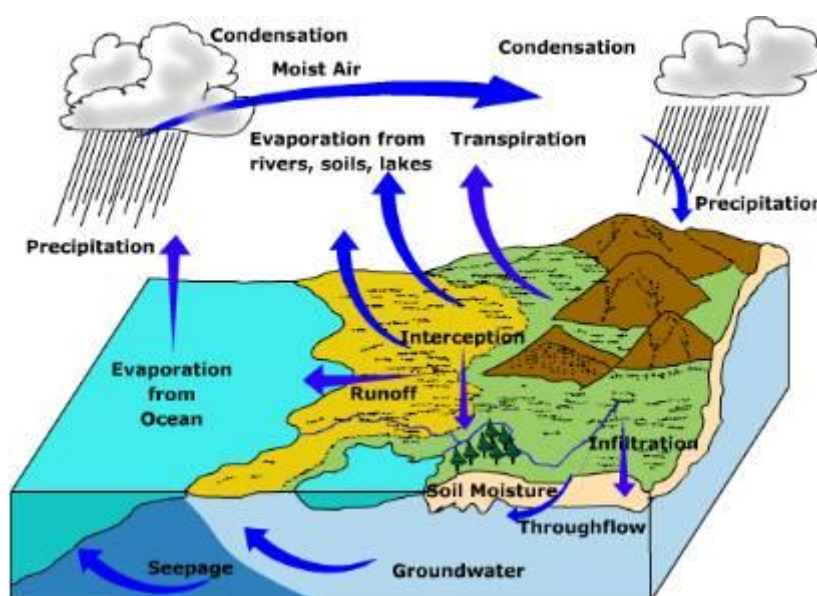


AGENDA AND AGENDA NOTES FOR THE 55th MEETING OF THE WORKING GROUP OF NIH

APRIL 28-30, 2025
AT 1000 HRS



NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE-247667

AGENDA AND AGENDA NOTES FOR THE 55th MEETING OF THE WORKING GROUP OF NIH

AGENDA ITEMS

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ITEM NO. 55.1 Opening Remarks by the Chairman

ITEM NO. 55.2 Confirmation of the minutes of 54th meeting of the Working Group

The 54th meeting of the Working Group was held during 22-23 Feb., 2024. The minutes of the meeting were circulated to all the members and invitees vide letter **No. RMOD/WG/NIH-10 dated 15th May, 2024**. No comments were received on the circulated minutes. A copy of the minutes of the 54th Working Group is given in **Annexure-A (Page # 4)**.

The Working Group may please confirm the minutes.

ITEM NO. 55.3 Action taken on the decisions/recommendations of the previous Working Group meeting

During the 54th 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. 55.4 Presentation and discussion on the status and progress of the work programme for the year 2024-25.

The approved 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:

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1. Ground Water Hydrology Division	37
2. Hydrological Investigation Division	88
3. Centre for Cyrosphere and Climate Change Studies	126
4. Environmental Hydrology Division	195
5. Surface Water Hydrology Division	261
6. Water Resources System Division	334

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 2024-25 shall be presented in detail. The Working Group may please consider the progress and status of the Work Programme for the year 2024-25.

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

ITEM NO. 55.5 Presentation and finalization of the work programme for the year 2025-26.

The proposed Work Programme of the six Divisions of the Institute for the year 2025- 26 has been given in the **Annexure B** in the following order:

	Page #
1. Ground Water Hydrology Division	39
2. Hydrological Investigation Division	89
3. Centre for Cyrosphere and Climate Change Studies	129
4. Environmental Hydrology Division	198
5. Surface Water Hydrology Division	263
6. Water Resources System Division	336

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

Division	No. of Studies/Projects During the Year 2025-26					
	New		Ongoing		Total	Consultancy Projects
	Internally funded	Sponsored	Internally funded	Sponsored		
Ground Water Hydrology	1	-	8	3	12	
Hydrologic Investigation	1	-	5	1	07	
Centre for Cyrosphere and Climate Change Studies	3	1	11	3	18	
Environmental Hydrology	3	-	8	5	16	5
Surface Water Hydrology	6	-	5	1	12	
Water Resources System	2	1	10	1	14	
Total	16	2	47	14	79	

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 2024-25 shall be presented.

ITEM NO. 55.6: Any Other Item with Permission of the Chair.

ANNEXURE – A

MINUTES OF THE 54th WORKING GROUP MEETING

NATIONAL INSTITUTE OF HYDROLOGY, ROORKEE

Minutes of the 54th Meeting of NIH Working Group (22-23 Feb., 2024)

The 54th meeting of NIH working group was held during 22-23 Feb., 2024 at Roorkee under the Chairmanship of Dr. M.K. Goel, Director (NIH). A list of participants of the meeting is given in Annexure-I.

ITEM NO. 54.1: 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 2023-24 and to formulate the work program of 2024-25. 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. No.	Member	Suggestion(s)
1.	Dr. Bhishm Kumar	Suggested to carry out extensive review while planning a new study Suggested to include beneficiary in all studies Develop a database and share it in the public domain Suggested to take up collaborative studies as team and avoid isolated studies
2.	Dr. Manoj P. Samuel	Need to work together with related organisations to overcome challenges of climate change. Suggestion for data base and data sharing
3.	Sh. Sudhindra Mohan Sharma	Dissemination of knowledge/R&D output from lab to field for benefit of public/stakeholders To carry out studies in focussed areas including the wetlands
4.	Prof. S.S Grewal	To do R&D keeping in view the need of common man and other stakeholders
5.	Prof. M.L. Kansal	Suggestion for carrying out inter-division & collaborative R&D work
6.	Dr. (Mrs.) Sadhana Malhotra	The WG meeting can be held for three days instead of two days in order to give more time for presentations and subsequent discussions. The suggestions/ recommendations by the experts in the previous meeting, and the action taken, should be mentioned during the presentations of ongoing studies. PERT/CPM and Gantt charts can be useful tools to plan and apply in all the research studies so that they are completed on time. Deliverables for stakeholders may be clearly delineated in all the presentations. A few short films can be regularly made highlighting some of the studies and uploaded on the NIH website, youtube and other social media for wider circulation and benefit of the society at large. Engagement of retired scientists to utilize their experience/knowledge for Institute's R&D activities

7.	Prof. Ramakar Jha (online)	The scientific divisions should plan to write text books in their domain areas of R&D Suggestion to convert R&D works in IS codes
8.	Dr.Praveen Thakur	To carry out collaborative research Assured full support to NIH for studies involving application of RS&GIS with state of art applications and facilities Encouraged to utilise all features of SWAT model for water quantity as well as for water quality aspects of watersheds Induction training of Scientists
9.	Er. Pankaj Kumar Sharma	Appreciated for having nice interactions with NIH during WG Need to devise a mechanism for data sharing b/w CWC & NIH

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

ITEM No. 54.2: CONFIRMATION OF MINUTES OF 53rd MEETING OF 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. The members confirmed the minutes of the 53rd Working Group meeting.

ITEM No. 54.3: ACTION TAKEN ON THE DECISIONS/RECOMMENDATIONS OF THE PREVIOUS WORKING GROUP MEETING

Er. Omkar Singh, Scientist G & Head (Technical Cell)/Member Secretary (WG) gave a brief account of the actions taken on the recommendations/ decisions of the 53rd working group meeting.

ITEM Nos. 54.4 & 54.5: PRESENTATION AND DISCUSSION ON THE STATUS AND PROGRESS OF THE WORK PROGRAMME FOR YEAR 2023-24 AND FINALIZATION OF THE WORK PROGRAMME FOR YEAR 2024-25

The Member-Secretary requested the respective Divisional Heads to present the progress of studies carried out during 2023-24 and also to present the proposed studies for F.Y. 2024-25. Accordingly, the progress of various studies and sponsored projects, and proposal for new studies and projects during 2024-25, were presented by all Scientific Divisions during the two-day deliberations of the Working Group. The outcome of the Division-wise study/project presented during the meeting are given in the following.

CENTRE FOR CRYOSPHERE AND CLIMATE CHANGE STUDIES (C4S)

The overview of the technical activities of Centre for Cryosphere and Climate Change Studies (C4S) was presented by Dr. Surjeet Singh, 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 2023-24

S. No.	Title of Project/Study	Recommendations/ Suggestions
Internal Studies (Completed)		
1.	Climate Change Scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River Basin	PI requested for an extension of 06 months, for completing the objective related to groundwater, which was approved by WG members till Sept. 30, 2024.
Internal Studies (Ongoing)		
1.	Ascertaining the efficacy of use of State-of-the-art technologies for spring mapping and sustainability of springs through suitable interventions	No specific comments.
2.	Geo-Hydro-Chemical and Isotopic aspects of occurrence of Springs: A case study from the major settlement areas of Bhagirathi basin, Uttarakhand, India	Sh. Sudhindra Mohan Sharma advised that local geology should also be considered in the study.
3.	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	Dr. Bhishm Kumar suggested to compare runoff fractions with isotopic measurements. Dr. R. P. Pandey enquired the need of ensembles-based modeling which was clarified by the PI.
4.	Investigation on occurrences of extreme rain events across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	Chairman, WG suggested to check extreme events with the cloudburst database developed in the earlier study (NMSHE). Dr Praveen Thakur suggested to use satellite data in addition to IMD gridded data to identify extremes.
5.	Early Signatures of 21st Century on Snow Cover Dynamics in Zaskar River Basin, Ladakh	PI requested for an extension of 03 months. WG Members approved the extension till June 30, 2024.
6.	Comparative Analysis of Fine Satellite & Reanalysis Products in Upper Ganga Basin using Multi-criterion Decision-Making	Dr. Praveen Thakur from IIRS proposed incorporating IMD gridded precipitation data and the CHIRPS dataset into the analysis. Chairman WG, on request of PI, approved the omission of MCDM and

		GDM analyses as performance evaluations are sufficiently evident from the performance metrics. PI also requested for an extension of 03 months which was approved by WG members till June 30, 2024.
7.	Monitoring and Modelling of the Gangotri glacier catchment under different Climate Scenarios	The title and objectives of this study were revised to include glacier mass balance and supraglacial lakes monitoring. Chairman, WG suggested speeding up the process of AWS installation at Gangotri catchment. Dr. Bhishm Kumar suggested to include isotopic observations and comparing them with past data. Dr. Praveen Thakur suggested comparing the observations with the ongoing data from the Gangotri town.
Internal Studies (New)		
1.	Inventory of Glaciers and Glacial Lakes in Indian Himalayan Region	Dr. Praveen Thakur suggested to change the title as “Updation of Glaciers and Glacial Lakes in Indian Himalayan Region” because NRSC has already prepared an inventory.
2.	Assessment of Hydrological Extremes and Impact on Future Water Availability in Pennar River Basin under Changing Climate	Chairman, WG suggested that the study period shall be reduced to 01 year.
3.	Glacio-hydrological and GLOF investigations over the Triloki glacier,	IIRS Dehradun has been included as collaborator in the study as per discussion during the meeting.
4.	WRF-based dynamical downscaling of CMIP6 climate projections over Himalaya and surrounding Region	Dr. R. P. Pandey suggested to compare the results with other dynamically downscaled datasets.
5.	Integrated long-term monitoring of Khatling Glacier, Bhilangana basin, Uttarakhand	Chairman, WG advised to shift the objective pertaining to establishment of base camp and hydro-meteorological observatories to the methodology part.
6.	A Spatially Explicit Assessment of CMIP6 General Circulation Models for the Indian Himalayan Region	No specific comments.
7.	Climate change impacts on water resources availability and hydropower potential assessment in the Himalayan Satluj river basin (up to Kasol).	Dr. Grewal suggested to incorporate Forest Department, Shimla data of the Satluj river basin in the study.
8.	Influence of Climate Change and Future Response of the Milam Glacier (Central Himalaya, India): Science – Practice - Policy	No specific comments.
Sponsored/Collaborative Projects (Completed)		

1.	Identification of Source and Causes of the gushing water in the premises of Jaypee Colony in the night of 02 January, 2023	No specific comments.
2.	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	Not presented.
Sponsored/Collaborative Projects (Ongoing)		
1.	Assessment of glacier-climate functional relationships across the Indian Himalayan region through long-term network observations	Not presented.
2.	Satellite based mountain hazard assessment and monitoring (MHAM) in Uttarakhand, joint with IIRS Dehradun – Sponsored by IIRS	Not presented.
Consultancy Studies (Ongoing)		
1.	System Studies for Proposed Farakka-Sundarban Link Project	Not presented.

Recommended Work Programme for the Year 2024-25

S. No.	Title of Project/Study	Study Team	Duration	Funding
Internal Studies				
1.	Ascertaining the efficacy of use of State-of-the-art technologies for spring mapping and sustainability of springs through suitable interventions	SS Rawat (PI), SM Pingale, PK Mishra, DS Bisht, Rajesh Singh	3 years (04/22-03/25) Ongoing	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	SS Rawat (PI), Suhas Khobragade, MK Sharma, MS Rao, SM Pingale, PK Mishra	03 Years (04/23-03/26) Ongoing	NIH
3.	Climate Change Scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River Basin	Sunil Gurrapu (PI) YRS Rao, RV Ramana, Nitesh Patidar, TVNAR Kumar, CE, WRD, AP	02 years (04/22-09/24) Ongoing	NIH
4.	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, Lavkush Patel, Akshaya Verma, Madhusudan Thapliyal	05 Years (03/23-02/28) Ongoing	NIH

5.	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	NIH
6.	Early Signatures of 21st Century on Snow Cover Dynamics in Zaskar River Basin, Ladakh	DS Bisht (PI) PG Jose	03 years (07/21-06/24)	NIH
7.	Comparative Analysis of Fine Scale Satellite & Reanalysis Precipitation Products in Upper Ganga Basin using Multi-criterion Decision-Making	DS Bisht (PI) MK Goel	02 years (06/22-06/24)	NIH
8.	Monitoring and Modelling of the Gangotri glacier catchment under different Climate Scenarios	Lavkush Kr Patel (PI), Akshaya Verma, Vishal Singh, Kapil Kesarwani, Surjeet Singh, Jatin Malhotra	03 years (04/23-03/26) Ongoing	NIH
9.	Updation of Glaciers and Glacial Lakes in Indian Himalayan Region	Surjeet Singh (PI), Vishal Singh, Lavkush Kr Patel, Akshaya Verma, M. Thapliyal	02 years (04/24-03/26) New	NIH
10.	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, M. Thapliyal, TVNAR Kumar, CE, WRD, GoAP	01 year (04/24-03/25) New	NIH
11.	Glacio-hydrological and GLOF investigations over the Triloki glacier, Bhaga basin, Western Himalaya	Lavkush Kr Patel (PI), Akshaya Verma, Vishal Singh, Surjeet Singh	03 years (03/24-03/27) New	NIH
12.	WRF-based dynamical downscaling of CMIP6 climate projections over Himalaya and surrounding Region	Kuldeep Sharma (PI), Ashwini Ranade, Sahidul Islam, Associate Director, CDAC, Pune	03 years (04/24-03/27) New	NIH
13.	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	NIH
14.	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	NIH
15.	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	NIH

16.	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	NIH
Sponsored/Collaborative Projects				
1.	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) Ongoing	Sponsored by NMHS- GBPNIHE
2.	Satellite based mountain hazard assessment and monitoring (MHAM) in Uttarakhand, joint with IIRS Dehradun – Sponsored by IIRS	Vishal Singh (PI-NIH), RS Chatterjee (Lead PI-IIRS), Praveen K Thakur, Pankaj R. Dhote, NIH Roorkee (PI-NIH) Sanjay K Jain (Ex. Sc., NIH)	01 year (01/23-01/24) Funds Recvd Nov-23. Ongoing	Sponsored by IIRS, Dehradun
Consultancy Studies				
1.	System Studies for Proposed Farakka-Sundarban Link Project	Surjeet Singh (PI), MK Goel, PK Singh, PK Mishra, Vishal Singh, Nitesh Patidar	1.5 years (12/22-05/24) Ongoing	Sponsored by NWDA

ENVIRONMENTAL HYDROLOGY DIVISION

The overview of the technical activities of the Environmental Hydrology Division (EHD) during the year 2023-24 was presented by Dr. R.P. Pandey, Scientist ‘G’ & Head, EHD. 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 2023-24

S.No.	Study	Recommendations/Comments
Sponsored Projects (Ongoing)		
1.	Title: Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS) Study Group: Omkar Singh (PI), Rajesh Singh, Jyoti P Patil, VK Tyagi, Kalzang Chhoden, Rajesh Agarwal Partners: MNIT-Jaipur, IIT-Bombay, IRMA-Anand Duration: 5 Years (04/19-09/24), Sought extn. for 6 months. Project Cost: 5.1 Crores Sponsored by: DST Status: In-progress	Dr. Rajesh Singh presented the progress of the study and the outcomes in the Working Group meeting. The WG members appreciated the outcomes of the study and emphasized the need for such types of studies to deal with the deteriorating water quality of water bodies. The members also visited the experimental sites of the study.

2.	Title: Irrigation Efficiency Improvement for Medium Irrigation Project (MIP) Shahnahar, H.P. Study Group: R. P. Pandey, (PI), J. P. Patra, Rajesh Singh, Shakti Suryavanshi, SK Kumre Duration: 3 Years (12/17-05/23), Further Extension to be Requested due to late installation of field instruments Project Cost: 75 Lakh Sponsored by: NHP Status: In-progress	Dr. R. P. Pandey briefed about the progress of the project and the extension has been requested to the sponsoring agency up to Dec 2024. The PI informed that the title of the project has been revised.
3.	Title: 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 Study Group: Vinay Kumar Tyagi (PI) Duration: 5 Years (04/2018 - 03/2023) Sponsored by: DBT; Project Cost: 106.5 Lakh Status: In-progress	Dr. Vinay Tyagi briefed about the progress of the project and the extension has been requested to the sponsoring agency up to Jun 2024.
Collaborative Sponsored Projects (Ongoing)		
4.	Title: Isotopic and geochemical approach to study vulnerable confined and unconfined drinking water aquifers in Varanasi and surrounding area, India Study Group: Rajesh Singh (PI), R.P. Pandey Collaborators: BHU, Varanasi (Lead), BARC, Mumbai, ICER, Hungary. Duration: 3 Years (07/21-06/24) Sponsored by: BHU; Status: In-progress	Dr. Rajesh Singh reported that this study is in progress in collaboration with other institutions.
5.	Title: SARASWATI 2.0 - Identifying best available technologies for decentralized wastewater treatment and resources recovery for India Study Group: Vinay Kumar Tyagi (Co-PI) A.A.Kazmi (PI, IITR) Duration: 4 Years (03/20-06/24); Sponsored by: DST Project Cost: 175.0 Lakh; Status: In-progress	Dr. Vinay Tyagi briefed about the progress of the project.
6.	Title: Comprehensive characterization of variably processed sewage sludge in Ganga basin to classify its suitability for safe disposal Study Group: Vinay Kumar Tyagi (Co-PI),	Dr. Vinay Tyagi briefed about the progress of the project.

	A.A.Kazmi (PI, IITR) Duration: 02 Years (01/22-03/24) Sponsored by: CPCB & NMCG; Status: In-progress	
Internal Study (Ongoing)		
7.	Title: Characterization of Groundwater Dynamics in Krishna-Godavari Delta interims using groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants Study Group: M. K. Sharma, (PI), Suhas Khobragade, Rajesh Singh Duration: 2 Years (04/22-03-24) Status: In-progress	Dr. M. K. Sharma presented the progress and the findings of the study. The members appreciated the work. Dr. S Grewal suggested to share the findings of the study with the stakeholder (farmers etc.) to realize the ground level scenario of water pollution. Dr. Sharma informed that after report submission, a workshop is planned for sharing the findings with stakeholders.
8.	Title: Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures Study Group: Rajesh Singh (PI), R. P. Pandey, Sumant Kumar, Pradeep Kumar, M. K. Sharma, V. K. Tyagi, Kalzang Chhoden Duration: 3 Years (07/21 – 06/24), 1 Year extension was requested by PI Project Cost: 30.1 Lakh Status: In-progress	Dr. Rajesh Singh presented the progress of the study. Members made following suggestions: Dr. Sudhindra Mohan Sharma, Ex-Nodal Officer, MoDWS, Indore suggested correlating As concentration with the drainage of the study area. Dr. Bhishm Kumar, IAEA (Retd.) suggested isotope analysis to understand the recharge in the aquifers. Dr. Samuel suggested to consider remediation of As through ex-situ treatment or others.
9.	Title: Simulation of Non-Point Source Pollution Processes in Song River Study Group: Pradeep Kumar, (PI), M.K. Sharma, Rajesh Singh Duration: 4 Years (11/19-10/23) Extension up to Jun 2024 for submission of report Status: In-progress	Dr. Pradeep Kumar presented the progress and the findings of the study. The PI requested to grant extension up to June 2024 for report submission to include the outcome of village level surveys.
10.	Title: Hydrological Studies for the Conservation of Rewalsar Lake Study Group: Kalzang Chhoden (PI), Rajesh Singh, R. P. Pandey, Pradeep Kumar, Vinay Kumar Tyagi, Omkar Singh, Suhas Khobragade, D.S. Malik (GKU, Haridwar) Collaborator: HPSWA, Shimla Duration: 3 Years (04/23-03/26) Project Cost: 53.16 Lakhs Status: In-progress	Dr. Rajesh Singh presented the progress of the study and future planned activities. There were no specific comments /suggestions.
11.	Title: Comprehensive evaluation of disinfection units of STPs in Ganga basin:	Dr. V. K. Tyagi presented the progress of the study and future planned activities.

	Formation & Control of emerging oxidation precursors. Study Group: Vinay Kumar Tyagi (PI), Rajesh Singh, Mukesh K. Sharma, Pradeep Kumar, J. P. Patra, Kalzang Chhoden, R.P.Pandey (NIH) Bhanu P Vellanki and A.A Kazmi (IITR) Duration: 3 Years (04/2023 – 03/2026) Project Cost: 73.66 Lakh Status: In-progress	
Proposed New Studies (Internal)		
12.	Title: Nanotechnology-enabled Multifunctional Materials for the Detection and Remediation of Arsenic in Contaminated Water Study Group: Prasanta Kumar Sahoo (PI), R. P. Pandey, M. K. Sharma, Rajesh Singh, Pradeep Kumar, Vinay Kumar Tyagi, Kalzang Chhoden, Sumant Kumar Duration: 3 Years (04/24-03/27) Project Cost: 73.7 Lakh Status: Proposed	Dr. Prasanta Kumar Sahoo presented the proposed plan of study to the Working group. The members agreed on the objectives and requirements of the suggested study and appreciated the proposed work. There were no specific comments /suggestions.
13.	Title: Land and water management plan for rejuvenation of river Tilodki Ganga, Ayodhya Study Group: Dr. Shakti Suryavanshi, Dr. Shailendra K. Kumre, Dr. R. P. Pandey, Dr. Pradeep Kumar, Dr. Rajesh Singh, Dr. M. K. Sharma, Dr. Kalzang Chhoden, Dr. Nitesh Patidar, Dr. V. K. Tyagi Duration: 3 Years (04/24-03/27) Project Cost: 36.6 lakh Status: Proposed	Dr. Shakti Suryavanshi presented the proposed plan of study to the Working group. The members suggested to share the results of study with implementation agency for its practical utility. The title of the study is proposed to be modified as “Land and Water Management Plan for Rejuvenation of River Manorama”.
14.	Title: Groundwater Quality Assessment of Tripura with Special Reference to Arsenic and Fluoride Study Group: Rajesh Singh (PI), V. K. Tyagi, M. K. Sharma, P. K. Sahoo, Kalzang Chhoden, S. Suryavanshi NIH-NERC: Sanjay K. Sharma, S. Barman, W. R. Singh TSPCB, Tripura: Rajib Paul Duration: 3 Years (05/2024 – 04/2027) Project Cost: 33.8 Lakh Status: Proposed	Dr. Rajesh Singh presented the proposed plan of study. The Working Group agreed on the objectives and need of the proposed study. Dr. Bhism Kumar, IAEA (Retd.) and Dr. Manoj P. Samuel, CWRDM, Kozhikode suggested to include solutions for As and F removal in the objective.
15.	Title: Comprehensive Hydrological Study for River Health Assessment and Development of Environmental Management Plan for River Yamuna	Dr. Pradeep Kumar presented the proposed plan of activities for the study. The members appreciated the work proposed to be undertaken and suggested to include CGWB,

	Study Group: Pradeep Kumar (Lead-PI) and team of scientists from EHD, GWHD & HI Duration: 5 Years (05/2024 – 03/2029) Project Cost: 538.7 Lakh Status: Proposed	CWC, Yamuna Basin Organization (YBO) and the Stakeholder State Departments also.

Recommended Work 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 (Co-PI), Jyoti P Patil, VK Tyagi, Kalzang Chhoden, Rajesh Agarwal Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand	5 Years (04/19 - 09/24) Sought extn. for 6 months. Project Cost: 5.1 Crore Sponsored by: DST Status: In-progress
2.	Irrigation Efficiency Improvement for Medium Irrigation Project (MIP) Shahnehar, H.P.	RP Pandey (PI), J P Patra, Rajesh Singh, Shakti Suryavanshi, SK Kumre, NK Bhatnagar	12/17 - 06/24 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)	6 Years (2018-2024) 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 (01/22-06/24) 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 (03/20-06/24) 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 (04/22-06/24) 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 (11/19-06/24) 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, Suhas 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 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.	Nano-technology-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 Manorama River	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), VK Tyagi, MK Sharma, PK Sahoo, Kalzang Chhoden, Shakti Suryavanshi, S.K. Sharma, Swapnali Barman, WR Singh, Rajib Paul (TSPCB)	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-Progress
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

GROUNDWATER HYDROLOGY DIVISION

Dr. Anupma Sharma, Scientist-G and Head, Groundwater Hydrology Division 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 2023-24, and the proposed work program for the year 2024-25. It was informed that in addition to progress in various studies and sponsored projects, work on the development of two software has continued, one patent has been awarded and five new internal studies have been planned. It was reported that a major project on Luni River basin is proposed to be undertaken. Subsequently, detailed presentations on various studies were made by the respective Scientists (PIs) of various studies. Sponsored studies were not presented. The recommendations/ comments of the Working Group members on these studies are summarized below.

Progress of Work Program for the Year 2023-24

S. No.	Title of Project/Study	Recommendations/Comments
Internal Studies (Ongoing)		
NIH/GWH/22-24	Conjunctive Management of Water Resources in IGNP Command	Dr. S.M. Sharma appreciated the work and suggested exploring the relationship between the waterlogged area and the area under the Kharif crops. PI agreed to the suggestion. Further, Dr. S.M. Sharma asked about the groundwater salinity in the IGNP and PI responded to the queries. WG members approved extension of study till May 2024.
NIH/GWH/23-24	Development of Archive of Soil Hydraulic Characteristics	On request, WG members approved extension of study till Sept. 2024. No other specific comments were received from the members.
NIH/GWH/23-25	Enhancement and application of NIH_WISDOM	No specific comments were received from the members.
NIH/GWH/22-25	Studying arsenic genesis and developing alternate water supply management strategies in the Ganga basin	The members suggested that instead of one-time sampling for water quality analysis, both pre & post-monsoon sampling should be carried out for better interpretation of the results. It was also suggested that a re-analysis

		of some samples may be done to double-check the results. PI agreed to the suggestion.
Sponsored Projects (Ongoing)		
NIH/GWH/CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin up to Delhi	Not presented due to time constraints as they are the sponsored research projects
NIH/GWH/DST/19-23	Enhancing Food and Water Security in Arid Regions Through Improved Understanding of Quantity, Quality, and Management of Blue, Green, and Grey Water	Not presented due to time constraints as they are the sponsored research projects
Sponsored Projects (New)		
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.	Not presented due to time constraints as they are the sponsored research projects
NIH/GWH/MoES/ 22-24	Carriers of Mass Transport Contamination in Delhi, NCR	Not presented due to time constraints as they are the sponsored research projects
Internal Studies (New)		
<u>Major Project with Sub-Projects from S. No. 9-12</u>	Enhancing the Sustainability of Water Resources Through Integrated Assessment and Management Techniques in the LUNI River Basin – Rajasthan	No specific comments were received from the members.
NIH/GWH/24-27	Hydrogeochemical Evolution and role of Paleochannels on groundwater quality in the Luni Basin	The members suggested to consider the geomorphology of the study area for understanding the recharge process and subsequent groundwater management.
NIH/GWH/24-26	Estimation of Soil Characteristics and Simulation of Groundwater Recharge in the Luni River Basin	Dr. S. M. Sharma raised concern over the depth of vadose zone, target zones for recharge, and different modeling techniques for recharge estimation. He suggested using an alternative word for 'groundwater recharge' in the title which was agreed by PI.
NIH/GWH/24-26	Hydrogeological Investigations in the Luni River Basin	No specific comments were received from the members
NIH/GWH/24-27	Characterization and Modeling of Multi Aquifer System of LUNI River Basin in Rajasthan Under Climate and Anthropogenic Influences	No specific comments were received from the members
NIH/GWH/24-27	Surface water - groundwater interactions through field techniques and hydrological modelling in Yamuna basin	Members suggested that Dr. Soumyaranjan Sahoo from Surface water Hydrology Division may be included in the team.

Recommended Work Programme for the Year 2024-25

S. No.	Project	Project Team	Duration	Funding
Internal Studies (Ongoing)				
NIH/GWH/2 2-25	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
NIH/GWH/2 2-24	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 – 3/24) In-progress ext. till May 2024	Internal Study
NIH/GWH/2 3-24	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 ext. till Sept. 2024	Internal Study
NIH/GWH/2 3-25	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 (Ongoing)				
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-NIH), Gopal Krishan, Nitesh Patidar, P.K. Mishra (Lead: CAZRI Jodhpur, Partners: NIH, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur)	5 years (03/19 - 07/24) Status: In progress	DST
Sponsored Projects (New)				
1. 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 focus on data scarce regions.	L. Surinaidu (PI-NIH) (Lead: IIT Hyderabad, Partner: McGill University, Canada)	2 years 06/23-07/25 Status: New Study Transferred to NIH from NGRI	DST-SERB
NIH/GWH/ MoES/22-24	Carriers of Mass Transport Contamination in Delhi, NCR	L. Surinaidu (PI-NIH) (Lead: NGRI, Hyderabad)	2 years 10/22-09/24 Status: New Transferred from	MoES

			NGRI	
Internal Studies (New)				
NIH/GWH/24-27	Surface water-groundwater interactions through field techniques and hydrological modelling in Yamuna basin	Sumant Kumar (PI), Nitesh Patidar, L. Surinaidu, Pintu Gupta, Ajit Kumar Behera, Anupma Sharma, Shailendra Kumre, Gopal Krishan	3 years (04/24 – 03/27) Status: New Study	Internal Study
<u>Major Project with sub-projects (S.N. 2-5)</u>	Enhancing 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
NIH/GWH / 24-26	Estimation of Soil Characteristics and Simulation of Groundwater Recharge in the Luni River Basin	Satendra Kumar (PI) Anupma Sharma, L. Surinaidu, Ajit K. Behera, Pintu K. Gupta, Nitesh Patidar	2 years (04/24 – 03/26) Status: New Study	Internal Study
NIH/GWH/24-27	Hydrogeochemical Evolution and role of Paleochannels on groundwater quality in the Luni Basin	Ajit Kumar Behera (PI), L. Surinaidu, Pintu Gupta, Malkhan Singh Jatav, Anupma Sharma, M. K. Sharma, Dr. A. H. Laskar (PRL)	3 years (04/24 – 03/27) Status: New Study	Internal Study
NIH/GWH/24-26	Hydrogeological Investigations in the Luni River Basin	Pintu Kumar Gupta (PI), L. Surinaidu, Nitesh Patidar, Ajit Kumar Behera, Satendra Kumar, Sudesh Chaudhary	2 years (04/24 – 03/26) Status: New Study	Internal Study
NIH/GWH/24-27	Characterization and Modeling of Multi Aquifer System of Luni River Basin in Rajasthan Under Climate and Anthropogenic Influences	L. Surinaidu (PI), Anupma Sharma, Ajit K. Behera Sumant Kumar, Sudesh Chaudhary	3 years (04/24 – 03/27) Status: New Study	Internal Study

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. He also informed about the technology transfer activities organized/proposed by the Division during 2022-23. The progress of each individual study for the year 2023-24 and the proposal for the new studies was presented by the respective P.I. of the study. The comments/actions suggested by the working group for various studies are given in Table below.

Progress of Work Program for the Year 2023-24

S. No.	TITLE OF STUDY	COMMENTS/SUGGESTIONS
Work Programme of 2023-24		
1.	Hydrogeological and Isotopic investigation of groundwater in Himalayan Watershed of Kashmir, India	Dr. Bhishm Kumar suggested to prepare d-excess plots and include in final report.
2.	Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions of India	Not presented
3.	Runoff and Water Storage Capacity Estimation Using Different Resolutions of Topographic Data for Deciding Rainwater Harvesting Strategies	Chairman, WG suggested modifying the title to "Runoff and Water Storage Capacity Estimation for Deciding Rainwater Harvesting Strategies"
4.	Sedimentation and Water Quality Study of Fulhar Lake, Pilibhit (U.P.)	Not presented
5.	Developing a Stable Isotopic Analysis System for Analyzing the Dissolved Nitrates in Water	Dr. Someshwar Rao informed that conducting a ^{15}N analysis using an online analysis system with the necessary Isotope Ratio Mass Spectrometry (IRMS) instrument may exceed a cost of Rs 4.5 crores. Due to the substantial budget, it is proposed to drop this project. In response to this, Dr. Bhishm Kumar recommended not to drop the project but to continue it by adopting an offline sample preparation technique, which is not only cost-effective but is also employed at various laboratories of repute. Dr. Bhishm Kumar also expressed his willingness to provide technical support for the development of such an offline system.
6.	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/	No specific comments/suggestions.

7.	Expansion of the Indo-German Competence Centre for Riverbank Filtration –CCRBF	No specific comments/suggestions.
8.	Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	No specific comments/suggestions.
9.	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	Not presented
Proposed New Studies for 2024-25		
1.	Development of radiocarbon dating facility	Dr. Bhishm Kumar suggested that Benzene line may also be prepared to explore groundwater age dating up to 50k yrs.
2.	Understanding Surface Water Groundwater Interactions in the Narmada River Basin and its Hydrological Implications	Chairman, WG suggested to discuss the study with NCA and Bhopal RC. Dr Bhishm Kumar suggested to include the Bhopal regional center and the state groundwater department in this study. Sh. Sudhindra Mohan Sharma suggested to carry out this study with more focus on factors controlling the base flow in the Narmada River basin.
3.	Hydrological and hydrogeological investigations in the Yamuna river basin using isotope techniques	No specific comments/suggestions.
4.	Fingerprinting of aquifer dynamics in India through isotopic and geochemical approach: demand driven investigations at regional scale under NAQUIM 2.0	No specific comments/suggestions.
5.	Quantifying Current and Future Meteorological Drought Characteristics and Identifying Risk Zones in Central India	Chairman, WG suggested to carry out the study for Uttar Pradesh region of Yamuna basin also. He also suggested to add an expert from Bhopal RC in the study Dr. Surjeet Singh, Sc-G and Head C4S, suggested to look into the work already done by Bhopal RC Dr. Grewal suggested to review the work done by various agricultural universities and other departments of the state

Recommended Work Programme for the Year 2024-25

S. No.	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	3 years (04/22-03/25)	On-going
2.	Runoff and Water Storage Capacity Estimation for Deciding Rainwater Harvesting Strategies	Dr. S.M. Pingale(PI) Dr. Soban Singh Rawat, Dr. S. D. Khobragade Sh. Rajeew Gupta	2 Years (04/23-03/25)	On-going
3.	Sedimentation and Water Quality Study of Fulhar Lake, Pilibhit (U.P.)	Sh. Rajeew Gupta (PI), Dr. S.D. Khobragade Dr. S.M. Pingale	2 Years (04/23-03/25)	On-going
4.	Development of radiocarbon dating facility	Dr. Tripti Muguli (PI) Dr. Someshwar Rao, Dr. 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	Dr. Amit Pandey (PI) Dr. S. D. Khobragade, Dr. Someshwar Rao Dr. Tripti Muguli	3 years (04/24-03/27)	New Study
6	Hydrological and hydrogeological investigations in the Yamuna River basin using isotope techniques.	Dr. Tripti Muguli (Project Coordinator), Dr. Suhas Khobragade, Dr. Someshwar Rao Sh. Ruchir Patidar, Sh. Vipin Agrawal, Dr. 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	Dr. Tripti Muguli (PI), Dr. S.D. Khobragade	3 years (04/24-03/27)	New Study
8.	Quantifying Current and Future Meteorological Drought Characteristics and Identifying Risk Zones in Central India.	Sh. Ruchir Patidar (PI), Dr. S.M. Pingale, Dr. 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	Dr. Gopal Krishan)PI(Dr. S .Singh, Dr. M .S .Rao BGS, UK: Dr .Dan Lapworth Dr .Alan MacDonald	7 years)12/17-11/24(	On-going

S. No.	Project Title	Study Team	Duration	Status
	by funding agency(	Dr .Daren Goody		
2.	Expansion of the Indo-German Competence Centre for Riverbank Filtration –CCRBF	Dr. Gopal Krishan)PI & Co-coordinator(Federal Min .of Education and Research, Germany	)07/20 – 03/24((likely to be extended further)	On-going
3.	Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen	Dr. Gopal Krishan)PI(, Dr. MS Rao DST-SERB	04/21 – 03/24 (likely to be extended up to 10/2024)	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. S.D. Khobragade Dr. Pradeep Kumar, Dr. Nitesh Patidar, Dr. Surjeet Singh.	5 years (04/22- 03/27)	On-going

SURFACE WATER HYDROLOGY DIVISION

Dr. A.K. Lohani, Sc G & Head, Surface Water Hydrology Division presented 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. The record of discussions for the respective study is given below:

Progress of Work Program for the Year 2023-24

S. No.	Title of Project/Study	Recommendations/Suggestions
Internal Studies (Completed)		
1.	Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Operation of Reservoirs	Completed. No specific action suggested.
2.	Hydraulic force-inversion equation for exact modeling of hydraulic jumps in rectangular channels	Completed. There were no specific comments from the members on the study.

Internal Studies (Ongoing)		
1.	Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model	No specific action was suggested.
2.	Hydrological Study for revival and restoration of traditional water bodies in Bikaner, Rajasthan	No specific action was suggested.
3.	Review of design flood and dam break analysis of Khadakhai Dam in Odisha	No specific action was suggested.
4.	Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes	Transferred to C4S.
5.	Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and Water Resources in India through Scientometrics.	Transferred to WRSD.
6.	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	No specific action was suggested.
7.	Estimation of confidence intervals of index flow duration curves	No specific action was suggested.
8.	Hydrologic and hydraulic study for Jata Ganga river at Jageshwar dham	No specific action was suggested.
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 presented by PI. There were no specific comments from the members on the study.
Internal studies (New)		
1.	Entropy and Image Processing Based Non-Contact Discharge Monitoring Techniques: Testing and Implementation for Indian rivers	PI presented the objectives and scope of the proposed study. There were no specific suggestions/comments from the members.
2.	A Flood Forecasting Framework Coupling a High Resolution WRF Ensemble with 2D Hydrodynamics Model for Himalayan Mountainous Area.	PI presented the objectives and scope of the proposed study. There were no specific suggestions/comments from the members.
3.	Basin-scale, integrated water resources assessment through integrated hydrological modelling	PI presented the objectives and deliverables of the proposed study. Suggestion from Dr. Praveen K. Thakur (member WG) were to include: i) Soil moisture data from Bhoonidhi; ii) An objective on satellite data assimilation.
4.	Comprehensive Mapping of Water Budget Dynamics and Reservoir Sedimentation in the Upper Krishna Basin using Google Earth Engine.	PI presented the objectives and deliverables of the proposed study. Dr. Praveen Thakur suggested to include SWOT mission data in the present study.

5.	Water Resources Planning and Management using DSS (PM) under Changing Climatic and Land-Use Conditions	PI presented the objectives and deliverables of the proposed study. Dr. Praveen Thakur suggested include Cartosat data for DEM generation.
6.	Web based platform for IDF Design Rainfall Estimates for India	PI presented the objectives and deliverables of the proposed study. Dr. Praveen Thakur suggested to use the word 'curve' instead of 'depth' and to incorporate PMP Atlas data in database.

Recommended Work Programme for the Year 2024-25

S. No.	Title of Project/Study	Study Team	Duration	Funding
Internal studies (Ongoing)				
1.	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	03 Year (July 2022 - June 2025)	NIH
2.	Hydrological Study for revival and restoration of traditional water bodies in Bikaner, Rajasthan	L. N. Thakural; J. P. Patra; M. K. Sharma; R. K. Jaiswal; P. K. Mishra; Nitesh Patidar; N. K. Bhatnagar; Jatin Malhotra; Anil Kumar Chhangani	02 Year (Apr 2022 - June 2024) (Extension required for Six months)	NIH
3.	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	03 Year (April 2022 - March 2025)	NIH
4.	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
5.	Estimation of confidence intervals of index flow duration curves	Sanjay Kumar; Sunil Gurrapu; L. N. Thakural J. P Patra	02 Years (April 2023 - March 2025)	NIH
6.	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 - July 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	B. Sahoo (PI, IIT-Kgp), R. V. Kale, (Co-PI)	04 years (July, 2020 – June, 2024)	STARS (MHRD, GoI)

	integrating human and climate induced impacts			
Internal studies (proposed)				
1.	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 - September 2025)	NIH
2.	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	03 Year (April 2024 - March 2027)	NIH
3.	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 - September 2026)	NIH
4.	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 - March 2026)	NIH
5.	Water Resources Planning and Management using DSS (PM) under Changing Climatic and Land-Use Conditions	Richa Pandey, Chandra Prakash, Sukant Jain, J. P. Patra, R. K. Jaiswal, A. K. Lohani	02 Years (April 2024 - March 2026)	NIH
6.	Web based platform for IDF Design Rainfall Estimates for India	Sukant Jain; A. K. Lohani; J. P. Patra; Richa Pandey; Chandra Prakash	1.5 Years (April 2024 - September 2025)	NIH

WATER RESOURCES SYSTEMS DIVISION

Dr. A. R. Senthil Kumar, Sc. G and Head, presented an overview of the division – work force, vision and missions, major research outputs, research and training facilities, the ongoing and new sponsored and internal studies, training courses and outreach activities organized and upcoming training calendar. Thereafter, individual studies were presented by the respective PIs as given below:

Progress of Work Program for the Year 2023-24

S. No.	Title of Project/Study	Recommendations/ Suggestions
Ongoing Sponsored/ Internal Studies		
1.	Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya Team: P K Singh; Vishal Singh; A K Lohani Duration: 3 years (11/19-11/22), Extended up to 03/24	Not presented due to time constraints as they are the sponsored research projects

	Funding: 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. Team: P K Singh; P K Mishra Duration: 2 years (08/20-07/22), Extended up to 03/24 Funding: NHP (14.50)	Not presented due to time constraints as they are the sponsored research projects
3.	Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya Team: M K Nema; P K Mishra Duration: 3.5 years (08/20-03/24) Funding: NIH (10.22)	Not presented due to time constraints
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. Team: P K Mishra; P K Singh Duration: 2 years (04/21-06/23), Extended up to 03/24 Funding: NHP (9.00)	Not presented due to time constraints as they are the sponsored research projects
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 Team: P K Singh; Vishal Singh; Harsh Upadhyay; Abhilash R. Duration: 3 years (04/22-03/25) Funding: NHP (54.0)	Dr. P K Singh presented the progress of the study. No specific comments/ suggestions were received.
6.	Spatio-temporal Water Availability under Changing Climate and Land-use Scenarios in Wainganga River Basin Team: M K Nema; P K Mishra Duration: 3 years (04/22-03/25) Funding: NIH (9.72)	Dr. M K Nema presented the progress of the study and informed that various Hydro-met, future climatic and other related data have been collected and preliminary analysis have been done. The SWAT model has also been set-up for the basin and further fine tuning is in progress. Dr. Nema also asked for an extension of one more year in order to complete all-study objectives, which has been approved by the WG.
7.	Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics Team: Archana Sarkar; Jyoti Patil; Charu Pandey	Dr. Archana Sarkar presented the background, objectives, methodology, details of analysis & results of the study. She emphasized that scientometric

	Duration: 2 years (05/22-04/24) Funding: NIH	analysis are very important for finding out the research growth in any particular domain and such analysis should be carried out before taking up any study. Dr. Sudhindra Sharma and Dr. Praveen Thakur, members of working group appreciated the work.
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 Team: M K Nema; P. K. Mishra; Praveen Thakur (IIRS) Duration: 3 years (04/22-03/25) Funding: IIRS (30.91)	Not presented due to time constraints as they are the sponsored research projects
New Internal/ Sponsored Studies		
1.	Simulation of operation of multiple reservoirs in Wainganga Basin for conservation and flood control under changing climate scenario Team: A R Senthil Kumar; T Thomas; M K Nema; Harsh Upadhyay; Sunil Gurrapu Duration: 3 years (04/24-03/27) Funding: NIH (21.02)	Dr. A R Senthil Kumar presented the proposed new study. The WG member, Dr. Bhishm Kumar inquired about the requirement of the study from the project authority and suggested to include the relevant personnel from WRD, Maharashtra/ Madhya Pradesh. Dr. Nema informed the requirement of the study as per the earlier discussion with the project authority. The Chairman suggested to replicate this type of study in Yamuna Basin at a later stage.
2.	ResSed – Tool development for prediction of elevation-area-capacity curves of the reservoirs Team: A R Senthil Kumar; U K Singh; P K Singh; Harsh Upadhyay; Nitesh Patidar Duration: 2 years (04/24-03/26) Funding: NIH (11.18)	Dr. A R Senthil Kumar presented the proposed new study. No specific comments/suggestions were received.
3.	Integrated operation of Bisalpur and Isarda reservoirs in Banas river basin, Rajasthan Team: Archana Sarkar; A R Senthil Kumar; P K Mishra; Harsh Upadhyay; Mr. Sanjay Agarwal Duration: 3 years (04/24-03/27) Funding: NIH (19.30)	Dr. Archana Sarkar presented the new study. She informed that the development of rule curve based integrated operational framework for existing Bisalpur dam and under construction Isarda dam is important to ensure reliable releases from the reservoirs for conservation purposes considering forecasted inflow and sediment yield.

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 Team: P K Singh; P K Mishra; Vishal Singh; Harsh Upadhyay; P R Patil; A. R. Senthil Kumar Duration: 2 years (04/24-03/26) Funding: NIH (43.48)	Dr. P K Singh presented the proposed new study. The WG suggested to remove objective number 04 and also advised to drop “...for sustaining water and food security” from the title of the project.
5.	Development of rule-based integrated operation framework for the Mahanadi basin. Team: P K Mishra; M K Goel; P K Singh; A R Senthil Kumar Duration: 1.5 years (04/24-09/25) Funding: NIH (5.0)	Dr. P K Singh presented the proposed new study and no specific comments/suggestions were received.
6.	Assessment of Precipitation Gradients and Temperature Lapse Rates for Hydrological Modelling in a Himalayan Catchment Team: P R Patil; M K Nema; P K Mishra; A R Senthil Kumar; Asif Duration: 3 years (04/24-03/27) Funding: NIH (20.0)	Dr. P R Patil presented the proposed study. Chairman suggested to remove the first objective of study. Dr. Nema informed that flow data will be recorded by installing a flow measuring device at outlet of Henva River under ongoing IIRS-DoS sponsored project Mr. Asif, RA, WRSD will also assist in this study.
7.	Evaluation of Area-Design Curve to estimate sediment distribution in Indian reservoirs Team: U K Singh; A R Senthil Kumar; M K Goel; P R Patil Duration: 2 years (04/24-03/26) Funding: NIH (1.0)	Dr. U K Singh presented the proposed new study and no specific comments/ suggestions were received.
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. Team: Harsh Upadhyay; P K Singh; A R Senthil Kumar; P R Patil Duration: 3 years (04/24-03/27) Funding: NIH (44.52)	Er. Harsh Upadhyay presented the proposed new study. The Chairman suggested to remove the first two objectives of the study. Further, the WG member Dr. Praveen Thakur (IIRS) suggested to add GLOF component in the study.

Recommended Work Programme for the Year 2024-25

S. No.	Title	Study Team	Duration	Funding
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) Ext. up to 03/24	NMHS- MoEF

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
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
4.	Development of Water Accounts for the selected sub-basins of Brahmaputra, Barak and Irrawady-Chindwin basins in 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
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	Vishal Singh, P K Singh, Harsh Upadhyay; Abhilash R.	3 years (04/22-03/25)	NHP
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
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; P. R. Patil; Praveen Thakur (IIRS)	3 years (04/22-03/25)	IIRS
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
2.	ResSed – Tool development for prediction of elevation-area-capacity curves of the reservoirs	A R Senthil Kumar; U K Singh; P. R. Patil; Harsh Upadhyay; Nitesh Patidar	2 years (04/24-03/26)	NIH
3.	Integrated operation of Bisalpur and Isarda reservoirs in Banas river basin, Rajasthan	Archana Sarkar; A R Senthil Kumar; P K Mishra; Harsh Upadhyay; Sanjay Agarwal	3 years (04/24-03/27)	NIH

4.	Water and Land Productivity Accounts for the major river basins of India using water accounting plus: WAPRO-India	P K Mishra; P K Singh; Vishal Singh; Harsh Upadhyay; P R Patil; A. R. Senthil kumar	2 years (04/24-03/26)	NIH
5.	Development of rule-based integrated operation framework for the Mahanadi basin	P K Mishra; M K Goel; A R Senthil Kumar, Harsh Upadhyay	1.5 years (04/24-09/25)	NIH
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; Asif	3 years (04/24-03/27)	NIH
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
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; Vishal Singh; P K Singh; A R Senthil Kumar; P R Patil	3 years (04/24-03/27)	NIH

Er. 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 54th WG meeting**

1.	Dr. M. K. Goel, Director, NIH	Chairman
2.	Dr. Bhishm Kumar, IAEA Consultant, Roorkee	Member
3.	Sh. Sudhindra Mohan Sharma, Ex-Nodal Officer, MoDWS, Indore	Member
4.	Dr. Praveen Thakur, IIRS, Dehradun	Member
5.	Dr. Manoj P. Samuel, CWRDM, Kozhikode	Member
6.	Dr. (Mrs.) Sadhana Malhotra, Mindspace, Dehradun	Member
7.	Dr. M. L. Kansal, WRDM, IIT, Roorkee	Member
8.	Dr. S.S. Grewal, (Retd.), Chandigarh	Member
9.	Er. Sudhir Kumar, CE (Design)/Director, IRI, Roorkee	Member
10.	Dr. Ramakar Jha, Professor, NIT Patna (Online)	Member
11.	Er. Vijay Singh, Dy. Director (Hydrology), CWC	Repr. Member
12.	Er. Pankaj Kumar Sharma, CWC, New Delhi (online)	Repr. Member
13.	Dr. A.K. Lohani, Sc. G & Head, SWH Division, NIH	Member
14.	Dr. R.P. Pandey, Sc. G & Head, EH Division, NIH	Member
15.	Dr. Suhas Khobragade, Sc. G & Head, HI Division, NIH	Member
16.	Dr. A R Senthil Kumar, Sc. G & Head, WRS Div., NIH	Member
17.	Dr. Anupma Sharma, Sc. G & Head, GWH Division, NIH	Member
18.	Dr. Surjeet Singh, Sc. G & Head, C4S Division, NIH	Member
19.	Er. Omkar Singh, Sc. G & Head, Technical Cell, NIH	Member-Secretary

Scientists of NIH:

	C4S Division		HI Division
1.	Dr. Surjeet Singh, Sc.G	24.	Dr. M S Rao, Sc.G
2.	Dr. Soban Singh Rawat, Sc.F	25.	Dr. Gopal Krishan, Sc.E
3.	Dr.(Smt) Ashwini A. Ranade, Sc.D	26.	Dr. Santosh M. Pingale, Sc.D
4.	Dr. Sunil Gurrapu, Sc.D	27.	Dr. Tripti Muguli, Sc.D
5.	Dr. Vishal Singh, Sc.D	28.	Sri. Rajeev Gupta, Sc.B
6.	Dr. Lavkush Kumar Patel, Sc.D	29.	Sri. Ruchir Patidar, Sc.B
7.	Dr. Deepak Singh Bisht, Sc.C	30.	Sri V K Agarwal, Sc.B
8.	Dr. Akshaya Verma, Sc.C	31.	Dr. Amit Pandey, Sc.B
9.	Dr. Kuldeep Sharma, Sc.C		SWH Division
10.	Sri. Rajat Kumar, Sc.B	32.	Dr. S K Singh, Sc.F
	EH Division	33.	Dr. P C Nayak, Sc.F
11.	Dr. M K Sharma, Sc.F	34.	Dr. Sanjay Kumar, Sc.F
12.	Dr. Rajesh Singh, Sc.E	35.	Dr. Ravindra Vitthal Kale, Sc.E
13.	Dr. Pradeep Kumar, Sc.E	36.	Dr. L N Thakural, Sc.E
14.	Dr. Vinay Kumar Tyagi, Sc.D	37.	Er. J P Patra, Sc.E
15.	Dr. Prasanta Kumar Sahoo, Sc.D	38.	Sri. Om Prakash, Sc.B
16.	Dr. Shakti Suryavanshi, Sc.C	39.	Dr. Soumyaranjan Sahoo, Sc.B
17.	Dr. Shailendra Kumar Kumre, Sc.B	40.	Dr. Richa Pandey, Sc.B
	GWH Division	41.	Sri. Chandra Prakash, Sc.B
18.	Dr. Sumant Kumar, Sc.E		WRS Division
19.	Dr. Lagudu Surinaidu, Sc.D	42.	Dr. Archana Sarkar, Sc.,F
20.	Dr. Nitesh Patidar, Sc.C	43.	Dr. P K Singh, Sc.E

21.	Dr. Ajit Kumar Behera, Sc.C	44.	Dr. Manish K. Nema, Sc.E
22.	Dr. Satendra Kumar, Sc.B	45.	Dr. P K Mishra, Sc.D
23.	Sri. Pintu Kumar Gupta, Sc.B	46.	Dr. Pravin Rangrao Patil, Sc.C
		47.	Dr. Umesh Kumar Singh, Sc.C
		48.	Sri. Harsh Upadhyay, Sc.B

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

ANNEXURE – B

Division-wise Work Programme

GROUND WATER HYDROLOGY DIVISION

Scientific Manpower

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



APPROVED WORK PROGRAMME FOR THE YEAR 2024-25

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/G WH/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/G WH/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: Completed	Internal Study
3. NIH/G WH/ 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: Completed	Internal Study
4. NIH/G WH/ 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
5. NIH/G WH/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: In progress	Internal Study
Major Project with Sub-Projects S.N. 6-9	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: In progress	Internal Study
6. NIH/G WH/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: In progress	Internal Study
7. NIH/G WH/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	3 years (04/24 – 03/27) Status: In	Internal Study

		Anupma Sharma, M. K. Sharma, A. H. Laskar, PRL	progress	
8. NIH/G WH/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 Dahiwalale	2 years (04/24 – 03/26) Status In progress	Internal Study
9. NIH/G WH/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: In progress	Internal Study
Sponsored Projects				
10. NIH/G WH/CE HM/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 <i>Partners</i> Haryana Irr. & WR Dept., UPGWD, UYRB, CWC	4 years (04/18- 03/24) Status: Completed	Special Project under “Centre of Excellence” (NHP)
11. NIH/G WH/DS T/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), Nitesh Patidar Satendra Kumar, Gopal Krishan (<i>Lead</i> : CAZRI Jodhpur, <i>Partners</i> : NIH Roorkee, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur)	5 years (03/19 - 01/25) Status: Completed	DST
12. NIH/G WH/DS T- SERB/2 3-25	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: In progress	DST-SERB
13. NIH/G WH/Mo ES/22- 24	Carriers of Mass Transport Contamination in Delhi, NCR	L.Surinaidu (PI from NIH) Lead agency: NGRI	2 years 10/22- 09/24 Status: Completed	MoES
14. NIH/G WH/TH DC/24- 27	Modelling micro-plastic movement through soil Matrix: A step towards plastic waste management	Anjali, (PI), Sunil Gurrapu, Ajay Ahirwar, Prof. C.S.P. Ojha (IITR)	3 years 03/24 – 02/27 Status: In progress	THDC

PROPOSED WORK PROGRAMME FOR THE YEAR 2025-26

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GW H/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/GW H/ 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
3. NIH/GW H/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 Kumre, Gopal Krishan	3 years (04/24 – 03/27) Status: In-Progress	Internal Study
Major Project with Sub-Projects S.N. 4-7	Enhancing the Sustainability of Water Resources Through Integrated Assessment and Management Techniques in the LUNI River Basin – Rajasthan	Head GWH Div. (Project Coordinator) Scientists from GWH Div & NWRC Jodhpur	3 years (04/24 – 03/27) Status: In-Progress	Internal Study
4. NIH/GW H/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, Dr. Sushindra Kumar Gupta	2 years (04/22 – 03/24) Status: In-Progress	Internal Study
5. NIH/GW H/24-27	Hydrogeochemical Evolution and role of Paleochannels on groundwater quality in the Luni Basin (sub-project 2)	Ajit Kumar Behera (PI), L. Surinaidu, Sh. Akshay Vyankat Dahiwal, Satendra Kumar, Pintu Kumar Gupta, Anupma Sharma, M. K. Sharma, A. H. Laskar (PRL)	3 years (04/24 – 03/27) Status: In-Progress	Internal Study
6. NIH/GW H/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 Dr. Sushindra Kumar Gupta	2 years (04/24 – 03/26) Status: In-Progress	Internal Study
7. NIH/GW H/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: In-Progress	Internal Study

Sponsored Projects				
8. NIH/GW H/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: In-Progress	DST-SERB
9. NIH/GW H/GWRD C/24-26	Preparation of Status Reports of the Salinity Ingress in Coastal Area of Saurashtra and Kachchh, Gujarat State	L. Surinaidu Ajit Behera Anupma Sharma Nitesh Patidar Sourabh Nema, Sudesh Chaudhary, Malkhan Singh Jatav (a) Madhavpur-Okha reach & Maliya-Lakhpur reach - L. Surinaidu (PI) (b) Bhavnagar-Una reach & Okha-Maliya reach - Ajit Behera (PI)	2 years 04/24 – 03/26 Status: Transferred from RC Jodhpur	GWRDC
10. NIH/GW H/THDC/ 24-27	Modelling Micro-Plastic Movement through soil Matrix: A step towards Plastic waste management	Anjali, (PI), Sunil Gurrapu, Ajay Ahirwar, Prof. C.S.P. Ojha (IITR)	3 years 03/24 – 02/27 Status: In progress	THDC
New Internal Studies				
11. NIH/GW H/25-27	Prediction of Hydro-Geological Parameters Using Machine Learning Techniques in the Luni River Basin, Rajasthan	Sushindra Kr. Gupta (PI), Sumant Kumar, L. Surinaidu, Satendra Kumar, Nitesh Patidar, Pintu Kr. Gupta	2 years 11/24 – 03/26 Status: study was initiated internally in Nov. 2024	New Internal Study

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); 3 months' extension is required

Location : Ganga basin (From Gangotri to Patna)

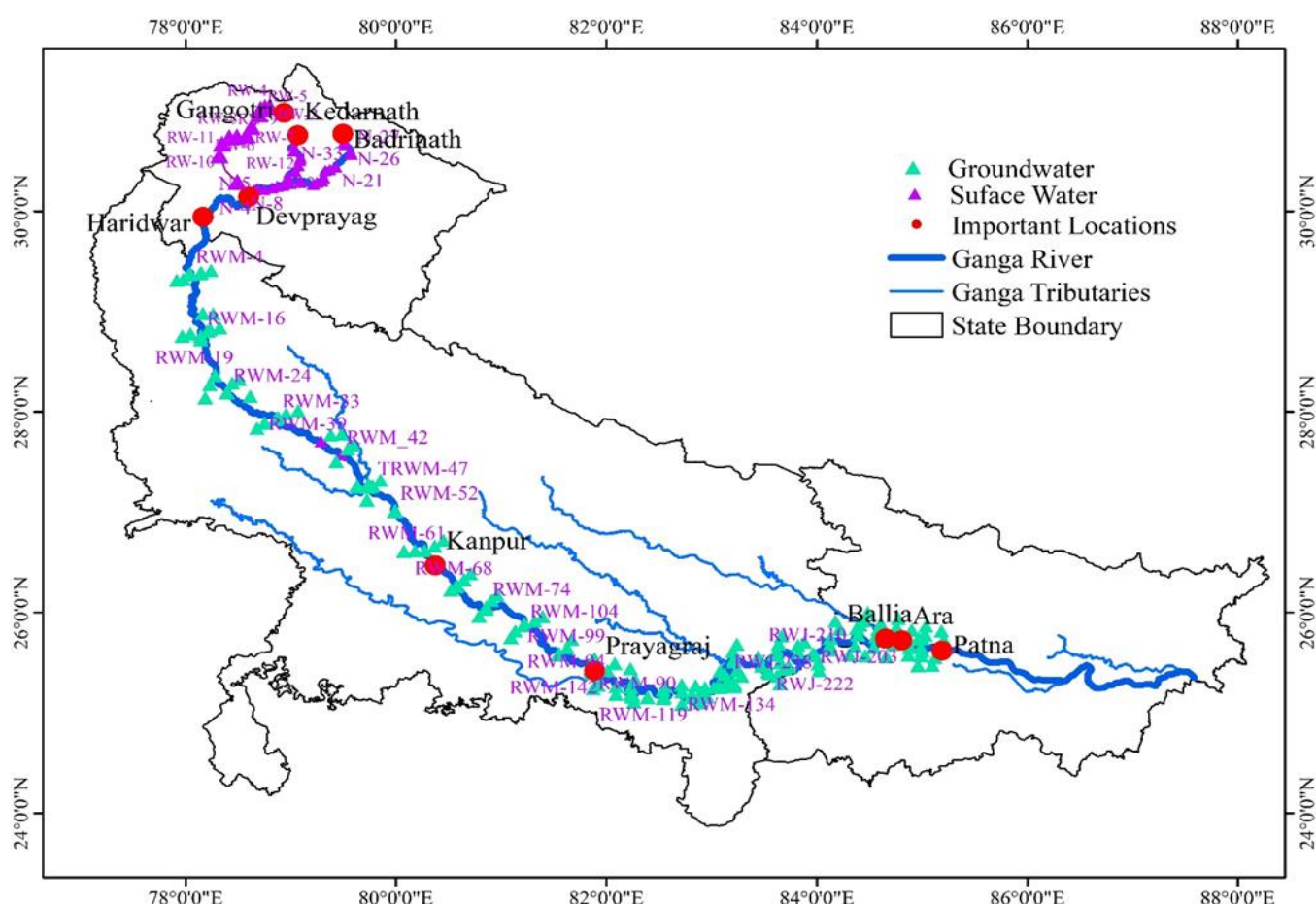


Figure 1: Study area map with groundwater and river water sampling location

Objectives vis-à-vis Achievements:

Objectives	Achievements
Mineralogical characteristic of sediments and water chemistry in the Indian Himalayan region to detect genesis of arsenic.	Pre and Post monsoon sampling of sediment and water completed from Gangotri to Patna for river Ganga and GW. Water quality (major Ions, trace metals and isotopes) analysis have been completed.

	Sediment Characterization: Grain Size analysis completed and further mineral characterization is underway.
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 water supply from the existing treatment units have been collected and analyzed, though very few units are available in the field.

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 are 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 O₂. 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 available in the field. The influent and effluent of treatment unit are tested and then removal efficiencies may be ascertained. It is also planned to develop cost effective treatment units in Lab and it may be upscaled at later stage.

Analysis of Results:

The pre and post monsoon sampling for the water and sediment from Gangotri to Patna on the stretch of Ganga River have been completed. Total 246 (28 surface, 218 groundwater and 54 sediment samples). In situ parameters like pH, EC, ORP and DO were measured at the sampling sites and further analysis of water samples were carried out in laboratory for major ions, trace metals and isotopes.

The pH of the water samples of study area varies from 6.9 to 9.0 (average 7.9) for Ganga river. The EC of the water samples varies from 150 to 729 $\mu\text{S}/\text{cm}$ (average 362 $\mu\text{S}/\text{cm}$) for Ganga river. EC values follows an increasing trend Haridwar to Kanpur. After Kanpur, EC spikes up very sharply and reaches above 602 $\mu\text{S}/\text{cm}$. The influence of river Yamuna can be observed as the EC values Prayagraj the value of 729 $\mu\text{S}/\text{cm}$. The DO values in the River varies between 5.0 to 13.6 mg/L with an average value of 8.4 mg/L. The ORP of the water samples in the study area varies between 19.1 to 213 mv for river water. The decreasing value signifies the increasing settlements and dumping of wastes in the river stream which consumes the oxidizing agents. The alkalinity of the river water samples was 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, Fe, Mn and Zn 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 Some Place. 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 6.29 to 8.62 (average 7.57). Overall the pH values are observed to be decreasing as we go down from Haridwar to Patna. The EC of the water

samples varies from 159 to 2105 $\mu\text{S}/\text{cm}$ (average 717 $\mu\text{S}/\text{cm}$) 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 and Cu were below the permissible level except in few instances however Fe, Mn and Zn are 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 361 $\mu\text{g}/\text{L}$ and with average value of 14 $\mu\text{g}/\text{L}$.

The availability of running arsenic treatment units are very low which 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 300 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. The sampling of water and sediment samples have also been completed from Badrinath, Kedarnath to Devprayag on the stretch of Alaknanda, Mandakini and Ganga River. Total 36 surface water samples and 27 sediment samples were collected in December 2024. In situ parameters like pH, EC, ORP and DO were measured at the sampling sites and further analysis of water samples were carried out in laboratory for major ions, trace metals and isotopes.

The pH of the water samples of study area varies from 5.4 to 8.08 (average 6.67) for Alaknanda and Mandakini river. The EC of the water samples varies from 35 to 226 $\mu\text{S}/\text{cm}$ (average 133 $\mu\text{S}/\text{cm}$) for Alaknanda and Mandakini river. EC values follows an increasing trend Badrinath to Devprayag. The DO values in the River varies between 8.1 to 9.7 mg/L with an average value of 8.8 mg/L. The ORP of the water samples in the study area varies between 32 to 174 mv for river water. 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 and Fe were found to be higher than permissible limit in bulk of the river water samples. In majority of the river samples As, Cr, Pb, Cd and Cu were below the permissible level except in few instances. 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. M.K. 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 (*Completed*)

Duration: Two years (April 2022 – March 2024; extended till June 2024)

Objectives and achievements

S. No.	Study objectives	Achievements
1	Analysis of present groundwater scenario in enroute command of IGNP	The data of groundwater levels acquired from CGWB were analyzed and trend analysis was performed.
2	Mapping of water-logged area in IGNP command using remote sensing	The water-logged areas are identified using remote sensing data. A Google Earth Engine (GEE) application was developed to derive the water-logged area with surface flooding.
3	Estimation of GW recharge from rainfall, canal and irrigation under present and future climatic scenarios.	The recharge due to rainfall and irrigation is estimated using NIH-WISDOM. The canal percolation is estimated using NIH's system model.
4	Conjunctive management of water resources in enroute command area of IGNP canal	The essential groundwater pumping for conjunctive management is estimated using the groundwater modelling within NIH-WISDOM.

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 the Thar Desert of Rajasthan and is therefore the most important water source in the arid Rajasthan. Since the inception of the project, there have 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, Jaisalmer, Barmer, and Jodhpur. It has a CCA of 1.963 million hectares. The project was completed in two stages, Stage-I having a 204 km long feeder which originates from Harike Barrage, Punjab, to reach Masitawali, Rajasthan, and a 189 km long main canal from Masitawali to Chattergarh in Bikaner district (Figure 1).

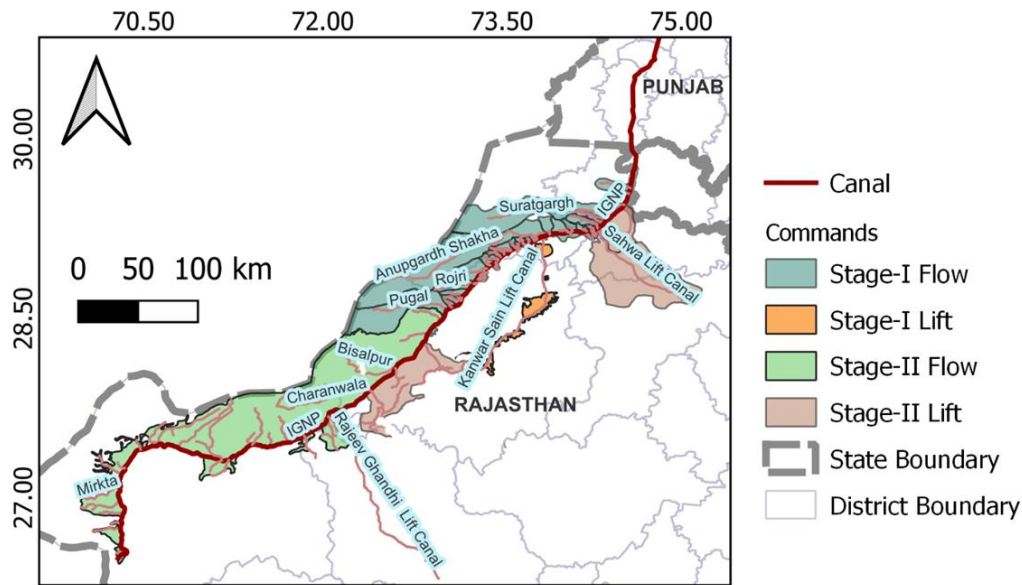


Figure 1. Indira Gandhi Nahar Pariyojna (IGNP) command area under stage-I and stage-II

Geophysical survey and field investigations

In this study, geophysical survey was performed using Electrical Resistivity Tomography (ERT) to investigate subsurface geologic conditions and identify thickness of fresh groundwater in some affected areas of IGNP stage-I. Four subsurface zones corresponding to freshwater, the fresh-saline water interface, saline water, and the unsaturated zone were identified.

GEE-based app for monitoring surface flooding

Real-time information about the water-logging in the sensitive areas is useful to plan management strategies. In this study, a web-based application (hosted at <https://ee-surveydaman.projects.earthengine.app/view/ignp-water-monitoring-app>) is developed to map the water-logged area for the period of interest (Figure 2). In addition, the area under surface flooding is quantified for the period from 1987 to 2023 for the Stage-I of IGNP. Hanumangarh and Sri Ganganagar were identified as the districts with most areas having waterlogging conditions. In the initial phase from 1987, both the districts show an initial rise in the waterlogged areas, leading to an initial peak in waterlogging in the year 1990, with the total area affected by waterlogging peaking at around 58 km². For the initial peak year of 1990, out of the total waterlogged area, Sri Ganganagar was the most affected, with the total area affected by waterlogging adding up to around 39 km². For the same year, the area of Hanumagarh district affected by waterlogging was around 18 km². The increase in waterlogging in the late 1980s could be attributed to canal leakages and the development

phase of the canal, leading extensively to waterlogging. After 1997, a significant decline in waterlogged areas has been observed in both districts. The decreasing trend has been observed after 1997. The period after 2015 shows a gradual increase in waterlogged areas, particularly noticeable in the latest years (2022-2023), which can be attributed to variability in precipitation.

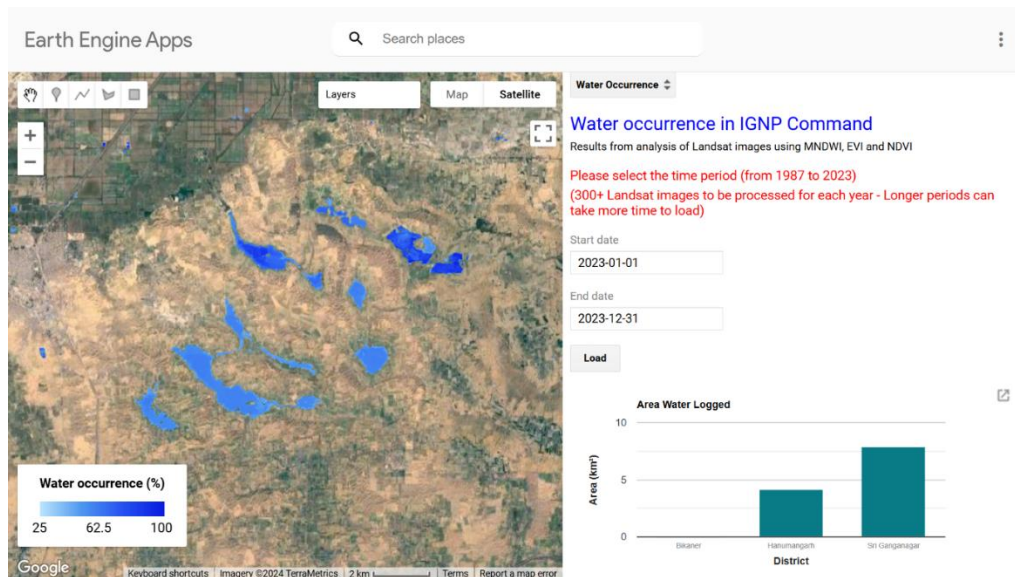


Figure 2: GEE App showing the water occurrence in the affected districts of IGNP.

Concluding remarks

The study highlights the critical role of canal lining and groundwater management in mitigating waterlogging in the IGNP region. Well-maintained lined canals exhibit the lowest percolation losses (8.0%), while poorly maintained and unlined canals lead to increased seepage, exacerbating waterlogging issues. Conjunctive water use scenarios demonstrate that controlled groundwater extraction can significantly reduce waterlogged areas, but high salinity limits its direct use for irrigation. Additionally, climate projections indicate rising temperatures and fluctuating precipitation patterns, impacting future water availability and irrigation demand. A strategic approach combining canal maintenance, groundwater management, and climate adaptation is essential for ensuring sustainable water use in the IGNP command area.

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 (**Completed**)

Duration: One year (April 2023 – March 2024; Extended till September 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.	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.	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	Data with latitude-longitude has been standardized. The GIS dashboard is developed to disseminate the results.

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.

Development of the automated system

An automated system is developed for processing and storing the results of soil analysis to be performed in the lab. 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 1).

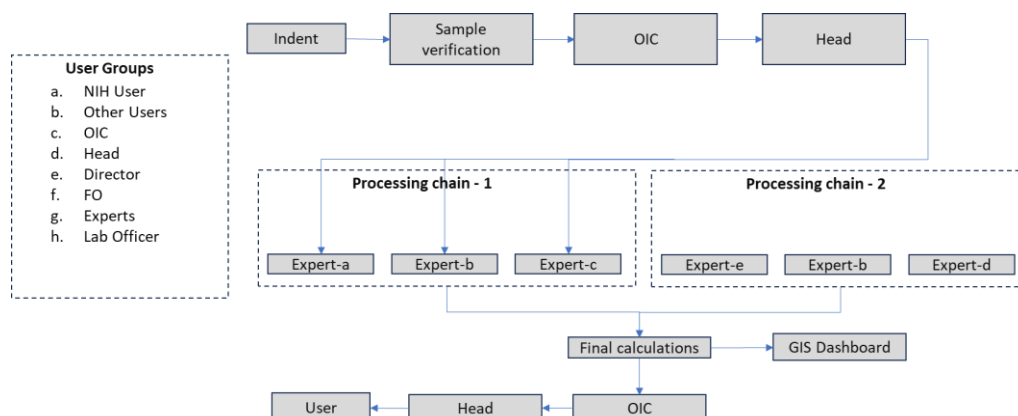


Figure 1. Schematic of the workflow of the automated system

The laboratory analysis of each soil property involves various calculations and plotting. The LabPro allows automated calculations and plotting to standardize the calculations and eliminate human errors. For instance, the estimation of hydraulic conductivity using ICW permeameter requires measurement of heads at various time intervals and finally the hydraulic conductivity is estimated using Darcy's law. Such calculations are automated in the LabPro so that standardized calculations and results could be obtained in an efficient manner. For each soil properties, including soil moisture retention, particle size analysis, sieve analysis, CHNS analysis, trace metal analysis, a separate data acquisition form is developed which is linked with respective calculations in the back-end. The data input form developed for soil moisture retention analysis using the pressure plate apparatus is shown in Figure 2. The data input form and visualization of soil particle size distribution is shown in Figure 3.

Weight (grams)	Container-1	Container-2	Container-3
Wet-soil with container			
Dry-soil with container			
Container			

Figure 2: Data input form developed for soil moisture retention analysis using the pressure plate apparatus



Figure 3: The data input form and visualization of soil particle size distribution for Master Sizer

Development of dashboards

To operate and monitor the soil testing in the laboratory, various user dashboards are developed (Figure 4). Each user will have a dashboard to monitor the progress of the assigned jobs and to submit/download the test results. Dashboard for OIC and Head has been developed to assign and monitor laboratory analysis. The technician's dashboards allow data inputs and visualizations. Each user groups have distinctive rights to view and submit data.

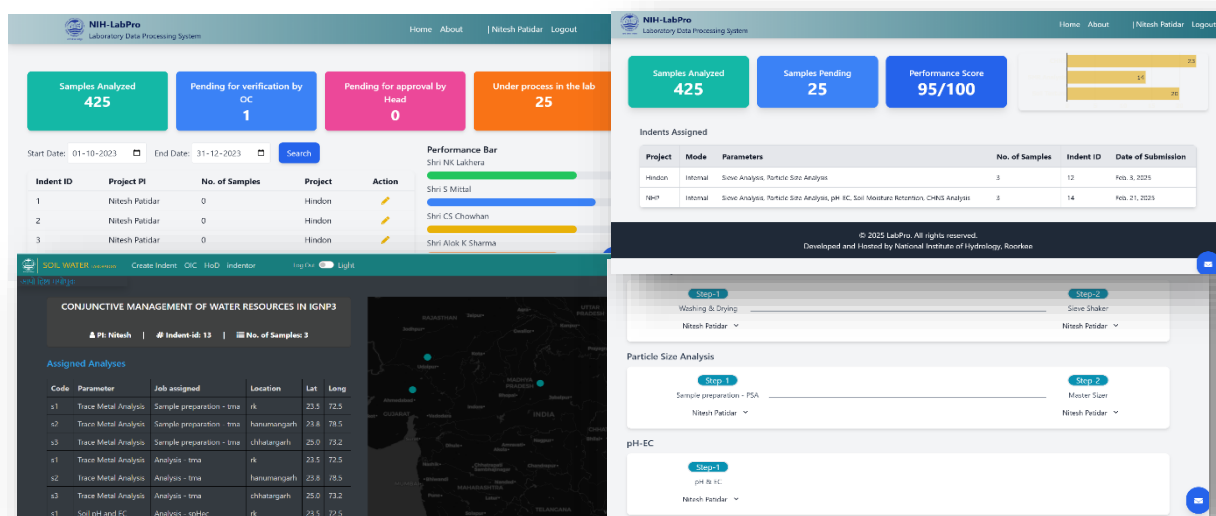


Figure 4. Snapshots of the dashboards developed to monitor, submit requests, and assign jobs

GIS-dashboard to publish the soil hydraulic characteristics

A GIS dashboard is developed to disseminate the soil hydraulic properties analyzed in the soil water laboratory. The historic data is being ingested in the archive to display on the GIS dashboard. The data that will be analyzed after the launch of the LabPro will be automatically ingested in the archive and will be disseminated after the lock-in period (Usually three years).

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	<i>In-progress</i> 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.	<i>In-progress</i> 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.	<i>In-progress</i> <i>The groundwater and aquifer data are being analyzed.</i>
4	Application of NIH_WISDOM in a hard-rock area by developing equivalent porous media model.	<i>Yet-to-be-started</i>

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 2025 to Sep 2025)

Work element	April - June 2025	July - Sep 2025
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 (completed)

Location Map:

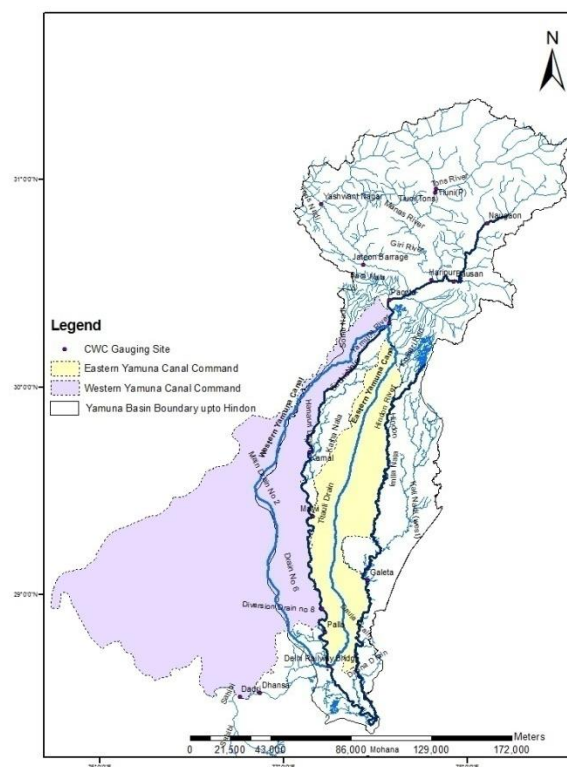


Fig. 1 Study area showing the Upper Yamuna Basin and the command areas of EYC and WYC

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.
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 modeling to study the subsurface flow dynamics.
6. Formulation of adaptation measures in the context of climate change.
7. Flood frequency analysis for Upper Yamuna Basin upto Okhla Barrage in Delhi.
8. Assessment of anthropogenic activities on water quality.
9. Numerical modelling of groundwater recharge dynamics and impact of climate variability on renewable groundwater resources.

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	Completed
Quantification of the contribution of snow and glacier melt to surface water resources through snowmelt runoff modelling	Completed
Assessment of changes in baseflow contribution to river Yamuna	Completed
Assessment of present and future water availability under alternate scenarios of climate change	Completed
Integrated Modeling to Study the Subsurface Flow Dynamics	Completed
Formulation of adaptation measures in the context of climate change	Completed
Flood Frequency Analysis for Upper Yamuna Basin upto Okhla Barrage in Delhi	Completed
Assessment of anthropogenic activities on water quality	Completed
Numerical modelling of groundwater recharge dynamics and impact of climate variability on renewable gw resources	Completed

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 on the water resources in UYB.
- 3) Evaluation of impact of climate variability on renewable groundwater resources.
- 4) Training Workshop for State Department officials of UP.

6 PROJECT REFERENCE CODE: NIH/GWH/DST/19-24

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 01/2025 (completed)

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 Achèvements:

Objectives	Achievements/ Activities
Enhancing water productivity at farming system as well as its components level	Completed.
Analyzing future demand and supply of water at regional and sub-regional level	Completed with project partners
To develop improved methods for reusing industrial effluents in agriculture	Work completed 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

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

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

Title of the study: Understanding the impact of climate change and land use change on groundwater resources in the future using deep learning models with special 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

Objectives vis-à-vis Achèvements :

S. No	Study objectives	Achievements/Responsibility	Status
1	Development of a structured database bearing data related to recharge, extraction and GW levels in the study region.	IIT Hyderabad and NIH	Completed
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	Completed
3	Development of deep-learning-based models for GW level simulation in the study regions considered.	IIT Hyderabad	Completed
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	In progress
5	Development of physics-based integrated hydrological models	NIH	Surface water model calibration is completed, and groundwater model setup has been completed and calibration is pending
6	Prediction of runoff and recharge dynamics under different historical and projected land use changes.	NIH	In progress
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	In progress

Statement of the Problem:

This research focuses on two aquifers, one in Canada and one in India, both vulnerable to climate change and significant land use changes. The Ganga River Basin in India will be studied due to its hydroclimatological diversity and varied aquifer characteristics, with Quaternary alluvium and hard rock aquifers in the north and northwest. Groundwater data is limited, and agro-hydro-climatic conditions are diverse, making it an ideal test case for the proposed methodology. Deep learning (DL) will be used to analyze groundwater trends using satellite and in situ data for the Ganga Basin, which will be integrated into numerical groundwater models to assess hydrological interactions.

Two test sites in Canada, the Chateauguay River watershed in Quebec and the Grand Forks (GF) aquifer in British Columbia, were chosen due to their similar climatic conditions to the Ganga Basin and abundant data. Cross-learning between these sites will facilitate the exchange of water management solutions.

Methodology:

Work Package 1: Gather relevant data for DL and numerical models from India and Canada.

Work Package 2: Use GRACE satellite data to reconstruct groundwater level time series and fill in missing data. The transfer-function-based model, like Convolution Neural Networks (CNN), will be tested in Canadian aquifers and then applied to the Ganga Basin.

Work Package 3: Develop deep learning models for groundwater simulation using climatic input variables. Unlike physics-based models, DL/ML models can predict groundwater levels at a regional scale without extensive aquifer data.

Work Package 4: Develop physics-based integrated hydrological models to cross-check DL results and assess climate impacts on runoff, recharge, and base flow. A regional-scale surface water-groundwater model (1.0 km resolution) will be coupled with an open-source tool like SWAT-MODFLOW.

Work Package 5: Once the ML/DL models are validated, they will predict future groundwater storage, using RCP scenarios from General Circulation Models to assess climate change impacts.

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

Objectives vis-à-vis Achèvements :

S. No.	Study objectives	Responsibility	Achievements
1	Near surface investigations of the Non-Sanitary Landfill (NSL) around the Ghazipur MSW for demarcating contaminant plume.	NGRI & NIH	Completed
2	To monitor soil and water quality around MSW	NGRI	Completed
3.	To Construct contaminant transport modeling for prediction pollution pathways	NGRI and NIH	Completed
4.	To provide suitable management solutions	NGRI and NIH	Completed by project partners

Statement of the problem:

Contaminant plumes from non-sanitary landfill sites, rich in organic matter, cause electrical potential variations that can be recorded at the surface, influenced by both the plume (geobattery) and water flow. This proposal aims to assess and model the impact of the Ghazipur landfill on the subsurface geological structure and hydrological environment. Geophysical methods will be used to determine the geological structure near the landfill and the extent of the contaminant plume. An integrated approach combining geophysical surveys, physical analysis, and hydrochemical methods will assess subsurface formations, aquifer locations, dynamics, and the intrusion of contaminated seepage water around the landfill. While significant leachate percolation occurs beneath the landfill, the direction, transport, and extent of contamination remain unclear. The data collected will help develop an aquifer conceptual model and a contaminant mass transport model for this major landfill site, predicting groundwater flow and the plume's migration. Additionally, the impact of the large built-up pile over the landfill site on the surrounding "critical zone" is a key concern. The study will assess whether these piled structures disrupt the critical zone and evaluate their effects on the immediate soil layers, in addition to the subsurface contamination.

