# AGENDA AND AGENDA NOTES

# 76th MEETING OF THE
# TECHNICAL ADVISORY COMMITTEE (TAC) OF NIH

# APPENDICES
## (Vol.-II)

**29th August 2022
at 1500 Hrs
Venue: Society Room, NIH, Roorkee**



# NATIONAL INSTITUTE OF HYDROLOGY
# ROORKEE-247667

# MINUTES OF THE 75<sup>th</sup> MEETING OF TAC OF NIH

# 75<sup>th</sup> MEETING OF TECHNICAL ADVISORY COMMITTEE (TAC)
# OF NATIONAL INSTITUTE OF HYDROLOGY

## Held on 1 September 2021(VC mode)

The 75<sup>th</sup> meeting of the Technical Advisory Committee (TAC) of the National Institute of Hydrology, Roorkee was held in VC mode on 1 September2021. The meeting was chaired by Er. S. K. Haldar, Chairman, CWC. The list of the participants is given in Annexure-I.

Dr. J. V. Tyagi, Director, NIH first welcomed the Chairman, members and invitees, and then invited the Chairman for his opening remarks. At the outset, the Chairman in his opening remarks welcomed the participants. He appreciated the research being carried out by NIH and desired that the Institute should try to carry out research for sustainable development of water resources in India.

After a round of introduction, Dr. V. C. Goyal, Member-Secretary, delivered a brief presentation on the organizational set up and activities of NIH for the benefit of new members. He then took up the agenda items.

## ITEM NO. 75.2: Confirmation of the Minutes of 74<sup>th</sup> Meeting of TAC

The Member-Secretary informed that minutes of the 74<sup>th</sup> meeting of TAC, held on Dec. 15, 2020, were circulated to all the members and invitees vide email dated Jan. 1, 2021. Since no comments were received from the members, the Minutes were confirmed by the TAC.

## ITEM NO. 75.3: Action Taken on Decisions/Recommendations in the Previous Meeting

The Member-Secretary presented a table showing comments and suggestions of the members during the previous meeting. Regarding the study on discharge measurement in Himalayan basins, Director, NIH mentioned that a study on discharge estimation using non-contact hydrometric measurements is being carried out by Prof M K Jain at Department of Hydrology, IIT Roorkee, and may be referred to. During discussion on the second item, i.e. preparation of a Research Digest in Hydrology, Director, NIH mentioned about the manpower constraint as no Documentation Officer is presently available in NIH. Dr Sikka, Prof Arup Sarma, Shri Azad and others strongly advocated the need of a Documentation Officer in any research organization, and advised to request the GB of NIH to create the post of a Documentation Officer in NIH. In the meantime, a consultant may be hired to initiate the compilation of hydrologic research in India on an identified topic, such as the theme of World Water Day-2021 i.e. Valuing Water, or Impact of Climate Change on Water Resources as suggested by the Director, NIH.

## ITEM NO. 75.4: Status of the Work Programme for the Year 2020-21

The Member-Secretary briefly mentioned about the studies carried out by the Institute during the year 2020-2021.He reported that twelve sponsored projects and fifteen internally funded studies were completed during the year. Members appreciated the number of publications brought out by the Institute and number of training/workshop/symposium organized by the Institute.

The following studies completed during 2020-2021 were presented during the meeting:

(i) Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework (PI: Dr. P K Singh, Sc.D)

(ii) Real time flood modelling using HEC-RTS modelling framework (PI: Dr. Vishal Singh, Sc.C)

Dr Sikka appreciated the work carried out by NIH using WA+ Framework. Prof Arup Sarma suggested to improve land productivity and examine its impact on water productivity. Prof Jayakumar opined that NIH should popularise WA+ by carrying out research in different climatic zones of India, and publish results in reputed journals. Dr Sanjay Jain (NIH) informed that two more studies on WA+ have been taken up on the request of Meghalaya and Nagaland States.

Dr. Wani appreciated excellent suggestion from Prof Jayakumar, as it will be excellent input for IDEA (India Digital Ecosystem for Agriculture). NIH can lead this and its Regional Centres can be roped in for preparing for each State. For resources DST, DBT, Jal Shakti Ministry, MiEITY could be tapped. Also, Dr Suhas Wani advised to consult soil maps prepared by NBSSLUP, Nagpur, for WA+ studies.

Regarding the second study, the Chair advised to send the report of this study to CWC. Prof Arup Sarma mentioned that the forecasting uncertainties and associated risks should be verified with river cross-section data.

TAC noted the progress of the works of the Institute during the year 2020-2021.


**ITEM NO. 75.5: Proceedings of the Working Group and Regional Coordination Committee (RCC)Meetings**

The Member-Secretary briefly mentioned about the 51$^{st}$ meeting of the Working Group of NIH which was held in VC mode during 14-15 June 2021and the RCC meetings held at the different Regional Centres. During these meetings, the Working Group/RCC members reviewed the progress of studies for the year 2020-2021 and recommended the work program for 2021-22.

Prof. Jayakumar advised NIH to consider Scopus Index while publishing research papers. Dr Sikka suggested dissemination of digital tools useful for hydrologists through social media. Prof Arup Sarma advised to widely disseminate short videos of success stories. Dr. Wani suggested tracking of research papers published by the scientists in different Divisions/Regional Centres. Also, he suggested compilation of a concept note on hydrological inputs as applicable to IDEA and make it available to various stakeholders, and on NIH website/portal.

**ITEM NO. 75.6: Work Program for the year 2021-22**

The Member-Secretary briefly mentioned about the proposed work programme of the Institute for the year 2021-22 which was discussed during the 51$^{st}$ Working Group meeting and various RCC meetings of NIH. The proposed work programme of the Institute for F.Y. 2021-22, as recommended by the Working Group and the respective RCCs, was also placed before the TAC.

TAC approved the work programme of the Institute for the year 2021-22 (Annexure-II).

**ITEM NO. 75.7: Major projects and activities of national importance**

It was informed by the Member-Secretary that the following three major R&D projects are currently ongoing at NIH:

1. National Hydrology Project (NHP)- funded by The World Bank & GoI
2. National Mission for Sustaining the Himalayan Ecosystem (NMSHE)- funded by DST (GoI)
3. Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)- funded by DST (GoI)

**ITEM NO. 75.8:  Reporting Items**

Details of the consultancy projects carried out by NIH during the year 2021-2022(up to August 2021) were noted by the TAC.

**ITEM NO. 75.9:  Additional items with the permission of the Chair**

No such items were discussed.

The meeting ended with a vote of thanks to the Chair.
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## LIST OF PARTICIPANTS INTHE 75thMEETING OF TAC OF NIH

| | | |
|---|---|---|
| 1. | Er. S.K Haldar, Chairman, CWC | In-chair |
| 2. | Smt. Poonam Sharma, CGWB | Rep. Chairman, CGWB |
| 3. | Dr.J V Tyagi, Director, NIH | Member |
| 4. | Dr. A K Das, IMD, New Delhi | Rep. DDGM(H) |
| 5. | Sh. S K Manik, IMD, New Delhi | Rep. DDGM(H) |
| 6. | Smt. Hemlata Bharwani, IMD, New Delhi | Rep. DDGM(H) |
| 7. | Sh. Rahul Saxena, IMD, New Delhi | Rep. DDGM(H) |
| 8. | Prof. K P Sudheer, IIT Madras | Member (Nominee of IITM) |
| 9. | Prof. K V Jayakumar, NIT, Warangal | Member |
| 10. | Dr. Suhas P Wani, Consultant, IRRI | Member |
| 11. | Prof. M K Jain, IIT, Roorkee | Member (Nominee of IITR) |
| 12. | Prof. Arup Sarma, IIT, Guwahati | Member |
| 13. | Dr. Alok Sikka, IWMI, New Delhi | Member (Rep. IWMI India) |
| 14. | Sh. Shambhu Azad, WAPCOS, New Delhi | Member (Rep. WAPCOS) |
| 15. | Dr.V C Goyal, Sc.G& Head RMO Division, NIH | Member-Secretary |

**INVITEES**

1. Dr.Sudhir Kumar, Sc.G& Head, HI Division, NIH, Roorkee
2. Dr. Sanjay Jain, Sc. G & Head, WRS Division, NIH, Roorkee
3. Dr. M K Goel, Sc. G & Head, GWHDivision, NIH, Roorkee
4. Dr. A K Lohani, Sc.G& Head SWH Division, NIH, Roorkee
5. Dr. R P Pandey, Sc. G & Head, EH Division, NIH, Roorkee
6. Sh. B. Chakraborty, Sc.G, CFMS, Patna
7. Sh. B. Ventkatesh, Sc.G, HRRC, Belgavi
8. Er. Omkar Singh, Sc.F, NIH, Roorkee
9. Dr. A R Senthil Kumar, Sc.F, NIH, Roorkee
10. Dr. Anupma Sharma, Sc.F, NIH, Roorkee
11. Dr. Surjeet Singh, Sc.F, NIH, Roorkee
12. Dr. P C Nayak, Sc.F, DRC, Kakinada
13. Dr. Chandra Mohan T., Sc.E, HRRC, Belgavi
14. Sh. N G Pandey, Sc.E, CFMS, Patna
15. Dr. S S Rawat, Sc.E, NIH, Roorkee
16. Dr. P G Jose, Sc.E, WHRC, Jammu
17. Dr. Manish Nema, Sc.D, NIH, Roorkee
18. Sh. J P Patra, Sc.D, NIH, Roorkee
19. Dr. Jyoti P. Patil, Sc.D, NIH, Roorkee
20. Dr. P K Singh, Sc.D, NIH, Roorkee
21. Dr. Sumant Kumar, Sc.D, NIH, Roorkee
22. Dr. S M Pingale, Sc.C, NIH, Roorkee
23. Dr. Sanjay Kumar Sharma, Sc. C, CFMS, Guwahati
24. Dr. Vishal Singh, Sc.C, NIH, Roorkee
25. Dr. Swapnali Barman, Sc.C, CFMS, Guwahati

## ENVIRONMENTAL HYDROLOGY DIVISION

### APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| SN | Study | Study Team | Duration/Status |
|---|---|---|---|
| **Sponsored Projects (Ongoing)** | | | |
| 1. | Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures | Rajesh Singh (PI) Pradeep Kumar, M. K. Sharma, Sumant Kumar **Partner:** Irrigation Department, Punjab | 3 Years (09/17-08/21) **Sponsored by**: NHP-PDS **Status:** In-progress |
| 2. | Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures | Anjali (PI) Sudhir Kumar, J. V. Tyagi M. K. Sharma **Partner:** CGWB (Delhi unit) | 3 Years (11/2019 – 5/2023) **Sponsored by**: NHP-PDS **Status:** In-progress |
| 3. | Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (Mip) Shahnehar | R.P. Pandey, (PI). Jagdeesh Patra, Rajesh Singh, N. K. Bhatnagar, Shekhar Saini | 3-years (12/17-06/22) **Status:** In-progress |
| **Sponsored Projects (New)** | | | |
| 4. | Isotopic and geochemical approach to study vulnerable confined and unconfided drinking water aquifers in Varanashi and surrounding area | Rajesh Singh (PI) R. P. Pandey BHU, Varanashi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary | 3 years 07/ 2021-07/24 **(proposed collaborative study)** |
| **Internal Study (Ongoing)** | | | |
| 5. | Water quality assessment of Haridwar District | R.K. Nema (PI) Rajesh Singh, J. V. Tyagi, Pradeep Kumar | 2 years (05/19-06/21) **Status:** completed |
| 6. | Simulation of Non-Point Source Pollution Processes in Song River | Pradeep Kumar (PI) J. V. Tyagi, M. K. Sharma, Rajesh Singh, R. K. Nema | 4 years (11/19-10/23) **Status:** In-progress |
| 7. | Development of rejuvenation plan for Hindon river system | M. K. Sharma (PI) Sudhir Kumar, R. P. Pandey, Anupma Sharma, Anjali, Vishal Singh, Pradeep Kumar, NiteshPatidar, Surjeet Singh, Rajesh Singh | 3 Years (07/20-06/23) **Status:**In-progress |
| 8. | Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar | Rajesh Singh (PI) J. V. Tyagi, R. P. Pandey, R.K. Nema, Pradeep Kumar, M. K. Sharma | 2 Years (06/20-05/22) **Status:** In-progress |
| **Internal Studies (New Study)** | | | |
| 9. | Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures | Rajesh Singh (PI) R. K. Nema, Sumant Kumar, Pradeep Kumar, M. K. Sharma | 3 Years (July 2021 – June 2024) |

# GROUND WATER HYDROLOGY DIVISION

## APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| SN | Title of Project/Study | Study Team | Duration | Status & Comments/ Suggestions | Funding |
|---|---|---|---|---|---|
| **Internal Studies** | | | | | |
| 1. NIH/GWH/NIH/20-22 | Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System | Nitesh Patidar (PI), Gopal Krishan, Suman Gurjar | Aug 2020-Jul 2022 | On-going | Internal |
| **Sponsored Projects** | | | | | |
| 2. NIH/GWH/BGS/17-20 | Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency Groundwater Level and Salinity Measurements | Gopal Krishan (PI), Surjeet Singh, C. P. Kumar, M. S. Rao *From: BGS, UK* Dr. Dan Lapworth (PI) Prof. Alan MacDonald | Dec 2017-Nov 2021 | On-going | Sponsored by BGS, UK |
| 3. NIH/GWH/PDS/17-21 | Assessment of Impacts of Groundwater Salinity on Regional Groundwater Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures | Gopal Krishan (PI), Surjeet Singh, C. P. Kumar, *IIT-Roorkee:*M. L. Kansal, Brijesh Yadav (PI) *Sehgal Foundation, Gurgaon:* Lalit Mohan Sharma | Dec 2017-Jul 2022 | On-going | Sponsored by NHP under PDS |
| 4. NIH/GWH/PDS/17-21 | Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study | Surjeet Singh (PI), M. K. Goel, Sudhir Kumar, Suman Gurjar, Gopal Krishan | Dec 2017-Jul 2022 | On-going | Sponsored by NHP under PDS |
| 5. NIH/GWH/DST/18-20 | Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA | B. Chakravorty (India Lead), Surjeet Singh (Dy. Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar *Other India Partners:* IITR, IITKg, MCS, Patna *UK Partners:* Univ. of Manchester, BGS, Salford University, Univ. of Birmingham | Jan 2018-Dec 2021 | On-going | DST-Newton Bhabha – NERC - India -UK Water Quality Research Programme |
| 6. NIH/GWH/DST/18-20 | Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micro-pollutants | Anupma Sharma (India Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar, M. K. Sharma *Other Indian Partners:* IIT Ropar, IIT Jodhpur *UK Partner:* Cranfield University *Project Partners:* Water Harvest, Excellent Development (UK based NGOs) | Jan 2018-Dec 2021 | On-going | DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme |

| 7. NIH/GWH/CEHM/18-22 | Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin upto Delhi | Anupma Sharma (PI), Sanjay K. Jain, Archana Sarkar, M. K. Sharma, L. N. Thakural, Sumant Kumar, Suman Gurjar, Vishal Singh, Nitesh Patidar *Partner Organizations:* Irrigation & Water Resources Dept. Haryana, Groundwater Dept. UP, Yamuna Basin Organization, CWC, New Delhi | Apr 2018-Mar 2022 | On-going | Special Project under "Centre of Excellence" (NHP) |
|---|---|---|---|---|---|
| 8. NIH/GWH/DST/19-23 | Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water | Anupma Sharma (Lead NIH), C. P. Kumar, Suman Gurjar, Nitesh Patidar (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI Bikaner, CIAH Bikaner, NIAM Jaipur) | Mar 2019-Feb 2024 | On-going | Sponsored by DST |
| 9. NIH/WRS/NMSHE/16-20 | Development of a project website and hydrological database in Upper Ganga basin (SP-1) | M. K. Goel (PI), M. Arora, A. K. Lohani, D. S. Rathore, D. Chalisgaonkar, A. R. S. Kumar, Surjeet Singh, P. Mani, A. Sarkar, M. K. Nema, Suman Gurjar, P. K. Mishra | Jan 2016-Sep 2021 | On-going | Sponsored by DST under NMSHE SP-1, |
| 10. NIH/GWH/CCRBF/20-23 | Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF | Gopal Krishan (PI & Coordinator) | Jul 2020-Jun 2023 *Status: Approval is under consideration of MEA* | On-going | Sponsored by Federal Ministry of Education & Research, Germany |

**Training Courses Proposed**

| 1 | Four Training courses shall be organized by the Division during 2021-22 under the National Hydrology Project (NHP). |
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# HYDROLOGICAL INVESTIGATIONS DIVISION

## APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| S. N. | Project Title | Study Team | Duration | Status |
|---|---|---|---|---|
| **INTERNAL STUDIES** | | | | |
| 1. | Hydrological investigations of selected springs in Tehri Garhwal District , Uttarakhand | S M Pingale (PI), Sudhir Kumar S. D. Khobragade Soban Singh Rawat Er. Padam Singh, (UUHF, Ranichauri) Rajeev Gupta | Apr 2019-Mar 2022 | Continuing Study |
| 2. | Assessment of impact of land use and land cover change on groundwater conditions in parts of Sabarmati river Basin, Gujarat | M. Someshwar Rao (PI) Sudhir Kumar Vipin Aggarwal | Apr 2021 – Mar 2023 | *Revised New Study* |
| 3. | Integrated Hydrological Investigations of Renuka lake, Himachal Pradesh, for its Conservation and Management | SD Khobragade (PI) Sudhir Kumar Hukam Singh Rajiv Gupta Vipin Agarwal Scientist from GoH.P. | Jul 2020-Jun 2023 | Continuing Study |
| 4. | Assessment of dissolved radon concentration in groundwater of Uttarakhand | Hukam Singh (PI), M Someshwar Rao, Soban Singh Rawat, Vipin Agarwal | Apr 2021-Dec 2022 | New Study |
| **SPONSORED PROJECTS** | | | | |
| 1. | Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques | Suhas Khobragade (PI) Sudhir Kumar, Rajesh Singh, M. Arora | Apr 2016 – Mar 2021 Extended upto Sep 2021 | NMSHE Project |
| 2. | Dating very old ground waters of deeper aquifers in Ganga Plains, India | M. Someshwar Rao (PI) Sudhir Kumar | Jun 2016 – Dec 2022 | IAEA under CRP |
| 3. | Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin | Sudhir Kumar (PI) M. Someshwar Rao Vipin Aggarwal | Jan 2018 – Jan 2022 | NHP (PDS) |
| 4. | Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management | M. Someshwar Rao (PI), Sudhir Kumar A. R. Senthil Kumar V. S. Jeyakanthan | Jan 2018 – Jan 2022 | NHP (PDS) |
| 5. | Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand | Suhas Khobragade (PI) Sudhir Kumar | Jan 2018 – June 2022 | NHP (PDS) |
| 6. | Unravelling Submarine Discharge (SGD) zones along the Indian subcontinent and its islands (Mission SGD) – Pilot Study | Sudhir Kumar (PI) SM Pingale, M. Someshwar Rao, BK Purandara, YRS Rao | Apr 2019 – Sep 2021 | Study under NCESS, MoES |
| 7. | Groundwater Rejuvenation As Climate change Resilience for marginalized and gender sensitive GangeS (GRACERS) | Sudhir Kumar (PI) M. Someshwar Rao SM Pingale | Jun 2019 – May 2022 | (IIT Bombay, Mumbai) |

| S. N. | Project Title | Study Team | Duration | Status |
|---|---|---|---|---|
| 8. | Web-GIS Based Spring Inventory for Vulnerability Assessment and Hydro-Geological Investigation of Selected Springs for Sustaining Local Water Demand in Ravi Catchment of Himachal Pradesh | S S Rawat (PI) Sudhir Kumar, P G Jose, Suman Gurjar, D S Bisht | Aug 2017 – Mar 2022 | NHP (PDS) |
| 9. | Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River | S S Rawat (PI) P G Jose, Suman Gurjar, D S Bisht | Jan 2019– Dec 2021 | NMHS |

## SURFACE WATER HYDROLOGY DIVISION

### APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| SN | Title of Project/Study | Study Team | Duration | Status & Comments | Funding |
|---|---|---|---|---|---|
| **Ongoing Sponsored Studies** | | | | | |
| 1 | Hydrological modelling in Alaknanda basin and assessment of climate change impact(NMSHE) | A.K.Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakanthan L.N. Thakural | 5 years (April 2016 to September 2021) | On-going | DST |
| 2 | Rainfall-Runoff Modelling of Selected Basin based on LULC pattern and development of Correlation (NHP) | A.K. Lohani R.K. Jaiswal Sushant Jain WRD Rajasthan Sanjay Agarwal Shailendra Kumar | 24 months (Oct. 2019 to April 2022) | On-going | NHP |
| **Ongoing Internal Studies** | | | | | |
| 1 | Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin | Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu | 2.5 years (Nov. 2018 August 2021). | On-going Extended upto August 2021 | NIH |
| 2 | Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario. | Ashwini Ranade Archana Sarkar | 3 years (April 2018 to October 2021) | On-going Extended upto October 2021 | NIH |
| 3 | Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent | Sunil Gurrapu Ashwini Ranade J.P. Patra | 3 years (Nov 2018 to October 2021) | On-going | NIH |
| 4 | Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan. | J.P. Patra Rakesh Kumar Pankaj Mani Sunil Gurrapu | 2 years (July 2020 to August 2022 | On-going | NIH |
| **New Internal Studies** | | | | | |
| 1 | Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Mahi & Sabermati subzone – 3a (2) Godavari subzone-3e. | S.K. Singh | One year (April 2021 to March 2022) | New Study | NIH |

| 2 | Uncertainty in rating curves and discharge estimation | Sanjay Kumar, L. N. Thakural Sunil Gurrapu N.K. Bhatnagar J P Patra | 2 Years (April 2021 to March 2023) | New Study | NIH |
|---|---|---|---|---|---|

## WATER RESOURCES SYSTEMS DIVISION

### APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| SN | Title of Project/Study | Study Team | Duration | Status & Comments | Funding |
|---|---|---|---|---|---|
| **Sponsored Studies** | | | | | |
| 1. | Development of a project website and hydrological database in Upper Ganga Basin (**Sub-project – 1**) | M. K. Goel; M. Arora; A. K. Lohani; D. S. Rathore; D. Chalisgaonkar; A. R. S. Kumar; S. Singh; P. Mani; A. Sarkar; M. K. Nema; P. K. Mishra | 5 years (01/16-03/21) (Extended till Sept., 2021) | On-going | DST |
| 2. | Real-time snow cover information system for Upper Ganga basin (**Sub-project – 2**) | D. S. Rathore; (Now Deepa Chalisgaonkar is PI) V. S. Jeyakanthan; L. N. Thakural; | 5 years (01/16-03/21) (Extended till Sept., 2021) | On-going | DST |
| 3. | Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region (**Sub-project – 3**) | Sanjay K. Jain; A. K. Lohani; Sudhir Kumar; Praveen Thakur (IIRS) | 5 years (01/16-03/21) (Extended till Sept., 2021) | On-going | DST |
| 4. | Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios (**Sub-project – 4**) | ~~Renoj J.Thayyen;~~ Sanjay K. Jain; Sharad K. Jain (Retd.) P. K. Mishra; M. Arora; AP Dimri (JNU) | 5 years (01/16-03/21) (Extended till Sept., 2021) | On-going | DST |
| 5. | Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin (**Sub-project – 5**) | M K Nema; Sharad K. Jain (Retd.); ~~Renoj J.Thayyen;~~ Sanjay K. Jain; P K Singh, P. K. Mishra; P. K. Agarwal AP Dimri (JNU) | 5 years (01/16-03/21) (Extended till Sept., 2021) | On-going | DST |
| 6. | Water Census and Hotspot analysis in selected villages in Upper Ganga basin (**Sub-project – 11**) | P. K. Mishra; M. K. Nema; ~~Renoj J. Thayyen;~~ Pradeep Kumar | 5 years (01/16-03/21) (Extended till Sept., 2021) | On-going | DST |
| 7. | Investigating Water Stress using Hydro-meteorological and Remote Sensing data | D. S. Rathore; (Now L. N. Thakural is PI); Sanjay Kumar; B. Venkatesh M. K. Jose; T. Chandramohan | 3 years 2017-2020 (Extended upto June, 2021) | On-going | PDS under NHP |

| 8. | Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya | Sanjay K. Jain P. K. Singh; M. Arora Renoj J. Thayyen; A. K. Lohani; Vishal Singh; | 3 years (11/19-11/22) | On-going | NMHS-MoEF |
|---|---|---|---|---|---|
| 9. | Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin | Renoj J. Thayyen Vishal Singh A. P. Dimri (JNU) Sanjay K. Jain | 3 years (06/19-11/22) | On-going | NRDMS-DST |
| 10. | Permafrost mapping and characterization of Ladakh Region | Renoj J. Thayyen; A. P. Dimri (JNU) will lead now; G. Jeelani (KU); V. Agnihotri (GBPNI) | 3 years (11/19-11/22) | On-going | NMHS-MoEF |
| 11. | 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; P K Agarwal | 2 years (08/20-07/22) | On-going | NHP |
| 12. | Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework. | P K Mishra; P K Singh; P K Agarwal | 2 years (06/21-05/23) | **New** | NHP |
| 13. | Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram | Vishal Singh; M K Nema; P K Singh; Vanlalpekhlua Sailo (SDO from Mizoram); Lalruatkima (JE from Mizoram) | 2.5 years (06/21-05/24) | **New** | NHP |
| 14. | Monitoring of Hydrological Processes in Glaciated and Non Glaciated Watersheds of North-West Himalaya | M K Nema; Sanjay K Jain; Manohar Arora; Vishal Singh; Praveen Thakur (IIRS) | 3 years (07/21-06/24) | This study will be taken up after MOU is signed with IIRS. | IIRS |
| **InternalStudies** | | | | | |
| 15. | Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios | M. Arora P K Mishra Vishal Singh | 3 years (04/18-03/22) | On-going | NIH |
| 16. | Impacts of glacier and climate change on runoff for selected basins of Himalayan region | Vishal Singh; Sanjay K. Jain; Manohar Arora | 2 years (08/20-07/22) | On-going | NIH |
| 17. | Monitoring and Hydrological Modelling of Henvel watershed in Lesser Himalaya (Phase II) | M K Nema; Sanjay K Jain; Renoj J. Thayyen; P K Mishra; P K Agarwal | 3 years (08/20-07/23) | On-going | NIH |

| 18. | Upgradation of NIH_ReSyP to .NET Platform– a Reservoir Operation Package | D. Chalisgaonkar M. K. Goel | 1 year (08/20-07/21) | On-going | NIH |
|---|---|---|---|---|---|

## RESEARCH MANAGEMENT AND OUTREACH DIVISION (RMOD)

### APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| SN | Title of Project/Study | Study Team | Duration | Funding | Status |
|---|---|---|---|---|---|
| **INTERNAL STUDY** | | | | | |
| 1 | Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system | NIH: Omkar Singh (PI) V C Goyal, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka; CEH-UK: Prof. Laurence Carvalho & Team | Apr 2018-Jul 2021 | NIH, CEH-UK | On-going |
| 2 | Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand region | Jyoti Patil (PI) T Thomas (Co-PI), P K Mishra Rohit Sambare | Jul 2020- Dec 2022 | NIH | On-going |
| 3 | Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand) | Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun | Jul 2020- Jun 2022 | NIH | On-going |
| 4 | Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana | A R Senthil Kumar (PI) Omkar Singh (Co-PI) Rajesh Agrawal, N R Allaka Scientist from KVK/Agri Univ. | Jul 2020- Jun 2022 | NIH | On-going |
| **SPONSORED PROJECTS** | | | | | |
| 1 | Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact | A R Senthil Kumar (PI) J. V. Tyagi, M. K. Goel, S. D. Khobragade, P. C. Nayak, Manohar Arora | Mar 2016-Mar 2021 (Extended upto Sep 2021) | DST-NMSHE | On-going |
| 2 | Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS) | V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare, Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand | Apr 2019-Mar 2024 | DST (GoI) | On-going |
| 3 | Preparation of Guidebook on S&T Interventions on Pond Rejuvenation | V C Goyal (PI), Jyoti Patil | Sep 2020- Jun 2021 (Ext. upto Dec 2021DST) | DST (GoI) | On-going |

### Proposed Training/Webinar/Outreach Activities of RMOD (2021-22)

| S. N. | Outreach Activity | Tentative Date & Month | Place | Target Participants | Team |
|---|---|---|---|---|---|

| 1 | Webinar on "Water for Public Health (W4PH): Preparing for Disasters & Pandemics" | Jul 2021 | Online mode | Medical and WASH professionals, water utility professionals, researchers | V C Goyal, Jyoti Patil, Varun Goyal, Amrendra Bhushan |
|---|---|---|---|---|---|
| 2 | Workshop/Webinar on rejuvenation of ponds and treatment of domestic wastewater through constructed wetlands | Sep 2021 | NIH Roorkee | R&D Institutes/University/Govt. Organizations | NIH: Omkar Singh, V.C. Goyal, Rajesh Singh, Digambar Singh UKCEH: Laurence Carvalho & Elliot Hurst |
| 3 | Awareness Programme for School Children | July-Sep 2021 | 2 Schools in Roorkee/ Nearby | School Children | Digambar Singh, Omkar Singh, Subhash Kichlu, Rajesh Agarwal, N R Allaka |
| 4 | Awareness Programmes on "Water Conservation/Pond Rejuvenation" for Stakeholders in Ibrahimpur Masahi village/schools | Sep-Dec, 2021 | Ibrahimpur Masahi/ schools | Villagers/ School children | Omkar Singh, V.C. Goyal, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agarwal, NR Allaka |
| 5 | Life cycle approach for rejuvenation of ponds and lakes using Nature Based Solutions (4 training courses of 5-days duration) Funded by NWM (MoJS, GoI) | Sep'21 – Jul '22 | Roorkee/ Online | Field engineers and practitioners | Jyoti Patil, V C Goyal, Omkar Singh, Digambar Singh, Rohit Sambare, N R Alakka |

**Other Outreach Activities:**

| S.N. | Activity |
|---|---|
| 1 | • Preparation of Short Video on Pond Rejuvenation & CW-NTS of Ibrahimur Masahi |
| 2 | • Coordination of 75 planned Activities at HQ & RCs under Bharat Ka Amrut Mahotsav @ India 75 <br> • Organizing activities as per mandate of Division under Bharat Ka Amrut Mahotsav @ India 75 |
| 3 | • River Walk of Solani River (stretch to be identified) |
| 4 | • Any other Outreach activity on demand/assigned |

# HARD ROCK REGIONAL CENTRE, BELAGAVI

## APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| S.N. | Project Title | Study Team | Duration | Status |
|---|---|---|---|---|
| **INTERNAL STUDIES:** | | | | |
| 1. | Development of Prediction Tools for Assessment of Water Resources in Ungauged Catchments of West Flowing Rivers of Western Ghats Region | Chandramohan T (PI), Venkatesh.B., Chandrakumar. S., and officials from WRDO Karnataka | 3 years April 2018-March 2021 | An extension of 6 months, i.e., till September 2021 was recommended by the RCC. |
| 2. | Climate Change Impact assessment for Jayakwadi Reservoir | B Venkatesh (PI), MK Jose, Chandrakumar, Ahilash and officers from WRD, Govt. Maharashtra) | 3 years May 2018 – April 2021 | An extension of 6 months, i.e., till September 2021 was recommended by the RCC. |
| 3. | Flood Vulnerability Assessment and developing mitigation plan for Thiruvananthapuram City, Kerala | Chandramohan T (PI), Venkatesh.B., MK Jose and Chandrakumar.S | 2 years (Sept 2019 – Aug 2021 | An extension of 6 months, i.e., till September 2021 was recommended by the RCC. |
| 4. | Impact Of Sand Mining On Groundwater Regime In Parts of Manjira River Basin, Telangana State | MK Jose(PI), B Venkatesh, Chandramohan, Abhilash and Officials form TSGWD | 2 years Sept 2020 – Aug 2022 | New Study |
| **SPONSORED PROJECTS:** | | | | |
| 1. | Estimation of Submarine Groundwater Discharge in Parts of Karnataka | BK Purandara(PI), Sudhir Kumar, JV Tyagi and N Varadarajan | Jan 2018 – March 2021  Extended till Sept 2021 by sponsoring authorities | Ongoing study sponsored by NCESS (MoES |
| 2. | Groundwater Model Development In Micro Basin Of Hard Rock In Krishna And Godavari River Basins Of Telangana | B Venkatesh (PI), MK Jose, Sudhir Kumar, Abhilash & Officials form TSGWD | 3 years (Sept 2019 – Aug 2022 Extended upto August 2023 | NHP (PDS) |

# WESTERN HIMALAYAN REGIONAL CENTRE, JAMMU

## APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| S. No. | Title of Study | Team | Duration | Remarks |
|---|---|---|---|---|
| **Internal Studies** | | | | |
| 1. | Hydrologic and hydraulic modelling for floodplain inundation mapping under future climate change scenarios: A case study of Tawi River, India. | R. V. Kale P. G. Jose D. S. Bisht | 03 years (August 2018 - March 2021) | Ongoing (Extended up to Sept. 2021) |
| 2. | Statistical evaluation of global precipitation estimates over data scarce Western Himalayan Region of India | D. S. Bisht S. S. Rawat P. G. Jose | 02 Years (Oct 2019 - Sept 2021) | Ongoing |
| 3. | Estimation of changes in snow cover and glacier mass balance for Upper Chenab River Basin | P. G. Jose D. S. Bisht | 02 Years (August 2020 - August 22) | Ongoing |
| 4. | Mass and Energy Balances of Phuche and Khardung glaciers, Ladakh Range with implications for downstream water availability under changing climate. | P. G. Jose D. S. Bisht D. Khurana | 03 Years (July 2021- June 2024) | New study |
| 5. | 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 D. Khurana | 03 Years (September 2021-July 2024) | New study |
| 6. | Early Signatures of 21st Century on Snow Cover Dynamics in Zanskar River Basin, Ladakh | D. S. Bisht P. G. Jose | 01 Year (July 2021 - June 2022) | New study |
| **Sponsored Projects** | | | | |
| 1. | Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River | S. S. Rawat P. G. Jose S. Gurjar D. S. Bisht | 03 years (April 1 March 2019 to 2022) | Ongoing study funded by NMHS |
| 2. | Operational coastal flood management through short-to-medium range (real-time) flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate induced impacts | B. Sahoo, (PI, IIT-Kgp) R. V. Kale, (Co-PI) | 03 years (July, 2020 – June, 2023) | Ongoing study funded under STARS by MHRD, GoI. |
| 3. | Preparation of PRI based geo-referenced biodiversity assessment, documentation and conservation plan of wild flora and fauna of Kishtwar High Altitude National Park (KHANP) - Hydrology of streams and Land use and ecosystem resource mapping | P. G. Jose D. S. Bisht | 02 years (July 2021-June 2023) | New study funded by UT of J&K |

**APPROVED WORK PROGRAMME FOR THE YEAR 2021-22**

| SN | Title of Project/Study | Study Team | Duration | Status & Comments/ suggestions | Funding |
|----|------------------------|------------|----------|--------------------------------|---------|
| **Internal Studies** | | | | | |
| 1 | An experimental assessment oflowcostAugerHoleTechniquefor accelerating ground waterrecharge | RaviGalkate R.K. Jaiswal Vivek Bhatt (WALMI) | Sep 2020- Aug 2023 | On-going (In collaboration with WALMI Bhopal) | NIH-WALMI Bhopal |
| 2 | Impact Assessment Study at WALMI, Bhopal Demonstration Farm | R.K. Jaiswal Ravi Galkate VivekBhatt (WALMI) R. Thakur (WALMI) | Oct 2020- Jun 2021 | On-going (In collaboration with WALMI Bhopal) | NIH |
| 3 | Re-assessment of evapotranspiration (*ETo*) estimation for irrigation planning in Madhya Pradesh | Ravi Galkate, R.K. Jaiswal, A.K. Lohani, Suhas Khobragade, Shashi Indwar Ex.Engg./Dy Dir, MPWRD | July 2021 – June 2023 | New (In collaboration with MPWRD Bhopal) | NIH New study |
| 4 | Assessment of water yield in river basins of Madhya Pradesh | R.K. Jaiswal Ravi Galkate, A.K. Lohani, Shashi Indwar Ex.Engg./Dy Dir, MPWRD | July 2021 – June 2023 | New (In collaboration with MPWRD Bhopal) | NIH New study |
| **Sponsored Projects** | | | | | |
| 1 | Evaluation of impact ofRabi irrigation in GangaRiversub- basin of MadhyaPradesh | R. V. Galkate R. K. Jaiswal, T. Thomas S.P. Indwar, MPWRD | Sep 2017-Sept. 2021 | On-going (In collaboration with MPWRD Bhopal) | NHP-PDS |
| 2 | Impacts of Upcoming Irrigation Projects and Climate Changeon the Droughts and Desertification Scenario for Chambal Basin in Western MadhyaPradesh | T. Thomas P.C. Nayak, Surjeet Singh, B. Venkatesh, R.V. Galkate, R. K. Jaiswal, S. P. Indwar | Dec 2017- Nov 2021 | On-going (In collaboration with MPWRD Bhopal) | NHP-PDS |
| 3 | IntegratedAssessment ofthe Impacts of ClimateChange and Land useChangeon the Hydrology of theNarmadabasin through Hydrological Modelling Approaches | T. Thomas S. Singh, B. Venkatesh P. C. Nayak, A. Sarkar, Manish Nema, P. Mishra, S. P. Indwar | Feb 2018- Jan 2023 | On-going (In collaboration with MPWRD Bhopal) | NHP-PDS |
| 4 | Hydrological Modeling for Evaluation of Return Flow and Irrigation Planning for Optimal Utilization of WaterResourcein | R. K. Jaiswal R. V. Galkate T. Thomas Shashi Indwar. | April 2019- Mar 2023 | On-going (In collaboration with MPWRD Bhopal) | NHP-PDS |

| | | | | |
|---|---|---|---|---|
| | the Command ofSanjay Sagar Project in MadhyaPradesh | A. K. Lohani, Sudhir Kumar, Surjeet Singh, MPWRD | | | |
| 5 | Development of Decision Tool for Efficient Utilization of Water Resource in Parbati Canal & Dholpur Piped Irrigation Project of Rajasthan | R. K.Jaiswal R. V. Galkate, A. K. Lohani, ShashiIndwar, RJWRD | April 2019-Mar 2022 | On-going (In collaboration with RJWRD Jaipur) | NHP-PDS |

## DELTAIC REGIONAL CENTRE, KAKINADA

### APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| S. No | Title of the Project | Team | Start date and End date | Funding |
|---|---|---|---|---|
| **Internal Study** | | | | |
| **1.** | Identification of Recharge and Discharge areas of Palar basin in Tamilnadu | V.S.Jeyakanthan (PI) J.V. Tyagi Sudhir Kumar, Y.R.Satyaji Rao, S. Raja | September 2021 to - March 2023 | Internal Funding (NIH) |
| **Sponsored Projects** | | | | |
| 1 | Groundwater salinity source identification in Godavari delta, Andhra Pradesh | Y.R.Satyaji Rao (PI) T.Vijay, Sudhir Kumar R.VenkataRamana Gopal Krishana S.V.Vijaya Kumar | March 2018 to October 2021 | NHP(PDS) (LA: DRC, NIH) (SP-28/2017-2018/PDS-13) |
| 2 | Study of the behaviour of Multi-Aquifer system & Aquifer mapping for an effective Groundwater Management in Gunderu Sub-Basin, West Godavari district, AP | S.V.Vijaya Kumar (PI) Anupama Sharma Y.R.Satyaji Rao T.Vijay Sudhir Kumar J.V.Tyagi | August 2018 to March 2022 | NHP(PDS) (LA:AP State GW&WA Dept.,) AP_1_2017_80 |
| 3 | Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh | P.C.Nayak (PI) Y.R.Satyaji Rao A.K. Lohani B. Venkatesh A. R. S. Senthil Kumar T. Thomas | April 2019 to March 2022 | NHP(PDS). (LA: DRC, NIH) SP-43/2019-21/1 |
| 4 | Urban hydrological studies of critical pilot area using of hydrological instruments in the Greater Hyderabad Municipal Corporation (GHMC) area Hyderabad. | R.VenkataRamana (PI) Y.R.Satyaji Rao V.S.Jeyakanthan T.Vijay | January 2020 to April 2023 | NHP(PDS) (LA: Hydrology and Investigations, I & CAD, Govt.,Telengana) TEL-6_2017_86 |
| 5 | High Performance Advanced Septic System for Villages and Roadside Restaurants | Y.R Satyaji Rao (PI) T.Vijay | April 2018 to March 2022 | IC-IMPACT, Canada |
| 6 | Unravelling Submarine | Y.R. Satyaji Rao | April 2019 to | MoES,Govt., of |

| Sl. No. | Title | Study Group | Duration (Month/Year) | Study Type | Remarks |
|---|---|---|---|---|---|
| | Groundwater Discharge (SGD) Zones along A.P and Odisha States (Mission SGD)-Pilot Study | (PI) T.Vijay | September 2021 | | India. |

## CENTRE FOR FLOOD MANAGEMENT STUDIES, GUWAHATI

## APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| Sl. No. | Title | Study Group | Duration (Month/Year) | Study Type | Remarks |
|---|---|---|---|---|---|
| **Internal Studies** | | | | | |
| 1. | Linear Hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin | Gulshan Tirkey, S. K. Sharma, P. Mani | 3 years (4/18 to 3/21) | Internal | On-going (Er Gulshan Turkey is on long medical leave.) |
| 2. | Impact of Climate Change on Runoff and Sediment Yield for a Major Tributary of River Brahmaputra | Swapnali Barman, J.V. Tyagi, R.K. Bhattacharya, W Rahul Singh | 3 years (11/18 to 12/21) | Internal | On-going |
| 3. | Groundwater Quality Assessment of Morigaon district of Assam with emphasis on Arsenic & Fluoride Contamination | S.K. Sharma Rajesh Singh G. Tirkey W Rahul Singh | 2 years (7/19 to 6/22) | Internal | On-going |
| 4. | Hydrological Behaviour of two mid-sized Mountainous Catchments under the influence of Climate and Land Use Changes | W Rahul Singh , A.K .Lohani, A. Bandyopahdyay Swapnali Barman Nitesh Patidar | 3 years (7/19-6/22) | Internal | On-going |
| 5. | Rainfall Induced Flood Hazard Risk Vulnerability Assessment in East Jaintia Hills, Meghalaya | G. Tirkey, S. K. Sharma, A. K. Lohani | 2 years (9/20-8/22) | Internal | On-going |
| **Sponsored Projects** | | | | | |
| 6. | River basin planning studies in Teesta basin up to confluence with Rangit River in Sikkim | Swapnali Barman M.K. Goel A.K. Lohani D.S. Rathore Deepti Raani W.R. Singh | 3 years (3/19 to 2/22) | Sponsored under NHP | On-going |
| 7. | Study on Behaviors of Flooding and Unexpected Drought like Situations in Garo Hills District of Meghalaya | S. K. Sharma R.P. Pandey GulshanTirkey Swapnali Barman W.R. Singh | 3 years (10/19 to 9/22) | Sponsored under NHP | On-going |
| 8. | A Coupled Hydrodynamic and Bank Dynamic Modeling Approach for Forensic Analysis of Bankline Erosion Process Along Majuli Island- the Largest Inhabited River Island in the World | Swapnali Barman, R.K. Bhattacharya M.K. Dutta, W.R. Singh | 3 Years (4/21-3/24) | Sponsored under DST-SERB Power grant | New Study |

# CENTRE FOR FLOOD MANAGEMENT STUDIES, PATNA

## APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| Sl | Title | Study Team | Duration |
|----|-------|------------|----------|
| **Internal Studies** | | | |
| 1 | Integrated Flood Management Plan for a stretch of Burhi Gandak River from Sikanderpur to Rosera | B Chakravorty(PI), Pankaj Mani and NG Pandey | 2 years (04/20-03/22) |
| 2 | Performance evaluation of Upper Morhor Canal System of South Bihar | NG Pandey(PI) B Chakravorty | 2 years (04/20-03/22). |
| 3 | Design flood estimation for small structures in the south Bihar area. | Pankaj Mani (PI), B Chakravorty, I C Thakur, Director WALMI | 1 years (04/21-03/22) |
| **Sponsored Project (PDS/NHP)** | | | |
| 4.* | Modelling and management of erosion and sedimentation processes in alluvial river using morphodynamic modeling* | Pankaj Mani(PI) J. P. Patra B. Chakravorty & WRD Bihar | New study proposed under PDS (05/21-04/24) |

*This study was started as an internal study in April, 2019. The proposal of this study was submitted to NHP as PDS. This study has been approved as PDS in Feb. 2021 with duration of 3 years from May, 2021 to Apr 2024 and therefore now this study has been taken up as PDS.*

# WORK PROGRAMME OF THE DIVISIONS AT THE H.Q. AND RC's/CFMS OF THE INSTITUTE FOR THE YEAR 2022-2023

# ENVIRONMENTAL HYDROLOGY DIVISION

**Scientific Manpower**

| S N | Name | Designation |
|---|---|---|
| 1 | Dr. R P Pandey | Scientist G & Head |
| 2 | Dr. M K Sharma | Scientist E |
| 3 | Dr. Rajesh Singh | Scientist D |
| 4 | Dr. Pradeep Kumar | Scientist D |
| 5 | Dr.Vinay Tyagi | Scientist D |
| 6 | Dr. Kalzang Chhoden | Scientist C |
| 7 | Sh. Rajesh K. Nema | Scientist B |
| 8 | Smt. Babita Sharma | SRA |
| 9 | Smt. Bina Prasad | SRA |

**Approved Work Programme for the Year 2021-22**

| SN | Study | Study Team | Duration/Status |
|----|-------|------------|-----------------|
| **Sponsored Projects (Ongoing)** | | | |
| 1. | Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures | Rajesh Singh (PI) Pradeep Kumar M. K. Sharma Sumant Kumar **Partner:** Irrigation Department, Punjab | 3 Years (09/17-03/22) **Sponsored by**: NHP-PDS **Project Cost**: Rs. 65.6 Lakh **Status:** Report submitted to NHP |
| 2. | Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures | Anjali (PI) Sudhir Kumar J. V. Tyagi M. K. Sharma **Partner:** CGWB (Delhi unit) | 3 Years (11/19-10/22) **Project cost:** Rs. 76.10 Lakh **Sponsored by**: NHP-PDS **Status:** In-progress |
| 3. | Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (MIP) Shahnehar | R.P. Pandey, (PI). Jagdeesh Patra, Rajesh Singh, N. K. Bhatnagar | 3 years (12/17-03/22) Extension till 03/22, further extension requested **Project cost:** Rs. 75.0 Lakh **Status:** In-progress |
| 4. | Isotopic and geochemical approach to study vulnerable confined and unconfided drinking water aquifers in Varanasi and surrounding area | Rajesh Singh (PI) R. P. Pandey BHU, Varanasi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary | 3 years (07/21-07/24) **Project cost:** Rs. 10.0 Lakh **Sponsored by**: BHU **Status:** In-progress |
| **Internal Study (Ongoing)** | | | |
| 5. | Water quality assessment of Haridwar District | R.K. Nema (PI) Rajesh Singh J. V. Tyagi Pradeep Kumar | 2 years (05/19-06/21) **Project cost:** 17.10 lakh **Status:** Completed |
| 6. | Simulation of Non-Point Source Pollution Processes in Song River | Pradeep Kumar (PI) J. V. Tyagi M. K. Sharma Rajesh Singh R. K. Nema | 4 years (11/19-10/23) **Project cost:** Rs.43.02 lakh **Status:** In-progress |
| 7. | Development of rejuvenation plan for Hindon river system | M. K. Sharma (PI) Sudhir Kumar | 3 Years (07/20-06/23) **Status: Transferred to HI Division** and merged with DST-NWO Project on River Hindon |
| 8. | Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar | Rajesh Singh (PI) J. V. Tyagi R. P. Pandey R.K. Nema Pradeep Kumar M. K. Sharma | 2 Years (06/20-05/22) **Project cost:** Rs. 23.71 Lakh **Sponsored by**: Internal **Status:** In-progress |
| 9. | Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures | Rajesh Singh (PI) R. K. Nema Sumant Kumar Pradeep Kumar M. K. Sharma | 3 Years (07/21 – 06/24) **Project Cost:** 30.1 Lakhs **Sponsored by:** Internally **Status:** In progress |
| **Consultancy Projects** | | | |

| 10. | Estimation of Economic Losses in Real Terms per Hectare Basis due to Forest Fire in Uttarakhand and Madhya Pradesh | J. V. Tyagi (Lead PI)<br>R. P. Pandey (PI)<br>P. Kumar (Co-PI)<br>T. Thomas (Co-PI)<br>L. N. Thakural<br>P. K. Singh<br>Rajesh Singh | 2.5 Years (03/20-08/22)<br>**Sponsored by:** ICFRE<br>**Project Cost**: Rs. 1.1033 Crore<br>**Status:** In-progress |
|---|---|---|---|
| 11 | Hydrological Study of New India Garden (NIG) Project at Village Indraprasth, New Delhi | J.V. Tyagi<br>R. P. Pandey (PI)<br>J. P. Patra<br>Pradeep Kumar | 10 months (03/21-01/22)<br>**Project Cost:** Rs. 41,30,000/-<br>**Sponsored by:** CPWD New Delhi<br>**Status:** Completed |
| 12. | Hydrological Study for Design of Drainage System and Evaluation of Flood Diversion Channel for the RBI Campus, Dehradun | J.V. Tyagi<br>R. P. Pandey<br>J. P. Patra<br>Pradeep Kumar (PI)<br>Rajesh Singh | 03 months (12/21-03/22)<br>**Project Cost:** Rs. 8,37,800/-<br>**Sponsored by:** CPWD Dehradun<br>**Status:** Completed |
| 13. | Estimation of Sediment Load and GHG Emission from Reservoir of Chamera-I Power Station, NHPC | J.V. Tyagi<br>R.P. Pandey<br>Rajesh Singh (PI)<br>M. K. Sharma | 15 months (09/21-03/23)<br>**Project Cost:** Rs. 3,24,500/-<br>**Sponsored by:** Innovate Solutions Pvt. Ltd. Noida.<br>**Status:** In-progress |

**Training Programmes/Workshop organized:**

| SN | Topic | Duration | Place |
|---|---|---|---|
| 1 | Online National Level Training Programme on "Floods and Drought Risk Mitigation Under Climate Change" Jointly Organized by NIH and NIDM New Delhi (Coordinator: Dr. R. P. Pandey) | 3 Days<br>2-4 February 2022 | Roorkee |
| 2 | Online Training Course titled "Data Processing for Water Quality Assessment and Management, NHP" (Coordinator: Dr. M. K. Sharma) | 5 Days<br>6-10 December 2021 | Roorkee |
| 3 | Online Mandatory Level-II training for Senior Research Assistants (SRAs) of CWC, (Coordinator: Dr. M. K. Sharma) | 4 Days<br>20-23 October 2021 | Roorkee |

**Publications:**

| Int. Journal | Nat. Journal | Int. Conference | Nat. Conference | Book Chapter | Total |
|---|---|---|---|---|---|
| 15 | - | 13 | - | 05 | **33** |

**Research Papers in Journals (15 Nos.)**

**International Journal**

1. Bhagwat, A., Rajat Kumar; Chandrashekhar Prasad Ojha, Mukesh Kumar Sharma, Apourv Pant, Babita Sharma and Jai Vir Tyagi (2021) Assessing efficiency and economic viability in treating leachates emanating from the municipal landfill site at Gazipur, India, Environmental Science and Pollution Research, https://doi.org/10.1007/s11356-021-16724-y (IF: 4. 3).

