the hydrological scenarios generated by the VIC model.
3. Assessment of water availability in the basin based on the projected scenarios of precipitation, streamflow, and evapotranspiration.
4. Drought risk assessment under changing climate using several drought indices including Precipitation Percentiles, Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index (SPEI), Standardized Runoff Index (SRI), etc.
5. Generate future climate scenarios of hydrological extremes using machine learning tools and quantify the uncertainties associated with the climate and hydrologic models.

METHODOLOGY:

- Statistical tools will be used to evaluate flood and drought characteristics, viz. intensity, frequency, duration, etc. In specific, historically observed time series of annual peak streamflow and drought indices based on climatic variables will be analysed for trend and variability patterns. So, Modified Mann-Kendall trend test and of other techniques of time series analysis will be adopted.

- A suite of HEC tools will be adopted for data management, flood hazard assessment, and flood zone mapping. In specific HEC-DSSVue will be used for organization and management of datasets for modelling, HEC-HMS will be used for Flood Hazard Assessment and HEC-RAS will be used for Flood Zone Mapping. These HEC tools are available for free provided by the U.S. Army Corps of Engineers.
- R scripts will be created to computed drought indices and other required indices in order to evaluate the temporal and spatial variability of drought across Pennar basin.
- Machine learning tools will be adopted to generate a set of future scenarios of hydrological extremes based on the hydrological scenarios generated by the VIC model of Pennar River basin developed in the earlier study. Uncertainty associated with the climate models and hydrological models will also be evaluated and quantified using machine learning techniques.
- Water availability in the basin will be assessed using the projected scenarios of precipitation, streamflow, evapotranspiration, and other water balance components. In addition, regular interactions will be held with the concerned professionals from WRD, irrigation department, NHPC, and other stake holders.

TIME SCHEDULE

Work Proposed	**Year 1**				**Year 2**				**Year 3**			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Mobilization of work Team	■											
Literature Review	■	■	■									
Field Visit & Interaction with Beneficiaries		■										
Data Collection	■	■	■	■								
Evaluation for flood & drought characteristics		■	■	■								
First Interim Report				■								
Flood hazard assessment				■	■	■						
Field Visit					■							
Flood zone mapping					■	■	■	■				
Second Interim Report								■				
Drought Risk Assessment							■	■				
Future scenarios & uncertainty assessment								■	■	■		
Water availability assessment										■	■	
Preparation & submission of final report											■	■

BUDGET ESTIMATE

S. No.	Sub-Head	Year I	Year I	Year I	Total
1.	Manpower	4,80,000	4,80,000	4,80,000	14,40,000
2.	Travel Expenditure	1,00,000	1,00,000	1,00,000	3,00,000
3.	Purchase of data and/or experimental charges	1,00,000	1,00,000	1,00,000	3,00,000
4.	Misc. Expenditure	50,000	50,000	50,000	1,50,000
	Grand Total	**7,30,000**	**7,30,000**	**7,30,000**	**21,90,000**

Deliverables: Report and Journal Publications, Flood inundation maps, Drought scenarios of the basin, comprehensive report on water availability.

End Users / Beneficiaries: Water Resources Department, Govt. of Andhra Pradesh, Irrigation Department, NHPC, Academicians, etc.

12.0 PROJECT CODE: NIH/C4S/2024-2027/KS

Title of the Study : WRF-based dynamical downscaling of CMIP6 climate projections over Himalaya and surrounding Region

Study Group : Dr Kuldeep Sharma (PI), Scientist-C
Ashwini Ranade (Co-PI), Scientist D
Sahidul Islam (Co-PI), Assoc. Director, CDAC, Pune

Date of Start : 1st April, 2024

Scheduled Date of Completion: 31st March, 2027

Duration of the Study : Three years

Type of Study : Internal

Nature of Study : Planning

Location Map : India

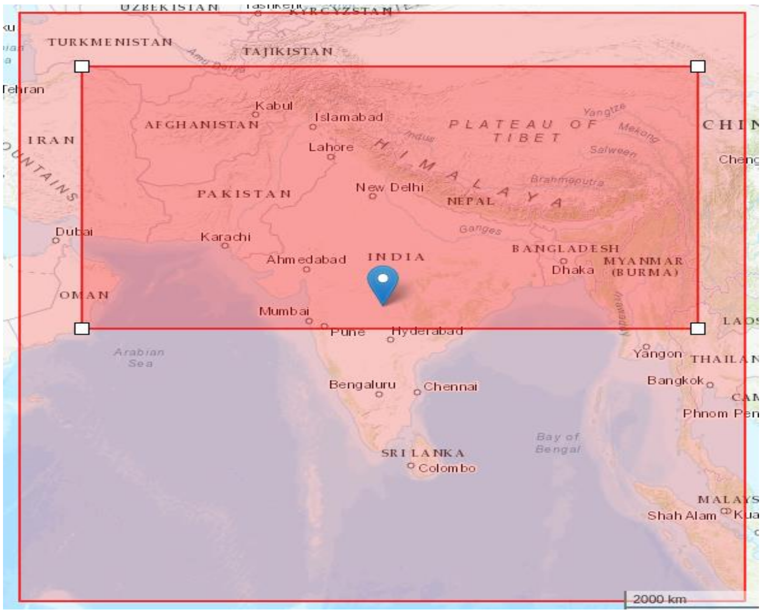


Figure 1 Domain used in the present Study

In recent decades, more frequent and intense extreme weather events have been experienced worldwide. There is a need for detailed climate information to aid in risk assessment and climate adaptation and mitigation strategies. Global climate models, such as those in the Coupled Model Intercomparison Project Phase 6 (CMIP6), typically have a grid spacing of 100–150 km, which is insufficient for capturing regional climate variability. Some high-resolution models in the High Resolution Model Intercomparison Project offer better resolution (25-50 km), but at the cost of smaller ensemble sizes and shorter simulations. To address this, researchers have developed statistical and dynamical methods to downscale global simulations to higher resolutions (4–50 km) for various regions. These methods have been comparatively studied to improve methodologies and provide uncertainty data for downscaled climate predictions. However, few studies have systematically compared these downscaling approaches under a uniform protocol. Dynamical downscaling involves high-resolution numerical simulations within a limited area, using global model outputs for boundary conditions.

The primary objective of this work is to produce a regional climate dataset by dynamical downscaling using Weather Research and Forecasting Model as Regional Climate Model (RCM) over India with a special focus on Himalayas to study the impact of climate change on severe weather events as well as other natural hazards such as landslides and Glacier Lake Outburst Flood (GLOF) etc.

Study Objectives:

Keeping in view above points, the study will be undertaken with the following objectives:

1. Optimal set up of the high resolution WRF at the 27 Km (over India) and 9 Km over Himalayas
2. Sensitivity experiments of simulated rainfall to different physical parameterization schemes
3. Dynamical downscaling using optimal set up of WRF for historical simulations over the time period 1985–2014 and two future scenarios of SSP245 and SSP585 over the time period of near future (2030–2059) and far future (2070–2099)

Study Area:

For the purposes of this study, the WRF model will operate over two simulation domains. The primary domain, denoted as D01 in Figure 1, is configured with a spatial resolution of 27 km while the nested domain, D02, has a finer spatial resolution of 9 km. D02 specifically encompasses the Tibetan region and adjacent mountainous areas, including the Himalayas, Karakoram, and others. This geographical region is crucial as natural hazards like landslides and Glacial Lake Outburst Floods (GLOF) represent significant risks to human safety in these regions.

Methodology:

In this study, the WRF-ARW version 4.5.2 atmospheric model will be selected as the Regional Climate Model (RCM). Initial and boundary conditions will be sourced Max Plank Earth System Model-High Resolution (MPI-ESM-HR), featuring a spatial resolution of 1.25° and a temporal resolution of 6 hours. This data encompasses a historical timeframe spanning from 1985 to 2014 and a projected future period from 2015 to 2100, under the SSP2-4.5 and SSP5-8.5 scenarios. Furthermore, the dataset undergoes bias correction with data from the ERA5 reanalysis for 1979–2014 (Hersbach et al. 2020). The specifics of the Bias correction methodology can be found in Xu et al. (2021).

Milestones and Expected Output / Outcome

Recent climate change studies increasingly demand high-resolution climate data, dynamically downscaled, to effectively understand and project the impacts of climate change. The developed dataset with improved horizontal resolution will be utilized to study extreme events. Also, it will be useful in local and regional policies and adaptation strategies to provide the detailed insight necessary for infrastructure planning, agricultural guidance, water resource management, wind & solar energy and disaster preparedness.

13.0 PROJECT CODE: NIH/C4S/2024-2028/AV

Title of the Study	: **Integrated long-term monitoring of Khatling Glacier, Bhilangana basin, Uttarakhand.**
Study Group	: Dr. Akshaya Verma, Scientist 'C' & PI Dr. Vishal Singh, Scientist 'D' & Co-PI Dr. Sunil Gurrapu, Scientist 'D' & Co-PI Dr. Lavkush Patel, Scientist 'D' & Co-PI Dr. Surjeet Singh, Scientist 'G' & Co-PI
Date of Start	: 1st April, 2024
Scheduled Date of Completion	: 31st March, 2028
Duration of the Study	: Four (04) years
Type of Study	: Internal
Nature of Study	: Planning
Location Map	: Khatling and adjoining glaciers in Bhilangana Basin, Uttarakhand

The Himalaya or the Third Pole is the water tower of rivers originating in the region, which are the life-line of ~1.7 billion people in the Indian sub-continent. The study of Himalayan glaciers, therefore, assumes foremost importance for the management of water resources, hydro-power generation, climate/weather prediction and in sustaining the ecological system. Glaciers of the Himalaya are unique as they lie in the tropical region at a formidably high altitude. Glaciers in such belt adapt to a change in climate conditions much more rapidly than does a large ice sheet, because they have a higher ratio between annual mass turnover and their total mass and thus better suited for determining the climate induced glacier fluctuations. This is largely due to the fact that the hydrological cycle is determined by the annual cycle of air temperature, with peak winter glacier accumulation (precipitation) and summer ablation (temperature). Direct or indirect observations on Himalayan glaciers echo the picture that glaciers are in general state of decline during recent times, although some exceptional results indicative of the complexity of climatic influence both on regional to local scale cannot be overlooked. For example, several glaciers in the central Karakoram are reported to have advanced and/or thickened at their tongues probably due to enhanced precipitation. The snout advance or retreat of glacier is an indirect indicator of the status of a glacier but not a definite pointer of the variation in temperature and precipitation, whereas, mass balance provides a more direct indication and a better marker of the status of the glaciers. Absence of long term mass balance and hydro-meteorological data has seriously hampered our confidence on the inter-annual and inter-decadal climatic impacts (global warming) on glacier behavior. Current inferences on the health of glaciers in the face of global warming remain inconclusive. However, noting the far reaching consequences of glacier variability, it is in the national interest to establish glacier-climate linkages.

Taking advantage of the new and advanced technology both in the field and laboratory facilities, the modern glacier monitoring programs can be approached by two modes viz. sustained decadal monitoring of glaciers by establishing multidisciplinary flagship field stations and supplementing the field observations by state-of-the-art lab based analytical techniques. In addition to this, direct observations on glaciers should be inter-compared with other climate sensitive proxies for a scientifically correct interpretation (cause–effect relationship). Ground observations are limited on various aspects of glaciology like thermal profile, precipitation (distribution and pattern), temperature gradients, mass balance, surge dynamics and hydrology in IHR due to harsh climate and rugged terrain. Therefore, in order to understand the processes governing the dynamics and hydrology of glaciers and to enhance scientific knowledge on the impacts of climate change, it is important to have integrated monitoring of glaciers. This would also be useful in the larger interest of the population living downstream and for management of water resources. Sustained long-term multifaceted observations on representative glaciers would help establish inter-linkages and dependence of glacier dynamics on climatic, hydrologic, environmental factors and glacial hazards. The immediate research focus should be to identify the factors that influence the dynamics of Himalayan glaciers, particularly in the face of global warming.

Study Objectives:

- **a.** To establish of base camp and hydro-meteorological observatories for understanding the glacier response.
- **b.** To understand glacier dynamics using remote sensing and ground-based observations on glacier mass balance, velocity, area-length changes and snow cover.
- **c.** To understand the characteristics of suspended sediment transfer from glacier to downstream.
- **d.** Isotopic characterization ($\delta^{18}O$ and δD) and major ion chemistry of different components of the hydrograph (snow, rain, glacier ice, meltwater).
- **e.** Establishment of inter-relationship of meteorological parameters with hydrology, mass balance and stable isotopes.

Statement of the Problem:

The National Institute of Hydrology (NIH) has recently established the Centre for Cryosphere and Climate Change Studies (C4S) at its headquarters. The main mandate or vision of the C4S is to act as a nodal agency for the cryospheric and climate change studies in the Himalayan region. Therefore, the aim of this internal study is to strengthen network of cryosphere observations in the study region.

Brief Methodology

- Establish base camp facilities with pre-fabricated huts, network of hydro-meteorological observatories with automatic weather stations (AWS) and automatic water level and velocity recorders (AWLVR) for collection high-resolution hydro-meteorological data at high-altitudes.
- Glacier dynamics (mass balance, velocity, area-length changes and snow cover) using satellite data and field measurements through establishing a network of stakes over the glacier surface and carrying out DGPS surveys.
- Collection and analysis of suspended sediments for particle-size, XRF and XRD and water samples from rain, snow, snow pits, surface ice and meltwater stream for stable isotopes and major ions.
- Inter-relationship of meteorological parameters with hydrology, mass balance and stable isotopes

Milestones and Expected Output / Outcome

- Acquisition of hydro-meteorological data using AWS and AWLVR to understand seasonal, annual and year to year variability and information about extreme events in the basin.
- Create the baseline database for the understanding of glacier dynamics (mass balance, velocity, area-length changes, rate of melting/ablation, etc.).
- Estimate the sediment erosion rates and yields in the basin.
- Understand the control of topography and climate on glacier mass balance and hydrology.
- Understand and quantify various processes like evaporation, evapotranspiration, sublimation, etc. within the basin.
- Integrated data sets would be utilized for development and parameterization of various mass balance and hydrological models for projection of future scenarios under global warming.

14.0 PROJECT CODE: NIH/C4S/2023-2026/LKP-1

Title of the Study	:	**Monitoring and Modelling of the Gangotri glacier catchment under different Climate Scenarios**
Study Group	:	Dr. Lavkush Kumar Patel, Sc. D, & PI
	:	Dr. Akshaya Verma, Sc. C
	:	Dr. Vishal Singh, Sc. D
	:	Dr. Kapil Kesharwani Sc. D
	:	Dr. Surjeet Singh, Sc. G & Head C
	:	Mr. Jatin Malhotra, PRA
Date of Start	:	1st April, 2023
Scheduled Date of Completion	:	31st March 2026
Duration of the Study	:	Three years
Type of Study	:	Internal
Nature of Study	:	Glacio-hydrological observations
Location Map	:	Gangotri Glacier, Uttarakhand

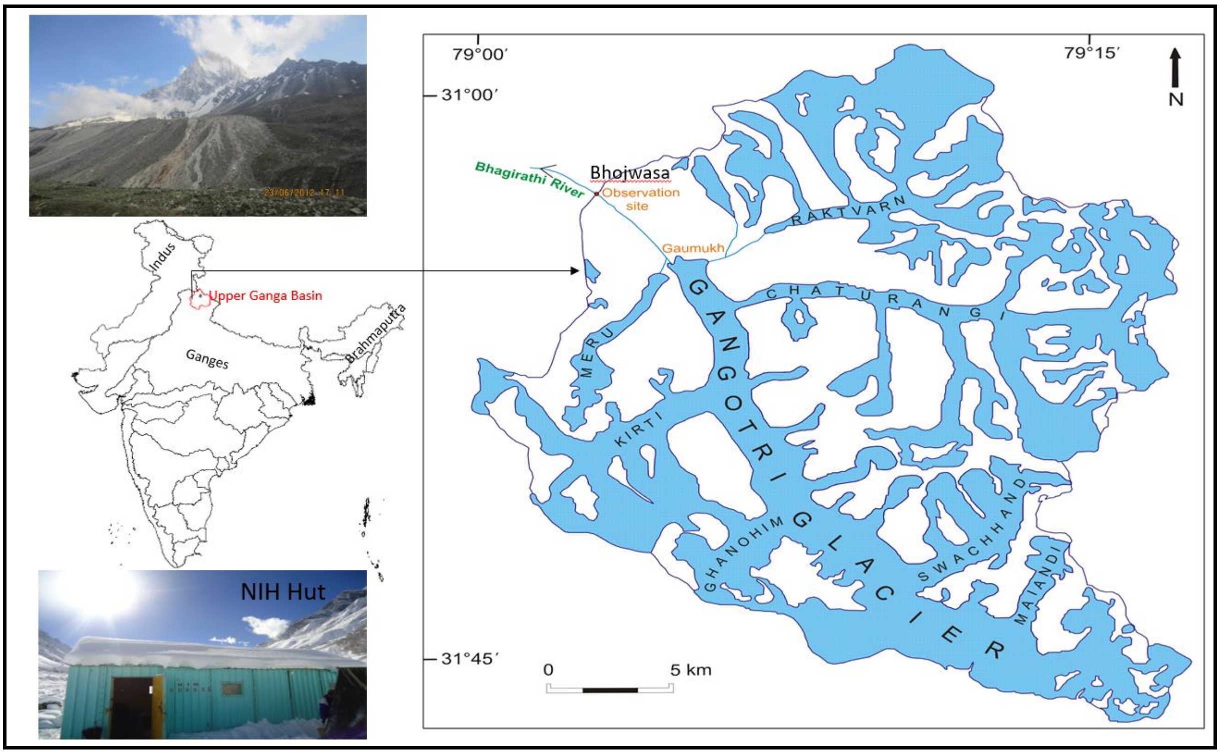


Figure: The location of the Glagotri glacier system.

Significance of the study:

The Gangotri Glacier (source of Bhagirathi River), one of the largest glacier of Himalaya, located in the Uttarakhand state (Central Himalaya, India) has immensely contributed to billions of people through irrigation, tourism, hydropower purposes. Because of these reasons, hydrological studies in the Cryospehere regime of Himalaya has gained a massive momentum in recent times. Climate change and global warming has added more concern to the health of the Gangotri Glacier and the River Ganga as well. It is, therefore, essential to study the hydrological system of the Gangotri Glacier System in a comprehensive way using observational methods, remote sensing based geospatial techniques and modelling so that prediction of future water supplies from these glacierized catchments in the downstream area can be performed precisely.

Department of Science and Technology (DST), in the year 1999, sanctioned a project to National Institute of Hydrology (NIH), Roorkee to carry out hydrological investigations on the Gangotri Glacier. Since then, many scientists and project staff from NIH has contributed immensely in carrying out the hydrological investigations through internal and external funding. To collect the information on the hydro-meteorological variables, NIH has established a standard observatory at about 3800 m altitude and set-up gauging sites at the basecamp at Bhojwasa. This observatory is equipped with Automatic Weather Station (AWS), ordinary and self-recording rain gauge, Thermograph, Max. & Min. thermometers, Dry & Wet bulb thermometers, Hydrograph, Pan evaporimeter, Anemometer, Wind vane, and Sunshine recorder. NIH is also carrying out the streamflow and sediment contribution through traditional approach. The installed AWS and Prefabricated Hut is quite old and require alteration, renovation and repairing. The site requires upgradation and adoption of new modern techniques for flow and sediment measurement.

Objectives:

- Continuous observations of Hydro-meteorological and estimations of temporal suspended sediment flux during the ablations season.
- Analysing the glacier mass balance, differential ablation, glacier dynamics, and melt-water flux.
- Geospatial monitoring of the supraglacial lake's dynamics.
- Hydrological modelling for runoff estimation under different climatic scenarios.

Methodology:

Continuous observations of Hydro-meteorological, Isotope and estimations of temporal suspended sediment flux during the ablations season.

Long-term observations, of the Hydrological discharge, meteorological datasets, sediment yield will be measured by using advance instruments and manually. The automatic water monitoring system, weather stations will be fixed at the proglacial stream for continuous monitoring. The water sample will be collected morning and evening for isotope, hydrochemistry and for suspended sediment yield estimations.

Analysing the glacier mass balance, differential ablation, glacier dynamics, and melt-water flux from a glacierized basin

The glacial mass balance will be quantified by incorporating field and photogrammetric techniques. In the field, the debris cover, ablation, and accumulation mass balance stake measurement, DGPS survey will be carried out for mass balance, differential ablation and glacier dynamics and melt-water flux estimation. The satellite photogrammetric techniques (geodetic) will be used to estimate the glacier mass balance in the gridded scale at local and regional level.

Geospatial monitoring of the supraglacial lake's dynamics.

The historical & recent satellite data will be utilized to map the supraglacial glacial lakes in the Gangotri glacial system. The temporal inventory will be prepared as per the availability of the satellite data (high resolution) sets specially for the ablation season.

Hydrological modelling for runoff/ runoff components estimation under different climatic scenarios.

In this research objective, the hydrological melt runoff from the Gangotri glacier catchment will be quantified through the glacial-hydrological modelling and the how it is sensitive to the meteorological components will be assessed. Further, the results from the all objectives will be merged to together to assess the hydrological regime ('peak water') and climatic sensitivity of a glacierised catchment over the Ganga basin, Central Himalaya.

<u>Deliverables:</u>

- **I.** Long-term hydro-meteorological and sediment data sets for the Gangotri glacier.
- **II.** Our intensive field-based data sets of the glacier mass balance, glacier dynamics, melt water flux, and glacial lakes will be a base data for glaciological modelling and validation.
- **III.** The glacier dynamics, mass balance variability will be provided and how the sensitivity with temperature and precipitation variability will be assessed.

IV. The impact of debris-cover over the glacier ablation, spatial- temporal melt rate and mass balance of the glacier will be quantified.
V. The present status and expansion rate of supra glacial lakes presents in the catchment and the processes involved in the formation of glacial lakes will be demonstrated.
VI. The hydrological modelling and Isotope analysis will be carried out to understand the melt-runoff components.
VII. The analysis will deliver a complete picture of the glacio-hydrological behaviour of a high altitude glacierised catchment as per the changing climate.

Budget and major equipment: Approved in the WG 2023-24

15.0 PROJECT CODE: NIH/C4S/2024-2026/SS

Title of the Study	:	**Inventory of Glaciers and Glacial Lakes in Indian Himalayan Region**
Study Group	:	Dr. Surjeet Singh, Sc-G & PI Dr. Vishal Singh, Sc-D Dr. Lavkush Kumar Patel, Sc-D Dr. Akshaya Verma, Sc-C Mr. Madhusudan Thapliyal, SRA
Date of Start	:	1st April, 2024
Scheduled Date of Completion	:	31st March, 2026
Duration of the Study	:	Two years
Type of Study	:	Internal
Nature of Study	:	Database Development
Location	:	Indian Himalayan Region

Background:

In the Northern Region of India, the Himalayas - the abode of snow and ice – play a very important role in the country's economic life. Himalayas contain over 50% of permanent snow and ice fields outside the Polar Regions. They are vast reservoirs of snow and glaciated ice. The major river systems of North India, namely, the Indus, the Ganges, the Brahmaputra and their tributaries originate in the Himalayas. Significant research work has been done in Bhutan, China, India, Nepal and Pakistan. ICIMOD with support from UNEP and national institutions of Bhutan and Nepal, had been engaged in a major study to prepare an Inventory of Glaciers and Glacier Lakes of Bhutan and Nepal (ICIMOD & UNEP, 2000). It is also necessary to have an accurate knowledge of the distribution of glaciers to estimate the runoff from snow and glacier melt. Various Space Applications Centres, state disaster management departments and other institutions are actively working on the impact of cryospheric variations, melt water runoff and GLOF in the Indian Himalayan Region. Some states have also prepared a glacier inventory either state wise or basin wise using the remote sensing technique. In many glaciers, small isolated lakes/ponds are formed and keep on increasing in size at a very fast rate. With above in view, this study is proposed with the following objectives:

Study Objectives:

1. Mapping of glaciers and glacial lakes in the Indian Himalayan Region.
2. Development of Atlas of glaciers and glacial lakes.
3. Dissemination of the results and outputs to relevant institutions.

Statement of the Problem:

The updated glacier information's are prime need for the better hydrological planning in the downstream locations. Various concerned institutions should be fully aware of the dangerous nature of large glacial lakes, especially if they happen to exist at the headwaters of rivers that flow through inhabited valleys or are harnessed for the generation of hydropower and other purposes. It is an utter necessity to identify such lakes initially from the study of satellite images (and aerial photographs if available) and to assess their field conditions immediately. Some of these lakes may need regular monitoring whereas others may need structural and alarming measures to reduce the hazards in the Indian Himalayan Region. Higher accuracy updated data on glaciers and glacial lakes are necessary for improved glacio-hydrological understanding, sustainability, and preparedness for unanticipated risks in the Himalayan region.

Brief Methodology

- Review of various methodologies and input data sources.
- Development of standard methodology for identification of glaciers and glacial lakes.

- Basic data preparation using remote sensing and GIS.
- Development of algorithm for mapping of glaciers and glacial lakes.
- Mapping of glaciers and glacial lakes.

Expected Outcome

- Database on glaciers
- Database on glacial lakes
- Atlas on glaciers & glacier lakes

Beneficiaries & Stakeholders

- DoWR, RD & GR, MoJS
- State Water Departments
- State Disaster Management Departments

Budget

Head	Particulars	Quantity	Amount (Lakh INR)
Salary	Research Associate	One	15.0
Procurement	High resolution data/DEM	1set	15.0
Contingency	Miscellaneous	-	2.0
Travel	TA/DA	-	2.0
Total			**34.0**

16.0 PROJECT CODE: NIH/C4S/2024-2027/LKP-2

Title of the Study	**: Glacio-hydrological and GLOF investigations over the Triloki glacier, Bhaga basin, Western Himalaya**
Study Group	: Dr. Lavkush Kumar Patel, Sc. D & PI : Dr. Akshay Verma, Sc. C : Dr. Vishal Singh, Sc. D : Dr. Surjeet Singh, Sc. G
Date of Start	**:** 1st March, 2024
Scheduled Date of Completion	**:** 31st March, 2027
Duration of the Study	**:** Three years
Type of Study	**:** Internal
Nature of Study	**:** Glacio-hydrological observations
Location Map	**:** Triloki glacier, Lahaul & Spiti, Himachal Pradesh

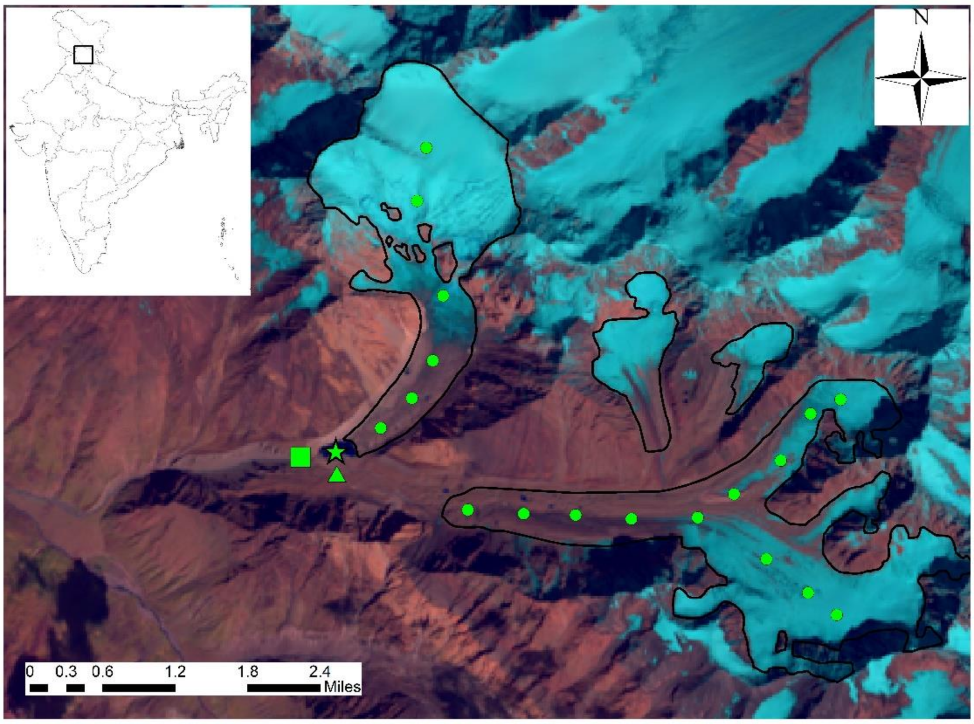


Figure: The location of the Triloki glacier in the western Himalaya, and a Schematic diagram for planned field observations.

Significance of the study:
In the Hindu-Kush Himalaya (HKH), glaciers are an important source of hydropower and water supplies (Immerzeel et al., 2010). Glaciers are essential for the almost 1.9 billion people who live in the region's three main river basins-the Indus, Ganga, and Brahmaputra-who depend on the water flowing from the glaciers for their socioeconomic requirements (Bolch et al., 2012; Mountain Research Initiative EDW Working Group, 2015). The ongoing global warming has substantial impact on the glacierized catchments of the region, such as the acceleration of the glacier melt rate, the increasing debris cover over the glacier, and the formation of several glacial lakes (Patel et al., 2021, 2017; Zemp et al., 2019). According to recent estimates, the HKH region will experience a 0.3°C increase in temperature if global warming continues at its current pace of 0.1°C each decade (Krishnan et al., 2019; Sabin et al., 2020). Studies also suggested an increase in the number of extreme warm events and variability in the western disturbances (Krishnan et al., 2019). Recent climate warming and its

consequences on the water availability of the Himalayan rivers is one of the major concerns (Azam et al., 2021; Huss and Hock, 2018; Immerzeel et al., 2010). As the glacier cover over the Himalaya is expected to significantly decrease and the number of glacier hazards is expected to increase by the end of the century (Kraaijenbrink et al., 2017), Several glacio-hydrological observations would be necessary for a comprehensive understanding of hydrological regime and the GLOF potential for the sustainability of the Himalayan regions to be prepared to mitigate such issues.

Scientific Objectives:

- Improved assessment of process involved in glaciological mass balance, glacier dynamics, and melt-water flux changes through the detailed field investigation.
- Mapping and monitoring the Glacial lakes in the region and its glacial lake outburst potential.
- Hydrological regime and Climatic Sensitivity of a glacierised catchment over the Upper Indus basin, Western Himalaya.

Methodology:

Analysing the glacier mass balance, differential ablation, glacier dynamics, and melt-water flux from a glacierized basin

The glacial mass balance will be quantified by incorporating field and photogrammetric techniques. In the field, the debris cover, ablation, and accumulation mass balance stake measurement, DGPS survey, discharge measurements will be carried out for mass balance, differential ablation and glacier dynamics and melt-water flux estimation. The satellite photogrammetric techniques (geodetic) will be used to estimate the glacier mass balance in the gridded scale at local and regional level.

Monitoring the Glacial lakes expansion and glacial lake outburst potential

The historical satellite data will be utilized to map quantify the expansion the present glacial lakes in the region. In the field, the moraine dams wall and bathymetric survey will be carried out with the advanced instruments over the proglacial lake for estimation of its depth the volume. The GLOF potential will be assessed by incorporating HEC-RAS 1D/2D modelling and mitigation plan will be prepared.

Hydrological regime and Climatic Sensitivity of a glacierised catchment over the Upper Indus basin, Western Himalaya

In this research objective, the hydrological melt runoff from the Triloki glacier catchment will be quantified through the glacial-hydrological modelling and the how it is sensitive to the meteorological components will be assessed. Further, the results from the all objectives will be merged to together to assess the hydrological regime ('peak water') and climatic sensitivity of a glacierised catchment over the Upper Indus basin, Western Himalaya.

Deliverables:

I. Our intensive field-based data sets of the glacier mass balance, glacier dynamics, melt water flux, glacial lakes expansion rate and bathymetry will be a base data for glaciological modelling and validation.
II. The glacier dynamics, mass balance variability will be provided and how the sensitivity with temperature and precipitation variability will be assessed.
III. The impact of debris-cover over the glacier ablation, spatial- temporal melt rate and mass balance of the glacier will be quantified. Further, the glacier thermal regime and stagnation processes will be identified.
IV. The present status and expansion rate of lakes presents in the catchment and the processes involved in the formation of glacial lakes will be demonstrated.
V. The 1D/2D GLOF modelling will provide the potential of these lakes and possible mitigation plans for the safety of the downstream population will be suggested.
VI. The analysis will deliver a complete picture of the glacio-hydrological behaviour of a high altitude glacierised catchment as per the changing climate.

Dissemination plan

With this proposal, the data sets acquired, the process understanding gained, the modelling (hydrological and GLOF), and obtained results will contribute to the scientific communities and society in many ways. The results and findings of the project will be communicated in the scientific journals like Journal of Glaciology, Journal of geophysical research-earth surface, The Cryosphere, Earth System Science data, and other peer reviewed journals. The dissemination plan also includes several oral and poster presentations during conferences organized by leading scientific organizations. Further, the training program will be organized at National Institute of Hydrology (Hybrid/direct mode) for scientists and students covering all aspects of the project.

Quarterly work plan:

Task Name	2024			2025				2026				2027			
	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
Equipment and satellite data purchasing and testing															
Field work over the Triloki glacier															
Data processing/Hydrological Modelling															
Publication writing															
Participation in Conferences and workshops															
Summary and assessment of future need															

Budget and major equipment:

SI. No.	Name of Activity	Y1	Y2	Y3	Y4	Total Rs (in Lacs)
1	Salaries and wages: (1 Resource Person- Junior/Senior)	5.00	5.00	5.00	5.00	20.00
2	Consumable materials: (Satellite Data/Other datasets)	1.00	1.00	1.00	-	3.00
3	Travel and field expenses: (Recurrence Surveys & Field Works)	3.00	2.00	2.00	2.00	9.00
4	Instruments: (Meteorological station, handheld GPS)	30.00	-	-	-	30.00
5	Other items and Contingencies	1.00	1.00	1.00	0.5	3.50
6	Non-recurring expenses	2.50	2.50	-	-	5.00
8	**Total Rs. (in Lacs)**	**41.5**	**11.5**	**9.00**	**7.5**	**70.5**

List of instruments required	Equipment	Quantity
Automatic Weather Station	Tripod	1
	Data logger	1
	Air T and H sensor	1
	Wind speed and direction	1
	Solar radiation I and O	1
	Precipitation	1

	Snow depth/precipitation	1
	Pressure sensor	1
Handheld GPS		2
Debris surface temperature sensor	Tiny tag with Thermal probe	2

17.0 PROJECT CODE: NIH/C4S/2024-2026/RK

Title of the Study: Climate change impacts on water resources availability and hydropower potential assessment in the Himalayan Satluj river basin (up to Kasol).

Study Group:	Rajat Kumar (PI) Vishal Singh (Co-PI) Surjeet Singh (Co-PI) Shakti Suryavanshi (Co-PI)
Duration of the Study:	Two Years (01.04.2024 - 31.03.2026)
Type of the Study:	Internal

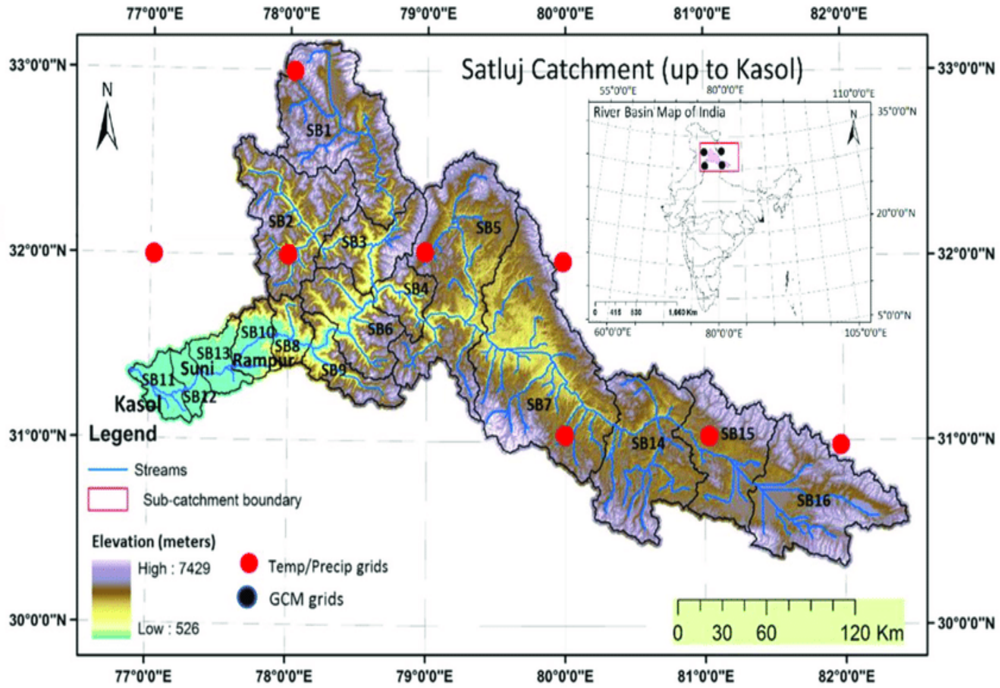
Statement of the problem- The Himalayan Satluj River Basin faces increasing vulnerability to the impacts of climate change, manifesting in altered precipitation patterns, rising temperatures, and shifting hydrological regimes. This complex environmental challenge necessitates a comprehensive assessment of the implications on water resources availability and hydropower potential within the basin. The overarching problem lies in understanding the multifaceted dynamics of climate change in the region, evaluating its direct and indirect effects on water resources, and quantifying the consequential impact on the hydropower potential of the Satluj River Basin. This study aims to address these critical issues, providing a thorough examination of the climate-induced challenges and opportunities for sustainable water resource management and hydropower development in the Himalayan context.

Objectives of the study:

1. Analyse the spatial and temporal variability of temperature and precipitation and projections using different emission scenarios.
2. Hydrological simulation and modelling to assess different runoff/water balance components and hydrological regime of the catchment.
3. Examine the Hydropower Potential, resilience and adaptability of existing and planned hydropower infrastructure to climate-induced variations.

Scope of the Study: A comprehensive assessment of the impact of climate change on water resources availability and the hydropower potential in the Himalayan Satluj River Basin, Western Himalaya will be performed. The study will include climatic analysis, examination of historical climate data to identify trends and variations in temperature and precipitation patterns, projection of future climate scenarios using state-of-the-art climate models, with a focus on the specific vulnerabilities of the Himalayan region, implementation of hydrological models to simulate the current and future hydrological conditions of the Satluj river basin, calibration and validation of the model to ensure accurate representation of the basin's hydrological processes, assessment of changes in streamflow patterns, snowmelt dynamics, and overall water availability, hydropower potential assessment with the utilization of hydropower models to estimate the current and future hydropower potential within the basin and evaluation of the resilience of existing & planned hydropower infrastructure to climate-induced changes, then identification of vulnerable areas within the basin based on changes in water availability and extremes, formulation of adaptive strategies to address changes in water availability, including optimization of water use and improvements in water storage infrastructure, exploration of mitigation measures to reduce the impact of climate change on water resources and hydropower potential.

Study Area: Satluj river basin (up to Kasol)



Methodology: The Following methodology will be adopted for this study:

(a) Hydrological Modeling: The Soil and Water Assessment Tool (SWAT) is a widely used hydrological model for simulating the impact of land management practices on water, sediment, and agricultural chemical yields in watersheds.

The first step is to selecting a study area or watershed for analysis. This involves identifying the geographic boundaries, land use/land cover, soil types, topography, and climatic characteristics of the area, the next step is to collect relevant data for input into the SWAT model. This includes spatial data such as land use, soil maps, digital elevation models (DEMs), weather data (precipitation, temperature, etc.), streamflow data etc., then we will set up the model by defining the watershed boundaries, dividing the watershed into sub-basins, assigning land use and soil properties to each sub-basin, specifying hydrological response units (HRUs), and configuring model parameters, in the next course of action we will calibrate the SWAT model to ensure that simulated outputs match observed hydrological behavior within the watershed. This involves adjusting model parameters such as curve numbers, soil properties, and routing coefficients to minimize the differences between simulated and observed streamflow, sediment yield, and other hydrological variables, in further action we will validate the calibrated SWAT model by comparing simulated outputs with independent observed data for a separate time period. This step helps assess the model's ability to accurately represent watershed processes under different conditions.

(b)Climate model (CMIP6) data selection and scenario generation: The latest global climate model simulations from the Coupled Model Intercomparison Project Phase 6 (CMIP6) will be utilized to evaluate climate change impacts on the study region's hydrology. Specifically, projections under Shared Socioeconomic Pathway (SSP) 2-4.5, representing a moderate emissions scenario, and SSP5-8.5, representing a high emissions scenario, will be acquired and downscaled to appropriate spatial resolutions. Output variables including precipitation, temperature, and other meteorological data will be extracted to force the hydrologic models. An ensemble modeling approach applying multiple CMIP6 general circulation models (GCMs) will quantify uncertainties in the projections. The modeled hydrologic outputs driven by the downscaled CMIP6 data will then be analyzed to assess shifts in timing, magnitude, and sources of runoff under the different emissions trajectories through the 21st century. Comparisons to historical modeled hydrology will determine climate change impacts on water availability, floods and droughts, and cryospheric runoff contributions. The CMIP6-informed modeling will provide critical insights into potential future hydrological conditions to guide water resource planning in the study watersheds.

(c) Hydropower assessment using energy equation:

The fundamental principle of hydropower generation, which is based on the conversion of the potential energy of water into mechanical energy and then electrical energy. The energy equation for hydropower can be expressed as: $P=\eta\rho gQH$

By estimating the hydropower output for different potential sites along the Satluj river basin up to Kasol, one can assess the overall hydropower potential of the area.

Expected Outcomes:

- quantitative assessment of climate change impact
- impact of climate change on temperature, precipitation, and hydrological components
- current and future water availability dynamics
- current and future hydropower potential

18.0 PROJECT CODE: NIH/C4S/2024-2026/DSB

Title of the Study	:	**A Spatially Explicit Assessment of CMIP6 General Circulation Models for the Indian Himalayan Region**
Study Group	:	Dr. Deepak Singh Bisht, Sc-C & PI Dr. Nitesh Patidar, Sc-C Dr. Soban Singh Rawat, Sc-F Dr. Surjeet Singh, Sc-G
Date of Start	:	1st April, 2024
Scheduled Date of Completion	:	31st March, 2026
Duration of the Study	:	Two years
Type of Study	:	Internal
Nature of Study	:	Climate Data Analysis
Location	:	Indian Himalayan Region

Background:

The intricacies of climate change demand detailed knowledge of future projections at regional and even local scales. For the Indian Himalayan Region (IHR), a vital and complex ecosystem harboring diverse populations and sensitive environments, understanding future climate trends holds immense importance. However, accurately representing climatic processes at such nuanced levels presents a significant challenge. The Coupled Model Intercomparison Project (CMIP) serves as a cornerstone for climate research, providing a suite of General Circulation Models (GCMs) that simulate Earth's climate system. These models offer valuable insights into potential future climate scenarios under various greenhouse gas emission pathways. With CMIP6, the latest phase of this project, an unprecedented abundance of data has become available, boasting over 35 participating models. While this expansion offers greater breadth and potential for improved accuracy, it also brings its own set of challenges. Even though GCMs provide crucial global-scale projections, translating these findings to regional and local levels, a process known as downscaling, remains a complex and skill-intensive undertaking. Each GCM possesses inherent strengths and weaknesses in representing various climate variables and processes. Factors like topography, land cover, and atmospheric dynamics further complicate the downscaling process, making a one-size-fits-all approach inadequate. The performance of individual GCMs varies significantly, and blindly applying any single model for regional impact studies can lead to misleading results. For the unique and multifaceted landscape of the Indian Himalayas, understanding the strengths and limitations of each CMIP6 model in representing regional climate dynamics becomes crucial. A comprehensive assessment and ranking system specifically tailored to the Himalayas would significantly enhance research efficiency and ensure well-informed decision-making.

With above in view, this study is proposed with the following objectives:

Study Objectives:

1) Identify appropriate climate projections from CMIP6 datasets by employing deterministic and stochastic Multicriteria Decision Making (MCDM) techniques.
2) Determine categorical rankings for climate projections using a Group Decision Making (GDM) approach.
3) Disseminate the findings and outputs via a dedicated web portal for broader accessibility and utilization.

Statement of the Problem:

Given the unique geographical and climatic characteristics of the IHR, there is a pressing need for a spatially explicit assessment of GCMs tailored to this region. Such an evaluation should consider not only the overall performance metrics but also the model's ability to capture local-scale variations.

General Circulation Models (GCMs) offering the most accurate representations of specific sub-regions within the Indian Himalayan Region (IHR) can be pinpointed by employing advanced statistical techniques. These techniques encompass deterministic and stochastic approaches within Multi-Criteria Decision Making (MCDM) framework. Integrating diverse performance rankings derived from varied MCDM assumptions through Group Decision Making (GDM) approaches further strengthens the overall evaluation. Furthermore, making the results of GCM evaluations readily accessible through a dedicated web portal is essential for facilitating informed decision-making and enhancing the efficiency of climate impact assessments. Providing stakeholders with user-friendly access to GCMs performance metrics can significantly reduce the time and resources required to conduct similar evaluations independently. This accessibility fosters collaboration among researchers, policymakers, and stakeholders, fostering a more integrated approach to climate risk management and adaptation planning in the IHR.

Brief Methodology

- Comprehensive review of methodologies and input data sources.
- Initial data preparation procedures.
- Development and implementation of algorithms for assessing the suitability of CMIP6 GCMs using deterministic and stochastic Multicriteria Decision Making (MCDM) techniques.
- Formulation and implementation of algorithms for spatially explicit assessment to determine categorical rankings of CMIP6 GCMs using a Group Decision Making approach.
- Dissemination of outputs and findings through a dedicated web portal.

Expected Outcome

- A comprehensive knowledgebase to guide effective application of CMIP6 GCMs, considering their location-specific suitability.
- Prioritization of climate model selection for targeted impact studies by creating a location-based ranking system for CMIP6 GCMs.
- Dissemination of findings through a web portal, promoting the application of suitable CMIP6 GCMs in decision-making and research on a regional scale.

Beneficiaries & Stakeholders

- Water and Agriculture sector of the Indian Himalayan Region
- Researchers and practicing engineers working in the domain of climate change impact analysis in the Indian Himalayan Region

Budget

Head	Particulars	Quantity	Amount (Lakh INR)
Procurement	Work station	1 set	3.5
	Network-attached storage (40 TB)	1 set	3.0
Contingency	Miscellaneous	-	0.5
Total			**7.0**

19.0 PROJECT CODE: NIH/C4S/2024-2027/KK

Title of the Study	**Influence of Climate Change and Future Response of the Milam Glacier(Central Himalaya, India): Science – Practice - Policy**
Study Group	: Dr. Kapil Kesarwani, Scientist 'D' (PI) Dr. Surjeet Singh, Scientist 'G' Dr. Lavkush Kumar Patel, Scientist 'D' Dr. D.S. Bisht, Scientist 'C' Dr. Akshaya Verma, Scientist 'C' Mr. Madhusudan Thapliyal, SRA
Date of Start	: 01st April, 2024
Date of Completion	: 31st March, 2027
Duration of the Study	: Three (03) years
Type of Study	: Internal
Nature of Study	: R&D and Database Development
Location	: Goriganga River Basin, Munsyari, Pithoragarh, Uttarakhand

Background and Statement of the problem:

The Himalaya contains the largest area of ice outside of the Polar regions and has largest volume of mountain glaciers in the world (Raina, 2009). Within the Himalayan Mountain range, the territorial limits of India have the largest ice cover in terms of number of glaciers (Raina and Srivastava, 2008). Even though, there are several topographical, geological, and glaciological reasons for the retreat or advance of glaciers over the Himalayas (Bolch et al., 2012), surface darkening due to Black Carbon (BC) deposition is being increasingly projected by modelling studies as a major factor contributing to the faster snow melting (Qian et al., 2011) and severalcaveats have been put forward. Recently, BC-induced free-tropospheric heating (elevated heat pump) (Lau et al., 2006) and snow-albedo reduction due to BC deposition over the Himalayan region (Qian et al., 2011) has received significant scientific attention because of its projected implications on the regional climate, monsoon and hydrological cycle (Nigam and Bollasina, 2010). Generally, climate model simulations of BC-induced snow darkening have revealed significant consequences on regional climate and hydrological cycles during the pre- monsoon season (Menon et al., 2010; Qian et al., 2011). However, it is very difficult to simulate the aerosol fieldsover complex and high terrain and most of the climate models simulate very low BC concentration in the atmosphere over south Asia especially over the Indian region (Nair et al., 2012). Even though aerosol BC over the Himalayas, in general, and glaciers in particular, have been a topic of prime scientific interest, there are not much measurements of BC over the western and southern slopes of the Himalayas, while measurements of BC on snow have been reported from several locations on the Tibetan plateau and south-eastern Himalayas (Huanget al., 2011).

Understanding the mechanism of debris-covered over the glacier surface is quite complicated in terms of exchange of various heat fluxes. The physically sound knowledge of the debris-covered glaciers is essential to quantify the meltwater discharge and also to predict their response to climate change. Thus, the present study aims to monitoring and model the physical processes that govern the dynamics of debris-covered glacier under the influence of climate change. Furthermore, the proposed study will also assess the atmospheric pollutants mass load in the Milam Glacier catchment, and its influence over the glacier dynamics under the changing climate scenario.

Objectives

1. Studying the physical processes of Milam Glacier by means of monitoring glaciological parameters (hydro- meteorology, hydrology, surface accumulation and ablation processes, terminus fluctuation, and snowcover changes) and climate forcers (absorbing aerosols).
2. Development of a physically based coupled glacio-hydrological model to assess the processes governing dynamics of snow and glacier-fed Himalayan watershed and future response.

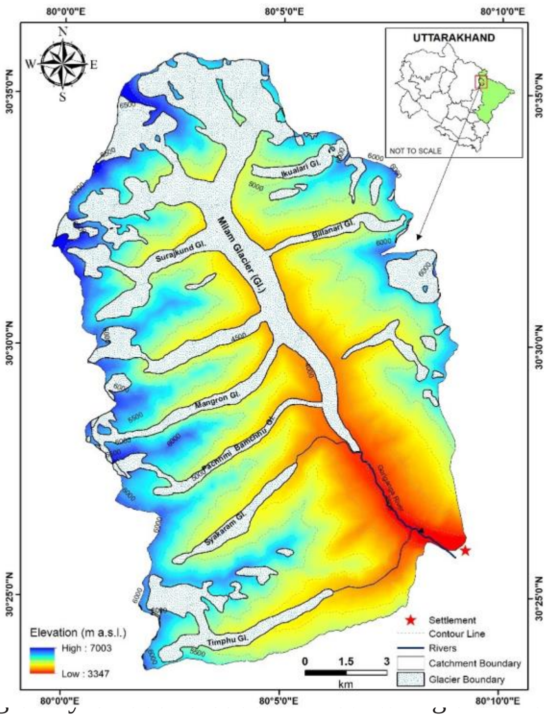
3. Assessing the possibilities of future catastrophic risks posed by the Himalayan Cryospheric Environment, and to develop policy recommendations/ brief related to Disaster Risk Reduction in Himalayan states

Study Area

The upper catchment of debris-covered Milam Glacier (Goriganga River basin, Pithoragarh, Uttarakhand) will be studied in terms of cryosphere mass fluctuation, hydrological and thermodynamical changes and impact of climate forcers (Fig.1).

Brief Methodology

- Review of available methodologies and input datasources.
- In-situ measurements- Hydro-meteorological and glaciological records
- Use of Ancillary dataset and long-term climate recordsobtained from Climate models
- Basic data preparation using remote sensing and GIS.
- Development of semi-distributed conceptual glacio-hydrological model.



Significance and Expected Outcomes

a) The study will generate a strong data base through monitoring and modelling of cryosphere-climateinteraction.

b) The developed coupled glacio-hydrological model will be beneficial for the melt-modellin ... nd to know the state andfate of Cryosphere in the changing climate.

c) The developed model will provide a road map to measure the influence of various climate forcers that are leading to climate change and may affect the future runoff.

d) The study will be helpful to bridge the gaps in our understanding of the contrasting climate forcers and their impacts on high-altitude Himalayan watersheds.

e) Using the different climate projections, the study will be useful to predict the future response and sensitivity of Himalayan cryosphere mass fluctuation and associated water supplies which is the backbone for the livelihood and hydro-power projects of the region.

f) Wide-spread dissemination of the project outcomes will be helpful for formulating the strategies of climate change adaptability of the Indian Himalayan Region (IHR) in relation to policy perspectives and planning.

Beneficiaries & Stakeholders

- DoWR, RD & GR, MoJS/ MoEFCC/ MoES/ MOS&T/ IMD/
- Central and State Universities / R&D Organizations / NGOs/ Agencis of IHR
- Central/ State Disaster Management Departments/ NITI Ayog
- Ministry of Agriculture / Organizations working in remote terrain / Tourism development board of IHR

Time Schedule (quarterly) of activities giving milestones

Activity	1st Year				2nd Year				3rd Year			
	I	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**	**I**	**II**	**III**	**IV**
• Execution of Project Activities	■											
• Literature review and work planning	■	■	■	■	■	■	■	■	■	■	■	
• Establishment & maintenance of hydro-meteorological observatory over the glacier catchment for Continuous monitoring of local weather parameters	■	■	■			■	■			■	■	
• Establishing/maintaining stake (using eco-friendly approach) and estimating the glacier wide mass balance	■	■	■			■	■			■	■	
• Mapping of glacier surface characteristics using in-situ & space-based methods	■			■	■			■	■			
• Development Physically based coupled glacio-hydrological model	■	■	■	■	■	■	■	■				
• Estimating sensitivity and future response of the glacio-hydrological components using long term climatic and non-climatic conditions through developed model	■							■	■			
• Projections of the risk prone area in the studied high-altitude Himalayan watersheds based on R&D findings	■								■	■		
• Developing guidelines/ framework for Policy Planners to combat climate change	■										■	■
• Publication and submission of Annual and Final Reports	■	■	■	■	■	■	■	■	■	■	■	■

Budget (in Lakhs)

Head	Particulars	Qty.	I Year	II Year	III Year
A. Recurring					
Manpower	1. Senior Project Associate (@ Rs. 42,000 + HRA p.m. p.p.) 2. Project Associate -II (@ Rs. 35,000 + HRA p.m. p.p.) 3. Field Assistant (@ Rs. 18,000 + HRA p.m. p.p.)	01 01 02	14.78	14.78	14.78
Contingency/ Consumables	Miscellaneous items (Field kits and gears, propane gascartridges, bamboo stakes, etc.)		7.00	7.00	6.00

Travel	TA/DA of project personals	-	6.00	6.00	5.00
Total A			**27.78**	**27.78**	**25.78**
B. Non-Recurring					
Field Equipment	1. Portable Automatic Weather Station	03	90.0	--	--
	2. Radar based Water level recorder and surface velocitySensor with all accessories	01	13.00	--	--
	3. Ice Drill Machine along with Snow Density Measurement Kit	01	13.20	--	--
	4. Portable Aethalometer with power arrangements	01	65.00	--	--
	5. Sunphotometer	01	19.12	--	--
	6. Ozonometer	01	18.77	--	--
	7. Handheld GPS	01	0.90	--	--
	8. Mirror Less Digital DSLR Camera with Lense	01	1.50	--	--
Total B			**221.49**	--	--
Grand Total (A+ B)			**249.27**	**27.78**	**25.78**
			₹ 302.83 lakhs		

<u>Proposed Trainings Planned for 2024-25:</u>

S. No.	Title	Coordinator	Tentative Date
1.	Application of Satellite Remote Sensing for Cryosphere and Climate Change Studies	Dr. Lavkush Kumar Patel and Dr. Kuldeep Sharma	November 11 to 15, 2024
2.	Hydrological Modelling using VIC	Dr. Sunil Gurrapu	14-18th Oct, 2024
3.	SWAT hydrological modeling and time series data analysis using Python programming	Dr. Vishal Singh	
4.	Leveraging ArcGIS Enterprise functionalities for effective knowledge dissemination and data management	Dr. DS Bisht Dr. SS Rawat	09-11 July 2024 at NIH Roorkee
5.	Springshed Management	Dr. SS Rawat Dr. DS Bisht	7-11 Oct 2024 at NEHARI, Guwahati

ENVIRONMENTAL HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. R P Pandey	Scientist G & Head
2	Dr. M K Sharma	Scientist F
3	Dr. Rajesh Singh	Scientist E
4	Dr. Pradeep Kumar	Scientist E
5	Dr. Vinay Kumar Tyagi	Scientist D
6	Dr. Prasanta Kumar Sahoo	Scientist D
7	Dr. Kalzang Chhoden	Scientist C
8	Dr. Shakti Suryavanshi	Scientist C
9	Dr. Shailendra Kumar Kumre	Scientist B
10	Smt. Babita Sharma	PRA
11	Smt. Bina Prasad	SRA

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जल विज्ञान संस्थान
आपो हिष्ठा मयोभुवः

Approved Work Programme for the Year 2023-24

S. No.	Study Title	Study Team	Duration/Status
Sponsored R&D Projects (Ongoing)			
1.	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	Omkar Singh (PI), Rajesh Singh, Jyoti P Patil, VK Tyagi, Kalzang Chhoden **Partners:** NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Ahmedabad	5 Years (04/19 - 03/24) **Project Cost**: 5.1 Crore **Sponsored by:** DST **Status:** In-progress
2.	Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (MIP) Shahnehar	RP Pandey (PI), JP Patra, Rajesh Singh, Shakti Suryavanshi, SK Kumre, NK Bhatnagar	3 Years (12/17-03/24) **Project Cost**: 75 Lakh **Sponsored by:** NHP **Status:** In-progress
3.	Anaerobic Co-digestion of Thermochemically Pretreated Organic Fraction of Municipal Solid Waste and Sewage Sludge: Effect on Process Performance and Microbial Community Development	Vinay Kumar Tyagi (PI)	5 Years (2018-2023) **Project Cost**: 106 Lakhs **Sponsored by**: DBT **Status**: In-progress
Collaborative R&D Projects (Ongoing)			
4.	Isotopic and geochemical approach to study vulnerable confined and unconfined drinking water aquifers in Varanasi and surrounding area, India	Rajesh Singh (PI), R.P. Pandey BHU, Varanasi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary	3 Years (07/21-06/24) **Sponsored by**: BHU **Status**: In-progress
5.	Comprehensive characterization of variably processed sewage sludge in Ganga basin to classify its suitability for safe disposal	VK Tyagi, (Co-PI) AA Kazmi (PI, IITR)	02 Years (01/22-12/23) **Sponsored by**: Central Pollution Control Board (CPCB)-NMCG **Status**: In-progress
6.	SARASWATI 2.0 - Identifying best available technologies for decentralized wastewater treatment and resources recovery for India	VK Tyagi, (Co-PI) AA Kazmi (PI, IITR)	4 Years (03/20-02/24) **Sponsored by**: Department of Science & Technology (DST) **Status**: In-progress
Internal Study (Ongoing)			
7.	Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims using groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants	MK Sharma (PI), Suhas Khobragade, Rajesh Singh	2 Years (04/22-03-24) **Status:** In-progress
8.	Understanding arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Rajesh Singh (PI), RP Pandey, Sumant Kumar, Pradeep Kumar, MK Sharma, VK Tyagi, Kalzang Chhoden	3 Years (07/21-06/24) **Status:** In-progress
9.	Simulation of Non-Point Source Pollution Processes in Song River	Pradeep Kumar (PI), MK Sharma, Rajesh Singh	4 Years (11/19-10/23) **Status:** In-progress
10.	Hydrological Studies for the Conservation of Rewalsar Lake	Kalzang Chhoden (PI) Rajesh Singh, RP Pandey, P Kumar, VK Tyagi, Omkar Singh, Shuhas Khobragade DS Malik, GKU, Haridwar	3 Years (12/22-11/25) **Status:** In-Progress

11.	Comprehensive evaluation of disinfection units of STPs in Ganga basin: Occurrence and control the formation of emerging oxidation precursors	VK Tyagi (PI), Rajesh Singh, MK Sharma, P Kumar, JP Patra, Kalzang Chhoden, RP Pandey	3 Years (04/23 - 03/26) **Status:** In-Progress
Consultancy Projects (Completed)			
12.	Estimation of Sediment Load and GHG Emission from Reservoir of Chamera-1 Power Station, NHPC	JV Tyagi, RP Pandey, Rajesh Singh (PI), MK Sharma	15 Months (12/21-03/23) **Funded by:** Innovante Water Solution Pvt. Ltd. **Cost**: Rs. 3.245 Lakh **Status:** Completed
13.	Performance evaluation of Nano Catalytical Instant Water Converter (NCIWC) equipment for water and wastewater treatment	JV Tyagi, RP Pandey, Rajesh Singh (PI), Sumant Kumar, VK Tyagi, MK Sharma, P Kumar	06 Months (05/22-11/22) **Funded by:** Envirogreen Minetech India Pvt. Ltd., Indore, M.P. **Cost**: Rs. 5.90 Lakhs **Status:** Completed
14.	Hydrological Study for Water Availability Assessment in Sukhnai River and Runoff Diversion to Saprar Dam	RP Pandey (PI), P Kumar (Co-PI), Rajesh Singh, VK Tyagi, Kalzang Mathus, Shakti Suryavanshi, Shailendra Kumre	06 Months (03/23-09/23) **Funded By:** Irrigation Deptt., UP Govt. **Cost:** Rs.29.50 Lakhs **Status:** Completed
15.	Hydrological Study for Design of Drainage System for Safe Disposal of Upland Runoff Passing through New Kendriya Vidyalaya Campus Bhimtal	RP Pandey (PI), P Kumar (Co-PI), Rajesh Singh, VK Tyagi, Kalzang Mathus, Shakti Suryavanshi, Shailendra Kumre	03 Months (07/23 - 10/23) **Funded By:** CPWD, Haldwani **Cost:** Rs.9.44 Lakhs
16.	Sampling/Analysis of Ground water samples for confirming the present status of petroleum contamination at Akolner Village, Tal. & Dist. Ahmednagar, Maharashtra	Sudhir Kumar, RP Pandey, MK Sharma (PI), P Kumar, Rajesh Singh	03 Months (07/23-09/23) **Funded by:** MPCB, Nasik **Cost:** Rs.17.70 Lakh **Status:** Completed
17.	Analysis of Water and Soil Samples for Major Ions, Trace Metals and Isotope Studies	Sudhir Kumar, RP Pandey, MK Sharma (PI), SS Rawat, P Kumar, Kalzang Chhoden	6 months (08/23-01/24) **Funded by:** Geosciences Consultancy Services, Roorkee **Cost:** Rs. 2.95 Lakh **Status:** On-going
Consultancy Projects (Ongoing)			
18.	Water Quality Studies for Tehri Reservoir Tehri HPP (4x250MW)	Sudhir Kumar, RP Pandey, MK Sharma (PI), P Kumar, Rajesh Singh, SK Kumre	2 Years (02/23-01/25) **Funded by:** THDC, India Limited **Cost:** Rs. 6.91 Lakh **Status:** In-Progrss
19.	Preparation of District/State Action Plans for Source Sustainability of Drinking Water Supply Schemes under Jal Jeevan Mission, Uttarakhand	RP Pandey (PI), Rajesh Singh (Co-PI), P Kumar, MK Sharma, VK Tyagi, Kalzang Chhoden, PK Sahoo, Shakti Suryavanshi, Shailendra Kumre	08 Months (10/23-06/24) **Funded by:** Uttarakhand Jal Jeevan Mission **Cost:** Rs. 1.06 Crore **Status:** In-Progress

ProposedWork Programme for the Year 2024-25

S. No.	Study Title	Study Team	Duration/Status
Sponsored R&D Projects (Ongoing)			
1.	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	Omkar Singh (PI), Rajesh Singh, Jyoti P Patil, VK Tyagi, Kalzang Chhoden **Partners:** NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Ahmedabad	5 Years (04/19 - 03/24) **Project Cost**: 5.1 Crore **Sponsored by:** DST **Status:** In-progress
2.	Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (MIP) Shahnehar	RP Pandey (PI), JP Patra, Rajesh Singh, Shakti Suryavanshi, SK Kumre, NK Bhatnagar	3 Years (12/17-03/24) **Project Cost**: 75 Lakh **Sponsored by:** NHP **Status:** In-progress
3.	Anaerobic Co-digestion of Thermochemically Pretreated Organic Fraction of Municipal Solid Waste and Sewage Sludge: Effect on Process Performance and Microbial Community Development	Vinay Kumar Tyagi (PI)	5 Years (2018-2023) **Project Cost**: 106 Lakhs **Sponsored by**: DBT **Status**: In-progress
Collaborative R&D Projects (Ongoing)			
4.	Isotopic and geochemical approach to study vulnerable confined and unconfined drinking water aquifers in Varanasi and surrounding area, India	Rajesh Singh (PI), R.P. Pandey BHU, Varanasi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary	3 Years (07/21-06/24) **Sponsored by**: BHU **Status**: In-progress
5.	Comprehensive characterization of variably processed sewage sludge in Ganga basin to classify its suitability for safe disposal	VK Tyagi, (Co-PI) AA Kazmi (PI, IITR)	02 Years (01/22-12/23) **Sponsored by**: Central Pollution Control Board (CPCB)-NMCG **Status**: In-progress
6.	SARASWATI 2.0 - Identifying best available technologies for decentralized wastewater treatment and resources recovery for India	VK Tyagi, (Co-PI) AA Kazmi (PI, IITR)	4 Years (03/20-02/24) **Sponsored by**: DST **Status**: In-progress
Internal Study (Ongoing)			
7.	Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims using groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants	MK Sharma (PI), Suhas Khobragade, Rajesh Singh	2 Years (04/22-03-24) **Status:** In-progress
8.	Understanding arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Rajesh Singh (PI), RP Pandey, Sumant Kumar, Pradeep Kumar, MK Sharma, VK Tyagi, Kalzang Chhoden	3 Years (07/21-06/24) **Status:** In-progress
9.	Simulation of Non-Point Source Pollution Processes in Song River	Pradeep Kumar (PI), MK Sharma, Rajesh Singh	4 Years (11/19-10/23) **Status:** In-progress
10.	Hydrological Studies for the Conservation of Rewalsar Lake	Kalzang Chhoden (PI) Rajesh Singh, RP Pandey, P Kumar, VK Tyagi, Omkar Singh, Shuhas Khobragade DS Malik, GKU, Haridwar	3 Years (12/22-11/25) **Status:** In-Progress

11.	Comprehensive evaluation of disinfection units of STPs in Ganga basin: Occurrence and control the formation of emerging oxidation precursors	VK Tyagi (PI), Rajesh Singh, MK Sharma, P Kumar, JP Patra, Kalzang Chhoden, RP Pandey	3 Years (04/23 - 03/26) **Status:** In-Progress
Internal Study (New)			
12.	Nanotechnology-enabled Multifunctional Materials for the Detection and Remediation of Arsenic in Contaminated Water	PK Sahoo (PI), Rajesh Singh, RP Pandey, MK Sharma, Pradeep Kumar, VK Tyagi, Sumant Kumar, Kalzang Chhoden	3 Years (04/24 - 03/27)
13.	Land and water management plan for rejuvenation of river Tilodki Ganga, Ayodhya	Shakti Suryavanshi (PI), SK Kumre, RP Pandey, Pradeep Kumar, Rajesh Singh, MK Sharma, VK Tyagi	3 Years (04/24 - 03/27)
14.	Groundwater Quality Assessment of Tripura with Special Reference to Arsenic and Fluoride	Rajesh Singh (PI)	3 Years (04/24 - 03/27)
15.	Comprehensive Hydrological Study for River Health Assessment and Development of Environmental Management Plan for River Yamuna	Pradeep Kumar (Lead-PI) and team of scientists from EHD, GWHD & HI	5 Years (04/24 - 03/29)
Consultancy Projects (Ongoing)			
16.	Water Quality Studies for Tehri Reservoir Tehri HPP (4x250MW)	Sudhir Kumar, RP Pandey, MK Sharma (PI), P Kumar, Rajesh Singh, SK Kumre	2 Years (02/23-01/25) **Funded by:** THDC, India Limited **Cost:** Rs. 6.91 Lakh **Status:** In-Progrss
17.	Preparation of District/State Action Plans for Source Sustainability of Drinking Water Supply Schemes under Jal Jeevan Mission, Uttarakhand	RP Pandey (PI), Rajesh Singh (Co-PI), P Kumar, MK Sharma, VK Tyagi, Kalzang Chhoden, PK Sahoo, Shakti Suryavanshi, Shailendra Kumre	08 Months (10/23-06/24) **Funded by:** Uttarakhand Jal Jeevan Mission **Cost:** Rs. 1.06 Crore **Status:** In-Progress

Technical Outputs of the EHD in the Year 2023-24

S. No.	Category	No. of outputs
1.	Technical Reports	06
2.	Books	02
3.	Book Chapters	23
4.	Research Papers	54
	(i) International Journals	30
	(ii) National Journals	01
	(iii) International Conferences	19
	(iv) National Conferences	04
5.	Training Courses Organized	03

Technical Reports:

1. Estimation of Sediment Load and GHG Emission from Reservoir of Chamera-1 Power Station, NHPC
2. Performance evaluation of Nano Catalytical Instant Water Converter (NCIWC) equipment for water and wastewater treatment
3. Hydrological Study for Water Availability Assessment in Sukhnai River and Runoff Diversion to Saprar Dam
4. Hydrological Study for Design of Drainage System for Safe Disposal of Upland Runoff Passing through New Kendriya Vidyalaya Campus Bhimtal
5. Sampling/Analysis of Ground water samples for confirming the present status of petroleum contamination at Akolner Village, Tal. & Dist. Ahmednagar, Maharashtra
6. Analysis of Water and Soil Samples for Major Ions, Trace Metals and Isotope Studies

Books:

1. Manish Kumar, Keisuke Kuroda, Santanu Mukherjee, Long D. Ngiehm, Meththika Vithanage, Vinay Kumar Tyagi (2024) Wastewater Surveillance for Covid-19 Management. The Handbook of Environmental Chemistry Series, Springer Cham, pp 374, ISBN: 978-3-031-53905-3.
2. Tyagi, V.K., Ojha, C.S.P (2023) Landfill leachate management. International Water Association publishing (IWAP). pp 496. ISBN: 9781789063301

Book Chapters:

1. A. Patel, A. K. Singh, R. Singh, N. Puthiyottil, S. P. Rai (2023). Fluoride Mobilization and Provenance Identification in Semi-arid Conditions: A Hydrochemical and Isotopic Approach (In. Surface and Groundwater Resources Development and Management in Semi-arid Region: Strategies and Solutions for Sustainable Water Management. Eds. C. B. Pande, M. Kumar, N. L. Kushwaha), Springer Nature, Switzerland AG (ISBN: 978-3-031-29394-8).
2. Ahmed Tawfik, Vinay Kumar Tyagi and Dominique Patureau Fate of emerging contaminants in anaerobic digestate. In: Tyagi, V.K., Kaoutar, A., Eskicioglu, C. (eds) Anaerobic Digestate Management. International Water Association Publishing (IWAP). UK. Pp. 327-338, Chapter 15, ISBN: 9781789062748
3. Ahmed Tawfik and Vinay Kumar Tyagi (2023) Aanerobic treatment of landfill leachate. In: Landfill leachate management. International Water Association publishing (IWAP). pp 37-56. ISBN: 9781789063301
4. Ahmed Tawfik and Vinay Kumar Tyagi (2023) Treatment of landfill leachate containing emerging micro-pollutants.In: Landfill leachate management. International Water Association publishing (IWAP). pp 195-212. ISBN: 9781789063301
5. Akansha Bhatia, Ankur Rajpal, Bhaskar Jyoti Deka, A.A. Kazmi, Vinay Kumar Tyagi (2022) Valorization of Biowaste to Biowealth Using Cellulase Enzyme During Prehydrolysis Simultaneous Saccharification and Fermentation Process. In: Enzymes in the Valorization of Waste. Ed. Pradeep Verma, CRC Press, pp. 25-37, eBook ISBN 9781003187721
6. Gahlot, P., Tyagi, V.K. (2023). WBE: An Integral Part of Mass Surveillance of COVID-19?. In: The Handbook of Environmental Chemistry. Springer, Berlin, Heidelberg. https://doi.org/10.1007/698_2023_993
7. Gowtham Balasundaram, Pallavi Gahlot, Absar Ahmad Kazmi, Vinay Kumar Tyagi (2023) Overview of Thermal Based Pre-Treatment Methods for Enhancing Methane Production of Sewage Sludge. In: Management of Wastewater and Sludge. 1st Edition, CRC Press (Taylor & Francis), pp. 14, eBook ISBN: 9781003202431.
8. Kalzang Chhoden, Chhavi K. Manchanda (2023), Ground Water and Pond Water Quality Assessment of District Ropar, Punjab, Water Science and Technology, Published by ABS Books; ISBN : 978-93-94424-62-3.
9. Kaoutar Aboudi, Ankur Rajpal, Vinay Kumar Tyagi, Ahmed Tawfik (2023) Aerobic treatment of landfill leachate. In: Landfill leachate management. International Water Association publishing (IWAP). pp 15-36. ISBN: 9781789063301

10. Mandeep Singh, Muntjeer Ali, Nehaun, Vinay Kumar Tyagi, Absar Ahmad Kazmi, C.S.P Ojha (2023) Landfill leachate management. In: Landfill leachate management. International Water Association publishing (IWAP). pp 429-462. ISBN: 9781789063301
11. Manojkumar Y, Sridhar Pilli, R.D. Tyagi, Puspendu Bhunia, Sumanth C, Vinay Kumar Tyagi and Ashok Pandey (2022) Per- and poly-fluroalkyl substances (PFASs): An introduction. In: Sustainable Treatment Technologies for Per- and Poly-fluoroalkyl Substances. Currents Development in Biotechnology and Bioengineering Series. Elsevier Publishing. pp.1-12, ISBN: 978-0-323-99906-9.
12. Muntjeer Ali, Sridhar Pilli, Puspendu Bhunia, R.D. Tyagi, Ashok Pandey and Vinay Kumar Tyagi (2022) Occurrence, fate, and persistence of perfluorinated compounds (PFCs) in wastewater treatment systems. In: Sustainable Treatment Technologies for Per- and Poly-fluoroalkyl Substances. Currents Development in Biotechnology and Bioengineering Series. Elsevier Publishing. pp. 207-233, ISBN: 978-0-323-99906-9.
13. Neelam Gunjiyal, C.S.P. Ojha, Vinay Kumar Tyagi (2023) Prevalence of antibiotics and antibiotic resistance genes (ARGs) in landfill leachate. In: Landfill leachate management. International Water Association publishing (IWAP). pp 393-410. ISBN: 9781789063301
14. O. Singh, R. Singh, K. Chhoden, N. R. Allaka, D. Singh, V. C. Goyal (2023). Rejuvenation of village ponds and performance evaluation of natural treatment system: Few case studies (In. Water Management and Governance. Eds. A. Rawat, B. Sharma, O. P. Nautiyal), ABS Books, Delhi (ISBN: 978-93-94424-71-5).
15. Pallavi Gahlot, Gowtham B., Banafsha Ahmed, Absar Ahmad Kazmi, Vinay Kumar Tyagi (2023) Microbe-material interactions for direct interspecies electron transfer in anaerobic digestion. In: Material-Microbe Interactions-Environmental Biotechnological Perspective. Academic Press (Elsevier), pp. 47-58. ISBN: 978-0-323-95124-1
16. Pallavi Gahlot, Kaoutar Aboudi and Vinay Kumar Tyagi (2022) Effect of digestate recirculation on anaerobic digestion performance. In: Tyagi, V.K., Kaoutar, A., Eskicioglu, C. (eds) Anaerobic Digestate Management. International Water Association Publishing (IWAP). U.K. Pp. 247-259. Chapter 11, ISBN: 9781789062748
17. Pallavi Gahlot, Kaoutar Aboudi, Ahmed Tawfik and Vinay Kumar Tyagi (2022) Biochar-augmented anaerobic digestate treatment. In: Tyagi, V.K., Kaoutar, A., Eskicioglu, C. (eds) Anaerobic Digestate Management. International Water Association Publishing (IWAP). UK. Pp. 265-282, Chapter 12, ISBN: 9781789062748
18. Pandey, RP (2021) Hydrological Drought in India – An institutionalized systemic hydrological management challenge (Case study 2). A policy-note contribution in FAO publication entitled "A rapid review of drought risk mitigation measures – Integrated drought management" (Author: Caroline King-Okumu; Eds: Maher Salman, FAO-UN and Daniel Tsegai, UNCCD). Rome, FAO, pp. 128-131, https://doi.org/10.4060/cb7085en.
19. S. K. Malyan, S. Kumar, R. Singh, S. Singh, G. Anand, S. Upadhyay, K. Saini, S. S. Kumar (2023). Algal intervention as nature-based solution for treatment of landfill leachate (In. Algae Based Bioelectrochemical Systems for Carbon Sequestration, Carbon Storage, Bioremediation and Bioproduct Generation. Eds. D. M. Mahapatra, S. S. Kumar, L Singh), Academic Press, Elsevier, London, UK (ISBN: 978-0-323-91023-1).
20. S. Singh, N. Pawar, S. S. Kumar, R. Singh, G. Anand, A. Kumar, S. K. Malyan (2023). Aromatic oils from medicinal plants, and their role in nanoparticles synthesis, characterization, and applications (In. Secondary metabolites from medicinal plants: Nanoparticles synthesis and their applications. Eds. R. K. Bachheti, A. Bachheti), CRC Press, Taylor & Francis Group, Boca Raton, FL (ISBN: 978-1-032-07515-0).
21. Sandeep Singh, Sandeep K. Malyan, Rajesh Singh, Vinay Kumar Tyagi, Sujata Kashyap (2023) Aerobic and anaerobic methods of landfill leachate treatment: limitations and advantages. In: Landfill leachate management. International Water Association publishing (IWAP). pp 411-428. ISBN: 9781789063301
22. Sanket Dey Chowdhury, R.D. Tyagi, Sridhar Pilli, Vinay Kumar Tyagi, Ashok Pandey and Puspendu Bhunia (2022) Per- and poly-fluoroalkyl substances (PFASs) in water and wastewater In: Sustainable Treatment Technologies for Per- and Poly-fluoroalkyl Substances. Currents

Development in Biotechnology and Bioengineering Series. Elsevier Publishing. pp. 299-327, ISBN: 978-0-323-99906-9.

23. Sharma, M. K., Thayyen, Renoj J., Jain, C. K., Arora, Manohar and Shyamlal (2022) “Seasonal Variations of Major Ion Chemistry and Solute Fluxes of Meltwater of River Bhagirathi, a Himalayan Tributary, India" in the Edited Book titled "Groundwater and Water Quality" Hydraulics, Water Resources and Coastal Engineering (Eds. R. Jha, V. P. Singh, V. Singh, L. B. Roy, Roshni Thendiyath) Water Science and Technology Library, Vol. 119 (ISBN 978-3-031-09550-4), Springer Nature Switzerland AG, pp. 387-398.

Research Papers in International Journals

1. A. Patel, S. P. Rai, N. Puthiyottil, A. K. Singh, J. Nobel, R. Singh, D. Hagare, U. D. S. Kumar, N. Rai, K. V. Akpataku. 2024. Refining aquifer heterogeneity and understanding groundwater recharge sources in an intensively exploited agrarian dominated region of the Ganga Plain. Geoscience Frontiers (accepted).
2. A. Gani, S. Pathak, A. Hussain, S. Ahmed, R. Singh, A. Khevariya, A. Banerjee, R. Ayyamperumal, A. Bahadur, 2023. Water quality index assessment of river Ganga at Haridwar stretch using multivariate statistical technique. Molecular Biotechnology, https://doi.org/10.1007/s12033-023-00864-2.
3. Ali Mohammad Rahmani, Vinay Kumar Tyagi, A. A. Kazmi, Chandra Shekhar P. Ojha (2023) Hydrothermal and thermal-acid pretreatments of wheat straw: Methane yield, recalcitrant formation, process inhibition, kinetic modeling. Energy, 283, 129083.
4. Ali Mohammad Rahmani, Vinay Kumar Tyagi, Neelam Gunjyal, A. A. Kazmi, Chandra Shekhar P. Ojha, Konstantinos Moustakas (2023) Hydrothermal and thermal-alkali pretreatments of wheat straw: co-digestion, substrate solubilization, biogas yield and kinetic study. Environmental Research, 216 (1), 114436.
5. Banafsha Ahmed, Pallavi Gahlot, Gowtham Balasundaram, Vinay Kumar Tyagi, Rajesh Banu J, Vivekanand Vivekanand, A.A. Kazmi (2023) Semi-continuous anaerobic co-digestion of thermal and thermal-alkali processed organic fraction of municipal solid waste: methane yield, energy analysis, anaerobic microbiome. J. Environ. Manag., 345, 118907.
6. Banu, J. Rajesh, Kavitha, S., Ravi, Yukesh Kannah, Tyagi, Vinay Kumar, Kumar, Gopalakrishnan (2023) Combined sodium citrate and ultrasonic pretreatment of waste activated sludge for cost effective production of biogas. Bioresource Technology. 376, 128857.
7. Gahlot, P., Alley, K. D., Arora, S., Das, S., Nag, A., & Tyagi, V. K. (2023). Wastewater surveillance could serve as a pandemic early warning system for COVID-19 and beyond. WIREs Water, 10 (4), e1650.https://doi.org/10.1002/wat2.1650
8. Ganesh Sude, Ankur Rajpal, Vinay Kumar Tyagi, Kapil Sharma, Pravin Kumar Mutiyar, B.K. Panday, R.P. Pandey, Absar Ahmad Kazmi (2023) Evaluation of sludge quality in Indian sewage treatment plants to develop quality control indices. Environmental Science and Pollution Research (Accepted). https://doi.org/10.1007/s11356-023-25320-1
9. Godvin Sharmila V, Surya Prakash Shanmugavel, Vinay Kumar Tyagi, Rajesh Banu J (2023) Microplastics as emergent contaminants in Landfill leachate: Source, potential impact and remediation technologies. Journal of Environmental Management, 343, 118240.
10. Gowtham Balasundaram, Pallavi Gahlot, Banafsha Ahmed, Pinakshi Biswas, Vinay Kumar Tyagi, Kine Svensson, Vinod Kumar, A.A. Kazmi (2023) Advanced steam-explosion pretreatment mediated anaerobic digestion of municipal sludge: Effects on methane yield, emerging contaminants removal, and microbial community. Environmental Research, 238, Part 2, 117195.
11. Gowtham Balasundaram, Pallavi Gahlot, Vinay Kumar Tyagi, A.A. Kazmi (2023) Advanced steam explosion as thermal hydrolysis process for high solids anaerobic digestion and enhanced methane yield: Proof of concept. Sustainable Chemistry and Pharmacy, 36, 101274.
12. Gowtham Balasundaram, Pallavi Gahlot, Vinay Kumar Tyagi, Yukesh Kannan, Rajesh Banu, A A Kazmi (2024) Mesophilic, thermophilic and thermal hydrolysis process coupled anaerobic digestion of sewage sludge: biomethane potential, pathogen removal and energy feasibility. Sustainable Chemistry and Pharmacy, 37, 101397.

13. Gupta Ajay, Manoj Kumar Jain, Rajendra Prasad Pandey, Vivek Gupta, Aniruddha Saha (2023) Evaluation of global precipitation products for meteorological drought assessment with respect to IMD station datasets over India. Atmospheric Research. Volume 297, January 2024, 107104,https://doi.org/10.1016/j.atmosres.2023.107104.
14. Himanshu S.K., Ashish Pandey, Kiran Karki, R.P. Pandey, S.S. Palmate, Avishek Datta (2023), Assessing the Applicability of Variable Infiltration Capacity (VIC) Model using Remote Sensing Products for the Analysis of Water Balance: Case Study of the Tons River Basin, India. Journal of the Indian Society of Remote Sensing (October 2023), Springer publisher, DOI:10.1007/s12524-023-01768-z.
15. K. Singh, R. Singh, G. Pandey, 2023. Impact of nitrogen and sulfur fertilizers on leaching behavior of heavy metals from aquifer sediments to groundwater. Journal of the Taiwan Institute of Chemical Engineers, 105056 (In Press), https://doi.org/10.1016/j.jtice.2023.105056, (I.F.: 5.7).
16. Khursheed, Anwar; Munshi, Faris Mohammad A; Almohana, Abdulaziz Ibrahim; Alali; Kamal, Mohab Amin; Alam; Shamshad, Alrehaili, Omar; Islam, Dar Tafazul; Kumar, Manish; Varjani, Sunita; Kazmi, AA, Tyagi, Vinay Kumar (2023) Resolution of Conflict of Reduced Sludge Production with EBPR by Coupling OSA to A^2/O Process in a Pilot Scale SBR. Chemosphere. 318, 137-345.
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1. Dwivedi, M., Mishra, A.K., Pandey, R.P., Panday, B.K. and Suryavanshi, S., 2024. Recent Precipitation Trends in Six Districts of the Ken River Basin of Bundelkhand Region, India. International Journal of Environment and Climate Change, 14(1), pp.490-495.

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1. Ankur Rajpal, Vinay Kumar Tyagi, A A Kazmi (2023) Potential utilization of sewage sludge for cost effective natural farming in India: Characterization and Treatment. In Proceedings: International Conference on Solid Waste Hong Kong (ICSWHK-2023), 31st May-2nd June 2023, Hong Kong. [Best Paper Award]
2. Anurag Tomar, Ankur Rajpal, A.A Kazmi, A.K. Goel, Vinay Kumar Tyagi (2023) Treatment of Blackwater by the Advanced Anaerobic Baffled Reactor". In Proceedings: International Conference on Solid Waste Hong Kong (ICSWHK-2023), 31st May-2nd June 2023, Hong Kong. [Best Poster Award]
3. Anurag Tomar, Ankur Rajpal, A.A Kazmi, A.K. Goel, Vinay Kumar Tyagi (2023) Onsite wastewater Treatment by Modified Anaerobic Baffled Reactor. In Proceedings: 10th International Conference on Sustainable Solid Waste Management, Chania 2023, 21-24 June, Organized by National Technical University of Athens.
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Papers in National Conference:

1. कुनारिका भनोट, **मुकेश कुमार शर्मा** और रजनीश दत्त कौशिक (2023) "बहुभिन्नरूपी सांख्यिकी का उपयोग करते हुए अलकनंदा नदी, उत्तराखंड के सतही जल का हाइड्रोकेमिकल मूल्यांकन" सातवीं राष्ट्रीय जल संगोष्ठी, 17-18 अगस्त 2023, राष्ट्रीय जल विज्ञान संस्थान, रूड़की।
2. **मुकेश कुमार शर्मा** ,बबीता शर्मा एवं बीना प्रसाद (2023) "गंगोत्री ग्लेशियर के मेल्ट-वॉटर मे रासायनिक अभिलक्षणों में अवसाद का योगदान" सातवीं राष्ट्रीय जल संगोष्ठी, 17-18 अगस्त 2023, राष्ट्रीय जल विज्ञान संस्थान, रूड़की।
3. मोहित कुमार, **मुकेश कुमार शर्मा** और देवेंद्र सिंह मलिक (2023) "जीआईएस एप्लीकेशन का उपयोग कर बेमेतरा जिले में भूजल प्रदूषण का मूल्यांकन और न्यून गुणवत्ता वाले क्षेत्रों की पहचान" सातवीं राष्ट्रीय जल संगोष्ठी, 17-18 अगस्त 2023, राष्ट्रीय जल विज्ञान संस्थान, रूड़की।

4. Shakti Suryavanshi, Keshni Raju, Hareesh Kumar, Deepa Elizabeth Johnson (2023) 'Long-Term Assessment of Extreme Temperature Events in Ganga Basin', in National Conference on the Role of Science Engineering and Technology, Swadeshi Sciences movement of India, In TMU, Moradabad 03rd November, 2023

TRAINING COURSE/WORKSHOP ORGNIZED (03 Nos.):

SN	Topic	Duration	Place
1	Training Course on "Hands-On Training of ICP-MS and GC-MS" for Scientific Cadre Officials of CWC (Coordinator: Dr. M. K. Sharma)	5 Days 11-15 December 2023	Roorkee
2	Training Course on "Hands-On Training of ICP-MS and GC-MS" for Scientific Cadre Officials of CWC (Coordinator: Dr. M. K. Sharma)	5 Days 08-12 January 2024	Roorkee
3	Training Course on "Hands-On Training of ICP-MS and GC-MS" for Scientific Cadre Officials of CWC (Coordinator: Dr. M. K. Sharma)	5 Days 19-23 February 2024	Roorkee

Study – 1 (Sponsored R&D Project)

1. **Title of the project:** Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)

2. **Project Team:**

Project Investigator	Er. Omkar Singh, Sc. G & Head, Technical Cell
Project Co-investigator	Dr. Rajesh Singh, Sc. E, EHD (Co-PI) Dr. Jyoti P. Patil, Sc. E, Technical Cell Dr. Vinay Kumar Tyagi, Sc, D, EHD Dr. Kalzang Chhoden, Sc. C, EHD Sh. Rajesh Agarwal, PRA, Technical Cell Dr. Jyoti Singh, Sr. Project Officer, Technical Cell
Project Partners	Prof. Pradeep Kalbar, IIT Bombay, Mumbai Prof. A. B. Gupta, MNIT Jaipur Prof. Indranil De, IRMA, Anand

3. **Type of Study:** DST Sponsored Study, **Budget:** Rs. 5.1 Crore
4. **Nature of Study:** Applied & Basic Research
5. **Date of start:** April 201
6. **Scheduled date of completion:** February 2024 (Extension upto August 2024)
7. **Duration of the Study:** 5 Years

8. **Objectives of the study:**

i) Establishment of a state-of-art Centre for Eco-prudent Wastewater Solutions (IC-EcoWS) to harness the potential Natural Treatment Systems (NTS) and other eco-prudent resource recovery technologies for water security and sustainability in India,

ii) Development of a Decision Support Tool (DST) based on Life Cycle Assessment (LCA) and Multiple Criteria Decision Making (MCDM) approach for selection of appropriate "Technology Packages" for resource recovery-oriented wastewater treatment infrastructure,

iii) Establishment of few pilot study sites ("Live Laboratories") for detailed assessment of selected NTS in urban, peri-urban and rural settings, for both secondary and tertiary treatment requirements as per new CPCB norms as well as for select emerging pollutants,

iv) To explore innovative ideas on the development (e.g. use of pre-fabricated structures, efficient structures for control of solid waste in sullage) and application (e.g. retrofitting of existing village ponds, drains, linkage to livelihood options) of NTS for wastewater treatment,

v) To organize capacity building, awareness creation, documentation and dissemination activities, and preparation of a TOT Module on NTS applications and an Indian handbook for promotion and propagation of NTS for resource recovery and wastewater treatment in India.

9. **Results achieved with progress/present status:**

The progress of the project is given below:

Objective/ Deliverables	**Milestones**	**Target Month**	**NIH-R**	**IIT-B**	**MNIT-J**	**IRMA**
Objective 1	Hiring of project staff	M6	Completed	Completed	Completed	Completed
	Development of Centre's portal	M12	Completed	NA	NA	NA
Objective 2	Operation of DST	M24	NA	Completed	NA	NA
	Dev. of Technology Packages	M42	NA	Ongoing	NA	Ongoing
Objective 3	Establishment of Live Laboratories	M18	Completed	NA	Completed	NA

Objective 4	Dev. & application of innovative ideas on NTS	M24	Ongoing	NA	Ongoing	Ongoing
Objective 5	Organization of Users Interaction Workshops (annual)	M12, M24, M36, M48, M58	Completed (M12)	Completed (M36)	Completed (M24)	Completed (M56)
	Dev. of TOT Module on NTS applications	M50	Ongoing	NA	Ongoing	NA
	Dev. of Indian handbook for NTS Technology Packages	M55	NA	Ongoing	NA	NA
	Submission of final Project Report	M60	Ongoing	Ongoing	Ongoing	Ongoing

10. Milestones achieved by NIH Roorkee (February 2024)

Milestones	Activities	Target Month	NIH-Progress
Hiring of Project staff	Hiring of project staff	M6	Completed
Dev. of Centre Portal	Development of IC-EcoWS Centre Website and social media pages for information dissemination	M12	Completed
Organization of Users interactions Workshop	IC-EcoWS Project Inception Cum Need Assessment Workshop (8-9 August, 2019)	M12	Completed
	Report on First Annual Workshop- IC-EcoWS Project Inception Cum Need Assessment Workshop		
Establishment of Live Laboratories	Procurement of several technical and scientific lab equipment for setting up the IC-EcoWS Innovative Centre at NIH Roorkee	M18	Completed
	Establishment of horizontal sub-surface -flow constructed wetland for domestic wastewater treatment (Peri-urban residential area in Roorkee)		
	Installation of Online Monitoring System for water quality monitoring		
Development and Application of Innovative ideas on NTS	Pilot-scale natural treatment system (4 cell floating wetlands) for the treatment of domestic wastewater using identified plant species *Bacopa monnieri* and *Acorus calamus*	M24	Completed
	Treatment of domestic wastewater using floating treatment wetlands using *Phragmites australis*, and *Canna indica*	M30	Completed
	In-situ treatment of domestic wastewater in urban drain using floating constructed wetland/Bio-Inoculum-Solanipuram/Adarshnagar (Roorkee)	M36	Completed
	Pilot-scale demonstration unit for wastewater treatment of residential building using Subsurface Horizontal Flow Constructed wetlands system at NIH Roorkee	M36	Completed
	Pilot-scale horizontal sub-surface-flow constructed wetland (HSSFCW) for Pesticide (chlorpyrifos) removal from synthetic wastewater using *Canna indica* in NIH Roorkee.	M49	Ongoing

	Evaluating biogas generation potential from canna indica harvested from horizontal sub-surface flow constructed wetland as an alternate source of energy at lab scale	M52	Ongoing
	Performance evaluation of horizontal sub-surface-flow constructed wetland (HSSFCW) for the treatment of domestic wastewater at NIH Colony (Real-time Monitoring of Water quality parameters)	M55	Ongoing
Documentation and dissemination	Capacity building, awareness creation, and dissemination activities (Factsheets/policy briefs, reports on NTS)	M58	Ongoing

Study – 2 (Sponsored R&D Project-NHP-PDS)

1. **Title of the Study:** Irrigation Efficiency Improvement for Shahnehar Major Irrigation Project (MIP)

2. **Study Group:**

Project Investigator/Co-Project Investigator Dr. R.P. Pandey, Scientist 'G'. Er. Jagdish Prasda Patra, Scientist 'E' Dr. Rajesh Singh, Scientist 'E' Dr. Shakti Suryavanshi, Scientist 'C' Dr. Shailendra Kumar Kumre, Scientist 'B' Sh. N. K. Bhatnagar, Scientist 'B'
Collaborating Agency Department of Irrigation & Public Health Engg. (I&PHE), Hydrology C&M Division, Tutikandi, Shimla-4. Himachal Pradesh

Type of study: PDS
Total Project Cost: Rs.75.0 lakh (**Funded by NHP)**
NIH Cost Allocation Rs. 18.1 lakh

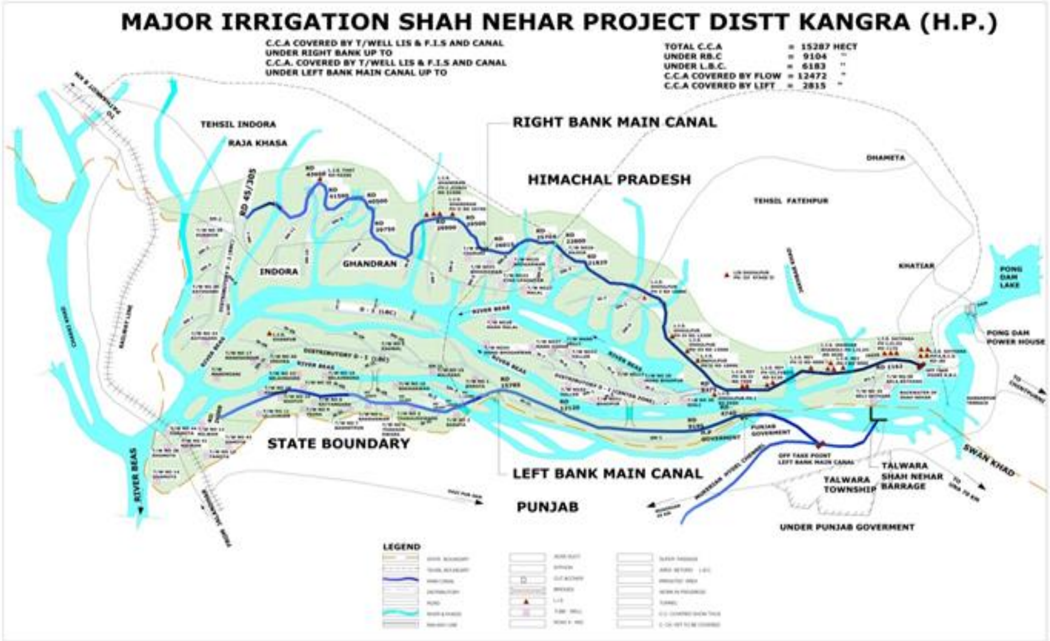
Project Duration: **3-years**
Date of start: **December, 2017**
Scheduled Date of Completion: **March, 2023 (after extension)**

OBJECTIVES OF THE STUDY:

The primary objectives of this study are 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

Study Area : Shah Nehar Command Area, Himachal Pradesh
Shah Nehar Irrigation Project in District Kangra, Himachal Pradesh is first Major Irrigation Project of the HP Govt state 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 according to agreement between Govt. of HP and Punjab Govt. signed on 4/8/1983.The index map of Shah Nehar project command area is given in Figure below.



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 needs interventions to enhance irrigation efficiency. 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 in the command area. The water demand of each outlet is based on the cropping pattern in the respective chak. It is envisaged 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 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 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.

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 components 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. Develop a system of water supply database of quantum of water used to each beneficiary so the charges can be levied accordingly.
5. Devising a possible system of change in cropping pattern owing to real time monitoring of available water at various reaches of the canal.
6. 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, experimental plots have been setup in pairs (controlled and un-controlled) at three sites and the irrigation supply is planned based on the soil moisture depletion. The measured amount of irrigation water is being applied in both the plots to quantify the difference in water applied. The experiment has started in Dec 2023 with the sowing of wheat crop.

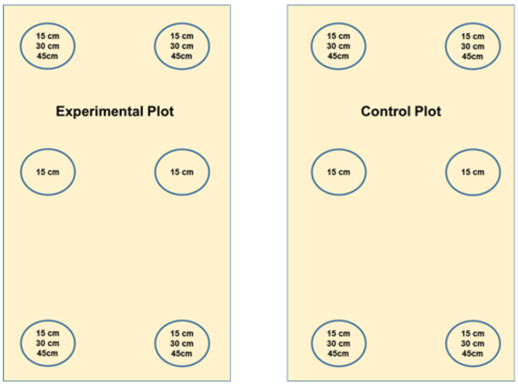
Progress of Work

The team NIH Scientist visited study area and conducted detailed survey of Shahnehar Project Command Area, along with Himachal Pradesh I &PHE department officials during Oct. 2023 for inspection of new experimental site and for technical inputs to the field staff of the I&PHD, HP.

Subsequently the second visit of NIH team was held in in Mid Jan 2024 for measurement and training of field staff at site. The instrumentation of one new experiment site at Rajgir was completed by October 2023 and it has subsequently completed by I&PHD, HP in other two sites at Sathana Khas and Indora (Thatti). The details of monitoring procedure were discussed with I&PHE officials regarding field measurement.

The progress of the analysis part of the study is given below

1. The meteorological data for the assessment of present irrigation requirement has been collected from BBMB meteorological station at pong dam site and analyzed.
2. Base maps for the study sites have been prepared.
3. The experimental sites have been instrumented and measurements are in progress.
4. The soil moisture observations are received in the Dashboard Site
5. The soil moisture sensors at experimental plots have been installed for measurement of crop root-zone moisture at the sites as follows.
6. The estimation Crop Water Requirement (CWR), Potential Evapotranspiration (ETo) of ETo for the study sites has been completed. The dependable monthly rainfall at 80% and 50% probability level during the period 1982-2018 has been used in the analysis. FAO (Food and Agriculture Organisation) CROPWAT 8.0 crop simulation model has been used to estimate reference 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 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 has been considered for safer and better irrigation management planning in the study area.