Methodology:

Geophysical investigations, including 2D electrical resistivity and self-potential (SP) surveys, have been conducted around the MSW Ghazipur landfill. Data analysis is ongoing to construct the aquifer geometry and delineate groundwater contamination zones. Water quality testing for major cations, anions, and heavy metals is also underway.

Groundwater Flow and Contaminant Transport Modeling:

The collected subsurface and water quality data will be used for groundwater flow and contaminant transport modeling. The study will use USGS MODFLOW, MODPATH, and MT3DMS with Visual MODFLOW Flex to simulate groundwater flow and contaminant movement. A 30 m resolution SRTM digital elevation model will be used for land surface elevation, and subsurface aquifer layer thickness will be incorporated after analyzing borehole lithologs.

Aquifer parameters such as hydraulic conductivity, storativity, and specific yield will be used, with aquifer tests conducted if data is lacking. Hydraulic boundaries, like streams and rivers, will be assigned based on topo maps and Google Maps. Groundwater recharge and discharge will be estimated using field observations and secondary data from various agencies. Recharge estimates from HYDRUS will serve as inputs for model calibration, which will be done using observed groundwater levels. Once calibrated, the model will assign pollution loads (TDS) to the dumpsite and simulate contaminant flow paths using MODPATH to propose control measures. Both groundwater flow and contaminant transport models will be calibrated using manual and automated techniques.

Analysis and Interpretation of Electrical Resistivity Tomography Data

The Electrical Resistivity Tomography (ERT) profiles (12 nos), conducted at various locations around the Ghazipur landfill, demonstrate significant variations in subsurface resistivity, reflecting the complex geological and hydrogeological conditions. These profiles, with depths ranging from 21.5 to 43.1 meters, reveal resistivity values varying from less than 35 ohm-meter to over 1200 ohm-meter, indicating the presence of different lithological formations such as freshwater recharge zones, coarse-grained sands, silts, clays, and potential water-bearing or contaminated zones (Fig.1). The profiles also highlight the influence of the landfill's proximity, with several sites showing evidence of low resistivity, possibly indicating contamination or saturated zones. For instance, ERT 7, near the Ghazipur base, shows a freshwater recharge zone in the upper 6.72 meters and low resistivity associated with a water-bearing zone. In contrast, ERT profiles in the north and west display higher resistivity, often linked to coarse-grained sands or non-contaminated zones. The resistivity data, integrated with geological interpretations, helps in understanding the subsurface structure, groundwater flow, and contamination spread around the landfill area

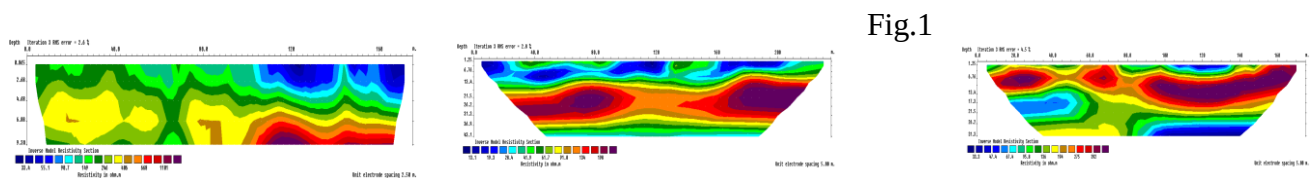


Fig.1

Electrical Resistivity Tomography at
three locations around the Ghazipur MSW

9 PROJECT REFERENCE CODE: NIH/GWH/GWRDC/24-26

Title of the Study: Preparation of Status Reports of the Salinity Ingress in Coastal Area of Saurashtra and Kachchh, Gujarat State

Study Team : Dr. L. Surinaidu
Dr. Ajit Behera
Dr. Anupma Sharma
Dr. Nitesh Patidar
Sourabh Nema (NWRC)
Sudesh Chaudhary (NWRC)
Malkhan Singh Jatav (NWRC)

(a) Madhavpur-Okha reach and Maliya-Lakhpat reach - Dr. L. Surinaidu (PI)

(b) Bhavnagar-Una reach and Okha-Maliya reach – Dr. Ajit Behera (PI)

Type of study : Sponsored study by GWRDC Gujarat
Date of start : April 2024
Scheduled date of completion : March 2026

Background:

The entire coastal stretch of Saurashtra and Kachchh in Gujarat State is affected by salinity, posing a significant challenge in terms of groundwater availability and quality. The Gujarat Water Resources Development Corporation Ltd. (GWRDC) conducts annual groundwater monitoring to assess changes in water levels and salinity concentrations. Given the large coastal stretch, the study area is systematically divided into four distinct reaches for effective assessment:

1. Bhavnagar – Una
2. Madhavpur – Okha
3. Okha – Maliya
4. Maliya – Lakhpat

To ensure a comprehensive analysis, GWRDC has approached the National Institute of Hydrology (NIH) to prepare status reports covering the past ten years for each reach. These reports will provide insights into long-term trends, status of salinity ingress, and mitigation strategies required to protect freshwater resources in coastal area of Saurashtra and Kachchh.

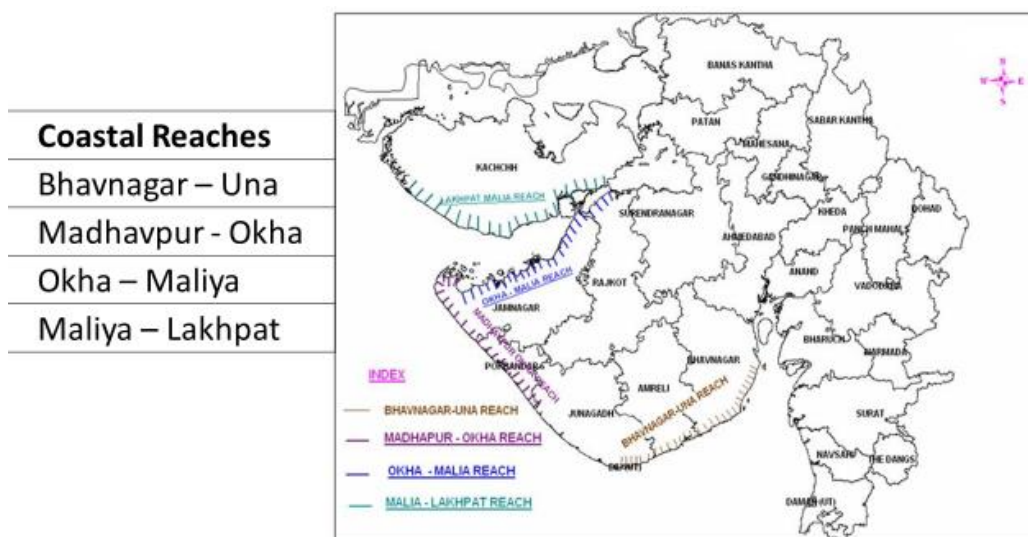
Objectives

Preparation of status report of the salinity ingress in coastal area of Saurashtra and Kachchh for the reaches: (i) Bhavnagar – Una (ii) Madhavpur-Okha (iii) Okha-Maliya (iv) Maliya-Lakhpat

Objectives vis-à-vis Achèvements:

S. No.	Reaches	Achievements
1.	Bhavnagar – Una	Evaluation of the extent and intensity of seawater intrusion in the Bhavnagar–Una coastal region for the year 2017 Identification of aquifer characteristics and water quality variations for the year 2017 Comparison with historical data (2000-2016) Report prepared for the year 2012 based on data provided Preparation of reports for other years is in progress.

2.	Madhavpur-Okha	Groundwater salinity observed up to 10-15 km inland in highly affected zones. EC values exceed 5000 $\mu\text{S}/\text{cm}$ in several wells, confirming high salinity. Chloride concentration above 1500 mg/l in many coastal locations. Report prepared for the year 2012 based on data provided Preparation of reports for other years is in progress.
3.	Okha-Maliya	Groundwater salinity observed up to 12–20 km inland, with varying severity across locations. Elevated EC values ($>6000 \mu\text{S}/\text{cm}$) in many coastal wells, indicating seawater influence. Chloride concentrations exceed 2000 mg/l in several locations. Report prepared for the year of 2015 Preparation of reports for other years is in progress.
4.	Maliya-Lakhpat	Groundwater salinity observed up to 10–18 km inland, with varying intensities. Higher salinity recorded near tidal creeks and estuarine regions. High EC values ($>8000 \mu\text{S}/\text{cm}$) in several wells near the coastline. Chloride concentrations exceeding 2500 mg/l, indicating marine influence. Report prepared for the year of 2008 Preparation of reports for other years is in progress.



Map of study area illustrating the four reaches along the coastal stretch of Saurashtra and Kachchh in Gujarat.

Progress:

Data for all the four reaches in Saurashtra and Kachchh has been provided by GWRDC over the last one year. Data has been analysed for these reaches for different years. A one day workshop to review the progress was held at GWRDC Office in Gandhinagar on Dec. 27, 2024. Discussions were held on the identified data gaps and other issues in the historical data as well as the geological cross-sections. It was decided that GWRDC shall provide additional information which shall be incorporated in the

maps and reports. It was informed by NIH that one report for each reach will be submitted in April.

Deliverables & Beneficiaries: Beneficiaries include GWRDC Gandhinagar and coastal communities in Saurashtra and Kachchh. Deliverables include forty-four reports, research papers, and workshops.

10 PROJECT REFERENCE CODE: NIH/GWH/THDC/24-27

Title of the Study: Modelling Micro-Plastic Movement through soil Matrix: A step towards Plastic waste management

Study Group:

Project Investigator/Co-Project Investigator

Anjali, Scientist C, GWHD, NIH (PI)

Dr. (Prof.) C.S.P. Ojha, IIT Roorkee

Dr. Sunil Gurrapu, Scientist 'D', CCCS, NIH

Dr. Ajay Ahirwar, Scientist 'C', WRS, NIH

Scientific/Technical / Project Staff

Mr. Himanshu , RA, IIT Roorkee

Type of Study: Sponsored project by THDC, Budget: Rs 40,11,000/-

Nature of Study: Core Research

Date of start: 1 April, 2024

Scheduled date of completion: 31 March, 2027

Duration of the Study: 3 Years

Study area: Roorkee city

Study Objectives:

- i. Monitoring microplastics in soil-matrix, surface and groundwater of selected study areas of Uttarakhand
- ii. Identification of processes responsible for microplastic formation.
- iii. Micro-plastic assessment through the vertical profile of the soil column.
- iv. Modelling the fate and transport of Microplastic through the soil matrix.
- v. Graphical User Interface for the developed model for making it more useful and easier for end users.
- vi. Scenario run for suggesting better plastic waste management practices.

Statement of the Problem:

Microplastics are the plastic particles of size ranging from 5 mm to 1 μ m and classified as primary and secondary based on its origin. The primary microplastics are tiny particles designed for commercial use, such as cosmetics, as well as microfibers shed from clothing and other textiles, such as fishing nets. The Secondary microplastics are particles that result from the breakdown of larger plastic items, such as water bottles. This breakdown is caused by exposure to environmental factors, mainly the sun's radiation and ocean waves. These small size plastic beads and fibers are reported to have deleterious health impacts (Ensign et al. 2012; Schirizzi et al. 2017; Deng et al. 2017; Smith et al. 2018; Prata et al. 2020). There are three methods through which microplastics may pose health hazards, viz. 1) hazards caused by microplastic particles themselves upon ingestion being small; 2) hazards due to various chemicals, colors, plasticizers, and additives present in the microplastics; and 3) hazards due to biofilm formation by microorganisms over microplastic particles (WHO 2019). Moreover, once introduced in the aquifer system, microplastic pollution poses serious threat to groundwater ecology and soil environment as well. United Nations Environment Programme (UNEP) has also listed microplastics pollution as one of the top ten environmental problems (UNEP, 2014). Since, there is no known monitoring mechanism to ascertain the micro-plastic and their environmental impacts, no policy guidelines are in place. Thus, the study aims to monitor microplastic pollution in

soil, surface and groundwater and develop a system for evaluating micro-plastic pollution in soil-matrix which ultimately causes pollution to our rivers and groundwater.

Methodology:

- i. Literature review to understand the present state of art and the existing modelling if any.
- ii. Construction of soil column experiments as a physical model for estimating movement of micro-fibers/ microplastics.
- iii. Analyzing the spatial-temporal movement of microplastics through the soil-column.
- iv. Developing mathematical relation based on particle movement.
- v. Mathematical model for simulating fate and transport of microplastic through soil matrix.
- vi. Scenario runs for finding out the best management practices for microplastics management.

Timeline:

S.No.	Year	Physical Achievements
1.	Year 1	Construction of Soil Column Purchase of Micro-plastics, Consumables Intake of PhD Sample collection and Analysis Interim Report
2.	Year 2	Sample collection and Analysis Formation of Mathematical Model and relations Interim Report
3.	Year 3	Sample collection and Analysis Formation of Mathematical Model and relations Development of Graphical User Interface Scenario Runs Interim Report

Recommendation / Suggestion: Nil

Analysis & Results:

- Literature review on the various methodology adopted for sampling and Analysis of micro-plastics.
- Standardisation of procedure for analysis and quantification of micro-plastics in soil, water and waste-water.
- Construction of columns for experimental analysis.

11 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 Behera, Sc.-C, GWHD
- Dr. Anupma Sharma, Sc.-G & Head, GWHD
- Dr. Shailendra Kumre, Sc.-B, EHD
- Dr. Gopal Krishan, Sc.-E, HID
- Dr. Soumyaranjan Sahoo, SC.-B, SWHD

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

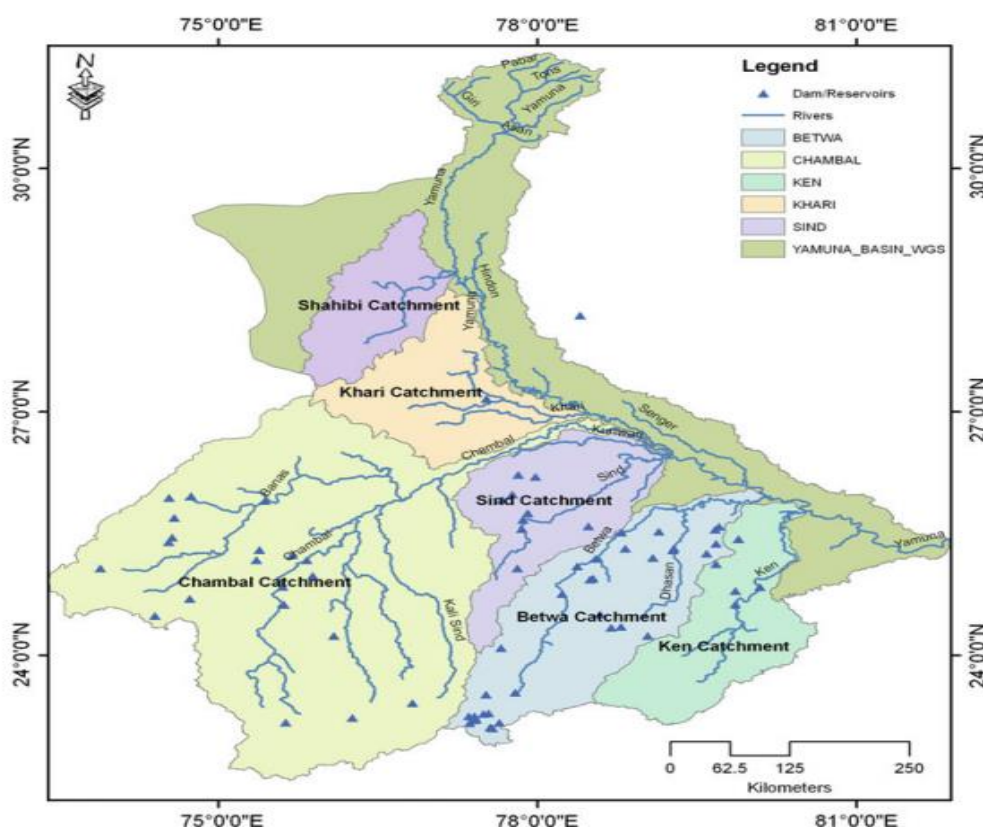


Figure: Yamuna River basin with the major tributaries and sub-basin
(Source: Upadhyay and Rai, 2013)

Objectives:

- (i) Identification of recharge sites and GW recharge estimation in the basin.
- (ii) Determination of river bed hydraulic conductivity with in-situ 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.

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 analyzing 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 analyzed 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.

Data Requirements:

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

Objectives vis-à-vis Achèvements :

Objectives	Achievements
Identification of recharge sites and GW recharge estimation in the basin	Hydrogeological and Groundwater Data: Seasonal (Pre-Monsoon and Post-Monsoon) groundwater level data from 1994 to 2018 were collected from CGWB. Various reports and papers are referred for compiling transmissivity, hydraulic conductivity, specific yield, storativity, groundwater level stages, and drafts for all uses Environmental and Geological Parameters: Data compiled for rainfall, discharge, geology, lithology, geomorphology, and hydrogeology for 96 districts across seven states in the Yamuna River Basin to analyze groundwater dynamics and sustainability. Groundwater Level Trend (1996–2019) in Yamuna basin falling under the administrative boundary of U.P: The U. P boundary was classified into three zones (upper, middle and lower). The analysis indicates significant pre-monsoon declines in Zone-1 (47.06%), Zone-2 (35.71%), and Zone-3 (30.67%), with Zone-1 being the most stressed. Post-monsoon declines follow a similar pattern, with excessive extraction and insufficient recharge being key factors. Transmissivity Variation: Zone-1 has lower transmissivity (25–2500 m²/day), while Zones 2 and 3 show higher ranges (20–5755 m²/day and 1.5–6338 m²/day, respectively), indicating better groundwater movement in the latter zones.
Determination of river bed hydraulic conductivity with in-situ and lab methods	Field visits have been planned to collect sediment samples and analysis in the Lab.
Identification of influent-effluent stretches and quantification of flow between SW and GW along the Yamuna River	GW Model will be set-up for studying the SW-GW interaction. Various model inputs are being acquired and analyzed.

Analysis of Results:

For achieving the study objectives, a comprehensive collection and analysis of hydrological and geological data were carried out. Groundwater level (GWL) data spanning from 1994 to 2018 were collected seasonally (Pre-Monsoon and Post-Monsoon) from the Central Groundwater Board (CGWB) and the National Aquifer Mapping Program (NAQUIM). Additionally, aquifer parameters such as Transmissivity, Hydraulic Conductivity, Specific Yield, and Storativity were analysed to assess groundwater movement and storage potential. Rainfall data, river discharge records, groundwater extraction (drafts) for domestic, agricultural, and industrial uses, as well as river stage levels, were incorporated to evaluate recharge and depletion trends. Geological, lithological,

geomorphological, and hydrogeological data were also acquired to understand the structural controls on groundwater dynamics.

The data processing and analysis phase involved statistical evaluations to identify spatial and temporal groundwater trends. The Non-Parametric Mann-Kendall and Sen's Slope (MKSS) tests were applied to detect trends in groundwater level changes from 1996 to 2019. To facilitate a focused analysis, the Yamuna Basin area within Uttar Pradesh was divided into three distinct zones based on hydrogeological characteristics. The findings revealed significant seasonal variations in groundwater levels. Pre-monsoon trends showed that Zone-1 experienced a 47.06% decline, 2.94% rise, and 50.00% stability in groundwater levels, while Zone-2 recorded a 35.71% decline, 4.75% rise, and 59.52% stability, and Zone-3 exhibited a 30.67% decline, 5.33% rise, and 64.00% stability. Zone-1 emerged as the most stressed zone, with the highest depletion levels, followed by Zone-2 and Zone-3. Post-monsoon trends indicated some recharge benefits, but groundwater decline remained significant. Zone-1 experienced a 41.18% decline, 11.76% rise, and 47.06% stability, while Zone-2 recorded a 26.19% decline, 9.52% rise, and 64.29% stability, and Zone-3 exhibited a 25.34% decline, 7.33% rise, and 65.33% stability. The continued decline in groundwater levels was attributed to excessive extraction, reduced recharge rates, and increased water demand.

The transmissivity analysis further highlighted the variation in groundwater movement potential across different zones. Zone-1 had transmissivity values ranging from 25 to 2500 m²/day, indicating moderate to low water movement. Zone-2 exhibited a broader range of 20 to 5755 m²/day, suggesting more heterogeneous aquifer properties and better water movement in certain areas. Zone-3 recorded the highest transmissivity range of 1.5 to 6338 m²/day, indicating substantial variation in aquifer permeability. The higher transmissivity values observed in Zones 2 and 3 suggest relatively better groundwater flow conditions compared to Zone-1, where limited transmissivity indicates lower groundwater availability. These results underscore the critical need for sustainable groundwater management, controlled extraction practices, and enhanced recharge mechanisms to mitigate further depletion in the Yamuna River Basin. A strategic approach, including artificial recharge techniques, efficient water use policies, and integrated water resource management, is essential to address the growing groundwater crisis in the region.

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: NIH/GWH/24-27**PROJECT REFERENCE CODE: MAJOR PROJECT WITH SUB-PROJECTS****Study Team:**

Project Co-Ordinator: Head, Groundwater Hydrology Division

Scientists from GWH Division: Dr. Anupma Sharma, Dr. L. Surinaidu; Dr. Ajit Behera;

Dr. Satendra Kumar; Er.Pintu K. Gupta

NWRC Jodhpur: Mr. Akshay Vyankat Dahiwalé; 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)

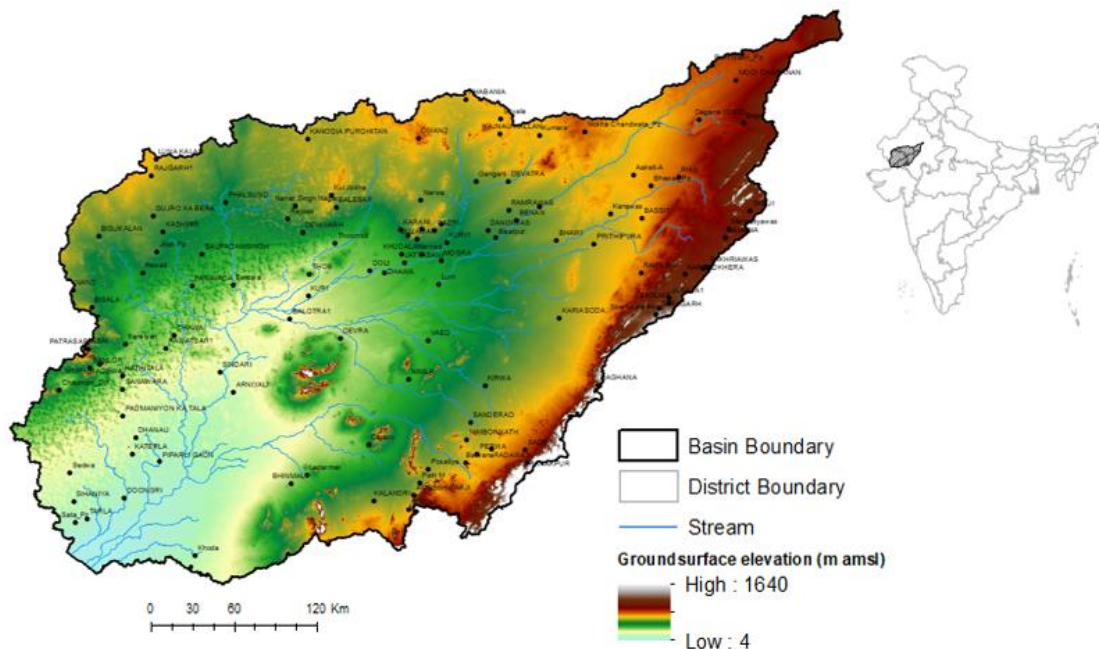


Fig. 1 Location map of the LUNI river basin

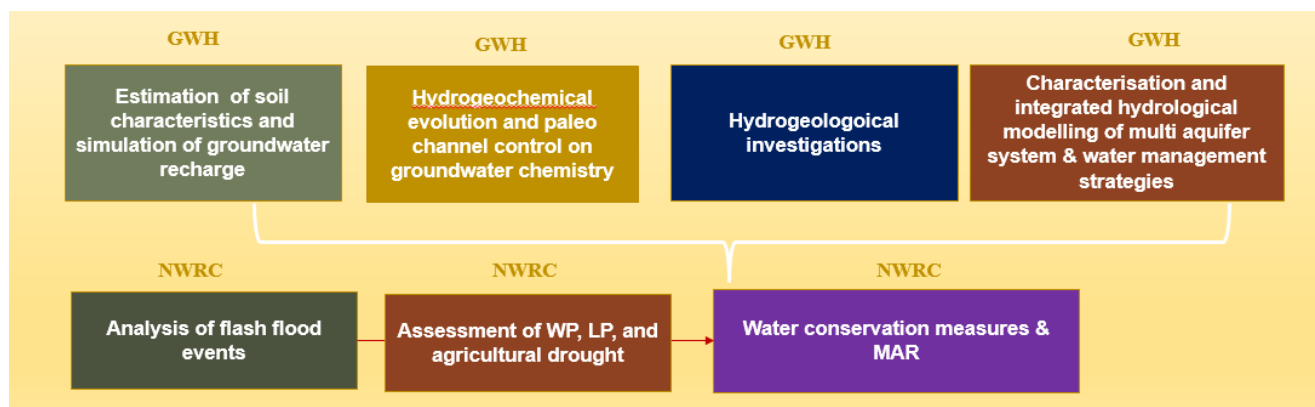


Fig.2 Proposed sub-projects

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

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

Study team PI Dr. Satendra Kumar, Scientist-B
 Co-PIs Dr. Anupma Sharma, Scientist-G
 Dr. L. Surinaidu, Scientist-D
 Dr. Ajit Kumar Behera, Scientist-C
 Er. Pintu Kumar Gupta, Scientist-B
 Dr. Nitesh Patidar, Scientist-C
 Dr. Sushindra Kumar Gupta, Scientist-C

Type of study: Internal (*Ongoing*)

Duration: Two years (April 2024 – March 2026)

Location

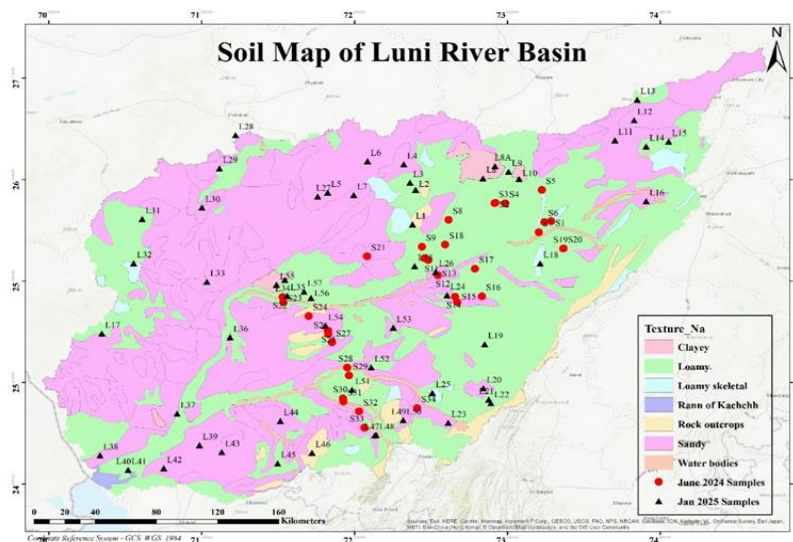


Figure 2 Sampling locations in the Luni Basin

Background

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. Modelling for flow through unsaturated zone by HYDRUS-1D by utilizing soil physical properties and soil water retention and hydraulic parameters to be done. During the project, field soil samples to 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 to 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.

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 168 soil samples were collected from the 92 locations and depths up to 1.2 m. The samples were subjected to laboratory analysis for physical and chemical properties. Textural analysis was performed by mechanical sieve shaker and particle sizer for coarse grained and fine grained particles. Chemical parameters were obtained by preparing 1:5 soil-water solution with 1 part of soil and 5 parts of distilled water. The chemical parameters, EC, pH, TDS and ORP were determined using the soil solution by multi parameter. Pressure plate experiments were conducted for 5 pressure points including field capacity, wilting point and other intermediate pressure points. The obtained water retention curve so obtained is inverted for fitting the van Genuchten (1980) water retention relationship for the determination of unsaturated soil hydraulic parameters.

Results

The results include the textural, chemical, and water retention properties of 53 samples collected of the total 168 soil samples in the Luni basin. Textural analysis performed on 53 soil samples collected in June 2024, indicated that soil vary in texture from sand to silt loam, with a predominant presence of sand in most of the areas. The Table given below lists the textural composition of samples analyzed. The Fig.3 below show the minimum, maximum and average distribution of clay, silt, sand and gravels in the collected soil samples.

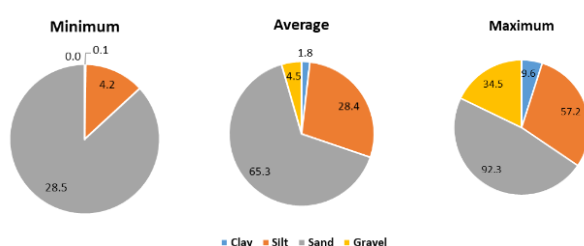


Figure 3 Variation of clay, silt, sand and gravels in the samples collected.

As mentioned in the texture analysis the samples ranges from sand to silt having sand loam, loam sand and silt loam as dominant texture. The pressure plate analysis of the samples shows that retention water content of all the samples vary between the loam and sand samples shown in blue and red color respectively.

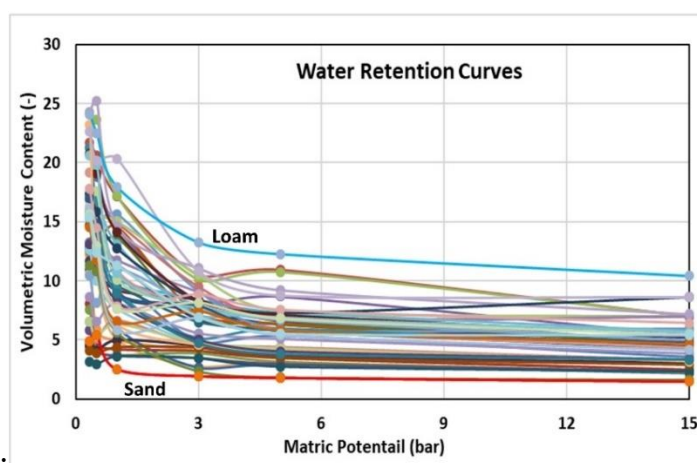


Figure 4 Water retention curves obtained from the pressure plate analysis

Objectives vis-à-vis Achèvements :

S. No.	Study objectives	Achievements
1	Determination of soil physical, chemical and hydraulic properties for top 1m unsaturated zone and preparation of soil data base.	<i>In-progress</i> 168 Soil samples were collected from 92 locations and depths. Physical properties of 54 samples is complete and for others is in progress.
2	Soil salinity characterization in the river basin.	<i>In-progress</i> Chemical analysis of the partial samples collected is complete and of others is in progress.
3	Estimation of groundwater recharge by modelling the moisture flow in the unsaturated zone along with climate change scenarios for future groundwater recharge projections.	<i>Yet to be started</i>

Action plan and timeline

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 samples and 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	Project report and research paper								

13 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
Sh. Akshay Vyankat Dahiwale
Dr. Satendra Kumar
Sh. Pintu Kumar Gupta
Dr. Anupma Sharma
Dr. M. K. Sharma
Dr. Amzad Hussain Laskar, PRL
Type of study Internal (*On-going*)
Duration 36 Months
Budget Rs. 46 Lakhs (Approximate)
Location Luni Basin

Objectives vis-à-vis Achievements:

S. No.	Study objectives	Achievements or Activities
1.	To assess groundwater recharge processes through isotopic analysis	Successfully completed the 1st and 2nd phases of field sampling. Completed the 1st phase of sample analysis for major ions, trace elements, and stable isotopes. Preparation underway for the 2nd phase of sample analysis.
2.	To determine the relative residence times (age) of the groundwater	Awaiting results from the 1st phase of tritium analysis. Identified the locations from which samples will be collected for Carbon-14 analysis. 2 nd phase of tritium samples has been collected from field
3.	To understand the role of paleochannels on groundwater quality	Several water bodies have been identified, and isotope samples have been collected to analyze their contribution to groundwater quality and potential paleochannel influence.
4.	To identify the primary factors and mechanisms controlling the geochemistry of the groundwater	A detailed analysis of geochemical and isotopic data is underway to identify the primary factors influencing groundwater composition.

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.

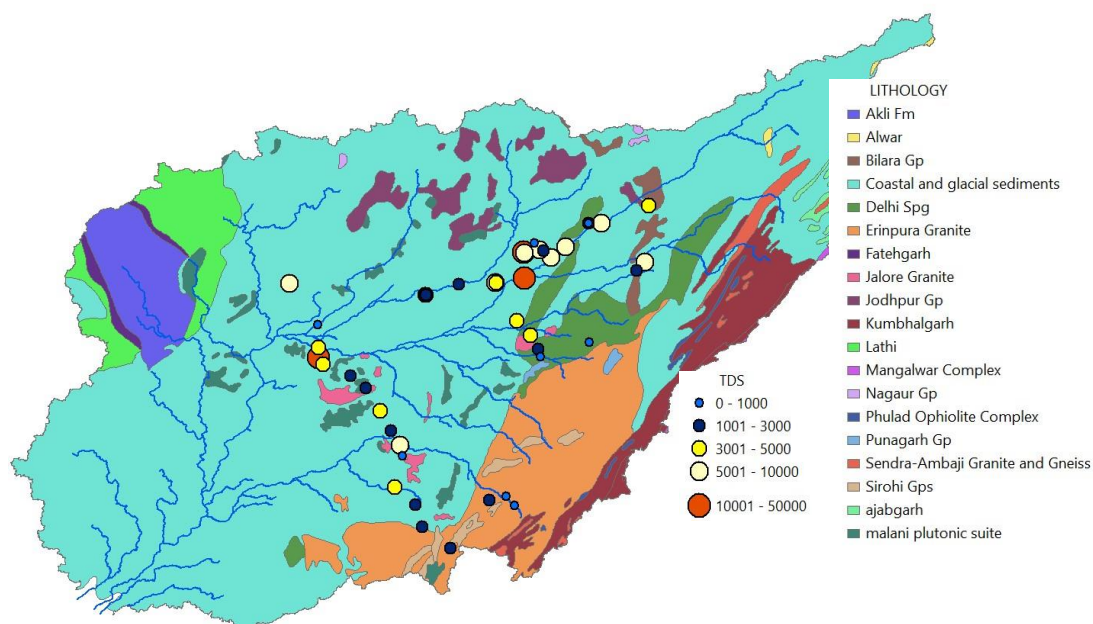


Figure 5 Sampling locations during the pre-monsoon period, indicating freshwater, brackish, and saline groundwater characteristics

Methodology:

Groundwater samples were collected during two distinct hydrological periods to capture seasonal variations in water chemistry, with 46 samples obtained in the pre-monsoon period (June 2024) and 109 samples during the post-monsoon period (January 2025). At each sampling location, key physicochemical parameters were measured in the field using multiparameter instruments. To ensure accuracy in subsequent laboratory analysis, all samples were filtered using a 0.45-micron filter paper to remove suspended particles. The samples were then preserved in dedicated bottles based on the required analysis: 15 ml of water was collected in a high-density polyethylene (HDPE) bottle without preservatives for stable isotope analysis, 60 ml was collected in an acid-washed HDPE bottle and preserved with ultrapure HNO_3 (nitric acid) for trace element analysis, and 250 ml was collected in an HDPE bottle without preservatives for major ion analysis. In the laboratory, major ions were analyzed using ion chromatography (IC) and titration methods, trace elements were measured using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), and stable isotopes ($\delta^{18}\text{O}$, $\delta^2\text{H}$) were analyzed using an Isotope Ratio Mass Spectrometer (IRMS).

Results and discussion:

The stable isotope plot (Fig. 3a) illustrates the relationship between $\delta^{18}\text{O}$ and $\delta^2\text{H}$, shedding light on groundwater evolution within the Luni Basin. The alignment of data along the Global Meteoric Water Line (GMWL) and Local Evaporation Line (LEL) provides insights into isotopic enrichment. The observed trend suggests significant evaporation, leading to the accumulation of heavier isotopes, particularly in Jawai Dam and open well samples. In contrast, tube wells and rainwater samples display lower enrichment levels, indicative of direct recharge and minimal

evaporative effects.

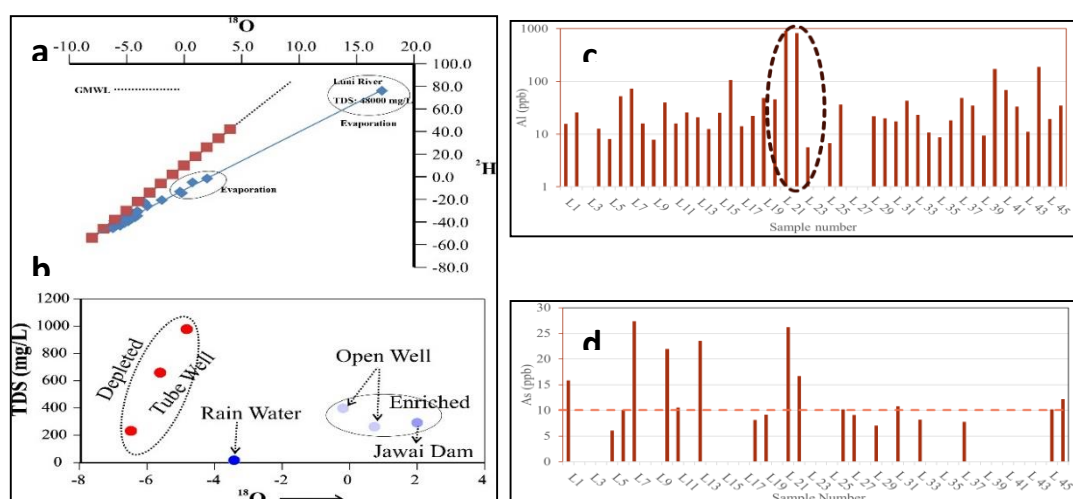


Figure 3 a) Stable Isotopes and Groundwater Evolution b) Total Dissolved Solids (TDS) vs. $\delta^{18}\text{O}$ c) Al concentration across various groundwater samples d) Arsenic concentrations vary across the samples

The total dissolved solids (TDS) versus $\delta^{18}\text{O}$ plot (Fig. 3b) presents groundwater salinity variations. Tube wells exhibit low TDS and depleted $\delta^{18}\text{O}$, implying recharge from fresh sources. Conversely, Jawai Dam and open wells contain enriched $\delta^{18}\text{O}$ with higher TDS, suggesting evaporation-driven concentration and potential interactions with mineralized aquifer components. The aluminum (Al) concentration distribution (Fig. 3c) highlights varying levels across groundwater samples. Elevated Al levels likely stem from the dissolution of aluminosilicate minerals such as feldspars and clays, particularly in areas with fluctuating water tables. The release of Al is enhanced in arid conditions due to prolonged weathering. The arsenic (As) concentration plot (Fig. 3d) shows variability among groundwater samples, with some exceeding WHO drinking water standards. The primary sources of arsenic include the reductive dissolution of arsenic-bearing iron oxides and sulfide oxidation within granitoid-derived sediments. Additionally, high evaporation rates may concentrate As in groundwater.

Research progress timeline:

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			✓	✓	✓	✓
	Completed			In-progress		

14 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 Kumar Behera, Scientist-C
Dr. Satendra Kumar, Scientist-B
Dr. Sumant Kumar, Scientist-E
Dr. Sushindra Kumar Gupta, Scientist-C
Er. Sudesh Chaudhary, Scientist-B

Type of study: Internal (*Ongoing*)

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.

Objectives vis-à-vis Achèvements :

S. No.	Study objectives	Achievements
1	Estimation of aquifer parameters by field and lab experiments.	<i>In-progress</i> Available Time-Drawdown data has been acquired from CGWB, and Pumping test analysis is done. Site selection has been done based on geological conditions from the 1 st field visit.
2	Spatio-temporal variation and trend analysis of groundwater level in the basin.	<i>Completed</i> Trend analysis was done for both the tube well and dug well, and spatio-temporal analysis of the GW levels was also done.

Aquifer Characterization and Hydraulic Properties

The transmissivity values obtained from the Jacob and Theis recovery methods for the nine sites (Time- Drawdown data were obtained from CGWB) exhibit significant variability across different geological formations. The analysis reveals significant spatial variations in transmissivity and storativity across different geological formations. Quaternary and Jurassic sandstones provide the best aquifer conditions, while schist, phyllite, and rhyolite formations show lower groundwater potential.

Groundwater Trend in Tube Wells

The trend analysis of tube wells across the Luni Basin reveals a spatially varied pattern of groundwater level changes over the past two decades:

Tube wells generally show a more pronounced decreasing trend compared to dug wells, suggesting that deeper aquifers are being depleted at a faster rate. Dug wells exhibit a relatively higher proportion of increasing trends compared to tube wells, which could indicate that some shallow aquifers are benefiting from recharge initiatives. The spatial distribution of trends suggests that groundwater extraction pressure is higher in specific regions, while other areas maintain more balanced conditions.

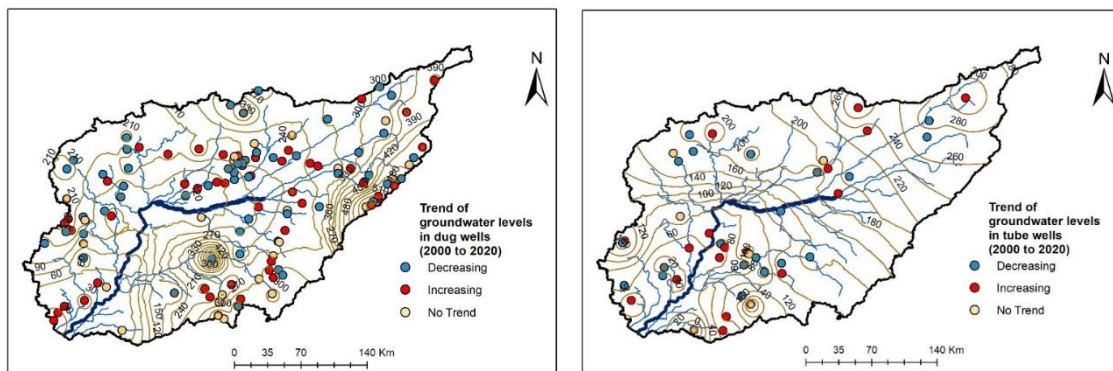


Figure 6 Trend of groundwater elevations for Dugwell and Tubewell shown in filled circle in the Luni river basin

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								

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

Title of the Project: Characterisation and Modeling of Multi Aquifer System of LUNI River Basin in Rajasthan Under Climate and Anthropogenic Influences

Study team: PI Dr. L. Surinaidu (PI), Scientist-D
Co-PIs Dr. Anupma Sharma, S-G; Dr. Ajit Behera, Sc-C;
Dr. Sumant Kumar, Sc-D; Mr. Sudesh Singh Choudary, Sc-B

Type of study: Internal

Duration: Three years (April 2024 – March 2027)

Objectives vis-à-vis Achèvements :

S. No.	Study objectives	Achievements
1	To map the multi-aquifer systems with fresh and saline aquifer demarcations in the LUNI river basin using advanced geophysical technique EVRI and ERT.	<i>In-progress (One time field visit has done and selected locations for geophysical investigations)</i>
2	To delineate the Paleo channels in the study area using geophysical techniques.	<i>In-progress</i>
3	To construct the 3D integrated hydrological model for the estimation of runoff, ET, and groundwater budget using finite element numerical model HYDROGEOSPHERE.	<i>In-progress</i>
4	To quantify the climate and land use change impacts on future groundwater resources availability under different climate change and land use.	<i>In-progress</i>
5	To develop the management strategies for sustainable groundwater utilisation.	<i>In-progress</i>

Background

The research aims to characterize the multi-aquifer system in the Luni basin using advanced geophysical techniques, including 3D Electrical Vector Resistivity Imaging and 2D Electrical Resistivity Tomography, validated by bore well lithologs and logging. A fully integrated 3D hydrological model will be developed using the HYDROGEOSPHERE code, incorporating climate, soil, land use, and aquifer data from related projects. The model will be calibrated with historical data from 2000 to 2023 and isotopic data to assess groundwater residence time. A water balance for the region will be calculated, and the model will predict future groundwater availability under various climate scenarios. Suitable water management strategies will be recommended based on these predictions. The work flow proposed in the project is show in Fig. 1.

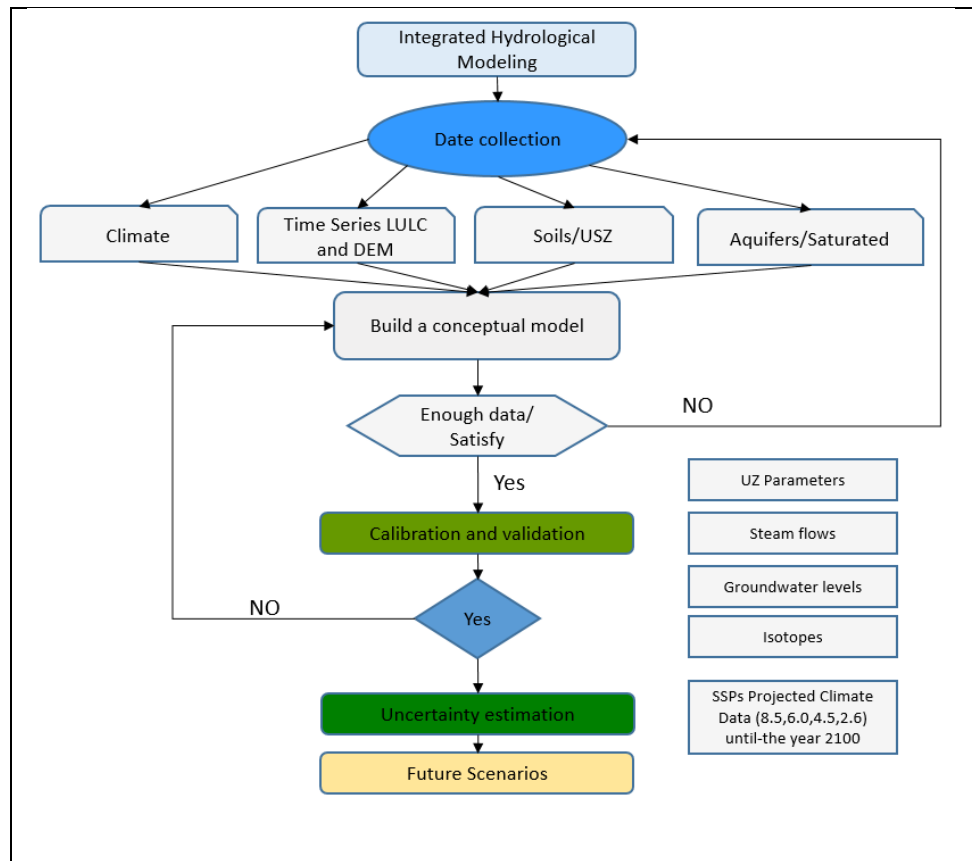


Fig. 1 representing workflow for integrated hydrological modelling and management

Results:

Geology, hydrogeology and 3D aquifer structure:

The Luni basin exhibits heterogeneous geohydrology, with formations ranging from recent alluvium to older tertiary and Jurassic rocks, including sandstone, phyllites, and schist. The eastern boundary features Aravalli and Delhi Supergroup formations, while the western region has Malani Volcanics and Cretaceous-Carboniferous formations, with faulted contacts involving rhyolites and granites. The southern basin is primarily Malani granite, with patches of Delhi Supergroup rocks, and the northern region contains Marwar Supergroup rocks. Quaternary alluvium and aeolian sand dunes cover the western and central areas.

The Luni basin, located in the Thar Desert, is an actively tectonic region with over 300 meters of sediment accumulation due to east-west faulting along the Sukri River. Flash floods increase sediment influx, forming thick deposits. Geological cross sections reveal a sequence where massive granite is overlaid by limestone and sandstone, with alluvium above. Downstream sections show alternating clay layers, suggesting confined aquifers, while upstream sections feature crystalline rocks, indicating unconfined aquifers.

Land use and groundwater storage:

Land use maps for 2005 and 2016 show that crop cultivation dominates the Luni basin, with croplands, rangelands, and built-up areas covering 48.5%, 47.3%, and 3.0% of the total 71,874 km² area, respectively. Water spread and bare land areas have decreased by 44% and 74%, while built-up areas increased by 51%. Groundwater storage changes from 2004 to 2023, analyzed using GRACE satellite data at a 25 km² scale, show fluctuations in hydrological load, with both accumulation and depletion patterns reflecting land use changes and ET variations. From 2007 to 2021, groundwater storage

depletion near Banaskanta increased from -49.7 to -86.32 mm, and in the Jodhpur, Pali, Jalol, and Jaisalmer areas, it shifted from -21.1 to -39.7 mm. Groundwater storage primarily accumulates during July, August, and September, with six out of twenty-one years (2004-2023) showing accumulation due to floods or increased recharge, despite most years showing depletion. The trend in annual groundwater storage follows rainfall patterns.

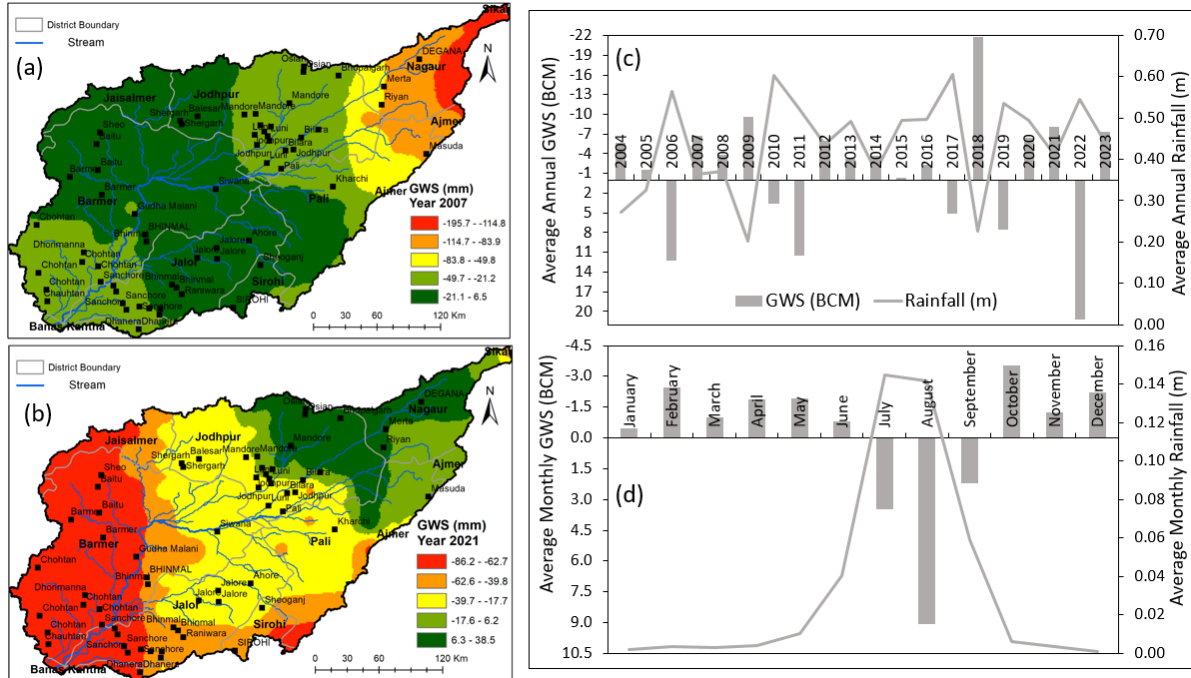


Fig. 2 Annual groundwater storage (GWS) anomaly for the year 2007 (a), for the year 2021 (b), long term annual (2004 to 2023) GWS anomaly with annual rainfall (c) and long term average (2004 to 2023) monthly GWS anomaly with rainfall (d)

16 PROJECT REFERENCE CODE: NIH/GWH/25-27

Title of the Project: Prediction of Hydro-Geological Parameters Using Machine Learning Techniques in the Luni River Basin, Rajasthan, India

Team Member:

Principle Investigator: Dr. Sushindra Kumar Gupta (PI)

Co-Principle Investigator: Dr. Sumant Kumar (Co-PI)

Dr. L. Surinaidu (Co-PI)

Dr. Satendra Kumar (Co-PI)

Dr. Nitesh Patidar (Co-PI)

Er. Pintu Kr. Gupta (Co-PI)

Type of the study: Internal Research Study

Nature of the study: Research

Duration: 17 Months

Budget: 15.75 Lakhs

Objectives:

1. Prediction of groundwater level changes based on machine learning techniques.
2. Prediction of soil surface wetness using bagging and boosting techniques.

Objectives vis-à-vis Achèvements :

S. No.	Study objectives	Achievements
1	Prediction of groundwater level changes based on machine learning techniques.	<i>Completed</i> The data of groundwater levels acquired from Water resources of Rajasthan, CGWB are analysed. Input feature selection, model setup, and etc was performed.
2	Prediction of soil surface wetness using bagging and boosting techniques.	<i>In-progress</i>

Background:

In India, around 30% of the globally irrigated area, as reported by AQUASTAT (2010, Becken.,2014, FAO AQUASTAT., 2019; Belleza et al., 2023) depends on groundwater as a critical resource supporting the nation's agriculture. Groundwater serves as the primary source for more than 60% of the irrigation water requirements, and it plays an essential role in ensuring access to safe drinking water in both urban and rural sectors (World Bank, 2010; World Bank 2019; World Bank Databank 2019; Doeffinger & Hall., 2020). Its substantial role in enhancing agricultural production and efficiency has played a pivotal role in ensuring food security in India (Sharma, 2009). To effectively manage the groundwater resources, it is crucial to accurately evaluate both the present and anticipated requirements for groundwater usage and the net groundwater resource available at both regional and local scales within the basin

Proposed Methodology for Prediction of GWL

In the present study REPTree RF and AdaBoost-CART models were applied for GWL prediction for Ajmer city of Rajasthan state, India

Results: Training and Testing Phase of Pre and Post Monsoon Season

Three most useful statistical model performance assessment indices applied the performance of the proposed model as shown in Table No 2 & 3. The evaluation of GWL results so paramount importance of study of the sustainable groundwater development, irrigation planning, reservoir operation and etc. Now a day's arid and semi-arid, humid, sub-humid, tropical, sub-tropical regions also day by day increased population with so badly effect on the water balance

Table No. 2. Training Phase of Pre-Monsoon Season

Statistical Indices	REPTree	RF	AdaBoost-CART
CC	0.6568	0.7445	0.7337
MAE	1.4787	1.2891	1.6401
RMSE	2.1685	1.8079	2.328

Table No. 3. Testing Phase of Pre-Monsoon Season

Statistical Indices	REPTree	RF	AdaBoost-CART
CC	0.6523	0.5366	0.4775
MAE	2.0815	2.3801	1.5432
RMSE	2.3896	2.8406	1.8843

For post-monsoon season the RF, REPTree and AdaBoost-CART models have been applied over seven observation wells. In terms of model performance, varies from 0.635 to 0.747, MAE varies from 1.311 to 1.597 and RMSE varies from 1.678 to 2.001 of training phase. Similarly, during testing phase of models, in terms of model performance analysis the CC varies from 0.099 to 0.168, MAE varies from 2.614 to 2.901 and RMSE varies from 3.221 to 3.398.

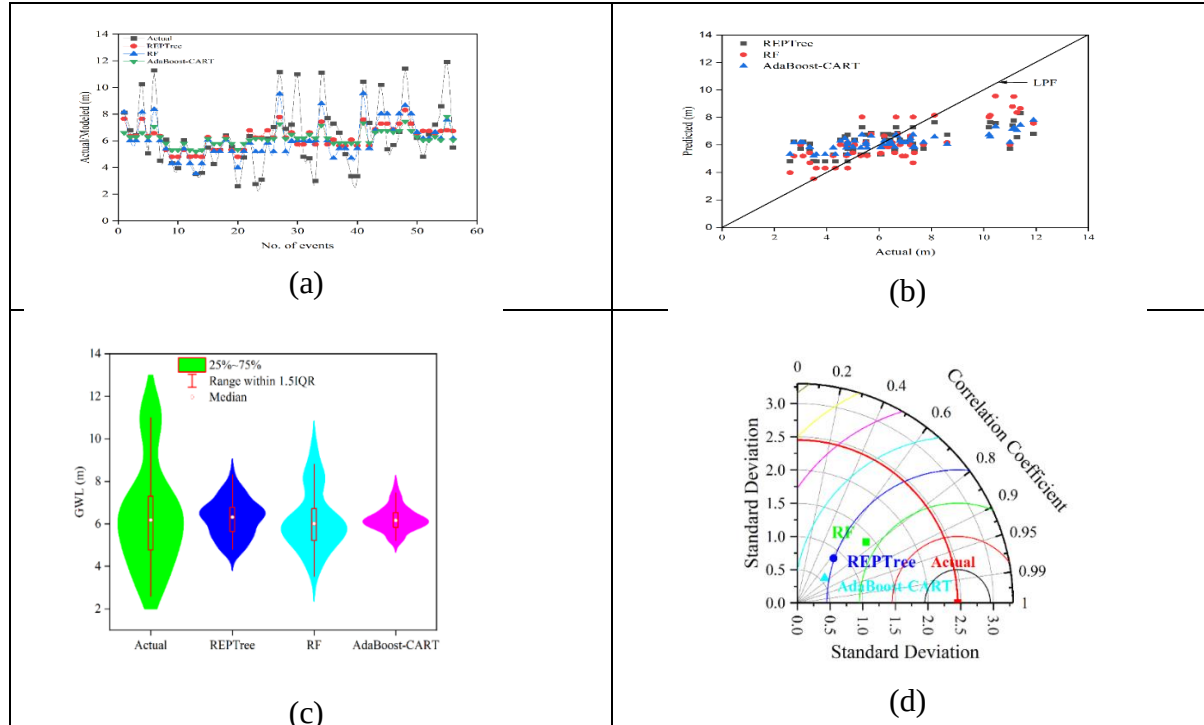


Figure.2. (a) Relationship between time and observed/modeled, (b) relationship between observed and modeled, (c) Violin with box of observed and modeled and (d) Correlation coefficient between observed and modeled of testing phase of post monsoon season.

In the present study REPTree RF and AdaBoost-CART models were applied for GWL prediction for

Ajmer city of Rajasthan state, India. The REPTree model give more accurate result as compared to hybrid (AdaBoost-CART) model. The results show that the performance of the REPTree model ($CC = 0.652$, $RMSE = 2.389$ m, & $MAE = 2.081$) with six input variables is found to be superior in comparison to the hybrid model in estimating seasonal GWL for Ajmer city. The study concludes with a call for ongoing research and development in the field of ground modeling. There is a clear need for further exploration and refinement of these models to enhance their accuracy and reliability. Future research efforts should aim to uncover the nuanced factors that influence model performance and to develop methodologies that can adapt to the changing dynamics of groundwater processes.

Table 4. Proposed time line of the project

S. No	Project elements	Months			
		4	8	12	17
1	Literature review and Secondary data collection for identification of representative soil locations	✓	✓	✓	✓
2	Field surveys for collection of soil, pore water samples GWL, and soil surface wetness data		✓	✓	✓
3	Preparation of data base			✓	✓
4	Model formulation and simulation of soil surface wetness and groundwater level changes in the river basin		✓	✓	✓
5	Publications			✓	✓
6	Final report				✓

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



APPROVED WORK PROGRAMME FOR THE YEAR 2024-25

S. N.	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1.	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 Rajeew Gupta	2 Years (04/23-03/25)	On-going
2..	Sedimentation and Water Quality Study of Fulhar Lake, Pilibhit (U.P.)	Rajeew Gupta (PI), S. D. Khobragade, S.M. Pingale	2 Years (04/23-03/25)	On-going
3.	Development of radiocarbon dating facility	Tripti Muguli (PI) Someshwar Rao , Amit Pandey	1 year (04/24-04/25)	On-going
4.	Hydrological and hydrogeological investigations in the Yamuna river basin using isotope geochemistry	Tripti Muguli, SD Khobragade, Someshwar Roa, Ruchir Patidar, Vipin K Agrawal, Amit Pandey	3 years (04/24-03/27)	On-going
5.	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)	On-going
6.	Understanding Surface Water Groundwater Interactions in the Narmada River Basin and its Hydrological Implications	Amit Pandey (PI) S. D. Khobragade, Someshwar Rao Tripti Muguli	3 years (04/24-03/27)	On-going
7.	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)	On-going
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: Dan Lapworth Alan MacDonald Daren Goody BGS, UK	5 years (12/17-11/24)	On-going
2.	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)	On-going

PROPOSED WORK PROGRAMME FOR THE YEAR 2025-26

S. N.	Project Title	Study Team	Duration	Status
<u>INTERNAL STUDIES:</u>				
1.	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
2.	Development of radiocarbon dating facility	Tripti Muguli (PI) Someshwar Rao , Amit Pandey	1 year (04/24-04/25)	On-going
3.	Hydrological and hydrogeological investigations in the Yamuna river basin using isotope geochemistry	Tripti Muguli, SD Khobragade, Someshwar Rao, Ruchir Patidar, Vipin K Agrawal, Amit Pandey	3 years (04/24-03/27)	On-going
4.	Understanding Surface Water Groundwater Interactions in the Narmada River Basin and its Hydrological Implications	Dr. Amit Pandey (PI) S. D. Khobragade, Dr. Someshwar Rao Dr. Tripti Muguli	3 years (04/24-03/27)	On-going
5.	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)	On-going
<u>SPONSORED PROJECTS:</u>				
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: Dan Lapworth Alan MacDonald Daren Goody BGS, UK	5 years (12/17-11/24)	On-going
<u>NEW STUDY:</u>				
1	Study on unexpected summer monsoon incursions in the Himalayan basins using precipitation stable isotopic compositions of precipitation	NIH, Roorkee, India Gopal Krishan, Sc. E (PI) SD Khobragade, Sc. G (Co-PI) Amit Pandey, Sc. B (co-PI) IIRS-Dehradun Praveen Thakur, Sc. SG (PI) Arpit Chouksey, Sc. SE (Co-PI)	2 years (04/25 – 03/27)	New Study

1. PROJECT REFERENCE CODE: NIH/HID/R&D/2023-24/

Title of the Project: RUNOFF AND WATER STORAGE CAPACITY ESTIMATION 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 study

Duration: 2 years

Date of Start: April 01, 2023

Date of Completion: March 31, 2025 **Whether externally funded or not:** Internal

Statement of the Problem

India generally experiences a diverse rainfall pattern due to its geographical and climatic variations. The country has a monsoon climate, characterized by a southwest monsoon and a northeast monsoon. The temporally concentrated nature of rainfall, it becomes imperative to address the challenge of fulfilling water demands during non-monsoon periods. Therefore, the implementation of rainwater harvesting (RWH) strategies is deemed necessary to efficiently capture and store rainfall for subsequent utilization. The estimation of surface runoff and water storage capacity of the structures in a catchment is a crucial aspect of hydrological modeling and sustainable water resource management. Also, understanding the spatial distribution of water storage capacity is critical for studying saturation-excess runoff. Open-source data can provide valuable insights for estimation of the water storage capacity and possible water spread area in the catchments. It can also help in decision-making on the optimal size, cost-effective selection of structures and number of RWH structures. It also acts as a critical tool for enhancing flood risk estimation. Therefore, this study aims to investigate the feasibility of different resolutions of topographic data using open-sources for the estimation of runoff and water storage capacity estimation in a catchment and RWH structures. This study examines the availability, reliability, and accuracy of open-source data to improve the runoff and water storage capacity estimations in the catchment. The findings will provide insights into the feasibility of RWH strategies using open-source data for potential benefits (i.e. optimal benefits, time and cost saving). The study will also identify any potential limitations or challenges for the various stakeholders and decision makers for selection of suitable rainwater harvesting and management 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 carried out with the following objectives:

- i. To compare the surface runoff in the catchments obtained using different resolutions of topographic data.
- ii. To assess water storage capacity of the rainwater harvesting structure based on the runoff obtained using different resolutions of topographic data.
- iii. To analyze uncertainty and volumetric error of runoff and water storage capacity estimation in the catchment for different resolutions of topographic data.

Methodology

The methodology has been described here:

- a. Systematic review has been carried out to investigate the feasibility of using open- source data for the estimation of runoff and water storage capacity in rainwater harvesting structures.
- b. The catchment has been selected where rainwater harvesting structure is already available for its quantitative & volumetric assessment.
- c. Presently, one catchment is selected from hilly terrain for this study.
- d. Creation of GIS database for the selected study site.
- e. The surface runoff (Peak rate and total volume) has been estimated by using Rational method and SCS curve number method. These are estimated using different resolutions of topographic data while other datasets were taken same.
- f. The Intensity-Duration-Frequency (IDF) curves for different return periods of rainfall and flow duration curves for sustainability analysis of the streamflow have been developed for safe design of rainwater harvesting structures.
- g. The water storage capacity of the rainwater harvesting structure has been estimated by using different resolutions of topographic data.
- h. Also, quantification & volumetric assessment of runoff and water storage capacity have been carried out for making rainwater harvesting strategies in the catchment.
- i. Finally, suitable recommendations and appropriate resolution of topographic data from different sources is 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.
- ✓ The outcome and procedures of estimates will be useful for policymakers, engineers, scientific community & stakeholders for making rainwater harvesting strategies in the catchment.

Progress of the study

The study site has been identified at Jagddhari Village in Chamba of Tehri-Garhwal District of Uttarakhand where rainwater harvesting structure is available. The different resolutions of topographic data have been downloaded 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. Details analysis is in progress and analysis of the results will be presented during the meeting.

2. PROJECT REFERENCE CODE: NIH/HID/R&D/2023/5

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 :	Internal Study
Budget:	INR 15.00 Lakh
Nature of Study:	Applied Research
Date of start:	April 01, 2023
Scheduled date of completion:	March 31, 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 Fulhar lake, which is one of the important and religious place of the Pilibhit U.P.

Objectives:

The ultimate aim of this study is to assess 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 the biggest and historical state U.P., originates from Gomati 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 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
- (iv) 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 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 ($\delta^{18}\text{O}$ and $\delta^2\text{H}$). Also, performed in-situ measurement of water quality parameters (e.g., Temp, EC, pH) using multi-parameter water quality analyser.

- Analysis of water quality and isotope samples of both season of 2023 & Pre monsoon of 2024 have completed and Post monsoon of 2024 in progress
- DGPS & Bathymetry survey of Lake was done in mid of Feb 2025
- Sediment sample cores of lake have been collected
- Maps (Digital Elevation Model, Land Use & Land Cover, Drainage & Slope) prepared
- The detailed data analysis is in progress and will be presented in the Working Group meeting

Future Plan:

- Report Writing

3. 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:	Internal study
Duration:	One year
Date of Start:	April 01, 2024
Proposed Date of Completion:	March 31, 2025
Budget:	Rs.20,00,000

Statement of the Problem

Water storage and its circulation in deep seated aquifers may be complex compared to the shallow aquifers. There is a need to understand the recharge pattern and the resultant residence time of deep-seated aquifers under the present status of climate change effect. The groundwater dating of such aquifers may provide better insights on the available critical water reserves. Therefore, it is important to develop a technique to measure the age of these deep-seated aquifers. The dating of groundwater using radioactive isotope of carbon as a tracer may measure age upto 35,000 - 50,000 years compared to the tritium dating technique which measures upto 50 years. However, 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 groundwater in deep seated aquifers.

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 groundwater dating in deep seated aquifers. For this, a systematic sample preparation line is needed. 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.

Achieved task against the expected outcome from the work:

The technique will strengthen the future hydrological investigation capability to date older groundwater.

- (a) The required materials for the project execution have been listed and identified.
- (b) Procurement process is in progress.

Therefore, an extension of another year is requested to achieve the set objective.

Work schedule

Sl. No.	Activity	Year-1 (2024-25)	Year-2 (2025-26)			
			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					

***Green: Completed, Grey: To be done.**

4. PROJECT REFERENCE CODE: NIH/HID/R&D/2024/25

Title of the Project : HYDROLOGICAL HYDROGEOLOGICAL INVESTIGATIONS IN THE YAMUNA BASIN USING ISOTOPIC AND GEOCHEMICAL TECHNIQUES

Project team: Dr. Tripti Muguli (Scientist-D; PI), Dr. Suhas Khobragade (Scientist-G and Head, HID), Dr. Someshwar Rao (Scientist-G), Sh. Ruchir Patidar (Scientist- B), Dr. Vipin Agrawal (Scientist-B), Dr. Amit Pandey (Scientist-B)

Type of Study: Internal study
Duration: Three years
Date of Start: April 01, 2024
Date of Completion: March 31, 2027

Statement of the Problem

Human civilization has evolved with global water resources availability. It is interesting to note that most human settlements and their migration are found along the river banks or palaeo- channels. Recently, the inter-annual and inter-seasonal river flow changes have been highly unpredictable due to climate change effect. This has shifted the focus on available regional groundwater exploration. However, the over exploitation of fossilized groundwater may result in higher regional water stress. Thus, an integrated approach of surface and groundwater water resource management is needed. In India, the Himalayan river systems have been facing severe water threat. The industrial revolution has also found to largely effect the glacial deposits in the Himalayas. Thus, it is pertinent to understand the water sources sustaining the Himalayan river systems and their role in regional hydrological cycle. The river systems of the Indus, Ganga and Brahmaputra have been extensively explored for its hydrology and hydrogeology. However, the Yamuna river which feeds the national capital has been less explored for hydrological and hydrogeological aspects due to the sensitivity between 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 following objectives have been proposed under this study to develop a systematic hydrological and hydrogeological database for the Yamuna river system using isotopic and geochemical techniques:

- To trace the sources of moisture contributing to precipitation in the Yamuna river system.
- To determine the relative contribution of different hydrological components to Yamuna river discharge.
- To assess the contribution of different tributaries to Yamuna river discharge.
- To understand the groundwater-surface water interaction along the Yamuna river.
- To monitor the radon concentration in groundwater at some specific location in the Yamuna river basin.
- To identify the recharge areas of a few selected springs along the Yamuna river system.
- To understand the hydrological aspects of a major lake in the Yamuna river basin.

Study area

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 were collected on spatial and temporal scales during June - July 2024 and November 2024 – January 2025. The water samples include precipitation, glacier, river, ground water, and springs along the river main channel. In addition, selected tributaries were sampled for river water and groundwater near the main channel confluence. Selected sediment samples were also collected from the Yamuna river. Few water samples have been subjected for measurement of geochemical and stable isotopic compositions and few are yet to be analyzed.

Analytical techniques

The following measurements were carried out:

- (i) Physico-chemical parameters: T, pH, EC, DO probes with handheld meter.
- (ii) Isotopic approach: Stable isotopes of oxygen and hydrogen in water samples using IRMS. Radon abundance was measured wherever applicable.
- (iii) Hydrogeochemical approach: Few water samples were analyzed for alkalinity and trace element composition using ICP-MS.
- (iv) Sediment characterization: Few sediment samples were dried under clean environment for geochemical analysis.

Achieved task based on expected outcome from the project

The work carried out to achieve the proposed outcome are as follows:

- (i) Isotopic data base for different hydrological compartments for Yamuna river basin:
 - (a) Two field work were carried out during June-July 2024 and November 2024 –January 2025.
 - (b) Samples collected from precipitation, glacier, river, groundwater and spring.
 - (c) Database for stable isotopes of oxygen and hydrogen during June-July 2024 are obtained while samples of November 2024 – January 2025 are yet to be completed.

- (ii) LMWL for Yamuna river basin
 - (a) Initial precipitation samples have been collected and is in progress.
 - (b) Samples are yet to be analyzed.
- (iii) Relative contribution of snow, rainfall and ground water to Yamuna river discharge
 - (a) Samples collected from precipitation, glacier, river, groundwater and spring.
 - (b) Samples collected for stable isotopes during June-July 2024 have been analyzed while samples of November 2024 – January 2025 are under analysis. Chemical analysis is yet to be completed.
- (iv) Contribution of tributaries to Yamuna river
 - (a) Samples collected for river and groundwater from selected tributaries at their confluence to main river channel.
 - (b) Samples collected for stable isotopes of oxygen and hydrogen during June-July 2024 were analyzed while samples of November 2024 – January 2025 are under analysis. Chemical analysis is yet to be completed.
- (v) Contribution of base flow to Yamuna river
 - (a) Samples collected from hand pumps along the Yamuna river channel from upstream to its joining to the Ganga river.
 - (b) Samples collected for stable isotopes of oxygen and hydrogen during June-July 2024 were analyzed while samples of November 2024 – January 2025 are under analysis. Chemical analysis is yet to be completed.
- (vi) Residence time of groundwater in the Yamuna river basin
 - (a) Samples collected from hand pumps (and selected springs) along the Yamuna river channel from upstream to its joining to the Ganga river.
 - (b) Samples collected for tritium dating are yet to be analyzed.
- (vii) Status of radon concentration at selected location in the Yamuna river basin.
 - (a) Samples collected from groundwater in Saharanpur area for detailed study.
 - (b) Samples collected from shallow groundwater along the Yamuna river channel from upstream to its joining to the Ganga river. For the first time, this study reports the radon concentration in groundwater along the entire stretch of Yamuna river.

The summary of the initial results has been provided below and the output will be discussed during the Working Group Committee meeting presentation.

Physico-chemical parameters and stable isotopic composition of river water, groundwater and spring samples of Yamuna river basin

The measured pH of river water, groundwater and spring samples were in the range of 7.3 to 9 with an average of 8.1, 6.8 to 8.2 with an average of 7.6, and 7.6 to 8.8 with an average of respectively during June-July 2024 sampling period. During the post-monsoon sampling period (November 2024 – January 2025), the pH of river water, groundwater and spring samples were in the range of 7.6 to 8.5 with an average of 8.2, 6.8 to 8.3 with an average of 7.7, and 7.2 to 8.5 with an average of 8.1 respectively. The electrical conductivity (EC) of river water, groundwater and spring samples were in the range of 32 to 2370 $\mu\text{S/cm}$ with an average of 736 $\mu\text{S/cm}$, 100 to 5860 $\mu\text{S/cm}$ with an average of 915 $\mu\text{S/cm}$, and 41 to 1067 $\mu\text{S/cm}$ with an average of 243 $\mu\text{S/cm}$ respectively during June-July 2024 sampling period. During post-monsoon sampling period (November 2024 – January 2025), the EC of river water, groundwater and spring samples were in the range of 77 to 2089

$\mu\text{S/cm}$ with an average of $628 \mu\text{S/cm}$, 102 to $6380 \mu\text{S/cm}$ with an average of $972 \mu\text{S/cm}$, and 55 to $1015 \mu\text{S/cm}$ with an average of $244 \mu\text{S/cm}$ respectively. The stable isotope ratios of oxygen obtained for river water samples of Yamuna river basin for the upstream to mid reaches during the two field campaigns are shown in Figure 1. There is a significant difference in the stable isotopic composition of river water samples collected during June – July, 2024 and November – December, 2024 indicating distinct sources of water contributing to river water during the two seasons. These sources will be traced after future investigations and quantified after completion of all sample analysis. Further to check the inter-annual difference, the second year field sampling will be carried out during the period April 2025 - March 2026.

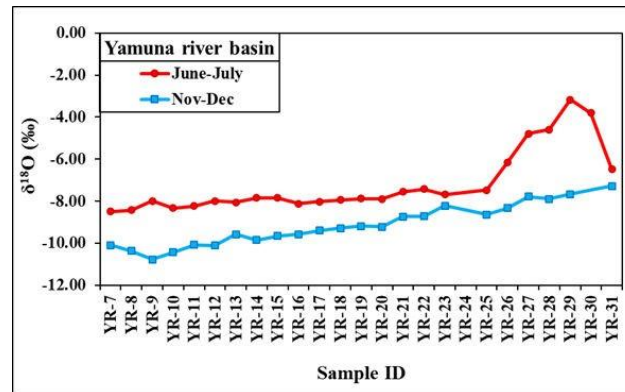


Fig. 1: Spatial variability of stable isotope ratio of oxygen in river water samples of Yamuna basin from upper reaches (YR-7) to mid-stretches (YR-31) during the two field campaigns.

Radon variability in groundwater and selected spring and river water samples of the Yamuna river basin

The spatial variability of radon in groundwater from upper reaches to lower reaches of Yamuna river is shown in Figure 2. The higher abundances of radon were observed in groundwater located at upper reaches of Yamuna river. This may be attributed to the higher interaction of groundwater with bed rocks which are usually having high uranium content. The lower radon abundances were found in the downstream stations which could be due to the interaction with clayey lithology. The lower radon concentration in groundwater along the river channel could also be due to the mixing of river water which are generally having lower concentrations. Thus, it was noted that the average radon concentration in measured groundwater samples of upper reaches was much higher than the global safety level (11 Bq/L). In addition, the higher radon abundances were also found in few measured spring samples. This is a matter of health concern for the local communities in the upper reaches of Yamuna basin as well as the tourists as they depend on these water resources for their domestic and agricultural activities. Therefore, the inter-annual variability needs to be checked by further investigations to confirm the observed report as well as sustainable water utilization.

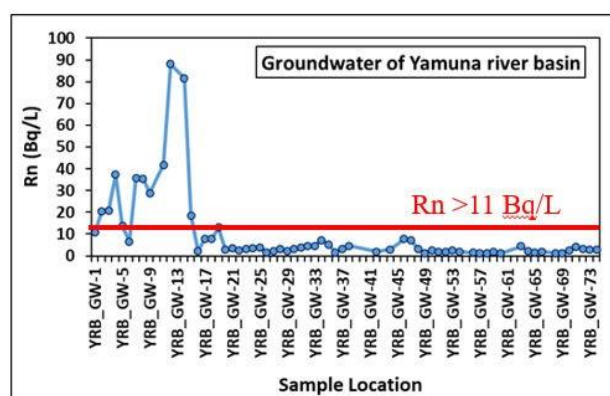


Fig. 2: Spatial distribution of radon concentration in groundwater of the Yamuna river basin from upstream (YRB_GW-1) to downstream (YRB_GW-73). Thick red line indicates the allowed maximum contamination level (11 Bq/L) for radon in drinking water as per the US EPA guidelines.

Work Schedule

Activity/ Year	Year-1	Year-2	Year-3
Literature Survey.	Green	Grey	Grey
Recruitment of project staff	Black		
Setting-up of laboratory facilities, purchase of consumables, scheduling field visit and lab work plan.	Green	Green	Grey
Field works – Daily, Monthly, seasonal sample collection.	Green	Green	Grey
Onsite analysis for physico-chemical parameters.	Green	Green	Grey
Chemical analysis of samples.		Blue	Grey
Isotopic analysis of samples.		Green	Grey
Data compilation for analysis and interpretation.		Green	Grey
Submission of manuscripts for publication in peer-reviewed journals.			Grey
Participation in workshop and training programs.		Green	Grey
National and international conference participations.		Green	Grey
Progress Presentations.		Grey	Grey
Preparation and submission of final report			Grey

*Green: Completed; Blue: Partially done but data not yet available; Black: Not yet done; Grey: Future work.

5. 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

Proposed Project Period: April 01, 2024 - March 31, 2027

Current Status: Project has been put on hold due to logistics.

6. 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: April 01, 2024
Date of Completion: March 31, 2027

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.

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 Vindhya, 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.

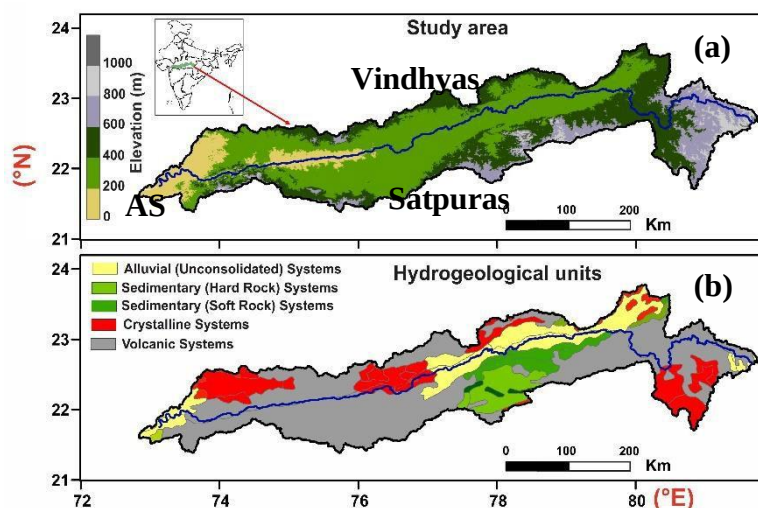


Fig 2: (a) Elevation profile of the Narmada River basin shows that most of the area has elevation in between 200 to 400m range, (b) hydrogeological setting of the study area.

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.

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 tapping 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.

Initial Findings:

The groundwater $\delta^{18}\text{O}$, δD , and d-excess for pre-monsoon season varies between -7.2‰ to - 0.3‰, -46.4‰ to -11.6‰, and -12.1‰ to 16.0‰ with an average of -4.3‰, -29.4‰, and 4.8‰ while for the post-monsoon season the ranges are -7.4‰ to -0.4‰, -51.0‰ to -15.2‰, and -11.6‰ to 13.7‰ with an average of -4.5‰, -31.0‰, and 4.7‰. The river water $\delta^{18}\text{O}$, δD , and d-excess for pre-monsoon ranges between -4.4‰ to 4.0‰, -38.9‰ to 7.9‰, and - 24.0‰ to 3.5‰ with an average of -1.7‰, -18.5‰ and -5.0‰ while the post-monsoon values varies between -6.7‰ to -4.0‰, -49.8‰ to -29.2‰, and 0.0‰ to 8.3‰ with an average of -

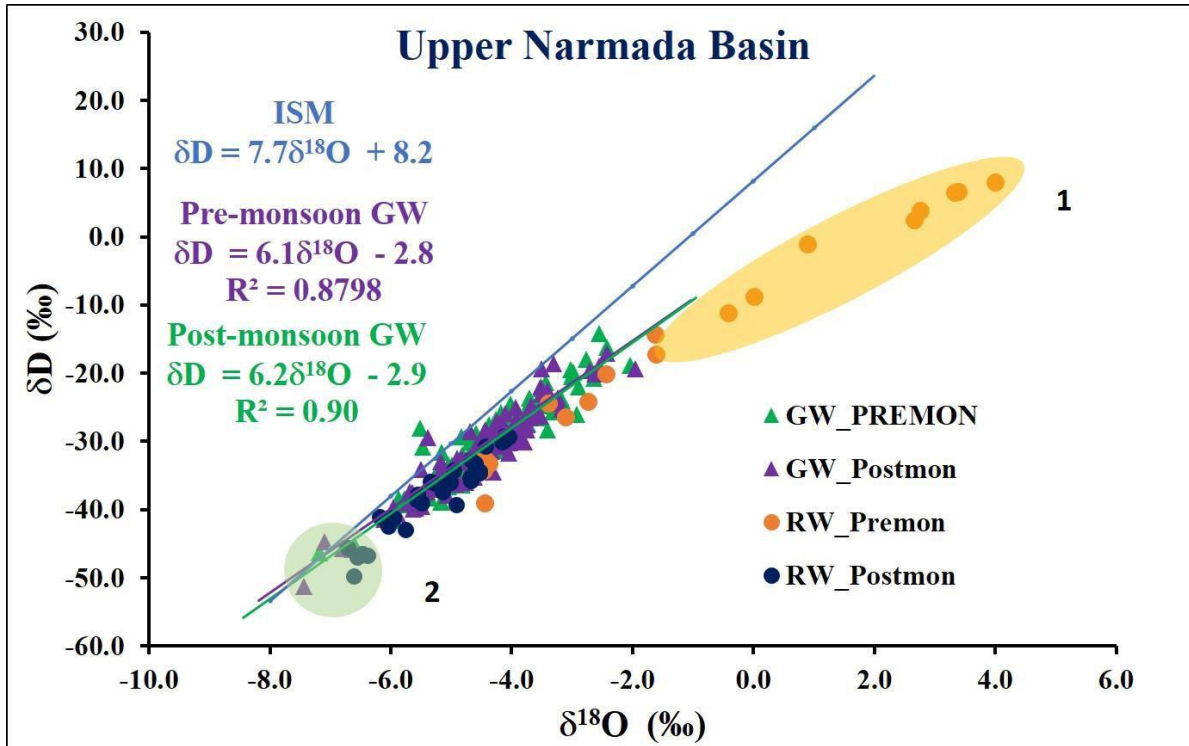


Fig 3: Relationship between $\delta^{18}\text{O}$ and δD for river water and groundwater during pre- monsoon and post-monsoon season.

5.3‰, -37.5‰, and 4.4‰. From Fig.2 it is evident that most of the river and groundwater samples fall below the LMWL (slope 7.7 given by Pandey et al., 2023) which indicates that evaporation is the dominant mechanism controlling the isotopic signature of different water reservoir. Compare to groundwater river water went higher extent of evaporation that can be seen in the isotopic composition of river water during pre-monsoon season (marked as region 1). Two distinct zones (marked as 1 and 2) indicate significant hydrogeological processes. Zone 1 represents the river water end-member, exhibiting a characteristic isotopic enrichment trend. Zone 2 highlights a subset of groundwater samples with more depleted signatures, potentially indicating recharge less evaporated sources.