2. Kumar S., M. Kumar, V. K. Chandola, V. Kumar, R. K. Saini, N. Pant, N. Kumari, A. Srivastava, S. Singh, R. Singh, G. Krishan, S. P. Induwar, S. Kumar, B. K. Yadav, N. S.

Maurya, A. Chaudhary (2021). Groundwater Quality Issues and Challenges for Drinking and Irrigation Uses in Central Ganga Basin Dominated with Rice-Wheat Cropping System. Water, 13, 2344 (IF: 3.103).

3.  Kumar S., V. Kumar, R. K. Saini, N. Pant, R. Singh, A. Singh, S. Kumar, S. Singh , B. K. Yadav, G. Krishan, A. Raj, N. S. Maurya, M. Kumar (2021). Floodplains Landforms, Clay deposition and irrigation return flow govern arsenic occurrence, prevalence and mobilization: A geochemical and isotopic study of the Mid-Gangetic floodplains. Environmental Research, In Press (IF: 6.498).

4.  Malakar A., R. Singh, K. A. Weber, J. Westrop, C. N. Elofson, M. Kumar, D. D. Snow (2021). Occurrence of arsenite in surface and groundwater associated with a perennial stream located in Western Nebraska, USA. Journal of Hazardous Materials, 126170, In press (IF: 10.588).

5.  Malyan S. K., S. S. Kumar, R. K. Fagodiya, P. Ghosh, A. Kumar, R. Singh, L. Singh (2021).  Biochar for environmental sustainability in the energy-water-agroecosystem nexus. Renewable and Sustainable Energy Reviews, 149, 111379 (IF: 14.982).

6.  Malyan S. K., S. Yadav, V. Sonkar, V. C. Goyal, O. Singh, R. Singh (2021). Mechanistic understanding of the pollutant removal and transformation processes in the constructed wetland system. Water Environment Research, In Press (I.F.: 1.946).

7.  Mishra PK., Thayyen RJ, Singh H, Das S, Nema MK, Kumar P. 2021. Assessment of cloudbursts, extreme rainfall and vulnerable regions in the Upper Ganga basin, Uttarakhand, India. International Journal of Disaster Risk Reduction (in Press, available online at https://authors.elsevier.com/a/1eLBX7t2zZ5nlG).

8.  Panday B. K., R. Singh, R. P. Pandey, S. Das, J. Kumar, P. Kumar, S. Kumar, V. K. Pandey (2021). Water quality appraisal of a mountainous river: A case study of Rispana River, Dehradun. Water & Energy International, 64(1), 14-23 (IF: 0.21).

9.  Pandey R.P., Pradeep Kumar, B.K. Panday, J.V. Tyagi, Rajesh Singh, Sumant Kumar, S. Saini, (2021). Development of Rejuvenation Plan for Rispana River System, Uttarakhand, India. Water & Energy International, 64(2), 6-18 (IF: 0.21).

10. Pant N., S. P. Rai, R. Singh, S. Kumar, R. K. Saini, P. Purushothaman, Y. S. Rawat, K. Pratap, M. Sharma (2021). Impact of geology and anthropogenic activities over the water quality with emphasis on fluoride in water scarce Lalitpur district of Bundelkhand region, India. Chemosphere, 279, 130496 (IF: 7.086).

11. Prakasam, C., Saravanan R., Kanwar, Varinder S., Sharma, M.K. and Sharma, Monika (2020) Assessment of Environmental Changes using GIS Applications, International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, 9(11), 16-20, DOI: 10.35940/ijitee.J7559.0991120.

12. Prakasam, C., Saravanan R., Sharma, M.K. and Kanwar, Varinder S. (2021) Assessment and distribution of water quality of Pandoh river basin (PRB), Himachal Pradesh, North India, Applied Water Science, 11(137), 1-9. https://doi.org/10.1007/s13201-021-01468-4.

13. Sharma M. K, Pradeep Kumar, Kunarika Bhanot and Parul Prajapati (2021) Assessment of Non-point Source of Pollution using Chemical Mass Balance Approach: A case study of River Alaknanda, a tributary of River Ganga, India, Environmental  Monitoring and Assessment, 193:424 https://doi.org/10.1007/s10661-021-09203-x.

14. Sharma M. K., Mohit Kumar, D. S. Malik, Surjeet Singh, A. K. Patre, Beena Prasad, Babita Sharma,Shekhar Saini, A. K. Shukla and P. C. Das (2022) Assessment of groundwater quality and its controlling processes in Bemetara District of Chhattisgarh State, India, Applied Water Sciences (IF: 3.874) (Under Printing).

15. Yadav, M., Pandey, G. and Kumar, P. (2021). Low Flow Frequency Analysis of Tawi River Discharge at Jammu Location. Int. J. of Hydrology Science and Technology, Inderscience (accepted for publication), (IF: 0.68).

**Papers in Conferences (13 Nos.)**

**International Conferences**

1. Bhagwat, A. (2021) "Rejuvenation of River Assi", 2nd International Conference on "River Health: Assessment to restoration (RHAR-2021)" during 22-24 Oct. 2021.
2. Bhagwat, A. and Himanshu Jain (2022). Modelling the solute migration through the landfill profile for Gazipur landfill site, Delhi, India. Roorkee Water Conclave 2022, 2-4 March, 2022.
3. Bhanot, K., M. K. Sharma and R. D. Kaushik (2022) Hydrochemical assessment of river Alaknanda, Uttarakhand, India using multivariate statistics, Roorkee Water Conclave 2022, 2-4 March 2022
4. Kumar, M., M. K. Sharma and D. S. Malik (2022) Groundwater quality evaluation of a semi-arid region for irrigation using Irrigation Water Quality Index (IWQI): A case study of Bemetara district of Chhattisgarh, India, Roorkee Water Conclave 2022, 2-4 March 2022.
5. Maithani C., Singh R., Goyal V. C., Singh O., Rao P. V., Malyan S, Yadav S., Kumar J., (2022). Wastewater pollutants removal in deep horizontal subsurface flow constructed wetlands for a circular water economy. International Conference on Integrated Approaches in Science & Technology for Sustainable Future (IASTSF-2022), 28 Feb – 1 March, 2022.
6. Malyan S., Maithani C., Goyal V. C., Singh R., Singh O., Yadav S., Kumar J., (2022). Removal of coliforms from domestic wastewater in deep horizontal subsurface flow constructed wetlands for a circular water economy. International Conference on Integrated Approaches in Science & Technology for Sustainable Future (IASTSF-2022), 28 Feb – 1 March, 2022.
7. Pandey R. P. (2021) "Application of hydrologic model for assessment of vulnerability to drought", A keynote Paper Presented in Hydro-2021, Organized by Indian Society of Hydraulics (ISH), 23-25 Dec 2021, at SVNIT Surat.
8. Pandey R. P. (2021) "Hydrological Impacts of Climate Change on Water Resource System and its Implications for Energy and Food: A Countrywide Assessment" under Theme-1: Food-Energy-Water-Climate Security Nexus and the Challenges, Key note paper presented in XV Agricultural Science Congress, 13-16 Nov. 2021 at BHU Varanasi.
9. Pandey R.P. (2022). Implications of Climate Change and Sustainable Water Resource Management in India, Key Note Paper under one of the themes "*Climate Change and Sustainable Development*" presented in International Seminar on Ecosystem Functioning in Anthropocene (ISEFA-2022), Organised by Banaras Hindu University (BHU) during 23-25th Feb 2022.
10. Pant, A. and Anjali Bhagwat (2022). Microplastics: Quantification, identification, and its effects on aquatic invertebrates, Roorkee Water Conclave 2022, 2-4 March, 2022.
11. Prakasam, C., Saravanan, R., Kanwar, Varinder, S. and Sharma, M. K. (2021) Environmental flow monitoring system– the need of the hour, Proceedings of International Conference on Advances In Multi-Disciplinary Sciences and Engineering Research (ICAMSER – 2021) at Dept. of Applied Sciences, Chitkara University, District Solan (H.P.) during 2-3 July 2021, (Eds: S. R. Sharma, Ishwar Dutt, Arun Lal Srivastav) ISBN No.: 978-81-953416-1-0, Paper No. 21, pp. 30.
12. Sharma M. K., Manohar Arora, Babita Sharma and Beena Prasad (2022) Diurnal variations of hydrological and hydro-chemical parameters in the meltwater of Gangotri Glacier, Uttarakhand, India, Roorkee Water Conclave 2022, 2-4 March 2022
13. Singh K., Pandey G., Singh R. (2022). Heavy Metals Occurrence in Groundwater of Punjab, India: A Review. International Conference on Integrated Approaches in Science & Technology for Sustainable Future (IASTSF-2022), 28 Feb – 1 March, 2022.

**Book Chapters (05 Nos.)**

1. Kumar, A., Tripathi, V. K., Sachan, P., Rakshit, A., Singh, R.M., Shukla, S. K., Pandey, R., Vihwakarma, A. and Panda, K.C. (2022). Sources of ions in the river ecosystem. In: S. Madhav, S. Kanhaiya, A. L. Srivastav, V. B. Singh and P. Singh (Eds.). 2022. Ecological

Significance of River Ecosystems: Challenges and Management Strategies, Elsevier Publications, Amsterdam, Netherlands, pp. 187-202.

2. Pandey, R.P., Kale, R.V., Patra, J.P. and Galkate, (2021) "Impact of Climate Change on Occurrence and Severity of Drought" Chapter accepted for publication in edited book on "Drought Assessment, Prediction and Management" under changing climate scenario (eds: Jhajhariya, D; V. P. Singh; R. Mirabbasi and R. Kumar), Publisher CRC Press, USA. (in press).

3. Patidar N. and Bhagwat A. (2022). *Data Assimilation in Groundwater Modelling*, Advances in Hydrology and Climate Change Historical Trends and New Approaches in Water Resources Management, CRC Press, a Taylor & Francis Group.

4. Prakasam, C., Saravanan R. and Sharma, M.K. (2022) "Assessment of Environmental Flow Requirements through Rainfall-Runoff Modelling for Hydropower Project", Lecture Notes in Civil Engineering 232 in the Book titled "Environmental Restoration" (Eds.: D. K. Ashish and J. de Brito), Springer Nature Switzerland AG

5. Prakasam, C., Saravanan R., Kanwar, Varinder S., Sharma, M.K. and Sharma, Monika (2021) "GI Science for Land Use Suitability Analysis in the Himalayas – A Case Study of Himachal Pradesh, India", Chapter published in the Book titled "Geographic Information Science for Land Resource Management" (Eds.: Suraj Kumar Singh, Shruti Kanga, Gowhar Meraj, Majid Farooq, and Sudhanshu, Scrivener Publishing LLC, pp. 301–318.

**Recommended Work Programme for the year 2022-23**

| SN | Study | Study Team | Duration/Status |
|---|---|---|---|
| | **Sponsored Projects (Ongoing)** | | |
| 1. | Water Efficient Irrigation by Using SCADA System For Medium Irrigation Project (MIP) Shahnehar | Dr. R.P. Pandey, (PI). Er. Jagdeesh Patra, Dr. Rajesh Singh, Sh N. K. Bhatnagar, | 3 years (12/17-12/20) Extension requested till 03/22 **Project cost:** Rs. 75.0 Lakh **Status:** In-progress |
| 2. | Isotopic and geochemical approach to study vulnerable confined and unconfided drinking water aquifers in Varanasi and surrounding area | Rajesh Singh (PI) R. P. Pandey BHU, Varanasi (Lead) Other Collaborators: BARC, Mumbai, ICER, Hungary | 3 years (07/21-07/24) **Project cost:** Rs. 10.0 Lakh **Sponsored by**: BHU **Status:** In-progress |
| | **Internal Study (Ongoing)** | | |
| 3. | Simulation of Non-Point Source Pollution Processes in Song River | Pradeep Kumar (PI) J. V. Tyagi M. K. Sharma Rajesh Singh R. K. Nema | 4 years (11/19-10/23) **Project cost:** Rs. 43.02 lakh **Status:** In-progress |
| 4. | Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar | Rajesh Singh (PI) J. V. Tyagi R. P. Pandey R.K. Nema Pradeep Kumar M. K. Sharma | 2 Years (06/20-05/22) **Project cost:** Rs. 23.71 Lakh **Sponsored by**: Internal **Status:** In-progress |
| 5. | Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures | Rajesh Singh (PI) R. K. Nema Sumant Kumar Pradeep Kumar M. K. Sharma | 3 Years (07/21 – 06/24) **Project Cost:** 30.1 Lakhs **Sponsored by:** Internally **Status:** In-Progress |
| | **Internal Study (New)** | | |
| 6. | Characterisation of Groundwater Dynamics in Krishna-Godavari Delta interims of groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants | M. K. Sharma (PI) RC, Kakinanda CGWB | 2 years (04/22-03/24) **Sponsored by:** Internally **Status:** Proposed |
| | **Consultancy Projects** | | |
| 7. | Estimation of Economic Losses in Real Terms per Hectare Basis due to Forest Fire in Uttarakhand and Madhya Pradesh | J. V. Tyagi (Lead PI) R. P. Pandey (PI) P. Kumar (Co-PI) T. Thomas (Co-PI) L. N. Thakural P. K. Singh Rajesh Singh | 2.5 Years (03/20-08/22) **Sponsored by:** ICFRE **Project Cost**: Rs. 1.1033 Crore **Status:** In-progress |

| 8. | Estimation of Sediment Load and GHG Emission from Reservoir of Chamera-I Power Station, NHPC | J.V. Tyagi<br>R.P. Pandey<br>Rajesh Singh (PI)<br>M. K. Sharma | 15 months (09/21-03/23)<br>**Project Cost:** Rs. 3,24,500/-<br>**Sponsored by:** CPWD Dehradun<br>**Status:** In-progress |
|---|---|---|---|

**Proposed Training Programmes**

| SN | Topic | Duration | Place |
|---|---|---|---|
| 1. | Water Quality: Concepts and Analysis under NHP for IRI officials<br>(Coordinator: Dr. M. K. Sharma) | 5 Days | Roorkee |
| 2. | Estimation of Recharge for improving the Water Quality using MODFLOW & MT3D under NHP<br>(Coordinator: Dr. M. K. Sharma) | 5 Days | Roorkee |
| 3. | Water Quality Assessment & Management under NHP-PDS<br>(Coordinator: Dr. Rajesh Singh) | 5 Days | Roorkee |
| 4. | Water Quality Data Processing<br>(Coordinator: Dr. Pradeep Kumar) | 5 Days | Roorkee |
| 5. | Leachate Transport in Groundwater under NHP-PDS<br>(Coordinator: Ms. Anjali) | 5 Days | Roorkee |

**Study - 1 (Sponsored Project)**

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

2. **Study Group:**

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

3. **Type of Study:** Sponsored project under NHP, **Budget: Rs 65.6 lacs**

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

5. **Date of start:** October 2017

6. **Scheduled date of completion:** 03/2022 with extension

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

8. **Study Objectives:**

   i) Spatial and temporal variation of water quality parameters and carcinogenic contaminants.

   ii) Quantification of mutagenic potential (carcinogenicity) of water samples.

   iii) Source identification of major contaminants in the study area and impact assessment on human health.

   iv) Suggestions for possible remedial measures to reduce the impact of contaminants.

   v) Dissemination of knowledge and findings to field engineers/scientists and common people through the preparation of manual, leaflets, booklets and by organizing workshops/training.

9. **Statement of the Problem:**

   Punjab has been the subject of much skepticism in the last decade. It has previously been called the "grain bowl of the country", but has recently adopted a new nickname, "the cancer bowl of the country". The pride of holding the title "a state with maximum per capita income" came with the price of cancer due to unrestricted use of chemicals (pesticides, fertilizers, metals, polycyclic aromatic hydrocarbons, pharmaceutically active hydrocarbons, etc.) in the

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

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

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

11.  **Timeline:**

| Sr. No. | Activities | YEAR 1 | | | | YEAR 2 | | | | YEAR 3 | | | | YEAR 4* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| 1 | Hiring of manpower & training | ■ | ■ | | | | | | | | | | | | | | |
| 2 | Purchase of equipment & consumables | ■ | ■ | | | | | | | | | | | | | | |
| 3 | Upgrading literature and data collection | ■ | ■ | ■ | ■ | | | | | | | | | | | | |
| 4 | Delineation of villages and finalization of sampling location | | | ■ | ■ | ■ | ■ | | | | | | | | | | |
| 5 | Collection and analysis of samples | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| 6 | Statistical analysis of data and Carcinogenicity test | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| 7 | Contaminant remediation | | | | | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | Training & capacity building | | | | | | | | ▮ | | | ▮ | | ▮(orange) | | | |
| 9 | Scientific publications | | | | | ▮ | ▮ | ▮ | ▮ | ▮ | ▮ | ▮ | ▮ | ▮ | ▮ | ▮ | ▮ |
| 10 | Final technical report | | | | | | | | | ▮ | ▮ | | | | ▮(orange) | ▮(orange) | ▮(orange) |

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

| Sr. No. | Activity | Achievements |
|---|---|---|
| 1 | Purchase of equipment & consumables | • Laptop, Multiparameter ion analyzer, GWB & AquaChem software has been purchased.<br>• Syringe pump purchase has been dropped due to escalation in the price.<br>• Standards and consumable has been procured. |
| 2 | Delineation of villages and finalization of sampling location | • Delineation of villages and finalization of sampling locations has been completed. |
| 3 | Collection and analysis of samples | • The pre-& Post-monsoon sampling for the delineated villages has been completed.<br>• Analysis of organoleptic, major ions, trace metals, pesticides, and radon has been completed. |
| 4 | Statistical analysis of data and Carcinogenicity test | • The statistical analysis and human health risk due to drinking water was computed. |
| 5 | Contaminant remediation | • The literature review related to contaminant remediation of major contaminants in the drinking water completed. |
| 6 | Training & capacity building | • A training course for the government officials was organized during June 17-21, 2019.<br>• One stakeholders' workshop is proposed to be organized in May 2022. |
| 7 | Scientific publications | • 01 research paper in national journal,<br>• 01 research paper in international journal,<br>• 01 research paper in international conference, &<br>• 03 manuscripts in review stage<br>• 02 manuscript in writing stage |
| 8 | Final technical report | • The draft final report has been prepared and submitted. |

**13. Recommendation / Suggestion:**

| Recommendation / Suggestion | Action Taken |
|---|---|
| No specific comments/suggestions | -- |

**14. Analysis & Results:**

**Upgrading literature and data collection:**

• The recently published literature related to carcinogens in the water and their assessment was reviewed and a review paper titled 'An overview of carcinogenic pollutants in groundwater of India' is published in "Biocatalysis and Agricultural Biotechnology",

published https://doi.org/10.1016/j.bcab.2019.101288. Three more research articles are under writing stage.

- Cancer related patient data collected from district and other Hospitals.
- Translation of cancer related data (2016-2018) from Punjabi to English language has been completed for of all districts.
- The cancer wise data has also been collected from all the districts except Faridkot.

**Delineation of villages and finalization of sampling location**

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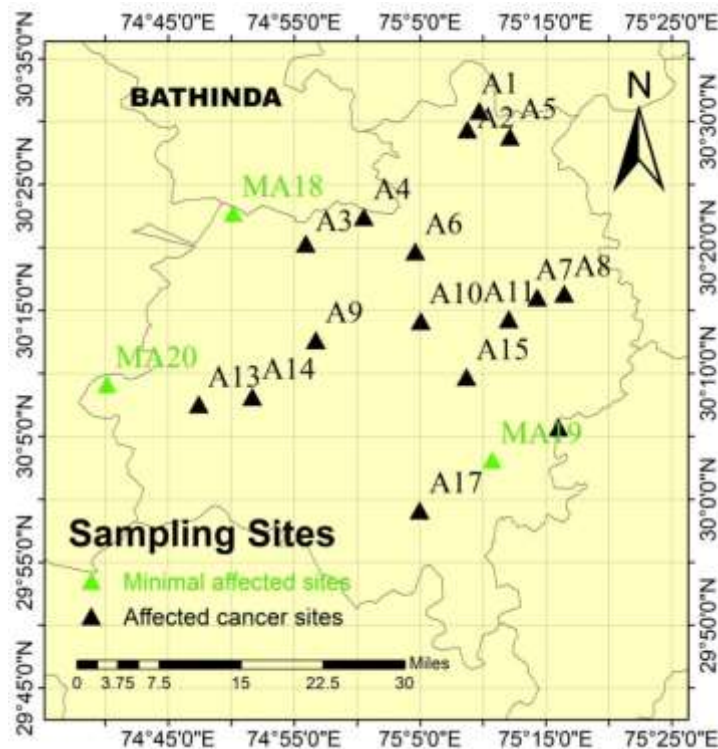


**Sampling Sites of Bathinda District**

**Sampling & Analysis**

- Drinking water samples from the identified villages were collected after discussion with the villagers based on the usage. The handpump were continuously pumped for at least 15 minutes prior to the sampling, to ensure the groundwater to be sampled was representative of groundwater aquifer. All the groundwater samples were collected from the sources, which are being used extensively.
- The samples from all the districts of the study were collected for pre- and post – monsoon period.

- The organoleptic parameters, major ion, trace metals, and pesticides analysis has been completed following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017).
- Onsite Radon measurement in groundwater from different locations in SW Punjab has been completed.

**Carcinogenicity / Mutagenicity/ Health Risk**

- The overall health risk was calculated based on $F$, $NO_3$, $NO_2$, $SO_4$, Li, B, Fe, Co, Ni, Pb, Be, As, Se, Hg, U Al, As, Cr, Cu, Fe, Mn, Pb, and Zn concentration in drinking water respectively. During the pre-monsoon period, 96.9% of samples were in the high-risk category which reduced to 88.1% in the post-monsoon period. The cancer-associated risk based on Ni, Pb, As, Hg, U, Cr, Be, Co, Se, Cd, and $NO_3$ was computed and around 83.7% of samples were in the high-risk category during pre-monsoon which got reduced to 61.1% in the post-monsoon period.
- The experiments to develop the mutagenicity scale is under progress. The initial experiments of Ames test have low success rate.
- The PCA analysis indicated $SO_4$ in the pre-monsoon samples and As, Al, Fe, and Zn in post-monsoon samples as a result of anthropogenic activities.
- The concentration of radon in the shallow groundwater (depth: 25-150 ft bgl) ranges from 11.1 pCi/l to 209 pCi/L, with average concentration 95.02±2.91 pCi/l and in the deep groundwater (>150 ft bgl), it ranges from 37.5 pCi/l to 319 pCi/L, with average concentration 104.5±6.6 pCi/l. Maximum concentration of radon was observed in the groundwater of Jalalabad, Fazilka. Carcinogenic risk assessment due to radon intake through drinking water, indicates possible number deaths/million population/year in the range from 197 to 1670 with average value of 548 for deep borewells, and 58.2 to 1100 with average value 498 for shallow borewells.
- The experiments for mutagenicity were repeated several times with the mutagens but the results were not consistent and therefore, the results of mutagenicity could not be estimated with the desired accuracy and it requires comprehensive investigation.

**Contaminant Remediation**

- Removal of U, As, Cr, and Pb from the groundwater samples will result in 93.9% and 98.4% groundwater samples under low-risk category for pre-monsoon and post-monsoon period respectively.

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

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

17. **Major items of equipment procured:** i) Multiparameter Ion Analyzer

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

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

20. **Study Benefits / Impacts:**

The outcome of the project will be beneficial for the concerned departments in a sense that it will provide the first-hand information on the water quality of the area related to carcinogenicity. This will also lead in preparing a protocol for monitoring the carcinogenicity of water and will be helpful for the monitoring agencies. The project will also suggest the

remedial measure for providing safe water to the habitation, which can be implemented by concerned state government agencies.

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

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

23. **Shortcoming/Difficulties:** NA

24. **Future Plan:**

   i) Organization of a stakeholders' workshop in May 2022.

**Study -2 (Sponsored Project)**

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

2. **Study Group:**

| Project Investigator/Co-Project Investigator |
|---|
| Er. Anjali, Scientist B, EHD |
| Dr. Sudhir Kumar, Scientist G & Head, HID |
| Dr. J. V. Tyagi, Director |
| Dr. M. K. Sharma, Scientist E, EHD |
| **Scientific/Technical / Project Staff** |
| Mrs.Babita Sharma, RA, EHD |
| Mrs.Beena Prasad, RA, EHD |
| Dr.Apoorv Pant, RA, EHD |
| Mr.Rajat Kumar, JRF, EHD |
| **Collaborating Agency** |
| Dr. G. Vijaykumar, Senior Hydrogeologist,, CGWB (Delhi Unit) |

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

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

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

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

7. **Duration of the Study:** 3 Years (+7 months extension)

8. **Study Objectives:**

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

9. **Statement of the Problem:**

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

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

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

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

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

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

   i) Literature review on chemical and isotopic characterization of leachate, groundwater contaminant transport modeling etc.
   ii) Field survey of the region and groundwater sampling – using standard protocols.
   iii) Characterization of leachate using EPA methods- TCLP (method no.- 1310) & column study (method no.- 1312).
   iv) Collection of groundwater levels to ascertain the flow direction.
   v) Identification of groundwater recharge and discharge areas.
   vi) Collection of groundwater samples on bi-monthly basis at identified locations.
   vii) Analyzing the physico-chemical parameters: pH, EC, DO, COD, TOC, Major anions, cations, and trace metals (Fe, Mn, Zn, Pb, Cd, Cr, Radium etc).
   viii) Analysing the stable isotopic characteristics of leachate and groundwater at various identified locations.
   ix) Analysing the groundwater samples and leachate for micro-plastic.
   x) Processing of hydro-chemical and isotopic data on bi-monthly basis.
   xi) Modeling the leachate migration from the landfill to groundwater table. The model will be developed for one dimensional vertical transport of contaminants through unsaturated zone.
   xii) Modeling of leachate plume movement in groundwater will be performed using MT3D MODFLOW and HELP. The leachate transport model will be calibrated based on chemical and isotopic data.
   xiii) Suggesting ameliorative measure for containment of contaminant plume based on groundwater modeling.

11. **Timeline:**

| S. No. | Activities | YEAR 1 | | | | YEAR 2 | | | | YEAR 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| 1. | Hiring of manpower & training | ▓ | ▓ | | | | | | | | | | |
| 2. | Purchase of equipment & consumables | ▓ | ▓ | | | | | | | | | | |
| 3. | Upgrading literature and data collection | ▓ | ▓ | ▓ | ▓ | | | | | | | | |
| 4. | Delineation of villages and finalization of sampling location | | | ▓ | | | | | | | | | |
| 5. | Collection and analysis of samples | | | | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | | |
| 6. | Statistical analysis of data and Carcinogenicity test | | | | | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ |
| 7. | Contaminant remediation | | | | | | ▓ | | | ▓ | | ▓ | |

| S. No. | Activity | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8. | Training & capacity building | | | | | | | | | | | | |
| 9. | Scientific publications | | | | | | | | | | | | |
| 10. | Final technical report | | | | | | | | | | | | |

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

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

| S. No. | Activity | Achievements |
|---|---|---|
| 1. | Field Investigation and sampling plan | • Groundwater sample collection from 130 grids from the vicinity of landfill.<br>• Leachate Samples taken from the landfill. |
| 2. | Decolourization of samples | • Samples colour removal was undertaken<br>• Reasons for coloured samples was identified<br>• Field applicability of chemical treatment assessed |
| 3. | Identifying Ameliorative measures | • Phytoremediation through marigold |
| 4. | Literature survey | • Literature on Microplastics, leachate characterization and isotopes in landfill was extensively surveyed. |

13.     **Recommendation / Suggestion:**

| Recommendation / Suggestion | Action Taken |
|---|---|
| The study was appreciated by the PDS committee | |

**14.     Analysis & Results:**

**Coagulation and flocculation experiments:**

- The samples were collected from the Gazipur landfill site and nearby areas. All the samples were analyzed for various water quality parameters. The results indicates high concentration of COD, BOD, TOC, EC in landfill leachate samples. The nearby ground water samples also shows high concentration of conservative chemicals such as chloride and fluoride.

- Leachate contains very high concentration of both organic and inorganic constituents that leach down in nearby groundwater and surface water resources.
- The landfill leachate samples were subjected to coagulation and flocculation experiments using ferric chloride ($FeCl_3$), ferrous sulfate ($FeSO_4$), and alum [$Al_2(SO_4)_3$] followed by advance fenton oxidation.
- The results show that ferric chloride leads to 99% color removal, 98% COD removal, 99% decrease in total organic carbon, 94.3% removal in $NH_3$–N, and 91.4% removal in total Kjeldahl nitrogen, and it proves to be the most efficient coagulant and surprisingly, proves to be even better than Fenton.
- Ammoniacal nitrogen and TKN are also very important wastewater treatment parameters. The three coagulants was compared on the ground of removal efficiency of ammoniacal nitrogen and TKN. The ammoniacal nitrogen ($NH_3$–N) after $FeCl_3$ treatment decreased to 70.62 mg/L (94.3% removal) at pH 3.5. The coagulation process with FeSO4 at pH 4.0 reduced the ammoniacal nitrogen ($NH_3$–N) to 168.3 mg/L making the removal efficiency 86.42%. The ammoniacal nitrogen ($NH_3$–N) value was observed to be 131.9 mg/L at pH 4.0 indicating 89.4% removal when treated with alum.
- Further, the results are compared with the UASB on-field application that proves ferric chloride ($FeCl_3$) treatment to decrease the operational cost by 71.9%, and conventional Fenton may decrease the operational cost by 76.8%.

## Phytoremediation study:
- To evaluate a sustainable solution, a phytoremediation experiment is conducted using Marigold plants supplied with different concentrations of leachate.
- Growth of *T. erecta* exposure to 9 heavy metals (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn) affected all of the studied growth parameters of *T. erecta*, namely, shoot, leave and root height, stem diameter and number of flowers.
- Cr inhibits maximum growth in aerial parts, As, and Pb concentrations. However, plant height and no. of flowers varied with HMs concentration in a quadratic fashion, with plant height reaching an estimated maximum value of 58 cm at 47.76 ppb Cr (III) and 37.52 ppb of lead (Pb), whereas the lowest growth of 48cm is observed at 310.45ppb Cr (III) and 79.90ppb Pb
- Plant bioaccumulate the heavy metals in different parts of the plant (shoot, leaves, flowers and roots). Individual HMs absorption capacity of aerial parts (shoot, leaves, and flowers) show overall higher accumulation of Zn, Mn, and Cr.
- Various bioaccumulation factors that helps in evaluating the nature of a particular plant (hyperaccumulator or non-hyperaccumulator). The ability of a plant to accumulate metals from a growth medium, in this case, "soil," can be assessed by computing shoot bioconcentration factor (BCF) – the ratio of shoot metal concentration to the metal concentration in soil, the translocation factor (TF) – the ratio of metal concentrations in the shoots to that in the roots.
- The BCF values of all the flowering plants for all the metals, i.e., Cd, Cr, Ni, and Pb, were significantly increased over control. The BCF values of Cd for all the plants grown in control and treated soil were much lower (varied from 0.28 to 0.61) than those of Cr (0.7–1.17), Ni (0.89–1.35), and Pb (0.85–1.30).
- Another indicator of the plants' reasonable amount of phytoremediation capacity is the phytoextraction coefficient (PHY); in this study, maximum treatments show a moderate value of phytoextraction coefficient, which indicates the average to good phytoremediation capacity of marigold plants.
- The marigold plant also serves the economic purpose of the local community. In this study the maximum flowers production was observed in leachate treatment of 12.5% diluted raw leachate which yield >50 flowers per treatment pot. Thus being a sustainable and cost effective option of treating the contaminated waste sites, the Marigold plant can also serves as a source of economical livelihood.
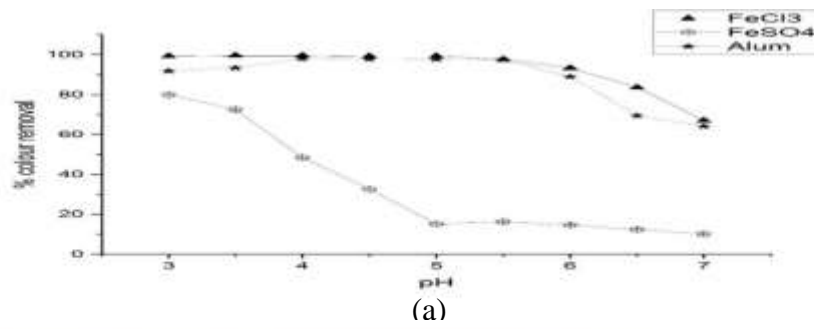
(a)



(b)



(c)



(d)

Fig. 1 (a) Variation in colour removal efficiency of the coagulants at different (b) intensity of colour observed in leachate treated with FeCl$_3$ at various pH. (c) Intensity of colour observed in leachate treated with FeSO$_4$ at various pH. (d) Intensity of colour observed in leachate treated with alum at various pH
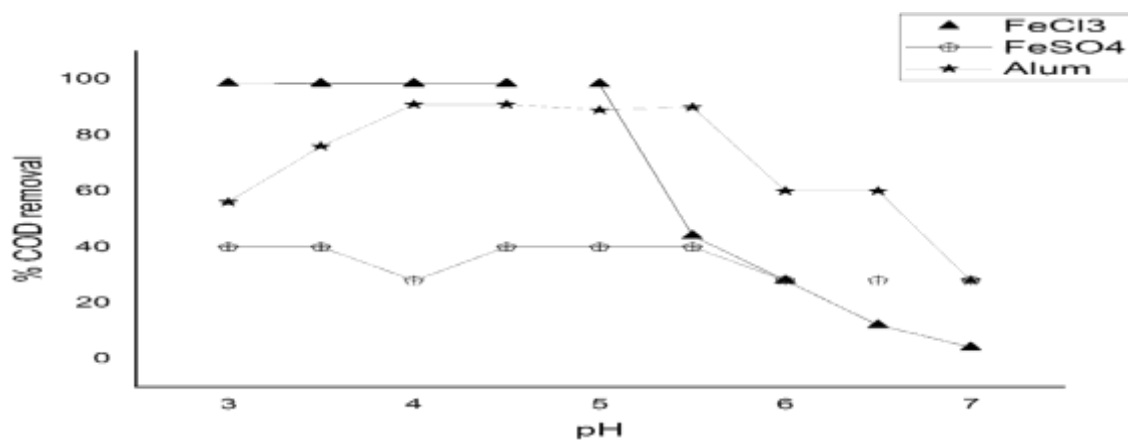


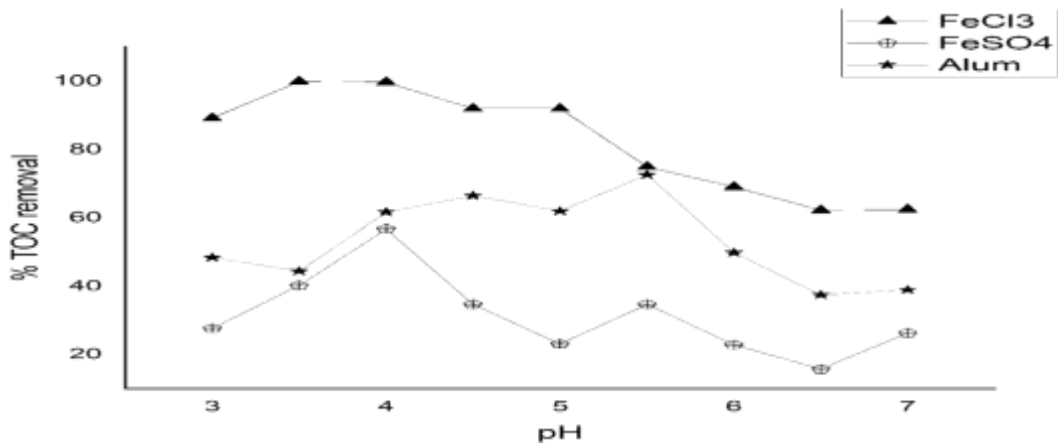Fig.2 Percentage decrease in COD in leachate when treated with coagulants: FeCL$_3$, FeSO$_4$ and alum at different pH

40

Fig. 3 Percentage decrease in TOC in leachate when treated with coagulants: FeCL$_3$, FeSO$_4$ and alum at different pH



(a)
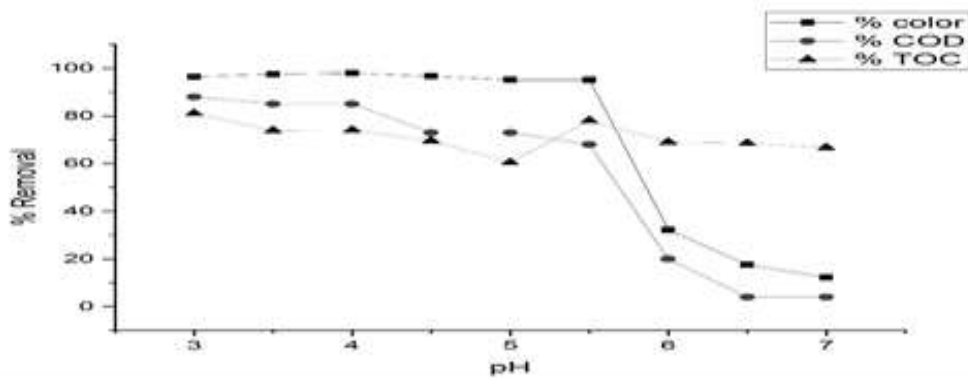


Fig. 4 a Variation in colour intensity of leachate treated with Fenton at various pH. b percentage decrease in colour, COD and TOC in leachate when treated with Fenton reagent at different pH
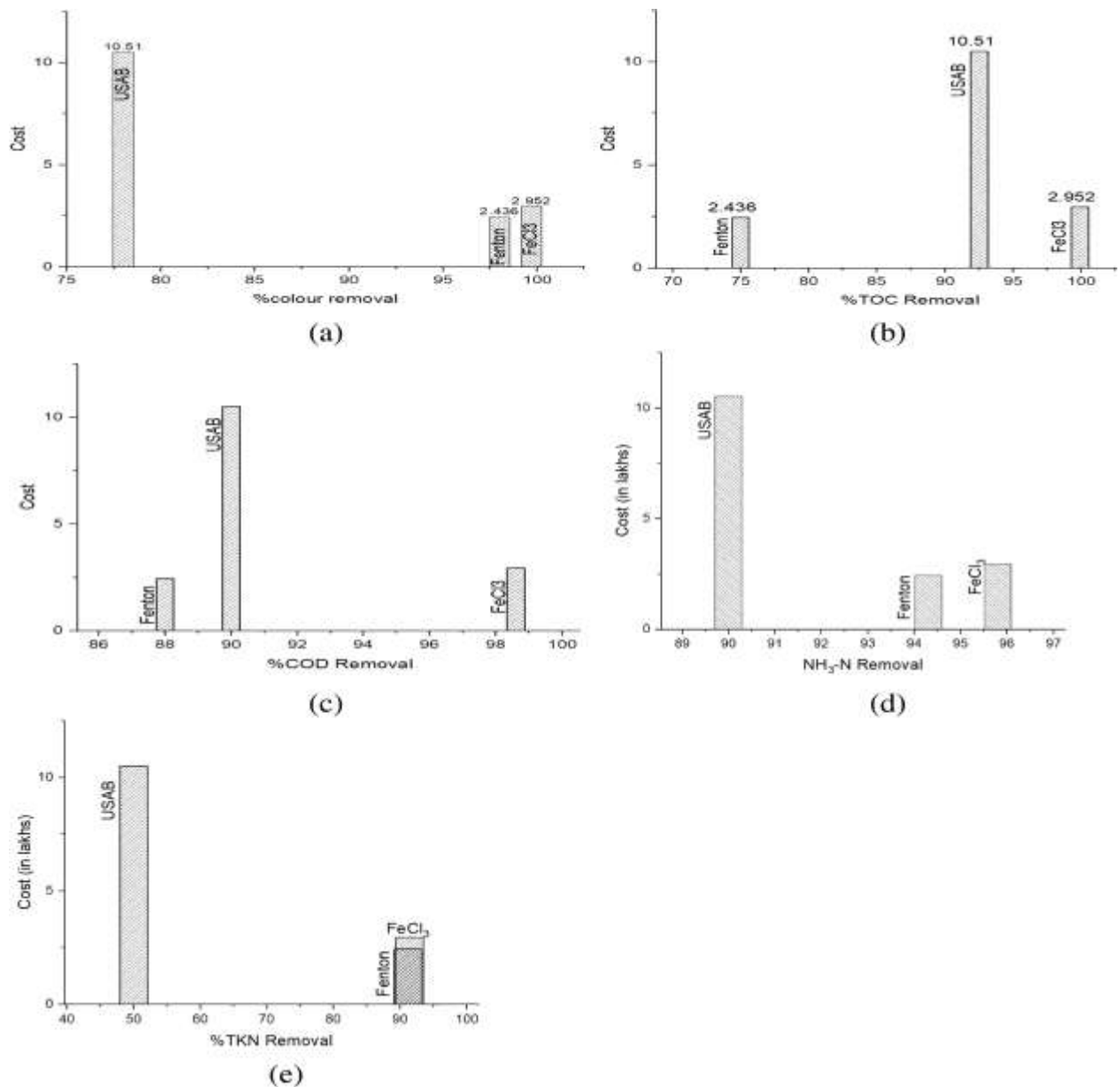
Fig. 5 Comparative bar charts for evaluating cost v/s efficiency of removal a colour, b TOC, c COD, d NH3–N and e TKN for the treatment methods: FeCl3, Fenton and UASB

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

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

14. **Major items of equipment procured:** Procurement procedure for FTIR imaging system on e-GEM initiated, MODFLOW purchased and TLC meter is yet be delivered.

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

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

17. **Study Benefits / Impacts:**

The study will identify the chemical and isotopic characteristics of leachate originating from the landfill site and help explaining its role in groundwater pollution. A new dimension will

be added to leachate transport through groundwater. Findings of the proposed PDS will be published in the form of leaflets/reports/research papers. It will also provide new data sets on leachate and groundwater quality, and thematic maps of contaminant plumes, vulnerable areas and hot spots of groundwater contamination in the study area.





Fig 6: Phytoremediation study (Marigold plant) with application of different dosage of landfill leachate.