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*


Latitude: 31.966571
Longitude: 75.907560
Elevation: 330.35±5.76 m
Accuracy: 4.52 m
Time: 18-10-2023 11:14:01
Note: Shahnehar
NoteCam @ iOS


SOIL MOISTURE CONDITIONER
Aimil
NODE: 6
Latitude: 32.072925
Longitude: 75.809699
Elevation: 312.69±6.66 m
Accuracy: 8.85 m
Time: 18-10-2023 13:24:49
Note: Rajgir
NoteCam @ iOS


Latitude: 32.072922
Longitude: 75.809745
Elevation: 312.99±11.83 m
Accuracy: 8.53 m
Time: 18-10-2023 13:25:03
Note: Rajgir

Further Work

1. Monitoring of field irrigation application under measured and controlled conditions at three sites.
2. Measurements for quantification of irrigation water loss in different conveyance & distribution systems, field channels, and irrigation application.
3. Review of irrigation scheduling considering the type of crops, soil moisture and prevailing climatic conditions.
4. Workshops on OFWM practices for all the stakeholders including farmers.
5. Review of the existing Cropping patterns during different sowing seasons and suggest suitable crops for each season to enable optimum utilization of available water.

Deliverables:

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 for enhancement of water use efficiency.

Study - 3 (Sponsored R&D Project)

1. **Title of the Study:** Anaerobic co-digestion of organic fraction of municipal solid waste and sewage sludge: Effect of thermal-chemical pretreatment on process performance and microbial community development
2.
3. **Study Group:**

Project Investigator	Dr. Vinay Kumar Tyagi, Sc. 'D', EHD
Research Staff	Ms. Banafsha Ahmed, PhD Student Mr. Ali Mohammad Rahmani, PhD Student

3. **Type of Study:** Sponsored Study, **Budget:** Rs. 103.6 Lakhs
4. **Nature of Study:** Applied Research
5. **Date of start:** April 2018
6. **Scheduled date of completion:** June 2023
7. **Duration of the Study:** 5 Years

8. Study Objectives

a) Improving the efficiency of anaerobic digestion by thermo-chemical pretreatment of co-mixed substrate (OFMSW+sewage sludge)

b) To address the influence of anaerobic co-digestion and thermo-chemical pretreatment on microbial community.

9. Statement of the Problem:

According to the Indian situation where a renewable energy program has been initiated in the recent past, the introduction of anaerobic digestion into urban areas seems to be a value addition. The failures of various projects are more due to technical problems, inadequate planning or inappropriate management. There is a need of research on the aspect of stakeholder's preference towards the benefits of a biomass to bioenergy project. One of the objectives of the project deals with the preference hierarchy of the various stakeholders for sustainability of a biomass project. The benefits derived from the bio-waste to bioenergy project can be classified as: (a) avoidance of danger from the burning of biomass residues. (b) creating additional job opportunities for local people. (c) transfer of technology and knowledge in renewable energy. (d) Increasing the usage of renewable energy and local content. (e) reduction of GHG emissions.

10. Methodology:

The research project has been structured in six work packages (WP):

WP 1: Waste characterization

Milestone Expect: Defining characteristics of the samples in order to adjust feeds.

WP 2: Optimization of best treatment conditions for OFMSW+Sewage sludge

Milestone Expect: Definition of best total solids percentage (%TS), best sludge combination, Optimum OFMSW to sewage sludge ratio.

WP 3: Optimization of thermo-chemical pretreatment of waste

Milestone Expect: Selection of optimum condition of thermo-chemical pretreatment

WP 4: Effect of thermo-chemical pretreatment on biogas production and microbial community development

Milestone Expect: Selection of optimum conditions of pretreatment in order to maximize the methanogenic activity and biogas production. Deep insight on the reactor functioning by microbial community study under different treatment conditions/ Identification of microbial community changes by under no-pretreatment and pretreatment conditions.

WP 5: Semi-continuous operation

Milestone Expect: Best organic loading rate and hydraulic retention time.

WP 6: Pilot scale study

Milestone Expect: Proof of upscaled process

WP 6: Results analysis, drawing conclusion and reporting

Milestone Expect: Document summary of results, National and International research publications and conferences.

11. Timeline:

Task	Description	Months									
		6	12	18	24	30	36	42	48	54	60
1	Litearture Review & Characterization of the wastes	■									
2	Optimization of best treatment conditions for OFMSW+Sewage sludge										
2.1	Effect of co-digestion on biogas production		■								
2.2	Best sludge combination with OFMSW		■								
2.3	Best TS percentage of substrate			■							
2.4	Best OFMSW:Sludge mixing ratio			■							
3	Optimization of thermo-chemical pretreatment				■						
4	Batch anaerobic co-digestion experiments on pretreated waste, microbial community analysis					■	■	■			
5	Semi-continuous operation (HRT & OLR)								■		
6	Pilot study									■	
7	Data analysis										■
8	Final report, National and International research publications.										■

12. Objectives and achievement during last twelve months:

S. No.	Objectives	Achievements
(i)	**Pilot scale study**	The pilot scale digester (150 kg capacity) was operated under variable HRTs for thermally pretreated OFMSW-SS mixture. – The HRT of 15 days and OLR of 5.1 kgVS/m^3.d is considered best for the anaerobic digestion of thermally (125°C for 30 min) pre-treated OFMSW and SS (mixing ratio 80:20, TS 10%) . – Energy analysis also shows the net positive energy output of the system at 15 days HRT and 5.1 kgVS/m^3.d OLR, which can be used to achieve higher sustainability.

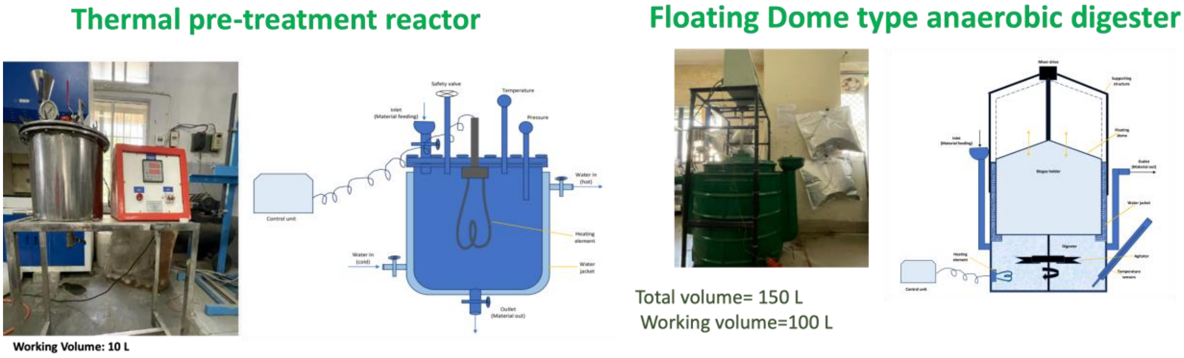
13. Recommendation / Suggestion:

S. No.	Recommendation / Suggestion	Action Taken
1.	No comments	--

14. Analysis & Results:

The pilot scale digester (150 kg capacity) was operated under variable HRTs for thermally pretreated OFMSW-SS mixture (Figure 1 & 2). An increase in COD solubilization of about 2.2 times is observed at pre-treatment conditions (125°C for 30 minutes). The anaerobic digestion of thermally pre-treated substrate at 15 days HRT and OLR of 5.1 kgVS/m^3.d achieved the highest biogas yield of 510 ml/gVS_{added}..which is about 24% and 104% higher than the best biogas yield of 408 ml/gVS_{added} and 250 ml/gVS_{added} at HRTs of 20 days and 30 days, respectively. The methane composition and methane yield under steady state conditions in 15 days HRT was 72% and 367 ml/gVS_{added}, respectively. The methane yield observed at 15 days HRT was almost 29% and 136% higher than that obtained at 20 days and 30

HRT respectively. A higher VS and COD removal was also achieved at 15 days HRT compared to 30 days and 20 days HRT. The VS removal of 50% is achieved at 15 days HRT and 5.1 $kgVS/m^3.d$ OLR in a steady state. Energy analysis also shows the net positive energy output of the system at 15 days HRT and 5.1 $kgVS/m^3.d$ OLR, which can be used to achieve higher sustainability. Thus, the HRT of 15 days and OLR of 5.1 $kgVS/m^3.d$ is considered best for the anaerobic digestion of thermally (125°C for 30 min) pre-treated OFMSW and SS (mixing ratio 80:20, TS 10%) .



(a) (b)

Fig. 1. (a) Thermal pretreatment reactor and (b) Pilot anaerobic digester of 150 kg capacity

15. **End Users / Beneficiaries of the Study:** Municipal corporation
16. **Deliverables:** Technical report and research papers
17. **Major items of equipment procured:** None
18. **Lab facilities used during the study:** Bioenergy Lab, IIT Roorkee
19. **Data procured or generated during the study:** Pilot study
20. **Study Benefits / Impacts:**

Municipal corporations will be the direct beneficiary, as the load of MSW handling will be lessened. Moreover, the obligation of stringent rules for the disposal of sewage sludge can be pacified as the sludge will be further used as a medium for electricity generation that can power the WWTP and the end product of digestion will be a highly stabilized end product that will not be harmful to that extent as the undigested sludge. Industrial sector i.e. different consultants and companies can get involved and, develop the design based on our results for better efficiency and ensure successful implementation at field scale. Moreover, a newly developed waste to energy recovery method can be circulated in the private sector and that can give green credits to the organization and it can be a stepping-stone to sustainable development. Researchers: Co-digestion and advanced pretreatment are emerging technologies with limited data availability on the integrated approach of both methods for organic waste treatment. The introduction of the findings of this study will benefit researchers working on municipal solid waste and sludge treatment as the option for two problematic waste management. In addition, the availability of large-scale microbial community data will aid in the development of fresh approaches involving manipulation of microbial composition and the formulation of inoculum for greater process efficiency.

21. **Involvement of end users/beneficiaries:** None
22. **Specific linkage with Institution and /or end users / beneficiaries**: Yes
23. **Shortcoming/Difficulties:** None
24. **Future Plan:**

(i) Techno-economic Analysis and Life cycle assessment

Study – 4 (Collaborative R&D Project)

1. **Title of the Project:** Isotopic and geochemical approach to study vulnerable confined and unconfined drinking water aquifers in Varanasi and surrounding area, India

2. **Project Team**

Lead Investigator	Dr. S. P. Rai, Assoc. Professor, Geology Dept., BHU Varanasi
Collaborator 1	Dr. Rajesh Singh, Sc. E, EHD, NIH Roorkee
Collaborator 2	Dr. Noble Jacon, Sc. G, Hydrology Section, BARC Mumbai
Collaborator 3	Dr. Laszlo Palcsu, Sr. Researcher, ICER, Hungarian Academy of Sciences, Hungary

3. **Type of Study:** Internal Study, **Budget:** Rs. 10 lacs
4. **Nature of Study:** Applied Research
5. **Date of start:** July 2021
6. **Scheduled date of completion:** June 2024
7. **Duration of the Study:** 3 Years

8. **Objectives**
   i) Identification of recharge sources and zones of aquifer system
   ii) Estimation of residence time, distribution and flow velocity of groundwater
   iii) Understanding interaction with aquifer and surface water bodies
   iv) Understanding rock water interaction affecting the water quality and assessment of impact of anthropogenic activities on groundwater.

9. **Statement of the Problem**
   Presently, the main problem of depletion of groundwater in Ganga Basin is due to the unsustainable abstraction of groundwater (Rodell et al., 2009; Tiwari et al., 2009). As the groundwater level is declining, people are drilling to deeper aquifers, to meet the groundwater demand. In the arsenic affected areas, deeper aquifer has been tapped for the extraction of groundwater to meet the drinking and other demands. Keeping in view of same, the study aims at identification of recharge sources and zones of aquifer system, understanding the surface and groundwater interactions, and the rock water interaction and anthropogenic activities affecting the groundwater quality.

10. **Approved Action Plan/ Methodology:**
   i) Thorough review of aquifer system and water quality status of the study area.
   ii) Collection and characterization of the water samples from the study area for physico-chemical, bacteriological, and isotopic parameters.
   iii) Geochemical, isotopic, and statistical modeling to understand the rock-water interaction, recharge zones, surface water interactions, and anthropogenic influence.

11. Timeline (Approved):

Sr. No.	Major Activities	2021-22			2022-23				2023-24				2024 -25
		Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q1
1.	Field Investigation and sampling plan												
2.	sample collection and analysis												
3.	Geochemical, isotopic, and statistical modeling												
7.	Publications												
8.	Interim Report												
9.	Final Report												

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared.
2.	Sample Collection and Analysis	• Following samples were collected from the study area- • Pre-monsoon (2021-22): 72 samples from urban Varanasi • Post monsoon (2021-22): 146 samples from Varanasi district • Pre-monsoon (2022-23): 220 samples from adjoining districts • Post-monsoon (2022-23): 220 samples from adjoining districts • Analysis for organoleptic, major ions, trace metals, coliforms, stable isotopes, and tritium (3H) in the pre- and post -monsoon samples of 2021-22 and pre-monsoon samples of 20223-23 completed and analysis of post-monsoon samples of 2022-23 is in progress. • Data analysis and processing for Varanasi (urban and entire district) has been completed. • Data processing of nearby areas is under process.
3.	Scientific Publications	• 02 research paper in international journal. • 01 Book chapter in Springer Hydrogeology Book Series. • 01 research paper in international journal (under review).

13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	No specific suggestion	--

14. Analysis & Results:

Upgrading literature and data collection

- The information related to geomorphology, geology, soil chemistry and mineralogy of the study area were extracted from the published reports of CGWB, GSI and SGWB.
- Important available data such as SRTM DEM, water level data, rainfall data, and borehole data are also acquired.

Field Investigation and sampling plan

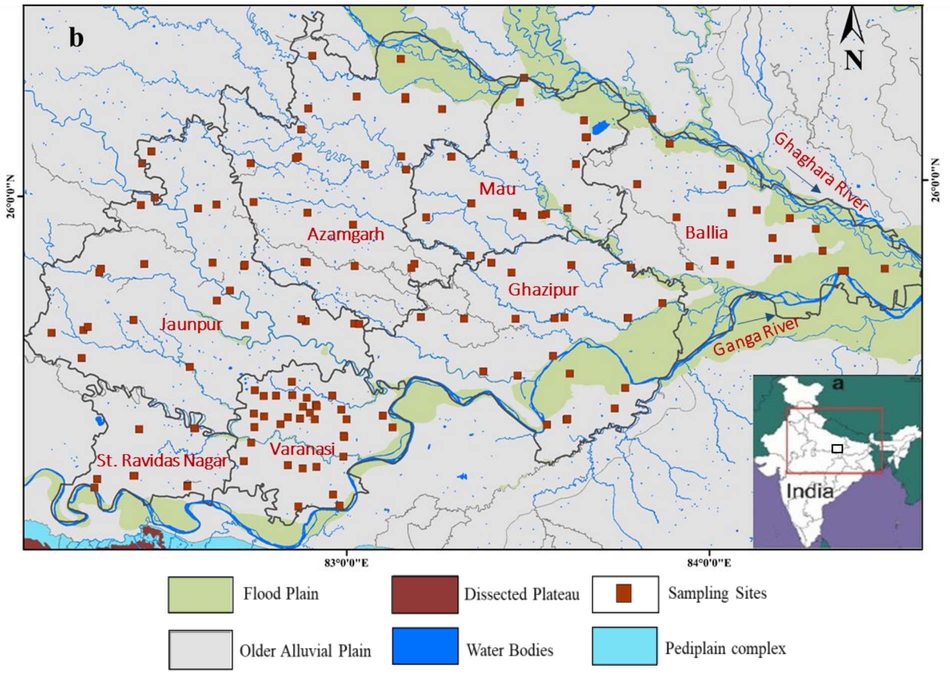


Fig. 1. (a) Ganga River Basin and black box showing study area, **(b)** the geomorphological settings of the study area, districts, major rivers along with the sampling sites.

The Middle Ganga Basin is characterized by multi aquifer system and the principal aquifer systems has been classified into four major types: Aquifer I which varies from soil depth to 150 m bgl, Aquifer II - 160-240 m bgl, Aquifer III - 260-370 bgl, and Aquifer IV - 370-480 m bgl (CGWB, 2020). Based on this, the major sampling strategy was designed to collect water samples from different borehole depth following the grid sampling at 15km × 15km. It was planned to collect groundwater samples from shallow and deep wells from each grids. However due to the limited number of deeper wells (>100 m bgl) tapped by government water supply Jal-Kal and irrigation tubewells, a fewer number of water samples could be collected. Groundwater samples from different borehole depth along with coordinates were collected from the Varanasi and adjoining districts encompassing an approximate area of 20,0000 sq. km. (Figure 1).

Sampling & Analysis

- The handpumps/tubewells of the identified location were continuously pumped for at least 15 minutes prior to the sampling and the water samples were collected in appropriate sampling bottles and preserved as per standard methods (APHA, 2017). The parameters such as coordinate, elevation, temperature, borehole depth, pH, ORP and EC were measured at the sampling sites.
- Alkalinity, HCO_3 and CO_3 were determined titrimetrically within a day, while major ions were measured within a month after entire groundwater sampling with Ion chromatograph. Samples for trace metals were preserved with HNO_3 and trace metals were analyzed with ICP-MS.
- A sharp decline in the EC was observed below 100 mbgl, probably due to the presence of the thin clay layer throughout the study area at 80-100 mbgl, and therefore the groundwater of Varanasi district can be classified into two zones. Moreover, the descriptive statistics reveal the elevated concentration of anthropogenic indicators (NO_3, Cl, SO_4) in group G1 up to a depth of 100, while their limited concentration in the group 2 samples. Further, more mineralization was observed at shallow to moderate depth.
- Group 1 (<100m bgl) samples shows varying water facies dominating in Mg-HCO_3 (43.8%), followed by Ca-HCO_3 (31.3%), mixed water types (13.4%), Na-HCO_3 (8%) and, a

few saline water types (3.6%). Group 2 (100-210 m bgl) samples are manifested by the presence of Mg-HCO_3 (53%) and Ca-HCO_3 (44%) freshwater types, and only 1 sample fall in the fixed facies

- Higher concentration of F (>1.5 mg/l) was observed in the northwestern and eastern region, while nitrate is randomly located.

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

16. **Deliverables:** Technical report and research papers, GW recharge sources and aquifer zonation, SW-GW interaction, and rock-water and anthropogenic influence on water quality.

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

18. **Lab facilities used during the study:** Hydrogeology Laboratory (BHU), Water Quality Laboratory (NIH), Isotope Laboratory (NIH)

19. **Data procured or generated during the study:** Water quality data of the study area and anthropogenic influence on the water quality.

20. **Study Benefits / Impacts:**
The outcome of the project would help the managers for the sustainable development and management of this scarce resource and plan for augmentation measures to ensure continuous supply of water to meet the demands of the people in the region. The project will also explore the remedial measures for providing safe and clean water to the densely populated regions of the MGB.

21. **Involvement of end users/beneficiaries:** Water Resources & Environment Directorate, Varanasi and adjoining districts, CGWB Lucknow

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

23. **Shortcoming/Difficulties:** None.

24. **Future Plan:**
    - Geochemical and statistical modelling for adjoining districts of Varanasi to identify the major hotspots sites.

Study – 5 (Collaborative R&D Project)

1. Title of the Project: Comprehensive characterization of variably processed sewage sludge in ganga basin to classify its suitability for safe disposal

2. Project Team

Lead Investigator	Dr. A A Kazmi, Professor, Civil Engineering Dept., IIT Roorkee
Co-PI	Dr. Vinay Kumar Tyagi, Sc. D, EHD, NIH Roorkee

3. **Type of Study:** Sponsored **Budget:** Rs. 58.11 lacs
4. **Nature of Study:** Applied Research
5. **Date of start:** Jan 2022
6. **Scheduled date of completion:** Dec 2023
7. **Duration of the Study:** 2 Years

8. Objectives

A: Sludge characterization and disposal

(i). Assessment of dewatered sludge for different quality control parameters

(ii). Characterize the treated sludge quality and compare with existing guidelines such as CPHEEO 2013, USEPA (Class A & B) and FCO standards 2009 to assign quality indices and grading for sludge composts in accordance with their fertilizing index and magnitude of environmental threats due to heavy metal content and pathogens.

(iii). To search out feasible sludge disposal methods based on sludge characterization.

B: Recommendation for best suited sludge management practice

(i). Overall, recommendations will be provided about feasible and best suited sludge treatment and disposal practices

9. Statement of the Problem

In India, it is observed that limited information is available on the characterization of sewage sludge in terms of heavy metals, pathogens and other elements. Once sludge production and characterization data area available from various sewage treatment plants in India, it will be easier to propose best suited sludge disposal and/or reuse alternates to the Government of India. Hence, the proposed study aims to comprehensively characterize the variably processed sewage sludge and recommend best sludge management options in Ganga Basin for proper sludge disposal and reuse purposes. The findings can be the stepping stone in the development of sewage sludge utilization standards and achieve the sustainable sludge management practices.

10. Approved Action Plan/ Methodology:

10.1. List of Sewage treatment plants (STPs)

10 STPs + 1 FSTP representing different climates and topographies installed by the municipalities and other government bodies in various cities of Ganga basin were selected for study (Table 1). The plants use different technologies according to wastewater type, fund availability, governing body suggestions, and effluent requirements etc.

Table 1. List of the selected STPs for the study

S. No.	Name of STP	Capacity (MLD)	Technology	Wastewater	Sludge type
1.	Dinapur, Varanasi	140	Conventional Activated Sludge Process	Sewage	Digested and post-dewatered sludges
2.	New Tehri, Garhwal	5	Extended Aeration	Sewage	Pre- and post-dewatered sludges
3.	Saharanpur	38	UASB	Sewage	UASB & Dried Sludge
4.	Bingawan, Kanpur	210	UASB	Sewage mixed with industrial wastewater	Digested and naturally dried sludges
5.	IIT Roorkee	3	SBR process	Sewage	Pre- and post-dewatered sludges
6.	Kargi, Dehradun	68	SBR	Sewage + Septage	Pre- and post-dewatered sludges
7.	Jagjeetpur, Haridwar	27	Primary Clarifier + SBR process	Sewage	Digested and post-dewatered sludges
8.	Indrapuram Ghaziabad	56	SBR	Sewage mixed with industrial wastewater	Pre- and post-dewatered sludges
9.	Coronation Pillar, Delhi	318	A2O process	Sewage	Digested and Post Dewatered Sludge
10.	Chorpani, Rishikesh	3.5	MBBR Process	Sewage	Pre- and post-dewatered sludges
11.	Jhansi	0.012	Anaerobic process based FSTP	Feacal sludge	Digested and dewatered sludges

10.2. Sludge characterization and comparisons with existing standards

i. Collection of samples

Before dewatering, dewatered and final dried sewage sludge/compost samples will be collected from selected 10 STPs and 1 FSTP of Ganga Basin and transported to Environmental Engineering Laboratory, IIT Roorkee for characterization study.

ii. Analysis of the collected sludge samples

To check the maturation period and optimize stability of sewage sludge, various physico-chemical and microbiological parameters.

a) Moisture, Bulk density, Organic matter (OM), Total Solid (TS), Volatile Solid (VS), VS/TS ratio, Total Organic Carbon (TOC), Nitrogen (N), Phosphorus (P), C/N ratio, C/P ratio, Potassium,

b) Heavy metals (As, Cr, Pb, Mo, Zn, Cu, Se, Cd, Ni and Hg),

c) sludge dewaterability (CST), Sludge rheology,

d) Pathogens and indicator microbes: Fecal coliforms, *Salmonella* species, *Shigella* species, *E. coli, Helminth egg etc*.

iii. Interpretation of data and report preparation

Data and observations will be interpreted and compared with the existing norms to prepare the regulations to use the sewage sludge on agricultural land for the improvement of soil conditions by using less chemical-based fertilizer in India. Regulations for sewage sludge and compost disposal are attached in annexure1.

11. Timeline (Approved):

Task	Description	Months							
		3	6	9	12	15	18	21	24
1	Sludge Characterization report on 10 STP and 1 FSTP- First Report (Winter Season)								
2	Sludge Characterization report on 10 STP and 1 FSTP- Second Report (Summer Season)								
3	Sludge Characterization report on 10 STP and 1 FSTP- Third Report (Monsoon Season)								
4	First Report on Seasonal Sludge Characterization								
5	Performance Evaluation of STPs wrt to Sludge quality and quantity. (Winter Season)								
6	Performance Evaluation of STPs wrt to Sludge quality and quantity. (Summer Season)								
7	Performance Evaluation of STPs wrt to Sludge quality and quantity. (Monsoon Season)								
8	Final Report on Seasonal Sludge Characterization for 2 years and Factors influencing its generation								

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared.
2.	Sample Collection and Analysis	• Sludge samples collected from different STPs in different seasons of summer, monsoon and winter (2023) • Sludge samples were analyzed for Moisture, Bulk density, Organic matter (OM), Total Solid (TS), Volatile Solid (VS), VS/TS ratio, Total Organic Carbon (TOC), Nitrogen (N), Phosphorus (P), C/N ratio, C/P ratio, Potassium, Heavy metals (As, Cr, Pb, Mo, Zn, Cu, Se, Cd, Ni and Hg), and microbiological parameters, i.e., fecal coliforms, salmonella, and Helminth eggs.
3.	Scientific Publications	• 01 research paper in international journal (published).

13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	The dewatered sludges satisfied the USEPA Class B criteria, thus, the following recommendation has been given to achieve Class A type sludge: ○ ***The first stage of quality improvement:*** • ***Pathogen and vector attraction reduction:*** *Drying/storing the dewatered sludge for three months under covered sheds to significantly reduce pathogens and vector attraction.* • ***Heavy Metal Limits:*** *Blending of dewatered sludge with cattle manure, husks or local soil for dilution of heavy metals. Inform Local pollution control boards about high concentrations of heavy metals in sludge. The blended sludge/compost can be used for non-edible crops.* ○ ***Second Stage quality improvement:*** *In-Vessel or Windrows composting, Greenhouse Sludge Drying to satisfy US EPA Class A Criteria.*	Report to be submit to CPCB and NMCG for future action.

14. Analysis & Results:

pH and conductivity of all dewatered sludge samples satisfy the FCO criteria and indicate that the sludges are non-saline and can be safely used in agriculture. As specified by FCO standards, the total organic carbon in all sludge samples were more than 12%, which is significant for improving the aeration, nutrient and moisture-holding capacity, microbial activity, and fertility rate of soil. Fertilizer values (NPK) of all sludge samples were higher than 0.8 and 0.4 %, except few sludges for K, as specified by FCO. C/N Ratio, a critical criterion for sludge stability, is less than 20 for all dewatered sludges. All sludge samples satisfy the US EPA Class B Fecal coliform criteria of $<2 \times 10^6$ MPN/ gTS. However, it fails to meet the US EPA Class A Fecal coliform criteria of <1000 MPN/ gTS. For Salmonella and Helminth Egg, all dewatered sludge samples fail to satisfy the USEPA Class A criteria.

All sludge samples satisfy the desired limits of heavy metal concentrations set by USEPA Class B Biosolids and almost meet the limits of USEPA Class A biosolids. However, many sludge samples fail to satisfy the stringent FCO 2009 heavy metal limits. The sewage treatment plants (STPs) operating at higher solids retention time (SRT) satisfy the USEPA vector reduction criteria of a specific oxygen uptake rate (SOUR) of 1.5 mgO2/g TS.h. The sludge samples have higher fertilizing potential (Fertilizing index > 4.0) except for K (as K_2O) and comply with the regulatory limits set by Indian Fertilizer Control Order for TOC, TN, TP (as P_2O_5), and C: N ratio. Sludge sample from STPs receiving only sewage was able to satisfy the clean index of Class A (Clean Index > 4.0). The calorific value of sludges varied from 1058 to 4137 KCal/kg of dry solids. No significant differences in the parameters were observed on the sludge characterization during the seasonal sampling (Winter, Summer and Monsoon). Based on the sludge wasting parameters and the sludge production data collected from the STPs, it was observed that in most of the cases 0.5 -1.0 m^3 of dewatered sludge produced from the treatment of 1 MLD wastewater in the treatment plant.

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

16. **Deliverables:** Technical reports and research papers

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

18. **Lab facilities used during the study:** Water quality and bioenergy laboratory of Civil Engineering Department, IIT Roorkee.

19. **Data procured or generated during the study:** Comprehensive sludge quality data at the variable technologies-based sewage treatment plants in Ganga basin and other zones and effect of seasonal variations on sludge quality

20. **Study Benefits / Impacts:**
    The outcome of the project would help the policy makers for the sustainable management of sewage sludge and plan for augmentation measures to ensure safe disposal and reuse of sewage sludge in Indian climatic conditions on a practical basis.

21. **Involvement of end users/beneficiaries:** National Mission for Clean Ganga (NMCG), Central Pollution Control Board (CPCB)

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

23. **Shortcoming/Difficulties:** None.

24. **Future Plan:**

    Following works are planned for Phase 2 of the project:

    (i). Field and Technical and Economic Evaluation of the full-Scale Sludge Processing Technologies (Tentative) in India.
    (ii). Literature review on well-established sludge processing technologies around the globe.
    (iii). Selection of appropriate and affordable Sludge processing technologies for Zero-Budget natural farming in the Ganga basin
    (iv). Field Evaluation of well-established full-scale sludge processing technologies (affordable) in India (if implemented) or Abroad
    (v). Techno-economic evaluation of selected technologies in terms of performance, Capital & O&M Cost (Present Worth)

Study – 6 (Collaborative R&D Project)

1. Title of the Project: SARASWATI 2.0-Identifying best available technologies for decentralized wastewater treatment and resources recovery for India

2. Project Team

Lead Investigator	Dr. A A Kazmi, Professor, Civil Engineering Dept., IIT Roorkee
Co-PI	Dr. Vinay Kumar Tyagi, Sc. D, EHD, NIH Roorkee

3. **Type of Study:** Sponsored **Budget:** Rs. 160.77 lacs
4. **Nature of Study:** Applied Research
5. **Date of start:** Mar 2020
6. **Scheduled date of completion:** Feb 2024
7. **Duration of the Study:** 4 Years

8. Objectives

The research objectives of the study are as follows,

(i). To optimize the thermal hydrolysis pretreatment (THP) operating conditions for maximizing the methane yield in the context of Indian sludge.

(ii). To study the effect of thermal hydrolysis followed by anaerobic digestion on the removal of organic micropollutants (emerging contaminants) and to analyze the microbial diversity.

(iii). To compare the performance assessment of mesophilic, thermophilic, and thermal hydrolysis coupled anaerobic digestion of sewage sludge in terms of biomethane potential and pathogen removal.

(iv). To study the efficiency of the thermal hydrolysis process in enhancing methane production in comparison with the raw sludge by operating the digesters in semi-continuous mode regime

(v). To find the best optimized HRT conditions by operating the semi-continuously fed digesters at varying HRTs for effective enhancement of methane generation via thermal hydrolysis.

9. Statement of the Problem

The management of waste sludge is becoming challenging in metro cities of India. The situation becomes worsened due to the unavailability of landfill area and reluctant to use by farmers. The cost of sludge management is increasing to 50-60 % of the plant operational cost. Anaerobic treatment of sludge for energy rich biogas recovery is a good option to offset the cost of sludge treatment at some extent. However, there are technical and operational difficulties obstructing the utilization of anaerobic sludge digestion method at wastewater treatment facilities. In order to fully utilize the potential of anaerobic digestion, higher gas yield, one of the most successful pre-treatment system is thermal hydrolysis process (THP). By providing THP pre-treatment, more than double digester loading can be achieved with shorter retention time: Reducing digester volume and construction cost, as well as saving space or increasing existing capacity.

10. Approved Action Plan/ Methodology:

The thermal hydrolysis process (THP) patented by Cambi Group AS is a pre-treatment of sludge combined with anaerobic digestion. Cambi THP works by dissolving and disintegrating sludge using pressure and temperature. Primary, biological or mixed sludge is pre-dewatered and introduced into a reactor where the direct application of saturated steam hydrolyzes and changes its internal structure (Fig. 2). This reduces sludge viscosity and increases its biodegradability and shortens hydraulic retention time of anaerobic digesters. The thermal hydrolysis increases the production of biogas in anaerobic digestion, reduces the digestervolume needed for digestion, increases the dryness of the final dewatering of digested sludge, eliminates odours, and provides pasteurized final sludge of Class A category, a valuable and natural fertilizer.

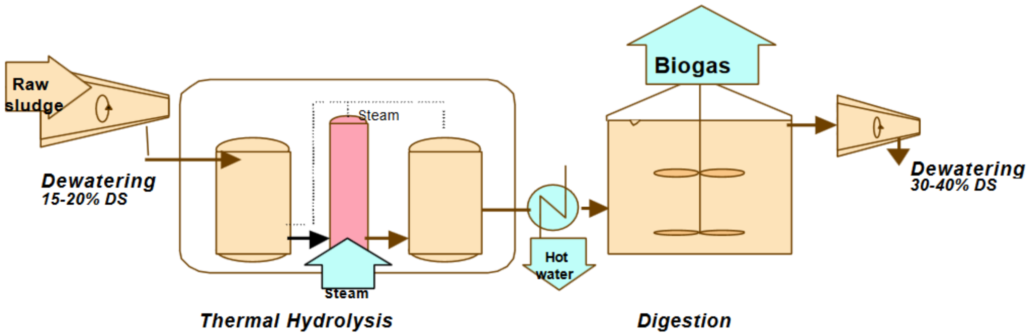


Fig. 2. Integrated Thermal hydrolysis and Anaerobic Digestion (Cambi)

<u>STUDY 01</u>: Thermal hydrolysis pretreatment mediated anaerobic digestion of municipal sludge: effects on methane yield, emerging contaminants removal, and microbial community

This study aimed to determine the effect of thermal hydrolysis on 1) sludge solubilization and methane yield 2) removal of organic micropollutants, and 3) microbial community structure in the digester. This work highlighted the efficiency of the thermal hydrolysis process for the sludge collected from a sequencing batch reactor (SBR) system operating at a higher solids retention time (SRT) of 40 days (Figure 3).

Fig.3. Batch biodegradability tests

<u>STUDY 02</u>: Comparative performance assessment of mesophilic, thermophilic and thermal hydrolysis coupled anaerobic digestion of sewage sludge: bio-methane potential, pathogen removal and energy feasibility study

In this study, the mesophilic (MAD-35 ℃), thermophilic (TAD-55 ℃) and THP (160 ℃, 30 min., 6 bar) integrated anaerobic digestion of municipal sludge at TS concentrations of 6% (MAD, TAD) and 16% (THP-AD) was investigated (Figure 4).

Figure 4 a) Inoculum collection b) Dewatered SBR Sludge (68MLD STP, Haridwar)

<u>STUDY 03:</u> Investigation of thermal hydrolysis process as a pretreatment technique prior to high solids anaerobic digestion under semi-continuous mode

This study deals with the investigation of the effects of advanced steam explosion as thermal hydrolysis pretreatment on high solids SBR sludge (15% total solids, TS) and anaerobic digestion process at a hydraulic retention time (HRT) of 15 days. A conventional digester was also operated in parallel at 5% TS, 15 days HRT, and under mesophilic regime (Figure 5).

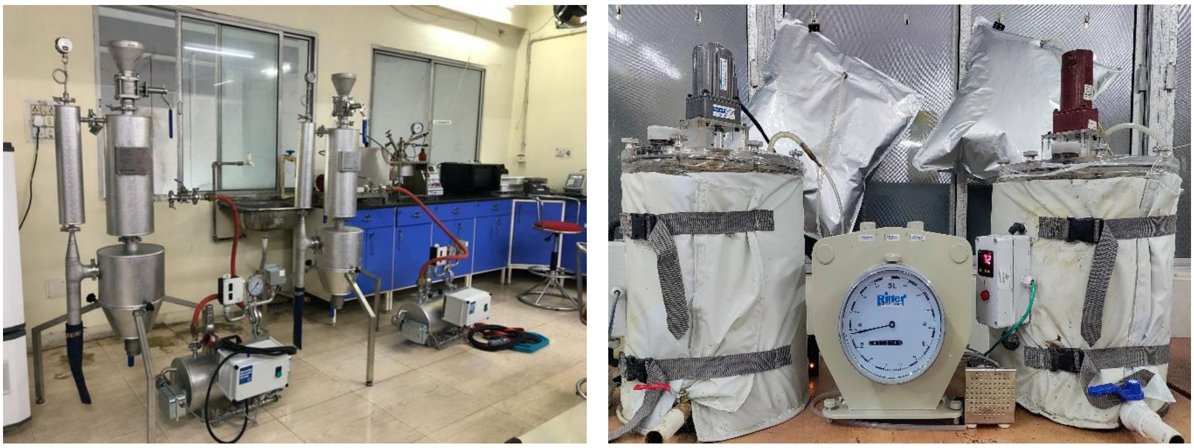


Figure 5 a) Pilot scale THP setup b) Semi-continuous digesters

<u>STUDY 04: Effect of varying hydraulic retention time on the anaerobic digestion of thermally hydrolyzed sewage sludge</u>

The main aim of this study was to investigate about what extent the HRTs of the THP assisted AD process can be reduced without deteriorating the methane generation and solids removal. Under this study control and thermal hydrolysed sludge digesters were operated in parallel and the HRT (Hydraulic retention time) of the digesters was reduced from 15-5 days by increasing the organic loading rate (OLR) (Figure 6).

Fig.6. a) Feeding on digesters b) Digesters under operation at varying HRTs c) Biogas composition measurement

11. Timeline (Approved):

12. Objectives and achievement during last twelve months:

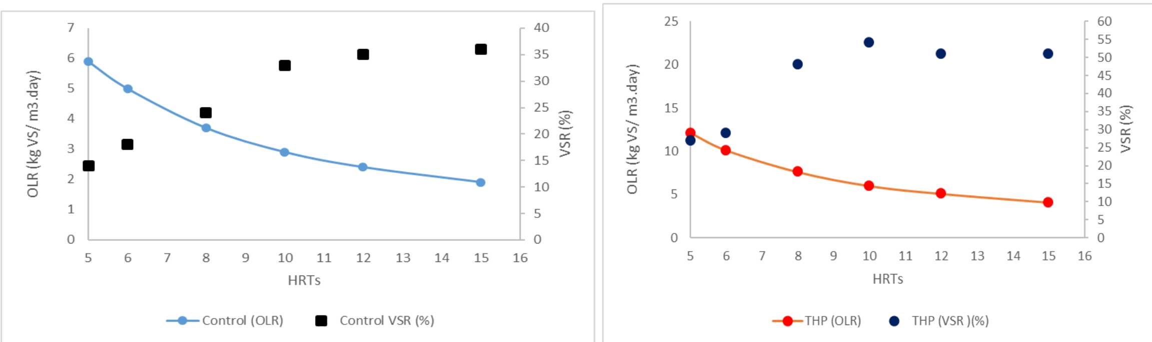
Sr. No.	Activity	Achievements
1.	Effect of varying hydraulic retention time on the anaerobic digestion of thermally hydrolyzed sewage sludge	• Among all the HRTs studied the highest methane generation of 408 L/kg VS_{added} was shown by the THP digester operated at 10 days HRT with a VS removal of 54%. Even at 8 days HRT, the THP digester performed well with only 11% deterioration in VSR (48%) and 15% reduction in methane yield (347 L/kg VS_{added}) in comparison with the THP digester operated at 10 days HRT.
3.	Scientific Publications	• 03 research paper in international journal (published).

13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	No Comments	----

14. Analysis & Results:

Among all the HRTs studied the highest methane generation of 408 L/kg VS_{added} was shown by the THP digester operated at 10 days HRT with a VS removal of 54%. Even at 8 days HRT, the THP digester performed well with only 11% deterioration in VSR (48%) and 15% reduction in methane yield (347 L/kg VS_{added}) in comparison with the THP digester operated at 10 days HRT. The CST values of THP pretreated sludge was 622.2 s, while, the digested samples showed CST values of 245.3, 273.1, 302.1, 394.2, 506.4, and 578.3 s at 15, 12, 10, 8, 6 and 5 days HRTs. Similarly, the CST value of feed sludge (5%TS) and digestate of the control digester was observed to be 410s (raw) and 122.7, 158.6, 183.5, 220.6, 300.5 and 320s at 15, 12, 10, 8, 6 and 5 days, respectively. Hence, the HRT of conventional anaerobic digesters (25-30 days) can be reduced by almost 3 times (to 10 days) with the implementation of THP integrated AD. Figure 7 shows the effects of variable HRTs on volatile solids removal in cotrol and THP digesters.



a) b)

Fig. 7. a) VSR Vs HRTs of control digester b) VSR Vs HRTs of THP digester

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

16. Deliverables: Technical reports and research papers

17. Major items of equipment procured: None

18. Lab facilities used during the study: Bioenergy laboratory of Civil Engineering Department, IIT Roorkee.

19. Data procured or generated during the study: Effect of varying hydraulic retention time on the anaerobic digestion of THP pretreated and non-pretreated sewage sludge were studied.

20. Study Benefits / Impacts:

Key benefits are Pathogen removal (produce Class A biosolids), high biogas yield, intensification of assets (smaller digesters), better dewatering, odour control and less odour of end- product – possibly combined with post-dewatering stabilization/composting and reduction of sludge volume to be disposed. Use digestate directly without dewatering (advantage is less than half volume of digestate – high concentration of nutrients, sterilized). Potential for India and scope of replication/upscaling across India: Cambi can catalyze all inefficient and junk anaerobic digesters of India. Higher methane and high-quality pathogen free digestate can be focal advantage. As sludge treatment market in India is in nascent stage, the Cambi can start THP equipment in India. The potentiality of the knowledge obtained in this research project for the valorization in the Indian industries is high.

21. Involvement of end users/beneficiaries: National Mission for Clean Ganga (NMCG)

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

23. Shortcoming/Difficulties: None.

24. Future Plan:

The effect of THP process under optimized conditions will be studied on :

- Pathogens Removal and Regrowth
- Fate of Emerging pollutants in THP mediated AD of sewage sludge
- Microplastics
- Micropollutants
- PFAS

Study – 7 (Internal Study)

1. **Title of the Study:** Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims using groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants

2. **Study Group:**

Study Team		
NIH, Roorkee	**DRC, Kakinada**	**CGWB,Southern Region, Hyderabad**
Dr. M. K. Sharma, Sc. F (**PI)** Dr. Suhas Khobragade, Sc. 'G' Dr. Rajesh Singh, Sc. 'E'	Dr. Y. R. S. Rao, (PI) Sc. G & Head	Sri J. Siddhardha Kumar (PI) Sc. E & Head
Supporting Staff Mrs. Babita Sharma, SRA Mrs. Beena Prasad, RA Mr. P. R. S. Rao, PRA		

3. **Type of Study:** Internal
4. **Nature of Study:** Applied Research
5. **Date of Start:** April 2022
6. **Scheduled date of Completion:** March 2024
7. **Duration of the Study: 2** years

8. **Study Objectives**
   i) To study the groundwater level fluctuations in Krishna-Godavari Deltas
   ii) Characterisation of groundwater using Hydro-chemical and Hydrogeochemical investigation
   iii) Isotopic Characterisation of groundwater
   iv) To study the status of Emerging Contaminants in the groundwater, their sources and its impacts on human health

9. **Statement of the Problem**

The presence of emerging contaminants is one of the issues that have been found in the groundwater in Krishna-Godavari delta region. Population in the region depend on the groundwater for meeting their various needs including drinking water. Therefore, this study has been taken up to identify the type, possible sources and extent of presence of emerging contaminants in the groundwater.

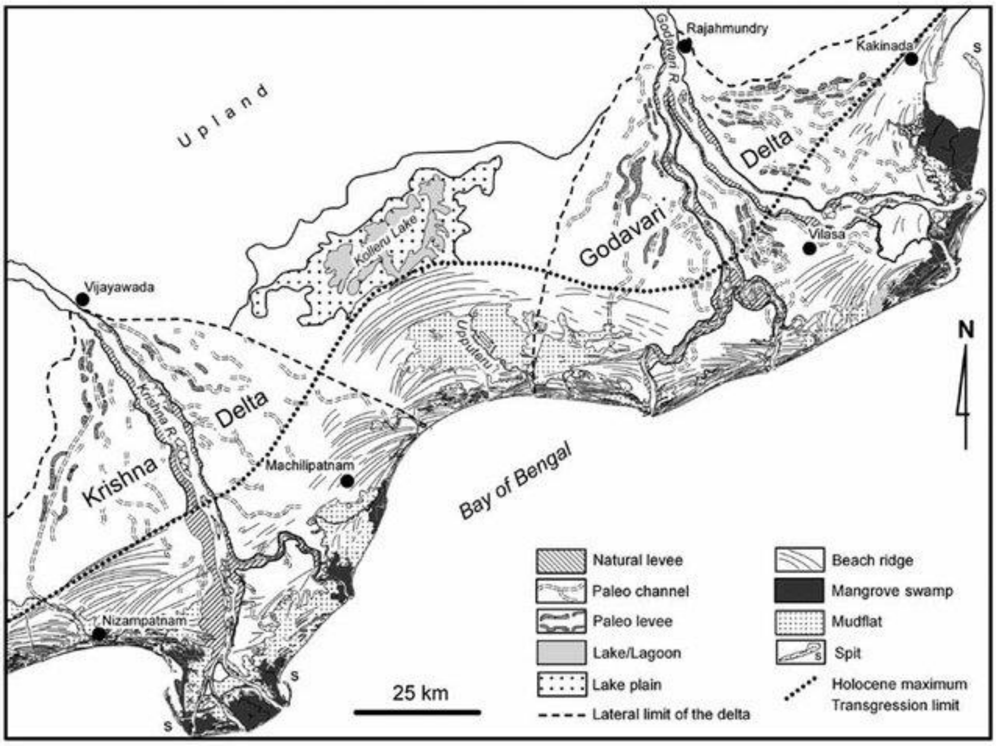


Fig. 1. Location map of Krishna Godavari deltaic region

10. Approved Action Plan/Methodology

i) Collection of groundwater level data, lithological data, water quality data from published report, literature and from various govt. agencies.
ii) Hydrogeological characterization of the study area and establish specific linkages of groundwater quality with hydrogeology.
iii) Collection of groundwater samples from selected sources in pre-monsoon (April-May) and post-monsoon (October-November) season at identified locations.
iv) Analysis on flow and movement of groundwater.
v) Analysis for physico-chemical parameters [pH, EC, TDS, Eh, Alkalinity, Hardness, Major Cations (Na, K, Ca, Mg), Major Anions (Cl, SO_4, NO_3, HCO_3), minor elements (Fluoride, PO_4, NH_4)] metal concentrations (As, Fe, Mn, Cd, Zn, Cu, Cr, Pb, Co, Ni, Ba, Sr, V, Se), and emerging contaminants (Pesticides, PAHs, PCBs, VOCs, BETEX) in the collected water samples.
vi) Analysis of Stable environmental isotopes of Hydrogen and Oxygen 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) 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.
ix) Processing of hydro-chemical data to understand the geochemical processes controlling the chemical composition of groundwater using Scatter Plots and Gibbs Plot.
x) Soil quality monitoring for metal concentrations (Zn, Cu, Cr, Co, Ni, Ba, Sr, V, Se) in the petroliferous regions of the study area during pre- and post-monsoon seasons.
xi) Probable impact of emerging contaminants in groundwater on human health.

11. **Approved Work schedule / Timeline**

S. No.	Major Activities	2022-23				2023-24			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Data collection	■	■	■	■	■	■		
2	Field surveys &Sample collection	■		■					
3	Sample Analysis		■	■	■	■	■		
4	Data Processing	■	■	■	■	■	■		
5	Interim Report				■				
6	Final Report							■	■

12. **Objectives and achievement during last twelve months:**

Sr. No.	Activity	Achievements
1.	Sample Analysis	• Analysis of metal concentrations in the soil samples completed. • Analysis of emerging contaminants (Pesticides, PAHs, PCBs, VOCs, BETEX, MTBE) in the collected groundwater water samples of post-monsoon season completed.
2.	Data Processing	• Processing of hydro-chemical data to understand the geochemical processes controlling the chemical composition of groundwater using Scatter Plots and Gibbs Plot is completed.
3.	Writing of Final Report	• Writing of Final Report is in progress.

13. **Recommendation / Suggestion:**

Sr. No.	Recommendation / Suggestion	Action Taken
1.	Dr. Bhishm Kumar suggested to involve state groundwater department in the study.	A workshop will be organized in collaboration of RC Kakinada to share the findings of the study after submission of the report.

14. **Analysis & Results:**

Sample Analysis & Data Processing

- Analysis of metal concentrations (As, Fe, Mn, Cd, Zn, Cu, Cr, Pb, Co, Ni, Ba, Sr, V, Se, Al, Hg, U, B)using ICP-MS in the soil samples of study area completed.
- Analysis of emerging contaminants (Pesticides, PAHs, PCBs, VOCs, BETEX, MTBE) in the collected groundwater water samples of pre-monsoon season using GC-MS/MS completed and of post-monsoon season is completed.
- Data processing of physico-chemical parameters, metal concentration and emerging contaminants is completed.
- Processing of hydro-chemical data to understand the geochemical processes controlling the chemical composition of groundwater using Scatter Plots and Gibbs Plot is completed.
- Data processing of Stable environmental isotopes of Hydrogen and Oxygen in the collected groundwater samples is under progress.

Findings

- TDS, Alkalinity, Hardness, Ca, Mg, Cl, SO_4 and NO_3 in the groundwater of the few locations of study area exceeds the maximum permissible limit prescribed by BIS for drinking purposes.
- The presence of heavy metals has been recorded in many samples and the water quality standards have been violated for iron, aluminium, boron, manganese, nickel, lead, mercury and arsenic in few of the samples in Godavari basin delta during the pre-

monsoon period while the concentrations of iron, aluminium, boron, mercury, manganese, lead, uranium and arsenic in few samples have been violated in Krishna basin delta.

- Presence of many pesticides were observed in many samples of the study area and BHC-Alfa has exceeded the maximum prescribed limit in few of the samples of the study area. Polychlorinated Biphenyls have also been detected in the samples of the study area but within the permissible limit of Total PCB.
- Total PAHs exceeded the maximum prescribed limit in more than 60% of the samples collected from Godavari basin delta.
- The presence of volatile organic compounds (Benzene) was also observed in few of the samples of Godavari and Krishna basin delta.
- Hydro-chemical data was also processed to understand the geochemical processes controlling the chemical composition of groundwater using Scatter Plots and Gibbs Plot which reveals that hydrochemistry of groundwater of the study area is controlled by evaporation crystallization process and dissolution of rock forming mineral in Godavari basin delta while dissolution of rock forming minerals in Krishna basin delta.
- Carbonate weathering is a major source of dissolved ions in the groundwater of the study area. Cation exchange process and halite dissolution control the chemistry of groundwater of the region.

15. **End Users / Beneficiaries of the Study:** Public Health Department, AP, Ground Water Department, AP, CGWB.

16. **Deliverables:** Technical report and research papers,

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

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

19. **Data procured or generated during the study:** Water quality data on Emerging Contaminants

20. **Study Benefits / Impacts:** The study will identify degraded groundwater quality zones, possible sources of pollution, understanding geochemical processes controlling the aquifer chemistry and will suggest the measures for sustainable groundwater supply for drinking purpose in the study area, therefore enable better planning and management of groundwater resources.

21. **Involvement of end users/beneficiaries: CGWB**

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

23. **Shortcoming/Difficulties:** None.

24. **Future Plan:**
Writing of Report

Study – 8 (Internal Study)

1. **Title of the Project:** Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures

2. **Project Team**

Project Investigator	Dr. Rajesh Singh, Sc. D, EHD
Project Co-investigator	Dr. R. P. Pandey, Sc. G & Head, EHD Dr. Sumant Kumar, Sc. D, GWHD Dr. Pradeep Kumar, Sc. D, EHD Dr. M. K. Sharma, Sc. F, EHD Dr. V. K. Tyagi, Sc, D, EHD Dr. Kalzang Chhoden, Sc. C, EHD

3. **Type of Study:** Internal Study, **Budget:** Rs. 30.1 lacs
4. **Nature of Study:** Applied & Basic Research
5. **Date of start:** July 2021
6. **Scheduled date of completion:** June 2024 (1 Year extension is required)
7. **Duration of the Study:** 3 Years

8. **Objectives**
   i) To determine the mechanisms governing the As mobility, and quantify the rate and extent of these reactions in order to develop a reactive transport model to predict As mobility in groundwater, and
   ii) To design alternatives to mitigate As contamination of drinking water

9. **Statement of the Problem**

Groundwater is the most important source of domestic water in the Haridwar district and is generally free of health hazardous contaminants, however, with increasing population and intensive agricultural practices, the groundwater is getting polluted resulting in the abiotic and biotic weathering reactions of primary and authigenic minerals containing As and other trace metals. The release of previously sequestered arsenic from soils and sediments is well-recognized to result in geogenic contamination of drinking water and presents significant health risks to human and other living organisms. Our recent study on 'Water Quality Assessment of Haridwar District' indicated higher As concentration in the groundwater of Laksar and Manglaur tehsil at few locations in the range 10 to 30 µg/l. Although, the As concentration were below maximum permissible limit of 50 µg/l prescribed by BIS for drinking water, it exceeded the acceptable limit of 10 µg/l. Previously, As was reported in a location near Solani river which is a monsoonal river and in the non-monsoon the flow in the river is contributed through the untreated/partially treated domestic and industrial discharge. This clearly indicates the role of pollutants entering the aquifer and initiating the secondary reaction resulting on the release of As from the aquifer sediments and requires thorough investigation before it is too late. The identification of the factors responsible for the release of the As from the sediments will help in containing the As and reducing the associated health hazard risk to consumers.

Keeping in view of same, the study aims at analyzing the groundwater and sediment samples for their As content and other parameters. Efforts will be also made to identify the factors responsible for the release of As from the sediments through batch/column experiments.

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

i) Thorough review of abiotic and biotic geochemical mechanisms known to contribute to As mobility in aquifers and determine the groundwater constituents or parameters influencing As mobility.

ii) Collection and characterization of the groundwater samples from and in the vicinity of identified locations with higher As concentration.
iii) Characterization of the aquifer sediment and As mobility in the aquifer where As was observed in exceeding the prescribed drinking water limit.
iv) Batch and column experiments for identifying the factors responsible for As mobilization.
v) Develop a model to identify As mobility in groundwater.
vi) Design alternatives to mitigate As contamination of drinking water.

11. Timeline (Approved):

Sr. No.	Major Activities	2021-22			2022-23				2023-24				2024-25
		Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q1
1.	Field Investigation and sampling plan												
2.	GW sample collection and analysis												
3.	Aquifer sediments collection and characterization												
4.	Batch & column experiments												
5.	Model development for As mobility												
6.	Alternatives to mitigate As												
7.	Publications												
8.	Interim Report												
9.	Final Report												

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared
2.	Sample Collection and Analysis	• Samples are collected from the selected locations. • Analysis for organoleptic, major ions, and coliforms in the collected samples completed. • Analysis of trace metals completed.

13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	Dr. Bhism Kumar (Ex. Scientist, NIH) appreciated the study and suggested to correlate the As in the GW with other relevant parameters.	Correlation analysis of As with other parameters completed.
2.	Dr. Sudhir Kumar, Director NIH said that As has not been reported in the sediments of Solani river and therefore, the Solani river sediments should be collected and analyzed for trace metals particularly As.	Solani river sediments were collected during monsoon period and analyzed for trace metals including As.

14. Analysis & Results:

Field Investigation and sampling plan

- Sampling locations were selected considering the identified location with high As concentration in the groundwater.

Sampling & Analysis

- The handpumps, which are being used extensively, of the identified villages were continuously pumped for at least 15 minutes prior to the sampling and the water samples were collected in appropriate sampling bottles and preserved as per standard methods (APHA, 2017). Samples were also collected from the deep wells as per availability.
- The organoleptic parameters, major ions, trace metals, and bacteriological analysis completed for all the samples collected bimonthly following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017).
- Both deep (150-660 ft) and shallow (20-150 ft) well samples were observed to be of Ca-Mg-HCO_3 type. The As concentration in the shallow well ranged from 0.01 ppb to 267 ppb and in the deep well ranged from 0.56 ppb to 26 ppb. As in the groundwater was observed to be more concentrated in the depth range 20-80 ft. As concentration was observed to be directly proportional to Fe and Mn concentrations in water and inversely proportional to nitrate except few exceptions. High As concentration was observed with alkalinity 180-600 mg/l. Similarly, highest As concentration were observed in the pH range 6.9-7.4.

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

16. Deliverables: Technical report and research papers, Factors impacting As mobilization, Model to identify As mobility, and alternatives for As mitigation.

17. Major items of equipment procured: Glove bag/anaerobic chamber will be procured for conducting experiments.

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

19. Data procured or generated during the study: Water quality data of the study area and As mobilization mechanism

20. Study Benefits / Impacts:
The outcome of the project will be beneficial for the concerned departments in a sense that it will provide the information on the factors impacting As mobilization in the groundwater. The alternatives for As mitigation will be also suggested which can be implemented by concerned departments of UK government.

21. Involvement of end users/beneficiaries: None

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

23. Shortcoming/Difficulties: None.

24. Future Plan:

- Collection and analysis aquifer sediment samples.
- Batch and column experiments.
- Procurement of glove bag/anaerobic chamber.

Study - 9 (Internal Study)

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

2. **Study Group:**

Project Investigator	Dr. Pradeep Kumar, Sc. 'E', EHD
Project Co-investigators	Dr. M. K. Sharma, Sc. 'F', EHD Dr. Rajesh Singh, Sc. 'E', EHD Er. R. K. Nema, Consultant, EHD
Scientific Staff	Mrs. Babita Sharma, RA Mrs. Beena Prasad, RA Mr. Rakesh Goyal, Tech. Gr. I

3. **Type of Study:** Internal Study**, Budget:** Rs. 43.02 lacs
4. **Nature of Study:** Applied Research
5. **Date of start:** Nov 2019
6. **Scheduled date of completion:** Oct 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:

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. Approved Action Plan/Methodology:

(i). Procurement of secondary data required for the analysis from various govt. agencies (discharge, sediment, 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

7. **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	Literature																	

	survey																	
2	Reconnaissance visit and sampling plan																	
3	Secondary data collection																	
4	Field surveys																	
5	Sample Collection and Analysis																	
6	SWAT Model: Preparation of database																	
7	SWAT Model: Calibration, Validation & Simulation																	
8	Interim Report																	
9	Final Report																	

12. Objectives and achievement during last twelve months:

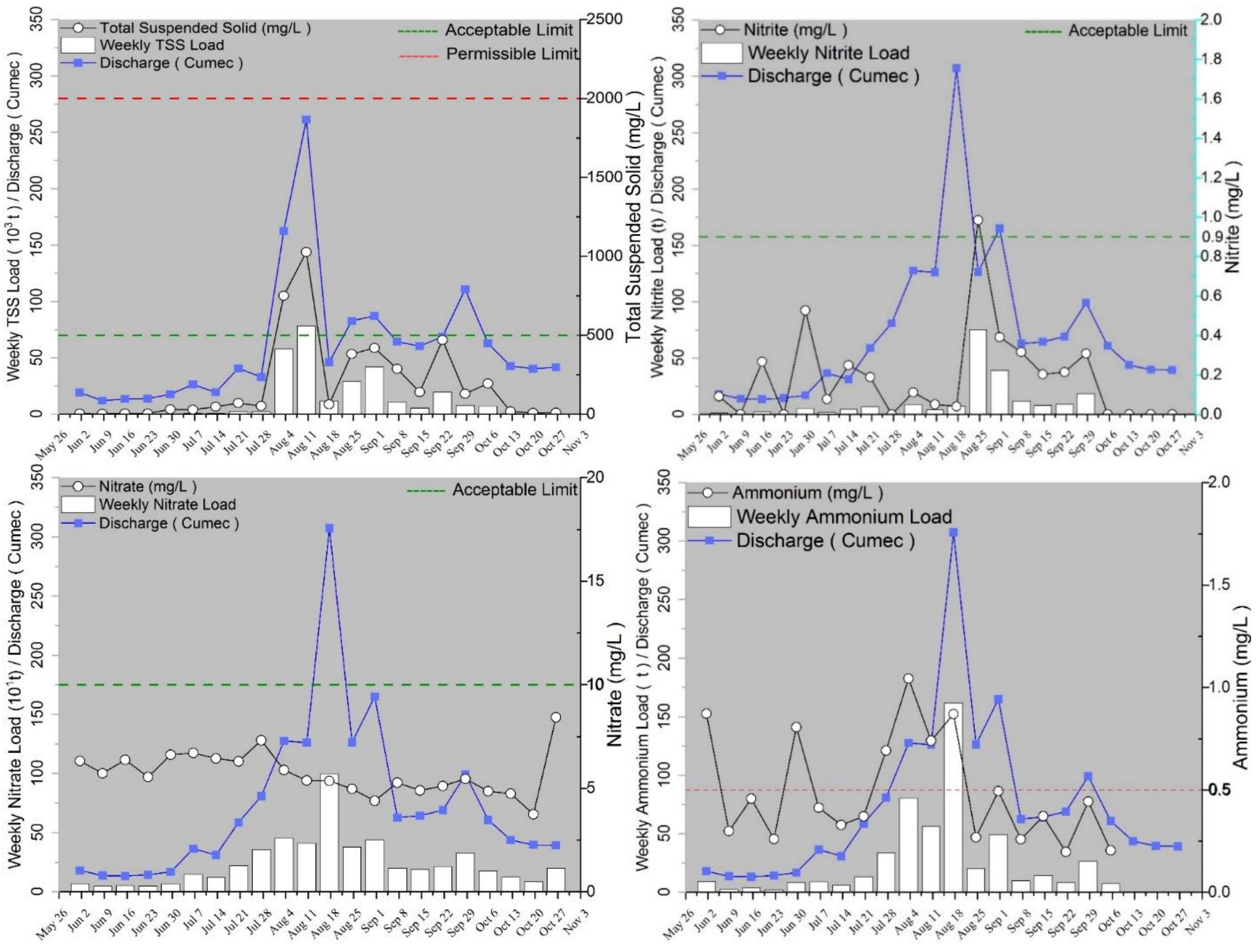
S. No.	Objectives	Achievements
(i)	Assessment of the point and non-point pollutant loads	Three sites have been selected for the assessment of point and non-point source pollutant loads. The water quality sampling and discharge monitoring at these three sites have been carried out on weekly basis during the monsoon season, and monthly basis during the non-monsoon season. Further, samples have been analyzed for the water quality parameters.
(ii)	Collection of data on usage of fertilizers and pesticides in the Song river catchment	The village level surveys have been conducted for collection of data on usage of fertilizers and pesticides.
(iii)	Simulation of various hydrological processes in the river catchment	The SWAT model set-up has been completed using the secondary data sources (freely available web sources). Discharge data from CWC and soil maps from NBSS&LUP have been obtained and the same have been used for the analysis.
(iv)	Simulation of non-point source pollution process for sediment, nutrients and pesticides in the river catchment	The model set-up for simulation of non-point source pollution processes is being carried out.

13. Recommendation / Suggestion:

S. No.	Recommendation / Suggestion	Action Taken
1.	No comments	--

14. Analysis & Results:

Three sites in the Song catchment have been selected for simulating non-point source pollution processes through the SWAT model. The first site selected is the CWC G&D site at Satyanarayana. Suswa is a major tributary of Song river and it meets Song river few kilometers upstream of Satyanarayana G&D site. So, the second site has been selected on Suswariver just before its confluence with Song river. Another site on the Song river have been selected in the upstream of the confluence of Song and Suswa rivers. These sites have been selected to isolate the point and non-point sources of pollution. Although sampling was planned to be started during monsoon season of 2021, but, due to uncertain travel restrictions caused due to Covid-19 pandemic, the same could be started from Jun 2022. The results of discharge and water quality monitoring are shown in the following figures:



15. End Users / Beneficiaries of the Study: Deptt. of Irrigation & Deptt. of Agriculture, Uttarakhand

16. Deliverables: Technical report and research papers

17. Major items of equipment procured: None

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

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 various sources of point and non-point pollution and will suggest various scenarios for mitigating these impacts. The research outcomes from the study will be as follows:

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
d.

21. Involvement of end users/beneficiaries: Irrigation Deptt., UK

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

23. Shortcoming/Difficulties: None

24. Future Plan:

SWAT Model calibration and validation for water quality incorporating the cropping pattern, fertilizer/pesticides usage data collected during village level surveys.

Study - 10 (Internal Study)

1. **Title of the Project:** Hydrological Studies for the Conservation of Rewalsar Lake

2. **Project Team**

Project Investigator	Dr. Kalzang Chhoden, Sc. C, EHD
Project Co-investigator	Dr. Rajesh Singh, Sc. E, EHD Dr. R. P. Pandey, Sc. G & Head, EHD Dr. Pradeep Kumar, Sc. E, EHD Dr. Vinay Kumar Tyagi, Sc, D, EHD Er. Omkar Singh, Sc. G & Head, Technical Cell Dr. Shuhas Khobragade, Sc. G & Head, HID Dr. D.S. Malik, Professor, GKU, Haridwar
Collaborating Organization	Himachal Pradesh State Wetland Authority, Shimla

3. **Type of Study:** Internal Study, **Budget:** Rs. 53.16 lacs
4. **Nature of Study:** Applied & Basic Research
5. **Date of start:** April 2023
6. **Scheduled date of completion:** March 2026
7. **Duration of the Study:** 3 Years

8. **Objectives**
   i) Identification of morphological features of the lake.
   ii) To understand the hydrological characteristics.
   iii) To identify the causes of fish mortality and eutrophication status of lake.
   iv) To Assess the rate of sedimentation.
   v) Suggestions for remedial measures for pollution abatement.
   vi) Mass awareness and outreach activity.

9. **Statement of the Problem**

The Himachal Pradesh State Wetland Authority (HPSWA) informed that Rewalsar lake is presently facing problems related to water quality, fish mortality, and siltation. Rewalsar wetland ecosystem is at the critical stage of deterioration mainly due to water pollution and siltation in the water body. Increasing tourism activity and human settlement around the lake create hydrological and ecological distresses. In addition to this, frequent incidents of high fish mortality in the water body due to increasing water pollution has been observed. An increase in nutrient levels in lake from the various non-point sources also leads to eutrophic conditions. Keeping this in view and as suggested by the HPSWA, the study aims a systematic and comprehensive hydrological investigation of Rewalsar Lake to identify the factors responsible for the water quality issues and rate of sedimentation taking place.

10. **Approved Action Plan/ Methodology:**
   i) Identification of physical features of the lake and sources of water in the lake.
   ii) Collection and characterization of the lake water samples for spatial and temporal variation.
   iii) Water balance study of lake using water balance components i.e. precipitation, evaporation, and inflow/outlflow.
   iv) The trophic status of the lake will be computed using TSI, Nygaard's algal index, and Shannon Weiner index.
   v) The rate of sedimentation will be estimated using conventional/radiometric dating techniques.
   vi) A management plan to improve the water quality and quantity of lake will be arrived at based on the outcomes of the study.

11. Timeline (Approved):

S.N.	Work Element/ Milestone	1st Year				2nd Year				3rd Year			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Literature Review and Reconnaissance survey	■											
2	Hiring of project staff, equipment purchasing/installation	■	■										
3	Water Mass balance assessment		■	■	■	■	■	■	■				
4	Assessment of water quality and eutrophication status		■	■	■	■	■	■	■	■	■		
5	Estimation of rate of sedimentation			■	■	■	■	■	■	■	■	■	
6	Remedial measures								■	■	■	■	
7	Outreach activity				■				■				■
8	Interim Report/Publications				■				■				
9	Final report submission												■

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared
2.	Hiring of project staff, equipment purchasing/ installation	• The purchase of the proposed equipments is in the final stage.
3.	Sample Collection and Analysis	• Samples are collected from the lake and incoming streams during the reconnaissance survey and analyzed for organoleptic, major ions, and trace metals.

13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	No specific comments	--

14. Analysis & Results:

- The sampling and bathometric survey plan has been prepared.
- The Hydro morphological Characteristics of Lake has been prepared (Figure 1).

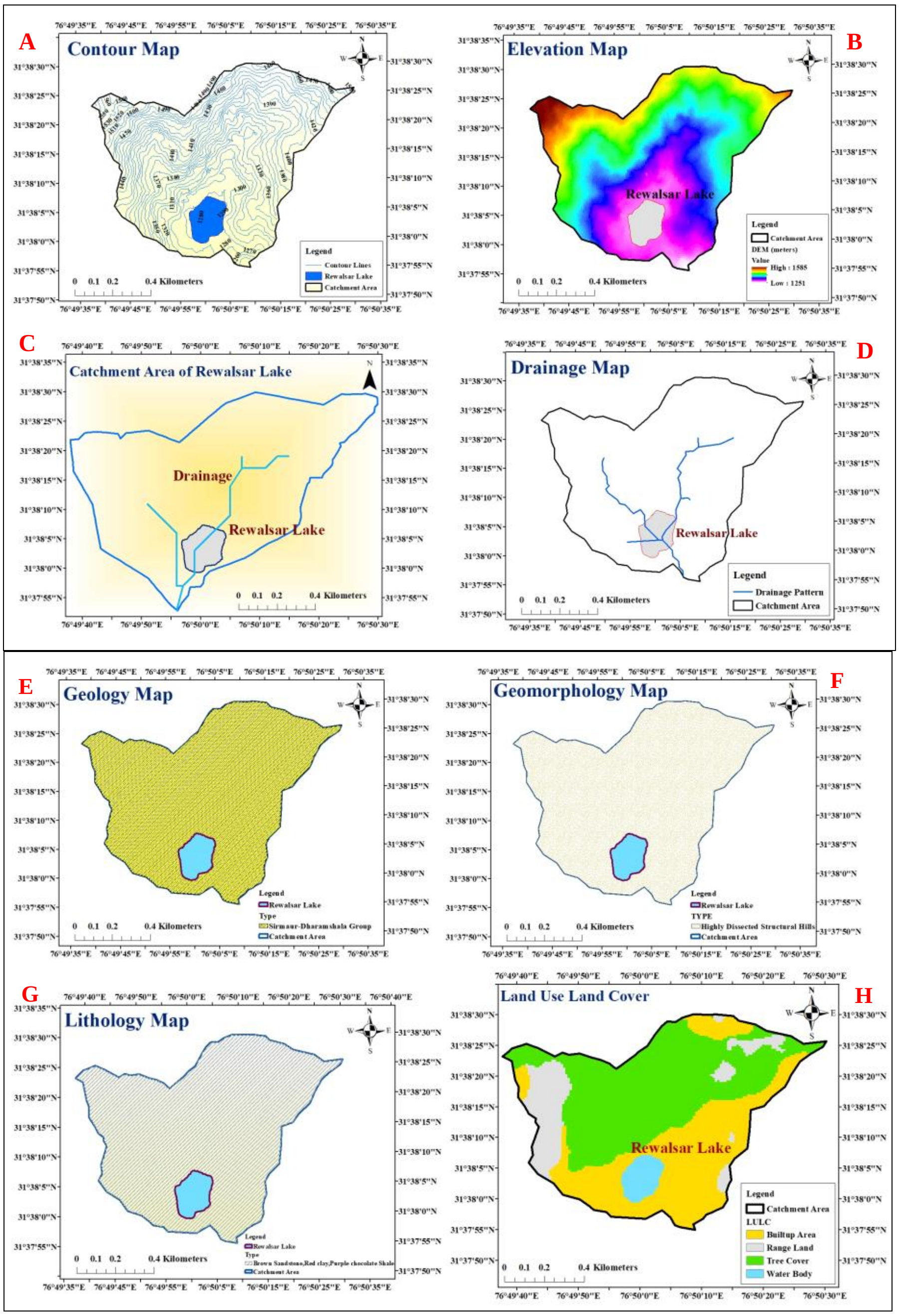


Fig. 1: Thematic maps of Rewalsar lake (A) Contour; (B) DEM; (C) Catchment area; (D) Drainage, (E) Geology; (F) Geomorphology; (G) Lithology; (H) LULC

- Sample from 6 locations were collected during the preliminary survey. Moreover, the diurnal variation of water temperature, pH, EC, and DO in lake water was monitored at 06:30 HR, 11:00 HR, 16:30 HR, and 20:00 HR (Figure 2).

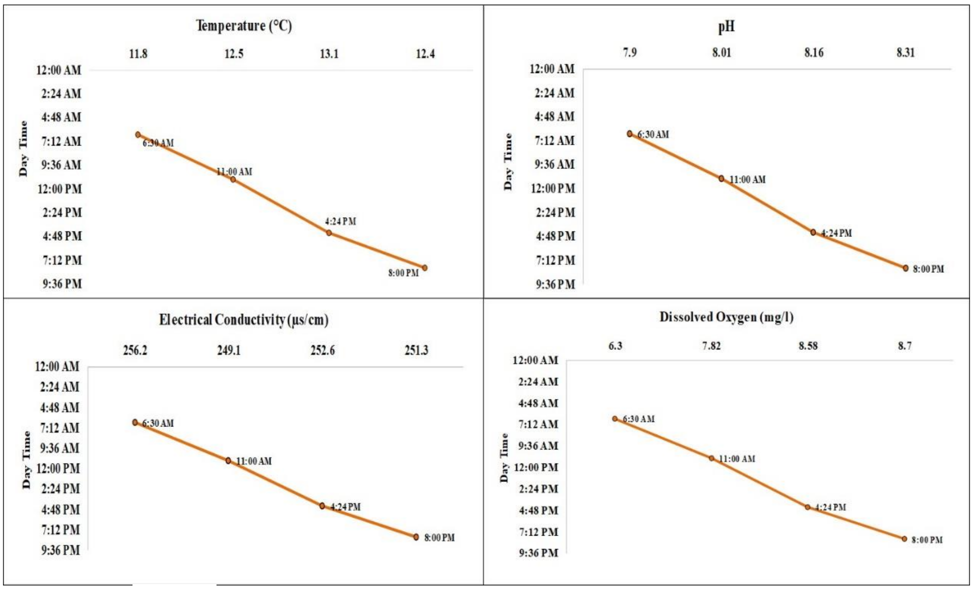


Fig. 2: The diurnal profile of in-situ parameters in the Rewalsar lake.

- $Ca\text{-}HCO_3$ is the dominant hydrochemical facie in the lake water samples. Further, significant concentration of NO_3 and NH_4 were observed in the samples indicating eutrophic nature of the lake. The trace metal concentrations were within the acceptable limits for drinking water.

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

16. **Deliverables:** Technical report and research papers, Factors responsible for WQ deterioration and sedimentation.

17. **Major items of equipment procured:** Flowmeter, Water level recorder, and AWS.

18. **Lab facilities used during the study:** Water Quality Laboratory (NIH), Soil-Water Laboratory (NIH), Nuclear Hydrology Laboratory (NIH)

19. **Data procured or generated during the study:** Water quality and sedimentation status of lake

20. **Study Benefits / Impacts:**
The outcome of the project will be beneficial for the concerned departments in a sense that it will provide the information on the factors impacting the water quality and sedimentation of the Rewalsar lake. A management plan to improve the water quality and quantity of lake will also be prepared.

21. **Involvement of end users/beneficiaries:** HPSWA, Shimla; HIMCOSTE, Shimla; Rewalsar Local Administration

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

23. **Shortcoming/Difficulties:** None.

24. **Future Plan:**
    - Bathymetric survey of lake
    - Installation of equipments for water balance study of lake.
    - Collection and analysis of lake water and sediment samples.

Study – 11 (Internal Study)

1. **Title of the Study:** Comprehensive evaluation of disinfection units of STPs in Ganga basin: Occurrence and control the formation of emerging oxidation precursors

2. **Study Group:**

Project Investigator/Co-Project Investigator
NIH Roorkee
Dr. Vinay Kumar Tyagi, Scientist D
Dr. Rajesh Singh, Scientist E
Dr. Mukesh K. Sharma, Scientist F
Dr. Pradeep Kumar, Scientist E
Er. J. P. Patra, Scientist E
Dr. Kalzang Chhoden, Scientist C
Dr. R. P. Pandey, Scientist G
IIT Roorkee
Dr. Bhanu P Vellanki, Professor
Dr. A. A. Kazmi, Professor

Type of study : Internal Study
Total Project Cost : Rs.73 lakhs (**Funded by NIH)**
Project Duration : **3-years**
Date of start : **April, 2023**
Scheduled Date of Completion : **March, 2026**

OBJECTIVES OF THE STUDY:
The specific objectives of this study are:
1. To study the pathogen removal efficiency of chlorination system in full-scale sewage treatment plants.
2. To study the factors affecting chlorination efficiency [dose, contact time, treated effluent quality, temperature, hydraulics, types of pathogens etc.,]
3. To study the formation of Emerging Oxidation Precursors (Qualitative and quantitative) in disinfection units of full-scale treatment plants.
4. To study the impact of chlorinated water discharge on water quality of receiving water body
5. To conduct pilot-scale studies for the removal of residual organics and nitrogen precursors and control the formation of EOPs in chlorination system
6. To suggest the optimal chlorine dose w.r.t secondary treated effluent to achieve effective pathogens removal and control EOPs formation.

Study Area : Twelve sewage treatment plants (STPs) representing different climates and topographies installed by the municipalities and other government bodies in various cities of Ganga basin were selected for study (Table 1). The plants use different technologies according to wastewater type, fund availability, governing body suggestions, and effluent requirements etc.

Table 1. List of the selected STPs for the study

S. No.	**Name of STP**	**Capacity (MLD)**	**Technology**	**Wastewater**	**Disinfection type**
1.	New Tehri, Garhwal	5	Extended Aeration	Sewage	Chlorination
2.	Kargi, Dehradun	68	SBR	Sewage + Septage	Chlorination
3.	Lakkarghat, Rishikesh	26	SBR + Filtration	Sewage	Chlorination
4.	Chorpani, Rishikesh	3.5	MBBR +Filtration Process	Sewage	Chlorination
5.	Jagjeetpur, Haridwar	27	Primary Clarifier +	Sewage	Chlorination

			SBR + Filtration		
6.	Chandreshwar Nagar, Rishikesh	7.5	MBBR + Disk Filtration	Sewage	Chlorination
7.	IIT Roorkee	3	SBR process	Sewage	UV
8.	Coronation Pillar, Delhi	318	A_2O process	Sewage	Chlorination
10.	Indrapuram, Ghaziabad	56	SBR	Sewage+Industrial wastewater	Chlorination
11	Dinapur, Varanasi	140	Conventional Activated Sludge Process	Sewage	Chlorination
12	Goitaha STP, Varanasi	120	SBR	Sewage	UV

Description of the Problem

In Indian STPs, the disinfection dosage of chlorine varies from a low concentration of 2 mg/L to as high as 10 mg/L. Chlorine oof organic matter results in the formation of trihalomethanes (THMs) and haloacetic acid (HAA), followed by other emerging oxidation precursors (EOPs such as N-nitrosodimethylamine (NDMA), chloramines, etc. Discharge of the treated water into natural water deficit water bodies, or where the flow rate is significantly less, results in a spike in EOPs concentrations. Accumulating EOPs in natural water bodies has been shown to cause serious environmental hazards even at very low concentrations. Therefore, the formation of EOPs is one of the major concerns, and need to be studied.

Methodology

The steps of the methodology of the study are as follows:

1. Efficiency estimation of disinfections units

Waste water samples will be collected from various stages of STPs, i.e., raw wastewater (STP inlet), biologically treated wastewater (inlet of disinfection unit) and finally treated wastewater (disinfection unit effluent). The collected water samples will be characterized for various physical-chemical and microbiological parameters.

(i). Physical-chemical parameters: COD, BOD, DOC, bDOC, TOC, TSS, pH, alkalinity, ammonia, nitrite, nitrate, residual chlorine, humic substances

(ii). Indicator organisms and pathogens: Total Coliforms, Fecal Coliforms, E. coli etc.

2. Factors affecting disinfection efficiency

The effects of various factors on disinfection efficiency (indicator microbes & pathogens removal) and EOPs formation will be studied comprehensively. Key factors will be taken into account: Disinfectant contact time, concentration/dosage of disinfectant, temperature, types of pathogens and indicator organisms, effect of water quality (suspended solids, organic matter), hydraulic retention time (HRT) of disinfection units (tracer study, designed and actual HRT verification), Cl_2 decay.

3. Quantitative and qualitative assessment of EOPs in disinfections units and receiving water bodies

Waste water samples will be collected from inlet of disinfection unit and outlet of disinfection unit. Samples will also be collected from different points of disinfection tank. Moreover, samples will be collected from upstream and downstream of receiving water body to realize the impact of chlorinated water discharge on water quality with respect to EOPs concentration. The collected water samples will be characterized for various emerging oxidation precursors (EOPs): Trihalomethanes, THMs; Haloacetic acids, HAA; and N-Nitrosodimethylamine, NDMA)

4. Pilot- reactor study

Pilot scale reactor (1000 L) study will be conducted to remove the residual organics and nitrogen precursors and control the formation of EOPs in disinfection units. The low cost pollutants removal solutions of activated carbon, biochar and biological activated carbon (BAC) processes for removal of residual organics and nitrogen precursors will be studied. The effects of integration of a bio/activated carbon/ biochar filter on organic pollutants removal and EOPs formation in downstream disinfection process will be studied.

Progress of Work

The team of project staff visited at 3 MLD STP IITR, 18 & 27 MLD STP, Jagjeetpur, Haridwar, 3, 5, 7.5, and 26 MLD STPs Rishikesh, 68 MLD STP, Kargi, Dehradun. Wastewater samples were also collected from above mentioned STPs for analysis purpose.

1. The tracer study was conducted and related data has been collected from STPs.
2. The estimation of various physio-chemical parameters like COD, BOD, DOC, TOC, TSS, pH, alkalinity, ammonia, nitrite, nitrate and residual chlorine has been conducted.
3. The estimation of indicator microorganisms and pathogens has been conducted for STPs's samples.
4. GC method for DBPs (Trihalomethanes (THMs)- Chloroform, Bromoform, Dichlorobromomethane, Dibromochloromethane) has been developed and these THMs estimated by GC-MSMS.

	
27 MLD, Jagjeetpur, Haridwar	18 MLD, Jagjeetpur, Haridwar
	
7.5 MLD, Chandreshwar Nagar, Rishikesh	68 MLD, Kargi, Dehradun

Further Proposed Work Plan for next year

1. Tracer study will be conducted for remaining STPs.
2. Wastewater samples will be collected from remaining STPs and various listed parameters will be analyzed.
3. Wastewater samples will be collected from listed STPs on seasonal basis and selected parameters will be analyzed.
4. The estimation of indicator microorganisms and pathogens will be conducted for remaining STPs's samples.
5. Indicator microorganisms and pathogens will be analyzed for STPs samples on seasonal basis.
6. Various DBPs (THMs, Haloacetic acids and NDMA) will be estimated on seasonal basis.
7. Review and research paper(s) will be prepared for publication.

Deliverables:

1. Comprehensive evaluation of disinfection units
2. Qualitative and quantitative database on EOPs formation in disinfection units
3. Technological solution to prevent the formation of EOPs through the integration of treatment units and design modifications
4. Technical report and papers

Study - 12 (Internal Study – New)

1. **Title of the Project:** Nanotechnology-enabled Multifunctional Materials for the Detection and Remediation of Arsenic in Contaminated Water

2. **Project Team:**

Project Investigator	Dr. Prasanta Kumar Sahoo, Sc. D, EHD
Project Co-investigator	Dr. Rajesh Singh, Sc. E, EHD Dr. R. P. Pandey, Sc. G & Head, EHD Dr. M. K. Sharma, Sc. F, EHD Dr. Pradeep Kumar, Sc. E, EHD Dr. Vinay Kumar Tyagi, Sc. D, EHD Dr. Sumant Kumar, Sc. E, GWD Dr. Kalzang Chhoden, Sc. C, EHD

3. **Type of Study** **:** Internal Study, **Budget:** Rs. 73.7 lacs
4. **Nature of Study** **:** Applied Research
5. **Date of start** **:** April 2024
6. **Scheduled date of completion** **:** March 2027
7. **Duration of the Study** **:** 3 Years

8. **Objectives**
   a) To prepare nano-enabled electrode materials for selective and sensitive electrochemical detection of Arsenic
   b) To design paper-based screen-printed electrochemical sensor kits based on nano-enabled electrode materials for on-field arsenic detection
   c) To prepare Nano-adsorbents for efficient removal of Arsenic in water
   d) To design a Nano-adsorbent-based household water filter for Arsenic remediation for drinking water

9. **Statement of the Problem**

Arsenic is the most toxic and carcinogenic metalloid element and has been ranked among the top 20 most hazardous elements necessitating prioritized control (Hall, 2002). Arsenic occurs in the natural environment in four oxidation states: As(V), As(III), As(0) and As(−III). The behavior of arsenic species changes depending on the biotic or abiotic conditions in water. In groundwater, arsenic is predominantly present as As(III) and As(V), with a minor amount of methyl and dimethyl arsenic compounds being reported. Global intake of As (III) and As(V) via drinking water and food has dramatically increased in recent years. Inorganic arsenic includes both As(III) and As(V) species and is a confirmed carcinogen the World Health Organization (WHO) has published a guideline value for arsenic in their 'Guidelines for Drinking Water Quality' and is on the WHO list of 10 chemicals of major public health concern. Chronic arsenic toxicity affects multiple physiological systems and can cause serious health issues such as keratinization of the skin (Bhat et al., 2023), hyperpigmentation of the palms and soles, arsenicosis, hyperkeratosis, coronary heart disease, bronchiectasis, Bowen's disease, etc. leading to death. The natural contamination of As in groundwater has been reported worldwide, and the majority of these belong to South Asian and South American regions (Hashim et al., 2019). Over all more than 230 million people worldwide, which include 180 million from Asia, are at risk of arsenic poisoning in India, it is reported that a population of over 50 million is currently at risk from groundwater arsenic contamination. Arsenic contamination in groundwater was first reported from the Chandigarh region of north India (Datta and Kaul, 1976), and the second case was reported in the lower Gangetic plain of West Bengal (Garat et al., 1984). The present study reveals that 20 states (West Bengal, Jharkhand, Bihar, Uttar Pradesh, Assam, Gujarat, Haryana, Madhya Pradesh, Panjab, Arunachal Pradesh, Karnataka, Tamil Nadu, Himachal Pradesh, Telangana, Andhra Pradesh, Orrisa, Nagaland, Tripura, Manipur, Chhattisgarh) and 4 Union territories (Delhi, Daman and Diu, Puducherry, Jammu, and Kashmir) of India are now risks from groundwater arsenic contamination (www.mapsofindia.com; Chakraborti et al., 2018 and CGWB, 2018). WHO, EU, and USEPA, and BIS maximum limit for arsenic in drinking water is 10 ppb. To meet this value, rapid, sensitive, cost-effective, and reliable analytical detection systems must be developed and put into use.

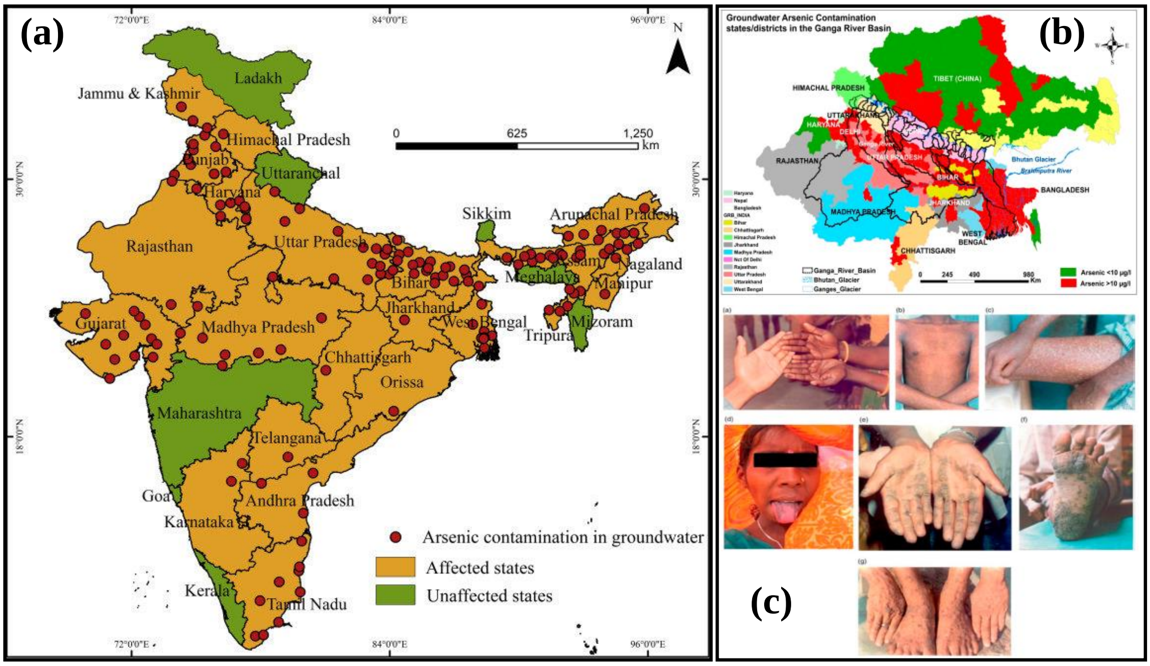


Fig.1 (a) Arsenic-affected states and Union Territories in India. (b) Current status of groundwater arsenic contamination in the Ganga River Basin (c) Impacts of Arsenic toxicity on human health. (source: www.mapsofindia.com; Chakraborti et al., 2018 and CGWB, 2018)

A plethora of standard analytical detection techniques include high-end sophisticated instruments (Proch and Niedzielski, 2020) such as hydride generation atomic absorption spectroscopy (HG-AAS), inductively coupled plasma mass spectrometry (ICP-MS), and atomic fluorescence spectroscopy (AFS), etc. have been developed and reported and some are capable of detecting arsenic below the WHO guideline value of 10 ppb. Although the above methods are selective and sensitive for the As, these techniques are bulky, expensive, intricate sample preparation procedures and require highly trained personnel for their maintenance and operation. Besides, instrumental techniques are not suitable for routine and on-field (field-portable) analysis as samples need to be collected and transported to the location where they should be analyzed. The possibility of a significant error in the collection, preservation, and transportation of samples warrants the need for onsite environmental monitoring particularly for the field survey of water sources. Various techniques such as colourimetry, fluorimetry, and electrochemistry are explored for the onsite detection of contaminants. Electroanalytical techniques are an attractive alternative for the onsite monitoring of pollutants. In addition, electrochemical sensing systems are sensitive and selective towards electroactive species, easy to operate, compact, fast, portable, and inexpensive (Sahoo et al., 2015; Sahoo et al., 2020). Cyclic and stripping voltammetry are proven techniques for the detection of trace inorganic metals electrochemically. Further, the three electrode cells can be replaced with screen-printed electrodes (SPE) which are prepared by coating electro-conductive and insulating ink on a plastic or ceramic substrate. Carbon screen-printed electrodes are popular due to their sensitivity, ease of use, and cost-effectiveness (Huang et al., 2024). These electrodes can be further modified with the appropriate characteristic receptors to obtain the desired selectivity and sensitivity.

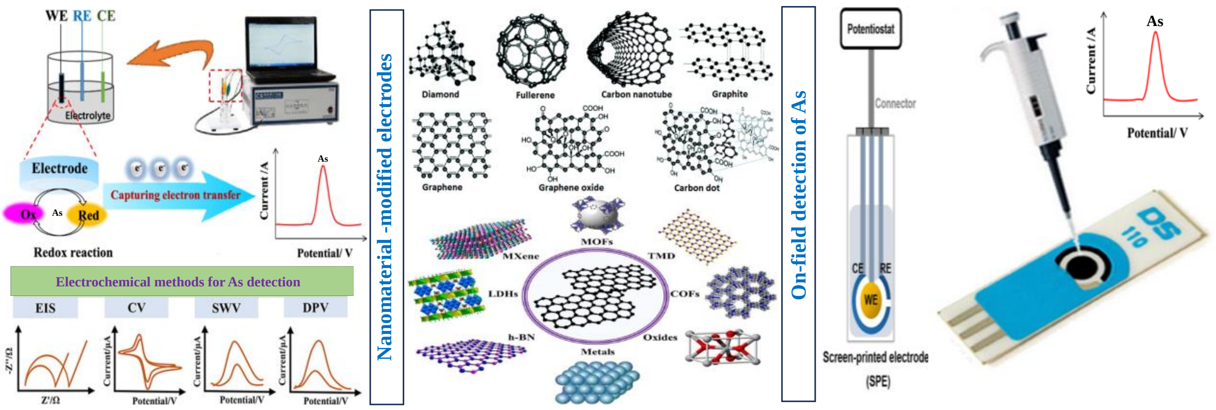
Further, to overcome arsenic toxicity, which has become a major concern worldwide, it is very important to develop and deploy environmentally compatible and sustainable solutions for the remediation of arsenic pollution and thereby overcome its toxic effects on the human population and save millions of people across the world. Several arsenic removal technologies such as oxidation and filtration, co-precipitation, sedimentation and filtration, use of ion-exchange resins, adsorption, and membrane technology including reverse osmosis and electrodialysis have been reported in the literature so far. Among those, adsorption is a widely acceptable technology due to its easy operation, high removal efficiency, and cost-effectiveness (Alka et al., 2021). It can be classified into physisorption and chemisorption where the earlier one involves intermolecular forces and later works on valence forces to attach the adsorb onto the adsorbent (Kumar et al., 2022). Some of the conventional adsorbents used are activated carbon, sand, coal, silica gel, resins, and wood (Bouazza et al., 2022; Jena et al., 2024). Even though the conventional adsorbents showed good economic benefits, high regeneration cost and column fouling made the research community search for alternative adsorbent material for water remediation. Recently, Nanotechnology is considered to play a crucial role in providing clean and affordable water to meet human demands. The use of nanomaterials as adsorbents for the removal of As from water samples offers distinctive advantages over other adsorbents conventionally used for the removal of heavy metals (Mohanapriya et al., 2023). Their high specific surface area and surface chemistry, short intraparticle diffusion distance, tunable pore size, chemical stability, and the more uniform dispersion of the deposited nanoparticles are properties that determine to a large extent their interaction with contaminants in an aqueous environment. Several reviews have highlighted the efficiency of inorganic and carbonaceous nanomaterials for the removal of As and other heavy metals greatly enhanced from water and wastewater (Lal et al., 2020; Bhattacharya et al., 2023). The performance of these materials is highly influenced by the composition, structure, and property of individual components and exhibit unusual characteristics. In addition, the vast majority of tests have been performed in a laboratory batch or column set-up, using artificially prepared As (III) or As (V) aqueous solutions. Real As-containing water samples have been rarely employed until now, therefore the efficiency of the nanocomposites in more complex conditions has not been examined. Therefore, the development of facile, cost-effective, and efficient methods, which are easy to handle and conveniently applied on a large scale at household and community levels for the remediation of arsenic from contaminated water is of the highest priority.

10. Action Plan/ Methodology:

(i) ***Preparation of Nanomaterials:*** Various nanomaterials (metal/metal oxide/ metal hydroxide/metal sulfides/metal phosphides/polymers/ carbonaceous) will be synthesized using a soft-chemical approach.

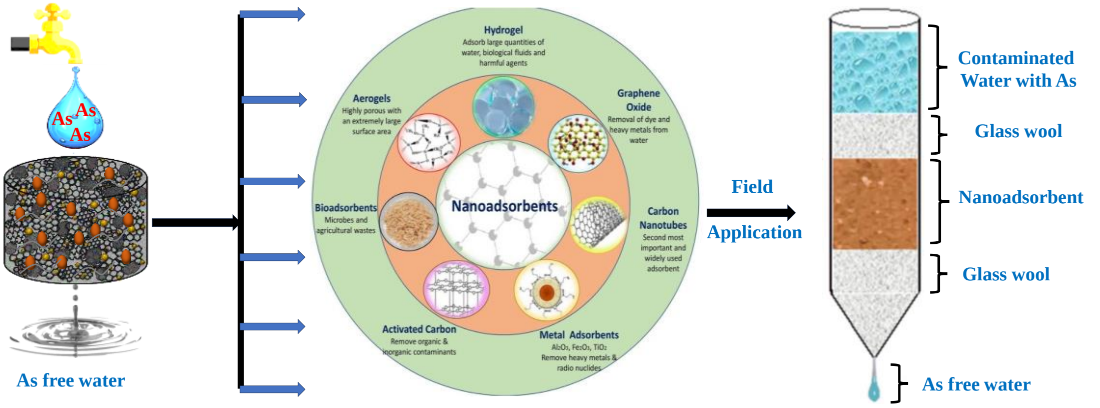
(ii) ***Characterization of as-prepared Nanomaterials:*** The developed nanomaterials will be well characterized and investigated by various sophisticated characterization techniques. XRD, Raman, FTIR, TEM, SEM-EDX, AES-ICP, and BET surface area. In most of cases, a combination of two or more techniques will be used to evaluate the nanomaterial's properties.

(iii) ***Arsenic detection by Electroanalytical techniques:*** The nanomaterial-modified electrodes will be applied for the ultra-trace selective and sensitive determination of As in water by using various electroanalytical methods such as Cyclic Voltammetry (CV) and Differential Pulse Stripping Voltammetry (DPSV).



(iv) ***Fabrication of paper-based screen-printed Arsenic electrochemical sensor:*** *Screen-printed* paper-based Arsenic electrochemical sensor will be fabricated in the lab and tested for on-field (field-portable) analysis of real Arsenic-contaminated water samples.

(v) ***Remediation of Arsenic-contaminated water using Nano-adsorbents:*** Effects of Operational Parameters on Adsorbent Performance (pH, Temperature, Contact Time, Initial Concentration, Adsorbent Dose), Adsorption Kinetics, and application of developed nano-adsorbent on Arsenic contaminated water samples.



(vi) ***Design of Nano-adsorbent-based household water filter for Arsenic remediation for drinking water:*** The water filter will be designed by using Nano-adsorbents for Arsenic remediation at household and community levels.

11. Budget Details

Full Summary of Budget (In Rs)

Sr. No.	Sub-Head	1st Year	2nd Year	3rd Year	Total
1	Manpower (Resource Person Jr.-2 no's) (35,000+HRA)	924000	924000	924000	2772000
3	Equipment (Electrochemical potentiostat and Freeze dryer)	2500000	---------	------------	2500000
4	Consumable (Glassware, Chemicals, Misc.)	300000	200000	200000	700000
4	Travel (Sample collection, Meeting & Others)	100000	200000	200000	500000
5	Experimental and Characterization charges	100000	100000	100000	300000
6	Misc. Expenditure	300000	200000	100000	600000
	Grand Total	**4224000**	**1624000**	**1524000**	**7372000**

Justification for Manpower

Two Resource Persons with a post-graduation degree in Environmental sciences/ Chemistry/Environmental Engineering/Chemical Engineering with research experience in the field of Nanomaterials, electrochemical sensors, water and wastewater treatment, and water quality analysis will be required for the extensive fieldwork, analysis work, and piloting experiments.

12. Work Schedule

S.No.	Work Element/ Milestone	1st Year				2nd Year				3rd Year			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Literature Review												
2	Hiring of project staff, equipment purchasing/installation												
3	Nanomaterials Preparation and Characterization												

4	Field Investigation, water sample collection												
5	Sensitivity and selectivity detection of As in water samples using Electroanalytical techniques												
6	Fabrication of screen-printed paper-based Arsenic electrochemical sensor for on-site As determination												
7	Evaluation of nano-adsorbents for As remediation from water samples												
8	Design of water filter using Nano-adsorbents for As at household/community level												
9	Publications/Patents												
10	Interim/Final report submission												

13. Contribution of PIs

PIs	Contribution
Dr. Prasanta Kumar Sahoo	Nanomaterials synthesis, Characterization, Electrochemical sensor development and designing, Nano-adsorbent-based As-specific water filter development and designing.
Dr. R. P. Pandey, Sc. G & Head, EHD	Guidance for proposal formulation
Dr. Mukesh K. Sharma, Sc. F, EHD	Investigation of physicochemical parameters and Arsenic detection
Dr. Rajesh Singh, Sc. E, EHD	Arsenic detection, remediation, and filter design
Dr. Vinay Kumar Tyagi, Sc. D, EHD	Remediation and water filter designing and fabrication
Dr. Pradeep Kumar, Sc. E, EHD	Application of the developed material in the field
Dr. Sumant Kumar, Sc. E, GWD	Column investigations for As remediation
Dr. Kalzang Chhoden, Sc. C, EHD	Nanomaterial characterization, batch, and column investigations

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Study - 13 (Internal Study – New)

1. **Title of the Project:** Land and water management plan for rejuvenation of river Tilodki Ganga, Ayodhya

2. **Project Team**
   - **Project Investigator:** Dr. Shakti Suryavanshi, Sc. C, EHD
   - **Project Co-investigator:** Dr. Shailendra Kumar Kumre, Sc. B, EHD
     Dr. R. P. Pandey, Sc. G & Head, EHD
     Dr. Pradeep Kumar, Sc. E, EHD
     Dr. Rajesh Singh, Sc. E, EHD
     Dr. M. K. Sharma, Sc. F, EHD
     Dr. Kalzang Chhoden, Sc. C, EHD
     Dr. Nitesh Patidar, Sc. C, GWHD
     Dr. V. K. Tyagi, Sc. D, EHD

3. **Objectives**
   a) Identification of degraded zones in terms of River continuum and water quality.
   b) Water budget study of surface and groundwater
   c) Assessment of water quality, source identification and recommendation for quality improvement
   d) Development of land and water management plan for eco-restoration of river
   e) Organization of Stakeholder Workshop

4. **Present state-of-art**

Rivers constitute vital components of freshwater ecosystems, serving as crucial sources of water for diverse human needs such as drinking, agriculture, and industrial activities. Additionally, rivers hold immense ecological significance, providing habitats for various aquatic organisms and supporting complex food webs. However, river ecosystems face numerous challenges that threaten their health and functionality. The quality of river water is influenced by a myriad of factors including physical, chemical, and biological parameters. Common issues encountered in river ecosystems include sedimentation, habitat degradation, pollution from agricultural runoff and industrial effluents, as well as eutrophication resulting from excessive nutrient input. These challenges are further exacerbated by anthropogenic activities such as deforestation, urbanization, and improper waste disposal practices. Moreover, climate change poses additional stressors on river systems, leading to alterations in flow regimes, increased temperatures, and changes in precipitation patterns. Effective rejuvenation and restoration of rivers require comprehensive understanding and management of these interconnected factors. Implementation of monitoring programs is essential to assess water quality, track ecosystem health, and evaluate the success of restoration efforts. By addressing these challenges through integrated management approaches and stakeholder engagement, we can ensure the long-term sustainability and resilience of river ecosystems, thereby safeguarding their invaluable ecological, economic, and societal benefits.