River water isotopic composition varies spatially as well as temporally during pre-monsoon season Narmada kund water isotopic composition was -2.7‰ as river flow towards Bargi dam (near Jabalpur) river water isotopic composition initially increases and went up to 4.0‰ and then started decreasing up to -1.7‰ after the dam river water isotopic composition was -

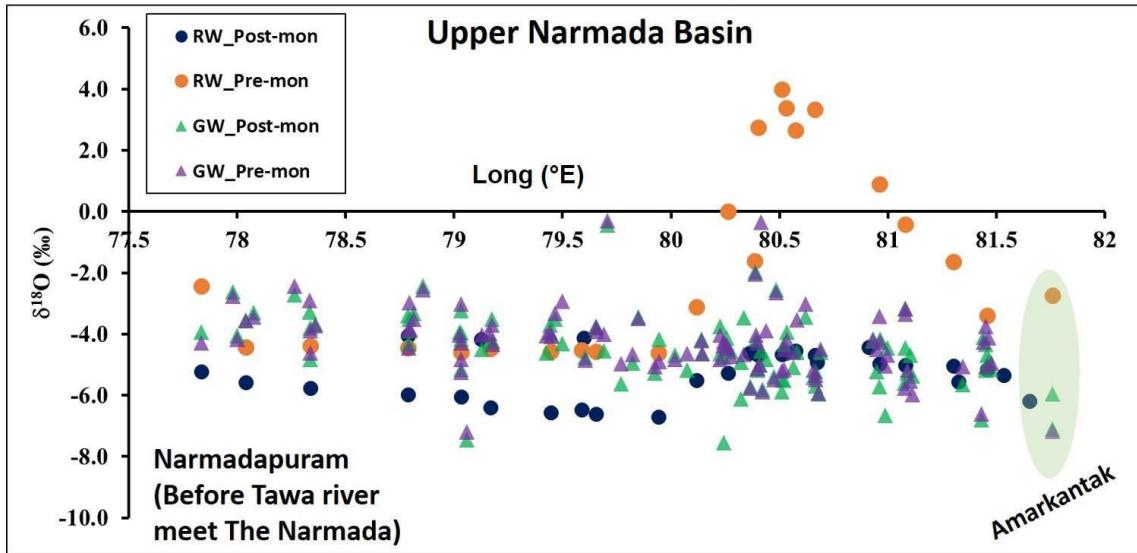


Fig 4: Variation of $\delta^{18}\text{O}$ with longitude (the Narmada River flow from east to west nearly parallel to 21°N latitude) for river and groundwater for Upper Narmada Basin

4.9 ‰ and it went up to -4.1‰ similar kind of pattern was also observed during post-monsoon season but the values were much lower i.e. Narmada kund water isotopic composition was 5.9‰ it went up to -4.4‰ and it started decreasing up to -5.5‰ and after the dam river water isotopic composition was -6.7‰ and it went up to -5.6‰ (Fig 3). Similar pattern was also observed in pH values of river water during both the season from Narmada kund to Hosangabad (Fig 4). Based on the isotopic data and pH some of the preliminary inferences

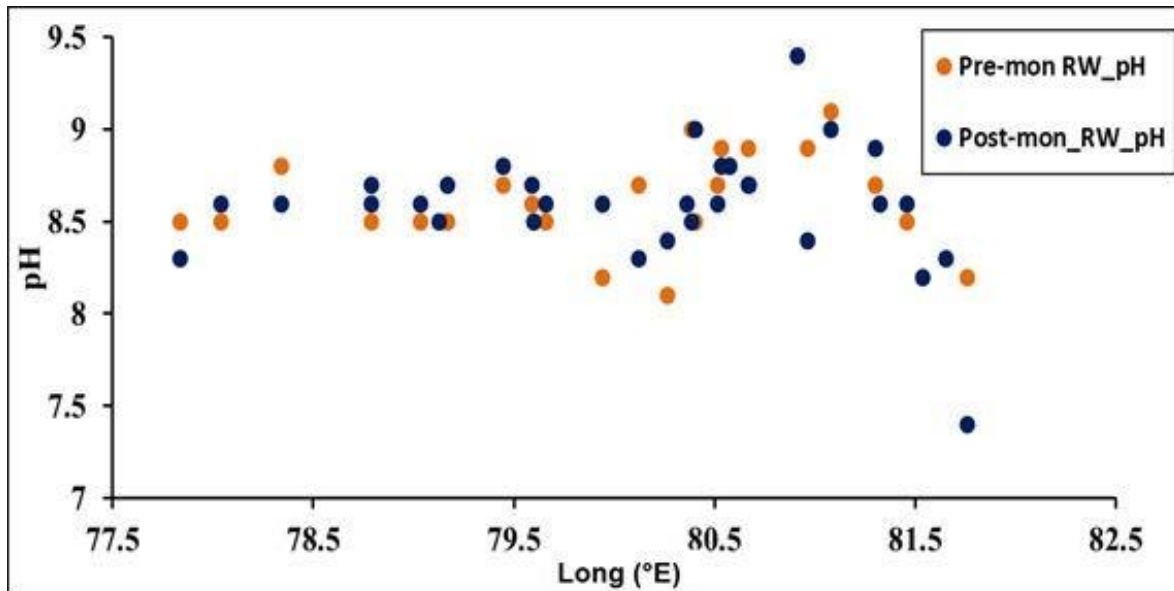


Fig 5: Variation of pH with longitude

drawn from this study are: (1) The initial increase in $\delta^{18}\text{O}$ value indicate higher extent of evaporation (2) The decrease $\delta^{18}\text{O}$ and pH before the dam indicated that this area receives base flow as groundwater in this part of lower isotopic composition and low pH values compared to river. (3) a decrease in isotopic composition after the dam is because of the stratification in isotopic composition of reservoir water (upper part of the reservoir water become enriched due to evaporation while bottom water preserves its initial and this water is further released in river.

Work done so far:

- Conducted pre-monsoon and post-monsoon field work and collected nearly 250 samples in each season for stable isotopes interpretation is in progress
- 18 samples were collected for tritium and analysis is going on
- 150 samples in each season were collected for measure ion and analysis is going on analysis and interpretation of these data is going on

Future Plan:

As per the schedule we will collect samples for one more year which include, stable isotopes, major ions, and tritium apart from this, from selected locations we will also collect samples for trace metals. These samples will be analysed and interpreted in future course of time.

Annexure – 1**Quarter wise 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												

7. 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, S.M. Pingale, S.D. Khobragade, Kuldeep Sharma

Type of Study: Internal study

Duration: 3 years

Date of Start: March 01, 2024

Date of Completion: February 28, 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, drought is frequent with additional impacts due to climate change. In 2016, 46 out of 52 districts were declared drought-affected by Madhya Pradesh's government. 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 region's current and future drought characteristics due 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 drought is to be studied. This will ensure a comprehensive surface and groundwater study to identify critical zones. Drought Characterization is based on water balance-based Standardized Precipitation Evapotranspiration Index (SPEI). It considers precipitation and temperature for drought assessment and is a better indicator than others. In addition, Future drought characteristics will 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 in terms of appropriate management and the adoption of suitable measures pertaining to current conditions and 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.

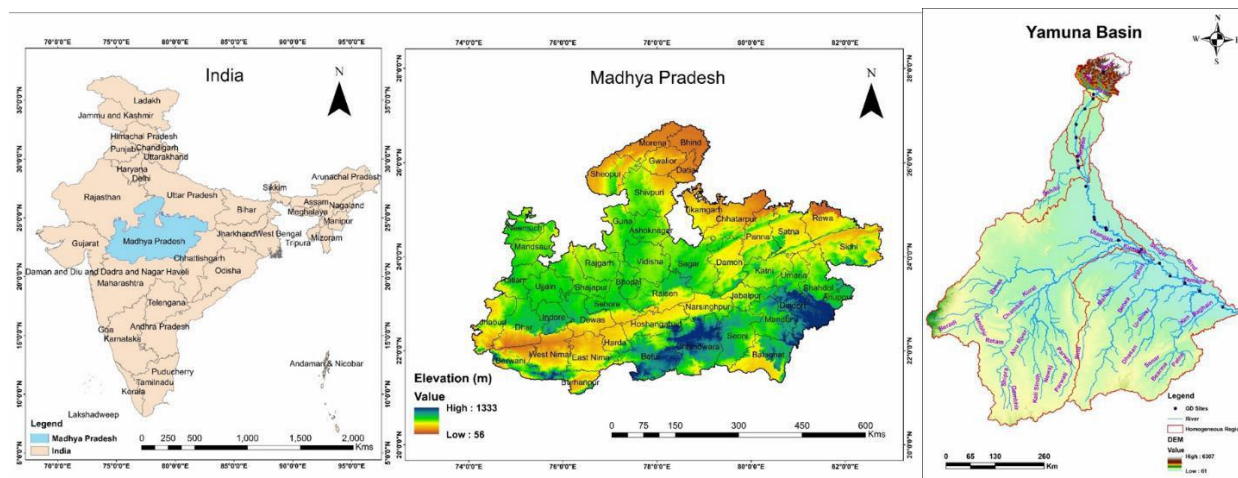
Specific objectives:

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 GRACE satellite data and validate with available groundwater wells data.
- Vulnerability assessment based on the region's SPEI, groundwater variability, and socio-economic data.
- To estimate the future drought characteristics based on SPEI from dynamically downscaled CMIP6 data.

Study Area

The present study will be carried out for the state of Madhya Pradesh and the Yamuna River basin (added after a suggestion in the Working group meeting in 2024).



Methodology

- The proposed methodology has been described here:
- Meteorological drought characteristics will be assessed based on the SPEI (precipitation and temperature) data from IMD.
- Based on critical regions, groundwater vulnerability will be assessed with long-term groundwater variability.
- Socio-economic data for the region, including population density, per capita income, etc., will be collected.
- An integrated vulnerability assessment will be done based on drought characteristics, groundwater depletion, and socio-economic data for zonation of regions.
- 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).
- Based on different scenarios, we will identify critical regions for drought in the future considering the near future and far-future.
- 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.

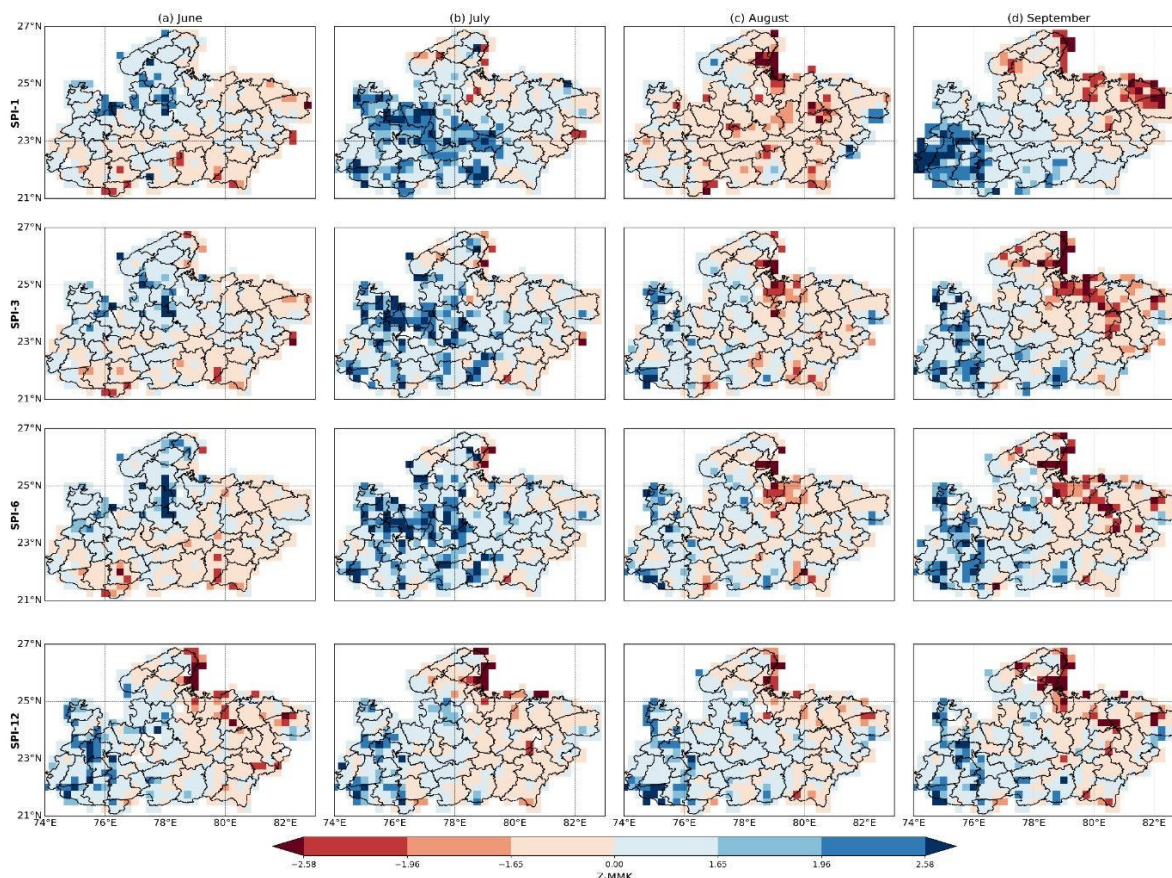
Research outcome from the project.

- ✓ 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.

Progress of the study Meteorological Drought Analysis

SPI-based Drought Trend Analysis: SPI-based drought trends indicate increasing drought conditions in northeastern regions, especially in August and September, for both short-term and long-term conditions.

Probability of Drought Occurrence: Drought probability assessments indicate a recurrence of dry spells across the study region.



Hydroclimatic Drought Analysis using SPEI

Daily rainfall and temperature data at 0.25-degree resolution.

Daily Potential Evapotranspiration (PET) is calculated using the Hargreaves method (T_{max} , T_{min} , Latitude).

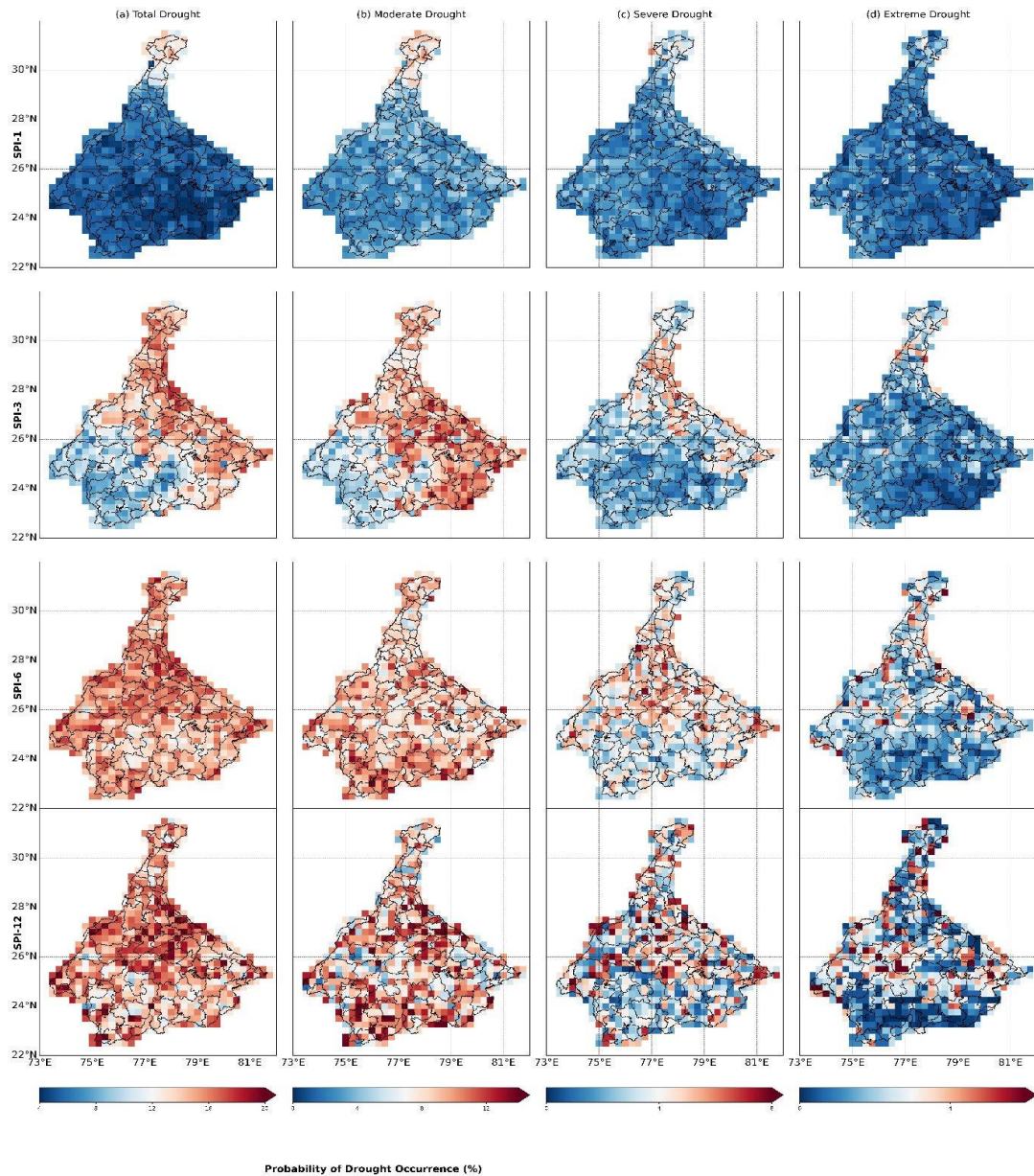
The 12-month SPEI of May and the 4-month SPEI of September were evaluated for Madhya Pradesh and the Yamuna River basin to assess water year and monsoon variability, respectively.

Groundwater Drought Analysis using GRACE-Based G-GDI

G-G DI is evaluated at a 0.5-degree resolution for Madhya Pradesh. Groundwater well data for the region has been collected and will be used to assess satellite-based data in future work. Groundwater depletion trends align with meteorological drought trends, reinforcing concerns about declining water availability.

Drought Characterization in the Yamuna River Basin

The medium-term and long-term drought probability is around 20%, indicating a frequency of once every five years. Severe drought events have a significant probability in the region, necessitating further investigation and mitigation planning.



Future Work

Further drought characterization will be conducted with dynamically downscaled data once available. Ongoing analysis of groundwater well data to validate GRACE-based groundwater drought assessments. Integration of multiple drought indicators for comprehensive drought risk assessment.

SPONSORED PROJECTS

PROJECT REFERENCE CODE: NIH/HID/BGS/2017-24

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)
Dr. Donald MacAllister Dr. Bentje Braun

Type of study : **Sponsored**, BGS, UK.
Date of start (DOS) : December 01, 2017
Scheduled date of completion : November 30, 2026
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 (96%)- 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	Characterise 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 (95%)– Samples for shallow (year 2023) and deep wells (year 2024) have been analyzed at BGS, UK for CFC and SF6, data interpretation is in progress
4	Assess groundwater vulnerability to salinization from water-logging from increased surface water flows (including canal flows) through	Achieved (95%)- 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

	glacial melt-water and identify 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%): Comparisons were made of current data with the previous years data and effects of floodings of the year 2023 were found and further interpretation is in progress
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 ingress 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).

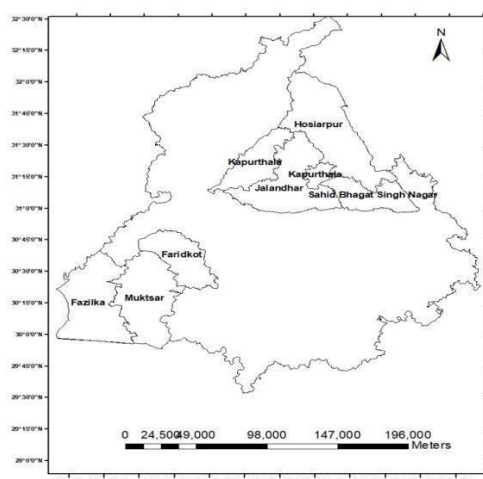


Fig. 1. Study area

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

Methodology:

In this study, groundwater level and conductivity data are monitored and high resolution field based observations are collected. For this 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).

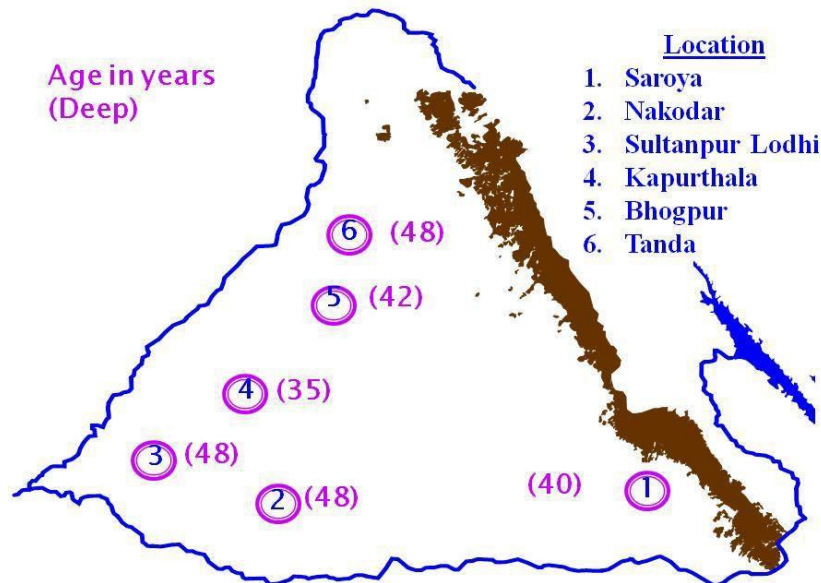


Fig. 2. Sites for installation of loggers in Bist Doab, Punjab

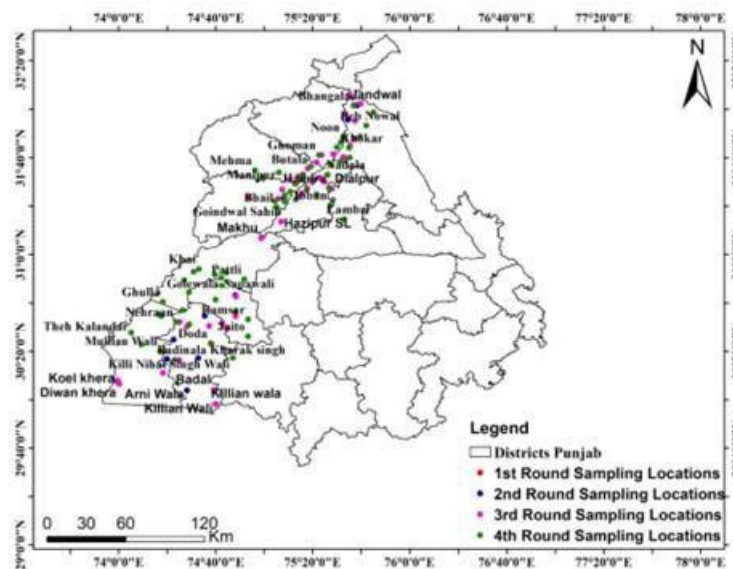


Fig. 3. Sites for sample collection, Punjab

Findings:

The groundwater responses varied and are shown below:

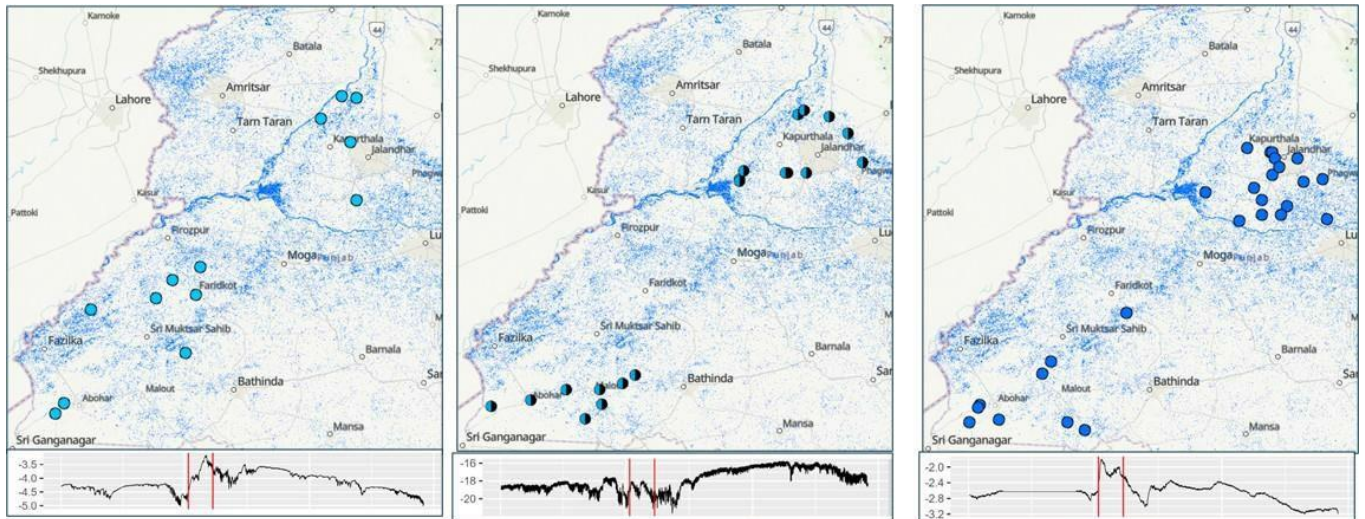
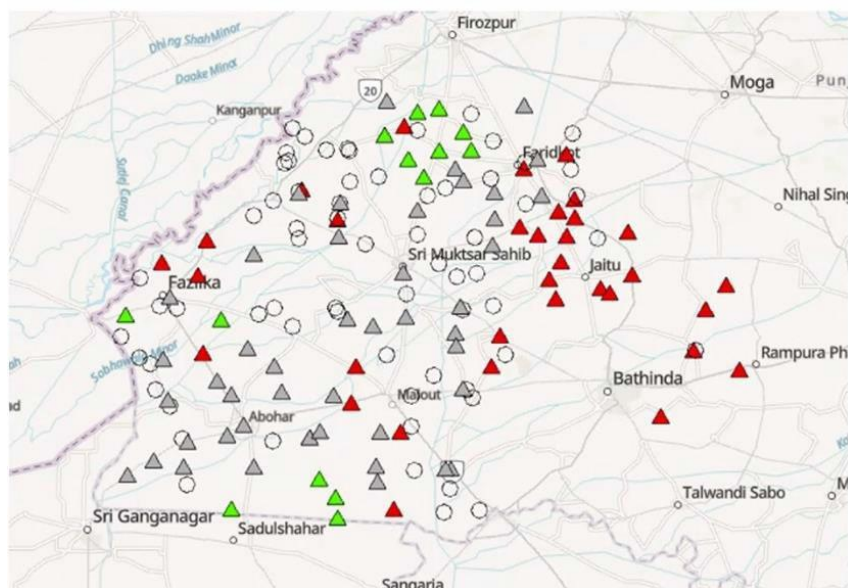


Fig.4. Groundwater level variations in a decade 2010-2023

It was found that there were only fewer sites which do not respond to the flooding events of 2023 and all the sites below 30 m have still declining groundwater levels.

The groundwater levels were rising in most of the wells in October due to the recharge. Trend distribution in SW Punjab is shown in Fig. 5.



	Bathinda	Faridkot	Fazilka	Muktsar	TOTAL
declining	5	17	6	6	34
no trend	0	7	25	16	48
rising	0	7	6	1	14

Fig. 5. Groundwater trend in SW Punjab

The salinity has decreased in wells in 2024 as compared to the well in year 2023

Work is being continued for some unanswered questions:

To find synchronicity 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., 2026 (Annexure 1)	Remark
Dec. 2017 to Nov. 2026	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

Supplementary details - 1

ACTIVITY SCHEDULE FOR THE GROUNDWATER FLUCTUATIONS AND CONDUCTIVITY MONITORING IN PUNJAB (QUARTER WISE FROM DEC. 2017 TO NOV. 2026)

Activity	1 st to 4 th h	5 th to 8 th h	9 th to 12 th h	13 th to 16 th h	17 th to 20 th h	21 st to 23 rd d	23 rd to 27 th h	28 th to 31 st t	31 st to 35 th h	36 th h
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 144 samples collected during March to June, 2024 analysed for ions, isotopes, heavy metals, CFC/SF6 and are to be analysed for pesticides and fungicides
- The data analysis and interpretation are in progress

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

1. 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) : March 31, 2021

Scheduled date of completion: December 30, 2024

Location: NIH Roorkee and IIT-Kanpur

Sr. No.	Study objectives	Achievements
1	Estimate evapo-transpiration (ET) flux at a study site in Kanpur	100% – 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);	100% - Experiments have been conducted for one wheat and two rice seasons. T
3	Quantify uncertainties in the estimates of E, T and ET fluxes	100% - Methods finalized for uncertainties quantification

Statement of the problem:

Agriculture is the single largest user of freshwater in India. A significant portion of the applied irrigation water eventually evapo-transpires. 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.

Table 1. Sample collection details (2023-24)

Sr. no.	Sample Type	Frequency	Samples Collected (C) and Analysed (A)	
			C	A
1	Atmospheric air moisture	Daily	668	668
2	Soil moisture evaporation	Daily	185	185
3	Transpiration	Daily	221	221
4	Rain	Event Based	89	89
5	Source (Irrigation) water	Random	34	34
Grand Total			1197	1197

The samples were collected for rain, air moisture, transpiration, soil moisture, Tree leaf moisture,

and soil moisture evaporation and analysed for isotopic compositions using an Isotope Ratio Mass Spectrometer (IRMS). Air moisture samples were collected from 1 meter, 2 meters, and 7 meters above the land surface in the experimental plot. Tree leaf moisture was collected from different trees inside the institute and its vicinity, and soil moisture was obtained up to 60 cm depth. In contrast, transpiration samples were obtained from potted *Symgonium podophyllum* plants Ashoka, etc. and moisture evaporated from the soil was collected using the model.

The temporal variations in the isotopic composition of air moisture of the pre-monsoon to monsoon season are presented in figure 1.

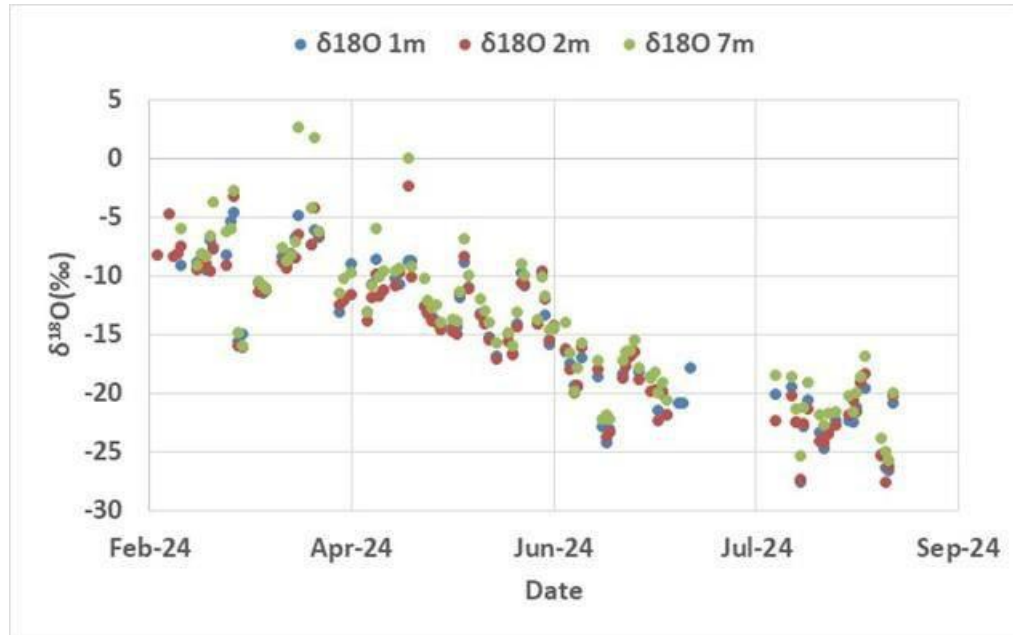


Fig.1. Temporal variations in the air moisture and different heights Following were the observations:

- In February, 2024 isotopic composition of surface and at different heights identical
- In March, 2024 isotopic composition of air moisture at 1 m height above the surface progressively depletes
- In April, 2024 surface vapor, an enrichment is observed, followed by a marginal depletion thereafter
- In June, 2024, average isotopic composition of surface vapor is nearly the same as was in first week of February
- With the onset of monsoon in July, 2024 air moisture at 1 m above surface shows a depletion of approximately 9 ‰ during the same period
- When compared with the evaporated soil moisture, the isotopic changes appear to occur much more rapidly in atmospheric vapor than in the evaporating liquid water within the soil pores.
- Transpiration samples are enriched by 10-18 ‰ as compared to air moisture in monsoon
- The isotopic composition ($\delta^{18}\text{O}$) of atmospheric moisture, grossly positively correlates with ($\delta\text{E}-\delta\text{T}$)
- Average difference in δ 's between pre-monsoon and monsoon :

Pre-monsoon: $[(\text{AM})-(\delta\text{E}-\delta\text{T})] = +3\text{‰}$; AM is highly enriched due to enriched top soil- moisture

Monsoon: $[(\text{AM})-(\delta\text{E}-\delta\text{T})] = -11\text{‰}$; AM is depleted as soil is wet from monsoon rains and is less evaporated

- Percent contribution of transpiration increased by about 50% after post monsoon (more humidity, less temperature) as compared to pre-monsoon (less humidity, more temperature).

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, 2023-24 rabi and kharif seasons, respectively. 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 December, 2024 (Annexure 1)	Remark
April 2021 to December 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

Supplementary details - 1

Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen

(QUARTERWISE WISE FROM APRIL 2021 TO DECEMBER 2024)

Activity	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th	11 th	12 th	13 th	14 th	15 th
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

ITEM NO. 55.3 PROPOSED WORK PROGRAM OF THE DIVISION FOR THE YEAR 2025-26

Apart from the internal studies and Sponsored Projects that shall continue during 2025-26 from the work programme of 2024-25, following New Studies are being proposed for the work programme of 2025-26:

NEW STUDIES FOR 2025-26:

1. PROJECT REFERENCE CODE: NIH/HID/R&D/2025/1

Title of the study	:	Study on unexpected summer monsoon incursions in the Himalayan basins using precipitation stable isotopic compositions of precipitation
Name of PI and members	:	NIH, Roorkee, India Dr. Gopal Krishan, Sc. E (PI) Dr. SD Khobragade, Sc. G (Co-PI) Dr. Amit Pandey, Sc. B (co-PI) IIRS-Dehradun Dr. Praveen Thakur, Sc. SG (PI) Dr. Arpit Chouksey, Sc. SE (Co-PI)
Type of study	:	Internal
Date of start (DOS)	:	April 01, 2025
Scheduled date of completion	:	March 31, 2027
Location	:	NIH Roorkee, IIRS-Dehradun, Chamba, Tehri

Statement of the problem:

The stable isotopic compositions of precipitation ($\delta^{18}\text{O}$ and $\delta^2\text{H}$) are important tools for revealing large-scale atmospheric circulation patterns and the local hydrological cycle and regional atmospheric circulations. Different moisture sources and moisture transport processes can strongly affect $\delta^{18}\text{O}$ and $\delta^2\text{H}$, and various moisture sources can be revealed by stable isotope records of precipitation. Previous studies have found that variations of $\delta^{18}\text{O}$ and controlling factors such as temperature are mainly affected by the Westerlies in the Himalayan Mountains. Located at the northern margin and may be within the modern non- monsoon region, the Himalayan Mountains have been traditionally considered far away from the northern edge of the summer monsoon. Whether these might be influenced by extremely strong summer monsoons in certain years has not been reported. The Asian summer monsoon (ASM) is a major monsoon system, which includes two sub-systems: the Indian summer monsoon (ISM) and the East Asian summer monsoon (EASM). The ISM is a typical tropical monsoon, associated with intense convective activity near the Bay of Bengal and the Indian subcontinent. The EASM is a unique monsoon system with a sphere of influence extending from the tropics to mid-latitudes. It brings water vapour from the Pacific and Indian Oceans to East Asia. The monsoon region is strongly zoned with respect to isotope composition of bulk precipitation.

The Himalayan Mountains, are mainly affected by the mid-latitude Westerlies. Himalayan region receives its moisture for precipitation from various sources including that from Western disturbances of extratropical weather system (which usually occur during pre- monsoon periods); from Indian Ocean, Arabian Sea and Bay of Bengal during southwest monsoon, and local moisture arising from evapotranspiration from snow cover, glaciers, Himalayan lakes, forest, rivers, etc. The

complex precipitation patterns combined with the high rising peaks, steep slopes and deep valleys of the Himalayan mountains enhances occurrence of intense rainfall events, cloud bursts, avalanches, flash floods, landslides, GLOF etc., which pose a significant threat to the livelihood of the dependent population of the region and the water resources of the Indo-Gangetic plains.

Study on resolving the complexities in precipitation patterns in the Himalayan region is important as these have significant implications for freshwater resources in plains of Indo-Gangetic basins, precipitation isotopic record serves as a crucial tool in unraveling the complexities of the Asian summer monsoon and its implication for regional and global climate.

By analyzing the isotopic records (in precipitation, air moisture, stream discharges, and snow cover), their trends, and the breaks in the trend, it is possible to decipher the changes in the precipitation pattern and the change in the contributing source.

Thus, the study can help in gaining insight into the dynamics of the water resources in the Himalayan region, which is useful in developing strategies for sustainable water development and assessing the potential impact on downstream communities and ecosystems.

Objectives

- (1) to understand variations of $\delta^{18}\text{O}/\delta^2\text{H}$ at event, monthly and longer timescales;
- (2) to study the effects of various controlling factors such as large-scale atmospheric processes and local factors (temperature, precipitation amount and altitude) on spatial and temporal distributions of $\delta^{18}\text{O}$;
- (3) to improve the understanding of changes in initial moisture sources and their relation to $\delta^{18}\text{O}$ and rainfall amount;
- (4) to explore how far ASM can transport water vapor to the northwest in July to September at mid-latitudes, for strong summer monsoon years; and
- (5) to evaluate past use of isotopic climate proxy data in the region.
- (6) to correlate with the satellite observed water stable isotope data

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

Methodology:

A network of at least 10-15 stations will be established from Shivalik to Himalayan region in Uttarakhand (Roorkee-Dehradun-Rishikesh-Narender Nagar-Chamba) which will be extended to upper Ganga basin for western disturbance in SW monsoon in this portion of Himalaya. Precipitation samples will be collected on event basis and atmospheric samples will be collected on daily basis.

Budget

Manpower (Jr. Resource Person)	Rs. 8,40,000/-
Travel cost	Rs. 2,00,000/-
Contingent:	Rs. 5,00,000/-
Consumables	Rs. 2,00,000/-
Total	Rs. 17,40,000/-

Action plan:

Period	April 2025 to March, 2027 (Annexure 1)	Remark
April 2025 to March 2027	Installation of instruments collection of rain and air moisture samples, isotope analysis Data analysis and uncertainty quantification Data dissemination and report writing	Report preparation as per Annexure 1

Study Benefits /Impact:

The study can help in gaining insight into the dynamics of the water resources in the Himalayan region, which is useful in developing strategies for sustainable water development and assessing the potential impact on downstream communities and ecosystems.

Specific linkages with Institutions:

- IIRS Dehradun

Supplimentary details - 1

(QUARTERWISE WISE FROM APRIL 2025 TO MARCH 2027)

Activity	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th	11 th	12 th
Literature review	♦	♦										
Installation of instruments	♦	♦	♦	♦								
Collection of waters samples			♦	♦	♦	♦	♦	♦	♦	♦		
Isotope analysis			♦	♦	♦	♦	♦	♦	♦	♦		
Data analysis and uncertainty quantification						♦	♦	♦	♦	♦		
Data dissemination and report writing											♦	♦

CENTRE FOR CRYOSPHERE AND CLIMATE CHANGE STUIDES (C4S)

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. Kapil Kesarwani	Scientist D
8	Dr. Deepak Singh Bisht	Scientist C
9	Dr. Akshaya Verma	Scientist C
10	Dr. Kuldeep Sharma	Scientist C
11	Shri Rajat Kumar	Scientist B
12	Shri Jatin Malhotra	Scientist B
13	Shri Madhusudan Thapliyal	SRA



APPROVED WORK PROGRAMME FOR THE YEAR 2024-2025

	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1. NIH/C4S/202 2-2025/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) <i>Extension Required</i>	Ongoing
2. NIH/C4S/202 3-2026/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), Suhaz Khobragade, MK Sharma, MS Rao, SM Pingale, PK Mishra	03 Years (04/23 - 03/26)	Ongoing
3. NIH/C4S/202 2-2024/SG	Climate Change Scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River Basin	Sunil Gurrapu (PI) YRS Rao, RV Ramana, Nitesh Patidar, TVNAR Kumar, CE, WRD, GoAP	02 years (04/22- 09/24) Ongoing	Completed
4. NIH/C4S/202 3-2028/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, Lavkush Patel, Akshaya Verma, Madhusudan Thapliyal	05 Years (03/23- 02/28)	Ongoing
5. NIH/C4S/202 2-2025/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)	Completed
6. NIH/C4S/202 1-2024/DSB- 1	Early Signatures of 21st Century on Snow Cover Dynamics in Zaskar River Basin, Ladakh	DS Bisht (PI) PG Jose	03 years (07/21- 06/24)	Completed
7. NIH/C4S/202 2-2024/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- 06/24)	Completed

	Project Title	Study Team	Duration	Status
8. NIH/C4S/202 3-2026/LKP- 1	Monitoring and Modelling of the Gangotri glacier catchment under different Climate Scenarios	Lavkush Kumar Patel, Sc. D (P.I.) Akshaya Verma, Sc. C Kapil Kesarwani, Sc. D Surjeet Singh, Sc. G Madhusudan Thapliyal, SRA	03 years (04/23-03/26)	Ongoing
9. NIH/C4S/202 4-2026/SS	Updation 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)	Ongoing
10. NIH/C4S/202 4-2027/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 (04/24-03/25)	Completed
11. NIH/C4S/202 4-2027/LKP- 2	Glacio-hydrological and GLOF investigations over the Triloki glacier, Bhaga basin, Western Himalaya	Lavkush Kumar Patel (PI), Akshaya Verma, Vishal Singh, Surjeet Singh	03 years (03/24-03/27)	Ongoing
12. NIH/C4S/202 4-2027/KS	WRF-based dynamical downscaling of CMIP6 climate projections over Himalaya and surrounding Region	Dr Kuldeep Sharma, Scientist-C Dr Ashwini Ranade, Scientist-D Mr Sahidul Islam, Associate Director, CDAC, Pune	03 years (04/24-03/27)	Ongoing
13. NIH/C4S/202 4-2028/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)	Ongoing
14. NIH/C4S/202 4-2026/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)	Ongoing

	Project Title	Study Team	Duration	Status
15. 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)	Ongoing
16. 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)	Ongoing
<u>SPONSORED PROJECTS:</u>				
17. 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
18. 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.	Dr. Vishal Singh	2.5 Years (June 2021 to September 2024)	Completed
<u>CONSULTANCY PROJECTS:</u>				
19. 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	Completed

PROPOSED WORK PROGRAMME FOR THE YEAR 2025-2026

	Project Title	Study Team	Duration	Status
INTERNAL STUDIES:				
1. NIH/C4S/202 2-2025/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/202 3-2026/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/202 3-2028/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, Lavkush Patel, Akshaya Verma, Madhusudan Thapliyal	05 Years (03/23-02/28)	Ongoing
4. NIH/C4S/202 3-2026/LKP- 1	Monitoring and Modelling of the Gangotri glacier catchment under different Climate Scenarios	Lavkush Kumar Patel (PI), Akshaya Verma, Kapil Kesarwani, Surjeet Singh, Madhusudan Thapliyal	03 years (04/23-03/26)	Ongoing
5. NIH/C4S/202 4-2026/SS	Updation 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)	Ongoing
6. NIH/C4S/202 4-2027/LKP- 2	Glacio-hydrological and GLOF investigations over the Triloki glacier, Bhaga basin, Western Himalaya	Lavkush Kumar Patel (PI), Akshaya Verma, Vishal Singh, Surjeet Singh	03 years (03/24-03/27)	Ongoing
7. NIH/C4S/202 4-2027/KS	WRF-based dynamical downscaling of CMIP6 climate projections over Himalaya and surrounding Region	Kuldeep Sharma (PI), Ashwini Ranade, Sahidul Islam, Associate Director, CDAC, Pune	03 years (04/24-03/27)	Ongoing

	Project Title	Study Team	Duration	Status
8. NIH/C4S/202 4-2028/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)	Ongoing
9. NIH/C4S/202 4-2026/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)	Ongoing
10. NIH/C4S/202 4-2026/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)	Ongoing
11. NIH/C4S/202 4-2027/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)	Ongoing
<u>NEW STUDIES:</u>				
12. NIH/C4S/AR /25-28	Exploring Atmospheric conditions and Triggering Mechanisms of Cloudburst Events in the Northwestern Himalayas	Ashwini Ranade (PI), Kuldeep Sharma	03 years (04/25-03/28)	New
13. NIH/C4S/JM /25-28	Seasonal variations in the Sediment Concentration and Organic Matter Dynamics in Neola Glacier, Uttarakhand	Jatin Malhotra (PI), Gopal Krishna, Vishal Singh, Kapil Kesarwani, Sumit Rai, Sc D, GBPIHE, Madhusudan Thapliyal	03 years (04/25-03/28)	New
14. NIH/C4S/SG /25-27	Assessing the Impact of Western Disturbances and ENSO on the Hydrology of the Bhaga River Basin	Sunil Gurrapu (PI), Vishal Singh, Ashwini Ranade, Kuldeep Sharma	02 years (04/25-03/27)	New
<u>SPONSORED PROJECTS:</u>				
15. 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

	Project Title	Study Team	Duration	Status
16. SP-74/2024- 25/NIH (C4S)	Isotopic and hydrogeochemical characterization of hot springs of Uttarakhand Himalayas	S Rawat Tripti Muguli Amit Pandey Akshaya Verma	03 years (09/24- 08/26) Sponsored by UCOST	Ongoing
17. SP-73/2024- 25/NIH (C4S)	Influence of climate change on Debris-covered Milam Glacier (Goriganga River Basin, Central Himalaya, India): Monitoring and Modelling of Physical Processes Governing Snow and Glacier-fed Watershed Dynamics	Kapil Kesarwani	3 years (02/23- 02/26) Sponsored by DST	Ongoing
18. SP/2025- 28/NIH (C4S)	Impact of Climate Change on the Glaciers in Indus basin and its Impact on water availability over the coming decades	Vishal Singh (PI), Surjeet Singh, Deepak Singh Bisht, Kuldeep Sharma, Akshaya Verma, Sachchidanand Singh, WHRC, Jammu	3 years (04/25- 03/28) Sponsored by DoWR, RD& GR, MoJS,	New

1.0 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.

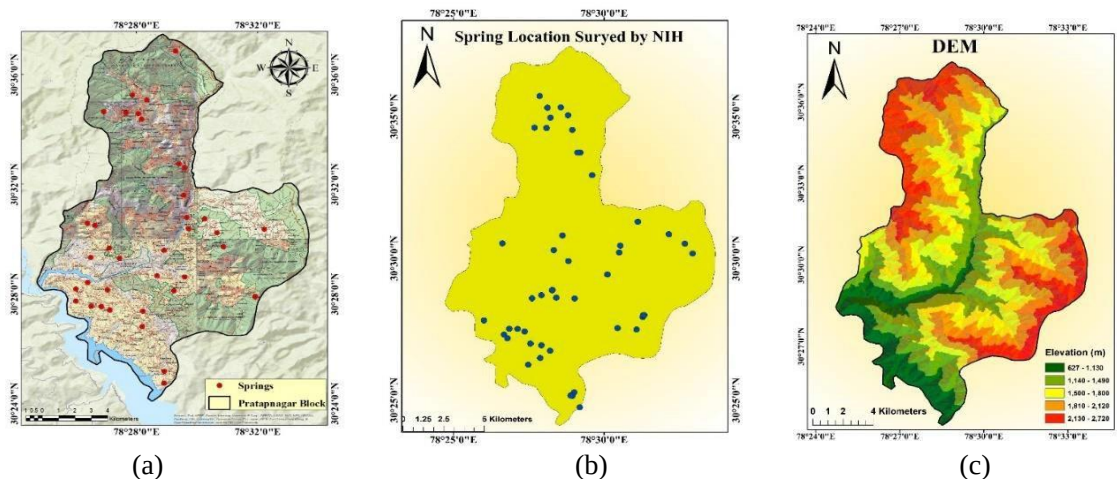
Progress:

- i. The water quality data of the Bhilangana block was analysed.
- ii. 03 field excursions were carried out by the project team during May, 2024 to December, 2024 for verification of the spring locations given by SoI and mapping of other springs which could not be mapped by the SoI in the Pratapnagar and Ukhimath block (Table 1).
- iii. A total of 50 springs were geotagged in the Pratapnagar block and 22 springs in Ukhimath using KoBo Toolbox, and spring water samples were collected during field visits for detailed water quality and isotopic analysis.
- iv. Measurement of physiochemical parameters i.e., pH, temperature, DO, ORP and EC were measured onsite. Details of the spring surveyed in Pratapnagar block as per field investigations is given in Table 2 and thematic maps of the Pratapnagar block are given in Fig. 1.

Table.2: Details of the spring surveyed as per field investigations in Pratapnagar Block.

Dataset	No. of springs
Spring locations given by SOI	37
Spring locations geotagged by NIH	50
New springs identified	28
Total spring locations verified	22

Springs locations found correct	17 ($\pm 100\text{m}$ from SOI location)
Springs not found at locations of SOI	15



(a) (b) (c)
Fig.1: (a) Spring location provide by SOI, (b) Spring Location by NIH Roorkee, (c) DEM

Future Plan:

- Water quality of the surveyed springs will be analysed in detail for understanding the detailed qualitative status of the springs in the area.
- The collected data and analysed hydro-geo-chemical and isotopic data will be investigated to understand the occurrence of the springs in the area.
- This work will be extended for Ukhimath CD block of Rudraprayag district.

2.0 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.

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.

Progress in brief:

- i. A comprehensive field survey was conducted of Pre-Monsoon sampling, resulting in the identification and collection of spring water samples. During this survey, meticulous records of on-site physiochemical parameters were maintained, and water samples for major ions, heavy metals, isotope were systematically collected. These samples undergo thorough laboratory analysis to understand the water quality and isotopic characteristics.
- ii. Rain gauges has been installed at different location; Chinyalisour, Uttarkashi, Maneri, Bhatwari, Songad, Harsil in the study area for collection of rainfall samples for isotopic analysis.
- iii. As part of the study, various base maps, including a Morphotectonic map (**Fig. 1a**) and Spring density map, Lineament density map (**Fig. 1b**), have been prepared. These maps serve as essential tools to better understanding the geological control on the genesis of springs within the study area.
- iv. An extensive classification of springs was undertaken, based on the characteristics of pH levels, electrical conductivity, discharge, Geology and Land Use Land Cover characteristics and isotopic variation and Tectonic zonation of watersheds.
- v. Using ArcGIS Bhagirathi Basin subdivided in 19 sub-watersheds (SW-1 to SW-19). Using the morphotectonic parameters like, Stream Length Gradient Index (SL), Valley floor with to-height ratio (Vf), Drainage basin asymmetry factor (Af), Hypsometric integral (HI), etc. Bhagirathi Basin divided in to different tectonic active zones; i.e. Very highly tectonic active zone, highly tectonic active zone, moderately tectonic active zone, low tectonic active zones (**Fig. 1a**).

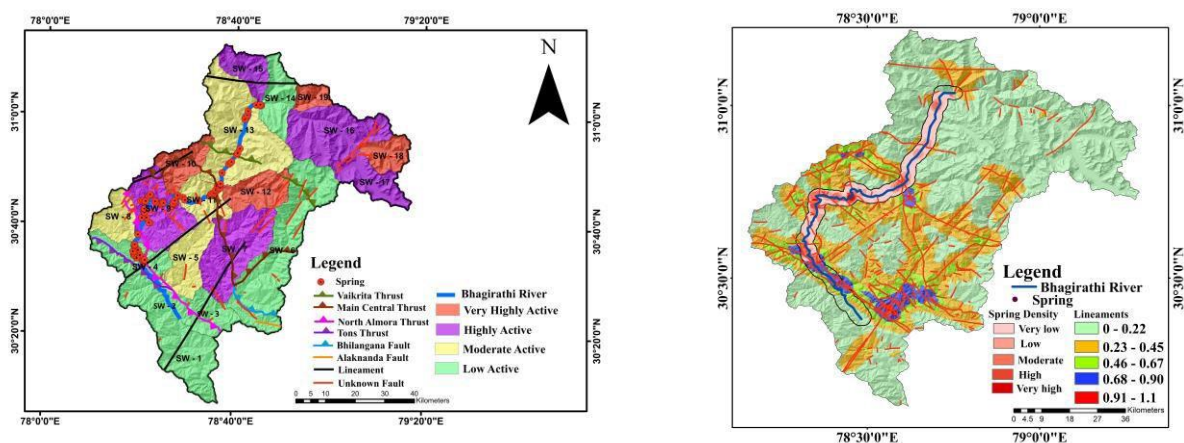


Fig. 1: (a) Morphotectonic map illustrates the classification of tectonic zonation of Bhagirathi Basin, and (b) Lineament and spring density map.

- vi. The major ions and heavy metals were analysed the concentrations of major ions in 77 spring samples, encompassing fluoride, chloride, nitrite, sulfate, bromide, nitrate, phosphate, lithium, sodium, ammonium, potassium, magnesium, and calcium, Aluminum, manganese and Iron.
- vii. Stable isotopic data, including $\delta^{18}\text{O}$, $\delta^2\text{H}$, and d-excess, were obtained from 77 spring samples, offering insights into water sources, evaporation effects and geological control.
- viii. Springs from B-SP-01 to B-SP-14, falling in the subwater shed 04, B-SP-15 to B-SP- 48 falling in SW – 09, B-SP-49 to B-SP-59 falling in SW- 11, B-SP-07, B-SP-60, B- SP-73 falling in SW-13 and B-SP-10, B-SP-74 to B-SP-77 are falling in SW- 14.
- ix. In SW -04 we reported moderate spring density, which are falling near the lineament- dominated area. The $\delta^{18}\text{O}$ ‰ varies from -8.44‰ to -11.81‰ range of 3.36 ‰, δD ‰ varies from - 56.16‰ to -61.91‰ range of 5.8‰, reflecting the characteristics of precipitation and groundwater interaction. This lower variation of the isotopic value indicates the classification of SW – 04 as a low tectonic area and suggests a stable ground system with limited mixing from different sources.
- x. In SW-09 sub-watershed, we reported wide variation of the isotopic composition of $\delta^{18}\text{O}$ ‰ varies from -7.50‰ to -11.81‰ range of 4.31‰, and δD ‰ varies from - 50.10‰ to - 58.93‰ range of 8.83‰, D excess varies from 8.01‰ to 14.97‰ range of 6.96‰. These large variations in the isotopic composition imply that the water in this area is sourced from a variety of places and mixed as it passes through the subsurface facilitated by the fault and fractures triggered by the tectonic activity.
- xi. Moderate tectonic activity in SW-11 has a significant impact on the density of springs, which is moderate and validated by isotopic narrow variation in spring water. SW – 13 and 14, which are low tectonically active in this zone, we reported low spring density.

Future Work:

- i. To enhance the study's depth, additional geochemical investigations during the different seasons of the year are needed. These would provide a comprehensive understanding of the geological controls influencing groundwater movement in the region.

3.0 PROJECT CODE: NIH/C4S/2022-2024/SG

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

PROJECT TEAM

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

Type of Study: Internal
Status: Completed
Duration: 2 years
Date of Start: 1st April 2022
Scheduled Completion Date: 31st March 2024 (Extended up to 30th September 2024)

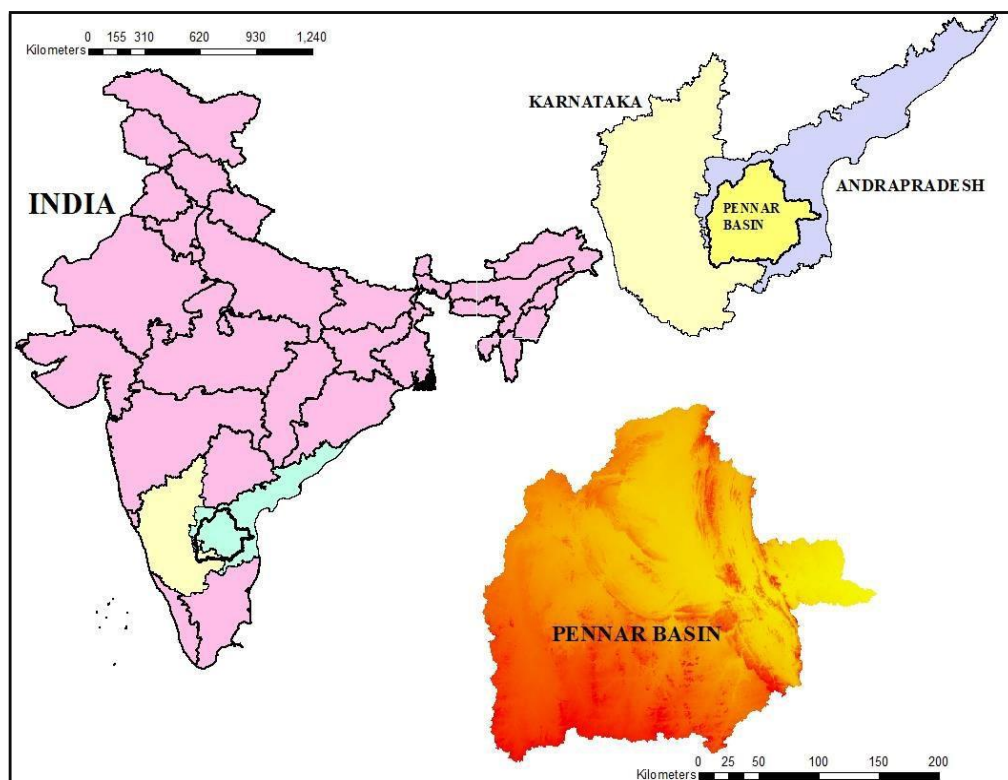
OBJECTIVES

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 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 analyse 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.



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

PROGRESS

Multi-model climate change scenarios for the state of Andhra Pradesh were generated, based on the global climate scenarios derived from General Circulation Model (GCM) runs conducted under the coupled Model Intercomparison Project Phase 6, (CMIP6). The climate scenarios generated under CMIP6 were downscaled, using Bias-correction Spatial Disaggregation (BCSD) method, to a common grid of 0.25×0.25 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 (0.25×0.25 degree) and temperature (1×1 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.

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 (0.25×0.25 degree) and temperature (1×1 degree) from IMD are used to run the model. In addition, windspeed dataset is required to force the VIC model, which is obtained from NASA POWER (Prediction of Worldwide Energy Resources), available at a 0.5×0.5 -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. Finally, a random forest-based machine learning model is developed and calibrate to simulate and project groundwater levels at selected sites within the Pennar 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.

Beneficiaries: Water Resources Department and Groundwater Board, Government of Andhra Pradesh.

4.0 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. Akshaya Verma, Sc. C (Co-PI)
 Dr. Kuldeep Sharma, Sc. C
 Dr. Atar Singh, RA, C4S)
 Mr. Bhupendra Joshi, PhD Scholar, C4S

Type of Study: R&D
Funding Agency: INTERNAL
Study Duration: 05 Years (2023 – 2028)

Background:

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 Objectives:

- a) Monitoring, and Collection of hydro-meteorological datasets for the Cryospheric 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 unravelling 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.

Brief Methodology

- a) Instrumentation hydro-observation sites
- b) Data monitoring and processing
- c) Snow and glacier maps generation
- d) Analyzing precipitation trends and changes
- e) Hydrological modeling, calibration and validation using SPHY model
- f) Climate change impact assessment using CMIP6 models

Results and Works Done and in Progress:

The hydro-meteorological observation stations viz. Automatic Weather Station (AWS) and Discharge and Velocity monitoring station have been installed near the Triloki group of glaciers, near Yotche Village, Keylong, Lahul and Spiti, Himachal Pradesh. The meteorological parameters viz. precipitation, temperature, wind speed, humidity and radiation are measuring for the analysis of snowmelt and glacier melt runoff responses in the Triloki glaciers (Bhaga basin).



Installed AWS at the Yotche site, Triloki glacier site, Bhaga basin, Keylong, HP.

The discharge and velocity at the upstream area of Bhaga basin near Triloki group of glaciers are measuring and these observational datasets will be utilized for performing the hydrological modeling to see the responses of snow and glacier melt runoff. The instrumentation and installation of AWS and Discharge monitoring station at Bhilangna basin (Khatling glacier) will be done in May 2025. In Triloki group of glaciers, Bhaga basin, hydrological modeling using SPHY has been setup. The meteorological data analysis is under progress. For the hydrological modeling of Bhilangna river basin, the SPHY model has been setup and the calibration and validation have been done. The meteorological data analysis such as rainfall changes and trend analysis has been completed. The

historical simulations for snowmelt runoff, glacier melt runoff and total runoff at different stations have been completed. The climate change analysis using CMIP6 models is under progress.

Expected Outcome

- Changes in glaciers and snow covers
- Modeling outcomes of snowmelt, glacier melt and runoff
- Climate projects of hydrological runoff components

Beneficiaries & Stakeholders

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

5.0 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

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 and Achievements:

S. No.	Objectives	Achievements
1	Identify large-scale Extreme rain events and isolated short duration heavy rainstorms across NWH during 1951-2021	An inventory of large-scale and spatio-temporal extreme rain events during 1951-2021 has been prepared. Long-term changes in parameters of extremes are evaluated.
2	To generate in-depth information about rain-producing weather systems associated with the extremes	Using literature survey and analysed weather charts, a detailed information about the rain producing weather systems across NW Himalaya has been prepared.
3	To investigate the association of EREs with global atmospheric thermal structure and general and monsoonal circulation.	Composite meteorological analysis of temperature and geopotential height at 12 isobaric levels has been performed for most extreme large-scale rain events.
4	To understand role of tropical-extratropical interactions and different thermo-hydro-dynamical processes causing EREs	Composite of relative vorticity and global weather regimes at different atmospheric levels

Statement of the problem:

Heavy rain events in the Northwest Himalaya have intensified in recent years, triggering catastrophic disasters. Cloudbursts, characterized by intense downpours over small areas in short durations, are becoming more frequent. The International Disaster Database (EM-DAT) reports a substantial rise in extreme rain events across the Western Himalayas over the past 30–40 years. Despite being widely studied, these phenomena remain poorly understood, largely due to the region's complex terrain and tropical-extratropical atmospheric interactions, making it particularly vulnerable during the monsoon season. Global warming believed to be accelerating the hydrological cycle, increasing extreme rain events. The IPCC Sixth Assessment Report (2021) projects that extreme rainfall will intensify by 7% for every 1°C rise in global temperature, with Africa and Asia experiencing the most frequent increases. Since 2010, around 17 extreme events have struck the Indian Himalayas (Leh, Uttarakhand, J&K, and HP), 5 in subtropical Pakistan, and 2 each in Nepal and China.

Studies suggest that large-scale interactions between deep westerly troughs, cross-equatorial Indian Ocean southwesterlies, and Pacific easterlies lead to the formation of intense monsoon troughs stretching from the Philippines to the Indus basin. Arabian Sea and Bay of Bengal moisture influx, combined with synoptic, mesoscale, and microscale weather systems, intensifies these events, particularly when interacting with Himalayan topography. However, trough intensification in

temperate westerlies is short-lived, making condensation and extreme rainfall events brief but severe due to the convergence of air masses with contrasting characteristics.

While various studies have analyzed rainstorm precipitation characteristics in the Himalayas, the evolution and intensification of rain-producing weather systems at the boundary of tropical (barotropic) and extratropical (baroclinic) regimes remain inadequately understood. Moreover, monsoonal and non-monsoonal weather systems exhibit distinct circulation dynamics, and even within the monsoon season, rainstorm dynamics differ during the early, peak, and withdrawal phases. Identifying a common atmospheric pattern for all Himalayan extremes is highly challenging. To address this, we propose a case-by-case analysis of large-scale extreme rain events across different seasons (winter, pre-monsoon, monsoon, and post-monsoon) over the Northwest Himalaya. Using station-based (hourly) and gridded (daily) rainfall data, along with reanalysis atmospheric parameters, this study aims to systematically examine the mechanisms driving heavy rainstorms in the region.

Study area and dataset used

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 $0.25^\circ \times 0.25^\circ$ 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.)

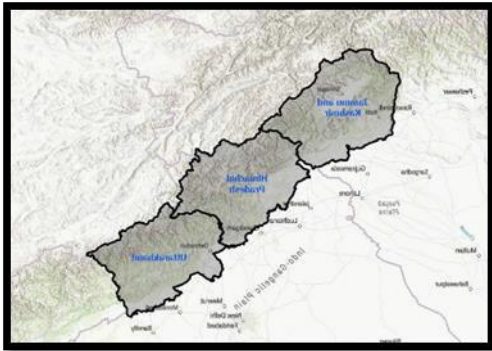


Fig 1. Study area: Northwest Himalaya

Analysis and Results

Annual and seasonal rainfall characteristics across NW Himalaya

The analysis of annual and seasonal rainfall characteristics across the Northwest Himalaya (NWH) over the period 1951–2021 reveals significant spatial and temporal variations. Using daily gridded rainfall data, the study examines area-averaged rainfall for Uttarakhand (UK), Himachal Pradesh (HP), and Jammu & Kashmir (J&K) across different seasons: monsoon (JJAS), post-monsoon (OND), winter (JF), and pre-monsoon (MAM). UK receives the highest mean annual rainfall (1444.7 mm), followed by HP (1244.85 mm) and J&K (1125.8 mm). Monsoon rainfall is highest in UK (1096.5 mm), followed by HP (746.78 mm) and J&K (465 mm), with notable spatial variability.

Trend analysis using the Mann-Kendall test shows no significant change in annual and monsoonal rainfall in UK, but post-monsoon (OND) rainfall has declined significantly, with a 35% drop in the last 20 years. HP exhibits a significant long-term decline in annual rainfall (~13% in the last two decades), with monsoon (-8.5%), OND (-33%), winter (-17%), and pre-monsoon (-17%) rainfall also decreasing. In contrast, J&K shows a long-term increase in winter (JF) rainfall, with monsoonal rainfall rising by ~18% in the last 20 years. Spatially, annual rainfall has declined across most of HP and parts of UK, while increasing in J&K. Monsoon rainfall is rising in J&K

and high-altitude regions of HP and UK but decreasing in low-lying areas. Post-monsoon rainfall is declining in UK, while winter rainfall is increasing in J&K. These shifts have critical implications for water resources, agriculture, and disaster risk management in the Northwest Himalaya.

Identification of Large-scale extremes concerning rainfall amount (ERE-RA) and rainwater (ERE-RW)

Large-scale extreme rain events (EREs) over the Northwest Himalaya (NWH) and its three states (Uttarakhand, Himachal Pradesh, and Jammu & Kashmir) are identified based on 1- to 10-day durations to quantify persistent intense rainfall during 1951–2021. An objective method classifies these events concerning rainfall amount (ERE-RA) and rainwater (ERE-RW, calculated as rainfall $\times$ area covered). A grid is considered wet if its daily rainfall exceeds the daily mean monsoon rainfall (DMR), which varies from less than 2 mm/day to over 18 mm/day across NWH. The ERE-RA represents the maximum cumulative rainfall over wet grids for durations ranging from 1 to 25 days, while ERE-RW accounts for total accumulated rainwater over these grids. Additionally, parameters like areal extent (AE) and event start date are documented.

Climatological analysis reveals that the rainfall amount of ERE-RA increases with event duration, ranging from 58.04 mm (± 20.77) to 203.36 mm (± 36.54) across NWH. In individual states, UK shows an increase from 71.50 mm (± 31.70) to 148.14 mm (± 54.54), HP from 57.05 mm (± 18.12) to 206.84 mm (± 42.47), and J&K from 58.58 mm (± 29.63) to 175.22 mm (± 46.26). The areal extent remains stable over time, with $\sim 70\%$ wet area in UK and J&K, and $\sim 57\%$ in HP.

Analysis of the seasonal and monthly distribution of 1-day large-scale EREs from 1951–2021 indicates that most events occur during the monsoon season (JJAS). However, in some years, non-monsoonal extremes surpassed monsoonal events, particularly in HP and J&K, highlighting unexpected seasonal variability in extreme rainfall occurrences.

Long-term trends and recent changes in parameters of large-scale extremes

Inter-annual variations in large-scale extreme rain events (EREs) analyzed using the Mann- Kendall test to assess trend significance (fig 2). Results indicate a significant decrease in rainfall amount (RA) for 8- to 10-day ERE-RA over NWH, while HP shows a decreasing trend for 3- to 10-day events, but no significant trend is observed in UK. The areal extent (AE) of 2-day ERE-RA over NWH shows an increasing trend, with JK exhibiting a significant increase for 1- to 6-day events, whereas no significant trend found in HP. For rainwater (RW), a significant increasing trend observed for 1-day ERE-RW over NWH during 1951–2021. While UK shows no significant trend, J&K exhibits an increase for 1- to 2-day ERE-RW, whereas HP shows a significant decline for 5- to 10-day ERE-RW.

In the last 20 years (2001-2021), RA of ERE-RA shows no significant change over NWH but, increases for 1- to 5-day events in UK and 1-day events in J&K, while HP sees a decline in 2- to 5-day ERE-RA. The areal extent of 1- to 3-day ERE-RA has significantly increased over NWH with no change in UK and HP, but a decline for 1-day and 4- to 5-day events in J&K. Rainwater of 1-day ERE-RW has significantly increased over NWH and J&K, with UK showing an increase for 1- to 5-day events, while HP experiences a decline in 4- to 5-day ERE-RW.

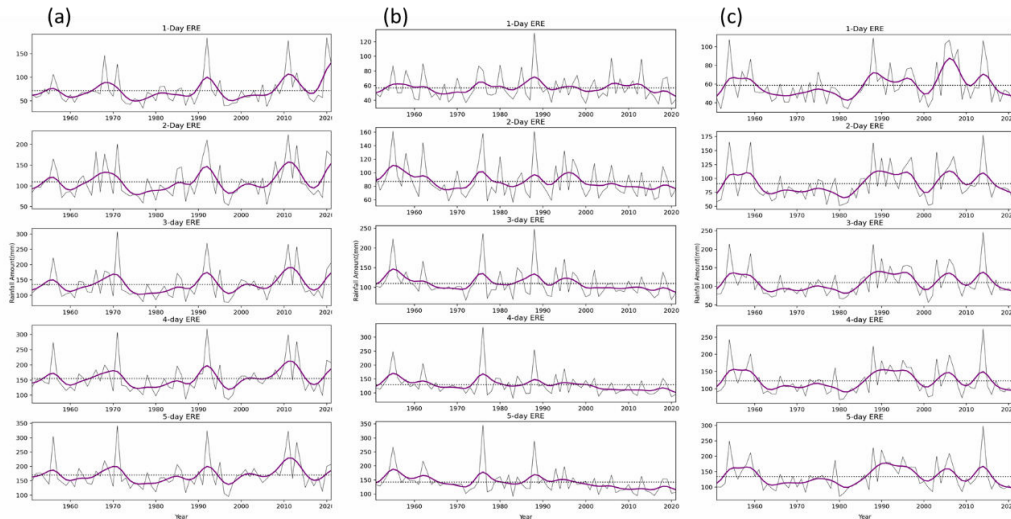


**Fig.2 Interannual variations in rainfall amount of large-scale ERE-RA over
a) UK b) HP and c) JK**

Identification and Characteristics of Small-scale spatio-temporal extremes (ST-EREs):

Small-scale isolated extreme rain events (ST-EREs) exhibit high inter-annual spatial variability across the NWH. To analyze their characteristics, 1- to 10-day duration grid-scale (0.25°) ST-EREs have been studied from 1951–2021. The annual maximum rainfall series was prepared by selecting the highest year-wise rainfall amount for each grid, with similar datasets created for 2- to 10-day durations. The mean rainfall for 1-day ST-EREs ranges from 50.3 mm to 168.9 mm, while for 10-day events, it varies between 121.23 mm and 528.15 mm. The highest recorded rainfall during the study period indicates that 1-day ST-EREs range from 106 mm to 762.9 mm, while 10-day ST-EREs vary between 263 mm and 1423 mm. Spatial distribution analysis shows that low-intensity ST-EREs are widespread across NWH, with a higher frequency in J&K, whereas severe ST-EREs (rainfall >8 times the Daily Mean Rainfall, DMR) are less frequent, occurring mainly in northern J&K and high-altitude regions of HP and UK.

Spatial Trend analysis of rainfall and frequency of occurrences of ST-EREs:

Spatial trend analysis using the Mann-Kendall test reveals a significant increase in 1-day ST-ERE rainfall over major parts of J&K and high-altitude areas of UK, while lower-elevation regions of HP and some parts of UK show a decline in long-duration (≥ 2 -day) ST-EREs. This indicates an intensification of short-duration ST-EREs in high-altitude areas, while prolonged-duration extremes are decreasing in lower elevations. However, no spatially coherent long-term trend is observed across NWH for 1- to 10-day ST-EREs. Trend analysis of ST-ERE frequency shows a significant increase in high-altitude regions, particularly in J&K and parts of UK, with more pronounced changes in high-intensity rainfall events (>8 DMR). Conversely, low-altitude regions of HP and UK exhibit a decline in moderate-intensity events. During the monsoon season, low-intensity ST-EREs (2-4 DMR) have significantly decreased in lower-altitude areas of HP and southern UK, while high-altitude regions of J&K and parts of UK show an increase. Moderate to high-intensity ST-EREs (6-12 DMR) are rising in a scattered pattern across northern J&K and UK. These trends indicate a shift towards more frequent extreme rainfall events in high-altitude regions, especially in J&K and northern UK, while moderate-intensity events are declining in lower-altitude regions, including HP and southern UK (fig 3).

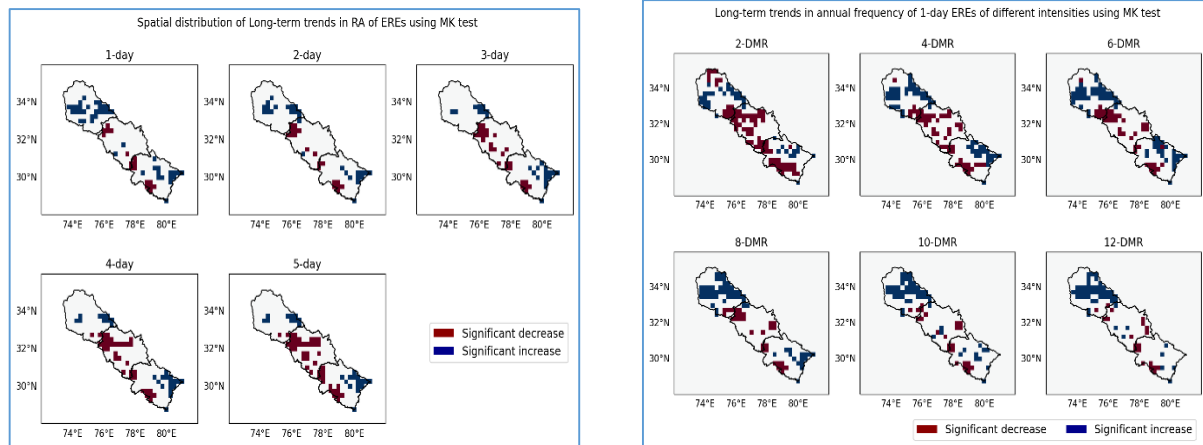


Fig 3. spatial distribution of long-term trend in rainfall of 1-to 5-day ST-EREs (left Pannel) and that of frequency of ST-EREs of different intensities (right panel) during 1951-2021

Composite meteorological analysis of most extreme LS-EREs in different seasons.

Most severe 1-day large-scale extreme rain events concerning rainwater are identified for each season (DJF: winter, MAM: pre-monsoon, JJAS: monsoon and ON: post-monsoon) during 1951-2021. Composites charts of temperature, geopotential, wind and relative vorticity at 12 isobaric levels for top three severe extremes (fig4) are prepared and analysed in details.

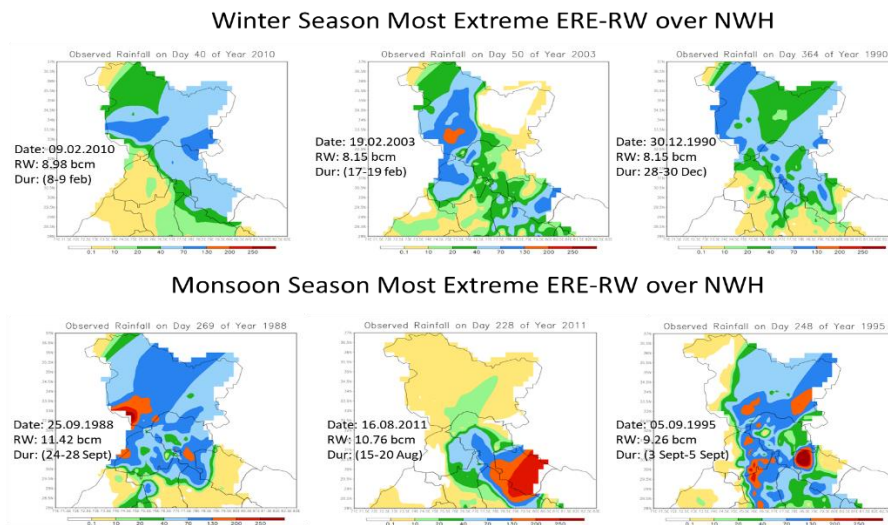


Fig.4. Most extreme large-scale extreme rain events during winter and monsoon season

During winter-time ERE days, strong cold anomalies develop over Eastern Europe and Central Asia, while warm anomalies appear over Northern Africa, the Arabian Sea, and the Bay of Bengal, creating a sharp temperature gradient. Cold air intrusion from higher latitudes interacts with warm, moist air, intensifying the unstable baroclinic zone. Upper-level troughs enhance vertical motion, supporting strong uplift and heavy precipitation. A deepening mid-level trough and upper-level divergence strengthen the low-pressure system, facilitating cold air advection. The alignment of low-level low pressure, a mid-level trough, and upper-level divergence forms a vertically stacked system, indicating a well-structured western disturbance. Positive vorticity and cyclonic anomalies intensify in the lead-up to the event, interacting with the jet stream to enhance instability. The progression of mid- and upper-level systems peaks on the event day, driving extreme rainfall and cold events before dissipating within 24 hours.

During monsoonal ERE days, wide spread cold anomalies and a negative geopotential height anomaly at lower level enhance moisture convergence and low-pressure deepening. Upper-level cooling, negative geopotential height anomalies, and upper-level divergence (due to jet stream interaction) drive extreme vertical motion and heavy precipitation. Monsoon LS-EREs over NWH are driven by a multi-layer interaction of cold anomalies, deepening low pressure, mid-level troughs, and upper-level divergence. Baroclinic instability, jet stream interactions, and cyclonic vorticity are key factors that intensify these extreme rainfall events. The system evolves in a vertically stacked manner, with peak intensity on the event day and dissipation within 24 hours.

Important Results:

1. Increasing rainfall amounts, rainwater, and areal extent, highlighting intensified extreme rainfall events over JK and UK states and declining rainfall amounts and rainwater, signalling a reduction in extreme rainfall activity in HP.
2. No overall change in rainfall totals for NWH, but a significant increase in areal extent of short-duration extreme rainfall events that reflect an increase in rainwater in recent years.
3. The year-wise most severe large-scale EREs mostly occurred during monsoon season, however, surprisingly in some years, the severity and areal extent of non-monsoonal extremes surpassed the monsoon extremes especially over HP and J&K.
4. Short-duration EREs in high-altitude areas are intensified while prolonged rainfall in lower regions are reduced.
5. High intensity EREs (>8 DMR) are less frequent and mostly occur in northern J&K and high altitude southern regions of HP and UK.
6. Winter LS-EREs are driven by the alignment of low-level low pressure, a mid-level trough, and upper-level divergence forming a vertically stacked system, indicating a well-structured western disturbance.
7. Monsoon LS-EREs have an alignment of warm moist low convective zone at the lower level and warm-moist upper level divergence indicate convective instability, moisture transport and transient monsoon circulation.

Deliverables

1. Analysis of various types of extremes over an extended period helps scientists to understand changing precipitation patterns due to climate change over NW Himalaya.
2. Helps to assess risks associated with various extremes for urban planning, disaster preparedness etc. and provide valuable insight for designing resilient infrastructure that can withstand extremity of precipitation.
3. Government and policymakers can use long-term analysis of EREs to formulate policies related to climate change adaptation, disaster risk reduction as well water resources management.
4. Meteorological analysis of the evolution and genesis of severe EREs will be helpful in improving the physical processes in numerical weather prediction models and to develop early warning systems.

Adopters of the results of the study and their feedback:

Weather analyst, water resources sectors, disaster management.

7.1 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 Group : Dr. Deepak Singh Bisht, PI & Sc-C
Dr. Manmohan Goel, Co-PI & Sc-G

Date of Start : June, 2022

Date of Completion : May, 2024

Duration of the Study : Two years

Type of Study : Internal

Nature of Study : Analysis of precipitation estimates

Location : Upper Ganga River basin

Background:

The Ganga River basin is divided into three distinct reaches: upper, middle, and lower. This study focuses on the Upper Ganga Basin (UGB) within the Indian Himalayan Region (IHR) up to Rishikesh, covering a catchment area of approximately 21,762 km². Geographically, UGB spans between 29°45' N to 31°27' N latitudes and 78°09' E to 80°15' E longitudes, exhibiting significant variations in elevation and climate. Elevation ranges from 324 m in the lower regions to 7,799 m in the high mountains, contributing to diverse climatic conditions predominantly characterized by tropical and sub-tropical temperature zones. The region experiences distinct topoclimatic regimes, with monsoon-driven precipitation patterns varying from 550 mm to 2500 mm annually. The southwest monsoon, active from July to late September, accounts for the majority of rainfall, while areas above 2,500 m mean sea level (msl) remain snow-covered, experiencing significant winter snowfall. Rainfall distribution across UGB exhibits topographical influences, with peripheral regions receiving higher precipitation compared to central areas. The Gangotri Glacier, spanning 256 km², is the largest glacier in the basin and a crucial source of meltwater.

A recent study by NIH analyzed rain gauge data from 47 IMD stations and 11 CWC stations, of which 37 stations (19 IMD and 11 CWC) were found suitable after data processing. Despite their distribution across the basin, significant portions remained uncovered, highlighting the need for alternative data sources with seamless spatial coverage for hydrological modeling. In response, various high-resolution precipitation datasets, such as CHIRPS, IMERG, ERA5-Land, and IMDAA, have been developed, offering spatial resolutions between 0.05° and 0.12°. While widely used in research, their suitability for UGB remains largely unverified, particularly in direct comparison with station-based observations. Additionally, no comprehensive studies have ranked these products based on their performance against ground-based measurements, emphasizing the need for further evaluation.

Study Objectives:

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

Brief Methodology

- Comprehensive review of methodologies and input data sources.
- Initial data preparation procedures.
- Graphical analysis of monthly and annual time series.

- Estimation of performance indicators, namely, Normalized Root Mean Squared Deviation, Pearson Correlation coefficient, and Perkins Skill Score.
- Application of MCDM techniques for evaluation of precipitation estimates at daily, monthly, and month-wise time series
- Application of GDM techniques for integration of performance ranking to obtain categorical ranking of precipitation estimates.

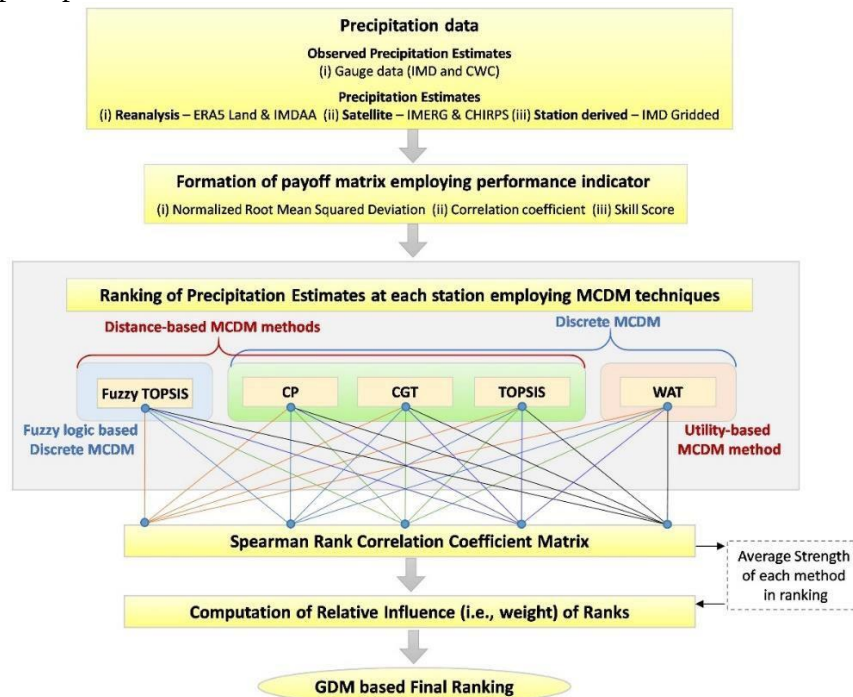


Fig. Methodology flowchart

Outcome

- Among the Precipitation Estimates (PEs) analysed, IMD, IMERG, and ERA5 exhibit superior skill in capturing the regional precipitation climatology compared to CHIRPS and IMDAA.
- CHIRPS consistently underestimates the annual precipitation regime.
- This underestimation by CHIRPS is particularly pronounced during the period from 2000 to 2008, where it systematically recorded lower precipitation than observed. However, its performance improved significantly after 2008, showing better agreement with observations.
- IMDAA demonstrates a consistent overestimation of annual precipitation across all analysed years.
- For daily and monthwise daily precipitation, IMD consistently ranked highest among all PEs for the majority of cases. ERA5 and IMERG also performed well, often emerging as the next best-suited PEs.
- IMERG exhibited the best performance for monthly precipitation, surpassing all other PEs at most stations.
- The performance of PEs varied significantly across grids, with different products outperforming one another for specific months in the monthwise daily precipitation analysis.