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

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

23. **Shortcoming/Difficulties:** NONE

24. **Future Plan:**
- Field Visits will be planned and sample collection will be undertaken.
- TCLP test will be performed
- Soil column experiment

1.      **Title of the Study:** Water Efficient Irrigation by using SCADA system formedium Irrigation Project (MIP) Shahnehar

2.      **Study Group:**

| Project Investigator/Co-Project Investigator |
| --- |
| Dr. R.P. Pandey, Scientist G.<br>Er. Jagdish Prasda Patra, Scientist D<br>Dr. Rajesh Singh, Scientist D,<br>Sh. N. K. Bhatnagar, Scientist B |
| **Collaborating Agency** |
| Department of Irrigation & Public Health Engg. (I&PHE), Hydrology C&M Division, Tutikandi, Shimla-4. Himachal Pradesh |

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

Project Duration: **3-years**

Date of start:  **December, 2017**

Scheduled Date of Completion: **March, 2022 (after extension)**

**OBJECTIVES OF THE STUDY:**

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

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

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

Whole of the Right bank canal enroots through the jurisdiction of Himachal Pradesh whereas about 4.0 Km of LBC out of 25.69 km falls in the state of Punjab.  Out of total cost of Rs 143.32 crore the Govt. of Punjab was to share Rs 88.49 crore and remaining Rs 54.83 crore was to be borne by the

Govt. of H.P. Later on due to price escalation revised DPR was prepared and approved to the tune Rs 387.17 crores at price level 2010 in 110th meeting of advisory committee of CWC. The project was included under Accelerated Irrigation Benefit Program (*AIBP*) with 90% Central Aid and balance 10% had to be shared by Govt. of Punjab and HP in the ratio of 61.74% and 38.26%.



MAJOR IRRIGATION SHAH NEHAR PROJECT DISTT KANGRA (H.P.)
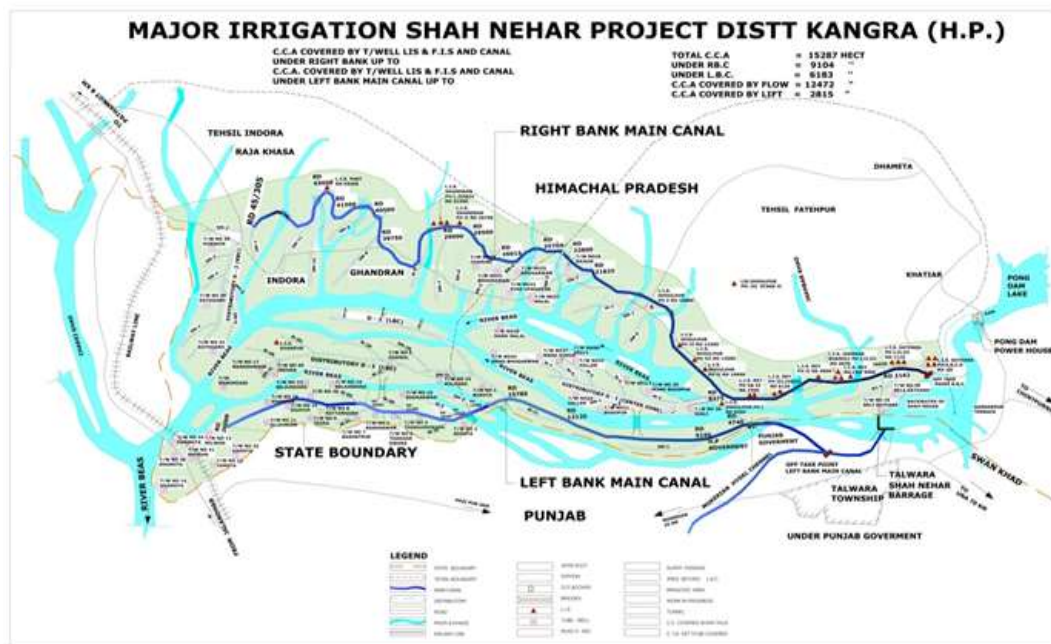
## Description of the Problem

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

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

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

- ✓ Non availability of water during peak demand of crops at the tail end of command area.
- ✓ No check over theft of water from the main canals.
- ✓ Irrigation systems play vital role for sustainable agricultural development in Himachal Pradesh, but major problem of which is rather low efficiency of water use.
- ✓ No accountability due to absence of water accounting & audits.
- ✓ Poor and low consistency management of the irrigation systems efficiency.

- ✓ Lack of reliable monitoring network and supervisory control for irrigation systems.
- ✓ Non availability of effective decision making tool to improve irrigation management.
- ✓ Huge water loss due to random irrigation process.
- ✓ Lack of awareness about modern and water efficient irrigation methods.

**Proposed Methodology**

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

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

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

**Progress of Work**

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

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

9. Field investigations have been carried out and the layout of the experimental plots for installation of moisture sensors for measurement of crop root-zone moisture at the three sites have been prepared as follows.
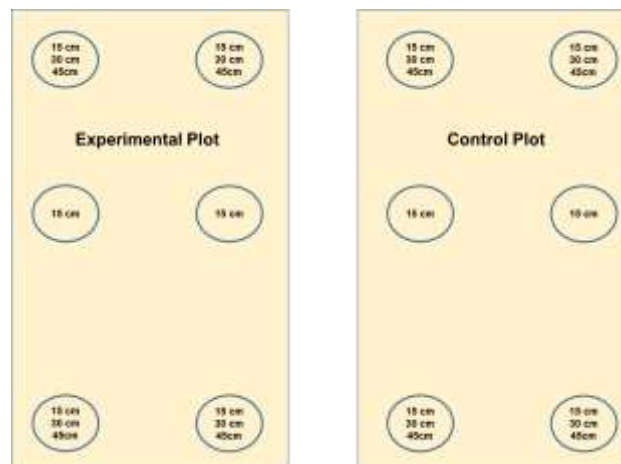




| S.N. (1) | Instrument/ Sensor (2) | At one Site (3) | For Three Site (4)=(3)*3 |
|---|---|---|---|
| 1 | Moisture and temperature sensor | | |
| | • at 15, 30, 45 cm depth | 8 | 24 |
| | • at 15 cm depth | 4 | 12 |
| 2 | Flow meter (Discharge measurement) | 3 | 9 |
| 3 | Data logger/transmitter | 1*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

Department of I & PHE, Shimla, Govt. of Himachal has processed for procurement of discharge & Moisture measurement sensor and installation in the field. The procurement is under process at present.

10. Installation of sensors and telemetry system for soil moisture monitoring and data transmission. (Work in progress).

11. Estimation of Irrigation requirement for different crops in the Shahnehar Command areas using meteorological data has been carried out and it will be presented in the working group meeting for comments/suggestion, if any. The summary of the estimated crop water requirement is as follows.

Crop Water Requirement (CWR), Potential Evapotranspiration (ETo) and Irrigation scheduling in the subtropical humid region are crucial in efficient use of irrigation supply, water resources assessment, hydrology and designing the irrigation projects as the supply of water through rainfall varies in space and time. In this context, dependable monthly rainfall at 80% and 50% probability level during the period 1982-2018 has been to assess distribution of effective rainfall and the minimum expected rainfall during the crop growing period in Shahnahar command area. FAO (Food and Agriculture Organisation) CROPWAT 8.0 crop simulation model has been used to estimate reference evapotranspiration (ETo), effective rainfall, crop water and irrigation requirement and irrigation scheduling for the Rice and Wheat crop. It is found that the average annual ETo is 4.11 mm/day and varies with highest value of 6.67 mm/day in the month of June and lowest value in January (1.99 mm/day). From the observation of probability analysis at P80 and P50, it is also found that the maximum deficit can be in the order of 33.02 mm in month of July and minimum deficit of 1.32 mm rainfall in the month of November. For seasonal agricultural planning, the 80% dependable rainfall level may be considered for safer and better irrigation management planning in the study area.

**Further Proposed Work Plan for next year**

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

**Deliverables:**

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

**Study – 4 (Sponsored Project)**

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

2. **Project Team**

| Lead Investigator | Dr. S. P. Rai, Assoc. Professor, Geology Dept., BHU Varanasi |
|---|---|
| Collaborator 1 | Dr. Rajesh Singh, Sc. 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: In collaboration with BHU**    **Budget:** Rs. 10 lacs

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

5. **Date of start:** July 2021

6. **Scheduled date of completion:** June 2024

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

8. **Objectives**

    i) Identification of recharge sources and zones of aquifer system
    ii) Transit time and flow velocity of groundwater
    iii) Interaction with aquifer and surface water bodies
    iv) Rock water interaction affecting the water quality and assessment of impact of anthropogenic activities on groundwater.

9. **Statement of the Problem**
Understanding the properties of available water resources is a key factor for sustainable water management. These properties include recharge conditions of the infiltration area, safe yield of groundwater, transit times, direction and velocity of an accidental pollution, hydraulic connection between aquifers, water – rock interactions affecting the water quality etc. These processes cannot be understood without the integrated approach of isotope and water chemistry. The investigation will help to better manage the groundwater resources of the study area and it will be a model study for the country too. Exploitation of depleting water resources results in deterioration of water quality. Groundwater contamination has also emerged as a serious issue that has posed serious threat to the people living in the Ganga River Basin. Groundwater, which is extensively used for drinking, cooking and/or irrigation, is contaminated with arsenic in many part of the Ganga Basin and is having severe detrimental effects on human health. Presently, the main problem of depletion of groundwater in Ganga Basin is due to the unsustainable abstraction of groundwater (Rodell et al., 2009; Tiwari et al., 2009). As the groundwater level is declining, people are drilling to deeper aquifers, to meet the groundwater demand. In the arsenic affected areas, deeper aquifer has been tapped for the extraction of groundwater to meet the drinking and other demands. The groundwater extracted from deeper horizons is becoming the most important fresh water resource in Ganga River Basin. However, little is known about the deeper aquifers which are in semi-confined and to confined condition.

Keeping in view of same, the study aims at identification of recharge sources and zones of aquifer system, understanding the surface and groundwater interactions, and the rock water interaction and anthropogenic activities affecting the groundwater quality.

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

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

11. **Timeline (Approved):**

| Sr. No. | Major Activities | 2021-22 | | | 2022-23 | | | | 2023-24 | | | | 2024-25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 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:**

| 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 the selected locations.<br>• Analysis for organoleptic, major ions, and coliforms in the collected samples is in progress. |

13. **Recommendation / Suggestion:**

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

14. **Analysis & Results:**

**Field Investigation and sampling plan**
   • Sampling locations were selected on grid basis uniformly distributed over the study area.

**Sampling & Analysis**
- The handpumps/tubewells of the identified location were continuously pumped for at least 15 minutes prior to the sampling and the water samples were collected in appropriate sampling bottles and preserved as per standard methods (APHA, 2017).

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:** Water Quality 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:** None

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

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

24. **Future Plan:**
- Collection and analysis of water samples.
- Geochemical and statistical modelling.

**Study - 5 (Internal Study)**

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

| Project Investigator | Er. Rajesh K. Nema, Sc. B, EHD |
|---|---|
| **Project Co-investigator** | Dr. Rajesh Singh, Sc. C, EHD<br>Dr. J. V. Tyagi, Director<br>Dr. R. P. Pandey, Sc. G & Head, EHD<br>Dr. Pradeep Kumar, Sc. D, EHD |
| **Scientific Staff** | Mrs. Anju Chaudhary, PRA<br>Mr. Rakesh Goyal, Tech. Gr. 1 |

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

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

5.  **Date of start:** June 2019

6.  **Scheduled date of completion:** May 2022

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

8.  **Study Objectives:**

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

9.  **Statement of the Problem:**

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

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

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

    a) Collection of groundwater samples during pre and post monsoon from selected locations of Haridwar district.
    b) Analysis of water samples for organoleptic parameters, major ions, trace metals, and pesticides.
    c) Processing the data to understand the contamination of water and suitability of various designated use.

**11.  Timeline (Revised):**

| Sr. No. | Major Activities | 2019-20 | | | 2020-21 | | | | 2021-22 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 |
| 1. | Field Investigation and sampling plan | ▓ | ▓ | | | | | | | |
| 2. | Sample Collection and Analysis | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | | |
| 3. | Data Processing and Interpretation | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | | |
| 4. | Interim Report | | | ▓ | ▓ | | | | | |
| 5. | Final Report | | | | | | | | ▓ | ▓ |

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

| Sr. No. | Activity | Achievements |
|---|---|---|
| 1. | Field Investigation and sampling plan | • The sample locations and sampling plan prepared |
| 2. | Sample Collection and Analysis | • Pre- and post-monsoon samples were collected from 68 locations.<br>• Analysis for organoleptic, major ions, trace metals, pesticides, and coliforms in the collected samples completed. |
| 3. | Data Processing and Interpretation | • The statistical analysis and indexing for various designated usage completed. |
| 4. | Interim Report | • 1$^{st}$ interim report prepared and submitted. |
| 5. | Final Report | • Final report has been submitted. |

**13.  Recommendation / Suggestion:**

| Sr. No. | Recommendation / Suggestion | Action Taken |
|---|---|---|
| 1. | Dr. Bhism Kumar (Ex. Scientist, NIH & IAEA) appreciated the study and its outcomes. He suggested that the study has very significant contributions in determining the deterioration in water quality at different areas in the Haridwar district and he suggested for further investigation to find out the causes of deterioration in next study. He also suggested that the outcomes of the study should be presented before the district administration for suitable dissemination of results of this study for the benefit of the mass. | A 1-day workshop will be conducted with the district administration in June 2022 |
| 2. | Dr. Sudhindhra Mohan Sharma (Former National Nodal Officer, MoDWS) suggested to incorporate layer of drainage map with the maps of water quality parameters. He also suggested publicizing the outcomes of the study. | The suggestions were incorporated in the report. |

**14.  Analysis & Results:**

**Field Investigation and sampling plan**

- The district was divided into grid of 5x5 km, and one village in each grid, totaling to 68 locations, was selected for sampling of organoleptic parameters, major ions, and bacteriological parameters.
- 19 samples for pesticide analysis were collected by dividing the district into 10x10 km grid.

**Sampling & Analysis**

- Groundwater and pond samples from the identified villages were collected after discussion with the villagers based on the usage. The handpumps were continuously pumped for at least 15 minutes prior to the sampling, to ensure the groundwater to be sampled was representative of groundwater aquifer. The water samples were collected in appropriate sampling bottles using grab sampling method and preserved as per standard methods (APHA, 2017).
- The organoleptic parameters, major ions, trace metals, pesticides, and bacteriological analysis of samples completed for both pre- and post-monsoon samples following APHA's Standard Methods for the Examination of Water and Wastewater (APHA 2017).
- The WQI for drinking and irrigation was computed following weighted arithmetic method.
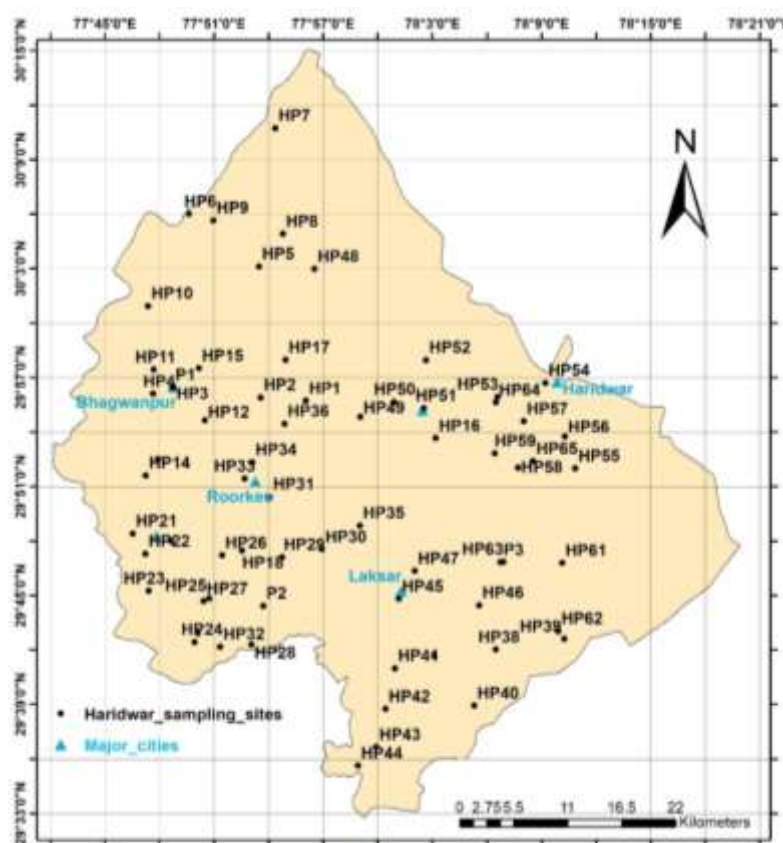


**Sampling Sites for Haridwar District**

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

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

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

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

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

**20.**   **Study Benefits / Impacts:**

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

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

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

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

**24.**   **Future Plan:**

- Organization of 1-day workshop

**Study - 6 (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. 'D', EHD |
|---|---|
| Project Co-investigator | Dr. J. V. Tyagi, Sc. 'G' & Director, NIH<br>Dr. M. K. Sharma, Sc. 'E', EHD<br>Dr. Rajesh Singh, Sc. 'D', EHD<br>Er. R. K. Nema, Sc. 'B', EHD |
| Scientific Staff | Mrs. Babita Sharma, RA<br>Mrs. Beena Prasad, RA<br>Mr. Rakesh Goyal, Tech. Gr. I |

3. **Type of Study:** Internal Study**, Budget:** Rs. 43.02 lacs

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

5. **Date of start:** Nov 2019

6. **Scheduled date of completion:** Oct 2023

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

8. **Study Objectives**

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

9. **Statement of the Problem:**

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

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

Since, point source pollution meets the river at known locations, it may be addressed by STPs or ETPs. Non-point source pollution reaches the river through the landscape after following a number of hydrologic, physical, chemical and biological processes. Hence, it is very complex to assess the causes and plan for its remediation. Very few assessments of non-point source pollution have been made in Indian rivers and they are mostly limited upto quantification of pollutant loads through the flux balance approach. Therefore, this study is being envisaged to

simulate the non-point pollution process in a lower Himalayan catchment to identify the sources and causes of non-point source pollution.

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

    a.    Procurement of secondary data required for the analysis from various govt. agencies (discharge, sediment, other water quality parameters, soil map etc.)

    b.    Collection of water samples at monthly frequency during non-monsoon and daily frequency during monsoon season from selected locations of Song river

    c.    Collection of data on usage of fertilizers and pesticides in the Song river catchment.

    d.    Analysis of water samples for general water quality parameters, total suspended solids, nutrients and pesticides

    e.    Hydrological and water quality modelling using SWAT model

**11.** **Timeline:**

| S.No. | Major Activities | 2019-20 | | 2020-21 | | | | 2021-22 | | | | 2022-23 | | | | 2023-24 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 3rd Qtr | 4th Qtr | 1st Qtr | 2nd Qtr | 3rd Qtr | 4th Qtr | 1st Qtr | 2nd Qtr | 3rd Qtr | 4th Qtr | 1st Qtr | 2nd Qtr | 3rd Qtr | 4th Qtr | 1st Qtr | 2nd Qtr | 3rd Qtr |
| 1 | Literature survey | ▓ | ▓ | | | | | | | | | | | | | | | |
| 2 | Reconnaissance visit and sampling plan | | ▓ | ▓ | ▓ | | | | | | | | | | | | | |
| 3 | Secondary data collection | | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | | | | | | | |
| 4 | Field surveys | | | | | | | ▓ | ▓ | ▓ | | | | | | | | |
| 5 | Sample Collection and Analysis | | | | | | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | | | |
| 6 | SWAT Model: Preparation of database | | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | | | | | |
| 7 | SWAT Model: Calibration, Validation & Simulation | | | | | | | | | | | ▓ | ▓ | ▓ | ▓ | | | |
| 8 | Interim Report | | | | | | ▓ | | | | ▓ | | | | ▓ | | | |
| 9 | Final Report | | | | | | | | | | | | | | | | ▓ | ▓ |

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

| S. No. | Objectives | Achievements |
|---|---|---|
| (i) | Assessment of the point and non-point pollutant loads | Four sites have been chosen for the assessment of point and non-point source pollutant loads. Plan for field sampling and other field investigations has been prepared starting from Apr2021, due to restrictions in the current Covid-19 situation. |
| (ii) | Mapping of various non-point pollution sources | After the assessment of pollutant loads, the mapping will be carried out. |
| (iii) | Simulation of various hydrological processes in the river catchment | The preliminary SWAT model set-up has been completed using the secondary data sources (freely available web sources). Discharge data from CWC and soil maps from NBSS&LUP have been obtained and the same have been used for the analysis. |
| (iv) | Simulation of non-point source pollution process for sediment, nutrients and pesticides in the river catchment | The model set-up for simulation of non-point source pollution processes will be carried out only after the primary data for at least one year is collected. |

**13.    Recommendation / Suggestion:**

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

**14.    Analysis & Results:**

**Field Investigation and sampling plan**

Four sites in the Song catchment have been selected for simulating non-point source pollution processes through the SWAT model. The first site selected is the CWC G&D site at Satyanarayana. Suswa is a major tributary of Song river and it meets Song river few kilometers upstream of Satyanarayana G&D site. So, the second site has been selected on Suswariver just before the confluence. Two other sites on the Song river have been selected upstream and downstream of Dehradun city boundaries. These sites have been selected to isolate the point and non-point sources of pollution. Although sampling was planned to be started in April 2021, but, due to Corona pandemic, the same will be started from April 2022.

**SWAT Model setup**

Most of the secondary data required for calibration of SWAT model i.e. discharge, meteorological data, soil map, LULC map etc. have been obtained. The same for the period of field investigations and monitoring will be obtained after the monitoring is over. SWAT model has been set up using the discharge data of Satyanarayana site and freely available web data sources. SWAT-cup is being run for improving the calibration results**.**
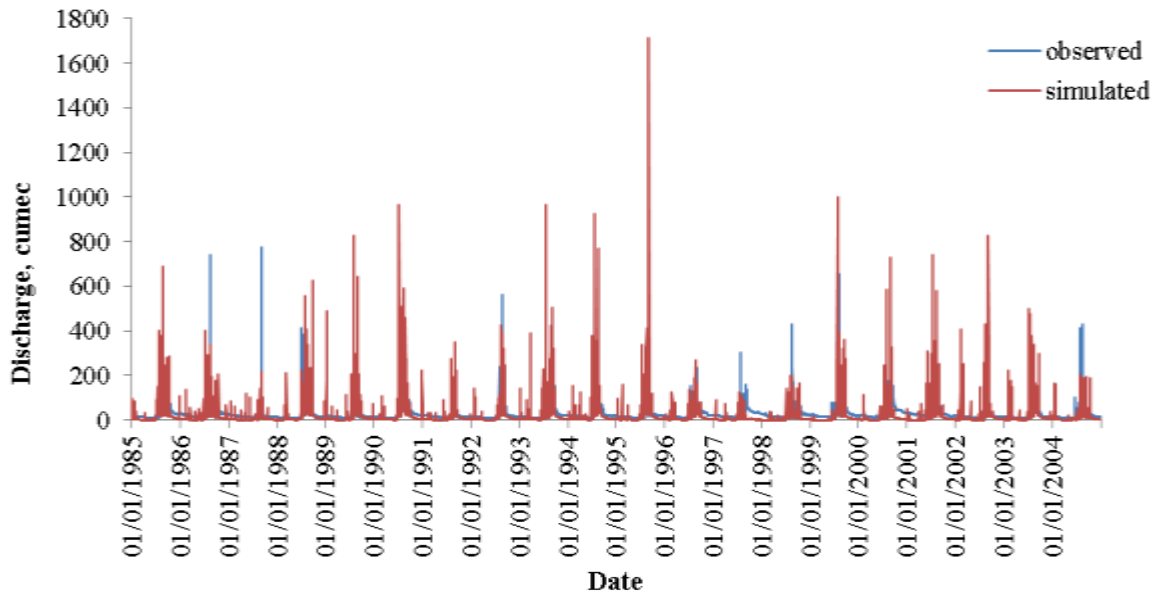
15. **End Users / Beneficiaries of the Study:** Deptt. of Irrigation & Deptt. of Agriculture, Uttarakhand

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) / IITR

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

20. **Study Benefits / Impacts:**

    The outcome of the project will be beneficial for the concerned departments in a sense that it will provide the various sources of point and non-point pollution and will suggest various scenarios for mitigating these impacts. The research outcomes from the study will be as follows:
    a. Point and Non-Point pollutant loads at various locations in Song river
    b. Quantum of non-point source pollution for various scenarios of fertilizers/ pesticides applications
    c. Technical report and papers

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

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

23. **Shortcoming/Difficulties:** The facility for analysis of pesticides is presently not available in the institute so the samples will be analysed at IITR facility.

24. **Future Plan:**

    i) Collection and analysis of samples (monthly sampling during non-monsoon and daily sampling during monsoon) from four selected sites in the Song catchment.
    ii) Secondary data procurement through various agencies required for SWAT model set-up.
    iii) SWAT Model calibration and validation both for flows and for water quality.

1.      **Title of the Study:** Development of rejuvenation plan for Hindon river system

**The study has been transferred to HI Division and merged with DST-NWO Project on River Hindon**

**Study - 8 (Internal Study)**

1.  **Title of the Project:** Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar

2.  **Project Team**

| Project Investigator | Dr. Rajesh Singh, Sc. D, EHD |
|---|---|
| **Project Co-investigator** | Dr. J. V. Tyagi, Director<br>Dr. R. P. Pandey, Sc. G & Head, EHD<br>Er. Rajesh K. Nema, Sc. B, EHD<br>Dr. Pradeep Kumar, Sc. D, EHD<br>Dr. M. K. Sharma, Sc. E, EHD |
| **Scientific Staff** | Mr. Rakesh Goyal, Tech. Gr. 1 |

3.  **Type of Study:** Internal Study, **Budget:** Rs. 23.71 lacs

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

5.  **Date of start:** July 2020

6.  **Scheduled date of completion:** June 2022

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

8.  **Objectives**

    i)   Improvement in river water quality due to covid-19 lockdown and deterioration due to anthropogenic activities over time and space,
    ii)  Self-purifying capability of river Ganga and factors responsible for it,
    iii) Variability in drug resistance bacteria, and
    iv)  Water quality indexing.

9.  **Statement of the Problem**

    The lockdown due to Covid-19 epidemic lockdown has provided an opportunity for the rivers to revive upto certain extent due to the restriction on anthropogenic activities. The deterioration of Ganga river water quality starts as it enters Rishikesh. Most of the pollution is from the tourist/pilgrimage activities associated with Rishikesh and Haridwar. On an average, approximately 1 million tourists visit Haridwar monthly, however, the population of the city is only 0.28 million. This clearly indicates the multifold increase in pollution load due to tourism. The lockdown period will provide a baseline data for the river water quality. Apart from organic load, the influx of pharmaceutical active hydrocarbons also increases with increase in tourist load. Further, Maha Kumbh, the largest religious gathering, is scheduled for Haridwar during March 11-April 27, 2021, in which around 50 million people are expected to take dip in the river during this period. Therefore, there is a need to monitor the fluctuation in the river water quality and the extent of deterioration due to the onset of anthropogenic activities. It would be interesting to examine the self-purifying capacity of river.

    There are few studies which has explored the non-putrefying nature of river Ganga. The first study goes back to 1896 by Ernst Hankin who demonstrated the antibacterial property of river Ganga water against Vibrio Cholera. Later on, in 1917, D'Herelles concluded that the antibacterial property is due to "bacteriophage". However, recent research from BHU and IIT

Delhi indicates high concentration of drug resistance bacteria in Ganga water which is a concern and requires close monitoring and would be interesting to see the variation in the population of these bacteria over time.

Keeping in view of same, the study aims at analyzing the river Ganga water sample for different physico-chemical and bacteriological parameters in a stretch from Rishikesh to Haridwar, on monthly basis or the dates which are of religious importance, to understand the impact of anthropogenic activities on the river water quality and its non-putrefaction ability. The variation in bacterial species with multidrug resistance is also studied to understand the source of drug resistance and their behavior.

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

i)   Collection of Ganga river water samples from selected locations on monthly basis and on ritualistic mass bathing events.
ii)  Analysis of water samples for organoleptic parameters, major ions, trace metals, and microbes.
iii) Processing the data to understand the contamination of water and suitability of various designated use and self-putrefaction properties of river Ganga.

**11.  Timeline (Approved):**

| Sr. No. | Major Activities | 2020-21 | | | 2021-22 | | | |
|---|---|---|---|---|---|---|---|---|
| | | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| 1. | Field Investigation and sampling plan | ▓ | ▓ | | | | | |
| 2. | Sample Collection and Analysis | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | |
| 3. | Data Processing and Interpretation | | ▓ | ▓ | ▓ | ▓ | ▓ | |
| 4. | Interim Report | | | ▓ | | | | |
| 5. | Final Report | | | | | | ▓ | ▓ |

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

| Sr. No. | Activity | Achievements |
|---|---|---|
| 1. | Field Investigation and sampling plan | • The sample locations and sampling plan prepared |
| 2. | Sample Collection and Analysis | • Monthly samples were collected from the selected locations.<br>• Samples were also collected on the ritualistic mass bathing events.<br>• Analysis for organoleptic, major ions, and coliforms in the collected samples completed.<br>• Analysis of trace metals in part of samples completed.<br>• Bacterial isolates were identified and tested for antibiotic resistance. |
| 3. | Data Processing and Interpretation | • Data processing and interpretation is under progress. |
| 4. | Interim Report | • 1st interim report prepared and submitted |
| 5. | Final Report | • Final report is under preparation |

**13.    Recommendation / Suggestion:**

| Sr. No. | Recommendation / Suggestion | Action Taken |
|---------|----------------------------|--------------|
| 1. | There was no specific comments comments. | - |

**14.    Analysis & Results:**

**Field Investigation and sampling plan**
- Sampling locations were selected considering the centers contributing to the anthropogenic inputs as shown below.
- The sampling locations were also selected at Jagjitpur from the braided channels of the river.
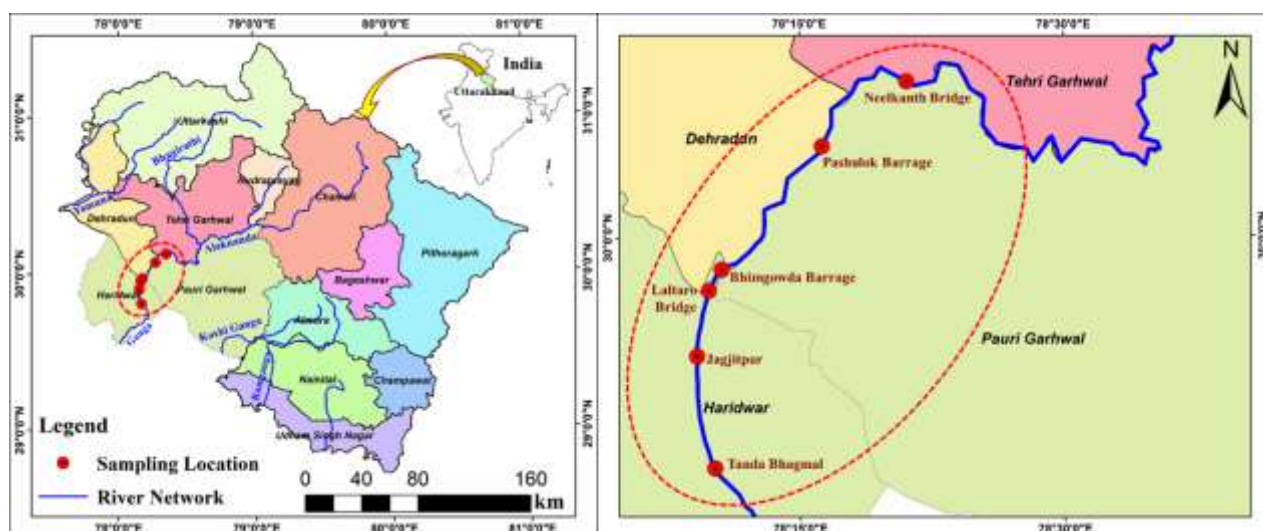


**Sampling Sites for River Ganga**

**Sampling & Analysis**
- The samples were collected from the river on every month and on ritualistic mass bathing events. The water samples were collected in appropriate sampling bottles using grab sampling method and preserved as per standard methods (APHA, 2017).
- The organoleptic parameters, major ion, and bacteriological analysis completed for all the samples. Trace metals analyzed for 3 month samples following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017).
- The bacterial isolates were identified through different biochemical tests in the water samples, and were subjected to eighteen antibiotics of different classes to check the susceptibility (Sept. 2020 & Feb. 2021).

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

**16.    Deliverables:** Technical report and research papers, Impact of anthropogenic (religious) activities on the water quality of river Ganga, Processes/reasons responsible for non-putrefying nature of river, First-hand information on multidrug resistance bacteria in the study reach.

**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 river stretch

20. **Study Benefits / Impacts:**
The outcome of the project will be beneficial for the concerned departments in a sense that it will provide the information on the water quality of the river reach (Rishikesh to Laksar). The project will also evaluate the variation in the microbial population, which will be beneficial for the government agencies to prepare the mitigate plan.

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

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

23. **Shortcoming/Difficulties:** Continuous availability of a project staff of microbiology background.

24. **Future Plan:**

- Collection and analysis of samples.
- Data processing & interpretation of results.
- Final report and manuscript writing.

**Study - 09 (Internal Study)**

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

2.    **Project Team**

| Project Investigator | Dr. Rajesh Singh, Sc. D, EHD |
|---|---|
| **Project Co-investigator** | Dr. R. P. Pandey, Sc. G & Head, EHD<br>Dr. Sumant Kumar, Sc. D, GWHD<br>Er. Rajesh K. Nema, Sc. B, EHD<br>Dr. Pradeep Kumar, Sc. D, EHD<br>Dr. M. K. Sharma, Sc. E, EHD |
| **Scientific Staff** | Er. Shekhar Saini, SRA |

3.    **Type of Study:** Internal Study, **Budget:** Rs. 30.1 lacs

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

5.    **Date of start:** July 2021

6.    **Scheduled date of completion:** June 2024

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

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

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

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

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

ii) Collection and characterization of the groundwater samples from and in the vicinity of identified locations with higher As concentration.

iii) Characterization of the aquifer sediment and As mobility in the aquifer where As was observed in exceeding the prescribed drinking water limit.

iv) Batch and column experiments for identifying the factors responsible for As mobilization.

v) Develop a model to identify As mobility in groundwater.

vi) Design alternatives to mitigate As contamination of drinking water.

11. **Timeline (Approved):**

| Sr. No. | Major Activities | 2021-22 | | | 2022-23 | | | | 2023-24 | | | | 2024-25 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 |
| 1. | Field Investigation and sampling plan | █ | | | | | | | | | | | |
| 2. | GW sample collection and analysis | | █ | █ | █ | █ | █ | █ | █ | █ | | | |
| 3. | Aquifer sediments collection and characterization | | | | | | | | | | | | |
| 4. | Batch & column experiments | | | | | | | | █ | █ | █ | █ | |
| 5. | Model development for As mobility | | | | | | | | | | █ | █ | |
| 6. | Alternatives to mitigate As | | | | | █ | █ | █ | █ | █ | █ | █ | |
| 7. | Publications | | | | █ | █ | █ | █ | █ | █ | █ | █ | █ |
| 8. | Interim Report | | | | | | | █ | | | | | |
| 9. | Final Report | | | | | | | | | | | █ | █ |

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

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

13. **Recommendation / Suggestion:**

| Sr. No. | Recommendation / Suggestion | Action Taken |
|---|---|---|
| 1. | Dr. Bhism Kumar (Ex. Scientist, NIH & IAEA) | Suggestion noted and taken care of. |

| appreciated the proposed study and suggested that this is the right time to take up this study, for the benefit of society, before the problem exaggerates. | |
|---|---|

14. **Analysis & Results:**

   **Field Investigation and sampling plan**
   - Sampling locations were selected considering the identified location with high As concentration in the groundwater.

   **Sampling & Analysis**
   - The handpumps, which are being used extensively, of the identified villages were continuously pumped for at least 15 minutes prior to the sampling and the water samples were collected in appropriate sampling bottles and preserved as per standard methods (APHA, 2017).
   - The organoleptic parameters, major ion, and bacteriological analysis completed for all the samples following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017). Trace metal analysis is under progress.

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

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

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

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

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

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

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

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

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

24. **Future Plan:**
   - Collection and analysis of GW and aquifer sediment samples.
   - Batch and column experiments.
   - Procurement of glove bag/anaerobic chamber.

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

2.  **Study Group:**

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

3.  **Type of Study:** Internal

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

5.  **Date of Start:** April 2022

6.  **Scheduled date of Completion:** March 2024

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

8.  **Study Objectives**

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

9.  **Statement of the Problem**

    Krishna and Godavari rivers are major and large rivers in Peninsula India. Water availability is more in Godavari River. Krishna delta has the water scarcity problem due to unavailability of water in Krishna River. So Andhra Pradesh government took the decision to interlinking the rivers through Polavaram canal. Flood water from the Godavari River could be diverted to the paddy growing region of Rayalaseema, which often suffers from insufficient water. In order to link the two rivers a 174 km-long canal, known as the Polavaram Right Canal, was constructed and supplied with pumps that will remove excess water from the Godavari River and send it to the Krishna River. Paddy farmers in the Krishna Delta are the main beneficiary of the linking of the two rivers. Diverted water will also provide Amaravati, the planned state capital, with drinking water. The project is seen as a means to ensure the future water and food security of Andhra Pradesh.

    Groundwater situation in different parts of India is diversified because of variation in geological, climatological and topographic set-up. Annual water level fluctuation of pre-monsoon has shown a fall in water levels for 59 % of the area, predominantly in Rayalaseema region. During post-monsoon about 90% area of the state experienced rise in annual water level fluctuation. Aquifer wise water level analysis shows that during pre-monsoon season shallowest water levels are observed in all the formations except in Intrusives. Deepest water

68

levels are observed alluvium, Limestone and BGC. During post-monsoon season, shallowest water levels are observed in all formations except in Intrusives and Laterites. Deepest water levels are observed in Gneiss, Granite, Limestone, Quartz and Sandstone (CGWB GW Year Book 2019-20 AP).

Geo-environmental conditions have a marked influence on the groundwater quality. Hydrogeochemical studies relevant to the water quality explain the relationship of water chemistry to aquifer lithology. Such relationship would help not only to explain the origin and distribution of dissolved constituents but also to elucidate the factors controlling the groundwater chemistry. Further, groundwater quality in a region is influenced by physical and chemical parameters that are strongly affected by natural processes such as water chemistry in the recharged area, water intermixing, groundwater recharge, aquifer discharge and recharge, water flow path.

The term emerging contaminants (ECs) is generally used to refer to compounds previously not considered or known to be significant in groundwater in terms of distribution and/or concentration, which are now being more widely detected and which have the potential to cause known or suspected adverse ecological or human health effects. ECs include perfluorinated compounds (PFCs), nanomaterials, pesticides, pharmaceuticals, industrial compounds, personal care products, fragrances, water treatment by-products, flame retardants and surfactants, UV-filters as well as caffeine and nicotine. Because of their rapidly increasing use in industry, transport, agriculture, and urbanization, these chemicals are entering the environment at increasing levels as hazardous wastes and non-biodegradable substances.
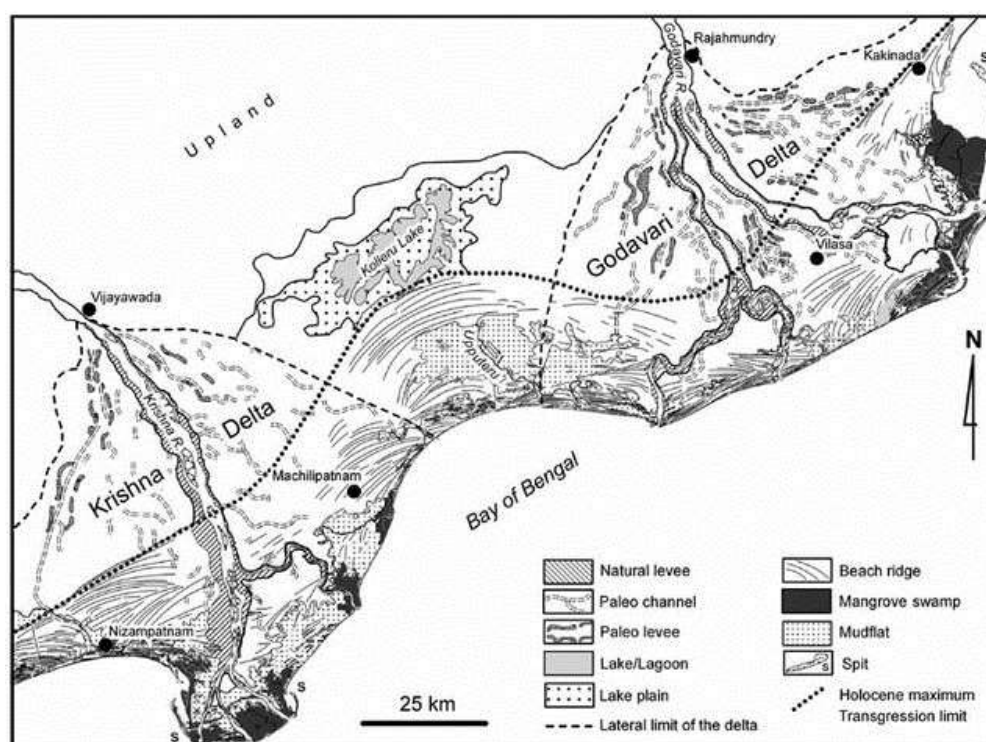


**Fig. 1. Location map of Krishna Godavari deltaic region**

The pathways through which these pollutants enter surface waters are well known and the main contributions are from effluents of wastewater treatment plants, where some residues are not removed, and from agricultural and industrial activities. Contacts and exchanges between the aquifers, rivers and sewage networks, and leaching from agricultural fields, can cause the contamination of shallow and deep groundwater. ECs may be a significant problem when surface and groundwater are used for drinking water production because the conventional drinking water treatments, like treatment with active carbon,

flocculation, and disinfection, are not specifically designed to remove these micropollutants. Traces of ECs in drinking water are actually measured and reported in only a few studies and the spatial and temporal variability of the majority of ECs in the environment is still poorly understood.

In view of the above, characterization of groundwater dynamics in Krishna-Godavari Deltas interims has been proposed using geochemical, Isotopes and emerging contamination and their sources and its impacts on human health for sustainable drinking water supply.

## 10. Methodology

i) Collection of groundwater level data, lithological data, water quality data from published report, literature and from various govt. agencies.
ii) Hydrogeological characterization of the study area and establish specific linkages of groundwater quality with hydrogeology.
iii) Collection of groundwater samples from selected sources in pre-monsoon (April-May) and post-monsoon (October-November) season at identified locations.
iv) Analysis on flow and movement of groundwater.
v) Analysis for physico-chemical parameters [pH, EC, TDS, Eh, Alkalinity, Hardness, Major Cations (Na, K, Ca, Mg), Major Anions (Cl, $SO_4$, $NO_3$, $HCO_3$), minor elements (Fluoride, $PO_4$, $NH_4$)] metal concentrations (As, Fe, Mn, Cd, Zn, Cu, Cr, Pb, Co, Ni, Ba, Sr, V, Sc), and emerging contaminants (Pesticides, PAHs, PCBs, VOCs, BETEX, MTBE) in the collected water samples.
vi) Analysis of Stable environmental isotopes of Hydrogen and Oxygen in the collected water samples
vii) Processing of hydro-chemical data for pre- and post-monsoon seasons as per BIS and WHO standards to examine the suitability of ground water for drinking purpose.
viii) Ionic relationships will be developed and water types will be identified. Spatial distribution map will be prepared in the form of contour diagrams to identify degraded water quality zones, possible sources of pollution and specific parameters not conforming to drinking/ & irrigation water quality standards.
ix) Processing of hydro-chemical data to understand the geochemical processes controlling the chemical composition of groundwater using Scatter Plots and Gibbs Plot.
x) Soil quality monitoring for metal concentrations (Zn, Cu, Cr, Co, Ni, Ba, Sr, V, Sc) in the petroliferous regions of the study area during pre- and post-monsoon seasons.
xi) Probable impact of emerging contaminants in groundwater on human health.

## 11. Work schedule / Timeline

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

## 12. Cost estimate: Rs. 17,60,000 (NIH Internal Fund)

| S. No. | Sub-Head | I Year | II Year | Total |
|---|---|---|---|---|
| 1. | Manpower | 480000 | 480000 | 960000 |
| 2. | Travelling expenditure | 100000 | 100000 | 200000 |

| 3. | Infrastructure /Equipment /Consumable | 150000 | 150000 | 300000 |
|---|---|---|---|---|
| 4. | Experimental charges/Analytical charges | 100000 | 100000 | 200000 |
| 5. | Misc. Expenditure | 50000 | 50000 | 100000 |
| **6.** | **Grand Total** | **880000** | **880000** | **1760000** |

a. **Justification for sub-head-wise abstract of the cost**
- Manpower: For timely analysis of water and soil samples and processing of data.

| S. No. | Manpower Category | Nos. | Gross Salary per month | 1st year | 2nd year | Total |
|---|---|---|---|---|---|---|
| 1. | Resource Person (Junior) | 1 | 40000 | 480000 | 480000 | 960000 |

- Travelling expenditure: For visit to study area and Sampling, attending conferences, data collection, surveys etc.
- Equipment/Consumables: Purchase of chemicals, reagents, standards etc.
- Experimental/Analytical charges: Towards analysis of samples in outside laboratories and in NIH water quality lab.