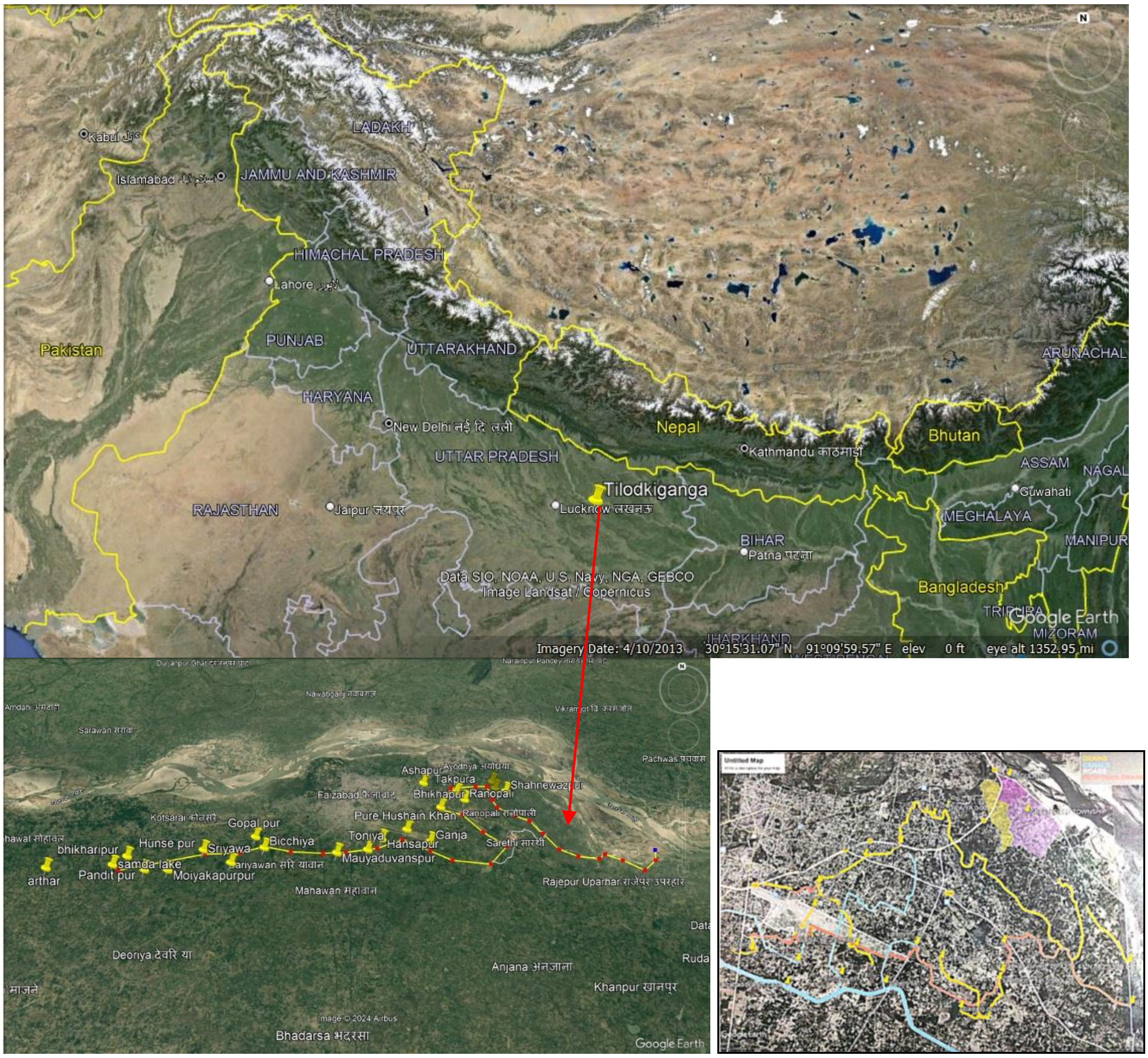
The optimal ecological outcomes in a river basin occur when environmental water flows through rivers and wetlands, mimicking natural conditions (Dutta et al., 2020). Numerous studies have been conducted to explore strategies for rejuvenating and restoring river ecosystems. Studies done for ecological impacts indicate the impacts of physio-chemical quality, Faecal Coliforms, fish and fisheries, and impact of other vertebrates on Ganga basin (Sinha et al., 2001). A study conducted to assess potential conservation and restoration areas of freshwater fish fauna in the Indian river basins indicate a call for urgent attention to the conservation of their fish fauna along with restoration of their degraded habitats (Bhatt et al., 2016). Some studies conducted to understand the hydrological considerations for restoration of river. Mondal and Patel (2018) examined the ecological techniques of flood and channel management, especially in monsoonal environments. Mazumder et al., (2018) presented a river action plan, flood management and basin development plan for Indian river basins. Some studies are conducted to understand the physical issues and their solutions related to restoring small rivers. Borthakur and Singh (2016) shed light on the challenges facing India's extinct or critically endangered rivers and rivulets as they traverse major Indian cities. They emphasize that encroachments greatly diminish the width of these water bodies, transforming them into little more than 'sewers,' as seen with the River Bharalu and the Bahini rivulet in Guwahati. Likewise, the River Assi in Varanasi is now nearly non-existent. Consequently, even brief rainfall events quickly inundate the riverbanks with water. Kumar et al., (2022) conducted a study on Kalyani River for catchment area treatment for eco-restoration of rivers and to restore the water flow in the kalyani river using HECRAS and geospatial techniques. A frequently overlooked aspect of river system studies in India is the country's network of small rivers (Borthakur and Singh, 2016). Therefore, maintaining and nurturing a healthy river ecosystem requires attention to these smaller waterways. Small rivers also serve crucial functions such as irrigation, drainage of excess water, and groundwater recharge (DTE, 2013; Gaurav, 2010; Singh et al., 2015). However, efforts to rejuvenate small rivers have been lacking.

In this context, the River Tilodkiganga, a small tributary of River Saryu was chosen for land and water management plan due to its religious and cultural significance and vital role for local communities. Unfortunately, the degradation of the Tilodkiganga River is occurring due to various natural and human-induced factors, including changes in river morphology, lateral migration of sediment deposited by flowing water, agricultural activities, and siltation in river beds. The waterbodies within the catchment are facing eutrophic conditions due to the various non-point sources. Keeping this in view, a systematic and comprehensive study on the Land and water management of Tilodkiganga river has been envisaged.

5. Study Area:

Tilodkiganga, also known as Tillai or Baha, is a sacred stream mentioned in the '*Skand Puran*', *Rudrayamala* and *Ayodhya Mahatyam*. Tilodkiganga river flow through Ayodhya city before joining river Saryu. The Tilodkiganga river originates from Samda lake near Panditpur village of Ayodhya. The length of river course is about 47 km. Unfortunately, the degradation of the Tilodkiganga River is underway due to a range of natural and human-induced factors, including changes in river morphology, sediment migration, agricultural activities, and siltation in river beds. River Trilodki is now flowing in the form of a storm water drain known as Tilaiya which serves as a drainage line for villages Hansapur, Pure Hushain Khan, Ganja, Janaura, Vhikhapur, Ranopali, Ashapur, Takpura, Haibatpur, Kazipur, Chitwa, Vasupur, Sirsa alias Jaisingpur,Shahnewazpur, Manjha etc. and finally joins Saryu River. This is a natural drain and carries only surface runoff. Presently, the river has not any regular flow in lean season. Just after 5 km from the origin, the Tilodkiganga exist in patches. The middle reach of the river moves through urban areas of Ayodhya, thus there is a problem of water pollution and encroachments. The eutrophication in waterbodies within the catchment is also prevalent due to various non-point sources. Some reaches of Tilodkiganga river carries significant flow in rainy season till the month of September. But, the flow reduces considerably in the winter season and it becomes confined to a smaller section of the river bed during hot summer months.

The climate of the study area experiences a humid subtropical climate. Summers (March to June) are hot and dry, with temperatures often exceeding 40°C (104°F). Monsoon season (July to September) brings heavy rainfall and slightly cooler temperatures. Winters (November to February) are mild and dry, with temperatures averaging around 15-25°C (59-77°F), although occasional cold spells can occur.



Study Area

6. Methodology:

Research objective wise detailed methodology is given below:

Objective 1:
Preliminary study will be carried out to identify the existing data on the river's morphology, flow regime, historical water quality records and information on land use and anthropogenic activities in the watershed. Field surveys will be conducted along the river to assess its physical characteristics, including width, depth, velocity, and substrate composition. Water sample will be taken at regular intervals to measure key water quality parameters such as pH, dissolved oxygen, turbidity, nutrients (nitrogen and phosphorus), and contaminants (heavy metals, pesticides, etc.).

Objective 2:
Estimation will be carried out for the various inputs and outputs of the water budget for both surface water and groundwater components. Calculation of surface water runoff will use hydrological models and empirical equations. The determination of groundwater recharge rates will be based on groundwater level fluctuations and hydrogeological properties. Calculation of the water balance will be carried out by comparing the total inputs (precipitation, surface water inflow, and groundwater recharge) with the total outputs (evapotranspiration, surface water outflow, and groundwater discharge).

Objective 3:
Analysis will be carried out for the collected samples for physicochemical parameters (pH, temperature, conductivity, dissolved oxygen, etc.) and pollutants (nutrients, heavy metals, organic contaminants, etc.). Field investigations and interviews with stakeholders will be conducted to gather information on point and non-point sources of pollution. Identification of priority pollutants and hotspots of contamination requiring immediate attention will be conducted. A comprehensive strategy will be developed for water quality improvement, including pollution prevention measures, wastewater treatment upgrades, and land use management practices.

Objective 4:
A comprehensive assessment of the catchment area, including land use, soil erosion, vegetation cover, hydrological processes, and ecological conditions will be conducted. Source identification of deforestation, agricultural runoff, industrial discharge, and urban development impacting the river ecosystem will be carried out. Afterwards, a tailored catchment area treatment plan will be developed incorporating a mix of restoration measures such as afforestation, soil conservation, wetland restoration, and sustainable land management practices. Prioritization of restoration actions will be based on their potential to improve water quality, enhance biodiversity, and restore ecosystem services.

Objective 5:
Key stakeholders including local communities, schools, government agencies, NGOs, and businesses with an interest in river conservation and water quality management will be identified. Community meetings, workshops, and educational events will be organized to raise awareness about the importance of river conservation, water quality protection, and sustainable water resource management.

7. Research Outcome from the Project:

a) Comprehensive map and report pinpointing degraded zones along the river continuum, specifying location, severity, and causative factors.
b) Detailed documentation of surface and groundwater dynamics, providing insights into water availability, usage, and potential stressors.
c) Thorough assessment of water quality, precise identification of pollution sources, and actionable recommendations for quality enhancement.
d) Formulation of a holistic eco-restoration plan for the river's catchment area, outlining specific measures for sustainable improvement.
e) Successful implementation of a mass awareness and outreach program, fostering community engagement and promoting sustainable practices for river conservation.
f) Dissemination of research findings through publications, presentations, and knowledge-sharing platforms to contribute to the wider body of scientific knowledge.

8. Cost Estimate

a. **Total cost of the project** : **Rs. 36.6 Lakh**
b. **Source of funding** : NIH internal
c. **Sub head-wise abstract of the cost:**

Sr. No.	**Sub-Head**	**1st Year**	**2nd Year**	**3rd Year**	**Total**
1	Manpower (Resource Person Jr. 2 nos) (30,000/- p.m.)	720000	720000	720000	2160000
2	Travelling expenditure	200000	200000	200000	600000
3	Infrastructure / Equipment / Consumable	300000	200000	100000	600000
4	Experimental charges	50000	50000	50000	150000
5	Misc. Expenditure	50000	50000	50000	150000
	Grand Total	1320000	1220000	1120000	3660000

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

- Travelling expenditure: For visit to the study area for data collection, surveys etc.
- Equipment/Consumables: Chemicals, glasswares, plasticwares, organization of workshop etc.
- Experimental charges: Towards the analysis of samples

9. Work Schedule

a) Probable date of commencement of the project : April 2024

b) Duration of the project : 3 Years

Stages of work & milestone

S.N.	Work Element/ Milestone	1stYear				2ndYear				3rd Year			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Literature Review and Reconnaissance survey	■											
2	Hiring of project staff	■	■										
3	Field Surveys	■	■	■		■	■	■		■			
4	Identification of degraded zones in terms of River continuum and water quality	■	■	■	■								
5	Water budget study of surface and groundwater					■	■	■	■				
6	Assessment of water quality, source identification and recommendation for quality improvement		■	■	■	■	■	■					
7	Development of catchment area treatment plan for eco-restoration of river								■	■	■	■	
8	Stakeholder Workshop				■				■				■
9	Interim Report/Publications				■				■				
10	Final report submission												■

10. Contribution of PIs

PI and Co-Investigators	Contribution
Dr. Shakti Suryavanshi, Sc. C, EHD	Project formulation, field surveys, water budgeting, hydrological modelling, synthesis of results and report writing
Dr. Shailendra Kumar Kumre, Sc. B, EHD	Field surveys, water budgeting, hydrological modelling
Dr. R.P Pandey Sc. G & Head, EHD	Project formulation and overall guidance
Dr. Pradeep Kumar Sc. E, EHD	Development of land and water management plan
Dr. Rajesh Singh Sc. E, EHD	Water Quality Assessment & Remediation Measures
Dr. M. K. Sharma, Sc. F, EHD	Water Quality Assessment
Dr. Kalzang Chhoden, Sc. C, EHD	Rejuvenation plan for Lentic ecosystems
Dr. Nitesh Patidar, Sc. C, GWHD	Groundwater behavior and site suitability for recharge interventions
Dr. Vinay Kumar Tyagi Sc. D, EHD	Remediation Measures for mitigation pollution loads

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Study – 14 (Internal Study - New)

1. **Title of the Project:** Evaluation of Groundwater Quality of Tripura with emphasis on Arsenic and Flouride

2. **Project Team**

Project Investigator	Dr. Rajesh Singh, Sc. EHD
Project Co-investigator	Dr. Vinay Kumar Tyagi, Sc. D; Dr. M. K. Sharma, Sc. F Dr. P. K. Sahoo. Sc. D; Dr. Kalzang Chhoden, Sc. C Dr. Shakti Suryavanshi, Sc. C; Dr. Sanjay K. Sharma, Sc. D, NIH-NERC, Guwahati; Dr. Swapnali Barman, Sc. D, NIH-NERC, Guwahati; Dr. Waikhom Rahul Singh, Sc. C, NIH-NERC, Guwahati
Collaborator	Dr. Rajib Paul, Junior Scientist, Tripura State Pollution Control Board, Tripura

3. **Objectives**
    1. Distribution and prevalence of As and F in the groundwater of Tripura
    2. Health risk assessment due to groundwater consumption

4. **Present state-of-art**

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.

Generally, water quality is the process to determine the chemical, physical and biological characteristics of water resources and identifying the source of any possible pollution or contamination, which might cause degradation of the water quality. Chemical weathering of the rocks leads to introduction of dissolved solids in the water resources and conversely water chemistry provides information on chemical erosion processes (Chetelat et al., 2008). Chemical weathering is a chemical reaction; therefore, it requires a “substrate” and “reacting agents” for it to occur. The substrates on the earth surface are the minerals in rocks and the reacting agents are acids, such as, carbonic acid (HCO^-_3 derived from dissolution of CO_2); sulfuric acid (H_2SO_4 derived from pyrite oxidative weathering and a number of organic acids (oxalic, acetic and humic), which liberate protons to weather the minerals. In addition to these acids, H_2O also acts an agent in dissolving evaporite minerals. In addition, the quality of water resources is also affected by the anthropogenic activities resulting in the degraded water quality. In case of groundwater pollutants reaching the aquifer results in various reactions and most of the times enhances the microbial reactions leading to release of harmful contaminants like arsenic, uranium, fluoride etc. from the aquifer minerals making the water unfit for consumption. These types of changes occur over a prolonged time scale and hence, continuous monitoring of the water resources helps in avoiding the havoc that may happen due to consumption of contaminated water. As and F contamination have been reported in the north eastern states and significant habitation have been reported to be affected due to presence of toxic contaminants in the groundwater.

Geographically, Tripura state of India is surrounded in three sides by Bangladesh, where groundwater arsenic contamination is a major problem. Further, the remaining side of Tripura is surrounded by two other North-Eastern hilly states of India, Assam and Mizoram, where groundwater is reported to be contaminated with fluoride. Hence, there is high chance of co-occurrence of fluoride and arsenic in the groundwater of Tripura. The information on the distribution of As and F in the groundwater of Tripura is very much inadequate. Thus, the main objective of the study is to to analyze the groundwater quality of Tripura state with special emphasis on As and F, associated health risk assessment to consumers, and to gain insight on the processes controlling the groundwater quality.

5. Methodology:

(i). Collection and analysis of groundwater samples during pre and post monsoon from selected locations of Tripura.
(ii). Processing the data to understand the processes controlling the groundwater quality.
(iii). Evaluating the associated health risks to consumers.

6. Research Outcome from the Project:

(i). Geo-spatial data base of groundwater quality
(ii). Health risk to consumers due to consumption of groundwater
(iii). Technical report and papers

7. Cost Estimate

a. Total cost of the project : Rs. 33 88 000.00
b. Source of funding : NIH (Internal)
c. Sub headwise abstract of the cost :

Sr. No.	Sub-Head	I Year	II Year	III Year	Total
1	Manpower (Resource Person: 1 No.) (30,000+HRA)	3 96 000	3 96 000	3 96 000	11 88 000
2	Travelling expenditure	3 50 000	5 00 000	3 50 000	**12 00 000**
3	Infrastructure / Equipment / Consumable	3 00 000	2 00 000	2 00 000	**7 00 000**
4	Misc. Expenditure	1 00 000	1 00 000	1 00 000	**3 00 000**
	Grand Total	**11 46 000**	**11 96 000**	**10 46 000**	**33 88 000**

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

- Travelling expenditure: For visit to study area, attending conferences, data collection, surveys etc.
- Equipment/Consumables: Purcahse of Ion selective electrodes, chemicals, glasswares, plastics, etc.

8. Work Schedule

(i). Probable date of commencement of the project : May 2024
(ii). Duration of the project : 3 Years
(iii). Stages of work & milestone

Sr. No.	Major Activities	2024-25				2025-26				2026-27			
		1st Qtr	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/Publications										■	■	■

Study – 15 (Internal Study - New)

Project Title:

Comprehensive Hydrological Study for River Health Assessment and Development of Environmental Management Plan for River Yamuna

Statement of Problem:

The Yamuna River, a significant tributary of the Ganges, holds ecological, cultural, and economic importance in Northern India. Anthropogenic activities, including urbanization, industry, and agriculture, have impacted the river's flow dynamics. The river experiences extremes of dry conditions from January to June and flooding from July to September, presenting challenges for water management. The deterioration of the Yamuna river due to pollution, altered flow patterns, and habitat degradation emphasizes the urgent need for a focused examination of the river health. Over exploitation of surface and groundwater and at the same time influx of pollutants from industries, municipalities and agricultural fields has put tremendous pressure on the riverine ecosystem. Studies over the past 30 years indicate rapid deterioration of water quantity & quality, loss of fisheries, and changes in biotic communities along the Yamuna's river course and the impacts have extended to the connected aquifer systems. This highlights the critical need for coordinated, long-term study to address the environmental issues to ensure the restoration and sustainable management of the Yamuna River.

Broad Objectives:

The broad objective of the study is to assess the river health of main Yamuna River course from Yamunotri upto Allahabad for development of Environmental Management Plan with the following objectives:

1. Rainfall-Runoff-Sediment Yield Modelling to Assess Water Availability and Sediment Loads
2. Environmental Flow Requirements at Critical Stretches of River Yamuna
3. Analysis of Irrigation Water Management Scenarios in Canal Command Areas for Sustaining Aquatic Ecosystem of Yamuna River
4. Assessment of water and sediment/soil quality including emerging pollutants in Yamuna river and the connected aquifers
5. Quantification of Point and Non-point Source Pollution Loads in Yamuna River
6. Study of Sediment - Water Interactions including Adsorption Characteristics of Bed Sediments in different stretches of the river Yamuna
7. Study of Surface Water - Ground Water interactions through hydrological, chemical and isotopic modelling
8. Occurrence, removal and fate of organic and emerging pollutants in STPs in Yamuna River
9. Detection and Remediation for Water using Nanotechnology-enabled Multifunctional Materials in selected highly polluted zones
10. Development of Environmental Management Plan for maintaining the river health of Yamuna River

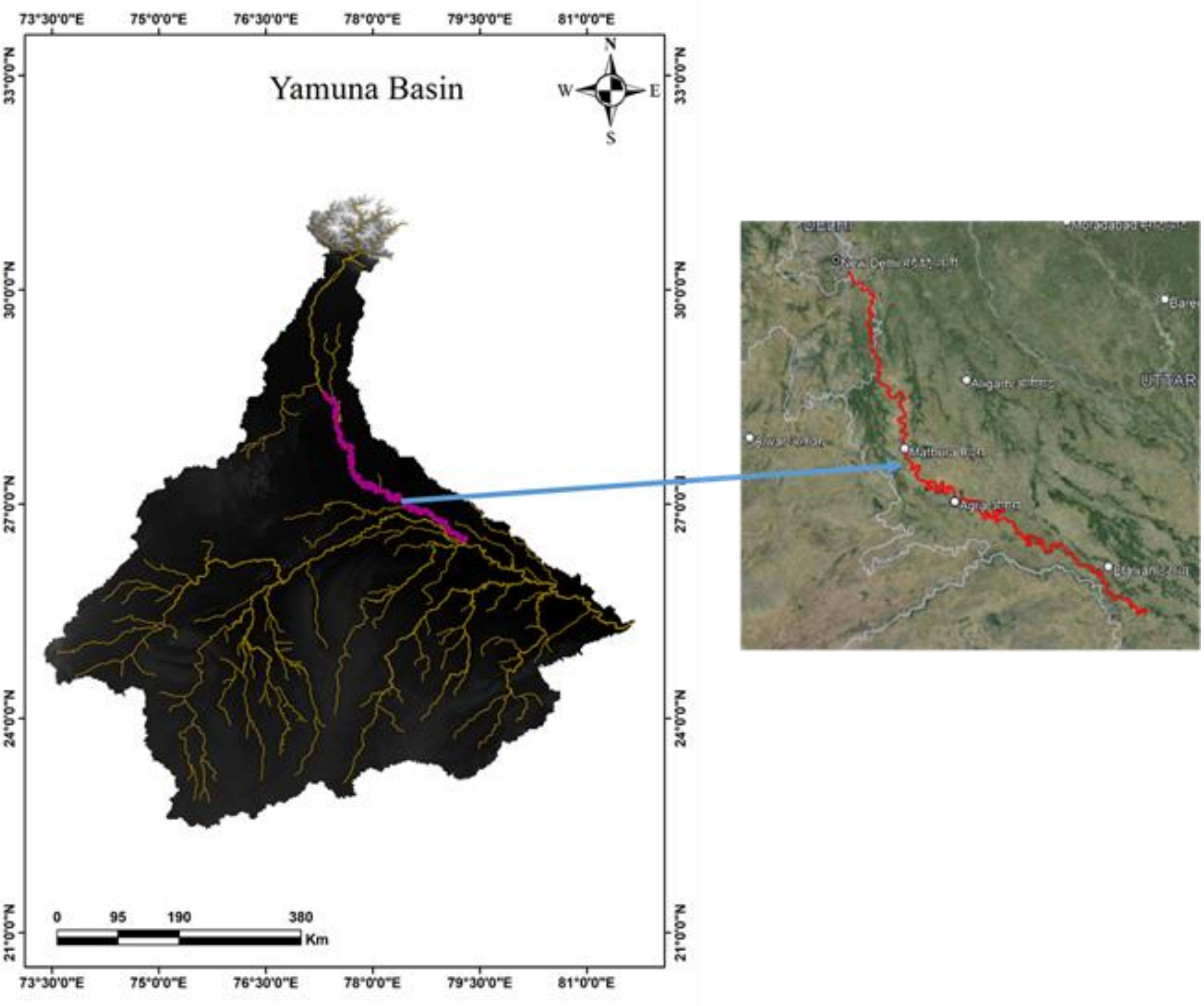
Study Area:

The Yamuna River, the largest tributary of the Ganges, flows gracefully through culturally rich cities like Delhi, Vrindaban, Mathura, and Agra, becoming an integral part of their historical tapestry. Its cultural significance is heightened as it merges with the timeless beauty of the 'Taj Mahal.' Spanning seven northern states, the Yamuna boasts a vast catchment area of 3,66,223 km², covering 42.5% of the total Ganga basin and contributing to 10.7% of India's fertile land.

The river's journey encompasses a 1376 km stretch, supporting diverse fish species for about 1300 km. The elevation in the Yamuna basin varies from 6320 m near Yamunotri Glacier to 100 m near the confluence with the Ganges at Allahabad. The Trans-Yamuna plain, where the study area lies, is characterized by alluvial deposits - sand, silt, gravel, and clay - in varying proportions, settled during the Quaternary period. The soil is loose, sandy, and calcareous, with a small clay fraction. In terms of land use, more than 60% of the catchment is cultivable land, with actual cultivation covering about 52%. Forest land constitutes only 12.5% of the catchment. The predominant soil types are alluvial (42%), medium black soil (25.5%), and mixed red and black soil (15%). The study also notes the annual average rainfall varying between 400 mm to 2000 mm, primarily occurring during the monsoon months from June to October.

The study focuses mainly on the main Yamuna river and based on various issues in different river stretches, the following homogeneous regions have been identified for covering different broad objectives:

Homogeneous Region 1: Almost pristine with no major water abstraction & quality issues
From Yamunotri upto Hathnikund Barrage
Homogeneous Region 2: Major water abstraction but slightly polluted
From Hathnikund Barrage upto Wazirabad Barrage
Homogeneous Region 3: Extremely polluted
From Wazirabad Barrage to Okhla Barrage (or upto confluence of Hindon River)
Homogeneous Region 4: negligible water availability and Highly Polluted
From Confluence point of Hindon river upto the confluence of Chambal River
Homogeneous Region 5: Significantly improved water quality
From Confluence point of Chambal River upto Allahabad



Study Teams and Duration:

Overall duration of the project is proposed to be Five Years with individual broad objectives will be of three years duration as detailed below:

S. No.	Objective	Study Team	Study Period
1.	Rainfall-Runoff-Sediment Yield Modelling to Assess Water Availability and Sediment Loads	Shakti Suryavanshi (PI) SK Kumre Pradeep Kumar	04/24-03/27
2.	Environmental Flow Requirements at Critical Stretches of River Yamuna	SK Kumre (PI) P Kumar, Shakti Suryavanshi, Rajesh Singh **Collaborators:** Wildlife Institute of India, Dehradun and Gurukul Kangri University, Haridwar	04/24-03/27
3.	Analysis of Irrigation Water Management Scenarios in Canal Command Areas for Sustaining Aquatic Ecosystem of Yamuna River	Pradeep Kumar (PI) Shakti Suryavanshi SK Kumre	04/24-03/27
4.	Assessment of water and sediment/soil quality including emerging pollutants in Yamuna river and the connected aquifers	Rajesh Singh (PI) MK Sharma VK Tyagi Kalzang Chhoden PK Sahoo SK Kumre	04/24-03/27
5.	Quantification of Point and Non-point Source Pollution Loads in Yamuna River	Pradeep Kumar (PI) Rajesh Singh MK Sharma Kalzang Chhoden SK Kumre	04/25-03/28
6.	Study of Sediment - Water Interactions including Adsorption Characteristics of Bed Sediments in different stretches of the river Yamuna	MK Sharma (PI) Rajesh Singh PK Sahoo Kalzang Chhoden	04/24-03/27
7.	**Study of Surface Water - Ground Water interactions**		
	7a. Surface Water - Ground Water interactions through hydrological monitoring and modelling	Sumant Kumar (PI) Nitesh Patidar	04/24-03/27
	7b. Surface Water - Ground Water interactions through chemical monitoring and modelling	Rajesh Singh (PI) MK Sharma VK Tyagi PK Sahoo Kalzang Chhoden	04/24-03/27
	7c. Surface Water - Ground Water interactions through isotopic monitoring and modelling	HI Division	04/24-03/27
8.	Occurrence, removal and fate of organic and emerging pollutants in STPs in Yamuna River	VK Tyagi (PI) Rajesh Singh Pradeep Kumar PK Sahoo Kalzang Chhoden	04/25-03/28
9.	Detection and Remediation for Water using Nanotechnology-enabled Multifunctional Materials in selected highly polluted zones	PK Sahoo (PI) VK Tyagi Rajesh Singh Kalzang Chhoden	04/25-03/28

10.	Development of Environmental Management Plan for maintaining the river health of Yamuna River	Pradeep Kumar (PI) Rajesh Singh VK Tyagi Sumant Kumar Nitesh Patidar Shakti Suryavanshi PK Sahoo Kalzang Chhoden SK Kumre	04/26-03/29

Cost Estimate:

a. **Total cost of the project** : Rs. 538.7 Lakh
b. **Source of funding** : NIH internal
c. **Sub head-wise abstract of the cost:**

Sr. No.	**Sub-Head**	**1st Year**	**2nd Year**	**3rd Year**	**4th Year**	**5th Year**	**Total**
1	**Manpower**						
1a	Project Scientist (02 Nos. for 5 years) @ Rs. 67000/- + HRA	1752720	1752720	1752720	1752720	1752720	8763600
1b	RA (02 Nos. for 5 years) @ Rs. 58000/- + HRA	1517280	1517280	1517280	1517280	1517280	7586400
1c	Resource Person Jr. - 08 nos for 1st Year, 11 nos for 2nd year, 12 nos for 3rd Year, 4 nos for 4th & 5th year @ Rs.40,000/- p.m.)	3840000	5280000	5760000	1920000	1920000	18720000
2	Travelling expenditure	800000	1500000	1500000	700000	300000	4800000
3	Infrastructure / Equipment / Consumable	500000	1500000	1500000	1000000	100000	4600000
4	Field Surveys	5000000	100000	100000	100000	100000	5400000
5	Misc. Expenditure	800000	1100000	1200000	500000	400000	4000000
	Grand Total	14210000	12750000	13330000	7490000	6090000	**53870000**

GROUND WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. Anupma Sharma	Scientist G & Head
2	Dr. Sumant Kumar	Scientist E
3	Dr. Lagudu Surinaidu	Scientist D
4	Dr. Nitesh Patidar	Scientist C
5	Dr. Ajit Kumar Behera	Scientist C
6	Dr. Satendra Kumar	Scientist B
7	Sh. Pintu Kumar Gupta	Scientist B
8	Sri Ram Chandra	SRA

APPROVED WORK PROGRAM OF GWHD FOR THE YEAR 2023-24

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GWH/22-25	Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin	Sumant Kumar(PI), Surjeet Singh Nitesh Patidar Rajesh Singh Gopal Krishan M.K. Sharma Vinay Tyagi Soban Singh Rawat P.K. Mishra	3 years (04/22 – 03/25) Status: **In-progress**	Internal Study
2. NIH/GWH/22-24	Conjunctive Management of Water Resources in IGNP Command	Nitesh Patidar (PI), M. K. Goel, Anupma Sharma, Surjeet Singh, Gopal Krishan, Sumant Kumar	2 years (04/22 – 03/24) Status: **In-progress**	Internal Study
3. NIH/GWH/22-24	Studying Groundwater Dynamics using Machine Learning and Numerical Modelling	Nidhi Kalyani (PI), Anupma Sharma, Nitesh Patidar, Sumant Kumar	2 years (04/22 – 03/24) Status: **Dropped**	Internal Study
4. NIH/GWH/ 23-24	Development of Archive of Soil Hydraulic Characteristics	Surjeet Singh (PI) Nitesh Patidar, M.K. Goel, Anupma Sharma	1 year (04/23 – 03/24) Status: **In-progress**	Internal Study
5. NIH/GWH/ 23-25	Enhancement and application of NIH_WISDOM	Nitesh Patidar (PI) Deepak Singh Bisht, M.K. Goel, T. Thomas, Sunil Gurrapu, Anupma Sharma, Surjeet Singh	2 years (10/23 – 09/25) Status: **In-progress**	Internal Study
Sponsored Projects				
6. NIH/GWH/CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi	Anupma Sharma (PI) S. K. Jain, A. Sarkar, M. K. Sharma, L. N. Thakural, S. Kumar, P.K. Mishra, V. Singh, N. Patidar, R. Kale *Partners* Haryana Irr. & WR Dept., UPGWD, UYRB, CWC	4 years (04/18-03/24) Status: **In progress**	Special Project under "Centre of Excellence" (NHP)
7. 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	Anupma Sharma (PI), Gopal Krishan, Nitesh Patidar (*Lead*: CAZRI	5 years (03/19 - 07/24) Status: **In**	DST

	Grey Water	Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur)	**progress**	
8. NIH/GWH/NHP(PDS)/2019-2024	Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures	Er. Anjali (PI) Sudhir Kumar J. V. Tyagi, M. K. Sharma,	4years (11/19 - 03/24) Status: **In progress Shifted from HID**	NHP (PDS)
9. NIH/GWH/BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab - Groundwater resilience in Punjab and adaptation to future changes in climate and water resource demands (title modified by funding agency)	Gopal Krishan (PI), S. Singh, C. P. Kumar (retd.), M. S. Rao *BGS, UK:* Dan Lapworth Alan MacDonald Daren Goody	5 years (12/17-11/22) Status: **In progress Shifted to HID**	BGS, UK
10. NIH/GWH/CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Co-coordinator)	3 years (07/20 – 03/24) Status: **In progress Shifted to HID**	Federal Min. of Education and Research, Germany
11. NIH/GWH/DST-SERB/21-24	Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	Gopal Krishan (PI), MS Rao	3 years (04/21 – 03/24) Status: **In progress Shifted to HID**	DST-SERB

PROPOSED WORK PROGRAMME OF GWHD FOR THE YEAR 2024-25

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GWH /22-25	Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin	Sumant Kumar(PI),Surjeet Singh, Nitesh Patidar, Rajesh Singh, Gopal Krishan, M.K. Sharma, Vinay Tyagi, Soban Singh Rawat, P.K. Mishra	3 years (04/22 – 03/25) Status: **In-progress**	Internal Study
2. NIH/GWH /22-24	Conjunctive Management of Water Resources in IGNP Command	Nitesh Patidar (PI), M. K. Goel, Anupma Sharma, Surjeet Singh, Gopal Krishan, Sumant Kumar	2 years (04/22 – 03/24) Status: **In-progress**	Internal Study
3. NIH/GWH / 23-24	Development of Archive of Soil Hydraulic Characteristics	Nitesh Patidar (PI), Surjeet Singh, M.K. Goel, Anupma Sharma	1 year (04/23 – 03/24) Status: **In-progress**	Internal Study
4. NIH/GWH / 23-25	Enhancement and application of NIH_WISDOM	Nitesh Patidar (PI) Deepak Singh Bisht, M.K. Goel, T. Thomas, Sunil Gurrapu, Anupma Sharma, Surjeet Singh	2 years (10/23 – 09/25) Status: **In-progress**	Internal Study
Sponsored Projects				
5. NIH/GWH/ CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi	Anupma Sharma (PI) S. K. Jain, A. Sarkar, M. K. Sharma, L. N. Thakural, S. Kumar, P.K. Mishra, V. Singh, N. Patidar, R. Kale *Partners* Haryana Irr. & WR Dept., UPGWD, UYRB, CWC	4 years (04/18-03/24) Status: **In progress**	Special Project under "Centre of Excellence" (NHP)
6. 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 (PI), Gopal Krishan, Nitesh Patidar (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur)	5 years (03/19 - 07/24) Status: **In progress**	DST
New Sponsored Projects				
7. NIH/GWH/ DST-SERB/23-25	Use of deep learning models to understand the impact of climate and land use changes on future groundwater resources, with a focus on data scarce regions.	L.Surinaidu (PI from NIH)) Lead agency: IIT-Hyderabad Partner: McGill University-Canada	2 years 06/23-07/25 Status: **New Study**	DST-SERB
8. NIH/GWH/ MoES/22-	Carriers of Mass Transport Contamination in Delhi, NCR	L.Surinaidu (PI from NIH) Lead agency: NGRI	2 years 10/22-09/24 Status: **New**	MoES

24			**Study**	
New Internal Studies				
9. NIH/GWH /24-27	Surface water-groundwater interactions through field techniques and hydrological modelling in Yamuna basin	Sumant Kumar (PI), Nitesh Patidar, Lagudu Surinaidu, Pintu Gupta, Ajit Kumar Behera, Anupma Sharma, Shailendra Kumhre, Gopal Krishan,	3 years (04/24 – 03/27) Status: **New Study**	Internal Study
Major Project with Sub-Projects S.N. 10-13	Enhancing the Sustainability of Water Resources Through Integrated Assessment and Management Techniques in the LUNI River Basin – Rajasthan	Anupma Sharma (Project Coordinator) Scientists from GWH Div & NWRC Jodhpur	3 years (04/24 – 03/27) Status: **New Study**	Internal Study
10. NIH/GWH/ 24-26	Estimation of Soil Characteristics and Simulation of Groundwater Recharge in the Luni River Basin (sub-project 1)	Satendra Kumar (PI) Anupma Sharma, L. Surinaidu, Ajit K. Behera, Pintu K. Gupta, Nitesh Patidar	2 years (04/22 – 03/24) Status: **New Study**	Internal Study
11. NIH/GWH /24-27	Hydrogeochemical Evolution and role of Paleochannels on groundwater quality in the Luni Basin (sub-project 2)	Ajit Kumar Behera (PI), L. Surinaidu, Pintu Kumar Gupta, Malkhan Singh Jatav Anupma Sharma, M. K. Sharma, A. H. Laskar, PRL	3 years (04/24 – 03/27) Status: **New Study**	Internal Study
12. NIH/GWH /24-26	Hydrogeological Investigations in the Luni River Basin (sub-project 3)	Pintu Kumar Gupta (PI), L. Surinaidu, Nitesh Patidar, Ajit Kumar Behera, Satendra Kumar, Sudesh Chaudhary Dilip Barman, Akshay Vyankat Dahiwale	2 years (04/24 – 03/26) Status: **New Study**	Internal Study
13. NIH/GWH /24-27	Characterisation and Modeling of Multi Aquifer System of LUNI River Basin in Rajasthan Under Climate and Anthropogenic Influences (sub-project 4)	L. Surinaidu (PI), Anupma Sharma, Ajit Kumar Behera, Sumant Kumar, Sudesh Chaudhary	3 years (04/24 – 03/27) Status: **New Study**	Internal Study

Trainings organized:

GWH Division organized **01** training course (two-week ToT on DSS(PM)).

Outreach activities since previous WG meeting:

1. Scientists published/accepted: **8 papers in int./ national journals**; **7 papers in int./ national conferences**; **03 book chapters**
2. Scientists guided/guiding thesis: **06 Ph. D**; **04 M. Tech/ M.Sc.**
3. Patent: **1 patent granted**
4. Consultancy studies completed/ ongoing: **01**
5. Scientists developed 2 Modelling Software: **PRAJAL**; **NIH-WISDOM**

1 PROJECT REFERENCE CODE: NIH/GWH/22-25

Title of the study: Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin

Study Team **:** Sumant Kumar, Sc-E, & PI, Surjeet Singh, Sc.-G, Nitesh Patidar, Sc.-C, Rajesh Singh, Sc.-E, Gopal Krishan, Sc.-E, M.K. Sharma, Sc. F, Vinay Tyagi, Sc. D, Soban Singh Rawat, Sc.-F, P.K. Mishra, Sc.-D

Collaborator	:	CGWB, Dehradun and NIT, Patna
Type of study	:	Internal
Date of start (DOS)	:	April, 2022
Scheduled date of completion:		March, 2025 (3 Years)
Location	:	Ganga basin (From Gangotri to Patna)

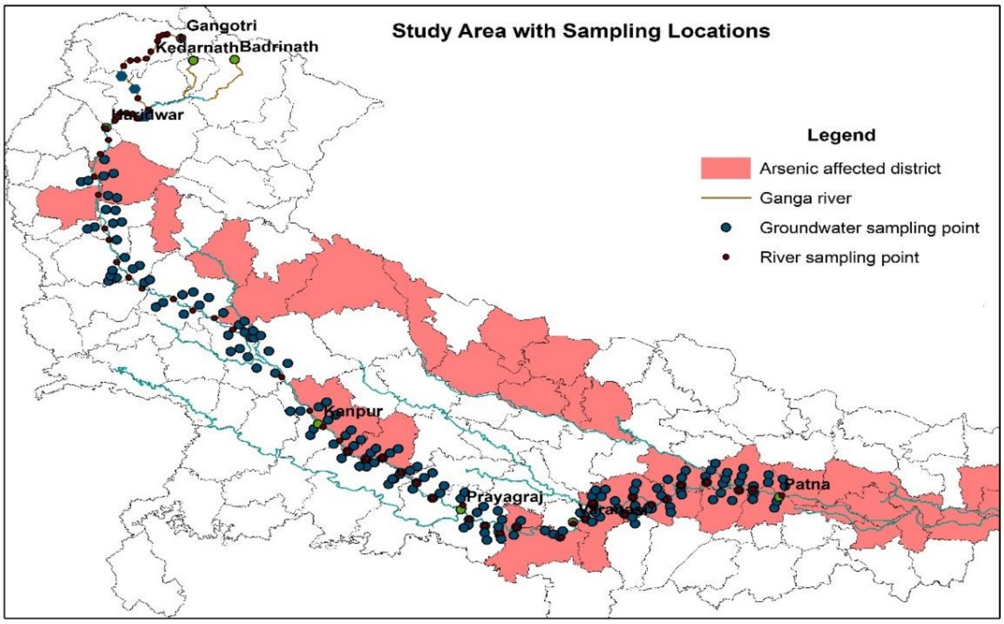


Figure: Study area map with groundwater and river water sampling location

Objectives:

- Mineralogical characteristic of sediments and water chemistry in the Indian Himalayan region to detect genesis of arsenic.
- Demarcating safe aquifer for drinking water supply in arsenic affected areas.
- Performance evaluation of existing treatment units and their comparison in terms of cost, efficiency and ease of operation etc in the central Ganga basin.
- Developing a new treatment technique with high removal efficiency in optimized cost.

Statement of the problem:

Chronic exposure to groundwater having an arsenic concentration of more than 10 μg/L leads to numerous adverse health impacts like lower intelligence quotients, type 2 diabetes, skin lesions, melanosis, keratosis, and cancer etc. Arsenic (As) contamination of water is producing the greatest impact on livelihoods in terms of public health and thus arsenic calamity in the Ganga river basin put millions of population in danger. Arsenic is a natural constituent in bedrock and soil. It usually occurs at low concentrations (average 1–2 mg/kg) in the Earth's crust, but may be concentrated in certain rock types and especially in gold and sulphide-bearing ore deposits and occurrences. Pyrite [FeS2; or arsenian pyrite Fe(AsS)2] and arsenopyrite [FeAsS] are typical sulphide minerals containing As. Weathering processes of rocks and minerals appears to be a major source of arsenic found in soils.

Because it accumulates due to weathering and translocation in colloid fractions, the arsenic concentration is usually higher in soils than in parent rocks. Under typical soil forming conditions, the nature of arsenic in soil is controlled by the lithology of parent rock materials, volcanic activity, bioactivity, weathering history, transport, sorption, and precipitation. The river Ganga and its major tributaries originate from the Himalaya and carry lots of sediment and these sediments determine the chemistry of water. In the mid Holocene period, the river Ganga likely to transport metals from Himalaya to the plains by erosion and sedimentation. The rivers originating from the Siwalik Hills are reported to release more arsenic and heavy metals from their sediments in comparison to those major rivers originating from the Higher Himalaya. In order to study the causes of arsenic occurrence in Ganga basin and its mobilization from solid to water phase, it is planned to carry out mineralogical, geochemical and mobilization study. The significance of the study is to help in demarcating safe aquifer, improved monitoring and mitigation measures at regional level.

With the grave problems of arsenic in India, Inter-Ministerial Group (IMG) on Arsenic Mitigation was constituted on the directions of Cabinet Secretariat by erstwhile Ministry of water Resources, River Development & Ganga Rejuvenation (MoWR, RD & GR) vide order No. 11014/1/2014-GW Desk (Part-V) dated 22 Dec. 2014 under the Chairmanship of Mission Director (MD), National Water Mission (NWM). The IMG desired that National Institute of Hydrology (NIH), Roorkee should take lead role on R & D activities related to "Arsenic Mitigation" as per the areas suggested by the 'Core Committee' on "Mitigation & Remedy of Arsenic Menace in India". The DoWR, RD & GR, Govt. of India (letter no. 50013/177/2020-E.II dated 20/07/2020) advised NIH to seek funding under the subcomponent "Sponsoring and Co-coordinating research in water sector" and accordingly may submit a project proposal to INCGW. A project proposal with budgetary requirement of 1259.50 Lakhs was submitted to INCGW with detailed work component and budget of multi-institutions. An online meeting of INCGW was scheduled in Nov. 2022 for evaluation of the NIH project proposal on Arsenic and other projects received from the Universities/Institutions. The Chairman of the INCGW committee informed that a committee would be further constituted to evaluate the work component of the project. The NIH and other project partners are still waiting for the project approval and release of funds to start the mega project The GWHD started working on project components pertaining to NIH under internal funding till receive the funds from INCGW considering national importance of project.

Methodology:
The study will cover the detailed hydrogeology and geochemistry of the As-contaminated aquifer of the Ganga basin. A grid-wise sampling is being done in upper and middle Ganga basin to study the spatio-temporal variation of water quality parameters including arsenic. The river bed sediment samples at different location are also collected from upper and middle Ganga river for sediment characterization using grain size characterization and elemental characterization. The mineralogical study is also being carried out to help in identifying the minerals of arsenic present in the Ganga basin.

Integrated hydrological survey of As concentrations is being carried out in the Ganga basin by using field test kits and collecting preserved samples for further analyses by more precise analytical instruments in laboratory. Groundwater and surface water samples are collected during multiple field campaigns from both deep and shallow aquifers. In addition to that, sediment samples (river bed material) are brought out to lab for further analyses. The locations of the wells are marked using a hand-held global positioning system (GPS). In-situ parameters and indicators of the oxidation state of ground water are measured in the field. Field measurements include temperature, electrical conductivity (EC), pH, oxidation-reduction potential (ORP) and dissolved O_2. The measured stable value of these water quality parameters will be representative of in-situ conditions. Samples are collected for all major anions, cations and trace elements for further laboratory level analysis. The isotopic samples are also being collected for understanding recharge source and SW-GW interaction. Different analytical instruments are being used for analyses of ions and metals. Performance of existing treatment units area are being evaluated, though there are few units are available in the field. It is also planned to develop cost effective treatment units in Lab and it may be upscaled at later stage.

Objectives vis-à-vis Achievements:

Objectives	Achievements
Mineralogical characteristic of sediments and water chemistry in the Indian Himalayan region to detect genesis of arsenic.	• Four phases of sampling of sediment and water completed from Gangotri to Patna along Ganga River. • Water quality (major ions, trace metals and isotopes) analysis and interpretation have been completed. • Sediment Characterization: Grain Size analysis completed and further mineral characterization is underway. • Sampling of river bed Sediments from Varanasi to Patna will be completed as soon as possible.
Demarcating safe aquifer for drinking water supply in arsenic affected areas.	• Arsenic affected areas along the Ganga River have been identified by extensive field sampling and analysis. • Vertical distribution of Arsenic contamination in groundwater is also investigated and identified in the heavily affected areas.
Performance evaluation of existing treatment units and their comparison in terms of cost, efficiency and ease of operation etc in the central Ganga basin.	• Inlet and outlet samples from the existing treatment units have been collected, analyzed and evaluated, though very few units are available in the field.
Developing a new treatment technique with high removal efficiency in optimized cost.	• After review, it is proposed that a biochar based adsorption system will be developed. • Review and selection of raw material for biochar development is under process.

Analysis of Results:

The pH of the water samples of study area varies from 6.8 to 9.3 (mean 8.1) for Ganga river. It can be observed that the pH values are increasing as the sampling location descends from the Gangotri up to Devprayag, after that it remains constant around 8 and further down, the pH rises to 9 around Prayagraj and then again comes down to 7-8 after Varanasi. The EC of the water samples varies from 107 to 604 µs/cm (mean: 218 µs/cm) for Ganga river. It has been observed that the EC values were following a declining trend in Bhagirathi river from Gangotri to Devprayag, thereafter the EC values follows an increasing trend up to Haridwar and after that it remains in the range of 150 -200 µs/cm up to Kanpur. After Kanpur, EC spikes up very sharply and reaches above 250 µs/cm. The influence of river Yamuna can be observed as the EC values spikes up to 3 folds around Prayagraj and then further gets down to the range of 200-300 µs/cm. The DO values in the River varies between 5.4 to 12.4 mg/L with an average value of 8.2 mg/L. The ORP of the water samples in the study area varies between 2.5 to 183 mv for river water. The ORP values are observed to be increasing from Gangotri to Rishikesh but after that the ORP kept getting low up to Patna. The decreasing value signifies the increasing settlements and dumping of wastes in the river stream which consumes the oxidizing agents. The only reduced condition was observed in river was in Kanpur (-73 mv). The alkalinity of the river water samples were found to be increasing as we go down the river. The river water samples were analyzed for trace metals (As, Fe, Mn, Zn, Cu, Cr, Cd, Ni, Pb) using inductively Coupled Plasma-Mass Spectrometer. The concentration of Al were found to be higher than permissible limit in bulk of the river water samples. The Chromium concentration were found to be more than permissible limit only at Kanpur. In majority of the river samples As, Cr, Pb, Cd and Cu were below the permissible level except in few instances.

The pH of the groundwater samples of study area varies from 6.4 to 7.9 (mean 7.2). Overall the pH values the samples are mildly alkaline and the variations in pH are not systematic. The EC of the water samples varies from 160 to 2910 µs/cm (mean: 704 µs/cm) for groundwater along Ganga River. It has been observed that the EC values were following an increasing trend. The ORP of the water samples in the study area varies between -171 to 162 mv for river water. The ORP values are observed to be decreasing sharply as the sampling points go down from Haridwar to Patna. In majority of the groundwater samples As, Cr, Pb, Cd, Al, Ni, Cu and Mn were below the permissible level except in few instances however Fe observed to be higher in most of the samples. Occurrence of arsenic in groundwater samples are rare in upper Ganga region but the frequency of getting higher arsenic is more in groundwater samples after Varanasi. The As concentration in the water samples in the whole study area varies between ND to 393.19 µg/L with and average value of 12 µg/L. In the lower stretch of sampling points along the Ganga River the arsenic occurrence was higher and the average value increases to 25.77 µg/L.

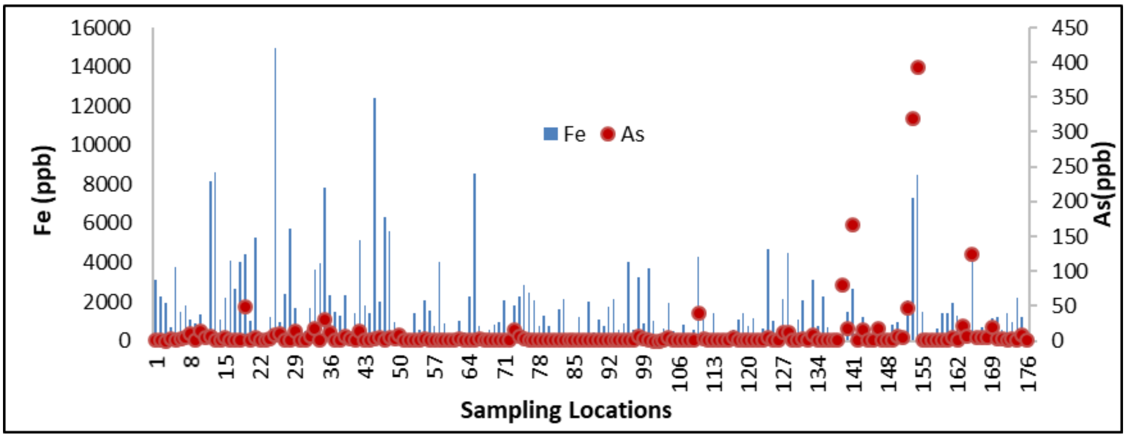


Figure: Fe and As concentration in groundwater samples (1 to 176 represents the sampling locations from Gangotri to Patna, along the Ganga River)

The availability of running arsenic treatment units are very low which is might be due to the recent implementation of 'Har Ghar Jal Scheme' under the Jal Jeevan Mission by Department of Drinking water and Sanitation, which ensured the safe and adequate drinking water supply. Two units were found running in Ara and Chapra district of Bihar, in both the system the feed water was being pumped up from the depths of more than 200 feet still were contaminated with arsenic. Both the filters were able to bring down the arsenic concentration below the permissible limit of drinking water standards. Further, sediment grain size analysis reveals that the sand and silt are the main constituents of the river bed samples. Characterization of sediment by the means of elemental composition XRD/XRF is under process.

List of Deliverables:

- Reports
- Research papers

Study Benefits /Impact:

A project report will be prepared highlighting the genesis of arsenic and its mobilization from solid to liquid phase. The research output and development of new technique for arsenic removal may help stakeholders for deciding the water supply management strategies in arsenic affected areas. The findings of the study will be presented in conferences/workshops and published in journals. Stakeholder (Public Health Engineering Department, Jal Nigam, Water Resources Department, Department of Drinking Water and Sanitation, Ministry of Jal Shakti etc.) engagement would be done for improving their knowledge and application of various mitigation options.

2 PROJECT REFERENCE CODE: NIH/GWH/22-24

Title of the Project: *Conjunctive Management of Water Resources in IGNP Command*

Study team:	PI	Dr. Nitesh Patidar, Scientist-C
	Co-PIs	Dr. MK Goel, Scientist-G
		Dr. Anupma Sharma, Scientist-G
		Dr. Gopal Krishan, Scientist-E
		Dr. Surjeet Singh, Scientist – G
		Dr. Sumant Kumar, Scientist-E

Type of study: Internal (Near completion)

Duration: Two years (April 2022 – March 2024)

Objectives and achievements

S. No.	Study objectives	Achievements
1	Analysis of present groundwater scenario in enroute command of IGNP	*Completed* The data of groundwater levels acquired from CGWB are analyzed. Trend analysis was performed.
2	Mapping of water-logged area in IGNP command using remote sensing	*Completed* The water-logged areas are identified using remote sensing data. A Google Earth Engine (GEE) application was developed to derive water logged area.
3	Estimation of GW recharge from rainfall, canal and irrigation under present and future climatic scenarios	*In-progress* The model setup for integrated modelling using NIH-WISDOM is under progress.
4	Conjunctive management of water resources in enroute command area of IGNP canal	*In-progress*

Background

Conjunctive management of surface water and groundwater for irrigation is recognized as an effective solution to water logging and root zone salinity. The conjunctive utilization of water resources also ensures consistent water availability for irrigation and support sustainable water management. However, despite these advantages the conjunctive management of water resources is scant in canal commands. The Indira Gandhi Nahar Pariyojana (IGNP) provides irrigation to an area of 1.963 million hectare (CCA) in Rajasthan. The project also provides domestic water supply to most of thar dessert of Rajasthan and is therefore the most important water source in the arid Rajasthan. Since the inception of the project, there has been various issues related to rising water table and increasing soil salinity. Several studies were conducted to assess the impact of canal on groundwater levels and water logging. It was observed that before the canal construction (before 1952) the depth to groundwater used to vary between 40 and 50 m. After the inception of irrigation through stage-I of IGNP groundwater level started rising. In 1972-82 the rise in groundwater level was observed to be 1.17 m/year. Later in 1995, an area of around 10% of CCA of stage-I was waterlogged and around 25% area was under critical condition (depth to GW in range 1-6 m). Such rise in groundwater level transports the salts from deeper soil layers to surface and impact the agricultural productivity in the area.

The present scenario of groundwater and mapping of water-logged area is essential in the IGNP command for effective management of land and water resources. Such analysis would help in quantifying the current potential of groundwater in conjunction with canal water to maximize the irrigation potential in command and to contain salt mobilization in root zone.

Study area

The IGNP project was initiated in the late 50's and is situated in the districts of Sriganganagar, Hanumangarh, Bikaner, Churu, Jaiselmer, Barmer, and Jodhpur. It has a CCA of 1.963 million hectares. The project was completed in two stage, Stage-I having a 204 km long feeder which originates from Harike Barrage, Punjab, to reach Masitawali, Rajsthan, and a 189 km long main canal from Masitawali to Chattergarh in Bikaner district. Stage-II is having a 256 km long main canal from Chattergarh to Mohangarh in Jaiselmer.

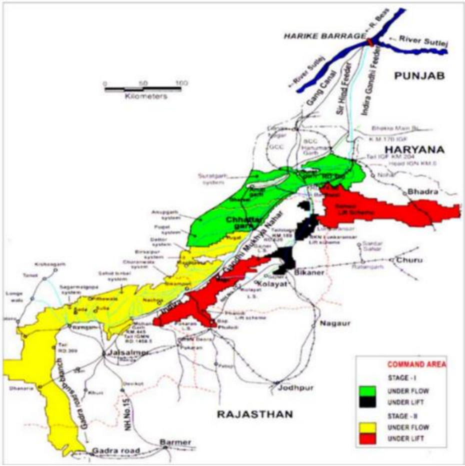


Image source: Gupta et al. (2002)

Figure 1. Indira Gandhi Nahar Pariyojna (IGNP) command area under stage-I and stage-II

Present groundwater scenario

The status of groundwater in the IGNP command was analyzed utilizing groundwater observations of CGWB. The analysis was performed utilizing seasonal groundwater data from 1994 to 2020. Spatial maps of depth to groundwater at seasonal and annual scales were generated. It is seen that the groundwater was deepest during 1994 which ranges between 20 to 50 m below ground level (bgl). During the years 2005-10, the groundwater was observed to be the shallowest which varies between 2 to 50 m bgl. During the recent years, groundwater declined again which varies in the range 10 to 35 m bgl.

The Mann-Kendall trend analysis was performed on the seasonal groundwater level data. It is observed that most of the wells show rising groundwater level (marked with blue color in the Figure 2 indicating decreasing depth to groundwater). Trend analysis revealed that 58% of the wells show rising groundwater, while the 16% wells show falling groundwater. Around 26% wells have no significant trend.

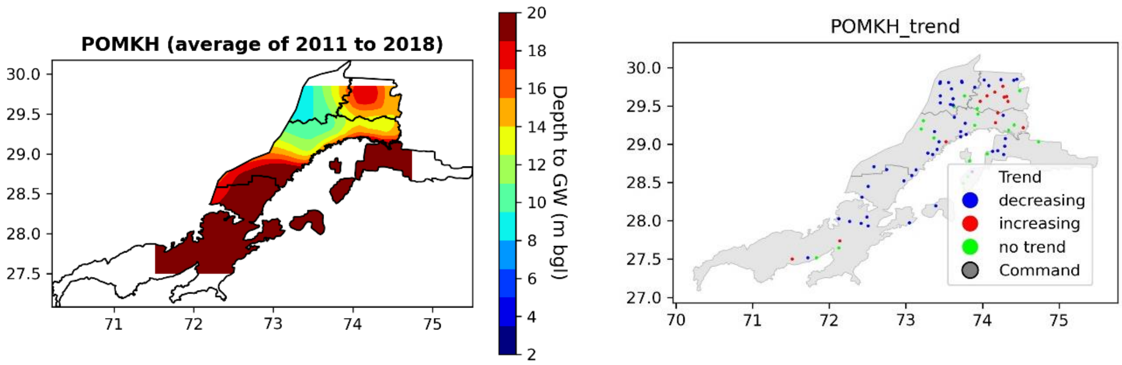


Figure 2. Depth to groundwater during post-monsoon (average of 2011-18) and trends in depth to groundwater

Water logging: Past trend and current situation

The water logged area was identified using water occurrence which was estimated using the time-series data of Landsat satellite in Google Earth Engine. The water occurrence – percentage of time a pixel is identified as water – is estimated for every year from 1985-2022. The JRS's (Joint Research Centre) water occurrence data was also utilized to identify the critical areas for water logging. The JRS data shows percentage of occurrence of water during the past ~35 years.

The estimated area water-logged during the years from 1985-2022 is shown in the Figure 3. Water logging seems to be started during 1988-89 which reached its peak during 1999-2000. During the recent year, the water logging has declined considerably.

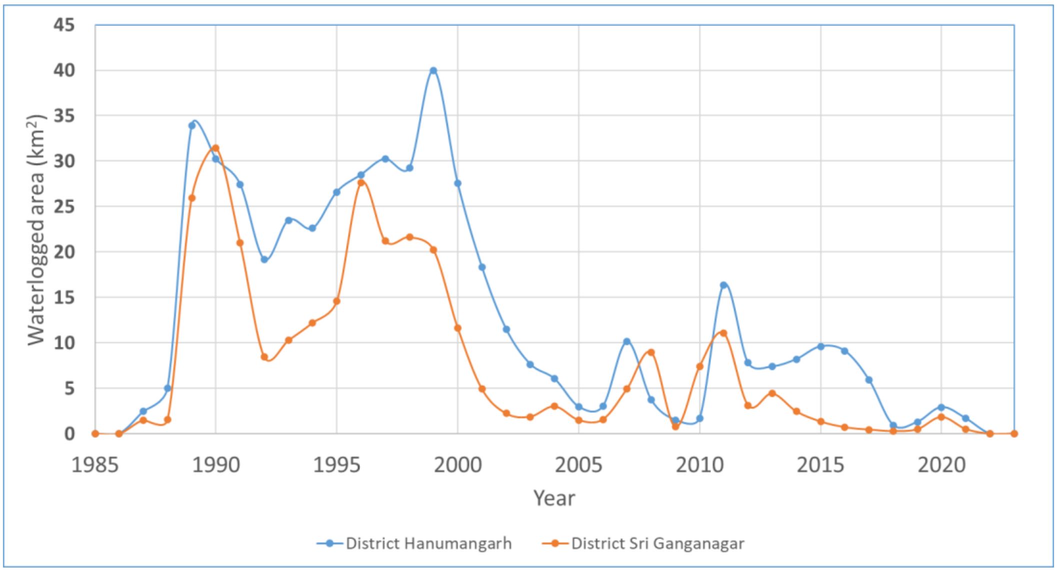


Figure 3. Time-series of water-logged area in the IGNP command within districts Hanumangarh and Sriganganagar

GEE app for monitoring water-logged area

To monitor real-time area under water logging, a GEE application is developed which can be accessed through the web. The application estimates water occurrence for the specified period and also displays depth to groundwater in the IGNP command (Figure 4).

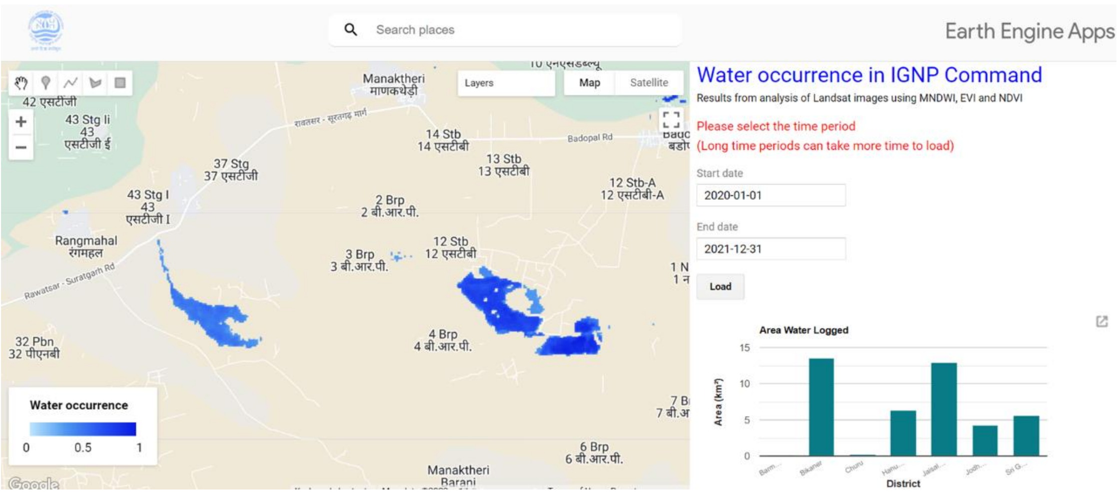


Figure 4. GEE application for monitoring area water-logged

ERT for identifying fresh-saline groundwater zones

The groundwater in the IGNP command is found to be saline. The EC is observed to be in the range from 0.3 to 6.6 mS/cm during the field visits. To identify the fresh groundwater zone in the area, Electrical Resistivity Tomography (ERT), was employed. ERT was conducted at nine different sites in the critical areas, mainly in stage-I of IGNP (Figure 4).

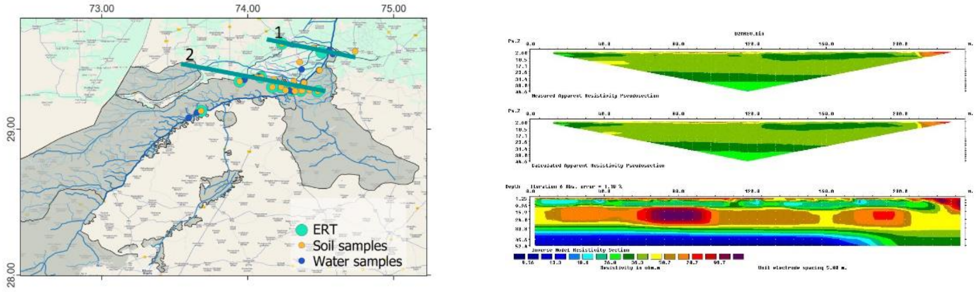


Figure 4. ERT locations and resistivity near Rawatsar.

GW Quality analysis

The water samples were collected from groundwater and canal from the stage-I of IGNP. The cation-anion analysis and trace metal analysis were performed. The trace metal, such as Zn, Al and Fe were found in high concentration acceding the permissible limits at many places.

Integrated modelling

The integrated modelling is performed to estimate groundwater recharge resulted from rainfall, canal percolation and irrigation. In order to estimate all these recharge components a comprehensive model utilizing NIH-WISDOM, system model and demand estimation routines, is developed. The crop acreage is estimated using a composite kharif-rabi crop map developed using the satellite data from the years 2016 to 2022. The district crop proportions were then utilized to assign the crops in each season. The irrigation demand is estimated using the crop coefficient-based approach under the framework of Soil Water Balance Module of WISDOM which also performs soil moisture accounting for the estimation of actual evapotranspiration. The supply to each branch canal is estimated using the system model which estimates canal losses in each segment and estimate the supply based on the available water at each node. All these inputs were used in the WISDOM for groundwater recharge and flow modelling (Figure 5 and Figure 6).

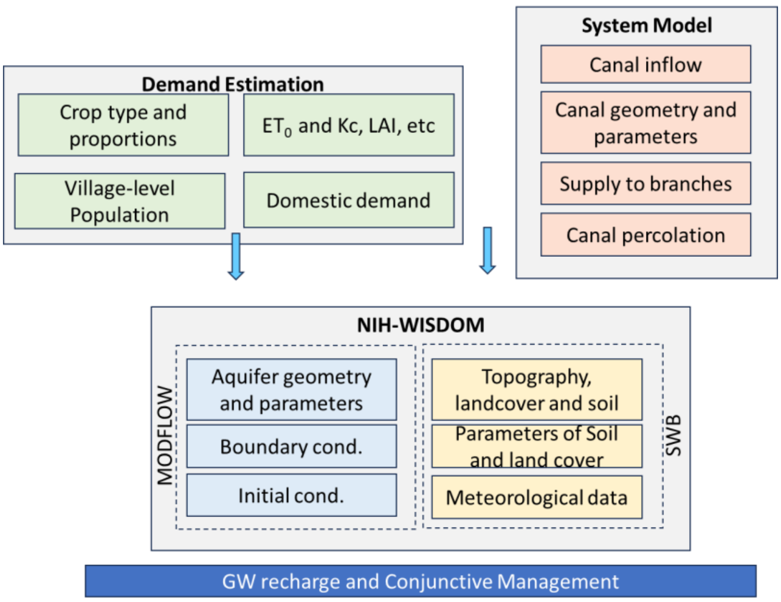


Figure 5. Schematic flowchart of the overall methodology for integrated modelling and conjunctive management of water resources

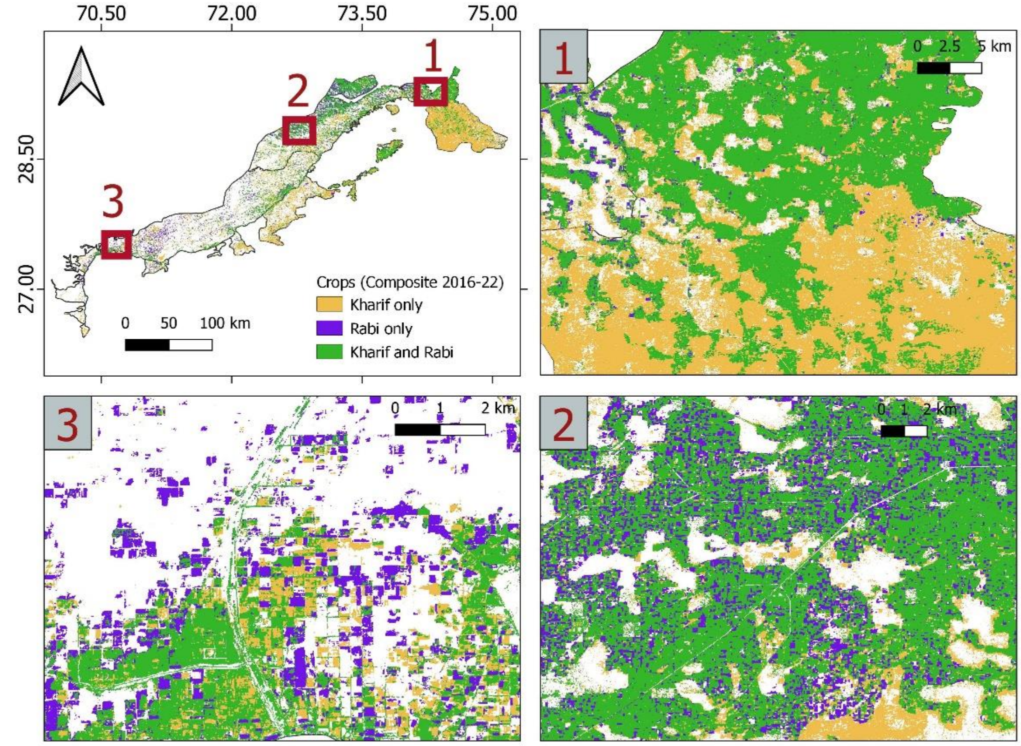


Figure 6. Crop coverage during kharif and Rabi seasons in the IGNP

3 PROJECT REFERENCE CODE: NIH/GWH/23-24

Title of the Project: *Development of Archive of Soil Hydraulic Characteristics*

Study team: PI Dr. Nitesh Patidar, Scientist-C
Co-PIs Dr. Surjeet Singh, Scientist-G
Dr. M.K. Goel, Scientist-G
Dr. Anupma Sharma, Scientist-G

Type of study: Internal (***Ongoing***)
Duration: One year (April 2023 – March 2024)

S. No.	Study objectives	Achievements
1	Development of archive of soil hydraulic characteristics. The results of soil analyses performed during the past years (2011-2022) will be digitized in a standardized format to append in the archive.	*Completed* The data has been digitized and standardized for the archive.
2	Development of an automated system to store the results of soil hydraulic analysis to be performed in future in the archive and publish them on the portal.	*In-progress* A framework has been developed for the automated system in Django. Dashboards for OC, Head, Technicians, etc. have been developed.
3	Development of a web-based GIS-dashboard to publish the soil hydraulic characteristics	*In-progress* Data with latitude-longitude has been standardized. The GIS dashboard will be developed after the development of automated system.

Background

Soil Hydraulic Properties, such as soil texture, hydraulic conductivity and soil moisture retention curve etc. are important inputs to various hydrologic analysis and modelling. Soil Water Laboratory of NIH has been conducting such investigations in various parts of India under various R&D studies funded by NIH and external agencies. Scientist of NIH and staff of Soil Water Lab make considerable efforts to collect soil samples from the field and conduct various investigations in the lab to derive soil hydraulic properties. Numerus soil samples have been tested since 2011 which provide abundant data for various hydrologic analysis. The analysis includes soil texture identification with measurement of sand, clay and silt fractions, analysis on pressure plate apparatus to derive soil moisture at different suction pressures for soil moisture characteristic curve, analysis of soil organic contents, estimation of soil hydraulic conductivity, etc. Such data are although very useful for hydrologic modelling, these are rarely available. It is envisaged that such soil test results conducted in past historical period (with a buffer gap of 4 years for reporting/publication by the project team), if published through a GIS-portal on NIH website, could help researchers and planners in their analysis towards better water management. In this context, it is planned to develop an Archive of Soil Hydraulic Characteristics to store the soil-test results in digital format and disseminate them through a GIS portal.

Digitization and standardization of past data

The soil test results in Soil Water Lab used to be stored in the form of printed/hand written sheets. These data are converted to digital format in order to process, store in the archive and publish on the portal. A standardized format for each soil hydraulic characteristic is decided and the same is followed while converting the data from hard copies to digital sheets. The data is stored along with latitude-longitude details in excel format which will be appended to SQL database for the archive and GIS dashboard. The locations of digitized data are shown in the Figure 1.

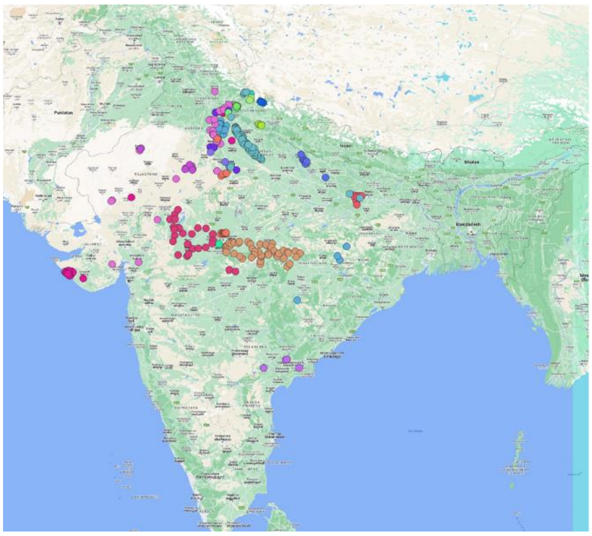


Figure 1. *Location of digitized data for soil hydraulic archive*

Development of automated system

An automated system is being developed for processing and storing the results of soil analysis to be performed in the future. This will enable automated data insertion to the archive and allow automated publishing after the analysis completes the assigned lock-in period (say four years). A framework has been developed in Python-Django for automated system (Figure 2).

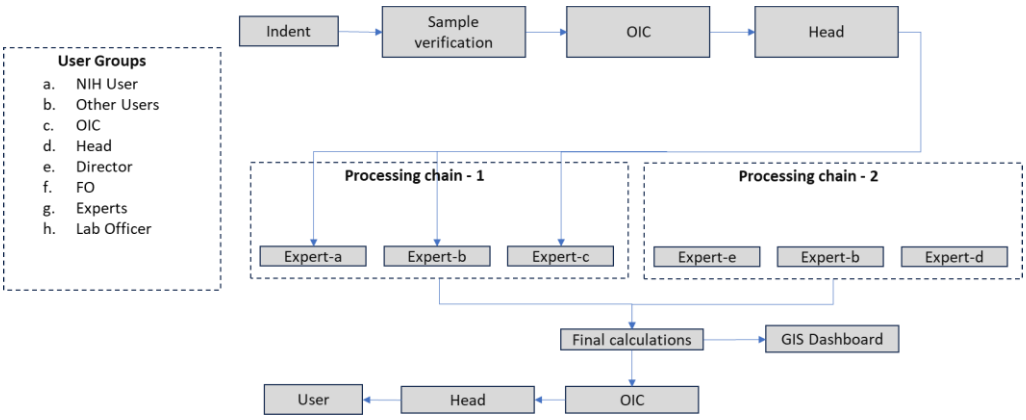


Figure 2. Schematic of the workflow of the automated system

Development of dashboards

To operate and monitor the soil testing in the laboratory, various user dashboards are being developed (Figure 3). Each user will have a dashboard to monitor the progress of the assigned jobs and to submit/download the test results. Dashboard for OIC, Head and Technicians have been developed. The development of automated calculations for the soil hydraulic properties is under progress.

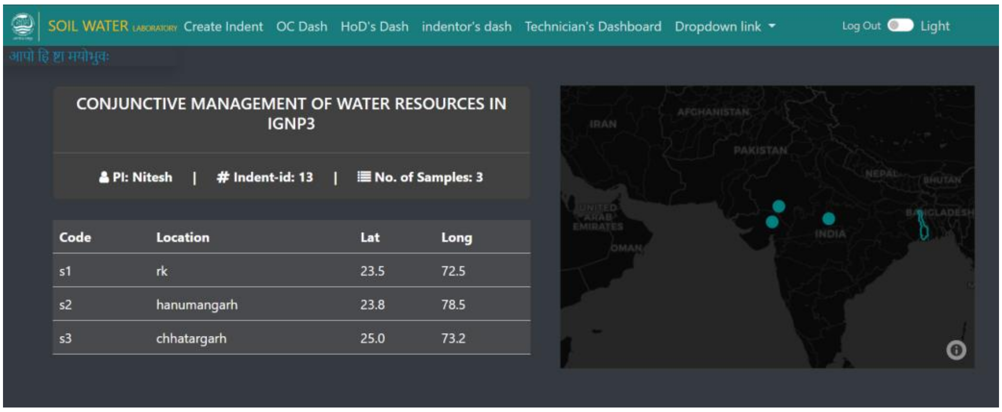


Figure 3. Oc's dashboard to monitor sample details

Timeline

Work element	Mar-Apr 2024	May-Jun 2024	Jul-Aug 2024
Development of automated system			
Development of GIS-dashboard			
Project report			

4 PROJECT REFERENCE CODE: NIH/GWH/23-25

Title of the Project: Enhancement and *application of NIH_WISDOM*

Study team:	PI	Dr. Nitesh Patidar, Scientist-C
	Co-PIs	
		Dr. Deepak Singh Bisht, Scientist-C Dr. M.K. Goel, Scientist-G Dr. T. Thomas, Scientist-F Dr. Sunil Gurrapu, Scientist-D Dr. Anupma Sharma, Scientist-G Dr. Surjeet Singh, Scientist-G

Type of study: Internal (***Ongoing***)

Duration: two years (Oct 2023 – Sep 2025)

S. No.	Study objectives	Achievements
1	Integration of surface hydrologic model in NIH_WISDOM	*In-progress* Scripts for preparation of inputs for VIC model is under process.
2	Development of tools for hydrologic analysis such as, map creator, trend analysis, etc.	*In-progress* Development of utility modules is under progress. A python module for groundwater trend analysis and calculation of domestic population have been developed.
3	Testing of developed models by comparing simulated groundwater recharge with CGWB's assessments in an alluvium aquifer.	*Yet to started*
4	Application of NIH_WISDOM in a hard-rock area by developing equivalent porous media model.	*Yet to started*

Background

The excessive groundwater withdrawal led by growing water demands has resulted in rapid and widespread groundwater declines in many parts of India. To manage water resources in a sustainable manner, comprehensive understanding of groundwater system is essential. Of particular importance are the understanding of recharge processes, quantification of recharge from various sources, such as rainfall and surface water bodies, assessment of the impacts of groundwater withdrawal, and understanding the exchange of fluxes between surface and subsurface hydrological systems.

Web-based Integrated catchment modelling System for Decision Making (WISDOM) is developed recently at NIH. For integrated hydrologic modelling a model, named "GEE-MODFLOW" is developed as a part of WISDOM for groundwater recharge estimation. Estimation of recharge requires simulation of both the surface and subsurface hydrological processes. The water that reaches to groundwater table, so called recharge, is an end result of various processes happening at surface/subsurface which are driven by various influxes, such as infiltration and irrigation, and outfluxes, such as root water uptake and soil evaporation. Therefore, in order to mimic all such processes, an integrated model is needed. The integrated GEE-MODFLOW model consists of various modules which simulate surface and sub-surface processes in unsaturated and saturated zones. The model has three simulation modules, namely Root Zone Flow (RZF), Unsaturated Zone Flow (UZF), and Groundwater Flow (GWF). During the development, the GEE-MODFLOW was tested in the Hindon river basin for groundwater recharge estimation. However, to ensure its applicability in other areas, a detailed testing and validation is required. Therefore, it is planned to test the GEE-MODFLOW model in other basins.

The current version of WISDOM has mainly two models, the RZF (developed at NIH) and MODFLOW (developed by USGS) which was developed to estimate groundwater recharge, although it estimates all other hydrological components, such as runoff, ET, soil moisture and streamflow. WISDOM have several advantages, such as easy-to-use and free access through web-browser. To extent its capability to model surface hydrology using state-of-the-art models, such Variable Infiltration Capacity (VIC) model, integration of a surface hydrologic model with MODFLOW is proposed. Further, inclusion of tools, like map creator, trend analysis, etc., would further enhance the utility of NIH_WISDOM.

Study area

Two basins/inter-basins will be identified for testing the GEE-MODFLOW model. An alluvium aquifer will be identified based on data availability, possibly in the Gangatic plain. Similarly, one basin/sub-basin will be identified in a hard-rock region where both the groundwater and streamflow data are available to test the model.

Methodology

The VIC model will be integrated with the MODFLOW model for integrated modelling. An interface for the integrated VIC-MODFLOW model will be developed and included in the NIH_WISDOM. The tools, such as map creator and trend analysis, will also be integrated in WISDOM using Python programs.

The NIH_WISDOM will be applied to an alluvium and a hard-rock area for estimating various hydrologic components, such as recharge, runoff, ET, streamflow, etc. In the hard-rock area, an equivalent porous media model will be developed by calibrating the GEE-MODFLOW/VIC-MODFLOW with the observed groundwater head. The simulated groundwater head, groundwater recharge and streamflow will be compared with observed data as procured by CGWB and CWC.

Action plan and timeline (quarter-wise from Mar 2024 to Sep 2025)

Work element	**Feb-May 2024**	**Jun-Sep 2024**	**Oct 2024-Jan 2025**	**Feb-May 2025**	**Jun-Sep 2025**
Development of VIC-MODFLOW	■	■			
Development of tools, such as map creator and trend analysis		■	■		
Application of WISDOM in alluvium aquifer			■	■	
Application of WISDOM in hard-rock aquifer				■	■
Project report and research paper					■

5 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: Six years
Location Map:

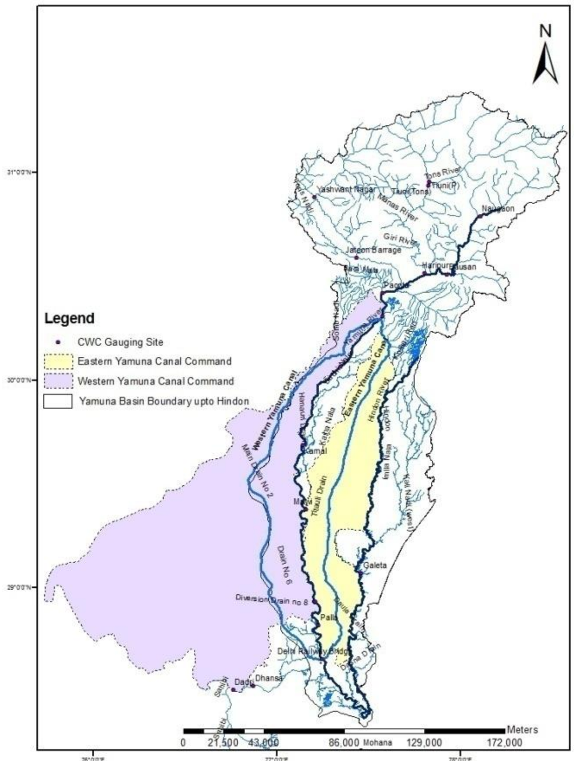


Fig. 1 Study area showing the Upper Yamuna Basin and the command areas of EYC and WYC

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
Application and performance evaluation of selected hydrological models for the simulation of the surface water, groundwater, and water quality	Application of hydrological models completed for SWAT, HEC-RAS, VIC, QUAL2K. Modflow application ongoing. Includes data collection from various agencies, field visits, data processing and analysis. In addition, equipment purchased under project.
Quantification of the contribution of snow and glacier melt to surface water resources through snowmelt runoff modelling for the Tons river	Snowmelt runoff modeling using SWAT for Himalayan portion completed.
Assessment of changes in baseflow contribution to river Yamuna	Assessment of changes in baseflow contribution to river Yamuna completed.
Assessment of present and future water availability under alternate scenarios of climate change	Extracted data for study area, data processing, prepared maps for climate change indicators using CMIP5, CMIP6.
Integrated water allocation planning based on present and future scenario of water availability for (i) Eastern Yamuna Canal Command, (ii) Western Yamuna Canal Command	In progress using Modflow for Yamuna-Hindon Interbasin. Groundwater related data collected for Eastern Yamuna Canal Command. Completed application of WA+ tool using satellite measurements for the study area.
Formulation of adaptation measures in the context of climate change	Ongoing
Flood frequency analysis and flood plain mapping of river Yamuna	River cross-section survey completed. Flood frequency analyses completed.
Assessment of anthropogenic activities on water quality	Field visits undertaken and data collected from central/ state agencies. Assessment of surface water quality of Yamuna river completed. Groundwater samples collected from different locations and analyzed.
Numerical modelling of groundwater recharge dynamics and impact of climate variability on renewable gw resources	Modeling using GIS based WetSpass distributed model. Field and lab experiments for soil parameters for selected sites completed.
Roll out of technical know-how through training workshops for partner organizations	One online training course organized for 24 officers of UP Ground Water Department.

Deliverables:

1) Application of various models pertaining to surface water hydrology, groundwater hydrology, basin planning 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) Evaluation of impact of climate variability on renewable groundwater resources;
4) Training Workshops for State Department officials of UP and Haryana.

5 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: 02/2019 to 07/2024
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)
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
Enhancing water productivity at farming system as well as its components level	Field experiments undertaken with CAZRI to study the impacts of different irrigation schedules on the water balance components. Numerical modeling to study various irrigation management scenarios. Database buildup for WA+ tool to process spatial information on water depletion and net withdrawal using satellite measurements in respect of study area. Equipment purchase completed.
Analyzing future demand and supply of water at regional and sub-regional level	To be taken up with project partners
To develop improved methods for reusing industrial effluents in agriculture	Work by project partners
Capacity building of stakeholders in enhancing water productivity and developing policy guidelines	Work by project partners

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.

6 PROJECT REFERENCE CODE: NIH/GWH/NHP(PDS)/2019-2024

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

2. **Study Group:**

PI/Co-PI: Er. Anjali, Scientist C, GWHD; Dr. Sudhir Kumar, Scientist G; Dr. J. V. Tyagi, Scientist G; Dr. M. K. Sharma, Scientist F, EHD
Scientific/ Project Staff: Mrs. Babita Sharma, RA, EHD; Ms. Beena Prasad, RA, EHD; Mr. Chandra Prakash, PA, GWHD; Ms. Shally Shaini, PA, GWHD
Collaborating Agency: Dr. G.Vijay Kumar, Sr. Hydrologist, 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 March, 2024
7. **Duration of the Study:** 4 Years,3 months

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. **Statement of the Problem:**

The growth in population, urbanization and industrialization has led to the increase in the generation of solid waste all over the world. It is believed that the rate of waste generation is an index of socio-economic development and an economic prosperity of a country. This is evident from the fact that the rate of waste generation is more prominent in the developing countries where there is an increased rate of unplanned urbanization of the cities.

In India, the total Indian urban population amounts to approximately 377 million (Census of India 2011). The cities which have more than 100,000 populations contribute to more than 72 percent of the total municipal solid waste. The growth rate of population in urban India is much higher than that in rural India. The Census figures also show Delhi to be the most urbanised State in India. Since waste generated by the city depends on its population and per capita income, it is estimated that the quantity of Municipal Solid Waste (MSW) would reach 17,000 – 25,000 MT/day by 2021 (Talyan et al.,2007).

For solid waste management in Delhi, twenty landfill sites were identified and developed since 1975, and of which 15 have already been closed and two were suspended. At present only three landfill sites are in operation. They are namely, Bhalaswa catering the needs of northern part of Delhi, Okhala in the southern part and Gazipur in the eastern part of Delhi.

The dumping of waste in these non-engineered landfill sites contributes to percolation of leachate in the groundwater. These percolating liquids have high concentration of hazardous chemicals. The harmful constituents of leachate then move along the groundwater in the surrounding region rendering it unfit for human consumption and pose various health risk.

The various attempts made so far to model leachate movement suffer from a common problem that no surety can be established as to whether the pollution is result of leachate or any other source is contributing towards groundwater deterioration in that region. The current study focuses on modeling of leachate movement through groundwater and apportionment of leachate which has not been attempted so far.

Methodology Adopted

a. Conducted a literature review on chemical and isotopic characterization of leachate, groundwater contaminant transport modeling, etc.
b. Carried out a field survey of the region and conducted groundwater sampling using standard protocols.
c. Characterized leachate using EPA methods - TCLP (Method No. 1310) & column study (Method No. 1312).
d. Collected groundwater levels to ascertain the flow direction.
e. Identified groundwater recharge and discharge areas.
f. Collected groundwater samples on a bi-monthly basis at identified locations.
g. Analyzed the physico-chemical parameters: pH, EC, DO, COD, TOC, major anions, cations, and trace metals (Fe, Mn, Zn, Pb, Cd, Cr, Radium, etc.).
h. Analyzed the stable isotopic characteristics of leachate and groundwater at various identified locations.
i. Analyzed the groundwater samples and leachate for micro-plastic.
j. Processed hydro-chemical and isotopic data on a bi-monthly basis.
k. Modeled the leachate migration from the landfill to the groundwater table. The model was developed for one-dimensional vertical transport of contaminants through the unsaturated zone.
l. Modeled the leachate plume movement in groundwater using MT3D MODFLOW and HELP. The leachate transport model was calibrated based on chemical and isotopic data.
m. Suggested ameliorative measures for containment of the contaminant plume based on groundwater modeling

10. Objectives and Achievements

S.No.	Objectives	Achievements
1.	Understanding of hydrodynamics of groundwater flow in the study area.	The Aquifer parameters and characteristics of study area are analyzed.
2.	Chemical characterization of Leachate.	Analyzed leachate seasonally over 2 years
3.	Isotopic characterization of leachate and its variation due to recharge and extraction of groundwater.	Isotopic character of both leachate and groundwater characterized.
4.	Assessment of Micro-plastic and metals (Hg, Ni, Co) in landfill leachate.	All emerging contaminants analyzed
5.	Modelling of leachate migration pattern in groundwater in space and time.	Modelling completed
6.	Suggesting ameliorative measures for contaminant plume migration.	Two different methods only chemical and other nature based solution identified.
7.	Dissemination of knowledge and findings to stakeholders through manuals, leaflets, booklets and workshops/training programs.	Published more than 10 research papers and conducted one online training; one patent

11. **Analysis & Results:**

   A. Groundwater sample collection from 130 grids from the vicinity of landfill. Leachate Samples taken from the landfill. Continuous sampling for three years have been conducted.

   B. The physico-chemical, metal contents and isotopic parameters of Leachate was identified.

   C. The physico-chemical, metal contents and isotopic parameters of Groundwater in the study arae identified.

   D. Presence of microplastics in leachate samples detected in soil, leachate and groundwater in the area surrounding groundwater.

   E. Modelling movement of contaminant within the landfill.

   F. Source Identification with statistical analysis.

   G. Training of Groundwater Monitoring and Modelling

12. **End Users / Beneficiaries of the Study:** Policy makers and planners of State Government Organizations, Delhi municipal corporation and CGWB and state groundwater board.

13. **Deliverables:** Technical report and research papers, First-hand information on water quality in and around Gazipur Landfill site, groundwater model simulating plume movement and fate and origin of pollutants.

14. **Major items of equipment procured:** Procurement procedure for FTIR imaging system to be purchased MODFLOW purchased and TLC Meter purchased.

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

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

17. **Involvement of end users/beneficiaries:** CGWB

18. **Specific linkage with Institution and /or end users / beneficiaries**: East Delhi Municipal n corporation, CGWB.

19. **Shortcoming/Difficulties:** NONE

20. **Future Plan:**
    - To conduct a training programme on source apportionment.
    - Publishing the results in International Journals
    - Final Report Submission.

7 PROJECT REFERENCE CODE: NIH/GWH/DST-SERB/23-25

Title of the study: Use of deep learning models to understand the impact of climate and land use changes on future groundwater resources, with a focus on data scarce regions.

Study Team	:	Dr.L.Surinaidu (PI from NIH) Lead agency: IIT-Hyderabad Partner: McGill University-Canada
Type of study	**:**	Sponsored, DST, India.
Date of start (DOS)	**:**	June 2023
Scheduled date of completion	**:**	July 2025
Location	**:**	Ganga Basin

S. No.	Study objectives	Achievements/Responsibility
1	Development of a structured database bearing data related to recharge, extraction and GW levels in the study region.	IIT Hyderabad and NIH
2	Development of a novel method for using GRACE satellite data for interpolation and reconstruction of a historical GW level time series in data scarce regions	IIT Hyderabad
3	Development of deep-learning-based models for GW level simulation in the study regions considered.	IIT Hyderabad
4	Prediction of GW levels under climate change, with different suitable GCMs/RCMs, for the next century, as well as understanding the impact of climate change on future GW levels (until 2100).	NIH and IIT Hyderabad
5	Development of physics-based integrated hydrological models	NIH
6	Prediction of runoff and recharge dynamics under different historical and projected land use changes.	NIH
7	Development of different scenarios along with the corresponding uncertainty to evaluate the impact of land use change, excessive pumping along with climate change	IIT Hyderabad and NIH

Statement of the problem:

In the work proposed here we will focus on two aquifers, one in Canada and one in India, that are vulnerable to climate change and significant land use changes. In the Indian context we shall consider the Ganga River Basin, given its hydroclimatological and land use diversity, as well as the aquifer's characteristics. The Ganga River Basin is underlain with quaternary alluvium, with thick layers of sentiment throughout the majority of the basin. However, the North and North-Western portions of the basin are characterized by hard rock aquifers. Groundwater monitoring data is very scarce, and agro-hydro-climatic conditions highly diverse; therefore, it is a perfect test bed for the proposed methodology. In the proposed research deep learning (DL) will be used to generate and identify trends in GW resources using satellite and in situ data for Ganga basin. This will then be used in numerical GW models to provide a detailed assessment of interactions among the different hydrological comportments.

Two test sites have been considered in Canada where data is abundant: The Chateauguay River watershed, located in Quebec on the Canadian–US border, and the Grand Forks (GF) aquifer in British Columbia, Canada. These study sites were selected because these watersheds are subject to similar climatic conditions as the Ganga basin. Moreover, the Canadian PI has experience in both watersheds. Accordingly, cross learning and transfer of knowledge of water management solutions can be exchanged.

Methodology: The following work packages are proposed to achieve the objectives.

Work Package 1: Gather databases and methodologies relevant to use in the other tasks.
The required data for the DL and numerical models will be obtained from different data sources for both India and Canada.
Work package 2: Reconstruction and interpolation of groundwater level data using GRACE Data.
In the present study, we propose to use monthly GRACE satellite data to reconstruct the GW level time series and to fill in missing data for certain times and locations. This will be achieved by using a transfer-function-based model [e.g., Convolution Neural Network (CNN) models]. The proposed approach would be tested in Canada's data rich aquifers, and would then be developed, calibrated and validated for Indian aquifers (particularly those of the Ganges River basin).
Work Package 3: Development of Deep Learning Models for GW simulation
In recent years, Artificial Neural Network (ANN) models drawing only on climatic input variables have been proven to be very useful in simulating GW levels. Accordingly, for this application, DL/ML-based models were chosen over physics-based models given that the development of the latter usually requires extensive data regarding the local aquifer's characteristics, and would also prove time consuming to build and calibrate at a regional scale. Therefore, for larger areas of the size of Ganga Basin, we have used the DL/ML models which can predict a target variable using only relevant driving forces.
Work Package 4: Development of physics based integrated hydrological models and prediction of runoff and recharge dynamics under different historical and projected land use changes.
Apart from the DL-based model framework for GW simulation a physics-based model would also be developed and would serve two purposes:
1. To cross check the results obtained from the DL models and,
2. To achieve insights on the impact of climate on different components of the hydrologic cycle such as runoff, recharge and base flow. For this purpose, a coupled regional-scale surface water-groundwater model, with a 1.0 km spatial resolution would be developed. An open-source tool such as the SWAT-MODFLOW would be coupled with the model.
Work Package 5 Understanding the impact of climate change on GW storage using Machine Learning Models
Once the reliability of the ML/DL models have been verified (WP4), the well-trained models will be used to predict future GW, up to the next century, by taking inputs from RCP scenarios of General Circulation Models.

Outcome:

1. The project aims to develop databases for different variables such as GW extraction and recharge for the regions under study.
2. This will result in a unique methodology for reconstructing GW time series data at locations where and when observations are not available.
3. A framework will be developed that will allow for an understanding of the impact of climate change and land use change on GW levels and storage in different aquifers in both alluvium and hard rock fractured zones.
4. Papers Published in SCI journals.
5. Students trained.

8 PROJECT REFERENCE CODE: NIH/GWH/MoES/22-24

Title of the study: Carriers of Mass Transport Contamination in Delhi, NCR

Study Team	:	Dr.L. Surinaidu (PI from NIH) Lead agency: NGRI
Type of study	**:**	Sponsored, MOES
Date of start (DOS)	**:**	Oct. 2022
Scheduled date of completion	**:**	Sep.2024
Location	**:**	NCR-Delhi

S. No.	Study objectives	Achievements
1	Near surface investigations of the Non-Sanitary Landfill (NSL) around the Ghajipur MSW for demarcating contaminant plume.	One time is Completed and second time need to be done.
2	To monitor soil and water quality around MSW	Completed
3.	To Construct contaminant transport modeling for prediction pollution pathways	No completed
4.	To provide suitable management solutions	No completed

Statement of the problem:

Contaminant plumes from non-sanitary landfill sites are rich in organic matter and provide a source of electrical potential variations. These variations can be recorded at the ground surface which is mixed with the contribution from plume (geobattery) and flow (water). The main objective of this proposal is to assess and model the impact of Ghazipur landfill on the subsurface geological structure and hydrological environment. The use of geophysical methods will ascertain the geological structure near the landfill and extent of contaminant plume. An integrated, geophysical survey, physical and hydrochemical analysis methods need to be employed to assess the subsurface geological formations, aquifer location, dynamics and intrusion of contaminated seepage water in the vicinity of the Ghazipur landfill. A considerable amount of contaminated leachate percolation takes place in the sub-surface of the landfill area, however the direction, transport and its extent is not yet established. The acquired datasets will lead to development of aquifer conceptual model and contaminant mass transport model of this major landfill site, both in space and time. The model will serve to ascertain and predict the groundwater flow of contamination and migration of the plume beneath the surface. Another important aspect is the intervention of such a huge built pile over of the landfill site to the existing ‘critical zone’ of the surrounding area. Are these piled structures disturbing the “critical zone” of the surrounding area? And to what extent? What can be its effect to the immediate layer of soil present apart from the subsurface contamination?