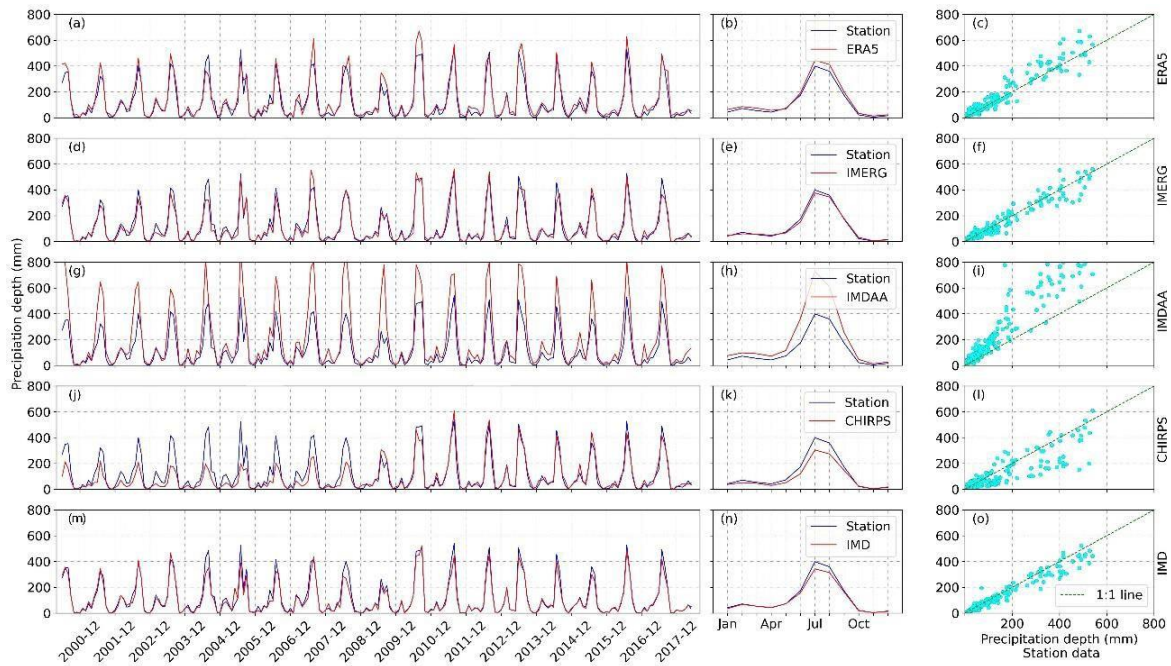


Fig. Comparison of regional precipitation of selected PEs with station records

Beneficiaries & Stakeholders

- The study will primarily aid hydrologists and researchers in decision-making pertaining to the selection of fine scale gridded precipitation products from the investigated products.
- A readily available information will be of immense use in formulating the subsequent studies on hydrological modeling and climate change in Upper Ganga Basin for researchers.

8.1 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 Team: Lavkush Kumar Patel, Sc. D (P.I.)
Akshaya Verma, Sc. C
Kapil Kesarwani, Sc. D
Surjeet Singh, Sc. G
Madhusudan Thapliyal, SRA

Type of Study: Internal

Study Duration: 03 years (April, 2023 to March, 2026)

Background:

The present study is being carried out for the Gangotri Glacier, which is one of the largest glaciers of the Himalayas. The glacier is located in district Uttarkashi of state Uttarakhand, falling in the Garhwal Himalayan region. The study area is shown in Figure-1. It lies within the latitudes 30°43'N - 30°01'N and longitudes 79°0'E - 79°17'E. The proglacial melt water stream, known as Bhagirathi River, emerges out from the snout of the Gangotri Glacier at an elevation of 4000 m. The snout of the Gangotri Glacier is known as 'Gaumukh'. The approach to the snout of the glacier includes a trek of about 18 km distance starting from the Gangotri town. The major part of the trek is along the Bhagirathi river. For studying the glacio-hydrological aspects, watershed of the Bhagirathi river up to Bhojwasa, located 4 km downstream from the Glacier snout was considered where a hydro-meteorological site has been set-up. The area of the considered watershed is 548 km², out of which 48.4% is glaciated according to the Randolph Glacier Inventory (RGI-7). The monitoring of such glaciated catchments is crucial as glaciers are more prone and sensitive to climate change impact. Due to the ongoing global warming effects, the glacier melting is increased which can have serious impact on the streamflow regime. This can adversely affect the population living in nearby downstream areas and also the hydro-power projects.

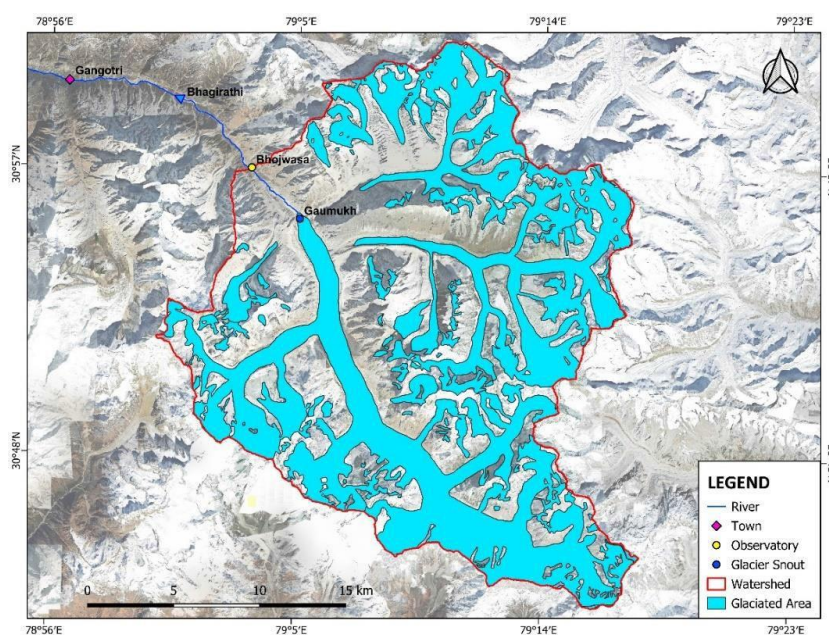


Figure-1: Study Area (Watershed) and Surrounding Region

Objectives:

The main objectives of the study are given below:

- Installation and monitoring of hydro-meteorological instruments for continuous observation and collection of meteorological and hydrological data. This data would provide monthly and seasonal specific water yield, which can be studied for its variability from the year to year.
- To study the melt water storage and drainage characteristics of the glacier.
- To simulate daily streamflow using a conceptual hydrological model using observed meteorological and hydrological data. Degree-day approach would be used for the modelling of runoff.
- Estimation of suspended sediment concentration and load from the Gangotri Glacier and its relationship with discharge.

Methodology:

- Review of available methodologies and data sources.
- Field Monitoring:
 - Meteorological (using Rain Gauges, Thermometers, Thermograph, Hygograph, Evaporimeter, Anemometer, Wind Vane, Sunshine Recorder and an Automatic Weather Station having various measurement sensors),
 - Hydrological (through Gauge-Section-Velocity Measurements at a fixed site),
 - Glaciological (using Stream Drill, Mass Balance Stakes etc.)
- Selection and use of long-term climate data obtained from various Climate models.
- Basic data preparation and analysis using Remote Sensing and GIS.
- Use of a glacio-hydrological model for simulating of the streamflow and other processes and subsequently using different climate scenarios upon the same.
- Mass Balance calculations using geodetic and field methods.
- Snow cover change analysis using MODIS data and Google Earth Engine.

Progress:

- ✓ The hydro-meteorological data has been compiled and computed as per the monitoring and observations during 2023 and 2024.
- ✓ Recently (in October, 2024), we have also installed Bamboo stakes for mass-balance estimations as a source of validation (Figure-2).

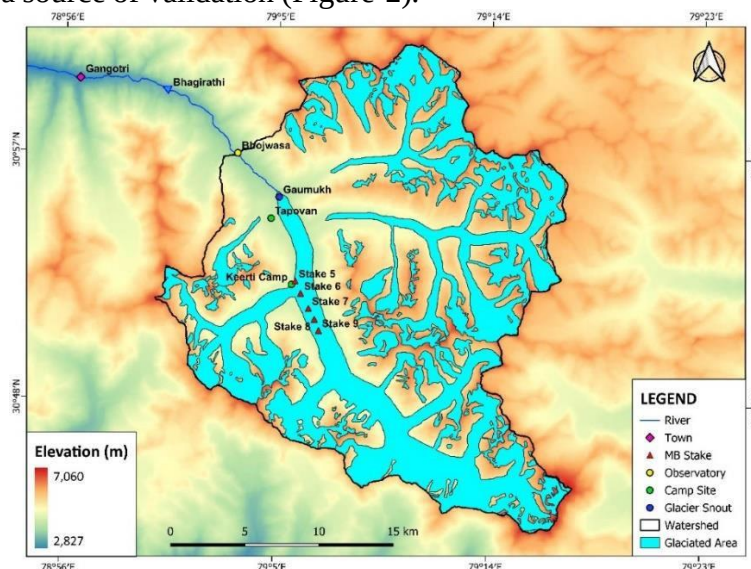


Figure-2: Mass-Balance Bamboo Stake Locations

- ✓ We have initially used the SPHY model to simulate the discharge for the Bhojwasa catchment. Long term climate data from NASA POWER was bias-corrected and used for providing meteorological forcing to the model. The model was calibrated and validated using some years of discharge observations. A long term simulation was also run to check the trends in discharge patterns and its variability (Figure 3).

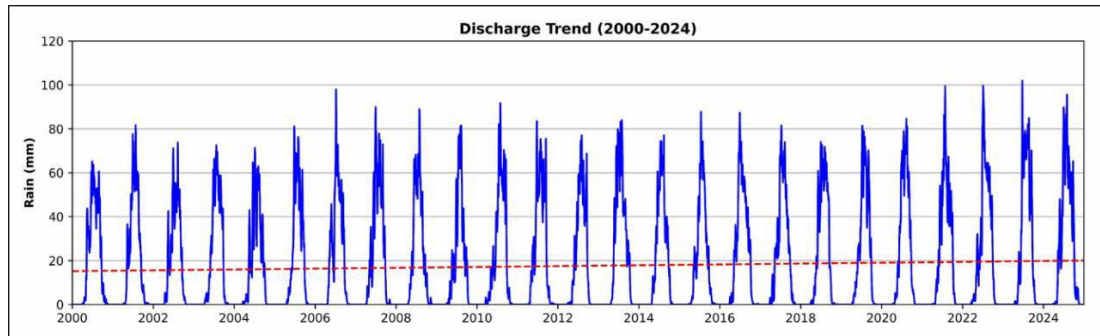


Figure-3: Discharge Simulation using SPHY model

- ✓ Site-identification for the installation of AWLR with Velocity Recorder was also carried out this year, in 2024.

Future Plan:

- The model can be further improved to better simulate the extreme events of discharge.
- Stakes' observations will be taken every year to monitor glacier health and compute the mass balance.
- Sediment monitoring and simulation will also be a crucial component which can be an important output for the hydropower projects, downstream on the Bhagirathi river.
- AWLR with Velocity Recorder and a New Automatic Weather station can strengthen our observation system at the site.

Beneficiaries:

The Research community, Hydro-power corporations etc.

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

Title of the Study	:	Updation 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	:	1 st April, 2024
Scheduled Date of Completion:	:	31 st 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.

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.

Progress of the Study

The spatial data on the mapping of glaciers in the IHR was collected from SAC, Ahmedabad. Further, on the mapping of glacial lakes in the IHR, HMA data of 2018 on has also been collected from the SAC, Ahmedabad. A web portal **NaMoH - National Monitoring System for Himlayan Cryosphere** is developed and the spatial information is available on the portal. It was suggested, during the Steering Committee for monitoring of glaciers held on 20th Jan, 2025, that the methodology for mapping of glaciers and glacial lakes should be standardized. A *Sectional*

Committee is formed by BIS under the WRD 32 for standardization of methodology for mapping of glaciers & GLs. The Chairperson advised that if no major initiative is taken by BIS, then NIH along with GSI, SAC, NRSC etc. shall modify the existing guidelines of WGMS and RGI to form a standard methodology for mapping of glaciers & GLs in the IHR. The updation of the glaciers/GLs shall be done after finalization of the standardized methodology.

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

10.1 PROJECT CODE: NIH/C4S/2024-2026/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' & Head, 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: Completed

Study Period: 1st April 2024 - 31st March 2025 (One Year)

(Initially proposed for 3 years but condensed to 1-year based on the comments in the 54th working group meeting)

STATEMENT OF PROBLEM:

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. Therefore, the primary objective of this study is to evaluate the 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. The second major objective is to assess the drought risk under changing climate using several drought indices including Precipitation Percentiles, Standardized Precipitation Index (SPI), Standardized Precipitation Evapotranspiration Index (SPEI), etc. The final objective is to generate future scenarios of hydrological extremes and quantify uncertainties associated using machine learning tools.

PROGRESS:

Historically observed datasets of streamflow and meteorological data was used to evaluate the characteristics, viz. intensity, duration, and frequency, of hydrological extremes, floods and droughts. Annual peak flow data is considered to evaluate the characteristics of floods and drought events are quantified by the indices such as Standardized Precipitation Evapotranspiration Index (SPEI). Modified Mann-Kendall trend test is adopted to analyse the trends in the historical datasets.

➤ R scripts will be created to compute 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.

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

11.0 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 Team: Lavkush Kumar Patel (PI), Akshaya Verma,
Vishal Singh, Surjeet Singh

Type of Study: Internal

Study Duration: 03 years (03/24-03/27)

Background

Triloki Glacier located in the high Himalayas of Himachal Pradesh, India, forms an integral part of the regional cryosphere in its crucial contributions to hydrology, climate interactions, and availability of freshwater. The glacier has been in full retreat in the past few decades due to increased global temperatures and other climate causes, leading toward the development and expansion of a proglacial lake at its front. This poses a serious challenge as the further expansion of the lake means greater chances for the occurrence of GLOFs (Glacial Lake Outburst Floods), which could cause serious threats downstream for communities, infrastructure, and ecosystems. For this reason, retreating glaciers and the lake formation give a clear indication of climate change, and therefore, monitoring such climate-induced changes becomes indispensable through scientific methods. This study intends toward the assessment of the dynamics of Triloki Glacier, the study of the rate of retreat, the assessment of GLOF risk, and the modeling of mass balance based on remote sensing and field techniques. A combined understanding of the glacier system could thus be attained through remote sensing techniques and field data observations regarding the present condition of the glacier and future risks.

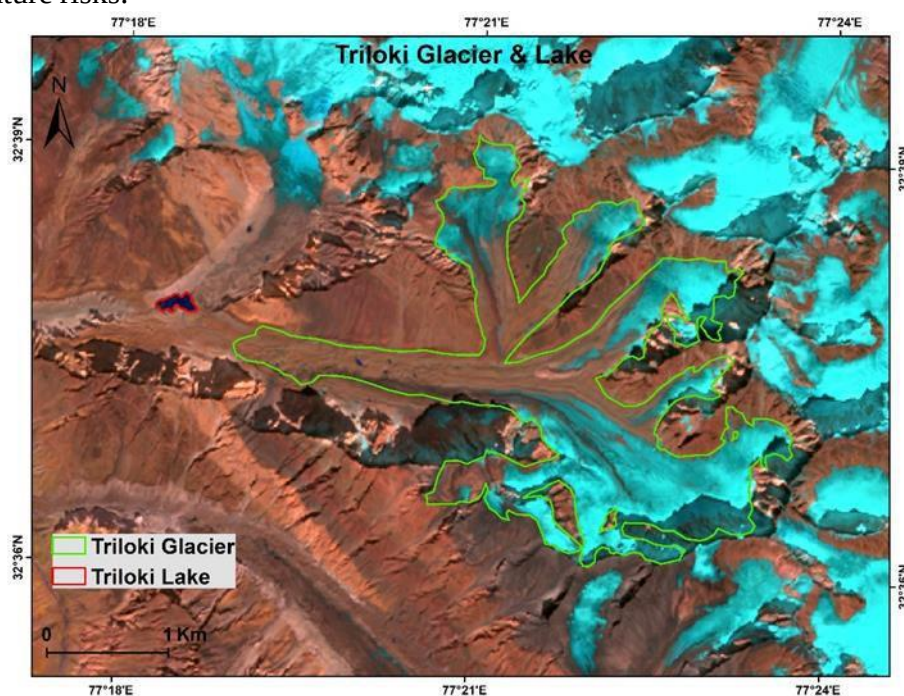


FIG: This figure shows the Triloki glacier and lake formed nearby the snout of the glacier.

Objectives

The primary objective of this study is to analyse the changes in the glacier's dynamics and quantify the rate of retreat over the last few decades. Understanding the extent of glacier retreat is vital for predicting its future evolution and its impact on regional water resources. Another key focus of this research is assessing the potential risk of GLOFs associated with the expanding glacial lake. With the formation of a large proglacial lake, it is essential to determine the structural stability of the moraine dam and the probability of sudden water release that could lead to catastrophic flooding events. Additionally, the study aims to model the glacier's mass balance using remote sensing data as well as field-based stake measurements. By estimating ice loss and accumulation patterns, a clearer picture of the glacier's long-term sustainability can be developed, which is essential for climate impact studies and water resource management in the Himalayan region.

Methodology

The methodology employed for this study involves a combination of satellite-based remote sensing analysis and field-based observations. To assess glacier-retreat and lake expansion, multi-temporal satellite imagery from Landsat & Sentinel-2 were used. These datasets enable a detailed examination of changes in the glacier's extent over time. The glacier boundaries and lake perimeters are manually delineated using GIS tools, ensuring accurate measurements of surface area fluctuations. Supervised classification techniques, particularly using Random Forest algorithms, are applied to differentiate between clean ice, debris-covered ice, and exposed bedrock, allowing for a comprehensive assessment of surface changes. Furthermore, hydrological modeling is performed to estimate potential flood scenarios resulting from a GLOF event, incorporating terrain analysis and moraine stability assessments.

Progress

Significant progress has been made in assessing the retreat rate of Triloki Glacier and the expansion of its proglacial lake. Initial results derived from satellite data indicate that the glacier has been retreating at an average rate of approximately 8-10 meters per year over more than two decades. This rate has shown an increasing trend in recent years, likely due to accelerated warming and reduced accumulation at higher altitudes. The analysis of lake area changes reveals a substantial increase, with the lake expanding from approximately 0.03 km² in 1998 to 0.08 km² in 2024. This rapid increase in lake size suggests an urgent need for further investigation into its stability and potential hazards. Preliminary hydrological assessments indicate rising water levels, which, combined with steep moraine walls, increase the likelihood of an outburst event. The ongoing analysis aims to refine these findings through further field validation and integration of high-resolution datasets.

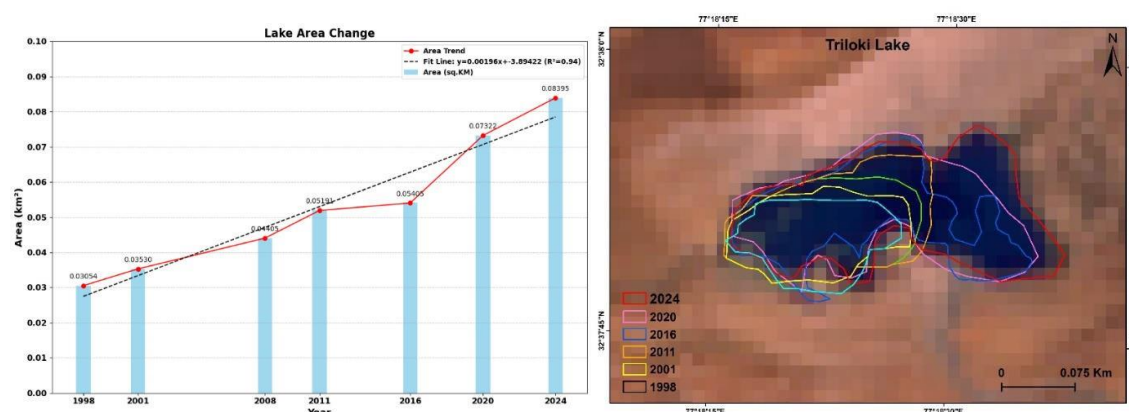


FIG: This figure shows the Triloki lake expansion from 1998 to 2024.

Future Plans

Moving forward, the study will focus on conducting a detailed GLOF risk assessment through field

verification and numerical modeling. Field expeditions will be carried out to verify satellite-derived measurements and assess the physical stability of the moraine dam. Bathymetric surveys will be conducted to estimate the volume of the glacial lake, as understanding the lake's storage capacity is critical for evaluating the potential magnitude of an outburst flood. Additionally, the study will implement an early warning system framework, which will involve hazard mapping and scenario-based simulations of GLOF events. Another key aspect of future research is the estimation of the glacier's mass balance through the installation of stakes at multiple elevations. These stakes will provide real-time data on ice melt and accumulation trends, allowing for a more precise determination of the glacier's health. The integration of field-based observations with remote sensing data will ensure a robust assessment of the glacier's dynamics and help formulate strategies for disaster risk reduction in the region. Given the critical implications of glacier retreat and lake expansion, continuous monitoring and further research will be essential for enhancing scientific understanding and informing policy decisions aimed at mitigating climate-related hazards in high-altitude glacierized regions.

The ongoing research on Triloki Glacier and its associated proglacial lake highlights the urgent need to monitor glacier retreat which is 165.7m retreat since 1998, assess GLOF risks, and evaluate mass balance variations. The integration of remote sensing techniques with field-based data collection provides a comprehensive framework for understanding these glacial changes and their broader environmental implications. The findings thus far indicate a significant retreat trend, an expanding glacial lake, and an increasing risk of hazardous flooding events. By continuing this research with field validation, bathymetric studies, and improved modeling techniques, a clearer assessment of future glacier behaviour and its impacts on downstream communities can be achieved. This study will contribute valuable insights into the changing Himalayan cryosphere and support efforts to develop mitigation strategies for climate-induced glacial hazards.

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

Study Group : Dr Kuldeep Sharma, Scientist-C Dr Ashwini Ranade, Scientist-D
Mr Sahidul Islam, Associate Director, CDAC, Pune

Date of Start : 1st April, 2024

Date of Completion : 31st March, 2027

Duration of the Study : Three years

Type of Study : Internal

Nature of Study : Planning

Location Map : India

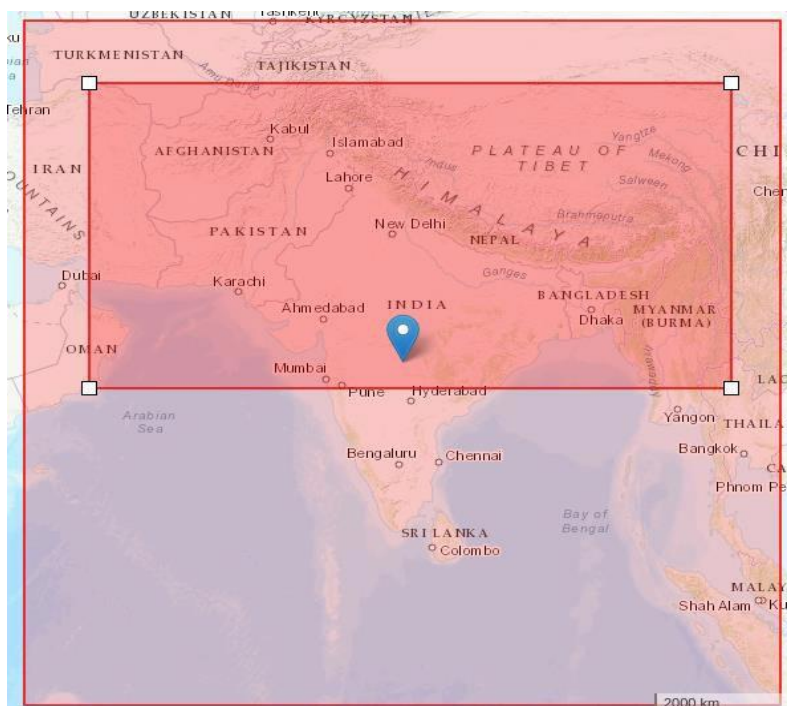


Figure 6 Domain used in the present Study

Background

In recent decades, the frequency and intensity of extreme weather events have increased globally, necessitating high-resolution climate data for risk assessment, adaptation, and mitigation strategies. While global climate models (GCMs) provide large-scale climate projections, their coarse resolution (100–150 km) limits their effectiveness in capturing regional climate variability. The Weather Research and Forecasting (WRF) model, when used as a Regional Climate Model (RCM), enables downscaling of GCM projections to finer resolutions, improving climate impact assessments.

This study aims to generate a high-resolution regional climate dataset by dynamically downscaling CMIP6 projections using WRF, with a focus on the Himalayan region. This will enhance understanding of climate change impacts on extreme weather events and natural hazards such as landslides and Glacial Lake Outburst Floods (GLOFs).

Study 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).

Brief Methodology

1. The WRF-ARW (version 4.5.2) atmospheric model is used for downscaling.
2. Initial and boundary conditions are obtained from the MPI-ESM-HR model (spatial resolution: 1.25°).
3. Bias correction is applied using ERA5 reanalysis data (1979–2014).
4. Simulations are conducted on CDAC Paramporul HPC resources, with no cost involved.
5. Historical and future climate simulations are analysed for rainfall patterns and climate extremes.

Progress of the Study:

There is a significant progress in setting up and running simulations:

1. WRF Model Setup: Successfully configured for 27 km resolution (India) and 9 km (Himalayas).
2. Historical Simulations (1985–2014): Completed, providing a reference dataset for climate analysis.
3. Future Projections:
SSP2-4.5: 25 years (2030–2055) completed; remaining years in progress. SSP5-8.5: 15 years (2030–2045) completed; further simulations ongoing.

Results and Discussion:

The WRF model predicted rainfall (horizontal resolution: 9 km) over Indian Himalayan Region (IHR) has been validated with the Indian Monsoon Data Assimilation and Analysis (IMDAA) reanalysis product. IMDAA is a regional high-resolution (12 km) atmospheric reanalysis dataset for the Indian subcontinent. It is the first regional reanalysis of its kind, produced by the National Centre for Medium Range Weather Forecasting (NCMRWF) and the UK Met Office in collaboration with the India Meteorological Department (IMD) under the National Monsoon Mission of the Ministry of Earth Sciences, Government of India. IMDAA integrates advanced data assimilation techniques to incorporate large volumes of satellite and ground-based observations, providing high-accuracy analysis of the Indian monsoon system. The mean seasonal rainfall and bias from IMDAA reanalysis and the WRF model simulation for 1980–2014 has been displayed in Figure 2. The left column presents IMDAA seasonal rainfall, the middle column shows WRF model output, and the right column depicts bias (WRF minus IMDAA). The analysis helps evaluate the performance of the WRF model in simulating seasonal rainfall patterns over the Indian region. During winter (DJF), the WRF model slightly overestimates rainfall over Jammu & Kashmir, Uttarakhand, and Himachal Pradesh, likely due to challenges in simulating orographic lifting and western disturbances. However, it effectively captures the spatial distribution of winter precipitation. In the monsoon season (JJAS), the model underestimates rainfall over Uttarakhand, Himachal Pradesh, and J&K, possibly due to difficulties in resolving complex monsoonal dynamics and orographic enhancement. Despite this, it reasonably represents large-scale monsoon patterns. The post-monsoon season (ON) shows minimal bias, indicating good model performance in

capturing the transition from monsoon to winter. In summer (MAM), rainfall is overestimated in Ladakh and higher-altitude areas of J&K, while a dry bias appears over Uttarakhand, likely due to misrepresentation of localized convection. Overall, WRF effectively simulates seasonal precipitation

patterns and topographic influences, making it valuable for regional climate studies despite some localized biases.

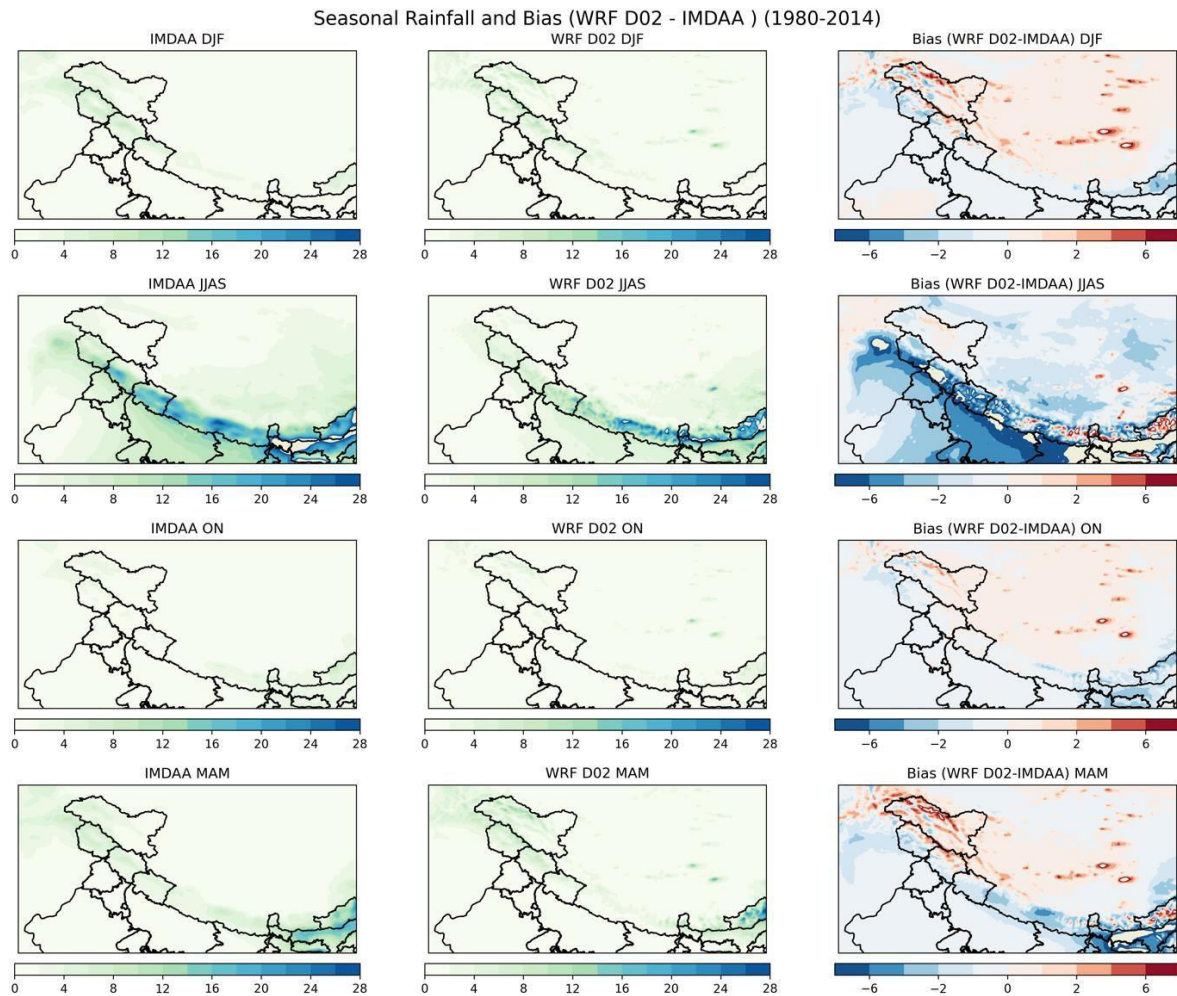


Figure 2: Seasonal mean rainfall (mm/day) and bias (WRF D02 - IMDAA) for the period 1980–2014. The left column represents IMDAA reanalysis rainfall, the middle column shows WRF model-simulated rainfall, and the right column displays the bias between WRF and IMDAA. The analysis highlights regional variations in rainfall patterns across different seasons (DJF, JJAS, ON, MAM)

Expected Output / Outcome

- High-resolution climate dataset for extreme weather and hazard studies.
- Improved understanding of climate variability over the Himalayas.
- Data to support disaster risk reduction, water resource management, and climate adaptation strategies.
- Scientific insights into the impact of climate change on monsoons, snow cover, and glacial dynamics.

Beneficiaries & Stakeholders

- Government agencies for disaster management and climate policy.
- Researchers and academic institutions studying regional climate change.
- Local communities and policymakers in Himalayan regions for adaptation planning.
- Infrastructure and energy sectors (hydropower, agriculture, and water management).

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

Title of the Study: Integrated long-term monitoring of Khatling Glacier, Bhilangana basin, Uttarakhand

Study Team: Dr. Akshaya Verma, Sc-C (PI);
Dr. Vishal Singh, Sc-D (Co-PI); Dr. Sunil Gurrapu, Sc-D (Co-PI);
Dr. Lavkush Kumar Patel, Sc-D (Co-PI);
Dr. Surjeet Singh, Sc-G & Head C4S (Co-PI)

Type of Study: R&D

Funding Agency: Internal

Study Duration: 04 Years (2024 – 2028)

Objectives:

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

Present state-of-art

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.

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.

Study area:

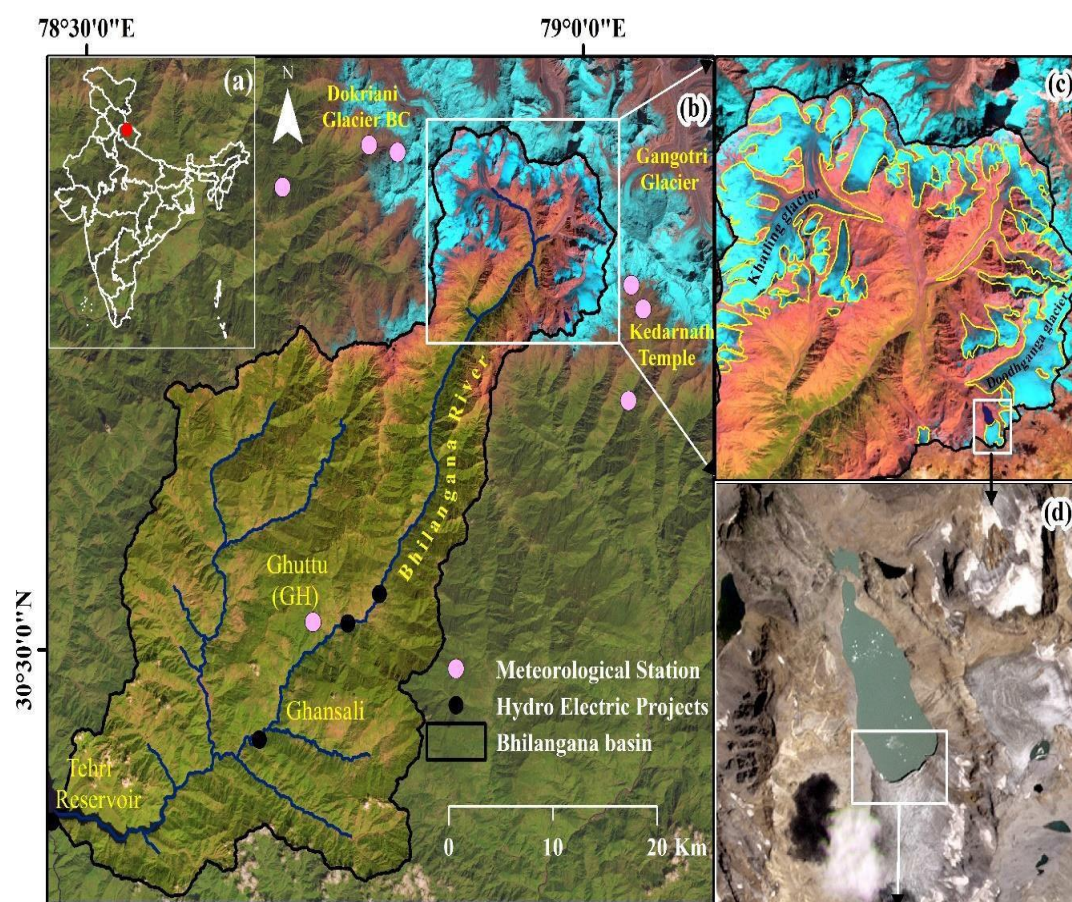


Figure 1. Image showing the location of the study area over Indian map (a), a network of Automatic Weather Stations (AWS) installed in and nearby Bhilangana river basin, locations of hydroelectric projects (HEPs), and major settlements (b), zoomed-in satellite image of glaciers, glacial lakes of the basin (c), high-resolution image of Bhilangana lake (d).

Methodology:

- Establish 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

Achievement vis-à-vis Objectives Progress of Work

A field visit to Bhilangna river basin was carried out during October 2024. During the visit, it was observed that the approach to Khatling Glacier was tough and risky. Therefore, the team approached Doodhganga and Miyali glaciers within the same valley. A pro-glacial lake associated with Miyali Glacier and partially blocked by the left lateral moraine of Doodhganga Glacier was

identified and some preliminary bathymetry was done using Deeper Pro Sonar.

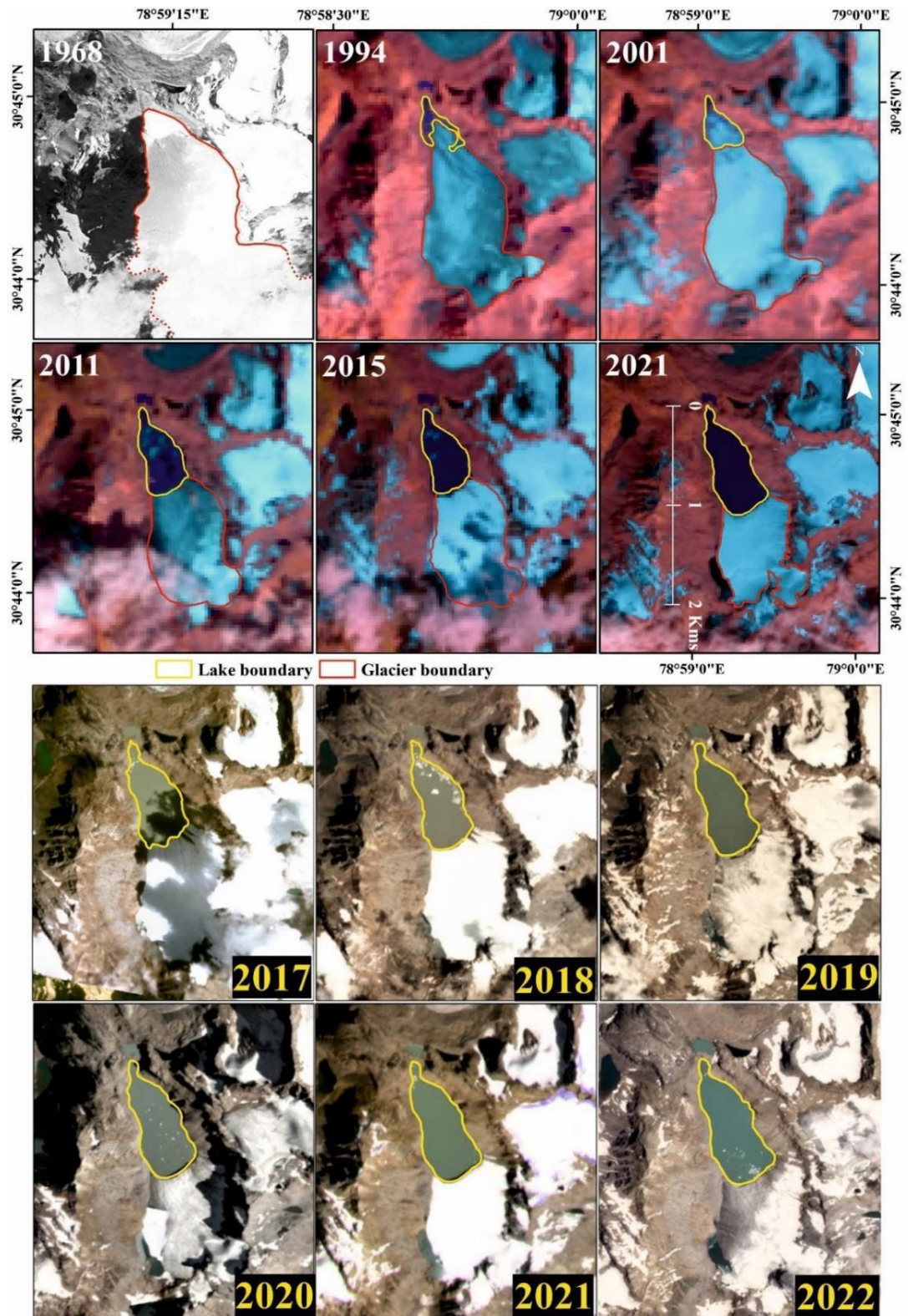


Figure 2. Evolution of the proglacial lake (Miyali Lake) between 1968 and 2021 visible in multiple satellite images.

Subsequently satellite data was used to understand the retreat of glaciers, formation and evolution of the glacier lake within the basin (Fig. 2). The GLOF potential of the lake was simulated using HEC-RAS model for the basin.

Future work plan:

- Purchase of automatic weather station (AWS) and automatic water level & velocity recorder (AWLVR) is under process and should be installed during the coming field season.
- A network of stakes for glacier mass balance shall be established over Doodhganga and Miyali glaciers.
- A baseline database for glacier retreat, velocity, etc. shall be established using available satellite data.
- 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.

14.1 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, PI & Sc-C
Dr. Kuldeep Sharma, Sc-C
Dr. Nitesh Patidar, Sc-C
Dr. Soban Singh Rawat, Sc-F
Dr. Surjeet Singh, Head & 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.

Progress of the Study

Monthly climate projections from CMIP5 GCMs were acquired from the Copernicus Climate Data Store. Observation data from IMD gridded observation record was collected. Data preprocessing has been completed. The High-Performance Computing (HPC) facility at IIT Roorkee was availed for climate data processing. Acquisition of a local storage facility is currently in progress. A comprehensive literature review has been conducted, and the methodology for GCM selection has been finalized.

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.

15. 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)

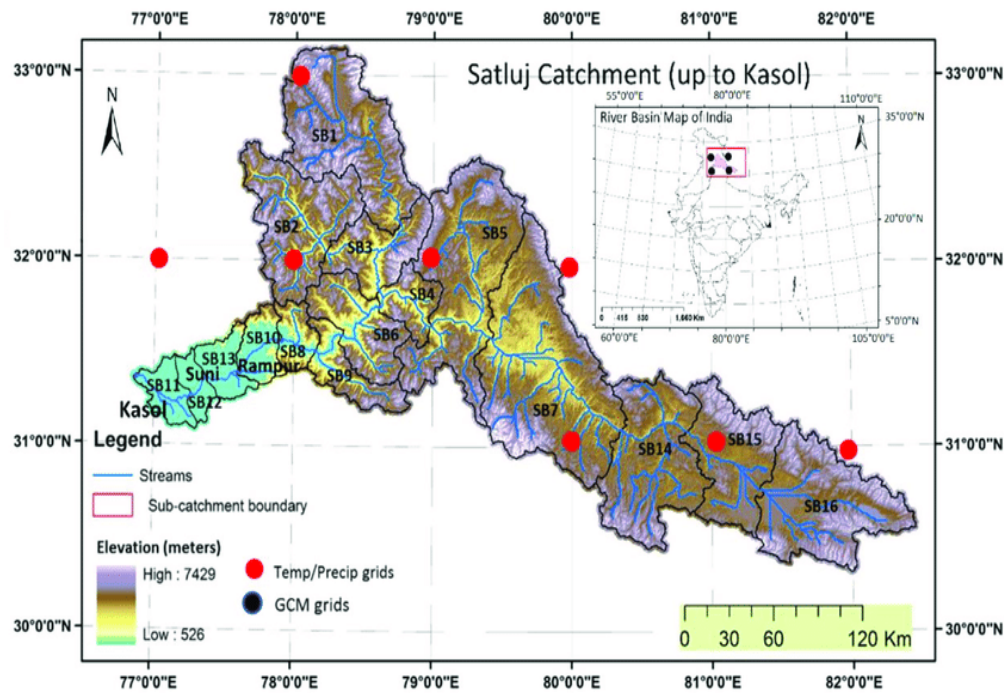
Duration of the Study: Two Years (01.04.2024 - 31.03.2026) **Type of the Study:** Internal

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. 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.

Progress of the Study

Identification of the geographic boundaries, LULC maps, soil types, topography, and climatic characteristics of the study area is done, watershed delineation had carried out around the outlet station Kasol, input data preparation for SWAT model has been precisely done i.e Digital Elevation model (Copernicus Glo -30) at a spatial resolution of 30m, LULC map (ERSI Sentinel 10m) nine classes of water, trees, flooded vegetation, crops, built area, Bare ground, Snow/ice, clouds, rangeland.

Soil map of study area is prepared from FAO, consisting of ten classes of soil of locally available area, hydro-meteorological data was prepared, namely precipitation and temperature of the study area, precipitation at a resolution of 0.1 degree (Imerg), temperature at a resolution of 0.5 degree (climate prediction centre), the index file is prepared for the data in SWAT format, number of grids of precipitation, temperature falling into study area was also identified, the study area lies in UTM zone 44, all the data is projected in to the required zone.

the model has been set up defining the watershed boundaries, dividing the watershed into sub-basins, assigning land use and soil properties to each sub-basin, specifying hydrological response units by providing land use, soil map, slope classes, various lookup tables had been prepared for soil and landuse as per swat database, the simulation period from 2000 to 2024 was considered, manual calibration of the swat model was done to ensure that simulated outputs match observed hydrological behavior within the watershed.

Expected Outcomes:

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

16.0 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’ - P.I.
 Dr. Surjeet Singh, Scientist ‘G’ Head-In-Charge: C4S - Co-P.I.
 Dr. Lavkush Kumar Patel, Scientist ‘D’ - Co-P.I.
 Dr. D.S. Bisht, Scientist ‘C’ - Co-P.I.
 Dr. Akshaya Verma, Scientist ‘C’ - Co-P.I.
 Mr. Madhusudan Thapliyal, SRA - Co-P.I.

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 several caveats 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 fields over 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 (Huang et 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.

Aim & Objectives

The present study aims to assess the response of Himalayan Cryosphere system and associated

water resources under the influence of climate change. The principal objectives of the study are-

- (i) Studying the physical processes of Milam Glacier by means of monitoring glaciological parameters (hydro-meteorology, hydrology, surface accumulation and ablation processes, terminus fluctuation, and snow cover changes) and climate forcers (absorbing aerosols).
- (ii) 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.
- (iii) 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 data sources.
- In-situ measurements - Hydro-meteorological and glaciological records
- Use of Ancillary dataset and long-term climate records obtained from Climate models
- Basic data preparation using remote sensing and GIS.
- Development of semi-distributed conceptual glacio-hydrological model.

Progress of the Study

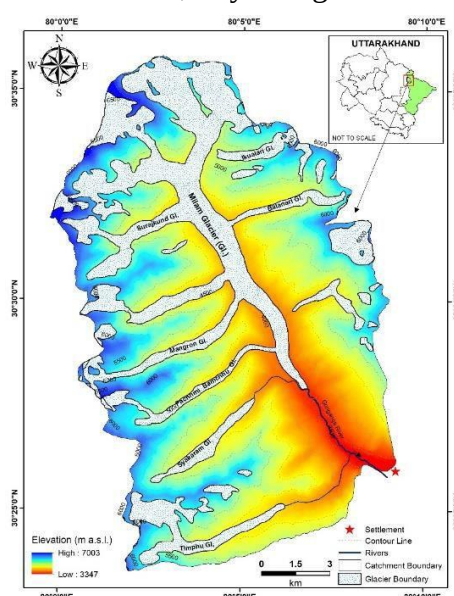
(i) Historical Observations

Analysis of historical records suggests that the recession rate of Milam Glacier has accelerated from 12.84 m yr^{-1} (1849–1906) to 24.67 m yr^{-1} (2016–2017), accompanied by increased glacier lake formation, surface thinning, and fragmentation due to rising temperatures. Between 1849 and 2017, the glacier's total snout recession was 2.90 km, with an average recession rate of 17.24 m yr^{-1} . These changes underscore the glacier's continuous response to climate forcing.

(ii) Meteorological Observations

A hydro-meteorological observatory was established at an altitude 3560 m a.s.l., near the snout and data was collected round the year. The findings reveal significant seasonal variations in temperature, precipitation, and atmospheric aerosols, which have direct implications for glacier dynamics in the Milam Glacier region. Temperature trends indicate a steady rise across all seasons, with the highest warming observed during the monsoon and post-monsoon periods. The maximum near-surface air temperature reaches approximately 25°C during the monsoon, while the lowest temperature drops to around -5°C in winter. Although winter temperatures remain relatively stable, they exhibit an overall warming trend.

Precipitation trends show the highest values during the monsoon season, peaking at around 18 mm, while winter precipitation remains the lowest, averaging below 5 mm. Pre-monsoon precipitation fluctuates over time, with moderate values, whereas post-monsoon precipitation remains low with a slight increasing trend. Increased monsoon precipitation likely accelerates glacier melt due to enhanced runoff, while winter warming could reduce snowfall accumulation, limiting glacier



recovery. Aerosol Optical Depth (AOD) trends reveal higher values in the afternoon, with the most significant increase observed at 440 nm and 500 nm, indicating a rise in atmospheric aerosol concentration. Concurrently, water vapour content also increases throughout the day, peaking in the afternoon, suggesting possible interactions between aerosols and atmospheric moisture. The increasing presence of aerosols may contribute to radiative forcing and black carbon deposition on glaciers, further accelerating melting. These findings emphasize the need for continuous monitoring of climate-glacier interactions, as both warming temperatures and shifting precipitation patterns contribute to glacier retreat, altering hydrological regimes and long-term water resource availability.

(iii) Long Term trends

Long-term climate trends (1968–2024) over the Milam Glacier catchment indicate a rising temperature trend (5.69°C to 7.63°C) and fluctuating precipitation (2221.37–2521.2 mm). These trends align with regional Himalayan climate changes, emphasizing the need for continued monitoring to assess glacier dynamics, water resource impacts, and potential hazards like GLOFs. Seasonal climate trends (1968–2024) over Milam Glacier show rising precipitation, particularly in the monsoon season, peaking in 2024. Winter and pre-monsoon precipitation fluctuate, with winter 2001 showing an anomaly. Temperature has increased across all seasons, with the highest warming in recent years (2023–2024). Monsoon and post-monsoon temperatures exhibit the most significant rise, while winter warming may reduce snowfall accumulation.

(iv) Glacier Dynamics

This study integrates ground-based observations with satellite monitoring to assess Milam Glacier's response to climate change from 1968 to 2024. The analysis from 1993 to 2023 shows a consistent decline in snow cover during the ablation season, while vegetation covers exhibited fluctuations, with notable increases in 1994, 2009, 2015, and 2023. The accumulation season remained predominantly snow-covered, with minimal vegetation presence. The glacier's snout has receded at an average rate of 28.30 m/yr, with a total area loss of ~1.0 km². Supraglacial lakes have increased from 28 in 2001 to 72 in 2024, indicating intensified melting. Lake area fluctuated, with a peak in 2001 (0.79 km²) and a decline in 2024 (0.029 km²), likely due to lake fragmentation. Field observations confirmed drainage of large lakes by the end of the 2023-24 ablation season, highlighting their role in accelerating glacier melt.

Significance and Expected Outcomes

- a) The study will generate a strong data base through monitoring and modelling of cryosphere-climate interaction.
- b) The developed coupled glacio-hydrological model will be beneficial for the melt-modelling study of debris-covered mountain glaciers and to know the state and fate of Cryosphere in the changing climate.
- c) 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.
- d) 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/ Agencies of IHR
- Central/ State Disaster Management Departments/ NITI Ayog
- Ministry of Agriculture / Organizations working in remote terrain / Tourism development board of IHR

B. Sponsored R & D Studies

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

Title of the Study: Assessment of glacier-climate functional relationships across the Indian Himalayan region (Kali/Sharda River Basin, Uttarakhand) through long-term network observations and hydrological Modeling.

Project Team:

Dr. Vishal Singh, Scientist 'D' (Co-PI, Lead NIH Roorkee), Dr. Ashutosh Tiwari Sc. D, GBPNIHE (Main PI); Dr. Sandeepan Mukherjee Sc. D GBPNIHE (Co-PI)

Project Duration: 03 Years (2023 – 2026) Objectives:

- 1) Assessment of glacial dynamics, changes in the glacial morphometry and mass balance using space-based resources and field measurement
- 2) Identifying changes in the glacier hydrodynamics and glacier melt-water using hydrological modeling and observation datasets
- 3) 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

Data assimilation and bias correction:

For meteorological datasets, a high resolution gridded daily precipitation dataset ($0.05^{\circ} \times 0.05^{\circ}$) 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).

Snow and Glacier 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, variable degree day factors-based Temperature Index model using SPHY has been applied.

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.

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. The climate change impact assessment is analyzed using the CMIP6 climate model datasets.

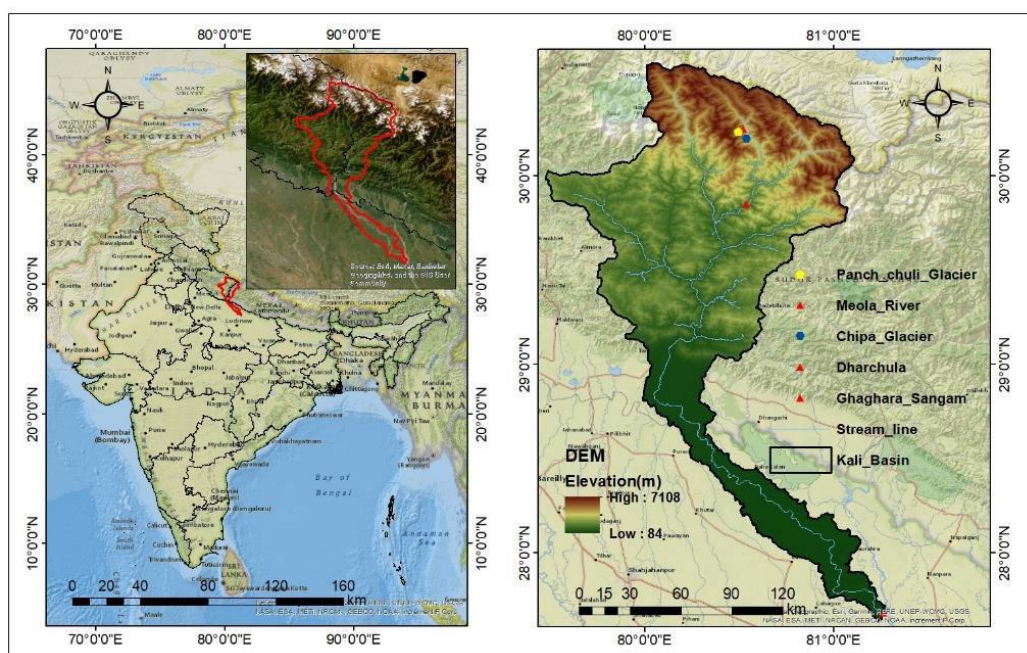


Figure 1. Showing the study area map of Kali river basin, Ganga river basin.

Results and work progress:

The precipitation samples (rain and snow) at multiple elevations are collected for isotopic analysis to distinguish rainfall from snowfall contributions. The samples have been collected in different seasons at regular intervals while maintaining the upstream to downstream hierarchy. The samples will be analyzed for isotopic tracers (e.g., $\delta^{18}\text{O}$, $\delta^2\text{H}$) to track moisture source variations and snow/rain phase transition under different climatic conditions. This analysis will be used to assess inter-seasonal and inter-annual variability in snowfall/rainfall ratios and its implications for glacier accumulation and runoff generation. The hydrological modeling for the computation of different runoff components such as snowmelt runoff, glacier melt runoff, base flow and rainfall induced runoff has been performed using SPHY model. The calibration and validation have been performed.

Location -1 Ghaghara Sangam

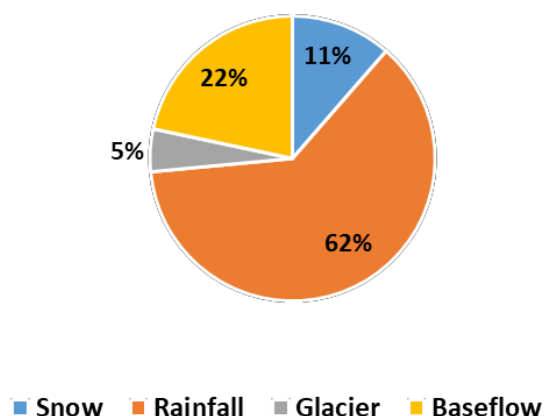


Figure 2. Showing the different runoff components and their contributions (%) at the outlet of Kali river basin, Ganga river basin.

18. Project Code: SP-54

Title: 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.

Name of PI	Dr. Vishal Singh
Budget (in lakhs)	Rs. 25.23
Duration	2.5 Years
Date of Start	June 2021
End Date	September 2024

Study 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.

Study Area:

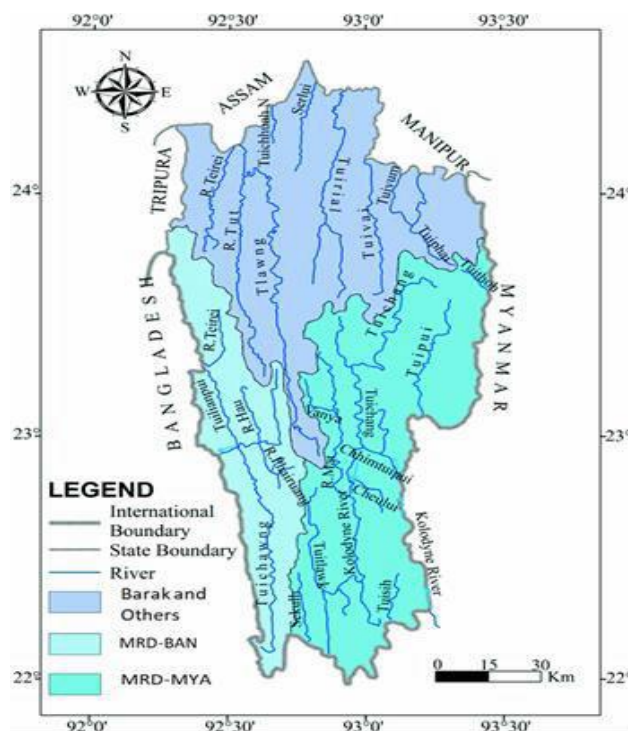


Figure 1: River basin map of the Mizoram showing river basins namely Barak and Other, Minor rivers draining into Bangladesh (MRD-BAN) and Minor rivers draining into Myanmar (MRD-MYA).

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 Officer for smooth conduct of the study. SE K. Hamlet and AE Vanlalpekhlu Sairo 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	100%	Done
5.	Development of SWAT model	100%	Model setup has been done. Model improvements, Calibration and Validation have been done and all watershed

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
			components 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
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

Sr. no	All Planned Activity as per original work plan in approved PDS	Cumulative % Progress	Comments / details of activities
			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	100%	Using Budyko framework, the water demand and deficit areas have been calculated and analyzed at district and sub- basin scale. The water availability surplus and deficit areas are computed.
12	Article and Report Writing	100%	One research article has been published. Report has been submitted. Second article is ready and about to submit.

Final Outcomes:

- This study presents a novel integrated SWAT-WEAP-Budyko framework to assess the combined impacts of LULC and climate changes on water availability and demand dynamics in the Mizoram and surrounding areas, with a focus on resilience.
- The SWAT model has been used to simulate and project hydrological scenarios and the WEAP model has been employed to evaluate irrigation and domestic water demand and supply under different scenarios. The Budyko framework provided insights into the energy and water balance across Mizoram's sub-basins to analyse resilience strategies.
- LULC change analysis revealed a significant decline in dense forest cover, dropping from 74% in 1985 to a projected 45% by 2090. Simultaneously, agricultural land and urban areas are projected to increase by 76% and 120%, respectively, which showed a significant impact on water availability and demands.
- The projected hydrological scenarios forced by CMIP6 models (e.g. ACCESS, EC-Earth3) and SSP scenarios (SSP245 and SSP585) suggest a substantial decline in water yield (up to -20%) during near terms (by 2050), while far terms (by 2090) show some positive responses (up to +15%).
- Results highlight a significant rise in agricultural and domestic water demands (i.e. 50-100 million m³) during near terms, while far terms it reached up to 350-400 million m³, due to increased population growth and climate changes.
- The Budyko framework indicated that some sub-basins are currently energy-limited, while others face water constraints due to high evapotranspiration. Future scenarios, particularly SSP585, intensify these limitations and many sub-basins are found not resilient under changing climate and LULC conditions.
- Results also projected that under different climate projection scenarios, the water surplus subbasins (~30, 000 mm water) will be enhanced and the deficit drops below 8,000 mm from near term to far term due to high variability of rainfall amount, especially in the Minor Rivers Draining into Bangladesh.

NEW STUDIES PROPOSED FOR THE YEAR 2025-26

19. PROJECT REFERENCE CODE: NIH/C4S/NIH/25-28 20.0

Title of the Project: Exploring Atmospheric conditions and Triggering Mechanisms of Cloudburst Events in the Northwestern Himalayas

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

Type of Study: Internal

Status: New Study

Duration: 03 years

Date of Start: 1st April 2025

Scheduled date of completion: 31st Mar 2028

Objectives:

1. Identification of Cloudburst Events and analyse the spatio-temporal variability across different seasons in the Northwestern Himalayas over Recent Decades
2. Examine role of monsoon circulation, western disturbances and orographic lifting on CBEs formation.
3. Simulation of past selected cloudburst events using WRF modelling framework and conduct sensitivity experiments
4. Investigate thermo-dynamical and hydro-dynamical conditions triggering cloudburst occurrences across different Himalayan regions.

Statement of the problem:

Cloudburst events (CBEs) are highly localized extreme precipitation events, often occurring over complex terrains like the Himalayas, causing flash floods and landslides. The complex topography of the Himalayas, with its steep and unstable slopes, creates an environment conducive to such events. Recent studies have highlighted an increasing frequency of cloudburst occurrences in this region, particularly in recent decades raising concerns about their underlying causes. This escalation attributed to various factors, including climate change, which has led to elevated temperatures and altered precipitation patterns. The warming climate intensifies the hydrological cycle, resulting in more frequent and severe extreme weather events. Additionally, the unique orographic features of the Himalayas play a crucial role in the formation of these localized intense precipitation events. Despite their devastating impacts, real-time forecasting and early warning systems remain a challenge due to their small spatiotemporal scales and the complex interplay of atmospheric variables involved. CBEs are driven by complex interactions between temperature, moisture, pressure, and wind patterns. Understanding these conditions will help in identifying potential precursors to cloudbursts and improving prediction accuracy. Understanding what initiates a cloudburst can improve forecasting accuracy. Triggers can be local (e.g., orography) or large-scale (e.g., monsoonal circulation).

Numerical weather models like 'Weather Research and Forecasting' (WRF) model has been extensively utilized to simulate extreme precipitation events. Studies have demonstrated that the WRF model can effectively reproduce the spatial distribution of extreme precipitation indices, offering valuable insights into the dynamics of cloudburst events. WRF framework can reconstruct past cloudbursts, helping us to analyse what went wrong in previous forecasts and how we can improve prediction techniques. Timely warnings can prevent loss of life and property. Since cloudbursts occur on very short timescales (~few hours), an early warning system must detect precursors several hours in advance. Despite technological advancements, forecasting cloudbursts

presents several challenges like the rugged and inaccessible terrain of the Himalayas limits the availability of ground-based observational data, which is crucial for accurate modelling and prediction. The intricate interactions between atmospheric processes and the Himalayan topography complicate the modelling of these events. In addition, the Cloudbursts develop quickly, often within a few hours, leaving a narrow window for prediction and warning dissemination.

To address these challenges, this research proposes a comprehensive study aimed to understand the thermo-dynamical and hydro-dynamical atmospheric conditions and mechanisms that lead to CBE formation, analysing role of orographic lifting, moisture convergence, and atmospheric general/regional circulations influences into the initiation of cloudburst. Further, it employs the high-resolution WRF simulations aid in reconstructing past events and refining predictive capabilities and at the outset, provide indicators for enhancing early warning systems.

Study area: Northwest Himalaya comprising, Jammu and Kashmir, Ladakh, Himachal Pradesh and Uttarakhand states

Datasets:

- **Meteorological Data:** Obtain historical atmospheric parameter's data (temperature, wind, gph, pressure, precipitable water, vorticity, divergence etc.) from ERA5 reanalysis datasets
- **Precipitation Data:** SRRG observed hourly rainfall from IMD, dynamically downscaled high resolution (10km) precipitation from 'The High Asia Refined Analysis' HAR V2.0 (Wang et al. 2021); IMERG V06B satellite rainfall data at 10km resolution.
- **Digital Elevation maps:** SRTM 30 m
- High resolution WRF simulated atmospheric parameters for the selected CBEs.

Deliverables:

- Improved understanding of the dynamics of the occurrences of cloudbursts.
 - Thermodynamic and hydrodynamic precursors of cloudbursts will be used to develop early warning system.
 - Best microphysics and cumulus parameterization schemes will be suggested for WRF simulations in Himalayas.
 - Recommendations for policy and disaster management authorities.
- These deliverables will contribute to scientific advancements in extreme precipitation forecasting and improve disaster resilience in the Himalayan region.

Work Schedule:

S.N.	Work Element	1 st Year	2 nd Year	3 rd Year
1	Identification of Cloudburst Events and analyse the spatio-temporal variability			
2	Examine role of monsoon circulation, western disturbances and orographic lifting			
3	Simulation of past selected cloudburst events using WRF			
4	Investigate precursor signals for CBs occurrences			
5	Report preparation			

Cost Estimate:

S. No.	Head	Amount (lakh)
1	Computational cost (run WRF model on CDAC-HPC)	10.0
2	Consumables/contingency/Misc. expenditure	1.0
3	Capacity building/Technology transfer (Training course)	1.0
4	Dataset purchase (IMD SRRG data)	2.0
5.	Software/hardware	1.0
	Total	15.0

20. Title of the Project: Seasonal variations in the Sediment Concentration and Organic Matter Dynamics in Neola Glacier, Uttarakhand

Study Team: Mr. Jatin Malhotra, Sc B (PI)
Dr. Gopal Krishna, Sc E (Co-PI)
Dr. Vishal Singh, Sc D (Co-PI)
Dr. Kapil Kesarwani, Sc D (Co-PI)
Dr. Sumit Rai, Sc D, G.B. Pant Institute of Himalayan Environment (NIHE) (Co-PI)
Mr. Madhusudan Thapliyal. SRA(Co-PI)

Type of study: Internal

Status: New

Study period: 3 years (1/4/2025 to 31/3/2028)

Statement of Problem

The Himalayan glaciers, critical sources of freshwater for millions, are undergoing rapid changes due to climate variations. These changes significantly influence sediment transport and the dynamics of organic matter in glacial meltwaters, including the carbon (C), nitrogen (N), and sulfur (S) cycles. The water resources of the high altitude region, where glaciers exist, are much controlled by the melt runoff derived from the glaciers. The major share of the melt runoff from the glaciers is produced during the ablation season (May-October). The amount of glacier melt runoff in the melt season, its monthly and diurnal distribution plays a vital role in the planning and management of water resources. As climate change continues to impact glacial environments, monitoring these components will be crucial for predicting ecological responses to ongoing environmental changes. Understanding these changes may provide initial information is essential for predicting future ecological responses to ongoing climate shifts.

Relatively few studies focus on organic carbon (OC) in glaciers as compared to studies on inorganic components (i.e., major ions, elements), thus OC is one of the least understood fractions in snow and ice. The concentrations and quality of OC in glaciers varies considerably, with high variability both temporally across the glacier meltwater season, and spatially across different regions. In addition, limited studies provide a comprehensive understanding of the sediment concentration and the interplay between organic matter and biogeochemical cycles in this Himalayan region. Furthermore, the impact of glacial meltwater on downstream ecosystems, particularly in terms of carbon-nitrogen-sulfur (C/N/S) ratios, remains understudied, leaving critical gaps in our understanding of glacial contributions to global carbon dynamics and nutrient fluxes.

This study provides critical insights into how changing meltwater dynamics influence sediment and organic matter transport and in-depth analysis of one glacier as a representative system and a broader comparative investigation across the Himalayan region. The present preliminary investigations of the study in the Neola Glacier Valley open new vision and possibilities for further extensive ground-based observation of pollutants in Himalayan glacier valley systems.

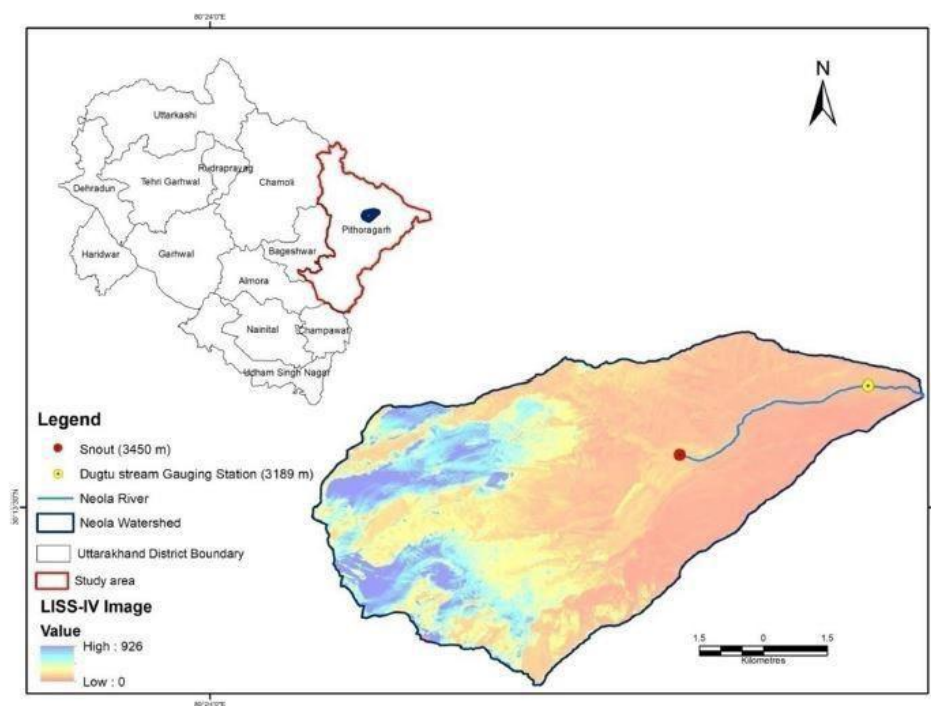


Fig 1 Location of the Study Area

Objectives:

- To characterize and quantify the Neola glacier drainage characteristics and seasonal sediment concentrations in its meltwater streams, and to determine the source identification of deposited organic matter.
- To assess the carbon content, including dissolved organic carbon in water and ice samples and evaluate of C/N (carbon to nitrogen) and C/S (carbon to sulfur) ratios in sediments, water and ice samples.
- To identify the key factors influencing sediment and dissolved organic carbon transport in Himalayan glacial systems, and develop a comprehensive understanding of these processes by integrating comparative data on sediment concentrations, organic matter in sediment and dissolved organic carbon from different Himalayan glaciers (Gangotri Glacier, Uttarakhand and Neola Glacier, Uttarakhand)

Methodology

- **Sampling Strategy:** Collection of suspended sediment, water and ice samples from multiple glacier-fed streams during different seasons over the study period for textural, particle size and isotope analysis. The methodology to collect the suspended sediment in the Glacier meltwater stream is a four-step process: Sample Collection, Sampling Frequency, Filtration, Drying, and Analysis.
- **Laboratory Analysis Organic Matter Analysis:** Employ techniques like CHNS elemental analysis for determining carbon, nitrogen, and sulfur content and the source identification.
- **DOC/TOC in water/ice samples:** Standard procedure will be used for determination of Dissolved Organic Carbon, and Total Organic Carbon (TOC) in water/ice samples using TOC analyzer.
- **Data Analysis:** Trend analysis using statistical approach, Statistical tools will be used to analyze CN and CS ratios to identify temporal trends. Efforts will be made to determine the correlation between different variables calculated from the sediment, water and ice samples and to comprehend sediment transport dynamics

- Installation of automatic weather stations (AWS) and Contactless flow measurement and surface velocity measurement instrument for continuous and long-term observations of Hydro meteorological data.
- **Modeling:** Use atmospheric transport model like HySplit model to analyze the movement and distribution of Black Carbon.

Action plan and timeline Yearly Time schedule

Activity	Year 1				Year 2				Year 3			
Field visits for sample collection, glacier expedition	←											→
Database development				←								→
Lab Analysis				←								→
Data Interpretation, Analysis and Modelling				←								→
Report writing											←	→

Monthly time schedule for data collection & Fieldwork

Activities	Jan - April	May	June	July	Aug	Sept.	Oct.	Nov -Dec
Sediment samples		Y	Y	Y	Y	Y	Y	
Water samples	Y	Y	Y	Y	Y	Y	Y	Y
Ice sample	Y	Y	Y	Y	Y	Y	Y	Y

Budget Estimate

S.no	Particulars	I Year	II Year	III Year	Total (in Lakh)
1	Salaries/wages (02No) at site	4.00	4.00	4.00	12.00
2	Consumables (Sampling bottles, filter papers etc)/ Contingency	4.00	4.00	4.00	12.00
3	Travel/Field Work	3.00	3.00	3.00	9.00
4	Portable Automatic Weather Station (01 No)	20.00			20.00
5	Radar based Discharge and weather monitoring system with all accessories (01 No)	13.00			13.00
6	Sediment Sampler	1.00			1.00
		45.00	11.00	11.00	67.00

Research outcome from the project:

The outcome of the study will helpful in improving the understanding of the process and transport mechanism sediment and organic matters.

21. PROJECT REFERENCE CODE: NIH/C4S/SG/25-27

Title of the Study: Assessing the Impact of Western Disturbances and ENSO on the Hydrology of the Bhaga River Basin.

Project Team: Dr. Sunil Gurrapu, Sc. 'D' (PI), NIH Roorkee
Dr. Vishal Singh, Sc. 'D', NIH Roorkee
Dr. Ashwini Rande, Sc. 'D', NIH Roorkee
Dr. Kuldeep Sharma, Sc. 'C', NIH Roorkee

Type of Study: Internal

Status: New

Study Period: 1st April 2025 - 31st March 2027 (Two Years)

Statement of Problem: The Bhaga River Basin (BRB), located in the Western Himalayas, is a critical water resource that sustains local ecosystems and human activities. This high- altitude Himalayan watershed is highly sensitive to climatic variability, particularly the influence of Western Disturbances (WDs) and the El Niño-Southern Oscillation (ENSO). These large-scale phenomena significantly shape the basin's hydrology, affecting precipitation patterns, snow accumulation, and streamflow regimes. Understanding their impact is crucial for effective water resource management and climate adaptation strategies. In BRB, WDs contribute to a substantial portion of annual precipitation, primarily in the form of snowfall. This snow accumulation plays a vital role in sustaining glacial mass and regulating river discharge during the melt season. A strong WD event can lead to excessive snowfall, increasing the risk of avalanches and delayed runoff, while weak or infrequent disturbance may result in lower winter precipitation and reduces summer streamflow. On the other hand, ENSO is known to influence summer monsoon rainfall over south Asia. El Niño is known to weaken monsoon activity resulting in reduced summer rainfall and streamflow, whereas La Niña is known to positively impact monsoon activity with increased precipitation and runoff. While WDs have been widely studied for their role in winter precipitation, their combined effect with ENSO on streamflow, snow accumulation, and glacier melt remains underexplored. Two recent studies published in January 2025 have illuminated the intricate relationship between the ENSO and WD, particularly concerning their impact on winter precipitation over the western Himalayas. Strong El Niño years are shown to enhance the intensity of WDs leading to a higher frequency of extreme precipitation events in the western Himalayas. While strong El Niño years tend to increase WD intensity and precipitation over western Himalayas, weaker events may not have a significant impact. On the other hand, La Niña years are associated with fewer and weaker WDs over India due to the northward displacement of the subtropical jet stream, leading to reduced winter precipitation in the western Himalayas. The combined effect of WDs and ENSO introduces significant variability into the hydrologic regime of the BRB and such variations pose challenges for hydropower generation, agriculture and water availability in downstream regions. So, understanding their interactions is essential for predicting water availability, managing risks associated with floods and droughts, and ensuring the sustainability of the region's water resources. This study aims to quantify and analyze the influence of WDs and ENSO on the hydrology of the BRB under historical and future climate conditions.

Objectives:

1. Assess the historical influence of Western Disturbances and ENSO on precipitation and streamflow dynamics in the Bhaga River Basin.
2. Evaluate the elevation dependent variability in winter precipitation and their consequences on snow spells (leading to snow drought) and snowmelt runoff.

3. Quantify the contribution of WD-driven precipitation to snow accumulation, glacier melt, and streamflow generation.
4. To evaluate ENSO's role in modulating WD activity and its cascading effects on glacier retreat and seasonal water availability.
5. To project future hydrological changes in response to shifting WD-ENSO patterns under climate change scenarios using downscaled CMIP6 data.

Methodology

BRB is a glacier-fed sub basin of the Chenab River, located in the Western Himalayas, Himachal Pradesh, India. The basin's hydrology is primarily governed by winter snowfall and summer glacier melt. The data required for the project include historical or observed datasets of precipitation, temperature, streamflow and glacier/snow cover. In addition, datasets of large-scale ocean-atmospheric indices (ENSO), other climatic indices to track the WD events and datasets of projected climate is required to accomplish the objectives of this study. These datasets are available from various sources including IMD (observed & gridded), ERA, CWC, state WRD's, and CMIP6. Reanalysis datasets will be used to identify WD events. Historical correlations between the characteristics, viz. frequency and intensity of WD events and Precipitation & streamflow will be analysed. In addition, the influence of ENSO on WD characteristics will be evaluated using composite analysis.

VIC and/or SPHY hydrological model will be used to simulate streamflow response to WD and ENSO variability. Sensitivity analysis will be performed to isolate the contributions of ENSO and ED events. Characteristics of WD and ENSO will be assessed using the statistically downscaled CMIP6 projections, viz. datasets available from NASA Earth Exchange Global Daily Downscaled Projections CMIP6 (NEX-GDDP-CMPI6). Hydrological response under different climate scenarios will be simulated using the calibrated model. Also, shifts in seasonal water availability due to changing WD-ENSO dynamics will be examined. In addition, several statistical tools such as Wavelet coherence analysis, EOF/PCA analysis will be used to detect long-term WD-ENSO-streamflow linkages and extract the dominant precipitation-streamflow variability patterns.

Expected Outcomes:

1. Quantification of WD and ENSO contributions to basin hydrology—critical for regional water resource planning.
2. Improved understanding of WD-ENSO interactions and their cascading effects on streamflow variability.
3. Better understanding of the role of elevation in winter precipitation and snow accumulation in the basin.
4. Hydrological impact projections under climate change, aiding policymakers in water management and disaster preparedness (e.g., flood/drought mitigation).
5. Scientific insights into high-altitude Himalayan hydrology, supporting future research on climate-glacier-hydrology linkages.

Deliverables: Report and Journal Publications, comprehensive report on the influence of WD-ENSO dynamics on winter precipitation, and streamflow.

End Users / Beneficiaries: Water Resources Departments, Disaster Management Agencies (NDMA, SDMA), Irrigation Department, NHPC, Academicians, etc.

22. PROJECT REFERENCE CODE: NIH/SP/25-28

Title of the Study: Impact of Climate Change on the Glaciers in Indus basin and its Impact on water availability over the coming decades.

Study Team: Vishal Singh (PI), Surjeet Singh, Deepak Singh Bisht, Kuldeep Sharma, Akshaya Verma, Sachchidanand Singh, WHRC, Jammu

Status: New

Type: Sponsored

Study Duration: April 2025 to March 2028

Statement of Problem:

The Indus basin heavily depends on its upstream mountainous part for the downstream supply of water while downstream demands are high. Water demands are high, primarily because of water consumption by irrigated agriculture, and hydropower generation. At the same time the downstream part of the basin is characterized by very dry conditions, making it largely dependent on water supply from the upstream areas. The glaciers in the Indus basin Himalayan range are seemingly losing mass at rates similar to other mountainous regions in the world, however the glaciers in the Karakoram and Pamir mountain ranges have neutral mass balances on average and are characterized by a large number of surging glaciers. On the other hand, decreasing trends in snow cover were seen for the most westerly-influenced sub basins.

As per the IPCC AR6, it is projected that in the Indus River basin, the projected runoff in the downstream portions will be increased due to accelerated melting snow, and glaciers. As per AR6, it is also projected that the future hydrological extremes of the Upper Indus basin suggest an increase in the magnitude of extremes towards the end of the 21st century by applying RCP4.5 and 8.5 scenarios, mainly due to increase in precipitation extremes. Rising temperatures in basins strongly dependent on glacier melt are likely to result in an increase in stream flow in the near future and a decline in the far future. This is caused by the fact that the total amount of glacier melt is a trade-off between increasing melt rates on one hand and reduced glacier volumes on the other hand. Furthermore, climate change led to increases in area and volume of glacial lakes has further exacerbated the risk of glacial lake outburst floods in Indus River basin. For snow, different processes combine in response to warming: a higher temperature accelerates snowmelt but reduces the fraction of precipitation that falls as snow, which eventually will lead to a decrease of snowmelt as a contributor to total runoff.

For the glaciers dominated regions in the Indus basin, increasing glacier melt water is projected by all ensemble members in both representative concentration pathways RCPs under CMIP5 GCMs. The future amount of snowmelt in the snow-covered areas of Indus River basin decreases slightly for all ensemble members in RCPs, as the increasing temperatures and limited change in precipitation result in a shift towards more liquid precipitation. Analysis of precipitation change signals in a large number of General Circulation Model was performed in Indus River basin. GCMs runs indicates that an increase in summer precipitation and on average no significant change in winter precipitation in Indus River basin. In the upper Indus Basin that is mostly covered by snow and glaciers, stream flow is dominated by glacier melt water, contributing 40.6% of the total runoff. As per CMIP6 observations, as a consistent increase in runoff is expected for Indus basin at least until 2050, a change of focus to coping with extreme events and intra-annual shifts in water availability is desirable. Based on the published observations, it has been seen that in Upper Indus basin the annual river flows will decrease by 16% with significant seasonal variations.

Summer flows will decrease and spring flows will increase, because of glacier retreat and higher precipitation.

Objectives

- To develop more accurate gridded high resolution climate data by adopting Data Assimilation (DA) approach for the Indus river basin to perform long-term trend and change analysis using available observations, open sources satellite and modelled datasets.
- Identification and selection of select key glaciers from the Upper Indus basin within by utilizing GSI and other standard database considering different factors viz. elevation zones, glacier area, slope and location/orientation.
- Computing glacier maps, glacier mass-balance (for key glaciers), snow cover maps, snow duration curves and snow cover trends and considering elevation zones to explore elevation dependent changes under warming conditions.
- Build a spatially distributed, climate-responsive glacio-hydrological model (i.e. SPHY modified version) with optimal temporal and spatial resolution to capture glacier dynamics during the baseline period and future times.
- Separation of snowmelt and glacier melt runoff from total streamflow by following the upstream to downstream hierarchy using SPHY model and isotope measurements.
- Evaluate the model's performance using established skill indicators, such as the coefficient of determination and Nash-Sutcliffe efficiency, ensuring reliable simulation of both raster and time-series variables.
- To analyze historical trends and project future changes in hydrological fluxes, water balance components such as snowmelt runoff, glacier melt runoff, base flow and rainfall induced runoff by applying downscaled and bias-corrected climate projections, thereby assessing the impacts of climate change on the study area.
- To develop subbasin wise quantifiable actionable plans and guidelines to adapt and mitigate climate change effects in the Indus river basin.

Study Area:

The proposed study work is based on the Indus River basin (within the Indian Himalaya) (Figure 1). The Upper Indus Basin (UIB) in India primarily includes the high-altitude regions of Ladakh, Jammu & Kashmir, and Himachal Pradesh. This region is characterized by extensive glaciation, with numerous glaciers contributing to the Indus River system. According to the Randolph Glacier Inventory (RGI), the UIB within India hosts a significant number of glaciers, particularly in the Karakoram and western Himalayas, with an estimated glaciated area of several thousand square kilometers.

The basin experiences substantial snowfall, particularly in winter, which serves as a primary source of glacier accumulation and runoff. The precipitation pattern is strongly influenced by both the western disturbances and the Indian monsoon, with winter snowfall dominating at higher elevations and summer rainfall contributing at lower altitudes. Climatological trends indicate a rise in temperature, leading to shifts in snowfall patterns and potential glacier retreat. Precipitation trends vary spatially and temporally, with some areas showing a decline in snowfall and an increase in rainfall, potentially altering the hydrological regime. The region exhibits

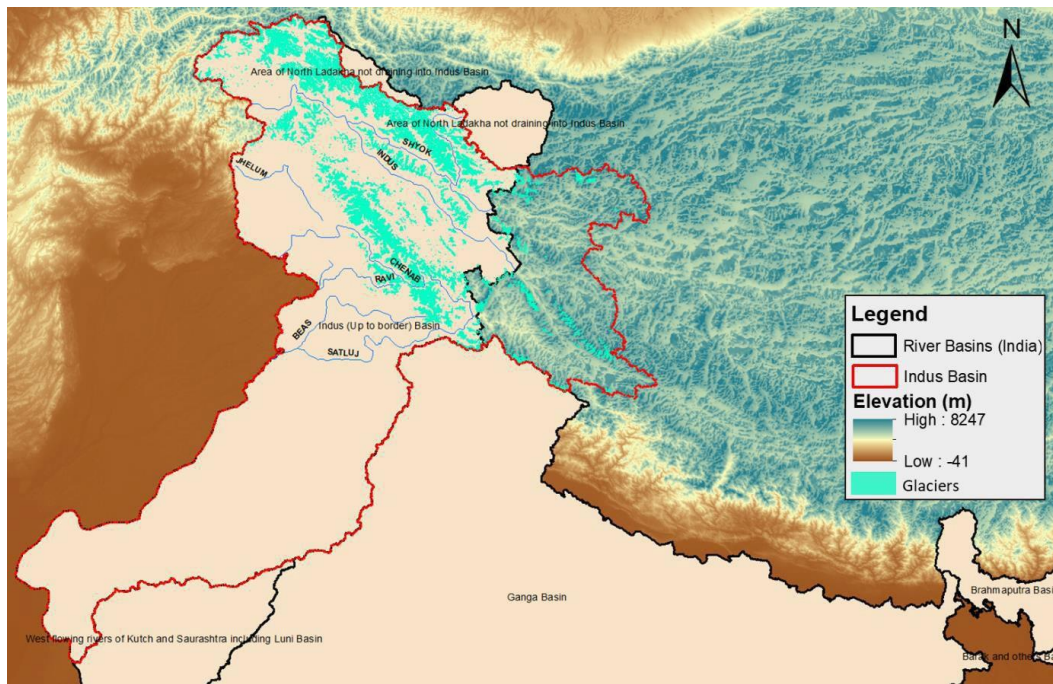


Figure 1. Map showing the study area i.e. Indus River basin, India.

extreme climatic variability, with annual precipitation ranging from less than 100 mm in the cold desert areas of Ladakh to over 1,000 mm in certain windward slopes of the Pir Panjal range. Long-term climate assessments suggest increasing warming trends, with potential implications for glacier mass balance, water availability, and downstream hydrology. Understanding these climatic and cryospheric dynamics is crucial for water resource management, given the dependence of millions on the Indus River for agriculture, hydropower, and sustenance.