13. **Research outcome from the project:**

a) The study will identify degraded groundwater quality zones, possible sources of pollution, understanding geochemical processes controlling the aquifer chemistry and will suggest the measures for sustainable groundwater supply for drinking purpose in the study area, therefore enable better planning and management of groundwater resources.
b) Technical report and papers

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

# GROUND WATER HYDROLOGY DIVISION

**Scientific Manpower**

| S N | Name | Designation |
|---|---|---|
| 1 | Dr. M K Goel | Scientist G & Head |
| 2 | Dr. Anupma Sharma | Scientist F |
| 3 | Dr. Surjeet Singh | Scientist F |
| 4 | Dr. Sumant Kumar | Scientist D |
| 5 | Dr. Gopal Krishan | Scientist D |
| 6 | Sh. Nitesh Patidar | Scientist B |
| 7 | Mrs. Nidhi Kalyani | Scientist B |
| 8 | Mrs. Anju Choudhary | PRA |
| 9 | Sri Sanjay Mittal | SRA |
| 10 | Sri S.L. Srivastava | SRA |
| 11 | Sri Ram Chandra | SRA |

# APPROVED WORK PROGRAMME OF GWHD FOR THE YEAR 2021-22

| S. No. | Project | Project Team | Duration & Status | Funding Source |
|---|---|---|---|---|
| **Internal Studies** | | | | |
| 1.<br>NIH/GWH/NIH/19-21 | Application of Satellite Data Products for Water Resources Assessment | Suman Gurjar (PI), Vishal Singh, Surjeet Singh | 2 years<br>(05/19 - 04/21)<br>*Status: Completed* | Internal Study |
| 2.<br>NIH/GWH/NIH/19-20 | The Regional Hydrological Impact of Agricultural Water Saving Measures in the Gangetic Plains | Sumant Kumar (PI), C. P. Kumar (retired Sep, 2020), Archana Sarkar, Surjeet Singh, P. K. Mishra | 1 year 8 months<br>(08/19 – 03/21)<br>*Status: Completed* | Internal Study |
| 3.<br>NIH/GWH/DoWR/20-20 | Impact on Salinity of River Mahadayi due to Proposed Dams on River Mahadayi | Gopal Krishan (PI), B. Venkatesh, Nitesh Patidar | 11 months<br>(07/20 – 05/21)<br>*Status: Completed* | Referred by DoWR (MoJS) |
| 4.<br>NIH/GWH/NIH/20-22 | Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System | Nitesh Patidar (PI), Gopal Krishan, Anupma Sharma | 2 years<br>(08/20 – 07/22)<br>*Status: In progress* | Internal Study |
| **Sponsored Projects** | | | | |
| 5.<br>NIH/GWH/NMSHE/16-20 | Development of a project website and hydrological database in Upper Ganga basin<br>(SP-1) | M. K. Goel (PI), M. Arora, A. K. Lohani, D. S. Rathore (retd. Jan. 2021), D. Chalisgaonkar, A. R. S. Kumar, Surjeet Singh, P. Mani, A. Sarkar, M. K. Nema, Suman Gurjar, P. K. Mishra | 5 years<br>(01/16 - 03/21)<br>Extended up to Sept. 30, 2021<br><br>*Status: Completed* | DST under NMSHE |
| 6.<br>NIH/GWH/BGS/17-20 | Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency GW Level and Salinity Measurements | Gopal Krishan (PI), Surjeet Singh, C. P. Kumar (retired Sep, 2020), M. S. Rao<br><br>*From: BGS, UK*<br>Dan Lapworth (PI)<br>Alan MacDonald | 5 years<br>(12/17-11/22)<br><br>Extension from 06/21 to 11/22 with approval of DoWR, RD & GR<br><br>*Status: In progress* | BGS, UK |
| 7.<br>NIH/GWH/PDS/17-20 | Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin | Sumant Kumar (PI), Sudhir Kumar, Rajesh Singh, Gopal Krishan, Anju Chaudhary<br>*Partner Org.:*<br>MWRD, Bihar<br>*Collaborator:*<br>Brijesh Yadav, IIT-R and N. S. Maurya, NIT Patna | 3.5 years<br>(12/17-06/21)<br><br>*Status: Completed* | NHP under PDS |
| 8.<br>NIH/GWH/PDS/17-21 | Assessment of Impacts of Groundwater Salinity on Regional Groundwater | Gopal Krishan (PI), Surjeet Singh, C. P. Kumar (retired Sep | 4 years<br>(12/17-07/22) | NHP under PDS |

| | | | | |
|---|---|---|---|---|
| | Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures | 2020), *IIT-Roorkee:* Brijesh Yadav (PI) M. L. Kansal *Sehgal Foundation, Gurgaon:* Lalit Mohan Sharma | *Status: In progress* | |
| 9. NIH/GWH/PDS/ 17-21 | Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study | Surjeet Singh (PI), C. P. Kumar (retired Sep 2020), Sudhir Kumar, Suman Gurjar, Gopal Krishan | 4 years (12/17-07/22) *Status: In progress* | NHP under PDS |
| 10. NIH/GWH/DST/ 18-20 | Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA | B. Chakravorty (PI), Surjeet Singh (Dy. Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar *Other India Partners:* IITR, IITKg, MCS, Patna *UK Partners:* Univ. of Manchester, BGS, Salford University, Univ. of Birmingham | 4 years (01/18 - 12/21) *Status: Completed* | DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme |
| 11. NIH/GWH/DST/ 18-20 | Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micro-pollutants | Anupma Sharma (PI) Sumant Kumar, Gopal Krishan, Suman Gurjar, M. K. Sharma *Indian Partners:* IIT Ropar, IIT Jodhpur *UK Partner:* Cranfield University, Water Harvest, Excellent Develop. (UK based NGO) | 4 years (01/18 - 12/21) *Status: Completed* | DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme |
| 12. NIH/GWH/CEH M/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, Sumant Kumar, Vishal Singh, Nitesh Patidar *Partners:* Haryana Irr. & WR Dept., UP GW Deptt., UYBO, CWC | 6 years (04/18-03/24) *Status: In progress* | Special Project under "Centre of Excellence" (NHP) |
| 13. 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 | Anupma Sharma (PI) Nitesh Patidar (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI & | 5 years (03/19 - 02/24) *Status: In progress* | DST |

| | | | | |
|---|---|---|---|---|
| | Water | CIAH, Bikaner, NIAM Jaipur) | | |
| 14. NIH/GWH/CCR BF/20-23 | Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF | Gopal Krishan (PI & Co-coordinator) | 3 years (07/20 – 06/23) *Status: In progress* | Federal Min. of Education and Research, Germany |
| 15. NIH/GWH/DST -SERB/21-24 | Partitioning ET into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen | Gopal Krishan (PI), M.S. Rao | 3 years (04/21 – 03/24) *Status: In progress* | DST-SERB |
| **Consultancy Projects** | | | | |
| 1. | Assessment of Saline and Freshwater Zone in Faridkot, Fazilka and Muktsar Districts of Malwa Region of Punjab | Gopal Krishan (PI) | 2.5 years (03/19-10/21) *Status: Completed* | Punjab Government |
| 3. | Water Availability Study based on HI and RF-RO Modeling of Upper Hindon Basin | Anupma Sharma (PI) | 2.5 years (04/19-09/21) *Status: Near completion* | Irrigation Deptt., Saharanpur |
| 4. | Hydro-geological Study in Vicinity of SEL Manufacturing Co. Ltd., Nawanshahr, Punjab | Surjeet Singh (PI) | 6 months (02/21-08/21) *Status: Completed* | NIT, Jalandhar (Punjab) |
| 5. | Geo Environmental study in/around OMC's in Manglia, Indore | Sumant Kumar (PI) | 6 months (11/20-5/21) *Status: Completed* | BPCL, Indore |
| 6. | Study of Scenarios for Long-term Effect of Enroute Canal Irri. for Proposed M - G Link | M. K. Goel (PI) | 12 months (07/20-06/21) *Status: Draft report submitted.* | NWDA, Delhi |

# RECOMMENDED WORK PROGRAMME FOR THE YEAR 2022-23

| S. No. | Project | Project Team | Duration & Status | Funding Source |
|---|---|---|---|---|
| **Internal Studies** | | | | |
| 1. NIH/GWH/NIH/ 20-22 | Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System | Nitesh Patidar (PI), Gopal Krishan Anupma Sharma | 2 years (08/20 – 07/22) *Status: In progress* | Internal Study |
| 2. NIH/GWH/NIH/ 22-25 | Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin | Sumant Kumar (PI), S. Singh, R. Singh, G. Krishan, S. S. Rawat, M.K. Sharma, N. Patidar, P. K. Mishra, M. K. Goel | 3 years (04/22 – 03/25) Status: **New Study** | Internal Study |
| 3. NIH/GWH/NIH/ 22-24 | Conjunctive Management of Water Resources in IGNP Command | Nitesh Patidar (PI), M. K. Goel, Anupma Sharma, Gopal Krishan, Surjeet Singh, Sumant Kumar, Nidhi Kalyani | 2 years (04/22 – 03/24) Status: **New Study** | Internal Study |
| 4. NIH/GWH/NIH/ 22-24 | Studying Groundwater Dynamics using Machine Learning and Numerical Modelling | Nidhi Kalyani (PI), Anupma Sharma, Nitesh Patidar, Sumant Kumar | 2 years (04/22 – 03/24) Status: **New Study** | Internal Study |
| **Sponsored Projects** | | | | |
| 5. NIH/GWH/BGS/ 17-20 | Groundwater Fluctuations and Conductivity Monitoring in Punjab - Groundwater resilience in Punjab and adaptation to future changes in climate and water resource demands (title modified by funding agency) | Gopal Krishan (PI), S. Singh, C. P. Kumar (retd.), M. S. Rao *BGS, UK:* Dan Lapworth Alan MacDonald Daren Goody | 5 years (12/17-11/22) *Status: In progress* | BGS, UK |
| 6. NIH/GWH/PDS/ 17-21 | Assessment of Impacts of Groundwater Salinity on Regional Groundwater Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and  Resilience Building Measures | Gopal Krishan (PI), Surjeet Singh, C. P. Kumar (Retd.), *IIT-Roorkee:* M. L. Kansal, Brijesh Yadav *Sehgal Foundation:* Lalit Mohan Sharma | 4 years (12/17-07/22) *Status: In progress* | NHP under PDS |
| 7. NIH/GWH/PDS/ 17-21 | Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study | Surjeet Singh (PI), C. P. Kumar, Sudhir Kumar, Suman Gurjar, Gopal Krishan | 4 years (12/17-07/22) *Status: In progress* | NHP under PDS |
| 8. NIH/GWH/CEH M/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, Sumant Kumar, P.K. Mishra, V. Singh, N. Patidar, N. Kalyani *Partners* Haryana Irr. | 4 years (04/18-01/24) *Status: In progress* | Special Project under "Centre of Excellence" (NHP) |

| | | | | |
|---|---|---|---|---|
| | | & WR Dept., UPGW Dept., UYRB, CWC | | |
| 9. NIH/GWH/DST/19-23 | Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water | Anupma Sharma (PI), Gopal Krishan, Nitesh Patidar (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur) | 5 years (03/19 - 02/24) *Status: In progress* | DST |
| 10. NIH/GWH/CCRBF/20-23 | Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF | Gopal Krishan (PI & Co-coordinator) | 3 years (07/20 – 06/23) *Status: In progress* | Federal Min. of Education and Research, Germany |
| 11. NIH/GWH/DST-SERB/21-24 | Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen | Gopal Krishan (PI), MS Rao | 3 years (04/21 – 03/24) *Status: In progress* | DST-SERB |
| 12. NIH/GWH/APN/22 | Capacity Development Program on Site Suitability Mapping for Managed Aquifer Recharge (MAR) under Varying Climatic Conditions using Remote Sensing and Machine Learning based Hydrological Modelling Tools | Nitesh Patidar (PI), S. Singh, G. Krishan *IIT Roorkee(lead)*: Basant Yadav, Ashish Pandey, R D Singh, B. J. Deka *In-kind support*: KU, Japan: Yutaka Matsuno, PNU, South Korea: Sanghyun Jeong | 10 months (01/22-10/22) *Status: New Study* | Asia-Pacific Network (APN) |
| **Consultancy Projects** | | | | |
| 1. | Groundwater Investigations of Rana Sugars Ltd. Buttar Seviyan Area of Amritsar District, Punjab | Surjeet Singh (PI) | 6 months (01/22 – 06/22) *Status: In progress* | NIT, Jalandhar (Punjab) |

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

**Trainings organized:**

GWHD organized **three** training courses, and **one** workshop since last WG meeting.

**Outreach activities since previous WG meeting:**
1. Scientists published/accepted **39** papers in international/national journals & conferences.
2. Scientists guided/guiding **6** M/Sc./M.Tech./Ph.D. students for their thesis work.
3. Scientists conducted **4** mass awareness activities.
4. Scientists developed **3** Modelling software:
    a. NIH_ReSyP
    b. IIT-Kgp NHM – GW module
    c. M-G Link System model for SW-GW interaction

# 1. PROJECT REFERENCE CODE: NIH/GWH/NIH/20-22

**Title of the Project:** *Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System*

Study team:        PI        Dr. Nitesh Patidar, Scientist-B
                   Co-PIs     Dr. Gopal Krishan, Scientist-D
                              Dr. Anupma Sharma, Scientist-F

Type of study:        Internal (On-going)

Duration:        Two years (August 2020 – July 2022)

## Objectives vis-à-vis Achievements

| Objectives | Achievements |
|---|---|
| Development of the integrated GEE-MODFLOW model to estimate groundwater recharge and to disseminate model outputs | *Near completion*<br>Development of the integrated model is near completion. Various modules to download data from GEE, process and utilize in MODFLOW have been developed. A surface water module to estimate infiltration, ET and percolation from the top soil layer has been developed.<br>MODFLOW has been integrated with developed surface water module and GEE. A web-based interface to run and disseminate the model outputs has also been developed. |
| Evaluation of the estimated recharge using in-situ observations | *In-progress*<br>The integrated model is being tested against the observed groundwater heads and soil moisture. |
| Assessment of the impacts of various recharge/abstraction scenarios on groundwater system of Hindon river basin | *In-progress*<br>Modules for assessing the impacts of changes in recharge and pumping is in progress. |

## Brief 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.

With the improved understanding of hydrological processes and recent advancements in the field of computers, many hydrological models have been developed. Although the models developed during the past decades produce useful results, a model alone may not be implemented to support decision making for groundwater management mainly due to (i) difficulties in incorporating the frequent changes in impervious surface, vegetation phenology and surface water bodies, and (ii) no provision to disseminate the outputs to open platforms so as to support decision making. Therefore, a Groundwater Recharge Assessment System that integrates state-of-the-art hydrological models, allows to incorporate frequently available remote sensing data, data visualization and dissemination, is required for precise estimation of groundwater recharge and to support decision making in India. In this context, the proposed system will help assessing the replenishable groundwater considering recharge from various sources (e.g. rainfall and surface water bodies), investigating impacts of various recharge/abstraction scenarios on groundwater system and analyzing the outputs on an open web-based GIS platform through Google Earth Engine (GEE).

**Study area**

　　The model will be tested in Hindon river basin. Hindon river originates from Saharanpur district of Uttar Pradesh and joins Yamuna river near Delhi. The basin lies between the latitudes 28°30′15″ to 30°15′12″ N and longitudes 77°20′18″ to 77°50′10″ E and has an area of ~7000 km$^2$. It is largely composed of Pleistocene and Quaternary alluvium represented by sand, clay and kankar. The ever-increasing groundwater abstractions to cater the agricultural needs have led to depleted groundwater levels in the area. These depletions have not only reduced the groundwater availability but also have made the groundwater more susceptible to pollution and have reduced the baseflow contribution to the streams. The alarming groundwater declines, emerging groundwater quality issues and ever-increasing water demand in the region necessitate proper planning and management of groundwater resources. This requires precise quantification of groundwater recharge, assessment of various recharge/abstraction scenarios on groundwater system and forming and implementation of water management strategies. As the groundwater is a dynamic resource which varies with the recharge and extraction, frequent assessments are needed for better planning.

**Progress**

　　A data preparation module is developed using GEE, a free cloud-based platform, and Python. A surface water module is developed to simulate processes in the top soil layer, named Root Zone Flow (RZF) Module. RZF simulates runoff using SCS-CN method or Grreen-Ampt method, potential evapotranspiration using Penman–Monteith, and percolation using soil water balance. The RZF is integrated to UZF (Unsaturated Zone Flow) module of MODFLOW which simulates the flow in unsaturated zone. The RZF and UZF are integrated such a way that the ET is partial estimated from top soil using RZF and partially from the bottom soil using UZF wherein the proportions depend on the root fractions in the top and bottom soil layers. An option is provided to estimate irrigation water requirement and recharge from irrigation using the model. The actual recharge from the UZF is used as recharge to GWF (Groundwater Flow) modules of MODFLOW. All the module, i.e. GEE, RZF, UZF and GWF are integrated using python programming so as reduce efforts in preparing input files for the model.

　　A web-based interface for the developed integrated model is also developed. The interface also includes Interactive output visualization module for visualizing outputs of the model.

**Action plan and timeline (month-wise from Apr 2022 to Jul 2022)**

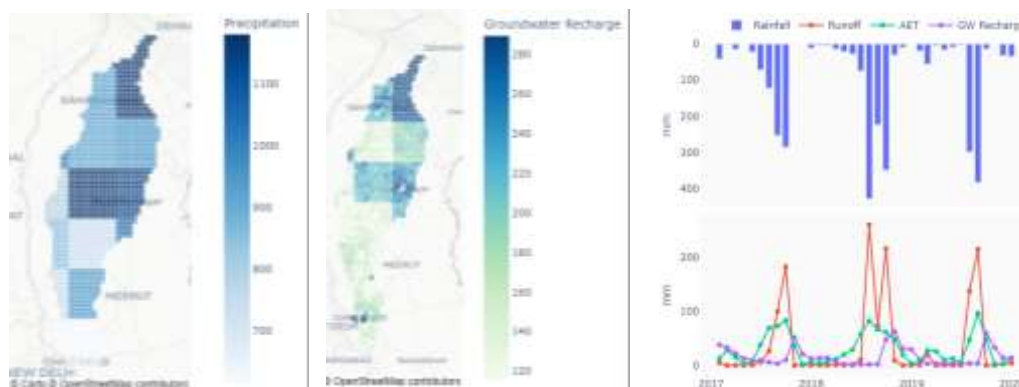| Work element | Apr 2022 | May 2022 | Jun 2022 | Jul 2022 |
|---|---|---|---|---|
| Model calibration and validation | ███ | ███ | | |
| Simulation runs for investigating various recharge/abstraction scenarios | | ███ | ███ | |
| Preparation and submission of reports, model manuals and research papers | | | | ███ |



**Fig. 1** Precipitation and GW recharge maps (2018) and monthly time series of precipitation, runoff, actual ET and GW recharge for the years 2017-19.

**PROJECT REFERENCE CODE: NIH/GWH/NMSHE/16-20**

**Title of Project:** *Development of a project website and hydrological database in UGB (SP-1)*

**Study team**

1. Dr. M. K. Goel, Scientist 'G', NIH, Roorkee - PI
2. Dr. M. Arora, Scientist 'E', NIH, Roorkee – Co-PI
3. Dr. A. K. Lohani, Scientist 'G', NIH, Roorkee
4. Mr. D. S. Rathore, Ex-Scientist 'F', NIH, Roorkee
5. Mrs. D. Chalisgaonkar, Scientist 'G', NIH, Roorkee
6. Dr. A. R. S. Kumar, Scientist 'F', NIH, Roorkee
7. Dr. Surjeet Singh, Scientist 'F', NIH, Roorkee
8. Mr. P. Mani, Scientist 'F', NIH, CFMS, Patna
9. Dr. A. Sarkar, Scientist 'E', NIH, Roorkee
10. Mr. M. K. Nema, Scientist 'D', NIH, Roorkee
11. Smt. Suman Gurjar, Ex-Scientist 'D', NIH, Roorkee
12. Mr. P. K. Mishra, Scientist 'D', NIH, Roorkee
13. Dr. D. S. Bisht, Scientist 'B', WHRC, NIH, Jammu

**Objectives & Achievements**

The objectives and achievements of the project are:

| Objectives | Achievements |
|---|---|
| Development of a hydrological and hydro-meteorological database for study basin. | Completed |
| Processing and analysis of hydro-meteorological data in study area. | Completed |
| Assessment of adequacy of hydro-meteorological network in study area. | Completed |
| Investigation and referencing of available spatial database from various sources. | Completed |
| Capacity building for use of hydrological data entry and processing software. | Few workshops organized in beginning of project. |
| Development of interactive project web site with hydrological information system. | Completed |

**Sponsored by**                    DST, New Delhi

**Brief Background**

The first important task in hydrological analysis for a river basin is the collection of true, accurate and regular hydrological and hydro-meteorological data. In our country, a number of organizations are involved in collection of hydrologic and meteorological data. However, it is also important to integrate the data related to different hydrological variables (say, rainfall, snowfall, temperature, humidity, wind speed, sunshine, river flow, groundwater observations etc.) in a database so that comprehensive analysis and processing of hydrologic variables in a river basin can be made. In addition to the point observations, a number of satellite platforms (such as Resourcesat, Cartosat, MODIS, TRMM, APHRODITE etc.) are now providing spatial information in various observation windows (or bands), some of which are on-line in public domain. This information can be used in hydrological analysis.

Data collected on hydrologic variables are generally raw which may not be used directly in most hydrologic analysis work. Processing of hydrological data has two major objectives: one to evaluate the data for its accuracy and the other to prepare the data in a form valuable to the users. The rapid advance in computer technology, in speed of operation and data storage capacity as well as the capability of hydrological software has greatly simplified the management of large quantities of hydrological data. All hydrological datasets can be maintained in well-defined computerized

databases using standard database management system. Surface Water Data Entry System (SWDES), developed under Hydrology Project – I, and HYMOS software can be used for entry and processing of hydrological data in standardized format. This is essential for the long-term sustainability of the datasets in proper form and their dissemination to the end users. Both, raw and processed data sets are to be properly stored and archived to specified standards so that there is no loss of information. NIH has trained manpower on SWDES and HYMOS software which can be used entry and process the hydrological database for the Upper Ganga basin up to Rishikesh and to build capacity in other organizations dealing with hydrological data for their effective utilization.

For mountainous areas, significant variation in altitude, slope, aspect, soil, and land use characteristics over short distances requires high density of hydrometric networks for reliable assessment of hydrological variables. However, due to various operational problems such as approachability, low temperatures, snowfall, high velocity flows with boulders and sediments etc., hydro-meteorological information available in the mountainous regions is quite limited due to lack of proper observation network. There is an urgent need to properly design and upgrade automated hydro-meteorological networks suitable for the prevailing climate in the region for long-term monitoring and database development. It is envisaged to analyze the existing hydro-meteorological network in the study area and analyze its adequacy using different techniques.

There has been widespread concern over the global change in climate and its impact on various hydrological variables. This impact is not uniform globally and mountainous regions are considered to be more susceptible to climate change. It is envisaged to carry out trend analysis of long-term data of hydrological variables to assess the possible impact of climate change on various hydrological processes. These findings can be used to analyze various scenarios of water availability and demand to develop strategies for proper management of water resources in future. Finally, it is envisaged to develop the web-site of the project for online information about various studies and sub-projects being carried out and the intermediate dissemination of results. It is also planned to link the web-based hydrological information system with the site to show the summary/gist of processed data at various observation sites in the study area.

**Present Progress**

The study has been completed and the report of the sub-project has been finalized and is being submitted shortly to DST. In this sub-project, extensive efforts have been made for the processing of hydro-meteorological data of IMD and CWC. Trend analysis has been carried out on different hydro-meteorological variables. Network analysis has been carried out and areas of probable new instrumentation have been identified using entropy analysis. Gridded reanalysis and satellite spatial data have been investigated for use in UGB. Finally, a project website has been designed which integrates the major outcomes of various sub-projects for their mass-communication.

A number of data processing techniques (graphical plotting, spatial homogeneity, double-mass curve analysis, trend analysis) have been applied in the present study and some suspect values have been identified. Majority of the errors can be identified by just simply plotting the long-term observations (say, plot of daily precipitation, precipitation at nearby stations, max. and min. temperature, long-term monthly observations, flow observations at u/s and d/s gauging stations, double-mass curves etc.) and cause of error (human, instrumental, or change in setting etc.) can be identified and corrected at the time and place of occurrence.

Using the spatial homogeneity test, around 24 events have been identified (during 1972 to 2016) with abnormal high or low rainfall. Using double mass analysis, 8 stations out of 30 stations of IMD/CWC have been identified with significant change of slope since different years (from break-point of slope). Plot of data also identified some entry errors in max. and min. temperature. Further, plot of monthly data of Uttarkashi gauging station identified significant low flow observations during 1986 to 2009.

Trend analysis has been carried out for the precipitation data, number of rainy days, temperature data, and flow data for various stations in Alaknanda and Bhagirathi basins and in the downstream UGB up to Rishikesh. It is broadly inferred that precipitation is increasing in UGB in the pre-monsoon and monsoon seasons with net increase at the annual time step. In the Bhagirathi and Alaknanda sub-basins, most stations show rising trend of rainy days in the pre-monsoon (April - May) and monsoon (June – September) seasons. The results at the annual time step show mixed trends with

some stations having increasing and some stations having decreasing rainy days. With regard to the river flows, it is inferred that flows are increasing in the Alaknanda basin as a whole with significant increasing trend in the monsoon, post-monsoon and winter months while in the Bhagirathi sub-basin, the Tehri dam has redistributed the flows with significant increase in the non-monsoon months at the cost of monsoon months.

Network analysis using average annual rainfall and 'Cv' method indicates sufficient network of hydro-meteorological stations (around 50) in UGB. However, it would be desirable if all the discontinued stations of IMD can be operationalized along with weather sensors. Entropy analysis has been carried out to indicate desirable areas of probable new stations in the UGB. To explore the potential usage of global precipitation estimates available from reanalysis products or satellite estimates, two reanalysis products (ERA5-Land hourly data and IMDAA daily dataset) and precipitation estimates from GPM-IMERG have been investigated. Though all these products were found to capture the seasonality of precipitation regime of UGB, IMERG is found to be satisfactorily representing the monthly magnitudes of precipitation and is found to be best suitable alternative for the UGB.

A website has been developed for the mass-communication of the findings of various sub-projects. It also provides average estimates of hydro-meteorological variables at various stations in UGB and trend results. Snow cover estimations (2000 – 2020) have been made for all the Himalayan basins in India and have been provided in Web-GIS.

## 3. PROJECT REFERENCE CODE: NIH/GWHD/BGS/2017-22

| | | |
|---|---|---|
| **Title of the study** | | Groundwater fluctuations and Conductivity Monitoring in Punjab- Groundwater resilience in Punjab and adaptation to future changes in climate and water resource demands |
| **Name of PI and members** | : | **NIH, Roorkee, India** |
| | | Dr. Gopal Krishan (PI) |
| | | Er. C.P. Kumar (co-PI) (Retired on Sept. 2020) |
| | | Dr. M.S. Rao (co-PI) |
| | | Dr. Surjeet Singh (co-PI) |
| | | **BGS, UK** |
| | | Dr. Dan Lapworth (PI) |
| | | Prof. Alan MacDonald (Project coordinator) |
| | | Prof. Daren Goody (Co-PI) |
| **Type of study** | : | **Sponsored,** BGS, UK. |
| **Date of start (DOS)** | : | December 2017 |
| **Scheduled date of completion** | : | November 2022 |
| **Location** | : | Bist- Doab and SW Punjab |

| S. No. | Objectives (3 New added) | Achievements |
|---|---|---|
| 1 | To characterize multi-year variability in groundwater level and SEC using high frequency groundwater measurements within nested shallow and deep piezometers | **Achieved** – There is a trend of GW depletion mainly due to the onset of pumping for irrigation during the Kharif season, a part of which is in the monsoon season. So the contribution of pumping could exceed natural replenishment. The rainfall increase is the dominant factor, suggesting that without considering pumping effects, the rainfall patterns indicator of climate change could provide larger GW sustainability in Northwestern India, currently experiencing depletion for supporting irrigated agriculture Agriculture and number of groundwater structures have positive correlation with the depth to groundwater indicating agriculture crop/paddy as the main source of GW depletion in Jalandhar, Kapurthala and part of Nawanshahr districts |
| 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 (80%)-** Analysis carried out so far indicated that there is inter-relation between various source waters. There are some commonalities in isotope values at a certain percentile. Satluj water and canal originating have highly depleted values as compared to Beas river values Reservoir samples are highly enriched. |
| 3 | Characterize groundwater residence times and water quality in southern Punjab through detailed sampling to assess the resilience of groundwater abstraction as an adaptation | **Achieved** (30%)– Sampling has been done from network of piezometers from 10 selected sites in southwest Punjab and samples has been sent to BGS, UK for analysis of CFC and |

| | strategy for continued food production. | SF6 |
|---|---|---|
| 4 | Assess groundwater vulnerability to salinization from water-logging from increased surface water flows (including canal flows) through glacial melt-water and identify potential solutions for future priority research, and inform robust conceptual models of GW salinization in this region. | **Achieved (30%)-** Analysis carried out so far indicated that there is inter-relation between various source waters. There are some commonalities in isotope values at a certain percentile. |
| 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 | Is under process |
| 6 | To prepare a status report on groundwater issues in Punjab | Will be prepared after getting the results of tracers |

**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. 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 SW Punjab where groundwater samples were taken from the network of depth wise piezometers developed by Department of Agriculture and Farmers Welfare at 40 sites in Fazilka, Faridkot and Muktsar districts of south-west Punjab. A total of 142 piezometers were developed in another study in the depth range of 5 m-32 m and categorized as shallow (<10 m); intermediate $1^{st}$ (10-15 m); intermediate $2^{nd}$ (18-20 m) and deep (28-32m). Electrical conductivity of the groundwater samples was measured on site. Analysis results for the values of EC show that 11% of groundwater in the study area is fresh. Of this, the major fraction is present in the shallow to $1^{st}$ intermediate depth aquifer (less than < 15 m depth). The fresh GW of this aquifer should be preserved for drinking water needs, should be safeguarded from any contamination; and their active recharge areas should be preserved from any unwanted encroachment which may affect the groundwater quality of these aquifers. Major fraction (58%) of the groundwater in (shallow to deep depth) is of marginal to moderately fresh water type. This is well suited for the purpose of irrigation and livestock. This groundwater may be used for irrigation after marginally mixing with fresh water and directly may be used by the industrial sector and for the salt tolerant crops. About 31% groundwater is marginally saline to saline. This may be used for salt tolerant crops, industrial applications, and other secondary water uses.

On the basis of the salinity profiles of the aquifers, in the present study, groundwater samples were collected from 10 selected sites for analysis of CFC, SF6 for better understanding of the aquifer systems

**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. 1). In addition to these sites water level loggers were installed in Bhogpur, Tanda and Nakodar in October, 2019 (Fig. 1). For extending the studies to southwest Punjab the samples from a network of piezometers from 10 sites were taken for analysis of CFC and SF6 to characterize groundwater residence times
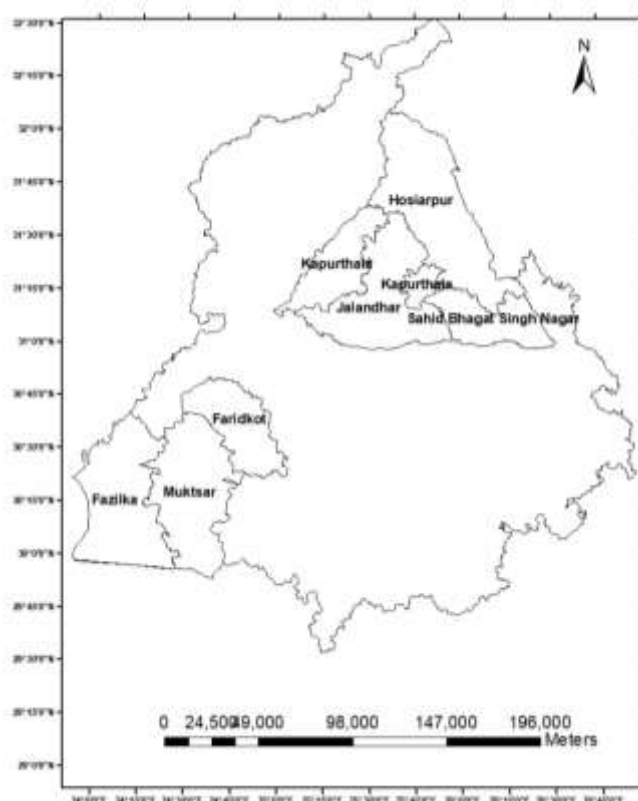
**Fig. 1.** Study area, Bist Doab and SW, Punjab

Some of the findings of the study states that there is a sharp decline in groundwater levels during the monsoon season due to higher extraction but this has also resulted in enhanced groundwater recharge in post monsoon season.

Water stable isotopes are tracers of physical processes water molecules undergo between evaporation from the ocean and arrival in the aquifer via recharge. It has been found that Sutlej river and canals origination from these rivers have depleted signatures due to the origin from Himalayan sources compared to the meteoric monsoon signature makes this an excellent tracer for assessing the significance of river/canal water sources in shallow groundwater recharge in this region.

Long-term average amount weighted isotope values for precipitation were also used to compare with groundwater isotope values to understand recharge sources and processes.

The contrasting isotope signatures of precipitation and surface waters in this area clearly demonstrate that both shallow and deep groundwater recharge is dominated by meteoric sources, rather than surface water sources including canal irrigation water which have been found dominating in SW Punjab in other study. Given the widespread canal coverage in this region this is an important finding, and contrasts with other areas in southwest Punjab where canal return recharge is thought to dominate shallow groundwater recharge

The depleted water isotope signatures in the deep groundwater relative to the shallow groundwater in entire Punjab can be explained by recharge sources from the deep groundwater having a component of groundwater recharged some distance up gradient from the sampling points at a higher elevation

Work is also going on to investigate the occurrence of low flow/ stagnant zones which may contain high residence time groundwater within unconsolidated sedimentary settings using environmental tracers.

**Some unanswered questions are:**

What is the synchronisity between deep and shallow groundwater level responses?
Do the slopes of the drawdown differ (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., 2022 (Annexure 1) | Remark |
|---|---|---|
| Dec. 2017 to Nov. 2022 | Literature review on available groundwater studies including water table, water quality and other hydrogeological aspects in Punjab<br>Monitoring of water level and conductivity fluctuations in Bist-Doab, Punjab<br>Water sampling and analysis for isotopes<br>Prepare a status report on groundwater issues in Punjab<br>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

**Activity schedule for the groundwater fluctuations and conductivity monitoring in Punjab (quarter wise from Dec 2017 to Nov 2022)**

| Activity | 1st to 4th | 5th To 8th | 9th | 10th | 11th | 12th | 13th | 14th | 15th | 16th | 17th | 18th | 19th | 20th |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 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 study has been extended to SW Punjab
- The water samples has been collected from piezometers

**Future plan**
- Downloading data from water level loggers and conductivity loggers
- Collection of samples from piezometers
- The hydro-meteorological data will be collected from state departments
- Data analysis work will be carried out with respect to various parameters like rainfall, land use etc. to observe the seasonal and spatial variation

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

| | |
|---|---|
| **Team members:** | 1) Dr. Sumant Kumar- Sc.- D & PI |
| | 2) Dr. Sudhir Kumar, Sc.-G |
| | 3) Dr. Rajesh Singh, Sc.-D |
| | 4) Dr. Gopal Krishan , Sc.- C |
| | 5) Mrs. Anju Chowdhary, PRA |
| | 6) Mr. Ramchander, RA |
| **Partner Organization**: | Minor Water Resources Dept., Govt. of Bihar |
| **Collaborators:** | Dr. Brijesh Yadav, IIT, Roorkee |
| | Dr. N.S. Maurya, NIT, Patna |
| **Type of study:** | Sponsored (NHP) |
| **Date of Start:** | December, 2018 |
| **Scheduled Date of Completion:** | October, 2021 |
| **Budget:** | Rs.70 Lakh |
| **Location:** | Bhojpur District, Bihar (Figure 1) |
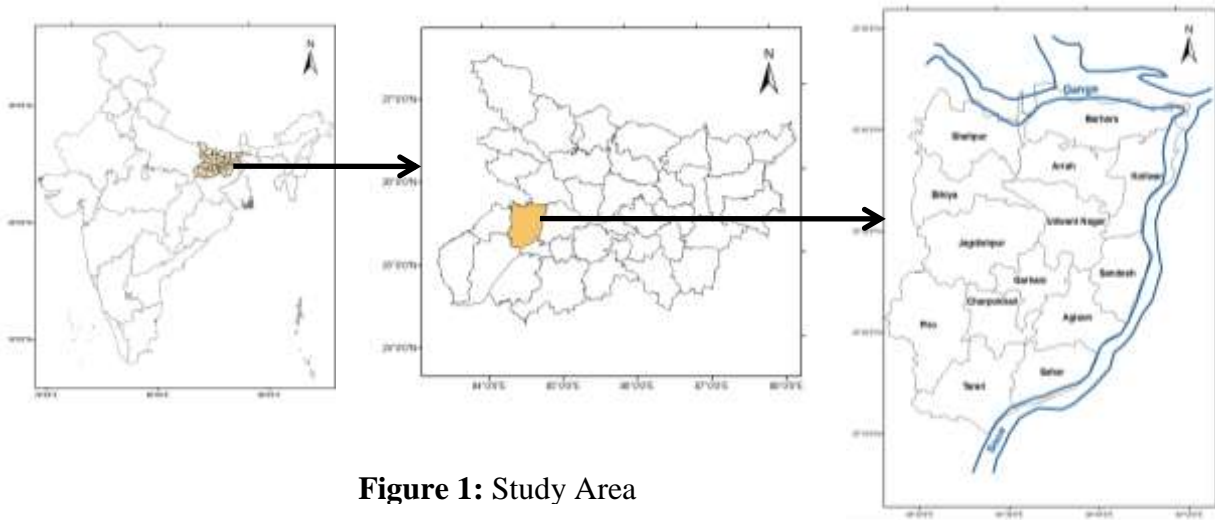


**Figure 1:** Study Area

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

**Statement of the problem**

The symptoms of chronic arsenic (As) from prolonged consumptions including skin lesions began to be observed in early 1980 in residents of the lower Gangetic plains of West Bengal and adjoining Bangladesh.  Subsequent research over the years reported that elevated As (relative to a 10

µg/L drinking-water standard of World Health Organization) is widely present in the potable groundwater, and as many as 15 million residents in West Bengal and 35 million residents in Bangladesh are at risk. This led to a huge number of hydro-geological studies in the lower Gangetic plain and delta for identification of the source and cause of As-contamination. But there is very little information available for central Ganges basin. The central Ganges basin comprises mainly Uttar Pradesh and Bihar is one of the largest fluvio-deltaic systems and most populous region\s of the India. In recent decades, increasing demand of groundwater for domestic, irrigation (round the year for food production) and industrial with the growing population rate led the extensive exploitations of fresh and potable GW.

In last decades, few investigators reported the elevated arsenic concentration and the process of the contamination in central Gangetic basin, but none seems to be studied the fate, transport and mobilization of the arsenic although initial estimates indicate that the poisoning might be widespread and several million people may be at risk. The study is focused on the hydrogeological controls on arsenic mobilization, fate and transport in order to develop an understanding of arsenic release mechanism and demarcation of arsenic safe aquifer for Bhojpur district, Bihar (Central Ganges Basin). Inferences about the processes controlling the composition of groundwater will be evaluated from field measurements, statistical analyses and geochemical modelling. Column experiment will be performed to define the fate and contaminant transport; and conclusions would be made by combining the above mentioned techniques with geospatial analyses to identify the safe aquifer.

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

## Objectives & Achievements

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

## Analysis and Results:

Groundwater abstraction from the alluvial aquifer system is reported to be approximately one-fourth of the world's total groundwater abstraction and supports the agricultural activity of south Asia. The alluvial formation of the Ganga plain in the state of Bihar and Uttar Pradesh comprises productive soils and aquifers. The use of groundwater for irrigation and domestic purposes have increased manifold in these states. The Indo-Gangetic aquifer is one of the most heavily exploited aquifer in the world. The excessive withdrawal of groundwater has adversely affected groundwater resources both in terms of quantity and quality. Water quality challenges mainly includes contamination by agricultural runoff, sewage leakage and seepage into groundwater and geogenic contamination such as arsenic, fluoride etc. Arsenic (As) contaminated drinking water is the most challenging environmental problem and is currently affecting around 220 million people across the globe, out of which around 94% affected people are in Asia. 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 contamination of water is producing the greatest impact on livelihoods in terms of public health and thus arsenic calamity in the Ganga river basin has put millions of population in danger.

Many researchers have reported rampant occurrence of As with elevated concentration in drinking water by evaluating groundwater quality in the middle and lower Ganga plain. However, very few studies have been carried out in the middle Ganga plain to understand arsenic geochemical behavior, seasonal change of arsenic, understanding groundwater recharge and its effect on arsenic mobilization in groundwater, its relation with declining/rising groundwater level, mineralogical analysis and leaching of arsenic from solid to groundwater phase etc. Thus, there is a considerable knowledge gap

in understanding the role of anthropogenic and geogenic factors in controlling the mechanism of arsenic mobilization in the middle Ganga basin. The present study explores the causes of rampant occurrence of arsenic and processes controlling the mobilization of As in groundwater of the Bhojpur district, Bihar located in central Ganga basin. The Bhojpur district is bounded by the rivers Ganges and Ghaghra in the north and east. The objectives framed under the study are: (i) determination of the spatio-temporal variation of arsenic along with other water quality parameters in groundwater, (ii) delineation of arsenic safe zone for drinking water supply, (iii) evaluation of the controls of hydro-geology on arsenic contamination through monitoring of contaminated aquifer and sediment characterization, and (iv) identification of the mechanism of release and transport of arsenic in GW through a column experiment. Significance of the study is to help in demarcating safe aquifer, improved monitoring and mitigation measures at regional level.

To achieve the objectives, 94 water samples for water chemistry and 62 samples for isotopic analysis, were collected in the Nov. 2018 (post- monsoon season) from the entire district by making grid of size 4 km x 4 km in northern side (along river Ganga) and 8 km x 8 km in southern part of the study area. The groundwater samples collected during sampling were generally from hand pumps with depth ranging from 15 to 80 m. After understanding the spatial variation of water quality parameters, particularly arsenic, the sampling and detailed investigation started in arsenic affected areas. The water samples (45 Nos.) from pre & post monsoon season (year 2019) were collected from arsenic affected area. Eight number of shallow piezometers (80-140 feet depth) were constructed in the study area for sediment characterization and water quality monitoring. The composite sediments samples were collected depth wise from top to bottom at an interval of 10 feet and when a changes in lithology were observed, while drilling. The XRD and XRF analysis were done for mineralogical study. The sediments were also used for performing batch and column experiment.

Based on the present analysis, the geochemistry of the groundwater is mainly controlled by carbonate weathering with less contribution from silicate weathering in the study area. It is observed that the dissolution/weathering of carbonate rock acts as a major contributor for Ca, Mg, and $HCO_3$, however, alumino-silicates minerals are the major contributor for Na, K, and $SiO_2$. Similar observations have been made by other researchers regarding the geochemistry in the middle Ganga plain. The hydro-geochemical facies for groundwater in the study area is Ca-Mg-$HCO_3$ type. In the study area (covering entire Bhojpur district), concentration of arsenic in groundwater during post-monsoon season (year 2018) varies between not detected (ND) to 206 ppb (Semaria ojha Patti of Sahpur block) with average concentration of 15 ppb. The results reveal that about 30 % of analysed ground water samples having As concentration above acceptable limit (10 ppb) and 8 % exceeding the permissible limit (50 ppb) as prescribed by BIS (2012) for drinking purposes. Spatial distribution map of arsenic shows that northern part of the study area associated with Ganga alluvium plain is more arsenic affected in comparison with southern part of the district. The As concentration is almost negligible in river water, i.e. Ganga water and Son water samples, varies between 2 to 5 ppb and ND to 2 ppb respectively. On the other hand, during pre-monsoon sampling (year 2019) results from arsenic affected areas suggest that about ~60% of water samples are enriched with dissolved As concentrations >10 µg/L, and it ranges from ND to 337 ppb (average 78 ppb). Arsenic in groundwater exhibited a wide spatial variation, even more than 100 times within a distance of 200 m. The elevated concentration samples area mainly from Sahapur and Barahara block of the study area which is located in younger alluvium of Ganga flood plain. Based on depth wise sampling, it is observed that arsenic is mainly contaminated in depth range of 20 m to 60 m and As conc. decreases rapidly beyond 60 m. It implies that only upper aquifer is contaminated by As. The temporal variation of arsenic indicates that it is more in pre-monsoon season as compared with post monsoon season and approximately 10-40 % reduction in As concentration was observed in post monsoon season. For the present case, variation in arsenic concentrations in groundwater are supposed to be due to the dilution effect and changes in redox conditions, which may cause desorption of arsenic from metal oxides. The parameters such as oxidation-reduction potential (ORP), Fe, Mn, $NO_3$ and $SO_4$ are the main redox parameters that control the release of As in groundwater. The good correlation between As and ORP (0.61) suggest a redox-dependent mobilization played an important role in As liberation. Fe is positively correlated with As, (0.627), but As shows a weak positive correlation with Mn, which indicate that As might get mobilized from dissolution/desorption from iron hydroxides in the

sediment. It is evidently noticeable that arsenic is high when ORP is negative and DO is less, reflecting the occurrence of arsenic in reducing conditions.

The isotopic analysis was also carried out to identify the zones of recharge, and recharge sources in the study area. The Son river is highly enriched in isotopic signatures as compare to the Ganga river, indicating highly enriched source or evaporation of the water during the travel from the Vindhyan mountains. The spatial variation of $\delta^{18}O$ reveals that there is a distinct isotopic difference between groundwater samples from the proximity of Ganga and Son rivers. The Ganga river has an average $\delta^{18}O$ value of -5.78‰ whereas the isotopic value for Son river is -3.17%. The groundwater samples for both the river water region ranges close to its river accompanying it, indicating depleted groundwater near to Ganga river and enriched groundwater close to Son river. We infer that the enriched value of groundwater samples close to Son river is due to recharge through the Son river, while the groundwater close to Ganga is contributing to Ganga river. This is also corroborating from the groundwater flow direction which is toward the Ganga River. The isotopic signature of the groundwater also indicates the vertical mixing of groundwater from the irrigation return flow or other sources.