Fig.1 Ghajipur MSW with tentative locations for soil and geophysical investigations

Methodology:

Geophysical investigations in the form of 2D electrical resistivity and self-potential (SP) have been carried out around MSW Ghajipur. The analysis of geophysical data is under progress for the construction of aquifer geometry and to demarcate the contamination of groundwater zones. The water quality that includes surface water and groundwater have been also carried out for major cations and anions and heavy metals. The analysis is under progress.

Groundwater flow and contaminant transport modeling:

The collected information mentioned above sections on subsurface and water quality parameters will be used as an inputs for groundwater flow and contaminant transport modeling. In the present study USGS MODFLOW, MODPATH and MT3DMS with Visual MODFLOW flex (Waterloo Hydrologic, 2012) will be used to simulate the groundwater flow and contaminant transport processes. In order to conceptualize the aquifer system 30 m resolution SRTM digital elevation model will be considered as land surface elevation, after care full analysis of available bore well lithologs the subsurface aquifer layer thickness will be incorporated in the model. The model resolution will be selected based on available data and complexity of aquifer heterogeneity. The aquifer parameters such as hydraulic conductivity, storativity and specific yield will be considered in the model based on available data, if data is not available the possibility of conducting aquifer test will be explored. The hydraulic boundaries such as streams, lakes and rivers in the area will be assigned in the model based on topo sheets and google maps. The groundwater recharge and discharge will be considered in the model based on field observation and other available secondary data from different agencies. The estimated recharge from HYDRUS will be used as a input to groundwater flow model in comparison with available secondary data. The groundwater flow model will be calibrated using observed groundwater levels. Once flow model is calibrated, the pollution loads (TDS) for dumpsite based on observations will be assigned. The both groundwater flow and contaminant transport model will be calibrated using manual and automated calibration techniques. The calibrated model will then be used to track the existing and future contaminant flow paths using MODPATH in order to propose suitable controlling measures.

Outcome:

1. Maps of aquifer contamination and its extent in and around MSW-NCR Delhi
2. Groundwater quality maps
3. Groundwater flow and contaminant transport model for remedial measures
4. 3 Publications

9 PROJECT REFERENCE CODE: NIH/GWH/24-27

Title of the study: Surface water-groundwater interactions through field techniques and hydrological modelling in Yamuna basin

Study Team: Dr. Sumant Kumar, Sc-E, GWHD & PI
Dr. Nitesh Patidar, Sc.-C, GWHD
Dr. Lagudu Surinaidu, Sc.-D, GWHD
Er. Pintu Gupta, Sc.-B, GWHD
Dr. Ajit Kumar Behera, Sc.-C, GWHD
Dr. Anupma Sharma, Sc.-G & Head, GWHD
Dr. Shailendra Kumhre, Sc.-B, EHD
Dr. Gopal Krishan, Sc.-E, HID

Type of study	**: Internal**
Date of start (DOS)	**: March, 2024**
Scheduled date of completion	**: February, 2027**
Budget	**: 87 Lakhs**
Location	**: Yamuna basin**

Objectives:

(i) Identification of recharge sites and GW recharge estimation in the basin
(ii) Determination of river bed hydraulic conductivity with insitu and lab methods
(iii) Identification of influent-effluent stretches and quantification of flow between SW and GW along the Yamuna river

Statement of the problem:
A thorough understanding of watershed hydrology is essential for sustainable water management in a watershed. The interactions of groundwater and surface water, especially in water intensive region where changes on the management or use of GW will impact the availability and use of the SW or vice-versa. Analysing and understanding the spatio-temporal variability of surface and groundwater interaction is important for improving the conjunctive use of surface water and groundwater. Traditionally, surface water and groundwater resources have been managed as separate entities. However, with the development of land and water resources, notable changes have been observed in the quantity and quality of these resources. The fluvial plains are regions where rivers and the groundwater system interact in complex ways. The SW-GW interaction depends on GW level, river stage, conductivity and bed geometry of the river. The Yamuna River is one of the important sacred river and a largest tributary of the River Ganga. The river water is generally used for irrigation, drinking and industrial purposes. The construction of diversion structures at Hathinikund, Wazirabad, Okhla, Gokul, etc. for different uses has largely modified the river’s flow regime. The lack of groundwater pumping regulation has led to ground water table depletion and causes modification in linkage between surface and ground water, resulting change in surface water dynamics during the lean season of the river. Hence, effective land and water (SW and GW) management necessitates a comprehensive understanding of the interaction between groundwater and surface water within a specific hydrological context. As per our knowledge, no such studies have been carried out in the basin, hence a study is being proposed to identify the influent-effluent stretches and quantification of flow between SW and GW along the Yamuna river.

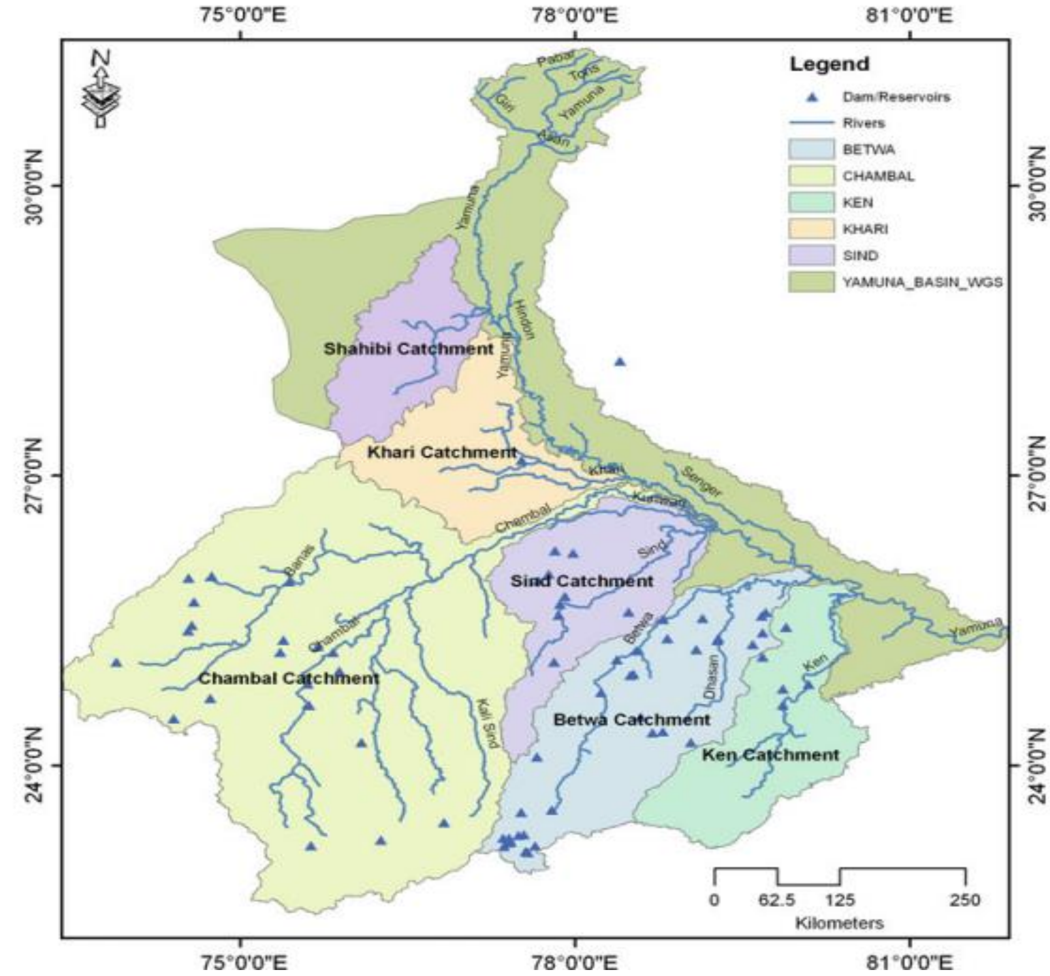


Figure: Yamuna River basin with the major tributaries and sub-basin (Source: Upadhyay and Rai, 2013)

Methodology:

For achieving the first objective, the satellite data would be processed in ArcGIS to prepare the various thematic layers viz. rainfall, geology, geomorphology, topography, soil, land use/land cover, slope, lineament, drainage and drainage density, GWL etc. The potential zones for GW recharge will be identified based on different thematic maps and multi-influencing factor techniques. The GW recharge may be estimated using GEC norms, soil moisture balance methods. SWAT modelling tool will also be used for getting deep percolation/recharge. The hydraulic conductivity (K) can be estimated by analysing the particle size of the sediment from the river bed, using empirical equations relating to size property of the sediment. The geophysical resistivity survey would be carried out to delineate the aquifer and determining the location and depth of piezometers. The piezometers will be designed and installed at site to measure GW heads and volumetric flow rate simultaneously. It is planned to install 50 shallow piezometers along the main river Yamuna. It is difficult to obtain base flow directly and continuously in the field. Therefore, various approaches will be employed for accurate estimation of base flow. Basically, three different methods will be employed: direct measurements, tracer-based separation (including isotopic tracer), and modelling. For applying all the methods, initially river stretch will be analysed based on the thermal images which may locate and characterize thermal (temperature) anomalies along streams. Variations in temperature can be used to track the heat carried by flowing water, such as groundwater discharge into a stream, pinpointing zones of water exchange and water mixing for further analysis. Accordingly, the location for direct measurements may be decided and various instruments such as seepage meters, mini-piezometer and/or other methods will be used to measure base flow values at discrete points. These instruments will be installed to measure water fluxes across the groundwater-surface water interface. Tracer-based methods will also be employed which would be mainly rely on various isotopic and chemical tracers. The mass balance (a mass balance of all known inflows to and outflows from a given stream reach) method for estimating base flow would also be applied. A positive mass balance will indicate a gaining reach (base flow) and a negative balance indicates a losing reach. Finally, a modelling would be carried out to study the SW-GW interaction and quantifying base flow or river seepage.

Action Plan & Timeline:

Work Element	1st Year	2nd Year	3rd Year
Existing GWL data, River stage data and other hydrological data collection from different agencies and preliminary analysis.			
Preparation of different thematic maps using Arc GIS. Identification of recharge sites			
Geophysical resistivity survey and Installation of piezometers and conducting field experiments			
Recharge estimation and hydrological modelling using MODFLOW			
Preparation and submission of reports and publications			

Budget breakup:

S. No.	Head	Expenditure			
		1st Year	2nd Year	3rd Year	Total
1	Emoluments for Manpower (2 JRP @ Rs. 40,000)	960000	960000	960000	2880000
2	Travelling expenditure	640000	640000	320000	1600000
3	Infrastructure/Equipment (@ 50 nos. piezometers and minor equipment)	1700000	1500000	-	3200000
4	Experimental analysis/Lab charges (Particle size analysis @150 samples, Lab Permeameter@100 samples, Isotopic analysis@200 samples)	193750	193750	-	387500
5	Contingency/Miscellaneous	100000	100000	100000	300000
6	Organization of a training cum workshop (3 to 5 days)			300000	300000
Total (Rs.)					**86,67,500**

Data Requirements:

- Groundwater levels
- Geological map
- River stage and discharge at different locations
- Aquifer parameters
- etc.

List of Deliverables:

- Reports
- Research papers

Study Benefits /Impact:

River bed hydraulic conductivity data will be generated based on lab and field experiments which will be used by NIH and other Scientists/Engineers/Academicians for modelling and studying SW-GW interactions. As per our knowledge, no data for river bed conductivity is available for the Yamuna basin. Recharge sites will be identified which will be further used by State/Central agencies to implement MAR structures. The identification of the influent-effluent stretches and quantification of flow between SW and GW along the Yamuna river will certainly help the policy makers for implementing the optimal use of surface water and groundwater. The findings of the study will be presented in conferences/workshops and published in journals. Stakeholder (Public Health Engineering Department, State GW departments, Jal Nigam, Water Resources Department, Department of Drinking Water and Sanitation, Ministry of Jal Shakti etc.) engagement would be beneficiaries.

PROJECT REFERENCE CODE: MAJOR PROJECT WITH SUB-PROJECTS

Study Team:
Project Co-Ordinator: Dr. Anupma Sharma
Scientists from GWH Division: Dr. L. Surinaidu; Dr. Ajit Behera; Dr. Satendra Kumar; Er.Pintu K. Gupta
NWRC Jodhpur: Mr. Akshay Vyankat Dahiwale; Mr. Malkhan Singh Jatav; Mr.Dilip Barman; Mr. Sudesh Singh Choudhary
EHD Division: Dr.M.K.Sharma

Type of the study	:	Internal Research Study
Nature of the study	**:**	Research
Duration	**:**	36 Months

Study area:

North-western India has emerged as a hotspot of the existing groundwater crisis. In the present project, focus is on the Luni river basin which is facing both water scarcity and water quality issues. Luni river is the largest river in the Thar desert of North-western India that provides water for irrigation and sustains local agricultural sector. It originates in the Aravalli Range near Ajmer and travels around 495 km and eventually drains into the Rann of Kutch in Gujarat. (Fig, 1). The main tributaries of Luni originating from the Aravalli hills and joining on the left bank are Jawai, Sukri, Guhiya, Bandi while Jojari is the only tributary that joins Luni on its right bank.

The climate in most parts of the basin have semi-arid to arid climatic conditions due to extreme temperatures, low rainfall and humidity. Annual precipitation is highly variable, ranging from 600 mm in the southeast to 300 mm in the northwest; 93% of which is received during the monsoon months of June to September. The demand for agriculture, livestock and industries has exerted increased pressure on the groundwater resource that is reflected in the declining groundwater levels. Droughts are a recurring phenomenon in the region while flash floods events are also witnessed in the basin that may increase due to climate change and favourable flat river topography. For the initial hundred kilometres, the water in Luni is fresh, but as it gets closer to Balotra in Barmer, it acquires saline characteristics. Further, pollutants from textile industries located along its banks further degrade the water quality. In this scenario, a holistic integrated approach is required to tackle different nature of hydrological problems including floods, water table depletion, multi-aquifer characterisation, provision of potable drinking water and control groundwater salinization/ degradation for sustainable water resource management in the Luni river basin. In order to achieve this, a major project titled Enhancing the Sustainability of Water Resources Through Integrated Assessment and Management Techniques in the Luni River Basin – Rajasthan' is proposed.

To fulfil the objectives of the major project, different sub-projects (Fig.2) are proposed as follows:

1. Estimation of Soil Characteristics and Simulation of Groundwater Recharge in the Luni River Basin (NIH-GWH Project)
2. Hydrogeochemical Evolution and role of Paleochannels on groundwater quality in the Luni Basin (NIH-GWH Project)
3. Hydro-geological investigations in the Luni River basin (NIH-GWH Project)
4. Analyzing the Flash Flood events in the Luni River Basin and Remedial Measures to Store Excess Water (NIH-NWRC Jodhpur Project)
5. Assessment of Water Productivity, Land Productivity, and Agricultural Drought in Luni River Basin (NIH-NWRC Jodhpur Project)
6. Estimation of variability in water demand for diverse crops types and water conservation measures (NIH-NWRC Jodhpur Project)
7. Characterisation and Modeling of Multi Aquifer System of LUNI River Basin in Rajasthan Under Climate and Anthropogenic Influences (NIH-GWH Project)

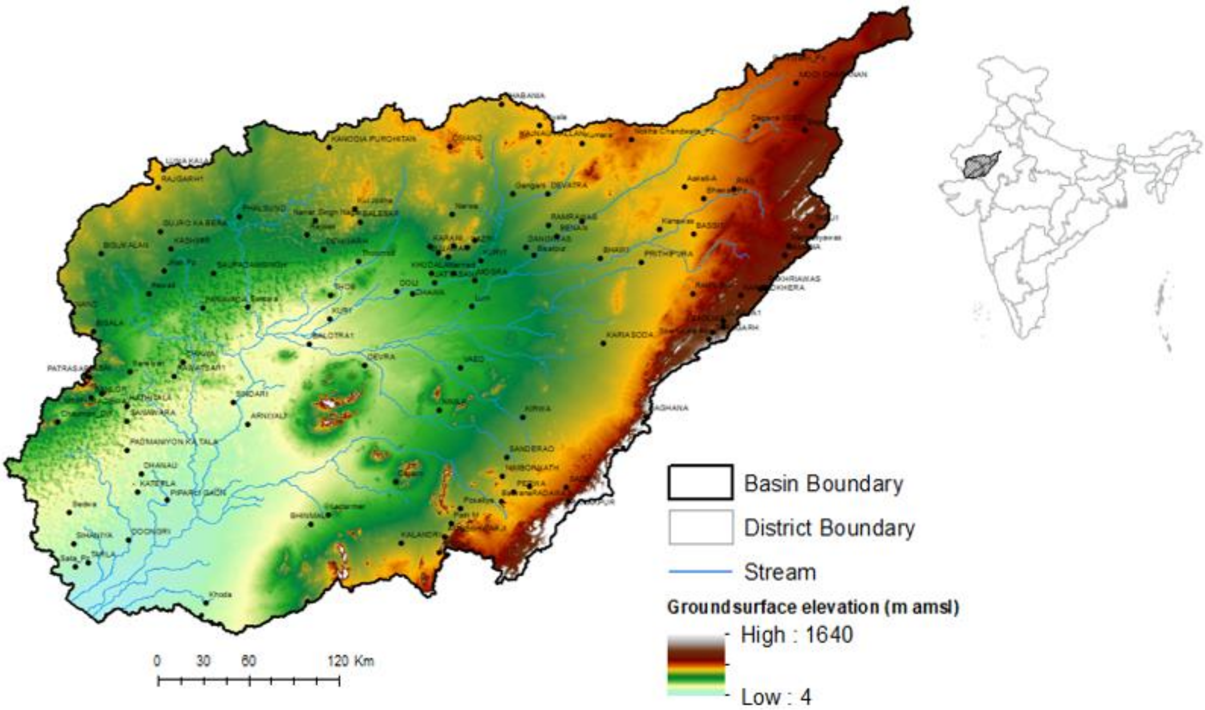


Fig. 1 Location map of the LUNI river basin

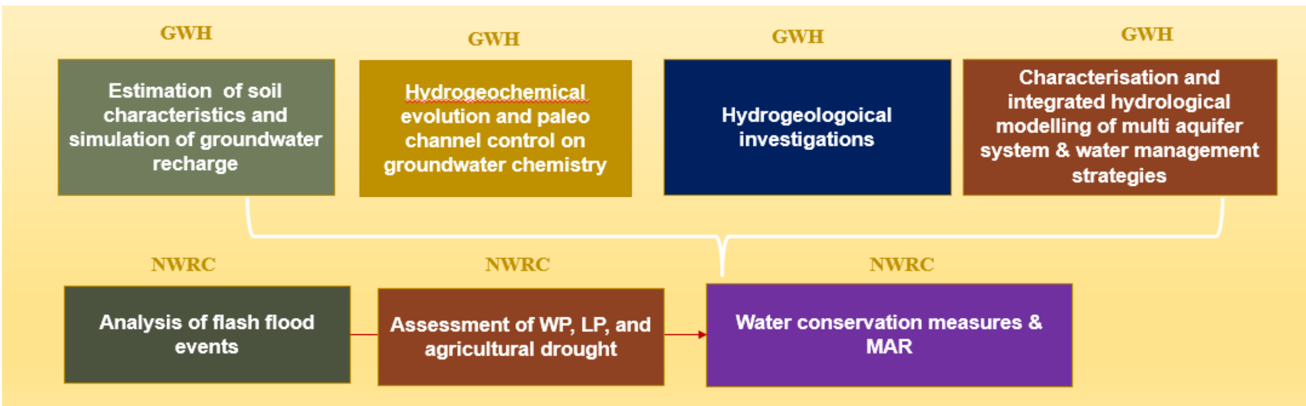


Fig.2 Proposed sub-projects

10 PROJECT REFERENCE CODE: NIH/GWH/24-26

Title: Estimation of Soil Characteristics and Simulation of Groundwater Recharge in the Luni River Basin

Team members: Dr. Satendra Kumar (PI)
Dr. Anupma Sharma (Co-PI)
Dr. L. Surinaidu (Co-PI)
Dr. Ajit K. Behera (Co-PI)
Er. Pintu K. Gupta (Co-PI)
Dr. Nitesh Patidar (Co-PI)

Type of study **:** Internal Research Study
Duration **:** 2 Years
Budget **:** Rs. 37 Lacs

Objectives:

1. Determination of soil physical, chemical and hydraulic properties for top 1m unsaturated zone and preparation of soil data base.
2. Soil salinity characterization in the river basin.
3. Estimation of groundwater recharge by modelling the moisture flow in the unsaturated zone along with climate change scenarios for future groundwater recharge projections.

Methodology:
The study aims to focus on Luni River basin, which is the largest river basin in the northwest India. Because of scarce surface water resources, groundwater is intensively used for irrigated crop production and livestock farming. Aquifer mining is a major environmental threat in western Rajasthan. Groundwater recharge in semiarid areas is difficult because of inadequate water resources and growing demands, therefore proper knowledge of aquifer recharge is essential for management of groundwater resources. The proposed research project aims for quantification of groundwater recharge and identification of groundwater recharge potential zones in the Luni basin. It is envisaged to carry out modelling of unsaturated zone by HYDRUS-1D by utilising soil physical properties and soil water retention and hydraulic parameters. During the project, field soil samples will be collected from various representative soil locations for the determination of soil physical, chemical and hydraulic properties for top 1m soil. Soil properties and water retention parameters will be determined by respective laboratory experiments. Saturated hydraulic conductivity will be determined by conducting field experiments at representative soil locations by Guelph Permeameter and double ring infiltrometer experiments. Pore-water samples will be collected for soil salinity characterisation. Soil data base with soil physical, chemical and hydraulic properties will be prepared. HYDRUS-1D model will be formulated for the modelling of moisture flow in the unsaturated zone in the basin for varying land use, surface and bottom boundary conditions. The model will be calibrated and validated for weather and groundwater data from year 2000 to 2023. Future climate scenarios will also be used for simulation of future groundwater recharge scenarios. The outcome from the project will result in the quantification of groundwater recharge to the aquifer and identification of potential groundwater recharge zones for formulation of optimal and sustainable water management strategies.

Lab facilities:

1. Soil water and water quality lab facilities will be utilised for soil physical and chemical properties determination of soil and pore water samples collected.
2. Field experiments using Guelph Permeameter and double ring infiltrometer for the estimation of saturated hydraulic conductivity.

Deliverables

1. Soil data base for top 1 m unsaturated zone for the entire Luni River basin.
2. Groundwater recharge estimates and potential groundwater recharge zones in the river basin.

3. Research Publications and Report.

Project timeline: Table. 1 Shows the time line of the project

S. No	Project elements	Months							
		3	**6**	**9**	**12**	**15**	**18**	**21**	**24**
1	Literature review and Secondary data collection for identification of representative soil locations	✓	✓						
2	Field surveys for collection of soil, pore water samples and profile soil moisture data	✓	✓	✓	✓	✓			
3	Field experiments for saturated hydraulic conductivity, infiltration rate etc.	✓	✓	✓	✓	✓			
4	Analysis and parameter estimation from field experiments		✓	✓	✓	✓	✓		
5	Preparation of soil data base			✓	✓	✓	✓		
6	Future weather data from climate change scenarios.				✓	✓	✓		
7	Model formulation and simulation of groundwater recharge in the river basin				✓	✓	✓	✓	
8	Publications					✓	✓	✓	✓
9	Final report						✓	✓	✓

Budget: Table 2 shows the budget components

S. No.	Description	Quantity	-	Budget (INR)
1	Field visits	6 visits/year	2 years	15,00,000
2	Lab analysis	250 samples	Rs. 6000 per sample	15,00,000
3	JRF	1	1 year	5,00,000
4	Miscellaneous	1 lakh/year	2 years	2,00,000
		Total		**37,00,000**

11 PROJECT REFERENCE CODE: NIH/GWH/24-27

Title of the Project: Hydrogeochemical Evolution and role of Paleochannels on groundwater quality in the Luni Basin

Project Team:

Project Investigator:	Dr. Ajit Kumar Behera
Project Co-investigator:	Dr. L. Surinaidu
	Dr. Amzad Hussain Laskar, PRL
	Sh. Pintu Kumar Gupta
	Sh. Malkhan Singh Jatav
	Dr. Anupma Sharma
	Dr. M. K. Sharma
Type of study	Internal
Duration	36 Months
Budget	Rs. 46 Lakhs (Approximate)
Location	Luni Basin

Objectives:

- To assess groundwater recharge processes and rates through isotopic analysis
- To determine the relative residence times (age) of the groundwater
- To understand the role paleochannels on groundwater quality
- To identify the primary factors and mechanisms controlling the geochemistry of the groundwater

Origin of the Proposal:

The inhabitants of arid and semi-arid regions in Western Rajasthan, India, are confronted with persistent challenges. In the absence of perennial water resources, groundwater assumes paramount importance as the primary water source in these areas. The escalating trend of groundwater extraction underscores the urgent necessity for comprehensive assessment of both the quantity and quality of available water across diverse aquifer systems within the region. Recognized as a precious natural resource, groundwater serves as a readily accessible and dependable water source for domestic, agricultural, and industrial purposes. In such cases paleochannels often serve as conduits for groundwater flow and storage, impacting the availability and distribution of groundwater resources. Understanding their presence and characteristics is crucial for assessing the potential of groundwater reserves in arid regions, where water scarcity is a significant concern.

In the Luni River, freshwater is detectable along its course for the initial 100 kilometers. However, upon reaching Balotra town in Barmer, situated approximately 110 kilometers southwest of Jodhpur city, the water undergoes a transition to a saline state (CGWB,2017). This proposed study aims to elucidate the hydrogeochemical evolution across various geological formations within the basin. Additionally, it seeks to identify the interface between saline and freshwater zones within the basin. Further, by assessing both the quantity and quality of available groundwater, taking into account the role of paleochannels, we can define the long-term sustainability of water resources in arid regions.

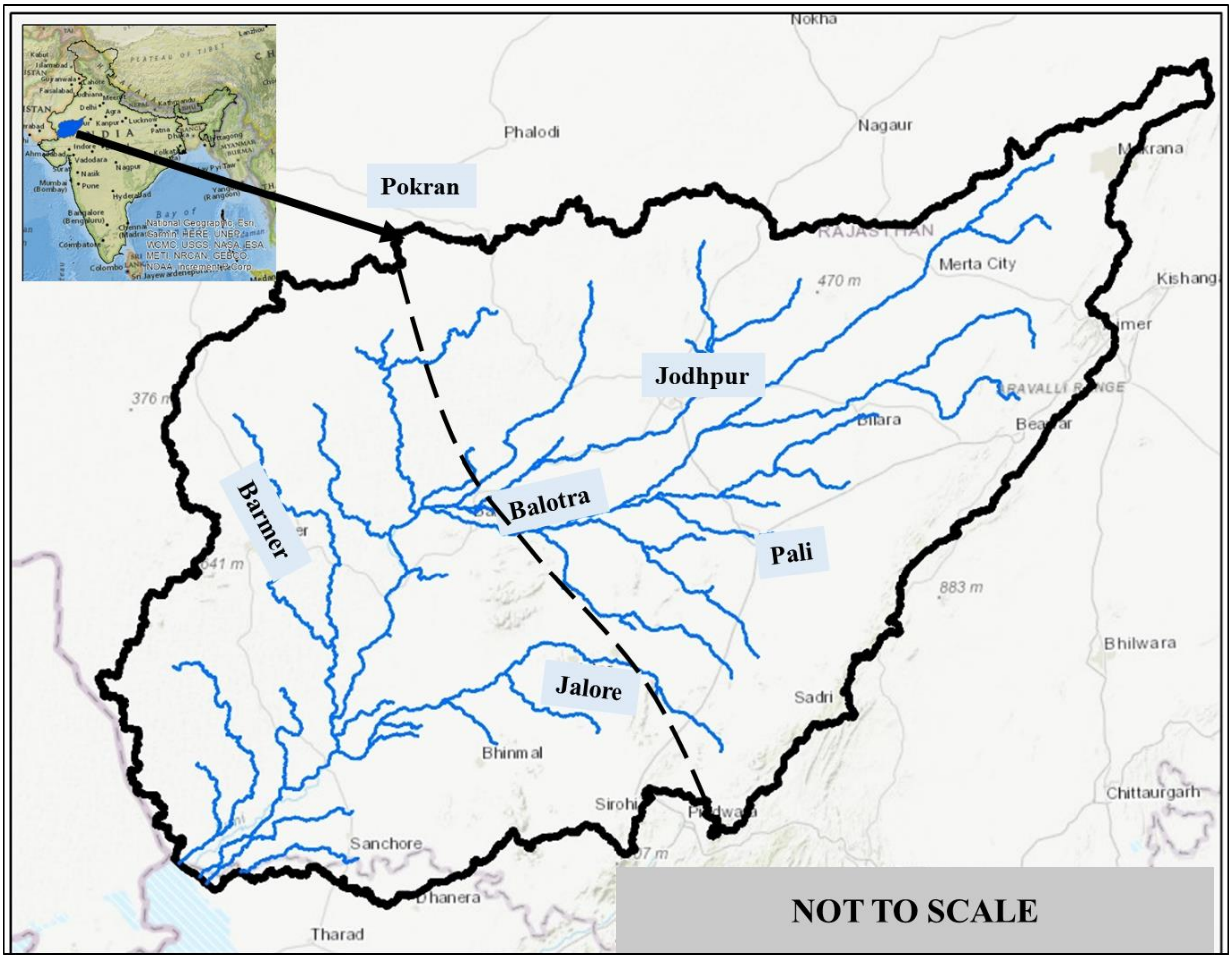


Figure 2 Study Area (Luni Basin)

Methodology:

Environmental isotopic and Geochemical Analysis

Environmental isotopes ($\delta^{18}O$, $\delta^{2}H$, and ^{3}H, ^{14}C), together with physical and geochemical (major ions and trace elements) data will be used in the determination of the distribution and origins of groundwater salinization and hydrogeochemical processes in the Arid regions. As part of sampling procedures, groundwater, river, canal, and lake samples will be collected in 500 ml high-density polyethylene bottles (applying the general sampling protocol) from different locations of the Luni Basin for measuring the major ion concentrations (Na, Ca, Mg, K, HCO_3, Cl, SO_4). All water quality parameters (Major ions) will be analysed by IC in Water Quality Laboratory of NIH Roorkee. During the collection of samples, in-situ parameters (pH, TDS, Temperature, ORP) will be recorded with the help of a multi-parameter analyzer. Apart from that some tracer tests will be performed to identify the recharge sources as well as rates. For isotope analysis ($\delta^{18}O$, $\delta^{2}H$, and ^{3}H), 250 ml of groundwater, lake, canal, and river water samples will be collected in Pyrex glass bottles and analyzed through IRMS at NIH Roorkee. Pre-treated groundwater samples will be collected in 1-liter HDPE bottles for Carbon-14 analysis, which will be conducted at PRL using an AMS instrument.

Expected Outcomes:

1. **Understanding Geochemical Process**: Several processes controlled the observed chemical composition: (i) the dissolution of evaporitic minerals, (ii) cation exchange reactions, and (iii) incongruent dissolution of carbonate minerals (calcite, dolomite)
2. **Tracing Water Sources**: Isotopic studies help trace the origin and movement of water.
3. **Determining Age of Water**: Radiocarbon dating can help estimate the age of water within the basin.

4. **Controls of paleochannels**: Understanding various geochemical factors on groundwater due to the presence of paleochannels in arid regions.
5. Research papers/ report

Work Element/ Milestone	0-6 months	7-12 months	13-18 months	19-24 months	25-30 months	31-36 months
Literature survey	✓					
Field visits, secondary data collection and Water sampling	✓	✓	✓	✓		
Data Processing in various labs.		✓	✓	✓	✓	
Geochemical and isotope data analysis, and interpretations			✓	✓	✓	
Paleo channels Identification and interpretation		✓	✓	✓	✓	
Report/Drafting manuscripts for publications			✓	✓	✓	✓

Beneficiaries:

- Local governments for policy formulation and resource management.
- Farmers for agriculture water management and fresh water supplies for domestic purpose.

Cost Estimate (Year Wise Budget Summary)

Budget Head	Year -1	Year -2	Year -3	Total (INR)
Manpower (Resource Person)@40000/month	480000.00	480000.00	480000.00	1440000.00
Consumables	300000.00	200000.00	100000.00	600000.00
Travel	300000.00	300000.00	200000.00	800000.00
Equipment	700000.00	0.00	0.00	700000.00
Contingencies	200000.00	200000.00	100000.00	500000.00
Lab Experiments	200000.00	200000.00	200000.00	600000.00
Total	***2180000.00***	***1380000.00***	***1080000.00***	***4640000.00***

Research plan timeline

12 PROJECT REFERENCE CODE: NIH/GWH/24-26

Title of the Project: Hydro-geological investigations in the Luni River basin

Study team:	PI	Pintu Kumar Gupta, Scientist-B
	Co-PIs	
		Dr. L. Surinaidu, Scientist-D
		Dr. Ajit Behera, Scientist-C
		Dr. Satendra Kumar, Scientist-B
		Dr. Sumant Kumar, Scientist-E
		Er. Sudesh Chaudhary, Scientist-B

Type of study: Internal (***New Study***)

Duration: Two years (April 2024 – March 2026)

Background

The Luni Basin in Rajasthan, India, features diverse geological formations such as alluvial plains, dunes, and sedimentary rocks, sustaining agriculture and local communities. The unsustainable groundwater extraction practices, coupled with limited recharge rates and climatic variability, have led to declining groundwater levels and quality. Assessing aquifer parameters like transmissivity, storativity, and hydraulic conductivity is crucial for understanding groundwater dynamics in the basin. There is also a need to investigate spatial variations in groundwater levels across different hydrogeological units, land use types, and administrative boundaries within the Luni River Basin. Despite the basin significance, very limited research work related to hydro-geological investigations and characterization has been carried out. The present study aims to accurately characterize aquifer parameters by conducting comprehensive pumping tests, facilitating better water resource management. Also, spatio-temporal variation of groundwater level along with trend analysis would be studied. It would be attempted to understand the underlying drivers of groundwater fluctuations in the Luni River Basin.

Objectives

The specific objectives of the study are as follows:

I. Estimation of aquifer parameters by field and lab experiments.
II. Spatio-temporal variation and trend analysis of groundwater level in the basin.

Study Area

This study targets the Luni River basin, flowing through Rajasthan and concluding at the Rann of Kutch in Gujarat. The Luni River is pivotal for irrigation and sustaining agriculture in Rajasthan. The river is originating near Ajmer and it spans 495 km before reaching Gujarat. Encompassing seven districts, the Luni River basin grapples with semiarid to arid climates, characterized by extreme temperatures, minimal rainfall, and humidity. The region's average annual rainfall is 464 mm based on IMD data from 2000 to 2022.

Methodology

The methodology includes identifying appropriate sites for pumping tests through a thorough examination of geological data. The hydrogeological data from the Central Ground Water Board (CGWB) will be collected for the analysis. It is proposed to construct exploratory wells (in confined and unconfined aquifer) for subsurface investigations. While drilling the sediment samples will be collected for preparing lithological profiles. The sediment samples will also be used for lab experiments to estimate hydraulic conductivity. The pumping tests experiments have been proposed to conduct at 20 sites where data is not available. The constant-rate or step-drawdown methods would be utilized for the experiments and then the acquired data would be analyzed using suitable methods such as Theis or Jacob methods to ascertain vital aquifer parameters, including transmissivity, storativity, and hydraulic conductivity. The trend analysis involves gathering historical groundwater level data from existing observation wells monitored by the CGWB within the basin. It's essential to distribute these wells strategically across different hydrogeological settings to capture groundwater level variations accurately. The statistical methods such as linear regression and the Mann-Kendall trend test would be employed to analyze temporal trends in groundwater levels in the study period. Additionally, periods of notable deviations from long-term averages, such as drought or wet cycles, would be identified and analyzed for their impact on groundwater dynamics. Furthermore, geostatistical techniques like kriging and other interpolation methods would be used to spatially interpolate groundwater level data, creating continuous surfaces of groundwater levels across the basin. The analysis may pinpoint hotspots of rising or declining groundwater levels. Correlations between groundwater level fluctuations and various factors such as land use/land cover changes, proximity to surface water bodies, and hydrogeological properties would also be thoroughly investigated.

Outcome/Deliverables:
A comprehensive technical report, research papers, and conference presentations would be done to disseminate the findings to stakeholders, water resource managers, academicians, and local communities etc.

Action plan and timeline

Work element	**March-Jun 2024**	**July-Sep 2024**	**Oct-Dec 2024**	**Jan-Mar 2025**	**Apr-Jun 2025**	**July-Sep 2025**	**Oct-Dec 2025**	**Jan-Feb 2026**
Literature Review, Secondary data collection from different organization and its analysis								
Field visit and conducting the field and lab experiments								
Statistical analysis of collected data								
Generation of spatio-temporal trend analysis map								
Report and publications								

Budget:

Items	**Quantity**	**Budget (INR)**
Travelling cost	6 visits/ year	1000000
Well Drilling and construction	2	350000
Field expenditure for conducting pumping test @ 25,000/test	20	500000
Contingencies/Miscellaneous expenditure	-	200000
Total		2050000

13 PROJECT REFERENCE CODE: NIH/GWH/24-27

Title of the study: Characterisation and Modeling of Multi Aquifer System of LUNI River Basin in Rajasthan Under Climate and Anthropogenic Influences

Team Members:
Dr. L. Surinaidu (PI); Dr. Anupma Sharma (Co-PI); Dr. Ajit Behera (Co-PI); Dr. Sumant Kumar (Co-PI); Mr. Sudesh (Co-PI)

Type of the study: Internal Research Study
Nature of the study: Research
Duration: 36 Months
Budget: Rs. 65 Lakhs

Objectives:

- To map the multi-aquifer systems with fresh and saline aquifer demarcations in the LUNI river basin using advanced geophysical technique EVRI and ERT.
- To delineate the Paleo channels in the study area using geophysical techniques.
- To construct the 3D integrated hydrological model for the estimation of runoff, ET, and groundwater budget using finite element numerical model HYDROGEOSPHERE.
- To quantify the climate and land use change impacts on future groundwater resources availability under different climate change and land use.
- To develop the management strategies for sustainable groundwater utilisation.

Methodology:
The proposed research aims for characterisation of multi-aquifer system in Luni basin with advanced geophysical techniques and precise groundwater balance by considering pertinent hydrogeological data. The present research work integrates/uses data generated from other projects in the LUNI river basin (P1, P2, P3 in figure 2). During the project period, the aquifer systems in the study area will be mapped using advanced geophysical techniques called 3D Electrical Vector Resistivity Imaging (3D full waver) which provide subsurface data in 3D with a high resolution and also with 2D Electrical Resistivity Tomography (ERT). The collected data will be validated with available bore well lithologs, well logging including resistivity and gamma logging will also be carried out to obtain distributed bore well lithology and to clearly demarcate the fresh and salt water interface at different depths. Finally, a fully 3D and coupled surface-subsurface hydrological model will be constructed using HYDROGEOSPHERE code.

The conceptualisation of fully integrated model will be attempted by integrating data collected and analysed under other related project in Luni basin during study period which includes climate, soil properties and time series land use data (Project 1), aquifer parameters and water quality data of both surface and groundwater (Project 4). The outcome of project 1 (UZ modelling-recharge) will be used to compare with portion of UZ model in the integrated groundwater model in the present study. The work flow/methodology of developing integrated hydrological model is presented in Figure 3. The model will be calibrated and validated against historical observed streams flows and groundwater levels data from the year 2000 to 2023. The isotopes data collected during study will also be utilised to calibrate the groundwater residence time (Project 3). Finally, a complete water balance will be estimated for entire hydrological processes for more than two decades from the year 2000 to till 2023.

The well calibrated and validated model will be used to predict the future groundwater availability by forcing model with projected climate change data in different scenarios (SSPs) until the year 2100.
A suitable water management practices and management strategies will be suggested based on distributed water availability for future and integrating other hydrogeological data considering different climate change scenarios.

Outcome/Deliverables:

1. Maps depicting subsurface aquifers and Paleo channels.
2. Water balance estimations including runoff, groundwater, ET and optimal groundwater extraction rates.
3. Optimal land use maps under different climate change scenarios and water resource availability.
4. Integrated water resource management plan for entire LUNI basin.
5. Three publications from research work that is planned in the project.

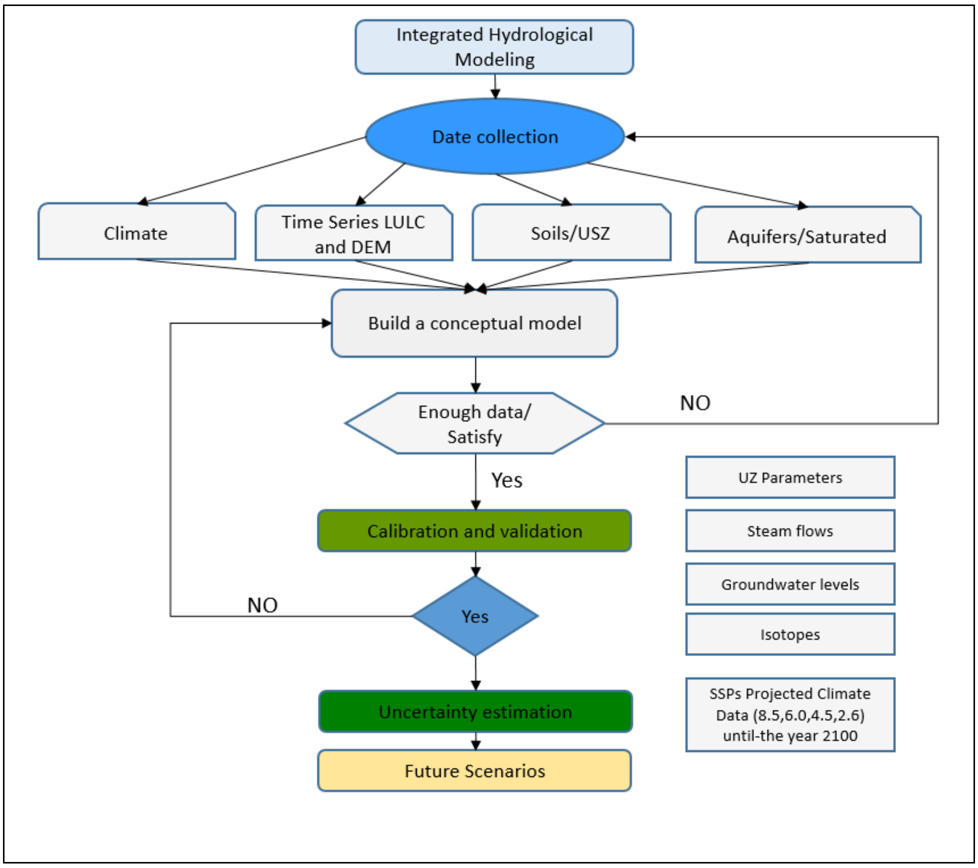


Fig.3 Figure representing work flow for integrated hydrological modelling and management

Beneficiaries:

- Local governments for policy formulation and resource management.
- Farmers for agriculture water management and fresh water supplies for domestic purpose.
- School children for capacity development on knowledge generation on different technologies available for resource assessment and management.

Lab facility: Will be used existing ERT geophysical equipment, and need to buy/subscribe integrated hydrological modeling software and need to hire well logging equipment.

Time Lines:

Table 1. Table showing sub-work components and time required for different work components

S.NO	Work Element	Months							
		3	9	15	18	24	30	33	36
1	Secondary Data collection, field visit and base maps preparation								
2	Carry out EVRI for subsurface mapping								
3	Well logging at represenative locations								
4	Interpretation of geophysical dtata with integration of hydrogeological data, well logging and Report writing								
5	Publication (2)								
6	Integrated hydrological modeling by integrating hydrogeological, hydrochemical and remotesensing data								
9	Water Management/allocation Plan								
7	Publication (2)								
8	Outreach activity for local school/colleges								
10	Publication								
11	Workshop								
12	Final Report								

Budget:

Table 2. Table showing budget required for different work elements

	Description	Number of months	Budget(INR)
Research Fellows (2)	1.Geophysics	36	1353375
	2.Hydrology/hydrogeology	36	1353375
Consumables	Field consumables		350000
Contingencies	Travel,Vehicle hire, labour hire, instrument hire(well logging) and miscellaneous		2500000
Software	HYDROGEOSHPERE (Subscription) for Two years		300000
Outreach activity for school/college students			150000
Workshop			500000
		Total	6506750
		Say	**6500000**

HYDROLOGICAL INVESTIGATION DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. S D Khobragade	Scientist G & Head
2	Dr. M S Rao	Scientist F
3	Dr. Gopal Krishan	Scientist E
4	Dr. Santosh M. Pingale	Scientist D
5	Dr. Tripti Muguli	Scientist D
6	Sh. Rajeev Gupta	Scientist B
7	Sh. Ruchir Patidar	Scientist B
8	Sri V K Agarwal	Scientist B
9	Dr. Amit Pandey	Scientist B
10	Sh. Drona Khurana	PRA
11	Sh. Vishal Gupta	PRA
12	Sh. Raj Kumar Dewansi	RA

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जल विज्ञान संस्थान
आपो हिष्ठा मयोभुवः

APPROVED WORK PROGRAMME FOR THE YEAR 2023-24

S. N.	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1.	Hydrogeological and Isotopic investigation of groundwater in Himalayan Watershed of Kashmir, India	Gopal Krishan (PI) M.S. Rao *SKUAST-Srinagar* Rohitashv Kumar	1.5 years (09/22 – 03/24)	On-going
2..	Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions Of India	SD Khobragade (PI), Dr. Vishal Singh, Sudhir Kumar	3 years (04/22-03/25)	On-going
3.	Runoff and Water Storage Capacity Estimation Using Different Resolutions of Topographic Data for Deciding Rainwater Harvesting Strategies	S.M. Pingale(PI) Soban Singh Rawat, S. D. Khobragade Rajeev Gupta	2 Years (04/23-03/25)	On-going
4.	Sedimentation and Water Quality Study of Fulhar Lake, Pilibhit (U.P.)	Rajeev Gupta (PI), S. D. Khobragade, S.M. Pingale	2 Years (04/23-03/25)	On-going
5.	Developing a Stable Isotopic Analysis System for Analyzing the Dissolved Nitrates in Water	Dr M Someshwar Rao, Sc. 'F' Mr Vishal Gupta, SRA	1 and half yrs 04/23-09/24	Dropped
SPONSORED PROJECTS:				
1.	Groundwater Fluctuations and Conductivity Monitoring in Punjab - Groundwater resilience in Punjab and adaptation to future changes in climate and water resource demands (title modified by funding agency)	Gopal Krishan (PI), S. Singh, M. S. Rao *BGS, UK:* Dr. Dan Lapworth Dr. Alan MacDonald Dr. Daren Goody BGS, UK	5 years (12/17-11/24)	On-going
2.	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Co-coordinator) Federal Min. of Education and Research, Germany	3 years (07/20 – 06/23)	On-going
3.	Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	Gopal Krishan (PI), MS Rao DSTSERB	3 years (04/21 – 03/24)	On-going
4.	Changing The Fate of The Hindon River By Evaluating The Impact Of Agriculture On The Water Balance: Developing a Template for a Cleaner Ganga River	Dr. M. K. Sharma (**PI**) Ms. Anjali Dr. Vishal Singh Dr. SM Pingale, Dr.Suhas Khobragade Dr. Pradeep Kumar, Dr.Nitesh Patidar, Dr.Surjeet Singh.	5years (04/22-03/27)	On-going

PROPOSED WORK PROGRAMME FOR THE YEAR 2024-25

S. N.	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1.	Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions Of India	SD Khobragade (PI) Vishal Singh Sudhir Kumar	3 years (04/22-03/25)	On-going
2.	Runoff and Water Storage Capacity Estimation Using Different Resolutions of Topographic Data for Deciding Rainwater Harvesting Strategies	S.M. Pingale(PI) Soban Singh Rawat S. D. Khobragade Rajeev Gupta	2 Years (04/23-03/25)	On-going
3.	Sedimentation and Water Quality Study of Fulhar Lake, Pilibhit (U.P.)	Rajeev Gupta (PI) S. D. Khobragade S.M. Pingale	2 Years (04/23-03/25)	On-going
4.	Development of radiocarbon dating facility	Tripti Muguli (PI) M Someshwar Rao Amit Pandey	1 year (04/24-04/25)	**New Study**
5.	Understanding Surface Water Groundwater Interactions in the Narmada River Basin and its Hydrological Implications	Amit Pandey (PI) S. D. Khobragade M Someshwar Rao Tripti Muguli	3 years (04/24-03/27)	**New Study**
6	Hydrological and hydrogeological investigations in the Yamuna river basin using isotope geochemistry.	Tripti Muguli Suhas Khobragade M Someshwar Rao Ruchir Patidar Vipin Agrawal Amit Pandey	3 years (04/24-03/27)	**New Study**
7	Fingerprinting of aquifer dynamics in India through isotopic and geochemical approach: demand driven investigations at regional scale under NAQUIM 2.0	Tripti Muguli Suhas Khobragade	3 years (04/24-03/27)	**New Study**
8.	Quantifying Current and Future Meteorological Drought Characteristics and Identifying Risk Zones in Central India	Ruchir Patidar (PI), S.M. Pingale, S.D. Khobragade	3 years (04/24-03/27	**New Study**
SPONSORED PROJECTS:				
1.	Groundwater Fluctuations and Conductivity Monitoring in Punjab - Groundwater resilience in Punjab and adaptation to future changes in climate and water resource demands *(*title modified by funding agency*)*	Gopal Krishan (PI), S. Singh, M. S. Rao *BGS, UK:* Dr. Dan Lapworth Dr. Alan MacDonald Dr. Daren Goody BGS, UK	5 years (12/17-11/24)	On-going
2.	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Co-coordinator) Federal Min. of Education and Research, Germany	3 years (07/20 – 06/23)	On-going

S. N.	Project Title	Study Team	Duration	Status
3.	Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	Gopal Krishan (PI), MS Rao DSTSERB	3 years (04/21 – 03/24)	On-going
4.	Changing The Fate of the Hindon River By Evaluating The Impact Of Agriculture On The Water Balance: Developing a Template for a Cleaner Ganga River	M. K. Sharma (**PI**) Ms. Anjali Vishal Singh SM Pingale, Dr. S.D. Khobragade Pradeep Kumar, Nitesh Patidar, Surjeet Singh.	5years (04/22-03/27)	On-going

HYDROLOGICAL INVESTIGATIONS DIVISION

ITEM NO. 54.2 ACTIONS TAKEN ON THE ADVICE / DECISIONS OF THE 53rd MEETING

The specific action taken on the advice/decision of the 51st meeting of Working Group of NIH are as follows:

SN	Project	Comments/ suggestions	Action Taken
INSTITUTE FUNDED R & D STUDIES			
1	Feasibility of Open Sources Data for the Estimation of Runoff and Water Storage Capacity for Rainwater Harvesting Strategies	(i) Dr. Praveen Thakur suggested to modify the title from feasibility to application since it is not a feasibility study. (ii) Sh. Sudhindra Mohan Sharma suggested to change the objectives as present objective are more like work elements	The title has been accordingly modified. The objectives have been modified as suggested.

ITEM NO. 54.3 PROGRESS OF THE WORK PROGRAM OF THE DIVISION FOR THE YEAR 2023-24

As per the approved work program, the status of studies carried out in HI Division during 2023-24 is given below:

Type of study/Project	Completed during 2023-24	To continue in 2024-25	Total
Internal R & D Studies	01*	04	05
Sponsored Projects	01*	02	03
Total	02	06	8

*one R& D study and one Sponsored project is to be completed by March, 2024.

Details of Research Publications by the Division during 2023-24

Research Publication	Published	Accepted	Communicated
Books/Book Chapter	2	-	-
International Journals	12	-	-
National Journals	-	-	-
International Conferences	9	-	-
National Conferences	10	-	-
TOTAL	**33**	**-**	**-**

Details of samples analysed by the Division Laboratories during 2023-24:

S.N.	Parameter analysed	No. of samples
1.	δ^2H on DI-IRMS	2552
2.	δ^{18}O on DI-IRMS / CF-IRMS	2808
3.	Tritium	180
4.	WQ samples on IC	870

Visits Abroad
Dr. Gopal Krishan, Scientist E, visited Germany during October 14-23 2023

Details of major instruments purchased by the Division & its labs during 2023-24

S.N.	Name of Instrument	Qty.	Total Cost (Rs.)
1	Automatic Weather Station	03	10,42,500.00
2	Portable Flow Probe	01	2,24,200.00
3	AMC of 20 KVA online UPS	01	24,780.00
4	Surface Velocity Radar	01	2,92,640.00
5	Guelph Permeameter	01	7,08,000.00
6	DWLR for pumping test in deep Piezometers	02	3,54,000.00
7	Automatic Temperature Profiler	02	1,09,571.42

Details of other major instruments/services in labs under during 2023-24

S.N.	Name of Instrument	Qty.	Total Cost (Rs.)
1	AMC of Ultra Low Level Scintillation Counter	01	Under Process
2	Digital Precision Balance	01	Under Process
3	Digital Analytical Balance	01	Under Process
4	Digital Platform Balance	01	Under Process
5	Hot Air Oven Big	01	Under Process
6	Hot Air Oven Small	01	Under Process
7	Water Potential measurement system	01	Under Process
8	Liquid Nitrogen Plant	01	Under Process
9	Spares of Dual Inlet IRMS		Under Process
10	Radon Measuring Instrument	02	Under Process

The progress of the various studies undertaken during 2023-24 is given below:

A. INTERNALLY FUNDED R & D STUDIES

1. PROJECT REFERENCE CODE: NIH/HID/R&D/2022/1

Study Title:	**ASSESSMENT OF THE POSSIBLE IMPACT OF CLIMATE CHANGE ON EVAPOTRANSPIRATION FOR DIFFERENT CLIMATIC REGIONS OF INDIA**
Study Team:	SD Khobragade (PI), Dr. Vishal Singh, Scientist-C, Dr. Sudhir Kumar, Sc-G;
Type of Study:	Institute Funded R & D Study
Duration:	3 years
Date of Start:	April, 2022
Date of Completion:	March, 2025
Budget:	10 Lakh

Statement of Problem

Evapotranspiration is one of the key components of the hydrologic cycle. Precipitation which falls on the land is subjected to evaporation and evapotranspiration before it reaches back to the oceans, causing a significant loss of the available water. Increasing scarcity of water due to increased ET losses may lead to difficulties in meeting the various demands of the growing population and its development needs. Most of the water bodies in the warm tropical regions undergo heavy evaporation losses. As per the CWC (2006) report, average annual evaporation loss from reservoirs/water bodies in India is about 27,000 MCM. As such, any change in evapotranspiration is likely to significantly affect the global hydrologic as well as energy cycle (IPCC, 2013). Being a cause of significant water loss, evapotranspiration plays a major role in determining the stream flow regime. Therefore, understanding the impact of temperature rise or climate change on evapotranspiration is essential for a proper understanding of the impact of climate change on the hydrological regime of the stream and water availability in the basin or water body. It shall provide a proper assessment of how much more or less water shall be available and, if less water is available, then how much additional water shall be required to meet the various demands. Unfortunately, not many studies have been reported on assessment of impact of climate change on evaporation and Evapotranspiration, more so for India.

Objectives

The major objectives of the proposed study are: ·

i) To assess the present ET regime of some selected climatic regions of India
ii) To assess the impact of rising temperature on various hydro-meteorological parameters used for ET assessment
iii) To predict and compare the possible impact of climate change on ET regimes of the selected climatic regions of India

Study Area

The study is proposed to be carried out for different climatic regions of India. About five areas are to be identified to represent different climatic regions.

Methodology

i) The present average ET rates for selected climatic regions of India shall be estimated from the present hydro-meteorological data of last few decades, using the Penman-Monteith model
ii) All temperature dependent hydro-meteorological paramours shall be identified.
iii) Projected climatic data variables such as minimum and maximum temperature from the latest GCMs developed under CMIP6 project shall be obtained to analyze the impact of climate change on ET factors.
iv) For this purpose, the evaluation of four best GCMs with SSP245 and SSP585 scenarios

v) (total eight scenarios) will be done for selected climatic regions and then the bias correction and spatial downscaling of the GCM variables will be performed for selected climatic regions of India.

vi) The downscaled and bias corrected GCM variables shall be used as input to the Penman-Monteith model and future changes in ET rates will be estimated by performing probabilistic linear and non-linear trends analysis (e.g. Quantile regression, Q-Q plots, and CDF).

vii) The present and projected ET rates shall be compared to assess the impact of climate change on ET variability (in terms of magnitude of change) for different regions.

viii) The present and predicted rates of different climatic regions shall be compared and factors responsible variation shall be identified

The progress of the study shall be discussed during the WG meeting.

2. PROJECT REFERENCE CODE: NIH/HID/R&D/2022-23/2

Title of the study	:	HYDROGEOLOGICAL AND ISOTOPIC INVESTIGATIONS OF GROUNDWATER IN HIMALAYAN WATERSHED OF KASHMIR, INDIA
Name of PI and members	:	NIH, Roorkee, India Dr. Gopal Krishan (PI) Dr. M.S. Rao (co-PI) **SKUAST-Srinagar** Prof. Rohitashv Kumar (co-PI)
Type of study	**:**	Internal
Date of start (DOS)	**:**	September 2022
Scheduled date of completion	**:**	March 2024
Location	**:**	Kashmir

Sr. No.	Study objectives	Achievements
1	To assess surface and groundwater quality using hydrogeochemical analysis	**100%** – Sampling sites are finalized
2	To characterize isotopic signatures in groundwater and surface water	**100%-** First set of samples collected and analysed
3	Delineation of the groundwater recharge zones and spring-water quality assessment	In progress

Statement of the problem

One of the main tributaries of the river Jhelum, the Doodhganga stream provides a vital source of drinking water and irrigation for the people of Budgam and Srinagar. Any contamination near recharge areas can lead to degradation of water quality in areas of discharge (streams and springs). Therefore, monitoring the water quality is a crucial issue for the sustainable management of water resources. Keeping in mind these concerns, it is important to delineate the potential recharge sites in order to prevent or at least reduce future contamination. Stable Water isotopes - hydrogen (δ^2H) and oxygen ($\delta^{18}O$) in conjunction with conventional hydrogeology and hydrogeochemistry have been shown to be effective tools for solving many critical hydrological problems (Clark and Fritz 1997; Bhat and Jeelani, 2015). Therefore, the mountain watershed of the Doodhganga River is selected for the research in this study. Combining field investigation and indoor analysis, this study will analyze the hydrogen and oxygen isotopes and hydrochemical characteristics of surface water and groundwater in the basin using environmental isotope and hydrochemical techniques. This study would discuss the effect of altitude on hydrogen and oxygen isotopes and the interaction between surface water and groundwater in the mountainous watershed of the Doodhganga River. This is of great significance for enhancing the understanding of the water cycle in mountain basins and understanding the interaction and transformation relationship between surface water and groundwater for the rational utilization and effective protection of water resources in mountainous areas, as well as preventing and controlling water pollution. This study also provides a theoretical basis for the study of the water cycle in the basin under changing environments.

Study area

Doodhganga literally means stream of milk and implies that the stream once carried water as pure as milk and as holy as the Ganges. Doodhganga catchment of Kashmir Valley located in the northern part of India between 33° 42′ to 34°50′ N and 74°24′to 74°54′ E, covers an area of 655 km². It is one of the left bank tributaries of the river Jhelum, originating on the eastern slopes of the Pir Panjal mountain range below the Tatakuti peak which is at an altitude of 4,500 m a.s.l (Hussain and Pandit 2011a, b). The topography of the watershed is varied and exhibits altitudinal extremes of 1,548–4,634 m a.m.s.l (Romshoo and Rashid 2012). The upper reaches of the catchment that is usually snow covered and has extremely steep slopes of more than 70 %, followed by comparatively lesser steep slopes of 60–70 % which reflect the different aspects of mainly the Karewa formations in the middle parts of the watershed. The downstream watershed area have very gentle slope of 0–1 % (Hussain and Pandit 2011a, b).

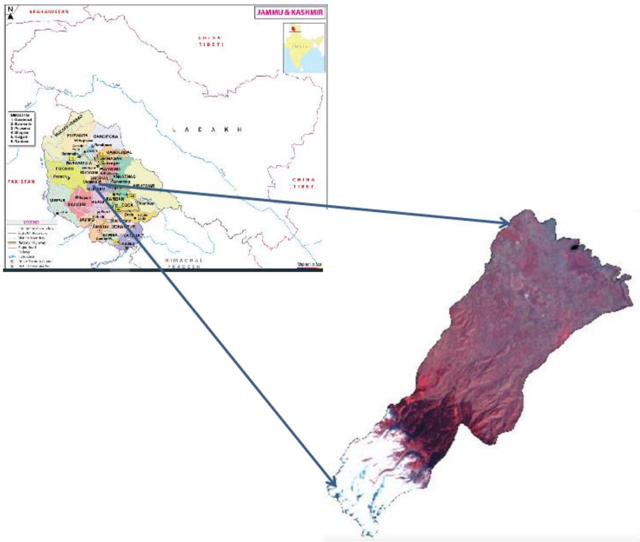


Fig. 1. Doodhganga Watershed

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

Methodology

Preliminary Work

Base map of the study area digitized from the survey of India toposheet using ArcGIS 10.2 software or delineating the area using HecGeoHMS in ArcGIS platform.

Precise locations of sampling points determined in the field and the exact longitudes and latitudes of the sampling points imported using a GIS platform.

Objective 1: To assess surface and groundwater quality using hydro-geochemical analysis.

Fieldwork, and collection of surface and groundwater water samples for the analysis of physio-chemical parameters and isotopic analysis carried out.

Physical parameters (temperature, pH, total dissolved solids, and electrical conductivity) measured and recorded in-situ using portable instruments.

Determination of major ions and trace elements

Objective 2: To characterize isotopic signatures in groundwater and surface water to delineate the sources of groundwater recharge using isotopic signatures.

Stable Water isotopes - hydrogen ($\delta^{2}H$) and oxygen ($\delta^{18}O$) analyzed

Objective 3: Delineation of the groundwater recharge zones and groundwater contamination sites / Or Assessment of groundwater contamination risk mapping.

Sources of Groundwater Recharge: The values of $\delta^{18}O$ and $\delta^{2}H$ measurements of precipitation and groundwater assessed to identify the recharge areas of groundwater. The area identified by measuring ^{2}H and ^{18}O concentrations and correlating them to the altitude at which precipitation could have infiltrated the ground.

Groundwater Contamination source assessment: The spatial variability of Hydro-geochemical and isotope values will be carried out in GIS software using geospatial analysis tool and the hotspots of aquifer contamination will be identified.

Progress

The sampling sites are identified (fig. 2) and samples are analysed for isotopes analysis

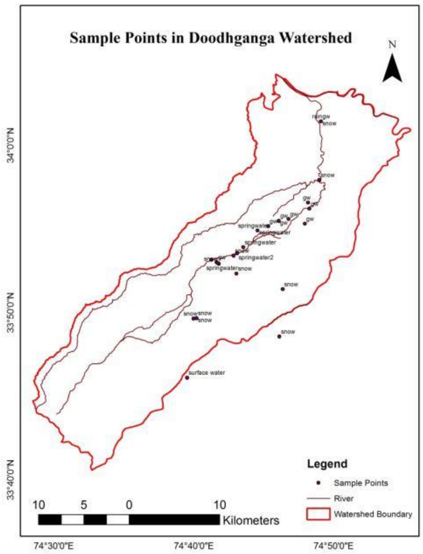


Fig.2. Sampling sites

The isotopic ($\delta^{18}O$) composition of rain exhibits significant monthly variations. December rains are the most depleted (< -20‰); in other months, it fluctuates between -4‰ and -9‰. During the pre-monsoon period (April), a highly enriched composition ranging from 0‰ to -3‰ is observed.

The isotopic data plotted for precipitation samples reveals a stable isotopic characteristic line with the equation $\delta D = 7.92\ \delta^{18}O + 14$. Some points deviate from the isotopic trend line (e.g., points 1 and 4), likely due to evaporation enrichment of falling raindrops. This observation is supported by a comparison with rainfall data from a similar date at another site (points 2 and 3) in the study area.

The isotopic composition of groundwater (GW) generally maintains an average value of -8±1.3 ‰ throughout the year, with occasional exceptions of enriched values, reaching up to -5‰ at certain locations.

The $\delta^{18}O$ of groundwater (GW) ranges from -6.7‰ to -9.3‰. With a few exceptions, the GW isotopic data aligns with the Local Meteoric Water Line (LMWL), indicating its origin from local rainwater and good surface recharge characteristic of soils (as evaporation enrichment is not observed for these points). However, certain groundwater isotopic data points (such as points 2 and 3 in the figure 3) deviate from MWL and fall along the evaporation line. Backward extrapolation traces their initial isotopic composition to the Meteoric Water Line (MWL), connecting to a GW point (point-1), indicating evaporation effect (due to combination of evaporation of falling raindrops and the evaporation of surface water and soil moisture).

Rainwater samples collected from various altitudes (ranging from 1600 m above mean sea level to 2100 m above mean sea level) show no significant dependence on altitude. This suggests that the stable isotopic composition of rainfall at a specific location is more influenced by the amount of rainfall and the evaporation effect of falling raindrops than the altitude of the sampling location.

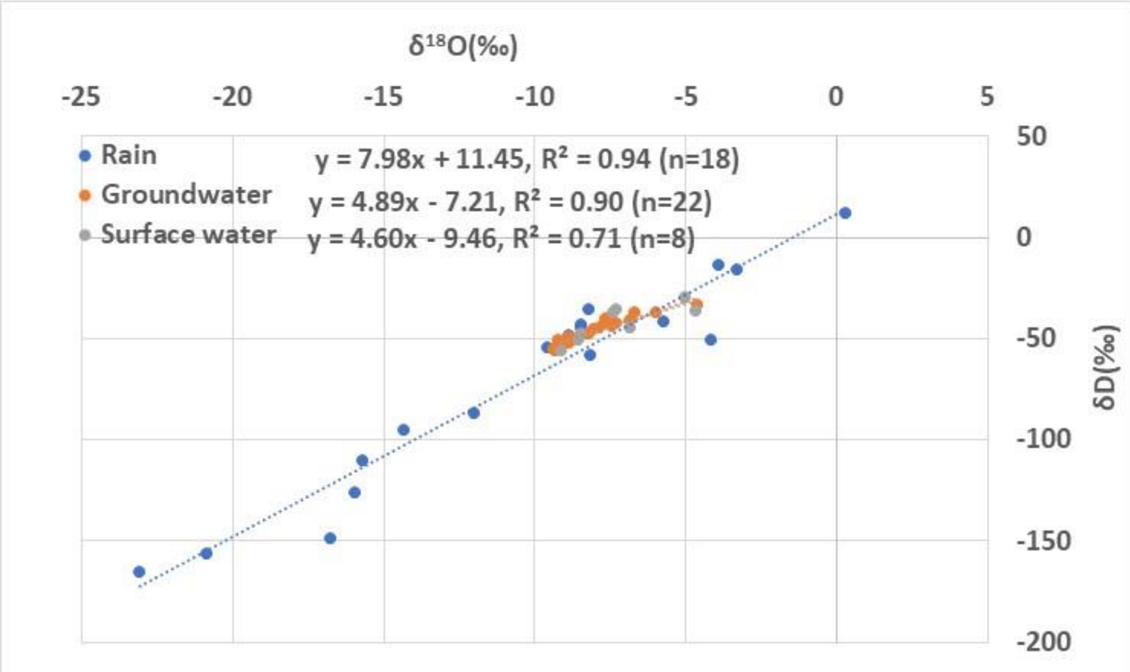


Fig.3. Isotope characterization

Action plan:

Period	September 2022 to March, 2024 (Annexure 1)	Remark
September 2022 to March 2024	Collection of waters samples Analysis of the samples Data analysis and interpretation Report writing and publication	Report preparation as per Annexure 1

Study Benefits /Impact:

- Isotope characterization of water resources in the study area
- Source identification
- Surface water-groundwater interactions
- Water quality assessment
- Reports and publications

Specific linkages with Institutions:

- SKUAST, Kashmir

Future plan

- Work continued to achieve the desired objectives

<u>Annexure - 1</u>

Hydrogeological and Isotopic investigation of groundwater in Himalayan Watershed of Kashmir, India
(QUARTERWISE FROM SEPTEMBER 2022 TO MARCH 2024)

Activity	1st	2nd	3rd	4th	5th	6th
Literature review	♦	♦				

Preparation of base maps	♦	♦				
Collection of waters samples	♦	♦	♦			
Isotope analysis		♦	♦	♦	♦	
Data analysis, data dissemination and report writing			♦	♦	♦	♦

3. PROJECT REFERENCE CODE: NIH/HID/R&D/2023-24/

Title of the Project: **RUNOFF AND WATER STORAGE CAPACITY ESTIMATION USING DIFFERENT RESOLUTIONS OF TOPOGRAPHIC DATA FOR DECIDING RAINWATER HARVESTING STRATEGIES**

Thrust Area under XII five-year plan

Sustainable water systems management: Adaptation of hydro-system to climate change
Project Team **:** S.M. Pingale (PI), S.S. Rawat, S.D. Khobragade, R. Gupta, R. Patidar

Type of Study **:** Internal R&D study
Duration **:** 2 years
Date of Start **:** 1^{st} April, 2023
Date of Completion **:** 31^{st} March, 2025
Budget **:** Rs. 18.88 Lakh
Whether externally funded or not: Internal

Statement of the Problem
The ultimate aim of this study is to understand the complexity of the different resolutions data on surface runoff and rainwater harvesting structure storage capacity estimation in the catchments. This study will do quantitative & volumetric assessment of runoff and rainwater harvesting structure storage capacity (i.e., check dam). The outcome will be useful for making effective rainwater harvesting strategies. This quantification and volumetric assessment is more important for accurate estimates and understanding the magnitude of runoff and storage capacity of the rainwater harvesting structures in the catchment. Therefore, this study will be useful for local community, policy makers, engineers and administration for appropriate management and adopting suitable rainwater harvesting strategies in the catchments.

Objectives

General objective
The general objective of the present study is to assess runoff and water storage capacity using different resolutions of topographic data from different sources.
Specific objectives:
The present study will be carried out with the following objectives:

- To compare the surface runoff in the catchments obtained using different resolutions of topographic data.
- Assessment of water storage capacity of the rainwater harvesting structure based on the runoff obtained using different resolutions of topographic data.
- Uncertainty and volumetric error analysis of runoff and water storage capacity in the catchment for different resolutions of topographic data.

Methodology

The methodology has been described here:

a. The catchment has been selected where rainwater harvesting structure is already available for its quantitative & volumetric assessment.
b. Presently, one catchment is selected from hilly terrain for this study.
c. Creation of GIS database for the selected study site.
d. The surface runoff (Peak rate and total volume) will be estimated by using Rational method and SCS curve number method. These will be estimated using different resolutions of topographic data while other datasets will be taken same.

e. The Intensity-Duration-Frequency (IDF) curves for different return periods of rainfall and flow duration curves for sustainability analysis of the streamflow will be developed for safe design of rainwater harvesting structures.
f. The water storage capacity of the rainwater harvesting structure will be estimated by using different resolutions of topographic data and hydrological modelling tool.
g. Also, quantification & volumetric assessment of runoff and water storage capacity will be carried out for making rainwater harvesting strategies in the catchment.
h. Finally, suitable recommendations and appropriate resolution of topographic data from different sources will be quantified for making rainwater harvesting strategies in the catchment.

Study area

The present study is being carried out for the selected structure and catchment considering hilly terrain of Uttarakhand State.

Research outcome from the study

- ✓ The quantification and volumetric assessment of surface runoff estimation in terms of total volume and peak rate of runoff using different resolution of topographical data from different sources.
- ✓ Also, the accurate quantification and volumetric assessment of water storage capacity of the rainwater harvesting structure based on different sources and scale of topographical data.
- ✓ We will know the impact of different resolution data on runoff & storage estimation & how we can utilize proper topographical data for further this estimation.
- ✓ Development of IDF curves, which can be used in the safe design of hydrologic, hydraulic, and water resource systems; and flow duration curves, which can be used for estimation of dependable flows for water availability and distribution planning in the catchment area.
- ✓ The outcome and procedures of estimates will be useful for policymakers, engineers, scientific community & stakeholders for making rainwater harvesting strategies in the catchment areas.

Progress of the study

Initially, one study site has been identified at Jagddhari Village in Chamba of Tehri-Garhwal District of Uttarakhand. This site has constructed one Amrit Sarovar (rainwater harvesting structure i.e., check dam) by the State Government. The downloaded different resolutions of topographic data from different sources (i.e., SRTM 90 m, ASTER DEM 30 m and ALOSPALSAR 12.5 m) for the study site. The catchment area of study site has been delineated and created GIS database for the study site. A field investigation will be carried out to investigates further details and confirm the accurate estimates. Details analysis is in progress and analysis of the results will be presented during the meeting. The research work is still ongoing and findings will be shared in future working group meetings.

4. PROJECT REFERENCE CODE: NIH/HID/R&D/2024/5

Title of the Study:	**SEDIMENTATION AND WATER QUALITY STUDY OF FULHAR LAKE, PILIBHIT (U.P.)**
Study Group:	Rajeev Gupta (PI), Suhas D. Khobragade, S.M. Pingale
Collaborating Institutions:	Distt. Administration, Pilibhit
Type of Study:	Institute Funded R & D Study
Budget:	INR 15.00 Lakh
Nature of Study:	Applied Research
Date of start:	April 2023
Scheduled date of completion:	March 2025
Duration of the Study:	2 Years

Statement of the problem

The present proposal is in line as per the requirement of the state government to conserve the lakes and conservation of Tortoises. The present study aims to understand the hydrological regime of the lake by investigating the various hydrological processes. The study will be useful in conserving the Fulahar lake, which is one of the important and religious place of the Pilibhit U.P.

Objectives

The ultimate aim of this study is to asses the sedimentation rate and water quality and of the Lake. The major objective s of the proposed study are: ·

i) To estimate sedimentation rate and expected life of the Lake

ii) To assess the environmental health of the Lake through assessment of its water quality

Study area

Fulhar lake in Madhotanda, about 30 km, 3 km east of the Pilibhit Town in Uttar Pradesh at an elevation of 185 m. The Gomti, a monsoon and groundwater-fed river and flows in the heart of Lucknow the capital of biggest and historical state U.P., originates from Gomat Taal which is formally known as Fulhar lake. The river Gomti as "pious mother of Maharshi Vashishth, spiritual guide to Lord Ram". Gomti river flows through UP and only and a tributary of Ganga river which rises from plains. Around 26 different type of Tortoise are available in the Fulhar Lake. The state administration is developing a Tortoise conservation and research centre at nearby lake area.

Methodology

For detailed hydrological investigations following methodology would be employed:

(i) Collection, processing and analysis of the available data

(ii) Generation of additional required data.

(iii) Field investigations and field surveys

Sample collection and laboratory analysis: Lake sedimentation would be studied using bathymetric survey method. Water quality status of the Lake would be assessed from the water quality data of the Lake. Water and sediment samples from the Lake would be collected and analyzed in the laboratory

Progress of the work

- Preliminary survey was conducted in April 2023 and sampling locations were identified.
- We have made two field visits to collect pre & post monsoon samples during the May & Oct 2023 respectively. Measured groundwater levels and collected groundwater samples for stable isotope analysis ($\delta^{18}O$ and $\delta^{2}H$). Also, performed in-situ measurement of water quality parameters (e.g., Temp, EC, pH) using multi-parameter water quality analysed..
- Pre & Post monsoon water quality and isotope samples have been analysed
- Maps (Digital Elevation Model, Land Use & Land Cover, Drainage & Slope) prepared

Future Plan

- Bathymetry survey of the lake to be done
- Pre & post monsoon sampling of the current year in 2024.
- Data collection

5. PROJECT REFERENCE CODE: NIH/HID/R&D/2023/1

Study Title:	**DEVELOPING A STABLE ISOTOPIC ANALYSIS SYSTEM FOR ANALYZING THE DISSOLVED NITRATES IN WATER**
Study Team:	Dr M Someshwar Rao, Sc. 'F' Mr Vishal Gupta, SRA
Duration:	One and half years (April, 2023-September, 2014)
Funding:	NIH Funds

This work is proposed to be dropped.

SPONSORED PROJECTS

1. PROJECT REFERENCE CODE: NIH/HID/BGS/17-24

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) Dr. M.S. Rao (co-PI) Dr. Surjeet Singh (co-PI) **BGS, UK** Dr. Dan Lapworth (PI) Prof. Alan MacDonald (project coordinator) Prof. Daren Gooddy (Co-PI)
Type of study	**:**	**Sponsored,** BGS, UK.
Date of start (DOS)	**:**	December 2017
Scheduled date of completion	**:**	November 2024
Location	**:**	Bist- Doab, and South-west Punjab

Sr. No.	Study objectives	Achievements
1	To characterise multi-year variability in groundwater level and SEC using high frequency groundwater measurements within nested shallow and deep piezometers	**Achieved** – The groundwater is depleting in Bist-doab part and more of canal usage is found in south west Punjab
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	**Achieved (95%)-** The results indicate that groundwater recharge in the part of northern Punjab is dominated by meteoric sources from high intensity events. However, in a small proportion of sites located in close proximity to some canals and rivers have significant surface water inputs. Isotope observations indicate rapid changes in groundwater recharge sources linked to post-monsoon pumping and seasonal connectivity to surface water inputs even at some deep sites.
3	Characterize groundwater residence times and water quality in southern Punjab through detailed sampling to assess the resilience of groundwater abstraction as an adaptation strategy for continued food production.	**Achieved (92%)**– Samples for shallow (year 2023) and deep wells (year 2024) have been analyzed at BGS, UK for CFC and SF_6, data interpretation is in progress
4	Assess groundwater vulnerability to salinization from water-logging from increased surface water flows (including canal flows) through glacial melt-water and identify	**Achieved (90%)-** There seems to be lower TDS at some shallow and intermediate sites in the Piezometer network, but this is not at a consistent depth and likely due to local pumping and canal effects

	potential solutions for future priority research, and inform robust conceptual models of groundwater salinization in this region of India.	
5	Deliver a new groundwater data set from southern Punjab to enable comprehensive and transparent discussions of adaptation solutions to water resources in this region	**Achieved (80%)**Is under process
6	To prepare a status report on groundwater issues in Punjab	Report is under preparation and in addition one manuscript is published this year and work is in progress for other

Statement of the problem

Punjab is underlain by the Indus Basin aquifer which has been rated as the second-most over stressed aquifer in the world. Among all the states of India, Punjab is drawing highest amount of groundwater resulting in its declination at an alarming rate. Bist-doab is one of the important regions of Punjab comprising of the districts of Hoshiarpur, Jalandhar, Kapurthala and SBS Nagar (fig. 1). In recent years, a large volume of groundwater reported to be extracted in Hoshiarpur and Jalandhar districts. Agriculture is dependent on groundwater irrigation and concerns exist over the sustainability of current and future exploitation of groundwater; tracer data can help quantify groundwater renewal processes. In the joint study with BGS, UK high frequency water level and conductivity data is interpreted along with the analysis of water samples for a suite of tracers.

In addition to the study in Bist-Doab, the study area has been extended to south-west (SW) Punjab where increasing demand of the irrigation water led to improper surface water irrigation policies resulting in water logging problems coupled with apprehension of saline zones formation by salinity ingression towards central Punjab due to excessive groundwater pumpage. To assess the inter-connection between aquifers sampling has been planned in Faridkot, Fazilka and Muktsar districts of Punjab (fig. 1).

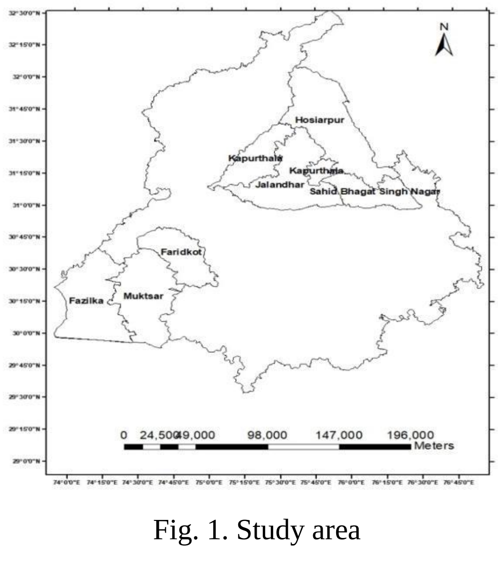


Fig. 1. Study area

Methodology:

In this study, groundwater level and conductivity data are monitored and high resolution field based observations are collected. For this loggers were installed in Saroya, Bhogpur and Sultanpur Lodhi in the month of May, 2019 (Fig. 2). In addition to these sites water level loggers were installed in Bhogpur, Tanda and Nakodar in October, 2019 (Fig. 2). The groundwater samples were collected for analysis of CFC, SF6 (at BGS, UK) for better understanding of the aquifer systems from 10 sites (fig. 3) from the network of depth wise piezometers . Piezometers were developed in the depth range of 5 m-32 m and categorized as shallow (<10 m); intermediate 1st (10-15 m); intermediate 2nd (18-20 m) and deep (28-32m).

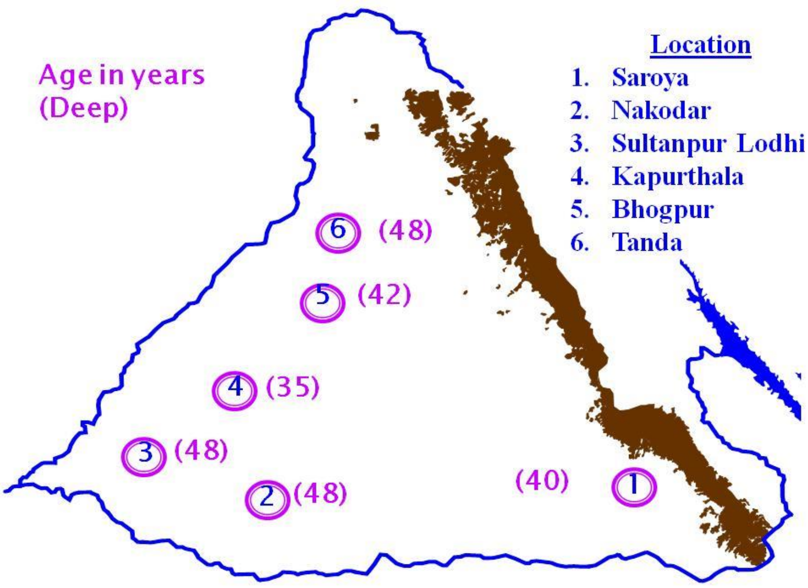


Fig. 2. Sites for installation of loggers in Bist Doab, Punjab

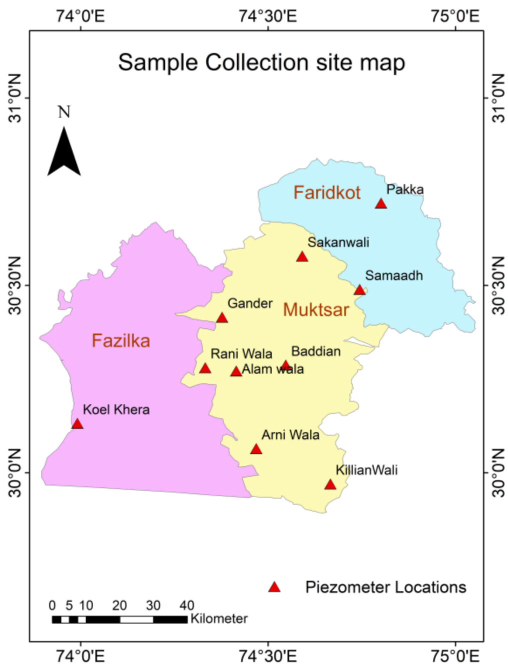


Fig. 3. Sites for sample collection in south-west, Punjab

Findings:

Bist-Doab

Figure 4 shows water stable isotope results as a cross-plot of δ18O vs δ2H for rainfall (Figure 4a), surface waters (Figure 4b-d) and average values for groundwaters as sample numbers vary considerably for different sites (Figure 4e-f). Long term weighted mean rainfall (LTWMR) values for the long term rainfall sites are shown for reference and cluster quite close together, average rainfall values across all 3 rainfall monitoring sites (1-10 mm, 11-30 mm and >30 mm) are also shown for reference as is the GMWL. The Dholbaha reservoir data clearly deviates from the GMWL, showing enrichment (more positive values) in δ2H relative to δ18O, consistent with an evaporative mixing line (d2D = 5.28 x d18O - 10.81, R^2 = 0.82, Figure 4b). The River Beas and canal samples are isotopically depleted compared to the weighted rainfall values (Figure 4c). The depleted end member relative to the meteoric rainfall is consistent with a higher altitude source of Himalayan water feeding the River Beas and associated canal networks. There is a small proportion of River Beas samples that show some limited evidence of evaporative enrichment (Figure 4c). The River Sutlej data fall on a mixing line between an isotopically depleted end-member relative to meteoric rainfall where most of the data points are found, presumably again consistent with a high altitude source of water, and the meteoric rainfall (Figure 4d). For a small number of surface water samples there is possible evidence of evaporative enrichment relative to the meteoric rainfall end-member. Groundwater samples are more consistent with the weighted rainfall values, however, both shallow (Figure 4e) and deep (Figure 4f) groundwater samples show a majority of data points that are isotopically depleted (more negative) relative to weighted mean rainfall and are more consistent with more depleted values found in more intense rainfall events (Figure 4f) and fall between rainfall end members and surface water end members. There is also considerably more variability in the isotope data from the shallow groundwater relative to the deeper groundwater, consistent with the homogenisation of the meteoric isotope signatures with depth due to groundwater mixing.

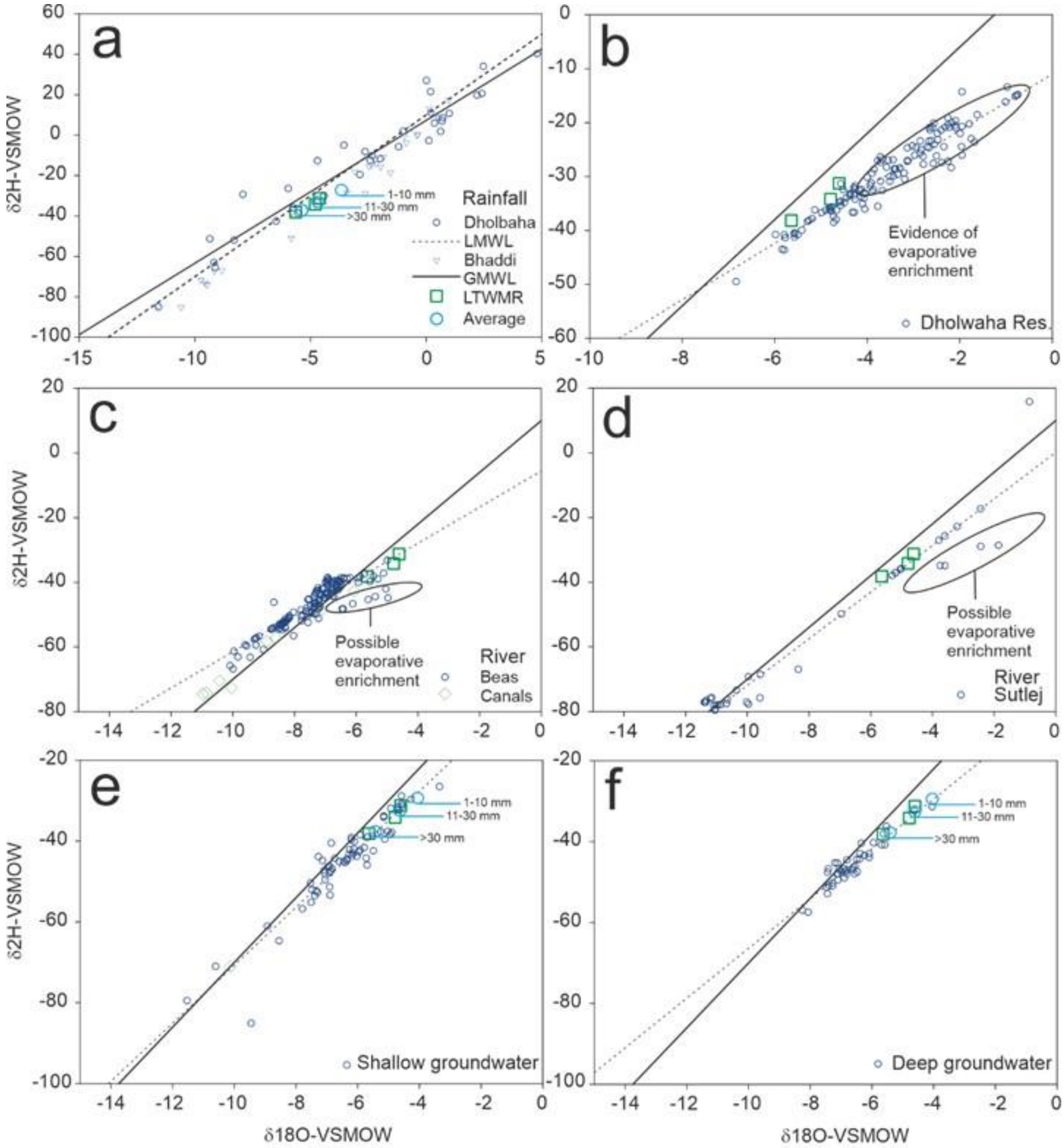


Figure 4. Cross-plots of $\delta^{18}O$ vs $\delta^{2}H$ for a) monthly amount weighted rainfall, b) Dholbaha reservoir, c) River Beas and canals, d) River Sutej, e) average shallow groundwater observations and f) average deep groundwater observations. Solid line is the GMWL for each plot, the dashed line is the LMWL for plot(a) or a regression line through the data points for plots (b-d). Long Term amount Weighted Mean Rainfall (LTWMR) for three rainfall stations in the Bist Doab (Dholbaha, Bhaddi and Dasuya) are shown as open square symbols for reference. Symbol size is comparable with measurement error for $\delta^{2}H$ VSMOW, the precision of $\delta^{18}O$ +/- 0.01 ‰. Large blue symbols show average stable isotope values for rainfall binned by rainfall amount (1-10 mm, 11-30 mm and >30 mm).

SW Punjab

In the south-west Punjab. Samples were analysed for stable water isotopes (^{18}O, ^{2}H) and electrical conductivity to delineate the sources of recharge and salinity of groundwater. Based on isotopic data ($\delta^{18}O$ = -8.8‰ to – 2.3‰) groundwater is recharged by two sources: the Sutlej river canal water ($\delta^{18}O$ = -12.6‰ to – 9.6‰) and rain water ($\delta^{18}O$ = -14.5.0‰ to 0.1‰) indicated by the depleted and enriched isotopic values. It was observed that the saline groundwater (EC=~9900 µS/cm) evolved in the formations due to the rock-water interaction, evaporation, return flow, rain and other associated human activities. The lateral and vertical aquifers interactions suggest the mixing of water between aquifer layers.

Groundwater isotope ranges are very close to those seen in in Bist-Doab for shallow groundwaters with little evidence of evaporative signatures

Work is being continued for some unanswered questions:

To find synchronisity between deep and shallow groundwater level responses
Assess the slopes of the drawdown difference (between and within sites) – does this tell us anything about the aquifer system or just the rates of pumping or both?

Action plan:

Year	**Dec. 2017 to Nov., 2024** (Annexure 1)	**Remark**
Dec. 2017 to Nov. 2024	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 Annexure 1

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

Annexure - 1

ACTIVITY SCHEDULE FOR THE GROUNDWATER FLUCTUATIONS AND CONDUCTIVITY MONITORING IN PUNJAB (QUARTER WISE FROM DEC. 2017 TO NOV. 2024)

Activity	1st to 4th	5th To 8th	9th to 12th	13th to 16th	17th to 20th	21st	22nd	23rd	24th	25th	26th	27th	28th
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

- The samples at BGS has been analysed for CFC, SF6 and other heavy metals collected in October, 2023
- The data analysis and interpretation are in progress

Publication

Krishan G, Lapworth DJ, MacDonald AM, Rao MS**.** 2023**.** Groundwater recharge sources and processes in northwest India**:** evidence from high frequency water isotope observations**.** Journal of Hydrology**-**Regional Studies**.** https://doi.org/10.1016/j.ejrh.2023.101570

Future plan

- Downloading data from water level loggers and conductivity loggers
- Collection of new data from state department from nearby piezometers
- Data analysis work will be carried out with respect to various parameters like rainfall, land use etc. to observe the seasonal and spatial variation

2. **PROJECT CODE:** NIH/HID/CCRBF/20-24

Title of the study:	EXPANSION OF THE INDO-GERMAN COMPETENCE CENTRE FOR RIVERBANK FILTRATION – CCRBF
Name of PI and members:	NIH, Roorkee, India Dr. Gopal Krishan (PI and co-coordinator) **University of Applied Sciences Dresden (HTW Dresden/HTWD), Germany** Prof. T. Grischek (Project Leader) Dr. C Sandhu (Project Coordinator)
Type of study:	**Sponsored,** Federal Ministry of Education and Research, Germany (BMBF)
Date of start (DOS):	**01** July 2020 (**Approval received in Feb, 22 Ministry of Jal Shakti & DEA**)
Scheduled date of completion:	**31** March 2024
Location:	Agra, UP and Phillaur & Dera Bassi, Punjab

Sr. No.	Study objectives	Achievements
1	Determination of the upper limit for removal of "emerging pollutants" by RBF	**95%** – Samples collected, analysed and plotted
2	Investigate the inclusion of RBF as a "smart water infrastructure concept" within the "Smart City" project of the city of Agra	**90%-** RBF technique has been proposed for master plan for the nation and is being conceptualized for selected sites including one at Agra
3	Synthesis of information for inclusion in the RBF Master Plan and guidelines	**90%-** Literature on RBF techniques used in India has been collected from various sources and compilation is in progress

Statement of the problem

Background

The floodplain of the Yamuna river between the National Capital Region of Delhi and the city of Agra (located approximately 200 km south of Delhi) is one of the most densely populated urban and rural regions in India (COI, 2011). Large quantities of untreated to partially treated domestic and industrial wastewater are discharged into the Yamuna between these two cities resulting in a critical river water quality (Agarwal and Trivedi, 1995; CSE, 2002; Seth and Babu, 2007). Despite the Yamuna's poor water quality, the river is a major source of raw water for domestic purposes for towns and cities located by it, including Agra city and for irrigation in the rural and semi-urban areas (GONCTD, 2013). After direct pumping from the river, the water is conventionally treated. However most of these conventional drinking water treatment plants are technically unable to remove the high concentrations of micro-biological, organic and inorganic parameters present in the river water thereby either resulting in deliberate interruptions in drinking water production or in widespread consumer dissatisfaction due to noticeable and unacceptable organoleptic quality of the supplied water (CSE, 2002; Sandhu et al., 2011). Furthermore, there is a widespread perception amongst the consumers that the water supplied in the taps is unsafe for consumption without prior treatment at the household level. That is why many households typically use reverse osmosis filters. There are also many areas that are not connected to the piped water supply. These areas have to rely either on groundwater (vertical wells, handpumps) or water delivered in tankers that is expensive and is not affordable by many people.

By using wells installed on the banks of flowing rivers, river bank filtration (RBF) combines the advantage of easy access to large volumes of induced surface water (SW) with the benefit of an improvement in water quality due to natural treatment processes occurring during aquifer passage. Field investigations at various locations across India including in Uttarakhand and the Yamuna floodplain (Delhi and Mathura) have confirmed that there is a large potential to use RBF as an alternative to directly abstracted SW for drinking water production, primarily because it provides an ecosystem service by effectively removing pathogens and turbidity even in monsoon (Sandhu et al. 2011, 2016).

The Preliminary surveys and 2 times sampling were conducted in Phillaur and Dera Bassi for the installation of RBF well on the bank of the Satluj and Ghaggar Rivers, respectively.

Proposed solution, technological intervention and demonstration up to 2018

In light of the previously described background and scientific investigations conducted on RBF at locations in Uttarakhand, NCR Delhi and other parts of India within the framework of the Saph Pani project (2011 – 2014) accompanied with construction of pilot RBF schemes in Uttarakhand, NIH was motivated to demonstrate RBF technology at six sites across India, including Agra, that have diverse environmental conditions within the project Peya Jal Suraksha (PJS, 2015–2018) funded by the Ministry of Jal Shakti (NIH, 2019). Consequently, the site in Agra was first investigated with standard geophysical, geotechnical and water quality investigations. Accordingly, the site was found feasible for the construction of a vertical exploratory well. The well was constructed on the riverbank in the premises of the Agra waterworks at Jeevani Mandi in February 2018. Due to the scheduled termination of PJS in 2018, only one water sample could be analysed during development of the well in 02/2018. Further investigations, including geohydraulic measurements (water levels monitored for at least one hydrological year) and water quality, could not be conducted. So it was not possible to evaluate the purification efficiency of the RBF system at Jeevani Mandi, because the system only became operational when the PJS project concluded.

Nevertheless, water quality investigations conducted at an existing high capacity horizontal RBF well in Mathura by collaborators from IIT Roorkee in 2007/2008 and subsequently by NIH Roorkee, HTW Dresden and TU Dresden at the same RBF well in Mathura and Yamuna river and near-bank groundwater from 2013 onwards in Agra and Mathura within the framework of the Saph Pani project and Indo-German Competence Centre for Riverbank Filtration (MoU NIH & HTWD, 2011) showed a high potential for RBF as a pre-treatment step for drinking water production. The main advantages of RBF in Agra-Mathura region are an improvement of organoleptic parameters (taste, odor and aesthetic appearance) and a substantial lowering of concentrations of organic compounds including dissolved organic carbon (DOC), turbidity and pathogens and a low risk of formation of disinfection by-products. The main positive observation is that while river water DOC concentrations are high and show a large seasonal fluctuation of around 9 mg/L (3 mg/L in monsoon – 12 mg/L in non-monsoon), the concentration of DOC in the RBF wells was found to be substantially lower at 3 mg/L and 6 mg/L in monsoon and non-monsoon respectively. Removal of total and fecal coliform of 1.3–1.7 and 2.3–3.2 log_{10} units respectively was observed at the high capacity RBF well in Mathura. Thus RBF can serve as an important pre-treatment step and provide cost-savings for post-treatment.