Deliverables:

(a) Generation of database

- Developing database for snow cover maps, glacier maps, glacier-mass balance and other thematic layers.
- Developing accurate and improved time series datasets for precipitation, temperature and other hydro-meteorological variables for the selected study basin.

(b) Hydrologic model

- Developing spatially varied gridded SPHY model (calibrated and validated) for generating different runoff components such as snowmelt, glacier melt, baseflow, rainfall induced runoff and total flow at the different locations and subbasins.

(c) Improved climate datasets for the Indian Himalayas

- Developing sub-grid scale climate model scenarios (CMIP6) at ~9km scale for the study basin in the Indian Himalayas for long-term period (i.e. 2001-2100).
- Improved Regional Climate Models for the Indian Himalayan Region without which we cannot examine the impact of climate change on Himalayan water resources.
- Projection and changes of different hydrological fluxes like snowmelt runoff, glacier melt runoff, baseflow and total flows.

ENVIRONMENTAL HYDROLOGY DIVISION

Scientific Manpower

S. N.	Name	Designation
1.	Dr. Y. R. Satyaji Rao	Scientist G & Head
2.	Dr. M. K. Sharma	Scientist F
3.	Dr. Pradeep Kumar	Scientist E
4.	Dr. Rajesh Singh	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.	Er. Poonam	Scientist B
11.	Smt. Babita Sharma	PRA
12.	Smt. Bina Prasad	SRA
13.	Sh. Amit Rawat	Technician



APPROVED WORK PROGRAMME FOR THE YEAR 2024-25

S. No.	Study Title	Study Team	Duration/Status
Sponsored R&D Projects (Completed)			
.	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	Omkar Singh, Rajesh Singh (PI), Jyoti P Patil, VK Tyagi, Kalzang Chhoden Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand	5 Years (04/19-01/25) Project Cost: 5.1 Crore Sponsored by: DST Status: Completed
.	Irrigation efficiency improvement for Shahnehar medium irrigation project	RP Pandey, Rajesh Singh (PI), Shakti Suryavanshi, SK Kumre, JP Patra	6 Years (12/17-09/24) Project Cost: 75 Lakh Sponsored by: NHP Status: Completed
Sponsored R&D Projects (Ongoing)			
.	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)	5 Years (2022-2027) Project Cost: 2.4 Crore Sponsored by: DST Status: Ongoing
Sponsored R&D Projects (New)			
.	Development of Innovative sewage treatment technology with a minimum energy requirement	Vinay Kumar Tyagi (PI) Rajesh Singh (Co-PI) Collaborators: IIT Roorkee -Prof. C.S.P Ojha -Prof. A A Kazmi	3 yr (08/2024-07/2027) Project Cost: 97.5 Lakhs Sponsored by: Tehri Hydro Development Corporation Ltd.
.	BioHythane production from Hydrothermally pretreated OFMSW and Sewage Sludge	Vinay Kumar Tyagi (PI) Rajesh Singh (Co-PI) Collaborators: IIT Roorkee -Prof. C.S.P Ojha -Prof. A A Kazmi	3 yr (08/2024-07/2027) Project Cost: 98.5 Lakhs Sponsored by: Tehri Hydro Development Corporation Ltd.
.	Environmental Flow Assessment for Chambal, Sone, Damodar and Tons Rivers at Critical Reaches	Pradeep Kumar (PI) and team of scientists from EHD, GWHD, C4S, WRSD Collaborators: WII, Dehradun ICAR-CIFRI, Barrackpore	3 Years (12/24-11/27) Project Cost: 1088 Lakhs Sponsored by: NMCG Status: New
Collaborative R&D Projects (Completed)			
.	Isotopic and geochemical approach to study vulnerable confined and unconfined drinking	Rajesh Singh (PI), R.P. Pandey BHU, Varanasi (Lead)	3 Years (07/21-03/25) Sponsored by: BHU Status: Completed

	water aquifers in Varanasi and surrounding area, India	Other Collaborators: BARC, Mumbai, ICER, Hungary	
Collaborative R&D Projects (Ongoing)			
.	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 (Completed)			
.	Understanding arsenic mobilization in groundwater of Haridwar and formulating remediation measures	Rajesh Singh (PI), Sumant Kumar, Pradeep Kumar, MK Sharma, VK Tyagi, Kalzang Chhoden	3 Years (07/21-03/25) Status: Completed
0.	Simulation of non-point source pollution processes in Song River	Pradeep Kumar (PI), MK Sharma, Rajesh Singh	5 Years (11/19-03/25) Status: Completed
Internal Study (Ongoing)			
1.	Hydrological Studies for the Conservation of Rewalsar Lake	Kalzang Chhoden (PI) Rajesh Singh, RP Pandey, P Kumar, VK Tyagi, Omkar Singh, S. D. Khobragade DS Malik, GKU, Haridwar	3 Years (04/23-03/26) Status: In-Progress
2.	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, PK Sahoo, Kalzang Chhoden, YRS Rao	3 Years (04/23-03/26) Status: In-Progress
3.	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) Status: In-Progress
4.	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) Status: In-Progress
5.	Evaluation of groundwater quality of Tripura with emphasis on arsenic and fluoride	Rajesh Singh (PI), VK Tyagi, MK Sharma, PK Sahoo, Kalzang Chhoden, Shakti Suryavanshi, SK Sharma, Swapnali Barman, WR Singh	3 Years (04/24-03/27) Status: In-Progress
6.	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) Status: In-Progress

7.	Rainfall-Runoff-Sediment yield modelling to assess water availability and sediment loads	Shakti Suryavanshi (PI), SK Kumre, Pradeep Kumar,	3 Years (04/24-03/27) Status: In-Progress
8.	Environmental flow requirements at critical stretches of River Yamuna	SK Kumre (PI), Pradeep Kumar, Shakti Suryavanshi, Rajesh Singh	3 Years (04/24-03/27) Status: In-Progress
Consultancy Projects (Completed)			
9.	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: Completed
Consultancy Projects (Ongoing)			
0.	Preparation of District/State Action Plans for Source Sustainability of Drinking Water Supply Schemes under Jal Jeevan Mission, Uttarakhand	RP Pandey, Rajesh Singh (PI), P Kumar, MK Sharma, VK Tyagi, Kalzang Chhoden, Shakti Suryavanshi, Shailendra Kumre	2 Years (10/23-07/25) Funded by: Uttarakhand Jal Jeevan Mission Cost: Rs. 1.06 Crore Status: In-Progress
1.	Site assessment for potential damage to the environment caused by pesticide manufacturing industry located at RIICO industrial area, Sotanala, Behror (Rajasthan)	MK Sharma (PI), Sumant Kumar	0.5 Year (03/25-08/25) Funded by: Rajasthan Pollution Control Board, Jaipur Cost: Rs. 23.6 Lakhs Status: In-Progress
2.	Prioritization of Sub-catchments of the Song and Nayar River Catchments for Development of River Rejuvenation Plan	Pradeep Kumar (PI), YRS Rao, SS Rawat, Shakti Suryavanshi, SK Kumre, SM Pingale	04 Month (11/24-03/25) Funded by: Watershed Management Directorate, Uttarakhand Cost: Rs. 5.90 Lakh Status: In-progress; Draft Report submitted
3.	Preparation of NGT Joint Committee Report on Solani River Catchment	YRS Rao (PI), Pradeep Kumar, VK Tyagi, Rajesh Singh, Shakti Suryavanshi, SK Kumre	03 Month (11/24-03/25) Funded by: Uttarakhand State Pollution Control Board Cost: Rs. 3.54 Lakh Status: In-Progress

PROPOSED WORK PROGRAMME FOR THE YEAR 2025-26

S. No.	Study Title	Study Team	Duration/Status
Sponsored R&D Projects (Ongoing)			
.	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)	5 Years (2022-2027) Project Cost: 240 Lakhs Sponsored by: DST Status: Ongoing
.	Development of Innovative sewage treatment technology with a minimum energy requirement	Vinay Kumar Tyagi (PI) Rajesh Singh (Co-PI) Collaborators: IIT Roorkee -Prof. C.S.P Ojha -Prof. A A Kazmi	3 yr (08/2024-07/2027) Project Cost: 97.50 Lakhs Sponsored by: Tehri Hydro Development Corporation Ltd.
.	BioHythane production from Hydrothermally pretreated OFMSW and Sewage Sludge	Vinay Kumar Tyagi (PI) Rajesh Singh (Co-PI) Collaborators: IIT Roorkee -Prof. C.S.P Ojha -Prof. A A Kazmi	3 yr (08/2024-07/2027) Project Cost: 98.50 Lakhs Sponsored by: Tehri Hydro Development Corporation Ltd.
.	Environmental Flow Assessment for Chambal, Sone, Damodar and Tons Rivers at Critical Reaches	Pradeep Kumar (PI) and team of scientists from EHD, GWHD, C4S, WRSD Collaborators: WII, Dehradun (UK), ICAR-CIFRI, Barrackpore (WB)	3 Years (12/24-11/27) Project Cost: 1088 Lakhs Sponsored by: NMCG Status: New
Collaborative R&D Projects (Ongoing)			
.	SARASWATI 2.0 - Identifying best available technologies for decentralized wastewater treatment and resources recovery for India	VK Tyagi, (Co-PI) AA Kazmi (PI, IITR)	5 Years (03/20-06/25) Sponsored by: DST Status: In-progress
Internal Study (Ongoing)			
.	Hydrological Studies for the Conservation of Rewalsar Lake	Kalzung Chhoden (PI) Rajesh Singh, YRS Rao, P Kumar, VK Tyagi, S. D. Khobragade, Shakti Suryavanshi, SK Kumre DS Malik, GKU, Haridwar	3 Years (04/23-03/26) Status: In-Progress
.	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, Kalzung Chhoden, YRS Rao	3 Years (04/23-03/26) Status: In-Progress
.	Nanotechnology-enabled multifunctional materials for the detection and remediation of arsenic in contaminated water	PK Sahoo (PI), Rajesh Singh, MK Sharma, Pradeep Kumar, VK Tyagi, Sumant Kumar, Kalzung Chhoden	3 Years (04/24-03/27) Status: In-Progress

.	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) Status: In-Progress
0.	Evaluation of groundwater quality of Tripura with emphasis on arsenic and fluoride	Rajesh Singh (PI), VK Tyagi, MK Sharma, PK Sahoo, Kalzang Chhoden, Shakti Suryavanshi, SK Sharma, Swapnali Barman, WR Singh	3 Years (04/24-03/27) Status: In-Progress
1.	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) Status: In-Progress
2.	Environmental flow requirements at critical stretches of River Yamuna	SK Kumre (PI), Pradeep Kumar, Shakti Suryavanshi, Rajesh Singh	3 Years (04/24-03/27) Status: In-Progress
3.	Rainfall-Runoff-Sediment yield modelling to assess water availability and sediment loads	Shakti Suryavanshi (PI), SK Kumre, Pradeep Kumar,	3 Years (04/24-03/27) Status: In-Progress
Internal Study (Proposed)			
4.	Fate, transport, and health risks of agricultural pollutants in the Yamuna River Basin: An integrated modelling and experimental approach	Poonam (PI), YRS Rao, MK Sharma, Pradeep Kumar, Rajesh Singh, VK Tyagi, Kalzang Chhoden, Shakti Suryavanshi, SK Kumre	3 Years (04/25-03/28) Status: Proposed
5.	Evaluating the impact of toilets on groundwater and surface water in diverse hydrogeological and climatic contexts without sewage treatment facilities	Y. R. Satyaji Rao (PI), Rajesh Singh, Vinay Kumar Tyagi, Kalzang Chhoden, Shakti Suryavanshi, Poonam	3 Years (04/25-03/28) Status: Proposed
6.	Nitrate-organic-bacteria nexus in mobilization of naturally occurring arsenic in groundwater	Rajesh Singh (PI), YRS Rao, Sumant Kumar, VK Tyagi, MK Sharma, Kalzang Chhoden, PK Sahoo, Poona Prashant Rai (CGWB, DDN)	3 Years (04/25-03/28) Status: Proposed
Consultancy Projects (Ongoing)			
7.	Preparation of District/State Action Plans for Source Sustainability of Drinking Water Supply Schemes under Jal Jeevan Mission, Uttarakhand	RP Pandey, Rajesh Singh (PI), P Kumar, MK Sharma, VK Tyagi, Kalzang Chhoden, Shakti Suryavanshi, SK Kumre	2 Years (10/23-07/25) Funded by: UK-JJM Cost: Rs. 1.06 Crore Status: In-Progress
8.	Site assessment for potential damage to the environment caused by pesticide manufacturing industry located at RIICO industrial area, Sotanala, Behror (Rajasthan)	MK Sharma (PI), Sumant Kumar	0.5 Year (03/25-08/25) Funded by: Rajasthan Pollution Control Board, Jaipur Cost: Rs. 23.6 Lakhs Status: In-Progress

9.	Hydrogeological Study of Feroze Gandhi Unchahar Thermal Power Station, Unchahar	Rajesh Singh (PI), YRS Rao, MK Sharma, Pradeep Kumar, VK Tyagi, K Chhoden, PK Sahoo, S Suryavanshi, SK Kumre	1.5 Year (03/25-07/26) Funded by: GCS, Roorkee Cost: Rs. 6.6 Lakhs Status: In-Progress
0.	Prioritization of Sub-catchments of the Song and Nayar River Catchments for Development of River Rejuvenation Plan	Pradeep Kumar (PI), YRS Rao, SS Rawat, Shakti Suryavanshi, SK Kumre, SM Pingale	04 Month (11/24-03/25) Funded by: Watershed Management Directorate, Uttarakhand Cost: Rs. 5.90 Lakh Status: In-progress; Draft Report submitted
1.	Preparation of NGT Joint Committee Report on Solani River Catchment	YRS Rao (PI), Pradeep Kumar, VK Tyagi, Rajesh Singh, Shakti Suryavanshi, SK Kumre	03 Month (11/24-03/25) Funded by: Uttarakhand State Pollution Control Board Cost: Rs. 3.54 Lakh Status: In-Progress

Study – 1 (Sponsored Study)

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

2. **Project Team:**

Project Investigator	Dr. V.C. Goyal, Ex. Sc. G & Head, RMOD (till Sept. 2022) Er. Omkar Singh, Ex. Sc. G & Head, Tech. Cell (Oct. 2022 to Jul. 2024) Dr. Rajesh Singh, Sc. E, EHD (w.e.f. Aug. 2024)
Project Co-investigator	Dr. Vinay Kumar Tyagi, Sc. D, EHD (Co-PI) Dr. Jyoti P. Patil, Sc. E, RC Belgavi 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 2019

6. **Scheduled date of completion:** February 2024 (Extension upto Jan. 2025)

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	Completed	NA	Completed
Objective 3	Establishment of Live Laboratories	M18	Completed	NA	Completed	NA
Objective 4	Dev. & application of innovative ideas on NTS	M24	Completed	NA	Completed	Completed
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	Completed	NA	Completed	NA
	Dev. of Indian handbook for NTS Technology Packages	M55	NA	Dropped	NA	NA
	Submission of final Project Report	M60	Will be submitted with UC/SE	Completed	Completed	Completed

10. Milestones achieved by NIH Roorkee (January 2025)

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 <i>Bacopa monnieri</i> and <i>Acorus calamus</i>	M24	Completed
	Treatment of domestic wastewater using floating treatment wetlands using <i>Phragmites australis</i> , and <i>Canna indica</i>	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 <i>Canna indica</i> in NIH Roorkee.	M49	Completed
	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	Completed
	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	Completed
Documentation and dissemination	Capacity building, awareness creation, and dissemination activities (Factsheets/policy briefs, reports on NTS)	M58	Completed

Study – 2 (Sponsored Study)

1. Title of the project: Irrigation efficiency improvement for Shahnehar Medium Irrigation Project

2. Project Team

Project Investigator	Dr. R.P. Pandey, Scientist ‘G’ (PI up to 04/2024) Dr. Rajesh Singh, Scientist ‘E’ (PI w.e.f. 05/2024)
Project Co-investigator	Dr. Shakti Suryavanshi, Sc, C, EHD Dr. Shailendra Kumar Kumre, Sc B, EHD Er. Jagdish Prasad Patra, Sc E, SWHD
Collaborating Organization	Irrigation & Public Health Engg. (I&PHE), Shimla

3. Type of Study: NHP-PDS, Budget: Rs.75.0 lakh (NIH Cost Allocation: Rs. 18.1 lakh)

4. Nature of Study: Applied & Basic Research

5. Date of Start: December, 2017

6. Scheduled Date of Completion: November 2024

7. Duration of Study: 7 years

8. Objectives of the study

- Rainfall frequency analysis to generate climate scenario at different categories such as Wet years, Normal years, Dry Years
- Crop water requirement modeling for different crops
- Irrigation scheduling for major crops.
- Field experimentation at the site for improving irrigation efficiency.

9. Statement of the Problem

Agricultural productivity in the region faces significant challenges due to unpredictable rainfall patterns, inefficient water use, and limited understanding of crop-specific water requirements. The absence of reliable climate scenarios hampers effective planning, while inadequate irrigation practices lead to water wastage and reduced crop yields. Addressing these issues is crucial to ensure sustainable water management and improve agricultural resilience.

10. Approved Action Plan/ Methodology:

The study was conducted at three experimental sites along the Right Bank Main Canal (RBMC), with plots set up at upper, middle, and lower sections. Each site featured controlled and uncontrolled irrigation plots to assess irrigation efficiency using soil moisture sensors installed at depths of 15 cm, 30 cm, and 45 cm. The experiment involved wheat cultivation during the Rabi season. Meteorological data spanning 37 years (1982-2018) were used to estimate reference evapotranspiration (ET_o) through the FAO Penman-Monteith method in CROPWAT 8.0 software. Rainfall probability analysis identified dry (P80), normal (P50), and wet (P20) years to determine effective rainfall and irrigation scheduling. Crop water requirements (CWR) were calculated based on crop coefficients (K_c) to ensure accurate water demand estimation. The study evaluated irrigation practices using indices like Relative Water Saving (RWS) and Water Productivity (WP), highlighting improved efficiency in controlled plots. The approach emphasized real-time monitoring of soil moisture for better irrigation timing. Data analysis ensured that the irrigation schedule aligned with crop needs in a semi-humid environment. This comprehensive framework aims to optimize water use and improve

agricultural productivity in the Shahnehar command area.

11. **Timeline (Approved):** As per approved in the proposal

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

S. No .	Activity	Achievements
1.	Field experiment	Experiment involved wheat cultivation during the Rabi season
2.	Crop data Collection and Analysis	Evaluation of irrigation practices using indices like Relative Water Saving (RWS) and Water Productivity (WP), highlighting improved efficiency in controlled plots.

13. **Analysis & Results:**

From the experimental sites under uncontrolled and controlled irrigation condition at Rajgir site, total irrigation applied (in three-applications) was 264 mm and 261 mm respectively, against the estimated average of net irrigation requirement (NIR) of 184 mm. This corresponds to the field irrigation efficiency of 69.69 % and 70.49%, respectively. Similarly, in case of Indora Site, the corresponding values are 155.7 mm and 148.6 mm, respectively, for two-irrigation applications, and the estimated average of NIR of 106.5 mm. This corresponds to the field irrigation efficiency of 68.40 % and 71.66%, respectively. These results indicate that the irrigation scheduling and controlled irrigation application may enhance irrigation efficiency for optimizing water use in agriculture. During the experiment it was observed that the irrigation requirement and the time interval of irrigation more or less follow the similar pattern of estimated irrigation. At both sites, controlled irrigation demonstrated relatively better water use efficiency and productivity compared to that in uncontrolled irrigation application. While the water savings were modest at the Rajgir site, the Indora site showed significant improvements in terms of water savings and efficiency.

14. **End Users / Beneficiaries of the Study:** Policy makers and planners of State/Central Government Organizations; NGOs, Agricultural & Industrial Sectors

15. **Deliverables:** Technical report and research papers.

16. **Data procured or generated during the study:** Agricultural yield data, crop water requirement, irrigation scheduling of the study.

17. **Study Benefits / Impacts:**

The study highlights the significant benefits of adopting controlled irrigation practices to enhance water use efficiency and improve agricultural outcomes. By implementing controlled irrigation schedules, water application was regulated based on real-time soil moisture data, ensuring crops received adequate water precisely when needed. This method minimized water losses due to over-irrigation, surface runoff, and deep percolation, which are common in conventional irrigation practices.

18. **Involvement of end users/beneficiaries:** Yes

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

20. Shortcoming/Difficulties: None.

21. Future Plan:

Due to delay in the procurement and installation of the moisture sensors, the irrigation efficiency has been evaluated based on the field experiment for single cropping season i.e. Rabi season. There is a need to validate the results with two more cropping seasons. Further, experiments for Kharif season are also required to be carried out to estimate the total irrigation water requirement for the command area. Further, the experiment with micro-irrigation techniques can also be examined using gravity head, as the sites condition are suitably favourable for some of the sites.

Study – 3 (Sponsored Study)

1. **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

2. **Study Group:**

Study Team			
NIH, Roorkee	IIT, Kanpur	NGO	The Netherlands
Dr. M. K. Sharma – PI, Dr Y. R. S. Rao, Dr. Sudhir Kumar (Retd.), Ms. Anjali, Dr. Vishal Singh, Dr. SM Pingale – Co-PI, 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 Mr. Shams Quamar-JRF, Mr. Kuldeep Singh-JRF, Mr. Gaurav Saini-PA, Ms. Anjali-PA.			

3. **Type of Study:** DST NWO Sponsored project **Budget:** Rs. 2,40,01,260.00
4. **Nature of Study:** Applied Research
5. **Date of Start:** April 2022
6. **Scheduled date of Completion:** March 2027
7. **Duration of the Study:** 05 years

8. Study Objectives

- 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.

9. 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. Though a large number of studies, to understand the pollution aspects of river Hindon, have been carried out by different workers 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:** As per approved in the proposal

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

S. No.	Activity	Achievements
1.	Observational Network	• AWLRs were installed in Piezometers and continuous observations of groundwater levels for one hour interval are being taken in Hindon River Basin. • 12 Stilling wells have been prepared and installed with DWLRs for taking stage in the river Hindon and its tributaries.
2.	Field investigations & Sample Analysis	• Surface water Level and Quality Monitoring: Monthly basis (22 samples being collected) • Discharge measurement using ADCP • Groundwater Level and Quality Monitoring: Level – Hourly basis using AWLRs Quality: Quarterly basis (36 Samples being collected) • Isotopic characterization of River Water and Ground Water for SW-GW interaction study • Soil property in Hindon River Basin using Soil Moisture Probes
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

- Water samples collected from groundwater (Piezometers) on quarterly basis and surface water sources (River Hindon, drains, its tributaries and Canal) on monthly basis and analysed for hydrochemical parameters, metal concentrations and being analysed for pesticides residues.

- DO values along River Hindon generally observed below 3 mg/L and even nil at few locations.
- High values of BOD and COD in the River Hindon, drains, its tributaries samples indicate the presence of organic pollution.
- TDS, Alkalinity, Hardness, Cr, Mn, As, Hg, Pb in the groundwater of the few locations exceeds the maximum permissible limit prescribed by BIS for drinking purposes.
- Identification of Influent & Effluent Section of River Hindon & its tributaries has been attempted using comparing water levels in the river and adjoining installed piezometers and preliminary findings revealed that River Hindon contributing to groundwater and deteriorating groundwater quality in the adjoining areas.
- Interaction of River Water and Ground Water was also observed using Isotope data analysis.
- Soil Property viz; water content, temperature, Permittivity, Conductivity and Porewater Conductivity in upper, mid and lower part of Hindon Basin were investigated using Soil Moisture Probe.

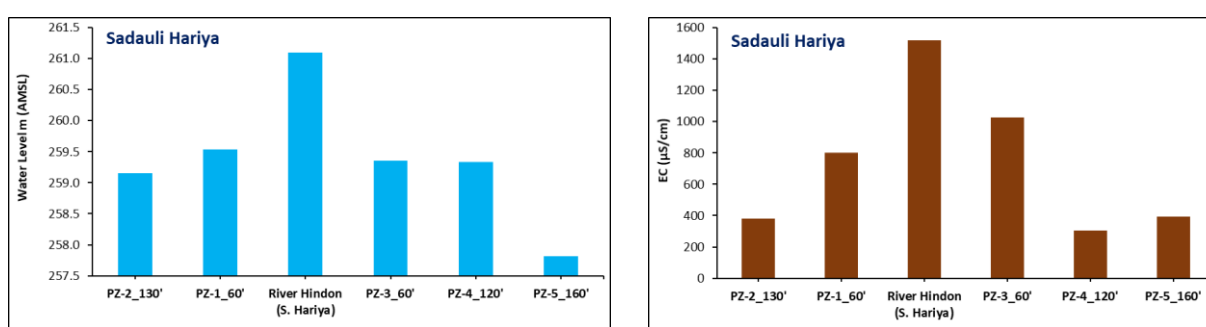


Figure showing water levels and EC in the River and adjoining installed piezometers

- End Users / Beneficiaries of the Study:** Irrigation Research Institute, Ground Water Department, UP, CGWB.
- Deliverables:** Technical report and research papers,
- Major items of equipment procured:** None
- Lab facilities used during the study:** Water Quality Laboratory (NIH) and Nuclear Hydrology Laboratory
- Data procured or generated during the study:** Water quality data, Groundwater level data, Discharge data
- 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.
- Involvement of end users/beneficiaries:** Groundwater Department, UP and CGWB
- Specific linkage with Institution and /or end users / beneficiaries:** Yes

23. Shortcoming/Difficulties: None.

24. Future Plan:

- Regular Monitoring of AWLRs in Piezometers
- Regular Monitoring of discharge measurement at G&D Sites and sample collection for Water Quality.
- Conceptualization of Groundwater model for the study area
- Identification of affluent and effluent sections of River Hindon.
- Water Balance of Hindon River Basin
- Reach-wise Recharge augmentation plan

Study – 4 (Sponsored Study)

1. **Title of the Study:** Development of Innovative sewage treatment technology with a minimum energy requirement

2. **Study Group:**

Lead Investigator	Dr. Vinay Kumar Tyagi, Sc. 'D' (PI)
Co-PI	Prof. CSP Ojha, IITR Prof. A A Kazmi, IITR Dr. Rajesh Singh, Sc. 'E', NIH

3. **Type of Study:** Sponsored Study **Budget:** Rs. 97.50 Lakhs
4. **Nature of Study:** Applied Research
5. **Date of start:** August 2024
6. **Scheduled date of completion:** July 2027
7. **Duration of the Study:** 3 Years

8. **Study Objectives**

- Development of integrated primary sedimentation basin (PSB) followed by the DHS reactor.
- Optimization of best Organic loading rate, OLR and hydraulic retention time, HRT
- Additional treatment strategy to remove organics, nutrient and pathogens [1] Effluent recirculation for enhanced nitrogen removal [2] Additional treatment (coagulation-flocculation) for enhanced phosphorus removal [3] Disinfection of DHS effluent
- Development of methane fermentation (anaerobic digestion) process for converting raw sludge (generated from PSB) into biogas and energy.
- Techno-economic feasibility of the integrated processes and comparison with conventional and modified activated sludge process systems.

9. **Statement of the Problem:** The project will Demonstrate PSB-DHS feasibility via lab and pilot-scale studies, explore **high-efficiency methane recovery** from PSB sludge, Build local capacity and technical expertise for future scale-up. Ultimately, this system aims to offer a **low-energy, sustainable wastewater treatment solution** for India, supporting cleaner water environments and integrated water resource management.

10. **Methodology:**

Stage 1: Fabrication of pilot scale PST-DHS system and anaerobic digester

Stage 2: Optimization of best operational conditions (Hydraulic retention time, hydraulic loading rate, Organic loading rate)

Stage 3: Development of bio-methanation process for converting raw sludge into biogas and fertilizer

Stage 4: Enhanced removal of organics, nutrient and pathogens

Stage 5: Mathematical modelling and numerical simulations

Stage 6: Techno-Economic analysis

Stage 6: Results analysis, drawing conclusion and reporting

11. **Timeline:** The proposed study will be carried out in 36 months.

12. Objectives and achievement during last twelve months:

S. No.	Objectives	Achievements
(i)	Development of integrated primary settlement basin (PSB) followed by DHS reactor.	Engineering design development of Pilot plant
(ii)	Lab scale reactor operation	Preliminary data on the performance of DHS reactor and conventional trickling filter was received.

13. Recommendation / Suggestion:

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

14. Analysis & Results:**14.1. Engineering design development of Pilot plant**

As per the research plan, the design of the DHS reactor has been finalized by technical screening and inputs from the experts. The procurement of PST-DHS-TF reactors are under the process.

14.2. Lab-scale reactors operation

Lab scale DHS reactor and trickling filter were operated. The average total COD removal efficiency of both the DHS systems was found to be around 89 % with a range of 86.3 to 91.2 %, while for the trickling filter, the removal efficiency was found to be around 75 %. The mean TSS in the raw wastewater was found to be 117 ± 23 mg/L, while the mean for the settled wastewater was around 74.6 ± 21 mg/L, indicating that around 37 % of the suspended solids were removed during the settlement period. The average TSS of the DHSI effluents was found to be 2.1 ± 1.3 mg/L to 3.9 ± 1.6 mg/L, achieving the TSS removal efficiency of 94-97%. The TSS removal in the trickling (TF) was significantly lower than the DHS system in the range of 87 to 90 %, as expected. The mean ammonia concentration of the inlet was 39.7 ± 19.1 mg/L within a range of 15.46 mg/L to 69.2 mg/L. This ammonia concentration was greatly reduced in the DHS system to below detection limits. However, the trickling filter was unable to achieve complete ammonia removal and it remained in the range of 2.7 mg/L to 20.8 mg/L, varying with change in the inlet ammonia of the wastewater. The DHS system showed significant removal of coliform and the effluent contained MPN in the range of 7.5×10^3 to 2.1×10^4 / 100 ml of sample. On the other hand, the MPN for the TF was found to be in the range of 1.34×10^4 to 6.4×10^5 . Thus, DHS media showed better efficiency in coliform removal. The dissolved oxygen for DHS was found to be in the range of 6.4 to 7.1 mg/L, and for TF it ranged from 5.6 to 7.

14. **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:** Water Quality Lab, NIH Roorkee

19. **Data procured or generated during the study:** Lab scale study
20. **Study Benefits / Impacts:**
This technique could be proved as one of the most economical and environmentally benign alternatives in comparison to the high energy demanding aerobic sewage treatment processes. National Mission for Clean Ganga (NMCG), National River Conservation Directorate and Ministry of Environment, Forest & Climate Change (MoEFCC) can direct the application of technology on commercial scales once proved in field conditions. Ultimately, the Central Pollution Control Board (CPCB) can devise standards based on this technology for the optimum treatment of wastewater.
22. **Involvement of end users/beneficiaries:** None
23. **Specific linkage with Institution and /or end users / beneficiaries:** Yes
24. **Shortcoming/Difficulties:** None
24. **Future Plan:**
- Pilot plant fabrication, commissioning, operation, and continuous monitoring for long-term evaluation

Study – 5 (Sponsored Study)

1. **Title of the Study: BioHythane production from Hydrothermally pretreated OFMSW and Sewage Sludge**

2. **Study Group:**

Lead Investigator	Dr. Vinay Kumar Tyagi, Sc. 'D' (PI)
Co-PI	Prof. CSP Ojha, IITR Prof. A A Kazmi, IITR Dr. Rajesh Singh, Sc. 'E', NIH

3. **Type of Study:** Sponsored Study **Budget:** Rs. 98.50 Lakhs
4. **Nature of Study:** Applied Research
5. **Date of start:** August 2024
6. **Scheduled date of completion:** July 2027
7. **Duration of the Study:** 3 Years

8. **Study Objectives**

- I. Optimization of Sewage Sludge and OFMSW anaerobic digestion for maximum H₂ & CH₄ production: mixing ratio, total solids percentage
- II. To obtain the effect of Hydrothermal Pretreatment conditions (Temp, Pressure & Reaction time) on H₂ & CH₄ production – Batch Assays & Semi Continuous Operation
- III. Effect of variable organic loading rates (OLR) and hydraulic retention times (HRT) on H₂ & Biogas production under semi-continuous operation

9. **Statement of the Problem:**

Rapid urbanization and poor waste management in India have led to growing solid waste problems, with only 24% of the 143,000 tonnes/day of municipal solid waste (MSW) being processed by 2017. Most waste ends up in landfills, resulting in resource loss and unsustainable practices in energy-constrained communities. The project aims to develop an **energy-efficient and scalable strategy** for maximizing H₂ and CH₄ recovery from MSW and sewage sludge through optimized waste blending, pre-treatment, and process integration—contributing to sustainable waste-to-energy solutions in India.

10. **Methodology:** The research project will be carried out under following work packages:
 Work Package 1: Inoculum preparation and Characterization of the wastes
 Work Package 2: Optimization of best treatment conditions for AcoD of MSW+Sewage sludge
 Work Package 3: Optimization of Hydrothermal pretreatment of waste
 Work Package 4: Optimization of Hydro-thermal pretreatments on biohythane production in batch mode operation
 Work Package 5: Optimization of the reactor operation in semi-continuous mode
 Work Package 6: Analysis of cost benefit and net energy balance, Results analysis, drawing conclusion and reporting
 Work Package 7: Biochemical methane and hydrogen potential assays for biochar selection and dose optimization

11. **Timeline:** The project will be carried out for 36 months.

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

S. No.	Objectives	Achievements
(i)	Raw waste characterization and Optimization of best mixing ratios for AcoD of MSW+ Sewage sludge	Preliminary experiments on the raw waste characterization and Optimization of best mixing ratios for AcoD of MSW+Sewage sludge were conducted

13. Recommendation / Suggestion:

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

14. Analysis & Results:

Understanding the composition of food waste and sewage sludge is crucial for its possible applications in anaerobic digestion and resource recovery. The pH of OFMSW, SS and inoculum was 4.8, 7.8 and 7.7, respectively. The average concentrations of total solids (TS) and volatile solids (VS) in the organic fraction of municipal solid waste (OFMSW) were 24% and 17.5%, respectively, yielding a VS/TS ratio of 74%. The VFAs concentration was 380 mg/L and 215 mg/l for OFMSW and SS, respectively, suggesting that the collected waste is relatively fresh and has not yet undergone significant fermentation. TKN values are higher in SS (22.3 g/kg) as compared with OFMSW (6.3 g/kg) since sludge is rich in proteins as compared to food waste, inturn leading to a higher C/N ratio in OFMSW (22) than SS (6.2). The biomethane potential (BMP) assays showed the highest methane production at the 70:30 ratio, with similar methane production observed in the 80:20 and 90:10 ratios. Hydrogen production is typically favored in environments with a higher proportion of easily fermentable organic materials, such as sugars, which are more abundant in the 90:10 ratio. However, the BHP effluent shifted to BMP conditions showed a longer lag phase for methane production in 90:10 ratio as compared to the 70:30 ratio.

15. End Users / Beneficiaries of the Study: Municipal corporation

16. Deliverables: Technical report and research papers

16. Major items of equipment procured: None

17. Lab facilities used during the study: Water Quality Lab, NIH Roorkee

18. Data procured or generated during the study: Lab scale study

20. Study Benefits / Impacts: New IPs are expected. **Municipalities** will be the direct beneficiary. At the successful completion of the project, we plan to translate the proposed technology into waste generation site to further **test at pilot and demonstration scale**. **Various consultants and companies** can get involved and, develop the design based on our results for better efficiency and ensure successful implementation at field scale. **A newly developed biofuel production strategy** can be circulated in the private sector which can give green credits to the organization and it can be a stepping-stone to sustainable development.

21. Involvement of end users/beneficiaries: None

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

25. **Shortcoming/Difficulties:** None

24. **Future Plan:**

Optimization of best treatment conditions for ACoD of substrate (OFMSW+Sewage Sludge); Optimization of hydro-thermal pretreatment of waste; Optimization of Hydro-thermal pretreatments on biohythane production in batch mode operation; Optimization of the reactor operation in semi-continuous mode (best OLR & HRT); Analysis of cost benefit & net energy balance, results analysis, drawing conclusion & reporting; BHP and BMP assays for biochar selection and dose optimization

Study – 6 (Sponsored - Collaborative Study)

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. D, 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 (Extended up to March 2025)
7. **Duration of the Study:** 3 Years

8. **Objectives**

- Identification of recharge sources and zones of aquifer system
- Estimation of residence time, distribution and flow velocity of groundwater
- Understanding interaction with aquifer and surface water bodies
- Understanding rock water interaction affecting the water quality and assessment of impact of anthropogenic activities on groundwater.

9. **Statement of the Problem**

Sustainable water management requires understanding key properties of water resources, such as recharge conditions, groundwater yield, transit times, pollution dynamics, aquifer connections, and water-rock interactions. These processes must be studied using an integrated approach of isotope and water chemistry. Groundwater depletion and contamination, particularly with arsenic in the Ganga River Basin, pose significant health risks. The main issue is the unsustainable abstraction of groundwater, leading people to tap deeper aquifers, which are becoming the primary freshwater source. However, little is known about these deeper, semi-confined, and confined aquifers.

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:**

- Thorough review of aquifer system and water quality status of the study area.
- Collection and characterization of the water samples from the study area for physico-chemical, bacteriological, and isotopic parameters.
- Geochemical, isotopic, and statistical modeling to understand the rock-water interaction, recharge zones, surface water interactions, and anthropogenic influence.

11. Timeline (Approved):

S. No.	Major Activities	2021-22			2022-23				2023-24				2024-25
		Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	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:

S. 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-/post-monsoon (2021-22): 72/146 samples from urban Varanasi - Pre-/post-monsoon (2022-23): 220/220 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, 2022-23, and pre-monsoon of 2023-24 completed and analysis of post-monsoon samples of 2023-24 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:

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

14. Analysis & Results:

Field Investigation, Sampling, analysis and results

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.

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 (NO₃, Cl, SO₄) 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-HCO₃ (43.8%), followed by Ca-HCO₃ (31.3%), mixed water types (13.4%), Na-HCO₃ (8%) and, a few saline water types (3.6%). Group 2 (100-210 m bgl) samples are manifested by the presence of Mg-HCO₃ (53%) and Ca-HCO₃ (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.

The Groundwater Line (GWL) has a lower slope of 5.70 compared to the Indian Meteoric Water Line (IMWL, 7.93) and the Local Meteoric Water Line (LMWL, 7.5), indicating substantial evaporative enrichment in groundwater. This suggests that evaporation plays a significant role in the isotopic composition of shallow groundwater.

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.
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:**
 - Submission of Final Report.

Study – 7 (Sponsored - Collaborative Study)

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:** June 2025

7. **Duration of the Study:** 5 Years

8. **Objectives:** The research objectives of the study are as follows:

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

- Thermal hydrolysis pretreatment mediated anaerobic digestion of municipal sludge: effects on methane yield, emerging contaminants removal, and microbial community
- Comparative performance assessment of mesophilic, thermophilic and thermal hydrolysis coupled anaerobic digestion of sewage sludge: bio-methane potential, pathogen removal and energy feasibility study
- Investigation of thermal hydrolysis process as a pretreatment technique prior to high solids anaerobic digestion under semi-continuous mode
- Effect of varying hydraulic retention time on the anaerobic digestion of thermally hydrolyzed

- sewage sludge
- (v) Techno-Economic and Life Cycle Assessment of the best process conditions.

11. Timeline (Approved): The project will be carried out for four years starting from March 2020 and to be completed by June 2025 (extended period).

12. Objectives and achievement during last twelve months:

S. No.	Activity	Achievements
1.	Effect of varying HRT on the biomethanation of THP 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%.
3.	Scientific Publications	05 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 control and THP digesters.

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:

Potential for India and scope of replication/upscaling across India: THP can catalyze all inefficient and junk anaerobic digesters of India. Higher methane and high-quality pathogen free digestate can be focal advantage. 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, ARGs], and N & P recovery.

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. E, EHD
Project Co-investigator	Dr. Sumant Kumar, Sc. E, GWHD Dr. Pradeep Kumar, Sc. E, EHD Dr. Mukesh Kumar Sharma, Sc. F, EHD Dr. Vinay Kumar Tyagi, Sc. D, EHD Dr. Kalzang Chhoden, Sc. C, EHD
Resource Person (Jr.)	Dr. Kaptan Singh

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:** March 2025

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

8.

9. **Objectives**

- 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
- To design alternatives to mitigate as contamination of drinking water

10. **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. 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. 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.

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

- Thorough review of abiotic and biotic geochemical mechanisms known to contribute to as mobility in aquifers.
- 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 exceeded the prescribed drinking water limit.
- iv) Batch and column experiments for identifying the factors responsible for as mobilization.
- v) Design alternatives to mitigate as contamination of drinking water.

12. Timeline (Approved): As per approved in the proposal

13. Objectives and achievement:

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 on a bimonthly basis. - Analysis for organoleptic, major ions, trace metals, and coliforms in the collected samples completed.
3.	Data Processing and Interpretation	Data processing and interpretation is under progress.
4.	Final Report	Final report will be submitted by April 2025.
5.	Publications	The manuscript for As mobilization is under preparation.

14. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	Dr. Bhism Kumar (Ex. Scientist, NIH & IAEA) suggested isotope analysis to understand recharge in the aquifers	Complied.
2.	Dr. Sudhindra Mohan Sharma, Ex-Nodal Officer, MoDWS, Indore suggested correlating As concentration with the drainage of the study area.	Complied.
3.	Dr. Samuel suggested considering remediation of As through ex-situ treatment or others.	The remediation of as is currently being attempted and will continue in a separate study. An ex-situ remediation method for arsenic is also being undertaken by another scientist from the division, Dr. P. K. Sahoo.

15. Analysis & Results:

- Both deep wells (150-660 ft) and shallow wells (20-150 ft) were classified as Ca-Mg-HCO₃ type. Arsenic concentration in shallow wells ranged from 0.01 ppb to 267 ppb, with an average value of 26.9 ± 38.2 ppb. In deep wells, the range was from 0.56 ppb to 38.4 ppb, with an average concentration of 8.1 ± 7.2 ppb.
- As in the groundwater was observed to be more concentrated in the depth range 20-80 ft, showing a strong negative correlation with depth. However, the arsenic concentration in deeper wells did not exhibit any correlation with depth.

- High arsenic concentrations were observed in groundwater samples with an alkalinity range of 180-600 mg/l. Similarly, the highest arsenic concentrations were recorded in a pH range of 6.9-7.4.
- Total organic carbon (TOC) levels in the analyzed samples varied from non-detectable (ND) to 17.5 mg/l, positively influencing arsenic dissolution. Even TOC concentrations as low as 0.5 mg/l were associated with arsenic levels exceeding 10 ppb.
- Arsenic concentration in shallow and deep wells exhibited different relationships with other parameters.
- In shallow wells, arsenic showed a significant positive correlation ($p \leq 0.05$) with electrical conductivity, alkalinity, Fe, Mn, B, Sr, and Ba. Among these, electrical conductivity, alkalinity, Fe, and B showed a poor correlation with arsenic, while Sr exhibited a good correlation. Mn and Ba had a strong correlation ($p \leq 0.01$) with arsenic levels.
- In deep wells, arsenic concentration was significantly correlated ($p \leq 0.05$) with F, Cd, Cr, Mn, Ni, Be, B, Sr, Ba, Ce, and Th. A strong ($p \leq 0.01$) but weak correlation was observed with Si and Zn.
- Attempts were made to isolate arsenic-resistant bacteria (ARBs) with arsenic-oxidizing potential to explore their ability to oxidize highly mobile as(III) to As(V). A total of 52 ARB isolates capable of tolerating up to 100 mM as(III) were identified, of which 30 demonstrated significant activity. Ten potential isolates were further identified using 16S rRNA sequencing and could be utilized for as bioremediation.

- 16. End Users / Beneficiaries of the Study:** Policy makers and planners of State/Central Government Organizations
- 17. Deliverables:** Technical report and research papers, Factors impacting As mobilization, and alternatives for As mitigation.
- 18. Major items of equipment procured:** None
- 19. Lab facilities used during the study:** Water Quality Laboratory (NIH)
- 20. Data procured or generated during the study:** Water quality data of the study area and As mobilization mechanism
- 21. 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 areas impacted by As contamination and the factors impacting As mobilization in the groundwater.
- 22. Involvement of end users/beneficiaries:** None
- 23. Specific linkage with Institution and /or end users / beneficiaries:** Yes
- 24. Shortcoming/Difficulties:** None
- 25. Future Plan:**
 - Submission of final report.
 - A new study will be undertaken in association with CGWB Dehradun to understand the As levels in the aquifer sediments and the mobilization mechanism.
 - 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 Dr. Shakti Suryavanshi, Sc. 'C', EHD Dr. Shailendra Kumar Kumre, Sc. 'C', EHD
Scientific Staff	Mrs. Babita Sharma, RA Mrs. Beena Prasad, RA

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: Mar 2025

7. Duration of the Study: 5 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 processes for sediment and nutrients

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

11. Timeline: As per approved in the proposal

12. Objectives and achievement during last twelve months:

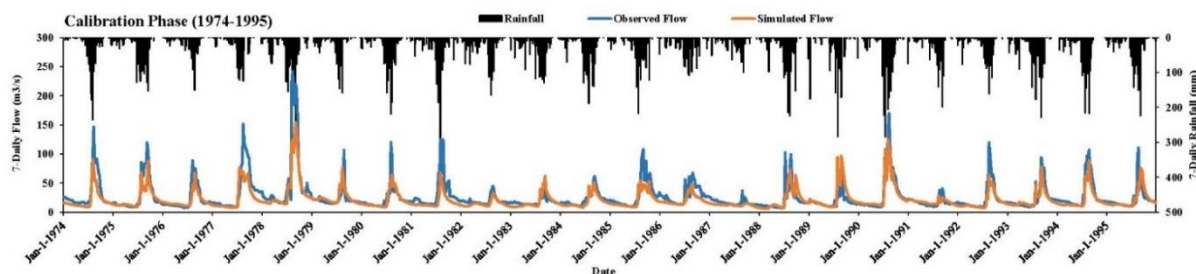
S. No.	Objectives	Achievements
(i)	Assessment of the point and non-point pollutant loads	Three sites have been selected for the assessment of point and non-point source pollutant loads. The water quality sampling and discharge monitoring at these three sites have been carried out on weekly basis during 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 crops, irrigation methods, 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, and nutrients in the river catchment	The model set-up for simulation of non-point source pollution processes has been carried out. The model has been calibrated and validated for runoff, sediment yield and nutrients.

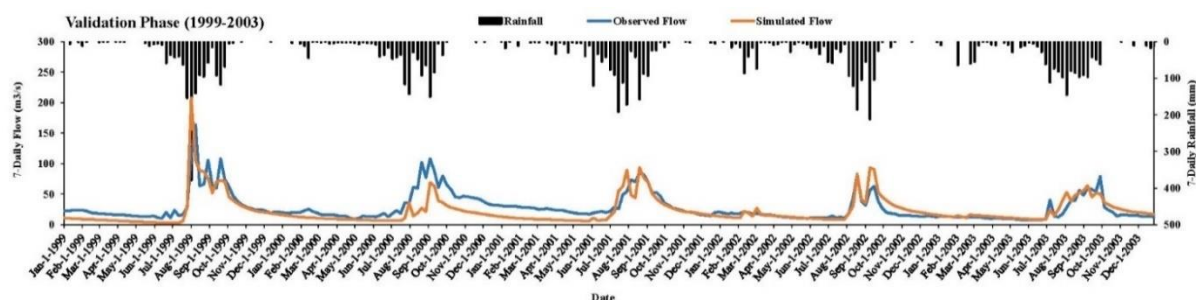
13. Recommendation / Suggestion:

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

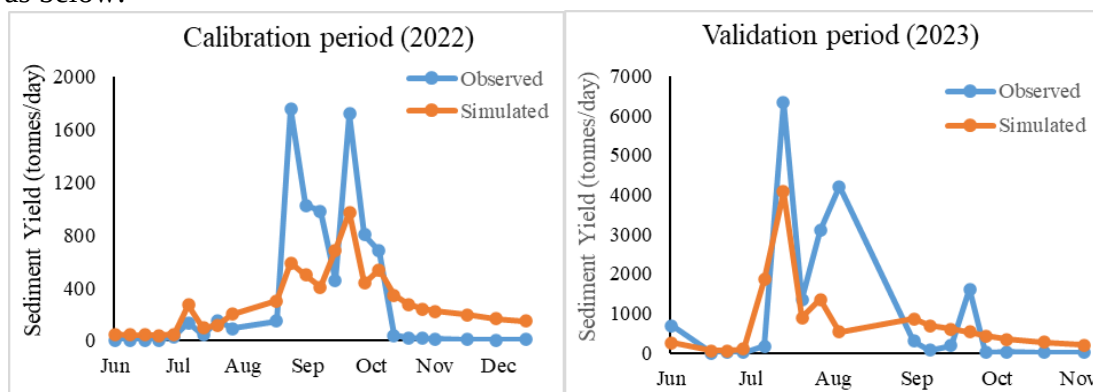
14. Analysis & Results:

Three sites in the Song catchment have been selected for simulating non-point source pollution processes through the SWAT model to isolate the point and non-point sources of pollution. The first site at CWC G&D site at Satyanarayana; second site on Suswa river just before its confluence with Song River and third site on the Song River in the upstream of the confluence of Song and Suswa rivers. The results of SWAT model during the calibration and validation phases for runoff simulation are as follows:





The results of simulation of sediment yields for the calibration and validation periods are shown as below:



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:** Discharge and 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.
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:** Manuscript for simulation of nutrients will be submitted for publication.

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. YRS Rao, Sc. G & Head, EHD Dr. Pradeep Kumar, Sc. E, EHD Dr. Vinay Kumar Tyagi, Sc, D, EHD Dr. Shuhas Khobragade, Sc. G & Head, HID Dr. M.K. Sharma, Sc F, EHD Dr. Shakti Suryavanshi, Sc, C, EHD Dr. Shailendra Kumar Kumre, Sc B, EHD Dr. Prasanta Kumar Sahoo, Sc. D, EHD 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

- Identification of morphological features of the lake.
- To understand the hydrological characteristics.
- To identify the causes of fish mortality and eutrophication status of lake.
- To Assess the rate of sedimentation.
- Suggestions for remedial measures for pollution abatement.
- 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:

- Identification of physical features of the lake and sources of water in the lake.
- Collection and characterization of the lake water samples for spatial and temporal variation.
- Water balance study of lake using water balance components i.e. precipitation, evaporation, and inflow/outflow.

- 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): As per approved in the proposal

12. Objectives and achievement during last twelve months:

Sr	Activity	Achievements
1	Sample collection and analysis	Samples are collected from the lake and incoming streams during the and analyzed for organoleptic, major ions, and trace metals.
2	Bathymetry survey of lake	Lake depth estimation has been done.
3	Ground water sample collection and analysis	Hand pump samples near the lake has been collected and ground water level also measured.
4	Assessment of trophic status of lake	Eutrophication of lake has been assessed using different water parameters.
5	Sediment samples collected	Collection and analysis of lake water and sediment samples.
6	Mass awareness activity	Awareness activity for School children and demonstrated the onsite water quality analysis.

13. Recommendation / Suggestion:

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

14. Analysis & Results:

- The depth calculations were performed to interpolate and map the lake's bathymetry using ArcGIS software. The maximum depth of the Rewalsar Lake ranges from 0.63 m to 4.65 m. This suggests an inclined basin morphology, influencing water movement, sediment deposition, and ecosystem distribution in the lake.
- Hydrochemistry of Lake was assessed to see the seasonal variation in lake, water samples were collected in the month of May & Dec. 2024. Lake inlet, outlet and sediment samples were collected. Total 30 locations were selected on the grid section basis at 20X 25 m grid size and analysed for various physico-chemical parameters. BOD of the lake varies from 12.03 to 2.76 mg/l. DO in water is essential to evaluate the extent of organic pollution. Multiple mechanisms including air diffusion, aeration, photosynthesis and respiration and decomposition all these have impact on the concentration of DO in water. In the lake the DO level of lake varies in 6.76 in summer & 10.35 mg/l during the winter season. Results indicates the DO level of lake is sufficient for the fish survival.

- Trophic status of Rewalsar lake was assessed by utilizing the Phosphate, Nitrate, Chlorophyll and the Secchi depth values of lake water. The calculated TSI helps in assessing the eutrophication level of Rewalsar lake. The reported TSI shows that during both season the lake experiences oligotrophic status with the TSI value of 31 in summer and 30 in winter, indicating moderate nutrient levels. The reported TSI difference suggests that the lake remains relatively stable across seasons, indicating consistent nutrient levels and productivity.
 - Ground water quality in vicinity of lake Total 09 Hand pump water samples collected and analyzed in water quality laboratory for different parameters. The GW level measured and level represents the depth at which groundwater is found. The observed groundwater values ranged from 1.06 to 40.85 m and indicate that HP 02 has a significantly deeper groundwater table compared to others.
 - Mass Awareness Activity NIH team organized awareness activity in collaboration with the NGO Development Action Group (DAG) and Nagar Panchayat officials and interacted with the school children of Government Model Senior Secondary School (GMSSS), Rewalsar. Also demonstrated the onsite Dissolve oxygen (DO) analysis and the Acoustic Doppler Current Profiler instrument for the depth measurement.
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,
 17. Factors responsible for WQ deterioration and sedimentation.
 18. **Major items of equipment procured:** -
 19. **Lab facilities used during the study:** Water Quality Laboratory (NIH), Soil-Water Laboratory (NIH), Nuclear Hydrology Laboratory (NIH)
 20. **Data procured or generated during the study:** Water quality and sedimentation status of lake
 21. **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.
 22. **Involvement of end users/beneficiaries:** HPSWA, Shimla; HIMCOSTE, Shimla; Rewalsar Local Administration
 23. **Specific linkage with Institution and /or end users / beneficiaries:** Yes
 24. **Shortcoming/Difficulties:** None.
 25. **Future Plan:**
 - Water balance study of lake.
 - Estimation of Ecological Health indices.

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 Disinfection by products**

2. **Study Group:**

NIH Roorkee: Dr. Vinay Kumar Tyagi, Scientist D (PI); Dr. Rajesh Singh, Scientist D; Dr. Mukesh K. Sharma, Scientist F; Dr. Pradeep Kumar, Scientist D; Er. J. P. Patra, Scientist D; Dr. Kalzang Chhoden, Scientist C; Dr. P.K. Sahoo, Scientist D; Dr. YRS Rao, Scientist G
IIT Roorkee: Dr. Bhanu P Vellanki, Assc. Prof.; Dr. A. A. Kazmi, Professor

3. **Type of study:** Internal Study, **Budget:** Rs.73 lakhs
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 of the Study:**

- (i) To study the pathogen removal efficiency of chlorination system in full-scale sewage treatment plants.
- (ii) To study the factors affecting chlorination efficiency [dose, contact time, treated effluent quality, temperature, hydraulics, types of pathogens etc.,]
- (iii) To study the formation of Disinfection by products (Qualitative and quantitative) in disinfection units of full-scale treatment plants.
- (iv) To study the impact of chlorinated water discharge on water quality of receiving water body
- (v) To conduct pilot-scale studies for the removal of residual organics and nitrogen precursors and control the formation of DBPs in chlorination system
- (vi) To suggest the optimal chlorine dose w.r.t secondary treated effluent to achieve effective pathogens removal and control DBPs formation.

Study Area:

Eleven 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. The plants use different technologies according to wastewater type, fund availability, governing body suggestions, and effluent requirements etc.

9. **Description of the Problem**

Chlorine is one of the most common chemicals used as disinfectant globally since it possesses all satisfactory properties suitable for treating both potable and treated wastewater. The efficiency of chlorination at sewage treatment plants (STPs) with similar effluent characteristics might vary due to the presence of variable organic compounds such as saturated, unsaturated, or polycyclic compounds. In Indian STPs, the chlorine doses vary from a low concentration of 2 mg/L to as high as 10 mg/L. Thus, the nature of the treatment process affects the efficiency of chlorination and also formation of disinfection by products (DBPs). Oxidation of organic matter results in the formation of undesirable byproducts, i.e., DBPs with the highest concentration being trihalomethanes (THMs) and haloacetic acid (HAA), followed by other DBPs such as N-nitrosodimethylamine (NDMA), chloramines, etc. The principal means for controlling the formation of DBPs is to avoid the direct addition of free chlorine and proper O&M of the treatment process. Discharge of the treated water into natural water

deficit water bodies, or where the flow rate is significantly less, results in a spike in DBPs concentrations. Accumulating DBPs in natural water bodies has been shown to cause serious environmental hazards even at very low concentrations. In addition, anthropogenic activities in water bodies add up the organic matter load, leading to the formation of intermediates due to the presence of free chlorine in the effluent from treatment plants. Organic compounds that comprise BOD, TOC, and COD exert chlorine demand, and other disinfectants are directly proportional. Ammonia reacts with chlorine to form chloramines. Oxidation of nitrite results in the formation of NDMA. Thus, the formation of DBPs is of great concern, and evidently, there is a need for effective technical efforts.

10. Methodology

- (i) Efficiency estimation of disinfections units
- (ii) Factors affecting disinfection efficiency
- (iii) Quantitative and qualitative assessment of DBPs in disinfections units and receiving water bodies
- (iv) Pilot- reactor study

11. 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, 5 MLD STP, Tehri. Wastewater samples were also collected from above mentioned STPs for analysis purpose.

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

BOD values at most STPs satisfied effluent discharge standards of 10 mg/L. TSS values at all the STPs satisfied effluent discharge standards of 20 mg/L. Chlorine Dosing (as per operator and onsite check) ranges from 2.1 to 5 mg/L. Residual chlorine in most of STPs were <0.2 mg/L. Low residual Cl affect pathogen's disinfection efficiency. High dosing is required for better disinfection, but chances of DPB's formation will be high. Effluent Fecal Coliforms values at 7.5 MLD Rishikesh, 26 MLD Rishikesh, 3 MLD Rishikesh and 5 MLD Tehri STPs were higher than the fecal coliform discharge standards of <230 MPN/100 mL. High residual Chlorine in disinfection tank inlet shows higher removal of fecal coliforms. Low residual chlorine at inlet correlated with high fecal coliforms values at outlet. Actual HRT (tracer) in Chlorine Disinfection units were found lower than designed HRT. Lower HRT will reduce disinfection efficiency, Higher chlorine dosage will need to achieve effective removal, which may aggravate the formation of DBP's. Except few occasion, THM concentration was lower than the standard criteria of BIS, EU and USEPA, in Disinfection units of studied STPs. High Cl₂ dosing leads to higher THMs formation. An optimum dosing analysis is the need of time to make disinfection system efficient. 4 mg/L Chlorine dosing is sufficient to achieve fecal coliform effluent discharge standard. 4 mg/L Chlorine dosing found safe regarding the THM formation (<80ug/L).

12. Further Proposed Work Plan for next year

Pathogens removal and optimization of dosing of chlorine; Tracer study of Chlorine

disinfection units (Using Computational Fluid Dynamics (CFD) and modelling); DBPs formation (THM, HAA, NDMA) Quantification; Review and research paper(s) will be prepared for publication.

13. Deliverables:

Comprehensive evaluation of disinfection units; Qualitative and quantitative database on DBPs formation in disinfection units; Technological solution to prevent the formation of DBPs through the integration of treatment units and design modifications of disinfection units; Technical report and papers

Study – 12 (Internal Study)

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. Y. R. Satyaji Rao, Sc. G & Head, EHD Dr. M. K. Sharma, Sc. F, EHD Dr. Pradeep Kumar, Sc. E, EHD Dr. Rajesh Singh, 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**

Inorganic arsenic includes both As(III) and As(V) species and is a confirmed carcinogen. 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. 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.

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

Preparation of Nanomaterials, Characterization, Arsenic detection by Electroanalytical techniques, Fabrication of paper-based screen-printed Arsenic sensor, Remediation of Arsenic-using Nano-adsorbents, Design of Nano-adsorbent-based household water filter for Arsenic

11. **Timeline (Approved)**

S. No.	Work Element/ Milestone	1 st Year				2 nd Year				3 rd Year			
		I	II	III	IV	I	II	III	IV	I	II	III	I
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												

12. Objectives and achievement during last twelve months:

S. No.	Activity	Achievements
1.	Literature Review	A literature review on various nanomaterials
2.	Hiring of project staff, equipment purchasing/ installation	“Freeze Dryer” was procured in February 2025.
3.	Nanomaterials Preparation and Characterization	- Biochar, Graphene oxide, Chitosan-based graphene oxide–Lanthanum–Iron hydrogel beads, La-Fe-Zr-based metal-organic framework, Mxene, Biochar-Red mud composite - A few characterization techniques, such as XRD, SEM, and FTIR, ICP-MS have been carried out.
4	Field Investigation, water sample collection	Filed investigations in the Bathinda, Panjab.
5	Evaluation of nano-adsorbents for As remediation	Batch adsorption experiments were carried out for Arsenic removal

13. Recommendation / Suggestion: No comments

14. Analysis & Results:

- Experimental section** - Synthesis of biocarbon, Graphene oxide, La,Fe-incorporated Chitosan-graphene oxide-based hydrogel beads, La-Fe metal-organic framework (MOF), and MXene by wet chemical method.
- Batch study for As (III) removal** - Batch experiments were carried out to explore the removal efficiency of Biocarbon. In this experiment, 5 mg of biocarbon was placed into 30 mL of 1ppm

As (III) aqueous solution in a shaker and shaken at 250 rpm at 25 °C for 1 h. After centrifugation, the residual content of the ions in the supernatant was measured by ICP-MS. All experiments were carried out in 15 mL centrifuge tubes except as otherwise stated. It was observed that the removal efficiency of As(III) is 10 %.

- **Batch study for U(VI) removal** - The ability of biocarbon to efficiently remove from aqueous solution was initially investigated by batch adsorption method. Initially, the effect of adsorbent dosage was investigated by varying the biocarbon dosage from 0.005 to 0.03 g under experimental conditions of $t = 120$ min, $T = 298$ K, $\text{pH} = 7$, $C_0 = 1$ ppm, and $V = 30$ mL (Figure 1a). It was observed that the removal efficiency of U(VI) increased rapidly from 80 to 98 % with an increase in adsorbent dosage from 0.005 to 0.05 g. Further, the effect of contact time (30 to 180 min) on the adsorption of was studied (Figure 1b) at experimental conditions of $m = 5$ mg, $T = 298$ K, $\text{pH} = 7$, $C_0 = 1$ ppm, and $V = 30$ mL. The adsorption of U(VI) was increased from 30 to 120 min and reached saturation from 120 to 180 min with a removal efficiency of 98 %. The adsorption capacity grew in the pH range of 2 to 5, and reached maximum of $60 \text{ mg} \cdot \text{g}^{-1}$ at pH 6.0 (Figure 1 (c)). The amount of uranium adsorbed decreased at pH higher than 6.0. The prepared biocarbon adsorbent performed better for uranium adsorption, and it was also able to be used favourably in acidic waste liquids, which was not achievable with most adsorbents.

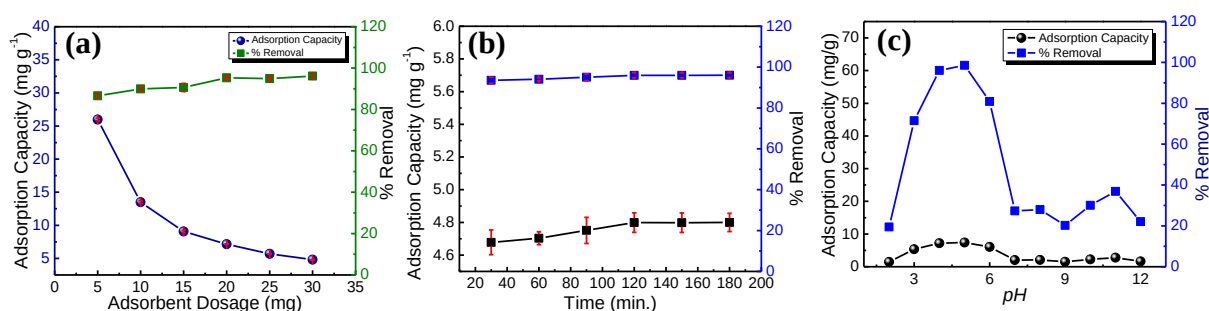


Figure.1 (a,b) Effect of adsorbent dosage and contact time, (c) pH variation on adsorption capacity and removal efficiency of biocarbon.

- End Users / Beneficiaries of the Study:** Policy makers and planners
- Deliverables:** Publications/ Patents and Technical reports
- Major items of equipment procured:** Freeze Dryer
- Lab facilities used during the study:** Water Quality Lab, Soil & Water Lab
- Data procured or generated during the study:** Batch adsorption data collected from ICP-MS study
- Study Benefits / Impacts:**
Water quality monitoring agencies (CPCB, CWC, CGWC, etc.), Research Institutes, Academician and public water supply agencies
- Involvement of end users/beneficiaries:** None
- Specific linkage with Institution and /or end users/beneficiaries:** Yes (IIT Roorkee, Central University of Punjab)

23. Shortcoming/Difficulties: None

24. Future Plan:

- Evaluation of Nano-adsorbents performance and design of household water filter for Arsenic removal
- Fabrication of screen-printed paper-based Arsenic electrochemical sensor for on-site Arsenic monitoring

Study – 13 (Internal Study)

1. **Title of the Project:** Land and water management plan for rejuvenation of river Manorama
2. **Project Team**
Project Investigator: Dr. Shakti Suryavanshi, Sc. C, EHD
Project Co-investigator: Dr. Shailendra Kumar Kumre, Sc. B, EHD
Dr. Dr. Y.R.S. Rao, 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
Ms. Poonam, Sc. B, EHD
3. **Type of Study:** Internal Sponsored Study, Budget: 36.60 lakh
4. **Nature of Study:** Applied & Basic Research
5. **Date of Start:** April, 2024
6. **Scheduled Date of Completion:** February 2027
7. **Duration of Study:** 3 years
8. **Objectives of the study**
 - a) Identification of degraded zones in terms of River continuum.
 - b) Water budget study of surface and groundwater
 - c) Assessment of water quality, source identification and remedial measures
 - d) Development of land and water management plan for rejuvenation of river
 - e) Organization of Stakeholder Workshop
9. **Statement of the Problem**

The Manorama River, a tributary of the River Saryu, is degraded due to morphological changes, sediment deposition, agricultural runoff, and siltation. Eutrophication in catchment water bodies is prevalent. A systematic study is required for effective rejuvenation.
10. **Approved Action Plan/ Methodology:**

Research objective wise detailed methodology is given below:

Objective 1: Data collection on river morphology, flow regime, and land use. Field surveys to assess physical characteristics and collect water samples for quality testing.

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 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.

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.

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.

11. Timeline (Approved):

S. N.	Work Element/ Milestone	1 st Year				2 nd Year				3 rd 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 rejuvenation of river												
8	Stakeholder Workshop												
9	Interim Report/Publications												
10	Final report submission												

12. Objectives and achievement during last twelve months:

S.N.	Activity	Achievements
1.	Field Investigation and sampling plan	The sample locations and sampling plan prepared along with the questionnaire
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.
3.	Hydrometeorological and agricultural dataset collection	Climate, Landuse, Soil moisture, crop data, Soil, DEM etc were collected and processed
4.	Hydrological Modelling	Initial SWAT model setup completed

13. Recommendation / Suggestion:

S. N.	Recommendation / Suggestion	Action Taken
1.	It was suggested to change the study area from Tilodkiganga to Manorama basin.	Complied

14. Analysis & Results:

Long-term analysis of meteorological datasets indicates a statistically significant decreasing trend in both annual precipitation volume and the number of rainy days. Observational records and piezometric data reveal that groundwater levels remain shallow throughout the year. The preliminary water balance assessment (pre calibrated) suggests an overall moderate hydrological condition of the basin, with annual precipitation, evapotranspiration, and runoff components maintaining a dynamic equilibrium within historical variability limits.

15. End Users / Beneficiaries of the Study: Policy makers and planners of State/Central Government Organizations; NGOs, Agricultural & Industrial Sectors

16. Deliverables: Technical report and research papers.

17. Major items of equipment procured: --

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

19. Data procured or generated during the study: Water quality data, Climate, Hydrometeorological and agricultural data of the study.

20. Study Benefits / Impacts:

The study enables targeted river restoration by mapping degraded zones, assessing water dynamics and quality, and identifying pollution sources. It formulates a holistic eco-restoration plan, promotes community engagement, and disseminates findings to advance scientific knowledge and sustainable management.

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:

- SWAT and HECRAS model calibration and validation followed by water balance.
- Field visit for data collection.
- Morphometric analysis and Sedimentation modelling.

Study – 14 (Internal Study)

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

2. **Project Team**

Project Investigator	Dr. Rajesh Singh, Sc. E, EHD
Project Co-investigator	Dr. Vinay Kumar Tyagi, Sc. D, EHD Dr. M. K. Sharma, Sc. F, EHD Dr. P. K. Sahoo. Sc. D, EHD Dr. Kalzang Chhoden, Sc. C, EHD Dr. Shakti Suryavanshi, Sc. C, EHD 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, Tripura State Pollution Control Board, Tripura

3. **Type of Study:** Internal Study, **Budget:** Rs. 33.9 lacs

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

5. **Date of start:** May 2024

6. **Scheduled date of completion:** April 2027

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

8. **Objectives**

1. Distribution and prevalence of As and F in the groundwater of Tripura
2. Health risk assessment due to groundwater consumption
3. To explore and provide evidence-based recommendations for practical solutions to mitigate As and F.

9. **Statement of the Problem**

Water quality is vital for sustaining socio-economic functions, as most water users rely on it for various activities. When water quality standards are not met, it leads to higher treatment costs or potential health risks due to contamination. With the growth of global populations and economies, water resources are increasingly polluted, making the degradation of water quality a major global concern. Among the challenges in water resource management, ensuring water quality protection is gaining significant attention due to its impacts on public health and economic well-being.

In Tripura, India, this issue is exacerbated by the state's proximity to Bangladesh, where groundwater arsenic contamination is widespread. Additionally, neighboring states like Assam and Mizoram face fluoride contamination, raising concerns about the co-occurrence of both contaminants in Tripura's groundwater. Despite these challenges, there is limited data on the extent and distribution of arsenic and fluoride contamination in the region. This study aims to analyze Tripura's groundwater quality, focusing on arsenic and fluoride levels, assess associated health risks, and better understand the processes affecting water quality. The findings will help bridge knowledge gaps and guide future water quality management and policy decisions.

10. 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.

11. Timeline (Approved):

Sr.	Major Activities	2024-25				2025-26				2026-27			
		Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
1	Field Investigation and sampling plan												
2	Sample Collection and Analysis												
3	Data Processing and Interpretation												
4	Interim Report												
5	Final Report/Publications												

12. Objectives and achievement:

Sr. No.	Activity	Achievements
1.	Field Investigation and sampling plan	The sample locations and sampling plan prepared
2.	Sample Collection and Analysis	- Samples were collected from selected locations during the pre-monsoon (58 locations) and post-monsoon (105 locations) periods of 2024-25. - The analysis of organoleptic, major ions, trace metals, and coliforms in the pre-monsoon samples has been completed. - Analysis of the post-monsoon samples is currently in progress. - Isotopic analysis of both pre- and post-monsoon samples is also ongoing.
3.	Data Processing and Interpretation	Data processing and interpretation is under progress.
4.	Interim Report	Interim report will be submitted by April 2025.
5.	Publications	The manuscript for As mobilization is under preparation.

13. Recommendation / Suggestion:

Sr. No.	Recommendation / Suggestion	Action Taken
1.	Dr. Bhism Kumar (Ex. Scientist, NIH & IAEA) and Dr. Manoj P. Samuel, CWRD, Kozhikode suggested to include solutions for As & F removal in the objective	Complied.

14. Analysis & Results:

- Sampling locations were selected in a 10x10 km grid covering all the 8 districts of the state.
- The handpumps/borewells, which are extensively used in the identified villages, were operated continuously for at least 15 minutes prior to sampling. Water samples were then collected in

appropriate sampling bottles and preserved according to standard methods (APHA, 2017). 58 samples were collected during the pre-monsoon period and 105 samples were collected during post-monsoon period. The depth of the wells ranged from 20 to 250 feet.

- The organoleptic parameters, major ions, trace metals, and bacteriological analysis were completed for the pre-monsoon samples, following prescribed protocols (APHA, 2017). The analysis of stable isotopes is under progress.
- The analysis of post-monsoon samples is under progress.

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

16. Deliverables: Geo-spatial data base of groundwater quality, Health risk to consumers due to consumption of groundwater, Treatment alternatives

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 study area and associated health risks

20. Study Benefits / Impacts:

The outcome of the project will be highly beneficial to the concerned departments, as it will provide valuable information on areas impacted by arsenic (As) and fluoride (F) contamination, along with contaminants source provenance. Additionally, treatment alternatives for arsenic and fluoride mitigation will be proposed, which can be implemented by the relevant departments of the Tripura government.

21. Involvement of end users/beneficiaries: Tripura Pollution Control Board, Agartala

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

23. Shortcoming/Difficulties: None

24. Future Plan:

- Analysis of samples and processing of data for further evaluation.
- Prepare and submit an interim report that summarizes the progress, findings, and preliminary conclusions of the study.
- Collection and analysis of pre- and post-monsoon period samples for 2025-26.

Study – 15 (Internal Study)

1. Title of the Project: Rainfall-Runoff-Sediment Yield Modelling to Assess Water Availability and Sediment Loads

2. Project Team

Project Investigator	Dr. Shakti Suryavanshi, Sc. C, EHD
Project Co-investigator	Dr. S. K. Kumre, Sc. B, EHD Dr. Pradeep Kumar, Sc. E, EHD

3. Type of Study: Internal Study, Budget: 30 lacs

4. Nature of Study: Applied & Basic Research

5. Date of start: April 2024

6. Scheduled date of completion: March 2027

7. Duration of the Study: 3 Years

8. Objectives

- (i) Development of SWAT model for Yamuna basin.
- (ii) Water availability assessment at selected location of River Yamuna
- (iii) Assessment of sediment yields at selected location of River Yamuna

9. Statement of the Problem

The Yamuna River basin faces significant hydrological challenges that threaten its water security and ecological stability. The region is characterized by erratic rainfall patterns, increasing water demands, and extensive land use changes, all of which contribute to fluctuating water availability. These factors have intensified the risk of water scarcity, particularly during lean flow periods, affecting agriculture, domestic supply, and industrial activities. Additionally, the basin experiences substantial sediment yield due to soil erosion, deforestation, and agricultural practices in the catchment. This sediment load not only reduces reservoir storage capacity but also deteriorates water quality, impacting aquatic ecosystems and downstream infrastructure. The lack of comprehensive data on the spatial and temporal variability of water resources and sediment dynamics further complicates effective management strategies. Addressing these issues requires a detailed assessment of water availability and sediment transport processes to support informed decision-making and sustainable development initiatives in the Yamuna basin.

10. Approved Action Plan/ Methodology:

The methodology for this study involves setting up the SWAT model to assess water availability and sediment yield in the Yamuna basin. The SWAT model will be configured by delineating the watershed, defining HRUs, and integrating climate data. Calibration and validation will be performed using observed discharge and sediment data. Long-term simulations will provide insights into water balance components such as surface runoff, baseflow, and evapotranspiration. The results will be analyzed using GIS tools to identify water availability zones and sediment-prone areas for improved resource management strategies. Objective wise methodology is given below:

a) Development of SWAT model for Yamuna basin.

- Collection of Topography, Land Use and Land Cover, Soil, Meteorological and hydrological datasets.
- Integrate collected data into the SWAT model interface.
- model calibration and validation.

b) Water availability assessment at selected location of River Yamuna.

- Perform long-term model simulations to estimate water availability.
 - Analyze seasonal and annual water balance components, including Surface runoff, Baseflow, Evapotranspiration
- c) **Assessment of sediment yields at selected location of River Yamuna**
- Extract sediment yield outputs from the model at the sub-basin level.
 - Identify erosion-prone areas and analyze sediment load distribution patterns.

11. Timeline (Approved):

S. No.	Major Activities	2024-25				2025-26				2026-27			
		1 st Qtr	2 nd Qtr	3 rd Qtr	4 th Qtr	1 st Qtr	2 nd Qtr	3 rd Qtr	4 th Qtr	1 st Qtr	2 nd Qtr	3 rd Qtr	4 th Qtr
1	Literature survey												
2	Secondary data collection												
3	Field surveys												
5	SWAT Model: Preparation of database and SWAT model calibration and validation												
6	Comprehensive assessment of water Availability												
7	Comprehensive assessment of sediment yield												
8	Interim Report												
9	Final Report												

12. Objectives and achievement during last twelve months:

Sr. No.	Activity	Achievements
1.	To setup SWAT model in the Yamuna basin.	• SWAT model setup is done for upper Yamuna basin.

13. Recommendation / Suggestion:

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

- 14. Analysis & Results:** The calibration process was conducted at four hydrological monitoring sites, namely Kalanaur, Karnal, Mawi, and Baghpat. The model exhibited strong performance with R² values of **0.93**, **0.87**, **0.99**, and **0.97**, respectively, across these locations. The high R² values, all exceeding 0.85, demonstrate a strong correlation between the observed and simulated streamflow values, indicating the model's ability to effectively capture the hydrological processes within the basin.

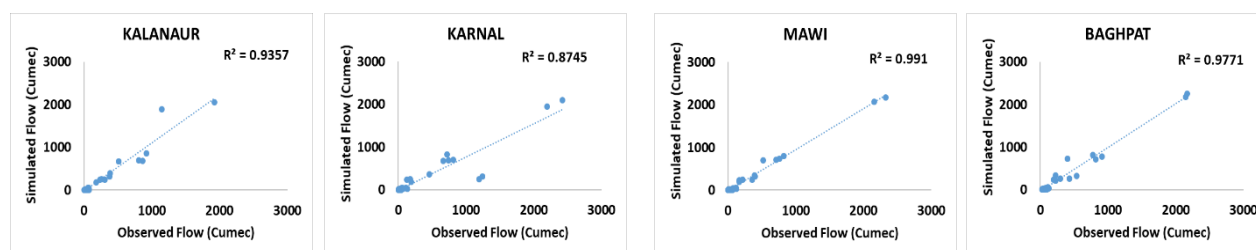


Fig. 1: Calibration of upper Yamuna River catchment (1978-81)

15. **End Users / Beneficiaries of the Study:** Policy makers and planners of State/Central Government Organizations; NGOs, Agricultural & Industrial Sectors
16. **Deliverables:** Technical report and research papers
17. **Major items of equipment procured:** None
18. **Lab facilities used during the study:** None
19. **Data procured or generated during the study:** None
20. **Study Benefits / Impacts:**
The study will provide valuable insights into the hydrological behavior of the Yamuna basin, aiding in effective water resource management. By assessing water availability, the research will help identify regions vulnerable to water scarcity, supporting informed decision-making for agricultural planning and domestic supply. The sediment yield analysis will highlight erosion-prone areas, guiding soil conservation strategies and reducing sedimentation impacts on reservoirs and river channels.
21. **Involvement of end users/beneficiaries:** NMCG, UP Irrigation and WRD department
22. **Specific linkage with Institution and /or end users / beneficiaries:** Yes
23. **Shortcoming/Difficulties:** None
24. **Future Plan:**
 - SWAT model setup in lower parts of the Yamuna basin
 - Assessment of Water Availability in the Yamuna basin.
 - Assessment of Sediment Yield in the Yamuna River

Study – 16 (Internal Study)

1. **Title of the Project: Environmental Flow Requirements at Critical Segment of Selected River Stretches in River Yamuna.**

2. **Project Team**

Project Investigator	Dr. S. K. Kumre, Sc. B, EHD
Project Co-investigator	Dr. Pradeep Kumar, Sc. E, EHD Dr. Rajesh Singh, Sc. E, EHD Dr. Dr. Shakti Suryavanshi, Sc. C, EHD

3. **Type of Study:** Internal Study, **Budget:** 30.6 lac

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

5. **Date of start:** April 2024

6. **Scheduled date of completion:** March 2027

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

8. **Objectives**

- 1) To identify the critical stretches in the Yamuna River between the Okhla Barrage and the Chambal Confluence.
- 2) To evaluate the environmental flow condition using hydrological tool like CHES, IHA, Hydra-Eflow, Flow Health Hydrology Assessment Tool.
- 3) To study the keystone species in these critical reaches and analyze their habitat preferences.
- 4) To assess the environmental flow requirements for selected segment of Yamuna River

9. **Statement of the Problem**

The Yamuna River's flow varies seasonally, with monsoon flows diluting pollutants and dry season flows increasing pollution. CPCB (2021) reports non-compliance with Bathing Criteria at Palwal, Mathura, and Agra. Moderate pollution (Class 'C') persists from Okhla Barrage to Allahabad, worsening at Etawah in summer (Class 'E'). The stretch between Okhla Barrage and the Chambal Confluence suffers from eutrophication due to industrial, domestic, and agricultural pollution, leading to low oxygen levels and degraded ecosystems. Urgent water management and pollution control measures are needed to restore ecological balance.

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

The study employs a combination of hydrological, hydraulic, and habitat simulation methods for the Yamuna River. Long-term discharge data were analyzed using flow duration curves (FDC) and Indicators of Hydrologic Alteration (IHA). Hydraulic and habitat simulations were conducted using the HEC-RAS model to establish depth-discharge relationships and evaluate flow requirements for maintaining suitable habitats for indicator fish species.

11. Timeline (Approved):

S.	Major Activities	2024-25				2024-25				2025-26			
		3	6	9	12	3	6	9	12	3	6	9	12
1	Literature survey												
2	Sec. data collection												
3	Field surveys												
4	Cross-section Survey and ecological Survey												
5	SWAT & HEC-RAS Model: Preparation of database												
6	SWAT & HEC-RAS Model: Calibration, Validation & Simulation												
7	Assessment of environmental flow requirements for various segment												
8	Interim Report												
9	Final Report												

12. Objectives and achievement during last twelve months:

Sr.	Activity	Achievements
1.	Identification of critical stretches in the Yamuna River	Conduct a literature review on Yamuna River pollution, flow conditions, and ecology using reports, research, and policy documents. Analysed hydrological data and E-flow studies to assess seasonal variations and flow impacts. Identify critical river segments facing ecological stress, flow alterations, or habitat degradation
2.	Evaluate the E-flow condition using hydrological tool using IHA software.	Collect historical hydrological data (river discharge, seasonal flow variation, precipitation). Applied IHA hydrological models to assess E-flow regimes and deviations from natural conditions.
3.	Setup the HEC-RAS 1D model for Okhla Barrage to Chambal confluence in Yamuna River.	The HEC-RAS 1D model was set up using public datasets for accurate river simulations. DEMs provided terrain data, while LULC maps defined roughness coefficients. Data preprocessing ensured consistency and spatial accuracy before integration into HEC-RAS for precise flow modeling.

13. Recommendation / Suggestion:

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

14. Analysis & Results: The Long-term discharge data (2006-2020) at four locations were analyzed using flow duration curves (FDC) and Indicators of Hydrologic Alteration (IHA). Initial setup of HEC-RAS 1D model for establishing the depth-discharge relationships for four locations.

• Flow Duration Curve (FDC)

FDC analysis was used to assess hydrologic scenarios across different dependability years. For a 15-year period (2006–2020), the analysis identified critical flow thresholds such as Q90 which

is representing 90% probability of flow availability. These thresholds inform the baseline for maintaining ecological health.

- **Indicators of Hydrologic Alteration (IHA)**

IHA analysis categorized flow conditions into five environmental flow components (EFCs): low flows, extreme low flows, high-flow pulses, small floods, and large floods. These EFCs highlight the ecological functions of various flow conditions, such as sustaining aquatic habitats, supporting biodiversity, and facilitating nutrient transport. By maintaining these flow components, the study ensures the ecological integrity of the river system, emphasizing the interconnectedness of hydrological patterns and ecological processes.

- **HEC-RAS 1D model for Okhla Barrage to Chambal confluence**

The initial setup for 1D modelling of the study from Okhla Barrage to Chambal Confluence has been completed.

15. **End Users / Beneficiaries of the Study:** Policy makers and planners of State/Central Government Organizations; NGOs, Agricultural & Industrial Sectors
16. **Deliverables:** Technical report and research papers
17. **Major items of equipment procured:** None
18. **Lab facilities used during the study:** None
19. **Data procured or generated during the study:** None
20. **Study Benefits / Impacts:**

The study of E-flow in the Yamuna River benefits a wide range of stakeholders, from government agencies and academic institutions to environmental groups and industries. It plays a critical role in river conservation, water resource management, and policy formulation to ensure a balanced approach between human needs and ecological sustainability.
21. **Involvement of end users/beneficiaries:** NMCG, UP Irrigation and WRD department
22. **Specific linkage with Institution and /or end users / beneficiaries:** Yes
23. **Shortcoming/Difficulties:** None
24. **Future Plan:**
 - Cross-section survey of selected location from Okhla barrage to Chambal
 - Study the keystone species in these critical reaches and analyze their habitat preferences.
 - Assess the environmental flow requirements for the Yamuna Rivers, focusing on the identified critical reaches.

Study – 17 (Internal Study - Proposed)

1. **Title of the Project:** Fate, Transport, and Health Risks of Agricultural Pollutants in the Yamuna River Basin: An Integrated Modelling and Experimental Approach
2. **Project Team**
Project Investigator: Poonam, Sc. B, EHD
Project Co-investigator: Dr. Y.R.S Rao, Sc. G & Head, EHD
Dr. M. K. Sharma, Sc. F, EHD
Dr. Pradeep Kumar, Sc. E, EHD
Dr. Rajesh Singh, Sc. E, EHD
Dr. V. K. Tyagi, Sc. D, EHD
Dr. Kalzang Chhoden, Sc. C, EHD
Dr. Shakti Suryavanshi, Sc. C, EHD
Dr. Shailendra Kumar Kumre, Sc. B, EHD
3. **Type of Study:** Internal Study, **Budget:** 40 lakhs
4. **Nature of Study:** Applied & Basic Research
5. **Date of start:** April 2025
6. **Scheduled date of completion:** March 2028
7. **Duration of the Study:** 3 Years
8. **Objectives:**
 - a) To identify high risk contamination hotspots in the Yamuna River basin for major pollutants, particularly agricultural pollutants, and prepare an inventory of vulnerability maps for the Yamuna River basin.
 - b) To assess the health impacts of specific agricultural pollutants on human populations.
 - c) Evaluate the fate and transport of agricultural pollutants in groundwater through numerical modeling (HYDRUS-1D/2D/3D) and soil-based batch and column experiments.
 - d) To propose site-specific and case-specific mitigation strategies for reducing agriculture pollutants in the Yamuna River basin and improving water quality in the river.
9. **Present state-of-art**

The Yamuna River is one of the most polluted in India, heavily impacted by urbanization, industrial discharge, and agricultural runoff. Agricultural pollutants, such as nitrates, phosphates, and pesticides, degrade water quality and pose serious environmental and health risks. However, research on their impact remains limited, especially for groundwater-dependent communities. Understanding their fate and transport in soil is crucial, yet studies on pollutant movement and retention are insufficient. While HYDRUS models are used for groundwater studies, their application in the Yamuna Basin's conditions is still unexplored. Similarly, batch and column experiments on soil interactions are lacking, making it difficult to assess pollutant mobility. Addressing these gaps requires a comprehensive approach that combines field studies, modeling, and experiments to understand pollutant movement. These insights will help develop effective solutions for improving water quality in the Yamuna River Basin.