The mineralogical properties of sediment was studied using X-Ray Diffraction (XRD) and X-ray fluorescence (XRF) technique for the selected samples. From XRD analysis, it is found that quartz, clay and feldspar are the major minerals for most of the samples, whereas goethite and dolomite are present rarely in few sample only as minor minerals. However, some minor peaks were observed which indicates the arsenic bearing minerals present in the soil sample such as the presence of iron arsenate ($Fe_2As_4O_{12}$). In general, the analysis reveals that all samples contain major amounts of $SiO_2$ as well as substantial $Al_2O_3$ concentrations. More specifically, average major elements of all the sediment samples indicate a predominant $SiO_2$ mass component (37.4% - 50.0%) with significant $Al_2O_3$ (4.0% - 16.2%), $Fe_2O_3$ (1.7% -10.0%), MnO (0.1% - 6.37%) and CaO (0.8 - 5.2 %) contributions; a few percent of $K_2O$ (1.7% - 3.3%), MgO (0.2 - 1.8 %), $P_2O_5$ (0.1% - 0.9%) and $TiO_2$ (0.3% - 1.0%), as well as trace amounts (<1%) of $SO_3$, $Cr_2O_3$, NaO, ZnO, CuO, BaO, SrO and NiO. The arsenic concentration in the sediment samples varies from 1 mg/Kg 19 mg/Kg. Sediment samples were also analysed for organic matter concentrations. The results indicate that organic matter has been found less whereas As and Fe have been found more concentrated in the depth range of 30-55 ft, which also support the mobilization of arsenic in groundwater by microbial reductive dissolution of iron oxides from shallow aquifer consisting organic rich clay.The batch and column experiment was performed to study the leaching of arsenic from sediment to water phase. Initially, batch experiment was performed on contaminated soil (simariya village sediment) in a single run of experiment for 8 days. It has been observed that the maximum arsenic leaching (52 µg/Kg) found on 1st day followed by 2nd (34.6 µg/Kg) and 3rd day (38 µg/Kg). After that leaching rate was found to be constant i.e. 12 µg/Kg. The water which mixed with sediment for batch experiment was artificially made groundwater (concentration of salts and pH (7.35) was kept same as it was in groundwater of simariya village). In the second run of experiment, the pH was varied from 6 to 8.5 and it is noticed that maximum arsenic leaches at pH 8. After completion of batch experiment, column experiment was started with a packing of contaminated soil in a column with flow rate of 2 ml/min of artificially made groundwater. the constant leaching rate of arsenic from sediment was found to be 4 ppb/day.
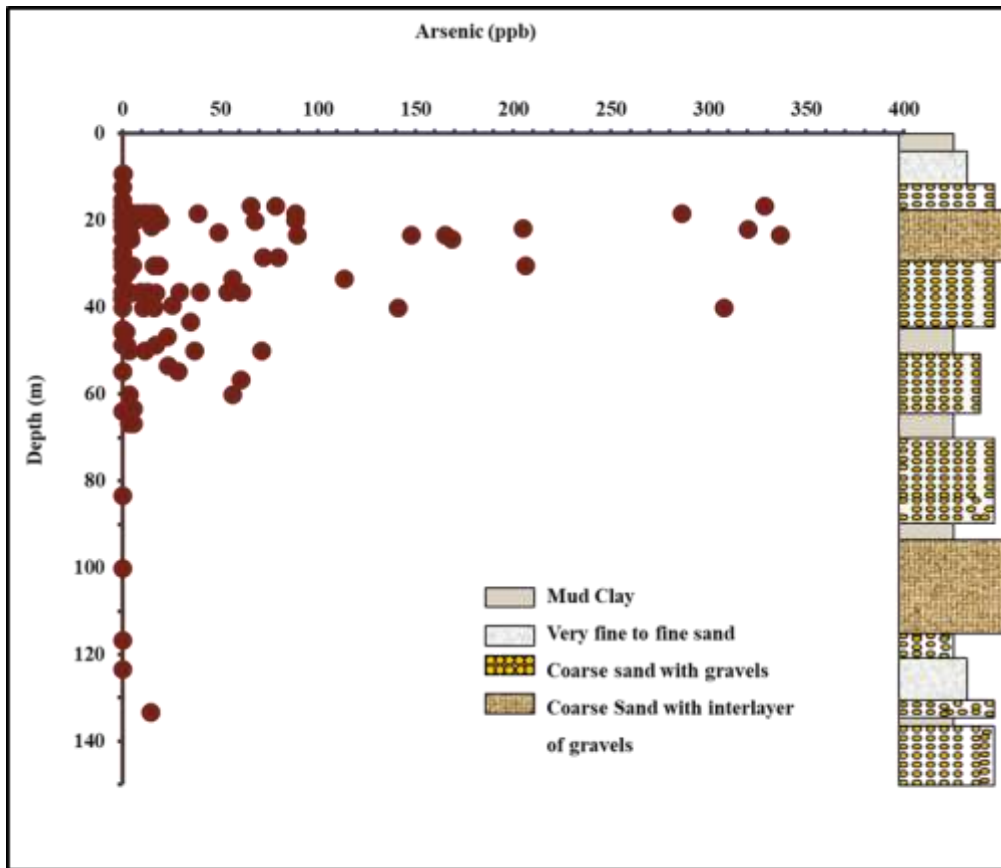
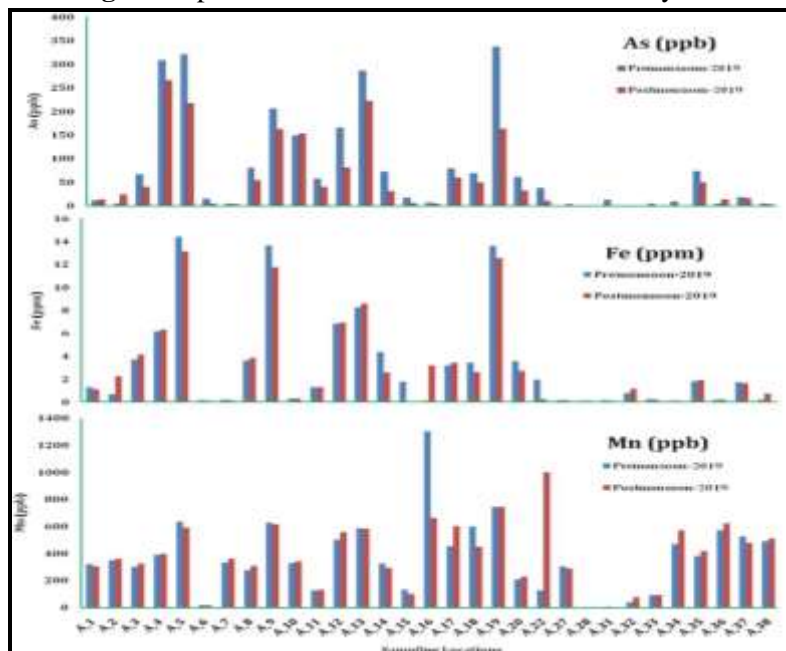**Fig 2.:** Depth-wise variation of arsenic in the study area



**Fig 3.:** Temporal variation of arsenic, iron and manganese in the study area

## 5.    PROJECT REFERENCE CODE: NIH/GWHD/2018-21

| | |
|---|---|
| **Title of the study** | Assessment of impacts of groundwater salinity on regional groundwater resources, current and future situation in Mewat, Haryana – possible remedy and resilience building measures |

**Name of PI and members**       :       **NIH, Roorkee, India**
Dr. Gopal Krishan (PI)
Er. C.P. Kumar (retired Sep, 2020)
Dr. Surjeet Singh, Dr. M.S. Rao
**Haryana Irrigation Department**
X'en Mewat
**Consultants**
**IIT-Roorkee**
Prof. M.L. Kansal, Dr. Brijesh Yadav
**Sehgal Foundation, Gurgaon**
Sh. Lalit Mohan Sharma

| | | |
|---|---|---|
| **Type of study** | : | Applied Research |
| **Date of start (DOS)** | : | January**,** 2018 (NHP-PDS) |
| **Scheduled date of completion** | : | July, 2022 |
| **Location** | : | Mewat district, Haryana |

| S. No. | Study objectives | Achievements |
|---|---|---|
| 1 | Assessment of lowering of water table (depletion in groundwater level) in the salinity impacted area using the historical data. | **Achieved** – Historical data collected from State groundwater Cell of Agriculture department, Haryana and found that water levels in Tauru, Firozepur zhirka and Punhana blocks is decreasing while no such observations are for salinity affected areas in Nagina block |
| 2 | Detailed qualitative analysis of the area and the aquifer depth impacted by higher salinity levels, and preparation of maps. | **Achieved –** Salinity variations maps on spatial and temporal levels have been prepared |
| 3 | To monitor influx of saline groundwater into fresh water zone | **Achieved (90%)-** Salinity variations have been found |
| 4 | To assess the impact of groundwater salinity on socio-economic aspects | **Achieved-**Work is completed |
| 5 | To develop and demonstrate management and resilience building measures | **Achieved (90%)** -Experimental model developed and tested for development of fresh water bubble and recovery efficiency under controlled as well as field conditions. |

**Statement of the problem**

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

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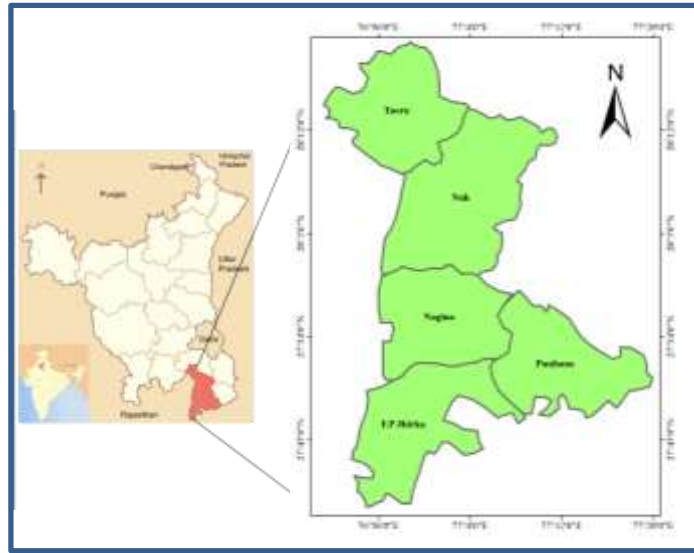


**Fig. 1.** Map of Mewat district

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

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

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

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

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

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

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

**Progress**

Socio-economic survey was carried out and found that the choice of subsistence crops is similar across all salinity categories. The subsistence crops cultivated in the region are wheat and mustard during rabi season and mustard and sorghum during kharif season. In highly saline villages, it was found that the percentage of people cultivating millet was relatively less. In commercial crops, diversity can easily be seen in sweet water villages with a predominance of water-intensive crops and onion cultivation. Interestingly, the crop choice is specific to villages in each category. Overall, it is found that in saline regions, crop choices (mainly commercial crops) are very restricted, whereas in sweet water villages, many diverse commercial crops could be grown by farmers, thereby impacting remuneration from agriculture.

Understanding the sources of salinization, and their relative contributions by different sources and seasonal variability has become priority for planning best practices in water management and suggesting remedial measures. For identifying the sources of salinization, the direct application of the relationship between $\delta^{18}O$ and $\delta D$ is limited as it depends upon initial isotopic composition showing no isotopic variation in the mineral dissolution process. The present study advocates the use of deuterium excess which is independent of initial isotopic composition and extends this concept for identifying the relative contribution of different sources towards seasonal variability in salinization. Mineral dissolution found to be responsible for overall groundwater salinization (fig. 2).
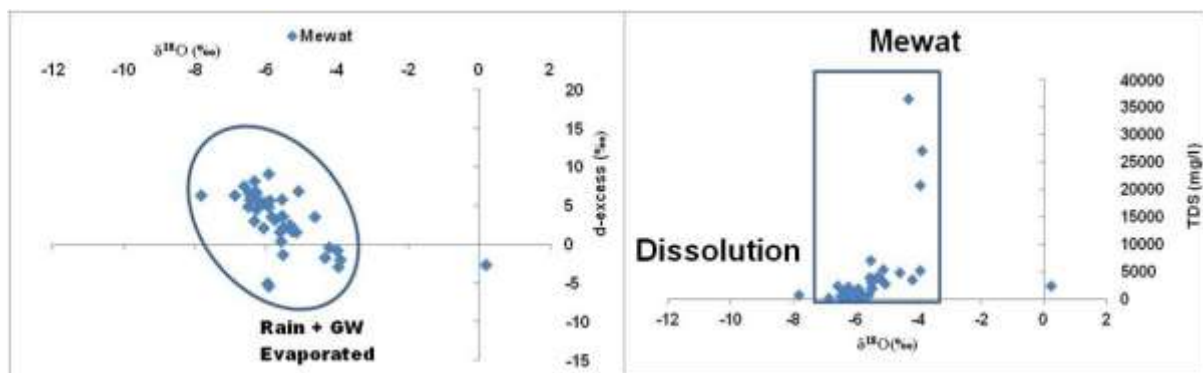


**Fig: 2** Recharge source identification and salinity mechanism

In order to determine the dominant ions, multiple regression analysis was carried out. For all the seasons, three trails were carried out in accordance to the p-value with 95 percent of significance level. The dominant ions in the pre-monsoon were $Cl^-$ & $SO_4^{2-}$ from anions and $Na^+$ & $Ca^{2+}$ from cations. The dominant ions in the monsoon season were $Cl^-$ & $HCO_3^-$ from anions, $Na^+$ & $Ca^{2+}$ from cations.

In order to understand the various processes responsible for the seasonal dominance of various ions modeling of precipitation and dissolution process is carried out using PHREEQC model. SI is obtained for $CaCO_3$, $CaSO_4$ and $NaCl$ from the model as shown in (Fig. 3). The highest level of dissolution is encountered in case of $NaCl$, followed by $CaSO_4$, whereas $CaCO_3$ depicts precipitation.
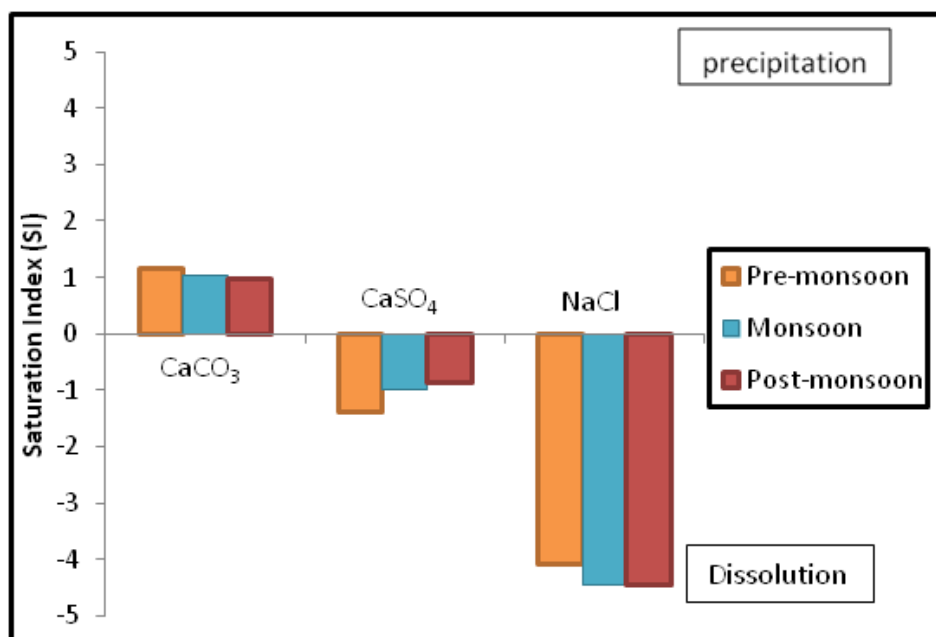
**Fig: 3** Season wise trend of Saturation Index (SI) with respect to $CaCO_3$, $CaSO_4$ and NaCl in the groundwater of Mewat, Haryana, India.

A cluster of piezometers were developed to study the salinity variations under field conditions following top down approach. Depth wise salinity variations are observed. More salinity has been observed at the bottom than top part. In addition to the depth wise salinity variations, these were also observed with time. Maximum salinity was observed during the summer time.

Aquifer Storage and Recovery (ASR) system can prove to be important technique for seasonal, durable and future storage of this resource mainly at the time of its inaccessibility due to contamination, water losses, natural disaster and other unexpected conditions. ASR depends on hydro-geological feasibility determined by soil and sub-surface characteristics which are related to percolation rates, porosity, permeability, water quality and connecting recharge zones. Some of the important aquifer characteristics are: type, permeability, thickness, storage, pore type, uniformity, groundwater redox and chemistry. Keeping in view above issues, an experiment was carried out at National Institute of Hydrology Roorkee in an experimental model fabricated under World Bank funded, Mewat Purpose Driven Study (PDS) under National Hydrology Project with an aim to recover fresh water from injected saline water and to assess recovery efficiency.

Recovery efficiency of 63% was found with EC of recovered water equal to or less than 1000 $\mu$S/cm after 29 hours of experiment. Aquifer storage and recovery was found to be a significant, suitable tool for water resource management and might act as a hydraulic barrier in saline environments. Similar experiment was carried out in field condition (fig. 4).



**Fig. 4** ASR experimental set up in field at Mewat

**Description of work planned**:
- Data analysis and interpretation work is in progress

**Action plan:**

| Year | Jan 2018 to Jul 2022(Annexure 1) | Remark |
|---|---|---|
| 2018 to 2022 | Data collection on available groundwater studies including water table, water quality and other hydro-geological aspects in Mewat district<br>Collection of water and soil samples to assess the salinity conditions<br>Dissemination of outputs in a workshop/review meeting under the project | Report preparation as per Annexure 1 |

**Study Benefits /Impact**:
- Problem of salinity to be identified
- Suggesting the suitable remedial measures

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

**Activity schedule for the baseline data collection and analysis in Mewat, Haryana (four months wise from Jan. 2018 to July 2022)**

| Item/Period quarterwise | 1-4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Data/literature collection | ■ | ■ | ■ | ■ | | | | | | | |
| Field Surveys | ■ | ■ | | | | | | | | | |
| Sample collection | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | | |
| Analysis | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| Data interpretation | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |
| Suggestions/remedial measures | | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| Report writing/publications | | | | ■ | | | | ■ | | | ■ |

**Data requirement & Expected source:**
Data will be downloaded from conductivity loggers.

**IPR potential and issues** : Work is in progress

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

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

**Title of the study:**      Ganges Aquifer Management in the Context of Monsoon Runoff
Conservation for Sustainable River Ecosystem Services - A Pilot Study

| | | |
|---|---|---|
| **Type of study** | : | Sponsored by NHP under PDS |
| **Date of start (DOS)** | : | December 2017 |
| **Scheduled date of completion:** | | July 2022 (Four Years) |
| **Location** | : | Sot River Catchment (Uttar Pradesh) |
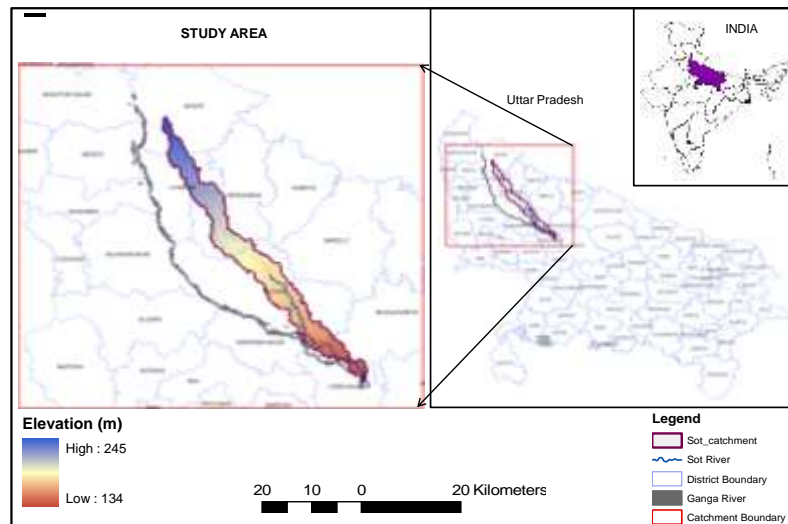


**Study objectives:**
- Hydro-geological characterization of the area.
- Analysis of meteorological and hydrological variables *vis-a-vis* cessation of river flows during lean season.
- Estimation of surface water and groundwater availability.
- Analysis of stream-aquifer interaction.
- Aquifer management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

**Statement of the problem:**

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

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

**Methodology:**
- Delineation of aquifers using litholog/ borelog data by developing fence diagram, cross-sections, profiles and 3D model in the Rockworks software.
- Time series analysis by synchronizing various temporal data (rainfall and groundwater) to study the variation in river flows and the cessation of river flows during the lean seasons of various years.
- Parametric and non-parametric trend analysis using Mann-Kendall and Sen-Slope Estimator, and change detection using Pettit technique on the hydro-meteorological variables to find the declining trends in river flows, groundwater levels and rainfall during both monsoon and non-monsoon seasons in various years.
- Estimation of surface water availability from river flow data using flow-duration curve and groundwater availability using GEC-2015 methodology.
- Vulnerability analysis using SAHP/DRASTIC approach.
- Catchment water balance using mass balance approach.
- Integrated surface water and groundwater modelling for river-aquifer interactions and future scenarios for river flows during lean seasons.
- Isotopic analysis to verify the reaches of recharge/discharge zones to/from the river.
- Development of plan for enhancement of surface and ground water resources.

**Objectives vis-à-vis Achievements:**

| Objectives | Achievements |
|---|---|
| Hydro-geological characterization of the area. | Completed |
| Analysis of meteorological and hydrological variables *vis-a-vis* cessation of river flows during lean season. | Completed |
| Estimation of surface water and groundwater availability. | Completed |
| Analysis of stream-aquifer interaction. | In progress |
| Aquifer management measures for enhancing river flow during lean season. | To be done |

**Analysis of Results:**

The study is envisaged on the river and groundwater flow interactions and dynamics to answer the questions on drying of Sot river. To carry out the study, existing catchment information, literature survey, meteorological, hydrological and geo-hydrological investigations, and groundwater data acquisition are essential. Review of literature related to the study was completed. The study area falls in the Uttar Pradesh state of India and covers an area of 3,027 sq.km. The elevation of the catchment varies from 138 to 245 m above mean sea level. Various thematic maps such as catchment boundary, catchment location, DEM, drainage, slope, soil, sub-basin, district/tehsil/road network, grid and land use have been prepared. Daily river flow data was collected and processed to analyze variations of river flow along with rainfall variation. Changes in land use and meteorological variables were also completed. Lithology data was processed and geological sections and fence diagram are prepared. Infiltration and hydraulic conductivity tests were conducted at 48 locations in the entire Sot river catchment for which infiltration and conductivity values were computed and infiltration equations were fitted. Disturbed and undisturbed soil samples were also collected from the same 48 locations of the catchment for the determination of soil properties.
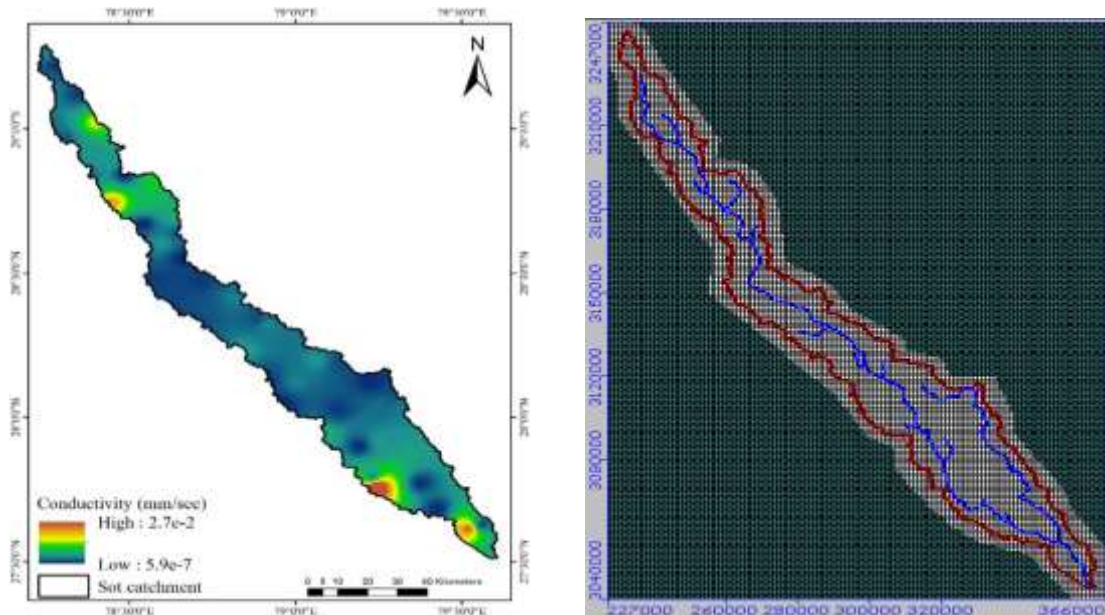
(a) Variation of hydraulic conductivity, (b) Discretized catchment in the Modflow model

MODFLOW setup is in progress for the groundwater flow modelling. Litholog data is processed and hydro-stratigraphy is finalized. Import of aquifer layers in the model is completed including initial and boundary conditions. Groundwater recharge and withdrawals are being assigned to the model, then the model shall be calibrated and validated for the river aquifer interactions.

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

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

**Laboratory Facility used during the Study:**
- Centre of Excellence for Advanced Groundwater Research
- Soil Water Laboratory
- Nuclear Hydrology Laboratory
- Water Quality Laboratory

**Data Procured/ Generated during the Study:**
- Toposheets, DEM, Meteorological data, Soil information, Groundwater Levels, Landuse, River flows, Lithologs.

**Study Benefits /Impact**:
    Increased surface water and ground water availability - Regional water security
- Farmers' access to irrigation
- Social and cultural activities
- Improvement in water quality by continuous flushing and dilution of domestic and industrial wastewaters

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

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

**Type of Study:** Sponsored by Indo-UK Project: DST-NERC-EPSRC Newton Bhabha Fund
**Nature of study:** Applied Research
**Duration:** 3 years (01/2018-01/2022)
**India Project Partners**: NIH (India Lead); IIT Kharagpur; IIT Roorkee; and Mahavir Cancer Sansthan, Patna.
**UK Project Partner**:   University of Manchester (UK Lead); British Geological Survey; Salford University; and University of Birmingham.
**Aims:**
•      Investigate the vulnerability of representative shallow sedimentary aquifer systems in the Ganges river basin to secular increases in arsenic.
•      Predict future secular changes in groundwater arsenic.
•      Communicate with key stakeholders to inform them of future hazards and risks and how groundwater management practices and strategic selection of water remediation technologies and approaches might accordingly be modified.

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

**Objectives vis-à-vis Achievements:**

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

**Progress**

Review on various arsenic remediation technologies was done. The technical and socio-economic analysis of Arsenic removal technologies were based on the reliability, operational ease/simplicity, plant performance, affordability and social acceptability. Further, Life Cycle Analysis (LCA) was also conducted for assessment of environmental impacts associated with these arsenic treatment plants.

For arsenic remediation, nano material for injection was developed by IITR. For this, examined the 1D transport behaviour of synthesized Maghemite nanoparticles (NP) injected under partially saturated porous media. For pilot scale remediation practices using NPs, the strategies to find out the arsenic groundwater patches through geophysical technique and tracer experiments to indent the groundwater flow were worked out. For arsenic remediation using permeable reactive barrier (PRB), Pumice supported nZVI particles and maghemite ($\gamma$-$Fe_2O_3$) nanoparticles with 20 % iron loading were developed by IITR for PRB.

FAR- Ganga team discussing with villagers      GW Sampling Sites in Bihar
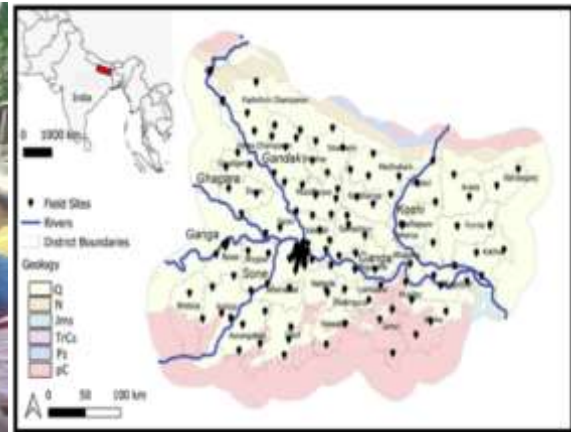
For potential natural Hyporheic zone experimental sites, NIH carried-out GW and SW sampling in Bijnor and Moradabad area. Groundwater of both Bijnor and Moradabad area indicated arsenic concentr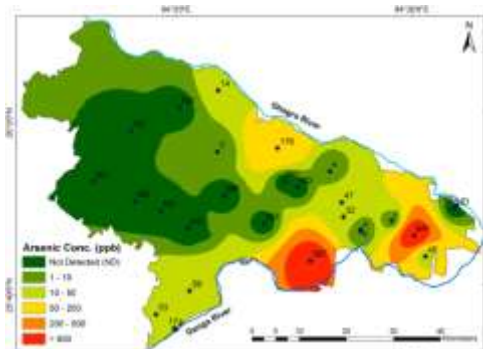ation below permissible limit except few locations. Laksar (Uttarakhand) and Ballia (UP) were therefore identified as reference stretch for Hyporheic zone experimental sites. In Ballia, two sections were identified one on the Ganga River and another on the Ghagra river. Groundwater sampling being done from 8 locations on each section including one sample from river on quarterly basis. Sediments samples from river bed in Ballia and Laksar show As conc. above the equivalent acceptable limit for water (10 ppb). UoM in collaboration with MCS, UoB, NIH & IIT Kharagpur, with equipment provided by UoB (PROTEUS and TriOS), undertook cross-sectional boat surveys of organics in River Ganga in/around Patna (2018 & 2019 – seasonal comparison), Varanasi (2018) & Ballia (2019).

Sampling of 24 sites of Ganga and key tributaries by UoM-MCS-UoB team (Nov 2019) from Begusarai to Varanasi as part of wider Ganga survey along with groundwater sampling near selected SW sites throughout Begusarai to Varanasi corridor. Detailed groundwater sampling in Patna was done to better understand the extend and interactions within the hyporheic zone. These inputs were used for pollutant transport modelling.



Hyporheic zone experimental sites in Laksar (UK) and Ballia District, UP      Arsenic Concentration Map of Ballia District (UP)

For MAR analysis, water samples (77) collected from Ballia and Bahraich districts of UP and clusters of arsenic contaminated areas were identified. Maximum concentration of 641 ppb was found in Murli Chhapra block followed by Maniyar block of Ballia to select the MAR site to study positive/negative impacts of MAR. Continuous quarterly groundwater sampling at 32 locations in Murli Chhapra block of Ballia for chemical/isotopic analysis was done. Surface water quality was also monitored. 10 out of 32 samples (31%) were found above the acceptable limit of As. Arsenic occurred along the river Ghaghara and Ganga with no As contamination in central and upper part of Ballia District. Samples contaminated with As above acceptable limit were found contaminated with high Fe and Mn.

Mapping of arsenic was done and modelling was done using the machine learning models of 2-D spatial distribution of groundwater arsenic. First quantitative country-specific all India model of groundwater arsenic attributable cardiovascular disease mortality was developed. The project enhanced the understanding of the tectonic, sedimentological/ hydrogeological and mineralogical controls on the distribution of groundwater arsenic in India. Systematic randomised sampling survey of groundwater arsenic and uranium across Bihar provided improved representative hazard estimates. The ingress of organics from the River Ganga into the groundwater were characterized. Regional controls on hydro-geochemistry of arsenic prone aquifers identified. Importance of hyporheic zones and river-groundwater exchange to vulnerability of aquifers in the Ganga river basin was demonstrated and modelled. Vulnerability of some MAR systems on arsenic was also identified. Wheat and rice were identified as the major dietary sources of inorganic arsenic. Key factors controlling the effectiveness of remediation systems were identified. Novel patented materials were developed for remediation of groundwater arsenic were developed and patents have been filed.

The project outputs were dissemination through interaction with the stakeholders and contributed by focusing on arsenic-remediation approaches in Bihar through the Mahavir Cancer Sansthan Hospital and Research Centre, Patna. It was challenging to quantify the extent of arsenic to which this has arisen specifically from FAR-GANGA published papers or from related discussions and meetings made possible by the DST-NERC funding for FAR-GANGA project. Ongoing community science actions with colleges and schools in Bihar have resulted in extensive knowledge transfer and engagement leading to greater awareness of the scale and nature of the health impacts of chronic arsenic exposure.

24 research papers were published in Journals; 23 research papers were published in conferences/ seminars and 2 Patents were filed. Project Management Board Meetings (PMB) were successfully organized in India and UK through online platform.

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

**Type of study (sponsored/consultancy/referred/internal):** Sponsored Indo-UK Project: DST-NERC-EPSRC Newton Bhabha Fund
**Nature of study**: Study components include technology development, technology dissemination, technology adaptation, capacity building
**Duration:** 01/2018 to 02/2022
**India Project Partners**: NIH Roorkee (India Lead); IIT Ropar; IIT Jodhpur
**UK Project Partner**:  Cranfield University

**Location Map**



**Fig. 1** Locations of study sites in Rajasthan

**Project Aim & Objectives**
        To assess the impact of rainwater used for MAR on groundwater quality and specifically understand how DOM present in rainwater affects fluoride and other pollutant levels, thereby improving MAR structure design and management practices. Specific objectives:
1.   Evaluate water level and quality at selected MAR sites in Rajasthan;
2.   Assess the proportion of recharged groundwater attributable to MAR systems at selected sites;
3.   Investigate the consequences of recharging aquifers with rainwater on the fate and transport of pollutants into aquifers, and understand the role of rainwater DOM levels in remediating fluoride and other groundwater contaminants;
4.   Develop analytical protocols to facilitate the detection of micropollutants in water bodies;
5.   Understand the interactions of local users with the MAR structure and also their role in water management.

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

**Objectives vis-à-vis Achievements:**

| Objectives | Achievements |
|---|---|
| Evaluate water level and quality at selected MAR sites in Rajasthan. | Evaluation of water levels and chemical analyses of water samples at regular intervals completed. |
| Assess the proportion of recharged groundwater attributable to MAR systems at selected sites. | Groundwater recharge assessment for chauka system in Laporiya. Completed |
| Investigate the consequences of recharging aquifers with rainwater on the fate and transport of pollutants into aquifers, and understand the role of rainwater DOM levels in remediating fluoride and other groundwater contaminants. | Work to be finalized. |
| Develop analytical protocols to facilitate the detection of micropollutants in water bodies | Work to be completed. |
| Understand the interactions of local users with the MAR structure and also their role in water management. | Completed. |
| Interaction with project partners and DST-NERC | Indo-UK Consortium Meeting (Sept 01, 2021), Indo-UK Consortium Workshop (Feb. 1 & 4, 2022), Indo-UK Consortium Brain Storming (Mar. 01, 2022), Project Presentation before DST-NERC (Mar. 4, 2022), Online meetings with Indian consortium. |

**Lab Facility used during the Study:**

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

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

**PROJECT REFERENCE CODE**: NIH/GWH/PDS/18-22

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

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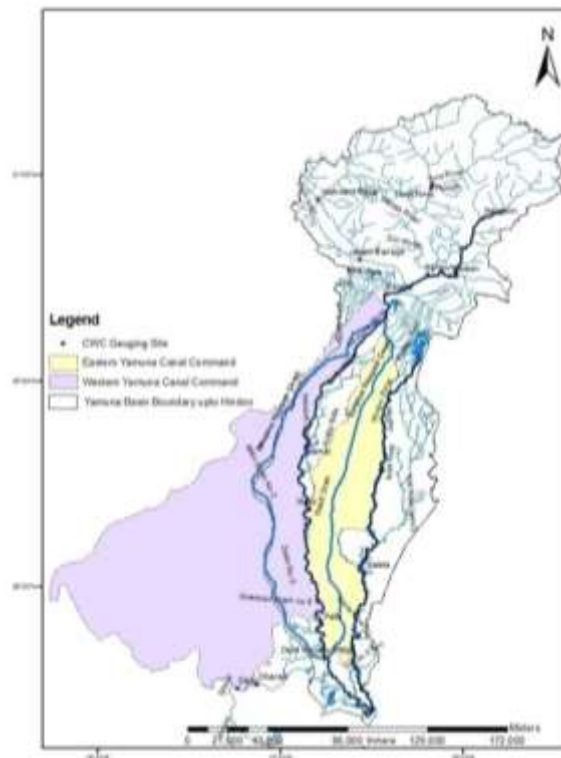


**Fig. 1** Study area showing the Upper Yamuna Basin and command areas of EYC and WYC

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

**Objectives vis-à-vis Achievements:**

| Objectives | Achievements/ Activities |
|---|---|
| Application and performance evaluation of selected hydrological models for the simulation of the surface water, groundwater, and water quality | Application of hydrological models completed for SWAT, HEC-RAS, VIC, QUAL2K. Application ongoing for MODFLOW, MIKE HYDRO. Includes data collection from various agencies, field visits, data processing and analysis. In addition, equipment purchased under project. |
| Quantification of contribution of snow and glacier-melt through snowmelt modelling for Tons basin | Data processing and work on snowmelt runoff model WinSRM and SWAT in progress for Himalayan portion.. |
| Assessment of changes in baseflow contribution to river Yamuna | Assessment of changes in baseflow contribution to river Yamuna completed. |
| Assessment of present and future water availability under Climate scenarios | Extracted data for study area, data processing, maps for climate change indicators |
| Integrated water allocation planning based on present and future scenario of water availability for (i) Eastern Yamuna Canal Command, (ii) Western Yamuna Canal Command | In progress using MODFLOW for Yamuna-Hindon Interbasin. Database buildup for WA+ tool to process spatial information on water depletion and net withdrawal using satellite measurements. GW related data collected for Eastern Yamuna Canal Command. |
| Formulation of adaptation measures in the context of climate change | To be taken up after assessment of future water availability |
| Flood frequency analysis and flood plain mapping of river Yamuna | River cross-section survey completed. Flood frequency analyses completed. Flood plain mapping for selected reach. |
| Assessment of anthropogenic activities on water quality | Field visits undertaken and data collected from central/ state agencies. Assessment of surface water quality of Yamuna river completed. |
| Numerical modelling of groundwater recharge dynamics and impact of climate variability on renewable gw resources | Modeling in progress using GIS based WetSpass distributed model. Field and lab experiments for soil parameters for selected sites completed. |
| Roll out of technical know-how through training workshops for partner organizations | One online training course organized for 24 officers of UP Ground Water Department. |

**Deliverables:**

1) Application of various models pertaining to surface water hydrology, groundwater hydrology, basin planning, optimal water utilization and their inter-comparison in respect of UYB;
2) Evaluation of the impact of climate change, land use change and population growth on the water resources in UYB;
3) Evaluation of impact of climate variability on renewable groundwater resources;
4) Training Workshops for State Department officials of UP and Haryana.

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

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

**Type of study (sponsored/consultancy/referred/internal):** Sponsored by DST
**Nature of study**: Applied research
**Duration:**  02/2019 to 01/2024

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

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

**Objectives**
  I.    To enhance water productivity in farming systems/regional level (Jodhpur, Jaisalmer, Barmer and Bikaner)
 II.    To develop improved methods for reusing industrial effluents in agriculture
III.    To analyze future demand and supply of water at regional and sub-regional level (Jodhpur, Jaisalmer, Barmer and Bikaner)
 IV.    To develop policy guidelines and capacity building of stakeholders

**Objectives vis-à-vis Achievements:**

| Objectives | Achievements/ Activities |
|---|---|
| Enhancing water productivity at farming system as well as its components level | Field experiments undertaken with CAZRI to study the impacts of different irrigation schedules on the water balance components. Data being used in developing numerical model to study various irrigation management scenarios. Equipment purchase completed. |
| Analyzing future demand and supply of water at regional and sub-regional level | To be taken up with project partners |
| To develop improved methods for reusing industrial effluents in agriculture | Work by project partners |
| Capacity building of stakeholders in enhancing water productivity and developing policy guidelines | To be taken up with project partners |

**Lab Facility used during the Study:**

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

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

| | | |
|---|---|---|
| **Title of the study:** | | Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF |
| **Name of PI and members** | : | **NIH, Roorkee, India** |
| | | Dr. Gopal Krishan (PI and co-coordinator) |
| | | **University of Applied Sciences Dresden** |
| | | **(HTW Dresden/HTWD), Germany** |
| | | Prof. T. Grischek (Project Leader) |
| | | Dr. C Sandhu (Project Coordinator) |
| **Type of study** | : | **Sponsored,** Federal Ministry of Education and Research, Germany (BMBF) |
| **Date of start (DOS)** | : | **01** July 2020 (**Approval received in Feb, 22 Ministry of Jal Shakti & DEA**) |
| **Scheduled date of completion** | : | **30** June 2023 |
| **Location** | : | Agra, Uttar Pradesh and others if necessary |

| S. No. | Study objectives | Achievements |
|---|---|---|
| 1 | Determination of the upper limit for removal of "emerging pollutants" by RBF | **30%** – Past data has been collected and plotted |
| 2 | Investigate the inclusion of RBF as a "smart water infrastructure concept" within the "Smart City" project of the city of Agra | **10%**- RBF technique has been proposed as an master plan for the nation and is being conceptualized for selected sites including one at Agra |
| 3 | Synthesis of information for inclusion in the RBF Master Plan and guidelines | 20%- Literature on RBF techniques used in India has been collected from various sources |

**Statement of the problem:**

*Background*

The floodplain of the Yamuna river between the National Capital Region of Delhi and the city of Agra (located approximately 200 km south of Delhi) is one of the most densely populated urban and rural regions in India (COI, 2011). Large quantities of untreated to partially treated domestic and industrial wastewater are discharged into the Yamuna between these two cities resulting in a critical river water quality (Agarwal and Trivedi, 1995; CSE, 2002; Seth and Babu, 2007). Despite the Yamuna's poor water quality, the river is a major source of raw water for domestic purposes for towns and cities located by it, including Agra city and for irrigation in the rural and semi-urban areas (GONCTD, 2013). After direct pumping from the river, the water is conventionally treated. However most of these conventional drinking water treatment plants are technically unable to remove the high concentrations of micro-biological, organic and inorganic parameters present in the river water thereby either resulting in deliberate interruptions in drinking water production or in widespread consumer dissatisfaction due to noticeable and unacceptable organoleptic quality of the supplied water (CSE, 2002; Sandhu et al., 2011). Furthermore there is a widespread perception amongst the consumers that the water supplied in the taps is unsafe for consumption without prior treatment at the household level. That is why many households typically use reverse osmosis filters. There are also many areas that are not connected to the piped water supply. These areas have to rely either on groundwater (vertical wells, handpumps) or water delivered in tankers that is expensive and is not affordable by many people.

By using wells installed on the banks of flowing rivers, river bank filtration (RBF) combines the advantage of easy access to large volumes of induced surface water (SW) with the benefit of an improvement in water quality due to natural treatment processes occurring during aquifer passage. Field investigations at various locations across India including in Uttarakhand and the Yamuna

floodplain (Delhi and Mathura) have confirmed that there is a large potential to use RBF as an alternative to directly abstracted SW for drinking water production, primarily because it provides an ecosystem service by effectively removing pathogens and turbidity even in monsoon (Sandhu et al. 2011, 2016).

*Proposed solution, technological intervention and demonstration up to 2018*

In light of the previously described background and scientific investigations conducted on RBF at locations in Uttarakhand, NCR Delhi and other parts of India within the framework of the Saph Pani project (2011 – 2014) accompanied with construction of pilot RBF schemes in Uttarakhand, NIH was motivated to demonstrate RBF technology at six sites across India, including Agra, that have diverse environmental conditions within the project Peya Jal Suraksha (PJS, 2015–2018) funded by the Ministry of Jal Shakti (NIH, 2019). Consequently, the site in Agra was first investigated with standard geophysical, geotechnical and water quality investigations. Accordingly, the site was found feasible for the construction of a vertical exploratory well. The well was constructed on the riverbank in the premises of the Agra waterworks at Jeevani Mandi in February 2018. Due to the scheduled termination of PJS in 2018, only one water sample could be analysed during development of the well in 02/2018. Further investigations, including geohydraulic measurements (water levels monitored for at least one hydrological year) and water quality, could not be conducted. So it was not possible to evaluate the purification efficiency of the RBF system at Jeevani Mandi, because the system only became operational when the PJS project concluded.

Nevertheless, water quality investigations conducted at an existing high capacity horizontal RBF well in Mathura by collaborators from IIT Roorkee in 2007/2008 and subsequently by NIH Roorkee, HTW Dresden and TU Dresden at the same RBF well in Mathura and Yamuna river and near-bank groundwater from 2013 onwards in Agra and Mathura within the framework of the Saph Pani project and Indo-German Competence Centre for Riverbank Filtration (MoU NIH & HTWD, 2011) showed a high potential for RBF as a pre-treatment step for drinking water production. The main advantages of RBF in Agra-Mathura region are an improvement of organoleptic parameters (taste, odor and aesthetic appearance) and a substantial lowering of concentrations of organic compounds including dissolved organic carbon (DOC), turbidity and pathogens and  a low risk of formation of disinfection by-products. The main positive observation is that while river water DOC concentrations are high and show a large seasonal fluctuation of around 9 mg/L (3 mg/L in monsoon – 12 mg/L in non-monsoon), the concentration of DOC in the RBF wells was found to be substantially lower at 3 mg/L and 6 mg/L in monsoon and non-monsoon respectively. Removal of total and fecal coliform of 1.3–1.7 and 2.3–3.2 $\log_{10}$ units respectively was observed at the high capacity RBF well in Mathura. Thus RBF can serve as an important pre-treatment step and provide cost-savings for post-treatment.