Validation, demonstration and exploitation of RBF technological intervention post 2018

With the impending conclusion of project PJS in 2018, NIH and HTWD endeavored to exploit the infrastructure created in PJS (pumping well), in a new collaborative project. The rationale for this is given below. None of the following were possible to investigate in the predecessor project PJS:

1. Validation of RBF process:
   a. Possibility to investigate the upper limit of the purification capacity for RBF w.r.t. organic micropollutants and pathogens because the Yamuna river is one of the most polluted rivers worldwide
   b. Comparison of RBF water quality with directly abstracted and conventionally treated surface water treated at the same location

c. Investigation of the effects of aquifer anisotropy (hydraulic conductivity changes in vertical/z-direction due to intermittent low and high conductivity layers) because the subsurface stratification found in the Yamuna floodplain in Agra is similar to many locations in the Ganga-Yamuna basin
d. Estimation of the portion of bank filtrate in pumped water from well and travel time of bank filtrate from river to well

2. Demonstration of RBF scheme:
a. Development of existing well into a demonstration site for RBF to show how a RBF site should be made and to display the benefits of RBF
b. Creation of infrastructure to monitor the RBF site by construction of at least 1 monitoring well
c. Demonstration of the purification capacity of RBF for conditions typical of extremely polluted rivers with complex subsurface geology

3. Exploitation of above by:
a. Development of a science-based masterplan for RBF water supply in India using above scientific results
b. Revision of existing guidelines on RBF into a second edition that will incorporate scientific / technical experiences of above
c. Investigate the inclusion of RBF as a "smart water infrastructure concept" within the "Smart City" project of the city of Agra

Methodology
NIH has already established the abstraction well infrastructure at the site at Agra in PJS project (2015-2018) including vertical borewell with submersible pump, provision of electricity supply to pump and construction of pump house. Samples will be collected from river, RBF exploratory well, adjoining drainages and groundwater to assess the removal of emerging pollutants and pathogens. So the main focus of this project will cover validation, demonstration and exploitation aspects (discussed above), especially:

- Determination of the upper limit of removal of "emerging pollutants" by RBF
- Equipping the site with water quality monitoring infrastructure
- To equip site with promotional/information materials on research done at site

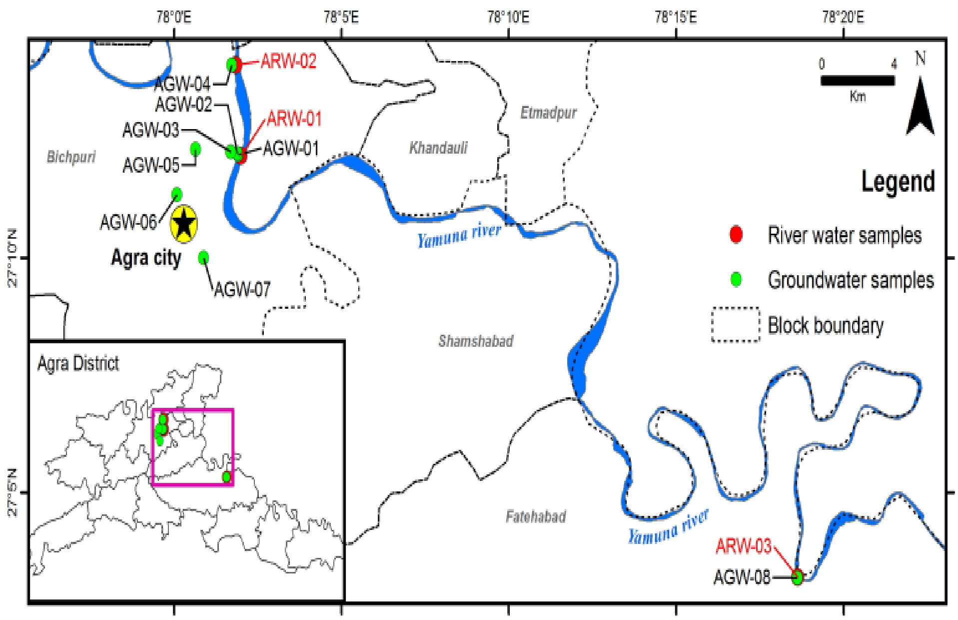


Fig. 1. Study site

Progress

1. **Work package/WP 1: Strengthening of network/collaboration**
   a. Completion of administrative formalities by signing Cooperation Agreement with 7 other Indian partners and 7 German partners in CCRBF consortium (total 15 partners).
   b. Obtaining permission from Ministry of Jal Shakti and Department of Economic Affairs, Govt. of India, for NIH to be a partner of CCRBF consortium and to participate in CCRBF project activities.
   c. Signing of Transfer Contract with HTWD (CCRBF project coordinator) to receive funds from the funding agency BMBF, Govt. of Germany.
   d. Application to MoJS to extend the existing MoU between NIH and HTWD on "Indo-German Competence Centre for Riverbank Filtration" (IGCCRBF) for third phase from 2021 to 2026. Extension of MOU granted for 5-year period 01.06.2021 to 31.05.2026 wide MoJS letter dated 11.10.2021
   e. Participation in 4 project/consortium meetings (online due to Covid-19 pandemic) on 21 July 2020, 03 February 2021, 08 July 2021 and 14 July 2022
   f. Participation in online CONNECT programme meeting organized by BMBF on 18 November 2021 and 06 October 2022

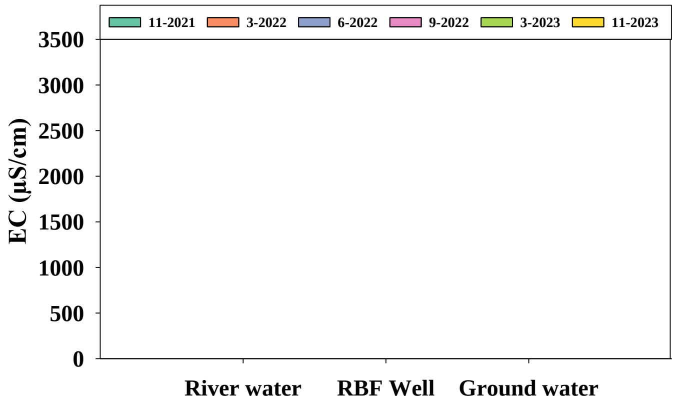
2. **WP2: Development of RBF demonstration site Agra**

Due to the Covid-19 pandemic, especially the critical second wave from March to May 2021 and subsequent monsoon season, it was only possible to commence field work in Agra from October 2021

   a. Scientific-technical support to CCRBF German partners HTWD & TUD for field investigations in Agra, liaison with stakeholder UP JAL Nigam (Oct. 2021 – Nov. 2022)
   b. Collection and analyses of water samples for Oxygen-18 and Deuterium isotope
   c. Co-supervision and scientific and logistic support to collaborative master thesis of:
      J. Nainan (2022) Synthesis of complex hydrogeological conditions for riverbank filtration in Agra and Guwahati, India. Master Thesis, TU Dresden, Institute of Groundwater Management; HTW Dresden, Division of Water Sciences; NIH Roorkee, Groundwater Hydrology Division & BBEC Kokrajhar, Dept. of Civil Engineering.
   d. Field work comprising water sampling for ions, heavy metals, dissolved organic carbon and organic micropollutants, shallow drilling with auger/tripod to determine groundwater level at site
   e. Review and synthesis of literature and preparation of project reports

The key conclusions from the work in Agra are:

   a. A careful analysis of the data since 2021 was carried out and it was found that electrical conductivity (E.C) was found to be in the range of 595-1986 µS/cm in river water for the months shown in the figure and in RBF Well value ranges as 1129-1556 µS/cm, It is observed that value of EC as 1129 µS/cm is found for the month of November 2021 (11-2021) which is higher than river water and electrical conductivity value observed to be less in comparison to river water for rest of the months. In ground water value ranges as 690-2940 µS/cm which is much higher than river water and RBF Well.



b. 20,000 persons of economically weaker sections of society solely receive water from RBF exploratory well. Therefore the well has a high social importance
c. Seepage of bank filtrate through silty fine sand layers possible
d. Portion of bank filtrate in exploratory well can be due to better hydraulic connection of river and aquifer upstream
e. Post-treatment of ammonium required for exploratory well water, otherwise good water quality of exploratory well

Inclusion of new project site by Sutlej and Ghaggar rivers in Punjab
Additionally, after including a potential RBF site in village Gagdhagara, near Talwan town by the Sutlej river in Punjab, and with reference to the progress report of CCRBF for the year 2022-2023, a potential RBF site in Dera Bassi by the Ghaggar river in Punjab has been included in the project. This is in tune with the World Bank report (2020) on "Managing Rural Drinking Water Quality in Punjab", wherein the following have been recommended:
i. Establishment of RBF systems in Punjab as a safe long-term solution
ii. And systematic inventory of existing sites and exploration of new sites for development of RBF systems along major rivers

Thereby cooperation with an additional stakeholder, namely the Department of Drinking Water Supply and Sanitation, Govt. of Punjab, has also been initiated.

Consequently, the quality of the Sutlej and Ghaggar rivers water and groundwater from a vertical well used for water supply and located 100-200 m from the riverbank in Gagdhagara and Dera Bassi were investigated within the CCRBF project in 2023-2024 with the following key results and conclusions:
a. current investigations in Gagdhagara and Dera Bassi by NIH & German partners HTWD and TUD reaffirm recommendations of World Bank report (2022, points i & ii above).
b. inorganic water quality of well within IS 10500 limits for drinking water
c. little to no removal of atrazine and carbamazepine during subsurface passage indicates river-aquifer hydraulic connection
d. potential for RBF at existing site exists, however further geohydraulic investigations and water quality monitoring needed
e. good example of RBF as a sustainable source in Jal Jeevan Mission

3. WP3 to WP5: Guideline for RBF in India (WP3), Education & Training (WP4) and RBF masterplan (WP5)
Are in progress. Results from WP2 are being synthesized into these WPs and accordingly disseminated/exploited.

4. WP6: Dissemination and exploitation of results
NIH contributed/disseminated for the period 01 July 2020 to 31 December 2022 as follows (details in annexure II):
- 16 conference presentations (annexure II, s.no. 1 to 16)
- 2 ad hoc/workshop presentations, including at a meeting with Ministry of Jal Shakti, New Delhi and Department of Water Supply and Sanitation, Govt. of Punjab, Chandigarh (annexure II, s.no. 17 & 18)
- 1 brainstorming session organized by Uttarakhand State Council for Science & Technology (UCOST), Dehradun, 31.07.2021 (annexure II, s.no. 19)
- 2 peer-reviewed book chapters published (annexure II)
- 12 conference abstracts included in proceedings (annexure II)
- 1 article in India's leading water industry publication "Everything About Water" (annexure II)

Action plan:
The project has been delayed due to the Covid-19 pandemic. Accordingly, the CCRBF project has been extended up to 31 March 2024 on a cost-neutral basis.

Period	**July 2020 to March, 2024** (Annexure 1)	Remark
July 2020 to March 2024	Monitoring of the site regularly Establishing the site with monitoring infrastructure Project works as listed in section "Validation, demonstration and exploitation of RBF technological intervention post 2018" Preparation of revised RBF guidelines and masterplan on RBF for India Prepare a status report Participation of NIH in 3rd International Riverbank Filtration Conference in Dresden from 14.– 23.10.2023 Participation of NIH in CCRBF project meeting in Dresden on 16.10.2023	Report preparation as per Annexure 1 and dissemination activities as per Annexure 2
01 July 2023 to 31 March 2024	Field work and water sampling during November, 2023 was carried out Preparation of input for RBF guidelines and masterplan Organisation of a final project conference in March 2024 during Roorkee Water Conclave 2024	

Strategic linkages for further work and follow-up

- Discussions with GiZ representative at the 5th India-EU Water Forum, New Delhi, 27 Oct. 2022, for advancement of activities on RBF in India. Follow-on discussion at GiZ head office with representative from HTW Dresden in New Delhi on 9 March 2023.
- Discussions with representative of Haryana Water Resources Authority (HWRA) at Internal Ground Water Conference, Roorkee, 02. – 04.11.2022 for advancement of activities on RBF in Haryana. Follow-on discussion at HWRA head office with representative from HTW Dresden in Panchkula on 13 March 2023.
- Discussions with Department of Water Supply & Sanitation, Govt. of Punjab for advancement of activities on RBF in Punjab. Further discussion planned.
- Networking with more than 80 participants from 14 countries at "International Riverbank Filtration Conference" in Dresden (Germany) from 16 to 18 October 2023.

Study Benefits /Impact:

- The result will be the creation of a road map within framework of RBF masterplan to increase contribution of RBF to total drinking water supply from currently less than 1% to at least 5% by 2030.
- Strengthening Indo-German/European scientific collaboration on managed aquifer recharge/RBF
- The project has a high socio-economic relevance for the underprivileged households living in Jeevani Mandi area of Agra because before implementation of the action they had no access to safe drinking water and after implementation of action they have access to safe drinking water.
- informing and collating experiences/knowledge; capacity development and strengthening competence on MAR/RBF.
- evaluating existing work bases and sharing or making them known within the network synergies with other Indo-European projects (e.g. DST–EU-Horizon2020 funded projects).

Specific linkages with Institutions:

- German partners: HTWD, TZWD, TUD, FHP, AUT, AKUT, GiZ (to be intensified)
- Indian partners: UJS, BHU, CSIR-CMERI, BBEC, AU, IITM, TERI, UPJN

Annexure - 1

Activity schedule for expansion of the Indo-German competence Centre for Riverbank Filtration – CCRBF

(QUARTERWISE WISE FROM JULY 2020 TO MARCH 2024)

Activity	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th to 15th
Data Collection	♦		♦		♦		♦		♦			♦
Sample collection and analysis			♦			♦			♦			
Equip the site with modern infrastructure				♦	♦	♦	♦	♦				
Organization of trainings/knowledge dissemination				♦				♦				
Final Report/ Publication(NIH-HTWD)											♦	♦

Progress

- One introductory meeting is held online with all partners
- See previous section “Progress”
- Editor of special issue on “Design and Operation of Riverbank Filtration Schemes” in Springer Journal “Sustainable Water Resources Management”
- Preparation of 3 manuscripts (lead & co-author) for submission to above special issue

Future plan

- Use of synergies from the competence-pool of RBF/CW/MAR through training and thematic cooperation between partners and stake holders
- Organizing a training on RBF for stakeholders on March 03, 2024 at NIH Roorkee
- Organizing a special session on RBF at RWC 2024 at IIT Roorkee.

3. PROJECT REFERENCE CODE: NIH/HID/DST-SERB/21-24

Title of the study	:	PARTITIONING EVAPOTRANSPIRATION INTO EVAPORATION AND TRANSPIRATION FLUXES USING STABLE ISOTOPES OF OXYGEN AND HYDROGEN
Name of PI and members	:	NIH, Roorkee, India Dr. Gopal Krishan (PI) Dr. M.S. Rao (co-PI) **IIT-Kanpur** Dr. Shivam Tripathi (PI) Dr. Richa Ojha (Co-PI) Dr. Rajesh Srivastava (Co-PI) Dr. Saumen Guha (Co-PI)
Type of study	**:**	**Sponsored,** DST-SERB
Date of start (DOS)	**:**	April 2021
Scheduled date of completion	**:**	March 2024 Extension requested upto October, 2024
Location	**:**	**NIH** Roorkee and IIT-Kanpur

Sr. No.	Study objectives	Achievements
1	Estimate evapo-transpiration (ET) flux at a study site in Kanpur	**90%** – Experiments has been set up at IIT Kanpur after the standardization of methodology at NIH
2	Partition ET flux into soil evaporation (E) and plant transpiration (T) fluxes, and investigate ➢ diurnal fluctuations in the fluxes; ➢ variations in the fluxes during a cropping season; differences in the fluxes between two cropping seasons, namely Rabi (wheat) and Kharif (rice);	**80%-** Experiments have been conducted for one wheat and two rice seasons. The data are being analysed to estimate components of ET fluxes.
3	Quantify uncertainties in the estimates of E, T and ET fluxes	**80%-** Experiments to finalize the methodology are in progress

Statement of the problem:

Agriculture is the single largest user of freshwater in India. A significant portion of the applied irrigation water eventually evapotranspires. The transpiration (T) component of the evapotranspiration (ET) is associated with crop productivity, while the undesirable soil evaporation (E) component represents losses. The knowledge of the relative magnitudes of E and T fluxes is therefore essential for designing efficient irrigation techniques and understanding energy and moisture transfer in the soil-plant atmosphere continuum. In this direction, the institute has developed methodologies for collection of air moisture samples, soil evaporation and evapotranspiration samples, transpiration samples. Wherever possible, instruments are designed and fabricated inhouse to suit the local conditions and give reliable data at a low cost. For experimentation in the field, two sites are selected in Kanpur to study ET partitioning at plot and field scales. The sites are instrumented for measuring ET fluxes using hydrometric and isotopic methods.

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

Progress

As part of the project, the following work has been completed at the NIH-Roorkee to date:

1. Soil Moisture Evaporation

A fabricated model for collecting soil moisture evaporation involves placing a glass slab on bare soil. A compressor creates negative suction pressure, drawing evaporated water from the soil through a tube. Condensation in the tube allows the collection of the soil evaporated sample in a glass tube.

2. Air Moisture

Moisture from the air is collected using a conical condensation instrument filled with ice cubes. The atmospheric moisture condenses into water droplets on the surface of the cone-shaped structure and is collected drop by drop in a sample bottle enclosed by a cylindrical structure.

3. Transpiration

The transpired water is collected in the polythene bag wrapped around the leaves of the potted plants.

4. Collection of Rainwater samples

A Standard non-recording rain gauge prescribed by the IMD (Symon's rain gauge) was used to collect the rainwater samples. The gauge consisted of a funnel with a sharp-edged rim of 127 mm diameter, a cylindrical body, a receiver with a narrow neck and handle, and a splayed base that was fixed in the ground. The rain falling into the funnel was collected in the receiver kept inside the body and measured using a special measure glass which was graduated in mm. The gauge was fixed on a concrete foundation of size 60 cm x 60 cm x 60 cm which was sunk into the ground. The rainwater samples were also used to develop the LMWL for the region.

5. Collection of Groundwater samples

Standing water within a bore is exposed to atmospheric conditions and can undergo changes to its physical and chemical characteristics and is not representative of the water in the aquifer. Unless aquifer quality is known to be vertically uniform, samples collected may include a mixture of groundwater entering the borehole using the open or screened casing methodology and can be considered to produce a composite sample or one of approximately average composition. The details of the samples collected provided in Table 1.

Sr. no.	Sample Type	Frequency	Samples Collected (C) and Analysed (A)	
			C	A
1	Atmospheric air moisture	Daily	195	120
2	Soil moisture evaporation	Daily	140	110
3	Transpiration	Daily	86	70
4	Rain	Event Based	26	26
5	Irrigated water	Random	10	10-
Grand Total			457	336

Table 1. Sample collection details

It has been observed with the onset of monsoon in mid-June, after one or two initial light rain showers of enriched isotopic composition ($\delta^{18}O$= -5.9‰, δD=-34.4‰), the isotopic composition of rainwater rapidly depleted and fluctuated at a value close to an average value: $\delta^{18}O$ =-9.7 ‰, δD= -70.3 ‰.

During the end of the monsoon, a few rains were of very depleted isotopic composition ($\delta^{18}O$ =-11.2‰, δD=-77.6‰). The increased depletion in the isotope values of the transpired vapor after the first few showers indicates the replacing of pre-monsoon highly enriched vapors of local origin by monsoon moisture of depleted isotopic composition.

The observed difference in the isotopic composition between the rain and the associated vapor was unexpected. As per the isotopic fractionation relation between water and its associated vapor, under isotopic equilibrium, at a temperature in the range of 25-30ºC (which is the average temperature between cloud base and ground level during monsoon at Roorkee), the isotope value of water vapor with respect to its source water is expected to be depleted by ~9‰ in $\delta^{18}O$ & ~74 ‰ in δD.

After the end of the monsoon, the process of evaporation of the soil surface progresses parallel to other soil hydrological processes like the upward movement of soil moisture due to capillary action and the negative pressure gradient and the dynamics of a diffusion-driven flux of water molecules from the isotopically enriched layer towards the deeper layers. These processes lead to the broadening of an isotopically enriched layer in the vadose zone with time. When the isotopically enriched layer reaches the root zone, the plants and trees transpire this enriched water to the atmosphere, and the atmospheric vapour composition becomes more and more enriched with heavy isotopic composition.

Work done at IIT Kanpur

Two experimental sites were established at Kanpur for measuring ET fluxes and partitioning its components. Experiments were conducted for wheat and rice during 2021-22 and 2022-2023 rabi and kharif seasons, respectively. Presently, experiments being conducted with wheat for the 2023-24 rabi season. Lysimeters, designed and fabricated at IIT Kanpur, were installed at both the experimental sites. In addition, meteorological parameters at the two sites were measured by automatic weather stations. Crop parameters (e.g., plant height, root depth, leaf area index and above-ground biomass etc.) and water samples for isotope analysis were collected periodically during the duration of experiments. The water samples consisted of soil water, plant water, atmospheric water, irrigation water, groundwater, and rainwater. Experimental protocols were developed to – (a) optimally extract water from soil and plant samples without compromising their isotopic compositions and (b) determine the isotopic composition of collected water samples using laser-based isotope analyzer. The analytical precision of the isotope analyzer was determined to quantify uncertainty in the measurements of isotopic compositions. Further, a mathematical framework was developed to propagate measurement uncertainties to uncertainties in estimated fluxes.

Action plan:

Period	**April 2021 to March, 2024** (Annexure 1)	**Remark**
April 2021 to March 2024	Installation of instruments Collection of waters samples, isotope analysis Data analysis and uncertainty quantification Data dissemination and report writing	Report preparation as per Annexure 1

Study Benefits /Impact:

1. Diurnal, inter- and intra- cropping seasonal variations in soil evaporation (E), plant transpiration (T) and evapotranspiration (ET) fluxes at the study sites. 2. A methodology to quantify uncertainty in ET partitioning. In addition, the results obtained and methodology developed during the proposed project will be useful for - (a) validating process based hydrological models that estimate E and T fluxes separately, and (b) improving irrigation efficiency by developing agricultural practices that reduce soil evaporation losses.

Specific linkages with Institutions:

- IIT Kanpur

<u>Annexure - 1</u>

Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen

(QUARTERWISE WISE FROM APRIL 2021 TO MARCH 2024)

Activity	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th
Literature review	♦	♦										
Installation of instruments	♦	♦	♦	♦								
Collection of waters samples			♦	♦	♦	♦	♦	♦	♦	♦		
Isotope analysis			♦	♦	♦	♦	♦	♦	♦	♦		
Data analysis and uncertainty quantification						♦	♦	♦	♦	♦		
Data dissemination and report writing											♦	♦

Future plan

- Experiments will be continued to achieve the desired objectives
- New instruments are being procured for sampling of xylem water and soil water

4. PROJECT REFERENCE CODE:

Title of the study: **CHANGING THE FATE OF THE HINDON RIVER BY EVALUATING THE IMPACT OF AGRICULTURE ON THE WATER BALANCE: DEVELOPING A TEMPLATE FOR A CLEANER GANGA RIVER**

Study Group:

Study Team			
NIH, Roorkee	**IIT, Kanpur**	**NGO**	**The Netherlands**
• Dr. M. K. Sharma - **PI** • Ms. Anjali • Dr. Vishal Singh • Dr. SM Pingale, • Dr.Suhas Khobragade • Dr. Pradeep Kumar, • Dr.Nitesh Patidar, • Dr.Surjeet Singh.	Prof. Vinod Tare	Dr. Ramankant Tyagi, Neer Foundation	• Dr. Albrecht Wreets Wageningen UR – **PI** • Dr. Paul Schott Utrecht University, • Dr.Frederiek Weiland, Deltaras • Ms. Annelieke Laning, Independent Consultant, WWO
Supporting Staff Mrs. Babita Sharma, PRA Mrs. Beena Prasad, SRA Mr. Amit Rawat, Tech. III JRF – 2 Nos., Project Asstt. – 2 Nos.			

Type of Study: DST NWO Sponsored project
Budget: Rs. 2,40,01,260.00
Nature of Study: Applied Research
Date of Start: April 2022
Scheduled date of Completion: March 2027
Duration of the Study: 05 years

Study Objectives
This research aims at providing scientific understanding on the hydrological functioning and the impact of agricultural water management of the Hindon subbasin of the Ganges river. Three areas of research are distinguished:

i) Integrated water systems analysis to understand the spatio-temporal relations between surface water and groundwater quantity and quality, and the impact of human activities and climate characteristics by setting up a monitoring network.
ii) Interventions to improve agricultural water management and reduce negative impacts on water quantity and quality.
iii) Develop recommendations for improvements in Hindon basin water quantity and quality, food production and economic revenues.

This project entails to increase our scientific understanding on the reduced availability and deteriorated quality of water resources, and the specific role of agricultural water management in the Hindon catchment. The main research question is: How can we increase water availability, lower its pollutant concentrations, diversify crop choices and stimulate farming practices with less pressure on the water system in the Hindon basin?

To answer this question, we will focus on three specific components:

i) Identify effective measures to store excess precipitation falling during the Monsoon to improve water supply
ii) Identify less intensive agricultural methods using different crops and farming practices to reduce water demand pressures
iii) Create an interactive data and model platform that can be adopted by government and stakeholders for impact assessment, scientific knowledge sharing and discussion.

The proposed approach can subsequently be used as a template for other subbasins within the Ganga.

Statement of the Problem

River Hindon, an important tributary of river Yamuna flowing through the districts of Western Uttar Pradesh, is subjected to varying degree of pollution caused by numerous untreated and/or partially treated waste inputs of municipal and industrial effluents. The toxic pollutants from these wastes will ultimately reach the ground water and enter in the food chain posing a threat to human health because of their carcinogenic nature. The pollution matrix in some stretches of the river becomes so complicated that anaerobic and septic condition prevails during the lean period due to discharge of effluents to the river from various industries and municipal areas. Though a large number of studies, to understand the pollution aspects of river Hindon, have been carried out by different workers (Verma and Mathur, 1971; Verma and Dalela, 1975; Verma et al., 1980; Patel et al., 1985; Singhal et al., 1987; Joshi et al., 1987; Seth, 1991; Seth and Singhal, 1994; Khare, 1994; Kumar, 1994; Lokesh, 1996; Jain, 1996, 2000; Kumar, 1997; Jain and Ali, 2000; Jain and Ram, 1997a, 1997b; Jain and Sharma, 2001a, 2002, 2006; Jain et al., 1997, 1998a, 1998b, 2002, 2003, 2004a, 2004b, 2005, 2007; Sharma, 2001; Sharma et al., 2009a, 2009b), but no comprehensive and holistic plan for rejuvenation of river has been attempted. This requires monitoring of water resources and pollutants within the river basin through data collection, modeling of river water and groundwater interaction and interpretation. Further hydrological study of the basin is important to understand the surface and groundwater interaction. Water Balance in Hindon River Basin will provide water allocation for different sectors for better water management in the basin. Reach-wise recharge augmentation plan may be implemented by identification of affluent and effluent sections in the river.

10. Approved Action Plan/Methodology

i) Literature review and collection of data from published reports and papers.
ii) Procurement of secondary data required for the analysis from various govt. agencies (discharge, rainfall, landuse/landcover, lithology, ground water level, aquifer parameters, sediment concentration, other water quality parameters, soil map etc.)
iii) Monitoring of water quality of River Hindon monthly basis for one year
iv) Study the relationships between different hydrological parameters
v) An inventory of pollution sources contributing to the River will be prepared from the collected information and Major Contaminant zones will be identified.
vi) Identification of affluent and effluent sections of River Hindon.
vii) Water Balance of Hindon River Basin using SWAT-MODFLOW model
viii) Reach-wise Recharge augmentation plan will be suggested

11. Approved Work schedule / Timeline

Year	Month	Consortium Activity	NIH action plan
Year-1 2022-23	Apr - Jun, 2022	Preparatory activities like approvals etc.	• Hiring of Project staff • Meetings with IIT K for formulating plans for field Visits • Forwarding request to state govt. for data • Literature Review
	Jul - Sep, 2022	Start of the project Kick of Meeting Hiring of Staff, PhD Creation of Advisory Board	• Administrative Approval for Equipment • Kick off Meeting and formal introduction of the members involved, role and responsibilities allocation. • Combined field visit of IIT K and NIH for G&D site and piezo-site locations.
	Oct - Dec, 2022	• Designing Observational Network • Identification of farms, urban and industry locations	• Installation of Piezometers and G&D sites • Inventory of pollution sources • Survey for morphometric analysis of river Hindon • Health, Agricultural and drinking issues identification.
	Jan - Mar 2023	• Stakeholders Identification • Installation of Base network & bathymetry Measurement	• Creation of Pollution Inventory • Stakeholders Identification • Groundwater level trend analaysis • Water quality over years inventory
Year-2 2023-24	Apr - Jun, 2023	Field investigations	• Soil, Groundwater and river water quality sample collection and analysis
	Jul - Sep, 2023	Data preparation for IHE-FEWS	• Contribute to FEWS data platform
	Oct - Dec, 2023	Stakeholders Meeting Field investigations	• Stakeholders Meeting • River discharge and water quality, • Groundwater levels and water quality
	Jan - Mar 2024	Report writing	• Preparation of Interim report • Scientific paper writing
Year-3 2024-25	Apr - Jun, 2024	Data collection	• Groundwater and river water quality sample collection and analysis
	Jul - Sep, 2024	Groundwater Investigation	• Recharge Estimation for Hindon river Basin • Estimation of Parameters for Groundwater Model Development.
	Oct - Dec, 2024	Mid- Project stakeholders meetings	• Stakeholders Meeting
	Jan - Mar 2025	Data interpretation and Report writing	• Preparation of Interim report • Scientific paper writing
Year-4 2025-26	Apr - Jun, 2025	Data collection	• Groundwater and river water quality sample collection
	Jul - Sep, 2025	Sample analysis	• Groundwater and river water analysis
	Oct - Dec, 2025	Scientific Advisory Board Meetings	• Final Groundwater-surface water interaction Model

Year	Month	Consortium Activity	NIH action plan
	Jan - Mar 2026	• Stakeholders workshop • Result sharing and analysis	• Effluent and affluent zone identification. • Integration of individual developed models
Year-5 2026-27	Apr - Jun, 2026	Development of GW Model	• Development of GW Model
	Jul - Sep, 2026	Calibration and Validation of the model	• Calibration and Validation of the model
	Oct - Dec, 2026	Data analysis and interpretation	• Suggestions and measures for Hindon rejuvenation
	Jan – Mar, 2027	Advisory Board Meetings for project finalization	• Working on finalization of results with Dutch Partners.

12. Objectives and achievement during last twelve months:

S. No.	Activity	Achievements
1.	Observational Network	• 36 Piezometers have been installed for observation of groundwater levels in Hindon River Basin. • Out of 12 proposed G&D sites, 03 Stilling wells have been prepared for taking stage in the river Hindon.
2.	Field investigations & Sample Analysis	• 53 water samples collected from groundwater and surface water sources along the transect passing through River Krishni, Hindon and Kali and analysed for hydrochemical parameters and metal concentrations. • DGPS Survey of 36 piezometric wells and 03 prepared stilling wells completed. • Soil samples collected from different depths during construction of piezometers and analysed for texture analysis.
3.	Writing of Interim Report	• Writing of Interim Report is in progress.

13. **Recommendation / Suggestion:**

S. No.	Recommendation / Suggestion	Action Taken

14. **Analysis & Results:**

Sample Analysis & Data Processing

- Inventory of pollution sources completed.
- Fifty three water samples collected from groundwater (shallow and deep aquifers) and surface water sources (Ponds, Canal and Rivers) along the transect passing through River Krishni, Hindon and Kali and analysed for hydrochemical parameters and metal concentrations.
- Hardness, NO_3, Na, K, Fe and Mn in the groundwater of the few locations and in few pond sample exceeds the maximum permissible limit prescribed by BIS for drinking purposes.
- High values of BOD and COD in the pond samples indicates the presence of organic pollution.
- Soil samples collected from different depths during construction of piezometers and analysed for texture analysis and fence diagrams were prepared.

15. **End Users / Beneficiaries of the Study:** Irrigation Research Institute, Ground Water Department, UP, CGWB.

16. **Deliverables:** Technical report and research papers,

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

18. **Lab facilities used during the study:** Water Quality Laboratory (NIH) and Nuclear Hydrology Laboratory

19. **Data procured or generated during the study:** Water quality data, Groundwater level data.

20. **Study Benefits / Impacts:** The study will identify degraded groundwater quality zones, possible sources of pollution and understanding the surface and groundwater interaction. Water Balance in Hindon River Basin will provide water allocation for different sectors for better water management planning in the basin. Reach-wise recharge augmentation plan may be implemented by identification of affluent and effluent sections in the river. Interventions will be suggested to improve agricultural water management and reduce negative impacts on water quantity and quality. Recommendations will be given for improvements in Hindon basin water quantity and quality, food production and economic revenues.

21. **Involvement of end users/beneficiaries:** Groundwater Department**,** UP and CGWB

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

23. **Shortcoming/Difficulties:** None.

24. **Future Plan:**

- Installation of Soil-moisture Probes.
- Installation of AWLRs in Piezometers
- Construction of 09 G&D sites.
- Field Investigation and sample collection.

NEW STUDIES FOR 2024-25:

1. PROJECT REFERENCE CODE: NIH/HID/R&D/2024/1

Title of the Project: **DEVELOPMENT OF RADIOCARBON DATING FACILITY**

Project Team: Dr. Tripti Muguli (Scientist-D), Dr. Someshwar Rao (Scientist-G), Dr. Amit Pandey (Scientist-B), HID, NIH

Type of Study **:** Internally Funded
Duration **:** One year
Date of Start **:** April 01, 2024
Date of Completion **:** March 31, 2025
Budget **:** Rs.20,00,000

Background
The radioactive isotope of carbon is used as a tracer for dating older groundwater (upto 35-50 ka). The radiocarbon dating technique involves intense sample preparation which require dedicated manpower, consumables and accessory instruments. Though the technique is old, it is pertinent to develop this facility to date older groundwater.

Objective of the proposed work
The objective of this work is to develop and validate the sample preparation line for facilitating radiocarbon dating of older groundwater using Liquid Scintillation Counter in the Nuclear Hydrology laboratory of Hydrological investigation division, National Institute of Hydrology, Roorkee.

Methodology
The radiocarbon dating technique is a basic requirement for different hydrological investigations to be carried out by the institute in deep seated aquifers. To develop the sample preparation line, new setup of metal and glass fixtures will be manufactured at local scale (Roorkee/Delhi) based on available guidelines. A new vacuum pump setup may also be procured to obtain optimum sample preparation efficiency. The consumables like sample preparation chemicals (calcium carbonate, barium chloride, orthophosphoric acid, etc.) and standards will be procured at appropriate quantity. The generated results will be validated by inter laboratory calibration to validate the efficiency of sample preparation line.

Outcome from the work
The technique will be helpful in determining the age of old groundwater in India. The generated age dataset will provide insights for better groundwater management in different terrains of India. This will strengthen the future hydrological investigation capability.

Budget estimates: Rs.15,00,000/-
The proposed budget is required to manufacture and procure specific metal fixtures and glass units for benzene line, procurement of stands and consumables, accessory instruments (hot air oven, ultrasonicator unit, vacuum pump, etc.), contingency as well as to cover travel expenditure involved in procurement of materials, inter-lab calibration and attending conference/training on analytical techniques.

Work schedule

Sl. No.	Activity	Month 1-3	Month 4-6	Month 7-9	Month 10-12
1.	Procurement of materials	■			
2.	Manufacture of glassware and metal fixtures	■			
3.	Testing of sample preparation line efficiency by replicate analysis in lab		■	■	

4.	Validation of sample preparation line efficiency by inter-lab analysis					
5.	Manual preparation					
6.	Final report submission					

2. PROJECT REFERENCE CODE: NIH/HID/R&D/2024/2

Title of the Project: **HYDROLOGICAL AND HYDROGEOLOGICAL INVESTIGATIONS IN THE YAMUNA RIVER BASIN USING ISOTOPE GEOCHEMISTRY.**

Project team: Dr. Tripti Muguli (Scientist-D; PI), Dr. Suhas Khobragade (Scientist-G and Head, HID), Dr. Someshwar Rao (Scientist-G), Mr. Ruchir Patidar (Scientist-B), Dr. Vipin Agrawal (Scientist-B), Dr. Amit Pandey (Scientist-B)

Type of Study **:** Internally Funded
Duration **:** Three years
Date of Start **:** April 01, 2024
Date of Completion **:** March 31, 2027

Statement of the Problem

Water forms the lifeline of all biotic components in the Earth. The human civilization has evolved depending upon the water availability across the globe, particularly in the tropics. In India, there have been reports stating that the rivers played a crucial role in human settlements and its migration since its existence. Geological evidences highlighted the significance of rivers in both landscape as well as human evolution. Recently, the effect of climate change and technical advancement in exploring other water resources have shifted the focus towards the groundwater. However, the over exploitation of fossilized groundwater may lead to increased stress on available water resources. This demands the regular monitoring of available water for sustenance during the Anthropocene.

In India, the river systems of the Himalayas and the Western Ghats form the major water towers fulfilling the need of entire population. The sustenance of these river systems is mainly dependent on seasonal precipitation. However, the Himalayan river systems are additionally fed by the large glacial mass at high altitudes. With the industrial revolution, there has been increased threat to the glacial deposits in the Himalayas. It is pertinent to understand the relative contribution of precipitation and glacial melt sustaining the Himalayan river systems to pinpoint the water sources and their role in regional hydrological cycle. The river systems of the Indus, Ganga and Brahmaputra have been intensively explored for its hydrology and hydrogeology. However, the Yamuna river which feeds the national capital has been less focused for the hydrological and hydrogeological studies due to the sensitivity involved in the competing interests between the river basin conservation and rapid urbanization. With this background, the present study proposes to assess the Yamuna river system spatially from its origin to the confluence with the Ganga river at Prayagraj while the monitoring period involves the demand driven temporal scale for its future sustainability.

Objectives of the proposed study

The water resources in the Yamuna basin have been explored for its quantity as well as quality by various researchers around the globe (Dalai et al. 2002, 2003; Gopal Krishan et al. 2016, 2017; Jha et al. 1998; Kumar et al. 2023; Lambs et al. 2005; Rengarajan et al. 2009). However, these studies have been carried out only in selected locations or in parts of different sub basins of the Yamuna river and mainly on one-time field monitoring of samples. Thus, the following objectives have been proposed under this study to develop a systematic hydrological and hydrogeological database for the Yamuna river system:

- To determine the isotopic composition to understand the sources of moisture contributing to precipitation in the Yamuna basin
- To determine the relative contribution of different hydrological components contributing to Yamuna river discharge
- To assess the contribution of different tributaries to Yamuna river discharge through isotopic characterization of the river and its tributaries
- To identify the recharge areas of a few selected springs in the Yamuna river basin
- To understand the groundwater-surface water interaction along the Yamuna river using isotopic techniques

- To understand the hydrological aspects of a major lake in the Yamuna river basin
- To monitor the radon concentration in groundwater at some specific location in the Yamuna river basin

Study area

The Himalayan river systems are globally known for their immense cultural, ecological and geological significance. The Yamuna River which originates in the Yamunotri Glacier (Uttarkashi district of Uttarakhand) of the Himalayas flows through several states downstream through Uttarakhand, Punjab, Haryana and Delhi before joining the Ganga River at Prayagraj, Uttar Pradesh. In addition, the southern tributaries flow through Rajasthan and Madhya Pradesh before joining the main channel of Yamuna river system. The river basin exhibits diverse climatic conditions with its upper reaches experiencing cold winter and mild summer while the downstream reaches and southwestern tributaries experiencing seasonal climate similar to major parts of Peninsular India with hot summer and relatively mild winter. The river basin receives precipitation mainly during the summer monsoonal months (June-September) in the lower reaches. The basin is characterized by diverse topography and landforms ranging from high altitudinal mountains of the Himalayas to the flat alluvial plains. The topography has undergone significant human interventions such as dams, reservoirs and irrigation channels during Anthropocene.

The river basin encompasses complex geological formations that contribute to the hydrology and landscape of the region. In the Himalayan Region, it is characterized by young fold mountains, comprising primarily metamorphic and igneous rocks such as granite, gneiss, and schist. The landscape and water quality of the upper reaches are influenced by the glacial erosion and sedimentation processes. In the Shivalik hills, the lithology is comprised of sedimentary rocks such as sandstone, shale, and conglomerates. The flow pattern and erosion dynamics of the Yamuna river basin is mainly controlled the river valleys and foothills of the Shivalik hills. In the downstream region, the terrain is dominated by the fertile alluvium deposits of the Yamuna and its tributaries which support extensive agricultural activities in the region. The alluvial deposits include sand, silt, clay and gravel. The rich fertile soils and seasonal water availability have supported higher anthropogenic activities in the region leading to higher environmental stress in the Yamuna river basin. Thus, it is essential to understand these geological and environmental aspects to propose effective strategies towards water resource management, environmental conservation, and sustainable development initiatives within the Yamuna river basin.

Methodology

Sampling

The samples for this study will be collected on spatial and temporal scales for a period of two years for stable isotopic composition as well physico-chemical. The water samples include precipitation, river, ground water, springs, lakes and leachates along the river main channel. In addition, precipitation and river water will be collected from the tributaries of the Yamuna river before the river confluence. The sediment samples will be collected from the selected lakes for chronological measurements to obtain sedimentation rate.

Analytical techniques

Water samples will be subjected to isotopic and geochemical characterization as well as its age determination in the Nuclear Hydrology laboratory, HID, NIH.

(i) Physico-chemical parameters: pH, EC, DO, ORP probes with handheld meter.

(ii) Isotopic approach: Stable isotopes of oxygen and hydrogen in water samples will be analyzed using IRMS. Dating of selected samples of spring and groundwater will be carried out using radioactive isotopes (tritium and ^{14}C isotopes).

(iii) Hydrogeochemical approach: Major ions in water samples will be analyzed using Ion chromatograph wherever applicable. Radon concentration will be measured.

(iv) Sediment characterization: Sediment samples will be subjected for ^{137}Cs and ^{210}Pb dating using Gamma spectrometer.

Research outcome from the project

The proposed study will support in better management and sustainable development of water resources in the Yamuna river basin. The expected outcome are as follows:

(i) Isotopic data base for different hydrological compartments for Yamuna river basin
(ii) LMWL for Yamuna river basin
(iii) Relative contribution of snow, rainfall and ground water to Yamuna river discharge
(iv) Contribution of tributaries to Yamuna river
(v) Contribution of base flow to Yamuna river
(vi) Residence time of groundwater in the Yamuna river basin
(vii) Status of radon concentration at selected location in the Yamuna river basin.

Budget estimates

Sl. No.	Budget Head	Cost (in Rs.)
1.	Man Power-1 (JRF at Rs.37,000 plus HRA for first two years and SRF for third year at Rs.42,000 plus HRA; HRA at 9%)	15,17,280
2.	Consumables	15,00,000
3.	Contingency	5,00,000
4.	Travel (include field visit, conference, training, workshop, etc)	15,00,000
5.	Equipment	15,00,000
	Total cost of Proposed Project	**60,17,280**

Work Schedule

Activity/ Year	Year-1	Year-2	Year-3
Literature Survey.			
Recruitment of project staff			
Setting-up of laboratory facilities, purchase of consumables, scheduling field visit and lab work plan.			
Field works – Daily, Monthly, seasonal sample collection.			
Onsite analysis for physico-chemical parameters.			
Chemical analysis of samples.			
Isotopic analysis of samples.			
Data compilation for analysis and interpretation.			
Submission of manuscripts for publication in peer-reviewed journals.			
Participation in workshop and training programs.			
National and international conference participations.			
Progress Presentations.			
Preparation and submission of final report			

3. PROJECT REFERENCE CODE: NIH/HID/R&D/2024/3

Title of the Project: **FINGERPRINTING OF AQUIFER DYNAMICS IN INDIA THROUGH ISOTOPIC AND GEOCHEMICAL APPROACH: DEMAND DRIVEN INVESTIGATIONS AT REGIONAL SCALE UNDER NAQUIM 2.0**

Project team : Dr. Tripti Muguli (PI; Nodal Officer, NIH), Dr. Suhas Khobragade (Head, HID)
Type of Study : Internal study
Duration : Three years
Date of Start : April 01, 2024
Date of Completion: March 31, 2027

Statement of the Problem

There is a need for detailed assessment of aquifers in India which can promote regional water sustenance. This requires long term observation of contributing sources, quality and age of water present in the aquifer system. HID, NIH and CGWB have initiated a collaborative work on aquifer mapping at microscale under NAQUIM 2.0. The focus is to assess the current status of regional aquifer systems and provide issue specific deliverables in priority areas of India. Aquifers of different locations in India will be monitored using isotopic and geochemical techniques to understand their dynamic response to the natural and anthropogenic factors. The hydrological, hydrometeorological, hydrogeological, and geophysical observational data from CGWB will strengthen the study.

Objective of the proposed study

Several monitoring programs to assess groundwater availability and management have been carried out earlier by various national agencies. However, the groundwater resource monitoring is complicated compared to surface water due to its existence as an invisible water pool. Each regional aquifer demands unique monitoring approach to attain its long-term sustenance. With this background, the proposed study is formulated to strengthen the capabilities of implementing strategies in groundwater management of India. The objective of this study is to assess the regional aquifer system of India through isotopic and geochemical fingerprinting of water for its future sustainability. The study will promote groundwater sustenance in India through long term assessment of water characteristics and age determination.

Study area

The proposed study will be carried out on demand driven regional aquifers of India (Fig. 1 and Fig. 2) covering water stressed areas, coastal areas, urban agglomerates, industrial/mining areas, deep-seated aquifers, springsheds, poor groundwater quality areas, command areas, etc. As India hosts different terrain characteristics (Fig. 1) and weather pattern, the regional aquifers respond uniquely to global climate change as well as increasing anthropogenic stress.

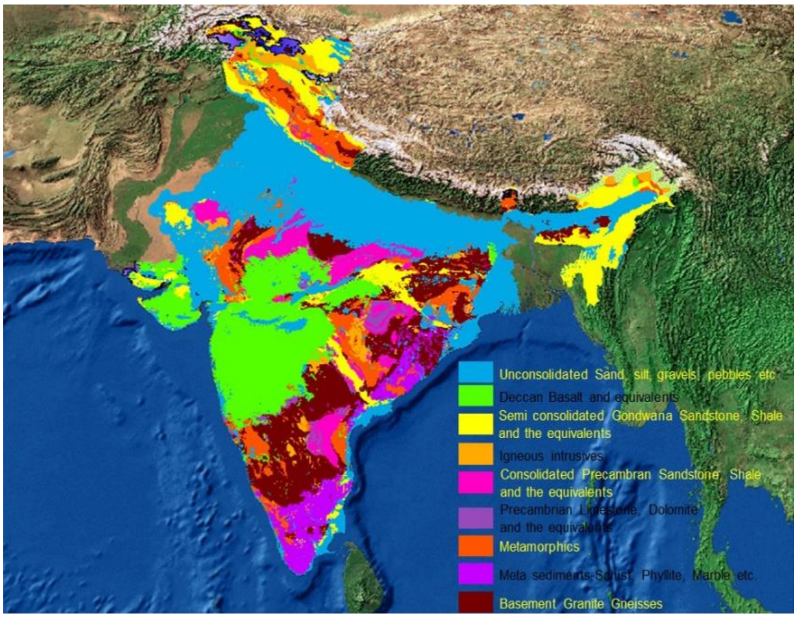


Figure 1: Maps of India showing regional terrain characteristics to identify priority areas (source: CGWB website).

Methodology

Sampling: Spatial and temporal water samples will be collected from different aquifers of India based on issues identified at regional scales. The samples will be collected mainly by CGWB and on case-to-case basis by NIH. Generally, the samples are collected during pre-monsoon and post-monsoon seasons by CGWB for aquifer characterization in India.

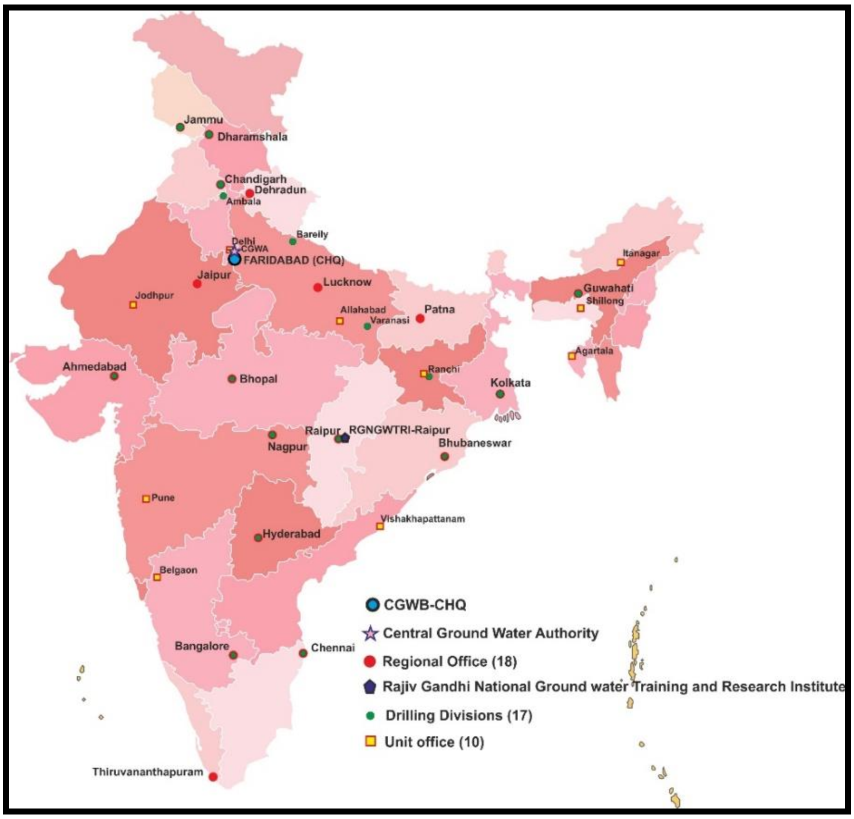


Figure 2: Map of India showing Regional Centre locations of CGWB to identify priority areas under their jurisdiction (source: CGWB website).

Analysis: Water samples will be subjected to isotopic and geochemical characterization as well as its age determination in the Nuclear Hydrology laboratory, HID, NIH.
(i) Physico-chemical parameters: pH, EC, DO, ORP probes with handheld meter.
(ii) Isotopic approach: Stable isotopes of oxygen and hydrogen in water samples (groundwater, precipitation and adjacent surface water) will be analyzed using IRMS. Groundwater dating will be carried out using radioactive isotopes (tritium and ^{14}C isotopes).
(iii) Hydrogeochemical approach: Major ions, trace elements and DOC in water samples will be analyzed using Ion chromatograph, ICPMS and TOC analyzer respectively wherever applicable.

Research outcome from the project

The integrated isotopic and geochemical technique have proved to be an effective tool to utilize in the formulation of implementable ground management plans. Though the deliverables will be specific to each priority areas, the main motto is to assess sustenance of regional aquifers in terms of water quality and quantity.

The expected outcome are as follows:
(i) NIH service towards national aquifer mapping.
(ii) Source tracing of water in different aquifers of India through isotope hydrology.
(iii) Assessment of natural and anthropogenic impacts on aquifer system through hydrogeochemistry.
(iv) Groundwater residence time estimation through dating techniques.
(v) Aquifer connectivity tracing in subsurface region through integrated approach.
(vi) Pollution assessment.
(vii) Tracing aquifer recharge pattern
(viii) Water flow pattern determination in coastal areas by tracing the dominance of freshwater discharge and saline water intrusion.
(ix) Aid in implementing strategies for better aquifer management.

Budget estimates

The budget will be provided in detail after finalizing the agenda with CGWB during March 2024.

Work Schedule

The Work Schedule will be provided in detail after finalizing the agenda with CGWB during March 2024.

4. PROJECT REFERENCE CODE: NIH/HID/R&D/2024/4

Title of the Project: **UNDERSTANDING SURFACE WATER GROUNDWATER INTERACTIONS IN THE NARMADA RIVER BASIN AND ITS HYDROLOGICAL IMPLICATIONS**

Project team: Dr. Amit Pandey (Scientist-B; PI), Dr. Suhas Khobragade (Scientist-G and Head, HID), Dr. Someshwar Rao (Scientist-G), Dr. Tripti Muguli (Scientist-D)

Type of Study **:** Internally funded (R&D)

Duration **:** 3 Years

Date of Start **: 1st April 2024**

Date of Completion **: 31st March 2027**

Budget: Budget details will be presented in the working group

Statement of the Problem

In India, several studies have been carried out to understand the surface water and groundwater interaction for Himalayan Rivers as well as a handful of peninsular rivers originating from the Western Ghats. However, no such study was carried out in central Indian rivers. In such a scenario, it is important to know how groundwater interacts with the river along its continuum and how these interactions vary with space and time. Stable isotopes of oxygen, hydrogen, and carbon, along with other hydrogeological parameters, are extensively used to understand different hydrogeological processes such as hydrograph separation, quantification of base flow, seasonality in groundwater recharge etc. In this study, we are going to use stable isotopes of oxygen, hydrogen, and carbon along with tritium, major ions and hydrogeology of the region to understand the spatiotemporal variation in river water groundwater interactions along the Narmada River.

Objectives:

- To understand surface water groundwater interaction in the Narmada River basin and quantification of base flow.
- To estimate groundwater residence time in the Narmada River basin.

Study area

Narmada basin extends over an area of 92,672.42 Sq.km and lies between east longitudes 72° 38‘ to 81°43’ and north latitudes 21° 27’ to 23° 37’ which is nearly 3% of the total geographical area of the country. The basin is bounded on the north by the Vindhyas, on the east by the Maikala range, on the south by the Satpuras and on the west by the Arabian Sea. Lying in the northern extremity of the Deccan plateau, the basin covers large areas in the States of Madhya Pradesh, Gujarat and a comparatively smaller area in Maharashtra and Chhattisgarh. The basin has an elongated shape with a maximum length of 953 km. from east to west and a maximum width of 234 km from north to south. The hilly regions are in the upper part of the basin, and the lower middle reaches are broad and fertile areas well suited for cultivation. From DEM (Fig 2a) it is noted that the maximum area of the basin falls in the 200 – 400 m elevation range. The maximum elevation is observed in the uppermost region of the basin. The highest elevation in the basin is 1,317 m. The climate of the basin is humid and tropical, although at places extremes of heat and cold are often encountered. Rainfall is heavy in the upper hilly and upper plains areas of the basin. It gradually decreases towards the lower plains and the lower hilly areas and again increases towards the coast and south-western portions of the basin. The details about the study area can be seen in the (https://indiawris.gov.in/wris/#/Basin) report published by India-WRIS. The basin is covered by different hydrogeological units (Fig 2b) which include basaltic rock, sedimentary hard rocks, sedimentary soft rocks, crystalline rock, and an alluvial system. The major part of the basin is covered by the basaltic system, which is highly fractured, and groundwater remains in the fracture zone. The alluvial setting forms a multilayered aquifer in which groundwater of different ages is stored in different layers.

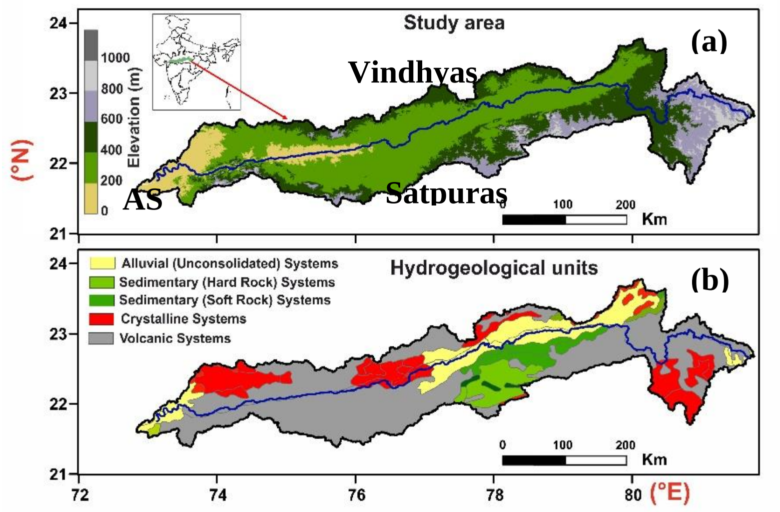


Fig 3: (a) Elevation profile of the Narmada River basin shows that most of the area has elevation in between 200 to 400m range, (b) hydrogeological setting of the study area.

Methodology

Sampling

In this study, seasonal groundwater, Narmada river water, and its tributaries samples will be collected across the river at a 5 km distance (up to 15 km on each side of the river) and along the river at a 30 km distance. The groundwater samples will be collected covering all the hydrogeological units present in the study area and taping different aquifers. The river water samples will be collected near the banks or in the middle section of the river depending upon the accessibility. These samples will be analysed for stable isotopes of oxygen, hydrogen, carbon (dissolved inorganic carbon), major ions present in the groundwater and river water, and tritium.

Isotopic Analysis: The oxygen, hydrogen, and carbon isotopic analysis of groundwater and river water samples will be done using Isotope Ratio Mass Spectrometer (IRMS).

Major ions analysis: Major ions {cations (Na^+, K^+, Ca^{2+}, and Mg^{2+}) and anions (Cl^-, $SO_4{}^{2-}$, NO_3^-, CO_3^{2-}, and HCO_3^-)} will be analysed using Ion Chromatography (IC). Ion Chromatography (IC) is the technique used for separating and analyzing the major ions in water samples. The ions are separated based on their retention time. The separation depends on the molecular weight or charge of the compounds or ions.

Groundwater residence: For groundwater residence time measurement, tritium will be used; this method involves enrichment of water samples and then radiation counting using an ultra-low level liquid scintillation counter present in NIH.

Research outcome from the project

i) Identification of the gaining and losing zones of rivers
ii) Contribution of groundwater as a base flow.

Work Schedule:

Work carried out	**2024**			**2025**				**2026**				**2027**
	Q2	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**
Sample bottles and consumables for field												
Pre-monsoon fieldwork												
Post-monsoon fieldwork												
Stable isotopes analysis												
Major ions analysis												
Tritium analysis												
Interpretation of data and report submission												
Preparation of manuscript												

5. PROJECT REFERENCE CODE: NIH/HID/R&D/2024/5

Title of the Project: **Quantifying Current and Future Meteorological Drought Characteristics and Identifying Risk Zones in Central India**

Project team **:** Ruchir Patidar (PI), S.M. Pingale, S.D. Khobragade
Type of Study **:** Internal R&D study
Duration **:** 3 years
Date of Start **:** 1st March 2024
Date of Completion **:** 31st February, 2027
Budget **:** -

Statement of the Problem

Madhya Pradesh has a very large agricultural rural population. Here around 70% population is agrarian and about 50% area is under cultivation. In addition, agriculture contributes to around 24 % of the GDP of the state. The agriculture is majorly rainfed with additional dependency on groundwater. In a state with 11 agro-climatic zones and a highly variable climate, the occurrence of drought is very frequent with additional impacts due to climate change. In 2016, 46 out of 52 districts were declared as drought-affected by the government of Madhya Pradesh. In 2019, 36 districts faced acute drought situations and water scarcity. Drought is a state subject and management usually takes along administrative boundaries. Hence, this study aims to understand the current and future drought characteristics of the region owing to climate change and identify vulnerable regions. In the case of droughts, the dependency on groundwater also elevates. To cater to this, variation in groundwater with the occurrence of drought is to be studied. This will ensure a comprehensive surface and groundwater study to identify critical zones. Drought Characterization is to be done based on water balance-based Standardized Precipitation Evapotranspiration Index (SPEI). It considers precipitation and temperature for drought assessment and is a better indicator compared to others. In addition, Future drought characteristics are to be assessed based on precipitation and temperature datasets from Coupled Model Intercomparison Project Phase 6 (CMIP6) data. Therefore, this study will be useful for the local community, policymakers, engineers, and administration for the appropriate management and adopting suitable measures pertaining to current conditions as well as for the future.

Objectives

General objective

The general objective of the present study is to assess the current and future Meteorological Drought Characteristics in Central India. In addition, groundwater variation is to be studied owing to drought in the region. Finally, identifying critical zones in the current scenario as well as for the future.

Specific objectives:

The present study will be carried out with the following objectives:

- To estimate the meteorological drought characteristics in Madhya Pradesh using SPEI.
- To assess the groundwater variability in the critical regions based on groundwater wells data.
- Vulnerability assessment based on SPEI, groundwater variability, and socio-economic data of the region.
- To estimate the future drought characteristics based on SPEI from CMIP6 data.

Study Area

The present study will be carried out for all districts of the state of Madhya Pradesh.

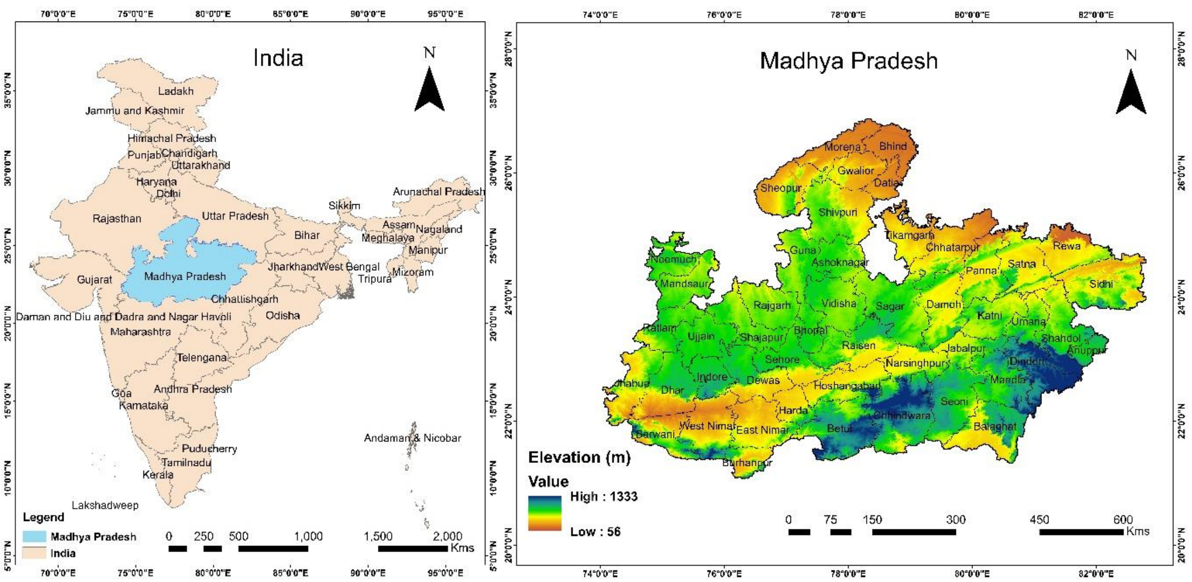


Figure 1 Location of the study area

Methodology

The proposed methodology has been described here:

i. Meteorological drought characteristics will be assessed based on the SPEI (precipitation and temperature) data from IMD.
j. Based on critical regions, groundwater vulnerability will be assessed with long-term groundwater level data.
k. Socio-economic data will be collected including population density, per capita income, etc. for the region.
l. An integrated vulnerability assessment will be done based on drought characteristics, groundwater depletion, and socio-economic data for zonation of regions.
m. Future drought characteristics will be evaluated based on future projections datasets. This will be done by first selecting a suitable model and assessing drought characteristics based on four different carbon emission scenarios (SSP126, SSP245, SSP370, and SSP585).
n. Based on different scenarios, we will identify critical regions for drought in the future considering the near future and far-future.
o. The results will enable us to demarcate critical regions at present and for the future. This will enable the decision-makers and stakeholders for short-term and long-term planning along administrative boundaries.

Research outcome from the project.

- ✓The assessment of drought characteristics (intensity, duration, frequency, trend) for the region.
- ✓In the absence of surface water, regions critical to groundwater as well will be identified.
- ✓Vulnerability of regions with overall issues of drought will be identified (Recurring droughts, groundwater depletion, socio-economic conditions).
- ✓The impact of climate change leading to drought in the future based on future projections will be identified.
- ✓The outcome and procedures of estimates will be useful for policymakers, Engineers, Planners, and various stakeholders for short-term and long-term planning and management.

SURFACE WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. A K Lohani	Scientist G & Head
2	Dr. S K Singh	Scientist F
3	Dr. P C Nayak	Scientist F
4	Dr. Sanjay Kumar	Scientist F
5	Dr. Ravindra Vitthal Kale	Scientist E
6	Dr. L N Thakural	Scientist E
7	Er. J P Patra	Scientist E
8	Sh. Om Prakash	Scientist B
9	Dr. Soumyaranjan Sahoo	Scientist B
10	Dr. Richa Pandey	Scientist B
11	Sh. Chandra Prakash	Scientist B
12	Sh. Gaurav Kumar	RA

APPROVED WORK PROGRAM OF SWHD FOR THE YEAR 2023-24

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1. NIH/SWHD/20-23 MoE-STARS/STARS-1/743	Operational coastal flood management through short-to-medium range (real-time) flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate induced impacts (Funded under STARS by MHRD, GoI)	B. Sahoo, (PI, IIT-Kgp) R. V. Kale, (Co-PI)	04 years (July, 2020 – June, 2024)

COMPLETED STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/22-24	Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Operation of Reservoirs	A. K. Lohani R. K. Jaiswal J.P. Patra P. C. Nayak Vishal Singh	Two Years April 2022 – March 2024
2. NIH/SWHD/23-24	Hydraulic force-inversion equation for exact modeling of hydraulic jumps in rectangular channels	Sushil K. Singh	One Year (April 2023 to March 2024)

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/22-24	Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model	P. C. Nayak A. K. Lohani J. P. Patra Sunil Gurrapu T. Thomas Om Prakash Jatin Malhotra	3 Year (July 2022 to June 2025)
2.NIH/SWHD/22-25	Hydrological Study for revival and restoration of traditional water bodies in Bikaner, Rajasthan	L. N. Thakural M. K. Shama R. K. Jaiswal J. P. Patra P. K. Mishra Nitesh Patidaar N. K. Bhatnagar Jatin Malhotra Anil Kumar Chhangani	2 Year (Apr 2022 to Mar 2024)
3.NIH/SWHD/22-24	Review of design flood and dam break analysis of Khadakhai Dam in Odisha	J.P. Patra A. K. Lohani Pankaj Mani P. C. Nayak Sanjay Kumar Jatin Malhotra	3 Year (April 2022 to March 2025)

4.NIH/SWHD/22-25	Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	Ashwini Ranade P.K. Mishra Sunil Gurrapu	3 years (April 2022 to March 2025) [**Transferred to C4S**]
5.NIH/SWHD/22-23	Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics	Archana Sarkar Jyoti Patil Rohit Sambare Charu Pandey	1.5 Year (May 2022 to Oct 2023) [**Transferred to WRSD**]
6.NIH/SWHD/21-24	Investigation of hydrodynamic approach of flood inundation mapping along with assessment of changes in river planforms using a cloud-based Google Earth Engine (GEE) computing platform in data-scarce Western Himalayan River basin	R. V. Kale A. K. Lohani J. P. Patra D. Khurana	03 Years (September 2021-October 2024)
7.NIH/SWHD/23-25	Estimation of confidence intervals of index flow duration curves	Sanjay Kumar, Sunil Gurrapu L. N. Thakural J. P Patra	02 Years (April 2023 to March 2025)
8.NIH/SWHD/23-24	Hydrologic and hydraulic study for Jata Ganga river at Jageshwar dham	J.P. Patra A. K. Lohani Pankaj Mani D. S Bisht S. S. Rawat	01 Years (July 2023 to July 2024)

PROPOSED WORK PROGRAMME OF SWHD FOR THE YEAR 2024-25

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1. NIH/SWHD/20-23 MoE-STARS/STARS-1/743	Operational coastal flood management through short-to-medium range (real-time) flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate induced impacts	B. Sahoo, (PI, IIT-Kgp) R. V. Kale, (Co-PI)	04 years (July, 2020 – June, 2024) (Funded under STARS by MHRD, GoI)

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/22-24	Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model	P. C. Nayak A. K. Lohani J. P. Patra Sunil Gurrapu T. Thomas Om Prakash Jatin Malhotra	3 Year (July 2022 to June 2025)
2.NIH/SWHD/22-25	Hydrological Study for revival and restoration of traditional water bodies in Bikaner, Rajasthan	L. N. Thakural J. P. Patra M. K. Shama R. K. Jaiswal P. K. Mishra Nitesh Patidaar N. K. Bhatnagar Jatin Malhotra Anil Kumar Chhangani	2 Year (Apr 2022 to June 2024) (***Extension required for Six months)***
3.NIH/SWHD/22-24	Review of design flood and dam break analysis of Khadakhai Dam in Odisha	J.P. Patra A. K. Lohani Pankaj Mani P. C. Nayak Sanjay Kumar	3 Year (April 2022 to March 2025)
4.NIH/SWHD/21-24	Investigation of hydrodynamic approach of flood inundation mapping along with assessment of changes in river planforms using a cloud-based Google Earth Engine (GEE) computing platform in data-scarce Western Himalayan River basin	R. V. Kale A. K. Lohani J. P. Patra D. Khurana	03 Years (September 2021-October 2024)
5.NIH/SWHD/23-25	Estimation of confidence intervals of index flow duration curves	Sanjay Kumar, Sunil Gurrapu L. N. Thakural J. P Patra	02 Years (April 2023 to March 2025)
6.NIH/SWHD/23-24	Hydrologic and hydraulic study for Jata Ganga river at Jageshwar dham	J.P. Patra A. K. Lohani Pankaj Mani D. S Bisht S. S. Rawat	01 Years (July 2023 to July 2024)

NEW STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWHD/24-25	Entropy and Image Processing Based Non-Contact Discharge Monitoring Techniques: Testing and Implementation for Indian rivers	**NIH** R, V, Kale M. K. Goel A. K. Lohani **CWPRS** Dr. Selva Balan **External Expert** Prof. M. Perumal	1.5 Years (April 2024 to September 2025)
2. NIH/SWHD/24-27	A Flood Forecasting Framework Coupling a High Resolution WRF Ensemble with 2D Hydrodynamics Model for Himalayan Mountainous Area.	R. V. Kale K. Sharma S. Kumar A. K, Lohani	Three Year (April 2024 to March 2027)
3. NIH/SWHD/24-26	Basin-scale, integrated water resources assessment through integrated hydrological modelling	S. Sahoo A. K, Lohani P. C. Nayak R. V. Kale J. P. Patra	2.5 Years (April 2024 to September 2026)
4. NIH/SWHD/24-26	Comprehensive Mapping of Water Budget Dynamics and Reservoir Sedimentation in the Upper Krishna Basin using Google Earth Engine.	Chandra Prakash A. K. Lohani R. V. Kale Richa Pandey	02 Years (April 2024 to March 2026)
5. NIH/SWHD/24-26	Water Resources Planning and Management using DSS (PM) under Changing Climatic and Land-Use Conditions	Richa Pandey A. K. Lohani J. P. Patra R. K. Jaiswal Chandra Prakash	02 Years (April 2024 to March 2026)

ONGOING STUDIES (SPONSORED)

1. Project Code: MoE-STARS/STARS-1/743

Title of the Project:	Operational coastal flood management through short-to-medium range (real-time) flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate-induced impacts
Project Team:	B. Sahoo, (PI, IIT-Kgp) R. V. Kale, (Co-PI, NIH Roorkee)
Collaborating agency	IIT Kharagpur
Type of Study	Sponsored by MoE under STARS Project
Duration	4 years
Date of Start	July 2020
Date of Completion	June 2024
Budget	56 Lakh (IIT KgP)

Statement of Problem

The inter-state Brahmani-Baitarani river basin is the second largest in Odisha which has undergone rapid industrialization and mining activities with the issues of flood havocs during monsoon season and reduced low flows during non-monsoon periods. This coastal river basin of the Bay of Bengal is flood prone due to its flat low-lying topography with flash floods, highly meandering dendritic drainage pattern, backwater effects from sea-surges, climate induced extreme precipitation and tropical cyclone, sea level rise, subjective reservoir operation, increased upstream river flux due to rapid urbanization, shifting cultivation practices, and floodplain encroachment reducing the river carrying capacity. Therefore, to aid for operational flood disaster management, this study proposes to develop a short-to-medium-range flood forecasting system accounting for all the aforementioned factors for an accurate real-time flood vulnerability mapping of the coastal Brahmani-Baitarani river basin. This method involves mapping of the delta region taking into account compound effect of rainfall, storm surge and upstream discharge.

Objectives:

a) Assessment of historical flood inundation and sedimentation scenarios in the study area through field survey, secondary data, and remote sensing approaches
b) Detection of historical changes in land use and river cross-sections due to sedimentation and anthropogenic activities using survey data and satellite imageries
c) Forecasting of inflows into and releases from the Rengali/Mandira reservoirs in real-time up to 10-days lead-time accounting for the effects of urbanization, paddy land use, and river sedimentation
d) Forecasting the tidal effect / sea-surges at the river-ocean confluence in the Bay of Bengal
e) Simulation of real-time 2-D flood inundation mapping in the deltaic river basin considering upstream streamflow forecasts, stream-aquifer exchange fluxes, and downstream tidal /sea-surge forecasts up to 10-days lead time.
f) Development of flood vulnerability maps in real-time (up to 10-days advance) for operational flood management using UNESCO-IHE guidelines

Brief Methodology

This study can be separated into four major categories viz., Land-surface process modeling, reservoir modeling, coastal flood plain dynamics, and ocean melding. In land-surface modeling SWAT Pothole model will be used with an error correction sub model to improve the streamflow forecast for future time period with different lead periods. Then streamflow information will be used in the reservoir operation modeling to reduce the flood peak and hydropower generation. Further the simulated release from the reservoir will be used for flood mapping in the delta region of the Brahmani-Baitarani River basin by accounting the tidal surge generated using ADCIRC+SWAN. The vulnerability map will be generated for different lead-time taking into account the UNESCO-IHE guidelines.

Study Area

The study area consists of the Brahmani and Baitarani River basins (Figure –1), extends over the states of Odisha, Jharkhand and Chhattisgarh having an area of 51,822 km^2 which is nearly 1.7% of the total geographical area of the country with a maximum length and width of 403 km and 193 km. It lies between 83°55' to 87°3' East longitudes and 20°28' to 23°38' North latitudes. The basin is bounded by the Chhotanagpur Plateau on the north, by the ridge separating it from Mahanadi basin on the west and the south, and by the Bay of Bengal on the east. The Brahmani sub basin covers 39,033 km^2 and has a long sausage shape.

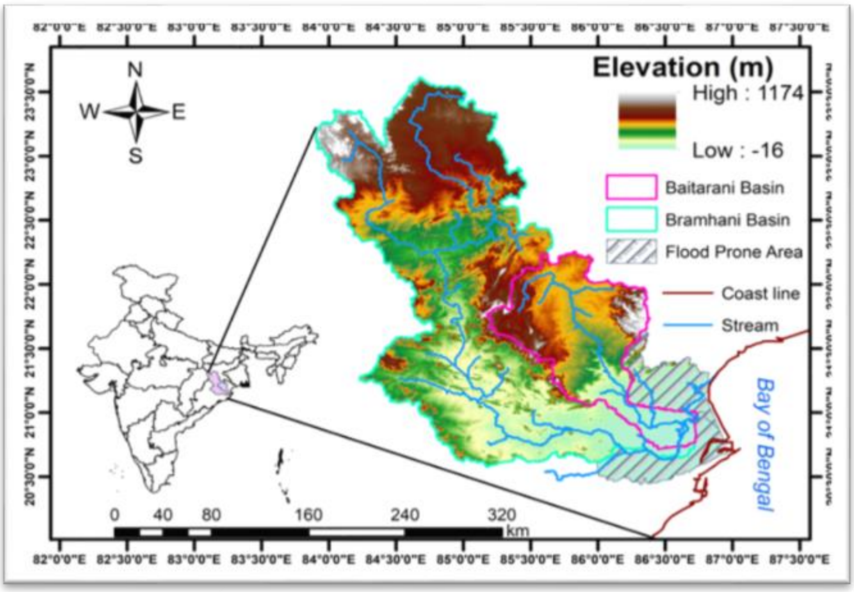


Figure –1. Elevation map of the Brahmani and Baitarani River basins.

The Baitarani sub-basin extends over 12,789 km^2 and is roughly circular in shape. The Brahmani, known as South Koel in its upper reaches, rises near Nagri village in Ranchi district of Jharkhand at an elevation of about 600 m. The river has a total length of 799 km. In its tail reach, the river is known as Maipura. The Baitarani River rises near Dumuria village in the hill ranges of Kendujhar district of Odisha at an elevation of about 900 m and has a length of about 355 km. The river is known as Dhamra in its lower reaches. The important tributaries of Brahmani joining it from left are the Karo, and the Sankh whereas the Tikra joins from the right. The main tributaries of Baitarani joining from the left are the Salandi and the Matai. Brahmani and Baitarani form a common delta area before outfalling into the Bay of Bengal. The major part of the basin is covered with agricultural land accounting to 52.04% of the total area and 2.95% of the basin is covered by water bodies. The basin spreads over 16 parliamentary constituencies (2009) comprising 10 of Odisha, 4 of Jharkhand, and 2 of Chhattisgarh.

Action Plan

Milestone/ Activity	July-Dec 2020	Jan-Jun 2021	July-Dec 2021	Jan-Jun 2022	July-Dec 2022	Jan-Jun 2023	July-Dec 2023	Jan-Jun 2024
Objective-1								
Objective-2								
Objective-3								
Objective-4								

Objective-5								
Objective-6								

Achievements vis-à-vis Objectives

Objectives	Achievements
Assessment of historical flood inundation and sedimentation scenarios in study area through field survey, secondary data, & remote sensing approach	Completed
Detection of historical changes in land use and river cross-sections due to sedimentation and anthropogenic activities using survey and satellite data	Completed
Forecasting of inflows into and releases from the Rengali/Mandira reservoirs in real-time up to 10-days lead-time accounting for the effects of urbanization, paddy land use, and river sedimentation	completed
Forecasting the tidal effect / sea-surges at the river-ocean confluence in the Bay of Bengal	Completed
Simulation of real-time 2-D flood inundation mapping in the deltaic river basin considering upstream streamflow forecasts, stream-aquifer exchange fluxes, and downstream tidal /sea-surge forecasts up to 10-days lead time.	In-progress
Development of flood vulnerability maps in real-time (up to 10-days advance) for operational flood management using UNESCO-IHE guidelines	In-progress

Progress of work

Objective (a)

Task #1: Collection and analysis of historical flood data over the Brahmani-Baitarani delta

- To study the historical flood characteristic, information was collected from published Government reports, news articles, scientific publications, and the internet. It can be inferred that the frequency of floods has been increasing since the last two decades with at least three floods in four years' time.

Task #2: Procurement and analysis of meteorological data and satellite imageries

- In order to assess the flooding due to extreme monsoon-precipitation, daily data at all available rain gauge stations as well as event-scale sub-hourly precipitation data are procured from 8 meteorological stations. For the flood mapping of historical events, the LISS-III and LISS-IV, SAR data for selected historical flood event has been procured from NRSC. The input data required for modelling for all the main revisors in Brahmani- Baitarani river system has been collected and processed. Further, the radar data available for the coastal area will be collected. Some of the other required data has been already procured/collected from respective government agencies.

Task #3: Preparation of Flood Maps of recent flood events

Satellite imageries were processed to determine the flood-affected areas during the recent floods in the basin. For this, the events of May 2021, July 2017, and July 2015 were chosen based on the availability of Sentinel satellite imageries. The results of the satellite image-based flood inundation mapping are presented in **Table –1** in the form of total inundated area and inundated crop area.

Table 1 Selected historical flood events in the Brahmani and Baitarani basin delta

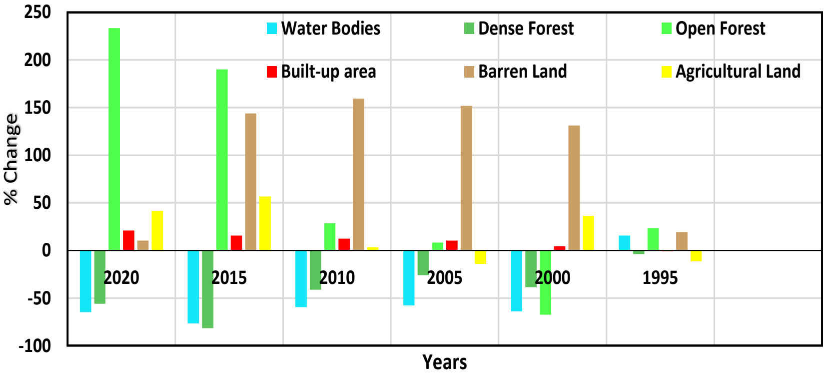
Date	Total inundated area (km^2)	Crop area inundated (km^2)
15 July 2016	1054.8	719.6
25 July 2017	1471.8	819.1
25-26 May 2021	136.0	27.2

Concluding Remarks of Objective #a: It is evident that there is a frequent occurrence of floods in the coastal region of Brahmani and Baitarani Basin. In the last 5 years, three major floods have occurred in the coastal plains creating major damages to the property and life. Flood event occurred in the month of July in 2016 inundated nearly 1054 Km^2 of landmass including cropland of 719 km^2. After a gap of 1 year, another major flood took place affecting a total landmass of 1471 km^2 including cropland of 819 km^2. Recently in May, 2021 the flood was caused due to cyclone 'Yaas', inundating 136 km^2.

Objective (b)

Task #1: Preparation of Land Use and Land Cover Map

Anthropogenic activities have substantially changed natural landscapes, especially in regions that are extremely affected by population growth and climate change such as the Eastern part of India. Understanding the patterns of land-use and land-cover (LULC) change is important for efficient environmental management, including effective water management practice. Using remote sensing techniques and geographic information systems (GIS), this study focused on changes in LULC patterns of Brahmani and Baitarani River Basins for over 30 years. Multi-temporal satellite imageries of the Landsat series were used to map LULC changes. The LULC map is divided into 6 classes, i.e. Water bodies, Dense forest, Open forest, Built-up area, Barren land, and Agricultural land. Further, the soil map of the study area has been generated.



Concluding Remarks from Objective #b: Brahmani and Baitarani Basin have undergone major LULC changes. The dense forest has decreased up to 56% and the open forest has increased significantly up to 200%. Human interference can be seen clearly as the built-up area has increased substantially to 15%. Agricultural and barren lands have also experienced substantial changes of up to 150% and 50%, respectively.

Task #2: Historical changes in river cross-sections

Concluding Remarks: The cross section changes in different years could be due to sedimentation problem for which further study is required.

Objective (c)

Task #1: Inflow forecasting into the reservoir

Flood forecasting plays a significant role in managing coastal flooding. In this study flood forecasting model is developed taking bias corrected Numerical weather prediction model forcings. The streamflow was simulated for using the SWAT model and a error forecasting sub-model was implemented to minimize the error. Streamflow forecast simulated by SWAT Pothole model is updated using an error correction model taking error time-series, i.e., $\varphi(t)$, $\varphi(t\text{-}1)$, ……, $\varphi(t\text{-}d)$ as input, which is obtained during the SWATP calibration phase; where $\varphi(t)$ is the simulated error between the observed (Q_{obs}) and SWATP estimated (Q_{sim}) discharge at any time, t, calculated as $\varphi(t) = Q_{obs}(t) - Q_{sim}(t)$. Where, d is the effectively correlated time lag obtained by auto-correlation function analysis of the error time series. The error-correction (forecasting) models are enlisted as: i) AutoRegressive (ARu); ii) AutoRegressive Moving Average with eXogenous inputs (ARMAXu), iii) Wavelet-based neural network (WNNu); iv) Dynamic wavelet-based Non-linear AutoRessive with eXogenous inputs (WNARXu). Among all the model variants, the performance of the PSWAT-WBiLSTM forecasting model was found to be the best (Fig. 2).

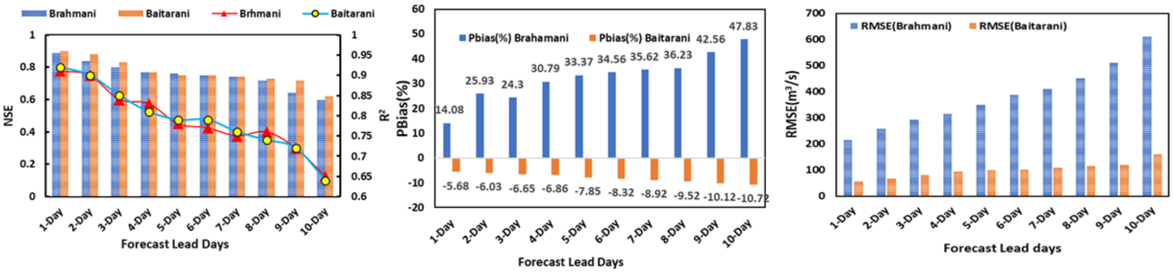


Figure 2. Performance of the PSWAT-WBiLSTM flood forecasting model up to 10 days lead-time.

Concluding Remarks from Objective #c: Using an error forecasting model to minimize the random error helped to improve the streamflow forecast at different lead-time. The NSE improved and falls in the range of 0.84 to 0.75 for a lead day of 1 to 5, respectively.

Objective (d)

Cyclones that make landfall on India's east coast are likely to cause inland floods and need real-time surge warnings to ensure minimum damage. The state-of-the-art numerical-wave models are often used for simulating such wind-driven events in the ocean. The work attempts to explore the effectiveness of a tightly coupled ADCIRC-SWAN model to compute water surface elevations as a combined effect of wind, astronomical tides, and waves. For the computation of storm tide, the coupled ADCIRC-SWAN model has been run for two simulations namely SIM1 and SIM2. The surge-wave model is calibrated for tropical Cyclone Fani (SIM1), which made its landfall on 3rd May 2019. Another Cyclone Yaas (SIM2), which hit the Bay of Bengal on 24th May 2021, is used to validate the model. As there are not many tide-gauge stations in the study region, the Dhamra tide gauge, located near the banks of Brahmani is considered for validation purposes. The computed water levels are compared with the measured tide gauge levels.

Concluding Remarks from Objective #d: The coupled model produced a Nash-Sutcliffe Efficiency (NSE) coefficient of 0.85 during the SIM1 run and 0.83 during the SIM2 run which shows good robustness of the tightly coupled model in predicting ocean water surface elevations i.e., tides and surges.

Objective (e)

Task #1: HEC-RAS 2D model simulation

The trials are initially carried out to map flood inundation in the BBD (Brahmani-Baitarani Delta) during the Yaas cyclone, which made landfall to the north of Dhamra port as a result of storm tide, upstream discharge, and precipitation. At BBD mouth, the ADCIRC-SWAN estimated temporal tide values serve as a downstream boundary condition. The HEC-RAS model has been set-up of BBD using Copernicus DEM with 30 metres resolution. The perimeter of the 2D flow area is defined along the boundary of the BBD. Computational points are generated with a grid spacing of 90 meters. The model based on 2D diffusive wave equation is run for the same period in which the ADCIRC-SWAN model has been executed. The results of the flood inundation simulation in BBD are presented in Figure 3 and performance criteria presented in Table 2.

Table 2. Performance of the HEC-RAS 2D model in simulating the flooded and non-flooded areas in the Brahmani-Baitarani delta during the cyclone 'Yaas'

	HEC-RAS 2D	**SAR**	**Error (%)**	**Accuracy (%)**
No. of flooded pixels	242562	209256	15.91	84.09
Flooded area (km^2)	1964.7522	1694.9736	15.91	84.09
No. of non-flooded pixels	987577	1020883	3.26	96.74
Non-flooded area (km^2)	7999.3737	8269.1523	3.26	96.74

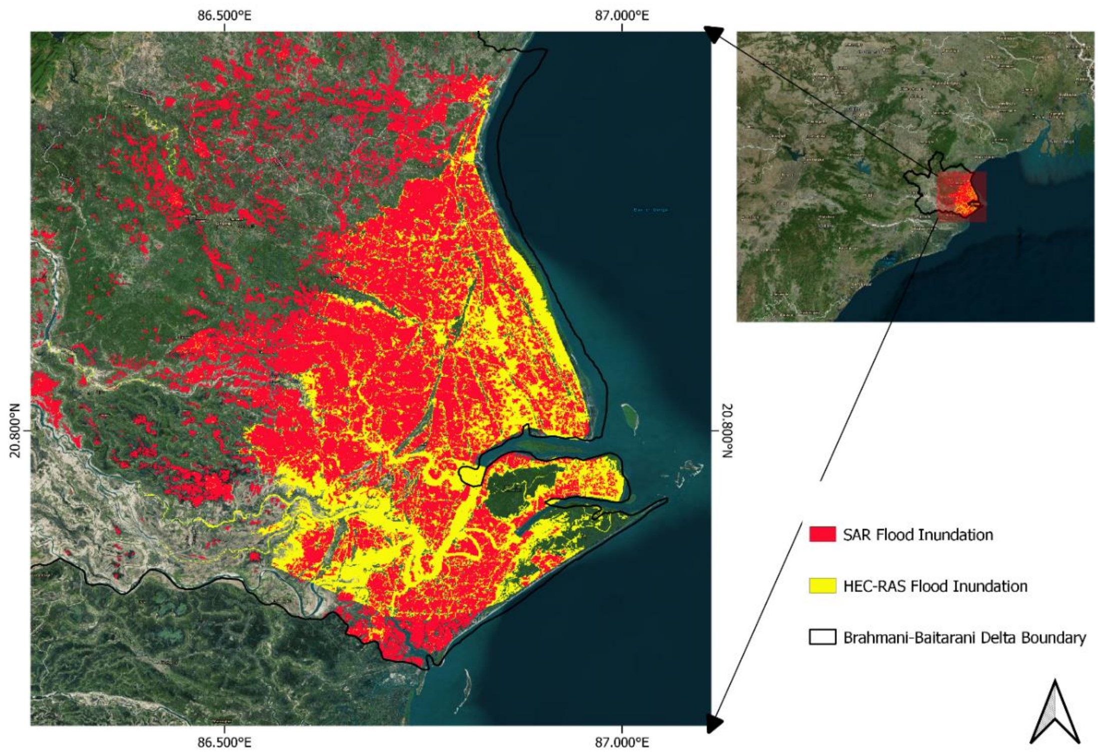


Figure 3. Flood inundation map of BBD generated based on HEC-RAS 2D simulation and SAR (Sentinel-1) extracted inundation extent.

Concluding Remarks from Objective #e: Flood inundation mapping in lower elevation zones close to coastal boundary require inclusion of tidal heights coming from ocean and entering into the river streams. This will account for the backwater effect in the river channel and will be helpful in correctly determining the inundated areas. Flood inundation computed from HEC-RAS 2D model as a combined effect of storm tide, upstream discharge and rainfall could reproduce the benchmark SAR based flooding extent. During the cyclone 'Yaas', the maximum flood depth and the flooding area in the Brahmani-Baitarani delta as simulated by the HEC-RAS model were 8 m, and 1964 km^2 (around 20 % of the total area), respectively.

Future Plan

- Setting up of RRI 2D flood inundation model for the river delta has to be initiated considering the upstream and downstream boundary conditions. For this, procurement of 10 m resolution DEM datasets is under progress.
- A vulnerability map will be prepared once objective (e) is completed.

COMPLETED STUDIES (INTERNAL)

1. PROJECT REFERENCE CODE: NIH/SWHD/22-24

1. Title of the Project

Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Flood Management

2. Project Coordinator:	Dr. A. K. Lohani, Sc-G (PI), NIH Roorkee Dr. R. K. Jaiswal, Sc-E (PI), NIH, CIHRC, Bhopal
Project Investigator(s)	
	Dr. J.P. Patra, Sc-E (Co-PI) Dr. P. C. Nayak, Sc-F (Co-PI) Dr. Vishal Singh, Sc-D (Co-PI)
3. Study Period:	**One Years (**April 2023 to March 2024)

4. Objectives

- To analyse rainfall and runoff for selected reservoirs
- To carry out water balance of reservoirs for computation of runoff
- To develop rainfall-runoff model for the catchment of reservoirs
- To develop integrated framework for real time flood forecasting using cloud based climatic data for early warning and efficient flood management
- To develop hydrodynamic model for assessment of flood impact downstream of dam

5. Present state-of-art

Flooding is an overflowing of water onto land that is normally dry. floods can happen during heavy rains, when ocean waves come on shore, when snow melts too fast, or when dams or levees break. flooding may happen with only a few inches of water, or it may cover a house to the rooftop. Floods are catastrophic events that cause damage to lives and properties. Due to the impact of climate change, high intensity rainfalls are being observed in the most part of world and India. These extreme precipitations may cause unprecedented runoffs and resulting in higher floods in the catchment. The recent change in climate pattern and land use in the catchment further aggravate the situation especially downstream of dams and reservoirs. The old formulae used to compute routed flood and flood protection works need to be evaluated and reformulated under changing climate situations.

Generally, regression based equations are commonly used for flood forecasting at reservoirs. In this method, water levels in the upstream and future forecast conditions from IMD are used to determine inflow in the reservoirs and according operation of gates are made during flood season. Nowadays, several sources of forecast data for climate variables on grid levels are available which can be used in well calibrated rainfall-runoff model to determine possible inflows to the reservoir through an integrated system. The gathered knowledge of future inflows can be used for efficient reservoir operation and assessment of downstream flood and issue appropriate preparedness for evacuation in the event of high flood.

6. Methodology

The automation methodology for the forecasting model is depicted in Figure-1. A Geographic Information System (GIS) database of the Tawa dam catchment, containing topographical, land use, soil, drainage, and downstream structures data, has been established. This GIS database serves as foundational information for modeling rainfall-runoff processes. Subsequently, a rainfall-runoff model has been developed to evaluate water production within the catchment under varying hydrological conditions. In this study, the HEC-HMS rainfall-runoff model has been developed for the Tawa reservoir catchments on a daily basis. Calibration and validation results of the model are presented in Figures 2to 7. The developed model is designed to incorporate future forecast climate data to predict runoff with a satisfactory level of accuracy.

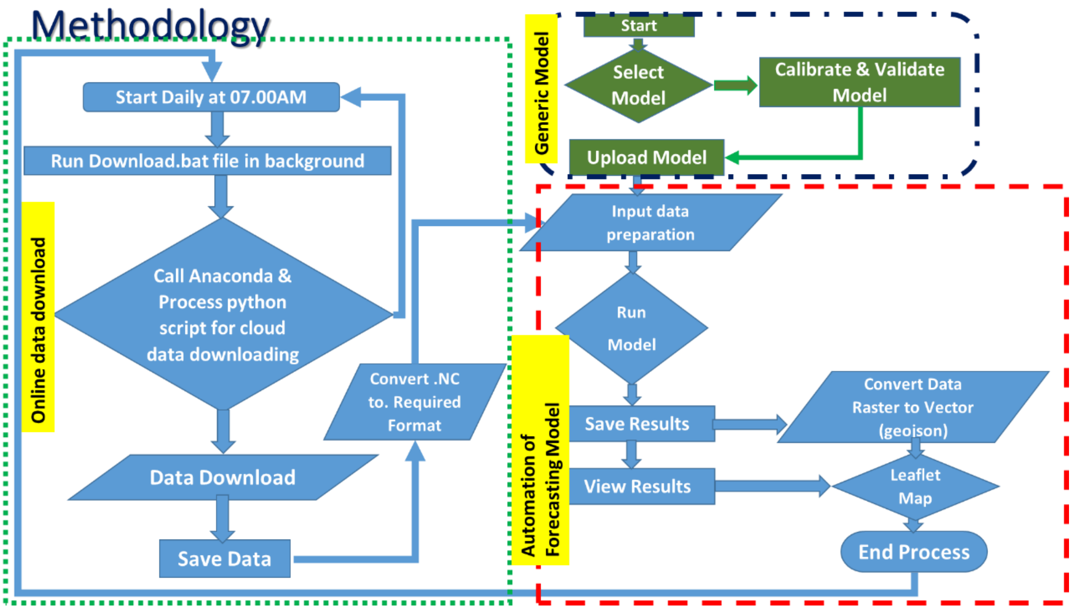


Figure-1: Methodology of Flood Forecasting System

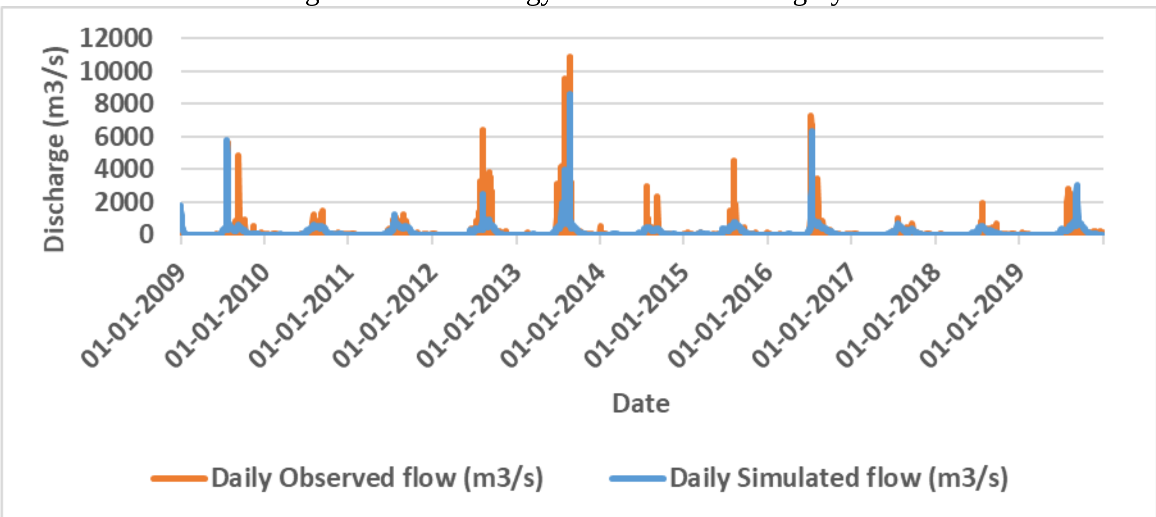


Figure-2: Calibration and validation of Tawa reservoir inflow

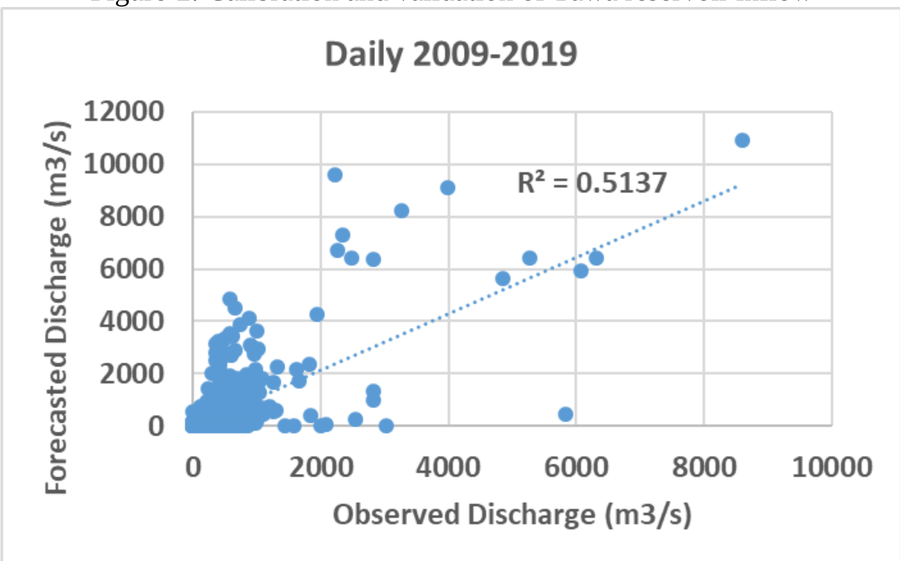


Figure-3: Scatter plot of observed and computed Tawa reservoir inflow (2009-2019)

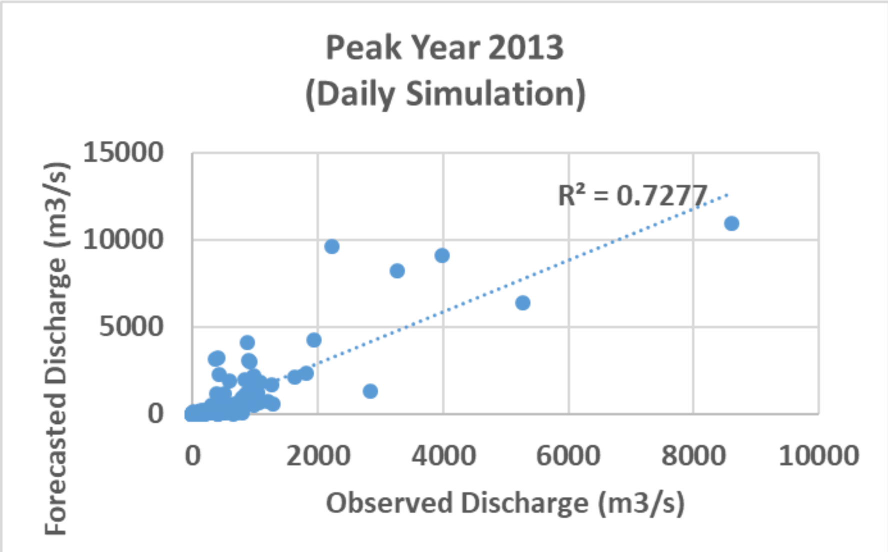


Figure-4: Scatter plot of observed and computed Tawa reservoir inflow (Peak flow 2013)

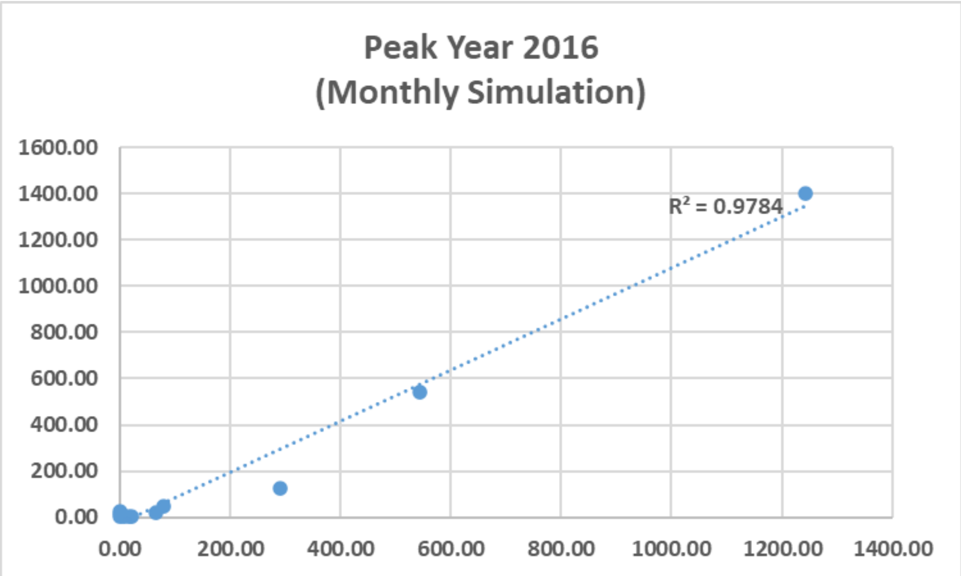


Figure-5: Scatter plot of observed and computed Tawa reservoir inflow (Peak flow 2016)

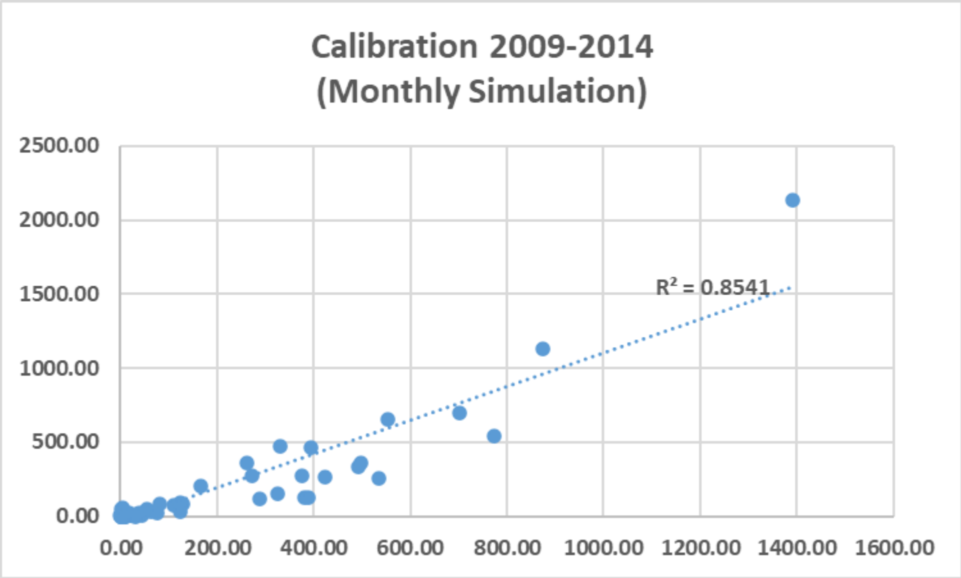


Figure-6: Calibration scatter plot: Tawa reservoir inflow (2009-2014)

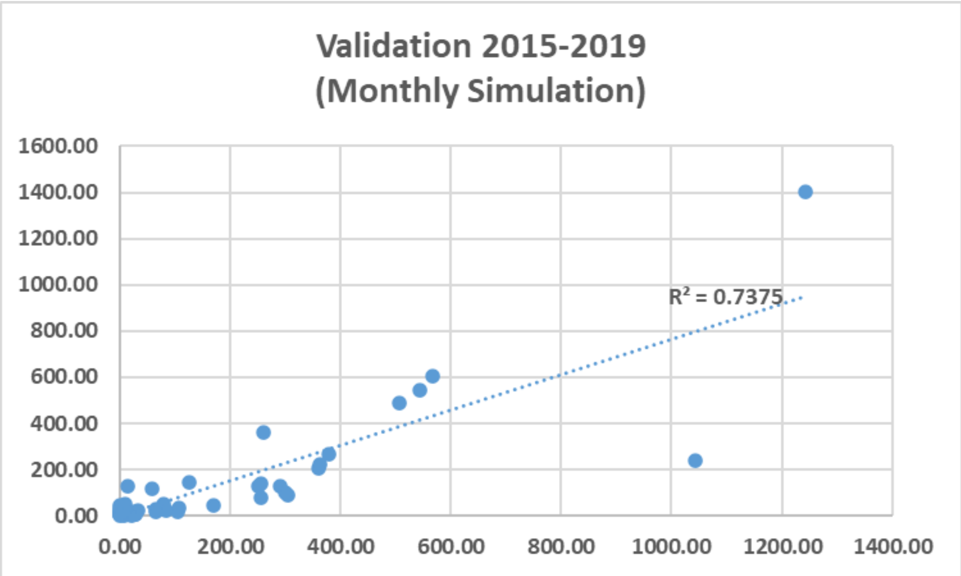


Figure-6: Validation scatter plot: Tawa reservoir inflow (2009-2014)

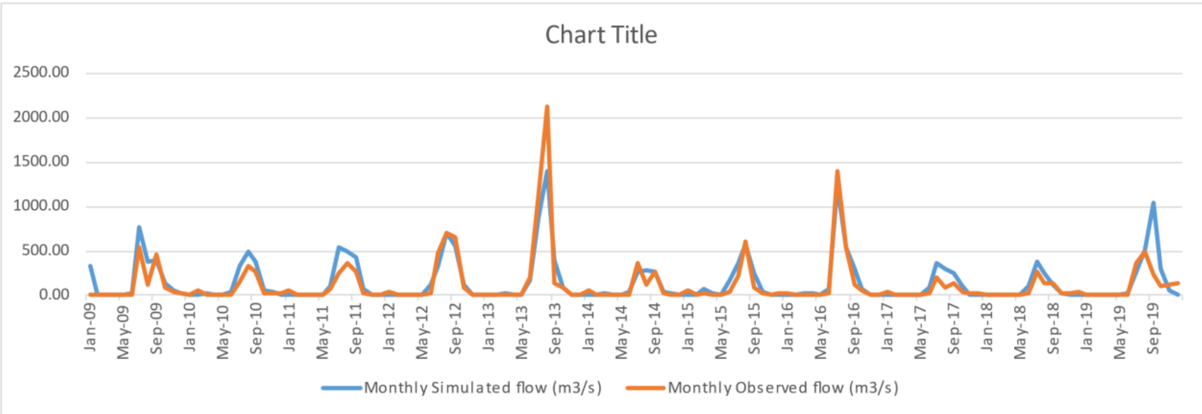


Figure-7: Monthly simulated and observed reservoir inflow (2019)

7. Research outcome from the project

Increasingly frequent catastrophic events are occurring worldwide, including in India. Implementing an integrated system to forecast reservoir inflows would greatly benefit the water resource departments of respective states, enabling more efficient reservoir operation and timely issuance of emergency warnings to evacuate people well in advance. The general public would benefit from receiving timely information during catastrophic flood situations.