Study Area:

The Yamuna River, originating from the Yamunotri Glacier in Uttarakhand at 6,387 meters, is a major tributary of the Ganges. The Yamuna River Basin, spanning Haryana, Uttar Pradesh, Madhya Pradesh, Rajasthan, and Delhi, supports extensive agriculture. Western Uttar Pradesh,

Haryana, and Madhya Pradesh contribute significant nitrate, phosphate, and pesticide runoff into the river.

10. Methodology: Research objective wise detailed methodology is given below:

Objective 1: High-risk contamination hotspots in the Yamuna River Basin will be identified through remote sensing, GIS, and data analysis. Field sampling will quantify agricultural pollutants, facilitating the development of vulnerability maps.

Objective 2: Health risks of agricultural pollutants will be assessed using risk assessment models and empirical equations, integrating water quality analysis.

Objective 3: Groundwater contamination will be evaluated using batch/column experiments to analyze pollutant transport in the soil. HYDRUS-1D/2D/3D modeling will simulate subsurface flow and predict long-term contaminant migration.

Objective 4: Site-specific mitigation strategies will be developed by integrating experimental research, groundwater modeling, and pollution control measures. Policy interventions and stakeholder engagement will ensure effective implementation and long-term sustainability.

11. Expected Research Outcomes from the Project:

- Hotspot maps will identify high-risk contamination zones, particularly those affected by agricultural runoff, aiding targeted pollution control.
- Assessment of human health risks from agricultural pollutants.
- Numerical (HYDRUS) and experimental (batch/column) models will analyze the fate, transport, and mobility of pollutants in groundwater.
- A site-specific mitigation framework integrating technical, policy, and community-based approaches will be developed to improve water quality.

12. Cost Estimate

a. **Total cost of the project** : 40,00,000

b. **Source of funding** : NIH internal

c. **Sub-head-wise abstract of the cost** :

S.	Sub-Head	1 st Year	2 nd Year	3 rd Year	Total
1	Manpower (Resource Person Jr. 1 no.) (37,000/- + 9% HRA p.m.)	4,83,960	4,83,960	4,83,960	14,51,880
2	Travelling expenditure	1,50,000	1,00,000	1,00,000	3,50,000
3	Infrastructure / Equipment / Consumable	5,00,000	2,00,000	1,50,000	8,50,000
4	Experimental charges	60,000	60,000	60,000	1,80,000
5	Software (HYDRUS 2D/ 3D)	4,50,000	0	0	4,50,000
6	Misc. Expenditure	4,00,120	2,48,000	70,000	7,18,120
	Grand Total	20,44,080	10,91,960	8,63,960	40,00,000

13. Timeline

a) **Probable date of commencement of the project** : April 2025

b) **Duration of the project** : 3 Years

S.	Work Element/ Milestone	1 st Year				2 nd Year				3 rd Year			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Literature Review and Reconnaissance survey												
2	Hiring project staff												
3	Field Surveys												
4	To identify high risk contamination hotspots in the Yamuna River basin for major pollutants and prepare an inventory of vulnerability maps for the Yamuna River basin.												
5	To assess the health impacts of specific agricultural pollutants on human populations												
6	Evaluate the fate and transport of agricultural pollutants in groundwater through numerical modeling (HYDRUS-1D/2D/3D) and soil-based batch and column experiments.												
7	To propose site-specific and case-specific mitigation strategies for reducing agriculture pollutants in the Yamuna River basin and improving water quality in the river.												
8	Stakeholder Workshop												
9	Interim Report/Publications												
10	Final report submission												

14. Contribution of PIs

PI and Co-Investigators	Contribution
Poonam, Sc. B, EHD	Project formulation, field surveys, Water Quality analysis, Hydrological modelling, synthesis of results, report writing and overall project monitoring
Dr. Y.R.S Rao, Sc. G & Head, EHD	Project formulation and overall guidance
Dr. M. K. Sharma, Sc. F, EHD	Water Quality Assessment
Dr. Pradeep Kumar, Sc. E, EHD	Assessment of agriculture pollution hotspot mapping
Dr. Rajesh Singh, Sc. E, EHD	Water Quality Assessment & Remediation Measures
Dr. Vinay Kumar Tyagi, Sc. D, EHD	Remediation Measures for mitigation pollution loads
Dr. Kalzang Chhoden, Sc. C, EHD	Health risk assessment
Dr. Shakti Suryavanshi, Sc. C, EHD	Field surveys and Hydrological modelling
Dr. Shailendra K Kumre, Sc. B, EHD	Field surveys and Hydrological modelling

Study – 18 (Internal Study – Proposed)

1. **Title of the Project:** Evaluating the impact of toilets on groundwater and surface water in diverse hydrogeological and climatic contexts without sewage treatment facilities

2. **Project Team**

Project Investigator	Dr. Y. R. Satyaji Rao, Scientist G & Head, EHD
Project Co-investigator	NIH Roorkee Dr. Rajesh Singh, Sc. E, EHD Dr. Vinay Kumar Tyagi, Sc. D, EHD Dr. Kalzang Chhoden, Sc. C, EHD Dr. Shakti Suryavanshi, Sc. C, EHD Er. Poonam, Sc. B, EHD
	Western Himlayan Regional Centre, Jammu
	North Western Regional Centre, Jodhpur
	Central India Hydrology Regional Centre, Bhopal
	Centre for Flood Managements Studies, Patna
	North Eastern Regional Centre, Guwahati
	Hard Rock Regional Center, Belagavi
	Deltaic Regional Centre, Kakinada

3. **Type of Study:** Internal Study, **Budget:** 85.13 lakhs for NIH Roorkee & 2.0 Crore for RCs
4. **Nature of Study:** Applied & Basic Research
5. **Date of start:** April 2025
6. **Scheduled date of completion:** March 2028
7. **Duration of the Study:** 3 Years

8. **Objectives**

- (i) Assess the impact of dual pit latrines/ septic tanks on water resources
- (ii) Evaluate waste management practices and community engagement
- (iii) Provide policy and design recommendations

9. **Present state-of-art**

Sanitation has long been a critical issue in India, especially in rural areas where open defecation was common. The Swachh Bharat Mission (SBM), launched in 2014, aimed to make India open defecation-free (ODF) by 2019, constructing millions of toilets across rural areas. Various toilet technologies, including Twin Pit, septic tanks, Eco-San, and Bio-toilets, were promoted to improve sanitation. As a result, over 100 million toilets were constructed by 2020, raising rural toilet coverage from 39% in 2014 to 98%. This led to significant improvements in public health, reducing Infant Mortality Rate (IMR) and Under-5 Mortality Rate (U5MR). However, disparities remain in remote areas, where access to infrastructure is limited, and cultural resistance to toilet usage persists due to traditional beliefs. Behavioral change efforts, such as community mobilization campaigns, have shown promising results, but further government-community engagement is needed to overcome these barriers.

Despite the success of SBM in improving sanitation, challenges regarding the long-term sustainability of sanitation systems remain. Poorly designed systems, such as septic tanks and pit latrines, can contaminate groundwater, particularly in regions with high water tables. Additionally, untreated sewage contributes to surface water pollution, affecting aquatic ecosystems. To address these issues, SBM must focus on improving sanitation system designs,

implementing water-efficient technologies, and promoting eco-toilets that reduce water usage and support resource recovery. The second phase of SBM (2020-2025) aims to ensure the sustainability of ODF status and improve Solid and Liquid Waste Management (SLWM). While SBM has made significant progress, continued research and innovation are necessary to address environmental concerns, ensure infrastructure sustainability, and overcome cultural resistance, securing long-term success.

10. Methodology

This study will employ a quantitative-qualitative mixed-methods design, which involves monitoring key variables (water quality, sanitation practices, etc.) over time. The research will use both statistical analysis (to measure water contamination levels) and qualitative methods (to understand local sanitation practices). The data will be collected from multiple sources to ensure comprehensive analysis.

- **Study Areas:** Selection of 5-10 rural villages with different sanitation systems (pit latrines, septic tanks, etc.) and varying proximity to water bodies in different hydrogeological regions (8 locations) spread across pan India
- **Sampling Units:** The study will focus on households and water sources within the villages, including wells and ponds located near toilets.
- **Sample Size:** A representative sample of 10–15 villages will be selected. Each village will include 50–100 households. For water sampling, at least three sampling points per water source will be selected.
- **Timeframe:** Data collection will take place over a 3-year period, with multiple water quality measurements and interviews conducted annually.
- **Data Collection Methods:** Field observations, water quality testing, household surveys and interviews

11. Research Outcome from the Project:

- Identification of the sources of water contamination in rural/peri-urban areas and the specific role played by different types of sanitation systems installed under SBM, along with data on seasonal and long-term fluctuations in water contamination levels.
- A deeper understanding of community engagement in sanitation practices, barriers to proper waste management, and the role of local knowledge in improving sanitation infrastructure.
- Recommendations for policymakers and practitioners on sustainable sanitation technologies, wastewater/biosolids management, safe distances between sanitation and pumping systems, and strategies to address climate variability and water resource preservation to enhance public health and sanitation.

12. Cost Estimate

- Total cost of the project** : Rs. 85 12 800.00 (For NIH Roorkee – HQ)
- Source of funding** : NIH (Internal)
- Sub headwise abstract of the cost:**

Sr. No.	Sub-Head	I Year	II Year	III Year	Total
1	Manpower				
	Research Associate: 1 No. @ 61000+HRA)	8,05,200	8,05,200	8,05,200	24,15,600
	JRF: 1 No. @ 37000 (1st YR) & 42000 (2nd & 3rd YR) +HRA	4,88,400	5,54,400	5,54,400	15,97,200

	Lab/Field Staff: 1 No. @ 25000	3,00,000	3,00,000	3,00,000	9,00,000
2	Travelling expenditure	5,00,000	5,00,000	5,00,000	15,00,000
3	Infrastructure / Equipment / Consumable	5,00,000	5,00,000	5,00,000	15,00,000
4	Misc. Expenditure	2,00,000	2,00,000	2,00,000	6,00,000
	Grand Total	27,93,600	28,59,600	28,59,600	85,12,800

The capabilities of the NIH Regional Centres (RC) to support the study were assessed. It was found that the RCs could play a key role in the project, provided their labs are equipped to analyze parameters that cannot be sent to the NIH Roorkee WQ laboratory. **Approximately Rs. 1.5 crore will be needed to purchase the equipment, and Rs. 50 lakhs will be required for consumables at the RCs to carry out the project.**

13. Work Schedule

- (i). Probable date of commencement of the project : May 2025
(ii). Duration of the project : 3 Years
(iii). Stages of work & milestone

Activity	Year 1				Year 2				Year 3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Literature Review & Initial Planning												
Site Selection & Initial Data Collection												
Sample/Data Collection & Analysis												
Contaminant Transport Modelling												
Progress Review & Report												

Study – 19 (Internal Study – Proposed)

1. **Title of the Project:** Nitrate-organic-bacteria nexus in mobilization of naturally occurring arsenic in groundwater

2. **Project Team**

Project Investigator	Dr. Rajesh Singh, Scientist E, EHD
Project Co-investigator	Dr. Y. R. S. Rao, Sc. G & Head, EHD Dr. Sumant Kumar, Sc. E, GWHD Dr. Vinay Kumar Tyagi, Sc. D, EHD Dr. M. K. Sharma, Sc. F, EHD Dr. Kalzang Chhoden, Sc. C, EHD Dr. P. K. Sahoo. Sc. D, EHD Er. Poonam, Sc. B, EHD
Collaborator	Er. Prashant Rai, CGWB, Dehradun

3. **Type of Study:** Internal Study, **Budget:** 91.97 lakhs

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

5. **Date of start:** April 2025

6. **Scheduled date of completion:** March 2028

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

8. **Objectives**

- To determine the mechanisms governing the reductive dissolution of As(V) leading to As mobility through synergistic or antagonistic interactions between nitrate, organic carbon, and microbial communities.
- To quantify the rate and extent of these reactions to develop a reactive transport model to predict As mobility in groundwater.
- To validate the model with field data to predict arsenic contamination in groundwater
- To develop recommendations for mitigating arsenic contamination based on the findings of nitrate, organic, and microbial interactions.

9. **Present state-of-art**

The mobilization of naturally occurring arsenic in groundwater is a significant environmental and public health concern, particularly in regions where groundwater serves as the primary source of drinking water. Arsenic, typically found in deep aquifers, can be mobilized under specific environmental conditions, leading to elevated concentrations in drinking water, which poses serious health risks. Research has shown that the mobilization of arsenic is influenced by a variety of factors, including geochemical, microbial, and hydrological processes. Among these factors, the role of nitrate, organic carbon, and bacteria is gaining increasing attention due to their potential interactions in enhancing the release of arsenic from aquifer sediments into groundwater. The presence of nitrate in groundwater has been identified as a key driver of metal mobilization. Nitrate, often originating from agricultural runoff or wastewater, can influence redox conditions in aquifers, which in turn affects the solubility of arsenic. Organic carbon, introduced through surface water infiltration, land-use changes, or microbial processes, can further enhance the mobilization of arsenic in groundwater. Organic compounds, such as humic substances, provide a source of energy for denitrifying bacteria that reduce nitrate under anaerobic conditions. This microbial activity is critical in facilitating arsenic release from solid phases into the aqueous phase, where it becomes bioavailable and mobile. Microbial communities in the subsurface play a crucial role in mediating these interactions. Certain

bacteria can directly reduce arsenic (V) to arsenic (III), making it more soluble, while others may also participate in the reduction of iron or sulfate, indirectly influencing arsenic mobilization. Recent studies have highlighted the complex interactions between nitrate, organic matter, and bacteria in mobilizing arsenic, emphasizing the need to understand these processes at a deeper, site-specific level. However, while considerable progress has been made, the precise mechanisms through which these factors interact to mobilize arsenic remain poorly understood, with conflicting results from different studies.

In conclusion, the nitrate-organic-bacteria nexus represents a promising but complex area of study in understanding arsenic mobilization in groundwater. Advancing our knowledge of how these factors interact at both the molecular and environmental levels is crucial for developing effective management strategies to mitigate arsenic contamination in affected regions. Further investigations into microbial pathways, the role of organic carbon, and the influence of nitrate on arsenic release will be essential to unravel the full scope of this environmental challenge.

10. Methodology

- Sediment cores from previously selected location with high As, NO₃, and TOC will be collected with the help of CGWB, Dehradun. The sediment cores will be preserved and characterized in the laboratory geochemically and mineralogically.
- Laboratory-scale batch/packed column experiments will be conducted in anoxic environment to simulate groundwater conditions with varying concentrations of nitrate, organic carbon, and microbial communities (e.g., nitrate-reducing and arsenic-reducing bacteria) to quantify As(V) reduction and As(III) release rate.
- Perform 16S rRNA sequencing to identify microbial species involved in As(V) reduction and their interactions with nitrate and organic carbon.

11. Research Outcome from the Project:

- The outcomes of the study will enhance the understanding on the important biogeochemical reaction mechanism controlling As, Fe, Mn, NO₃, and TOC behavior in the aquifer.
- Recommendations for policymakers and practitioners for mitigating arsenic contamination.

12. Cost Estimate

a. Total cost of the project : Rs. 91,97,200.00

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 JRF: 1 No. @ 37000 (1st YR) & 42000 (2nd & 3rd YR) +HRA	4,88,400	5,54,400	5,54,400	15,97,200
2	Travelling expenditure	1,00,000	2,00,000	1,00,000	4,00,000
3	Infrastructure / Equipment / Consumable	50,00,000	5,00,000	5,00,000	60,00,000
4	Misc. Expenditure	5,00,000	5,00,000	2,00,000	12,00,000
	Grand Total	60,88,400	17,54,400	13,54,400	9197200

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

- Travelling expenditure: For visits to study areas, attending conferences, data collection, surveys, etc.

- Equipment/Consumables: Purchase of Anaerobic Chamber/Glove bag, Ion selective electrodes, chemicals, glassware, plasticware, etc.

13. Work Schedule

- (i). Probable date of commencement of the project : April 2025
(ii). Duration of the project : 3 Years
(iii). Stages of work & milestone

Activity	Year 1				Year 2				Year 3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Literature Review, Initial Planning, Purchase of equipment/consumables												
Site Selection, sediment core collection, & analysis												
Batch/Column experiments												
Interpretation & analysis of results												
Progress Review & Report												
Publication												

SURFACE WATER HYDROLOGY DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. A K Lohani	Scientist G & Head
2	Dr. P C Nayak	Scientist F
3	Dr. Sanjay Kumar	Scientist F
4	Dr. Ravindra Vitthal Kale	Scientist E
5	Dr. L N Thakural	Scientist E
6	Er. J P Patra	Scientist E
7	Sh. Sukant Jain	Scientist C
8	Dr. Soumyaranjan Sahoo	Scientist B
9	Sh. Gaurav Kumar	RA



APPROVED WORK PROGRAM FOR THE YEAR 2024-25

COMPLETED 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	Hydrological Study for revival and restoration of traditional water bodies in Bikaner, Rajasthan	N. Thakural 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 Sep 2024) (Extension was requested for Six months)
2.NIH/SWHD/22-25	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)
3.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)
4.NIH/SW25	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)
5.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)

ONGOING STUDIES (INTERNAL)			
S No. & Ref.	Title	Study Team	Duration
1.NIH/SWHD/22-25	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/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 CWC Chief Engineer, KGBO, CWC CWPRS Dr. Selva Balan External Expert Prof. M. Perumal	1.5 Years (April 2024 to September 2025)
3. 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)
4. 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)
5. 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) [Transferred to WHRC Jammu]
6. 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) [Transferred to WRS Division]
7. NIH/SWHD/24 - 25	Web based platform for IDF Design Rainfall Estimates for India	Sukant Jain, A.K. Lohani, J. P Patra, Richa Pandey, Chandra Prakash	1.5 Years (April 2024 to Sept 2025)

PROPOSED WORK PROGRAMME FOR THE YEAR 2025-26

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	Title	Study Team	Duration
SP-77/2024-25/NIH(SWHD)	Flood Plain Zone Delineation of Burhganga a tributary of the Ganga River from Village Dabal in Dist. Muzaffarnagar to Garmukteshwar	J.P.Patra A. K. Lohani P. C. Nayak Sanjay Kumar S. Sahoo	Six Months (Jan 2024 to Jun 2025)

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	Title	Study Team	Duration
1.NIH/SWHD/22-25	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/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 CWC Chief Engineer, KGBO, CWC CWPRS Dr. Selva Balan External Expert Prof. M. Perumal	1.5 Years (April 2024 to September 2025) [Extension of 01 year is requested]
3. NIH/SWHD/24-27	A Flood Forecasting Framework a High Resolution WRF Ensemble with Hydrodynamics Model for Mountainous Area.	R. V. Kale K. Sharma S. Kumar A. K, Lohani	Three Year (April 2024 to March 2027)
4. NIH/SWHD/24-26	Basin-scale, integrated water assessment through integrated modelling	S. Sahoo A. K, Lohani P. C. Nayak R. V. Kale J. P. Patra	2.5 Years (April 2024 to September 2026)
5. NIH/SWHD/24-25	Web based platform for IDF Rainfall Estimates for India	Sukant Jain, A.K. Lohani, J. P Patra, Richa Pandey, Chandra Prakash	1.5 Years (April 2024 to Sept 2025)

NEW STUDIES (INTERNAL)			
S. No. & Ref. Code	Title	Study Team	Duration
1. NIH/SWHD/2-27	Application of Annual Flow Duration Curves (AFDC) in Flood Flow and Low Flow Frequency Analysis	Sanjay Kumar, J. P Patra, R. V. Kale, L. N. Thakural, Soumyaranjan Sahoo	Two (April 2025 to March 2027)
2. NIH/SWHD/2-27	Development of Web-based Baseflow Separation Analysis Tool.	R. V. Kale, Sanjay Kumar, A. K. Lohani M. K. Goel	Two Years (April 2025 to March 2027)
3. NIH/SWHD/2-27	Development of Integrated Flood Analysis and Mapping System (I-FAMS) for India	R. V. Kale, A. K. Lohani M. K. Goel J. P. Patra P.C. Nayak	Two Years (April 2025 to March 2027)
4. NIH/SWHD/2-28	An Integrated approach for Irrigation Scheduling in a Command area	L. N. Thakural, Sukant Jain, S. K. Gupta, Richa Pandey, Sanjay Kumar, Gaurav Kumar	Three Years (April 2025 to March 2028)
5. NIH/SWHD/2-27	Evaluating Rain-on-Grid Hydraulic Modelling for Dam Break Analysis: A Comparative Study of HEC-RAS and TUFLOW in Indian Catchments	Sukant Jain Chandra Prakash A. K. Lohani	2.5 Years (April 2025 to Sept 2027)
6. NIH/SWHD/2-26	Web-Based Flood Hydrograph Estimation Tool for Hydraulic Structure Design in India	Sukant Jain A. K. Lohani	1.5 Years (April 2025 to Sept 2026)

COMPLETED STUDIES (SPONSERED)

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 km² 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 km² and has a long sausage shape.

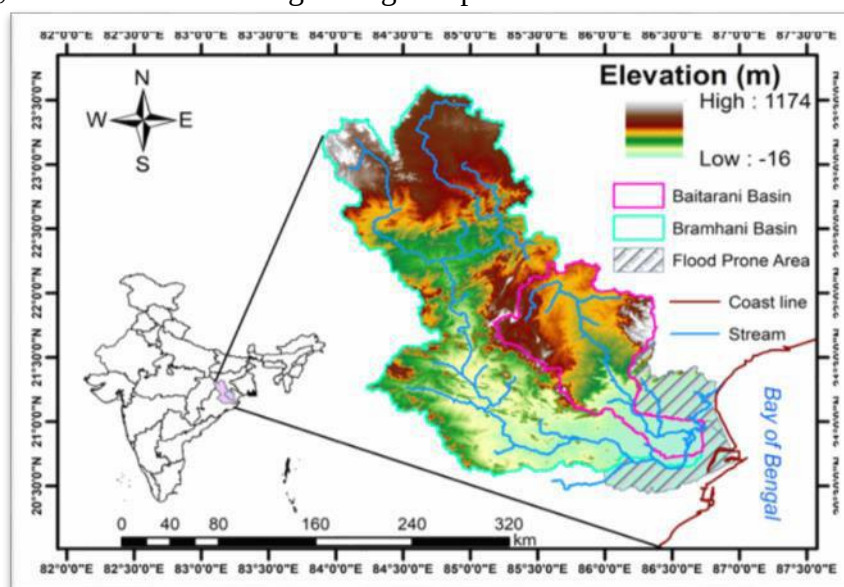


Figure –1. Elevation map of the Brahmani and Baitarani River basins.

The Baitarani sub-basin extends over 12,789 km² 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.	Completed
Development of flood vulnerability maps in real-time (up to 10-days advance) for operational flood management using UNESCO-IHE guidelines	Completed

Progress of work/Achievements/Conclusions

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

Both the river basins lie within the subtropical monsoon climate zone. About 80% of the annual normal rainfall occurs during the four months of the southwest monsoon season (June to September). Therefore, to assess the flooding due to extreme monsoon precipitation, meteorological data are procured from the India Meteorological Department (IMD).

Task #3: Preparation of Flood Maps of recent flood events

Sentinel-1 satellite imageries were processed to determine the flood-affected areas during the recent floods in the basin. For this, the typical events of Titli, Fani, and Yaas were chosen 45 based on the availability of Sentinel-1 satellite imageries. In the coastal region of the Brahmani and Baitarani Basin, frequent flooding has been a persistent challenge, with significant events occurring in recent years. In October 2018, Cyclone Titli caused widespread flooding, inundating

approximately 4,226 km² of land, including 982 km² of cropland. Following this, Cyclone Fani in April-May 2019 led to the flooding of 2,892 km², with 528 km² of cropland submerged. Most recently, in May 2021, Cyclone Yaas resulted in the inundation of 1,964 km², affecting 410 km² of agricultural land (Table 1). These events highlight the recurring nature of floods in this vulnerable coastal region, causing extensive damage to both land and agriculture.

Table 1 Selected historical flood events in the Brahmani and Baitarani basin delta

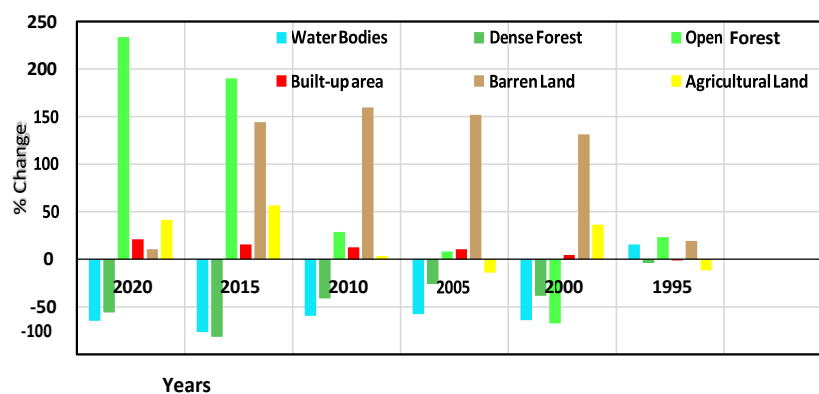
Date	Total inundated area (km ²)	Crop area inundated (km ²)
Titli (Oct 7 th , 2018 - Oct 14 th , 2018)	4226	982
Fani (April 25 th , 2019 - May 4 th , 2019)	2892	528
Yaas (May 23 rd , 2021 - May 28 th , 2021)	1964	410

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 Km² of landmass including cropland of 719 km². After a gap of 1 year, another major flood took place affecting a total landmass of 1471 km² including cropland of 819 km². Recently in May, 2021 the flood was caused due to cyclone ‘Yaas’, inundating 136 km².

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., $e(t)$, $e(t-1)$, ..., $e(t-d)$ as input, which is obtained during the SWATP calibration phase; where $e(t)$ is the simulated error between the observed (Q_{obs}) and SWATP estimated (Q_{sim}) discharge at any time, t , calculated as $e(t) = Q_{obs}(t) - Q_{sim}(t)$. 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 AutoRegressive 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).

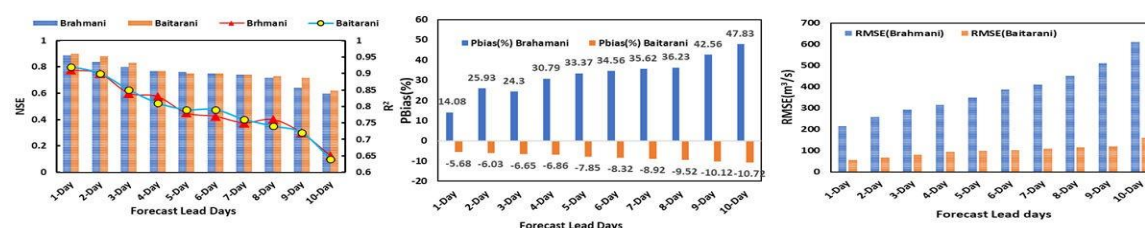


Figure 2. Performance of the PSWAT-WBiLSTM flood forecasting model up to 10 days lead-time.

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)

The computed water levels are compared with the measured tide gauge levels. For storm surge forecasting in the deltaic regions of the Brahmani-Baitarani River basin, an integrated approach was employed using the ADCIRC-SWAN model coupled with the Wavelet-Based Bidirectional Long Short-Term Memory (WBiLSTM) model. The increasing frequency and intensity of tropical cyclones, coupled with complex river basin dynamics, underscore the urgent need for accurate storm surge forecasting as part of effective flood management strategies. ADCIRC-SWAN was utilized to simulate coastal dynamics during cyclone events, providing high-resolution data on water levels and currents. This data was then used to train the WBiLSTM model, which incorporates wavelet analysis to enhance the accuracy of non-stationary time series forecasting. The WBiLSTM model, trained on synthetic data generated by ADCIRC-SWAN, effectively forecasted ocean water surface elevation with 1–8 days lead-times, using GFS meteorological inputs. The results were validated against corrected ERA5 reanalysis data of storm surge residual data were utilized.

Concluding Remarks from Objective #d: The integration of the ADCIRC-SWAN model with

the Wavelet-Based Bidirectional Long Short-Term Memory (WBiLSTM) model demonstrated strong predictive capabilities for storm surge forecasting in the Brahmani- Baitarani River basin with NSE = 0.74-0.95, R2 = 0.82-0.98, and RMSE = 0.12-39 m.

Objective (e)

Task #1: Real-time 2D flood inundation maps in the deltaic basin at different lead times This study aims to develop a comprehensive coastal flood inundation forecasting model by employing the Rainfall-Runoff-Inundation model (RRI) hydraulic model, which incorporates key inputs such as upstream flux, storm surge, and inland rainfall data across varying lead times. The upstream flux is forecasted using a novel PSWAT-WBiLSTM framework, which combines the SWAT-Pothole hydrological model with a Wavelet-based Bi-directional LSTM error-forecasting model. In regions with reservoirs, the HEC ResSim module is used to simulate regulated outflow based on forecasted streamflow and reservoir operations. Additionally, forecasted ocean water elevations and bias-corrected meteorological data from the Global Forecasting System (GFS) are integrated into the H2D model to simulate flood extents. These simulations are then calibrated and validated against flood extents derived from Sentinel-1 SAR imagery. Fig. 3 illustrates the capability of RRI model to capture the flood extent during Gulab cyclone event for 1-8 lead days.

Concluding Remarks from Objective #e: The developed coastal flood inundation forecasting model demonstrated strong performance, with fit scores ranging from 75% to 42% for 1-8 days lead times when compared to observed flood extents derived from Sentinel-1 SAR imagery. These results indicate that the model is capable of providing reliable flood extent forecasts, which is crucial for effective early warning systems and flood management in vulnerable coastal regions. The gradual decrease in fit scores with longer lead times underscores the inherent challenges of forecasting in complex environments, but the overall accuracy achieved highlights the model's potential as a valuable tool for mitigating flood risks and protecting lives and property in the Brahmani-Baitarani delta region.

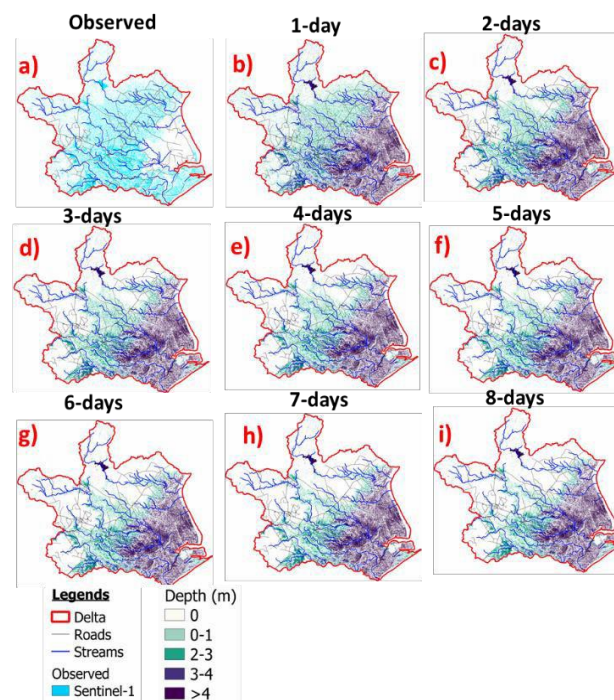


Fig. 3. Assessment of flood extent of RRI with the a) observed flood extent for b-i) 1-8 days' lead Gulab cyclone event

Objective (f):

Task #1: Development of flood vulnerability maps in real-time (up to 10-days advance) for operational flood management using UNESCO-IHE guidelines.

To develop real-time flood vulnerability maps for the Brahmani-Baitarani River Basin, a GIS-based approach was used, integrating various geospatial layers such as rainfall, temperature, flood depth at 1-8 days lead time, population, population density, land use, and slope into an exposure index. Susceptibility was evaluated based on the distance from hospitals, while resilience was determined by considering proximity to roads and emergency services. The overall flood vulnerability was calculated using the formula: $\text{Flood Vulnerability} = \text{Exposure} + \text{Susceptibility} - \text{Resilience}$. Weights for the exposure factors were determined using the Analytical Hierarchy Process (AHP) to ensure a systematic assessment. This methodology provided a robust framework for identifying and mapping areas at high risk of flooding, which can be used to inform real-time flood management and response strategies.

Research outcome of the project

The results provide a scientific foundation for developing early warning systems, flood mitigation strategies, and improved reservoir management practices.

End Users/Beneficiaries of the study: Central and state government departments dealing with flood disaster management/Early warning system like CWC/State WRD's, NDMA/SDMAs IMD/INCOIS etc.

COMPLETED STUDIES (INTERNAL)

1. 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. Lohani, SC-G
- b. PI Project Investigator(s) Dr. L. N. Thakural, Sc-D, Lead PI
Sh. J. P. Patra, Sc-D
Dr. M. K. Shama, Sc-E
Dr. Rahul Kumar Jaiswal, Sc-E
Dr. P. K. Mishra, Dc-D
Dr. Nitesh Patidaar, Sc-B
Sh. N. K. Bhatnagar, Sc-B, Co-PI
Sh. Jatin Malhotra, SRA, Co-PI

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 adaptive 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: Completed**

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 ($0.25^{\circ} \times 0.25^{\circ}$), maximum temperature, and minimum temperature ($1^{\circ} \times 1^{\circ}$) 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.

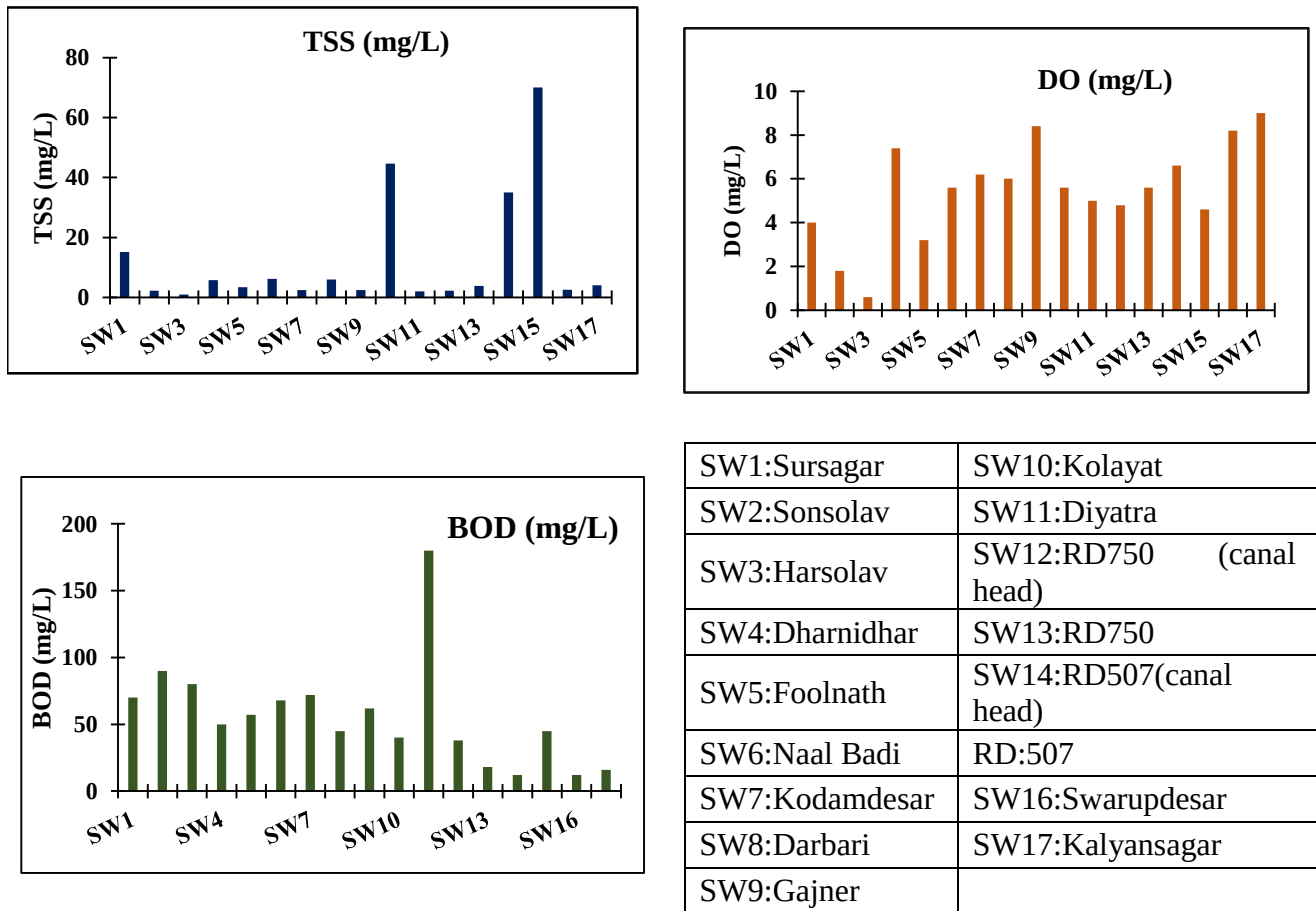


Fig 1: water samples for TSS and Demand parameters (DO, BOD)

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

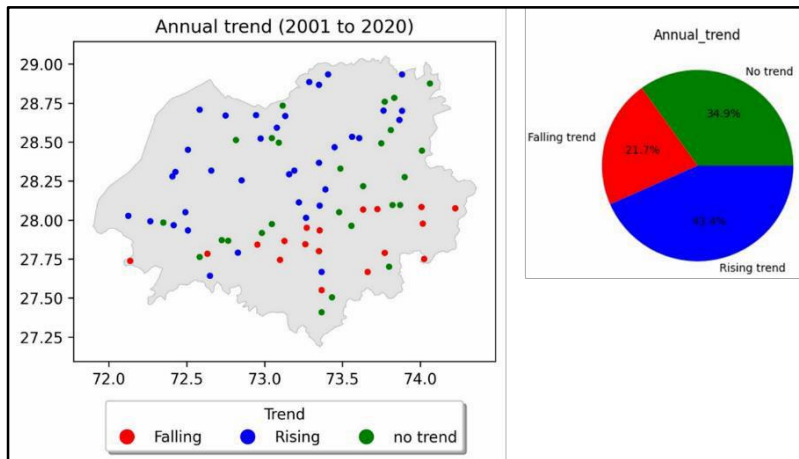


Fig. 2. Trend in groundwater levels in the Bikaner district

Recharge to groundwater due to rainfall and irrigation is estimated using RZF module of NIH-WISDOM. It is observed that the total recharge varies from 0 to 70 mm in the Bikaner district. Moreover, the recharge from irrigation dominates in the area. The Northeastern part gets irrigation from IGNP while the Southwestern part is mainly irrigated through farm-ponds and groundwater.

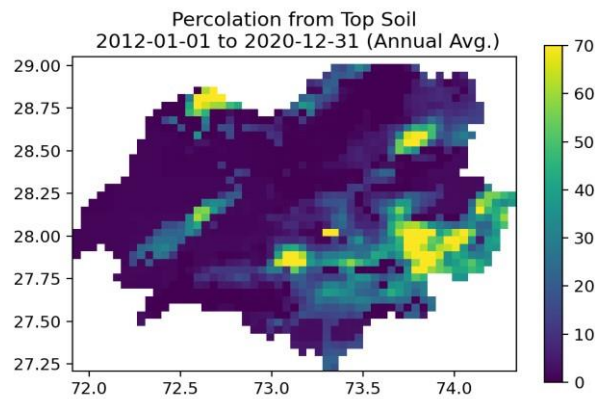


Fig. 3. Total recharge variation in the Bikaner district

Also, recharge to groundwater and LAI in the Bikaner district analysis shows that the LAI highlights the irrigated crop areas in the Northeastern parts and Southwestern parts. LAI (aggregated) and LAI (Vegetation) are the inputs in the WISDOM. The former is aggregated LAI within the grids, while the later show LAI of vegetation pixels within grids. The areas with high LAI exhibit higher recharge due to irrigation.

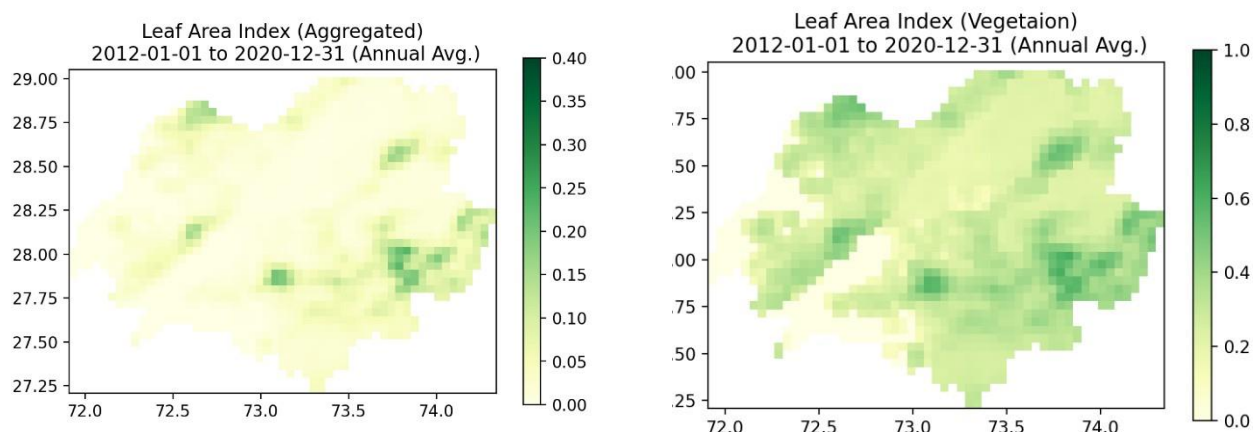
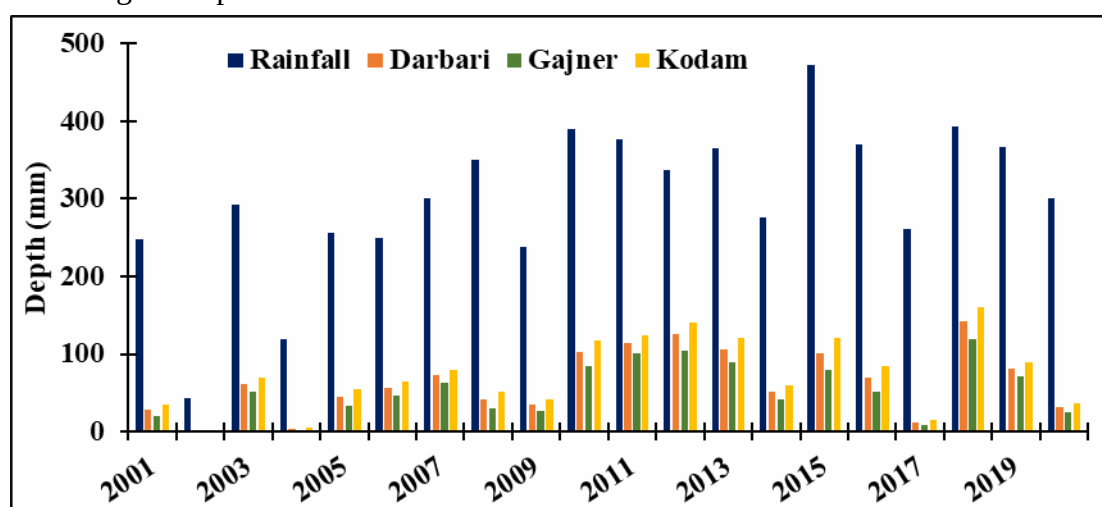


Fig. 4. LAI variation in the Bikaner district

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.

The runoff analysis from 2001 to 2020 reveals significant variability across catchments, influenced by factors like soil, vegetation, and topography. Years of intense rainfall, such as 2018 and 2012, saw high runoff, while dry years like 2002 showed minimal runoff. Each catchment's unique conditions affect its runoff patterns, emphasizing the need for effective water management. Similarly, pond data show periods of overflow and deficit, highlighting the impact of precipitation and water management practices.



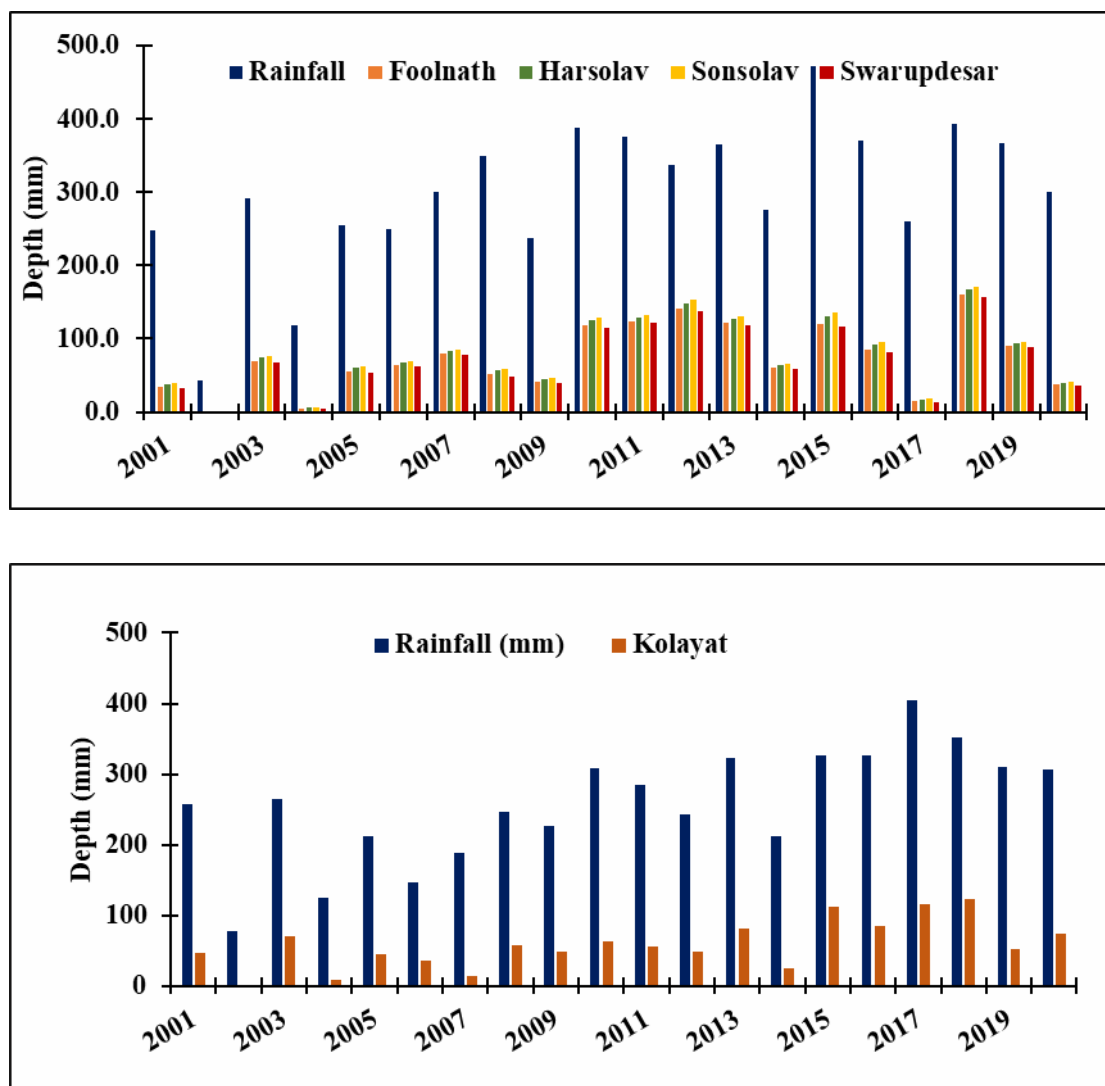


Fig. 5 Rainfall-Runoff analysis in the different catchments of Bikaner district

Further, Universal Soil Loss Equation (USLE) has been utilized on Remote Sensing (RS) and Geographical Information System (GIS) platform for spatial soil erosion modeling to predict the average annual rate of soil loss from the catchment. The results reveal that slight erosion class is widespread across all catchments, but, there is considerable variation in the extent of more severe erosion classes. In the catchments like Sonsolav and Swarupdesar, a high percentage of the area is classified as having slight erosion, indicating relatively stable soil conditions and suggesting effective erosion control measures. These catchments show minimal severe erosion, reflecting a lower risk of significant soil degradation. On the other hand, catchments like Foolnath and Kodamdesar exhibit significant proportions of high and very high erosion, highlighting areas with critical erosion issues that could impact agricultural productivity and environmental sustainability. Hence, these areas may require more intensive management strategies to mitigate the effects of erosion.

The variation in severe and very severe erosion across catchments further underscores the need for targeted approaches to erosion management. For example, Harsolav, with notable percentages of severe and very severe erosion, may benefit from specialized interventions focused on these hotspots to prevent further land degradation. Meanwhile, catchments like Darbari and Kolayat show a mix of erosion classes, indicating that while much of the area remains relatively stable,

there are portion having significant erosion that need attention. This diverse erosion profile suggests that proper erosion management strategies are necessary, emphasizing the importance of localized assessments and interventions. Overall, the results highlight the critical importance of understanding the specific erosion dynamics within each catchment to implement effective soil conservation practices. Addressing areas with severe and very severe erosion is crucial to maintaining land productivity and ecological balance, while ongoing monitoring and adaptation of erosion control measures are essential to ensure long-term sustainability across the catchments.

Pond rejuvenation is essential for maintaining ecological balance, supporting biodiversity, and ensuring sustainable water resources in both urban and rural areas. However, the strategies for rejuvenation may differ based on the specific needs and challenges of urban as well as rural environments and short term and long-term rejuvenation which may range from include watershed management to awareness and Legal Protection and Policy Support.

2. 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. – E, 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
Sunil Gurrapu, Sc. – D, SWHD
 - 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**

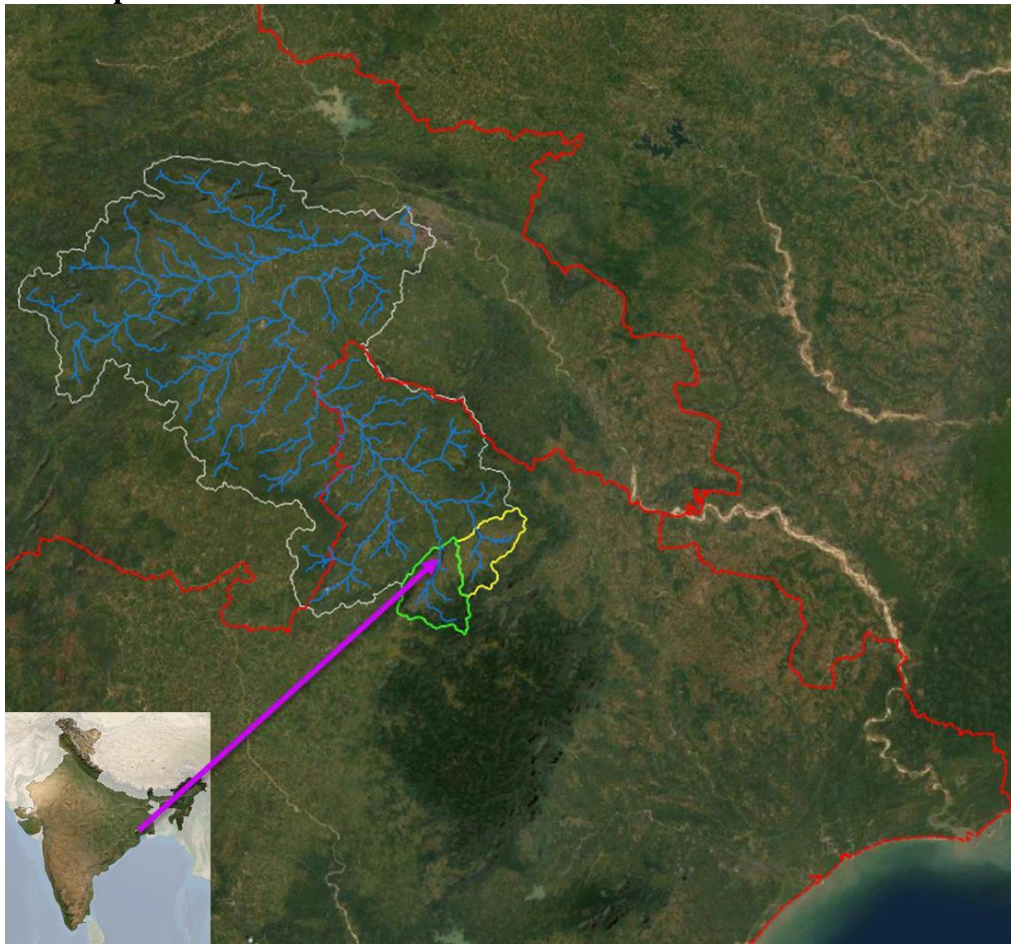


Figure 1: Location map of the study area

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. 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.

9. 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-recording 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 2071 to 2100. The corresponding design flood hydrographs are also developed. The HEC RAS model for Dam break modelling is under progress.

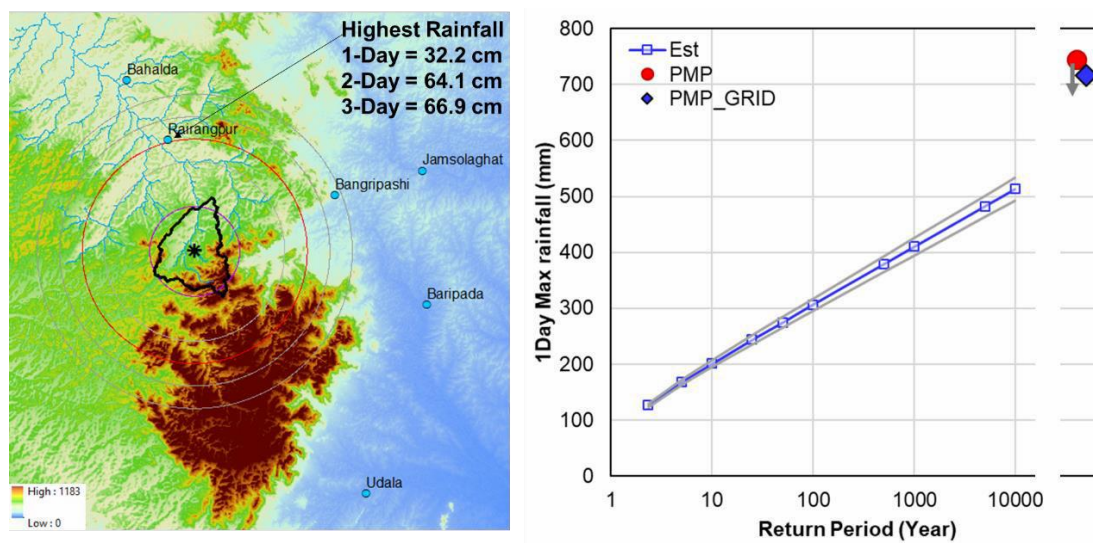


Figure 2: 1-day Maximum rainfall for various return periods and PMP.

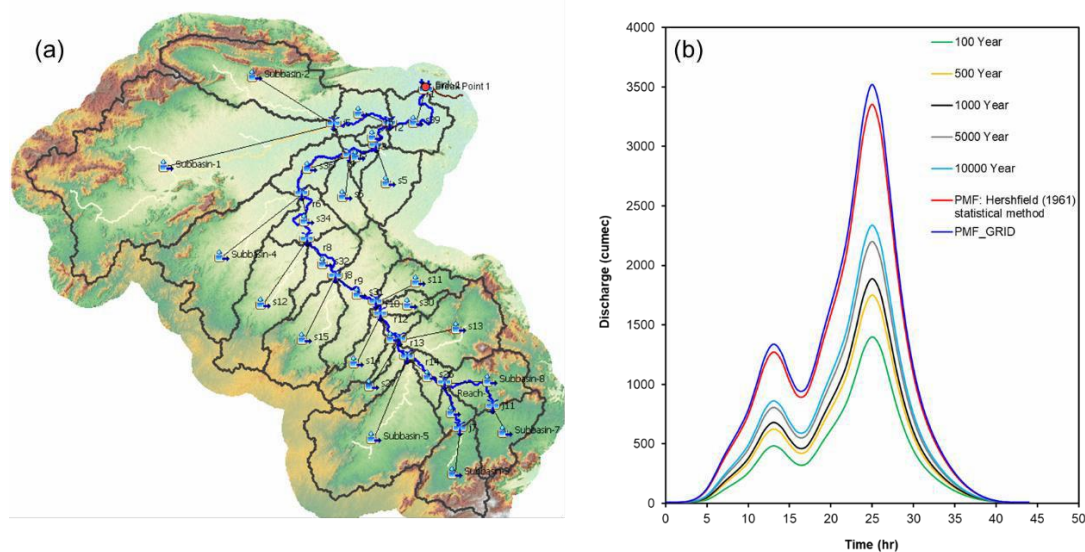


Figure 3: (a) HEC-HMS model setup; (b) design flood hydrographs at dam site.

10. 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 dam break of Khadakhai Dam.
- Capacity building in line with DRIP.

11. End Users/Beneficiaries of the study: WRD Odisha

3.PROJECT REFERENCE CODE: NIH/SWHD/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 km² 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.

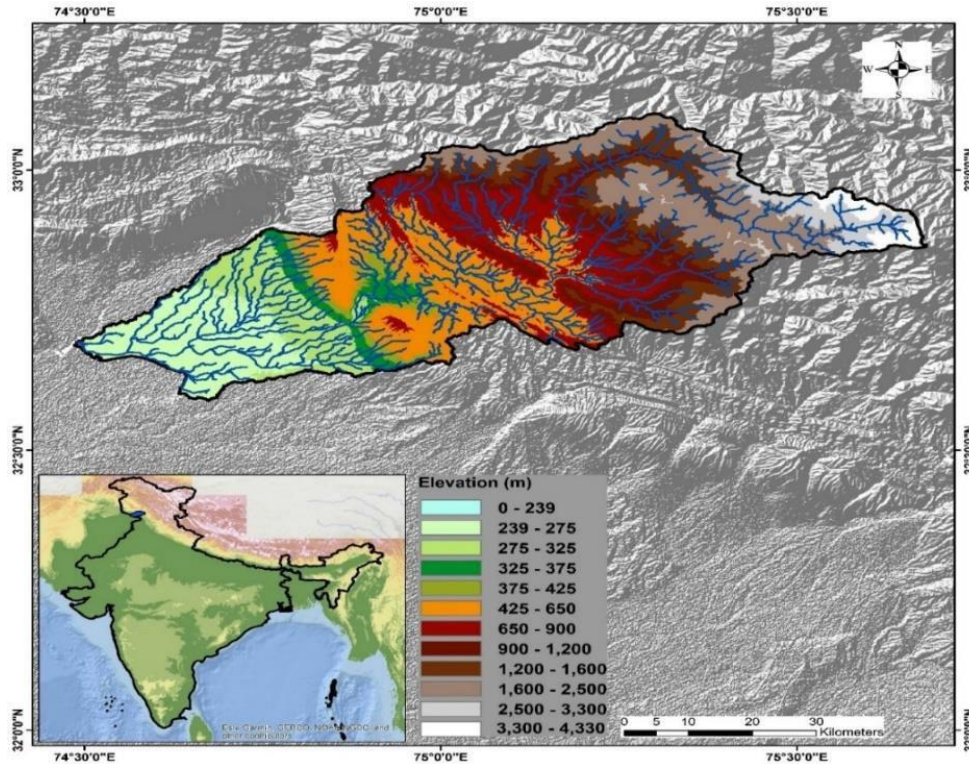


Figure – 1: Location map of Tawi river basin.
Stages of work and milestone:

Action Plan

Work Element	1 st Year				2 nd year				3 rd 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	Completed
(d)	To carry out comparison of the RRI model-based flood inundation maps with those obtained by using HEC-RAS and HEC-HMS models.	Completed

Progress of work and Conclusions

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.

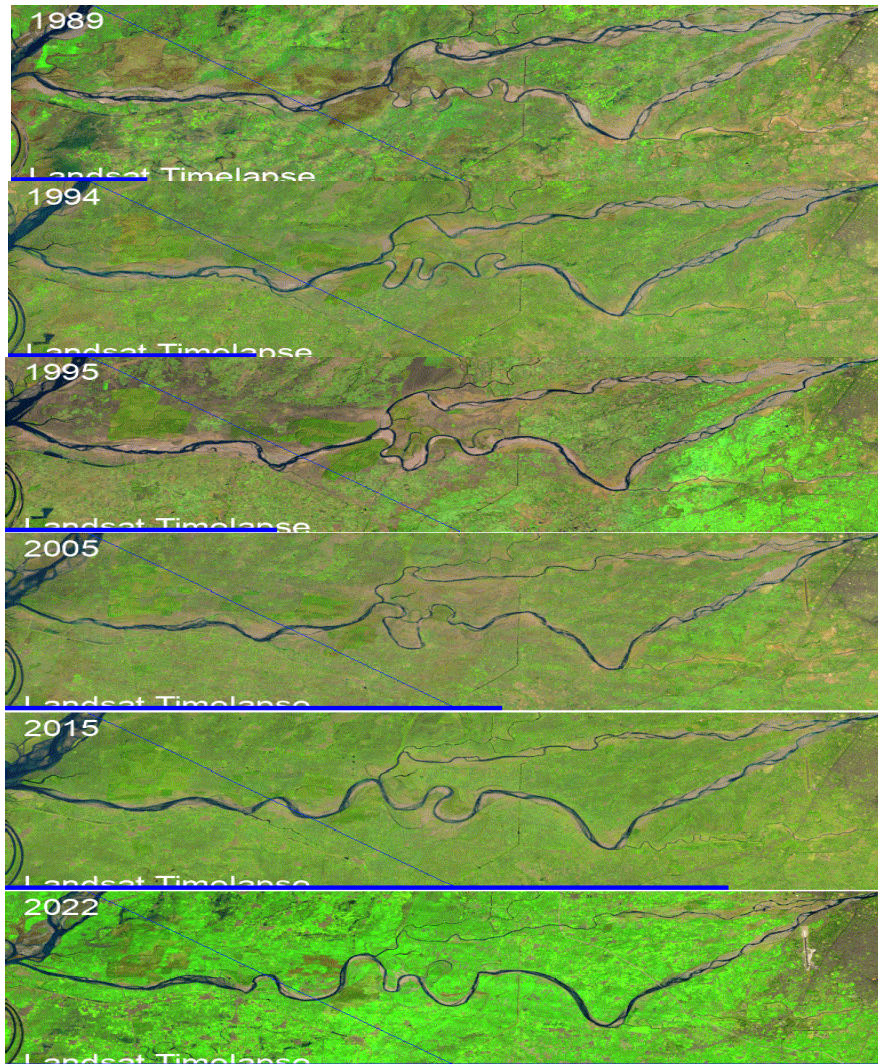


Figure 2: Observed changes in the Lower Tawi river planform during 1988 to 2022.

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 to 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.

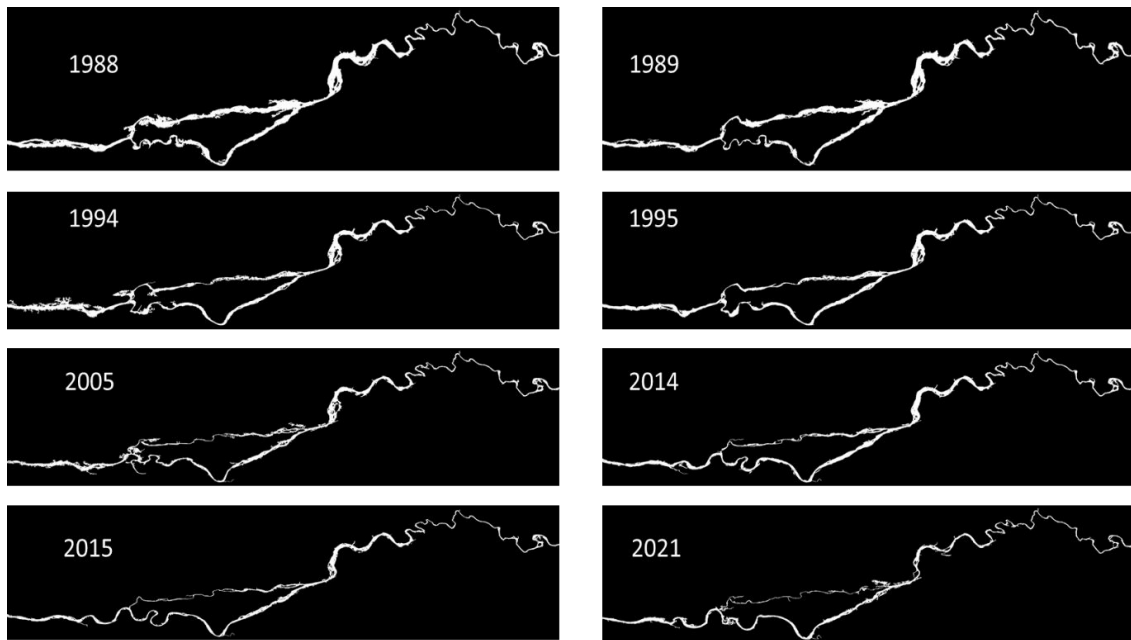


Figure 3. Extracted active lower Tawi river channel mask from a series of Landsat satellite images in Google Earth Engine

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. The meandering dynamics and morphological transformations in the Tawi River during 1988–2021 is shown in Figure 4.

#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.

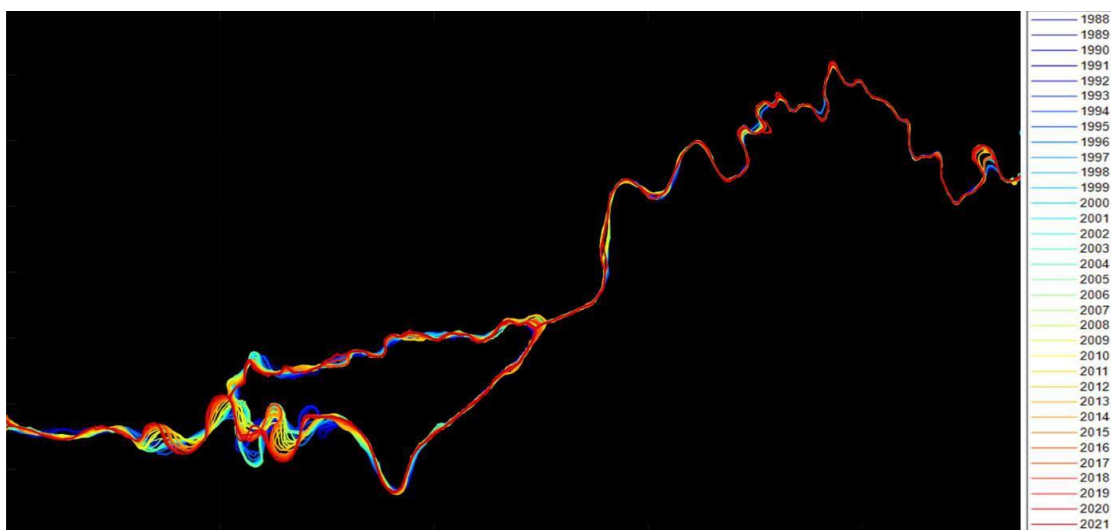


Figure 4: Meandering Dynamics and Morphological Transformations in the Tawi River (1988–2021).

#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 (RRI) model is completed. The required input parameter files and GIS layers were prepared. Presently, the calibration of model parameters is under-progress. The achieved results of the RRI models will be shown in the WG meeting.

Objective (d)

The flood inundation map achieved with RRI model for the event of 2014 flood in Tawi basin is compared with the inundation map obtained using coupled HEC-HMS model (for Rainfall- runoff simulation up to Sidhara gauging0 and HEC-RAs model (for 1D simulation of flood inundation below Sidhara G&D site). The results achieved by both the method were comparable. It was observed that RRI model is capable of simultaneously simulate rainfall- runoff process as well as inundation.

Research outcome of the project

- Geomorphological analysis of Tawi river basin using historical LANDSAT Satellite data.
- RRI and HEC-HMS and HEC-RAS based modelling framework for flood inundation mapping in the Tawi river basin.

End Users/Beneficiaries of the study:

CWC, Irrigation and Flood Control Department (IFCD) Jammu and other government departments dealing with flood disaster in Jammu & Kashmir

4. PROJECT REFERENCE CODE: NIH/SWHD/NIH/23-25

1. Title of Study: Estimation of confidence intervals of index flow duration curves

2. Study Group: Sanjay Kumar, Sunil Gurrapu,
L. N. Thakural, J. P Patra
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 interval (90%) 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

$$P = 1 - F(X \leq x_p)$$

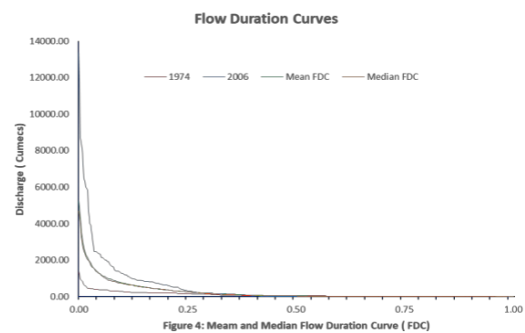
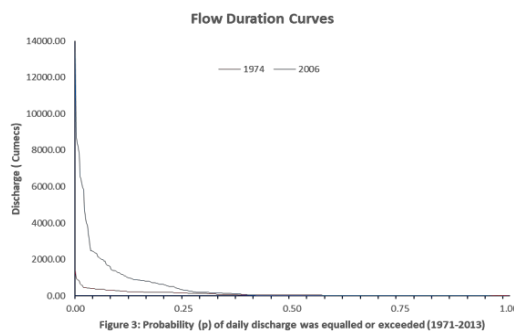
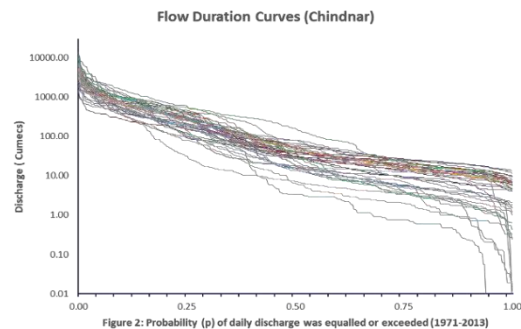
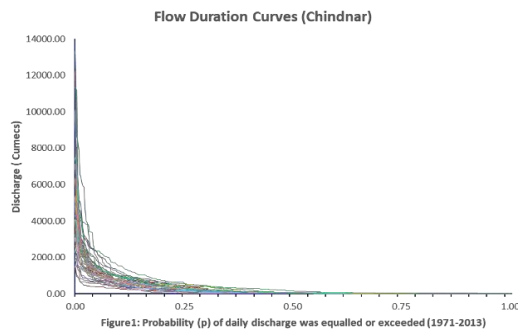
To estimate index flow duration curve and CIs, the FDC are developed on annual base by considering N annual FDCs, each corresponding to one of the N years of the data. For daily data each curve is a sequence of $n=365$ values X_i with $i=1 \dots n$ arranged in ascending order $X_{1:n} \leq X_{2:n} \dots X_{n:n}$, 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.

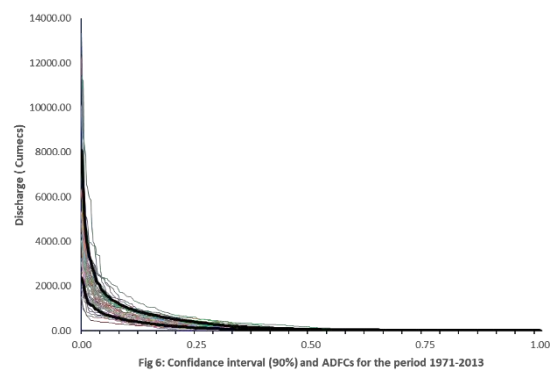
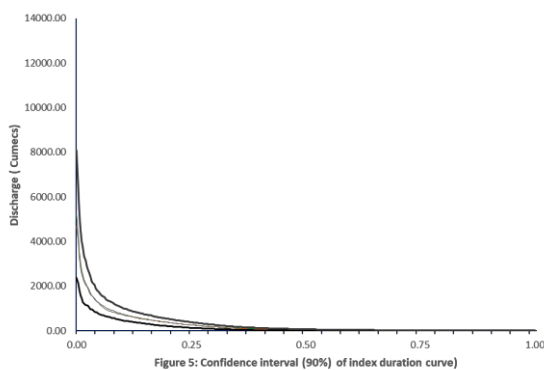
7. Analysis and Results

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. Sites having sufficient length of records (around 50 years) has been selected to demonstrate the methodology.



The annual discharge data has been plotted to construct AFDCs. Figure 1 shows the AFDCs for the period 1971-2013 for the gauging site Chindnar. Figure 2 shows the AFDC in the log scale (Y axis) for better clarity. The Figure 1 gives a graphical view of the variability of AFDC over the period of 1971 to 2013 with Figure 3 shows the lower and upper boundaries of variation. The index flow duration (mean and median) curve are constructed based on median (or mean) flow corresponds to each order statistics (Figure 4). As index duration curves is based on



median values corresponds to probability of exceedance 0.50, it also represents the flow duration curves corresponds to return period 2 years ($T=1/p$). Figure 5 shows the confidence interval (90%) (lower and upper bounds) of the index duration curve. Figure 6 shows all AFDC for the period 1971-2013 along with the 90% confidence interval. Based on the distribution of flow values corresponds to each order statistics and plotting positions (Weibull) flow duration curves for different return period are estimated. Similar analysis has been conducted for Polavaram gauging site.

- 8. End users/beneficiaries of the Study:** Central and State government departments, academicians, BIS etc.
- 9. Deliverables:** Report/Manual, Publications

5. **PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-24**

1. **Title of the Project:** Hydrologic and hydraulic study for Jata Ganga river at Jageshwar dham.

2. **Project team:**

Project Investigator:

J.P.Patra, Sc. – E, SWHD

Project Co-Investigator:

A. K. Lohani,, Sc. – G & Head SWHD

Pankaj Mani, Sc. – G, CFMS Patna

D. S Bisht, Sc. – C, C4S

S. S. Rawat, Sc. – F, C4S

3. **Duration of the Study:** 1 years (July 2023 to July 2024): Completed

4. **Type of Study:** Internal Study

5. **Location Map**

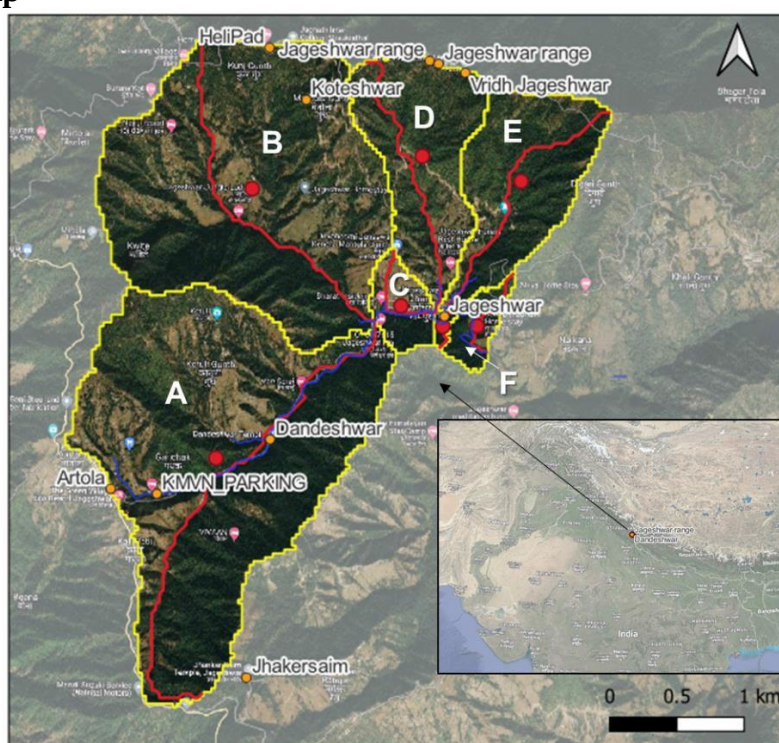


Figure 1: Location map of the study area

6. **Objectives**

Estimation of floods of various return periods viz. 25 year, 50 year and 100 year with corresponding water level.

- Estimation of water levels after incorporating the proposed riverfront for 25 year, 50 year and 100 year discharge.
- 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. The project site is about 3.5 kilometres and the drone images of the site provided by M/s INI Design Studio is shown in Figure 2. The INI Design Studio also provided the DEM of the concerned river reach.

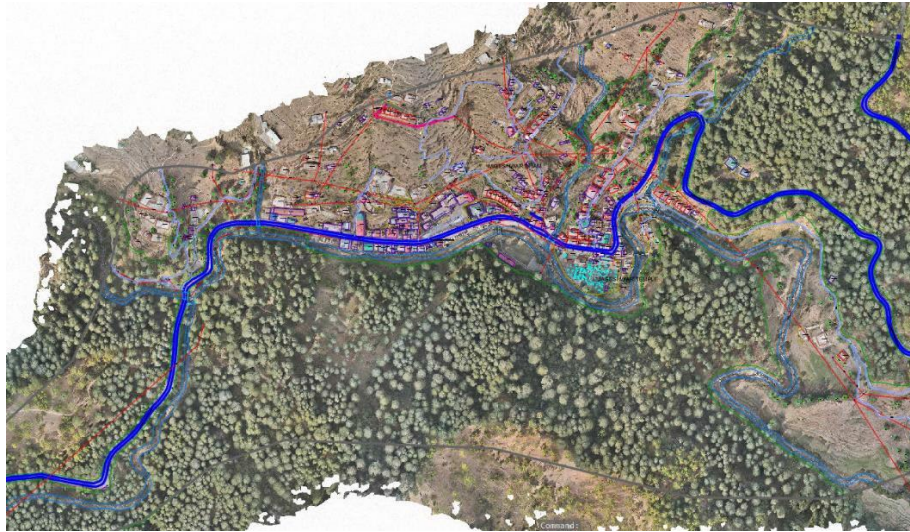


Figure 2: Index Map of the Study Area

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. Moreover, The 30 minute temporal resolution 4.4 Global Precipitation Measurement (GPM) rainfall data was also obtained for the period 2000 to 2023. Rainfall frequency analysis is carried out using L-moments approach for development of Intensity Duration Frequency Curve (IDF). The catchment and sub catchment area are very small. Hence, SUH is not derived and rational formula is used for computation of discharge. Here HEC-RAS is used for hydraulic modelling with the DSM provided by M/s INI Design Studio.INI.

9. Results achieved with progress/present status

Field Investigations: The NIH team discussed about the area with INI team through video conference and visit to the study area was made during 28 April 2024. The photographs during filed visit are shown in Figure 3. During the field visit it was observed that the earlier constructed soil conservation structures (check dam/ weir) have been field with sediment. The flow was also very less. The INI team informed that there is no observation of discharge or water level in the area. However, INI team shared the photographs of flood during 2024, when the flood water has overtopped

the bridge.



Figure 1: (a) Field visit photographs, (b-c) Flood of 2024 (as share by INI)

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. The 30 minute temporal resolution GPM rainfall data was also obtained for the period 2000 to 2023. Rainfall frequency analysis is carried out using L- moments approach for development of Intensity Duration Frequency Curve (IDF). The comparison of estimated design runoff shows that the flood values for cloud burst condition (Intensity = 10 cm/h) is higher and adopted for further hydraulic analysis as conservative approach. 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 4 (a). The simulated water surface profile for various return periods at RS 753 is shown in Figure 4(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 (m³/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

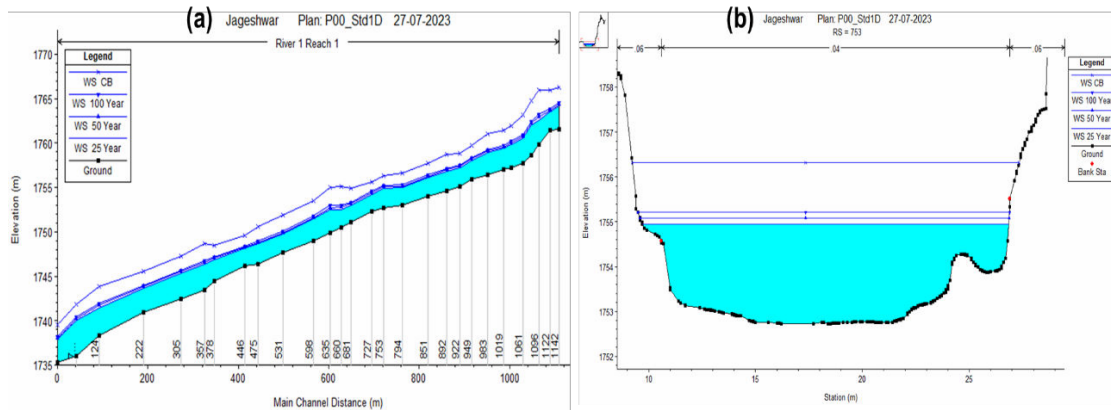


Figure 4: Simulated water surface profile for different return period floods (a) longitudinal; (b) cross-section at RS 753.

10. Conclusions

The proposed masterplan of Jageshwar Dham and Jata Ganga Formation Plan explained by INI. The flow is very less during lean seasons. Hence at about six locations weirs/water retention structures are proposed to be constructed for making water available during lean season. It is recommended that appropriate provision should be made to pass the flood water during monsoon seasons uninterruptedly (KT weir, Inflatable Weirsetc.). Any restriction in flow and subsequent reduction in flow velocity will not only rise the maximum water level in the river but also may lead to rise in river bed level due to sedimentation. Limited de-silting activity can also be performed as to maintain a flow depth of about 3.3 m and the road level shall be maintained at 5.25m above the river bed level.

11. Research outcome of the project

Design input for riverfront development for Jata ganga.

12. End Users/Beneficiaries of the study:

Tourism department of Uttarakhand

ONGOING STUDIES (SPONSERED)

1. Project Code: SP-77/2024-25/NIH(SWHD)

1. **Title of the Project:** Flood Plain Zone Delineation of Burhganga a tributary of the Ganga River from Village Dabal in Dist. Muzaffarnagar to Garmukteshwar.

2. **Project team:**

Project Investigator: J.P.Patra, Sc. – E, SWHD
Project Co-Investigator: A. K. Lohani, Sc. – G & Head SWHD
P. C. Nayak, Sc. – F, SWHD
Sanjay Kumar, Sc. – F, SWHD
S. Sahoo, Sc. – B, SWHD

3. **Type of Study:** Sponsored Study (Irrigation and Water Resources Department, Govt. of UP)

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

5. **Date of Start:** January 2025

6. **Scheduled date of Completion:** Jun 2025

7. **Duration of the Study:** Six Months

8. **Objectives**

- Estimation of design flood for various return periods viz. 5, 25 and 100 year.
- Flood plain demarcation based on satellite data/images.
- Flood plain demarcation based on hydraulic modelling
- Demarcation of flood plain by combining results of satellite data/images and hydraulic modelling.

9. **Present state-of-art**

The Executive Engineer, Drainage Division-I, Meerut, Irrigation and Water Resources Department, Govt. of UP has approached Director, National Institute of Hydrology Roorkee to carryout the study for “Flood plain zone delineation of Burhganga a tributary of the Ganga river from village Dabal in Dist. Muzaffarnagar to Garh Mukteshwara” as per direction given by Hon’ble NGT. Director, NIH has assigned Surface Water Hydrology Division to take up this study. From the initial discussion with the Drainage Division-I, it has been found that the Burhganga a tributary is having very less width and water flows mainly during the rainy seasons and joint to the Ganga river at 3 to 4 locations. It is also reported that no observation of flood/discharge or water level is available at this tributary. Under these condition following methodologies will be applied for delineation of flood plain corresponding to frequency of once in hundred-year flood.

10. **Methodology**

Catchment Delineation: The catchment area of the Burhganga tributary will be delineated from the CartoSat DEM and Survey of India Topo Sheets in GIS platform.

Flood Frequency Analysis: Since historical flood discharge data is not available. The flood value will be estimated from rainfall of corresponding return period using unit hydrograph (UH) approach.

Hydraulic Modelling: Once the flood corresponding to 100 year return period is estimated, the hydraulic model (HEC RAS) will be used to simulate the flow pattern on the existing topography (represented through cross-section, Bathymetry i.e. Digital Elevation Model) for estimating flood inundation extent. The river cross-section and Digital Elevation

Model is to be provided to NIH by the Irrigation and Water Resources Department, Govt. of UP.

Flood Plain Zone Demarcation: The hydraulic model will provide the flood inundation extent for 100 year return period flood. NIH will process the output and the line corresponding to outer extent of flood plain will be provided as a KML file and Shape file to the Irrigation and Water Resources Department, Govt. of UP. The coordinates (Lat, Log) at suitable interval (or bend to bend) will also be provided for further use. The Irrigation and Water Resources Department, Govt. of UP after verification/validation of the line may take up the work for physical demarcation and notification as per necessity and directive of Hon'ble NGT.

11. Research outcome of the project

Flood plain demarcation of Burhanga river

12. Work Schedule:

SN	Activity	Month					
		1	2	3	4	5	6
1	Catchment delineation and selection of river reaches						
2	Data collection and Processing						
3	Flood frequency analysis: Estimation of flood for 100 year return period						
6	Hydraulic model setup using HEC RAS						
7	Finalization of hydraulic model results with sponsoring agency						
8	Submission of interim findings for discussion, result verification with sponsoring agency.						
9	Finalization of delineation of flood plain						
10	Submission of draft Report						
11	Submission of final Report						

13. End Users/Beneficiaries of the study:

Irrigation and Water Resources Department, Govt. of UP

ONGOING STUDIES (INTERNAL)

1.PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-25

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 Gurrupu, T. Thomas, Om Prakash, Jatin Malhotra
3. **Type of Study:** Internal Study
4. **Nature of Study:** Basic and Applied Research
5. **Date of Start:** July 2022
6. **Scheduled date of Completion:** June 2025
7. **Duration of the Study:** 3 years
8. **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

Water resource management and hydrological forecasting are critical components of sustainable development, particularly in the face of increasing water demands and climate variability. Accurate streamflow prediction plays a pivotal role in flood management, irrigation planning, hydropower generation, and ecosystem preservation. Traditional methods for streamflow prediction, such as physically based hydrological models, often require extensive domain-specific knowledge, large-scale calibration, and significant computational resources. These limitations have spurred the development of data-driven approaches that leverage historical observations and meteorological variables for streamflow forecasting.