*Validation, demonstration and exploitation of RBF technological intervention post 2018*

With the impending conclusion of project PJS in 2018, NIH and HTWD endeavored to exploit the infrastructure created in PJS (pumping well), in a new collaborative project. The rationale for this is given below. None of the following were possible to investigate in the predecessor project PJS:

1. Validation of RBF process:
   a. Possibility to investigate the upper limit of the purification capacity for RBF w.r.t. organic micropollutants and pathogens because the Yamuna river is one of the most polluted rivers worldwide
   b. Comparison of RBF water quality with directly abstracted and conventionally treated surface water treated at the same location
   c. Investigation of the effects of aquifer anisotropy (hydraulic conductivity changes in vertical/z-direction due to intermittent low and high conductivity layers) because the subsurface stratification found in the Yamuna floodplain in Agra is similar to many locations in the Ganga-Yamuna basin
   d. Estimation of the portion of bank filtrate in pumped water from well and travel time of bank

filtrate from river to well

2. Demonstration of RBF scheme:
   a. Development of existing well into a demonstration site for RBF to show how a RBF site should be made and to display the benefits of RBF
   b. Creation of infrastructure to monitor the RBF site by construction of at least 1 monitoring well
   c. Demonstration of the purification capacity of RBF for conditions typical of extremely polluted rivers with complex subsurface geology

3. Exploitation of above by:
   a. Development of a science-based masterplan for RBF water supply in India using above scientific results
   b. Revision of existing guidelines on RBF into a second edition that will incorporate scientific / technical experiences of above
   c. Investigate the inclusion of RBF as a "smart water infrastructure concept" within the "Smart City" project of the city of Agra

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

**Methodology:**
    NIH has already established the abstraction well infrastructure at the site at Agra in PJS project (2015-2018) including vertical borewell with submersible pump, provision of electricity supply to pump and construction of pump house. Samples will be collected from river, RBF exploratory well, adjoining drainages and groundwater to assess the removal of emerging pollutants and pathogens. So the main focus of this project will cover validation, demonstration and exploitation aspects (discussed above), especially:
    • Determination of the upper limit of removal of "emerging pollutants" by RBF
    • Equipping the site with water quality monitoring infrastructure
    • To equip site with promotional/information materials on research done at site
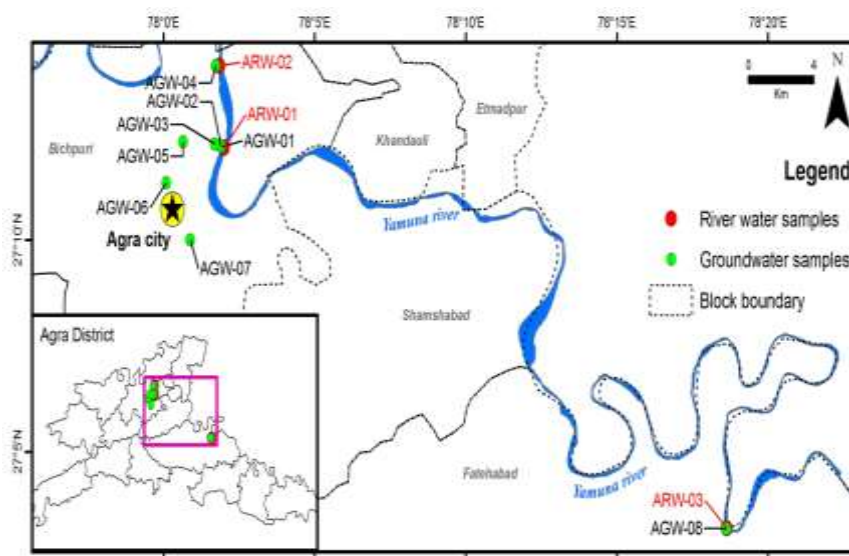


**Fig. 1**. Study site

**Progress**
1. **Work package/WP 1: Strengthening of network/collaboration**
   a. Completion of administrative formalities by signing Cooperation Agreement with 7 other Indian partners and 7 German partners in CCRBF consortium (total 15 partners).
   b. Obtaining permission from Ministry of Jal Shakti and Department of Economic Affairs, Govt.

of India, for NIH to be a partner of CCRBF consortium and to participate in CCRBF project activities.

c. Signing of Transfer Contract with HTWD (CCRBF project coordinator) to receive funds from the funding agency BMBF, Govt. of Germany.

d. Application to MoJS to extend the existing MoU between NIH and HTWD on "Indo-German Competence Centre for Riverbank Filtration" (IGCCRBF) for third phase from 2021 to 2026.

e. Participation in 3 project/consortium meetings (online due to Covid-19 pandemic) on 21 July 2020, 03 February 2021 and 08 July 2021

f. Participation in online CONNECT programme meeting organized by BMBF on 18 November 2021

## 2. WP2: Development of RBF demonstration site Agra

Due to the Covid-19 pandemic, especially the critical second wave from March to May 2021 and subsequent monsoon season, it was only possible to commence field work in Agra from

a. Scientific-technical support to CCRBF German partners HTWD & TUD for field investigations in Agra, liaison with stakeholder UP JAL Nigam (Oct. – Dec. 2021 & Mar. 2022)

b. Collection and analyses of water samples for Oxygen-18 and Deuterium isotope analyses

c. Scientific and logistic support to Mr. J. Nainan, student (Indian national) of TU Dresden who is doing hydrogeological investigations for Agra site for his master thesis

d. Field work comprising water sampling, shallow drilling with auger/tripod to determine groundwater level at site (planned $3^{rd}$ week March)

## 3. WP3 to WP5: Guideline for RBF in India (WP3), Education & Training (WP4) and RBF masterplan (WP5)

In progress. Results from WP2 will be synthesized into these WPs and accordingly disseminated/exploited.

## 4. WP6: Dissemination and exploitation of results

NIH contributed/disseminated for the period 01 July 2020 to 31 March 2022 as follows (details in annexure 2):

- 7 conference presentations (annexure 2, s.no. 1 to 7)
- 1 ad hoc presentation at meeting with Ministry of Jal Shakti, New Delhi, on 29.11.2021 (annexure 2, s.no. 8)
- 1 brainstorming session organized by Uttarakhand State Council for Science & Technology (UCOST), Dehradun, 31.07.2021 (annexure 2, s.no. 9)
- 2 peer-reviewed book chapters (1 submitted & 1 published)
- 3 conference proceedings
  1 article in India's leading water industry publication "Everything About Water"

**Action plan:**

| Period | July 2020 to June, 2023 (Annexure 1) | Remark |
|---|---|---|
| July 2020 to June 2023 | Monitoring of the site regularly<br>Establishing the site with monitoring infrastructure<br>Project works as listed in section "Validation, demonstration and exploitation of RBF technological intervention post 2018"<br>Preparation of revised RBF guidelines and masterplan on RBF for India<br>Prepare a status report | Report preparation as per Annexure 1 and dissemination activities as per Annexure 2 |

**Study Benefits /Impact**:
- The result will be the creation of a road map within framework of RBF masterplan to increase contribution of RBF to total drinking water supply from currently less than 1% to at least 5% by 2030.
- Strengthening Indo-German/European scientific collaboration on managed aquifer recharge/RBF
- The project has a high socio-economic relevance for the underprivileged households living in Jeevani Mandi area of Agra because before implementation of the action they had no access to safe drinking water and after implementation of action they have access to safe drinking water.
- informing and collating experiences/knowledge; capacity development and strengthening competence on MAR/RBF.
- evaluating existing work bases and sharing or making them known within the network
  synergies with other Indo-European projects (e.g. DST–EU-Horizon2020 funded projects)Keeping in mind the title of the CCRBF project, viz. "Expansion of the Indo-German Competence Centre for RBF", the inclusion of an additional and potential RBF site by the Sutlej river in Punjab is being considered (Phillaur town in Ludhiana urban area). It is hoped to thereby transfer RBF experiences and to expand the RBF network to Punjab that is affected by aquifer depletion and deteriorating groundwater quality due to groundwater over abstraction. Thereby the thematic topic of RBF within the "food-water-energy" nexus can be investigated in North India. This topic has been studied in South India under different hydro-climatic and environmental conditions.

**Specific linkages with Institutions:**
- German partners: TZWD, TUD, FHP, AUT, AKUT
- Indian partners: UJS, BHU, CSIR_CMERI, BBEC, AU, IITM, TERI, UPJN

**Activity schedule for expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF (quarter-wise wise from July 2020 to June 2023)**

| Activity | 1st | 2nd | 3rd | 4th | 5th | 6th | 7th | 8th | 9th | 10th | 11th | 12th |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Data Collection | ♦ | | ♦ | | ♦ | | ♦ | | ♦ | | | ♦ |
| Sample collection and analysis | | | ♦ | | | ♦ | | | ♦ | | | |
| Equip the site with modern infrastructure | | | | ♦ | ♦ | ♦ | ♦ | ♦ | | | | |
| Organization of trainings/knowledge dissemination | | | | ♦ | | | | ♦ | | | | |
| Final Report/Publication(NIH-HTWD) | | | | | | | | | | | ♦ | ♦ |

**Progress**
- One introductory meeting is held online with all partners
- See previous section "Progress"

**Future plan**
- Use of synergies from the competence-pool of RBF/CW/MAR through training and thematic cooperation between partners and stake holders
- See previous section "Action plan"

**12.     PROJECT REFERENCE CODE: NIH/GWH/DST-SERB/21-24**

| Title of the study | | Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen |
|---|---|---|
| **Name of PI and members** | : | **NIH, Roorkee, India** |
| | | Dr. Gopal Krishan (PI) |
| | | Dr. M.S. Rao (co-PI) |
| | | **IIT-Kanpur** |
| | | Dr. Shivam Tripathi (PI) |
| | | Dr. Richa Ojha (Co-PI) |
| | | Dr. Rajesh Srivastava (Co-PI) |
| | | Dr. Saumen Guha (Co-PI) |
| **Type of study** | : | **Sponsored,** DST-SERB |
| **Date of start (DOS)** | : | April 2021 |
| **Scheduled date of completion** | : | March 2024 |
| **Location** | : | **NIH** Roorkee and IIT-Kanpur |

| S. No. | Study objectives | Achievements |
|---|---|---|
| 1 | Estimate evapo-transpiration (ET) flux at a study site in Kanpur | **20%** – Experiments has been set up at IIT Kanpur |
| 2 | Partition ET flux into soil evaporation (E) and plant transpiration (T) fluxes, and investigate<br>➢ diurnal fluctuations in the fluxes;<br>➢ variations in the fluxes during a cropping season;<br>differences in fluxes between Rabi & Kharif seasons, | %- Work in this will start soon |
| 3 | Quantify uncertainties in the estimates of E, T and ET fluxes | **20%**- Experiments to finalize methodology are in progress |

**Statement of the problem**

The irrigation water demand in the Ganga basin is among the highest in the world (more than 90% of the total freshwater used in the basin). A major portion of the applied irrigation water eventually evapotranspires. The transpiration (T) component of the evapotranspiration (ET) is associated with crop productivity, while the undesirable soil evaporation (E) component represents losses. The knowledge of the relative magnitude of E and T fluxes in ET is therefore essential to design efficient irrigation techniques. The knowledge of ET partitioning is also crucial to understand the mechanism of energy and moisture transfer in the soil-plant-atmosphere continuum. In spite of its importance, few, if any, studies have investigated ET partitioning over the Ganga basin. In this project, we propose to estimate E and T fractions of ET by conducting field experiments at a site in the Upper Ganga Plains. A method based on stable isotopes of oxygen and hydrogen will be used. The main outcome of the project will be an understanding of the diurnal, inter- and intra- cropping seasonal variations in ET partitioning over rice-wheat system at the study site.

Estimation of evaporation (E) and transpiration (T) components of evapotranspiration (ET) is critical for the closure of energy and water balance equations in a hydrological study. Traditional hydrological modelling approach of lumping different components of ET into a single term has many disadvantages because the processes governing different components of ET have different physical characteristics, time scales and responses to climate feedbacks. Partitioning of ET is important to improve irrigation practices, particularly in water limited environments. The T component of ET is associated with crop productivity, while the undesirable E component represents losses due to soil evaporation. Thus, knowledge of ET partitioning can help in designing irrigation techniques that increase the fraction of T in ET, thereby improving water use efficiency. The main objectives of the project are to understand the diurnal, inter- and intra- cropping seasonal variations in ET partitioning over rice-wheat system at the study site in Kanpur.

The methods developed for ET partitioning can be divided into two categories – (i) stable isotope based method and (ii) hydrometric method. The isotopic method partitions ET based on the

differences in the isotopic signatures of evaporated and transpired water. When water evaporates from soil it fractionates, i.e. the concentration of heavier isotopes enriches in the soil water and depletes in the vapour formed. However, negligible fractionation occurs during transpiration. Thus, by knowing the isotopic compositions of E, T and ET, the relative contribution of individual components can be estimated. The hydrometric method partitions ET by directly measuring E, T, and ET fluxes. The reliability of this method depends on the quality of individual flux measurements.

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

**Methodology:**

To achieve the objectives stated in the proposal, the work is divided into 4 tasks. The following describes the methodology for implementing each task.

Task 1: ET partitioning by using Isotopic method

The key concept behind the isotopic method is that the heavier isotopes of oxygen and hydrogen in water $\left(^{18}O \text{ and } ^{2}H\right)$ have different physical properties than the abundant isotopes $\left(^{16}O \text{ and } ^{1}H\right)$. The following methodology will be followed to estimated isotopic signatures of ET, T and E fluxes.

*Estimation of* $\delta_{ET}$ : The value of $\delta_{ET}$ will be estimated by *Keeling plot method* (Keeling, 1958). The method assumes that the atmospheric water vapour in the boundary layer is the combination of background vapour already present and ET flux added locally to it.

*Estimation of* $\delta_{T}$ : We propose to use two methods. In *the first method*, the value of $\delta_{T}$ will be obtained by measuring the isotopic composition of xylem water $\left(\delta_{x}\right)$ in the plant. Under the assumption that there is no fractionation during the transpiration process, $\delta_{T}$ will be equal to $\delta_{x}$ . In *the second method*, the direct measurement approach proposed by Wang et al. (2012) and successfully applied by Wei et al. (2015) and Dubbert et al. (2014) will be used. This approach uses a customized leaf chamber filled with high purity nitrogen to collect vapour transpired by the leaves. Mass balance equation is then applied to water vapour and water vapour isotopes inside the leaf chambers to estimate $\delta_{T}$ .

(i) *Estimation of* $\delta_{E}$ : The value of $\delta_{E}$ will be obtained by applying the *Craig-Gordon model* (Craig and Gordon, 1965) that accounts for equilibrium and kinetic fractionation during phase change, and diffusion of water vapour from the soil surface to the atmospheric boundary layer.

Task 2: ET partitioning by using hydrometric method

The ET partitioning results obtained from the isotope based method in Task 1 will be corroborated by hydrometric method in Task 2. The hydrometric method partitions ET by estimating the magnitude of ET, and E and/or T fluxes. In this study, we propose to measure all the three fluxes independently

(i) *Estimation of* ET: The magnitude of ET flux will be obtained by *Bowen ratio method*.

(ii) *Estimation of* T: The magnitude of T will be estimated by measuring the rate of sapflow in the plant stem. In this *sapflow method*, a constant low grade source of heat will be attached to the plant stem, and the resulting heat fluxes in the vertical and radial directions will be measured. The rate of sapflow will then be estimated by applying the energy balance equation.

(iii) *Estimation of* E: We proposed to measure E by using *micro-lysimeter* (ML). The ML, also called mini-lysimeter, consists of a cylindrical tube of small diameter (generally between 0.1m to 0.3m). The tubes are inserted into the soil without disturbing the soil structure, particularly the upper soil structure is maintained.

<u>Task 3: Estimation of interception losses</u>

The interception losses will be determined by calculating the differences between the amount of rainfall collected by rain gauges outside the canopy (total rainfall) and the amount of rainfall collected by rain gauges (or catch cans) under the canopy (net rainfall). This method of finding the *difference between total and net rainfall* to estimate interception losses is the most common method for different kinds of vegetation including crops (Ward and Robinson 1999). As the method ignores stemflow, the estimated interception losses may have a positive bias. We propose to measure stemflow at a few randomly selected plants by placing collection cups sealed around the stem near the base of the plants. In addition, water wiping method (Wang et al., 2006) will be used for a few storms to account for the biases, if any, in the estimates of interception losses. The uncertainty in interception loss estimate can be due to uncertainties in rainfall measurement, sampling bias in determining net rainfall, and errors in stemflow measurements.

<u>Task 4: Quantification of uncertainties</u>

Uncertainties in the ET partitioning may arise from observational uncertainty, parameter uncertainty and model uncertainty. In this study, we propose to use the approach given in ISO Guide to the Expression of Uncertainty in Measurement (GUM, 2008). The uncertainty will be quantified at every step and will be propagated all the way to quantify uncertainties in the estimate of E and T fractions of ET. For the forward propagation of uncertainty, Mote Carlo method will be used where the tractable analytical expressions will not be feasible.

**Progress**

As part of project, the following work has been completed at the NIH-Roorkee to date:

**a)** **Collection of Air moisture samples:** Moisture in the form of vapour behaves similarly to any other gas. Even when it mixes with other gases in the air, it retains its identity and features. The conventional method to harvest moisture is cooling the ambient air below its dew point and collecting the condensate.

For our study, we used the cone-condensation technique to collect the air moisture samples. Depending on the prevalent relative humidity, the time taken to collect the air moisture sample varied (as shown in the table below).

| Date of sampling | Average Relative Humidity (%) | Time taken to collect 15 ml sample (minutes) |
|---|---|---|
| 27/12/2021 | 76 | 180 |
| 04/01/2022 | 97 | 30 |
| 15/02/2022 | 73 | 210 |

**b)** **Collection of Plant transpiration samples:** The physiological process by which excess water is lost from living tissues of plants in the form of vapours is known as transpiration. For our study, transpiration bags were used to collect the plant transpiration samples. The stomata disperse water into the atmosphere, which can be collected using transpiration bags.

To date, we've collected a large number of plant transpiration samples and studied their isotopic composition. Currently, we have set up transpiration bags at different elevations to determine the variance in sample volume collected.

**c)** **Model development to collect soil evaporation and evapotranspiration samples:** We used a cold trap set up to collect samples. In the previous set up, the air was pushed to the glass tube through connecting pipes. The glass tube was kept inside a cylindrical thermosteel flask containing ice as coolant (refilled twice a day) to condense the vapors that were pushed by the pump. The entire set-up was sealed using plastic sheets and weights on the border in order to avoid any leakage/contact with external environment. The vapors got condensed and were collected as liquid droplets in the glass tube. The problems associated with our previous set up were **(i)** Exposure of the outlet pipe to

the surrounding atmosphere **(ii)** No provision for temperature and humidity measurement **(iii)** Presence of atmospheric moisture representation in collected soil moisture sample.

   Our current model, which is made of transparent Acrylic Sheet (5 mm thickness) and measures 75x75x60 cm, includes an air compressor for suction and trapping the soil evaporated vapors in the glass tube. To control the suction and trap process, the compressor is linked to a rotameter and a nozzle valve. This model was designed to overcome the drawbacks of our previous experiment set up.

**d)      Miscellaneous:** Apart from the above mentioned work, different literatures related to sampling of air moisture, plant transpiration, soil evaporation and evapotranspiration sampling are being continuously studied to achieve better results. Moreover, a paper entitled "Methodological considerations for the collection of Air moisture for Isotopic Analysis" would be presented in the Roorkee Water Conclave 2022.

**Action plan**

| Period | April 2021 to March, 2024 (Annexure 1) | Remark |
|---|---|---|
| April 2021 to March 2024 | Installation of instruments<br>Collection of waters samples, isotope analysis<br>Data analysis and uncertainty quantification<br>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

Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using   Stable Isotopes of Oxygen and Hydrogen **(quarter-wise from April 2021 to March 2024)**

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

**Future plan**

- Experiments will be continued to achieve the desired objectives

## 13. PROJECT REFERENCE CODE: NIH/GWH/APN/22

| | |
|---|---|
| **Title of the study** | Capacity Development Program on Site Suitability Mapping for Managed Aquifer Recharge (MAR) under Varying Climatic Conditions using Remote Sensing and Machine Learning based Hydrological Modelling Tools |
| **Name of PI and members** | **NIH, Roorkee** (Partner organization) Nitesh Patidar (PI), Surjeet Singh, Gopal Krishan, *IIT Roorkee* (Lead organization): Basant Yadav (PI), Ashish Pandey, R D Singh, Bhaskar Jyoti Deka *KU, Japan* (In-kind support): Yutaka Matsuno, *PNU, South Korea*: Sanghyun Jeong |
| **Type of study** | **Sponsored,** Asia-Pacific Network (APN) |
| **Date of start (DOS)** | 01 Jan 2022 |
| **Scheduled date of completion** | 31 Oct 2022 |

**Objectives vis-à-vis Achievements**

The project is aimed at finding and disseminating an integrated approach for site suitability mapping of MAR under changing climate that suits the most affected parts of India, including states of Rajasthan, Punjab, Haryana, and Delhi. This involves developing a knowledge base to bridge the gap between science and decision-making to ensure effective implementation of MAR schemes. Thereby alleviating water supply problems, even as a measure to mitigate climate change. The capacity building program will aim at enhancing the capacity of implementing agencies, NGOs, and communities in implementing Managed Aquifer Recharge (MAR) projects effectively.

| S. No. | Study objectives | Achievements |
|---|---|---|
| 1 | Disseminate knowledge on MAR, climate variability, and emerging planning tools and techniques. This would primarily be aimed at forming a necessary base in the trainees to understand various groundwater processes, groundwater-climate interactions, and sustainable MAR planning | A five-day training is planned to be conducted during Jun 2022 |
| 2 | Develop and disseminate an integrated approach, considering quantity and quality, for site suitability mapping for MAR under changing climate to support effective MAR planning in the identified Indian hot-spots. The integrated approach will utilize remote sensing and machine learning-based hydrological modeling tools | Development of web-portal and a web-application is under progress. A training will be organized in Jul 2022 |
| 3 | Evaluating the MAR projects using available field observations and hydrological models | A workshop will be conducted during Aug 2022 |

**Problem statement**

In the states with inadequate surface water supplies and low rainfall, the major part of irrigation water is provided using the groundwater source. Under the threat of climate change, groundwater resources, therefore work as a cushion against climate variability. Managed aquifer recharge (MAR) has already been accepted as a reliable approach for groundwater recharge, however, the implications of such recharged water on groundwater quality are still not well understood. Nevertheless, to tackle the twin hazards, alarming decline in groundwater levels, and consequent deterioration of groundwater quality, artificial recharge has now been widely propagated in India. Central Ground Water Board (CGWB) in 2013 proposed the master plan for artificial recharge to groundwater in different states. Recently, a more detailed master plan for artificial recharge to

117

groundwater (2020) is proposed identifying the total area for artificial recharge of 11.23 lakh sq. km. However, this large scale recharge project can only succeed if the implications of MAR on environment and health at the local, regional and global scale are well understood. Global knowledge sharing and capacity building at the local scale would make sure that the MAR projects are well planned and have the potential to tackle challenges in MAR development, operation, and management.

The capacity building trainings and workshops will attempt to address various issues relating to the MAR development, operation, and management at the local and regional scale. The site suitability mapping using Multi-Criteria Decision Analysis (MCDA), Google Earth Engine, machine learning, and hydrological models will help the scientists, policymakers and other relevant stakeholders in addressing the issues of water quantity/quality and climatic variability. The developed science-based knowledge platform along with theoretical documents and hands-on manuals will help various stakeholders (civil society and policymakers) in addressing the issues of MAR design, sustainable operation strategy and management at regional and global level as well.

**Progress**

The methodology for site suitability mapping for Managed aquifer recharge is being developed. Multi-criteria Decision Analysis (MCDA) is being used for identifying the potential sites considering various influencing factors, such hydrological, topographical, climatological and geological. The methodology is being tested for Jaipur district. A web-application is being developed for MCDA using Google Earth Engine (GEE) cloud-based platform and Python programming. The web-based toll will allow quick mapping of the suitable sites on the web wherein the outputs could be downloaded for further analysis. A web-portal is being developed for disseminating knowledge on MAR. The portal will be utilized for conducting the training and disseminating lecture, video tutorials, manuals and sample data sets for training. Two trainings and one workshop are being planned for the officers of Rajasthan, Haryana, Punjab and Delhi.

**Action plan and timeline (month-wise from Apr 2022 to Oct 2022)**

| Work element | Apr 2022 | May 2022 | Jun 2022 | Jul 2022 | Aug 2022 | Sep 2022 | Oct 2022 |
|---|---|---|---|---|---|---|---|
| Preparation of methodology for site suitability mapping for MAR | ■ | ■ | | | | | |
| Selection of trainees from the Indian hot-spots where MAR is required | | ■ | | | | | |
| Preparation and dissemination of training modules, and documents | | ■ | ■ | ■ | | | |
| Organization of training and workshops | | | ■ | ■ | ■ | | |
| Report preparation and submission | | | | | | ■ | ■ |

## 14. PROJECT REFERENCE CODE: NIH/GWH/NIH/22-25

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

**Study Team**:
Dr. Sumant Kumar, Sc-D, GWHD & PI
Dr. Surjeet Singh, Sc.-F, GWHD
Dr. Rajesh Singh, Sc.-D, EHD
Dr. Gopal Krishan, Sc-D, GWHD
Dr. Soban Singh Rawat, Sc.-E, HID
Dr. M.K. Sharma, Sc.-E, EHD
Dr. Nitesh Patidar, Sc.-B, GWHD
Dr. P. K. Mishra, Sc.-D, WRSD
Dr. M.K. Goel, Sc.-G & Head, GWHD

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

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

**Statement of the problem:**

Chronic exposure to groundwater having an arsenic concentration of more than 10 μg/L leads to numerous adverse health impacts like lower intelligence quotients, type 2 diabetes, skin lesions, melanosis, keratosis, and cancer etc. Arsenic (As) contamination of water is producing the greatest impact on livelihoods in terms of public health and thus arsenic calamity in the Ganga river basin put millions of population in danger. Arsenic is a natural constituent in bedrock and soil. It usually occurs at low concentrations (average 1–2 mg/kg) in the Earth's crust, but may be concentrated in certain rock types and especially in gold and sulphide-bearing ore deposits and occurrences. Pyrite [FeS2; or arsenian pyrite Fe(AsS)2] and arsenopyrite [FeAsS] are typical sulphide minerals containing As. Weathering processes of rocks and minerals appears to be a major source of arsenic found in soils. Because it accumulates due to weathering and translocation in colloid fractions, the arsenic concentration is usually higher in soils than in parent rocks. Under typical soil forming conditions, the nature of arsenic in soil is controlled by the lithology of parent rock materials, volcanic activity, bioactivity, weathering history, transport, sorption, and precipitation. The river Ganga and its major tributaries originate from the Himalaya and carry lots of sediment and these sediments determine the chemistry of water. In the mid Holocene period, the river Ganga likely to transport metals from Himalaya to the plains by erosion and sedimentation. The rivers originating from the Siwalik Hills are reported to release more arsenic and heavy metals from their sediments in comparison to those major rivers originating from the Higher Himalaya. In order to study the causes of arsenic occurrence in Ganga basin and its mobilization from solid to water phase, it is planned to carry out mineralogical, geochemical and mobilization study. The significance of the study is to help in demarcating safe aquifer, improved monitoring and mitigation measures at regional level.

With the grave problems of arsenic in India, Inter-Ministerial Group (IMG) on Arsenic Mitigation was constituted on the directions of Cabinet Secretariat by erstwhile Ministry of water Resources, River Development & Ganga Rejuvenation (MoWR, RD & GR) vide order No. 11014/1/2014-GW Desk (Part-V) dated 22 Dec. 2014 under the Chairmanship of Mission Director (MD), National Water Mission (NWM). The IMG desired that National Institute of Hydrology (NIH), Roorkee should take lead role on R & D activities related to "Arsenic Mitigation" as per the areas suggested by the 'Core Committee' on "Mitigation & Remedy of Arsenic Menace in India". The DoWR, RD & GR, Govt. of India (letter no. 50013/177/2020-E.II dated 20/07/2020) advised NIH to seek funding under the subcomponent "Sponsoring and Co-coordinating research in water sector" and accordingly may submit a project proposal to INCGW. A project proposal with budgetary requirement of 1259.50 Lakhs was submitted to INCGW with detailed work component and budget of multi-institutions. Now, INCGW provided their comments/suggestions for submitting the project proposal. The NIH is under process for incorporating the comments/suggestions and the project proposal would be submitted again to INCGW for their considerations. The GWHD wish to start working on project components pertaining to NIH under internal funding till receive the funds from INCGW considering national importance of project.

**Proposed Methodology:**

The study will cover the detailed hydrogeology and geochemistry of the As-contaminated aquifer of the Ganga basin. A Pre-monsoon and post-monsoon grid-wise sampling would be done in upper and middle Ganga basin to study the spatio-temporal variation of water quality parameters including arsenic. The sediment samples at different location would be collected from upper and middle Ganga basin focusing on Himalayan sediments for sediment characterization using XRD & XRF techniques. The mineralogical study would help in identifying the minerals of arsenic present in the Ganga basin.

Integrated hydrological survey of As concentrations would be 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 will be collected during multiple field campaigns (pre-monsoon and post-monsoon season) from both deep and shallow aquifers. In addition to that, sediment samples (from hilly and plain region along with river bed material) would be brought out to lab for further analyses. The locations of the wells will be marked using a hand-held global positioning system (GPS). Unstable parameters and indicators of the oxidation state of ground water will be measured in the field. Field measurements will include temperature, electrical conductivity (EC), pH, oxidation-reduction potential (ORP) and dissolved $O_2$. The measured stable value of these water quality parameters will be representative of *in-situ* conditions. Samples will be filtered in the field with disposable 0.45-micron filters and will be collected for all major anions, cations and trace elements for further laboratory level analysis. Different analytical instruments would be used for analyses of ions and metals. Performance of existing treatment technology available and which are being used in arsenic affected areas would be evaluated. The influent and effluent of treatment unit would be 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.

**Action Plan& Timeline:**

| Work Element | 1st Year | 2nd Year | 3rd Year |
|---|---|---|---|
| Sediment and water sampling | | | |
| Sediment and water characterization | | | |
| Performance evaluation of existing treatment units | | | |
| Development of cost effective arsenic removal technology | | | |

| Preparation and submission of reports and publications | | |  |
|---|---|---|---|

**Data Requirements:**

- Geological map and bore logs of various location
- Groundwater levels
- Surface water and groundwater quality etc.

**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.

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

Study team:                  PI          Dr. Nitesh Patidar, Scientist-B
                             Co-PIs      Dr. MK Goel, Scientist-G
                                          Dr. Anupma Sharma, Scientist-F
                                          Dr. Surjeet Singh, Scientist "F"
                                          Ms. Nidhi Kalyani, Scientist-B


Type of study:              Internal (New study)

Duration:                   Two years (April 2022 – March 2024)


**Objectives**
1.  Analysis of present groundwater scenario in enroute command of IGNP
2.  Mapping of water-logged area in IGNP command using GW observations
3.  Estimation of GW recharge from rainfall, canal and irrigation under present and future climatic scenarios
4.  Conjunctive management of water resources in enroute command area of IGNP canal


**Problem statement**

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

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

**Study area**

The IGNP project was initiated in the late 50's and is situated in the districts of Sriganganagar, Hanumangarh, Bikaner, Churu, Jaiselmer, Barmer, and Jodhpur. It has a CCA of 1.963 million hectares. The project was completed in two stage, Stage-I having a 204 km long feeder which originates from Harike Barrage, Punjab, to reach Masitawali, Rajsthan, and a 189 km long main canal from Masitawali to Chattergarh in Bikaner district. Stage-II is having a 256 km long main canal from Chattergarh to Mohangarh in Jaiselmer.
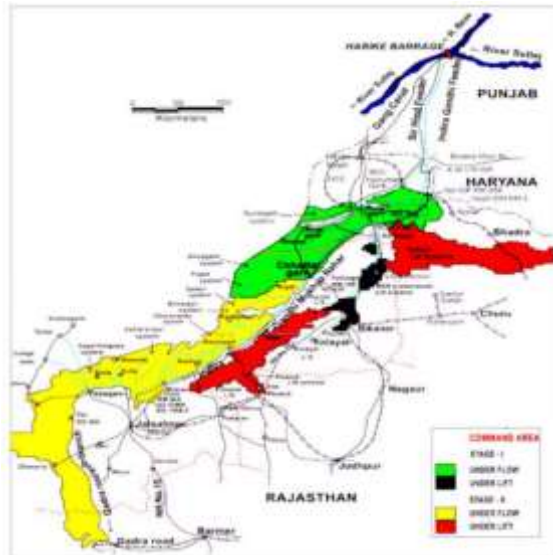
*Image source: Gupta et al. (2002)*

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

**Methodology**

The assessment of the present groundwater scenario will be done utilizing the groundwater observation of Central Ground Water Board (CGWB). Trend analysis will be performed on groundwater levels to identify the trend in groundwater. The mapping of water-logged area will be performed using the groundwater data. The conjunctive management of surface water and groundwater requires an integrated simulation-optimization model. A model developed at NIH which integrated Google Earth Engine (GEE), an surface water module and MODFLOW, will be utilized for estimating recharge to groundwater. A system model was developed at NIH which will be used to simulate the demand-supply and recharge due to canal percolation and irrigation. Iterative simulation runs will be performed to optimize the groundwater extraction so as to contain the rising water level and increase irrigation intensity. The Effect of climate variability will be considered using the most recent data of climate projections under different emission scenarios.

**Action plan and timeline (quarter-wise from Apr 2022 to Mar 2024)**

| Work element | Apr-Jul 2022 | Aug-Nov 2022 | Dec 2022-Mar 2023 | Apr-Jul 2023 | Aug-Nov 2023 | Dec 2023-Mar 2024 | Apr-Jul 2024 | Aug-Nov 2024 | Dec 2024-Mar 2024 |
|---|---|---|---|---|---|---|---|---|---|
| Collection of data and preliminary analysis | ▓ | ▓ | | | | | | | |
| Field investigations | | ▓ | | ▓ | | ▓ | | | |
| GW trend analysis and mapping of water-logged area | | | ▓ | | | | | | |
| Model simulations for quantifying GW recharge | | | | ▓ | | ▓ | | | |
| Simulation for conjunctive water management | | | | | | ▓ | ▓ | | |
| Project report and research paper | | | | | | | | | ▓ |

**16.    PROJECT REFERENCE CODE: NIH/GWH/NIH/22-24**

**Title of the Project:**    Study of groundwater dynamics with numerical modelling and machine learning in the Yamuna River Basin

**Study team:**
   a.    Nidhi Kalyani (PI)
   b.    Anupama Sharma, Nitesh Patidar, Sumant Kumar

**Objectives:**
   a) Review of AI/ML techniques and their application in Groundwater studies
   b) Application of AI/ML techniques for analysis of groundwater dynamics in a part of the Yamuna-Hindon inter-basin and its comparison with numerical modeling techniques.

**Methodology**

MODFLOW is a physically based numerical model of groundwater flow. It uses the equation of groundwater flow to simulate groundwater dynamics. Solution of the groundwater flow equation is achieved by finite-difference method in which the groundwater flow system and simulation time are discretized into grids and stress periods, respectively. Each stress period is a period of simulation within which specified stress data are constant.

A recurrent neural network (RNN) processes sequences by iterating through the sequence elements and maintaining a state containing information relative to what it has seen so far. In effect, an RNN is a type of neural network that has an internal loop. The state of the RNN is reset between processing two different, independent sequences. What changes is that this data point is no longer processed in a single step; rather, the network internally loops over sequence elements.



**A recurrent network: a network with a loop**
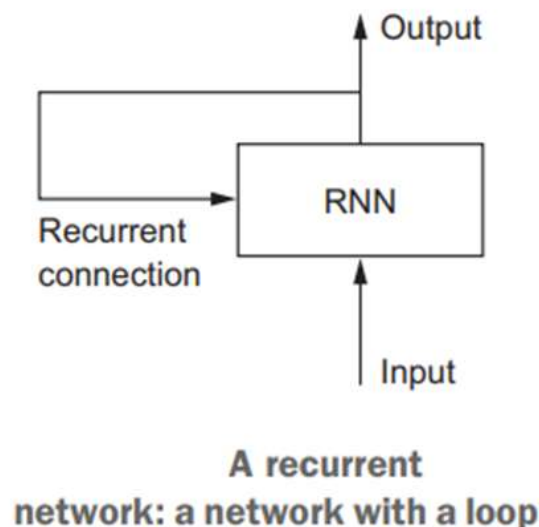
Deep learning is a specific subfield of machine learning that puts an emphasis on learning successive layers of increasingly meaningful representations. How many layers contribute to a model of the data is called the depth of the model. Modern deep learning often involves tens or even hundreds of successive layers of representations and they're all learned automatically from exposure to training data. These layered representations are learned via models called neural networks, structured in layers stacked on top of each other.

The model can be evaluated using three data sets: training, validation, and test. The model is trained on the training dataset and evaluated on the validation data. Once the model is ready, it can be tested on the test data.
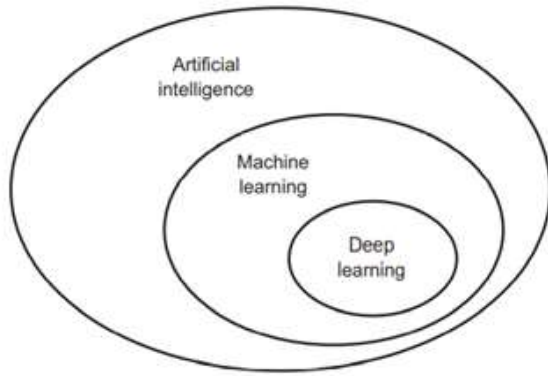
Artificial intelligence, machine learning, and deep learning



output_t = activation(
    Wo•input_t +
    Uo•state_t +
    bo)
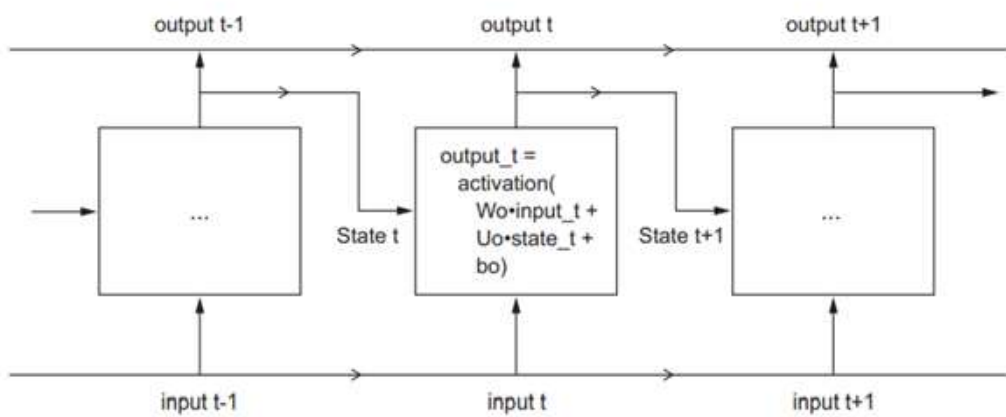
The starting point of an LSTM layer: a SimpleRNN



output_t = activation(
    Wo•input_t +
    Uo•state_t +
    Vo•c_t +
    bo)
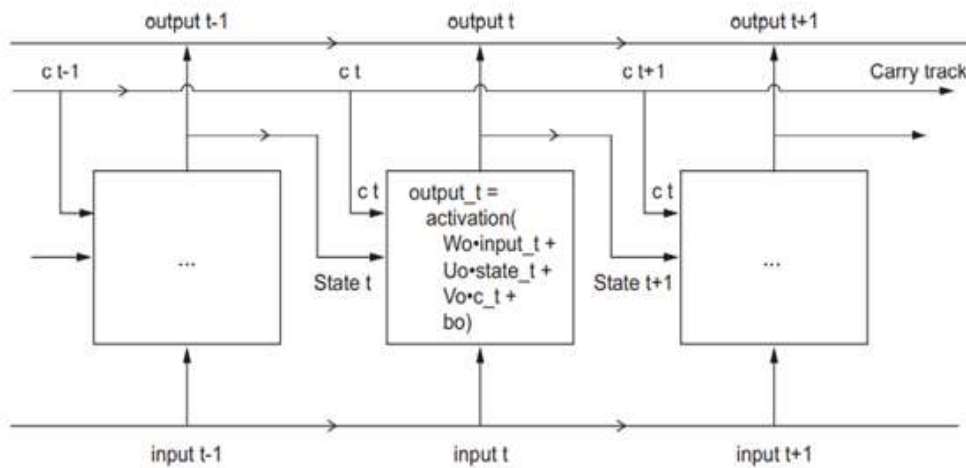
Going from a SimpleRNN to an LSTM: adding a carry track

**Research outcome from the project**

     The output of the study would be in the form of a comprehensive report.

# HYDROLOGICAL INVESTIGATION DIVISION

**Scientific Manpower**

| S N | Name | Designation |
|-----|------|-------------|
| 1 | Dr. Sudhir Kumar | Scientist G & Head |
| 2 | Dr. S D Khobragade | Scientist G |
| 3 | Dr. M S Rao | Scientist F |
| 4 | Dr. Soban S. Rawat | Scientist D |
| 5 | Dr. Santosh M. Pingale | Scientist C |
| 6 | Sri Hukam Singh | Scientist B |
| 7 | Mrs Anjali | Scientist B |
| 8 | Sri Rajeev Gupta | PRA |
| 9 | Sri V K Agarwal | PRA |
| 10 | Sri Vishal Gupta | SRA |

# APPROVED WORK PROGRAMME FOR THE YEAR 2021-2022

| S. N. | Project Title | Study Team | Duration | Status |
|---|---|---|---|---|
| **INTERNAL STUDIES:** | | | | |
| 1. | Hydrological investigations of selected springs in Tehri Garhwal District, Uttarakhand | S M Pingale (PI), Sudhir Kumar S. D. Khobragade Soban Singh Rawat Er. Padam Singh, (UUHF, Ranichauri) Rajeev Gupta | 3 years (04/19-03/22) | Completed (Report to be finalized) |
| 2. | Assessment of impact of land use and land cover change on groundwater conditions in parts of Sabarmati river Basin, Gujarat | M. Someshwar Rao (PI) Sudhir Kumar Vipin Aggarwal | 2 years (04/20 – 03/22) | Continuing Study |
| 3. | Integrated Hydrological Investigations of Renuka lake, Himachal Pradesh, for its Conservation and Management | SD Khobragade (PI) Sudhir Kumar Hukam Singh Rajiv Gupta Vipin Agarwal Scientist from GoH.P. | 3 years (07/20-06/23) | Continuing Study |
| 4. | Assessment of dissolved radon concentration in groundwater of Uttarakhand | Hukam Singh (PI), M Someshwar Rao, Soban Singh Rawat, Vipin Agarwal | 1 ¾ years (04/21-12/22) | New Study |
| **SPONSORED PROJECTS:** | | | | |
| 1. | Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques | Suhas Khobragade (PI) Sudhir Kumar Rajesh Singh M. Arora R. J. Thayyen | 5 Years (04/16-09/21) | Completed (NMSHE Sub-Project_09) |
| 2. | Dating very old ground waters of deeper aquifers in Ganga Plains, India | M. Someshwar Rao (PI) Sudhir Kumar | 3 Years (06/16 -12/22) | Continuing Study IAEA under CRP |
| 3. | Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin | Sudhir Kumar (PI) M. Someshwar Rao Vipin Aggarwal | 3 ½ year (01/18 – 06/22) | Continuing Study NHP (PDS) |
| 4. | Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management | M. Someshwar Rao (PI), Sudhir Kumar A. R. Senthil Kumar V. S. Jeyakanthan | 3 ½year (01/18 – 06/22) | Continuing Study NHP (PDS) |
| 5. | Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand | Suhas Khobragade (PI) Sudhir Kumar | 3 Years (1/18 – 12/20) Extended upto 06/22 | Continuing Study NHP (PDS) |
| 6. | Unravelling Submarine Discharge (SGD) zones along the Indian subcontinent and its islands (Mission SGD) – Pilot Study | Sudhir Kumar (PI) SM Pingale BK Purandara YRS Rao | 1 year (04/19 – 12/21) | Completed (Study under NCESS, MoES) |

| S. N. | Project Title | Study Team | Duration | Status |
|---|---|---|---|---|
| 7. | Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS) | Sudhir Kumar (PI) M. Someshwar Rao SM Pingale | 2 years (06/19 – 9/22) | Continuing Study (IIT Bombay, Mumbai) |
| 8. | Web-GIS Based Spring Inventory for Vulnerability Assessment and Hydro-Geological Investigation of Selected Springs for Sustaining Local Water Demand in Ravi Catchment of Himachal Pradesh | S S Rawat (PI) Sudhir Kumar P G Jose, Suman Gurjar, D S Bisht | 4 Years (08/17 – 09/22) | Continuing Study NHP (PDS) |
| 9. | Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River | S S Rawat (PI) P G Jose, Suman Gurjar, D S Bisht | 3 Years (1/19 – 06/22) | Continuing Study (NMHS) |

## RECOMMENDED WORK PROGRAMME FOR THE YEAR 2022-2023

| S. N. | Project Title | Study Team | Duration | Status |
|---|---|---|---|---|
| **INTERNAL STUDIES:** | | | | |
| 1. | Assessment of dissolved radon concentration in groundwater of Uttarakhand | Hukam Singh (PI), M Someshwar Rao Soban Singh Rawat Vipin Agarwal | 1 ¾ years (04/21-12/22) | Continuing Study |
| 2. | Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions Of India | SD Khobragade (PI) Dr. Vishal Singh Sudhir Kumar | 3 years (04/22-03/25) | New Study |
| 3. | Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions | Soban Singh Rawat, (PI) Sudhir Kumar, Santosh M. Pingale P K Mishra D. S. Bisht Rajesh Singh | 3 years (04/22-03/25) | New Study |
| 4. | Studies for selected springs of Tehri Garhwal region, Uttarakhand | MS Rao (PI) and Team | | Chairman suggested that instead of Tehri Garhwal, a proposal on study of springs of North-East region may be formulated. |
| **SPONSORED PROJECTS:** | | | | |
| 1. | Dating very old ground waters of deeper aquifers in Ganga Plains, India | M. Someshwar Rao (PI) Sudhir Kumar | 3 Years (06/16 -12/22) | Continuing Study IAEA under CRP |
| 2. | Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin | Sudhir Kumar (PI) M. Someshwar Rao Vipin Aggarwal | 3 ½ year (01/18 – 06/22) | Continuing Study NHP (PDS) |
| 3. | Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management | M. S. Rao (PI), Sudhir Kumar A. R. Senthil Kumar V. S. Jeyakanthan | 3 ½ years (01/18-06/22) | Continuing Study NHP (PDS) |
| 4. | Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand | Suhas Khobragade (PI) Sudhir Kumar | 3 years (01/18-06/22) | Continuing Study NHP (PDS) |
| 5. | Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS) | Sudhir Kumar (PI) SM Pingale | 2 years (06/19 – 09/22) | Continuing Study (IIT Bombay, Mumbai) |
| 6. | Web-GIS Based Spring Inventory for Vulnerability Assessment and Hydro-Geological Investigation of Selected Springs for Sustaining Local Water Demand in Ravi | S S Rawat (PI) Sudhir Kumar P G Jose Suman Gurjar D S Bisht | 4 Years 17/08)– 0922/) | Continuing Study NHP (PDS) |

| S. N. | Project Title | Study Team | Duration | Status |
|-------|---------------|------------|----------|--------|
|       | Catchment of Himachal Pradesh |  |  |  |
| 7. | Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River | S S Rawat (PI) P G Jose Suman Gurjar D S Bisht | 3 years (01/19-09/22) | Continuing Study (NMHS) |
| 8. | Leachate transport modelling for Gazipur landfill site for suggesting ameliorative measures | Anjali (PI) Sudhir Kumar, J. V. Tyagi M. K. Sharma Partner: CGWB (Delhi unit) | 3½ years (11/19 – 06/23) | Continuing Study NHP (PDS) Transferred from EHD |
| 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 | Sudhir Kumar, (Proj. Coordinator), M. K. Sharma, (PI) Suhas Khobragade Anjali Vishal Singh SM Pingale Nitesh Patidar Surjeet Singh | 5 years (04/22-03/27) | DST |

**ITEM NO. 52.2          ACTIONS TAKEN ON THE ADVICE / DECISIONS OF THE 51st MEETING**

The specific action taken on the advice/decision of the 51st meeting of Working Group of NIH are as follows:

| SN | Project | Status & Comments/ suggestions | Action Taken |
|---|---|---|---|
| **INSTITUTE FUNDED R & D STUDIES** | | | |
| 1. | Hydrological Investigations of Selected Springs in Tehri-Garhwal District of Uttarakhand | i) Dr. Bhishm Kumar suggested to contact Uttarakhand Government and get funding for this study.<br><br>ii) Director, NIH suggested to take this study outcome to the logical end and show utility of this study to the end users. | Efforts were made to get the study financed from Forest Department, Uttarakhand. Now Forest department is collaborating in the study but without any financial support.<br><br>Noted |
| 2. | Assessment of Impact of Land Use and Land Cover Change on Groundwater Recharge in Parts of Sabarmati River Basin, Gujarat | Dr. Bhishm Kumar advised to use tritium tagging technique only at places where estimation of vertical recharge to groundwater is of utmost necessity. | The study could not be started due to covid-19. The collaborator from CU, Gujarat is now not willing to participate in the study. |
| 3. | Integrated Hydrological Investigations of Renuka Lake, Himachal Pradesh, for Its Conservation and Management | Dr. Khobragade informed that lake catchment is a protected reserved forest hence permission of the Dept. of Forests & Wildlife, Govt. of HP is necessary for carrying out the study. He further informed that communication in this regard has been made with the Forest Department but response is still awaited. Dr. Bhishm Kumar suggested that efforts be continued to get the response from the department | Telephonic communication was made and reminder email has also been sent to Forest Department of Himachal Pradesh., but response is still awaited. |
| **SPONSORED PROJECTS** | | | |
| 1. | Understanding hydrological processes in Upper Ganga basin using isotopic techniques | Dr. Bhishm Kumar commented that different studies have given different contribution show/ice, GW etc. to river Ganga. The final report should include a review of these studies and possible reasons for variation in reported contribution | Review of studies has been included in the final report. |

**ITEM NO. 52.3     PROGRESS OF THE WORK PROGRAM OF THE DIVISION FOR THE YEAR 2021-22**

As per the approved work program, the status of studies carried out in HI Division during 2021-22 is given below:

| Type of study/Project | Completed during 2021-22 | Continuing in 2022-23 | Total |
|---|---|---|---|
| Internal R & D Studies | 01 | 03 | 04 |
| Sponsored Projects | 02 | 07 | 09 |
| Total | 03 | 10 | 13 |

Details of training Courses/Workshops organised by the Division during 2021-22:

| S.N. | Topic | Duration | Coordinator | Venue | No. of Participants |
|---|---|---|---|---|---|
| 1. | Scientific data collection and processing techniques for springshed management and rejuvenation | 05 Days (13-17 Dec 2021) | Dr S S Rawat | Guwahati | 25 |
| 2. | Tools and techniques for springshed management | Two Days (06-07.01.2022) | Dr SS Rawat | Jammu | 39 |
| 3 | Stakeholder Consultation Workshop on "GRACERS Project" | March 22, 2022 (01 day) | Dr. SM Pingale | Haldia, West Bengal | 50 |

**Mass Awareness activity organised**

| S.N. | Name and Details of Outreach Activity | Date | Participants |
|---|---|---|---|
| i. | "आजादी का अमृत महोत्सव अ भयान" के अंतर्गत "आत्मनिर्भर भारत हेतु जल संरक्षण एवं जल प्रवंधन की वैज्ञानिक तकनीकें" वषय पर एक दिवसीय ई-संगोष्ठी का आयोजन रा.ज. व., रुड़की कया गया| | 05/07/2021 | 27 |
| ii. | "आजादी का अमृत महोत्सव" अ भयान के अंतर्गत "जल संरक्षण एवं जल सुरक्षा" वषय पर स्कूली बच्चों के लए सूचना, शक्षा और संचार (आईईसी) कार्यक्रम का आयोजन जल वहार कॉलोनी रुड़की में कया गया| | 28/05/2021 | 20 |
| iii. | "आजादी का अमृत महोत्सव" अ भयान के अंतर्गत "जल संरक्षण एवं जल सुरक्षा" वषय पर ग्राम बेलड़ी-साल्हापुर, रुड़की में जागरूकता कार्यक्रम का आयोजन कया गया| | 02/09/2021 | 50 |
| iv. | "आजादी का अमृत महोत्सव" अ भयान के अंतर्गत "जल संरक्षण एवं जल सुरक्षा" वषय पर स्कूली बच्चों के लए सूचना, शक्षा और | 29/10/2021 | 50 |

| | | | |
|---|---|---|---|
| | संचार (आईईसी) कार्यक्रम का आयोजन राजकीय उच्चत्तर माध्य मक वद्यालय, बेलडी (हरिद्वार) में किया गया| | | |
| v. | "आजादी का अमृत महोत्सव" अभियान के अंतर्गत "जल संरक्षण एवं जल सुरक्षा" वषय पर ग्राम **Dhanderi Khwazgipur** (ढन्डेरी ख्वाज़्गीपुर) **village, District: Haridwar** में जागरूकता कार्यक्रम का आयोजन किया गया| | 29/12/2021 | 50 |
| vi | "आजादी का अमृत महोत्सव" अभियान के अंतर्गत "जल संरक्षण एवं जल सुरक्षा" वषय पर स्कूली बच्चों के लिए सूचना, शिक्षा और संचार (आईईसी) कार्यक्रम का आयोजन **Government Inter-College** रुड़की में किया गया| | 18/02/2022 | 40 |

Details of samples analysed by the Division Laboratories during 2021-22:

| S.N. | Parameter analysed | No. of samples |
|---|---|---|
| 1. | $\delta^2$H on DI-IRMS | 4078 |
| 2. | $\delta^{18}$O on DI-IRMS / CF-IRMS | 4776 |
| 3. | C-13 on CF-IRMS | 185 |
| | Tritium | 243 |
| 4. | WQ samples on IC | 900 |

Details of Research Publications by the Division during 2021-22:

| | Published | Accepted | Communicated |
|---|---|---|---|
| Books/Book Chapter | 01 | - | - |
| International Journals | 10 | - | 06 |
| National Journals | 01 | 01 | 01 |
| International Conferences | 06 | 02 | 08 |
| National Conferences | 02 | - | - |

Details of important instruments purchased by the Division during 2021-22:

| S.N. | Name of Instrument | Qty. | Cost (Rs.) |
|---|---|---|---|
| 1 | DGPS | 01 No. | Rs. 15.50 Lakhs |
| 2 | Imaging System | 01 No. | Rs. 36.75 Lakhs |

The progress of the various studies undertaken during 2021-22 is given below:

*1.0 PROJECT CODE:  NIH/HID/INT/19-22*

| | |
|---|---|
| **Title of the Study:** | **HYDROLOGICAL INVESTIGATIONS OF SELECTED SPRINGS IN TEHRI-GARHWAL DISTRICT OF UTTARAKHAND** |
| **Study Team:** | Santosh M. Pingale (PI), Sudhir Kumar, S.D. Khobragade, Soban Singh Rawat, Rajeev Gupta, |
| **Collaborator:** | Padam Singh, Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Ranichauri |
| **Type of Study:** | R & D Study |
| **Funding Agency:** | NIH |
| **Study Duration:** | 03 Years (April 2019 to March 2022) |
| **Budget:** | Rs. 31.82 Lakh |

**Objectives:**

1. To inventorize, characterize and evaluate the sustainability of the springs in Tehri Garhwal district.

2. To assess the impact of anthropogenic activities/climate variability on hydrologic responses of springs and develop the adaptive measures to sustain the livelihoods.