COMPLETED STUDIES (INTERNAL)
2. PROJECT REFERENCE CODE: NIH/SWHD/NIH/21-23

1. **Title of Study:** Hydraulic force-inversion equation for exact modeling of hydraulic jumps in rectangular channels
2. **Study Group:** Sushil K. Singh, Scientist F, PI
3. **Study Period:** **One Years (**April 2023 to March 2024)
4. **Objectives of the Study:** The objectives of the study are:

Deriving a new closed-form analytical inversion equation of nondimensional hydraulic force for channel-flow with implicitly accounting for the nonuniform velocity, nonhydrostatic pressure distribution over flow-depth, bed friction, and turbulence. In view to very closely simulate the classical experimental data on hydraulic jump, and make it useful and handy to apply for field engineers, practitioners and academicians.

5. **Statement of the Problem:**

New analytical solution as envisaged has been derived. This is a single term solution derived in terms of trigonometric sine or cosine function. This basically is an analytical solution of the hydraulic force equation, a three degree (cubic) equation. The application of this solution and method on the several sets (23 sets containing around two hundred hydraulic jumps) of classical laboratory data published through different sources from 1917 to 2013 has been taken. These data were obtained under varying conditions of channel width (from normal to narrow to very narrow up to two-inch width), bed roughness, Froude number (normal to very small). Few jump data are also on air-flow experiment.

6. **Results**:

The results of application show that this method very closely simulates these experimental data, improving upon and outperforming the prior methods. The calculations for the method can well be accomplished on a hand-held calculator or on a spread sheet such as EXCEL, enhancing the ease and applicability of the method for field engineers, practitioners, and academicians.

7. **Status of the Study**: The study is complete and writing of the report is at final stage.

8. **Adopters of the results of study and their feedback**: Practitioners, field engineers, and academicians.

9. **Deliverables:** Report/Manual, Publications

ONGOING STUDIES (INTERNAL)

1. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-24

1. Title of the Study: Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model

2. Study Group: PI :P. C. Nayak, A. K. Lohani, J. P. Patra, Sunil Gurrapu, T. Thomas, Om Prakash, Jatin Malhotra

3. Type of Study: Internal Study

4. Study Period: Three Years (Jul 2022 to Jun 2025)

5. Study Objectives

- Develop a deep neural network-based hydrologic model to predict the long-lead-time flood forecasting
- Comparison between conceptual/distributed model with deep neural network to improve the flood forecasting
- The performance of the proposed model will be tested for Baitarani basin in Odisha state
- To predict the long leand time flood forecasting under changing climatic conditions, *i.e.*, include the GCM models output for future predictions

6. Results:

One of the most challenging problems in hydrology is Flood Forecasting (FF), owing to its critical contribution to the loss of economy and life. Therefore, this study intends to perform FF in the Baitarani River basin of India using both machine learning and physical tools. The Baitarani basin drainage area extends over 12,789 km^2, with a significant portion situated in Odisha and a smaller part of its upper reach in the state of Jharkhand. Two gauging sites, namely Champua and Anandapur of Baitarani basin, were chosen for modelling in this study. The discharge, rainfall and water level data of 30 years (1991-2021) are used for modelling.

Deep Learning (DL) techniques have recently been applied in hydrological modelling with its big data fitting capability and enhanced computing power. For rainfall-runoff modelling of the Baitarani basin, the **as machine learning tools such as** Long Short Term Memory (LSTM), CNN and E-D model are chosen as they perform well for time series forecasting, **especially when there is a longer-term trend in the data. The 30 years daily data of average rainfall, daily discharge, and daily water level is considered, in which 70% of data is** considered for training and the remaining for testing. **This study uses SWAT and HEC-HMS as physical models to perform rainfall runoff modeling. For both the physical models, the LULC, soil, and slope maps were used for data preparation.** The parameters chosen for SWAT modelling were CN2, ALPHA_BF, GW_DELAY, GWQMN, SOL_K, SOL_BD, and SOL_AWC. The 30 years of daily data of average rainfall of the basin and daily discharge data is provided, in which two years of data is taken as skip years for modelling. HEC-HMS can perform - based and continuous modelling of events according to the modeler's choice. Continuous rainfall rainfall-runoff modeling is performed using 30 years of gridded rainfall data and daily discharge data. The Deficit and Constant loss method with simple canopy, simple surface, Modclark transform method, Recession baseflow and Muskingum routing methods are opted for this study. The FF model is developed in HEC-HMS, and after trial and error of data, the model is finalized, and R^2 value is computed.

This study suggests that machine learning is better as compared to physical model it serves as a time-efficient approach in emergency situations, providing results more quickly than physical models. However, it is widely recognized that machine learning is a black box method. Nonetheless, in physical models, accurate parameterization prior to modeling can also yield results comparable to those of machine learning. In this study as in physical model, HEC-HMS outperformed SWAT in predicting rainfall runoff as shown in figure and table.

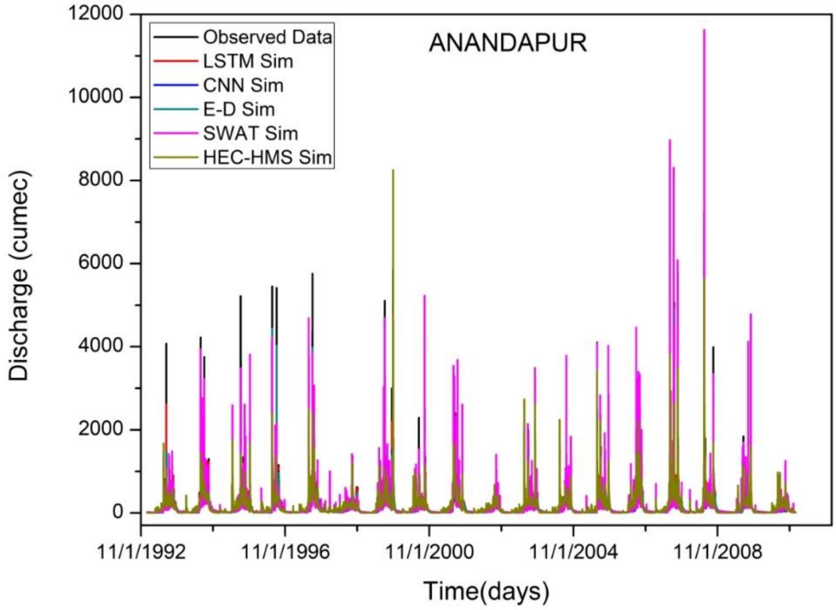


Fig 1: Daily simulated discharge performance graphs of LSTM, CNN, E-D, SWAT and HEC-HMS model at Anandapur outlet station of Baitarani basin for 1 day lead forecasting

Table 1: R^2 performance indices value of LSTM, CNN, E-D, SWAT and HEC-HMS model at Anandapur outlet station of Baitarani basin for 1 day lead forecasting

MODEL	LSTM	E-D	CNN	HEC-HMS	SWAT
R^2 VALUE	0.96	0.94	0.93	0.587	0.467

The preliminary result indicated that LSTM model is performing better that other models and two physical based model viz HEC-HMS and SWAT model's performance is not comparable with deep learning models.

7. Objective vis-a-vis Achievement

As mentioned in the objectives, preliminary investigation has been conducted to forecast flood for Champua and Anandpur gauging site for 1day and 2 day lead.

8. Progress since last meeting

The required hydrological has been collected from Odisha Water Resources Department and CWC, Bhubaneswar. Analysis is under progress

9. Future work for the next year: Flood forecasting using conceptual/physics based model is under progress and effect of climate change on flood forecasting is under progress.

ONGOING STUDIES (INTERNAL)
2. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-24

1. **Title of the Project**: Hydrological Study for revival and restoration of traditional water bodies in Bikaner, Rajasthan
2. **Project team:**

a. Project Coordinator — Dr. A. K. Lohni, SC-G

b. PI Project Investigator(s) — Dr. L. N. Thakural, Sc-D, Lead PI
Dr. M. K. Shama,Sc-E
Dr. Rahul Kumar Jaiswal, Sc-E
Sh. J. P. Patra, Sc-D
Dr. P. K. Mishra, Dc-D
Dr. Nitesh Patidaar, Sc-B
Sh. N. K. Bhatnagar, Sc-B,
Sh. Jatin Malhotra, SRA,

c. PI from Partner Organisation:
Dr. Anil Kumar Chhangani, Professor
Department of Environmental Science,
Maharaja Ganga Singh University,
Bikaner

3. Present state-of-art

Small traditional waterbodies including ponds and tanks are the most important water sources especially in rural areas. These waterbodies are increasingly recognized for their role in meeting rural water needs, aquifer recharge, providing livelihood opportunity, maintaining ecological balance and ecosystem services (Biggs et al., 2016). Small waterbodies are playing vital role in socio-cultural, economic and environmental development. Often, tanks and ponds support rural livelihoods of the marginalized community in rural, urban, coastal and tribal areas. There are about 5,00,000 tanks in India and mostly situated in semi-arid parts of India. As per 5th Census of Minor Irrigation Schemes Report, in surface flow schemes, tanks/ ponds have largest share of 41% followed by reservoir (14%) and temporary diversions (10%). These tanks help in capturing the runoff during monsoon and providing water for irrigation and other multiple uses for the community. However, continued unsustainable exploitation, increasing negligence and lack of conservation and urban growth resulting in huge adverse impact on these small waterbodies. Waterbodies are the lifeline for human existence and always the backbone of water resource sustainability in any urban area. They are going to disappear around the world. Solid waste dumping, industrial pollution, sewage pollution, encroachments, commercial fish farming and other practices are the main causes of this situation. Urbanization and industrialization have increased the intensity of pollution to such an extent that waterbodies' self-healing capacities are no longer enough to counter these multiple onslaughts. Flood mitigation, groundwater recharge, biodiversity enhancement, industrial development and water security are just a few of the benefits that waterbodies provide to a city. It is time their role is properly evaluated in the urban economy and effective actions are initiated for their rejuvenation. Bikaner city has a number of water bodies since ancient time, which has been disappeared due to ignorance and non-maintenance of these water bodies. Bikaner city will be studied followed by broad recommendations on site-specific approaches for revival and restoration.

4. Objectives:

a) To prepare inventory of water bodies in Bikaner and to understand the role of the water bodies in the human survival, livestock and livelihood sustainable and in biodiversity conservation.
b) Long-term spatio-temporal analysis of rainfall, temperature and meteorological variables.
c) Landuse land cover (LULC) change detection in the study area and selection of pilot water bodies (ponds).
d) Trend analysis of groundwater levels and assessment of recharge to groundwater in Bikaner district
e) Surface water availability analysis of pilot water bodies.
f) Identification of various issues both quantitative and water quality assessment of pilot water bodies.

g) To understand the socio-economical role of the water bodies to meet the daily requirement of community for water and other natural resources in and around water body.
h) To understand the existing governance and management practices of water bodies by the local community or any other authorities.
i) Suggesting ameliorative measures to restore water quality of water bodies and daptive and mitigation measures for rejuvenation and sustenance of water bodies.

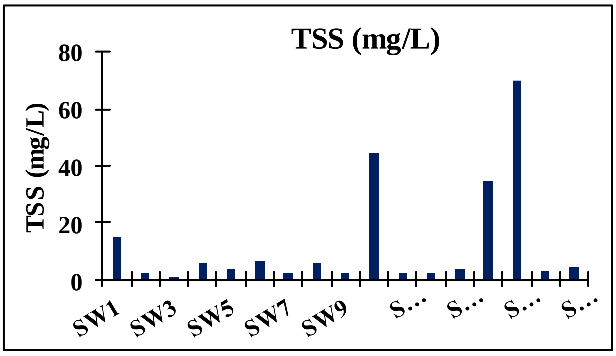
5. Methodology:

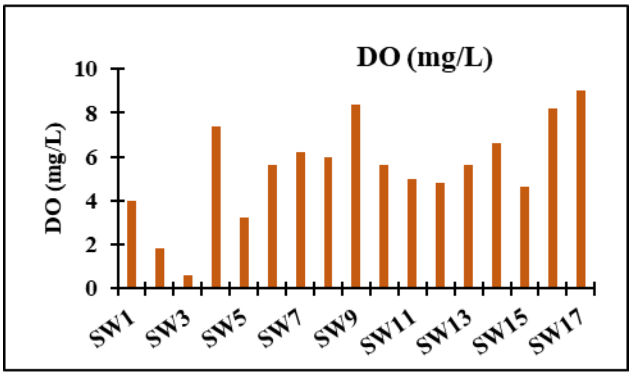
- Present GW Scenario and trend analysis
- Estimation of GW recharge
- Trend analysis using statistical approach
- Assessment of Land use/Land Cover and its impact on runoff characteristics in the catchments of Waterbodies
- Assessment of Soil Loss from the catchments
- Surface water availability analysis
- Water Quality Assessment from water bodies
- Site-specific approaches for revival and restoration
- True repositories of biodiversity

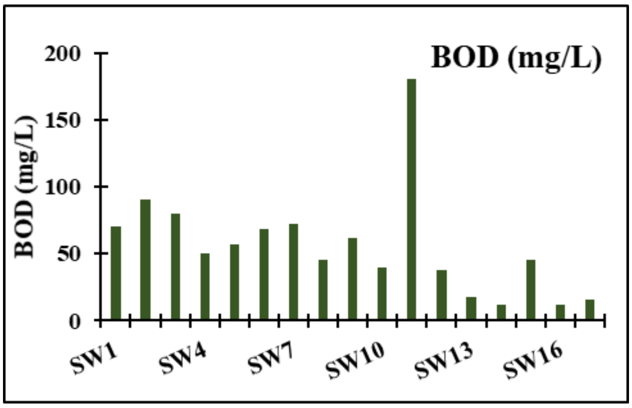
6. Research outcome from the project:

The outcome of the study will help in the revival and restoration of ponds in Bikaner. bodies.

7. **Progress:** The water bodies in Bikaner were identified and mapped. The catchment area of selected water bodies located in both urban and rural areas has been delineated using a digital elevation model (Cartosat DEM) with a spatial resolution of 30 m in the GIS environment. The Lanuse/Landcover for the study area has also been prepared using Landsat 8 imagery for the year 2020. The daily gridded IMD data of rainfall (0.25°x0.25°), maximum temperature, and minimum temperature (1°x1°) for the period 1951-2020 were downloaded. The daily data were processed and converted to a monthly scale. Homogeneity Tests for rainfall, T_{max}, and T_{min} series were performed to detect the change point using four widely used tests namely the Pettitt test, standard normal homogeneity test (SNHT), Buishand range test, and von Neumann ratio test on an annual and seasonal time scale. Moreover, non-parametric approaches (Mann Kendall and Sen slope of Estimator) were employed to detect and quantify trends in these variables. A reconnaissance survey and collection of water samples of the 15 water bodies including the water bodies referred by the Ministry of Jal Shakti has been carried out during the post-monsoon and pre-monsoon field visit of Bikaner. Some parameters like pH and electrical conductance were measured on the spot by means of portable meters (HACH, USA). For other parameters, samples were preserved by adding an appropriate reagent and brought to the laboratory in sampling kits maintained at 4°C for detailed chemical analysis. The analysis of physico-chemical parameters DO, BOD, COD was performed as per standard methods (APHA, 2017). Major Cations (Na, K, Ca, Mg), Major Anions (HCO_3, Cl, SO_4, NO_3), Minor Ions (F, PO_4) were analyzed using Ion Chromatograph. The results of water sample analysis during pre-monsoon are presented in Fig. 1.







SW1:Sursagar	SW10:Kolayat
SW2:Sonsolav	SW11:Diyatra
SW3:Harsolav	SW12:RD750 (canal head)
SW4:Dharnidhar	SW13:RD750
SW5:Foolnath	SW14:RD507(canal head)
SW6:Naal Badi	RD:507
SW7:Kodamdesar	SW16:Swarupdesar
SW8:Darbari	SW17:Kalyansagar
SW9:Gajner	

Fig 1: water samples for TSS and Demand parameters (DO, BOD)

Soil investigation was performed in the urban and rural areas of the Bikaner district. Soil samples from seven different locations were collected and analyzed in the Soil Water Lab of NIH for deriving soil texture and soil moisture characteristic curves. It was observed that the texture is mainly sandy in the area with more than 50% sand proportion at all locations. An infiltration test was performed in the field using a double ring infiltrometer at four locations. The infiltration rate varies approximately from 16 to 20 mm/hr in the study area. The groundwater status and trends were also carried out for the detection of trends in groundwater level utilizing groundwater level data acquired from CGWB. The results reveal that a rising trend (in 43% wells) is observed towards the IGNP canal, while the groundwater is falling in the Southern parts (in 21% wells) and approximately 35% of wells show a no-trend in groundwater levels of the Bikaner district for the period 2001-2020

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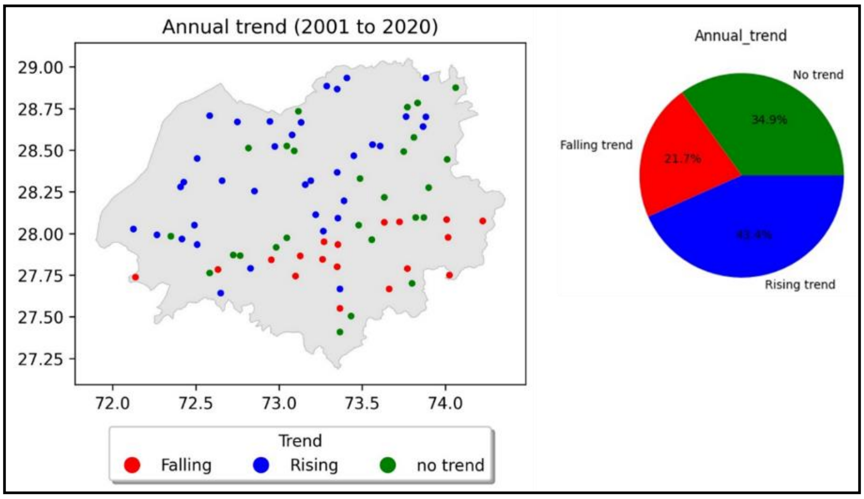


Fig. 2. Trend in groundwater levels in the Bikaner district

The NRSC curve number method is employed to estimate runoff depth within the catchment areas of various water bodies in the Bikaner district of Rajasthan. The catchments soil map is created using the FAO soil map within ArcGIS, and subsequently, hydrologic soil groups (HSG) are designated based on soil map. Additionally, the Land Use and Land Cover (LULC) maps of the catchments are generated using ArcGIS. Curve numbers are then assigned to the catchments based on the combination of LULC classes and HSG, following the guidelines provided by USDA-NRCS (1986). To determine the Antecedent Moisture Condition (AMC), the 5-day rainfall preceding the event date is considered. CN values corresponding to AMC II are adjusted to represent AMC I and AMC III using the SCS Standard Tables (USDA-SCS, 1993). The runoff estimation results from different catchments are illustrated in Fig. 3.

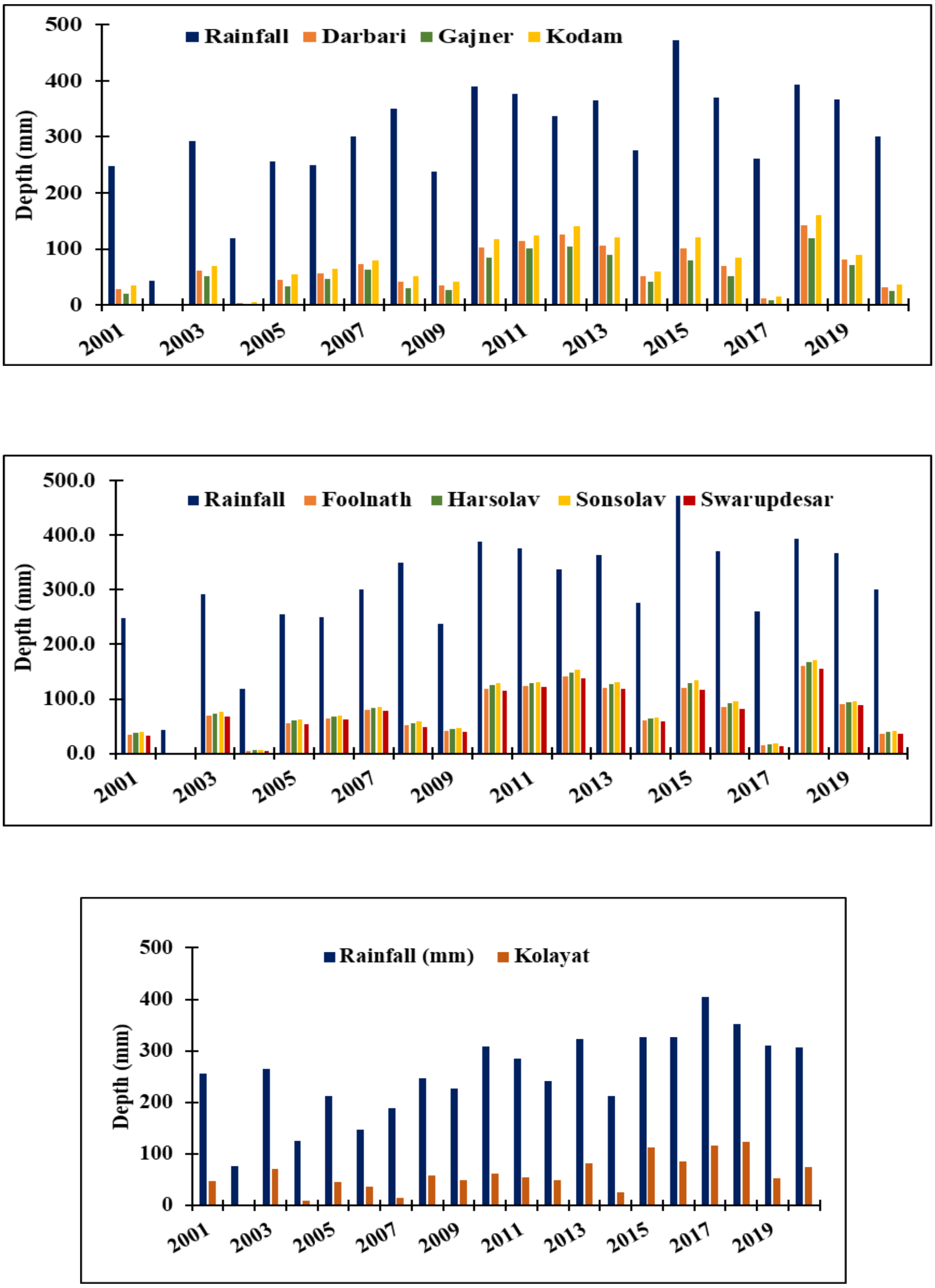


Fig. 3 Rainfall-Runoff analysis in the different catchments of Bikaner district

ONGOING STUDIES (INTERNAL)
3. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-25

1. **Title of the Project**
   Review of design flood and dam break analysis of Khadakhai Dam in Odisha.

2. **Project team**:
   a. Project Investigator: J.P.Patra, Sc. – D, SWHD
   b. Project Co-Investigator: A. K. Lohani,, Sc. – G & Head SWHD
   Pankaj Mani, Sc. – F, CFMS Patna
   P. C. Nayak, Sc. – F, SWHD
   Sanjay Kumar, Sc. – F, SWHD
   Jatin Malhotra, SRA
   c. WRD Odisha: Tapas Pattanaik, Damsaftey
   Tareni Sen Dhala, CE & BM Subarnarekha

3. **Duration of the Study**: 3 years (April 2022 to March 2025) : Ongoing
4. **Type of Study**: Internal Study
5. **Location Map**

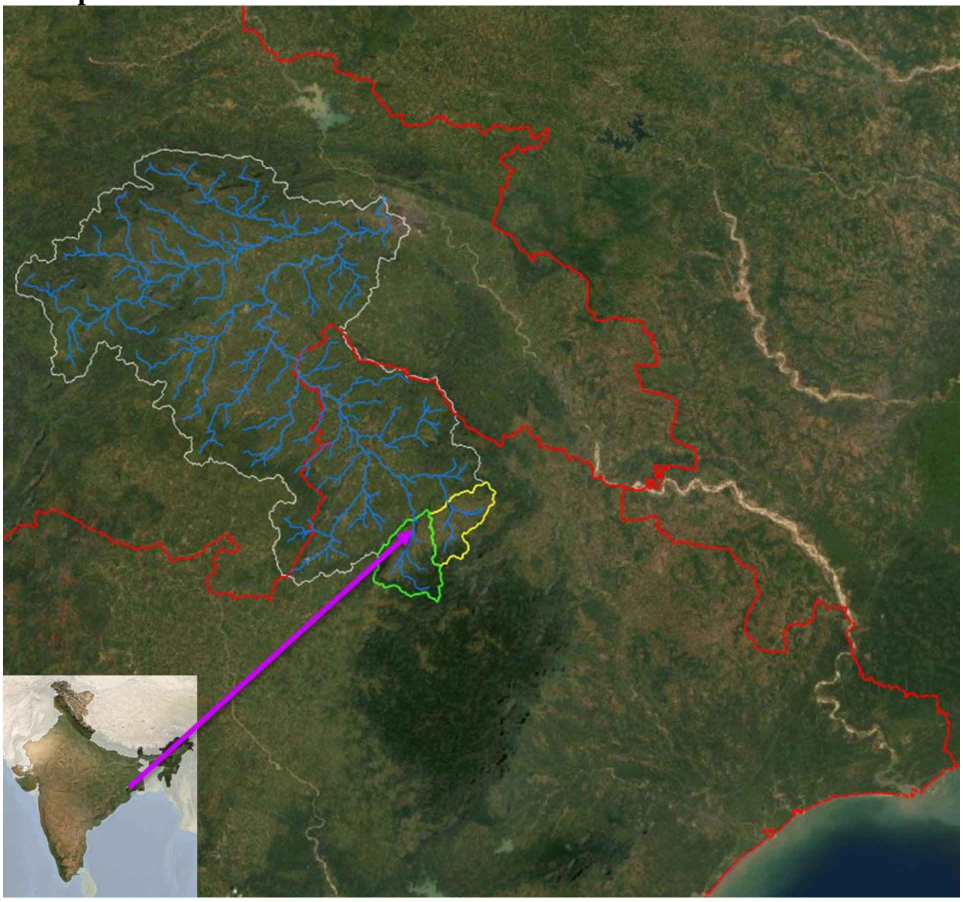


Figure 1: Location map of the study area

6. **Objectives**
   a. To estimate design flood for the Khadakhai Dam.
   b. To analyses uncertainty associated with estimation of design floods in view of future climate projections.
   c. To review and improvement of Khadakhai Dam operation rule curve.
   d. To prepare dam breach flood inundation maps for various scenarios.
   e. To access sensitivity of the flood inundation maps due to uncertainty in estimate of design flood, breach parameters and reservoir sedimentation.

7. **Statement of the problem**

The Khadakhai Dam is an earthen dam of 365.4 m length build across Khadakhai river in 1981. The maximum height above foundation of the dam is 37 m. It has been constructed on two ends of hills i.e., Bhitarmda hill and Karanjharan hill end points. The reservoir is known as Suleipat reservoir, created mainly for irrigation purpose. In April 2012, Ministry of Water Resources, River Development & Ganga Rejuvenation through Central Water Commission with an objective to improve safety and operational performance of selected dams started the Dam Rehabilitation and Improvement Project (DRIP) with World Bank assistance. Design flood review and preparation of EAP are two important activity in DRIP. The older dams are designed with limited data and atmospheric realities of that period. Now, as those realities shift dramatically with the climate crisis, and need to be relooked. A dam operator has to manage the water release and storage cycle in such a manner that at the end of the monsoon period, its reservoir is at its full capacity. The storage and release schedule of a dam is governed by a rule curve. However, these rule curves are based on monsoon patterns of a time when such patterns were far more predictable, and less disrupted by climate change than they are today. Dam breach modelling is a key component to a well-rounded and robust dam safety program. Various researcher and guidelines recommended combination of breach parameters. The parameters are highly sensitive to peak flood and resulting flood inundation extent. This is further increased with uncertainty in design flood, reservoir operation policy, reservoir sedimentation etc. These needs to be addressed systematically while developing flood inundation map and EAP.

8. **Approved action plan and timeline**

S.N.	Work Element	1st Year				2nd Year				3rd Year			
1	Collection of basic data, topography, cross-section, satellite images, thematic maps etc.	■	■				■						
2	HEC-HMS model setup, review & estimate design flood		■	■	■								
3	Uncertainty analysis for design floods with future climate projections.				■	■	■						
4	Analysis of operation rule curve								■	■			■
5	HEC RAS model setup for dam beach modelling			■	■								
6	Dam breach flood inundation modelling and combined general flood hazard classification							■	■			■	
7	Review and analysis of reservoir sedimentation and updating of EAC table									■	■		
8	Sensitivity of the flood inundation maps.									■	■	■	
9	Workshop/ Training.			■				■				■	
10	Report.				■				■				■

9. **Brief Methodology**

It is proposed to develop a rainfall runoff model using HEC-HMS for estimating design flood hydrographs at the dam site. Design flood will be estimated using the recently developed PMP atlas. Further, the future climate projections (INCC), non-stationarity in the rainfall/ discharge pattern along with LULC changes will be analysed for assessing uncertainty in the design flood estimates. Based on the estimates of design flood it is proposed to evaluate and improve the existing rule curve in DSS (PM) platform. The dam break analysis will be carried out using HEC RAS. Sensitivity analysis will performed to access sensitivity of the flood inundation maps due to uncertainty in uncertainty in design flood, reservoir operation policy, reservoir sedimentation etc.

10. **Results achieved with progress/present status**

The salient features of Khadakhai dam is obtained from the project authority and literatures. The physiographic parameters of the river catchment at dam site have been estimated by GIS processing of STRM DEM.The Synthetic Unit Hydrograph is developed using these catchment characteristics and relationships provided in flood estimation report for Lower ganga plains subzone-1g (CWC, 1994). The manual on estimation of design flood analysed time distribution pattern of storms in the area for which adequate self-recoding rain-gauge data are available. In the manual, depth duration analyses of maximum rainfall depths for standard duration of 6, 12, 18, 24, 36, 48 hours etc., were obtained for each of the storms and expressed as percentage of the total storm depth. Enveloping percentages are then obtained and applied to adjust the design rainfall based on observational data. In absence of hourly rainfall data it is recommended to apply a factor of 1.15 to convert 1-day maximum rainfall to 24-h maximum rainfall. The 1day annual maximum rainfall for various return periods and PMP are shown in Figure 2. The 24 hour rainfall is divided in to incremental hourly rainfall according to time distribution provided in the CWC report. To obtain the critical sequence of rainfall the largest of increments is placed against the peak of UH, then the next largest against the next UH ordinate and so on until all rainfall increments get arranged. Then the sequence is reversed to get the critical sequence for all spells. In case of 24-h duration rainfall the first and second 12 h blocks are interchanged to get critical situation. The design loss rate is subtracted from the hourly rainfall to obtain effective rainfall hyetograph and then direct runoff hydrograph is estimated by convoluting this effective rainfall with SUH. Finally, the base flow is added to obtain design flood hydrograph. The HEC HMS model has also been prepared with IMD gridded rainfall data as input as shown in Figure 3. Sarkar and Maity (2020) suggested to consider temporal change of PMP in India for planning, designing and future risk assessment of any major high risk water resources infrastructure. Base on their findings the PMP may decrease by 2.2% under RCP 4.5 and may increase by 12.75% under RCP 8.5 for the projected time period of 2071to 2100. The corresponding design flood hydrographs are also developed. The HEC RAS model for Dam break modelling is under progress.

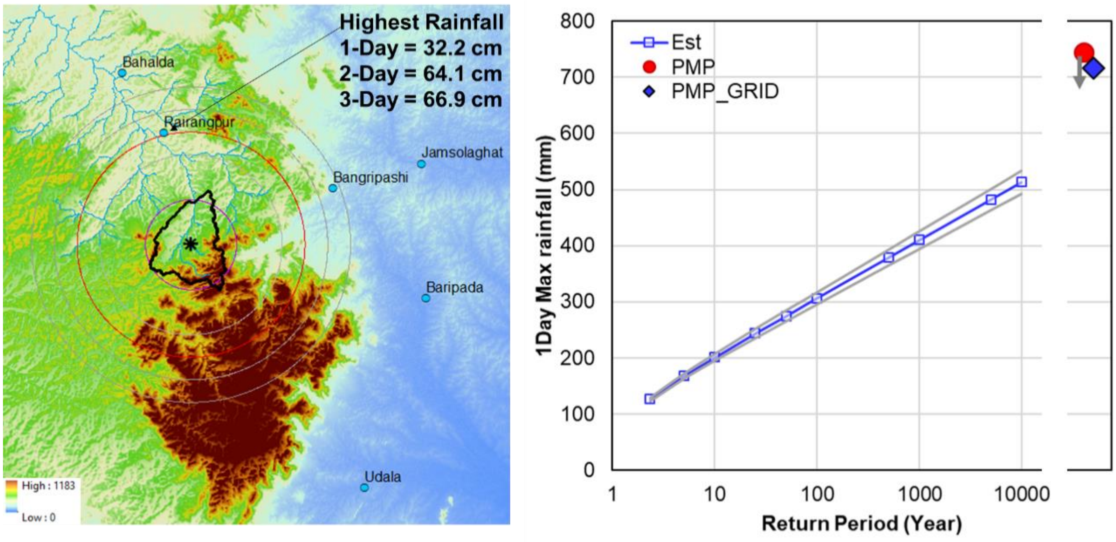


Figure 2: 1-day Maximum rainfall for various return periods and PMP.

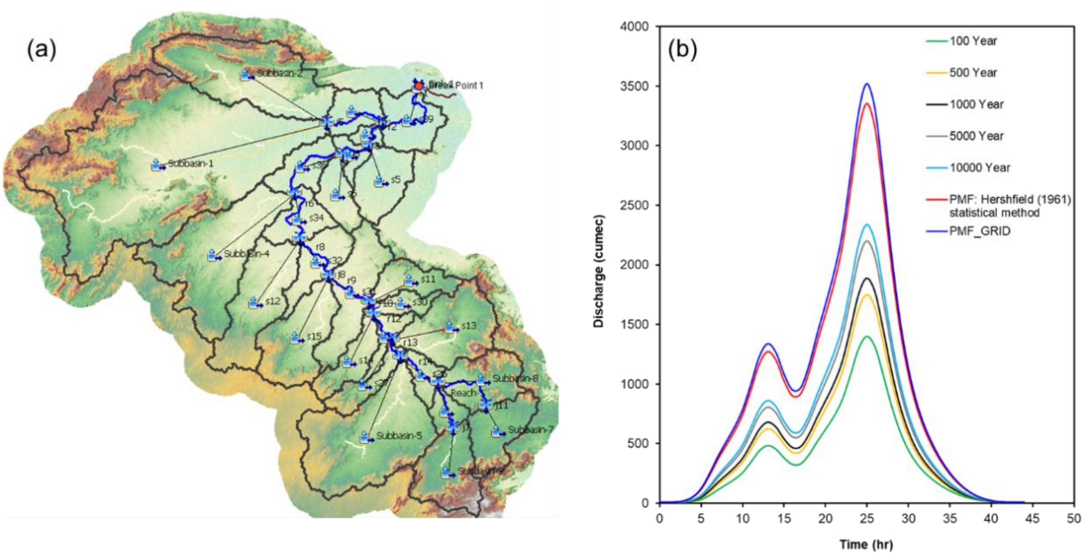


Figure 3: (a) HEC-HMS model setup; (b) design flood hydrographs at dam site.

11. **Research outcome of the project**
    - Revised design flood for the Khadakhai Dam.
    - Flood inundation maps along with depth, velocity, time of flood arrival, combined flood hazard due to large controlled release and dam break of Khadakhai Dam.
    - Capacity building in line with DRIP.
    - Application of DSS (PM) developed under NHP

12. **End Users/Beneficiaries of the study**:
    Department of Water Resources, Govt. of Odisha

ONGOING STUDIES (INTERNAL)
6. PROJECT REFERENCE CODE: NIH/SWD/NIH/21-24

Title of the Project:	Investigation of hydrodynamic approach of flood inundation mapping along with assessment of changes in river planforms using a cloud-based Google Earth Engine (GEE) computing platform in data-scarce Western Himalayan River basin
Project Team:	Dr. R. V. Kale, Sc. E, SWHD, PI Dr. A. K. Lohani, Sc. G & Head SWHD, Co-PI Er. J. P. Patra, Sc. E SWHD, Co-PI Er. D. Khurana, SRA, HID, Co-PI
Collaborating agency	
Type of Study	Internal Project (NIH)
Duration	3 years
Date of Start	September 2021
Date of Completion	October 2024
Budget	Rs. 90,000/-

Statement of Problem

The water-related disasters particularly flood hazard is on rise all over the world particularly in the western Himalayan region in its frequency, magnitude and damage caused to property and society. Therefore, there is very high societal demand to cope with flood hazards and incurred damages. Usually, in conditions of scarce data availability, a preliminary and cost-effective floodplain delineation can be carried out using procedures that relay on the analysis of geomorphic features (Manfreda et al., 2014). The worldwide conducted studies have shown that geomorphic behaviour and form of rivers across the world have changed strongly compared to a century ago due to land cover change and/or infrastructure construction (Schwenk et al., 2017). These changes to river planform and geomorphic dynamics have caused, and continue to cause, ecological, hydrological and environmental impacts. These river changes can be attributed to processes occurring over multiple timescales. As observed changes in geomorphic dynamics in rivers are strongly timescale-dependent, limiting a geomorphic study to a single timescale can cause biased observations in channel dynamics, with long-term measurements leading to underestimations of the total change occurring over shorter timescales (Harvey and Gooseff, 2015; Donovan and Belmont, 2019). With recent technological advancements, access to Google Earth Engine (GEE), a cloud-based computing platform for planetary-scale geospatial analyses offers access to petabytes worth of remotely sensed Earth observation data (e.g., multi-spectral satellite imagery) (Gorelick et al., 2017), enabling meaningful geomorphological analyses at higher spatial resolutions, over greater spatial extents and at finer temporal resolutions than ever before. Relevant to flood risk management, recent applications of GEE include the integration of Synthetic Aperture Radar (SAR) imagery with optical satellite imagery (e.g., Landsat collections) for event scale flood detection and monitoring (e.g., DeVries et al., 2020).

A considerable number of studies have demonstrated the use of the one- and two-dimensional (1D and 2D) numerical models to delineate floodplains, which allow an accurate representation of river hydraulics and floodplain inundation dynamics. Simplified 2D models have a solid advantage by being computationally significantly more efficient than, for instance, fully 2D models based on the complete St Venant equation (Néelz and Pender 2013). Previous research study by Néelz and Pender (2013) clearly indicates that for the representation of flood extent all 2D packages perform comparably (those which solve full shallow water equations and those, which neglect/simplify certain terms). For the data-scarce areas and flashy river basin, hydrological and inundation models play a critical role on flood simulations, planning of an emergency flood disaster risk management activity, planning of long-term flood control counter measures and risk assessment (Chao et al., 2019, Yu et al., 2018).

Taking into account all the issue discussed in above section, the present study likely to attempt to utilize power of a cloud-based GEE to analyses the planforms changes. Further, this study attempts to evaluate the predictive capabilities of two-dimensional Rainfall-Runoff-Inundation (RRI) model and its comparison with HEC-RAS/HEC-HMS model results in development of flood inundation mapping.

Objectives

a) To use a cloud-based Google Earth Engine (GEE) computing platform to systematically identify inter-annual changes in river planform morphology
b) Interpret changes in channel conveyance that are relevant for flood risk assessment
c) To evaluate predictive capabilities of Rainfall-Runoff-Inundation (RRI) model in development of flood inundation map
d) To carry out comparison of the RRI model-based flood inundation maps with those obtained by using HEC-RAS and HEC-HMS models.

Brief Methodology

The methodology followed to achieve the objectives of the study is briefly presented as follows:

a) To investigate spatial differences in river planform, the rivers will be classified into number of reaches defined by their physiographic setting and valley gradient
b) Google Earth Engine will be used to extract information on river planform morphology from multitemporal, multi-spectral satellite imagery. Landsat surface reflectance products (Landsat 5 Thematic Mapper, Landsat 7 Enhanced Thematic Mapper and Landsat 8 Operational Land Imager) and sentinel data products (Sentinel-1 SAR GRD and Sentinel-2 MSI) will be used as the primary source of satellite imagery available from 1988 onwards and other imagery data may be used in the investigation.
c) Various indices particularly Normalized Difference Water Index (NDWI), Modified Normalized Difference Water Index (MNDWI) and or Automated Water Extraction Index (AWEI) and other suitable approaches will be used to achieve active channel mapping at multi-temporal scale.
d) Numerous automated and semiautomated tools in python or MATLAB programming languages for planform analysis exist, with the outputs from GEE ready to be used to derive planform statistics and quantify change. These tools will be used to derive planform statistics and quantify the changes.
e) The Rainfall-Runoff-Inundation (RRI), a two-dimensional coupled hydrological and inundation model, which include three key components: a rainfall-runoff model, a river routing model, and a flood inundation model will be used develop the flood inundation map for the selected high flood events in the study as well as for 10-, 50- and 100-year return year flood at gauging site based on standard frequency analysis and unit hydrograph techniques.
f) Further, the flood inundation results for the study area by RRI model will be compared with those obtained by the application of the HEC-RAS and HEC-HMS model.

Study area

The River Tawi, which passes through the heart of the Jammu city, is an important tributary of the Chenab River in the Western Himalayan region. Tawi river originates from the lap of Kailash Kund glacier and adjoining area southwest of Bhadarwah in Doda district of the Union Territory of Jammu and Kashmir, India. The catchment area of the Tawi river basin is bounded by latitude 32° 35' 20"-33° 6' 6" N and longitude 74° 29' 8"-75° 40' 54" E which varies between 239 and 4331 m. The total catchment area up to its confluence with the Chenab river is around 2964 km. The basin shape in the upper part is elongated while broad in the lower part. The catchment of Tawi river up to Indian border is about 2745 km^2 falls mostly within the districts of Jammu and Udhampur of J&K state. Location of the Tawi catchment is shown in Fig. 1. The average height of the catchment is about 2200 m above mean sea level (msl). Being a mountainous river Tawi has more than 2000 numbers of tributaries and sub-tributaries. However, there are nine numbers of predominant tributaries of the river Tawi. The Tawi River is comprised of streams of 1-6 orders.

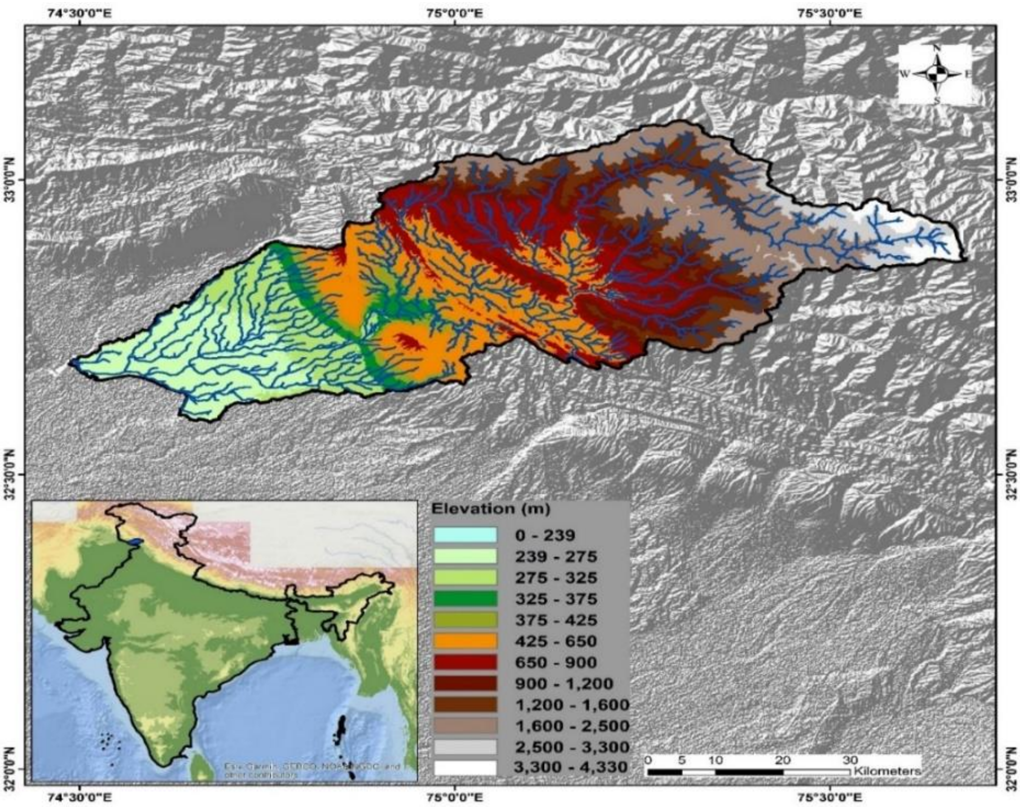


Figure – 1: Location map of Tawi river basin.

Action Plan

Stages of work and milestone:

Work Element	**1st Year**				**2nd year**				**3rd year**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Literature Review and detailed formulation of research approach	■	■										
Procurement/Collection of available hydro-meteorological data, river cross-section, gauge/discharge data, rating curve, satellite images, thematic maps. Collection of GCP and flood water mark data through field work (if condition permits) etc	■	■	■	■	■	■	■	■	■	■		
Development of codes in GEE	■	■	■	■	■							
Analysis of fluvial geomorphometric Planform results				■	■	■	■	■	■	■		
RRI model set-up for study area			■	■	■	■	■	■	■			
Comparison with HEC-RAS/HEC-HMS model results							■	■	■	■	■	
Results analysis							■	■	■	■	■	
Assessment of flood inundation under current and future changing climate			■	■			■	■			■	■
Report writing	1st interim report				2nd interim report				Final report			

Achievements vis-à-vis Objectives

Sr. No.	Objectives	Achievements
(a)	To use a cloud-based Google Earth Engine (GEE) computing platform to systematically identify inter-annual changes in river planform morphology	Completed
(b)	Interpret changes in channel conveyance that are relevant for flood risk assessment	Completed
(c)	To evaluate predictive capabilities of Rainfall-Runoff-Inundation (RRI) model in development of flood inundation map	In-Progress
(d)	To carry out comparison of the RRI model-based flood inundation maps with those obtained by using HEC-RAS and HEC-HMS models.	In-Progress

Progress of work

Objective (a)

Literature Review and detailed formulation of research approach

A through literature of the review has been carried out to formulate the research approach in the present study. These changes to river planform and geomorphic dynamics have caused, and continue to cause, ecological, hydrological and environmental impacts. These river changes can be attributed to processes occurring over multiple timescales. As observed changes in geomorphic dynamics in rivers are strongly timescale-dependent, limiting a geomorphic study to a single timescale can cause biased observations in channel dynamics, with long-term measurements leading to underestimations of the total change occurring over shorter timescales (Harvey and Gooseff, 2015; Donovan and Belmont, 2019). The changes in the Tawi planform during 1988 to 2022 based on the composite Landsat data is shown in Figure 2. It has been observed that significant changes in the planform of the Tawi river has been observed in the lower reaches downstream of the Sidhara gauging site as observed from following Figure 2. The further work is under progress to extract the planforms for various time scale from sentinel-1 and sentinel-2 images using proposed water masking filters.

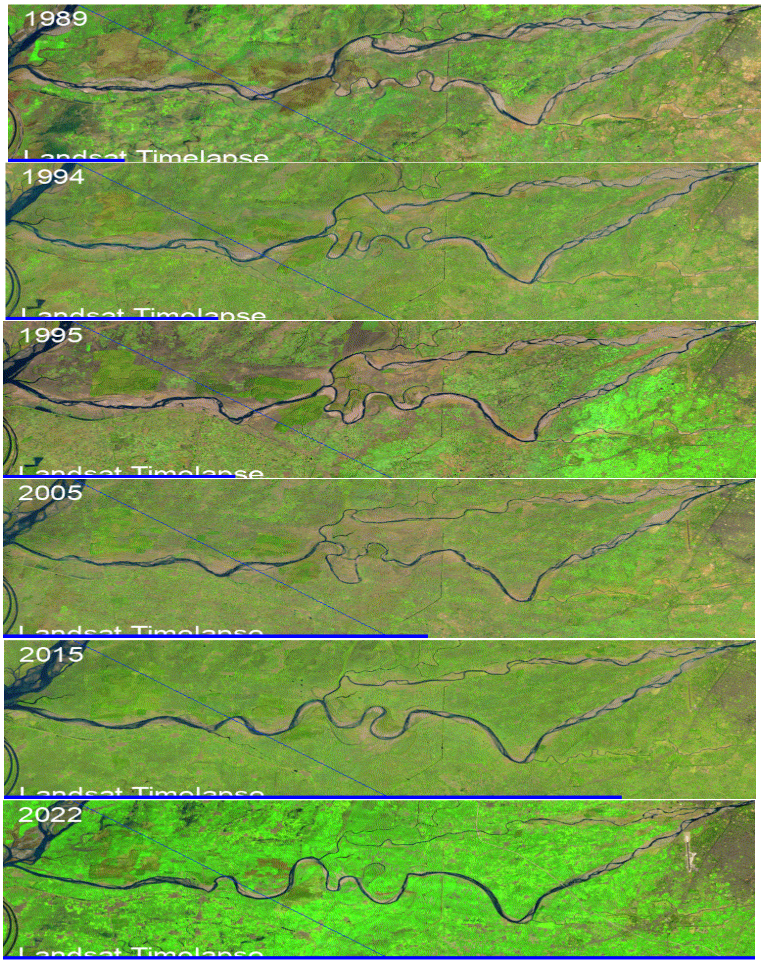


Figure 2: Observed changes in the Lower Tawi river planform during 1988 to 2022.

Most of the required available hydro-meteorological data, river cross-section, gauge/discharge data, rating curve, satellite images, thematic maps are collected.
The necessary programming codes in GEE were tested to achieve the results.

Objective (b)
Extracting the active river channel within Google Earth Engine (GEE): The programming code within Google Earth Engine (GEE) was used extract active river channel masks from Landsat 5, 7 and 8 satellite imagery. Three main processing steps: (i) cloud masking and temporal compositing; (ii) active river channel classification; and, (iii) cleaning and image export. Figure 3, shows the active river channel masks for various time-scales will be extracted for period 1988-2021.

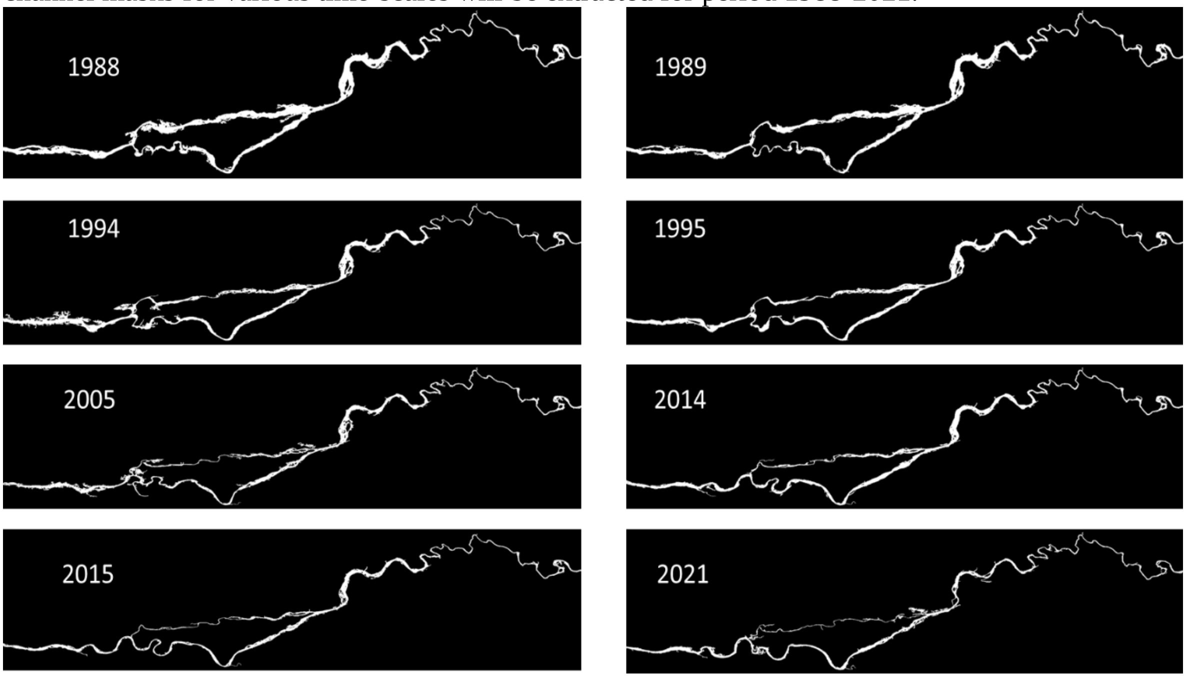


Figure 3. Extracted active lower Tawi river channel mask from a series of Landsat satellite images in Google Earth Engine

The binary active channel images were processed in MATLAB. RivMAP is a set of tools specifically created for the analysis of static planform geometries derived from binary channel masks. It facilitated operations like centerline and bankline extractions (Figure 4), width and length measurements, angle and curvature computations. This toolkit assessed temporal changes, including migrated areas of centerline and bankline, erosion and accretion rate, erosion and accreted areas. Typical extracted centerline and banklines of the river is shown in Figure 4. The meandering dynamics and morphological transformations in the Tawi River during 1988–2021 is shown in Figure 5.

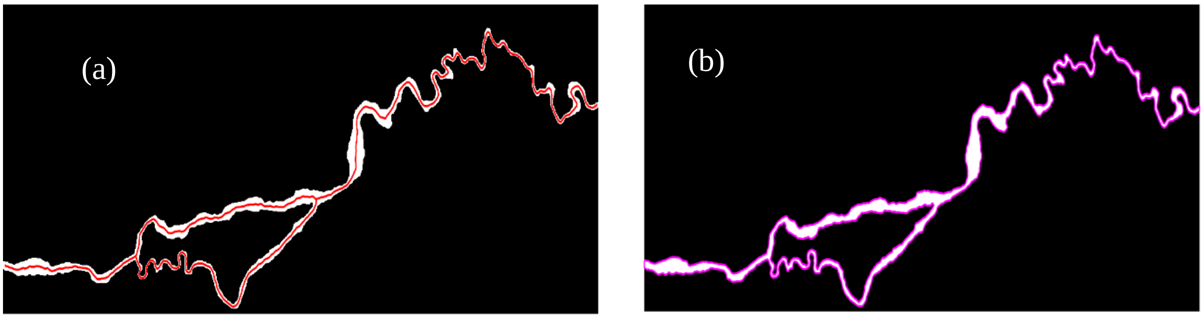


Figure 4: (a) Centerline and (b) Bankline

#In the study period (1988-2021), two significant cutoff events were observed within the river channel. The first cutoff event occurred between 2001 and 2005, leading to the formation of an area approximately 2.7 square kilometers in size. The second event took place between 2015 and 2020, resulting in an area encompassing approximately 1.2 square kilometers.

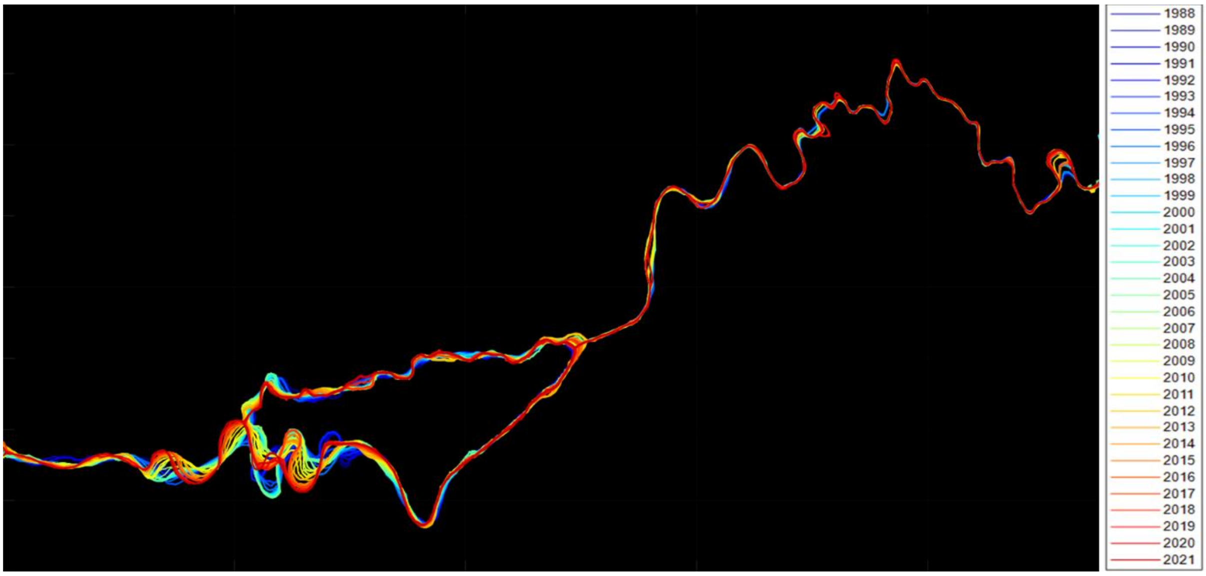


Figure 5: Meandering Dynamics and Morphological Transformations in the Tawi River (1988–2021)

#In 1988, the erosion rate was remarkably high at 3,553.61 m/year, indicating significant channel incision. In 2012, the accretion rate reached 4,100 m/year, indicating a notable period of sediment deposition within the river channel.

#Erosion rates demonstrated a declining trend from 3,554 m/year in 1988 to 373 m/year in 2021, suggesting reduced sediment removal.

#These findings provide essential insights into the Tawi River's behavior, emphasizing the need for adaptive management strategies to ensure the long-term sustainability of this crucial fluvial system and its surrounding environment.

Objective (c)

The setting up the 2D Rainfall Runoff Inundation model is almost completed. The required input parameter files and GIS layers are prepared. Presently, the calibration of model parameters is under-progress. The achieved results of the RRI models will be shown in the WG meeting.

Future Plan

- RRI model set-up and calibration and validation for study area
- The flood inundation results for the study area achieved with RRI model will be compared with those obtained by the application of the HEC-RAS and HEC-HMS model
- Writing up of interim report

ONGOING STUDIES (INTERNAL)
7. PROJECT REFERENCE CODE: NIH/SWD/NIH/23-25

1. Title of Study: Estimation of confidence intervals of index flow duration curves

2. Study Group:

Sanjay Kumar, Sc-F, PI
Sunil Gurrapu Sc-D, Co-PI
L. N. Thakural Sc E, Co-PI
J. P Patra, Sc E Co-P

3. Study Period: **Two Years (**April 2023 to March 2025)

4. Objectives of the Study: The objectives of the study are:

1. To develop Annual Flow Duration Curves (AFDC) and index flow duration curve.
2. To estimate the confidence intervals (90%, 95% & 99%) of index flow duration curves.

5. Statement of the Problem:

A flow duration curve (FDC) illustrates the relationship between magnitude and frequency of daily, weekly, monthly (or some other time period) streamflow, providing an estimate of the percentage of time a given streamflow was equaled or exceeded. FDC provides a graphical view of overall historical variability associated with stream flow in a river and thus have been used to solve problems in water resources engineering such as hydropower planning, water quality management, flood control, river and reservoir sedimentation etc.

An FDC is the complement of the cumulative distribution function (cdf) of daily streamflow and their interpretation depends on the particular period of records on which they are based. However, if one considers N individual FDCs, each corresponding to one of the individual N years of record, then one may treat those N annual FDCs in the same way as one treats a series of annual maximum and annual minimum stream flows. This annual based interpretation enables confidence intervals and recurrence intervals to be associated with FDCs in a nonparametric framework.

6. Methodology:

A nonparametric framework based on annual flow duration curve (AFDC) and index flow duration curve is being used for estimation of the confidence intervals (CIs) of AFDCs. Considering that the quantile x_p are values of a variables X(discharge) having exceedance probability P then FDC can be described simply as a plot of x_p verses P, where P can be computed as complement of the distribution function F of X such that

$$P= 1-F(X\leq x_p)$$

To estimate index flow duration curve and CIs, the FDC are developed on annual base by considering N annual FDCs, each corresponding to one of the N years of the data. For daily data each curve is a sequence of $n=365$ values X_i with $i=1 \ldots n$ arranged in ascending order $X_{1:n} \leq X_{2:n} \ldots . X_{n:n}$, where $X_{i:n}$ is the i^{th} order statistics.

AFDCs summarizes the distribution functions of the n order statistics $X_{i:n}$ from annual minima $X_{1:n}$ to annual maxima $X_{n:n}$. Considering the average of the N values available for each $X_{i:n}$, a average AFDC, which represent a typical year wherein the interpretation is not affected by abnormal observations during the period of records. Moreover, other percentile as well as the average can be taken into account to provide α percentile of AFDCs which can be used for estimating CIs for the average.

7. Progress

Daily discharge (and water level) data for several gauging sites in the lower Godavari basin has been collected from field organizations and related reports published by CWC. Literature on the methodology and analysis has been reviewed. The collected discharge data has been processed on annual basis. The daily discharge data for each year at a gauging site has been analyzed as per the described methodology for developing Annual Flow Duration Curves (AFDC) and index flow duration curve. The computation of the confidence interval for the developed AFDC are in progress.

8. **End users/beneficiaries of the Study:** Central and State government departments, academicians, BIS etc.

9. **Deliverables:** Report/Manual, Publications

ONGOING STUDIES (INTERNAL)

8. PROJECT REFERENCE CODE: NIH/SWD/NIH/23-24

1. **Title of the Project**
   Hydrologic and hydraulic study for Jata Ganga river at Jageshwar dham.
2. **Project team:**
   a. Project Investigator: J.P.Patra, Sc. – E, SWHD
   b. Project Co-Investigator: A. K. Lohani, Sc. – G & Head SWHD
   Pankaj Mani, Sc. – F, CFMS Patna
   D. S Bisht, Sc. – D, C4S
   S. S. Rawat, Sc. – F, C4S

3. **Duration of the Study**: 1 years (July 2023 to July 2024) : Ongoing
4. **Type of Study**: Internal Study
5. **Location Map**

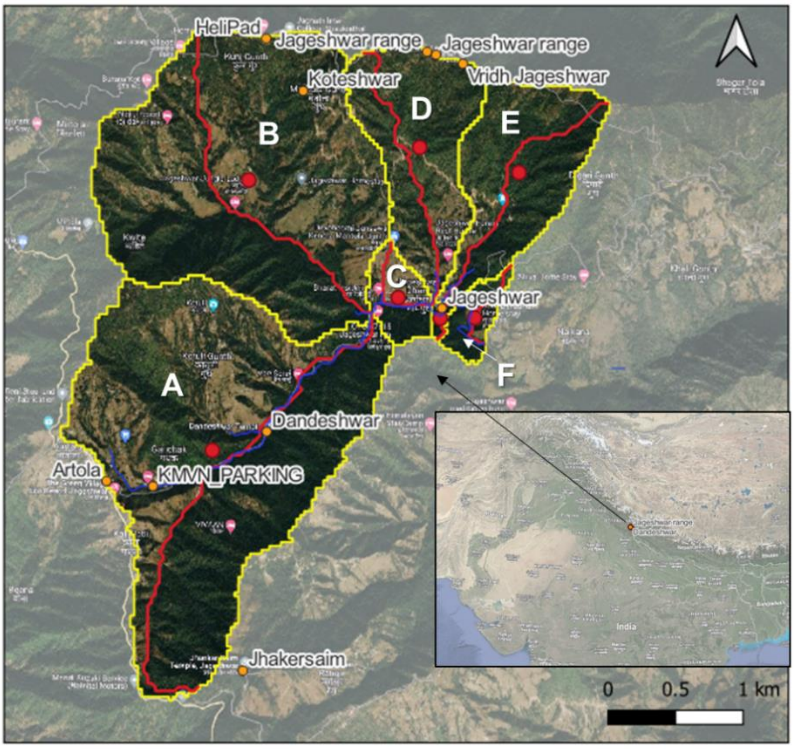


Figure 1: Location map of the study area

6. **Objectives**
   a) Estimation of floods of various return periods viz. 25 year, 50 year and 100 year with corresponding water level.
   b) Estimation of water levels after incorporating the proposed riverfront for 25 year, 50 year and 100 year discharge.
   c) Evaluation of water retention strategy for the proposed riverfront

7. **Statement of the problem**

The Jageshwar is a Hindu pilgrimage town near Almora in Almora district of the of Uttarakhand. The site is protected and managed by the Archaeological Survey of India (ASI). Jageshwar is about 36 km northeast of Almora, in the Jataganga river valley near a Deodar forest. The temple clusters begin starting near the confluence of two streams Nandini and Surabhi after they flow down the hills in the narrow valley. The Government of Uttarakhand is committed to develop Jageshwar Temple (Part of Manas Khand) and its surrounding areas in a planned manner as per the vision of the Hon'ble Prime Minister to develop the Manas Khand circuit in the Kumaon region, For this purpose, the state government have appointed INI Design Studio, Ahmedabad as a master planning consultant. The consultant has developed the master plan, which comprises different components like temple illumination, Infrastructure facilities, parking facilities, streetscape development etc. Further to this, riverfront development for Jata ganga (which flows behind the temple complex) is also one of components of master plan. For this aspect, the Tourism department of Uttarakhand approached National Institute of Hydrology, Roorkee to carrying out hydrological and hydraulic studies to support the riverfront development plan by INI Design Studio.

8. Brief Methodology

The Digital Elevation Model of the study area is developed from the CARTO DEM V3 data. Hydro Tool has been used for basin delineation in ArcGIS. It is to be noted that the catchment and sub catchment area are very small. Hence, SUH is not derived and rational formula is used for computation of peak discharge for various return periods. The Time of Concentration is estimated by Kirpich, Kerby and California formula and average value is considered. The nearest rain gauge station is at Almora. The observed 1-day highest rainfall is 223 mm in 29/09/1924 (CWC, 2015). The 1 day annual maximum return period rainfall for various return periods at Almora is used as design rainfall. Further the time distribution coefficients as per the CWC sub basin 401A is adopted to compute hourly and smaller time steps. High resolution DEM of study area is provided by M/s INI Design Studio. However, it is observed that the various bridges/culverts and tree canopy are not removed from the DEM, which is essentially a Digital Surface Model (DSM). However, for river flood modelling a Digital Terrain Model (DTM) is essential. The INI is asked to provide river cross-section for pre and post project condition. For hydraulic modelling with HEC-RAS, this DSM is used for extraction of river cross-section.

9. Results achieved with progress/present status

The delineated various sub catchments are shown in Figure 1. The computed runoff for various return period and for cloud burst condition (intensity = 10 cm/h) are given in Table 1. For hydraulic modelling in HEC-RAS the manning’s n value of 0.04 and 0.06 are have been used for main river channel and over banks considering it as a mountain stream. Steady flow simulation is carried out for design discharge of various return periods viz. 25, 50 and 100 year return period respectively. The longitudinal water surface profile for different return period floods for the study reach is shown in Figure 2 (a). The simulated water surface profile for various return periods at RS 753 is shown in Figure 2(b). The simulated water level for pre-project scenario for 100 year return period flood has been provided. The details of proposed intervention are awaited and will be incorporated in the post project scenario.

Table 1: Design runoff (m^3/s) for various return periods

Sub catchment	**Return period (Year)**				**Intensity = 10 cm/h**
	2.33	**25**	**50**	**100**	
A	17.23	33.78	38.26	42.73	104.55
B	18.71	36.69	41.55	46.41	91.55
C	1.48	2.90	3.28	3.66	7.13
D	6.21	12.19	13.80	15.41	29.10
E	5.73	11.23	12.72	14.21	27.80
F	0.94	1.85	2.09	2.33	4.65

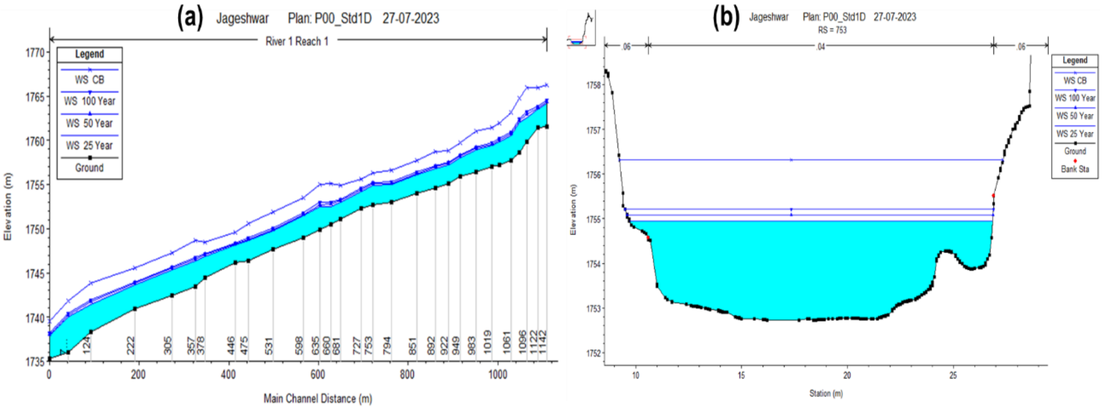


Figure 3: Simulated water surface profile for different return period floods (a) longitudinal; (b) cross-section at RS 753.

10. Research outcome of the project

- Design input for riverfront development for Jata ganga.

11. End Users/Beneficiaries of the study:

Tourism department of Uttarakhand

NEW STUDIES (INTERNAL)
1. PROJECT REFERENCE CODE: NIH/SWHD/NIH/24-25

1.1 Project Title
Entropy and Image Processing Based Non-Contact Discharge Monitoring Techniques: Testing and Implementation for Indian rivers

1.2 End-user Department/Organization/Agency: CWC, State Water Resources Departments, Irrigation and Public Health Departments/ Water Sector Public Undertakings and other Government departments and NGOs etc.

1.3 Duration of the project: 1.5 years [April 2024 – September 2025]

1.4 Lead Organization: National Institute of Hydrology

1.5 Partner Organization (if any): CWC and CWPRS

1.6 PI and Co-PI from Lead Organization:
Principal Investigator (PI):
Name& Designation : Dr. Ravindra V. Kale, Scientist-E
Co-Principal Investigators (Co-PIs):
Name& Designation : Dr. M. K. Goel, Director
Name& Designation : Dr. A. K. Lohani, Scientist-G & Head, SWHD

1.7 Co-PI from Partner Organization
Co-Principal Investigator (Co-PI):
Name& Designation : Dr. Selva. Balan, Scientist-E, CWPRS
Partner Institute : Head, Instrumentation, CWPRS, Pune

1.8 Subject Expert
Name& Designation : Dr. M. Perumal, Former Professor,
Partner Institute : DoH, IIT Roorkee

1.9 PI and Co-PI from Partner Organization
Principal Investigator (PI):
Name& Designation : Chief Engineer, CWC

1.10 Project Summary (Max. 200 words)

The determination of discharge from the Indian rivers is of prime importance for the estimation of streamflow much needed for an improved water resources management for flood and drought control, irrigation water management, planning and operation of the hydro-power projects and regulate ecological flow requirements etc. It is now well accepted fact that the understanding the temporal and spatial variability of river hydrology requires direct measurement of discharge, systematically, and periodically. The most popular conventional method (current-meter method) for directly measuring discharge is not suitable to measure discharge in many steep rivers especially during high flood conditions. Extreme rainfall events and high current rapid flows in rivers channels, combined with threats to the safety of hydrologists and instruments, add to the difficulties associated with obtaining accurate measurements. Due to these unsuitable conditions, using a velocity meter to measure discharge is difficult. Further, the water depth of the most of the mountainous rivers is usually very shallow. Conclusively, measuring discharge levels using conventional methods and instruments during flooding is frequently impossible and very impractical. Thus, many discharges are determined after floods using indirect methods assuming a steady and uniform flow. However, rapid floods which typically move along steep river courses with debris, are generally unsteady and vary rapidly. Hence, using indirect

methods to calculate estimated discharges frequently results in significant errors with accuracy rates of only 30 % or greater (Bathurst, 1990). The intense and frequent rainfall events are enough to cause significant high concentrations of suspended sediment in rivers that can also limit the function of ADCP. Therefore, much needed discharge data for rivers are very sparse in India.

As stated earlier, in-situ discharge monitoring in upper reaches of the rivers is quite difficult especially during high floods due to the danger posed by adverse weather conditions, typical topography and area accessibility etc. Therefore, the present study is proposed to investigate the feasibility of innovative entropy and image processing based non-contact direct discharge monitoring techniques for typical Indian Rivers without much shift control. Particularly, the attempt will be made to verify the applicability of the commercially available (portable or fixed) surface velocity radar (SVR) and water level radar (WLR) for noncontact stream flow measurement with application of modified entropic velocity model for indian condition using one-point velocity measurement at 0.6d (e.g. Vyas et al. 2021) and 2D entropic velocity model (Chiu, 1991, Morammarco et al., 2004 and 2017) at the selected G&D sites operated by CWC in the Krishna and Godavari river basin (See Fig. 1). Apart from entropy approach, it is also proposed to apply video image processing-based discharge measurement technique by processing of the thermal / Infra-red images acquired through a camera setup with the application of the cross correlation imaging method (e.g Lin et al., 2013; Balan et al. 2014). These proposed methodologies were developed at CWPRS and has been successfully validated for testing of physical model developed for Yettinahole project, VJNL, Karnataka during 2018-19, in Pune. This technique has been applied successfully in several other parts of the country and recently under application in the Muvattupuzha River, Kerala. The accuracy of this technique is depends on the camera resolution and the modelling tool used to calculate velocity below water. It is envisaged that the proposed direct discharge measurement techniques will be easy and accurate to measure the flood discharge of an Indian rivers.

2.1 Origin of the Proposal & Problem Definition (Maximum 350words)

(Describe the research proposal, the background, how the idea originated etc.)

Government of India has lunched the National Action Plan on Climate Change (NAPCC) which identifies the approach to be adopted to meet the challenges of impact of climate change through eight National Missions including National Water Mission (NWM) and National Mission for Sustaining the Himalayan Ecosystem (NMSHE). The main objective of NWM is “conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within States through integrated water resources development and management”. These tasks envisaged to be achieved through the establishment of efficient and optimal observational and monitoring network to assess freshwater resources and health of ecosystem. Further, the accurate quantification of discharge is required to improve the planning, development and management of water resources, as well as flood forecasting and reservoir operations in real time. The one of the important component of National Hydroloy Project is the “In-Situ Hydromet Monitoring System and Hydromet Data Acquisition System”. Through this initiative the NHP will help in gathering Hydro-meteorological data which will be stored and analysed on a real time basis.

Krishna and Godavari River basins in the southern region are of great importance for sustainable water resources management to ensure the adequate water supplies and other important ecosystem services to the millions of people depending upon water resources of this river basin. A quick and accurate monitoring of discharge in a natural river section is fundamental for a large number of engineering applications, such as flood forecasting models and the real time water resources management to enable populations to distribute and manage finite water supplies. Further, understanding the temporal and spatial variability of mountain river hydrology requires measuring discharge directly, systematically, and periodically. However, discharge measurement for these river is usually insufficient due to lack of funding, limitations of conventional measurement methods and instruments for discharge measurement, riverbed instability due to rapid scouring and deposition during flooding, extreme unsteady flow conditions during high floods, difficulties in accessing gauging stations, and harsh environments that hinder discharge measurements. Consequently, the discharge measurement sites in upper reaches are very limited which have adverse impact on hydro-power generation, maintaining the adequate ecological flow in the river reaches as well as operating various hydraulic structure, understanding the catchment hydrology etc. Therefore, there is vital and urgent need of investigating the innovative discharge measurement techniques which are feasible to adopt under adverse weather and topographic conditions.

In this connection, it could be seen that the conventional discharge measurement techniques for the determination of water discharge in rivers usually rely on mechanical, electromagnetic or acoustic velocimetry instrumentation requiring contact with the flow. As a consequence, safety and logistic issues limit the applicability of conventional methods to gauge high flows. Noncontact methods based on remote sensing of water surface velocity using Doppler radars or image sequence analysis have been developed in the past two decades. In the recent few years, Surface Velocity Radars (SVRs) have been increasingly used by some national hydrological services, e.g., in USA, France, Italy etc., for flood stream gauging operations. Due to their convenience and suitability for flood conditions, SVRs have begun to provide valuable discharge data in upper-end sections of rating curves that had previously been impossible to obtain. Another important issue is that the radars represent a cheaper, easy-to-use solution to gauge multiple field sites. Further, Pantelakis (2022) found that conventional methods, such as the one-point and two-point methods, can estimate river discharge with an error of about 3%, while nonconventional methods, including the entropy-based method, have a higher error range of 11-14%. However, the main issues related to applying entropy discharge estimation method for Indian rivers are: (1) Area-velocity method is used by CWC which is very time consuming method (2) Depth-averaged velocity is measured for each vertical (3) Discharge assessment is not possible during night-time (4) Chiu's mean flow velocity equation is not applicable for the Indian River gauged sites as velocity is measured only at 0.6D. Alternatively, image analysis techniques are becoming popular to measure the surface water velocity as well as flow discharge by capturing images with infrared cameras mounted in a waterproof case. This technique can be used to cross validate the discharge measurements by entropy-based technique. However, the uncertainty of such new velocimetry techniques requires assessment and information on the optimal use and performance before its widespread adoption in the Indian rivers. Therefore, the present study is undertaken with the aim to investigate the feasibility of the entropy as well as Infra-red (IR) image processing based non-contact discharge measurement techniques at the selected G&D sites in the Krishna and Godavari river basin maintained by CWC.

Study Area:
Total five G&D sites operated by CWC in the Krishana and Godavari river basin will be selected for this study purpose.

2.2 Specify Objectives of the Study

[Briefly list the objectives (not exceeding five)]

i) To analyze the entropy-based discharge measurement technique for direct discharge monitoring at selected G&D sites from Krishna and Godavari rivers especially during extreme weather events and its comparison with conventional discharge measurement techniques.
ii) To analyze the performance of an alternative image processing-based discharge measurement technique for real-time discharge monitoring from the rivers at the selected G&D sites.
iii) To develop Web App for use of entropy-based discharge measurement technique

2.2.1 Brief Description of the Objectives

(Classify the objectives under one or more of the following and explain)

a. *Finding answers to as yet un-answered questions.*
b. *Development of a new computational procedure.*
c. *Development of software/application.*
d. *Development of new field technique.*
e. *Design and/or develop a new device.*
f. *Investigation of the behavior of a natural process.*
g. *Any other*

i) The main aim of this objective is to investigate the feasibility of new technique for discharge monitoring at the selected G&D sites. In Indian river, discharge monitoring is quite challenging task due to difficulty in sampling the velocity points during high floods, especially in the lower portion of flow area which may cause the danger to the operators. In this context, an important contribution could be provided by the entropy theory which identifies a linear relationship between the mean flow velocity and the maximum flow velocity. Further, the maximum flow velocity can be easily sampled during high floods due to its position in the upper portion of the flow area. The entropic relationship is robust and based on the estimation of a sole parameter (M). Therefore, if one was able to estimate the dependence of (M) on hydraulic river characteristics and/or morphological basin characteristics then it would be possible to assess the mean flow velocity and, hence, the discharge just by sampling the maximum velocity through, for instance, non-contact radar sensors, for ungauged basins or weakly gauged ones. However, in many developing countries including our country, river discharge is still estimated by the velocity-area method following the procedure established based on the point-velocities measured at 0.6D depth from the water surface of many verticals of flow section. This study explores the establishment of a relationship between the maximum point velocity estimated at 0.6D depth of the vertical located at or nearer to the deepest flow depth, and the maximum point-velocity occurring somewhere along the same vertical which in turn can be linked to the sectional mean flow velocity based on the established entropy theory. The appropriateness of the proposed two-steps based approach of discharge estimation is first verified on the Tiber River and the Po River of Italy and two Indian river gauging stations. The study finds that the discharges estimated by both the proposed approach and the velocity area method closely match with each other with the estimated Nash-Sutcliffe Efficiency (NSE) values greater than 0.99. Thus the proposed two-steps approach involving the entropy concept based relationship for discharge estimation enables to replace the tedious and time-consuming velocity-area approach. Development of a relationship between the maximum depth-averaged velocity, $u_{0.6D,max}$, (used in the area-velocity method) and the maximum flow velocity (used in the entropy theory) at or near the deepest vertical can be established for enabling the discharge estimation..

ii) Alternatively, the feasibility of the image processing based approach will be investigated for the water flow velocity measurement as well as direct discharge measurement at the selected G&D sites. The inter comparison of the advanced entropy and imaging processing based approaches of the discharge measurement will enable to know about the capabilities and limitations of these techniques for its application for the real-time discharge monitoring in the Indian rivers. Further, it also provides opportunity to confirm the suitability of these techniques for discharge measurements in the India over the conventional methods.

iii) The web-app of the entropy based discharge measurement technique will be developed in the python environment.

2.3 **Present State-of-Art**

a. Describe the work already done at International/National Level

Discharge monitoring techniques

Discharge data monitoring for mountain rivers is insufficient due to lack of funding, limitations of conventional measurement methods and instruments for discharge measurement, difficulties in accessing gauging stations, and harsh environments that hinder discharge measurements (Chen, 2013). The most popular conventional method (current-meter method) for direct measuring discharge first measures velocities and then multiplying it with cross-sectional areas gives the discharge estimate. The required velocity measurements are obtained by placing a current meter at a desired location. The observations of velocity depend on the methods for estimating mean velocity of the vertical. Generally, those methods include velocity distribution method, 0.6 depth method, 0.2 and 0.8 depth method, six-point method, five-point method and three-point method (Herschy, 2009). In addition to the 0.2 and 0.8 depth method observing velocities in each vertical at 0.2 and 0.8 of the depth below the surface, hydrologists also use the 0.6 depth method in shallow depths. However, during rapid flows associated with floods, submerging a meter in water is almost impossible, even when an adequate sounding weight is utilized. Additionally, riverbed instability due to rapid scouring and deposition during flooding make sounding water depth impossible; thus, measuring a cross-sectional area is extremely difficult. Flow conditions during floods are highly unsteady and water stages and discharges vary considerably. Heavy rains and rapid flows, combined with threats to the safety of hydrologists and instruments, add to the difficulties associated with obtaining accurate measurements. Consequently, discharge data for mountain rivers are lacking in Himalayan region. Due to these unsuitable conditions, the use of a current meter to measure discharge cannot be advocated. Recently, the introduction of Acoustic Doppler Current Profilers (ADCP) installed on moving-vessels has allowed operators to address the above mentioned problems even if several limitations still remain. Some new monitoring systems apply fixed side-looking Doppler profilers (H-ADCP) to measure river discharge (Nihei and Kimizu, 2008; Le Coz et al., 2008). However, the water depth of the mountain rivers is usually very shallow. Intense rainfall events are frequent enough to cause significant high concentrations of suspended sediment in rivers that can also limit the function of ADCP (Corato et al. 2011; Chen, 2013).

Measuring discharge levels using conventional methods and instruments during flooding is frequently impossible and very impractical. Thus, many discharges are determined after floods using indirect methods. Most commonly employed indirect methods are the slope–area method (Chow, 1973), step-backwater method (O'Connor and Webb, 1988), contracted opening method (Benson and Dalrymple, 1967), and flow through culverts (Bodhaine, 1968). These methods assume a steady and uniform flow conditions in the river. Mountainous floods, which typically move along steep river courses with debris, are generally unsteady and vary rapidly. Hence, using indirect methods to calculate estimated discharges frequently results in significant errors with accuracy rates of only 30% or greater (Bathurst, 1990).

Unfortunately, the discharge estimation is often affected by the lack of velocity measurements, often restricted by the excessive cost involved, which does not permit to establish a reliable stage-discharge relationship. Besides, even if velocity measurements are available, they are restricted in most cases to low flows, thus enabling a good discharge assessment only for lower water levels. Therefore, many studies attempted to overcome this shortcoming by addressing the analysis in terms of velocity profiles distribution. Although there are a large number of studies, few studies have been addressed for estimating the spatial velocity distribution during high flood conditions, wherein it is not possible to sample the whole velocity field, particularly in the lower portion of the flow area. In this case, the sampling procedure of velocity measurements at a river cross section could be difficult and particularly dangerous for cableway operators. On the contrary, the value of maximum flow velocity could be more easily obtained since its position is located in the upper portion of the flow area where velocity measurements can be carried out also during high flow conditions (Fenton, 2002; Moramarco et al., 2004; Fulton and Ostrowski, 2008; Corato et al. 2011), and using probability distribution function (Chen and Chiu, 2004), the discharge can be estimated. Therefore, a model able to assess the velocity profiles, also when velocity data are not available in any portion of the flow area should be welcome. For this purpose, many researchers have resorted to the use of the analysis tool based on the entropy theory (Shannon, 1948) and the pioneer among them is Chiu (1987, 1988, 1989, 1991). Based on this theory, it was found that the mean flow velocity can also be estimated from the value of maximum flow velocity through a linear relationship identified by the entropic parameter M (Moramarco et al., 2004, Moramarco et al., 2008; Moramarco et al., 2011; Farina et al., 2015). Moreover, it was found that the M value is constant not only at each gauged site but also the same along the main channel reach, where these sites are located (Moramarco et al., 2004; Moramarco et al., 2008; Ammari et al., 2017). Moramarco et al. (2017) presented new methodology for estimating the discharge starting from the monitoring of surface flow velocity (u_{surf}). Their approach, based on the entropy theory, involves the actual location of maximum flow velocity (u_{max}), which may occur below the water surface (dip phenomena), affecting the shape of velocity profile. This method identifies the two-dimensional velocity distribution in the cross-sectional flow area by just sampling (u_{surf}) and applying an iterative procedure to estimate both the dip and u_{max} (See Fig. 2).

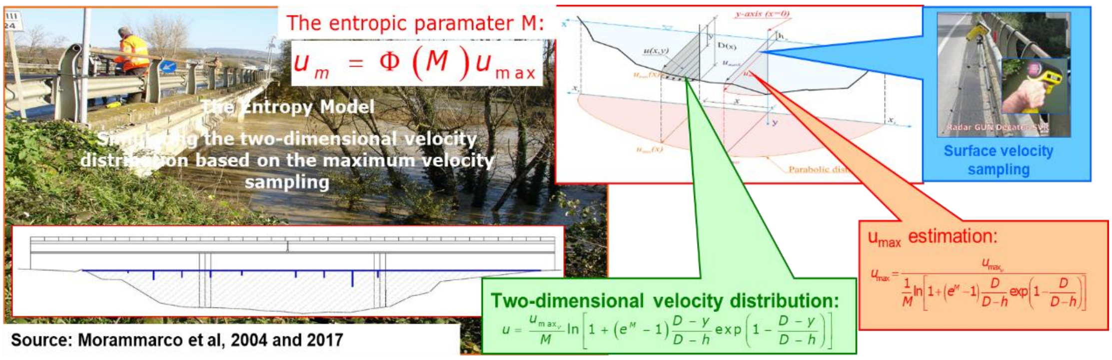


Figure 2. Schemes of entropy-based discharge measurement.

The comparison with the velocity index method for the estimation of the mean flow velocity using the measured (u_{surf}), Moramarco et al. (2017) have demonstrated that their proposed method was more accurate mainly for rivers with a lower aspect ratio where secondary currents are expected. Moreover, the dip assessment is found more representative of the actual location of maximum flow velocity with respect to the one estimated by a different entropy approach. In terms of discharge, the errors do not exceed 3% for high floods, showing the good potentiality of the method to be used for the monitoring of high flood events. Welber et al. (2016) attempted to verify the applicability of a portable, commercially available surface velocity radar (SVR) for noncontact stream gauging through a series of field-scale experiments which were carried out in a variety of sites between 2010 and 2013 in Israel, Italy and France and under varied deployment conditions. They have concluded that SVR-based discharge estimates are accurate within 10% for intermediate roughness flows, while larger errors are observed at very low relative roughness (< 0.05). Moreover, accuracy does not strongly depend on the cross-sectional spacing of SVR points, implying that SVR can be used to gauge unsteady flow conditions. Finally, they have shown that noncontact devices can be used to extend the range of validity of rating curves by providing much-needed direct information on water velocity at high flows, especially so in flashfloods.

The 2D entropy based discharge method (Moramarco et al., 2017) requires the measurement of maximum velocity for each vertical across the river cross-section at the G&D site. Further, the mean flow velocity equation using this method is not applicable for the Indian River gauged sites as velocity is measured only at 0.6D. to overcome this limit Vyas et al. (2021) presented entropy based river discharge estimation using one-point velocity measurement at *0.6d*. In this method a relationship between the maximum depth-averaged velocity, $u_{0.6D,max}$, (used in the area-velocity method) and the maximum flow velocity (used in the entropy theory) at or near the deepest vertical can be established for enabling the discharge estimation. Estimation of c. Relation between u_{max} and $u_{0.6D,max}$ is given by

$$u_{max\_c} = \frac{k\, u_{0.6D,max}}{ln\left[1+\left(e^{k}-1\right)\frac{y_{0.4D}}{D(x)}\, exp\left(1-\frac{y_{0.4D}}{D(x)}\right)\right]}$$

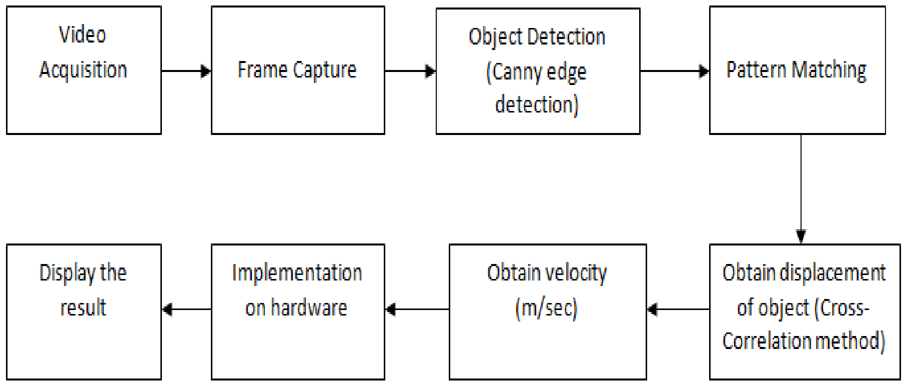
The Mean flow velocity is given by equation

$$\frac{u_m}{u_{max}} = \frac{e^{k}}{e^{k}-1} - \frac{1}{k} = \Phi(k)$$

Here, k is an entropic constant similar to *M*.

The imaging processing method

The surface water velocity measurement using image based technique is a reliable, easy, cheapest and instantaneous measurement approach. The main advantage is that it is applicable to measure high flood as well as slow flows velocity. In this technique, the preprocessing of frames is done to remove noise and then image processing is applied to detect the object. The motion estimation module is applied to finally calculate displacement. After that flow vector calculations are done to calculate velocity in meter per seconds. Finally, the velocity of water in the cross-section and flow discharges are estimated using the given system.



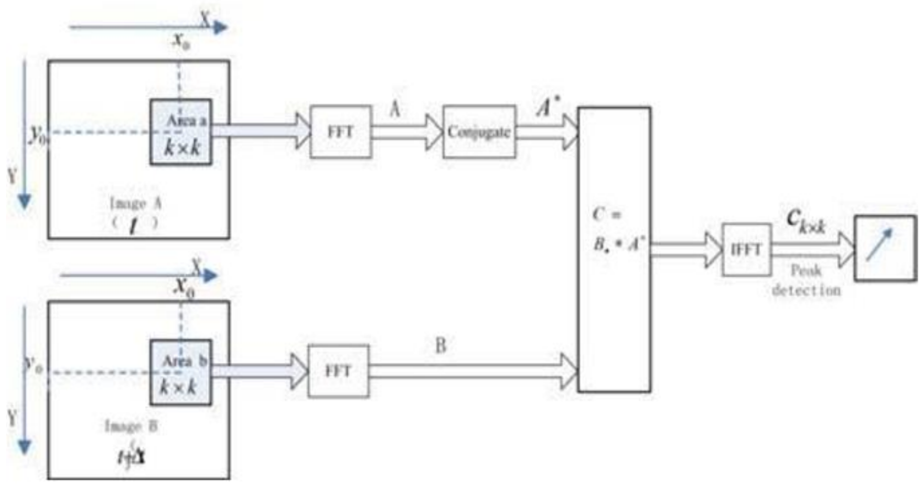
The components of the camera-based system

Interface module

The embedded system is required to interface with the camera setup and take inputs from the radar water level sensor in order to calculate the discharge as accurate to the manual methods

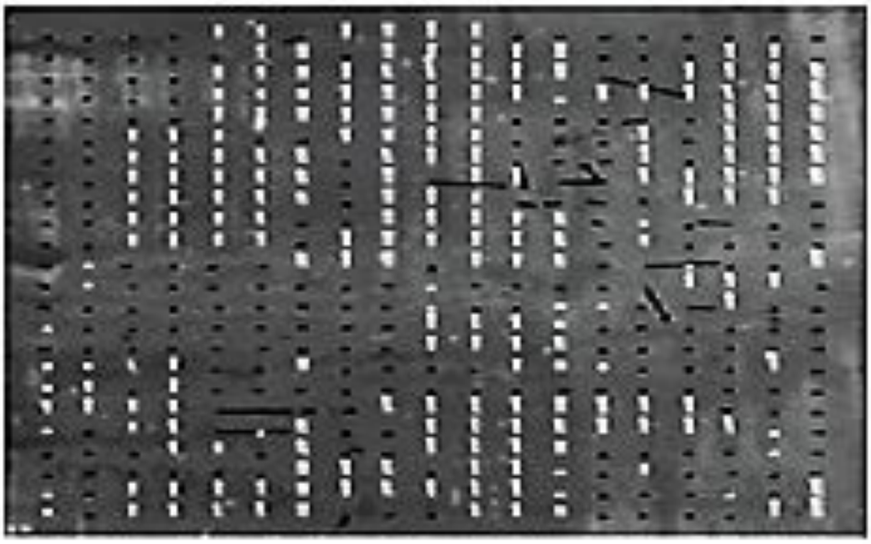
Image Processing Module:

The image processing module is required to be developed and installed considering the site specific requirements to calculate the discharge by using the data from camera and other input data from the sensors installed at site which are transferred through the telemetric connections. The computational techniques such as Particle Image Velocimetry (PIV) and other appropriate techniques will be used to achieve the flow level match of at least 90% with existing technique. The output results are required to be tuned till the output matches to the discharge calculated with other standard measurement techniques followed by the department.



A Graphical User Interface (GUI) Module

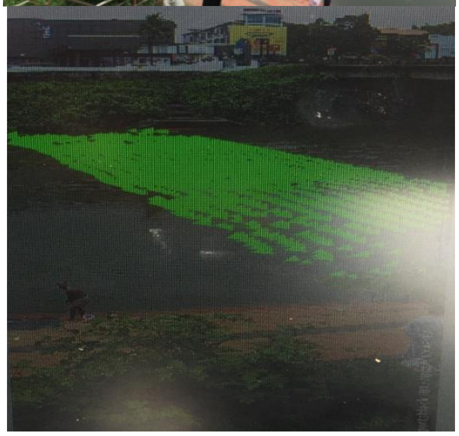
The GUI is used to enable the configuration of various input parameters and to facilitate the local visualization of output results.