Hourly rainfall and river water level data of 8 years (2014-2021) is considered for flood forecasting study using DL techniques for Baitarani basin. The data has been divided into two segments, of which 5 years of the data is taken as a training data and remaining 3 years data used as a testing data. Water level data of is provided by Central Water Commission, Government of India (CWC, GOI) and hourly rainfall data is downloaded from NASA POWER's (<https://power.larc.nasa.gov/data-access-viewer/> extensive meteorological) dataset, was utilized in this study for a period 2014 to 2021.

Two deep learning algorithm mainly LSTM, Transformer model have been applied for hourly water level forecasting at Anadapur gauging site. The LSTM and Transformer was implemented using MATLAB software. For training, we utilized the adaptive Moment Estimation (Adam) optimization algorithm (Kingma & Ba, 2017). Optimal convergence was achieved with a small learning rate of 0.001. The training process aimed to minimize the Root Mean Squared Error (RMSE) as the loss function. A batch size of 32 samples was used, with a maximum of 100 epochs. To prevent overfitting, early stopping was applied, halting the training if the model. The result indicated that Transformer model is performing better than

LSTM model in higher lead time forecasting. Correlation and Efficiency plots during calibration and validation period are plotted in Figure 1 & 2. From the plots it is observed that Transformer model is outperforming in water level forecasting at Anandapur gauging site.

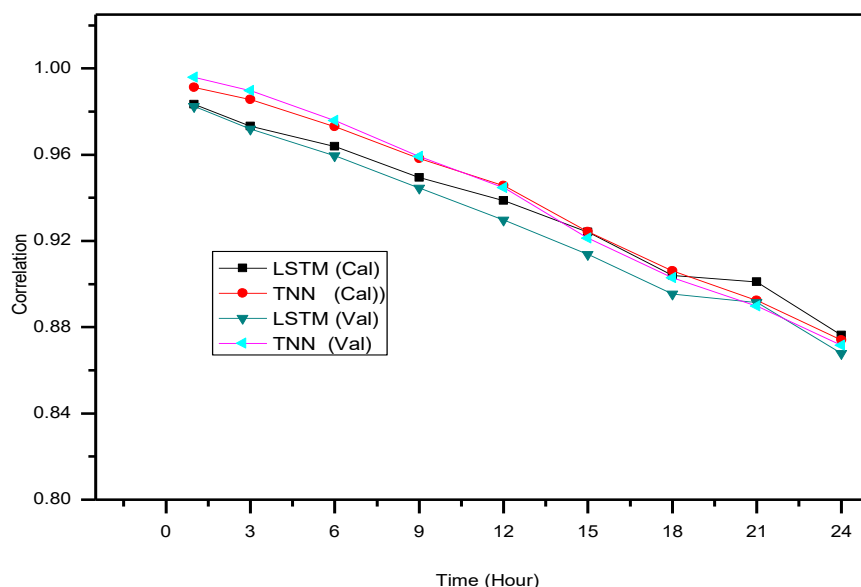


Figure 1: Correlation plot during calibration and validation period

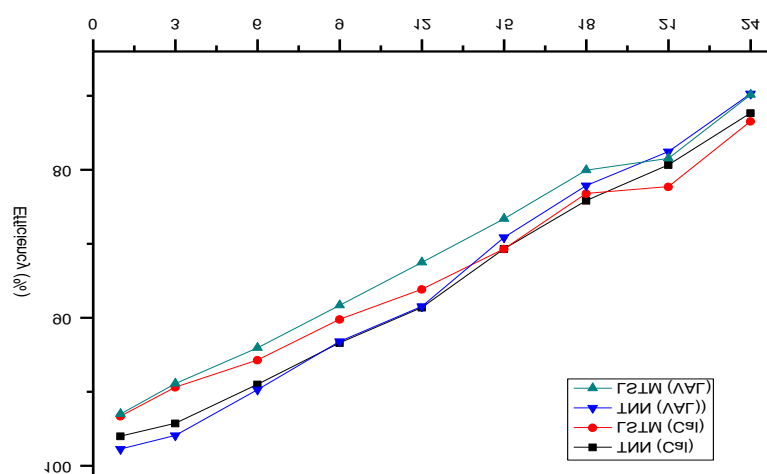


Figure 2: Efficiency plot during calibration and validation period

9. Objective vis-a-vis Achievement

As mentioned in the objectives, preliminary investigation has been conducted to forecast water level at Anandpur gauging site for 1 hour to 24 hour lead.

10. Progress since last meeting

The required hydrological has been collected from Odisha Water Resources Department and CWC, Bhubaneswar. Analysis is under progress

11. 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.

2. **PROJECT REFERENCE CODE: NIH/SWHD/NIH/24-25**

1. **Title of the Project**

Entropy Based Non-Contact Discharge Monitoring Techniques: Testing and Implementation for Indian rivers

2. **Project Team**

Lead Organization: National Institute of Hydrology

Partner Organization (if any): CWC

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

Subject Expert

Name& Designation : Dr. M. Perumal, Former Professor,

Partner Institute : DoH, IIT Roorkee

PI and Co-PI from Partner Organization Principal Investigator (PI):

Name& Designation : Chief Engineer, CWC

3. **Duration of the project:** 1.5 years [April 2024 – September 2025]

4. **Type of Study:** Internal Study [NIH and CWC]

5. **Location Map**

Total 5 G&D sites operated by CWC in the Krishana and Godavari river basin are selected for this study purpose. The Selected G&D Sites in consultation with River Data Directorate- II (RDC-II),CWC New Delhi are given below and are shown on map in Fig. 1:

1. **Arjunwad** (GDSQ) on river Krishna under Upper Krishna Division - Maharashtra
2. **Kurundwad** (GDSQ) on river Krishna under Upper Krishna Division - Maharashtra
3. **Karad** (GDSQ) on river Krishna under Upper Krishna Division - Maharashtra
4. **Mancherial** (GDSQ) on river Godavari under Upper Godavari Division – Telangan
5. **Bhadrachalam** (GDQ) on river Godavari under Lower Godavari Division - Telangana

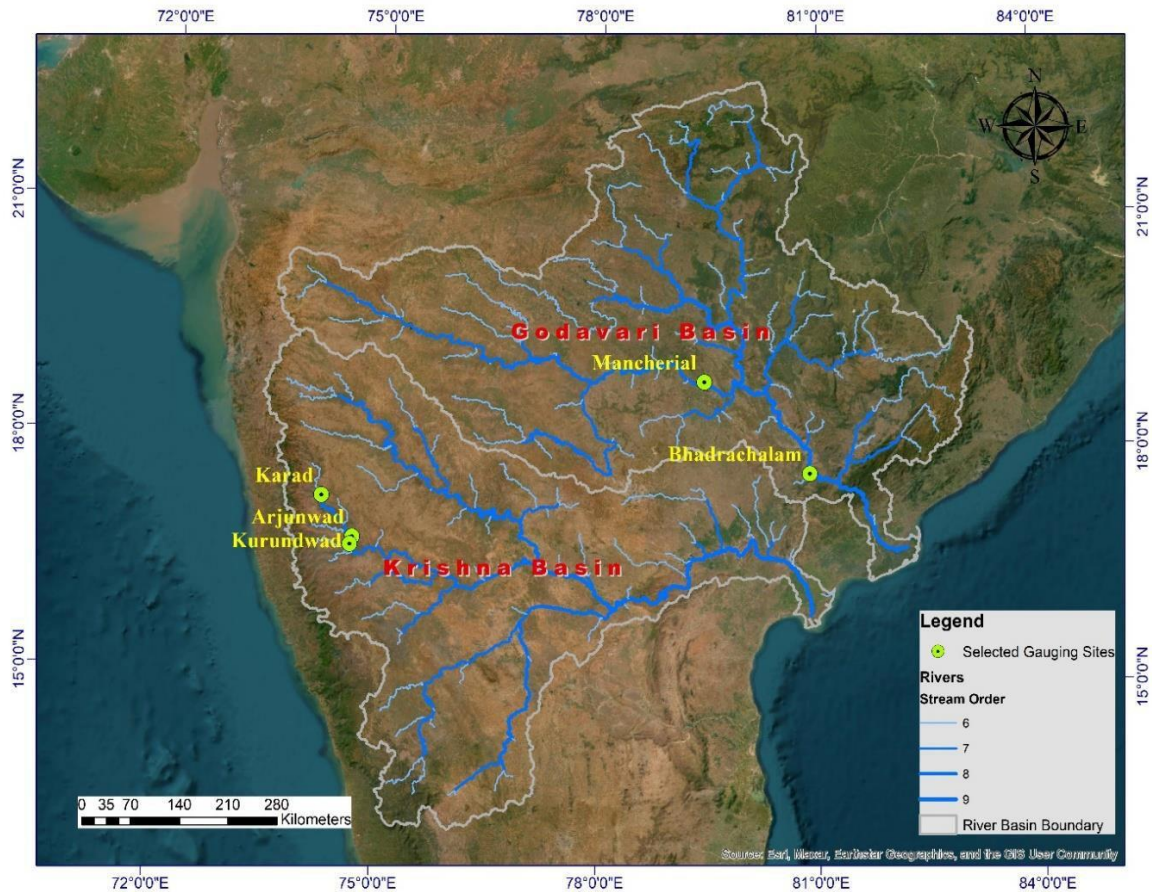


Figure 1. The selected G&D sites for this study.

6. Objectives

1. To analyze the entropy-based discharge measurement techniques for direct discharge monitoring at selected G&D sites from Krishna and Godavari rivers especially during extreme weather events and its comparison with discharge monitoring by conventional discharge measurement techniques.
2. 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.
3. To develop Web App for use of entropy-based discharge measurement technique.

7. Statement of the problem

Government of India has launched 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 Hydrology Project is the “In-Situ Hydromet Monitoring System and Hydromet Data Acquisition System”. Through

this initiative the NHP is helping 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. 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. Therefore, in this study, entropy concept-based method which are more efficient for estimating discharge during high streamflow and at nighttime at the river sites will be investigated.

8. Brief Methodology

This study aims to investigate innovative discharge measurement techniques which are feasible to adopt under adverse weather and topographic conditions. The Fig. 1 shows the methodologies followed in conventional discharge measurement techniques followed by CWC and entropy based discharge measurement techniques.

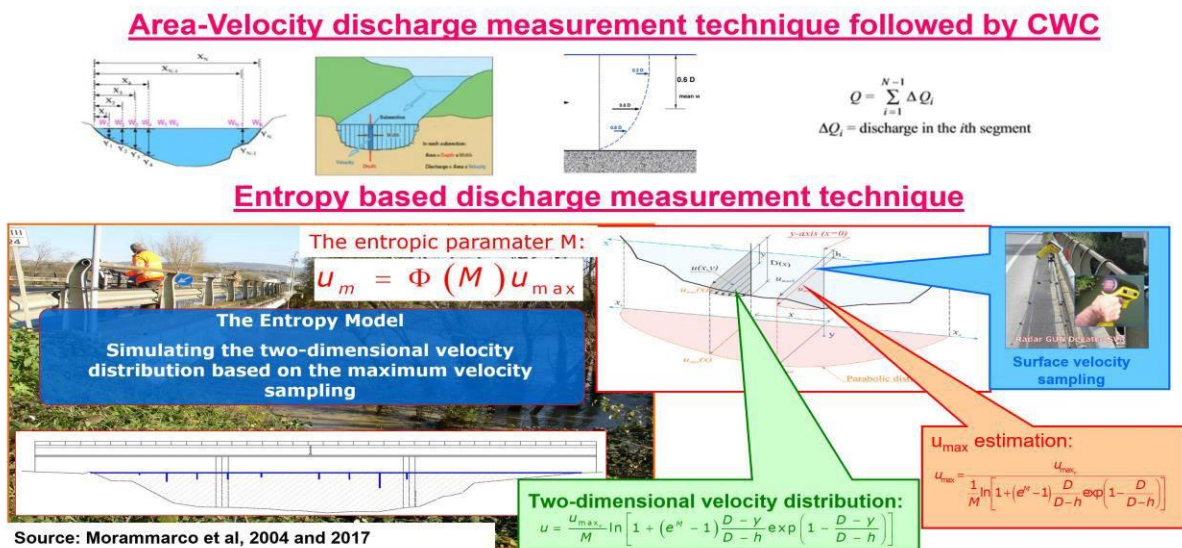


Figure 1. Brief methodology followed in proposed study

The steps followed to conduct this study is given as below:

- 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.

- Site selection and installation of instruments at the selected G&D sites.
- Field investigations to estimate parameters of entropy based discharge measurement model using one-point velocity measurement at $0.6d$. In this technique, 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.
- Another new approach developed will consider only the maximum surface flow velocity measured at the free surface of the y-axis using the SVR, without measuring the surface flow velocities across the entire river section of the gauging station. The method accounts for the dip phenomenon, i.e., the location of u_{max} below the water surface, and does not require the use of additional SVR measurements, other than the one deployed at the singular water surface point of the y-axis. The location of the maximum flow depth of a section can be identified from the historical records of that section.
- An alternative approach of discharge estimation based on the use of an equation developed using hydrodynamic principles to estimate discharge using only the observed stage data at a river site is proposed in this study. The governing equation of the proposed model in this study is based on the use of Approximate Convection- Diffusion wave (ACDW) equation combined with the Diffusive Wave model, known herein as the Approximate Convection- Diffusion Wave (ACDW) method. This method can be considered as a more generalized approach ideally suited for field applications. Due to its simplicity, easy applicability, versatility and accuracy of estimating discharge for a wide range of roughness and channel bed slope conditions, this method can be considered ideal for field applications.
- Discharge measurement by entropy-based and ACWD approaches 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 echo sounder 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.

9. Results achieved with progress/present status

- Entropy theory applied to hydrometric measurements enables establishing a relationship between the maximum and the mean velocities of flow passing a river section. As in India, 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. This methodology is coded in python open source software. The developed web-based app is shown in the Fig. 2.

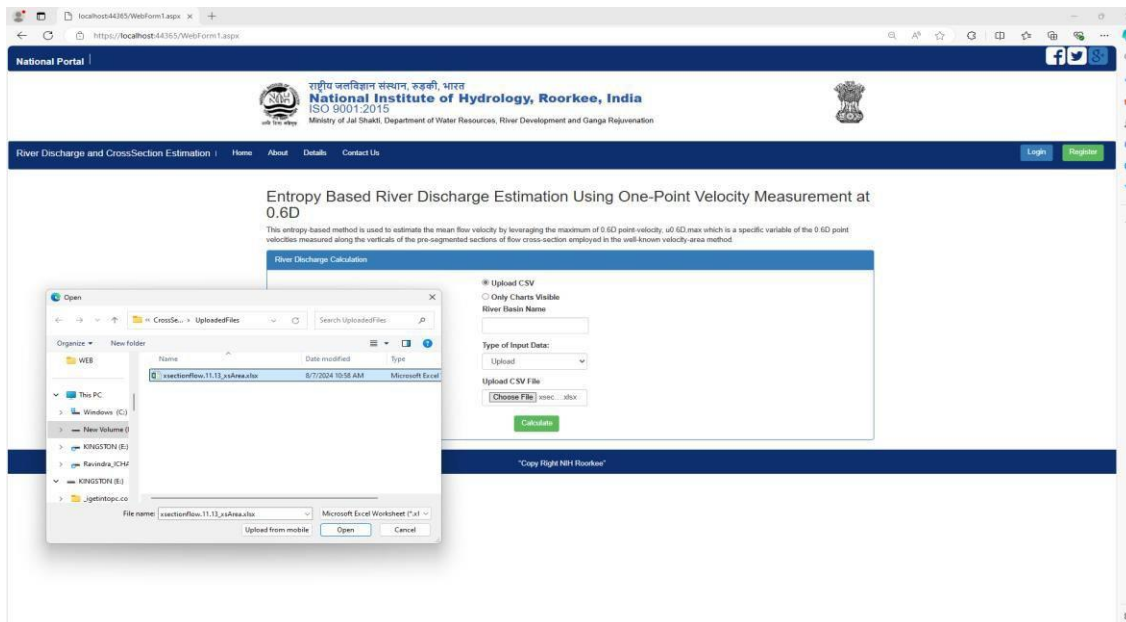


Figure 2. The web-based application developed for non-contact entropy based river discharge estimation using one- point velocity measurement at 0.6d method.

- The mathematical development is carried out to improve approximate convection- diffusion wave (ACWD) method to compute discharge using only stage. The python based code is developed to apply this method. The ACDW method is subjected to numerous hypothetical test and its ability to correctly approximate the parameter $\partial y/\partial x$ is evaluated using the regression based approach between the model estimate and the benchmark solutions estimates of $(1/so) \partial y/\partial x$. This method is tested using available standard dataset. The results of this method using streamflow data from USA is shown in Figure 3.

Future works to be undertaken:

- The investigation of proposes a novel method of computing river discharge based on the maximum surface velocity recorded using a non-contact-based measurement at a singular water surface point is under progress. This method will be coded in the python software.
- The procurement of 05 set of Water Level Radar (WLR) and Surface Velocity Radar (SVR) is under progress. Already supply order for the selected firm is sent through GeM portal. In the month of April/May field investigation will be carried out to install this procured equipment's for measurement of discharge and stage in the field at selected G&D sites.
- Image-processing based discharge measurement techniques will be applied and tested by CWPRS, Pune. They have not signed MoU between CWC and NIH as previously invesiaged. However, they have willing to participate in this study. The required formalities on the part of CWPRS may be completed in near future by them.

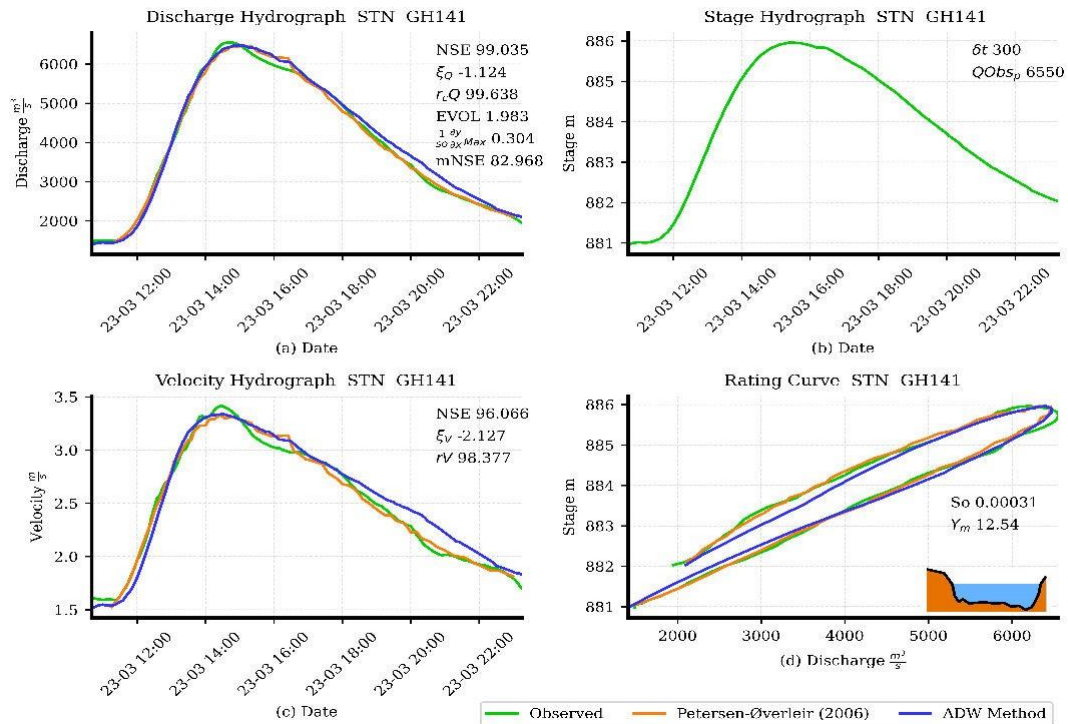


Figure 3. Typical results of ACWD method.

10. Research outcome of the project

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.

11. End Users/Beneficiaries of the study:

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.

3.0 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
Scientific Staff:	Er . Shivangi Barsainya

3. Type of Study: Internal Study

4. Duration: Three years (April, 2024- March, 2027)

5. Budget: Rs. 41,25,000/-

6. Statement of Problem

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.

7. Objectives:

1. 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.
2. To establish a proficient 2D hydrodynamic model such as TUFLOW (Classic) model to generate flood inundation map.
3. To evaluate performance of coupled WRF ensemble with 2D hydrodynamic model to enhancing

flood inundation forecasting capabilities during extreme flood event.

8. 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.

9. Brief 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.

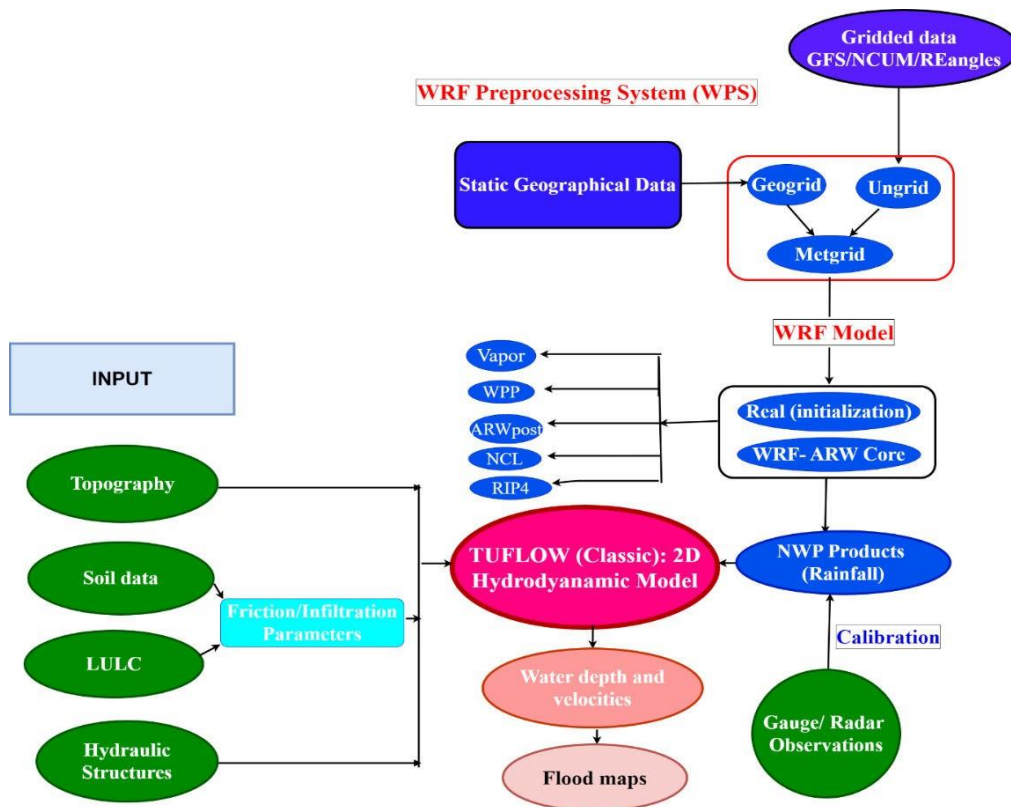
2D Hydrodynamics Model:

- 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 detailed methodology that will be followed in this study is presented in the below flow chart.

- 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.

Action plan

Work Element	1 st Year				2 nd year				3 rd 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			

10. Progress of work and conclusions

Objective (a) # 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. [Under Progress] A thorough literature review of the river has been carried out to formulate the research approach in the present study. The Weather Research and Forecasting (WRF) model is a numerical weather prediction system designed for both atmospheric research and operational forecasting. It incorporates multiple physics schemes and data assimilation techniques to provide high-resolution weather predictions. The model setup involves the use of gridded datasets from GFS, NCUM, and Re analysis, processed through the WRF Preprocessing System (WPS), which integrates static geographical data and applies Geogrid, Ungrid, and Metgrid tools. The WRF-ARW Core initializes the model using real-time meteorological data, enabling detailed rainfall forecasting. Post-processing tools such as ARWpost, RIP4, and NCL are utilized for analyzing and refining the outputs.

We have employed WRF with 6 km spatial grid resolution to generate high-resolution (hourly) ensemble rainfall forecasts for the Jammu region, specifically focusing on the Tawi River basin to simulate the 2014 high flood event in Tawi during 1-6 September 2021. Various ensemble members were analyzed to assess the reliability of rainfall predictions, which will be subsequently validated using observational data, including gauge and radar measurements. The processed rainfall outputs from WRF will subsequently use as inputs for the TUFLOW (Classic) 2D hydrodynamic model. Essential inputs such as topography, soil data, land use/land cover (LULC), and hydraulic structures were incorporated into TUFLOW, alongside friction and infiltration parameters, to enhance the accuracy of flood simulations

Objective (b) #Setting up-TUFLOW (Classic) Model for the study area [Under progress]

The TUFLOW (Classic) model for the Tawi River has been successfully set up for the area below Sidhara G&D site, covering an extensive reach of approximately 80 km from upstream of Jammu to its confluence with a Chenab river. This 1D-2D coupled model fully integrates the main river channel with the adjacent floodplain, allowing detailed flood dynamics simulation. The model incorporates 450 cross sections and accounts for key hydraulic structures, including 10 prominent bridges, ensuring accurate representation of flow interactions. The primary results achieved are shown in Figure 1.

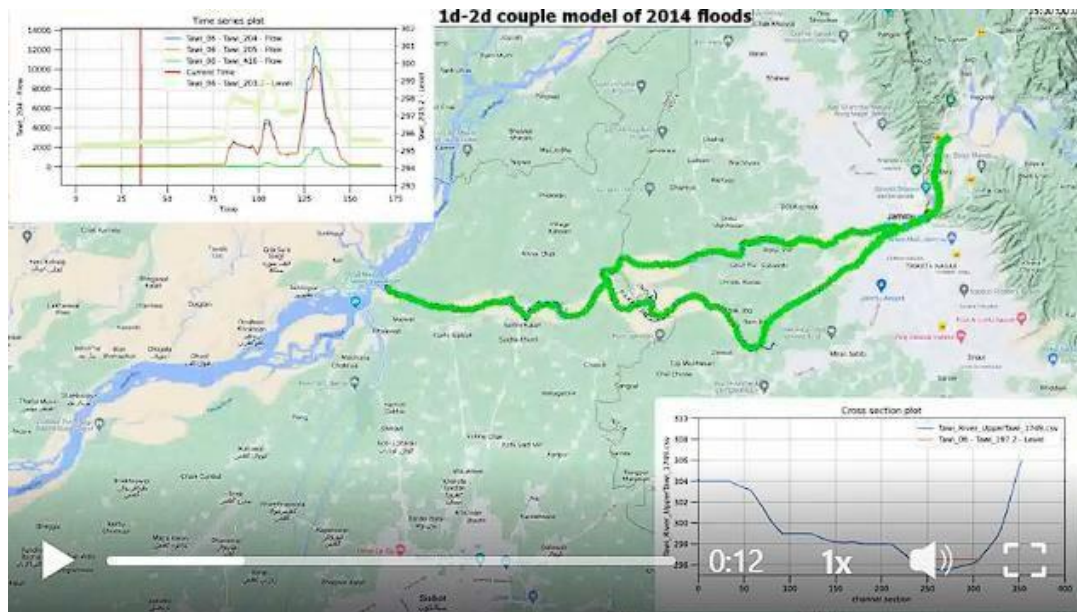


Figure 1. TUFLOW model simulation results for 2014 high flood event.

A significant challenge addressed in the model setup is the river's branching behavior, where a smaller branch goes dry during the simulation. TUFLOW's capability to handle dynamic wetting and drying conditions without instability has been successfully demonstrated. The model efficiently captures flow and water level variations, especially downstream of the Tawi Bridge, a crucial location where an iconic riverfront park is under development. The video plots showcase the flood event's impact, including water level distribution and flow split patterns in the river.

The study extent spans 1800 km², with a high-resolution 2D computational domain consisting of approximately 18.16 lakh (1.816 million) cells, each with a 30m resolution. The Digital Terrain Model (DTM) used for the simulation also has a 30m resolution, ensuring detailed topographic representation. The simulation duration covers a 7-day (167-hour) flood event, enabling comprehensive analysis of flood behavior over an extended period.

This set-up need further improvement to cover whole catchment area and also input from WRF model such as simulated hourly ensemble rainfall forecast data.

11. Future work for the next year:

- Improvement WRF model results
- Setting up-TUFLOW (Classic) Model for the study area
- Coupling of WRF-TUFLOW model

4. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-26

1. Title of Study: Basin-scale Integrated Water Resources Assessment through Integrated Hydrological Modelling

2. Study Group: S Sahoo, Sc-B, (PI)
A K Lohani, Sc-G, (Co-PI)
PC Nayak, Sc-F, (Co-I)
R V Kale, Sc-E, (Co-PI) and
J P Patra, Sc-E, (Co-PI)

3. Study Period: Two-and-half years (Apr-2024 to Sep-2026)

4. Objectives of the Study: The objectives of the study are as follows:

1. To set up the Soil and Water Assessment Tool (SWAT) for modelling and assessment of surface water
2. To set up the Modular three-dimensional finite-difference ground-water flow model (MODFLOW) for modelling and assessment of subsurface water
3. To perform integrated hydrological modelling based on already set SWAT and MODFLOW models
4. To evaluate various reanalysis data products for hydrological modeling and thus identify the best datasets for Indian condition
5. To perform integrated water resources assessment at basin-scale

5. Statement of the Problem:

In many river basins worldwide, the lean season surface water (SW) resources are depleting at an alarming rate due to the anthropogenic land use land cover (LULC) change. The impact is directly visible on the SW resources (river discharge). However, in most of the non-glacial perennial streams the dry season flow is sustained by aquifer discharge from groundwater (GW) resources. Further, urbanisation and decrease in forest land cover has resulted in decrease in recharge pattern. Hence, rather than traditional approach of considering the SW and GW as separate components, to combat the water management challenges in upcoming times, both SW-GW components must be considered as single entity. On this note, this study attempts to propose a framework for integrated assessment of both SW-GW resources through integrated modelling framework using in situ, or alternate data products.

6. Methodology:

The overall methodological framework to achieve the above objectives is detailed in Figure 1.

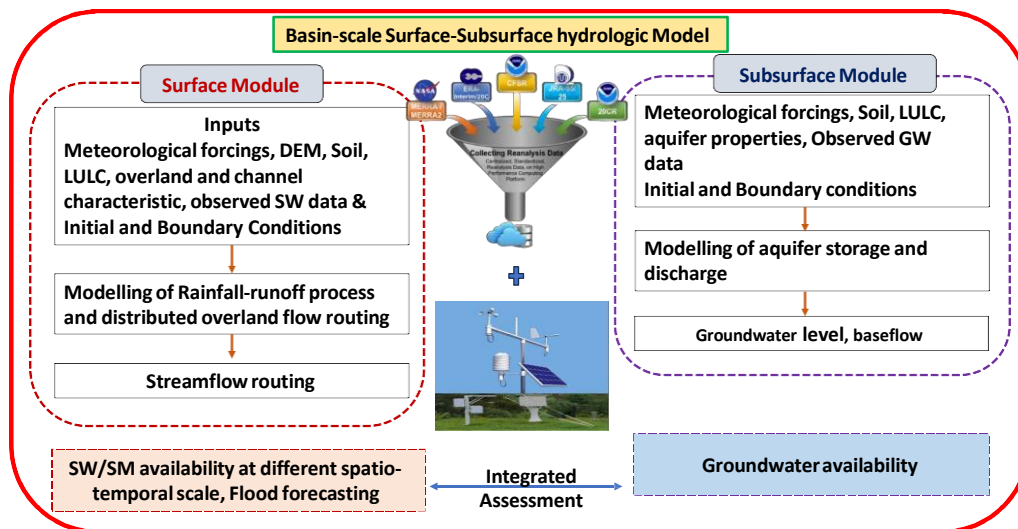


Fig. 1. Overall methodological framework to be followed for the integrated water resources assessment at basin-scale.

7. Study Area and Data:

The study area considered herein is the Baitarani River basin, originating from the Eastern Ghats and draining to the Bay of Bengal, spanning over 12,800 km².

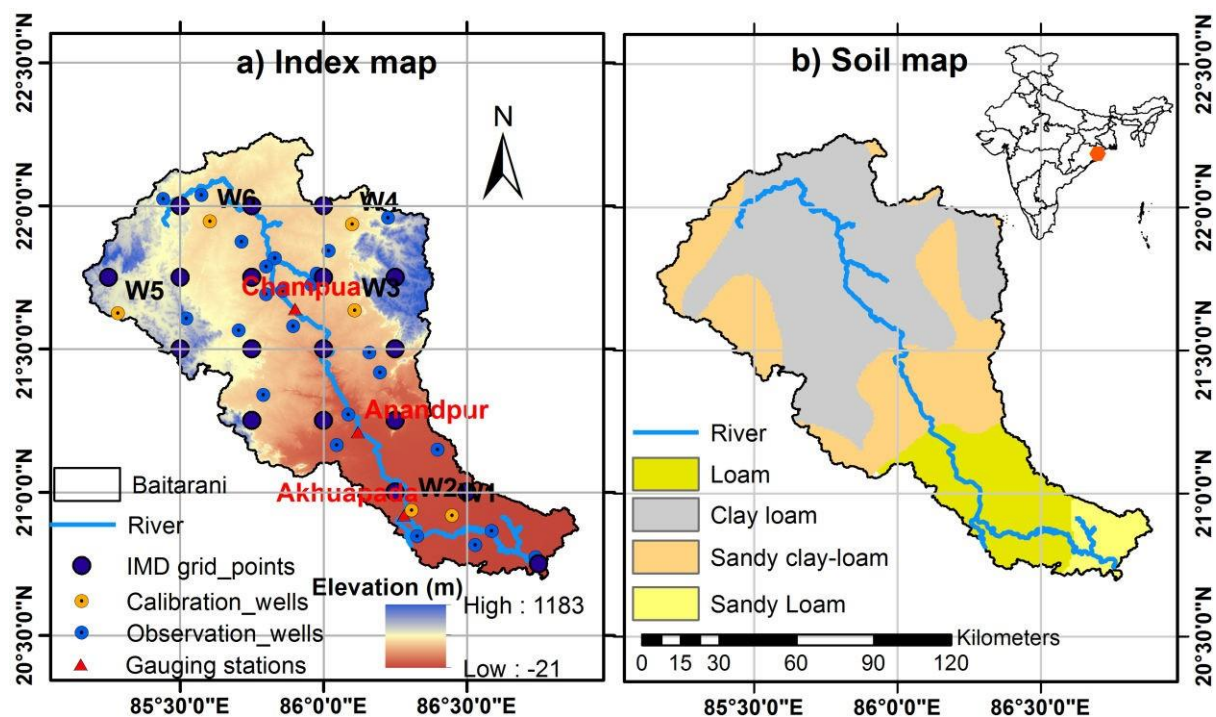


Fig. 2. (a) Index-cum-elevation map with the streamflow gauging stations, groundwater observation wells, and observed meteorological grid points; and (b) Soil map of the Baitarani River basin.

The different data used in this study and setting up of the SWAT model can be categorized as topography and land use land cover, soil, meteorological, and hydrological as detailed in Table 1. SWAT input files in desired format were prepared using the data detailed in Table 1.

Table 1. Data sources for setting up the surface water model

Data type	Source	Data Description	Resolution
Topography	U.S Geological survey https://earthexplorer.usgs.gov/	Digital Elevation Model (DEM)	30 m
Land Use /Land cover	Odisha Remote Sensing Application Centre (ORSAC)	Land use and Land cover Distribution	30 m
Soil	NBSS-LUP and ORSAC	Soil Properties	
Meteorological	National Aeronautics and Space Administration from https://power.larc.nasa.gov/data-access-viewer/ India Meteorological Department, Pune https://www.imdpune.gov.in/lrfindex.php	Daily Max., Min Temperature, Daily Humidity, Daily Wind speed, Daily Solar radiation Daily Rainfall	
Hydrological	Water Resource Information System of India https://indiawris.gov.in/wris/#/RiverMonitoring	Daily discharge data	

8. Progress:

The tasks proposed to be completed by 1st year were: i) Literature survey; ii) Data collection, preliminary analysis, and input data preparation; iii) Surface Water module setup; iv) Technology dissemination. The literature survey has been performed to identify the recent developments in the domain of integrated modelling of the surface water-groundwater systems. Further, it will be updated with upcoming publications before the closing of this study. The preliminary data processing steps to set up the surface water module (the Soil Water Assessment Tool, SWAT in this case) have been completed. The SWAT model has been set up for the study basin. Historical land use land cover (LULC) change has been assessed, and it was observed that built-up and barren land classes are expanding. As a part of technology dissemination, a 5-day training course has been conducted on ‘Hydrological Modelling using Satellite-Based and Reanalysis Data Products’. A total of 29 participants completed the course. They were taught the basics of reanalysis, satellite-based data, and hydrological modelling using such data products.

9. Results and Analyses

As a task of the Objective #1, the SWAT model was set up to reproduce the observed discharge hydrograph at the Akhuapada gauging station at the downstream region. Ranking of the different parameters were obtained through sensitivity analysis. The following parameters were considered following literature and looking into the dominant process in the considered basins. The parameters are CN2.mgt, CH_K2.rte, CH_N2.rte, ESCO.hru, OV_N.hru, SOL_K.sol,

SOL.AWC.sol, HRU_SLP.hru, ALPHA_BF.gw, GW_DELAY.gw, GWQMN.gw, and SURLAG.bsn. During both calibration and validation, the model performed with $NSC > 0.55$ and $RMSE < 450 \text{ m}^3\text{s}^{-1}$.

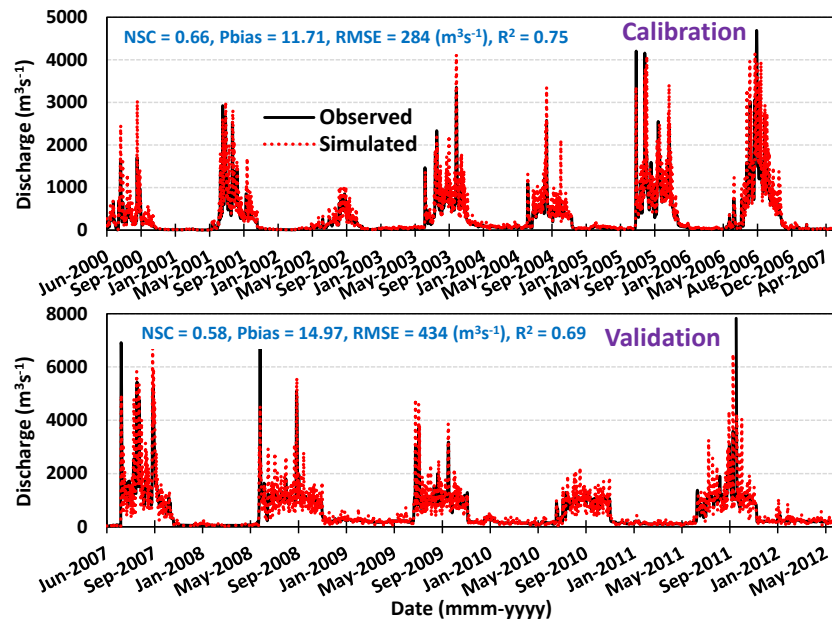


Fig. 3. Calibration and validation of SWAT model to reproduce the observed discharge at the Akhuapada gauging station.

- 10. End users/beneficiaries of the Study:** Central and State government departments, Water users' associations, policy makers.
- 11. Deliverables:** Report/Manual, Publication

7. PROJECT REFERENCE CODE: NIH/SWHD/NIH/24-25

1. Title of Study: Web based platform for IDF Design Rainfall Estimates for India

2. Study Group: Sukant Jain, Sc-C, PI
A.K. Lohani Sc-G, Co-PI
J. P Patra, Sc E Co-PI
Richa Pandey Sc B Co-PI
Chandra Prakash Sc B Co-PI
3. Study Period: 1.5 Years (April 2024 to Sept 2025)

4. Objectives of the Study

The primary objective of this study is to develop a nationwide web-based platform to streamline access to Intensity-Duration-Frequency (IDF) curves and Probable Maximum Precipitation (PMP) data for India. Specific goals include:

1. **Data Integration:** Utilize gridded historical and projected rainfall data to estimate IDF values for diverse durations (e.g., 1-hour to 72-hour) and return periods (e.g., 2– 1,000 years).
2. **Climate Resilience:** Evaluate the impact of climate change on design storms under scenarios such as SSP2-4.5 and SSP5-8.5 to support future-proof infrastructure planning.
3. **User Accessibility:** Create an intuitive platform to enable engineers, hydrologists, and policymakers to extract location-specific IDF curves, SPS and PMP values without manual data processing.
4. **Standardization:** Establish guidelines for integrating climate projections into design rainfall assessments, addressing a critical gap in current Indian hydrometeorological practices.

5. Statement of the Problem

In India, estimating design floods for hydraulic structures (e.g., dams, stormwater drains) relies on hydrometeorological approaches using unit hydrographs and design storms.

However, stakeholders face significant challenges:

- **Time-Consuming Data Retrieval:** Users manually extract design storm data from static isohyet maps or PMP atlases published by the Central Water Commission (CWC), leading to inefficiencies.
- **Lack of Climate Adaptation:** Existing guidelines do not account for future rainfall variability under climate change, risking under-designed infrastructure.

3. Methodology

The study adopts a **four-phase approach**:

1. Data Acquisition & Processing:

- Extract **hourly rainfall data** from ERA5 (ECMWF reanalysis) and IMDAA (IMD's high-resolution assimilated dataset).
- Use **IMD daily gridded rainfall data** (0.25° resolution) to identify optimal probability distribution functions (e.g., Gumbel, Generalized Extreme Value etc) for IDF curve development.

2. IDF Estimation:

- Apply the **Annual Maxima Series (AMS)** method to derive rainfall intensities for durations (1–72 hours) and return periods.

3. PMP Atlas

- Extracting the Grid based PMP and SPS design rainfall values of PMP atlases of various Basins in India by CWC

4. Climate Projection Integration:

- Incorporate CMIP6 climate models to assess shifts in design storms under SSP scenarios.

5. Platform Development:

- Develop a **web portal** using Python (Flask backend), JavaScript, and CSS/HTML for interactive visualization.
- Enable users to select coordinates, adjust climate scenarios, and download IDF/PMP values in standard formats (CSV, JPEG).

4. Progress

To date, the project has achieved the following milestones:

- **Data Collection:** Hourly rainfall data for India has been retrieved from ERA5 and IMDAA.
- **Distribution Analysis:** Best-fit probability distributions were identified using IMD gridded data.
- **PMP Extraction:** Gridded PMP and SPS values for the Ganga Basin have been extracted from the atlas.
- **Prototype Development:** A beta version of the web portal has been built, allowing users to visualize IDF curves for select location (e.g., Points or GeoJson).
Next Steps: Scaling the platform to cover all Indian grids and integrating climate projection modules.

5. End Users/Beneficiaries

The platform will serve:

- Government Agencies /Civil Engineers/ Urban Planners/ Academic Researchers

6. Deliverables

1. **Web Platform:** Interactive portal for extracting IDF curves, PMP, and SPS values (live URL hosted on a server).
2. **Gridded Database:** Open-access repository of IDF values (historical and projected) for all Indian grids.
3. **Technical Reports:** Guidelines for integrating climate change into IDF analysis

NEW STUDIES (INTERNAL)

1. PROJECT REFERENCE CODE: NIH/SWHD/NIH/25-27

1. Title of Study: Application of Annual Flow Duration Curves (AFDC) in Flood Flow and Low Flow Frequency Analysis

2. Study Group:

Sanjay Kumar, Sc. F
J. P Patra, Sc. E
Ravindra V. Kale, Sc. E
L. N. Thakural, Sc. E
Soumyaranjan Sahoo, Sc. B

3. Study Period: Two Years (April 2025 to March 2027)

4. Objectives of the Study: The objectives of the study are:

1. Non-Parametric and Parametric flood flow frequency analysis using AFDC.
2. Non-parametric and Parametric low flow frequency analysis using AFDC.

5. Statement of the Problem:

Annual Flow Duration Curves (AFDC) provides a graphical view of overall historical annual 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 and estimation of maximum and low flows for design purposes.

The AFDCs provide a generalized alternative for estimating the magnitude and frequency of the complete continuum of daily streamflow ranging from the T-year annual maximum to T- year annual minimum low flows. The subsequent section describes the methodology how an AFDCs can be used to estimate extreme design events.

6. Methodology:

In a given particular year, an unbiased estimation of the expected probability of exceedance associated with largest observed average daily flow (annual maximum flow q_1) using order statistics and Weibull plotting positions is $p = 1/(n+1)$ i.e. $1/366 = 0.00273$. Similarly an unbiased estimation of the expected probability of exceedance associated with smallest observed average daily flow (annual Minimum flow q_n) is $p = n/(n+1)$ i.e. $365/366 = 0.99726$.

Thus the distribution of distribution of annual maximum average daily flood flows is given by $Q_{p,e}$ with $p = 0.002732$ and the distribution of annual minimum average daily low flows is given by $Q_{p,v}$ with $p = 0.99726$. The nonparametric (for n numbers of years) and parametric methods will be used to estimate the different T year (2, 10 20, 25, 50 years) maximum flood flows and minimum low flows. A comparison will be made with parametric method (log Pearson (LP3)) of maximum and low flows.

7. Data Requirements:

Daily discharge data. Data sources would be from field organization (CWC or State Water Resources Department) and related literature.

8. Action Plan and Timeline:

S.N.	Major Activities	1 st Year		2 nd Year	
1	Literature review				
2	Development of annual flow duration curves (AFDC)				
3	Non-Parametric and Parametric flood flow frequency analysis (Interim Report)				
4	Non-Parametric and Parametric low flow frequency analysis.				
5	Estimation of flood and low flows corresponds to different return periods. (Final Report).				

9. End users/beneficiaries of the Study: Central and State government departments, academicians, BIS etc.

10. Deliverables: Report/Manual, Publications

2. PROJECT REFERENCE CODE: NIH/SWHD/NIH/25-27

1. Title of the Project: Development of Web-based Baseflow Separation Analysis Tool.

2. Project team:

Project Investigator:	Dr. Ravindra.Vitthal Kale, Sc. E, SWHD
Project Co-Investigator(s):	Dr. Sanjay Kumar, Sc. F, SWHD Dr. A. K. Lohani, Sc. G & Head, SWHD Dr. M. K. Goel, Director, NIH Roorkee
Scientific Staff:	Er. Shivangi Barsainya

3. Type of Study Internal Project (NIH)

4. Duration 02 years (April 2025 to March 2027)

5. Budget Rs. 27,10,000/-

6. Objectives:

The primary objectives of this project are as follows:

1. Develop a web-based baseflow separation tool using multiple baseflow separation techniques that can process streamflow data and generate baseflow separation results.
2. To developed the Master Recession Curve Parameterization tool in Python that allows for a comparison between recession analysis methods
3. Use Python for backend computations, including implementing baseflow separation algorithms and handling data processing.
4. Use React for frontend development to provide an interactive, user-friendly graphical user interface.
5. Develop an interactive user interface that enables users to upload streamflow datasets in various formats (e.g., CSV, Excel), visualize the results graphically, and interactively explore and choose the optimal outcomes.

7. Present state-of-art:

Hydrological studies often require the separation of streamflow into direct runoff and baseflow components. Baseflow represents the portion of streamflow that comes from groundwater contributions, which is important for understanding long-term water availability and managing water resources. Several methods for baseflow separation exist, including the Eckhardt method, the Lyne & Hollick method, and the recursive digital filter method, but these are often implemented in desktop software or custom scripts that require technical expertise.

There is a growing need for a user-friendly, accessible, and efficient tool for performing baseflow separation. This research proposes the development of a web-based tool that simplifies this process by allowing users to upload streamflow data, choose from a range of baseflow separation techniques, and visualize the results through an intuitive interface.

8. Methodology

8.1 Backend Development (Python):

The backend will be implemented using Python, a language widely used in scientific computing and data analysis. The following components will be developed:

1. **Baseflow Separation Algorithms:** The web-based tool will implement well **recognized baseflow separation algorithms**. Some of well-known methods which will be available for users to choose from will be
 - **Eckhardt Filter Method:** A recursive filtering algorithm to determine baseflow.

- **Lyne & Hollick Filter Method:** Another popular baseflow separation method implemented using a digital filter.
 - **Recursive Digital Filter (RDF):** Implementation of the iterative filter method.
 - **Hydrograph Separation Method:** A graphical method to estimate baseflow contributions by visualizing the hydrograph.
 - **Woods Method:** A recursive moving average filter method.
 - **Digital Filter Method:** A low-pass filter to isolate baseflow from total streamflow.
 - **Master Recession Curve Parameterization:** this tool will offers automated resources to perform: (i) hydrograph separation using numerical filters; (ii) automatic extraction of recession periods; (iii) creation of the MRC with the matching strip method; (iv) creation of the MRC for different flow classes defined from the flow duration curve; (v) analysis of flow recession rates ($-dQ/dt$) as a function of flow (Q); and (vi) creation of the MRC from simulated recession curves with different analytical approaches, including linear and nonlinear models.
2. **Data Handling and Processing:**
 - File upload functionality for users to submit streamflow data in formats such as CSV or Excel.
 - Data validation and error handling to ensure that the uploaded data is in a suitable format.
 - Computation of baseflow separation results, which will be returned as JSON data for easy integration with the frontend.
 3. **Backend Framework:**
 - Use **Flask** or **FastAPI** as the web framework to handle HTTP requests, data processing, and API responses.
 4. **Database (Optional):**
 - Implement an SQLite or PostgreSQL database to store user-uploaded datasets and results for later retrieval.

8.2 Frontend Development (React):

The frontend will be developed using **React**, a powerful JavaScript library for building user interfaces. Key frontend features will include:

1. **User Interface:**
 - Upload form for users to submit streamflow data.
 - Dropdown or radio buttons to select the desired baseflow separation method.
 - Real-time visualizations of the input data and baseflow separation results
2. **Real-time Data Visualization:**
 - Interactive plots to visualize the baseflow separation results and compare different methods.
 - Graphical user interface (GUI) to interact with the backend, submit requests, and display results.

8.3 Testing and Deployment:

- **Testing:** Unit tests will be developed for both the frontend (using Jest) and backend (using pytest).
- **Deployment:** The application will be deployed on a cloud platform for accessibility and scalability.

9. Expected Outcome:

- A fully functional web-based tool for baseflow separation, capable of processing data and generating real-time results.

- Users will be able to easily upload streamflow data, perform baseflow separation, and visualize the results.
- The tool will be flexible, allowing users to choose from **various different baseflow separation techniques** and compare their results.
- A report generation feature, where users can download their analysis results in a standard format.

10. Cost estimate:

- Total cost of the Rs. 27,10,000/-
- Source of NIH internal funds
- Sub Head wise abstract of the cost

Sr. No.	Resource	Estimated Cost (INR)
1.	Developer Salary (JRF/SRF/Research Associate)	12,50,000
2.	Travelling expenditure	10,000
3.	Data procurement	NIL
4.	Infrastructure/Equipment/software	12,00,000
5.	Training/workshop	2,00,000
7.	Misc. expenditure (Hosting, Licenses)	50,000
	Grand Total:	27,10,000

11. Work Schedule:

- Probable date of commencement of the project: April, 2025
- Duration of the project: 02 years (2025-2027)
- Stages of work and milestone:

Work Element	1st Year				2 nd year			
	1	2	3	4	1	2	3	4
Literature Review and detailed formulation of research approach								
Backend algorithm development								
Frontend development (UI & Visualizations)								
Integration of frontend and backend								
Testing and Debugging								
Deployment and Finalization								
Report writing	1st interim report				Final report			

3.PROJECT REFERENCE CODE: NIH/SWHD/NIH/25-27

1. Title of the Project: Development of Integrated Flood Analysis and Mapping System (I-FAMS) for India

2. Project Team

Principal Investigators : Dr. Ravindra V. Kale, Sc. E, SWHD
Co-Principal Investigators : Dr. A. K. Lohani, Scientist-G & Head, SWHD
Dr. M. K. Goel, Director, NIH
Dr. J. P. Patra, Sc. E., SWHD
Dr. P. C. Nayak, Sc. F., SWHD

3. Type of Study: Internal Study [NIH]

4. Duration 02 years (April 2025 to March 2027)

5. Budget Rs. 20,10,000/-

6. Objectives

The broad objective of the present study is to provide information on potential flood water maps, flood ages, and flood depths to improve decision-making on flood preparedness and humanitarian response. The detailed objectives are as follows

1. To develop an advanced web-based flood mapping and analysis system at river basin and sub-basin levels that integrates satellite based geospatial data.
2. To utilize optical and SAR satellite imageries and remote sensing and machine learning techniques for generation of flood inundation extent maps for flood monitoring and prediction.
3. Estimation of water depth using FwDET (Flood Water Depth Estimation Tool) methodology.
4. Analysis and classification of Land Use and Land Cover (LULC) outputs using Machine Learning techniques on optical satellite imagery.
5. Integration of precipitation and forecast data from IMD and satellite sources for better flood mapping and response.
6. To incorporate an automatic watershed delineation algorithm, applicable for delineating multiple watersheds of different sizes, and using only flow directions and outlet coordinates as inputs.
7. To enhance public awareness and preparedness through a user-friendly web-based platform.

6. Statement of the problem

India experiences severe and frequent flooding, affecting millions of people and causing significant economic and environmental damage. The increasing unpredictability of rainfall due to climate change exacerbates flood risks. An advanced flood analysis and mapping system is essential for effective flood risk management. However, current flood analysis systems often lack real-time spatial data and integrated analysis capabilities. This research aims to develop an Integrated Flood Analysis and Mapping System (I-FAMS) tailored to India, inspired by the successful implementation of HydraFlood in the Mekong River system. This system will aid in early response planning, risk assessment, and long-term policy formulation to mitigate flood impacts.

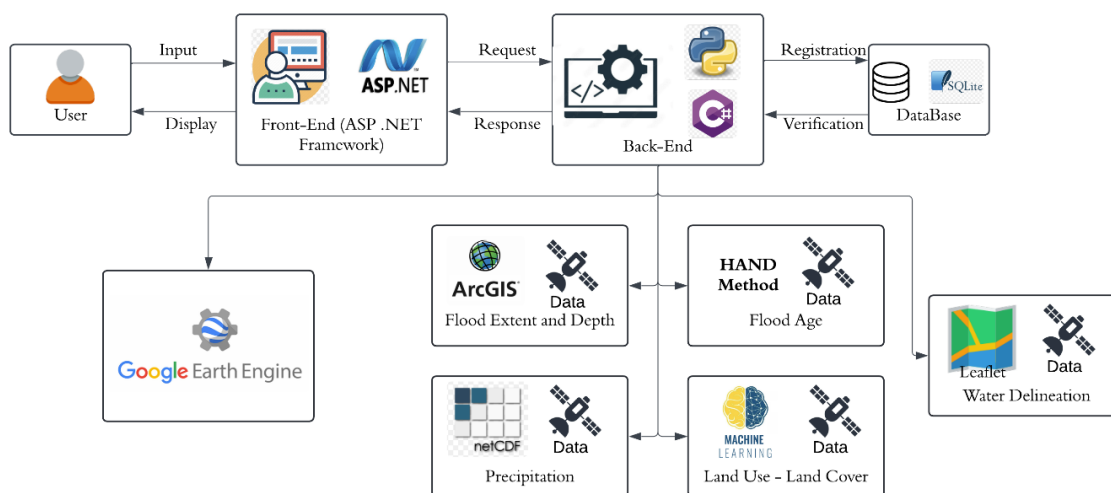
7. Brief Methodology

The development of I-FAMS for India will follow the methodologies adopted in HydraFloods, incorporating satellite remote sensing, hydrological modeling, and advanced data analytics. Key steps include:

- **Data Collection and Preprocessing:**

- **Satellite Imagery** acquisition:
 - a) Optical and Microwave satellite (such as Sentinel-1 SAR) imageries (flood inundation extent)
 - b) Sentinel-2 and Landsat optical imagery (LULC classification)
- **DEM Data:**
 - c) SRTM/Copernicus/ and ALOS PALSAR DEM from Google Earth Engine (GEE)
- **Precipitation and Forecast Data:**
 - d) From IMD and satellite-based platforms (such as GFS/ERA-5 etc.)
- **Historical Flood Data:**
 - e) Satellite-derived flood maps and available flood maps from central/State government agencies
- **Flood Extent and Depth Mapping:**
 - a) Use Synthetic Aperture Radar (SAR) and optical satellite images to detect water bodies and flooded regions.
 - b) Employ AI-based image classification and deep learning models to extract flood extent.
 - c) Application of FwDET (Flood Water Depth Estimation Tool)
 - Inputs: DEM data and flood extent polygons
 - Outputs: Spatial water depth maps for the flood-affected areas
 - d) Cross-validate data with ground observations and hydrological models (if available).
- **Hazard and Risk Assessment Mapping:**
 - a) Generate flood hazard maps by analyzing historical flood trends and vulnerability data.
 - b) Incorporate land use, population density, and infrastructure datasets to assess flood impact.
 - c) Develop dynamic maps that update with new flood events.
- **LULC Classification:**
 - a) Using **Machine Learning algorithms** (Random Forest / SVM) for classification of Sentinel-2 and Landsat imagery
 - b) Generation of **current land use maps** for impact assessment and flood risk analysis
- **Automatic watershed delineation** using only flow directions and outlet coordinates as inputs
- **Integration and Analysis:**
 - Combined analysis of flood extent, water depth, LULC, and precipitation datasets
 - Mapping and visualization using **web-based GIS tools**
 - Validation using historical data and field data (where available)

The workflow used to achieve the proposed objectives are shown as below.



8. Cost estimate:

- (i) Total cost of the project : Rs. 20,10,000/-

- (ii) Source of funding : NIH internal funds
 (iii) Sub Head wise abstract of the cost

Sr. No.	Resource	Estimated Cost (INR)
1.	Developer Salary (JRF/SRF/Research Associate)	12,50,000
2.	Travelling expenditure	10,000
3.	Data procurement	NIL
4.	Infrastructure/Equipment/software	5,00,000
5.	Training/workshop	2,00,000
7.	Misc. expenditure (Hosting, Licenses)	50,000
	Grand Total:	20,10,000

9. Action Plan/Timeline

- Probable date of commencement of the project: April, 2025
- Duration of the project: 2 Years (2025-2027)
- Stages of work and milestone:

Work Element	1 st Year				2 nd year			
	1	2	3	4	1	2	3	4
Data Collection and Preprocessing								
Flood Extent and Depth Mapping								
Hazard and Risk Assessment Mapping								
Integration of precipitation and forecast data								
Validation and comparison with historical flood records								
Web-based application development for IFAMS visualization								
Testing, Validation, and Deployment								
Report writing	1st interim report				2nd interim report			

10. Expected outcome of the project

A user-friendly web-based interface enables stakeholders to visualize flood-prone areas and access crucial data, aiding in disaster preparedness and response. Additionally, IFAMS incorporates socio-economic vulnerability assessments, ensuring targeted risk management. Its scalability allows adaptation to diverse river basins, making it a vital tool for national and regional flood mitigation efforts. By supporting near real-time decision-making and strengthening disaster response frameworks, IFAMS plays a crucial role in minimizing flood-induced damages and enhancing resilience across India.

11. End Users/Beneficiaries of the study:

- Central and State Government Departments (Central Water Commission (CWC), the National Disaster Management Authority (NDMA), and state disaster management departments, Irrigation, Agriculture departments etc.)
- Academics and Research Institutions

- Urban Planners and Development Authorities
- NGOs and Disaster Response Agencies
- Vulnerable communities in flood-prone regions

12. Significance of the Study

By implementing I-FAMS, India can achieve a more effective flood risk management strategy, ultimately reducing the socioeconomic impact of floods. This system will provide policymakers, emergency responders, and communities with crucial insights for making informed decisions.

13. Deliverables:

- India Flood Analysis and Mapping System (IFAMS): A web-based GIS platform
- Water Depth and Flood Inundation Maps
- Land Use / Land Cover Maps
- Technical Reports and User Manuals
- Publications in Peer-Reviewed Journals

4. PROJECT REFERENCE CODE: NIH/SWHD/NIH/25-28

1. Title of the Project – An Integrated approach for Irrigation Scheduling in a Command area

2. Project team:

Project Investigator

Dr. L. N. Thakural, Sc-E, PI

Co-PI Project Co-Investigator(s)

Sh. Sukant Jain, Sc-C

Dr. Sushindra Kumar Gupta, Sc-C

Dr. Richa Pandey, Sc-B

Dr. Sanjay Kumar, Sc-F

Sh. Gaurav Kumar, RA

3. Objectives-

- To classify the major crops in a command and to obtain area under each crop using multi-temporal satellite data.
- To analyze historical and projected future trends in Evapotranspiration (ET).
- To develop predictive evapotranspiration models using ensemble machine learning algorithms (e.g., CART, RF, & SVM).
- To evaluate the Crop Water Requirements and Irrigation scheduling under changing scenarios.

4. Present state-of-art

Irrigation is of paramount importance in development of agriculture. Scientific irrigation scheduling is a tool used for improved irrigation water management. When used properly, it indicates when to irrigate, how much water to apply, and how to apply water to satisfy crop water requirements and to avoid plant moisture stress and, in turn, the crop yield. India has a unique agro-climate permitting the cultivation of variety of crops adapted to tropical, subtropical, temperate, semi-arid and arid environments. The scarcity of available land and water resources due to growing population has necessitated its proper planning and management. Inadequate and uneven distribution of available water resources results in frequent crop failures and shortage of fodder and drinking water. Attempts have been made to predict water availability to overcome the problems created due to temporal and spatial variations of rainfall. According to field researches, high crop yields are attainable even when water supplies are limited, if irrigation scheduling is based on an understanding of crop water needs and responses in a given environment [CBIP, 1991].

For optimizing yield vis-à-vis the available water resource, it is essential to assess the timing of crops needing water so that they are not irrigated arbitrarily, and thus, creating scope for irrigation scheduling, the primary decision tool to maximize irrigation efficiency. The irrigation schedule allows the application of exact amount of water needed to replenish the soil moisture to the desired level to enhance crop yield and, in turn, to save water and energy. The usefulness of remote sensing technique in derivation of information on land use, irrigated area, biomass development, crop type, crop water requirements, salinity, and water logging etc. has been recognized in various investigations [Bastiaanssen et al., 2000]. Such information is potentially useful in water distribution planning, performance diagnosis and impact assessment [Bastiaanssen et al., 2000].

Morten et al. (1984) carried out irrigated crop inventory by using classified satellite image data for determining area of crop land under irrigation in an arid region of the state of New South Wales in Australia. Kuo, et al. (2006) has estimated irrigation water requirements for ChiaNan Irrigation Association, Taiwan, using CROPWAT irrigation management model for paddy and upland crops.

The present study is primarily carried out for assessment of crop acreage, crop water requirements, and irrigation need for scheduling of irrigation in a command area. Multi-temporal imagery from remote sensing will be used for deriving the actual cropping pattern in the command

area; and reference evapotranspiration, crop water requirement, and irrigation requirement which are sequentially responsible for irrigation scheduling.

5. Methodology-

Collection, processing and analysing the multi temporal satellite data for classification of the crop acreage to be used as input for the model in geospatial technique and gather historical and projected climate data viz. temperature, wind speed, humidity, and solar radiation and apply the relevant evapotranspiration equation for ET estimation and employing the statistical trend analysis methods to identify trends and perform time-series analysis to assess variations in ET over time and to assess potential changes in crop water demand. Thereafter comparing projected ET trends with historical values and evaluate the implications of future ET variations on irrigation scheduling and water resource allocation.

Classification and Regression Trees (CART).

It's a decision tree algorithm that can be used for both classification and regression tasks. CART constructs binary trees and is known for its simplicity and effectiveness. The splitting rule in regression trees is made in accordance with the squared residuals minimization algorithm, which means that expected sum variances for two resulting nodes should be minimized (Timofeev., 1984)

$$\begin{aligned} & \operatorname{argmin} [P_i \operatorname{Var}(Y_i) + P_r \operatorname{Var}(Y_r)] \\ & x_j \leq x_j^R, j = 1 \dots \dots \dots M \end{aligned} \quad (1)$$

Where $\operatorname{Var}(Y_i)$ and $\operatorname{Var}(Y_r)$ are response variables for corresponding child nodes of a parent node, x_j is variable j ; x_j^R is the best splitting value of variable x_j ; M is number of variables x_j . x_j^R and $j = 1 \dots$; and M is an optimal splitting question which satisfies Eq. (1).

Random forest (RF)

RF is a powerful machine-learning algorithm that can be utilized for groundwater prediction (Gupta et al., 2024; Naghibi et al., 2017). RF belongs to the ensemble learning family, where multiple decision trees are combined to form a robust predictive model (Breiman, 2001). In the context of groundwater prediction, RF can help analyze and interpret complex datasets to make accurate predictions about groundwater levels, quality, or other relevant parameters. One of the significant advantages of using RF for groundwater prediction is its ability to handle large and high-dimensional datasets with diverse input variables (Catani et al. 2013).

Support Vector Machine (SVM) Model

SVM model is most widely used for the estimating complex problem in the form of nonlinear classification, estimation and function and density estimation (Sihag et al., 2019). It uses a linear model to distribute sample data set in the form of non-linear mapping from the input vectors into the high-dimensional feature space according to the structural risk minimization (SRM) principle (Singh et al., 2019). The basic equation of SVM for regression scenario analysis as given below

$$F(x) = W.T_f(x) + b \quad (2)$$

Where, W is the weight age vector, T_f is the nonlinear transfer function, which projects the put vectors towards a very high dimension feature space, and b is the constant variable.

Finally, estimation the crop water requirements, irrigation needs and scheduling the irrigation for the command area for different irrigation scenarios with varying cropping pattern using the CROPWAT model in the GIS environment.

6. Research outcome from the project

- The outcome of the study will help in estimation of crop water requirement and scheduling irrigation in a command area.
- Recommendations for long-term irrigation planning considering future ET dynamics.

7. Cost estimate:

a.	Total cost of the project	:	Rs. 16,00,000
b.	Source of funding	:	NIH internal funds
c.	Sub Head wise abstract of the cost		

S. No.	Sub-head	Amount (in Rupees)
1.	Travelling expenditure	10,00,000
2.	Infrastructure/Equipment	3,00,000
3.	Experimental charges	Nil
4.	Misc. expenditure	3,00,000
	Grand Total:	16,00,000

8. Work Schedule:

- a. Probable date of commencement of the project: April 2025
- b. Duration of the project: : 3 Years (April 2025 to March 2028)
- c. Stages of work and milestone:

S. No.	Work Element	First Year	Second Year	Third Year
1.	Literature survey and Data collection and selection of Command	*	*	
2.	Processing and analysis of hydrometeorological data, GIS database development and soil moisture	*	*	*
3.	Classification of the major crops using multi-temporal satellite data & field data.	*	*	
4.	Estimation of Crop Water Requirements using CROPWAT model and GIS.		*	
5.	Irrigation scheduling for the existing cropping pattern.		*	*
6.	Analysis for different irrigation scenarios with varying cropping pattern and Report writing			*

5. PROJECT REFERENCE CODE: NIH/SWHD/NIH/25-27

1. Title of Study: Evaluating Rain-On-Grid Hydraulic Modelling for Dam Break Analysis: A Comparative Study of HEC-RAS and TUFLOW in Indian Catchments

2. Study Group: Sukant Jain, Sc-C, PI
Chandra Prakash Sc-B, Co-PI
A.K. Lohani Sc-G, Co-PI

3. Study Period: 2.5 Years (April 2025 to Sept 2027)

4. Objectives of the Study: The objectives of the study are:

- Assess the effectiveness of rain-on-grid modelling for dam break flood simulation.
- Compare HEC-RAS and TUFLOW in terms of accuracy, computational efficiency, and usability for small/medium catchments.
- Evaluate how catchment scale (small vs. medium) influences model performance.

5. Statement of the Problem:

Traditional dam break and flood modeling in India predominantly relies on boundary conditions defined by flood hydrographs derived from hydrometeorological methods (e.g., unit hydrographs or event-based hydrological models). While practical, this approach simplifies flood dynamics by assuming water enters the system only through predefined streams, neglecting spatially distributed rainfall-runoff contributions across the floodplain. Consequently, it risks underestimating inundation extents and flow pathways, particularly in regions with intense, localized rainfall—a critical gap in disaster preparedness. The emerging rain-on-grid (ROG) approach addresses this by directly integrating rainfall into 2D hydrodynamic models, simulating overland flow from every grid cell. This not only enhances spatial accuracy but also reduces reliance on pre-calculated hydrographs, which are often data-intensive and prone to estimation errors.

Despite its advantages, ROG's applicability for dam break scenarios remains underexplored in India, with limited comparative studies evaluating industry-standard tools like HEC-RAS and TUFLOW. Furthermore, the influence of catchment scale (small vs. medium) on ROG performance is poorly understood, hindering its adoption in diverse hydrological settings. This study bridges these gaps by rigorously testing ROG-based dam break modeling across small and medium catchments using HEC-RAS and TUFLOW. By quantifying model accuracy, computational efficiency, and scalability, the research aims to provide actionable insights for improving flood risk management frameworks in India, where climate extremes and aging dam infrastructure demand robust, adaptive modeling solutions.

6. Methodology:

Data Collection:

- Topography: DEM (10m resolution or finer), land use/soil maps.
- Hydrometeorology: Historical rainfall data (IMD), dam breach parameters (e.g., breach width, time-to-failure).
- Validation Data: Historical inundation maps (if available) or synthetic benchmarks.

Model Setup: HEC-RAS 2D:

- Configure ROG using precipitation grid.
- Test multiple breach scenarios (sudden vs. gradual failure).

TUFLOW:

- Use Quadtree/GPU acceleration for efficient ROG simulation.
- Couple 1D channel networks with 2D overland flow.

Scenarios:

- Scenario 1: Dam break with traditional hydrograph boundary.
- Scenario 2: Dam break + ROG (spatially distributed rainfall).
- Sensitivity Tests: Vary rainfall intensity, breach parameters, and Manning's roughness.

Performance Metrics:

- Accuracy: Inundation extent/depth (compared to validation data).
- Efficiency: Computational time, stability.
- Usability: GIS integration, user-friendliness.

-
- 7. End users/beneficiaries of the Study:** Hydraulic engineers, Infrastructure developers, CWC, etc
 - 8. Data Requirements:** High Resolution DEM (NRSC), Rainfall Data, Discharge Data and Dam Parameters
 - 9. Deliverables:** Reports & Publications
 - 10. Cost Estimate:**
 - Total cost of the project : Rs. 20,00,000
 - Source of funding : NIH internal funds
 - Sub Head wise abstract of the cost

S. No.	Sub-head	Amount (in Rupees)
1.	Travelling expenditure	5,00,000
2.	Infrastructure/Equipment	5,00,000
3.	Experimental charges	Nil
4.	Misc. expenditure (Including Satellite data & others)	10,00,000
	Grand Total:	20,00,000

6. **PROJECT REFERENCE CODE: NIH/SWHD/NIH/25-26**

1. **Title of Study: Web-Based Flood Hydrograph Estimation Tool for Hydraulic Structure Design in India**

2. **Study Group:** Sukant Jain, Sc-C, PI
A.K. Lohani Sc-G, Co-PI

3. **Study Period:** **1.5 Years** (April 2025 to Sept 2026)

4. **Objectives of the Study:** The objectives of the study are:

1. Develop a **user-friendly Web GIS application** to simplify flood hydrograph estimation using CWC's Flood Estimation Reports (FERs).
2. Integrate automated workflows for generating **synthetic unit hydrographs** as per CWC's sub-zonal guidelines.
3. Incorporate empirical formulas (e.g., Rational, Dickens, Ryves) and state-specific flood estimation methods for **comparative analysis**.
4. Enable rapid estimation of **peak flood discharge** and full hydrograph visualization for hydraulic structure design.

5. **Statement of the Problem:**

Existing CWC FERs require manual extraction of catchment parameters, complex calculations, and interpolation of regional curves, leading to time-consuming and error-prone processes. Engineers struggle to reconcile differences between unit hydrograph methods and state-specific empirical formulas. A centralized, automated platform is needed to streamline flood estimation, improve accessibility of guidelines, and support decision-making.

6. **Methodology:**

- **Data Integration:**

Compile CWC's sub-zonal FERs, empirical formulas, and regional catchment datasets into a geodatabase.

- **Web GIS Development:**

Build an interactive interface using **Python, Django/Flask, HTML, etc** for frontend backend.

7. **End users/beneficiaries of the Study:** Hydraulic engineers, Infrastructure developers, State WRDs, etc

8. **Deliverables:** Web application with modules for hydrograph generation, peak discharge comparison, and GIS-based visualization.

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. Manish Nema	Scientist E
4	Dr. P K Mishra	Scientist D
5	Dr. Pravin Rangrao Patil	Scientist C
6	Dr. Umesh Kumar Singh	Scientist C
7	Dr. Ajay Ahirwar	Scientist C
8	Dr. Richa Pandey	Scientist B
9	Sh. Harsh Upadhyay	Scientist B
10	Sh. Asif	RA



APPROVED 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); P. R. Patil	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 (20.0)
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 (44.52)

PROPOSED WORK PROGRAMME FOR THE YEAR 2025-26

SN	Title	Study Team	Duration	Funding (Rs. Lakhs)
Completed Sponsored/ Internal Studies				
1.	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)
Ongoing Sponsored/ Internal Studies				
1.	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)
2.	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); P. R. Patil	3 years (04/22-03/25)	IIRS (30.91)
3.	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)
4.	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)
5.	Integrated operation of Bisalpur and Isarda reservoirs in Banas river basin, Rajasthan	Archana Sarkar; A R Senthil Kumar; P K Mishra; Harsh Upadhyay; Sanjay Agarwal	3 years (04/24-03/27)	NIH (19.30)
6.	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)
7.	Development of rule-based integrated operation framework for the Mahanadi basin	P K Mishra; M K Goel; P K Singh;	1.5 years (04/24-09/25)	NIH (5.0)

		A R Senthil Kumar		
8.	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 (20.0)
9.	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; Harsh Upadhyay	2 years (04/24-03/26)	NIH (1.0)
10.	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 (44.52)
11.	Water resources planning and management using DSS (PM) under changing climatic and land-use conditions	Richa Pandey; Ajay Ahirwar; Sukant Jain; A R Senthil Kumar; A K Lohani	2 years (04/24- 03/26)	NIH
New Sponsored/ Internal Studies				
1.	Hydrological Investigation and Climatic Trend Analysis of a Lesser Himalayan Forested Catchment	P R Patil; M K Nema; P K Mishra; S S Rawat; D S Meena (IFS); P Tomar (IFS); J Dagade (IFS)	10 Months	UKFD (15.81)
2.	Comprehensive Reservoir Sedimentation Analysis of Major Indian Reservoirs Using Google Earth Engine	A. Ahirwar, R. Pandey, U K Singh; A R Senthil Kumar;	3 years (04/25 – 03/28)	NIH (10.00)
3.	Application of Decision Support System for Planning & Management (DSS (PM)) in the Narmada River Basin	A. Ahirwar, Harsh Upadhyay; R. Pandey, A R Senthil Kumar;	3 years (04/25 – 03/28)	NIH (10.00)

COMPLETED STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2021-24/01

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' (On lien)
3. **Project Duration: 02 Years (04/21 – 06/23)*** extended up to 03/2024.
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 km². The major part of the State is drained by the Brahmaputra basin (~10881 km², 65.6%) followed by Barak basin (~814 km², 4.9%) and by Irrawady-Chindwin basin (~4884 km², 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. Data sources are given in Appendix 1.

- 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)		
	1 st Year	2 nd year	Total
1: Manpower: JRF@31,000/ + HRA and others	-	-	-
2: Work Station-high configuration	3.50	-	3.50
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	1.50	1.50	3.00
4: 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	Q	Q	Q	Q	Q	Q	Q	Q
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, and								
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: Completed & Final report submitted

In this study, WA+ Framework has been utilized to assess the total water consumptions, agricultural water consumptions (using green water and blue water), and estimation of land and water productivity, estimation of utilized water, and total water balance in different basins/sub-basins situated in the state of Nagaland. 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 (Tizu) basins in the state of Nagaland for estimating the status of the water resources.

The following conclusions are drawn from this study as given below:

1. WA+ framework was set-up for the period 2001-02 to 2019-20. Six factsheets viz. Sheet 2 (evapotranspiration), Sheet 3 (part 1: agricultural water consumption; part 2: land and water productivity), Sheet 4 (part 1: man-made utilization; part 2: natural utilization), Sheet 5 (surface water), Sheet 6 (groundwater) and Sheet 1 (Resource base) were generated.
2. Sheet 2 revealed that an average water loss of 14.9 BCM (~ 900 mm) was occurring in the form of evapotranspiration from different basins and sub-basins annually. 56% of the evapotranspiration loss was contributed from evaporation, the remaining 44% of loss was due to the transpiration. Out of the total evaporation loss, about 44% is due to interception loss and the remaining is from the soil surface and water bodies. Utilized land use contributes maximum to the evapotranspiration loss, followed by modified land use, managed water use and protected land use. The study also revealed that a considerable chunk of ET (75.88%) is manageable. This implies that this portion of ET, which is a significant loss from the system, has the potential to be managed through scientific measures. Presently, almost 23% of ET loss is being managed through rainfed and irrigated agriculture. 37% of the ET loss is beneficially contributing to the intended purpose. The remaining loss of 63% is non-beneficial, and can be suitably managed to beneficial component by adopting the agronomical and mechanical measures (Figure 1).
3. Sheet 3 estimates the crop-wise agricultural water consumption (km³/year), land productivity (kg/ha/year) and water productivity (kg/m³) on monthly and yearly basis. The study estimated a total agricultural water consumption of 2.50 BCM and 2.55 BCM, predominantly met from the rainfall, during a dry and wet year respectively. The land productivity and water

productivity during a dry year for rainfed rice were 3707.95 kg/ha/year and 0.93 kg/m³ respectively. However, the land and water productivity reduced during a wet year to 3097.5 kg/ha/year and 0.76 kg/m³ respectively. A higher productivity was seen in case of irrigated rice. These rich information, with spatial productivity maps, enables the water managers to understand the interventions undertaken at local level by both progressive and less progressive farmers. This helps in planning different interventions for a particular area for higher productivity. The water productivity and the land productivity data can also be coupled with the prevalent crop price to estimate the income of farmers. Such information will be helpful in preparing poverty alleviation programs and in improving the livelihoods of farmers.

4. Sheet 4 provides the utilized flow for both manmade and natural sources of the basin. Sheet 4 is also known as the 'Withdrawal' sheet which provides the surface water and groundwater withdrawal. The annual average gross withdrawal for man-made and natural land uses are 0.8 BCM and 1.94 BCM respectively. Out of the total man-made utilizations, almost 63% of withdrawal was from the surface water. Whereas, surface water utilization was 23% for the natural land uses. 45% of the total withdrawal (SW+GW) for man-made utilizations was consumed to meet incremental ET requirement, and the remaining water was non-recoverable. 55% of total man-made withdrawal was non-consumed, and can be recovered back to the system.
5. Sheet 5 describes about the surface water availability of different sub-basins. The state of Nagaland is divided into three important basins viz. Brahmaputra, Barak and Tizu (Irrawady-Chindwin). The study revealed that the total outflow from the seven sub-basins viz. Dhansiri, Chathe-Dzuza, Doyang, Dikhu, Tizit, Tsurang and Milak to the river Brahmaputra were about 14051 MCM. The estimated outflow from the catchment within the Nagaland to the Barak and Tizu (Irrawady-Chindwin) basins were about 572 MCM and 4435 MCM respectively.
6. Nagaland being a hilly state, estimating the groundwater conditions is very challenging. As per the estimates in Sheet 6, an annual vertical recharge of 15.68 BCM was estimated, out of which 87% was contributing to the baseflow. Groundwater withdrawal was about 1.77 BCM.
7. Sheet 1 provides the overall water balance of the basin. A gross annual inflow of 29 BCM of water was estimated. A net inflow of 28.5 BCM was estimated with a net storage contribution of -0.5 BCM (a negative sign indicates net recharge). The landscape ET was estimated to the tune of 10.3 BCM (36% of net inflow). This implies that 64% of the net inflow (18.3 BCM) is available as 'exploitable water' in the state. The committed flow, as provisioned in the WA+ framework, was estimated to the tune of 3.1 BCM (17% of exploitable water). An annual average of 15.3 BCM of water is available for utilizations in the state, of which about 22% (3.4 BCM) is utilized, and the remaining 11.7 BCM of water was available for utilization (utilizable flow), but yet to be harnessed. The available water varies from 19 BCM to 14.7 BCM between a wet and dry year respectively (Figure 2).
8. Out of the total net inflow into the basin (28.5 BCM), 48% of water is consumed to meet mainly the ET requirements (ET green and ET blue). The remaining amount of water is non-consumed (52%), and can be considered as an asset which is utilizable, but yet to be explored. It can be seen that a major chunk of water consumed in the basin is moving out of the basin as landscape ET (75%) followed by incremental ET (15%) and non-recoverable (10%) water. The study estimated an annual average outflow of 16.2 BCM.

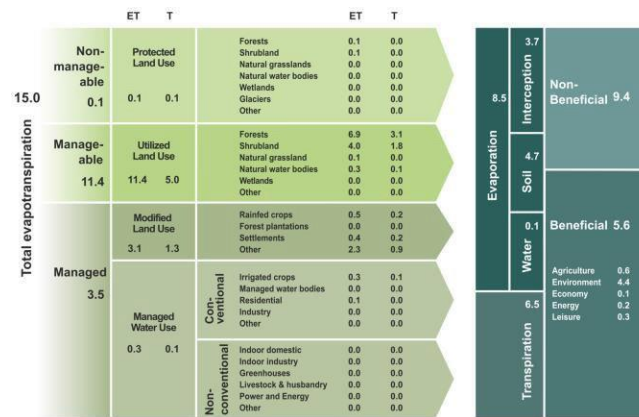


Fig. 1 Sheet 2 generated for the wet year (2003-04).

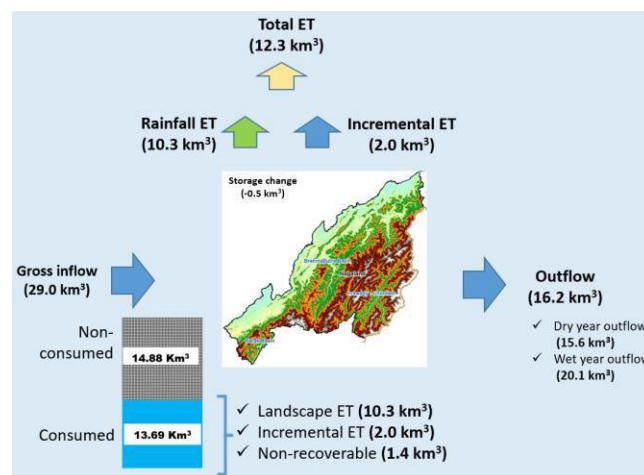


Fig. 2 Overall water balance in the Nagaland state.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2022-25/01

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 'D'
Dr. P. K. Mishra, Scientist 'C'
3. **Project Duration:** 03 Years (04/22 – 03/25)
4. **Objectives**
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:
 - To study the historical climate change, morphological properties and land use/land cover change pattern over the Wainganga River basin
 - To calibrate and validate a hydrological model at different spatial scales for the river basin using current land use and observed climatic conditions
 - To develop future expected land-use change and climate change scenarios (CMIP6) for the base period and compare them with the observed period
 - To model spatial and temporal future water availability using climate and land-use change scenarios
 - To quantify the uncertainty in modeling analysis arising from model parameters and input conditions
 - 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 sectorial 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 7⁰ C to 13⁰ C. Maximum temperature ranges from 39⁰ C to 47⁰ C. Month of May is the hottest month, and December is the coldest month.

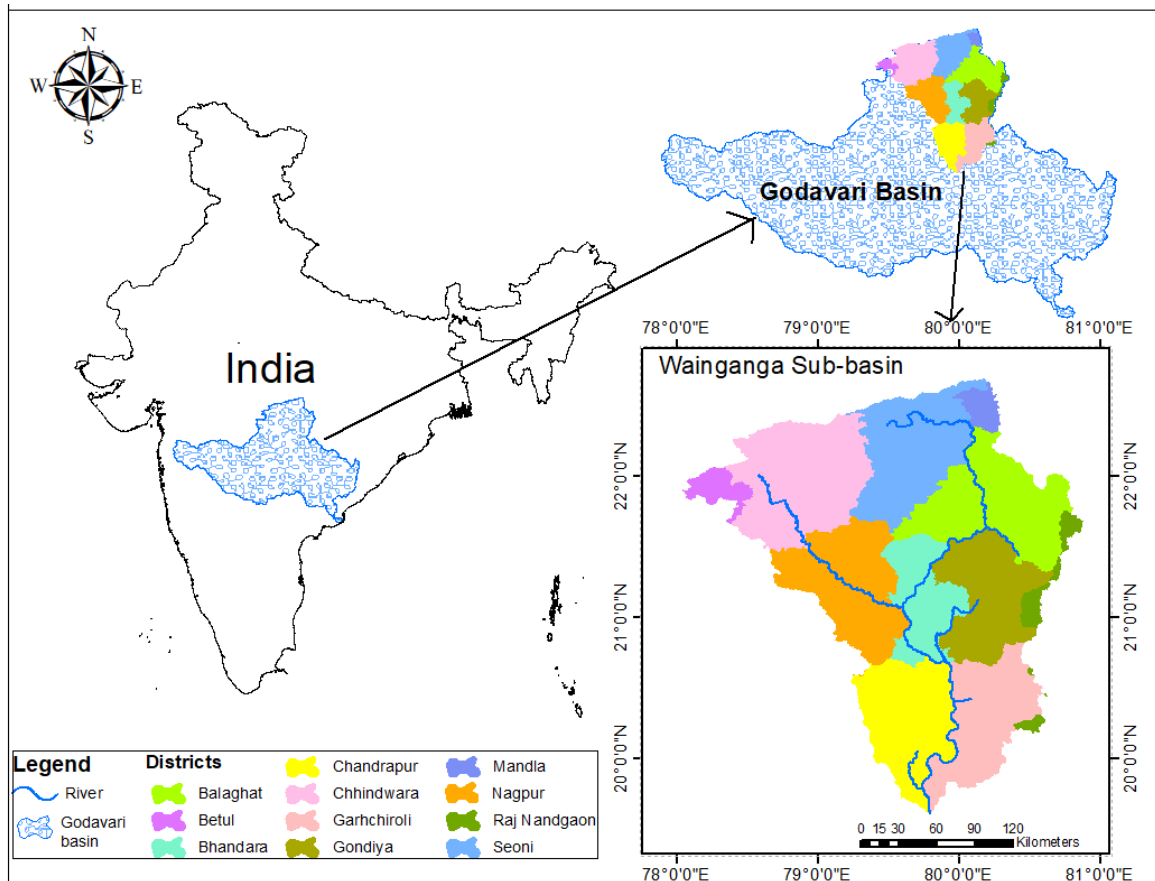


Fig. 1 Location Map of Wainganga River sub-basin of Godavari Basin in India

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:

SN	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 to 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 second Objective of the study about calibration and validation of hydrological model has been completed and presented in previous working group.