**Statement of the Problem:**

The watershed/springshed are dynamic and complex systems involving a range of physical processes, which may operate simultaneously and have different spatial and temporal influences. Understanding these processes is essential for managing the quality as well as quantity of water available from both surface runoff and natural springs flow under the changing LULC and climatic conditions. Protection and management of the springs cannot be facilitated unless one has basic understanding physical and climatic characteristics of the watershed/springshed. Otherwise, spring rejuvenation measures cannot be successful in the adverse climatic conditions. Therefore, this study has been undertaken with an objective to conduct systematic investigations on the selected springs of Tehri-Garhwal district of Uttarakhand. The output of the study is expected to go as an input for planning augmentation measures for theses springs and to rejuvenate the drying springs in the district.

**Study area:**

The present study is being carried out for the selected springs in the Tehri-Garhwal district of Uttarakhand (*Fig. 1.1*).
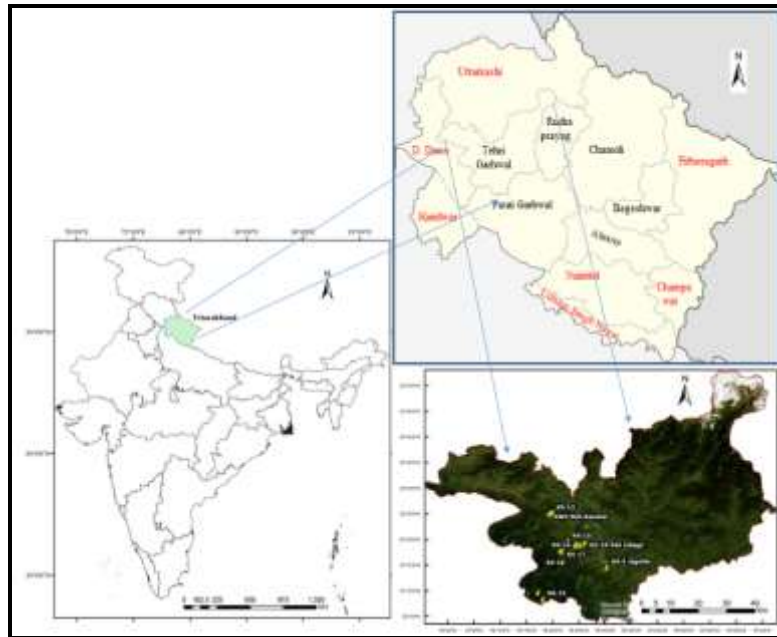
**Fig. 1.1 Location of the study area**.

**Methodology:**

The methodology adopted in the present study is described here:

  a. Preparing comprehensive inventory of available springs in the study area.

  b. Creating geo-database for the springs, which can be updated from time to time.

  c. The representative springs from different lithological units selected for continuous monitoring hydro-chemical, physical and social parameters (e.g. Discharge, pH, EC, TDS, major anion and cation), dependent population, use of water and land use conditions around the spring's source / springshed / watershed.

  d. The characterization of spring in different lithological units is being carried out using hydrological investigation techniques.

  e. The trends and shifts in hydro-climatic variables using different statistical techniques and LULC change have been taken up for the selected study area.

  f. The characterization and development of IDF curves for rainfall and FD curves of the springs flow is under process.

  g. The impacts of anthropogenic activities/climate variability on selected springs flow in different lithological units within the study area is under process.

  h. Finally, suitable interventions and scaling out plan will be suggested based on hydrological investigations.

**Achievement vis-à-vis Objectives**

| Objectives | Achievements |
|---|---|
| To inventorize, characterize and evaluate the sustainability of the springs in Tehri Garhwal district. | • Springs inventory and geo-tagging have been prepared based on field visits. About 40 springs have been inventoried. |
| | • Local Meteoric Water Line (LMWL) has been established using $\delta^{18}$O and $\delta^{2}$H of identified springs water. In addition, temporal plots of the isotopic composition of spring water ($\delta^{18}$O and $\delta^{2}$H) have been prepared. |
| | • The spring water and rainwater samples for isotopic composition at different locations/altitude have |

135

| | |
|---|---|
| | been collected within study area and tritium analysis is in progress.<br>• The hydrometeorological analysis have been carried out at different temporal scales.<br>• The IDF curves for rainfall and FDC for spring flow have been constructed. |
| To assess the impact of anthropogenic activities/climate variability on hydrologic responses of springs and develop the adaptive measures to sustain the livelihoods. | • The impact of anthropogenic activities/climate variability on hydrologic responses of the selected springs in the study area is in progress. |

**Progress of Work**

**Archival data collection:** The historical hydro-climatic data for Ranichauri & Fakua springs were obtained from College of Forestry, Ranichauri. These two perennial springs are being monitored for their spring flow on daily basis.

**Springs Inventory:** During the field visits, more than 40 natural springs have been identified in the selected blocks of Tehri-Garhwal district (Fig.1). The spring related data have been collected (e.g. discharge, pH, EC, location, elevation). It was found that all spring water are slightly in alkaline nature (pH: 6.8 to 8.5; EC: 40 to 1440 µs/cm).

**Hydro-geological investigation of study area:** In the present study, aquifer and lithological formation maps of Tehri Garhwal district have been used for detail hydrogeological investigations of the study springs. It has been found that district comes under Schist, Gneiss, Quartzite, Phyllite and Shale with limestone aquifer formations. Of the twenty springs, two springs fall in older alluvium and Pebble/gravel/Bazada/Kandi formation, while remaining springs lie in the Phyllite, Quartzite, Shale with limestone, and Schist group.

**Establishment of spring monitoring sites:** The monitoring stations have been identified to collect the water samples from rain and spring water for isotopes analysis. In addition to Ranichauri & Fakua springs, two more spring sites have been identified for monitoring and details hydrological investigations in the area, where spring monitoring can be started to understand the spring's responses in different lithological and geographic settings.

**GIS database creation & statistical analysis:** The base maps have been prepared for the study area such as DEM, Slope, stream network etc. Trends and shifts detection analysis have been carried out for the archival data of springs and meteorological parameters using different statistical techniques for the Ranichauri campus and Fakua springs in the study area.

**Characterization and development of IDF and FD curves:** The IDF curves for rainfall and FD curves of the springs flow is prepared for the selected springs. Tritium dating of the collected spring water and rainwater is under progress.

**Future work plan:** As per activity schedule
- Additional field visits are required for spring inventory in the study area.
- The springs location map along with isotopic values of spring water and rainwater will be prepared for the identified selected springs in the study area. Further, results of tritium dating of the collected spring water will be analyzed.
- The impact assessment of anthropogenic activities/climate variability on hydrologic responses of the selected springs.
- Development of adaptive measures to sustain the springs.

## 2.0 PROJECT CODE:  NIH/HID/INT/19-22

| | |
|---|---|
| **Title of the Study:** | **ASSESSMENT OF IMPACT OF LAND USE AND LAND COVER CHANGE ON GROUNDWATER RECHARGE IN PARTS OF SABARMATI RIVER BASIN, GUJARAT.** |
| **Study Team:** | M S Rao (PI), Sudhir Kumar, Hukum Singh, V. K. Agarwal, Vishal Gupta and S.L. Srivastava |
| **Collaborating agencies:** | (Mrs.) Rina Kumari, Asstt. Prof., Sch. of Env. & Sustainable Develop, Central University, Gujara |
| **Type of Study:** | R & D Study |
| **Funding Agency:** | NIH |
| **Study Duration:** | 2 Years [1/4/2021 to 31/3/2023] |
| | (Work could not be initiated from 1/8/2020 due to COVID -19 pandemic. As per the discussion held with Dr. Rina Kumar, the fieldwork will be initiated from May 2021) |
| **Budget:** | Rs. 15.00 Lakh |

**Objectives:**

The specific objectives of the project are as given below:

  i.  Decadal change in LULC

  ii.  Groundwater mapping (flow, fluctuation & availability)

  iii.  Stable isotope characterization of groundwater and surface water sources

  iv.  $^3$H dating of groundwater

  v.  Identification of surface water groundwater interaction zones

  vi.  Analysis of change in groundwater recharge rates over the last 4 decades due to the change in LULC pattern and groundwater demand

**Origin of the Proposal & Problem Definition:**

Groundwater is a valuable natural resource. Depletion of groundwater resources and deterioration of its quality can have a serious impact on both the socio-economic growth and the eco-environment. Factors like urbanization, changing land use land cover patterns, increasing water demand for food production to support the growing population growth, etc., affect the groundwater recharge conditions, groundwater resource, and its quality. In the present study, change in land-use and land cover and its impact on the groundwater recharge will be assessed.

**Study Area:**

The study will be conducted in the Sabarmati river basin near the city of Ahmedabad. Groundwater samples will be analyzed from the locations where the previous study on groundwater recharge estimate (Gupta et al., 1980) was conducted.
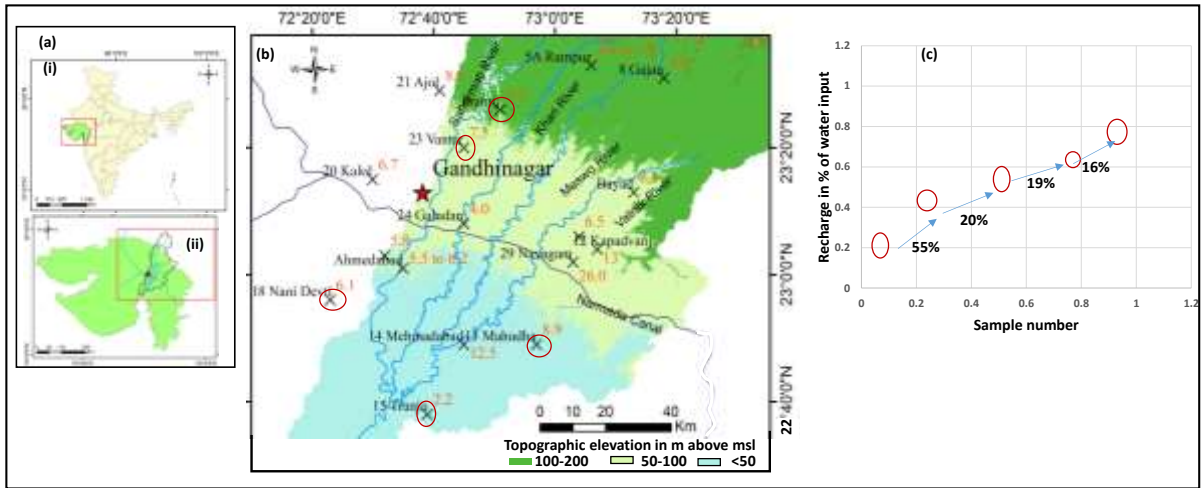
**Fig 2.1: Study area. (a) (i) The state Gujarat in India (ii) Sabarmati river basin in Gujarat (b) Rivers and canal in the study area. The values shown in orange colour are the groundwater recharge rates as estimated in the previous study (Gupta et al., 1980). Red circles are the proposed sites for groundwater recharge experiments, (c) Groundwater recharge rate as observed in the previous study (Gupta et al., 1980). The red circles indicate the recharge values that will be re-estimated in the present study (as marked in the fig (b)**

**Methodology:**

Changes in LULC over the last 4 decades will be analyzed using the remote sensing data. Decadal scale fluctuation in groundwater level will be analyzed by using archival data. To identify the change in groundwater recharge rates, the published data on groundwater recharge rates for the year 1977 (Datta et al., 1980) will be compared with the recharge rates to be estimated during the present study. In the previous study, recharge rates of 2.2% to 10% were observed in the study area. In the present study, experiments will be conducted to estimates the recharge rates once again at 5 locations, where recharge rates were observed to be 2.2%, 4.9%, 6.1%, 7.5%, and 8.9% of the input water. The difference in the recharge rates observed between the present and the past study will be interpreted in terms of the change in LULC and any other parameters that have influenced the recharge rate. It is also important to notice that during the previous study, the Narmada canal did not exist and hence its impact on the change in groundwater isotopic composition and water quality will also be assessed. Environmental tritium in groundwater will also be analyzed to estimate the average turnover time of the groundwater.

**Time Line**

| Work components | May-Oct, 2021 | Nov-Apr, 2022 | May-Oct 2022 | Nov-Apr 2023 |
|---|---|---|---|---|
| Data collection (LULC, rainfall, irrigation data, archival water quality & ground water level data etc. ) | ✓ | ✓ | | |
| Preparation of various thematic layers | ✓ | ✓ | ✓ | |
| Collection and analysis of water sampling for water quality & isotopic ($^2$H, $^{18}$O, $^3$H) characteristics | ✓ | ✓ | ✓ | |

| | | | | |
|---|---|---|---|---|
| Soil analysis (grain size, soil moisture stable isotopic composition of soil moisture) | ✓ | ✓ | ✓ | |
| Estimation of vertical recharge to groundwater | | ✓ | ✓ | |
| $^3$H dating of groundwater | | ✓ | ✓ | |
| Data interpretation | | | ✓ | ✓ |
| Report and publication | | | ✓ | ✓ |

**Progress of Study:**

No progress was made as the field investigations could not be started due to covid-19. In addition, the Collaborator from CU, Gujarat is no more interested in the study.

**Working Group may consider dropping the study.**

139

**3.0** *PROJECT CODE: NIH/HID/R&D/2021/1*

| | |
|---|---|
| **Title of Project:** | **INTEGRATED HYDROLOGICAL INVESTIGATIONS OF RENUKA LAKE, HIMACHAL PRADESH, FOR ITS CONSERVATION AND MANAGEMENT** |
| **Project team:** | SD Khobragade (PI), Sudhir Kumar, Sc-G; Hukam Singh, Sc-B,; Rajiv Gupta, PRA, Vipin Agarwal, SRA and Scientist from H.P. State Council for Science Technology & Environment. |
| **Type of Study:** | Institute Funded R & D Study |
| **Duration:** | 3 years |
| **Date of Start:** | 1$^{st}$ July, 2020 |
| **Date of Completion:** | 30th June, 2023 |
| **Budget:** | 46.5 Lakh |

**Statement of Problem:**
The Renuka lake in Himachal Pradesh is facing some serious environmental problem such as pollution, growth of weeds and, reduction in water spread area and capacity due to siltation, etc. However, there is no proper conservation plan for the lake based on systematic scientific investigations. The National Institute of Hydrology, Roorkee carried out some preliminary investigations on the lake and it was felt that further detailed investigations are required on various aspects such as water balance, ground water–lake interaction, water quality, sedimentation etc for understanding the hydrological regime of the lake so that a comprehensive conservation and management plan for the lake can be developed. The matter has been discussed with the authorities of the Himachal Pradesh and it was agreed upon that systematic and detailed scientific investigations need to be carried out on the Renuka Lake. So, the present study is proposed to carry out detailed and integrated hydrological investigations on the lake to develop a conservation plan for its long term conservation.

**Objectives:**
The major objectives of the proposed study are: ·

   i)     To assess the environmental health of the lake through assessment of its water quality
   ii)    To understand the hydrological regime of the lake through analysis of its water balance
   iii)   To estimate sedimentation rate and expected life of the lake ·
   iv)    To determine the causes of quantitative and qualitative degradation of the lake, and
   v)     To develop a Conservation Plan for conservation and management of the lake

**Brief 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 including bathymetric survey
   (iv)   Sample collection and laboratory analysis

For the assessment of the water balance components, the inflow and outflow would be monitored. Water levels in the lake would be monitored. Lake evaporation would be estimated using Penman Method. Groundwater-lake interaction will be studied using conventional technique and isotope technique. Ground water levels in the lake would be monitored. Morphmetric characterization and morphological analysis would be carried out using remote sensing and GIS techniques. 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.

**Study Area**
Renuka lake, is located at a distance of about 37 km from Nahan in district Sirmaur.in Himachal Pradesh at 30°36′36″N 77°27′30″E at an altitude of 672 m above mean sea level.
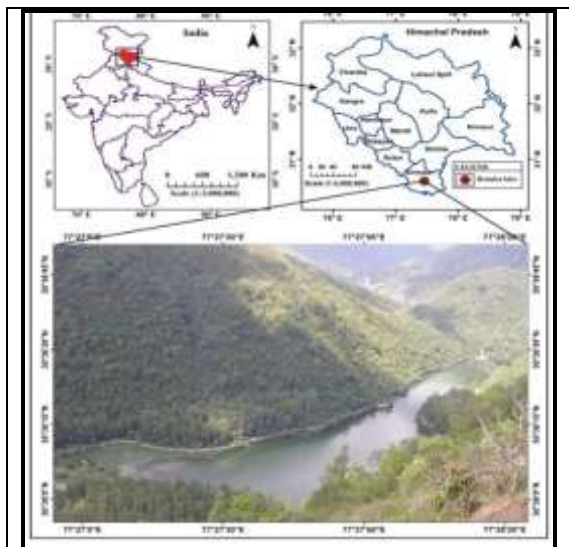

**Figure 1: Location map of study area**

It has a circumference of 3,200 meters, with a maximum depth of about 13m. There are two views regarding the origin of the lake. According to one view it is of glacial origin while the other view considers that the lake basin is a part of a former river valley. Besides being the largest lake of Himachal Pradesh, it is one of the most sacred lakes of northern India and a great tourist attraction for its picturesque location and biodiversity. It is the site of an annual fair held in the month of November. The lake is known to be home to at least 443 species of fauna. The Ministry of Environment and Forests, Government of India has recognized it as Wetland of National Importance in 2005. The lake was included in the list of Ramsar Sites in India during 2005 attaining international importance under the declaration of Ramsar Convention. The State Government has also declared 402 ha. in and around the lake as Wild Life Sanctuary.

**Work Plan:** As per activity schedule

**Achèvements vis-à-vis Objectives**

| Objectives | Achievements |
|---|---|
| To assess the environmental health of the lake through assessment of its water quality | Water quality samples have been collected and results of laboratory analysis awaited |
| To understand the hydrological regime of the lake through analysis of its water balance | Isotopic samples have been collected for post monsoon 2020, water levels of existing hand pumps monitored for post monsoon 2020 |
| To estimate sedimentation rate and expected life of the lake · | --- |
| To determine the causes of quantitative and qualitative degradation of the lake | -- |
| To develop a Conservation Plan for conservation and management of the lake | To be done after all analysis are completed |

**Progress of work**

A field visit of Renuka lake and catchment was undertaken during December 2020. Following works were carried out:

   i)     Reconnaissance survey of the lake & catchment and finalization of sampling locations & locations for installation of equipment
   ii)    Collection of samples for water quality and isotopes analysis & in-situ measurement of EC, pH and temperature
   iii)   Measurement of water levels from the available 4 hand pumps
   iv)    Discussion with local officers of Forest Department

During the discussion with the local officials of the forest Department it was informed that since the lake catchment area is a protected forest, no study can be taken up on the lake without prior permission from the Principal Chief Conservator of Forest & Wildlife Warden, Govt. of Himachal Pradesh. Accordingly, the Principal Chief Conservator of Forest & Wildlife Warden, has been contacted and necessary permission has been sought. The response is still awaited. The study shall be initiated only after the permission is officially received.



**Some photographs of fieldwork carried out during December 2020**

### ACTIVITY SCHEDULE

| SN | Activity | Quarter | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Year- I | | | | Year- II | | | | Year- III | | | |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| **1.0** | **PREPARATORY WORK** | | | | | | | | | | | | |
| 1.1 | Reconnaissance survey, & finalization of various sampling locations | √ | | | | | | | | | | | |
| 1.2 | Review of all available data/information & Identification of Data Gaps | √ | √ | √ | | | | | | | | | |
| 1.3 | Procurement of meteorological Data | √ | √ | √ | | | | | | | | | |
| 1.4 | Installation of equipment in field | √ | √ | | | | | | | | | | |
| 1.5 | Preparation of basic maps of lake and catchment | √ | √ | | | | | | | | | | |
| 1.6 | Arrangement for discharge measurement | | √ | √ | | | | | | | | | |
| **2.0** | **FIELD WORK** | | | | | | | | | | | | |
| 2.1 | Generation of hydro-meteorological data | | √ | √ | √ | √ | √ | √ | √ | √ | | | |
| 2.2 | Collection of water samples for water quality & isotope analysis | | √ | √ | √ | √ | √ | √ | √ | √ | | | |
| 2.3 | Infiltration tests to determine Infiltration rates | | | √ | √ | | | | | | | | |
| 2.4 | Monitoring of discharge | | √ | √ | √ | √ | √ | √ | √ | √ | | | |
| 2.5 | Bathymetric Survey of lake | | √ | | | | | | | | | | |
| 2.6 | Monitoring of lake & ground water levels | | √ | √ | √ | √ | √ | √ | √ | √ | | | |
| **3.0** | **LABORATORY ANALYSIS** | | | | | | | | | | | | |
| 3.1 | Analysis of samples for Water Quality | | √ | √ | √ | √ | √ | √ | √ | √ | | | |
| 3.2 | Analysis of water samples for isotope characterization | | √ | √ | √ | √ | √ | √ | √ | √ | | | |
| 3.3 | Analysis of sediment samples | | | | | √ | √ | | | | | | |
| **4.0** | **DATA INTERPRETATION & ANALYSIS** | | | | | | | | | | | | |

| No. | Activity | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4.1 | Processing of bathymetric data | | | √ | √ | | | | | | | | |
| 4.2 | Development of depth-area-capacity curve for the lake | | | | √ | | | | | | | | |
| 4.3 | Preparation of other maps, morphometric characterization and morphological analysis | | | √ | √ | | | | | | | | |
| 4.4 | Analysis of rainfall and other meteorological data | | | | | | | | | √ | | | |
| 4.5 | Estimation of evaporation losses from the lake | | | | | | | | | | √ | | |
| 4.6 | Assessment of lake-ground water interaction | | | | | | | | | | √ | | |
| 4.7 | Estimation of water balance of the lake | | | | | | | | | | √ | √ | |
| 4.8 | Isotopic characterization of waters of study area | | | | | | | √ | √ | √ | √ | | |
| 4.9 | To develop local meteoric water line | | | | | | | | | | √ | | |
| 4.10 | To estimate sedimentation rate of the lake | | | | | | | | | | √ | | |
| 4.11 | To assess the water quality of the lake | | | √ | | √ | | √ | | √ | | | |
| 4.12 | Assessment of suitability of lake water for various uses | | | | | | | | | | | √ | |
| 4.13 | To develop conservation plan for the lake | | | | | | | | | | | √ | |
| **5.0** | **PREPERATION OF REPORT** | | | | | | | | | | | | |
| 5.1 | Preparation of Interim Project Report | | | | √ | | | √ | | | | | |
| 5.2 | Preparation of Final Project Report | | | | | | | | | | | | √ |
| **6.0** | **ORGANIZATION OF TRAINING WORKSHOP** | Post-Project | | | | | | | | | | | |

**4.0** *PROJECT REFERENCE CODE: NIH/HID/R&D/2021/2*

| | |
|---|---|
| **Title of the Study:** | **ASSESSMENT OF DISSOLVED RADON CONCENTRATION IN GROUNDWATER OF UTTARAKHAND** |
| **Project team:** | Hukam Singh (PI), M Someshwar Rao, Soban Singh Rawat, Vipin Agarwal |
| **Collaborating agencies:** | CGWB, Dehradun |
| **Type of Study:** | MoU with CGWB |
| **Funding Agency:** | Internal Funding |
| **Budget:** | Rs. 4.00 Lakh |
| **Duration:** | One Year Nine Months (April 2021 to December 2022) |

**Objectives:**

Mapping the spatial distribution of radon levels in groundwater in Uttarakhand.

**Present state-of-art:**

Radon in groundwater originates due to decay of parent radioactive member radon-226, which is derived from the decay of the ultimate parent source uranium-238. The uranium-238 is present in groundwater as uranyl complex or is present in the host aquifer matrix as radioactive contaminant. Solubility of parent members of radon (radium and uranium) in groundwater depends upon geochemical conditions and temperature of groundwater. Radon-222 concentration in groundwater is a function of radioactivity concentration of radium (and hence uranium) in aquifer matrix, aquifer porosity (dry pores may lead to escape of radon) and physico-chemical condition of groundwater. During rainfall recharge, moisture filled pores in the vadose zone may slow down the escape rate of radon and also rise in groundwater levels due to rainfall induced groundwater recharge may dilute the radon levels in the groundwater. Thus, radon concentration in groundwater at a given location depends on the local hydrogeology, groundwater fluctuation and soil moisture conditions. Thus, a temporal variation in dissolved radon concentration in groundwater may provide a new way to look into the aquifer system and recharge conditions. Due to the short half-life of radium & radon isotopes compared to timescales at which groundwater levels and soil moisture fluctuation take place; the variation of these hydrological parameters may be recorded in the radon signals.

**Study Area:**

The study will be carried out in various districts of Uttarakhand.

**Methodology:**

In order to study the radon contamination in the study area at different locations, groundwater samples from shallow as well as deeper aquifers for pre and post monsoon seasons will be collected for in-situ radon measurement for studying the spatial and temporal variation of radon concentration. The hydro-geological data will also be collected for the study area in order to study the hydro-geological features to be linked with the radon concentration in pre and post monsoon season groundwater samples.

**Progress of Work/Results and Analysis:**

Samples have been collected from 29 locations in the Haridwar and Dehradun districts of Uttarakhand. These samples have been analyzed in the Institute Lab. The results will be presented in the WG meeting.

*1.*     *PROJECT REFERENCE CODE:*     *NIH/HID/SPON/16-20*

**Title of the Study:**     UNDERSTANDING   HYDROLOGICAL   PROCESSES   IN
                            UPPER GANGA BASIN USING ISOTOPIC TECHNIQUES

**Study Team:**             S. D. Khobragade (P.I.), Sudhir Kumar, Suneel Kumar Joshi (Res.
                            Sc-C), Rajesh Singh, M. Arora and S. K. Verma
**Collaborating agencies:** WIHG and HNB Garhwal University
**Type of Study:**          Sponsored (under NMSHE Project)
**Funding Agency:**         DST, Govt. of India
**Budget:**                 Rs. 177.228 lakh
**Date of Start:**          April 2016
**Date of Completion:**     September 2021
**Study area**

The study area (Figure 1). covers the upper catchment of the Ganga River, and lies between latitudes of ~29°45'34''N and 31°27'39'' N, and longitudes of ~78°9'18''E and 80°15'16'' E Bhagirathi and Alaknanda Rivers are the two headwater streams that join at Devprayag to form Ganga River. The catchment area of the Ganga River, up to Rishikesh, is ~21,780 km$^2$. The topography in the upper catchment area (altitude: ~2000 to ~7500m) is very rugged and gentle to rugged in the lower valley region (altitude:332 to <2000 m). The variation in altitude and latitude has led to the prevalence of different climate types within the study area. The upper part of the catchment, extending between the elevation of ~4000 m to ~7000 m, experiences an alpine environment, while the region is lying below ~4000 m exhibits characteristics of the sub-humid tropical climate.

**Study Objectives**
- Isotopic characterization of precipitation and identification of sources of vapor
- Runoff generation processes in the headwater region of Ganga using isotope and modeling
- Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries.
- The contribution of transient groundwater and its role in the sustainable flow of Ganga.
- Groundwater dynamics in the mountainous area, including identification of recharge sources and zones of major springs
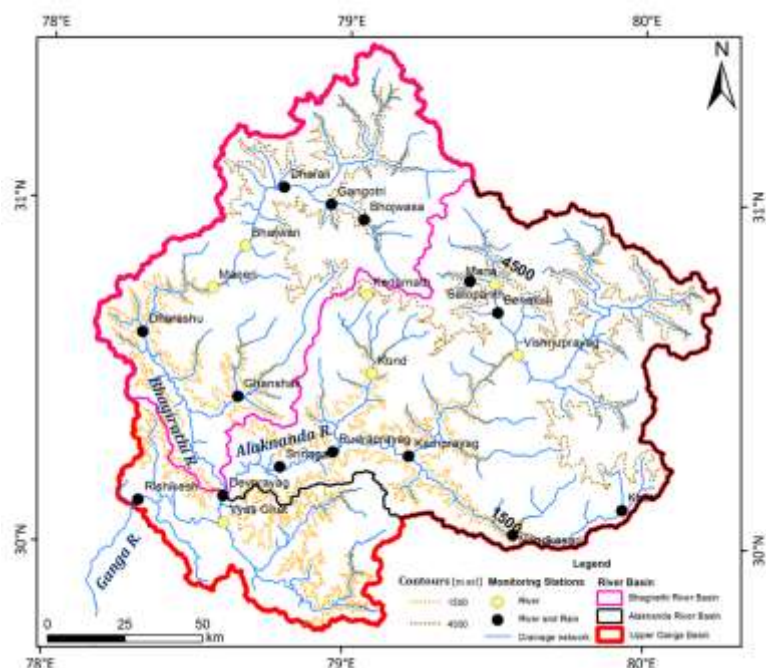
Figure 1 Study area map showing rain and river monitoring stations

**Statement of the Problem**

The Himalayan mountain system is the source of one of the world's most extensive supplies of freshwater. However, these sources are under threat due to severe environmental degradation and climate change. These changes are likely to dramatically impact the river flows, groundwater recharge, natural hazards, and the ecosystem, consequently affecting the people and their livelihoods, although the effects are not expected to be the same in terms of magnitude and intensity in all parts of the region. To understand the possible impacts of these changes on the water resources and hydrological regime of the Ganga basin, it is first essential to have a thorough understanding of the hydrological processes operating in the Ganga river basin. The present study has therefore been undertaken as part of the larger NMSHE project, sponsored by DST, Govt. of India, for the Upper Ganga basin up to Rishikesh. Considering the utility of the environmental isotopes to understand complex hydrological processes, isotope techniques are being used in the present investigations.

**Brief Methodology**

- Field survey and site selection for monitoring stations
- Sample collection from various water sources such as precipitation, river, groundwater, snow and ice melt and their laboratory analysis for stable isotopes, radioactive isotopes, and hydrochemistry
- Isotopic characterization, including altitude effect
- Application of two- and three-component isotope model for assessment of the relative contribution of tributaries at confluence points
- Modeling of snow and glacier melt

**Action Plan: (2016-2021)**

| Activities | 1st year | | 2nd year | | 3rd year | | 4th year | | 5th year | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | I | II | I | II | I | II | I | II |
| Appointment of Project staff | √ | | | | | | | | | |
| Procurement of instruments | √ | √ | | | | | | | | |

146

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Literature Collection | √ | √ | √ | | | | | | | |
| Sample collection and analysis for stable and radioisotopes | | √ | √ | √ | √ | √ | √ | √ | | |
| Compilation of data, interpretation and analysis | | | | | | | √ | √ | √ | √ |
| Organization of training course and workshop | | | | | | √ | | √ | | |
| Preparation of final report | | | | | | | | | | √ |

*Achievements vis-à-vis Objectives*

| Objectives | Achievements |
|---|---|
| Isotopic characterization of precipitation and identification of sources of vapor | Achieved |
| Runoff generation processes in headwater region of Ganga using isotope and modeling | Achieved |
| Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries | Achieved |
| The contribution of transient groundwater and its role in the sustainable flow of Ganga | Achieved |
| Groundwater dynamics in the mountainous area including identification of recharge sources and zones of major springs | Achieved |

**Outcome of the study**

A total number of nine field visits have been made to the study area since 2016, including Satopanth and Gangotri glacier. Water samples were collected from springs, snow/ice melt, groundwater, river, and rainfall during the field visits for stable isotope and tritium analysis. Also, 21 monitoring stations were established to collect the water samples from precipitation and river for stable isotope and tritium analysis. A total of 6828 water samples from springs (n=333), groundwater (n=303), rain (n=1003), river (n=4999), and snow/ice (n=190) have been analyzed for stable isotopes. In comparison, a total of 191 water samples have been analyzed for tritium measurements.

Several analyses have been carried out which include spatio-temporal distribution of isotopic composition of different sources of water and their altitudinal variation, comparative analysis of isotopic characteristics of Alaknanda and Bhagirathi river basins, Back Wind Trajectory analysis of rain events for identification of vapor sources of precipitation, analysis of altitudinal variation in isotopic characteristics of groundwater and springs, isotopic characterization of Satopanth glacier, analysis of groundwater chemistry, linkages of hydrological processes with geomorphic and geologic features in the upper Ganges basin, the contribution of Alaknanda and Bhagirathi river system to river Ganga at Devprayag, long-term snow covers distribution in the study area, etc.

Enriched isotopic signature has been observed during pre-monsoon and winters showing local effects. The UGB-MWL and 13 separate LMWL line(s) have been established. The RMWL and 13 LMWL show seasonal variations in the isotopic composition of rainfall in the upper Ganga river basin. The isotopic composition of rainfall for all 13 rain gauge stations is close to the GMWL, suggesting no secondary evaporation in the study area during rainfall events. Also, there is no correlation between the isotopic composition of rainfall and the amount of rainfall. The temporal variation in the isotopic composition of precipitation depends on the seasonal dynamics of moisture source and transport pathways. Results of the study suggest that two distinct moisture sources are present in the upper Ganga river basin. The western disturbance brings moisture from the Mediterranean region during winters (November to March) and the vapor from the Arabian Sea, during the Indian Summer Monsoon (ISM).

Analysis of the relative contribution of the Bhagirathi and Alaknanda rivers to Ganga at Devprayag indicates monthly and seasonal variability. During the monsoon season (i.e., from July to September),

the contribution of the Bhagirathi river to the Ganga river at Devprayag is about 15-20 %, which increases during the non-monsoon months. Using three-component isotope modeling, the groundwater, surface runoff, and glacier contributions to the river discharge have been estimated for the Bhagirathi river. It indicates that the groundwater contribution increases toward the downstream, whereas glacier contribution decreases toward the downstream. Results also show marked spatial variation in isotopic composition of springs and groundwater, suggesting different recharge sources and altitudes. The isotopic composition of spring water shows a wider variation than groundwater.
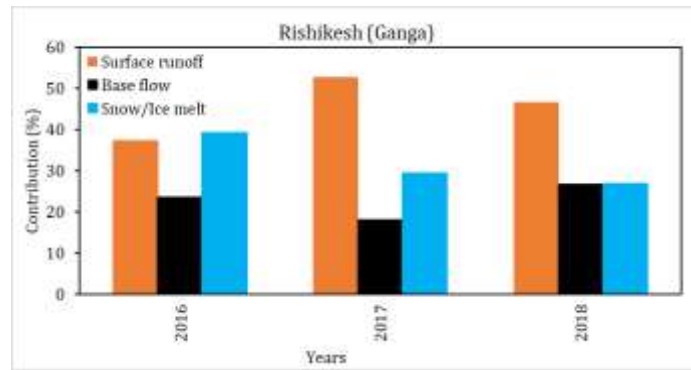


**Figure 1:** Annual average relative contribution from various sources to Ganga river discharge at Rishikesh.

**2.0 *PROJECT CODE: NIH-26_2017_62***

| | |
|---|---|
| **Title of the Study:** | **CHEMICAL AND ISOTOPIC INVESTIGATION OF GROUNDWATER IN DEEP AQUIFERS OF MIDDLE GANGA BASIN, INDIA** |
| **Study Team:** | Sudhir Kumar (PI), M. Someshwar Rao |
| **Study Duration:** | 03 Years (January 2018 to June, 2022) |

**Objectives:**

  i. To identify the source of recharge to deep aquifers

 ii. To assess interaction of deep aquifer with the overlying aquifers.

iii. Water quality of deep & shallow groundwater

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

**Statement of the Problem:**

Uttar Pradesh is one of the most populous states in the country. The population of the state in the last two decades has increased from 16.62 crores to 23.5 crores, meaning an annual increase by 2.07% per year (or 2.07 lakhs per year). The state is striving towards increasing food productivity. The volume of food grain production in the state has increased from 42.75 Million metric Ton (Source: RBI, Govt of India) to 54.64 MT (Source: Statista during the period from 2001 to 2019), which means an increase in productivity by 14.69 thousand MT per year. To keep pace with the growing population and food production the water demand in the state is steeply increasing. Population growth, urbanization, runoff from the agri-zones is also increasing the solid and liquid waste, and causing contamination to the freshwater resources. As a result, per capita availability of freshwater resources is continuously reducing in the state. Therefore, the time demands to assess the availability of freshwater resources in the state and to identify the possible solutions to augment it for its sustainability.

**Study Area:**

The study area is part of the state Uttar Pradesh, and it is hydrologically bounded by three rivers; the river Ganga in the south, and the rivers Sharda, and Ghaghara in the north. The study area is well-drained by the tributary of the river Ganga viz., the rivers Ramgnga, Gomti, Ghaghara, and Sai; and the canal networks originating from these rivers (*Figure 2.1*). The total study area is spread over 95,600 sq. km and is divided into 28 administrative districts.
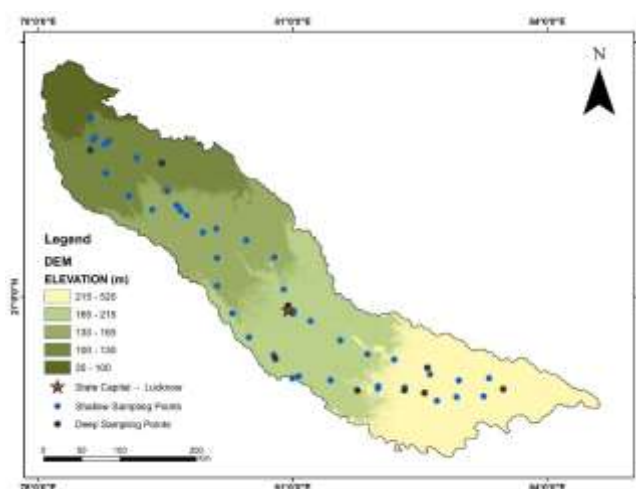


**Figure 2.1: Study area, groundwater sampling points on DEM.**

149

**Methodology:**

- Preparation of base map
- Field survey, groundwater sampling, and analysis of the collected samples ($^2$H, $^{18}$O, $^3$H, dissolved ion concentration and heavy metals)
- Watershed based analysis of decadal change in LULC, rainfall, demography, change in per capita water availability; and effect of these parameters on groundwater quality
- Rainfall-runoff modelling
- Data interpretation for groundwater availability, identification of potential groundwater recharge zones and the effective surface water recharge sources
- Developing the conceptual model for groundwater dynamics and augmentation measures

**Work accomplished and work planned for the remaining period:**

| Work components | Work done till Feb 2021 | Work programme for March –December, 2021 |
|---|---|---|
| Preparation of thematic maps and data interpretation | Prepared the following maps:<br>- Study area outline map, district boundaries and block boundaries<br>- Rivers and watershed map<br>- DEM (ASTER data; 30m resol., year 2019; CARTOSAT data 2020; 2.5 m resol. March 2020)<br>- LULC (Source: Landsat, Resol.:30m; Year: 2005, 2020)<br>- Soil cover map<br>- Downloaded groundwater level, population, and rainfall data | Data interpretation for:<br>- LULC (urban sprawl, agriculture area, surface water bodies, etc.) change from 2005 to 2020<br>- Change in rainfall pattern<br>- Groundwater fluctuation<br>- Per capita change in water availability<br>- Identification of water stressed area<br>- Impact of land use change on water resources and water availability<br>- Rainfall-runoff modelling<br>- Identification of potential ground recharge zones |
| Groundwater sampling, analysis and data interpretation | - 9 deep (depth > 200 m) and 49 shallow (depth: 30-40m) groundwater samples collected. 90% of the collected samples were analyzed for water quality and isotopic composition. The data interpretation, based on the analyzed data is completed. | - 2 more field works will be done for groundwater sampling.<br>- The results of these samples together with the previous fieldwork data will be integrated and interpreted in terms of contamination issues, groundwater recharge sources, and recharge zones. |
| End use | | - Trainings, mass awareness, publication and preparation of final report will be done in the 2nd half of the year 2021 |

*Progress shall be presented in the WG meeting.*

*3.0 PROJECT CODE: NHP-NIH-22_2017_38*

| | |
|---|---|
| **Title of the Study:** | **INTEGRATED STUDY ON GROUNDWATER DYNAMICS IN THE COASTAL AQUIFERS OF WEST BENGAL FOR SUSTAINABLE GROUNDWATER MANAGEMENT** |
| **Study Team:** | M.S. Rao (PI), Sudhir Kumar, A.R. Senthil Kumar, V.S. Jeyakanthan. |
| **Collaborating Agency:** | Er.Subrata Halder, SWID, Govt. of West Bengal |
| **Type of Study:** | Sponsored Project (PDS-NHP) |
| **Budget:** | Rs 51.0 Lakhs |
| **Nature of Study:** | Applied Research |
| **Study Duration:** | 03½ Years (March 2018 to June, 2022) |

**Study Area:**

The study area is spread along the 5 coastal districts of West Bengal viz., West Midnapore, East Midnapore, Howrah N. 24 Parganas, and S. 24 Parganas; and Kolkata Municipal Corporation (KMC) (*Figure 3.1*). Groundwater in the study area exists in unconfined to confined conditions in the multi-layered aquifer system.