Implantation platform

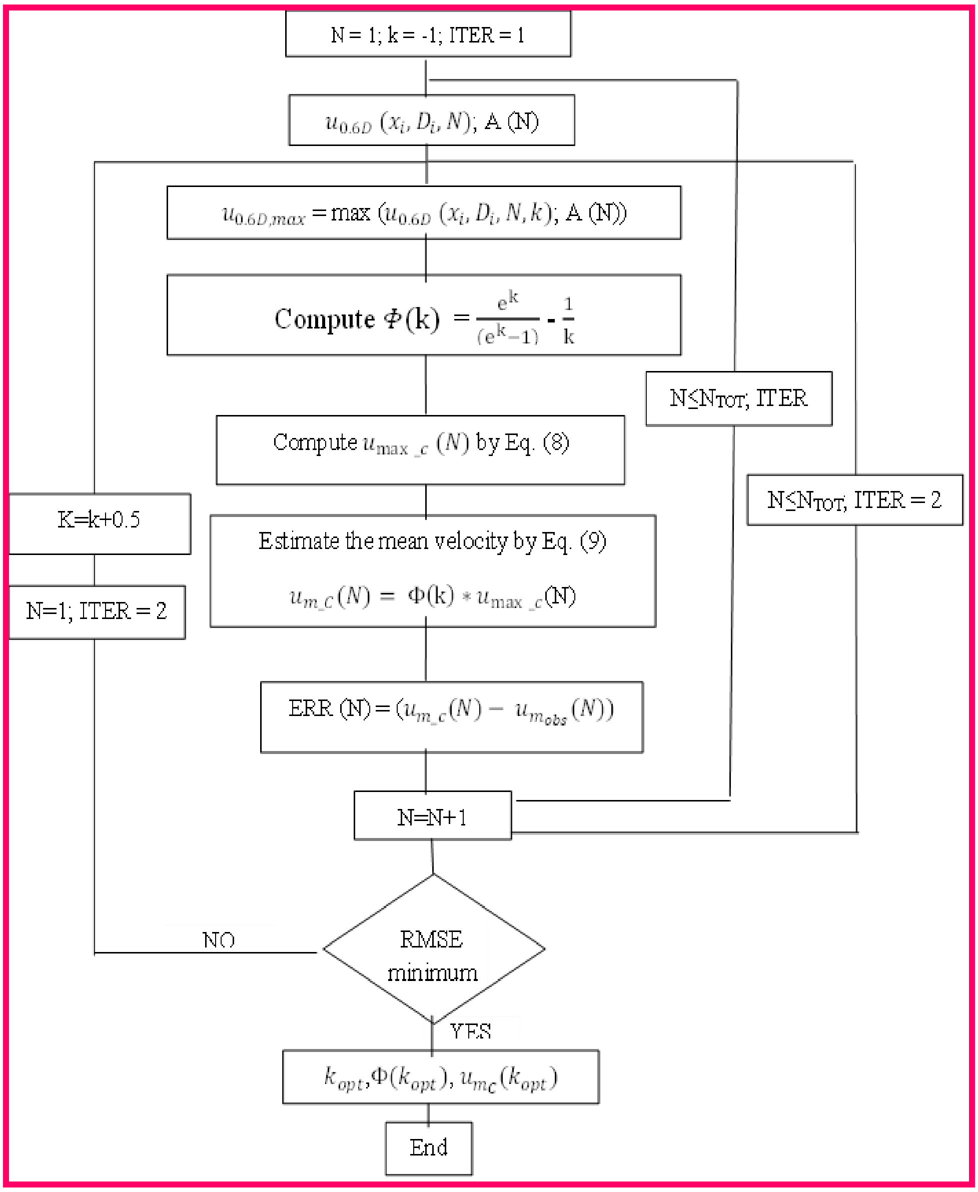
User defined algorithms and all other developed modules will be capable of working on the same ARM platform. The software developed will be of cross-platform in nature having the following specification for discharge measurement related application:

- Cross-platform GUI software will work in windows, *nix
- Input and output mapped and routed through scripting engine like "SPSS - Statistical and data management package" commercially available
- User friendly scripting engine language
- Acquire level data from remote sensor data server. Server serves data in XML format with data tags.
- The data tag is configurable in the software for input variable mapped in the software. At least 10 data tag configurations for input variable will be used by scripting engine to facilitate noise correction with environmental factors like illumination, rain and wind required for low river velocity
- Programmable data interval retrieval and calculation
- Receive IP video streaming from external server with source configuration facility in the GUI
- Import bathymetry data from delimited file format
- Initial setting like reference points and other parameters through GUI
- The computational technique will be Particle Image Velocimetry (PIV) and other appropriate techniques to get surface velocity with error less than 5% as compared to the existing measurement. This method should have documented proof for its accuracy.
- Output of surface velocity map for the cross section
- Facility to view in the remote location through internet
- Alarm and SMS facility – configurable through GUI
- Storage of processed images for future use
- Training sessions for user

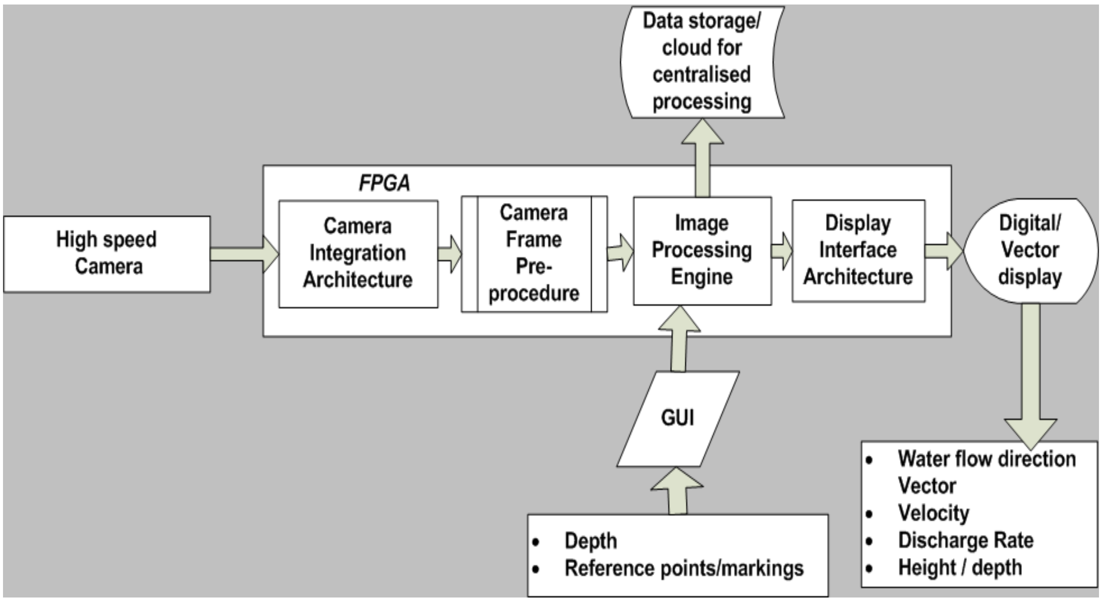


b. Explain how the work proposed to be done will be different from the work already done

The main aim of this study is to investigate the feasibility of innovative entropy based non-contact discharge monitoring technique using one-point velocity measurement at *0.6d* (Vyas et al. 2021). This method estimates state equilibrium constant using the historical records of the area-velocity method. Based on this constant estimate the discharge is directly measured by knowing the cross-sectional flow area by just sampling single surface flow velocity the maximum flow velocity (used in the entropy theory) at or near the deepest vertical. Thus, the applicability of portable, commercially available surface velocity radar (SVR) (continuous and hand held) will be verified for noncontact stream gauging for the Indian rivers. The flowchart of the proposed entropy-based procedure to estimate discharge starting from $u_{0.6D,max}$ and flow area A is given as follows:



Alternatively, the feasibility of the image processing-based technique for direct discharge measurement will be analyzed by processing of the images acquired through IR camera and by using the Particle Image Velocimetry (PIV) and other appropriate computational techniques for the Indian Rivers. To our knowledge no any such attempt has been made so far to investigate such methodologies in Indian Rivers. Further, the proposed method seems to be more efficient for flood discharge measurement in rivers that accounts for personal safety, accuracy, and reliability, which is fundamental for a large number of engineering applications such as flood forecasting models and the real time water resources management. The brief methodology followed is as follow:



Description:

High speed camera- The High-Speed Camera Block is an advanced imaging component designed to capture and deliver live feeds of the river or water body with exceptional speed and precision. This device is engineered to record fast-paced events with remarkable clarity.

The FPGA block

Camera integrated architecture-The Camera Integration Architecture with FPGA (Field-Programmable Gate Array) emphasizes the use of FPGA technology to enhance the processing capabilities, flexibility, and real-time performance of the camera system within a larger integrated framework. It involves FPGA-based Image Processing Pipeline which includes parallel processing and high-speed data interfaces.

Camera pre-frame processing-As the name suggests,it involves pre-frame processing and image analysis.Various techniques like noise reduction using filters(median or gaussian),edge detection and enhancement,image scaling and cropping,at parallel speed.With the use of FPGA,we can use these techniques in parallel to each other.

Image processing engine- The Image Processing Engine Block is a dedicated module within a larger system designed for advanced visual data analysis. This block incorporates specialized components, including particle detection, frame size detection, and PIV (Particle Image Velocimetry), to enhance the processing and analysis of images in real-time.

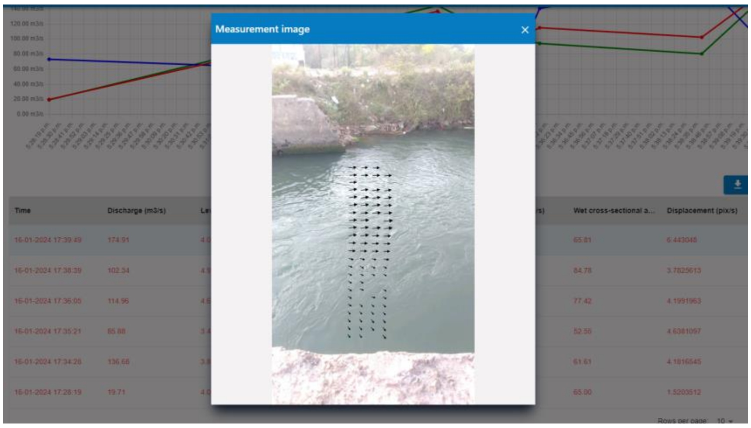
Display interface architecture-The Display Interface Architecture Block refers to a modular component within a larger system that is dedicated to managing the connection and communication between a graphics source and a display device. This block typically incorporates various subcomponents and functionalities to ensure seamless and efficient data transfer, supporting the rendering and display of visual content.

Digital/Vector display-The Digital Display Block is used for the processing, rendering, and presentation of digital content. This block encompasses various elements to ensure the effective conversion of digital data into visible images on a display device. Elements like DAC, frame buffer,timing generator as required to diplay the flow vectors, velocity or flow discharge of the water, depth etc.

In addition to these blocks,two more blocks are stated,

GUI-This Graphic user input block will give the input values to the processing engine block.Input values like the depth of the water,the light conditions,the time of the day,location of the image frames, reference points if required.

Storage/Cloud for centralised processing-This block will be used to store the values of the flow vectors, velocity or flow discharge rate of the water, depth etc. via cloud to a website or an app so that it can be easily accessible from different locations.
The mobile app and computer outputs will look as below



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2.4 Methodology to be Adopted

(*Describe clearly the proposed methodology for the study*)

- Collection and pre-processing of available historical Hydro-metrological data
- Procurement of SVR's, thermal or optical camera's and other accessories for up-gradation of the selected G&D sites [As per requirement].
- Site selection and installation of instruments at the selected G&D sites.
- Field investigations to estimate parameters of entropy based discharge mesurement model using one-point velocity measurement at *0.6d.*
- Discharge measurement by entropy-based approach using data from SVR and WLR and its comparison with conventional discharge measurement techniques.
- Acquisition of the surface video showing water particle movement precisely at every cm level with at least 40 frames per second or whatever best in market for the complete river width either by using thermal or an optical camera during day and nights. Camera calibration required to be carried out before installation by considering the atmosphere and water level variation corrections.
- Development of mathematical logic to predict depth up to the bed based on hydrological and bed characteristics.
- Measurement of the velocity profile using echosounder which is part of the supply.
- Calculate discharge for the selected cross section and validate the results with other discharge measurement methods
- Development of Graphical User Interface (GUI) to graphically display the real-time discharge in user specified format
- Rating curve development at the selected G&D sites.

2.4.1 List new data to be generated under the project, if any

- The daily/hourly (during floods) discharge data will be generated by application of the proposed entropy and image processing based discharge measurement techniques at the selected G&D sites in the Krishna and Godavari river Basin. This discharge data would be used to develop the rating curve for the selected G&D sites.

2.5 Envisaged Contribution of the Proposal

(*Describe briefly the contribution of the proposed study to the Water Resources Sector)*

Study focus:

- Investigations to verify feasibility of surface velocity radar (SVR) for noncontact stream gauging in the typical Indian rivers based on entropy approach.
- Investigations to verify feasibility of image processing based technique for noncontact stream gauging in the typical Indian rivers.

New Hydrological Insight:

- The new insight into estimation of the mean flow velocity (particularly advantageous to gauge unsteady flood flows and very large floods) based on the entropy approach using the measured surface velocity (u_{surf}) and IR image processing approach, and thereby extending the range of validity of rating curves for the Indian rivers.

2.6 How Research Outcome will benefit the End-user Department and Society

(*Describe how the research outcome will be useful to end-user department and society)*

- New discharge monitoring techniques using noncontact devices to extend the range of validity of rating curves by providing much-needed direct information on water velocity at high flows, especially so in flashfloods. Such new techniques will be helpful to upgrade the existing G&D sites. The accurate discharge data is required for real time management of the dams and hydro power projects as well as design of efficient flood warning system. The output of this study will be very useful for CWC, State Water Resources Departments and other Government departments and NGOs etc. to plan and operate various integrated water resources management schemes in the selected river basin.

2.7 End-of-project Deliverables

(Describe the envisaged deliverables of the study)

The following deliverables from this study are expected: 1) establishment of new discharge monitoring techniques for the Indian rivwers using noncontact radars/optical and/or thermal cameras (2) improved rating curves with extended range of validity by providing much-needed direct information on water velocity at high flows, and (3) report and publication etc.

2.8 Work Plan & Activity Chart

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

1. Field visit to collect the study related data and information [NIH/CWC/CWPRS].
2. Procurement of SVR's, thermal or optical camera's and other accessories for up-gradation of the selected G&D sites and also other instruments and software's [NIH/CWPRS].
3. Recruitment of project staff [NIH]
4. Site selection and installation of instruments at the selected G&D sites [CWC/ NIH/CWPRS]
5. Field investigations to estimate parameters of entropy based discharge measurement model [NIH]
6. Discharge monitoring by entropy-based approach using data from SVR and WLR and also by conventional discharge measurement techniques [NIH/CWC].
7. Calibration of thermal or an optical camera's and other instruments before installation [CWPRS/NIH]
8. Development of mathematical formulation to enable discharge measurement using image processing technique [CWPRS]
9. Discharge measurement by image processing based technique and validation of the results with other discharge measurement methods used in the study [CWPRS/NIH]
10. Development of GUI to graphically display the real-time discharges [CWPRS]
11. Development of web-app for entropy based discharge measurement technique [NIH]
12. Rating curve development at the selected G&D sites [NIH].
13. Final Stakeholders Meeting/Workshop [NIH/CWC/CWPRS].
14. Preparation of Final Report covering all the above aspects [NIH/CWPRS/CWC].

Note: The three-monthly chart depicting the planned activities is given in Annexure-I.

***Annexure-I*: Schedule of planned activities under the proposed Purpose Driven Study titled: "**Entropy and Image Processing Based Non-Contact Discharge Monitoring Technique for Himalayan Basin**".**

S. No.	Items of work	1st Year				2nd	
		Q1	Q2	Q3	Q4	Q1	Q2
1.	Field visit to collect the study related data and information.	■					
2.	Procurement of SVR's, thermal or optical camera's and other accessories for up-gradation of the selected G&D sites and also other instruments and software's	■	■				
3.	Recruitment of project staff	■					
4.	Site selection and installation of instruments at the selected G&D sites	■					
5.	Field investigations to estimate parameters of entry based discharge model		■	■	■	■	
6.	Discharge monitoring by entropy-based approach using data from SVR and WLR and also by conventional discharge measurement techniques.			■	■	■	
7.	Calibration of thermal or an optical camera's and other instruments before installation		■	■			
8.	Development of mathematical formulation to enable discharge measurement using image processing technique		■	■	■	■	
9.	Discharge measurement by image processing based technique and validation of the results with other discharge measurement methods used in the study				■	■	■
10.	Development of GUI to graphically display the real-time discharges				■	■	
11.	Development of web-app for entropy based discharge measurement technique				■	■	■
12.	Rating curve development at the selected G&D sites.					■	■
13.	Final Stakeholders Meeting/Workshop					■	■
14.	Preparation of Final Report				Report		Report

3.1 Total Cost of Project

Total cost of the project (in Rupees): **85,57,000.00**+ **75,42,000.00**= 1, 60, 99, 000 **(One Crore Sixty lakhs and Ninety-Nine thousand only).**

3.1.1 Head-wise budge (NIH) [Tentative]

S. No.	Head	Amount (Rs)
1.	Remuneration/Emoluments for Manpower (1 Nos. JRF/SRF)	13,92,000
2.	Travelling expenditure	10,00,000.00
3.	Data procurement	30,000.00
4.	Infrastructure/Equipment/software etc.(SVR and WLR @ 5 G&D sites, 1 Handheld SVR)	56,85,000.00
5	Experimental charges/Field work/Consumables	3,00,000.00
6.	Misc. expenditure (@ Rs. 50000/- per year)	1,50,000.00
	Total	85,57,000.00
	Grand Total (Say)	**85,57,000.00**

(***Note***: *Year-wise details provided with justifications of each head in separate table.*)

3.1.2 Head-wise budge (CWPRS) [Tentative]

S. No.	Head	Amount (Rs)
1.	Remuneration/Emoluments for Manpower (1 Nos. JRF/SRF)	13,92,000
2.	Travelling expenditure	10,00,000.00
4.	Infrastructure/Equipment/software etc.(SVR and WLR @ 5 G&D sites, 1 Handheld SVR)	30,00,000.00
6.	Experimental charges/Field work/Consumables (Installation and commissioning)	20,00,000.00
8.	Misc. expenditure (@ Rs. 50000/- per year)	1,50,000.00
	Total	75,42,000.00
	Grand Total (Say)	**75,42,000.00**

NEW STUDIES (INTERNAL)
1. PROJECT REFERENCE CODE: NIH/SWHD/NIH/24-27

1. Title of the Project: A Flood Forecasting Framework Coupling a High Resolution WRF Ensemble with 2D Hydrodynamics Model for Himalayan Mountainous Area.

2. Project team:

Project Investigator:	Dr. Ravindra.Vitthal Kale, Sc. E, SWHD
Project Co-Investigator(s):	Dr. Kuldeep Sharma, Sc. C, C3S
	Dr. Sanjay Kumar, Sc. F, SWHD
	Dr. A. K. Lohani, Sc. G & Head, SWHD

3. Objectives:

- To assess the potential of high-resolution Weather Research and Forecasting (WRF) model to provide Numerical Weather Prediction (NWP) especially for an extreme event in typical western Himalayan river catchment.
- To establish a proficient 2D hydrodynamic model such as TUFLOW (Classic) model to generate flood inundation map.
- To evaluate performance of coupled WRF ensemble with 2D hydrodynamic model to enhancing flood inundation forecasting capabilities during extreme flood event.

4. Present state-of-art:

The sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC) observes that human-induced warming is increasing at 0.2°C per decade which will lead to an inevitable increase of 1.5°C in the global temperature (Allen et al., 2018). This would imply a substantial increase in the occurrence/intensity of extreme events which is evident from the rising numbers of extreme events in the western Himalayan region. Flash flood of 2014 was the deadly flash flood strike in Jammu and Kashmir exceeding the normal rainfall pattern. Jammu regions receive over 70% rainfall during SW monsoon, and experiences disastrous weather events mostly flood and flash flood (in hilly areas) and cloud bursts on some occasions. During monsoon season (June to September), Jammu receives 570 mm of rainfall which is 73% of annual total rainfall. As per official report of Rajya Sabha, 282 people have died, 6.48 lakh hectare of crop area affected and 2.53 lakh houses have been reported damaged due to the floods, adding 61,326 cattle were also killed (Daily Greater Jammu).
Numerical Weather Prediction (NWP) models play a crucial role in extending flood forecast lead times beyond the concentration time of a watershed. The substantial progress in NWP technology and increased computational power over the past decades have enabled the generation of high-resolution precipitation forecasts specifically tailored to the catchment scale. This progress has been instrumental in the development of Quantitative Precipitation Forecasts (QPFs) derived from high-resolution NWP models (Rogelis & Werner, 2018).
Therefore, these high-resolution QPFs are increasingly integrated into flood forecasting systems. By leveraging the advancements in NWP models, forecasters can provide more detailed and accurate precipitation predictions at the catchment level. This improved precision in forecasting allows for extended lead times in flood predictions, enhancing the preparedness and response capabilities of water resource managers and emergency responders. The synergy between high-resolution NWP models and flood forecasting systems represents a notable stride in harnessing technology to mitigate the impacts of floods and protect vulnerable regions.

5. Study Area

The Tawi River is a significant river that flows through the Jammu region in the union territory of Jammu and Kashmir. It serves as a major left bank tributary of the Chenab River, which is one of the major rivers in the region. Tawi river is lifeline of Jammu city originates from the Kali Kundi glacier located on the southwest of Doda district of Jammu and Kashmir (part of Himalayas). The catchment area of the Tawi river basin is bounded by latitude 32° 35' 20"-33° 6' 6" N and longitude 74° 29' 8"-75° 40' 54" E which varies between 239 and 4331 m. Tawi river is in danger of being struck with flash floods which occur periodically following the rains of summer and in the season of more irregular winter rain. Based on the topography and morphology of the Tawi River, it is construed that the Tawi River Basin shows significant ecological and morphological diversity beginning from the Kali Kund to its confluence point with Chenab River. As the River enters the plains near Nagrota Town of Jammu where it starts widening and depositing sediments in the form of alluvial plains, makes it further wider and more dynamic in Jammu city with significant human interventions, narrowed the path of the Tawi River by making concrete embankments and after passing through the Jammu city it becomes more prone to flood hazards due to its entry into alluvial plains makes it dangerous and threatening to the inhabitants of the border Tehsils of the Ranbir Singh Pura, Gho Manhasa, Suchetgarh, etc are more prone to floods comes under the category of very high to high hazards.

6. Methodology

The proposed flood forecasting framework integrates two main components: a high-resolution Weather Research and Forecasting (WRF) ensemble for meteorological forecasting and a 2D hydrodynamics model (TUFLOW- Classic) for simulating flood inundation. The stepwise methodology followed is:

High-Resolution WRF Ensemble:

- The WRF model which is a numerical weather prediction system designed for both research and operational forecasting needs.
- Ensemble forecasting involves running multiple simulations with slight variations in initial conditions and/or model parameters to account for uncertainty in weather predictions.
- High-resolution WRF simulations (with spatial resolution of 2-6 km) will be used to assess the capability of predicting extreme events which are crucial, especially in mountainous areas where weather patterns can vary significantly over short distances due to complex terrain.
-

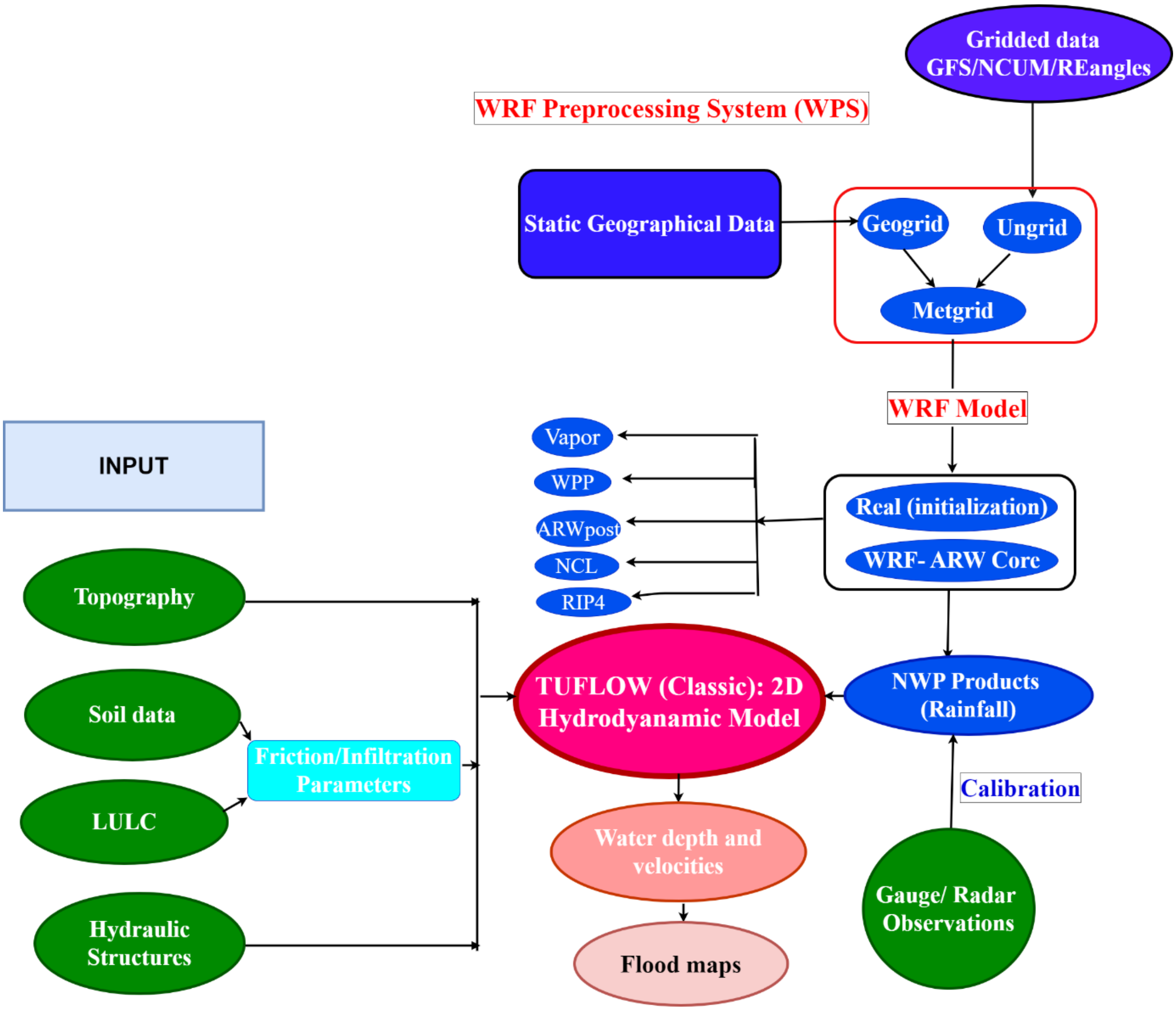
2D Hydrodynamics Model:

- Highly efficient and HPC TUFLOW (Classic) 2D hydrodynamic model will used to simulate flood inundation dynamics in the study area.
- This model represents the terrain using a 2D grid and solves the shallow water equations to predict water flow and inundation extents during flood events.
- The model considers factors such as topography, land use, soil properties, and hydraulic structures to accurately simulate flood behavior.
- Calibration and validation of the hydrodynamics model are crucial to ensure its accuracy in representing real-world flood events.
-

Coupling Framework:

- The outputs from the WRF ensemble, which include probabilistic forecasts of rainfall and other relevant meteorological variables, are used as inputs to the hydrodynamics model.
- The hydrodynamics model, coupled with the WRF ensemble outputs, simulates flood inundation dynamics under various weather scenarios predicted by the ensemble.

The detailed methodology that will be followed in this study is presented in the following flow chart.



7. Expected Outcome:

- By coupling a high-resolution WRF ensemble with a 2D hydrodynamics model, this framework aims to provide timely and probabilistic forecasts of flood inundation in mountainous areas, helping communities and authorities better prepare for and mitigate the impacts of flood events.
- Reports and research articles

8. Cost estimate:

a. Total cost of the project (Rupees): 41, 25,000/-
b. Source of funding: Internal
c. Sub Headwise abstract of the cost:

1.	Salary (JRF/SRF)	13,92,000
2.	Travelling expenditure	1,50,000
3.	Data procurement (High resolution satellite based spatial data, soil data and climate data)	5,00,000
4.	Infrastructure/Equipment/software (SVR and WLR @ 5 G&D sites)	17,00,000
5.	Training/workshop	2,00,000
6.	Experimental charges	1,50,000
7.	Misc. expenditure	33,000
	Grand Total:	41,25,000

9. **Work Schedule:**

a. Probable date of commencement of the project: April, 2024
b. Duration of the project: Three years (2024-2027)
c. Stages of work and milestone:

Work Element	**1st Year**				**2nd year**				**3rd year**			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Literature Review and detailed formulation of research approach												
Procurement/Collection of available hydro-meteorological data, river cross-section, gauge/discharge data, rating curve, satellite images, thematic maps etc												
Setting-up WRF model												
Analysis of WRF model ensembles results												
Setting up-TUFLOW (Classic) Model for the study area												
Coupling of WRF-TUFLOW model												
Analysis of Flood inundation forecasting results												
Report writing	1st interim report				2nd interim report				Final Report			

NEW STUDIES (INTERNAL)
3. PROJECT REFERENCE CODE: NIH/SWHD/NIH/24-26

Title of the study: Basin-scale, integrated water resources assessment through integrated hydrological modelling

Study team:
PI Dr. Soumyaranjan Sahoo, Scientist 'B'
Co-PIs
(1) Dr. A. K. Lohani, Scientist 'G'
(2) Dr. P. C. Nayak, Scientist 'F'
(3) Dr. R. V. Kale, Scientist 'E'
(4) Er. J. P. Patra, Scientist 'E'

Type of study: Internal (New)

Duration: Two-and-half years

Objectives

(i) To set up the Soil and Water Assessment Tool (SWAT) for modelling and assessment of surface water
(ii) To set up the Modular three-dimensional finite-difference ground-water flow model (MODFLOW) for modelling and assessment of subsurface water
(iii) To perform integrated hydrological modelling based on already set SWAT and MODFLOW models
(iv) To evaluate various reanalysis data products for hydrological modeling and thus identify the best datasets for Indian condition
(v) To perform integrated water resources assessment at basin-scale

1. Problem Statement

In many river basins in India and worldwide, water resources are depleting at an alarming rate due to anthropogenic activities and climate change. Supplying freshwater to the growing population under the challenges of urbanization, increased water demand-based lifestyle, and meeting irrigation demand for intensive agriculture pose a grand challenge to water managers. Further, policies such as the *Atal Bhujal Yojna* and the *Jal Jeevan Mission* demand assessment and development of local/regional surface water and groundwater resources. Hydrologists rely on statistical analysis of hydro-meteorological data, such as rainfall, streamflow, and depth to water table for water resources assessment. Conversely, the non-stationarity of the hydro-meteorological variable is a challenge for decision-making based on statistical interpretation (Pichuka and Maity, 2018). The potential alternative to the issue mentioned above is hydrological modelling. However, conventional hydrological modelling efforts often consider the surface water (SW) and groundwater (GW) resources as separate entities (Barthel and Banzhaf, 2016). Based on the project objective, one of the SW or GW systems is modelled, and the other is taken as a boundary condition, wherein simple approaches estimate the state variables. For example, most of the currently used large-scale hydrological models, viz., the Variable Infiltration Capacity (VIC, Liang et al., 1994) and Soil and Water Assessment Tool (SWAT, Arnold et al., 1998), do not effectively model the baseflow contribution to the rivers. Conversely, both SW-GW resources are connected by a bidirectional SW-GW interaction (SGI) flux. The SGI process prolongs the duration of water availability (Boutt, 2017). Hence, for basin-scale water resources assessment, water balance closure is necessary (Neysiani et al. 2022), considering SGI and other components of the hydrologic cycle (Sahoo and Sahoo, 2020).

The biggest challenge in integrated hydrological modelling is the lack of observed data at the required spatio-temporal scale (WMO, 1997). Further, many streamflow gauging stations and hydro-meteorological observatories are becoming defunct. With growing numbers of remote sensing-based satellites and reanalysis datasets, there is a scope for modellers to solve the data and scale issues. Addressing the above-mentioned issues, this study plans to develop an integrated surface water-groundwater modelling framework to perform hydrological modelling based on the data availability scenarios of i) *in-situ* data, ii) satellite-derived datasets, and reanalysis products (detailed in **Table 1**) for application in data-rich and data-scarce river basins, respectively.

Table 1 Description of different satellite-based and reanalysis datasets

Sr. No.	Dataset	Spatial Resolution	Temporal Resolution
1	CHIRPS	0.25° x 0.25°	Daily
2	SM2RAIN-CCI	0.25° x 0.25°	Daily
3	APHRODITE-2	0.05° x 0.05°	Daily
4	TRMM-3B42 Research Product	0.25° x 0.25°	Daily
5	GPM-IMERG Research Product	0.1° x 0.1°	Daily
	SMAP	36 km	2/3 days
7	ERA5-Land reanalysis	9 km	Daily
8	Merra-2	0.5° x 0.625°	Daily
9	Sentinel	10/20/60 m	5/10 days

2. Methodology

Schematic overview of the steps to be followed is given in Fig. 1.

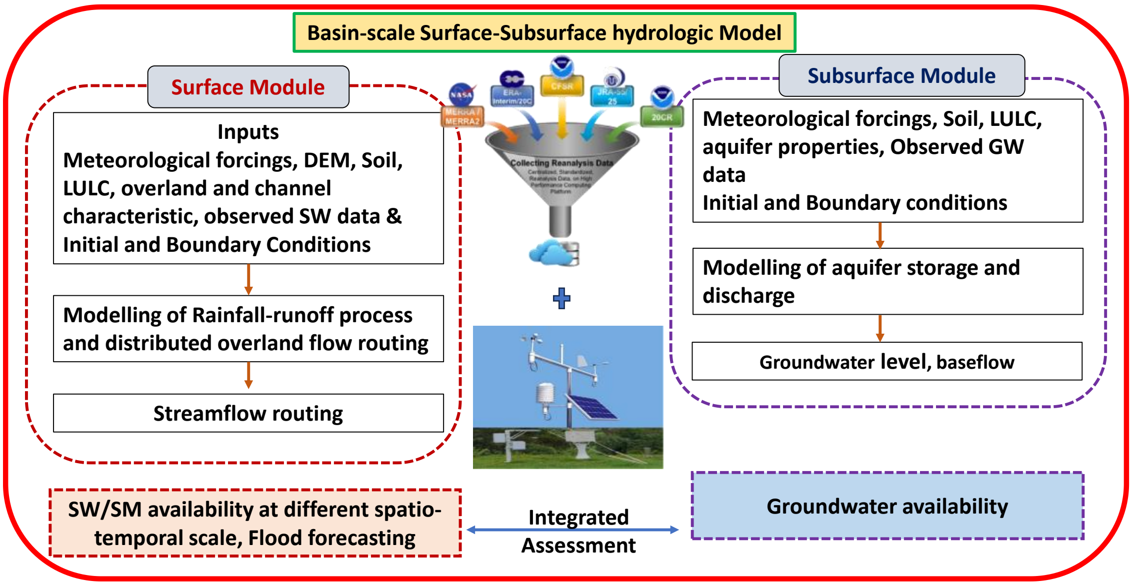


Fig. 1. Schematic of methodology to be followed for basin-scale integrated water resources assessment.

The steps to be followed are as follows:

1. Surface water, i.e., rainfall-runoff and streamflow modelling will be carried out using the Soil Water Assessment Tool (SWAT, Arnold et. al., 2012).
2. Subsurface modelling will be carried out by the MODELMUSE software based on the MODFLOW (Harbaugh, 2005) model.
3. The surface-subsurface module will be integrated on the QSWATMOD platform (Park et. al., 2019), enabling the integrated assessment of surface and groundwater resources.
4. Subsequently, an integrated modelling framework will be developed using satellite-based and reanalysis datasets.

3. Study Area

The Baitarani River basin (≈12,900 km^2) in eastern India is chosen as the study area. It lies within 20.67-22.28°N latitude and 85.16-86.89°E longitude **(Fig. 2)**. The river originates from the Gonasika

Hills towards the northern part of the basin at an altitude of 900 m above the mean sea level (msl). It drains into the Bay of Bengal in the East, traversing about 350 km. The area can be physiographically divided from north to southeast as eastern ghats, central table land, and coastal plains. The Baitarani River is perennial, baseflow being the sole contributor to non-monsoon streamflow. The basin witnesses frequent floods during monsoons. However, it has been observed that the non-monsoon flow has been decreasing over the last two decades (Uniyal et al. 2015). Hence, this study attempts to model the different water balance components of the study area to investigate the cause of the decline in non-monsoon streamflow.

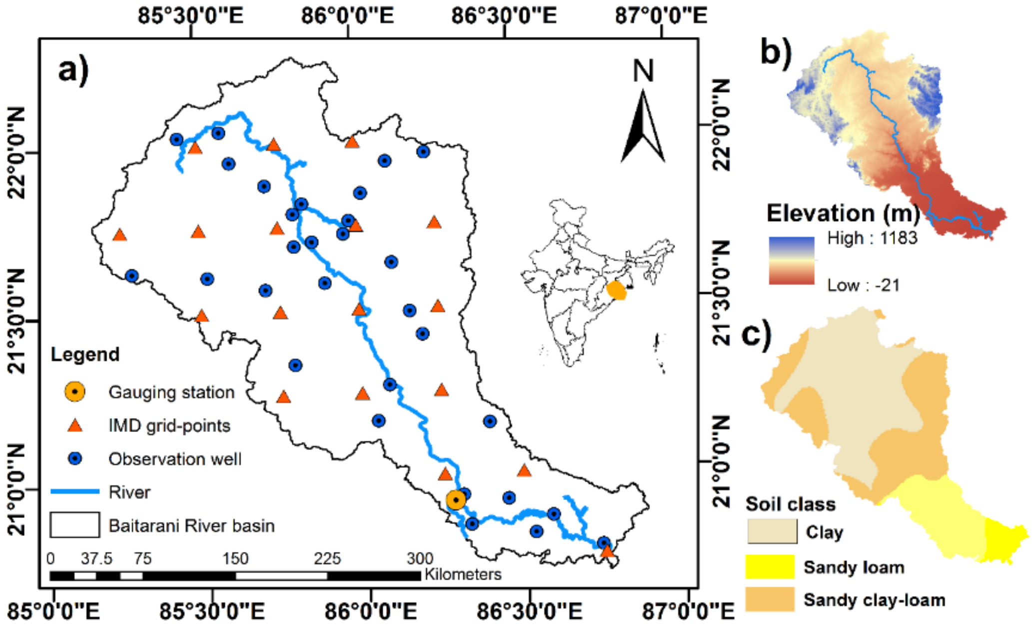


Fig. 2. (a) Index map with the streamflow gauging station, groundwater observation wells, and observed meteorological grid points; (b) Elevation map; and (c) Soil map of the Baitarani River basin.

4. Data requirements

- Hydro-meteorological data (rainfall, temperature, wind speed): i) observed from IMD gridded data sources; ii) Reanalysis data products, such as MERRA and ERA-Interim,
- Observed discharge data of the selected River basins and depth-to-water table data
- Maps concerning topography (DEM), soil type (from FAO and NBSSLUP)
- Remote sensing products on soil moisture and land use (e.g., Sentinel and Landsat)

5. Deliverables

1. Scientific
   a. Methodology for combined use of in-situ, remote sensing-based and reanalysis datasets
   b. Closure of water balance
   c. To answer: 'Are we getting the right answer for the right reasons?'
2. Technical
   a. Basin-scale water availability assessment for basin planning
   b. Identification of best satellite/ reanalysis product for Indian condition
   c. Methodology for using reanalysis products for water resources management of data-scarce or ungauged basins

6. Beneficiaries of the study

The prime beneficiaries of this study would be the State Water Resources Department and the River Basin Authorities. The proposed framework, when developed, could aid the local/regional Government bodies for integrated assessment that could be subsequently used for basin-scale planning and integrated water resources management. Further, the use of reanalysis datasets for hydrological modelling would benefit the scientific community in developing/testing methodologies for integrated assessment in the data-scarce river basins.

7. Quarterly work plan and timeline (from Mar 2024 to Aug 2026)

Sr. No.	**Activity**	1st Year				2nd Year				3rd Year	
1	Literature survey	■									
2	Data collection, preliminary analysis, and input data preparation	■	■								
3	Surface water module setup			■	■						
	1st interim report	■	■	■	■						
4	Subsurface module setup					■	■				
5	Integration of surface and subsurface modules							■			
6	Integrated assessment of surface and groundwater resources								■		
	2nd interim report					■	■	■	■		
7	Integrated modelling using reanalysis datasets									■	■
8	Technology dissemination, manuscript communication, and final report submission				■				■		■

8. Budget requirement

Sr. No.	**Item**	**Justification**	**Approx. Cost (in INR)**
1	Travelling expenditure	Field visit of the study team for data collection from the concerned departments	1,50,000 /-
2	Data	Hydro-meteorological data procurement	75,000 /-
3	Remuneration	Monthly remuneration to Masters students working on the project @ 12,400/ × 18 Months	2,23,200 /-
4	Training/ Workshop	Technology dissemination through training, workshop	5,00,000/-
4	Miscellaneous/ Contingency	Procurement of storage devices and items required for the preparation of reports	50,000 /-
		Total	**9,98,200 /-**

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NEW STUDIES (INTERNAL)
4. PROJECT REFERENCE CODE: NIH/SWHD/NIH/24-26

1. **Title of the study:** Comprehensive Mapping of Water Budget Dynamics and Reservoir Sedimentation in the Upper Krishna Basin using Google Earth Engine.

2. **Study team:** **PI** **:** Chandra Prakash, Sc. B, SWHD
   Co-PIs : Dr. Anil Kumar Lohani, Sc. G & Head, SWHD
   Dr. Ravindra Vitthal Kale, Sc. E, SWHD
   Dr. Richa Pandey, Sc. B, SWHD

3. **Type of Study:** Internal (New)

4. **Duration:** Two years

5. **Objectives:**

1. To obtain operational water information of water bodies based on remote sensing data

a. To monitor water bodies in the upper Krishna basin based on remote sensing data sets.

b. To track water levels, water areas, water volumes, and crop areas at a high temporal and spatial resolution.

c. Conducting water budget analysis and trends of water storage.

2. To carry out sediment balance and erosion analysis of the water bodies in Google Earth Engine(GEE)

a. Estimation of sediment balances, reservoir capacity, and reservoir storage changes over time.

3. To develop a Google Earth engine app for seasonal and annual water as well as sediment balance assessment

6. Background

Monitoring the water level and volume changes of lakes and reservoirs is essential for deepening our under- standing of the temporal and spatial dynamics of water resources in the, with a view to better utilizing and managing water resources (Liu et al., 2022). In recent years, there have been many studies on monitoring water level, sedimentation analysis and volume changes in natural water bodies had been done by (Biswas et al., 2021; Condeça et al., 2022; Gemitzi & Kofidou, 2022; Lahay & Koem, 2021; Liu et al., 2022; Markert et al., 2018; Wang et al., 2018; Yang et al., 2020; Yao et al., 2023; Zhao et al., 2023). In these studies, remote sensing techniques and Google Earth Engine (GEE) had been used to map the water budget components and sediment balance analysis. The upper Krishna river basin confronts multifaceted challenges in reservoir management, which happens due to climate variability, land use changes, and competing water demands. Rapid urbanization and agricultural expansion have altered natural hydrological processes, impacting sedimentation rates in water bodies. This project seeks to conduct a comprehensive mapping of water budget dynamics and reservoir sedimentation using the advanced capabilities of cloud-based platforms such as Google Earth Engine (GEE). The proposed initiative focuses on a comprehensive sediment assessment, water budget analysis (reservoir capacity, reservoir storage, water levels, storage, water areas), and the development of an integrated web application.

Stakeholder engagement, community involvement, decision-making, and continuous monitoring are integral components of the proposed solutions, encouraging collaboration and adaptive management strategies. By adopting a holistic approach that integrates technological advancements, the output of this study aims to enhance reservoir resilience and optimize water resource utilization in the upper Krishna river basin.

7. Study Area

The study area considered in this study will be part of the upper Krishna river basin. The Krishna River Basin in India features diverse terrain. The western edge is marked by the Western Ghats, with heavy rainfall and humid conditions, while the eastern Deccan plains are drier. The basin consists of rolling terrain with a sparse delta region. Elevation varies from 500 to 1903 meters.

The Krishna basin has a tropical climate. The climate is dominated by the southwest monsoon, which provides most of the precipitation for the basin. Four distinct seasons occur in the basin. They are 1) the cold weather, 2) the hot weather, 3) the southwest monsoon, 4) the post-monsoon. The annual mean temperature is 26.32°C. The major part of the basin (75.86%) is covered with agricultural area. Approximately 10% of the basin area is covered by forest, wasteland covers around 7% of the total basin area, and around 4% of the basin area is covered by water bodies. The other categories of land use/land cover in the basin are wasteland, built-up Land, and grassland. The important soil types found in the basin are black soils (regur), red soils, laterite and lateritic soils, alluvium, mixed soils (red and black, red and yellow, etc.), and saline and alkaline soils.

The Krishna basin houses 855 manmade water structures, including 660 dams, 12 barrages, 58 weirs, 6 anicuts, and 119 lifts. Most dams (81.36%) have storage under 25 MCM, primarily for irrigation. The upper Krishna basin consists of 188 dams, 4 barrages, 57 weirs, 61 lifts, and 10 power houses.

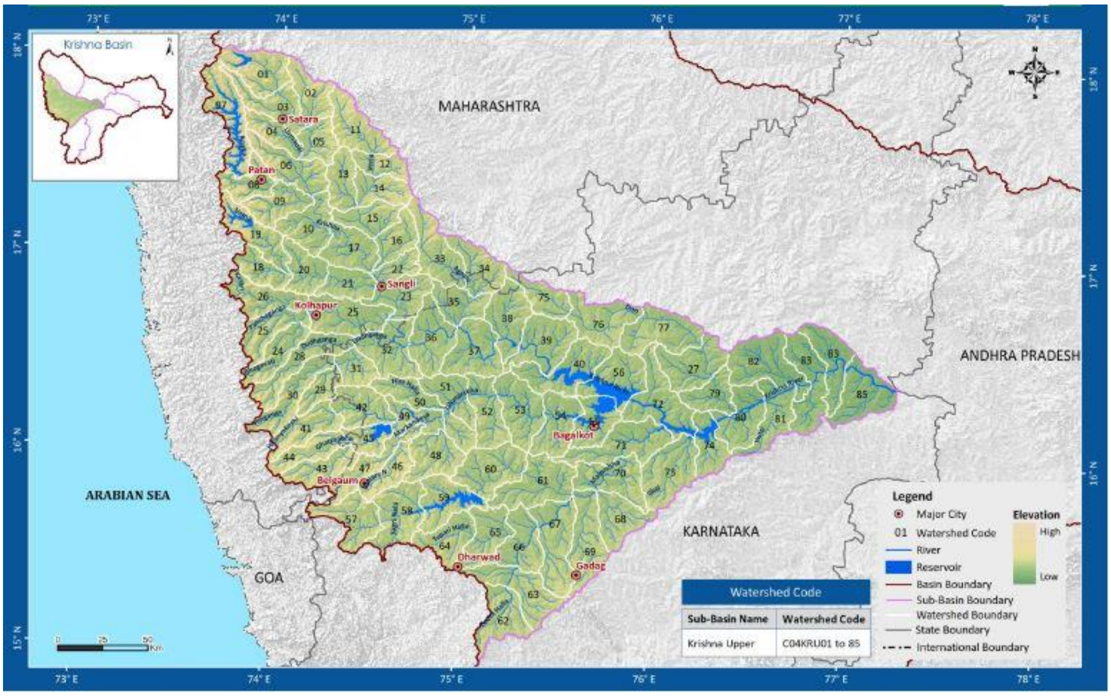
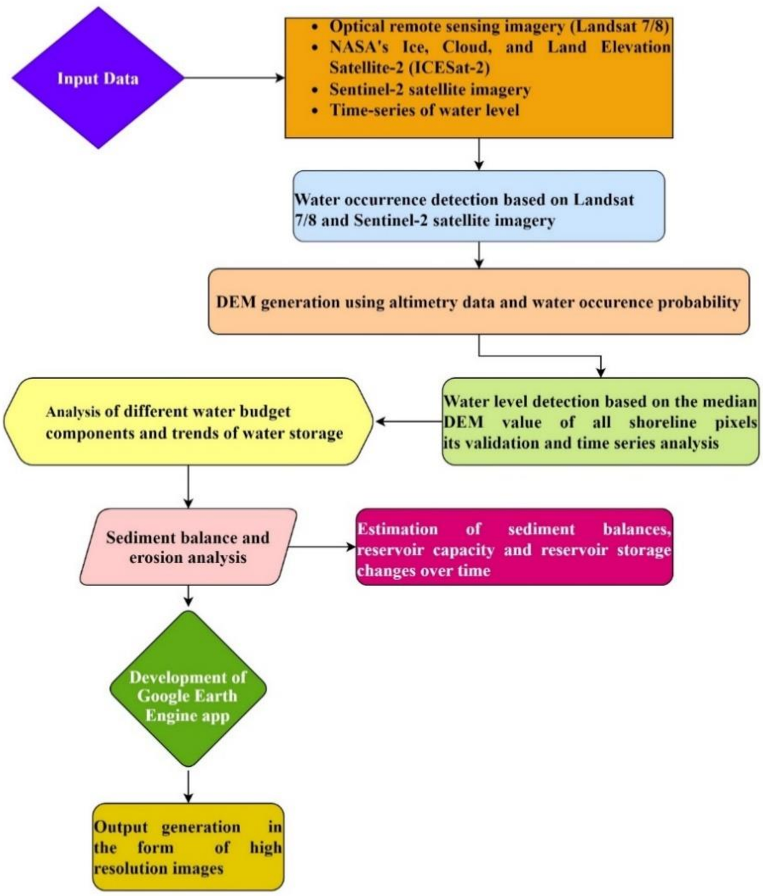


Fig. 4 Location Map of the Upper Krishna Basin

8. Methodology

- Obtaining the optical (Landsat 7/8), and radar remote sensing imagery (Sentinel-2) for the study area.
- Data from NASA's Ice, Cloud, and Land Elevation Satellite-2 (ICESat-2) will be acquired for the generation of DEM and Bathymetry.
- Time-series data of water level will be collected from the concerned authority for validation.
- Generation of Digital Elevation Model (DEM) using altimetry data and water occurrence probability.
- Detection of water levels based on the median DEM value of all shoreline pixels.
- Validation of water level detection results and conduct time series analysis.
- Estimation of different water budget components and trends analysis of water storage.
- Perform sediment balance and erosion analysis.
- Estimation of sediment balances, reservoir capacity, and changes in reservoir storage over time.

- Develop a Google Earth Engine application to track water levels, water areas, water volumes, sediment balances, and crop areas at a high temporal and spatial resolution for user-defined water bodies.
- Generate outputs in the form of high-resolution images, graphs, and charts.



9. Data requirement

SI. No.	Data Type	Description
1.	Remote Sensing Imagery	Landsat 8 and Sentinel-2 imagery
2.	Altimeter Data	ICESat-2 data sets required
3.	Digital Elevation Model (DEM)	DEM will be prepared from ICESat-2 data sets
4.	Water Level	Water level data at reservoirs
5.	Reservoir data	Area capacity, sediment data, and other specifications will be collected from the concerned authority

10. Beneficiaries of the Study

The proposed study on mapping water budget dynamics and reservoir sedimentation with Google Earth Engine (GEE) in the part of the upper Krishna river basin will provide valuable insights for informed decision-making and optimized water allocation. Water resource managers gain insights for informed decision-making, and conservation agencies will benefit from data on sedimentation patterns and water budget dynamics, aiding in the development of conservation strategies. Urban planners can make decisions related to water infrastructure. Industries gain insights into water availability, and local communities can participate in sustainable water management. Government agencies can formulate policies, and researchers contribute to the knowledge base. This study will lay the foundation for future planning initiatives and encouraging sustainable water management in the part of the upper Krishna river basin.

11. Work Plan and Timeline (April 2024 to April 2026)

a. Probable date of commencement of the project: April 2024

b. Stages of work and milestones:

Sr. No.	**Work element**	1st Year				2nd Year			
1	Literature review	■							
2	Data collection and preliminary analysis	■	■						
3	Water occurrence detection using satellite imagery and DEM generation using altimetry data		■	■	■				
4	Water level detection using remote sensing and its validation and water level time-series analysis		■	■	■				
5	Sediment balance analysis					■	■		
6	Estimation of Sediment balance, Storage volume lost, Erosion Zones, and Deposition Zones						■	■	■
7	Analysis of different components of the water budget and development of web app in GEE						■	■	■
8	Report writing				■				■

12. Budget requirement

Sr. No.	**Description**	**Approx. Cost (INR)**
1.	Salary (JRF)/Project staff	7,50,000/-
2.	Travelling expenditure	2,50,000/-
3.	Data Procurement (High-resolution satellite-based spatial data, DEM, soil data, and climate data)	1,00,000/-
4.	Equipment/software	2,00,000/-
5.	Miscellaneous	50,000/-
	Grand Total:	13,50,000/-

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NEW STUDIES (INTERNAL)
5. PROJECT REFERENCE CODE: NIH/SWHD/NIH/24-26

1. **Title of the study:** Water Resources Planning and Management using DSS (PM) under Changing Climatic and Land-Use Conditions

2. **Study team:** PI : Dr. Richa Pandey
Co-PIs : Dr. A. K. Lohani
Er. J. P. Patra
Dr. R. K. Jaiswal
Er. Chandra Prakash

3. **Type of Study:** Internal (New)

4. **Duration:** Two years

5. **Objectives:**

   A. ***Comprehensive Study on Streamflow and Sediment Yield Prediction under Changing Climatic and Land-Use Conditions incorporating SWAT***
   1. To simulate reservoir inflow and sediment yield, using the Soil and Water Assessment Tool (SWAT).
   2. Analyze the impact of different climate scenarios and land use changes on streamflow patterns and sediment yield, considering variations in precipitation, temperature, and extreme weather events.

   B. ***Water Resources Planning and Management under Changing Climatic and Land-Use Conditions using DSS (PM)***

   3. To develop an optimal water allocation plan to cater to water user demands in the reservoir command area
   4. To analyze the impacts of land use and climate change impact on optimal water allocation in the reservoir command area using DSS (PM)

6. Background

The part of the upper Krishna river basin encounters a complex set of challenges caused due to dynamic changes in climate patterns, evolving land use practices, and the increasing demands of various water user groups(Naga Sowjanya et al. 2022). Over time, the region has witnessed observable shifts in climate, marked by alterations in precipitation patterns, temperature extremes, and changes in weather events. These variations directly impact the hydrological processes within the basin, leading to uncertainties in streamflow patterns and water availability. Understanding the specific implications of climate change on water resources is imperative for implementing effective mitigation and adaptation measures (Deshpande NR 2014; Uniyal et al. 2015). Simultaneously, rapid urbanization, agricultural expansion, and alterations in land cover contribute to changing the natural hydrological processes in the part of the upper Krishna river basin. These land use changes play a significant role in sediment yield, influencing the overall health of water bodies and the sustainability of the basin's ecosystems. As a result, there is a growing need for effective and proper distribution of the available water resources within the study area with the expanding demands of water users, including agricultural communities, industrial sectors, and urban populations.

The part of the upper Krishna river basin faces the challenge of meeting the competing demands of various user groups while ensuring sustainable water management practices. Inconsistent water availability and changing water quality further complicate the task of managing water resources effectively. Various studies have been carried out by (Deshpande NR 2014; Uniyal et al. 2015; Chanapathi et al. 2018; Naga Sowjanya et al. 2022; Dubey et al. 2023) in this study area to encounter the impact of changing climatic conditions and land use patterns. However, there is a noticeable gap in understanding how climate change, land use changes, and the demands of water users collectively

influence streamflow and sediment transport. The absence of an integrated modeling framework limits the development of comprehensive strategies for sustainable water resource management.
This project aims to address these existing gaps by integrating the Soil and Water Assessment Tool (SWAT) and MIKE HYDRO Basin to predict streamflow and sediment dynamics under different climate scenarios and land use changes in the part of the upper Krishna river basin. The incorporation of water user demands into the modeling framework is crucial for promoting a holistic understanding of the complex interactions within the basin. By providing a comprehensive decision support system, this research endeavors to empower stakeholders and decision-makers with actionable insights, facilitating the development of sustainable and inclusive water management strategies for the part of the upper Krishna river basin.

7. Study Area

The study area considered in this study will be part of the upper Krishna river basin. The Krishna River Basin in India features diverse terrain. The western edge is marked by the Western Ghats, with heavy rainfall and humid conditions, while the eastern Deccan plains are drier. The basin consists of rolling terrain with a sparse delta region. Elevation varies from 500 to 1903 meters.
The Krishna basin has a tropical climate. The climate is dominated by the southwest monsoon, which provides most of the precipitation for the basin. Four distinct seasons occur in the basin. They are 1) the cold weather, 2) the hot weather, 3) the southwest monsoon, 4) the post-monsoon. The annual mean temperature is 26.32°C. The major part of the basin (75.86%) is covered with agricultural area. Approximately 10% of the basin area is covered by forest, wasteland covers around 7% of the total basin area, and around 4% of the basin area is covered by water bodies. The other categories of land use/land cover in the basin are wasteland, built-up Land, and grassland. The important soil types found in the basin are black soils (regur), red soils, laterite and lateritic soils, alluvium, mixed soils (red and black, red and yellow, etc.), and saline and alkaline soils.
The Krishna basin houses 855 manmade water structures, including 660 dams, 12 barrages, 58 weirs, 6 anicuts, and 119 lifts. Most dams (81.36%) have storage under 25 MCM, primarily for irrigation. The upper Krishna basin consists of 188 dams, 4 barrages, 57 weirs, 61 lifts, and 10 power houses.

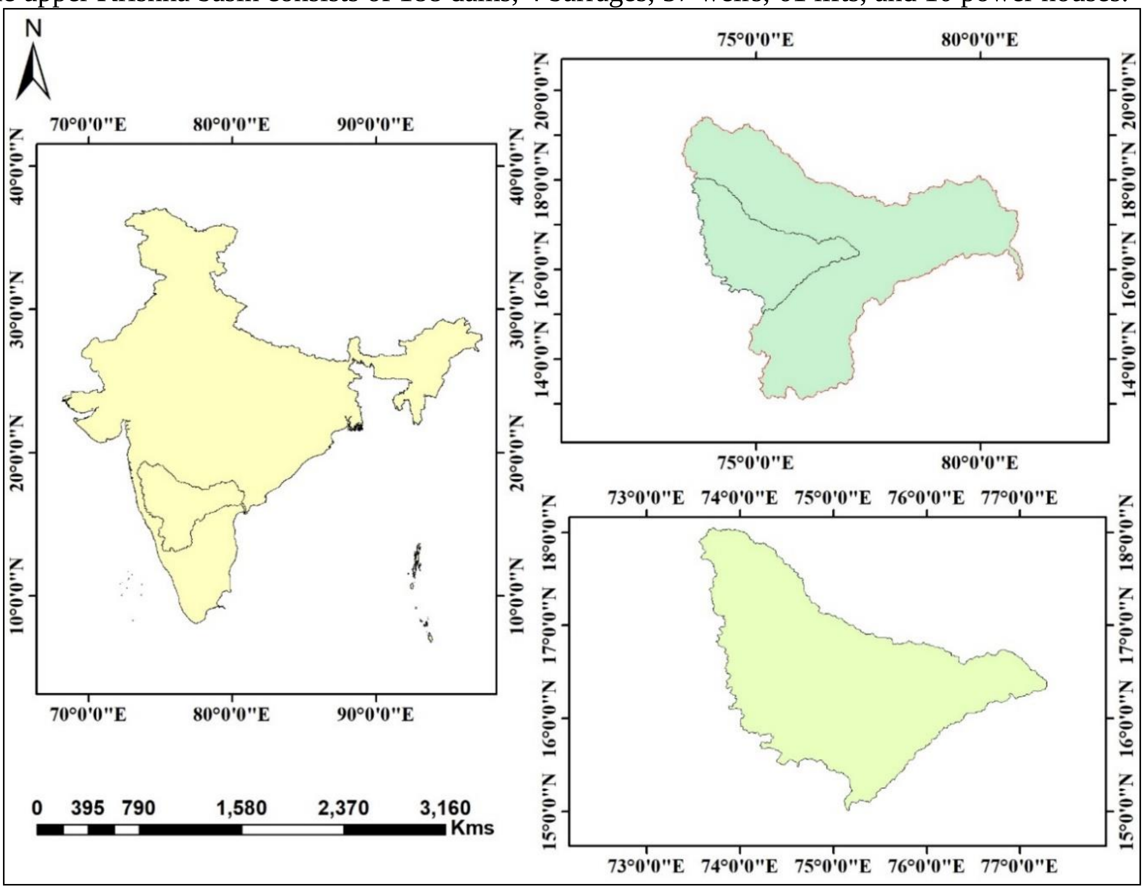

Fig. 5 Location Map of the Upper Krishna Basin

8. Methodology

- Collection and analysis of relevant data sets such as DEM, soil properties, land use/land cover, climate data (temperature, precipitation), and hydrological data (streamflow).
- Setup of the SWAT (Soil and Water Assessment Tool) model to simulate runoff and sediment yield.
- Conduct sensitivity analysis, calibration, and validation of the SWAT model using SWAT-CUP.
- Use appropriate methods or software tools to forecast future changes in land use/land cover (LULC), considering factors such as urbanization, agriculture expansion, and deforestation.
- Utilization of the calibrated and validated model to forecast streamflow and sediment yield under diverse future climate scenarios and predicted LULC changes.
- Incorporation of SWAT-Generated streamflow into MIKE HYDRO Basin.
- Distribution of Total Water Availability to Different Water Users Allocated into MIKE HYDRO Basin.
- Multicriteria optimization for optimal water allocation in the MIKE HYDRO platform, and subsequent visualization in DSS(PM).

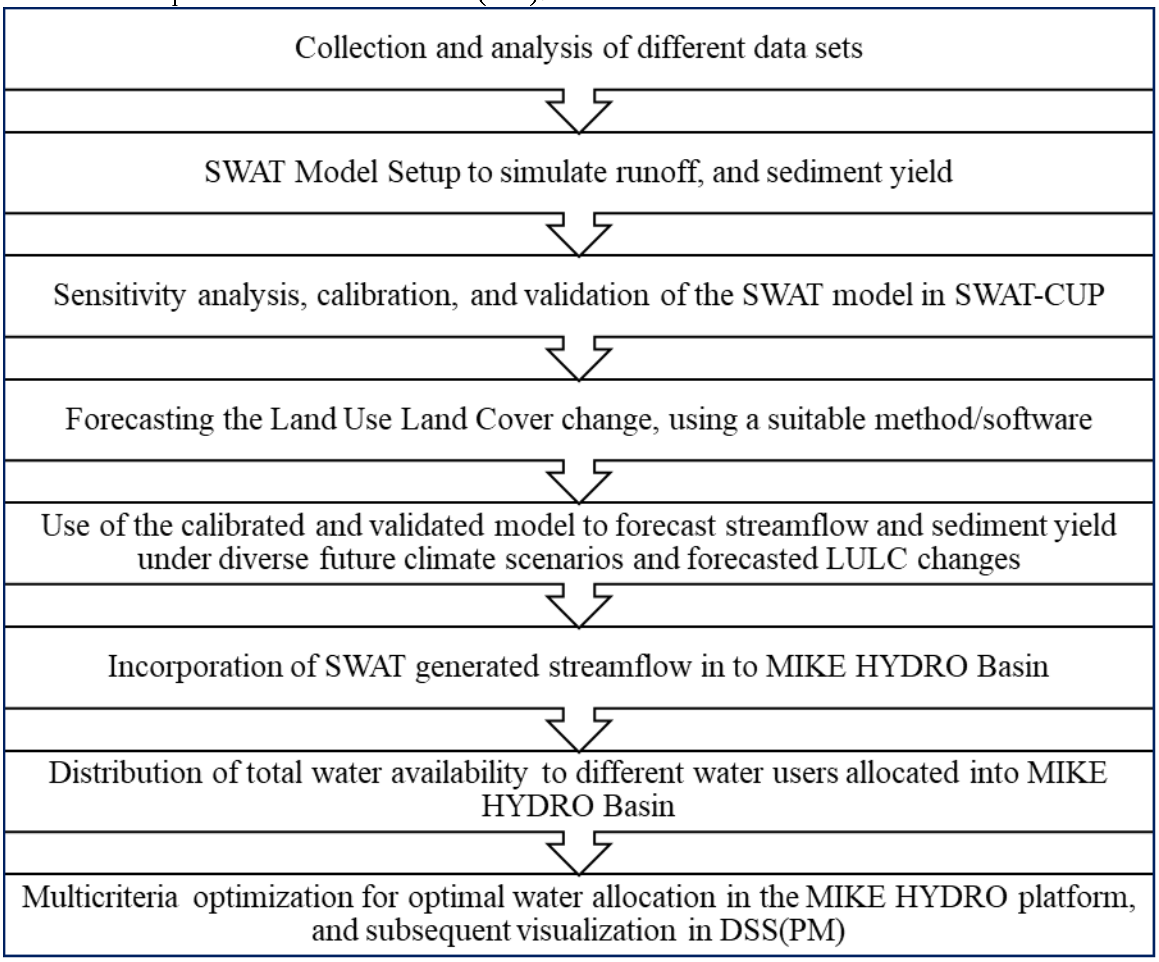

Fig. 2 Flow Chart Depicting Study Methodology

9. Data requirements

SI. No.	Data Type	Description
1.	Digital Elevation Model (DEM)	High-resolution DEM (LISS IV/ surveyed data) will be used
2.	Soil Data	NBSS Soil map will be used and will be collected from the concerned authority
3.	Land Use/ Land Cover	LULC map will be generated using the Sentinal-2 imagery

4.	Rainfall Data	Gridded rainfall given by IMD will be used
5.	Temperature Data	Gridded maximum-minimum temperature given by IMD will be used
6.	Discharge Data	Observed discharge at different gauging sites will be collected from the concerned authority
7.	Reservoir data	Area capacity, water level, and other specifications will be collected from the concerned authority.

10. Beneficiaries of the Study

The proposed study on predicting streamflow and sediment yield in the part of the upper Krishna River Basin using SWAT and DSS(PM) holds numerous benefits for stakeholders. Water resource managers gain insights for informed decision-making, while conservation agencies can develop strategies to protect ecosystems. Agricultural communities receive information to optimize water use, and urban planners can make decisions related to water infrastructure. Industries gain insights into water availability, and local communities can participate in sustainable water management. Government agencies can formulate policies, and researchers contribute to the knowledge base. The DSS(PM) provides user-friendly tools, laying the foundation for future planning initiatives and encouraging sustainable water management in the Upper Krishna River Basin.

11. Work Plan and Timeline

a. Probable date of commencement of the project: April 2024

b. Stages of work and milestones:

Sr. No.	**Work element**	**1st Year**				**2nd Year**			
1	Literature review								
2	Data collection and preliminary analysis								
3	SWAT model setup, sensitivity analysis, calibration, and validation								
5	Forecasting LULC dynamics and analyzing the impact of future climate scenarios and forecasted land use changes on streamflow and sediment yield								
6	Compilation of first objective reports and research papers								
7	Incorporation of SWAT-generated streamflow into MIKE HYDRO Basin and distribution of total water availability to different water users								
8	Analysis of MIKE HYDRO basin outputs with water user demands in DSS(PM) for optimized water allocation								
9	Compilation of second objective reports and research papers								

12. Budget requirement

Sr. No.	**Description**	**Approx. Cost (INR)**
1.	Salary JRF/ Project Staff	7,50,000/-
2.	Travelling expenditure	2,00,000/-
3.	Data Procurement (High-resolution satellite-based spatial data, DEM, soil data, and climate data)	1,50,000/-
4.	Equipment/software	1,50,000/-
5.	Miscellaneous	50,000/-
	Grand Total:	13,00,000/-

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WATER RESOURCES SYSTEM DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. A R Senthil Kumar	Scientist G & Head
2	Dr. Archana Sarkar	Scientist F
3	Dr. P K Singh	Scientist E
4	Dr. Manish Nema	Scientist E
5	Dr. P K Mishra	Scientist D
6	Dr. Pravin Rangrao Patil	Scientist C
7	Dr. Umesh Kumar Singh	Scientist C
8	Sh. Harsh Upadhyay	Scientist B
9	Sh. Asif	RA

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जल विज्ञान संस्थान
आपो हि ष्ठा मयोभुवः

APPROVED WORK PROGRAMME FOR THE YEAR 2023-2024

SN	Title	Study Team	Duration	Funding (Rs. Lakhs)
Completed Sponsored/ Internal Studies				
1.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora P K Mishra Vishal Singh	3 years (04/21-03/23)	NIH
2.	Impacts of glacier and climate change on runoff for selected basins of Himalayan region	Vishal Singh Sanjay K. Jain Manohar Arora	2 years (08/20-07/22)	NIH (9.30)
3.	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	Vishal Singh Sanjay K. Jain A P Dimri (JNU)	3 years (06/19-12/22)	NRDMS-DST (23.19)
Ongoing Sponsored/ Internal 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 A K Lohani Vishal Singh	3 years (11/19-11/22) Extended up to 03/23	NMHS-MoEF (143)
2.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.	P K Singh P K Mishra	2 years (08/20-07/22) Extended up to 03/23	NHP (14.50)
3.	Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework.	P K Mishra; P K Singh; Vishal Singh; P K Agarwal	2 years (04/21-06/23)	NHP (9.00)
4.	Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram	Vishal Singh M K Nema P K Singh Vanlalpekhlua Sailo (SDO from Mizoram); Lalruatkima (JE from Mizoram)	3 years (04/21-03/24)	NHP (25.00)
5.	Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya	M K Nema; Sanjay K Jain; P K Mishra;	3 years (08/20-07/23)	NIH (10.22)
6.	Spatio-temporal Water Availability under Changing Climate and Landuse Scenarios in Wainganga River Basin	M K Nema; P K Mishra; Rahul Jaiswal	2 years (04/22-03/24)	NIH (9.72)
7.	Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya	M K Nema; Sanjay K Jain; P. K. Mishra; Praveen Thakur (IIRS)	3 years (04/22-03/25)	IIRS (30.91)

8.	Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka	P K Singh; Vishal Singh; Sanjay K Jain; Abhilash R.	3 years (04/22-03/25)	NHP (54.0)
9.	Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin	Sunil Gurrapu; Nitesh Patidar; YRS Rao; R Venkata Raman; TVNAR Kumar	2 years (04/22-03/24)	NIH
New Internal/ Sponsored Studies				
1.	Monitoring and Modelling of Gangotri (Bhojwasa) watershed under different Climate Scenarios	P K Mishra; Vishal Singh; Sunil Gurrapu; Manohar Arora; Sanjay K Jain; Jatin Malhotra	3 years (04/23-03/26)	NIH (57.0)
2.	Glacier recurrence survey, Instrumentation and Modeling to study the Batal Glacier in part of Western Himalaya, India	Vishal Singh; P K Mishra; Sunil Gurrapu; Sanjay K Jain; Manohar Arora; Jatin Malhotra	5 years (04/23-03/28)	NIH (71.0)

PROPOSED WORK PROGRAMME FOR THE YEAR 2024-25

SN	Title	Study Team	Duration	Funding (Rs. Lakhs)
Ongoing Sponsored/ Internal Studies				
1.	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya	P K Singh; Vishal Singh; A K Lohani	3 years (11/19-11/22) Extended up to 03/24	NMHS-MoEF (143)
2.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.	P K Singh; P K Mishra	2 years (08/20-07/22) Extended up to 03/24	NHP (14.50)
3.	Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya	M K Nema; P K Mishra	3.5 years (08/20-03/24)	NIH (10.22)
4.	Development of Water Accounts for the selected sub-basins of Brahmaputra, Barak and Irrawady-Chindwin basins in the state of Nagaland using Water Accounting Plus (WA+) Framework.	P K Mishra; P K Singh	2 years (04/21-06/23) Extended up to 03/24	NHP (9.00)
5.	Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka	P K Singh; Vishal Singh; Harsh Upadhyay; Abhilash R.	3 years (04/22-03/25)	NHP (54.0)
6.	Spatio-temporal Water Availability under Changing Climate and Land-use Scenarios in Wainganga River Basin	M K Nema; P K Mishra	3 years (04/22-03/25)	NIH (9.72)
7.	Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics	Archana Sarkar; Jyoti Patil; Charu Pandey	2 years (05/22-04/24)	NIH
8.	Monitoring and Assessment of Mountain Ecosystem and Services in North-West Himalaya (Phase-II): Monitoring and Modeling of Hydrological Processes in Glaciated and Non-Glaciated Watersheds of North-West Himalaya	M K Nema; P. K. Mishra; Praveen Thakur (IIRS)	3 years (04/22-03/25)	IIRS (30.91)
New Internal/ Sponsored Studies				
1.	Simulation of operation of multiple reservoirs in Wainganga Basin for conservation and flood control under changing climate scenario	A R Senthil Kumar; T Thomas; M K Nema; Harsh Upadhyay; Sunil Gurrapu	3 years (04/24-03/27)	NIH (21.02)
2.	ResSed – Tool development for prediction of elevation-area-capacity curves of the reservoirs	A R Senthil Kumar; U K Singh; P K Singh; Harsh Upadhyay; Nitesh Patidar	2 years (04/24-03/26)	NIH (11.18)

3.	Integrated operation of Bisalpur and Isarda reservoirs in Banas river basin, Rajasthan	Archana Sarkar; A R Senthil Kumar; P K Mishra; Harsh Upadhyay; Mr. Sanjay Agarwal	3 years (04/24-03/27)	NIH (19.30)
4.	Water and Land Productivity Accounts for the major river basins of India using water accounting plus for sustaining water and food security: WAPRO-India	P K Singh; P K Mishra; Vishal Singh; Harsh Upadhyay; P R Patil; A. R. Senthil kumar	2 years (04/24-03/26)	NIH (43.48)
5.	Development of rule-based integrated operation framework for the Mahanadi basin	P K Mishra; M K Goel; P K Singh; A R Senthil Kumar	1.5 years (04/24-09/25)	NIH (5.0)
6.	Assessment of Precipitation Gradients and Temperature Lapse Rates for Hydrological Modelling in a Himalayan Catchment	P R Patil; M K Nema; P K Mishra; A R Senthil Kumar	3 years (04/24-03/27)	NIH (17.10)
7.	Evaluation of Area-Design Curve to estimate sediment distribution in Indian reservoirs	U K Singh; A R Senthil Kumar; M K Goel; P R Patil	2 years (04/24-03/26)	NIH (1.0)
8.	Water yield potential and flash flood risk assessment under changing climate and land use and strengthening of existing instrumentation in the Teesta River basin up to Domohani	Harsh Upadhyay; P K Singh; A R Senthil Kumar; P R Patil	3 years (04/24-03/27)	NIH (28.52)

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-24/01

1. Title of the Study

Snow and glacier contribution and impact of climate change in Teesta basin in Eastern Himalaya

2. Study Team

NIH Roorkee:

Dr. P. K. Singh, Scientist 'E'
Dr. Vishal Singh, Scientist 'D'
Dr. A. K. Lohani, Scientist 'G', SWHD

JNU, New Delhi:

Dr. A. P. Dimri, Professor

CAU Sikkim:

Dr. S. R. Yadav, Assistant Professor (SWCE)

IITM Pune

Dr. (Mrs) Nayana Deshpande, Scientist 'D'

3. Project Duration: 3 years (11/19-11/22) Extended up to 03/24

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:

- Assessment of recent changes in snow, glacier, rainfall and its impact on the hydrology of the Teesta basin through Hydrologic modelling.
- To understand the influence of glacier size, debris cover, topographic (i.e., altitude, aspect, and slope) and climatic variables on recent glacier changes?
- Sediment transfer characteristics of Teesta River at selected sites and identification of major drivers.
- Assessing climate change in the basin and future scenarios and resultant hydrological responses
- To understand and simulate the magnitude of the GLOF hazard of glacial lakes formed due to glacier recession using MIKE-II breach modeling.
- Identification of key change indicators for water resources of the region and their impact on local communities
- To develop a comprehensive and interactive web-enabled database repository of the hydro-met database and modelling spatial outputs with basic GIS functionalities.

5. Sponsored by: NMHS, MOEF & CC

6. Project Cost: Rs. 143 Lakhs

7. Methodology

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 to achieve the objectives.

- Snow/glacier melt runoff modelling will be done using SNOWMOD and VIC models. Landuse/landcover, snow/glacier maps etc. will be prepared for the study basin using standard RS and GIS techniques. Hydro-meteorological data will be collected from different sources such as CWC, IMD, NHPC and state agencies.
- Sediment yield modelling and assessment will be done using Delivery Ratio and GIS coupled empirical models, SWAT model and conceptual SCS-CN based sediment yield models.

- 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. Data and knowledge generated will be used to implement a sub-grid scale parameter scheme for Regional Climate Model using RegCM4 model with sub-grid parameterization and refined future projections for climatic variables.
- The satellite data along with field investigations will be used to assess glaciers and glacial lakes. MIKE 11 model will be used for GLOF simulations.
- A comprehensive web enabled database repository will be developed based on information from the field data collection and modelling results.

8. Time-Line and Activities

	Activities	1st Year		2nd Year		3rd year	
NIH	Hiring Manpower	■					
	Procurement of the instruments	■	■				
	Data collection and database preparation		■	■	■		
	Model data need and requirement by other PIs			■	■	■	
	Model simulations and sensitivity analysis			■	■	■	
	Study of impact of climate change			■	■	■	
	Sediment studies				■	■	
	GLOF studies			■	■	■	■
	Development of a comprehensive and interactive web-enabled database repository			■	■	■	■
	Workshops/Trainings				■	■	■
	Report writing					■	■
CAU	Hiring Manpower	■					
	Procurement &installation of Met. stations	■	■	■			
	Data collection and Data synthesis		■	■	■	■	
	Sediment studies			■	■	■	■
	Report writing						
JNU & IITM	Hiring of manpower	■					
	Climate modelling work		■	■	■	■	
	Report writing					■	■

9. Progress till-the-Date

- Spatial Process in Hydrology (SPHY) model has been used for the overall water balance computation and then the separation of all main runoff (Q) components (e.g. snow melt runoff, glacier melt runoff, base flow and rain induced runoff) for Teesta river basin. At outlet (Teesta lower dam IV), the contributions from different runoff components are recorded as 78% from rain induced runoff, 10% from glacier melt runoff, 9% from snowmelt runoff and 3% from baseflow. Based on these findings a research paper has been published in the journal of Cold Regions Science and Technology. 10.1016/j.coldregions.2023.103965
- For future assessment of changes in snow melt runoff, glacier melt runoff and other runoff components, the CMIP6 based climate models have been evaluated and after uncertainty analysis, the best fitted models such as Access-CM2, EC-Earth3 and MRI-ESM2-0 with moderate and extreme emission scenarios, viz., SSP245 and SSP585, respectively have been applied. The long term scenarios of snow melt runoff, glacier melt runoff and other runoff components (base flow rainfall runoff and total flow) for the year 2015-2100 have been generated and the change assessment has been carried out. Overall, a significant change in snow melt runoff and glacier melt runoff (increase/decrease) has been observed in the Teesta river basin.
- A reconstruction of historical GLOF events of South Lohnak lake (during October 04-06, 2023) has been carried out using an integrated hydrologic and hydrodynamic model. The

flood inundation depth, velocity and peak flood discharge at different sections have been computed.

- A comprehensive and interactive web-enabled database repository of the hydro-met database and modelling spatial outputs with basic GIS functionalities have been developed. http://nih-teesta.in/gistool.aspx.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-24/02

1. Title of the Project

Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.

2. Project Team

Dr. P. K. Singh, Scientist 'E'
Dr. P. K. Mishra, Scientist 'D'

3. Project Duration: 02 Years (08/20 – 07/22) Extended till 03/24

4. Objective of the Study

The major objective of this study is to apply newly developed WA+ framework for sub-basins of Brahmaputra and Barak basins in the state of Meghalaya.

a) To develop water accounts for the study basins/sub-basins.
b) To estimate ET consumption patterns and beneficial and non-beneficial water consumptions.
c) To develop accounts for agricultural services (i.e., land productivity and water productivity).
d) To prepare the detailed WA+ report for study basins/sub-basins.
e) To impart training on WA+ to the state officials of Water Resources, Agricultural and other related Depts.

5. Present state-of-the-art

Water accounting (WA) can provide a coherent and consistent solution to the spatial & temporal assessment of WP and the allocation of water across various competing sectors to avert the looming water crisis. WA also considers the consumption of water and the benefits and services - including ecosystem services - that result from that consumption, including the return flow of non-consumed water. 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 WA frameworks. FAO's global information system on water and agriculture (AQUASTAT) is an important source of data, however, it does not distinguish between consumptive use and non-consumptive use. The System of Environmental Economic Accounting for Water (SEEA-WATER) of the United Nations Statistics Division (UNSD) (UN, 2012) requires a variety of data from numerous sources, which are unlikely to be available at many times (Dimova et al., 2014; Perry, 2012). It does not distinguish between the green and blue water resources (Falkenmark and Rockstr¨om, 2006; Rockstr¨om and Gordon, 2001). The Australian Water Accounting Standard (AWAS) developed by the Water Accounting Standards Board (WASB) of the Australian Bureau of Meteorology (BOM) accounts for water withdrawals rather than consumptive use. However, AWAS 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 in India (Molden, 1997); Zhanghe Irrigation System in China (Dong et al., 2004)) and at the 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 (WA+) Framework 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 understood by 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) (Figure 1) and WATERPIX model (IHE, 2016) for this purpose. The basis of this water balance approach is that outflow from a certain area of interest (e.g., river basin) are explicitly related to the net inflow and depletion through a measurable ET processes.

WA+ framework classifies land use land cover (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) (Figure 2). 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.

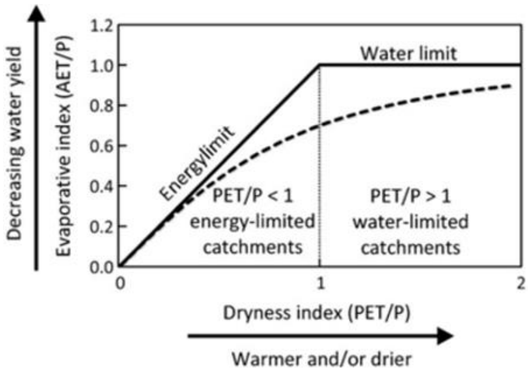

Figure 1: Budyko Framework **Figure 2: WA+ Based WMC**

6.1 Study Area and Major Input Data

The state of Meghalaya is the north eastern part of India and is bounded in the north and east by Assam plains and in the south and west by Bangladesh plains. In the north, it is bounded by Kamrup and Goalpara districts of Assam and on the east by Karbi Anglong and North Cachar. The southern border is the international border with Bangladesh which is about 496 km long. Meghalaya is located between 25º01’51.58” N to 26º07’10.31” N latitude and 89º49’10” E to 92º48’04” E longitude with altitude ranging from 50 to 1966 meters. The State covers geographical area 22,429 km^2. Figure 3 shows the basin map of the Meghalaya state.

The WA+ framework makes use of open source remote sensing data in an effort to maintain a high level of transparency. Remote sensing is a reliable and objective source of data. Data products from the National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) are provided free of charge for all users regardless of nationality or intended application. Following datasets will be used for WA+ analysis in this study:

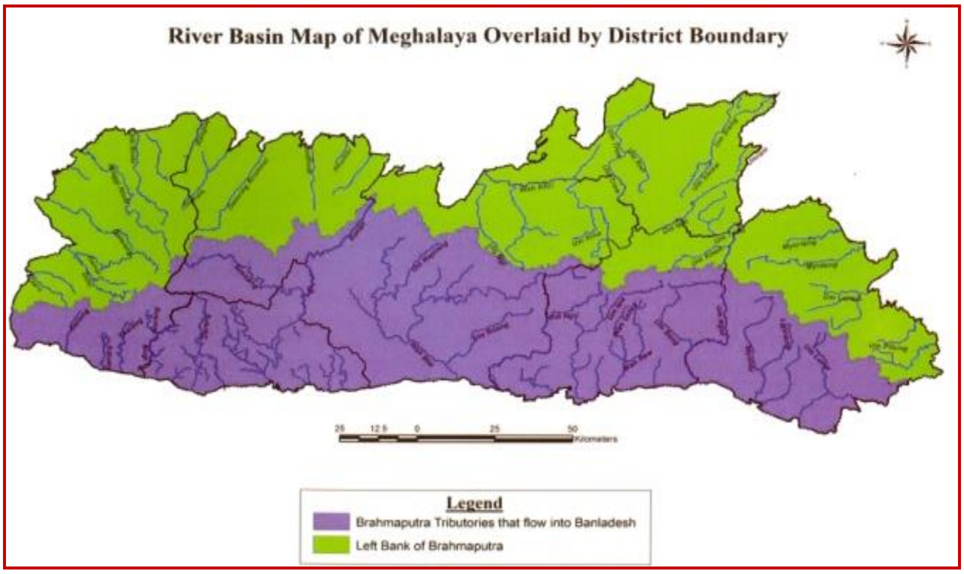

Figure 3: River basin map of Meghalaya overlaid by district boundary
(Source: WRD, Meghalaya)

- Precipitation (CHIRPS - or TRMM rainfall)
- Evapotranspiration (MODIS/ ETensV1.0/GLDAS)
- Meteorological data (GLDAS-Noah)
- WA+ system based Land Use / Land Cover (WALU using GlobCover, IWMI crop maps, MODIS, FAO, etc.)
- Soil moisture (EUMETSAT-ASCAT: Advanced SCATterometer (ASCAT)/GLDAS
- Vegetation, leaf area index (MODIS)
- Net primary production (NPP) and gross primary production (GPP) (MODIS)
- Crop types and crop calendar
- Basin DEM, boundary, drainage network map, etc.
- GRACE (Gravity Recovery and Climate Experiment) dataset
- GMIA (Global Map of Irrigated Areas) dataset
- MIRCA (Monthly Irrigated and Rainfed Crop Areas) dataset
- Grey Water Footprint/WPL datasets

7. Research Outcome from the Project

- Water Accounts: Supply-Demand and Consumptions and Water Availability
- Water Consumption Patterns and beneficial non-beneficial consumptions.
- Accounts for Land Productivity and Water Productivity.
- LULC map, soil maps, and river networks.
- WA+ Report and Recommendations.
- Training modules on WA+ Framework.

8. Cost Estimates

The total cost of the project: **₹ 14.50 Lakh**

a. Source of funding: NHP
b. Sub-head wise abstract of the cost:

Head	Amount (in Lakh)		
	1st Year	2nd year	Total
1: Manpower: JRF @31,000/ + HRA and others	5.00	5.00	10.00
2: Others (Hiring of services, field visits, consumables, stationary, printing of reports & brochures, and sample analysis, etc.)	1.00	1.00	2.00
3: Travel Expenditure	1.00	1.00	2.00

4: Contingency	0.25	0.25	0.50
Grand Total			14.50
	Rs. Fourteen Lakhs Fifty Thousand Only		

9. 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	**Aug. 2020-July 2021**				**Aug. 2021-July 2022 (Extended up to March 2024)**			
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. Development of Water Accounts					↔	↔	↔	
e. Detailed Analysis of Water Accounts and Validation and research paper publications						↔	↔	↔
f. Final report writing recommendations and Training							↔	↔

10. Progress till Date

- All the meteorological (satellite precipitation products (08), evapotranspiration (AET) (GLEAM v3.7b) and hydrological (flows) datasets have been processed. Best precipitation (P) dataset (CHIRPS) has been identified and used in developing agricultural and water accounts.
- Spatio-temporal variability of the CHIRPS, consumption dataset (AET), water yield (P-AET), GRACE TWSC, GPP dataset using ITA and MK Test and behavioral patterns of these variables with the WA+ based land use land cover, i.e., WALU.
- The agricultural accounts (land productivity) estimates have been validated using the field data obtained from WRD Meghalaya and the results have been found in good agreement for all the sub-basins/districts.
- The web-portal for WA+-Meghalaya is under development and will be operational by the end of March 2024.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2020-24/03

1. Title of the Project

Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya

2. Project Team

Dr. M. K. Nema, Scientist 'E'
Dr. P. K. Mishra, Scientist 'D'

3. Project Duration: 3.5 Years (08/20 – 03/24)

4. Objectives of the Study

a. To develop a baseline runoff and meteorological data of Henval watershed with the established experimental setup.
b. To carry out Hydrological modelling of Henval river
c. To model the spatial-temporal variability and temporal-stability of the soil moisture
d. To compare and validate the satellite soil moisture data with the in-situ observations

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. Experimental hydrology still has a unique place with no alternative for testing and developing new research hypotheses and models. Given the importance of experimental hydrology, NIH has initiated an experimental hydrologic project for a small lesser Himalayan watershed, namely, Henval. In the first phase of the project, a state-of-art field observatory was established with various instruments and sensors during 2016-2019. Preliminary data analysis on the estimation of evapotranspiration by various methods and water balancing of the watershed was performed. The field station developed at Henval watershed is envisaged to operate for long-term monitoring of different hydro-climatic variables. This study is supposed to be the second phase of the project.

The field monitoring of the various variables and development of baseline datasets for the Henval watershed shall be a continuous process in this study. Hydrological modeling of the stream is planned to understand the catchment characteristics and runoff behaviour of the watershed. Soil moisture is the crucial variable for partitioning rainfall into infiltration and runoff, thus playing a fundamental role in runoff modelling and flood forecasting. Recently, the scientific community is making an excellent effort to address soil moisture estimation over large areas through in situ sensors, remote sensing, and modelling approaches. There is sizeable spatial-temporal variability of soil moisture that exists in field conditions. Currently, we are able to estimate soil moisture accurately at the point scale through in-situ sensors.

Moreover, satellite sensors can obtain less accurate measurements at a coarse scale (~20 km). Finally, spatial downscaling/upscaling approaches can be used to integrate the different techniques and observations with modelling. Data assimilation and merging methods can also be considered to integrate in-situ, satellite and modelled data optimally.

6. Methodology

In the present study, meteorological variables soil and runoff monitoring shall be done within the established experimental watershed. Modelling of runoff, soil moisture monitoring and modelling and comparison and validation of satellite soil moisture product with in-situ sensors are proposed. The methodology for these is described in the following sections.

Hydrologic Modelling:

Several models are available for runoff modelling. In the proposal work, a semi-distributed model with proven capabilities, namely the Soil and Water Assessment Tool (SWAT) model, will be used for the estimation of streamflow in the basin.

Soil Moisture Modeling:
The SWAT, Soil Water Balance Model, etc., shall be applied to carry out soil moisture modelling. The observed soil moisture data shall calibrate and validate the soil moisture model. Study of the effects of static factors such as land use, topography, soil texture, etc., on the spatial variability of soil moisture, also envisaged in this study.

Validation of Satellite-based Soil moisture products:
Various satellite-based soil moisture products such as ASCAT, SMAP, SMOS, etc., with different resolutions, shall be validated and compared against the in-situ soil moisture sensor. The interrelation of soil moisture and surface runoff shall be performed.

7. Research Outcome from the Project

- Validation of the SWAT model for a lesser Himalayan watershed.
- Assessment of the spatial-temporal variability and temporal-stability the soil moisture
- Validation of satellite-based soil moisture product for Himalayan watershed.
- The error characterization of the satellite-based soil moisture products.

8. Cost Estimates
The total cost of the project: **₹ 10.2236 Lakh**

a. Source of funding: NIH
b. Sub-head wise abstract of the cost:

SN	Sub-head	Amount (₹)			
		Year - I	Year - II	Year - III	Total
1	Salary (Part-Time Field Staff)	156000	171600	188760	516360
2	Travelling expenditure	78000	78000	78000	234000
3	Infrastructure/Equipment	0	0	0	0
4	Experimental /Rental Charges	66000	76000	76000	218000
5	Misc. expenditure	18000	18000	18000	54000
	Sub- Total:	318000	343600	360760	
	Grand Total:	**1022360**			

9. Work Schedule

SN	Description of Activity	2020-21			2021-22				2022-23				2023-24	
		Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
1	Data Collection and up-keeping of the instruments	■	■	■	■	■	■	■	■	■	■	■	■	■
2	Hydrological Modelling		■	■	■	■	■							
3	Soil Moisture Modelling				■	■	■	■	■	■				
4	Satellite data acquisition, assimilation and processing		■	■	■	■	■	■	■	■	■	■		
5	Validation and comparison of satellite and in-situ data							■	■	■	■	■	■	■
6	Report Writing				■				■					■

10. Progress to date
In the previous working group meeting, the results related to soil moisture modelling using empirical models and data-driven machine learning algorithms were shared with the members. The results of the hydrological modeling using the Soil and Water Assessment Tool (SWAT) were also discussed in the last working group meeting. A hydrological modeling tool suitable for a wide range of water resource management applications named the Spatial Processes in Hydrology (SPHY) model, has been attempted for the study catchment with the same datasets, which was used for the SWAT model.

SPHY is a spatially distributed leaky bucket type of model and is applied on a cell-by-cell basis. Attempts have been made to perform rigorous sensitivity analysis and parameterization of the calibrating parameters. After multiple simulations, we were able to achieve a good agreement between the model simulated and observed discharge values. A new study pertaining to precipitation lapse rate and temperature lapse rate has also been proposed in the same catchment.

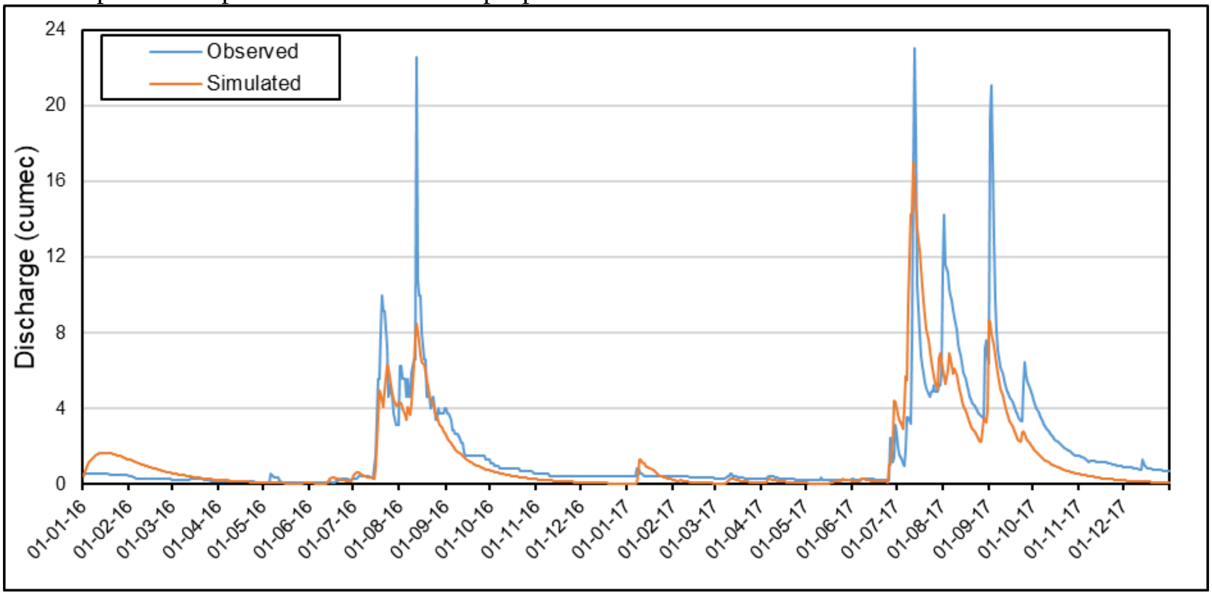

Fig. 1 Comparison of observed and SPHY model simulated discharge for the Henval Watershed

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2021-23/04

1. Title of the Project

Development of Water Accounts for the selected sub-basins of Brahmaputra, Barak and Irrawady-Chindwin basins in the state of Nagaland using Water Accounting Plus (WA+) Framework.

2. Project Team

Dr. P. K. Mishra, Scientist 'D'
Dr. P. K. Singh, Scientist 'E'

3. Project Duration: 02 Years (04/21 – 06/23)

4. Objective of the Study

The major objective of this study is to apply the newly developed WA+ framework for the selected sub-basins of Brahmaputra, Barak and Irrawady-Chindwin basins in the state of Nagaland for estimating the status of the water resources. This will generate useful base data to help development of proper water management strategies and decision processes. The specific objectives are:

1. To set-up WA+ Framework for the selected study basins/sub-basins.
2. To estimate ET consumption patterns for the selected basins/sub-basins.
3. To estimate land and water productivity for the selected basins/sub-basins.
4. To develop Resource Base (Surface water & Groundwater) for the selected basins/sub-basins.
5. To develop capacity on WA+ to the State Govt. officials from WRD, Nagaland through training programmes

5. Scope of the Study

The scope of this study is as follows:

a. To estimate ET consumption patterns and beneficial and non-beneficial water consumptions.
b. To develop accounts for agricultural services (i.e., land productivity and water productivity).
c. To collect hydrological and meteorological data.
d. To collect data on topography, soils, river networks, drainage networks and land-use & land-cover.
e. To validate, analyze and process the data collected and give necessary inputs.
f. To develop water accounts for the study basins/sub-basins.
g. To prepare the detailed WA+ report for study basins/sub-basins.
h. To impart training on WA+ to the state officials of Water Resources, Agricultural and other related Depts.

6. Study Area and Input Data

The state of Nagaland is a north eastern state of India and is surrounded by the states of Assam, Manipur, Arunachal Pradesh and also by Myanmar in the East. The state covers a geographical area of approximately 16580 km^2. The major part of the State is drained by the Brahmaputra basin (~10881 km^2, 65.6%) followed by Barak basin (~814 km^2, 4.9%) and by Irrawady-Chindwin basin (~4884 km^2, 29.5%). The state of Nagaland is divided into three river basins viz, rivers flowing to Brahmaputra, rivers flowing to Barak and the rivers flowing to the Irrawady-Chindwin basin.

Input Data:

The WA+ framework focuses on the use of open source and remote sensing satellite datasets in an effort to maintain a high level of transparency and applicability in ungauged basins. Remote sensing is a reliable and objective source of data. Data products from the National Aeronautics and Space Administration (NASA), European Space Agency (ESA) and many other agencies are provided free of charge for all users regardless of nationality or intended application. Following datasets will be used for WA+ analysis in this study.

- Precipitation: Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)/ Tropical Rainfall Measuring Mission (TRMM)
  [now available as Global Precipitation Measurement (GPM)]
- Evapotranspiration (MODIS/ ETensV1.0/GLDAS)
- Meteorological data (GLDAS-Noah)
- GMIA (Global Map of Irrigated Areas)
- IWMI LULC map
- GlobCover LC v2
- MIRCA (Monthly Irrigated and Rainfed Crop Areas) dataset
- Leaf area index (LAI) and NDVI
- Net primary production (NPP) and gross primary production (GPP) (MODIS)
- Soil moisture (EUMETSAT-ASCAT: Advanced SCATterometer (ASCAT)/GLDAS
- GRACE (Gravity Recovery and Climate Experiment) dataset
- Crop types and crop calendar
- Basin DEM, boundary, drainage network map, etc.

The resolution of the above datasets varies from 250 m (MODIS) to 300 km (GRACE). However, all the dataset will be re-sampled to 250 m x 250 m resolution to develop water accounts of the study sub-basins/basins.

7. Project Budget

Head	**Amount (in Lakh)**		
	1st Year	2nd Year	Total
1: Manpower: JRF@31,000/ + HRA and others	-	-	-
2: Work Station-high configuration	3.50	-	3.50
3: Others (Hiring of services, field visits, consumables, stationary, printing of reports & brochures, and sample analysis, etc.)	1.00	1.00	2.00
4: Travel Expenditure	1.50	1.50	3.00
5: Contingency	0.25	0.25	0.50
Grand Total			**9.00**
	Rs. Nine Lakhs only		

8. Expected Deliverables

- Water Consumption Patterns and beneficial non-beneficial consumptions.
- Land Productivity and Water Productivity.
- Basin/sub-basin wise Water Accounts: Supply-Demand and Consumptions and Water Availability
- WALU map, soil maps and river networks.
- WA+ Report and Recommendations of best practices suitable for the catchments
- Trainings on WA+ to the officers from Meghalaya WRD and other Implementing Agencies of the NHP.