The third major task pertaining to land use land cover modeling, withal the required biophysical drivers of change have been prepared completed and projected maps LULC maps for 2030, 2040 and 2050 had been prepared and presented in the last working group meeting. Results showed an increase in built-up with 411 km² in 2050, a decrease in agriculture with 33,087.40 km², and forest with 17,463.70 km² in 2050. There is a deliberate change in agriculture, which is more intervention for agriculture practices. The impact of projected LULC changes has also seen on the hydrological responses of the basin. There is increase in the flows of the Wainganga with projected LULC, although not much changes have been seen in the further future periods. Pre-monsoon month, i.e., May has witnessed the highest increase of 31% in the average flows as compared with the baseline period. Monsoon and winter season average flows are also likely to increase ranging from 10.06% to 17.92%.

The calibrated and validated SWAT the model needs to be implemented for understanding the hydrological response of the basin under the changing climatic conditions using the CMIP6 Data and then the water availability analysis shall be carried out.

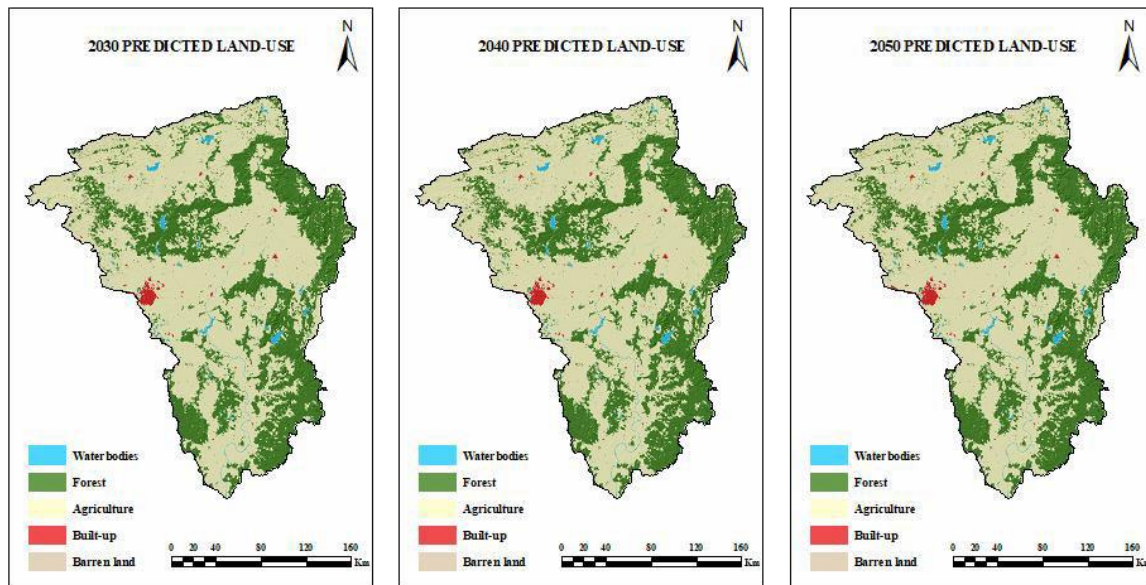


Fig. 2 Projected LULC maps (2030, 2040 and 2050) of the Wainganga River Basin

ONGOING STUDIES

INTERNAL RESEARCH PROJECT: NIH/WRS/2024-27/03

- 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. 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
- 5. 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 km² 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 km²), Madhya Pradesh (23,109 km²) and small portions of Chhattisgarh (962 km²). 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 Sarovar Reservoir (Bhimgarh Reservoir) and Pench Reservoir (Totladoh reservoir) located in Madhya Pradesh, Gosekhurd, Itiadoh, Kairi, Kindisi and Bagh complex (Sirpur, Kalisara and Pujaritola reservoirs) in Maharashtra and Rajiv Sagar Reservoir (Bawanthadi 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.
- 6. 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 (ET_o) by Penman-Monteith equation for projected temperature for climate scenarios of SSP2-4.5 and SSP5-8.5 of CMIP6 models, crop coefficient (K_c) 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.

An integrated operational framework comprising of these 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 an integrated basis considering the operational framework for present and projected scenarios.

7. 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 land use, existing cropping pattern, command area details, crop coefficient and other crop information, population and livestock data

8. 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, T _{min} , T _{max} , RH(%), Sunshine hours); preparation of land use / land cover maps 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											

9. Cost Estimate

- Total cost of the project: Rs. 21.02 lacs
- Source of funding: NIH
- Sub Head wise cost

Sl. No.	Sub-head	Amount (in Rupees)
1.	Salary for one 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

10. Progress till Date

- Sent letter to Chief Engineer, Water Resources Department, Nagpur; Chief Engineer, Gosekhurd Project, WRD, Nagpur; Chief Engineer, BODHI, Bhopal; and Chief Engineer, Wainganga Basin, Seoni, MP to obtain the data related to the proposed study.
- Visited Sanjay Sarovar Reservoir (Bhimgarh Reservoir) and Pench Reservoir (Totladoh reservoir), Khairi Reservoir, Khindisi Reservoir and Rajiv Sagar Reservoir (Bawanthadi Reservoir) during 08.12.2024 to 16.12.2024 and collected the data of elevation-area-capacity curves, daily and monthly reservoir working table containing beginning and end reservoir level, inflow, evaporation, rainfall, canal releases (LBC and RBC) and spill, salient features of the reservoirs and gate operation during the flood season by meeting Divisional Engineer and Engineer in-charges of these dams.
- Visited Gosekhurd Reservoir, Itiadh Reservoir, and Bagh complex (Sirpur, Kalisara and Pujaritola Reservoirs) during 12.01.2025 to 17.01.2025 and collected the data of elevation-area-capacity curves, daily and monthly reservoir working table containing beginning and end reservoir level, inflow, evaporation, rainfall, canal releases (LBC and RBC) and spill, salient features of the reservoirs and gate operation during the flood season by meeting Divisional Engineer and Engineer in-charges of these dams.
- The photographs of these daily and monthly datasets which is substantially large is being

- computerised and it shall be processed after the completion of data entry.
- e. The climate scenarios of rainfall, maximum and minimum temperature of CMIP6 GCMs under SSP2-4.5 and SSP5-8.5 future climate scenarios are being downloaded and being analyzed.
 - f. SWAT model has been setup for the study area and the reservoir releases for all these dams shall be incorporated once the data gets computerized and thereafter the calibration and validation exercise shall be initiated.

ONGOING STUDIES

INTERNAL RESEARCH PROJECT: NIH/WRS/2024-26/04

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. **Objective of the study**
Development of tool for the prediction of elevation-area-capacity curves of the
5. **Study area**
Data from the Bhakra and Pong reservoirs will be utilized to develop the tool for predicting elevation-area-capacity curves.
6. **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.

7. 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								

8. Cost Estimate

- Total cost of the project: Rs. 11.18 lacs
- Source of funding: NIH
- 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

9. Progress till Date

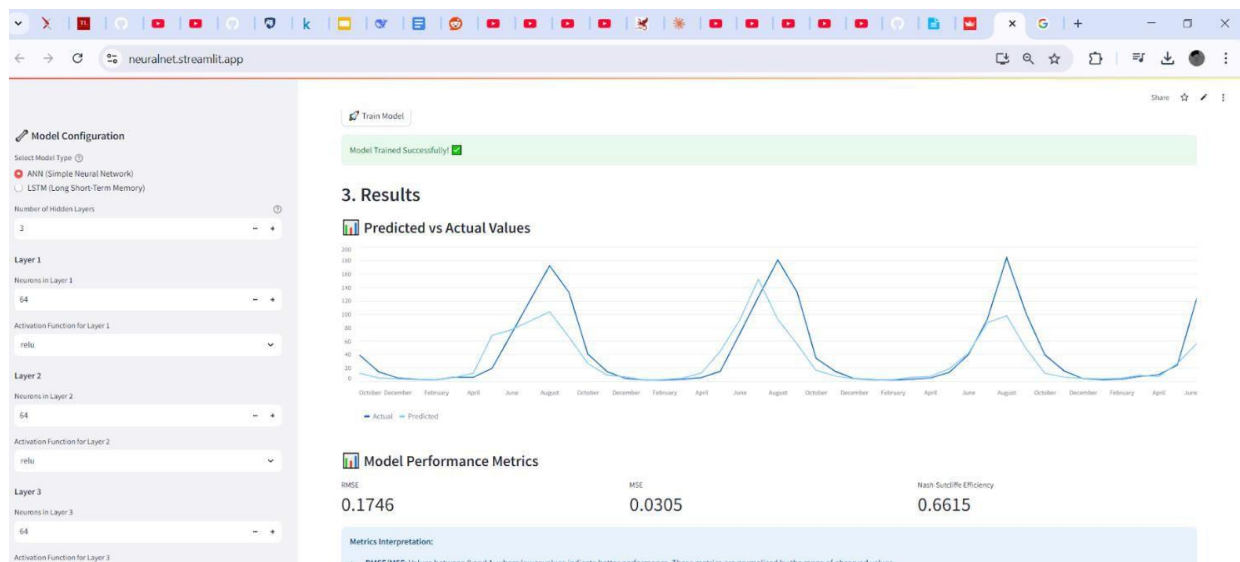
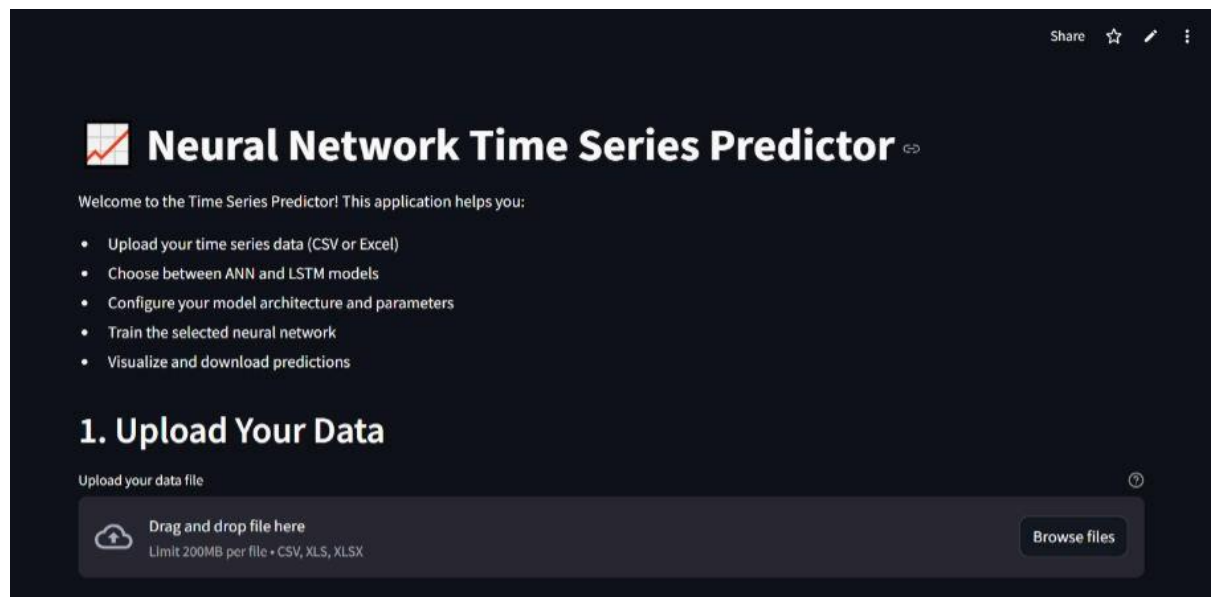
- Python modules have been developed for ANN, Random Forest and LSTM based RNN models. Initially the developed models have been trained and validated to predict the rainfall and evapotranspiration using multivariate times series with inputs varying from max and min temperature, humidity, evaporation and wind velocity, ground water level, antecedent rainfall for the data from 1987 to 2021.
- Alongside ML modules, the modules for preprocessing the time series have also been implemented, such key features have been implemented to lay foundation for a robust and interactive WebApp developed to offer user a highly interactive experience from importing the dataset to generating excel file for the time series user is interested in predicting.
- The aforementioned WebApp “ResSed” has been developed using the Streamlit library, which offers rich set of features for User Interface and a Seamless experience for users to interact with developed modules in an abstract way, the library has been used to train and test the models as well in the backend so that user can predict the features of their interest without the hassle of worrying over running a ML model locally on their machines. Some of the key features of the app are the following:

➤ Visualizing the Target Feature time series, the user wishes to predict.

➤ Select the input features (generalized up to n variables in the app) and selecting a target feature.

- The freedom for user to opt for either LSTM, ANN.
 - For the model of their choice, user can select various hyperparameters from number of layers to the batch size and many more customization to build the model.
 - The WebApp, then, offers an overview of the architecture with the customization made by user.
 - The App offers “Train the Model” option leading to a display of resulting graphs of “Predictions vs Actual” Results. The user also has the feature of grasping the performance of the model(s) with the help of performance indicator metrics such as NSE, MSE, Coefficient of Correlation.
 - The last thing user gets the option of exporting the results in the format of excel sheet.
- d. The WebApp has been employed to simulate the monthly sediment yield using the monthly rainfall of three number of upstream stations and flow volume into the reservoir for the data of Bhakra reservoir. The generalization of input variables has been considered for the application of the tool for any reservoirs.
 - e. Python modules have been developed for time series modelling to generate rainfall of three number of stations and inflow volume for any future periods, for example, 25, 50, 75, 100 years. The generalization of time series input variables have been considered for the application of the tool for any reservoirs.
 - f. Some of the clippings which shows the capabilities of the WebApp are given below:

The screenshot displays the 'Artificial Neural Network' configuration window. At the top, there are four tabs: 'Import Data', 'Correlation Analysis', 'Data Preprocessing', and 'Model'. The 'Model' tab is currently selected. The main area is titled 'Artificial Neural Network'. It features several adjustable parameters: 'Number of layers' is set to 1; 'Number of neurons' is shown in a box; 'Epochs' is set to 100; 'Batch size' is set to 0; 'Learning rate' is set to 0.00100; and 'Dropout rate' is set to 0.20. Additionally, there are dropdown menus for 'Activation function' (set to ReLU), 'Optimizer' (set to Adam), and 'Loss function' (set to MSE). On the right side, under the heading 'Run Model', there are three buttons: 'Train Model', 'Test Model', and 'Save Results'.



ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-27/05

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'
Dr. 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 m³ 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

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 km² 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 km². Bisalpur and Isarda Reservoirs are located in the Banas basin.

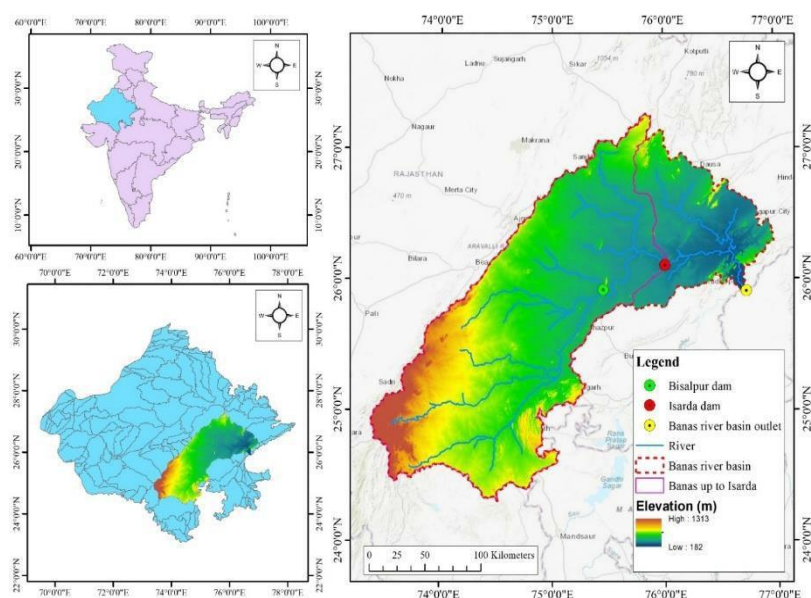


Fig. 1 Banas River basin

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 (ET_o) by Penman-Monteith equation, crop coefficient (K_c) 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 purposes. The simulation module of NIH_ReSyP would be used to derive the reliability of releases from reservoirs integrately.

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, T _{min} , T _{max} , 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. Progress

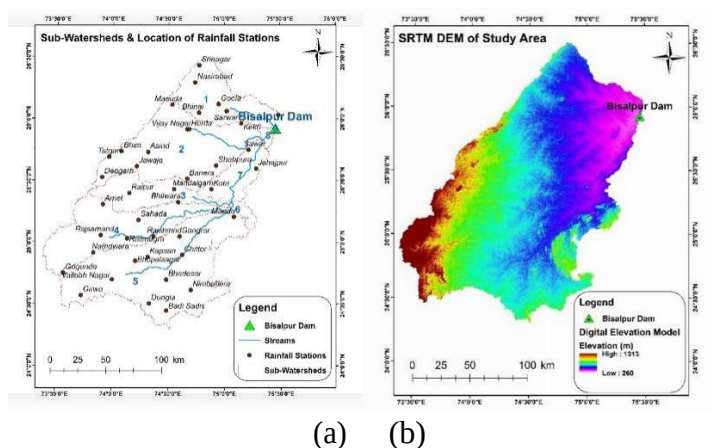
Objectives (April 2024 - Feb 2025)	Achievements
Collection of information and meteorological data (rainfall, Tmin, Tmax, RH (%), Sunshine hour) as well as soil samples from field, Preparation of base maps	Completed (Testing of soil Samples for part of basin in Soil- Water laboratory in Progress)
Collection of data on inflow and sediment load to reservoirs, physical features of reservoirs, command area boundary, existing cropping pattern, crop information and crop coefficient, population data	Completed (Collected all the available data during two field visits)
Calibration and Validation of SWAT Model for modelling of inflow and sediment load to the reservoirs	Completed
Estimation of demands for irrigation, present and future (2070) drinking water and industrial use	Completed
Development of ANN Models for prediction of Inflow and sediment load	In progress

Analysis and Results

Collection of Soil Samples

Soil samples were collected from 18 locations in the basin starting from Jaipur to Kumbalgarh

Basin Maps



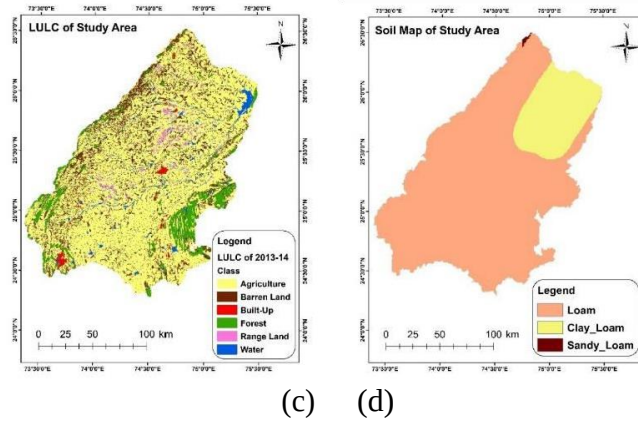


Fig. 2 Inputs for SWAT (a) SRTM DEM (b) Sub-watersheds & Rainfall stations (c) LULC (d) Soil map of the Banas catchment

SWAT Model Calibration and Validation

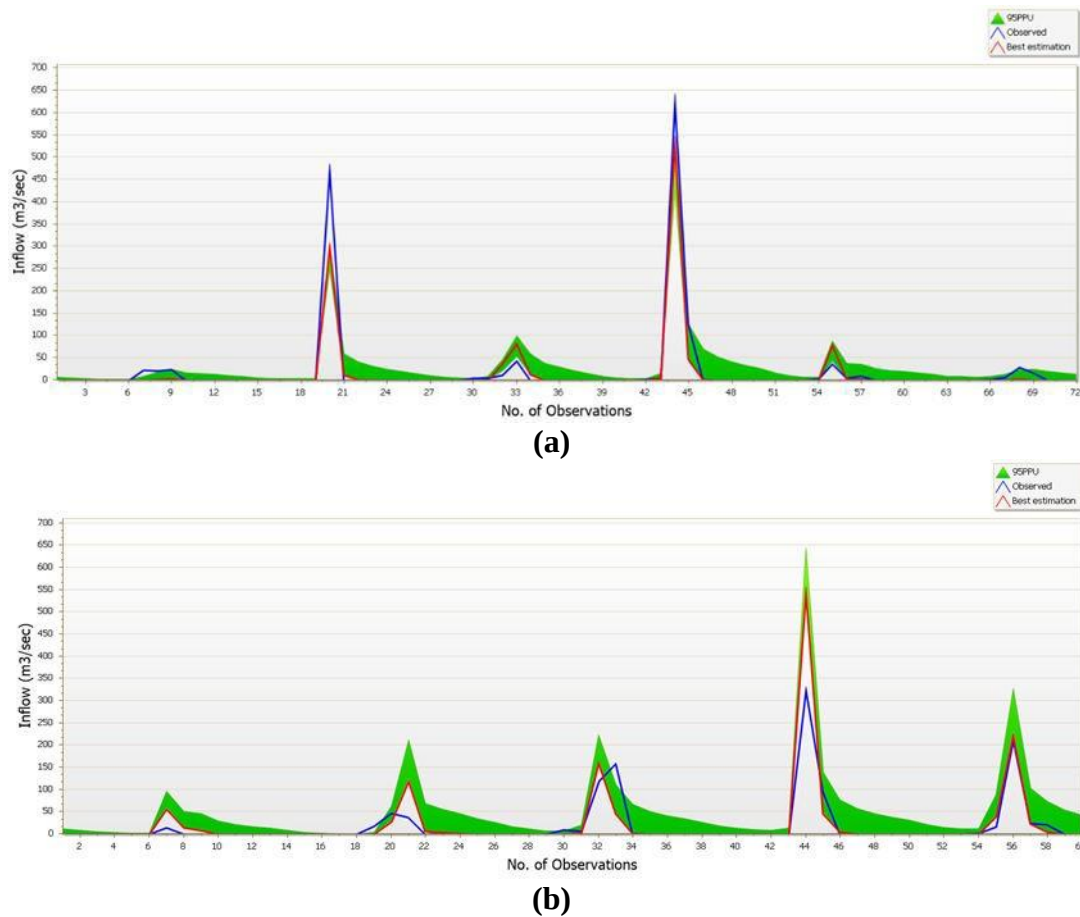


Fig. 3 Monthly inflow comparison for simulated and observed data for Bisalpur Dam for (a) calibration (period 2003-2008) and (b) validation (period 2009-2013)

Computation of Demands

- The mean monthly crop water demands for the irrigated areas were computed using Google Earth Engine. The datasets used in the computation are shown:

Dataset	Spatial Resolution	Temporal Resolut	Source	Duration used
Land cover	10	Annual	ESRI	2018-2023

Irrigated area	300	Annual	Globcover	2009
Actual evapotranspiration	300	Monthly	WaPOR	2018-2023

- The mean monthly water demands over irrigated areas thus computed are shown in the following figure 4:

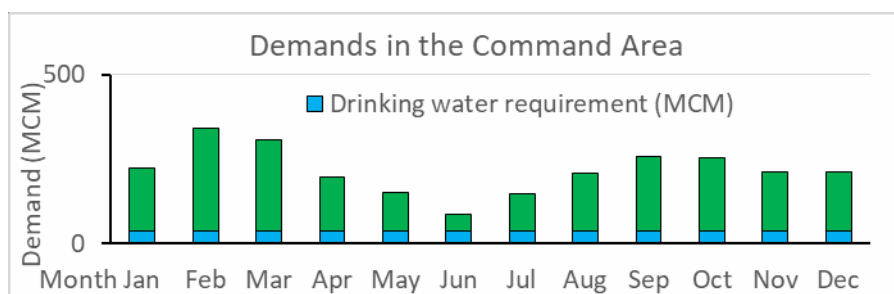


Fig.4 Mean monthly demands in irrigated areas of the command area.

- Drinking water demands are set to a constant monthly value (38.2 MCM) based on annual water requirement (458.36).
- High demands were observed in the months of February and March (peak Rabi season) as well as September and October (peak Kharif season) with the demands in Rabi season being comparatively higher.
- The mean monthly spatial variation in demands over irrigated areas of the command area is shown in following figure 5:

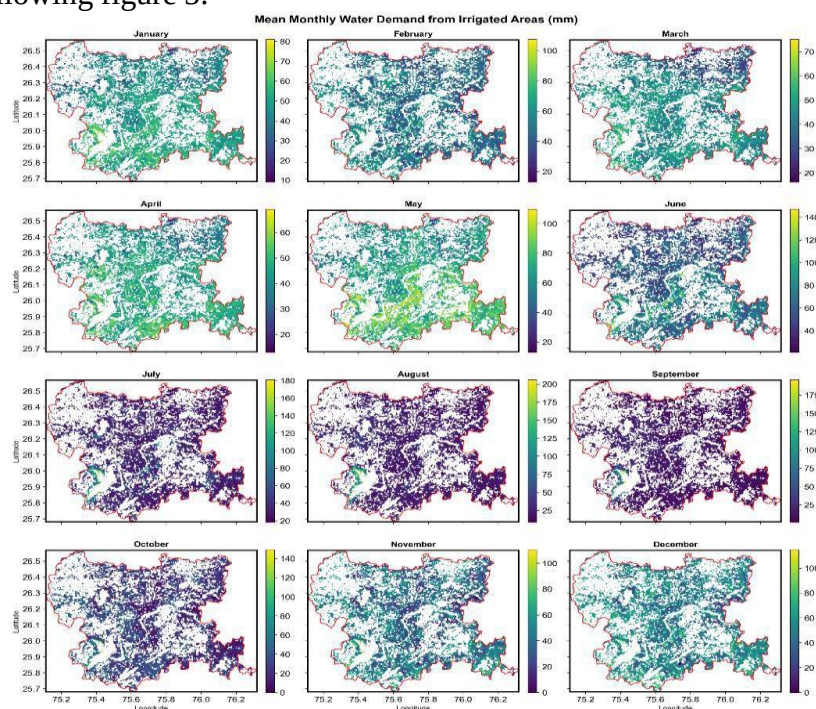


Fig. 5 Spatial variation in demands

Deliverables

Research papers, reports, stakeholder engagement

Future Plan

As per the Time line

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-26/06

1. **Title of the Project**
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. Pravin R. 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 Rockström, 2006; Rockström 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.

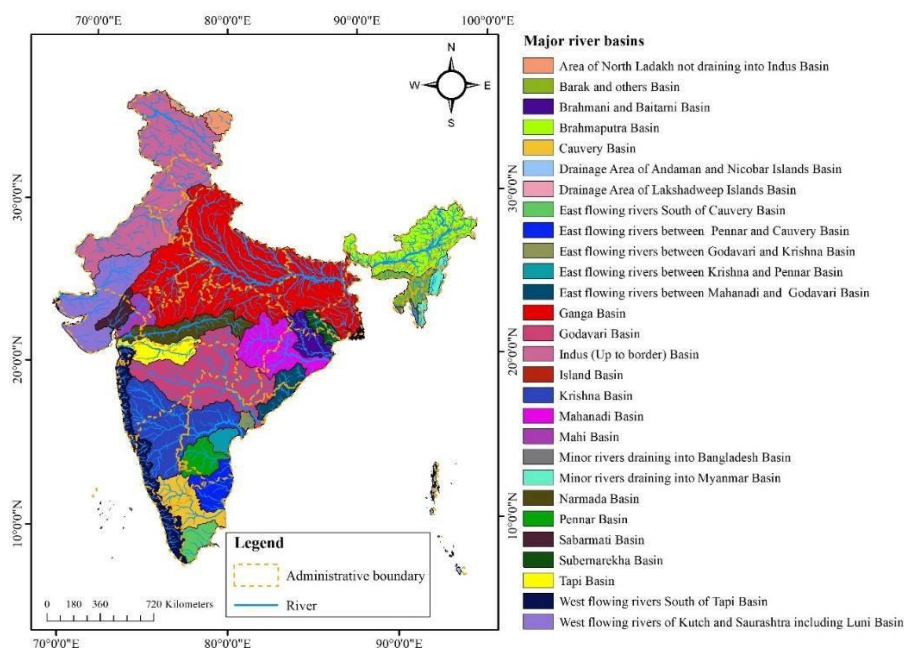


Fig. 1 River basin map of India

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/feeds/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_per_mwb-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**

a. Source of funding: NIH Roorkee

b. Sub-head wise abstract of the cost:

Head	Amount (in Lakh)		
	1 st Year	2 nd 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		

5. Work Schedule

- Probable date of commencement of the project:
- Duration of the project: 02 Years
- Stages of work and milestone: Shown below

Project Year	March 2024- February 2025				March 2025- February 2026			
Project Quarter	Q	Q	Q	Q	Q	Q	Q	Q
a. Data downloading, processing, and generation of database								
b. Basic data analysis in WA+ framework, Ground trothing surveys for LULC and data collection from NRSC, and state govt. departments								
c. WA+ Framework Application								
d. Development of Land and Water Productivity Accounts								
e. Development of the operational WAPRO-India portal								
f. Final report writing recommendations and stakeholders Training								

6. Progress till date:

In this study, it is envisaged to develop land and water productivity accounts in the major river basins of India using water accounting plus framework (WA+) which include development of water consumption patterns and beneficial and non-beneficial water consumptions in the respective basin. Further, it is also planned to develop an operational WAPRO-India portal to disseminate the estimated accounts as discussed above. The WA+ framework has been set-up and run to estimate the land and water productivity of following basins: (i) Kaveri basin (Pilot-basin for ToT), (ii) Subernarekha basin, (iii) Basins in Meghalaya, (iv) Basins in Nagaland, (v) Mahanadi basin, (vi) Yamuna basin, (vii) Betwa basin, (viii) Godavari basin, (ix) Pennar basin, (x) Mahi basin, (xi) Luni basin, (xii) Gomti basin, (xiii) Ghaghra basin, (xiv) Narmada basin (Ongoing), (xv) Other sub-basins of Ganga (Ongoing), and (xvi) Krishna basin (Ongoing). A pilot dashboard/ web-portal has also been developed for the state of Meghalaya with the support from ESRI, India under the National Hydrology Project (NHP) as referred in the link: <https://solutions.esri.in/portal/apps/experiencebuilder/experience/?id=76f1ff0f6c5f49f5aa3691329f7ffd97&page=Home>.

In recent developments, Ministry has also conceptualized to set-up WA+ Framework all the Indian basins with the updated WA+ models with the support from the developer from the IHE-Delft, The Netherlands. The WAPRO-India portal will be suitably modified incorporating the estimated productivity of all the basins as and when completed with due course of time. Few findings of the estimated land and water productivity will be shared in the Working Group meeting.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-25/07

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°-33' to 86°-50' east longitudes and 19°-20' to 23°-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 Chhattisgarh 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 & Medium projects including EAC curves
 - Working Tables of Major & Medium 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 Chhatisgarh 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:

- Analysis of data from the Working Tables (WT)
- Estimation of different demands of Project(s)
- Estimation of minor irrigation utilization in a Project catchment
- Estimation of net inflow series to a Project
- 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: (i) Disaggregation/ aggregation of time step of different data will be done as per the need

9. Project Budget

Head	Amount (in Lakh)		
	1 st year	2 nd year	Total
1: Field visits, consumables, stationary, printing of reports & brochures, workshops, outreach	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	Q	Q	Q 3	Q	Q 5	Q 6
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						

12. Progress till date:

This study proposal was prepared in response to the email request from Er. Adikanda Patra, Additional Chief Engineer, Inter-State Water Issues, Water Resources Department, Govt. of Odisha with an assurance of allotment of the work order. We were also assured of providing hydrological data, MWDT award documents, etc. from the WRD, Odisha. Unfortunately, things were kept pending due to new government formation during May, 2024. We were informed further that the study can be proceeded once the new Government will undertake detailed review on the Mahanadi matters. In the meantime, the water accounting plus (WA+) framework, a python based open data-based accounting tool, has been set-up for the Mahanadi basin. Few major findings will be shared during the Working Group meeting.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-27/08

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. **Objectives of the Study**
 - a. Monitoring of hydro-met variables in the Henval catchment (data generation)
 - 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.
5. **Present state-of-art**

In the Himalayas, a critical knowledge gap exists in understanding the precipitation-temperature interplay influenced by altitudinal orographic forcing. Enhancing the accuracy of distributed hydrologic models (DHMs) and reducing their uncertainties require effective parameterization based on field observations—particularly challenging in high-altitude regions. Many glacio-hydrological models (Immerzeel et al., 2014; Ragetti et al., 2015; Heynen et al., 2016) rely on uniform vertical and horizontal precipitation gradients (PGs) and literature-based air temperature lapse rates (TLRs), introducing uncertainties. TLRs and PGs determine form and amount of precipitation, as well as the spatial distribution of air temperature (Kattel et al., 2013) and precipitation (Immerzeel et al., 2012). Given their role in water availability projections, accurate temperature and precipitation estimates are essential. Despite advances in satellite products, improved climate reanalysis (Hersbach et al., 2020), and high-resolution atmospheric modeling (Collier et al., 2015), field-based validation of derived meteorological variables in the Himalayas remains limited.

Environmental lapse rate (ELR) is often treated as calibration parameter or assumed constant due to scarce field data. However, ELRs based on hypotheses or free atmospheric conditions yield unrealistic temperature fields (Shrestha et al., 2012; Roe & O'Neal, 2009). Unlike ELR, TLRs vary seasonally and diurnally with elevation, influenced by sensible heat flux (Gardner et al., 2009; Li et al., 2013). They tend to be shallower than ELR (6–6.5 °C/km) due to local circulation and humidity effects. Standard seasonal or monthly TLRs derived from extrapolated temperature records (Kattel et al., 2013, 2015; Zhang et al., 2015, 2017; Shrestha et al., 2015; Valéry et al., 2010) fail to capture local variability, especially in data-sparse high-altitude regions. The use of linear or mean TLRs in modeling introduces significant uncertainties, affecting precipitation phase partitioning (rain, snow, mixed-phase), snow/glacier melt, and runoff (Minder et al., 2010). Temperature distribution strongly influences precipitation patterns in mountainous regions. Typically, precipitation is modeled using predefined PGs (Bergström, 1992; Viviroli et al., 2007; Markstrom et al., 2015) or gauge-

based geostatistical interpolation (Frei & Schär, 1998; Daly et al., 2008; Isotta et al., 2014; Foehn et al., 2018; Frei & Isotta, 2019). However, PGs exhibit nonlinear altitude- dependent correlations, leading to inaccuracies in mountain precipitation representation (Dahri et al., 2016). Limited datasets and extreme spatial variability further complicate precipitation characterization (Buytaert et al., 2006; Immerzeel et al., 2014).

Accurate forcing fields (TLRs and PGs) are crucial for interpolating point observations into gridded inputs for DHMs (Ahrens, 2006; Tahir et al., 2011; Immerzeel et al., 2012). However, capturing diurnal spatio-temporal variability without field observations based forcing fields remains a challenge. Short-term field campaigns (1–2 years) can improve forcing field calibration, underscoring the need for expanding and reinforcing the hydro- meteorological monitoring network in the Henval catchment. This study aims to enhance understanding of precipitation and temperature dynamics in a monsoon-dominated, high- relief environment through real-time monitoring of forcing fields. By evaluating valley-scale atmospheric controls and hydrological responses in a Himalayan catchment, it seeks to reduce conventional modeling uncertainties. Additionally, the study will systematically assess the sensitivity of advanced hydrological model to observed TLRs and PGs, compared to standard ELRs and linear PGs

6. Methodology Study Catchment

The Henval catchment (254 km², Fig. 1) in Tehri Garhwal, Uttarakhand, India, is a benchmark site for hydrological studies in the Lesser Himalaya. It lies between 30°07'N– 30°25'N latitude and 78°17'E–78°26'E longitude, with elevations ranging from 379 to 2673 m a.m.s.l. The region has a monsoon-driven climate, receiving 1200–1800 mm of annual rainfall, and features a well-defined, south-west-facing drainage network. The catchment's soils, derived from metamorphic rocks, range from sandy loam to loamy sand. Largely undisturbed, it is dominated by forest cover, with agricultural land and an urban settlement at Chamba. The Henval River, fed by springs, originates from the forests near Kaddukhal/Surkunda Peak and flows ~50 km before joining the Ganga at Shivpuri. It is the primary water source for several settlements, including Chamba, Kaddukhal, Kanataal, Ranichuri, Fakot, Agrakhal and Gaja. The NIH has studied its upper sub-watersheds (102 km²) under DST/MOES projects.

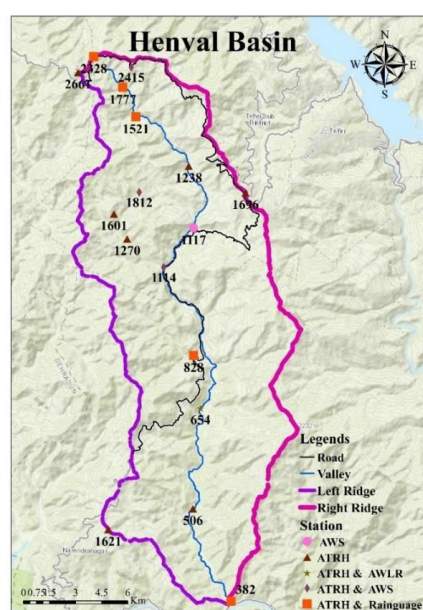


Fig. 1 Location Map of Henval Catchment Showing Instrumentation at Different Elevations along a Valley

Research Approach

To achieve proposed objectives, the following tasks will be undertaken:

- 1 Hydro-met data collection and development of reliable diurnal forcing and digital database including DEM, slope maps, aspect maps, and elevation profiles etc.
- 2 Analysis of diurnal, monthly, seasonal, and intra-annual variations in TLRs and PGs.
- 3 Identification of meteorological and local processes influencing temperature-precipitation dynamics. Establishment of realistic spatial distributions of temperature and precipitation in the catchment.
- 4 Set up and calibration of model. Sensitivity analysis, validation and execution using different forcing fields.
- 5 Analyze the impact of meteorological forcing fields on the catchment's hydrological response. Streamflow estimation using the SPHY (Spatial Processes in Hydrology) model.

7. Study Outcomes

- Long- term observations and improved understanding of precipitation and temperature dynamics in monsoon-dominated, mountainous terrain.
- Enhanced modeling accuracy through field-based parameterization and refined input forcing fields capturing realistic spatial and temporal distribution of meteorological variables.
- Insights into valley-scale processes and local factors influencing meteorological forcing fields and their impact on hydrological response.
- Evaluation of hydrological model sensitivity to observed TLRs and PGs compared to standard ELR and linear PGs, providing insights into model performance and potential refinements.
- Contribution to the correction of grid-based climatic estimates for elevation- dependent variations in complex mountainous terrain.

8. Cost Estimates

The total cost of the project: **₹ 20 Lakh**

i. Source of funding: **NIH**

ii. Sub-head wise abstract of the cost:

SN	Sub-head	Amount (₹)			
		I	II	III	Total
1	Salary (Part-Time Field Staff, Approx. 20 Field Stations)	240000	240000	240000	720000
2	Travelling Expenditure	150000	120000	110000	380000
3	Data/Infrastructure/Equipment's/Repair & Maint.	500000	100000	100000	700000
4	Workshop/Meeting/Experimental Charges/Rent	20000	20000	100000	140000
5	Misc. Expenditure	20000	20000	20000	60000
	Sub-Total:	930000	500000	570000	
	Grand Total:	₹ 20,00,000			

9. Work Schedule

S N	Description of Activity	2024-25				2025-26				2026-27			
		Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4
1.	Field Visits												
2.	Hydro-met data collection & Database development												
3.	Analysis of TLRs and PGs variability, valley-scale temperature and precipitation dynamics												
4.	Hydrological model implementation												
5.	Hydrological response and forcing fields impact assessment												
6.	Stakeholder's workshop												
7.	Report writing												

10. Progress till date

Suitable sites at different elevations (watershed outlet: 379 m to ridge: 2673 m) along the Henval River valley have been identified. To develop a diurnal forcing database, 15 air temperature-relative humidity (AT-RH) sensors and 05 tipping bucket rain gauges were repaired (through GeM) and installed at these selected remote locations (Fig. 1). A new data shuttle has been procured (through GeM), and the recording of meteorological variables in the Henval catchment has been initiated. A suitable bridge site for water level monitoring of the Henval River was identified. An AWLR was installed (under ISRO-DoS sponsored project) at this site in April, 2024 and is now recording and transmitting data via GPRS at 10-minute intervals to IIRS, Dehradun. The technical check of three existing AWS towers in the Henval watershed (Nagni-NIH Plan, Kanatal-MoES, and Kumhargaoon-NMSHE) has been completed. Repair, maintenance, calibration, and the replacement of faulty sensors, loggers, and parts of these AWS towers are currently in progress through GeM.

TLRs (Fig. 2) and PGs have been derived based on available field observations. However, continuous or long-term observations are necessary to identify seasonal trends and confirm the range of TLRs/PGs in the catchment. Ridge and valley TLRs from April 2024 to mid-January 2025 show clear seasonal variations influenced by elevation and atmospheric conditions. Both ridge (1659–2673 m) and valley (690–2673 m) TLRs decline from April to July, reaching their lowest in July (4.11°C/km for the ridge and 5.54°C/km for the valley) due to monsoonal moisture and atmospheric stability. From August onward, ridge lapse rates steadily rise, peaking in Nov–Dec (~7.3°C/km), while valley lapse rates continue to decline, reaching their lowest in mid-Jan (3.36°C/km), likely due to temperature inversions and cold air pooling. The ridge consistently maintains higher TLRs, indicating stronger vertical cooling and drier conditions, whereas the valley shows more seasonal variability, particularly in winter. Data recorded from mid-Oct 2024 to mid-Jan 2025 shows a non-linear rainfall distribution, with Station S3 (1544m) receiving the highest total rainfall (62.23 mm), followed by S1 (2367m), S4 (864m), and S2 (1800m), likely due to orographic effects. The PG fluctuate, with

negative values indicating more rainfall at lower elevations and vice versa. These variations highlight complex weather influences beyond elevation alone, emphasizing the need for localized rainfall analysis rather than assuming a uniform trend. However, the spatial and temporal variability of rainfall poses a major challenge in analyzing PGs due to the lack of a single storm event across different elevations and low rainfall magnitudes.

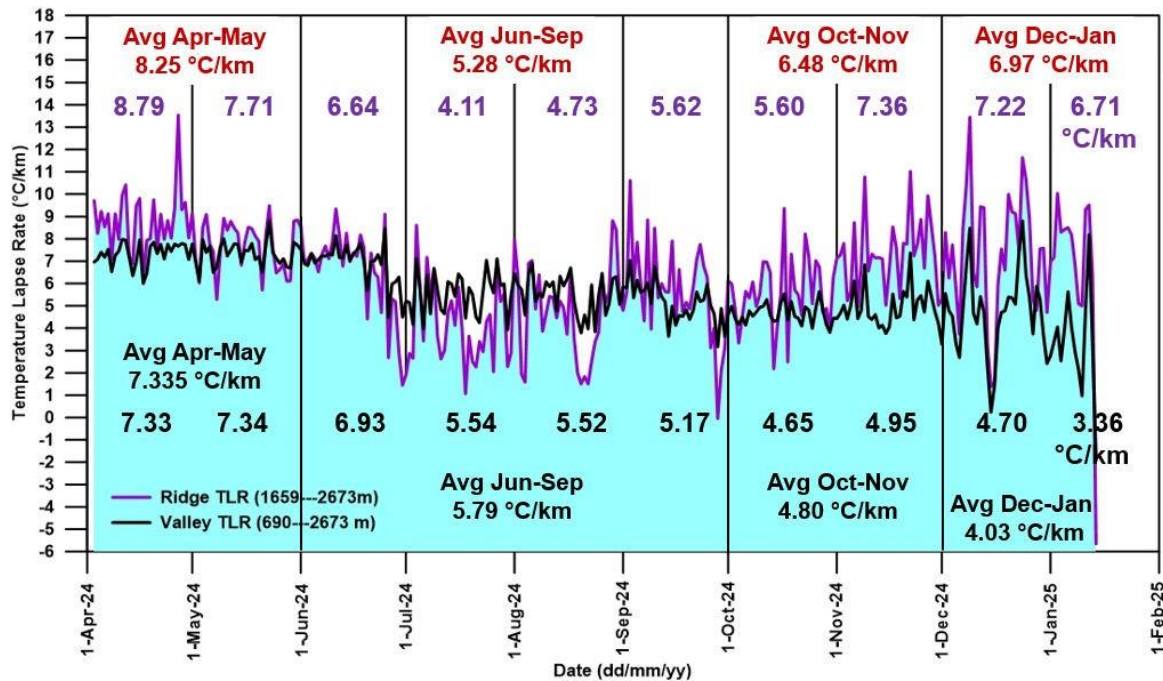


Fig. 2 Ridge and Valley TLRs

The ASTER-DEM (30 m resolution) was downloaded from the USGS Earth Explorer to prepare slope, aspect, and hill shade maps of the study area (Fig. 3). Sentinel-2 data (10 m resolution) was downloaded from the ESRI Sentinel Land Cover Explorer, and land use-land cover (LULC) maps (Fig. 4) were prepared for the years 2019–2024.

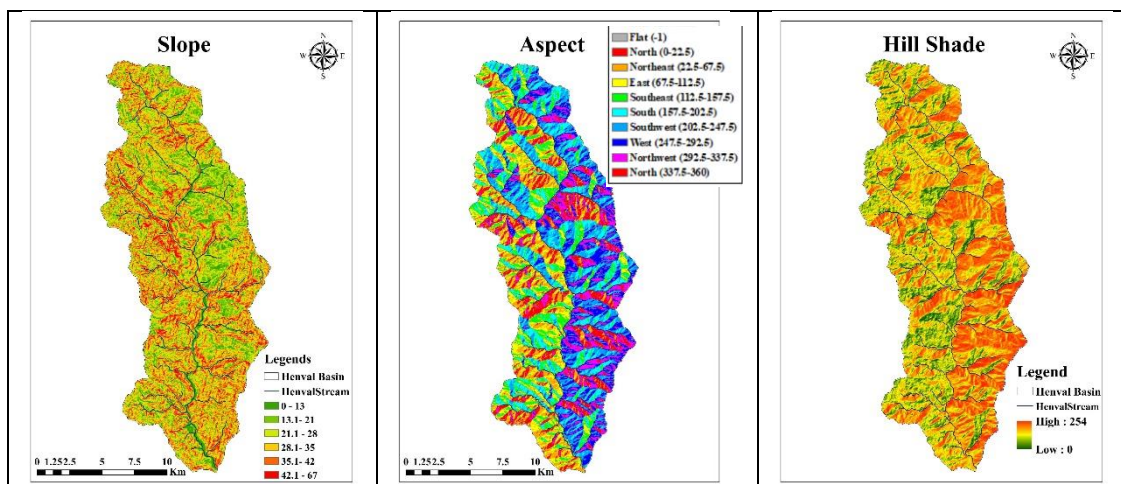


Fig. 3 Slope, Aspect, and Hill-Shade maps of the Henval Catchment

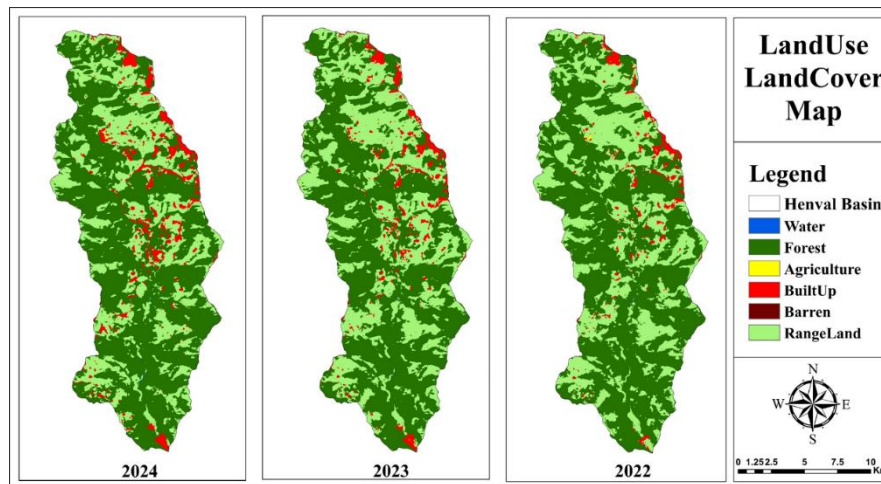


Fig. 4 LULC Maps of the Henval Catchment

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-26/09

1. **Title of the Project**
Evaluation of Area-Design Curve method for 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'
Dr. Harsh Upadhyay, Scientist 'B' (New Inclusion)
3. **Project Duration: 02 years (04/24 – 03/26)**
4. **Statement of the problem**
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 (1958). Borland and Miller (1958) 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. **Objective of the Study**
To evaluate the Area-Design-Curve method to estimate revised capacity for Indian reservoirs in response to sedimentation.
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**
 - 1 Original elevation-area-capacity curve of the reservoirs
 - 2 Observed elevation-area-capacity curve from resurvey
8. **Methodology**
Empirical Area Reduction method based on “Area-Design-Curve” will be used to estimate revised reservoir capacity in response to sedimentation in Indian reservoirs.

Empirical Area Reduction Method:

The method was developed by Borland and Miller (1958) 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 reservoir.

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	$A_p = 3.417p^{1.5} (1-p)^{0.2}$
II	2.3240	0.5	0.4	$A_p = 2.324p^{0.5} (1-p)^{0.4}$
III	15.8820	1.1	2.3	$A_p = 15.882p^{1.1} (1-p)^{2.3}$
IV	4.2324	0.1	2.5	$A_p = 4.232p^{0.1} (1-p)^{2.5}$

The Empirical Area-Reduction Method for determining the probable sediment distribution is accomplished through two main steps:

- 1 Classify the reservoir using 4 basic standard type curves which were developed from actual resurvey data.
- 2 Make a trial and error type computation until the capacity computed equals the predetermined capacity.

9. Progress

Empirical Area Reduction (EAR) method was used to compute the revised capacity of reservoirs in response to sedimentation. The computed revised capacity was then compared with the observed values. The evaluation of the Empirical Area Reduction method was conducted for twenty-one Indian reservoirs. The distribution of reservoir types, as shown in Fig. 1, follows the Empirical Area Reduction method. Most of these reservoirs fall under Type-3, i.e., Hill-type reservoirs. The New Zero Elevation (NZE) was found to be close to the MDDL level for all twenty-one reservoirs, as illustrated in Fig. 2. The revised capacity was computed and compared with the observed values, revealing a deviation in the computed results. The static PBIAS (%) was plotted, as shown in Fig. 3, for these reservoirs. Figure 3 indicates that reservoirs having PBIAS value higher than 10%, signifying a deviation between computed and observed values. Further, efforts are ongoing to obtain more reservoir data on EAC to extend the study to a larger number of reservoirs across India.

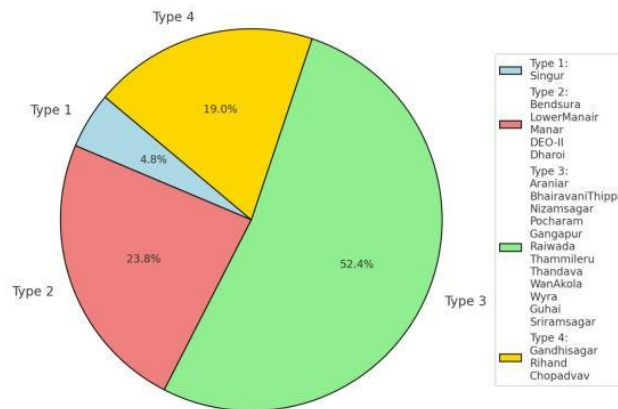


Fig. 1 Classification of reservoir type as per EAR method

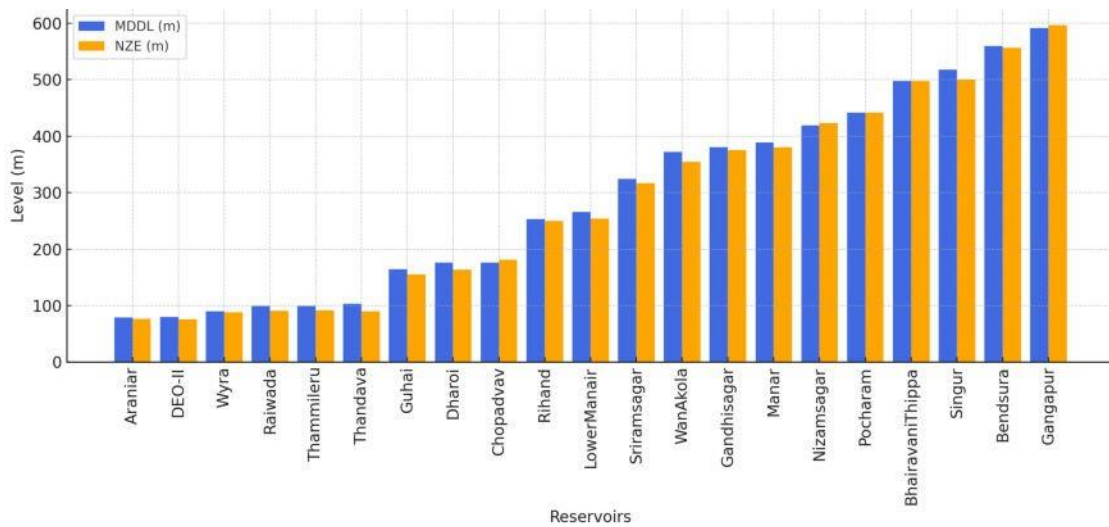


Fig. 2 Comparison of NZE and MDDL level

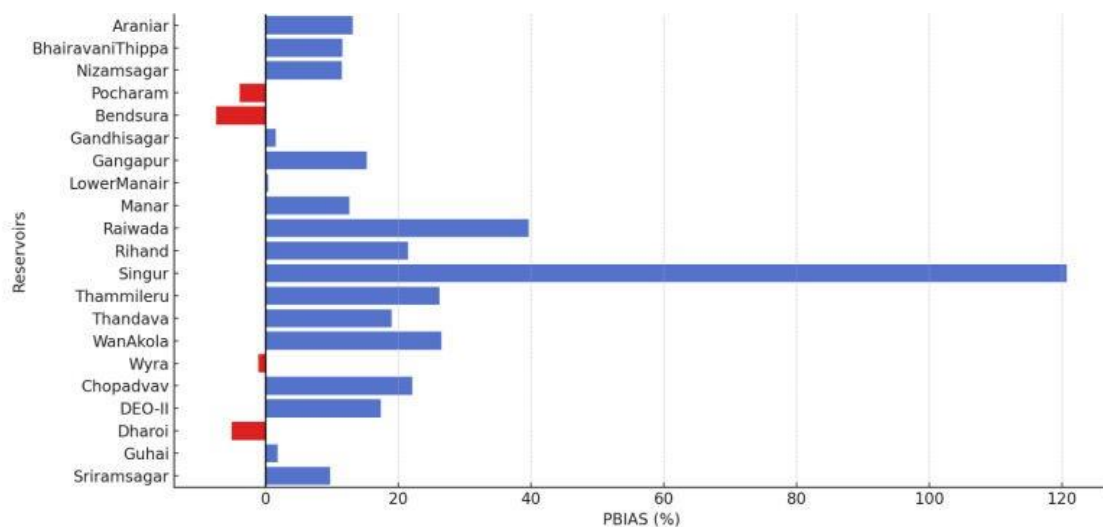


Fig. 3 PBIAS (%) for reservoirs

10. 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	Analysis, Results and Discussion								
5	Preparation of final report								

11. Deliverable

Research papers, reports, stakeholder engagement.

12. 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.

13. Adopters of the results of the study and their feedback: Researchers, Engineers.**14. 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	1,00,000.00
	Grand Total:	1,00,000.00

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-27/10

1. **Title of the Project**
Water yield potential and 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**
Dr. Harsh Upadhyay, Scientist 'B',
Dr. Vishal Singh, Scientist 'D'
Dr. A. R. Senthil Kumar, Scientist 'G'
Dr. P. R. Patil, Scientist 'C'
3. **Project Duration: 03 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) Assessment of the impacts of climate change upon the different hydro-meteorological parameters associated with the basin.
 - b) Water yield assessment of the different tributaries of the TRB and impacts assessment of climate change and land use change using SWAT model.
 - c) Determination of flooding extents in TRB due to historical and projected extreme events using HEC-RAS model.
 - d) 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 km². 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.

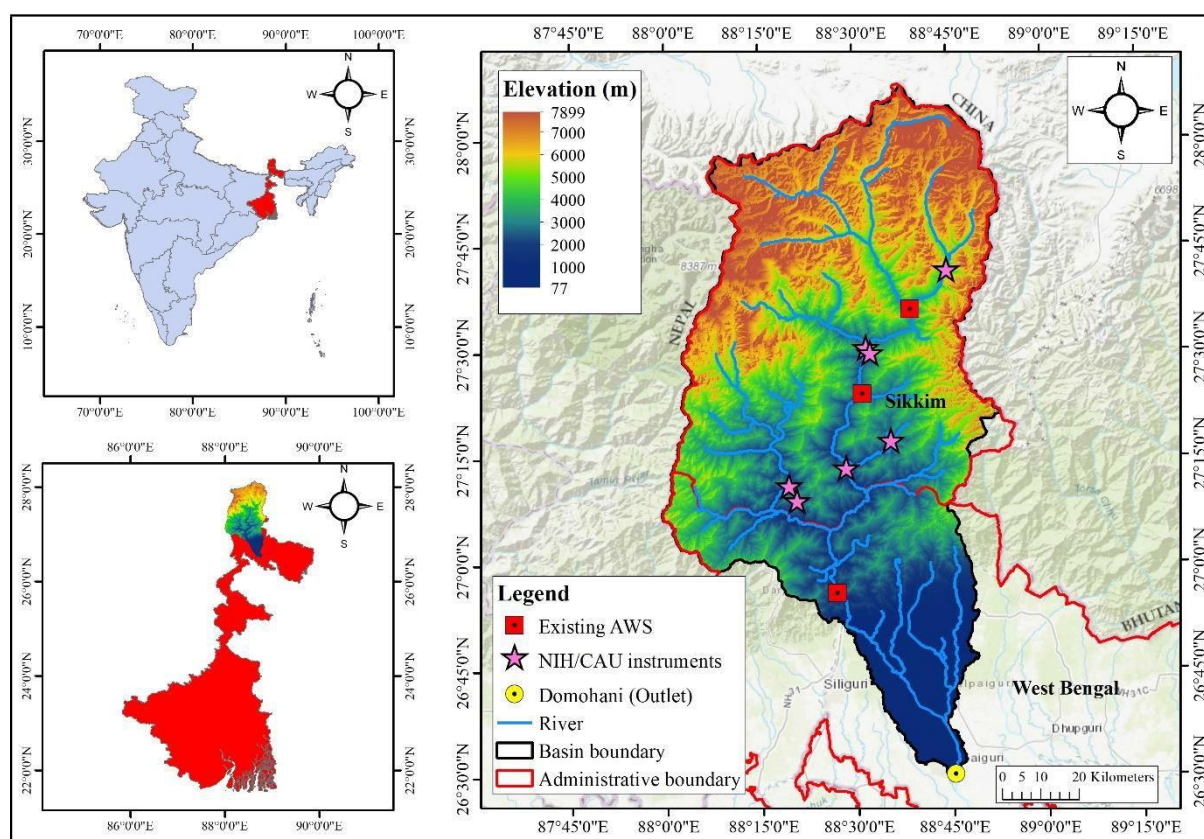


Fig. 1 Study area map of TRB Table 1 Data requirement

S. No.	Data	Source(s)
1.	DEM	SRTM, Copernicus, ASTER
2.	LULC	NRSC, ESRI, LANDSAT
3.	Soil	FAO
4.	Hydro-meteorological	IMD, IMDAA, State WRD, CWC, NHPC
5.	Climate	CMIP6

7. Proposed Methodology

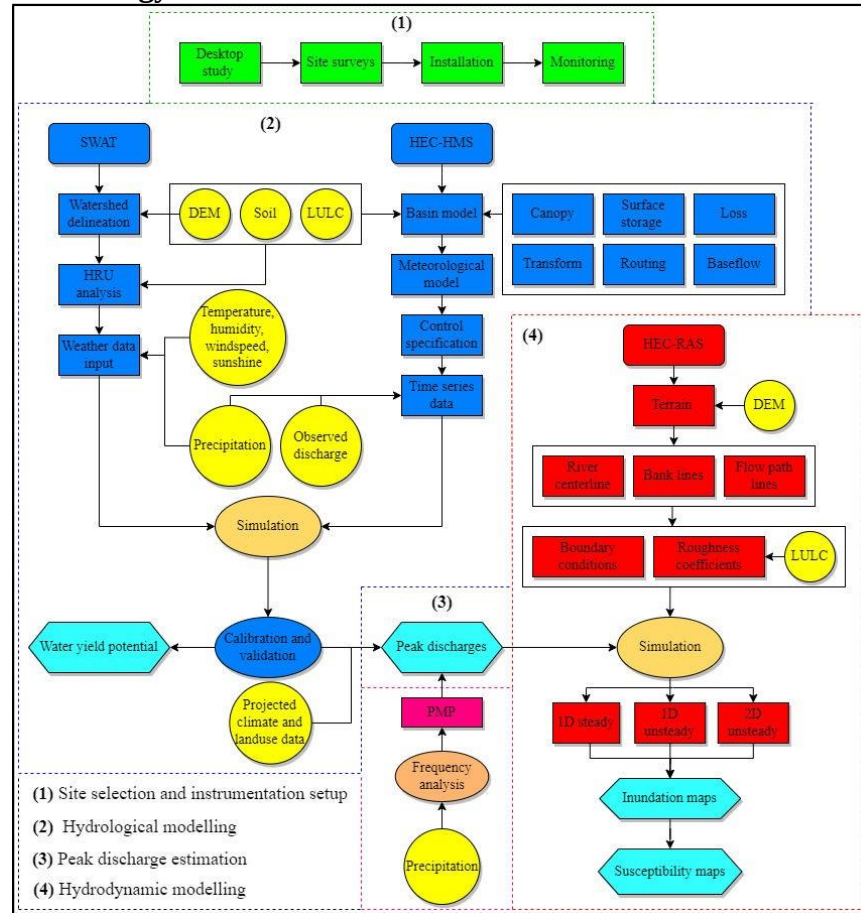


Fig. 2 Workflow of study

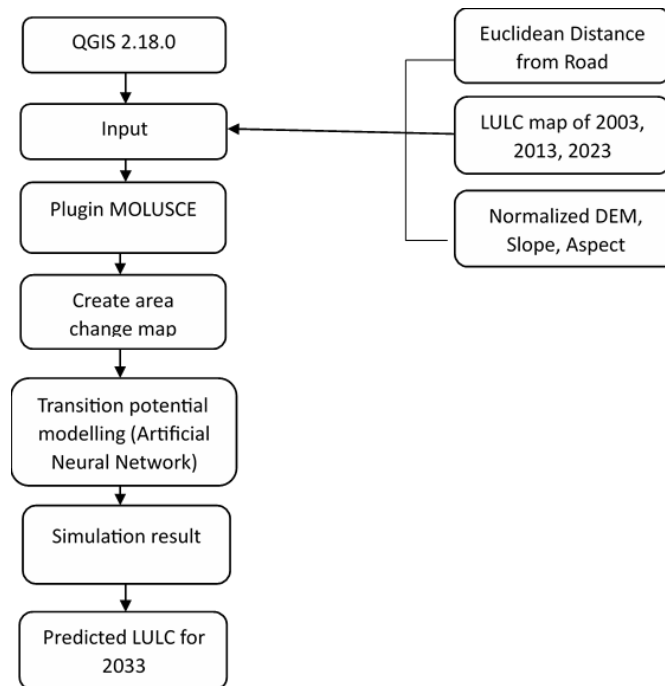


Fig. 3 Land use prediction process in QGIS MOLUSCE plugin

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	1 st year				2 nd year				3 rd 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

- Total cost of the project: ₹ 35.52 lacs
- Source of funding: NIH
- Head-wise cost:

Head/Post	Amount (₹ In Lakh)			
	Year 1	Year 2	Year 3	Total
Project Staff: Resource person	3.30	3.30	3.30	9.90
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

Non-contact Radar-based discharge monitor (1)	15.00	-	-	15.00
Total				30.90

11. Progress till date

- Collection and comparison of satellite imageries for different dates depicting land cover of the Teesta basin was completed with selection of three images (2003, 2013 and 2023) to be used for land use prediction.
- Unsupervised classification of said images was carried out using Google Earth Engine in order to develop land use land cover (LULC) maps for the basin. The LULC maps are shown as follows:

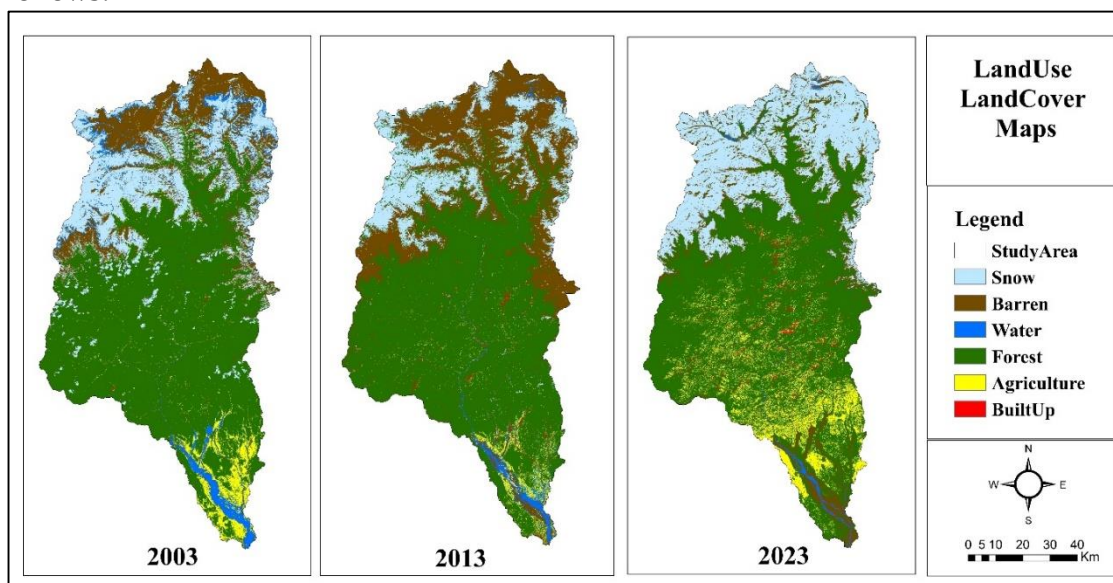


Fig. 4 LULC maps of different years used in the study

- The LULC maps of 2003 and 2013 along with DEM, slope and aspect maps of the study area were used as inputs in the MOLUSCE plugin of QGIS for the simulation of LULC in the basin utilizing an Artificial Neural Network (Fig. 3).
- The LULC map simulated for 2023 was validated against the LULC map of 2023 prepared as described earlier. The comparison showcased an excellent classification accuracy as per the overall Kappa coefficient of 0.931.
- Based on this validated model, maps were generated for future years such as 2033 and the variation were compared as shown below:

Table 1: Decadal variation in LULC

Class	Initial Area (%)	Change 2003-2013	Change 2013-2023	Change 2023-2033
Snow	29	26	27	25.7
Barren	14	16.7	13.6	14.6
Water	17	16	14	14.3
Forest	34	28.6	26.4	24.2
Agriculture	4	10	13	14.2
Builtup	2	2.7	6	7
Snow	29	26	27	25.7

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2024-26/11

1. **Title of the Project:**
Water Resources Planning and Management using DSS (PM) under Changing Climatic and Land-Use Conditions
2. **Revised Project Team:**
Dr. Richa Pandey; Scientist 'B'
Dr. Ajay Ahirwar; Scientist 'C'
Er. Sukant Jain; Scientist 'C'
Dr. A. R. Senthil Kumar, Scientist 'G'
Dr. A. K. Lohani; Scientist 'G'
3. **Project Duration:** Two years (April 2024 – April 2026)
4. **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)
5. **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.

6. 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).

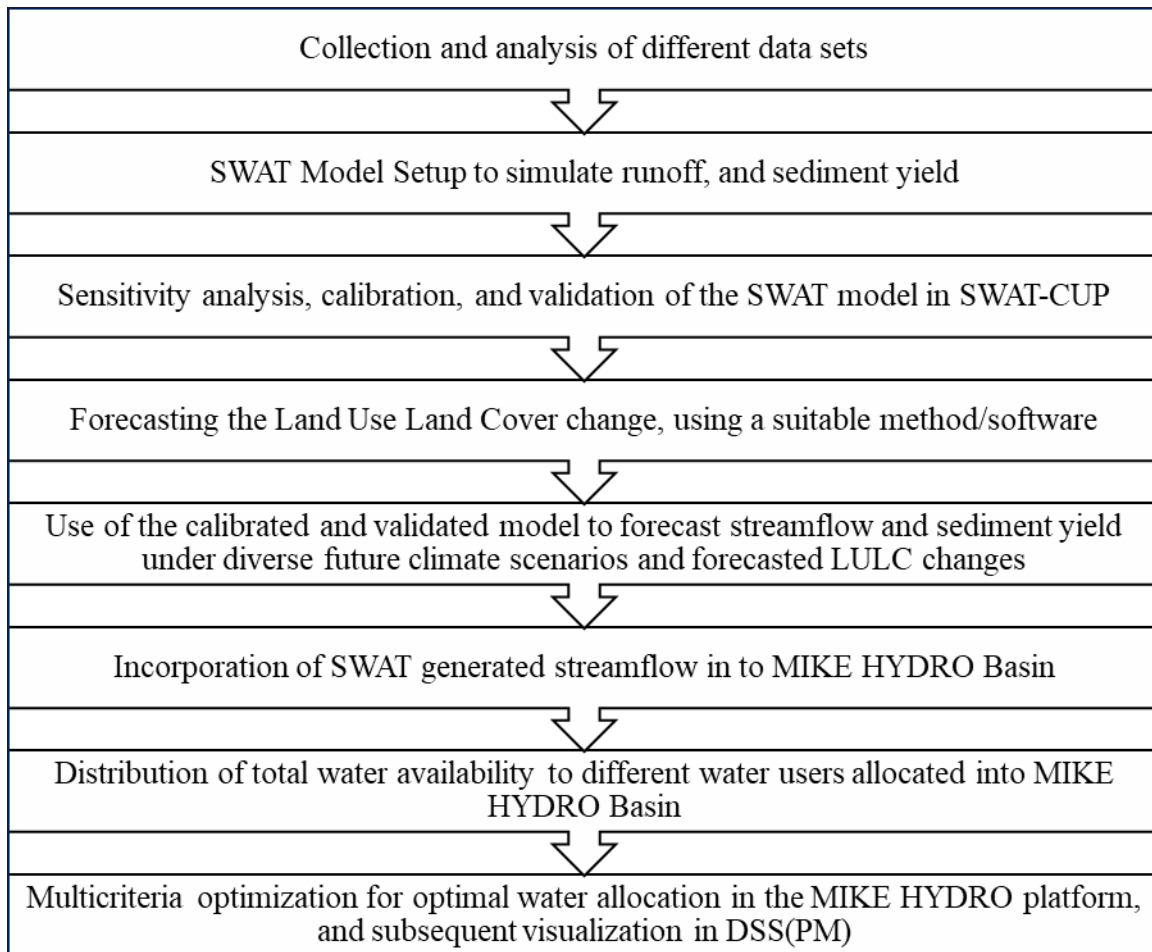


Fig. 2 Flow Chart Depicting Study Methodology

7. Work Plan and Timeline

a. Date of commencement of the project: April 2024

b. Stages of work and milestones:

S. No.	Work element	1 st Year				2 nd 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								■

8. Progress of the Project:

During the current reporting period, the project primarily focused on the first phase: **“Comprehensive Study on Streamflow and Sediment Yield Prediction under Changing Climatic and Land-Use Conditions Incorporating SWAT.”** To implement this objective, the SWAT model was set up for the Upper Krishna Basin, integrating major and medium reservoirs along with 30 years of meteorological data. Multisite calibration was performed using discharge measurements from five gauge-discharge stations available on the WRIS platform.

Future land use and land cover (LULC) maps were generated using the **CA-Markov Chain** machine learning algorithm in **TerrSet** (formerly IDRISI) software, while LULC changes were analyzed through **ArcGIS**. Additionally, among the various models in the **CMIP6 dataset**, the five best models were identified for study area through literature review. For these models, precipitation and temperature (minimum and maximum) data were obtained for two climate scenarios: **SSP 2-4.5** and **SSP 5-8.5**. The impact of these climate scenarios and LULC changes was then assessed using the previously calibrated SWAT model.

S. No.	Sub-Objectives	Status
1	To simulate reservoir inflow and sediment yield, using the Soil and Water Assessment Tool (SWAT)	Completed
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	In progress. Compilation of results are due (Will be completed in the coming fortnight)
3	Draft Report preparation	Ongoing

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2025-28/02

1. **Title of the Project**
Comprehensive Reservoir Sedimentation Analysis of Major Indian Reservoirs Using Google Earth Engine
2. **Project Team:**
Dr. Ajay Ahirwar, Scientist 'C'
Dr. Richa Pandey, Scientist 'B'
Dr. Umesh Kumar Singh, Scientist 'C'
Dr. A. R. Senthil Kumar, Scientist 'G'
3. **Project Duration: 3 Years (04/25 – 03/28)**
4. **Statement of Problem**
Reservoir sedimentation significantly reduces water storage capacity, affecting irrigation, drinking water supply, and hydropower generation. Traditional methods of sediment assessment are expensive and time-consuming. With advancements in remote sensing and cloud-based geospatial analysis platforms like Google Earth Engine, it is possible to develop an efficient and cost-effective sediment monitoring framework. This study aims to harness GEE's capabilities for analyzing sedimentation patterns across Indian reservoirs and provide actionable insights for sustainable water resource management.
5. **Study Area**
The study will focus on selected reservoirs across India. The final selection will depend on the availability of remote sensing and sedimentation data.
6. **Objective of the Study**
This study aims to leverage advanced remote sensing techniques and geospatial tools to enhance sedimentation assessment in major Indian reservoirs. By integrating ICESat-2 laser altimetry data, Sentinel-2 imagery, and Google Earth Engine (GEE), the study will develop a streamlined workflow for monitoring sediment deposition trends and estimating volume changes. The proposed approach will combine satellite-derived insights with empirical models for improved sedimentation analysis and management. The specific objectives are:
 - a. To analyze reservoir sedimentation trends using satellite-based remote sensing data in Google Earth Engine (GEE).
 - b. To assess sediment accumulation and volume changes using ICESat-2 ATL08 & ATL13 datasets.
 - c. To develop an automated web based workflow for reservoir sedimentation monitoring using GEE and Python.
 - d. To validate the results with historical sedimentation data and refine the approach for better accuracy.
 - e. To compare the remote sensing-based sedimentation assessment with empirical models like the Area-Design Curve method.
7. **Data Needs and brief Methodology Input Data**
 - ICESat-2 ATL08 & ATL13 elevation datasets
 - Sentinel-2 multispectral imagery
 - Landsat 7/8/9 data for long-term shoreline analysis

- Historical reservoir bathymetric and sedimentation survey data
- DEMs (Digital Elevation Models) for terrain analysis
- Reservoir boundary shapefiles
- Surface Water Occurrence Probability (SWOP) maps
- Shoreline elevation anomaly (SEA) datasets for tracking sedimentation
- Empirical sedimentation data based on the Area-Design Curve method

Methodology

The study on Comprehensive Reservoir Sedimentation Analysis of Major Indian Reservoirs Using Google Earth Engine (GEE) follows a structured approach integrating remote sensing, GIS, and numerical modeling techniques to assess and monitor sedimentation trends. The methodology begins with data collection, including retrieval of ICESat-2 ATL08 & ATL13 datasets, Sentinel-2 imagery, Landsat 7/8/9 data, historical bathymetric surveys, and DEMs (Digital Elevation Models). These datasets will be processed in Google Earth Engine (GEE), R and Python to ensure consistency and accuracy for sedimentation analysis.

Following data acquisition, preprocessing steps will involve cloud masking, geometric corrections, and atmospheric corrections to enhance the quality of remote sensing data. The study will utilize Modified Normalized Difference Water Index (MNDWI) and Surface Water Occurrence Probability (SWOP) to accurately delineate water boundaries and detect long-term sedimentation patterns. ICESat-2 laser altimetry data will be employed to derive shoreline elevation changes, facilitating precise volumetric sediment estimation.

The sedimentation analysis will be conducted through spatial and temporal trend assessments, utilizing multi-date satellite imagery and elevation datasets. Sedimentation patterns will be compared across multiple reservoirs using shoreline elevation anomaly (SEA) analysis, which enables tracking of erosion and deposition zones. Additionally, the study will integrate empirical sedimentation models, such as the Area-Design Curve method, to validate satellite-derived sedimentation estimates.

To ensure accuracy, the results from remote sensing-based sedimentation assessments will be validated using historical survey data, in-situ measurements, and available hydrological records. A comparative analysis between empirical models and satellite-derived sedimentation estimates will be performed to refine the methodology and enhance prediction capabilities. Finally, the study will develop a web based automated Python-GEE workflow for continuous reservoir sedimentation monitoring as well as for repeatability and scalability. The workflow will enable long term assessment, stakeholder engagement, and decision-making support for reservoir managers and policymakers. The results of this study will contribute to better sedimentation management strategies, improved reservoir capacity planning, and sustainable water resource management across major Indian reservoirs.

8. Project Budget

- Total cost of the project (Rs.): 10,00,000.00 (Ten lakhs only)
- Source of funding: Internal funding from NIH
- Sub Headwise abstract of the cost

Sl. No.	Sub-head	Amount (in Rupees)
1	Travelling Expenditures	8,00,000/-
2	Miscellaneous	2,00,000/-
	Grand Total:	10,00,000/-

The funding will support data acquisition, computational resources for processing large datasets, and dissemination of findings through research publications and stakeholder workshops.

9. Expected Deliverables

- Research papers and reports
- An automated web application based on Python-GEE sedimentation analysis workflow
- Comparative analysis of empirical and remote sensing-based sedimentation results
- Stakeholder engagement and knowledge dissemination

10. Expected Timeline against the Deliverables:

S. No.	Work Element	Year 1	Year 2	Year 3
1	Data Collection	Q1-Q2		
2	Sedimentation Analysis using GEE	Q3-Q4		
3	Model Development and Automation		Q1-Q2	
4	Validation and Refinement		Q3-Q4	
5	Comparison with Empirical Models			Q1-Q2
6	Report Preparation and Dissemination			Q3-Q4

NEW STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2025-28/03

1. **Title of the Project**
Application of Decision Support System for Planning & Management (DSS (PM)) in the Narmada River Basin
2. **Project Team:**
Dr. Ajay Ahirwar, Scientist 'C'
Dr. Harsh Upadhyay, Scientist 'B'
Dr. Richa Pandey, Scientist 'C'
Dr. A. R. Senthil Kumar, Scientist 'G'
3. **Project Duration: 3 Years (04/25 – 03/28)**
4. **Statement of Problem**
The Narmada River Basin plays a crucial role in India's water security, supplying irrigation, drinking water, and hydroelectric power to multiple states. However, challenges such as fluctuating water availability, flood risks, and climate variability require data-driven decision-making tools for sustainable water resource management. The Decision Support System for Planning & Management (DSS-PM), developed by NIH Roorkee with DHI India, is a robust web-based (www.dsspmwater.com) platform designed to assist stakeholders in integrated reservoir operations, flood and drought management, and water allocation planning. The system enables future scenario analysis and multi-stakeholder collaboration, ensuring sustainable and equitable water distribution. DSS (PM) provides an interactive decision-making framework that incorporates hydrologic, hydraulic, water allocation, water quality models and drought dashboard, empowering users to simulate various operational strategies for improved water governance.
5. **Study Area**
The study will focus on the Narmada River Basin, one of the most significant river basins in India. The basin covers multiple states and hosts major reservoirs such as Indira Sagar, Sardar Sarovar, and Bargi. Implementing DSS (PM) in this region will enhance decision-making for reservoir operations, water resource planning, flood and drought management, and overall basin-wide water governance.
6. **Objective of the Study**
The Decision Support System for Planning & Management (DSS-PM) is a web-based platform designed to support decision-making for water resource management. This study aims to implement DSS-PM in the Narmada River Basin to improve reservoir operations, flood and drought management, and water quality assessment. By utilizing DSS-PM's integrated modeling capabilities, the study will enhance data-driven planning, ensuring sustainable and efficient water resource management. The specific objectives are:
 1. To implement the Decision Support System for Planning & Management (DSS(PM)) in the Narmada River Basin for improved water resource management.
 2. To apply existing hydrological, hydraulic, and water quality models within DSS (PM) to enhance decision-making.
 3. To utilize DSS (PM) for long-term reservoir operation management, flood control, and drought mitigation.
 4. To establish a web-based GIS platform for interactive visualization, stakeholder

collaboration, and policy decision support.

5. To facilitate multi-criteria analysis (MCA) for balancing economic, environmental, and social aspects of water resource management.

7. Data Needs and brief Methodology Input Data

- Hydrological datasets (rainfall, river discharge, evaporation, temperature, etc).
- Water quality datasets (pH, dissolved oxygen, turbidity, biochemical oxygen demand, heavy metal concentrations etc.).
- GIS layers (watershed boundaries, reservoir locations, administrative zones).
- Reservoir operation records (water release schedules, storage levels).
- Socioeconomic data (water demand, land use, population density).

Methodology

The application of the Decision Support System for Planning & Management (DSS (PM)) in the Narmada River Basin involves a systematic approach integrating hydrological, meteorological, and water quality datasets with a web-based decision support framework. Initially, data collection will focus on acquiring hydrological records (rainfall, discharge, evaporation, etc.), reservoir operation datasets (storage levels, water release schedules), GIS layers (watershed boundaries, reservoir locations), and water quality parameters (pH, dissolved oxygen, turbidity, biochemical oxygen demand, and heavy metals, etc.) and groundwater levels. These datasets will be compiled and configured within the DSS (PM) platform to ensure seamless accessibility for decision-makers.

DSS (PM) will be accessed through its web-based interface, where existing models for hydrological, hydraulic, and water quality assessments will be utilized for scenario-based decision-making. The system will support reservoir operation planning, flood forecasting, drought assessment, groundwater assessments and water allocation strategies through interactive tools and multi-criteria analysis (MCA). Stakeholders will be trained on system functionalities to ensure effective adoption.

The next phase will involve validating DSS (PM) outputs by comparing model simulations with historical records and observed data. Scenario testing will be conducted to evaluate different operational strategies for water distribution, environmental flow management, and pollution control under varying climatic and demand conditions. The system's reliability will be assessed through long-term simulations, and refinements will be made based on stakeholder feedback. Finally, implementation and capacity building will be carried out through stakeholder training sessions and policy workshops. This will ensure that government agencies, water managers, and decision-makers can effectively utilize DSS (PM) for long-term sustainable water governance in the Narmada River Basin. The study will conclude with the preparation of comprehensive reports, policy recommendations, and guidelines for integrating DSS (PM) into India's water resource management framework.

8. Project Budget

- a. Total cost of the project (Rs.): 10,00,000.00 (Ten lakhs only)
- b. Source of funding: Internal funding from NIH
- c. Sub Headwise abstract of the cost

Sl. No.	Sub-head	Amount (in Rupees)
1	Travelling Expenditures	8,00,000/-
2	Miscellaneous	2,00,000/-
	Grand Total:	10,00,000/-

The funding will support data acquisition, computational resources for processing large datasets, and dissemination of findings through research publications and stakeholder

workshops.

9. Expected Deliverables

- A fully configured Decision Support System (DSS(PM)) for the Narmada River Basin.
- Scenario-based analysis reports for reservoir operation simulations.
- Policy recommendations for sustainable water resource management.
- Training modules for government agencies and water managers to enhance DSS (PM) adoption.
- Stakeholder engagement workshops for long-term DSS (PM) sustainability

10. Expected Timeline against the Deliverables:

Year	Work Element	Details
I	Data Collection & System Configuration	Compilation of hydrological, meteorological, and water quality datasets. Integration of reservoir operation records and GIS layers into DSS-PM.
	DSS (PM) Platform Setup	Configuring DSS-PM for Narmada Basin, ensuring compatibility with existing databases and models.
	Preliminary Training & Stakeholder Engagement	Conducting workshops for water managers, policymakers, and agencies on DSS (PM) functionalities.
II	Scenario Testing & System Calibration	Running simulations for water allocations, flood control, and drought assessment. Verifying system accuracy by comparing with historical records.
	Water Quality Monitoring & Integration	Incorporating water quality data into DSS (PM), enabling pollution analysis and compliance monitoring.
	Model Validation & Refinement	Refining DSS (PM) outputs based on stakeholder feedback and real-world application results.
III	Full-Scale Implementation & Operational Training	Expanding DSS (PM) usage to multiple agencies and training officials on future scenarios decision-making.
	Policy Recommendations & Institutional Adoption	Developing policy frameworks for DSS (PM) applications into national and state-level water management strategies.
	Final Report & Dissemination	Preparing comprehensive project reports, policy briefs, and recommendations for long-term sustainability.