9. Expected Timeline against the Deliverables

Project Year	**Apr. 2021-Mar. 2022**				**Apr. 2022-Mar. 2023**			
Project Quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
a. Data downloading and processing, and generation of data bases and maps; data collection from CWC, and state govt. departments	↔	↔						
b. Data analysis in WA+ Framework		↔	↔					
c. Water Consumption Patterns and beneficial non-beneficial consumptions			↔	↔				

d.	Accounts of Land Productivity and Water Productivity				↔	↔			
e.	Catchment wise Water Accounts: Supply-Demand and Consumptions and Water Availability					↔	↔	↔	
f.	WA+ Report and Recommendations of best practices suitable for the catchments							↔	↔
g.	Training modules on WA+							↔	↔

10. Progress till date

Major Outputs:

Generation of WA+ land use; Sheet-2 (Evapotranspiration), Sheet-3 (Agricultural Services including Water and Land Productivity), Sheet-4 (Utilized Flow for Natural and Man-made resources), Sheet-5 (Sub-basin-wise surface water status); Sheet-6 (Groundwater); Sheet-1 (Resource Base – Basin water balance).

Sl. No.	Deliverables	Time/Period (As per Contract)	Date of submission as per the Contract (project start 01-06-2021)
1.	Data downloading and processing, and generation of data bases and maps; data collection from CWC, and state govt. departments	Jun-Nov, 2021	Completed
2.	Setting-up of WA+ Framework; Generation of WALU	Sep, 2021-Feb, 2022	Completed
3.	Water Consumption Patterns and beneficial non-beneficial consumptions	Dec-May, 2022	Completed
4.	Accounts of Land Productivity and Water Productivity	Mar-Aug, 2022	Completed
5.	Catchment wise Water Accounts: Supply-Demand and Consumptions and Water Availability	Jun, 2022-Feb, 2023	Relevant Sheets, as stated above, are already generated;
6.	WA+ Report and Recommendations of best practices suitable for the catchments	Dec, 2022-May, 2023	Under progress. The final draft report will be submitted on or before March 31, 2024.
7.	Training modules on WA+	Dec, 2022-May, 2023	A training programme was already conducted during 28 Nov.-02 Dec., 2022 at Kohima, Nagaland. A concluding workshop/ training will be organized after submission of Final Draft Report.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2022-25/05

1. Title of the Project

Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka

2. Project Team

Dr. P. K. Singh, Scientist 'E'
Dr. Vishal Singh, Scientist 'D', C4S
Er. Harsh Upadhyay, Scientist 'B'
Er. Abhilash R., Scientist 'C', HRRC, Belagavi

3. Project Duration: 03 Years (04/22 – 03/25)

4. Objectives of the Study

The major objective of this study are as follows:

1. To collect, prepare and evaluate various thematic datasets such as DEM, land use/Land cover (LULC) map, soil map, and hydro-meteorological data-sets such as precipitation, temperature, discharge (if available) etc.
2. To analyze long-term hydro-meteorological variables such as precipitation, evapotranspiration, and water consumption patterns in the basin and assessment of their possible impacts on water management in the basins.
3. To estimate water potential of the west-flowing rivers, i.e., Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins using hydrological models and Frameworks.
4. To assess the effects of climate and landuse changes on the water yield using Budyko conceptual framework.
5. To analyze the hydrological sensitivity and resilience capacity of the basins under adverse climatic impacts.
6. To impart training on the hydrological models to the state officials of the water resources department including IAs of NHP.
7. To prepare the detailed sub-basin wise project report for the state water resources department for planning purposes.

5. Study Area

Figure 1 shows the map of the west flowing rivers in the state of the Karnataka. As discussed above, this study is aimed to assess the water potential yields and other hydro-meteorological analysis of the six sub-basins, e.g., Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins.

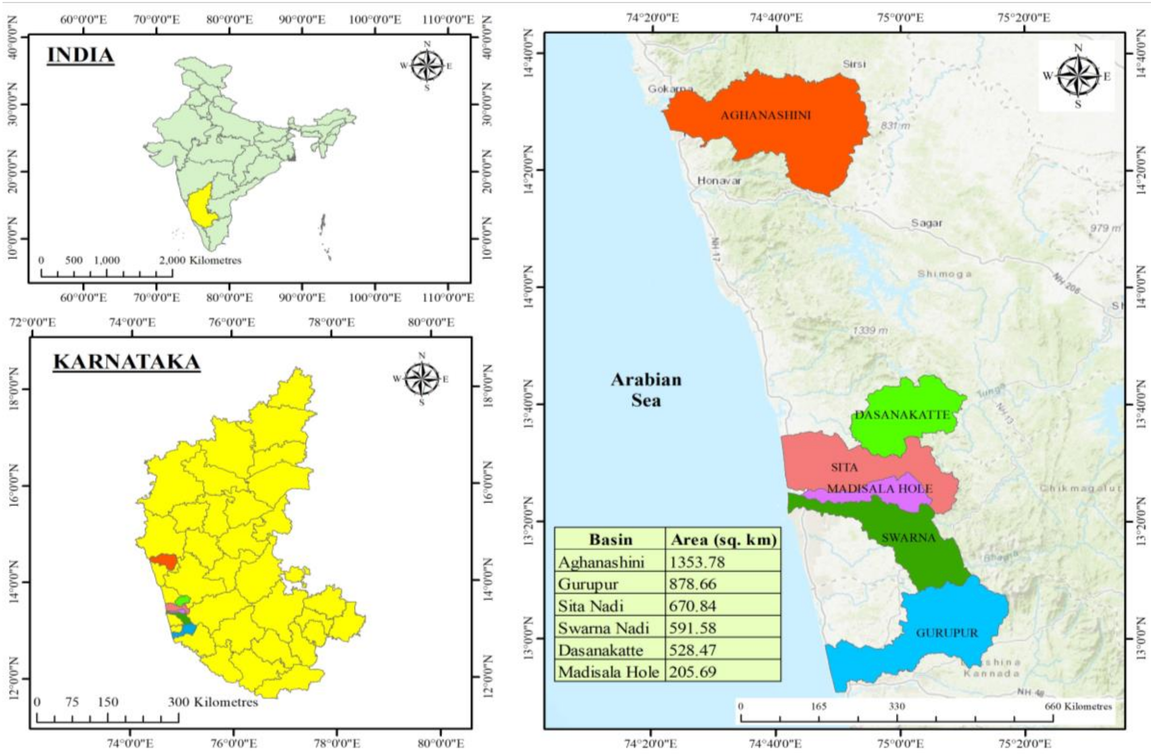

Figure 1: West-flowing Rivers in Karnataka

6. Input Data

Looking into the un-availability of the measured/monitored hydro-meteorological datasets in these basins, it is planned to utilize the earth observation and satellite datasets for calibration and validation purposes and yield estimation in this study. Following datasets (not limited to) will be used in this study:

SI. No.	Data-sets/Name	Availability/Source/Resolution	Time-Period
1	DEM	SRTM/CARTOSAT – 30 m/ALOS-PALSAR 12.5 m.	
2	Daily Rainfall and Temperature Gridded (Observed)	IMDAA –12 km^2	1979-2022
3	Daily Rainfall Gridded (Satellite based-open sources)	CHIRPS – 5 km^2; TRMM+GPM -25 km^2, IMDAA, APHRDITE, SM2RAIN.	1991-2022
4	Other Hydro-Meteorological Datasets	NOAA/NASA/ ESA/ISRO	1991-2022
5	Population Data and population growth Data	As per census	2011 and older
6	LULC maps	Glob cover, NRSC, IWMI, ESRI	For different time periods
7	Soil Maps	FAO, USGS, Water Base, Future Water Group Netherlands	As per availability

A detailed information about the data sources and their resolution can be had from their respective sources.

7. Methodology

The modelling tools/framework such as SWAT, HEC-HMS, WA+ and Budyko based approach will be applied for quantifying the water yield potential of these basins. The study will also assess the effects of climate and landuse changes on the water yield. Along with this, the hydrological sensitivity and resilience capacity of these basins will also be assessed using the Budyko framework. For climate change analysis CMIP5/CMIP6 projections will be used in this study. For LULC change and impact assessment, decadal and projected LULC maps will be prepared and analyzed accordingly. For future projection of LULC change Markov chain based approach will be applied in this study. Figure 2 shows the flow chart of the methodology.

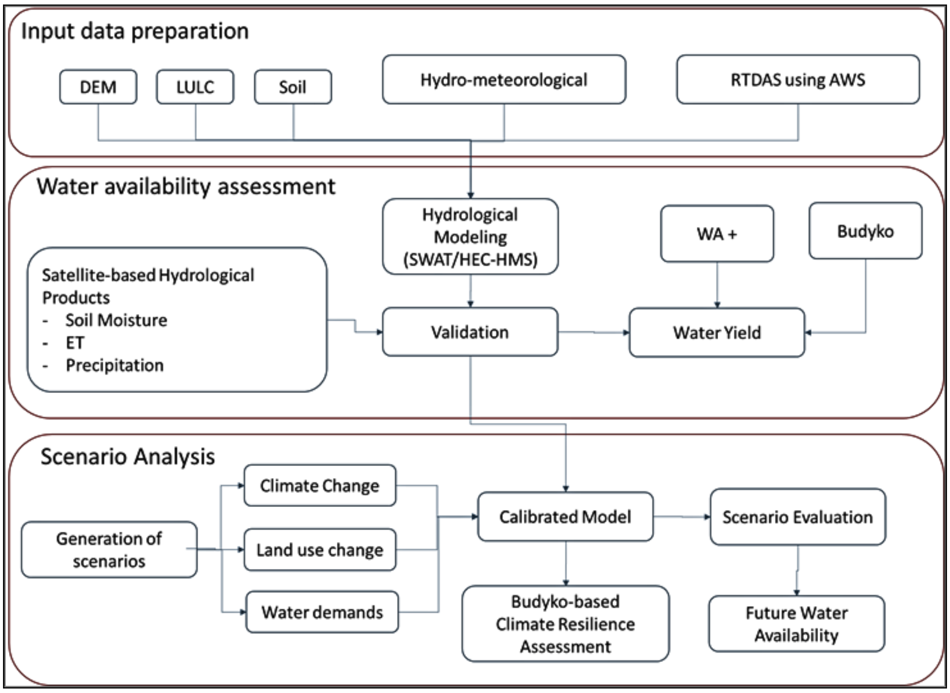

Figure 2: Modelling Steps

8. Project Budget: Year-wise breakup of the budget

Sl. No.	**Head**	**Amount (in Lakh)**			
1	**Manpower (Salaries/ wages of project staff)**	**1st Year**	**2nd Year**	**3rd Year**	**Total**
	JRF (02 nos.) as per DST Norms	8.50	8.50	8.50	25.50
2	Travel Expenditure	2.00	2.00	2.00	06.00
3	Meetings/Workshop	1.50	1.50	1.50	04.50
4	Others (Hiring of services, field works, consumables, stationary, printing of reports & brochures, and sample analysis, etc.)	3.00	5.00	5.00	13.00
5	Contingency	2.00	2.00	1.00	5.00
	GRAND TOTAL	**17.00**	**19.00**	**18.00**	**54.00**

9. Expected Deliverables

- Thematic maps: DEM, soil and LULC, stream network maps
- Improved and bias free high resolution gridded precipitation and ET datasets
- Basin wise water availability estimates: Historical (BAU)
- Revised basin-wise water availability estimates: CC with no LU change
- Revised basin-wise water availability estimates: LU change with no CC
- Revised basin-wise water availability estimates: both CC and LU change
- Resilience and Non-resilience basins under changing climates
- Sub-basin wise project report for the state water resources department for planning
- Training on the modelling frameworks to the state officials of the water resources department and other Implementing Agencies of the NHP.

10. Advantages, Challenges and Limitations

- The proposed modelling frameworks/tools will be very useful for estimating the water yield potential for ungauged basins using satellite and open data sources including the datasets obtained from the field.
- All satellite data products have some level of uncertainty and error which will be effectively taken care of in this study for generating error free and bias corrected datasets for future use.
- The hydrological resilience analysis will be an effective criterion to understand the historical as well as future changes in the basin to ensure the sustainability of the water resources.
- The main challenge of this study is that the study basins are ungauged hence the dependability on the satellite datasets will be on the larger side. Therefore, the alternative hydrological calibration strategies can be accounted utilizing the relevant hydrological variables such as ET and soil moisture which can be measured/estimated in the absence of the observed discharge datasets.

11. Expected Outcome (Quantifiable Deliverables) of Key Activities with Timeline (Tentative):

Sl. No.	Expected Outcomes/Quantifiable Deliverables	1st Year				2nd Year				3rd year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1:	Hiring Manpower												
	Data downloading and processing, and generation of data bases and maps; data collection from CWC, and state govt. departments												
4:	Analyse long-term hydro-meteorological variables												
5:	Hydrological Modelling: SWAT model Setup												
6:	Hydrological Modelling: HEC-HMS model Setup												
7:	WA+ and Budyko Frameworks:												
8:	Model's validation using satellite and observed (if available) datasets												
9:	Water potential of the west-flowing rivers												
10:	Hydrological sensitivity and resilience capacity												
11:	Training on the hydrological models												
12:	Detailed basin wise project report for the state water resources department and Regional Conference with NHP												

12. Progress till date:

- The spatio-temporal variability of the six rainfall products, i.e., APHRODITE, IMDAA, TRMM, CHIRPS, SM2RAIN, PRINCETON for all the six study basins have been done. The MK test and ITA have been also done for all the six study basins. Along with this we also assessed the spatio-temporal variability of the evapotranspiration, soil moisture and gross primary production in the study basins.
- Satellite-derived and open sources soil moisture and evapotranspiration datasets have been used for the simulation and calibration of water yield at sub-basin scale for an ungauged river basin by employing the Soil and Water Assessment Tool (SWAT). The satellite soil moisture and evapotranspiration datasets were bias corrected before application. This has resulted into the water yield potential assessment of all the six ungauged basins of the Western Ghats Karnataka.
- As an example, for a long-tern average annual rainfall of 3606.24 mm of the rainfall, the long-term average annual water yield potential of the Aghanashini basin due to satellite AET is found to be 2599.23 mm and 2615.23 mm, respectively due to satellite AET and soil moisture datasets. The observed (extrapolated) water yield potential of the Aghanashini basin was 2834.79 mm. Similar estimates have been done for all the remaining five sub-basins.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2022-25/06

1. Title of the Project

Spatio-temporal Water Availability under Changing Climate and Land-use Scenarios in Wainganga River Basin

2. Project Team

Dr. M. K. Nema, Scientist 'E'
Dr. P. K. Mishra, Scientist 'D'

3. Project Duration: 03 Years (04/22 – 03/25)

4. Objectives of the Study

Wide-scale interventions and other water-related activities have occurred in the Wainganga River Basin (WRB), which sustains the northern industrial region of Nagpur and large expanses of highly irrigated rice-growing districts. The water demands of the basins have steadily increased over time, and among the diverse nature of the purposes driving such a continually growing demand for drinking water, an increased reliance on irrigated agriculture, as well as numerous developmental projects such as thermal power plants, are expected to intensify competition for the limited water resources. As a result, the study's goal is to examine the basin's water resources availability and, more importantly, to estimate the influence of current and future changes in climate and landuse on the Wainganga river basin's water balance. The specific objectives of the study are as follows:

a. To study the historical climate change, morphological properties and land use/land cover change pattern over the Wainganga river basin
b. To calibrate and validate a hydrological model at different spatial scales for the river basin using current land use and observed climatic conditions
c. To develop future expected land-use change and climate change scenarios (CMIP6) for the base period and compare them with the observed period
d. To model spatial and temporal future water availability using climate and land-use change scenarios
e. To quantify the uncertainty in modeling analysis arising from model parameters and input conditions
f. To prepare adaptation/management strategies under changing climate and land-use scenarios

5. Present state-of-art

Presently, the total water availability of the Wainganga basin is 9225 MCM (325.89 TMC). The various sectoral demands such as domestic, industrial and agricultural for the basins water resources have grown steadily over the years, leading to an intensification of competition and conflicts for the limited water resources. Therefore, the study aims to assess the basin's water resources availability and, further, to evaluate the impact of existing and other prospective water resources developmental initiatives on the overall water balance of WRB. It is an interstate river, and the water is being shared based on the Water Dispute Tribunal Award for the Godavari Basin (Eastern Godavari Basin (EGB)). The majority of the inhabitants in this basin depend on farming, fisheries, and forest-dependent livelihood activities. The WRB fall under the parts of the Eastern Vidarbha region of Maharashtra has been in the news for many farmer suicides for more than a decade due to crop failures and increasing debts. While most districts in Vidarbha are known for cotton and soybean cultivation, eastern-Vidarbha, through which Wainganga flows, is historically known for its paddy cultivation. Bhandara and Gondia districts are known as the 'rice bowls' of Maharashtra. The rice and sugarcane production in the region was supported by the Maji-Malguzari (MM) tanks, which needs to be rejuvenated. The MM tank system, albeit feudal, was a well-designed decentralized system for irrigation and could have served as a hallmark of development in eastern Vidarbha.

6. Methodology

Study Basin:

The Wainganga rises in the Seoni District of Madhya Pradesh at an elevation of 640 m above M.S.L. Wainganga basin extends over approximately 50,000 square kilometers up to the Ashti gauging site, which spreads across the States of Madhya Pradesh and Maharashtra. The total length of this river is ~638 km up to the Ashti gauging site just before the confluence with the Wardha River. In the beginning, it flows eastward for a distance of about 175 km and then Southward for a length of about 100 km in Seoni and Balaghat District of Madhya Pradesh. It also serves as a border between Madhya Pradesh and Maharashtra state for 32km. Before joining the Godavari, it flows about 479 km in the Bhandara, Chandrapur, and Gadchiroli District of Maharashtra. The Wainganga basin lies in the medium rainfall zone, situated between 900 mm and 1600 mm. Most of the rainfall is received during the southwest monsoon from June to October. In the winter, the minimum temperature varies from 7^0 C to 13^0 C. Maximum temperature ranges from 39^0 C to 47^0 C. Month of May is the hottest month, and December is the coldest month.

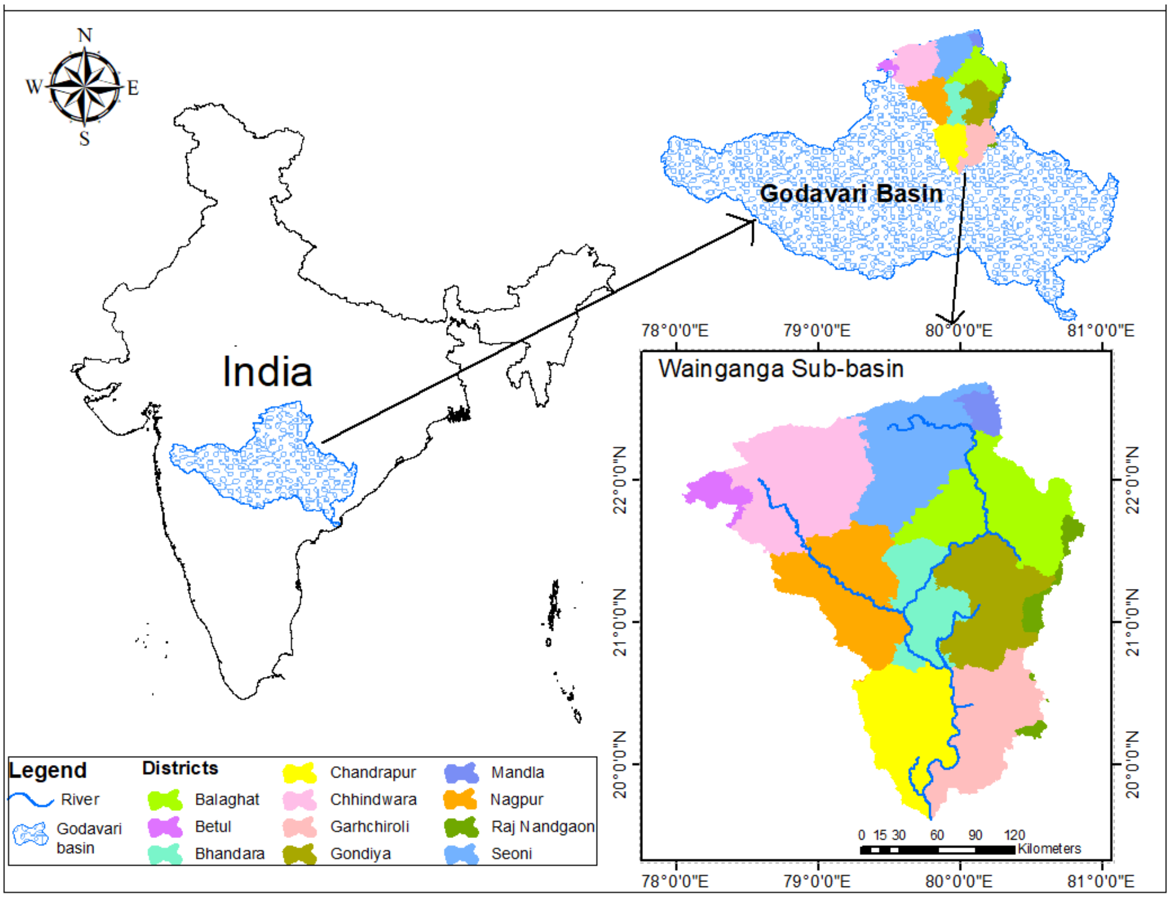

Fig. 1 Location Map of Wainganga River sub-basin of Godavari Basin in India

Research Approach:

A few activities/tasks have been defined to accomplish the study's research objectives, including collecting the data sets, field visits, surveys, analysis of collected data, model setup, scenario-based analysis, assessment of water availability, etc. The task-wise methodology proposed for analyzing the impact of climate change on the hydrology of Wainganga Basin is described below:

Task 1: Data collection, pre-processing and development of digital database including DEM, LULC, SOIL, Climatic time series, etc.

Task 2: Analysis of Trends for the climatic and hydrological extremes

Task 3: Modeling of surface hydrology and assessment of climate change impacts. In the proposal work, a semi-distributed model with proven capabilities, namely the Soil and Water Assessment Tool (SWAT) model, will be used to estimate streamflow in the basin.

Task 4: Water resources availability under changing climate & landuse scenario using the FDC based analysis. Uncertainty analysis shall be performed for the water availability assessments made using these scenarios

Task 5*:* Preparation of adaptation/management strategies /plans

7. Research Outcome from the Project

- Assessment of the spatial-temporal water availability under the different climatic and land-use scenarios.
- Future Land-use scenarios for the study region.
- Climate change adaptation plan for the Wainganga river Basin

8. Cost Estimates

The total cost of the project: **₹ 9.72 Lakh**

a. Source of funding: NIH

b. Sub-head wise abstract of the cost:

S.N.	Sub-head	Amount (₹)		
		Year - I	Year - II	Total
1	Salary (Part-Time Field Staff)	156000	156000	312000
2	Travelling expenditure	150000	150000	300000
3	Data /Infrastructure/Equipment	50000	50000	100000
4	Workshop/ Meeting / Experimental Charges	20000	200000	220000
5	Misc. expenditure	20000	20000	40000
	Sub- Total:	396000	576000	
	Grand Total:			**972000**

9. Work Schedule

SN	Description of Activity	2022-23				2023-24				2024-25			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Data Collection, pre-processing and development of digital database	■	■	■									
2	Analysis of trends for the climatic and hydrological extremes	■	■	■	■								
3	Landuse modeling and predictions for the future periods			■	■	■							
4	Modeling of Surface Hydrology and Assessment of Climate Change Impacts			■	■	■	■						
5	Water Resources availability under changing climate & landuse scenario			■	■	■	■						
6	Uncertainty Analysis					■	■	■	■	■	■	■	■
7	Adaptation/management Strategies /Plans					■	■	■	■	■	■	■	■
8	Stakeholder's Workshop										■		
9	Report Writing					■				■			■

10. Progress till date

The first task of the study has been completed in terms of the collection of basic data, their pre-processing and the development of digital databases including DEM, LULC, SOIL, etc. The CMIP6 Data for the Wainganga basin has been downloaded and climatic series generation. Extreme event analysis is yet to be done for climate data. For task three pertaining to land use land cover modeling, all the required biophysical drivers of change have been prepared. The data relating to socio-economic drivers of change are being collected and prepared, and then the model has to be setup. The various input datasets of SWAT have been prepared and the initial model run has been completed, now the model needs to be calibrated and validated for understanding the hydrological response of the basin under the changing climatic and land use conditions.

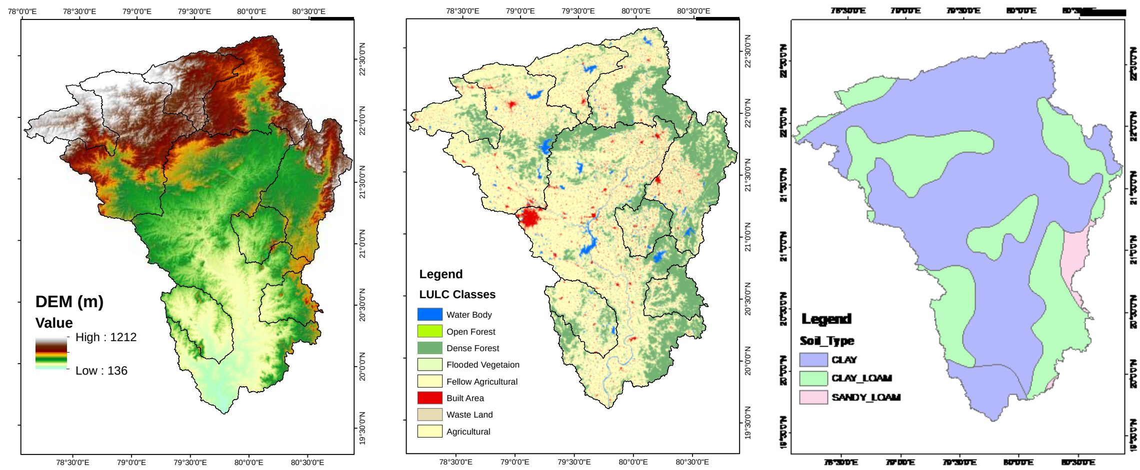

Fig. 2 Spatial Inputs of SWAT model for the Wainganga River

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2022-24/07

1. Title of the Project

Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics

2. Project Team

Dr. Archana Sarkar, Scientist 'F'
Dr. Jyoti Patil, Scientist 'D', NIH New Delhi
Mrs. Charu Pandey, A.L.I.O.

3. Project Duration: 02 Years (05/22 – 04/24)

4. Objective of the Study

- To study and analyze the growth and direction of research in the field of climate change impacts on hydrology and water resources in India during 1992-2021
- Identification of gap areas and emerging areas in the research on climate change impact on hydrology and water resources to address the water security issues in India
- Evaluation of research productivity of institutions engaged in research on climate change impact on hydrology and water resources in India through scientometrics
- Dissemination of study findings through workshop/training course, scientific documentation and other outreach means.

5. Background

Scientometrics is considered a powerful tool of tracing the development of a given scientific field, thereby revealing the gap areas and emerging research problems, and evaluation of scientific contributions and research productivity of research community, institutions, regions, countries, etc. As technological advancements occur, there is a paradigm shift in the working trends in any field. So it is recommended to look for emerging trends and propose new developments when the current trends of any research domain are studied. Bibilometric analysis and scientometric mapping can show the change in mindset of researchers by studying the research works over a time period. Also by identifying the research questions in the water sector today, one can have insight into the future of research in the field. As Boyack et al. (2005) stated that a correctly constructed science map help to understand the inputs, associations, flows and output of science and technology: "Just like in physical world, maps help us to understand our environment- where we are, what is around us and the relationships between neighbouring things". In recent years, scientometrics has come to play a major role in the measurement and evaluation of research performance.

Potential climate change and its unfavourable impacts on hydrologic systems pose a threat to water resources throughout the world. As per the latest report of IPCC (AR6) released in August 2021, it is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. The scale of recent changes across the climate system as a whole and the present state of many aspects of the climate system are unprecedented over many centuries to many thousands of years. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5. Many changes in the climate system become larger in direct relation to increasing global warming. They include increases in the frequency and intensity of hot extremes, marine heatwaves, and heavy precipitation, agricultural and ecological droughts in some regions, and proportion of intense tropical cyclones, as well as reductions in Arctic sea ice, snow cover and permafrost.

The effect of climate change on hydrology in tropical Asia has many facets. The Himalayas, which act as a mountain barrier on the earth, where polar, tropical and Mediterranean influences interact, play an important role in maintaining and controlling the monsoon system over the Asian continent. In the Himalayas, the storage of precipitation in the form of snow and ice (in glaciers) over a long period provides a large water reservoir that regulates annual water distribution. As a populous, tropical developing country, India faces a bigger challenge in coping with the consequences of Climate Change than most other countries. It is now clear that enhanced climate variability and climate change due to continued emission of greenhouse gases in the Earth's atmosphere will alter the key characteristics of summer monsoon rainfall and could significantly impact water supply and demand throughout the Indian subcontinent. Continued global warming is projected to further intensify the global water cycle, including its variability, and the severity of wet and dry events. Natural drivers and internal variability will modulate human-caused changes, especially at regional scales and in the near term, with little effect on centennial global warming. These modulations are important to consider in planning for the full range of possible changes. There is a strong need to reconnect climate science and policy development with the local context to generate relevant knowledge supporting future climate change adaptation and disaster risk reduction strategies on a local to national to international level. The ability to undertake policy action requires information, knowledge, tools, and skills.

6. Statement of the Problem

Many researchers/academicians/policy makers in India have studied and published various aspects of climate change impact on hydrology vis-à-vis water resources and policy implications. However, such studies have been carried out in isolation focusing on specific region/river basin and specific aspect of climate change impact (floods/droughts/water availability/etc). As such, a scientometric analysis of research on climate change impact on hydrology and water resources by Indian scientists has not yet been carried out. The proposed study is expected to highlight the gap areas, emerging trends, and potential opportunities in taking forward the research on climate change impact on hydrology and water resources, which is gaining momentum in view of the looming water scarcity. The study will provide an insight into the dynamics of research on climate change impact on hydrology and water resources and also provide a roadmap to the policy planners in India to address the Sustainable Development Goals (SDG).

7. Approved Action Plan and Timeline

S. No.	Work Element	Ist Year				IIndYear	
		Q1	Q2	Q3	Q4	Q1	Q2
1	Identification of computational tools						
2	Identification of search strings relevant to research on climate change impact on hydrology and water resources in India						
3	Data collection from various sources						
4	Bibliometric analysis using bibliographic databases						
5	Manual analysis by searching and analyzing data from websites						
6	Scientometric mapping						
7	Interpretation of bibliometric analysis						
8	Preparation of research publications, outreach material, and synthesis report						

8. Progress

Objectives	Achievements
May 2022- Jan 2023	
Identification of computational tools	Completed
Identification of search strings relevant to research on climate change impact on hydrology and water resources in India	Finalized
Data collection from various sources	completed
Bibliometric analysis using bibliographic databases	In progress
Manual analysis by searching and analyzing data from websites	In progress
Scientometric mapping	In progress

9. Analysis and Results

The Scopus cited research database (1992-2021) by Indian authors in for the 'Hydrology' and 'Climate Change' keywords was collected from Library of Indian Institute of Technology (IIT), Roorkee. The 31 years Scopus database includes research papers, book chapters, conference papers, review articles, books, editorials, short surveys, and conference proceedings. The collected data were processed and analyzed in R-biblioshiny package to extract the preliminary results related to hydrology- climate change research in India.

The main information of the collected data includes the author's contribution to the research articles (single authored, multi- authored, authors per document, Co-authors per documents etc.). The average citations per documents and collaboration index of the research was also highlighted in the main information. The results of analysis of Hydrology-Climate Change (CC) database includes most cited documents, most relevant documents, word cloud and thematic evolution. The Word Cloud result showed that research in the hydrology along with climate change are mainly focused on climate models, water supply, hydrological modelling, water resources, environmental monitoring, rainfall, runoff, rivers, evapotranspiration and hydrological response etc. The thematic evolution observed in the research database from 1992 to 2021 shows that in the recent database, the research is not limited to studying the parameters or impact of climate change on hydrology, monsoon patterns and groundwater but impact on humans and environment were evolved in research. Another important finding is about the most relevant sources of research information as shown in the figure below. Other graphs, tables and word cloud figures would be presented during the working group.

Further, biblometric database has been searched and prepared using more number of keywords, i.e., including various sub-themes of Hydrology like rainfall-runoff, glacier change, water quality and climate change etc. The analysis of different databases is under progress.

10. Deliverables

Research papers, synthesis report, policy brief

11. End users/Beneficiaries of the Study

Research Organizations, Academic Institutes, Central and State Government Agencies, Policy Makers, NGOs.

12. Future Plan

As per the approved/proposed action plan.

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-27/01

1. Title of the Project

Simulation of operation of multiple reservoirs in Wainganga Basin for conservation and flood control under changing climate scenario

2. Project Team

Dr. A. R. Senthil Kumar, Scientist ‘G’
Dr. T. Thomas, Scientist ‘F’, CIHRC, Bhopal
Dr. M. K. Nema, Scientist ‘E’
Er. Harsh Upadhyay, Scientist ‘B’
Dr. Sunil Gurrapu, Scientist ‘D’, C4S

3. Project Duration: 3 Years (04/24 – 03/27)

4. Statement of the Problem

Many major and medium reservoirs have been constructed in India for spatial and temporal distribution of water during the lean season considering the population and livestock details, sediment load, streamflow and irrigation potential at the time of planning of these structures. Over the years, the performance of the reservoirs in meeting the demand has been reduced mainly due to the changes in the inflow pattern in the reservoirs owing to the large scale water resources based developmental activities in the catchment and high spatial and temporal variability of rainfall. Further, population and industrial growth has led to enhanced water demands. The ingress of sediment inflow resulting from the unprecedented anthropogenic activities in the catchment has also led to the reduction in the capacity of these reservoirs. A survey of reservoirs in India shows that the sediment inflow to the reservoirs is 200 percent more than the sediment inflow assumed during the design of these structures (Tejwani, 1984). Climate change adds a new dimension to the optimal operation of the reservoirs, as both extreme rainfall and dry spells poses challenges for conservation operation as well as operation of reservoirs for flood control. So it is important to evolve an operational framework for the reservoirs in a basin to protect the riparian rights of the stakeholders considering present and future streamflow and sediment load and projected future water demands. Simulation of the integrated operation of reservoirs under present and future scenarios of input variables will help in the development of an operational framework to meet the ever-growing demands for conservation purposes and flood control. In this study, the integrated operational framework for reservoirs would be developed for the Wainganga basin using a water availability and sediment yield model, climate scenarios of CMIP6 Global Climate Models and simulation model for reservoir operation.

5. Objectives of the Study

i. Modelling of inflow and sediment yield to the selected reservoirs using the SWAT model
ii. Simulation of streamflow and sediment yield for future climate scenarios using CMIP6 climate models
iii. Estimation of present and future water demands for irrigation and drinking water supply
iv. Revision of elevation-area-capacity curves based on the projected sediment yield
v. Development of integrated operational framework (Rule Curves) for the selected reservoirs for present and future scenarios

6. Study Area

The study area is the catchment of the Wainganga basin up to Ashti. Wainganga basin is a sub-basin of the Godavari River basin which is located between 78°00′ to 81°00′ East longitudes and 19°60′ to 22°07′ North latitudes, as shown in the following figure. The total catchment area of the basin is 51,421 km^2 with an elevation ranging from 144 to 1208 m above mean sea level. The basin is bounded in the North by Central India hills, in the South and East by the Eastern Ghats and in the West by Maikala hill range. The Chiroli Hills form the watershed divides the Wainganga basin from the Narmada basin. It is a typical basin considered from geographical and geological point of view covering major parts of the States of Maharashtra (27,350 km^2), Madhya Pradesh (23,109 km2) and small portions of Chhattisgarh (962 km^2). The river in its initial reaches flows westwards and thereafter turns southwards in Madhya Pradesh and continues to flow southwards through the Maharashtra State. The climate of the basin is characterised with summer season from March to May, monsoon season from June to September and some rains in post-monsoon season too. The mean daily maximum temperature varies from 26–30°C in July to 32–33°C in October. The minimum temperatures are observed in January in the range of 10–15°C during the winter season. The basin upto Ashti consists of five medium and small reservoirs, Sanjay Sagar Reservoir located in Madhya Pradesh, Gosekhurd, Itiadoh and Sirpur reservoirs in Maharashtra and Totladoh Reservoir located on the border of Maharashtra and Madhya Pradesh. These reservoirs will be considered for the simulation of integrated operation of reservoirs for the present and future scenarios of input variables. The location of the reservoirs is given in the following figure.

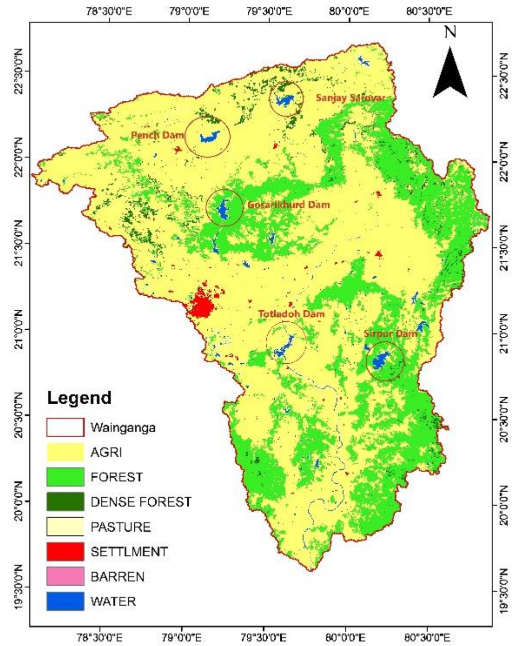

Fig. The Wainganga Basin and its Major Reservoirs

7. Methodology

The inflow and sediment yield to the reservoirs would be modelled using the SWAT model with the input of landuse and soil map, and other hydro-meteorological data such as rainfall, maximum and minimum temperature, relative humidity and sunshine hours and sediment yield. The parameters of the SWAT model would be optimized using SWAT-CUP.

The climate scenarios of rainfall, maximum and minimum temperature for SSP2-4.5 and SSP5-8.5 of CMIP6 models would be used to simulate future inflow and sediment yield to the reservoirs using SWAT with optimized parameters.

The future Gross Irrigation Requirement (GIR) shall be estimated using Reference Evapotranspiration (ETo) by Penman-Monteith equation for projected temperature for climate scenarios of SSP2-4.5 and SSP5-8.5 of CMIP6 models, crop coefficient (Kc) from FAO, projected effective rainfall by SCS Method for climate scenarios of SSP2-4.5 and SSP5-8.5 of CMIP6 models (CROPWAT 8.0) and irrigation efficiency. The projected human (based on the 2011 census) and livestock (based on the 2012 census) population will be used to estimate the future demand for domestic needs by taking the per capita water demands for rural, urban and livestock populations as 70 lpcd (liter per capita per day), 135 lpcd and 50 lpcd respectively. The industrial demands will be estimated based on the future plans of industrial development in the study area and the water demands that may be allocated from the projects.

The development of an integrated operational framework for the reservoirs would be developed using NIH_ReSyP considering the present and projected inflow and revised elevation-area-capacity curves based on projected sediment yield, and future water demands for irrigation, drinking and industrial purposes. The simulation module of NIH_ReSyP would be used to derive the reliability of releases from reservoirs on and integrated basis considering the operational framework for present and projected scenarios.

8. Data Requirements

Daily data of rainfall, minimum and maximum temperature, wind speed, relative humidity, sunshine hours, discharge and sediment yield to the reservoirs, satellite data, Survey of India toposheets, NBSS&LUP and FAO for preparation of soil and landuse, existing cropping pattern, command area details, crop coefficient and other crop information, population and livestock data

9. Action Plan and Timeline

S. No	Work Element	First Year				Second Year				Third year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Collection of information and meteorological data (rainfall, Tmin, Tmax, RH(%), Sunshine hour), preparation of landuse and soil maps												
2	Collection of inflow and sediment load/yield data to reservoirs, physical features of reservoirs, command area boundary, existing cropping pattern, crop information and crop coefficient, population and livestock data												
3	Calibration and Validation of SWAT Model for modelling of inflow and sediment yield to the reservoirs												
4	Estimation of future demands for irrigation, drinking water and industrial use												
5	**Preparation of the First Interim Report**												
6	Simulation of inflow and sediment to reservoirs using climate scenarios – SSP2-4.5 and SSP5-8.5 of CMIP6 models												
7	Development of operational framework (rule curves) for the reservoirs based on present and future scenarios using NIH_ReSyP												
8	**Preparation of Second Interim report**												
9	Simulation of integrated operation of reservoirs to derive the reliability of the releases based on present and future scenarios using NIH_ReSyP												
10	**Preparation of Final report**												

10. Deliverables:

An operational framework for the integration operation of these reservoirs for both conservation purposes and flood control dall be developed. The study will also result in research papers publication and report.

11. End users/beneficiaries of the study

Water Resources Department and Agriculture Department of Maharashtra and Madhya Pradesh.

12. Cost Estimate

a. Total cost of the project: Rs. 21.02 lacs
b. Source of funding: NIH
c. Sub Head wise cost

Sl. No.	Sub-head	Amount (in Rupees)
1.	Salary for 1 JRF for three years	14,52,000
2.	Travelling expenditure	5,00,000
3.	Purchase of data	1,00,000
4.	Misc. expenditure	50,000
	Grand Total:	21,02,000

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

Salary: One full-time personnel (Junior Resource Fellow) for the project will be required for assistance in the field data collection, data processing and technical analysis.

Travel: Travels would be essential for data collection and interaction with project authorities.

Data: Rainfall and hydrological information will be obtained/procured from the agencies that are operating in the area. Also, the required data will be procured/purchased from IMD, CWC, NRSC and other State Govt. agencies.

13. References

1. Tejwani, K.G. (1984). “Reservoir sedimentation in India - Causes, Control, and Future course of action.” *Water International*, 9, 150-154.
2. Taxak, A. K., A. R. Murumkar and D S Arya. (2014). “Long-term spatial and temporal rainfall trends and homogeneity analysis in Wainganga basin, Central India.” *Weather and Climate Extremes*, 4, 50-61.

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-26/02

1. Title of the Project

ResSed – Tool development for prediction of elevation-area-capacity curves of the reservoirs

2. Project Team

Dr. A. R. Senthil Kumar, Scientist 'G'
Dr. U. K. Singh, Scientist 'C'
Dr. P. K. Singh, Scientist 'E'
Er. Harsh Upadhyay, Scientist 'B'
Dr. Nitesh Patidar, Scientist 'C', GWHD

3. Project Duration: 2 Years (04/24 – 03/26)

4. Statement of the Problem

Sedimentation in reservoirs is a continuous process that gradually diminishes their capacity and in turn performance to meet demands over time (Morris, G. L. and Fan, J., 1998). Many large reservoirs in India were initially designed based on historical sediment data. However, recent increases in sediment deposition over the designed sediment volume, driven by unforeseen changes in landuse within the catchment area (Tejwani, 1984), threaten to reduce reservoir performance prematurely before the designed life. Currently, there is a lack of comprehensive tools to predict reservoir elevation-area-capacity curves accurately in light of sediment accumulation. The principal investigator (PI) of this study has developed a methodology to forecast elevation-area-capacity of reservoir over future periods (25, 50, 75, and 100 years) by incorporating sediment volume changes from a base year. This methodology has been successfully applied to Bhakra and Pong reservoirs (Bhakra Beas Management Board (BBMB), 2003). The next step involves developing a practical tool using data from these reservoirs to predict elevation-area-capacity (EAC) curves for reservoirs.

5. Objective of the study

Development of tool for the prediction of elevation-area-capacity curves of the reservoirs

6. Study area

Data from the Bhakra and Pong reservoirs will be utilized to develop the tool for predicting elevation-area-capacity curves.

7. Methodology

The tool for predicting elevation-area-capacity curves for future periods (say 25, 50, 75, and 100 years) will be developed using Python and FORTRAN languages. It will comprise the following modules:

i. Modelling of sediment yield from the contributing catchment using ANN.
ii. Generation of time series for runoff and rainfall for future periods using time series modelling
iii. Simulation of sediment yield for future periods using generated series of rainfall and runoff and developed ANN
iv. Estimation of initial and consolidated unit weight of the sediment using particle size distribution of suspended sediment concentration, hydrographic survey, porosity of uniformly distributed sediment, empirical and statistical methods
v. Estimation of consolidated sediment volume for future periods using the consolidated unit weight of the sediment
vi. Distribution of consolidated sediment volume of the future periods in the reservoir to predict the elevation-area-capacity curve of the reservoir.

8. Action Plan and Timeline

S. N.	Work Element	First Year				Second Year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Planning and development of framework for the integration of different modules								
2	Module development for the simulation of sediment yield using ANN								
3	Module development for the generation of time series								
4	Module development for the simulation of sediment yield using the generated time series and developed ANN								
5	**Preparation of first Interim Report**								
6	Module development for the estimation of initial and consolidated unit weight of the sediment using different methods								
7	Module development for the estimation of consolidated sediment volume for future periods using the consolidated unit weight of the sediment								
8	Module development for the distribution of consolidated sediment volume of the future periods to predict the elevation-area-capacity curve of the reservoir								
9	Performance evaluation of the tool using the relevant data of Bhakra and Pong reservoir								
10	**Preparation of manual for the tool development and final report**								

10. Deliverables

Tool and manual for the prediction of elevation-area-capacity curve for the reservoirs.

11. End Users/Beneficiaries of the Study

Engineers and policymakers for planning and operation of the reservoirs

12. Cost Estimate

a. Total cost of the project: Rs. 11.18 lacs
b. Source of funding: NIH
c. Sub head wise cost

Sl. No.	Sub-head	Amount (in Rupees)
1.	Salary for 1 JRF for two years	9,68,000
2.	Travelling expenditure for updating the data	1,00,000
3.	Misc. expenditure	50,000
	Grand Total:	11,18,000

d. Justification for Sub-head-wise abstract of the cost
Salary: Full time one personnel (junior resource fellow) for the project will be required for assistance in the tool development.
Travel: Travels would be essential for updating the relevant data

13. References

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iv. Bhakra Beas Management Board (BBMB) (2003). Sedimentation Studies: Period 2001-03, Sedimentation Survey Report, Bhakra Dam Circle, BBMB, Nangal Township, Punjab, India.

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-27/03

1. Title of the Project

Integrated operation of Bisalpur and Isarda reservoirs in Banas river basin, Rajasthan

2. Project Team

Dr. Archana Sarkar, Scientist 'F'
Dr. A. R. Senthil Kumar, Scientist 'G'
Dr. P. K. Mishra, Scientist 'D'
Er. Harsh Upadhyay, Scientist 'B'
Mr. Sanjay Agarwal, S.E, WRD Rajasthan

3. Project Duration: 3 Years (04/24 – 03/27)

4. Statement of the Problem

The effective management of reservoirs and dams often requires an understanding of the inflows and sediment loads they receive. The sedimentation in reservoirs reduces their storage capacity, affects water quality, and can impede dam operations. Monitoring sediment load is essential for predicting dam lifespan and ensuring water quality. The sedimentation of reservoirs can significantly reduce their lifespan. Therefore, understanding and predicting inflow and sediment load in reservoirs is paramount for sustainable management and effective dam operations. The Bisalpur Dam, located at Banas River in Rajasthan, India, plays a pivotal role in the region's water supply and irrigation. Bisalpur drinking water cum irrigation project was constructed 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. Under Isarda dam project, drinking water will be supplied to six towns and 1,256 villages of Dausa and Sawai Madhopur districts.

The region's semi-arid nature makes the Bisalpur dam vulnerable to sedimentation. Understanding inflow patterns and sedimentation rates for this dam is essential for sustainable reservoir management, ensuring water availability and extending the dam's lifespan. Numerous models have been developed and applied for such purposes. One of the most recognized and utilized models is the Soil and Water Assessment Tool (SWAT). The SWAT has been extensively employed in hydrological studies to predict these variables. The application of SWAT has gained prominence in predicting inflow and sediment load, aiding in better dam management. On the other side, AI techniques have become very popular for hydrological modelling in the past mainly in the form of Artificial Neural Network (ANN) techniques.

An accurate estimation of water requirements for various purposes including domestic, irrigation, hydropower, industries and navigation is essential for any planning of water resources development and management. So it is required to estimate the irrigation demands for existing cropping pattern and present and future domestic and industrial water use for sustainable management of the Bisalpur and Isarda reservoirs.

Many reservoirs are operated using Standard Linear Operating Policy (SLOP) which results in less reliable release to various conservation purposes many times. The SLOP does not consider the variability in the inflow and availability of storage in the reservoir. Rule curve development considers the variability in the inflow and available storage after the sedimentation for a specified period, say 25 years. The integrated operation of the reservoirs based on rule curve will improve the reliability of the releases for the conservation purposes. The predicted inflow and sediment load to the Bisalpur and Isarda reservoirs, irrigation and domestic and industrial water demands would be used in the simulation of reservoir operation to evolve best operating strategies of reservoirs.

5. Objectives of the Study

1. Modelling of Inflow and sediment load to Bisalpur and Isarda reservoirs using SWAT and ANN Models

2. Comparison of results of SWAT and ANN models
3. Estimation of water requirements of the command area for Bisalpur and Isarda reservoirs
4. Development of rule curves for conservation (irrigation and drinking and industrial water supply) based on the simulation of integrated operation of Bisalpur and Isarda reservoirs

6. Study Area

The study area is the Banas river basin up to the Isarda Dam. 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 km^2 with a length of about 512 km. The Banas River passes through the 13 districts 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. The Banas basin upto Isarda dam falls under Seven districts of Rajasthan, namely Ajmer, Bhilwara, Tonk, Sawai Madhopur, Udaipur, Rajsamand, and Chittorgarh having a total area of 37,173 km^2. Bisalpur and Isarda Reservoirs are located in the Banas basin.

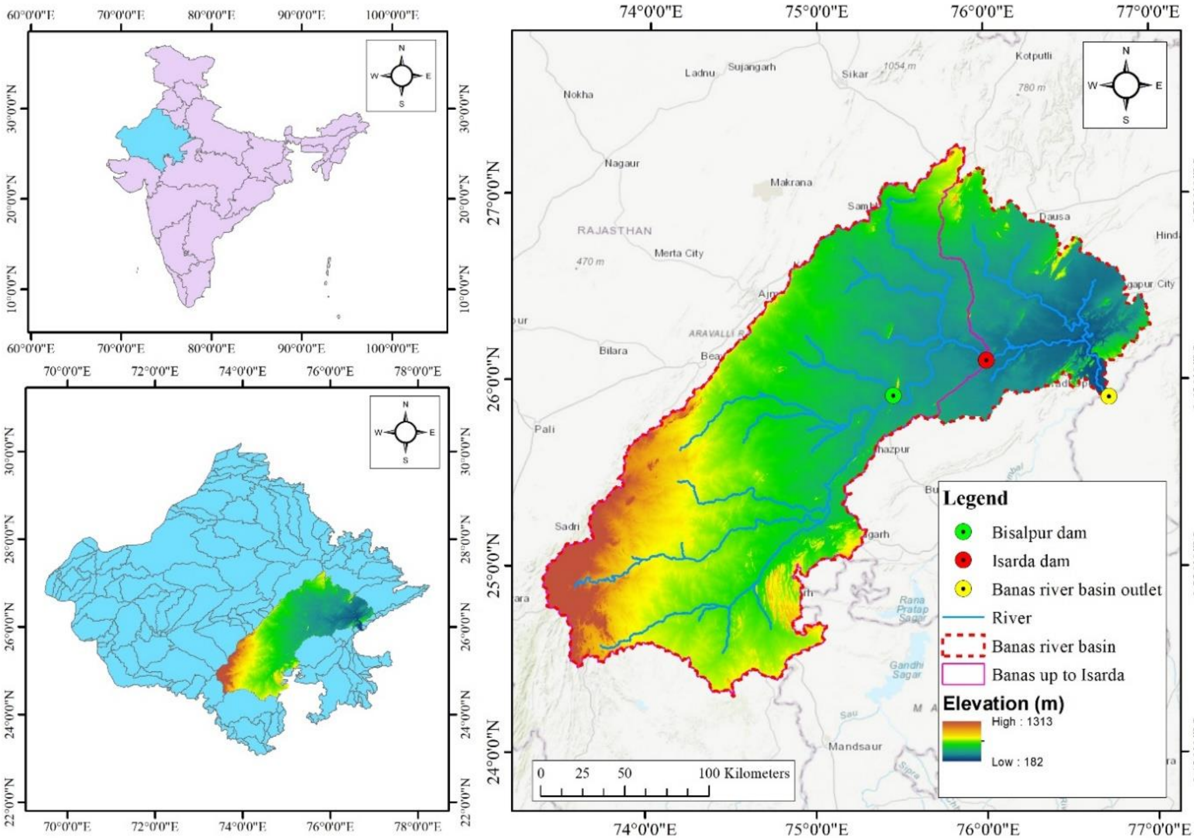

Fig. Banas River basin

7. Data Requirement

Daily data of rainfall, minimum and maximum temperature, wind speed, relative humidity, sunshine hours, discharge and sediment load to the reservoirs, remote sensing data and Survey of India toposheets, existing cropping pattern, command area details, crop coefficient and other crop information, population and livestock data.

8. Methodology

Modelling of Inflow and Sediment Load to Bisalpur and Isarda Reservoirs would be carried out using SWAT Model. ANN modelling technique would also be utilized for inflow and sediment load prediction to Bisalpur and Isarda reservoirs. A comparison of the two modelling techniques would be carried out.

It is proposed to bring soil samples from various parts of the basin for detailed information on soil parameters to be used in the SWAT model.

Gross Irrigation Requirement (GIR) is estimated using Reference Evapotranspiration (ETo) by Penman-Monteith equation, crop coefficient (Kc) from FAO, effective rainfall by SCS Method (CROPWAT 8.0) and irrigation efficiency. The exiting human (2011 census) and livestock (2012 census) population is used to estimate the demand for domestic and industrial needs by taking the per capita water demands for rural, urban and livestock population as 70 lpcd (liter per capita per day), 135 lpcd and 50 lpcd respectively.

The development of rule curves for the integrated operation of the reservoirs would be carried out using NIH_ReSyP considering the predicted inflow and sediment load water demands for irrigation, drinking and industrial puposes. The simulation module of NIH_ReSyP would be used to derive the reliability of releases from reservoirs integratedly.

9. Action Plan and Timeline

S. No.	Work Element	First Year				Second Year				Third year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Collection of information and meteorological data (rainfall, Tmin, Tmax, RH(%), Sunshine hour) as well as soil samples from field, Preparation of base maps												
2	Collection of inflow and sediment load to reservoirs, physical features of reservoirs, command area boundary, existing cropping pattern, crop information and crop coefficient, population and livestock data												
3	Calibration and Validation of SWAT Model for modelling of inflow and sediment load to the reservoirs												
4	Estimation of demands for irrigation, present and future (2070) drinking water and industrial use												
5	**Preparation of first Interim Report**												
6	Development of ANN Models for prediction of Inflow and sediment load												
7	Comparison of Modelling Techniques												
8	Development of rule curves												

	for the reservoirs												
9	**Preparation of second Interim report**												
10	Simulation of integrated operation of reservoirs												
11	**Preparation of final report**												

10. Deliverables

Research papers, reports, stakeholder engagement.

11. End Users/Beneficiaries of the Study

Water Resources Department and Agriculture Department in particular and people at large in general.

12. Adopters of the Results of the Study and their Feedback

Water Resources Department, Agriculture Department, Govt of Rajasthan. The methods and results generated in the present study will help the Water Resources of Rajasthan State for formulating strategies for the sustainable management of Bisalpur and Isarda reservoirs. Developed model could be used for analysis of different scenarios based on expected land use land cover change or climate.

13. Cost Estimate

a. Total cost of the project: Rs. 19.272 Lacs
b. Source of funding: Internal funding from NIH
c. Sub Headwise abstract of the cost

Sl. No.	Sub-head	Amount (in Rupees)
1.	Salary for 01 Junior Resource Person for 03 years	11,77,200
2.	Travelling expenditure	5,00,000
3.	Purchase of data	1,00,000
4.	Misc. expenditure	1,50,000
	Grand Total:	**19,27,200**

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

Salary: Full time one personnel (Junior Resource Person) for the project will be required for assistance in the field data collection, data processing and technical analysis.

Travel: Travels would be essential for data collection, soil sample collection, ground truth survey in the study area and stakeholder meetings.

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-26/04

1. **Title:** Water and Land Productivity Accounts for the major river basins of India using water accounting plus (WA+) for sustaining water and food security (WAPRO-India).

2. **Project Team:**
   Dr P. K. Singh, Scientist 'E'
   Dr P. K. Mishra, Scientist 'D'
   Dr Vishal Singh, Scientist 'D'
   Er. Harsh Upadhyay, Scientist B
   Dr Parvin D. Patil, Scientist 'C'
   Dr A. R. Senthil Kumar, Scientist 'G'

3. **Project Duration: 02 Years (03/24 – 02/26)**

4. **Objectives**
   The major objective of this study are as follows.

   1. To develop Water and Land Productivity Accounts in the major river basins of India for sustaining water and food security.
   2. To develop accounts of water consumption patterns and beneficial and non-beneficial water consumptions.
   3. To develop operational WAPRO -India portal on-line enhanced applications.
   4. To prepare detailed WA+ report for study basins/sub-basins.
   5. To impart training on developed portal to the state officials of Water Resources, Agricultural and other related Depts.

5. **Present state-of-the-art**
   Water Accounting Plus (WA+) can be helpful for development of the accounts of water and land productivity using satellite earth observation datasets. 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 WA frameworks. FAO's global information system on water and agriculture (AQUASTAT) is an important source of data, however, it does not distinguish between consumptive use and non-consumptive use. The System of Environmental Economic Accounting for Water (SEEA-WATER) of the United Nations Statistics Division (UNSD) (UN, 2012) requires a variety of data from numerous sources, which are unlikely to be available at many times (Dimova et al., 2014; Perry, 2012). It does not distinguish between the green and blue water resources (Falkenmark and Rockstr¨om, 2006; Rockstr¨om and Gordon, 2001). The Australian Water Accounting Standard (AWAS) developed by the Water Accounting Standards Board (WASB) of the Australian Bureau of Meteorology (BOM) accounts for water withdrawals rather than consumptive use. However, AWAS does not provide any information on rainfed systems and natural evapotranspiration (ET) processes.

   More recently, FAO has developed WAPOR (https://wapor.apps.fao.org/home/WAPOR_2/1) portal for spatio-temporal variability of actual evapotranspiration (AET), Gross biomass water productivity and other parameters for the African continent only. And hence, there is a need for development of such accounts and portal for India.

6. **Methodology**
   In this research work, we will apply newly developed WA+ Framework, 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 hypothesis (Budyko, 1974) and WATERPIX model (IHE, 2016). The basis of the water balance approach is that outflow from a certain area of interest (e.g., river basin) is explicitly related to the net inflow and

depletion through a measurable ET processes. The ET process is now-a-days measurable by the satellite technology and the available products in open domain are GLEAM, SSEBop, MODIS, GLDAS, and others. WA+ uses satellite remote sensing datasets and open access datasets for developing agricultural and water accounts. The outputs of the WA+ are represented in the form of the fact sheets (06 nos.) and spatial maps for easy understanding by the stakeholders and policy makers as well. WA+ has its specified land use land cover (LULC) map known as WALU. WA+ framework recognizes the essential difference between Blue water and Green water. The green water is the soil moisture from precipitation, used by plants via transpiration. It is part of the evapotranspiration flux in the hydrologic cycle. Blue water is the freshwater: surface and groundwater. It is stored in lakes, streams groundwater, glaciers and snow.

6.1 Study Area and Major Input Data

In this study it is proposed to develop accounts of the water productivity and land productivity using WA+ framework for the major river basins (28 nos.) as shown in Figure 1. The WA+ framework makes use of open source remote sensing data in an effort to maintain a high level of transparency. Remote sensing is a reliable and objective source of data. Data products from the National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) are provided free of charge for all users regardless of nationality or intended application.

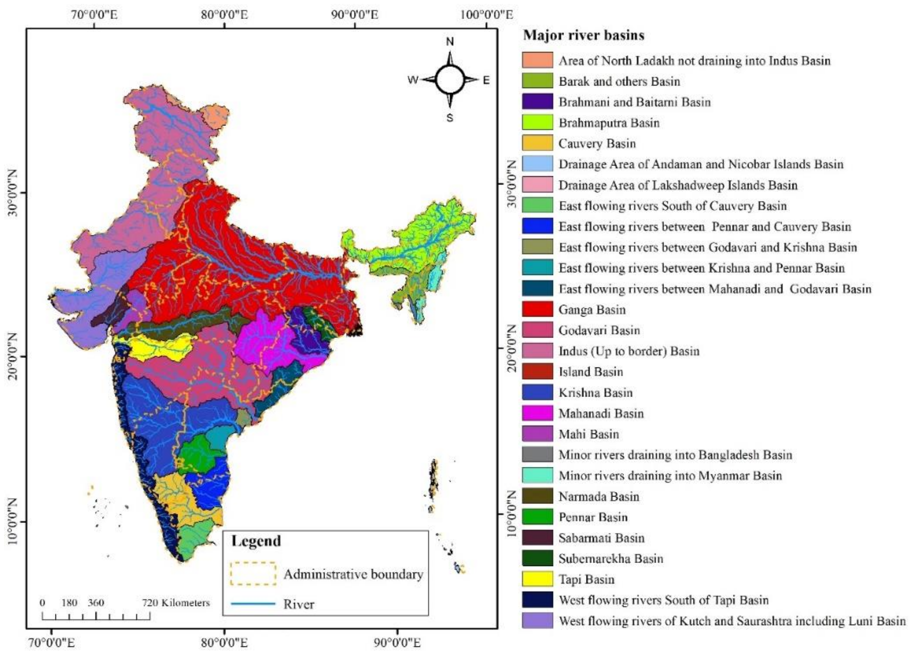

Figure 1: River basin map of India

6.2 Datasets required:

Following datasets will be used to conduct this study.

Data	Temporal resolution	Spatial resolution	Availability	Data Source
Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS)/Global Precipitation Measurement (GPM)	Daily, Monthly	5 km/10 KM	1981 onwards/2014 onwards	https://data.chc.ucsb.edu/products/CHIRPS-2.0/ https://gpm.nasa.gov/data/imerg
Actual Evapotranspiration (SSEBop)/GLEAM	Monthly	1 km/25 km	2003 onwards	https://earlywarning.usgs.gov/fews/datadownloads/Continental%20Africa/Monthly%20ET%20Anomaly

MOD-15; Leaf area index (LAI)	8-daily	500 m	2000 onwards	https://lpdaac.usgs.gov/products/mcd15a2hv006/
Gross primary production (GPP)	8-daily	500 m	2000 onwards	https://lpdaac.usgs.gov/products/mod17a2hv006/
Net primary production (NPP)	Yearly	500 m	2000 onwards	https://lpdaac.usgs.gov/products/mod17a3hv006/
IWMI LULC map	2000	250 m		http://waterdata:iwmi:org/applications/irri_area)
ESA-GlobCover LC v2	Annual	300 m	1992-2015	http://due.esrin.esa.int/page_globcover.php
MIRCA (Monthly Irrigated and Rainfed Crop Areas)	Annual	10 km	1998-2002	https://www.uni-frankfurt.de/45218023/MIRCA
WDPA (World Database on Protected Areas)	Annual	Shapefile	-	https://www:protectedplanet:net
JRC (Joint Research Center) Data Catalogue	Annual	30 arc seconds	2017	https://data.europa.eu/euodp/en/data/dataset/jrc-floods-floodmapgl_permwb-tif
NRSC-250k	Annual	56 m	2004/05 – 2015/16	https://bhuvan-app1.nrsc.gov.in/thematic/thematic/index.php

6.3 Software Required:

- ArcGIS Pro (Already in NIH)
- ArcGIS Enterprise (Already in NIH)
- WA+ Tool (Open Source)
- QGIS (Open Source)
- Visual Studio (Already in INH).

7. Research Outcome from the Project:

- Land and Water Productivity Accounts (Spatial and Temporal)
- Water Consumption Patterns and beneficial non-beneficial consumptions.
- Operational WAPRO-India portal.
- WA+ Report and Recommendations.
- Training on WA+ based WAPRO-India Portal

8. Cost Estimates:

The total cost of the project: **₹ 43.48 Lakh**

c. Source of funding: NIH Roorkee

d. Sub-head wise abstract of the cost:

Head	**Amount (in Lakh)**		
	1st Year	2nd year	Total
1: Research Scientist/Software developer @67,000/ + HRA	9.00	9.30	18.30
2: Research Associate/GIS and Remote Sensing expert @58,000/ + HRA	7.59	7.59	15.18
3: Others (Hiring of services, field visits, consumables, stationary, printing of reports & brochures, and sample analysis, etc.)	1.00	1.00	4.00
3: Travel Expenditure	3.00	2.00	5.00
4: Contingency	0.50	0.50	1.00
Grand Total			43.48
	Rs. Forty three Lakhs Forty Eight Thousand Only		

9. **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	**March 2024-February 2025**				**March 2025-February 2026**			
Project Quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**
g. Data downloading, processing, and generation of database	⟷	⟷						
h. Basic data analysis in WA+ framework, Ground trothing surveys for LULC and data collection from NRSC, and state govt. departments		⟷	⟷					
i. WA+ Framework Application			⟷	⟷				
j. Development of Land and Water Productivity Accounts					⟷	⟷	⟷	
k. Development of the operational WAPro-India portal						⟷	⟷	⟷
l. Final report writing recommendations and stakeholders Training							⟷	⟷

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-25/05

1. Title of the Project

Development of rule-based integrated operation framework for the Mahanadi basin

2. Project Team

Dr. P. K. Mishra, Scientist 'D'
Dr. M. K. Goel, Scientist 'G'
Dr. P. K. Singh, Scientist 'E'
Dr. A. R. Senthil Kumar, Scientist 'G'

3. Project Duration: 1.5 Years (04/24 – 09/25)

4. Statement of Problem

With increasing abstraction of water in the upstream reaches (here Chhattisgarh state), inflow to the downstream reaches (here Hirakud reservoir, Odisha state) is gradually diminishing, thereby affecting flow of non-monsoon water into Hirakud reservoir. As per an estimate by the WRD, Govt. of Odisha, the inflow at Hirakud during November 2016 and December 2016 have been observed to be drastically reduced by around 41.1% & 32.8% respectively in comparison to the flow received during last ten years between 2005-06 to 2015-16. It is apprehended at that time that if this trend is allowed to continue, there will be virtual stoppage of non-monsoon flow in Hirakud reservoir which will have very severe adverse impact on the agriculture economy and livelihoods of the people of Odisha besides severely impacting the ecology and environment. The Supreme Court constituted the Mahanadi Water Disputes Tribunal (MWDT) during March, 2018, to address any disputes between the States of Chhattisgarh and Odisha. This study proposal has been prepared in response to the email from Er. Adikanda Patra, Additional Chief Engineer, Inter-State Water Issues, Water Resources Department, Govt. of Odisha for comprehensive study covering these aspects.

5. Study Area

The Mahanadi basin encompassing a total drainage area of 1415529 Sq. Km extending between 80^0-33' to 86^0-50' east longitudes and 19^0-20 to 23^0-35' north latitudes.

6. Objective of the Study

The major objective of this study is to develop an integrated operation protocol for the operation of various water structures in Mahanadi River System. This will help in development of proper water management strategies and decision processes between the states of Chhatisgarh and Odisha. The specific objectives are:

1. To evaluate the impact of different upstream interventions on the performance of Hirakud dam.
2. To suggest a rule-based operation framework to address the basin needs, regulation policies from the viewpoint of downstream riparian rights.

7. Data Needs and brief Methodology

Input Data:

- GIS layers of basin features
- Salient features of Major projects including EAC curves
- Working Tables of Major projects including inflows, releases & spills
- Evaporation and seepage losses (Project-wise)
- Project-wise utilizations as per MWDT awards
- Minor irrigation utilization in project catchments, if any
- Water demands for various project
- Hydro-meteorological data
- Relevant reports, guidelines, etc.

Note: The onus of ensuring timely data availability will be the responsibility of WRD, Odisha.

8. Methodology

Initially, the study team will peruse the MWDT awards in the perspective of water distribution between the state of Chhattisgarh and Odisha. The water availability at different dependability for major projects up to the Hirakud reservoir will be analyzed to evaluate the impact of different upstream interventions on the performance of Hirakud dam. Accordingly, analysis Working Table of upstream projects, computation of evaporation depth, assessment project-wise various water demands, minor irrigation utilizations in the project catchment will be carried out if required. Finally, computation of flows corresponding to different dependability viz. 50%, 65%, 75%, and 90% dependability will be done. It is planned to use NIH ReSyP for the system analyses. To develop the rule-based integrated operation framework, following steps will be followed:

- Estimation of mean monthly & 10-daily demand pattern from the Working Table
- Estimation of minor irrigation utilization in a Project catchment
- Estimation of net inflow series to a Project
- Estimation of different demands at a Project
- Estimation of Demands of downstream Project(s)
- Policies for integrated operation for different Project(s)
  (It is planned to simulate the integrated operation of the system with two policies: SLOP and rule-curve based operation policy in conjunction with the MWDT guidelines)
- Output of Operation analysis

Note: Disaggregation/ aggregation of time step of different data will be done as per the need

9. Project Budget

Head	**Amount (in Lakh)**		
	1st year	**2nd year**	**Total**
1: Field visits, consumables, stationary, printing of reports & brochures, workshops, outreach etc.	0.75	0.75	1.50
2: Travel Expenditure	2.00	1.00	3.00
3: Contingency	0.25	0.25	0.50
Grand Total			**5.00**
	Rs. Five Lakhs only		

10. Expected Deliverables

- Rule-based integrated operation protocol for different projects for the Mahanadi River systems in conjunction with MWDT guidelines.
- Report and recommendations

11. Expected Timeline against the Deliverables

Project Year	**Apr. 2024-Mar. 2025**				**Apr. 2025-Sep. 2025**	
Project Quarter	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**
a. Generation of databases and maps; data collection from CWC, and state govt. departments, etc.	■	■	■			
b. Customization and Setting-up of computer programme		■	■			
c. Analysis of water availability for different projects			■	■		
d. Development and Analysis of Rule-based operation protocol			■	■	■	
e. Report and Recommendations						■

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-27/06

1. Title of the Project

Assessment of Precipitation Gradients and Temperature Lapse Rates for Hydrological Modelling in a Himalayan Catchment

2. Project Team

Dr. P. R. Patil, Scientist 'C',
Dr. M. K. Nema, Scientist 'E',
Dr. P. K. Mishra, Scientist 'D',
Dr. A. R. Senthil Kumar, Scientist 'G'

3. Project Duration: 03 Years (04/24 – 03/27)

4. Present state-of-art

In Himalayas, a significant knowledge gap pertains to the precipitation-temperature interplay driven by altitudinal orographic forcing. Improving distributed hydrologic models (DHMs) accuracy and reducing uncertainty require effective parameterization using field observations, especially challenging in high-altitude areas. Utilizing uniform vertical and horizontal gradients of precipitation (PGs) and literature based air temperature lapse rates (TLRs), distributed glacio-hydrological models (Immerzeel et al., 2014; Ragettli et al., 2015; Heynen et al., 2016) invites uncertainties. The TLRs and PGs determine form and amount of precipitation and spatial distribution of air temperature (Kattel et al., 2013) and precipitation (Immerzeel et al., 2012). Water availability projections rely on temperature and precipitation time series. Despite advancements in satellite products, improved climate reanalysis (Hersbach et al., 2020), and developments in climate-model downscaling and high-resolution atmospheric modeling (Collier et al., 2015), validation of derived meteorological variables using field observations in the Himalayan region is pending.

An environmental lapse rate (ELR) is often treated as calibration parameter or assumed to be constant in space and time due to limited field data. An ELR based on hypotheses or assuming free atmospheric conditions seems unrealistic, results in inaccurate temperature fields (Shrestha et al., 2012; Roe & O'Neal, 2009). Unlike ELR, TLRs exhibit elevation-dependent seasonal and diurnal variations due to varying sensible heat flux (Gardner et al., 2009; Li et al., 2013) and are generally shallower than the ELR (6 to 6.5 °C/km) due to local circulation and humidity. TLRs derived on a seasonal or monthly basis and using extrapolated temperature records (Kattel et al., 2013, 2015; Zhang et al., 2015, 2017; Shrestha et al., 2015; Valéry et al., 2010) are unable to capture local variability, particularly when stations are sparsely located at lower or remote altitudes. The linear or mean TLRs used are unjustifiable and can introduce ambiguities in modeling, as derived temperature and its spatial variability significantly affect rainfall, snowfall, mixed-phase precipitation, rain-snow portioning, snowmelt, glacier-melt and runoff (Minder et al., 2010). The spatial distribution of temperature governs the precipitation pattern in mountains. Precipitation pattern typically involve assigning a priori PGs (Bergström, 1992; Viviroli et al., 2007; Markstrom et al., 2015) or interpolating gauge data with varying geostatistical complexities (Frei and Schär, 1998; Daly et al., 2008; Isotta et al., 2014; Foehn et al., 2018; Frei and Isotta, 2019). However PGs, exhibit nonlinear correlations with altitudes, thus, does not gives a true precipitation distribution in mountains (Dahri et al., 2016). Characterizing precipitation proves challenging due to limited datasets and extreme variability over short distances in mountains (Buytaert et al., 2006; Immerzeel et al., 2014).

Realistic forcing fields (TLRs and PGs) are crucial for interpolating point observations into gridded input for DHMs (Ahrens, 2006; Tahir et al., 2011; Immerzeel et al., 2012). Obtaining a reliable diurnal forcing datasets capturing spatio-temporal variability without field observations poses a challenge. Thus, short-term (1-2 years) field campaigns can facilitate better calibration of forcing fields. Hence, expansion, reinforcement, and operation of the hydro-met monitoring network in the Henval catchment are imperative. The proposed study envisaged to enhance the understanding of precipitation and temperature dynamics in a monsoon-dominated climate with extreme topography by real time monitoring of forcing fields. This approach will evaluate valley-scale controlling mechanisms, assess hydrological responses in a Himalayan catchment, and mitigate conventional modeling uncertainties. Additionally, the sensitivity of a cutting-edge hydrological models to observed TLRs and PGs, compared to the standard ELR and linear PGs, will be systematically examined.

5. Objectives of the Study

a. Strengthening/establishment of the instrumentation in the Henval catchment up to Shivpuri (outlet) for regular monitoring of hydro-met variables.
b. To estimate TLRs and PGs in the catchment by analyzing the field observations.
c. To identify the potential controlling mechanisms and local factors governing temporal and spatial variability of TLRs and PGs.
d. To evaluate the distributed hydrologic model and hydrological response of the catchment using observed TLRs and PGs as well as conventional ELR and linear PGs.

6. Methodology

Study Catchment:

The Henval catchment (254 km^2, Fig. 1) in the Tehri Garhwal district, Uttarakhand, India, is a benchmark site for hydrological studies in the outer Himalaya. It features minimal disturbance, primarily forest cover, with agriculture and urbanization in Chamba. Henval, a first-order tributary to the River Ganga. Geographically located between $30^0$07’N–$30^0$26’N latitude and $78^0$16′E–$78^0$25′E longitude, it receives a monsoon-dominated annual rainfall of 1200–1400 mm. The Henval valley, with a South-West aspect, has a well-defined drainage network. Soil types, originating from metamorphic rocks, vary from sandy loam to loamy sand. The NIH has studied upper sub-watersheds under DST/MOES projects, and an ongoing ISRO-DoS project aims to add a flow measuring device at Shivpuri. To develop diurnal forcing database, tipping bucket rain gauges and temperature loggers will be installed along the valley's elevation transects (362 to 2676 m a.s.l.). Additionally, maintaining existing instrumentation is essential.

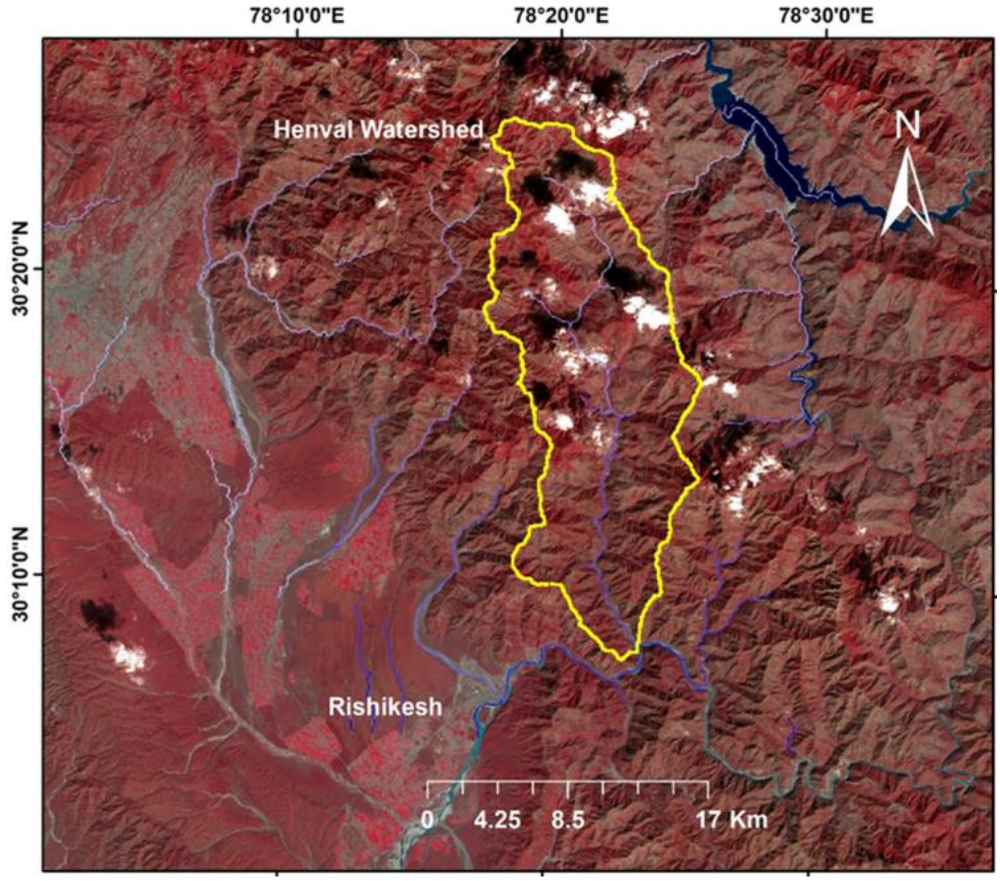

Fig. 1 Location Map of Henval Catchment

Research Approach:

The following activities/tasks have been defined to accomplish proposed research objectives:

1 Field visits/site surveys, strengthening of instrumentation, hydro-met data collection, pre-processing and development of reliable diurnal forcing and digital database including DEM, slope map, elevation profile etc.

2 Analysis of diurnal, monthly and intra-annual variability in TLRs and PGs for defined seasons (Pre-Monsoon, Monsoon, Post-Monsoon, Winter).

3 Identification of meteorological controls and local processes affecting the valley-scale temperature-precipitation dynamics and their inter-relationships. Establishment of realistic spatial distributions of temperature and precipitation in the catchment.

4 Hydrological model setup, calibration, sensitivity analysis of model calibrating parameters, validation and execution for different forcing fields.

5 Assessment of hydrological response and analysis of impacts of meteorological forcing fields in the catchment. The distributed hydrologic model with proven capabilities will be used to estimate streamflow. The possible models are: SPHY (Spatial Processes in Hydrology), TOPKAPI (TOPographic Kinematic APproximation and Integration)-ETH, HBV (Hydrologiska Byråns Vattenbalansavdelning), Variable Infiltration Capacity (VIC), DHSVM (Distributed Hydrology Vegetation Soil Model), GERM (Glacier Evolution Runoff Model).

6 Report Writing

7

7. Research Outcomes

- A strengthened instrumentation network for long-term monitoring and better understanding of precipitation and temperature dynamics in monsoon-dominated rugged terrain.
- Enhanced modeling accuracy by adopting field observations for model parameterization or refinement of input forcing fields capturing realistic spatial and temporal distribution meteorological variables.
- Identification of valley-scale controlling mechanisms or local factors governing meteorological forcing fields and their impact on hydrological response.
- Sensitivity of hydrological model to the observed forcing fields (TLRs and PGs) compared to the standard ELR and linear PGs, may provide insights into model performance and areas for further improvement.
- The study outcomes will be useful in correcting grid-based climatic estimates for elevation in complex terrain.

8. Cost Estimates

The total cost of the project: **₹ 17.10 Lacs**

i. Source of funding: NIH

ii. Sub-head wise abstract of the cost:

SN	Sub-head	Amount (₹)			
	Year	**I**	**II**	**III**	**Total**
1	Salary (Part-Time Field Staff, Approx. 20 Field Stations)	180000	240000	240000	660000
2	Travelling Expenditure	150000	100000	100000	350000
3	Data/Infrastructure/Equipment's/Repair & Maint.	300000	100000	100000	500000
4	Workshop/Meeting/Experimental Charges/Rent	20000	20000	100000	140000
5	Misc. Expenditure	20000	20000	20000	60000
	Sub-Total:	870000	480000	560000	
	Grand Total:	**₹ 17,10,000**			

9. Work Schedule

SN	Description of Activity	2024-25				2025-26				2026-27			
		Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
1.	Field visits												
2.	Strengthening of												

	instrumentation												
3.	Hydromet. data collection, pre-processing and development of reliable database												
4.	Analysis of variability in TLRs and PGs, valley-scale temperature and precipitation dynamics and spatial distribution												
5.	Hydrological model setup, calibration, validation												
6.	Assessment of hydrological response and analysis of impacts of forcing fields												
7.	Stakeholder’s workshop												
8.	Report writing												

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-26/07

1. Title of the Project

Evaluation of Area-Design Curve to estimate sediment distribution in Indian reservoirs

2. Project Team

Dr. U. K. Singh, Scientist 'C'
Dr. A. R. Senthil Kumar, Scientist 'G'
Dr. M. K. Goel, Scientist 'G'
Dr. P. R. Patil, Scientist 'C'

3. Project Duration: 02 years (04/24 – 03/26)

4. Statement of the Problem

India, since the 1960s, has become one of the major dam builders in the world and at present stands only next to China in terms of the number of dams and their combined capacity (Sanyal and Chowdhury 2023). Reservoirs serve multifunctional roles including irrigation, water supply, flood control, navigation, and power generation. Globally, reservoirs contribute to over 40% of irrigation water (Biemans et al., 2011). Kothyari (1996) reported that the 80% of the reservoirs are expected to lose 50% of their capacity by 2050 in India that highlighted reservoir sedimentation as a major problem. The storage capacity of Nizam Sagar (India) was lost about 60.7% over a period of 62 years, whereas the corresponding loss in Maithon reservoir in Jharkhand was about 55% over 50 years reported by Rathore et al. (2006). Accuracy in the prediction of sediment accumulation is essential not only for planning, design, and operation of reservoirs but also for sustainable water resources management and mitigate economic losses. Hence, prediction of sediment deposition patterns and available storage capacity will provide the update on it which is crucial for sustainable water resources management. Various empirical methods are available to predict the distribution of sediment in a reservoir (Cristopano 1953; Borland and Miller 1960; Lara 1962; Garde et al. 1978; Gharaghezlou et al. 2014, Chaudhuri 2017). However; the most widely used empirical method is "Empirical Area Reduction" method by Borland and Miller (1960). Borland and Miller (1960) have given an expression of distribution of relative sediment area for any level above the reservoir bed in the Empirical Area Reduction method. They used 30 reservoirs from USA for Empirical Area Reduction method. The proposed study aims the evaluation of Area-Design-Curve to estimate sediment distribution in Indian reservoirs. Further, refinement of Area-Design-Curve will be done if required, to closely match with observed data for Indian reservoirs.

5. Objectives of the Study

a. To evaluate the Area-Design-Curve to estimate sediment distribution in Indian reservoirs
b. Refinement in Area-Design-Curve; if required, to closely match with observed data for Indian reservoirs.
c.

6. Study Area

Reservoirs across the Country will be considered for the study. It is expected to consider the data of around 80 number of reservoirs across India. However, final number of reservoirs considered for the study will depend on the availability of sedimentation data of reservoirs.

7. Data Requirements

i. Original elevation-area-capacity curve of the reservoirs
ii. Observed elevation-area-capacity curve from resurvey
iii.

8. Methodology

Empirical Area Reduction method based on "Area-Design-Curve" will be used to evaluate sediment distribution in Indian reservoirs. Further, refinement in Area-Design-Curve will be done if required, to closely match with observed data for Indian reservoirs.

Empirical Area Reduction Method:
The method was developed by Borland and Miller (1960) from analysis of sediment distribution data obtained from surveys of 30 reservoirs from USA. The curves could be represented by the equation:

$A_p = C\ p^m\ (1 - p)^n$

where

A_p = Relative sediment area at relative depth p above streambed,

C, m and n = Constants determined by the type of reservoirs.

Table 1 Reservoir types for sediment distribution

M	Reservoir Type	Standard classification
1 - 1.5	Gorge	IV
1.5 - 2.5	Hill	III
2.5 - 3.5	Flood plain foot hill	II
3.5 - 4.5	Lake	I

"M" is the reciprocal of the slope of the line obtained by plotting reservoir depth as ordinate against reservoir capacity as abscissa on log-log paper.

Table 2 Values of C, m, and n

Type	C	m	n	Equation of area design curve
I	3.4170	1.5	0.2	$Ap = 3.417p^{1.5}\ (1\text{-}p)^{0.2}$
II	2.3240	0.5	0.4	$Ap = 2.324p^{0.5}\ (1\text{-}p)^{0.4}$
III	15.8820	1.1	2.3	$Ap = 15.882p^{1.1}\ (1\text{-}p)^{2.3}$
IV	4.2324	0.1	2.5	$Ap = 4.232p^{0.1}\ (1\text{-}p)^{2.5}$

The Empirical Area-Reduction Method for determining the probable sediment distribution is accomplished through two main steps:

i. Classification of the reservoirs using four basic standard type curves which were developed from actual resurvey data.
ii. Apply trial and error computation until the capacity computed equals the predetermined capacity.

9. Action Plan and Timeline

S. No.	Work Element	First Year				Second Year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Collection of data on reservoir sedimentation	■	■						
2	Computation of reservoir sedimentation using Area Design Curve		■	■	■				
3	Evaluation of Area Design Curve		■	■	■				
4	Preparation of first Interim Report				■				
5	Refinement of Area Design Curve					■	■	■	
6	Preparation of final report								■

10. Deliverable
Research papers and reports.

11. Utility
The dam built across the water body to serve specific purpose for a certain period of time, however; sedimentation shortens the designed life of dam. The accurate prediction of sediment distribution is required to properly regulate the reservoirs for its designed life.

12. Adopters of the Results of the Study and their Feedback: Researchers and Engineers

13. Cost Estimate

a. Total cost of the project (Rs.): 1,00,000.00 (One lakh only)

b. Source of funding: NIH

c. Sub Head wise abstract of the cost

Sl. No.	Sub-head	Amount (in Rupees)
1	Miscellaneous expenditure	1,00,000.00
	Grand Total:	**1,00,000.00**

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-27/08

1. Title of the Project

Water yield potential and flash flood risk assessment under changing climate and land use and strengthening of existing instrumentation in the Teesta River basin up to Domohani

2. Project Team

Er. Harsh Upadhyay, Scientist 'B'
Dr. P. K. Singh, Scientist 'E'
Dr. A. R. Senthil Kumar, Scientist 'G'
Dr. P. R. Patil, Scientist 'C'

3. Project Duration: 3 Years (04/24 – 03/27)

4. Present state-of-art

The previous few decades have witnessed a marked increase in the occurrences of extreme weather events and their erraticism in the wake of climate change. Coupled with the perilous topography of the Himalayan range, these extremities form a prime concoction for hydrological disasters in the region. Among the Himalayan River basins, the Teesta River basin (TRB) in north-east India is one that has been significantly affected by extreme precipitation events. These extreme events have impacted the combined discharge of rivers Lachen, Rangeet and Teesta and the rising water levels have caused significant flooding in the downstream reaches. In the high elevation regions, i.e., the upper reaches of the basin, increased frequency in cloudbursts have caused extensive damage resulting in widespread loss of life and property. Moreover, the region of basin encompassing the state of Sikkim and the Darjeeling Himalayas is prone to landslides due to torrential rainfall. On account of aforementioned factors, interventions to control and minimize the losses due to floods and consequential disasters are necessary therefore culminating into a requirement of in-depth assessment of the inundation scenario in the basin. Taking this into consideration along with a dearth in relevant studies in the region, the following objectives have been framed for the study.

5. Objectives

a) Strengthening of the existing instrumentation network in the basin for improved monitoring of hydro-meteorological parameters.
b) Assessment of the impacts of climate change upon the different hydro-meteorological parameters associated with the basin.
c) Water yield potential assessment of the different tributaries of the TRB and impacts assessment of climate change and land use change using SWAT model.
d) Determination of flooding extents in TRB due to historical and projected extreme events using HEC-RAS model.
e) Preparation of inundation and flood susceptibility maps for TRB using HEC-RAS and earth observation satellite datasets.

6. Study Area and Data Requirement

The Teesta River originates in the Teesta–Khangtse glacier in the Himalayas, flows through the Indian states of Sikkim and West Bengal, and eventually reaches a confluence with the Brahmaputra River in Bangladesh, flowing in a north–south direction. In the proposed study, Teesta basin up to Domohani (CWC gauging site location) has been selected as the study area. With a geographical extent of 26°30'5.95"N–28°7'35.972"N latitude and 87°59'16.728"E–88°53'14.8632"E longitude, the area of interest is 9679.18 km^2. A study area map of TRB is shown in Fig. 1. During the monsoon season from June to September, variation in precipitation of around 4000–6000 mm has been recorded in the hilly region, while 1000–2000 mm has been recorded near the Rangit valley.

An extensive amount of geospatial as well as time series data would be required in the course of study. The geospatial datasets required include the digital elevation model (DEM), land use land cover (LULC) map, soil map, administrative and watershed boundaries, instrument locations etc.

Time series data consist of hydro-meteorological variables such as precipitation, temperature, discharge, water level etc. Besides historical time series data, CMIP6 time series data which relay the effects of climate change upon hydro-meteorological variables, generally precipitation and temperature, would also be obtained. An overview of data required and their sources for possible procurement is shown in Table 1.

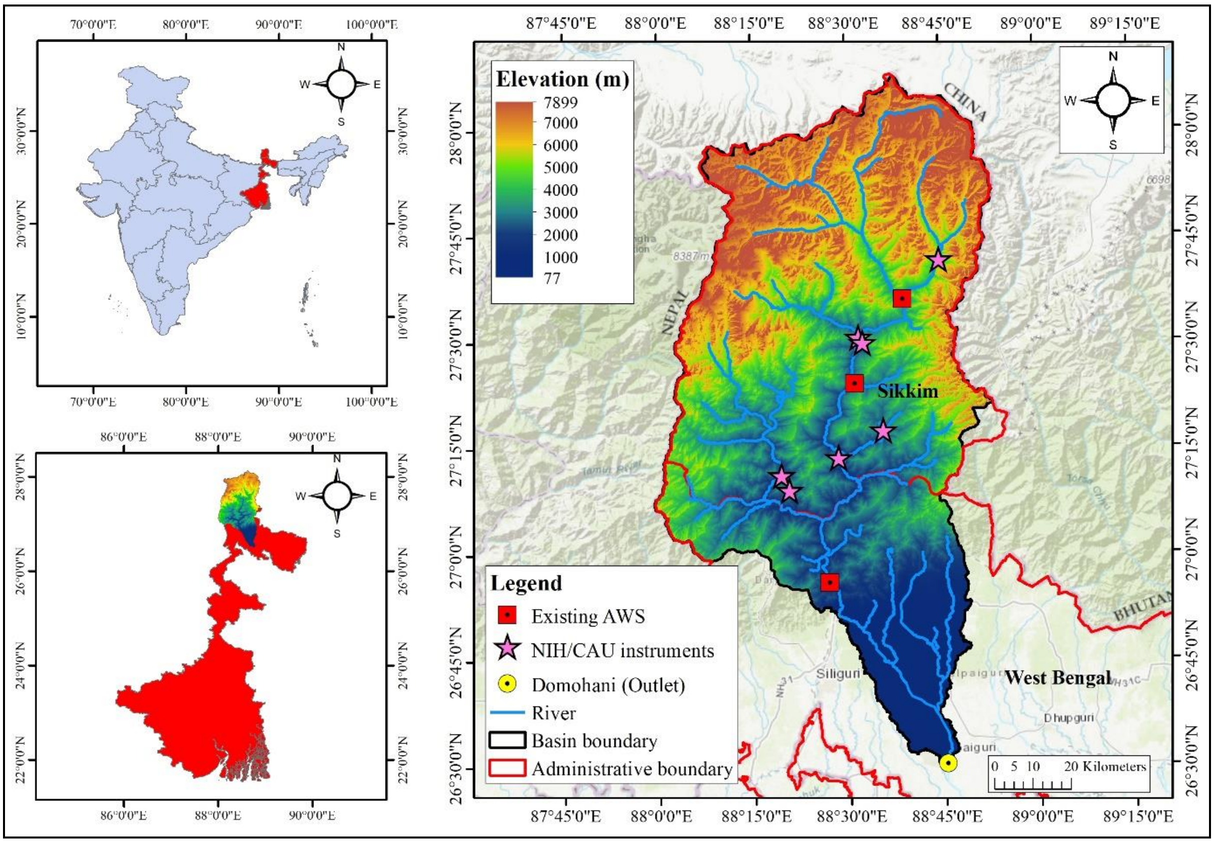

Fig. 1 Study area map of TRB

Table 2 Data requirement

S. No.	Data	Source(s)
1.	DEM	SRTM, Copernicus, ASTER
2.	LULC	NRSC, ESRI, LANDSAT
3.	Soil	FAO, HiHydroSoil
4.	Hydro-meteorological	IMD, IMDAA, State WRD, CWC, NHPC
5.	Climate	CMIP6

7. Proposed Methodology

An AWLR has been proposed for installation to monitor the water levels of critical upstream reaches in TRB. Hydrological modelling would be carried out using SWAT and HEC-HMS in order to estimate the water yield potential of major tributaries in the basin and also to determine the peak discharges in the rivers based on rainfall frequency analysis as well as CMIP6 projected climate data. These peak discharges would be further incorporated into HEC-RAS as input to generate inundation maps and consequently, flood susceptibility maps. The workflow of the proposed methodology is shown in Fig. 2.

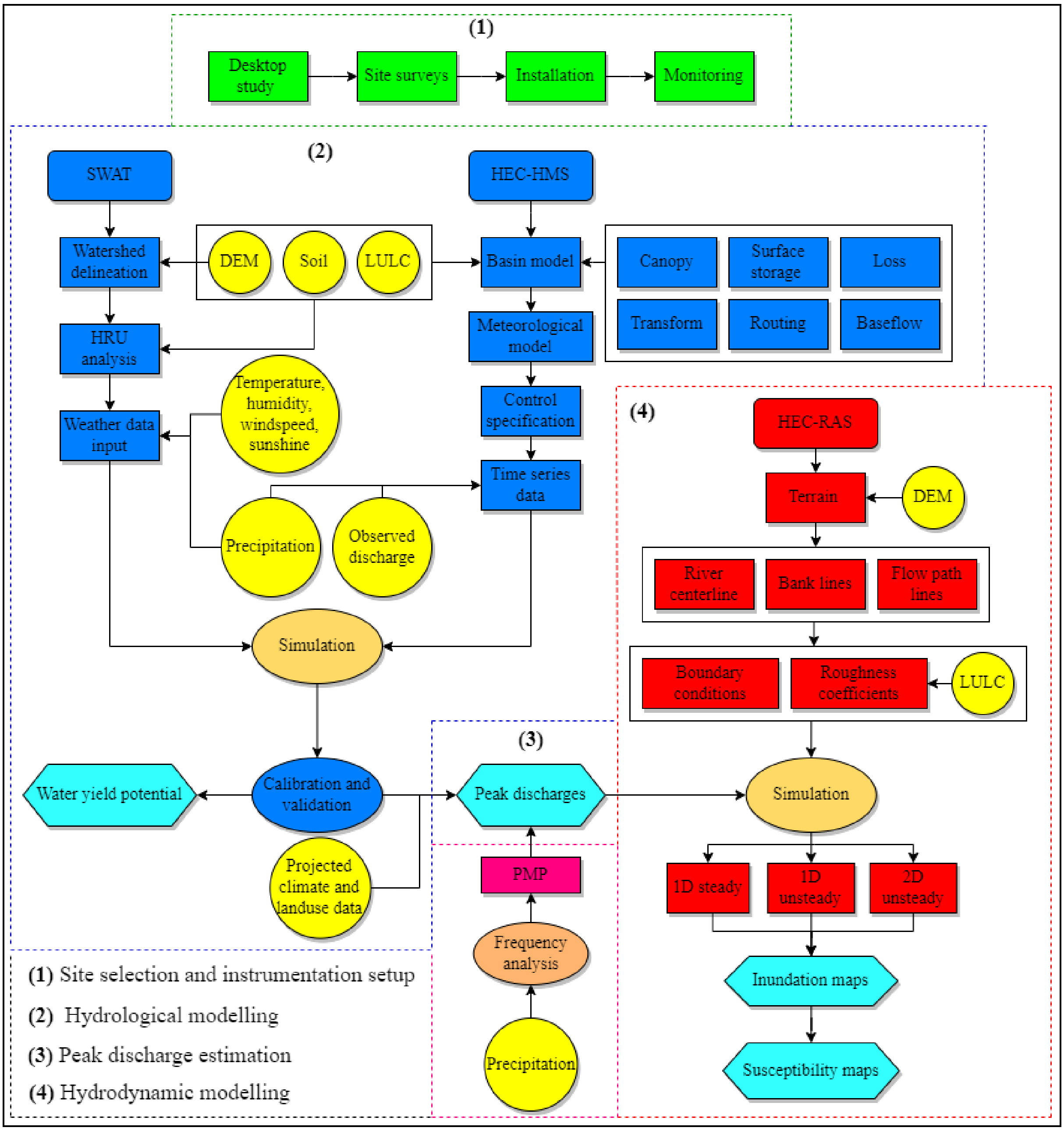

Fig. 2 Workflow of study

8. Beneficiaries/End-users of the study

- Water Resources and River Development Department, Sikkim
- Sikkim State Disaster Management Authority
- Flood Management Program, Sikkim
- Irrigation and Waterways Department, West Bengal
- West Bengal Civil Disaster Management and Civil Defence Department
- Water Resources Investigation and Development Department, Govt. of West Bengal
- Ministry of Urban Planning and Development, State and Central Government
- Ministry of Environment, Forest and Climate Change
- Ministry of Water Resources, River Development and Ganga Rejuvenation
- Academic and research institutions
- Local populace

9. Proposed Timeline of the Study

S. No.	Work element	1st year				2nd year				3rd year			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.	Development of plan and procedure for scientific work	■											
2.	Recruitment of personnel	■	■										
3.	Procurement of instruments and setup	■	■	■	■	■							
4.	Data acquisition and generation			■	■	■	■	■	■	■	■	■	
5.	Data analysis			■	■	■	■	■	■	■	■	■	
6.	Hydrological modelling and water yield potential assessment					■	■	■	■	■	■		
7.	Hydrodynamic modelling and inundation mapping							■	■	■	■	■	
8.	Report writing				■				■				■

10. Cost Estimate

a) Total cost of the project: ₹ 28.52 lacs
b) Source of funding: NIH
c) Head-wise cost:

Head/Post	Amount (₹ In Lakh)			
	Year 1	Year 2	Year 3	Total
Project Staff: JRF (1)	4.84	4.84	4.84	14.52
Consumables	0.30	0.30	0.30	0.90
Contingency	0.50	0.50	0.50	1.50
Travel and field expenses	1.2	1.2	1.2	3.60
AWLR (1)	8.00	-	-	8.00
Total				28.52

d) Justification of head-wise costs:

Salary: Full time one personnel (junior resource fellow) for the project will be required for assistance in the field data collection, data processing and technical analysis.

Consumables: Proposed amount is very nominal and will be mainly used to meet the stationary and other consumables.

Contingency: This mainly includes the contingent amount for unforeseen expenditures.

Travel and field: Travels would be essential for installation of instruments, data collection and interaction with local authorities and populace.

AWLR: An AWLR is required to monitor the water levels in the ungauged tributaries of the basin.

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