The quality of the groundwater varies in space, time and depth from fresh to saline conditions and, in some parts, it is arsenic contaminated. Approximately, 22.74 million people residing in the 59 blocks of the three coastal districts are in the range of seawater-groundwater interaction zone and under the threat of changing groundwater salinity.
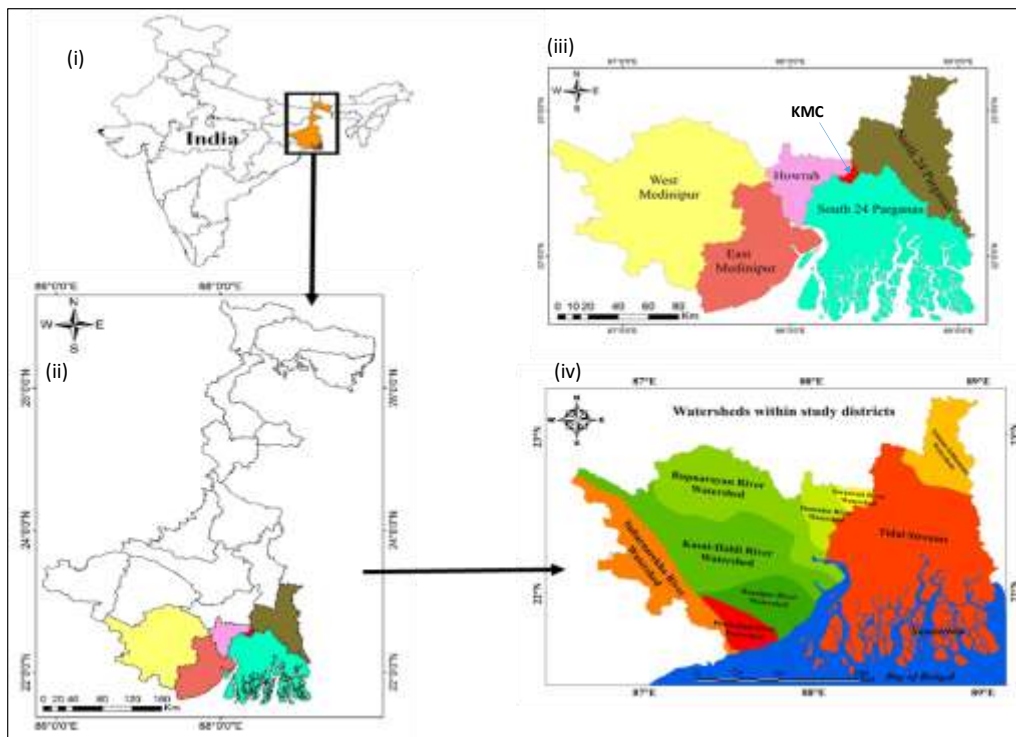


**Figure 3.1: Study area. (i) Location of West Bengal in India map (ii) Coastal districts of West Bengal (iii) Map of the 5 coastal districts and the Kolkata Municipal Corporation (KMC) (iv) Watersheds in the study area**

**Statement of the problem**

Due to the combined effect of climate change and anthropogenic activities, the coastal districts of West Bengal is now in danger position. As a result, its districts are now fragile. Therefore, a detailed hydrological study is a very much need. The detailed analysis will be watershed based which has never been done in this region.

**Objectives:**

➢ Mapping of seawater intrusion and fresh groundwater discharge to sea is a fundamental problem in the coastal zone groundwater dynamics. Specific to West Bengal, there exists little or no database on this aspect. Through this project, the un-answered question –how much fresh groundwater zone got invaded by seawater, how much area comes under vulnerability and from which area large quantity of fresh groundwater is getting lost to sea will be examined. The specific objectives of the project are:

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

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

➢ Identification of source of salinity in groundwater

➢ Identification of groundwater recharges sources & flow pattern and temporal and spatial pattern of excess surface water available in the coastal zone for artificial recharge measures

➢ Management measures for safe & sustainable coastal groundwater use

**Methodology:**

The adopted methodology involves field investigations and collection of hydrological, meteorological, groundwater quality, geological, topographic and land use data from different sources. The collected data will be analysed to prepare a situation analysis report, groundwater potential and recharge estimates. A conceptual model would be constructed to understand current water stress and future water stress. The changes in LULC shall be assessed to quantify the degree of anthropogenic impact on groundwater levels in the basin. Data related to aquifer characteristics will be procured from State and Central water related agencies.

**Time Line of the Planned Activities and the Action Taken:**

| Planned Activities | Status till Dec 2020 | Activities for 2020-21 |
|---|---|---|
| Preparation of thematic maps:<br>Index map<br>DEM (ASTER 30m)<br>Variation in population distribution from 2001 to 2011<br>LULC map of 2018<br>Hydrogeological Map<br>Soil map (Source: NBSS LUP)<br>Groundwater level & fluctuation (1995-2018) (source: India WRIS) | Completed | ----- |

| | | |
|---|---|---|
| LST (MODIS 2019 & 2020), Resol: 1km<br>SST (2019 & 220) | | |
| Rainfall pattern & change during (2000-2018)<br>Sea level fluctuation (Daily data since Jan 2019)<br>Litholog correlation (50% of the study area completed) | Data collected | Analysis to be done |
| Water sampling & analysis (Water quality and isotopic analysis) | Pre-monsoon (2 nos.) Sampling completed. 80% samples analyzed | Post monsoon analysis is to be done |
| Rainfall-runoff modelling | Data collected | Analysis is to be done |
| Data interpretation for:<br>Mapping of salinity intrusion and fresh groundwater discharge zones<br>Water scarcity hotspots<br>Parameters influencing the water quality and water availability<br>Identification of recharge areas & surface water storage zones<br>Coastal hydrological processes<br>Groundwater sustainability measures<br>Conceptual framework | | To be done |
| Training & mass awareness program | | |
| Reports & publications | | |

*Progress shall be presented in the WG meeting.*

**4.0** *PROJECT CODE:  NIH/HID/NHP/2018-21/1*

| | |
|---|---|
| **Title of the Project:** | **DEVELOPMENT OF A COMPREHENSIVE PLAN FOR CONSERVATION AND SUSTAINABLE MANAGEMENT OF BHIMTAL AND NAUKUCHIATAL LAKES, UTTARAKHAND** |
| **Project team:** | S.D. Khobragade (PI), Sudhir Kumar, C. K. Jain and team from IRI, Roorkee |
| **Collaborating agency:** | IRI, Roorkee (Lead Organization for NHP PDS) |
| **Type of Study:** | PDS under NHP |
| **Duration:** | 3 years |
| **Date of Start:** | 1$^{st}$January, 2018 |
| **Date of Completion:** | 30$^{th}$ June, 2022 |
| **Budget:** | 36 Lakh (NIH) |

**Statement of Problem:**

The lake region of Kumaun Himalaya is known for its biodiversity and socio-economic value. The catchment areas of the Bhimtal and Naukuchiyatal lakes is are hot spots of biodiversity with about 500 species of resident and migratory birds, 20 species of mammals, over 525 species of butterflies and over 11,000 species of moths, beetles, bugs and other insects. Both Bhimtal and Naukuchiatal lakes have traditionally been used as primary sources of drinking and irrigation water for their regions. However, anthropogenic disturbances in the lake catchment over the last few decades, are threatening the existence of these lakes with problems such as heavy sedimentation, pollution etc. As such, the lakes need a comprehensive conservation plan. The lakes have been identified for conservation under the National Lake Conservation Plan (NLCP) of the Government of India. However, conservation plan for any lake needs proper understanding of the hydrology of the lake ecosystem. Many studies have been reported on the Bhimtal and Naukuchiatal lakes on water quality, ecology and sedimentation but there are no reported hydrological studies. The lakes are owned by the Irrigation department, Uttarakhand who want to rejuvenate the lakes, particularly the Bhimtal and Naukuchiatal, as these are prime sources of drinking water.

**Objectives:**

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

**Brief Methodology**

    i)   Field surveys and field investigations
    ii)  Bathymetric survey
    iii)  Collection, processing and analysis of the available data
    iv)  Generation of additional required data.
    v)   Preparation of base maps and morphometric characterization
    vi)  Sample collection and laboratory analysis
    vii) Data interpretation and analysis
    viii)  Assessment of Water balance components, water quality status, sedimentation rates, isotopic characterization

**Study Area**

Bhimtal is largest lake of all the lakes of Kumaun lesser Himalayan lakes. The lake is situated at 29° 21' N and 79° 34' E at an altitude of 1345 m, amsl. The surface area of the lake is about 0.46 km$^2$, maximum depth is about 24.7 m and storage capacity is about 5.27 Mm$^3$. Naukuchiatal is deepest of all the lakes of Kumaun lesser Himalaya. It is situated at 29° 19' N and 79° 35' E at an altitude of about 1320 m, amsl. The surface area of the lake is about 0.30 km$^2$, the maximum depth is about 42.7 m and storage capacity is about 5.17 Mm$^3$.and perimeter of the lake is about 3.13 km. The maximum

length is about 983 m and maximum width is about 693 m. Both the lakes are significant in terms of drinking water, irrigation requirements, fisheries, recreation and aesthetic values. Due to the various anthropogenic activities (intensive construction and increase in population), the lake and their respective catchments are suffering from various environmental problems, particularly since two decades. The study area is a sub-tropical climate region, with maximum temperature of 32°C during summer (May and June) and minimum temperature below 0°C during winter. The average annual rainfall of the study area is about 1600 mm.
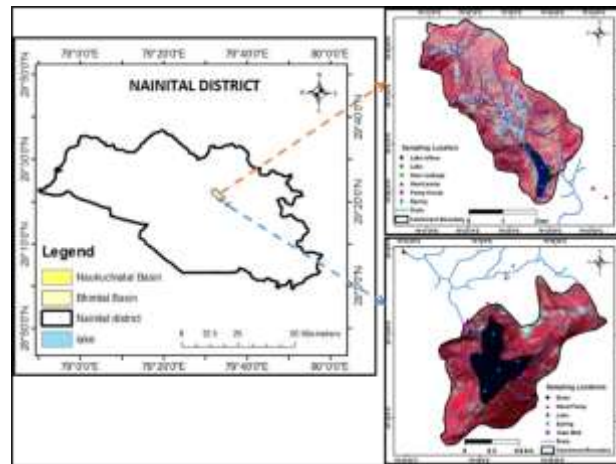


**Figure 1:** Study area map of Bhimtal and Naukuchiatal lakes

**Action Plan:**          As per activity schedule

**Achèvements vis-à-vis Objectives**

| Objectives | Achievements |
|---|---|
| To assess the seasonal water availability of the lakes and assess its adequacy in meeting future demands | Hydro-meteorological data required for the purpose is to be generated by IRI, Roorkee. Data are still awaited from IRI. |
| To assess the water quality of the lakes and possible causes of its degradation | Achieved |
| To estimate sedimentation rate and expected life of the lake | Achieved |
| To suggest a comprehensive plan for conservation and sustainable management of the lakes | To be prepared after all the analysis is completed. |

**Progress of work**
Number of field visits were undertaken during 2018-2021 and samples were collected for water quality and isotope analysis. Water quality analysis has been completed for the study covering two pre-monsoon and two post monsoon seasons. Isotopic analysis of samples have been collected till October 2020. The analysis has been completed. The data required for water balance etc which was supposed to be provided by IRI, Roorkee, has not been provided so far. However, efforts have been made to estimate evaporation rates from available meteorological data. All other components of water balance shall be possible to be estimated only after the required data are provide by IRI, Roorkee.

**Important results obtained:**
(i)     Bathymetric surveys of both the lakes have been carried out and depth-area-capacity curves have been developed.

(ii)     There is no declining trend in rainfall at the study area during 2004-2018.
(iii)    Lake water levels are significantly correlated with the rainfall. However, in case of Bhimtal lake the mean water level reached by the lake also shows some correlation with the dam leakage.
(iv)     Average monthly evaporation rates have been estimated for the for the study area based on available meteorological data (Figure 2). Average monthly evaporation from the Bhimtal lake varies from 1.4 mm/d (Dec., Jan) to 4.4.mm/d (May). Total evaporation losses from the lake are insignificant relative to the change in storage. They vary in the range of 0.01 MCM to 0.06 MCM.
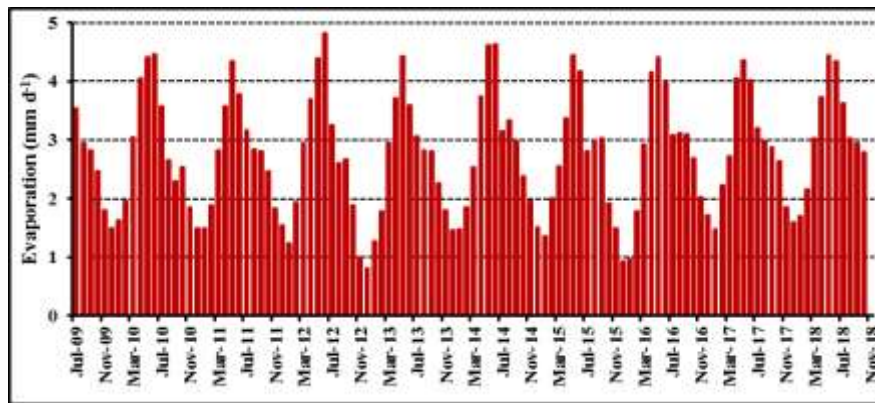


**Figure2:** Average monthly evaporation rates for the study area

(v)      The major LULC in the study area are agriculture, open forest and dense forest. The statistics clearly indicate that the agriculture has reduced significantly in the Bhimtal lake catchment from 40% in 2002 to 29% during 2018 while the built-up area has significantly increased from 5% to 16% during this period. In the Naukuchiatal lake catchment agriculture has reduced significantly from 48% in 2002 to 32% while the built-up area has increased from 3% to 9% in the same period.
(vi)     Analysis of d-excess for the study area indicates higher values during winter and lower values during the summer & monsoon periods. The higher d-excess during winter follows the reported pattern for the western Himalayas, due to moisture source from Mediterranean region.
(vii)    The isotopic values of Bhimtal lake water do not show any variation from mid-September to mid-March after which they start showing enrichment till mid-July due to evaporation of the lake. In case of Naukuchiatal lake there is not much variation in the isotopic signatures throughout the year. This indicates different hydrological behaviour of the two lakes (Fig. 3).



(a) Bhimtal                              (b) Naukuchiatal
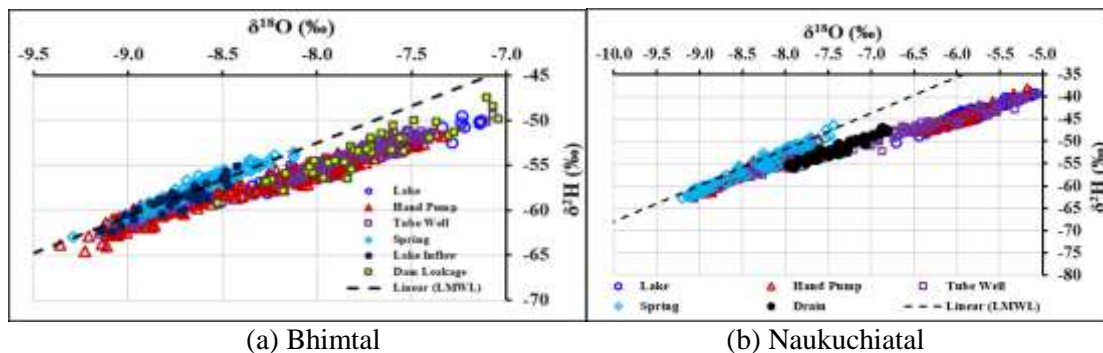
**Figure 2:** Isotopic variation of lake waters

(viii)   Isotopic investigations also indicate that the groundwater at some locations downstream of both the lakes are almost completely recharged by the lake while at some locations they are

recharged by the lake as well as by rainfall. The recharge source for all the springs in upstream of both lake catchments are observed to be precipitation.

(ix)   Water quality analysis brings out that the quality of the lakes water is mainly determined by the geochemistry of the catchments. $Ca^+$ and $Mg^+$ dominate as major cations in both the lakes and surrounding groundwater, while $HCO_3^-$ dominates as the major anions. The water type in both the lakes and catchments is basically calcium dominated because of the dominating limestone ($CaCo_3$) as a basement rock. Bhimtal lake also shows some organic pollution.

**Future Plan:** Water balance and conservation plan

**Activity Schedule:** Combined activity schedule of NIH & IRI

| SN | Activity | Quarter | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Year- I | | | | Year- II | | | | Year- III | | | |
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| **1.0** | **PREPARATORY WORK** | | | | | | | | | | | | |
| 1.1 | Reconnaissance survey,  Recruitment of project staff, Review of all available data/information, Procurement of instruments and peripherals, Installation of equipment etc | √ | √ | √ | √ | | | | | | | | |
| **2.0** | **FIELD WORK** | | | | | | | | | | | | |
| 2.1 | Generation  of hydro-meteorological | | √ | √ | √ | √ | √ | √ | √ | √ | | | |
| 2.2 | Collection of water samples for water quality analysis & Isotopes | | √ | √ | √ | √ | √ | √ | √ | √ | | | |
| 2.3 | Collection of sediment samples | | | √ | | | | | | | | | |
| 2.4 | Infiltration tests to determine Infiltration rates | | | √ | √ | | | | | | | | |
| 2.5 | Monitoring of discharge | | √ | √ | √ | √ | √ | √ | √ | √ | | | |
| 2.6 | Bathymetric Survey of lake | | √ | | | | | | | | | | |
| 2.7 | Monitoring of lake & GW  levels | | √ | √ | √ | √ | √ | √ | √ | √ | | | |
| **3.0** | **LABORATORY ANALYSIS** | | | | | | | | | | | | |
| 3.1 | Analysis of samples for Water Quality & Isotopes | | √ | √ | √ | √ | √ | √ | √ | √ | | | |
| **4.0** | **DATA INTERPRETATION & ANALYSIS** | | | | | | | | | | | | |
| 4.1 | Processing of bathymetric data | | | √ | √ | | | | | | | | |
| 4.2 | Development of depth-area-capacity curve for the lake | | | | √ | | | | | | | | |
| 4.3 | Preparation of other maps,  morphometric characterization and morphological analysis | | | √ | √ | | | | | | | | |
| 4.4 | Analysis of rainfall and other meteorological data | | | | | | | | | √ | | | |
| 4.5 | Estimation of  evaporation losses from the lake | | | | | | | | | | √ | | |
| 4.6 | Assessment of  lake-ground water interaction | | | | | | | | | | √ | | |
| 4.7 | Estimation of water balance of the lake | | | | | | | | | | √ | √ | |
| 4.8 | Isotopic characterization of waters of study area | | | | | | | | | √ | | | |
| 4.9 | To develop local meteoric water line | | | | | | | | | √ | | | |
| 4.10 | To estimate sedimentation rate of the lake | | | | | | | | | √ | | | |
| 4.11 | To assess the water quality of the lake | | | √ | | √ | | √ | | √ | | | |
| 4.12 | Assessment of  suitability of lake water for various uses | | | | | | | | | | | √ | |
| 4.13 | To develop conservation plan for the lake | | | | | | | | | | | √ | |
| **5.0** | **PREPERATION OF REPORT** | | | | | | | | | | | | |
| 5.1 | Preparation of Interim Project Report | | | | √ | | | | √ | | | | |
| 5.2 | Preparation of Final Project Report | | | | | | | | | | | | √ |
| **6.0** | **ORGANIZATION OF TRAINING WORKSHOP** | Post-Project | | | | | | | | | | | |

| | |
|---|---|
| **Title of the Study:** | **UNRAVELLING SUBMARINE GROUNDWATER DISCHARGE (SGD) ZONES ALONG THE INDIAN SUBCONTINENTS AND ITS ISLANDS** |
| **Study Group:** | Sudhir Kumar (PI), SM Pingale, BK Purandara, YRS Rao |
| **Collaborating Institutions:** | RC Kakinada and Belagavi |
| **Type of Study:** | Sponsored Project, National Centre for Earth Science Studies, (Thiruvananthapuram), Ministry of Earth Sciences, Government of India |
| **Budget:** | Rs 46.44 Lakhs |
| **Nature of Study:** | Applied Research |
| **Date of start:** | March 2019 |
| **Scheduled date of completion:** | Dec, 2021 |
| **Duration of the Study:** | 1 ¾ Year |

**Study area:** The study area included the coastal districts of West Bengal (i.e. Purba Medinipur, North & South 24 Parganas) (Fig.1).

**Objectives:**

i. To collect archival data of groundwater (GW level, GW chemistry, aquifer properties, lithology etc.) in the potential SGD zones in the coastal aquifers.
ii. To investigate the SGD zones using Landsat 8 thermal infrared images.
iii. To collect water samples from open/bore wells at every average 1 km along the coast at selected intervals.
iv. To measure salinity and temperature of sediment pore water, groundwater and seawater
v. To collect data on water temperature, salinity, Alkalinity, DO, pH, DIC, DOC, Silicon and Nutrients, dissolved inorganic nutrients: Silica (Si); nitrate and nitrite (N+N); ammonium (NH4); and phosphate (PO4), Oxygen and Hydrogen isotope for selected locations where SGD has been identified using thermal imaging or hydrogeological surveys.
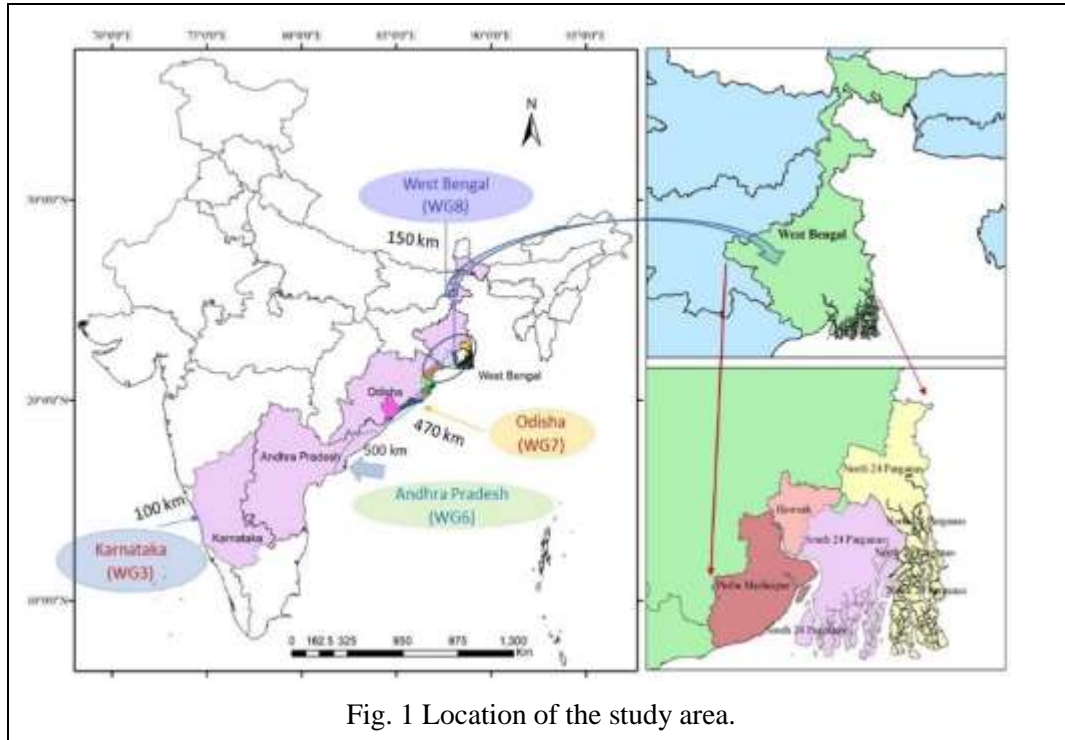
Fig. 1 Location of the study area.

## Achievement vis-à-vis Objectives (as on date)

| Objectives | Achievements |
|---|---|
| To collect archival data of groundwater (GW level & chemistry, aquifer properties, hydrogeology etc.) in the potential SGD zones | • Literature survey have been completed on SGD.<br>• Collected archival data related with groundwater from different sources in the potential SGD zones located the coastal aquifers.<br>• Detail analysis is completed. |
| To investigate the SGD zones using Landsat 8 thermal infrared images. | • Digital Elevation Model (DEM) (30m) was downloaded and Landsat 8 remote sensing data for the pre and post monsoon season (2017, 2018 & 2019) for the different time period have been obtained and processed (Fig. 2).<br>• Detail analysis is completed. |
| To collect water samples from open/bore wells at every average 1 km along the coast at selected intervals. | • Water samples [groundwater (bore well/hand pump), pore water, seawater] for chemical and stable isotope analysis have been collected in the coastal district of Purba Medinipur.<br>• Detail analysis is completed. |
| To measure salinity and temperature of sediment pore water, groundwater and seawater | • The in-situ salinity and temperature measurement of pore water, groundwater and seawater water have been carried out for the selected locations in the Purba Medinipur district.<br>• Detail analysis is completed. |
| To collect data on water temperature, salinity, Alkalinity, DO, pH, DIC, DOC, Silicon and Nutrients, dissolved inorganic nutrients: Silica (Si); nitrate and nitrite (N+N); ammonium (NH4); and phosphate (PO4), Oxygen and Hydrogen isotope for selected locations where SGD has been identified using thermal imaging | • The some of the water quality data related with pore water, groundwater and seawater have been collected. The water quality parameters and Radon concentrations have been directly determined in the field. While water samples have been collected for $\delta^{18}O$ and $\delta^{2}H$ isotope for selected locations.<br>• Temporal plots of the isotopic composition of water samples and Local Meteoric Water Line (LMWL) has been established using $\delta^{18}O$ and $\delta^{2}H$ of pore water, groundwater and seawater for the study region.<br>• Detail analysis of $\delta^{18}O$, $\delta^{2}H$, Radon and water chemistry is |

159

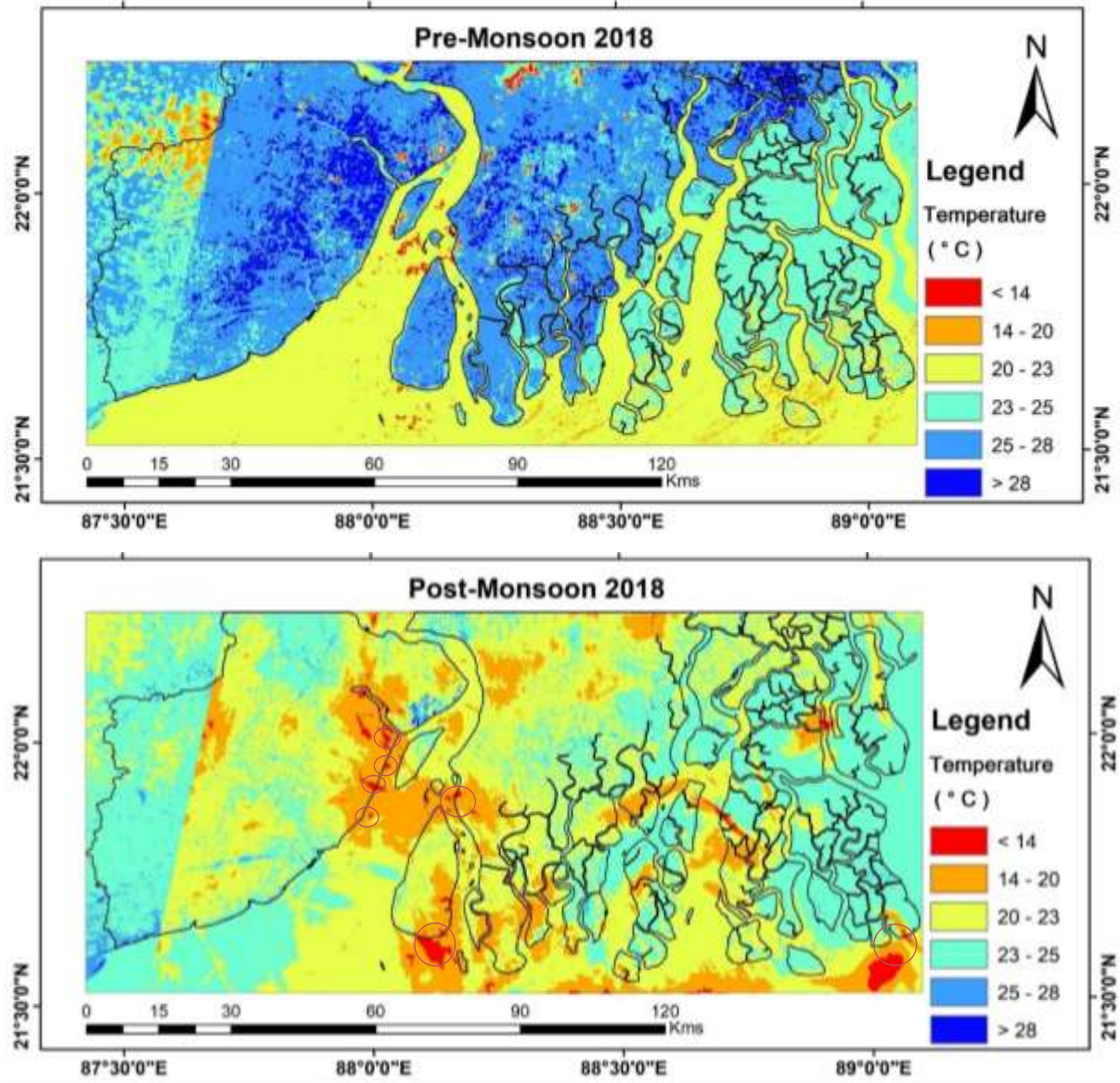| or hydrogeological surveys. | completed for the collected samples. |
| --- | --- |
| | • The linkages between the isotopic signature of water, its chemistry, and hydrogeological processes is established for the identification of possible SGD zones in the study area. |
| | • Signature SGD and SWI locations were identified (Fig.3). |



Fig. 2 Land surface temperature estimation using Landsat8 thermal infrared imageries over the coastal districts of West Bengal of the year 2018
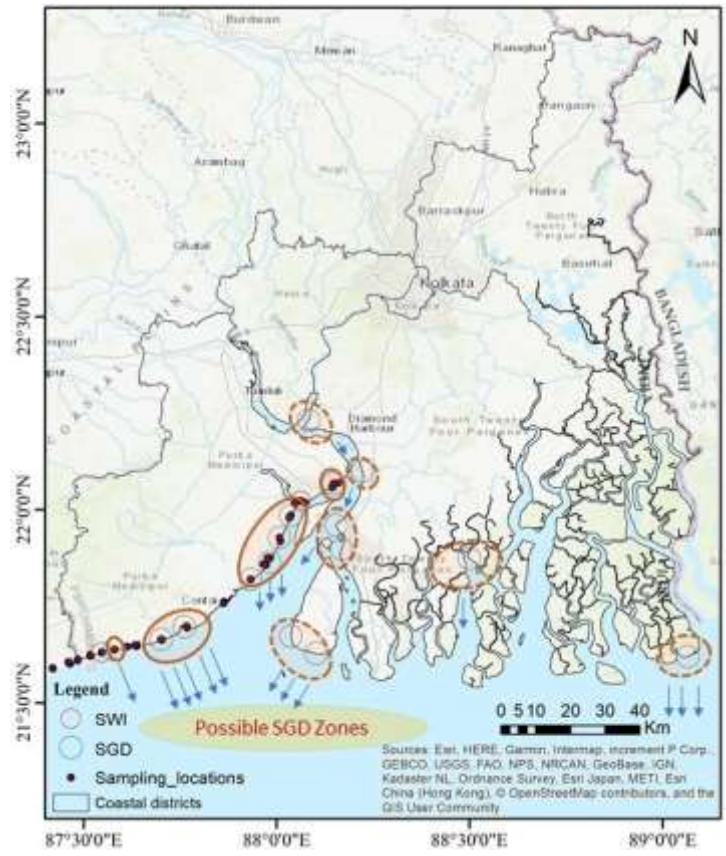
Fig. 3 Possible zones of SGD & SWI in the coastal regions of West Bengal.

**Project has been completed and final report has been submitted to the sponsoring agency.**

161

## 2. *PROJECT REFERENCE CODE: SP-42/2019-2021/HID*

| | |
|---|---|
| **Title of the Study:** | **GROUNDWATER REJUVENATION AS CLIMATE CHANGE RESILIENCE FOR MARGINALIZED AND GENDER SENSITIVE GANGES (GRACERS)** |
| **Study Group:** | Sudhir Kumar (PI), S.M. Pingale |
| **Collaborating Institutions:** | IHE Delft through IIT Bombay |
| **Type of Study:** | Sponsored Project, |
| **Budget:** | Euro 18400 |
| **Nature of Study:** | Applied Research |
| **Date of start:** | May 2019 |
| **Scheduled date of completion:** | May 2021 extended project till September 2022 |
| **Duration of the Study:** | 2 Years |

**Statement of the problem**

Due to the combined effect of climate change and anthropogenic activities, many tributaries of the Ganges River are changing from perennial to seasonal. As a result, the groundwater levels in the Ganges basin are also fast declining and are affecting the rural communities. Augmentation of groundwater recharge is very important to meet the water demands of the different users by increasing groundwater availability. A study in collaboration with IIT Bombay has been taken up to develop decentralized/distributed groundwater recharge scheme for a part of Purba Medinipur district in West Bengal. This site has witnessed unsustainable groundwater extractions, less natural groundwater recharge and groundwater pollution.

**Objectives:**

The main research objective is to identify hot-spots for decentralized and distributed groundwater recharge networks.

**Specific Objectives for the NIH team**

- To identify socio-economic stress due to poor groundwater quality and quantity.
- To identify limitations in groundwater recharge due to centralized water supply schemes.
- To develop conceptual groundwater model to understand current water stress and future water stress.
- To quantify the changes in Land Use/Land Cover (LULC) to assess the degree of anthropogenic impact on groundwater levels in the study area.
- To provide scientifically validated management plans for up-scaling distributed groundwater recharge networks.

**Study area:**

The study area is selected in the Nandigram and Haldia block of the Purba Medinipur district (Fig.1), highlighting the problem of groundwater table decline at alarming rate. Water Authority has notified the area and has imposed embargo on further exploitation of fresh water from the aquifer occurring within the depth of 120–300 metres below ground level (mbgl). Major Problems in the area are (i) Groundwater depletion, (ii) Water quality (salinity in the upper aquifers), and (iii) Lack of proper implementation of existing legislative acts for guiding the groundwater extraction.
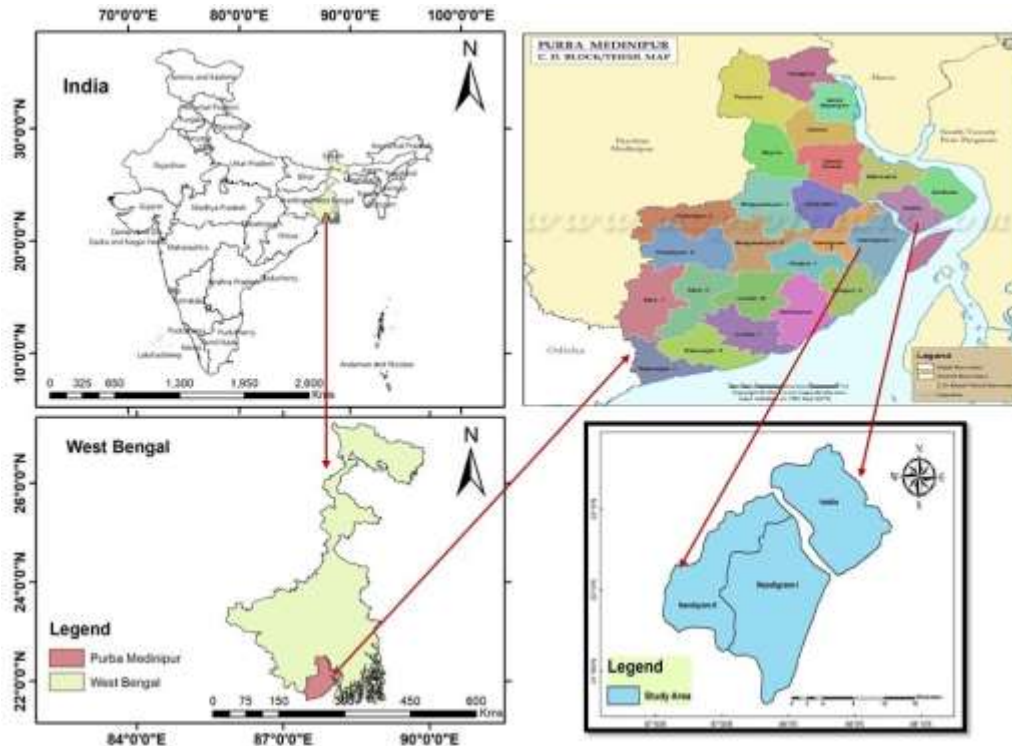
Fig. 1 Location of the study area (i.e. Nandigram & Haldia blocks)

**Methodology:** The adopted methodology involves field investigations and collection of hydrological, meteorological, groundwater quality, geological, topographic and LULC data from different sources. A social survey would be conducted to understand the water related health and social issues. The collected data will be analysed to prepare a situation analysis report, groundwater potential and recharge estimates. A conceptual model would be constructed to understand current water stress and future water stress. The changes in LULC shall be assessed to quantify the degree of anthropogenic impact on groundwater levels in the basin. Data related to aquifer characteristics will be procured from State and Central water related agencies.

**Progress of the work:**
- Literature survey have been completed related with study.
- Primary and secondary data from different sources have been collected.
- We have made field investigations in the Nandigram & Haldia blocks of Purba Medinipur district in West Bengal. Measured groundwater levels and collected groundwater samples for stable isotope analysis ($\delta^{18}O$ and $\delta^2H$). Also, performed in-situ measurement of groundwater quality parameters (e.g., salinity, temperature, EC, pH, TDS) using multi-parameter water quality analyser (Fig. 2).
- Some of the data related with groundwater, its chemistry, general aquifer properties and hydrogeology have been collected from CGWB & SWID.
- Historical groundwater level data of different groundwater observation wells in the selected blocks have been collected from CGWB and SWID and analyzed (e.g. Fig.3). This is prepared to understand the groundwater dynamics in the study area.
- We have conducted a one-day stakeholders consultation workshop on March 22, 2022 at Haldia in collaboration with IIT Bombay & local support of the State Water Investigation Directorate (SWID), Government of West Bengal (Fig.4). The workshop was focused on the groundwater depletion scenario in the Haldia and Nandigram blocks. The project findings are shared with local stakeholders and government officials.
- Obtained hydro-climatic data for groundwater analysis and detail analysis is in progress.

Fig. 2 Groundwater level measurement & groundwater quality analysis at Haldia & Nandigram blocks
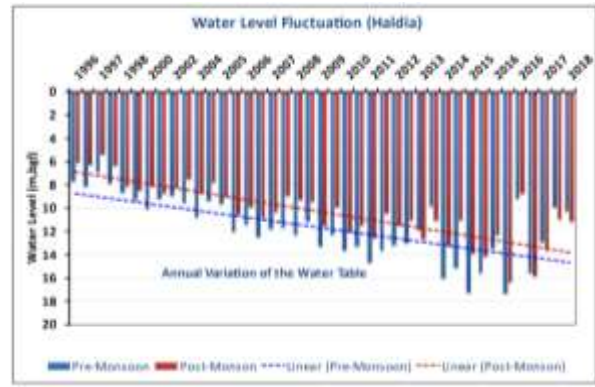

Fig. 3 Water table Fluctuation of Haldia block for Twenty Year (1996 to 2018) (CGWB, 2021)


Fig. 4 Stakeholders consultation workshop at Haldia

**Future Plan**:

- Additional field visits are required in the study area (Haldia and Nandigram Block) for data collection, survey and stakeholder's discussions.
- Hydro-stratigraphic cross section across the study area to understand the flow of groundwater system.
- Conceptual model based on data collected.
- Development of groundwater vulnerability maps and potential recharge zone map of the study area.

**7.0** *PROJECT CODE:* **NIH-21_2017_31**

| | |
|---|---|
| **Title of the Study:** | WEB GIS BASED SPRING INVENTORY FOR VULNERABILITY ASSESSMENT AND HYDRO-GEOLOGICAL INVESTIGATION OF SELECTED SPRINGS FOR SUSTAINING LOCAL WATER DEMAND IN RAVI CATCHMENT OF HIMACHAL PRADESH |
| **Study Team:** | S S Rawat (P.I.), Sudhir Kumar, P G Jose, Suman Gurjar, and D S Bisht |
| **Collaborating agencies:** | Himachal Pradesh Jal Shakti Vibhag |
| **Type of Study:** | Sponsored (under NHP-PDS) |
| **Funding Agency:** | World Bank |
| **Budget:** | Rs. 69.00 lakh |
| **Duration of Study:** | 04 Years (August 2017 to March 2022) (to be extended up to Sept., 2022) |

**Study Area:** Ravi River catchment of Himachal Pradesh having an area of about 5400 sq. km is the area selected for this study (Fig. 1). Hilly part of the Ravi River catchment completely falls in hill Chamba district and almost entire Chamba district drains into Ravi River. Geographically, Chamba is the second largest district of the Himachal Pradesh and significant part of the district is under scheduled tribes (highest ST population in the state). Topographically catchment having very rugged terrain and elevation varies from 467 m to 5872 m, amsl. All four agro-climatic zone of the state found only in this district i.e. Shivalik hill zone (350-650 amsl), Mid zone (650-1800 amsl), High hill zone (1800-2200 amsl), Cold dry zone (>2200 amsl, snowfall).
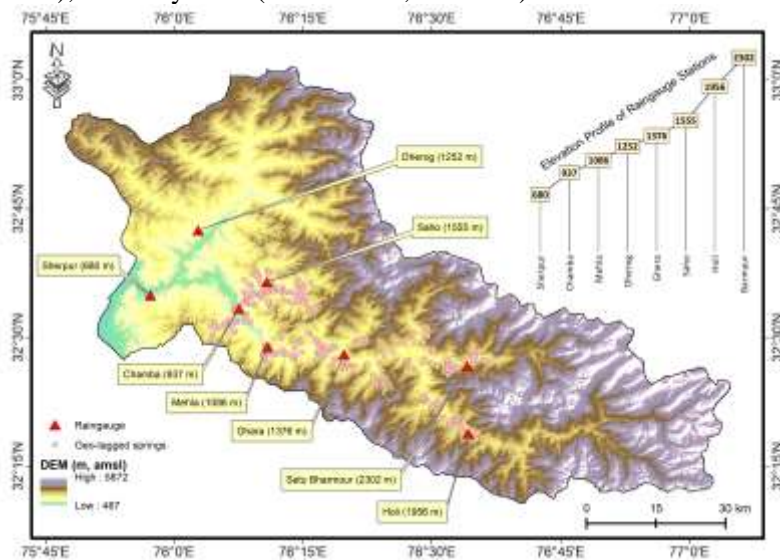


**Fig. 1: Study area showing location of raingauges.**

**Objectives:**
- ➢ Creation of web-enabled database of the springs emerging in the catchment based on extensive inventory of physical and hydro-chemical characteristics.
- ➢ Mapping of vulnerable springs using hot-spot analysis.
- ➢ Hydrogeological investigation of some selected springs, which are vulnerable and having high societal importance for identification of their spring-shed area and potential.
- ➢ To suggest adaptive strategies for selected hot-spot springs for spring sanctuary development to sustain the local water demand.
- ➢ To build capacity among the local stakeholders through creating para-hydrogeologists for conserving and managing the springs.

**Statement of the Problem:**

The demand for the water in the rural areas is much higher than in urban areas as a majority of the population of the Himachal Pradesh, a Himalayan state of India, lives in the rural areas. Furthermore, there is an imbalance between the supply and consumption of water, particularly by the poor and weaker section of society, the traditional sources (normally springs) of water play a significant role. There are 10512 traditional sources of water in the Himachal Pradesh for drinking water in rural habitats (Survey of status of drinking water in rural habitats, 1991-93). Chamba district has about 2598 traditional water sources, which are maximum among all the districts of the state. According to Himachal Pradesh Human Resource Development Report (2002), water demand for the population of Chamba district will increase from 36.53 mld (2001) to 58.04 mld (2021). About 85% of this total water demand is from the rural areas that are largely dependent on traditional water resources. HP State Council for Science, Technology and Environment has carried out a survey in 169 *Panchayats* of seven districts in the state of Himachal Pradesh on traditional water sources, which clearly showed that there were only 30% sources in good working condition and recharging properly throughout the year, while 70% sources were not in proper working condition and going to dry up in near future. In Chamba district, less than 1% sources were found working well, while more than 99% were in poor condition. It is worth noting that the entire Chamba district is part of Ravi River basin. Keeping in view of the importance of traditional water resources in sustaining the water demand of the state, a Purpose Driven Study (PDS) has been taken under National Hydrology Project (NHP) for investigations of the springs of Ravi River Catchment of Himachal Pradesh.

**Brief Methodology:**

➢ Conducting the Survey using handheld GPS
➢ Preparation of GIS layers and Base line data collection
➢ Development of Web-GIS Information System using open source technologies such as Geo-Server, Post-GIS, HTML, Java etc.
➢ Identify the vulnerable springs through Hot-spot analysis
➢ Identification of recharge area using the integration of Hydro-geo-chemical and isotopic analysis.

**Progress of Work/Results and Analysis:**

➢ Spring survey work for the entire Ravi River catchment of Himachal Pradesh (≈5400 sq. km) has completed. Total 925 springs have been geotagged, surveyed and water samples collected for water quality analysis.
➢ Samples for water quality analysis for all surveyed springs were collected and analysis in water quality lab at WHRC, Jammu. Total 14 water quality parameters viz. pH, EC, $Ca^{+2}$, $NO_3^+$, $SO_4^-$, $F^-$, $SiO_2$, $K^+$, Fe, $Na^+$, $Cl^-$, $HCO_3^-$, $CO_3^{-2}$ and alkalinity have been quantified.
➢ Web-GIS based portal named, ISHVAR (**I**nformation **S**ystem of **H**imalayan springs for **V**ulnerability **A**ssessment and **R**ejuvenation) having the information of 925 surveyed springs on 35+ parameters have been created with all supporting GIS layers and geotagged spring photographs (Fig. 2). All springs data are also available in the form of infographics for easy to understand.
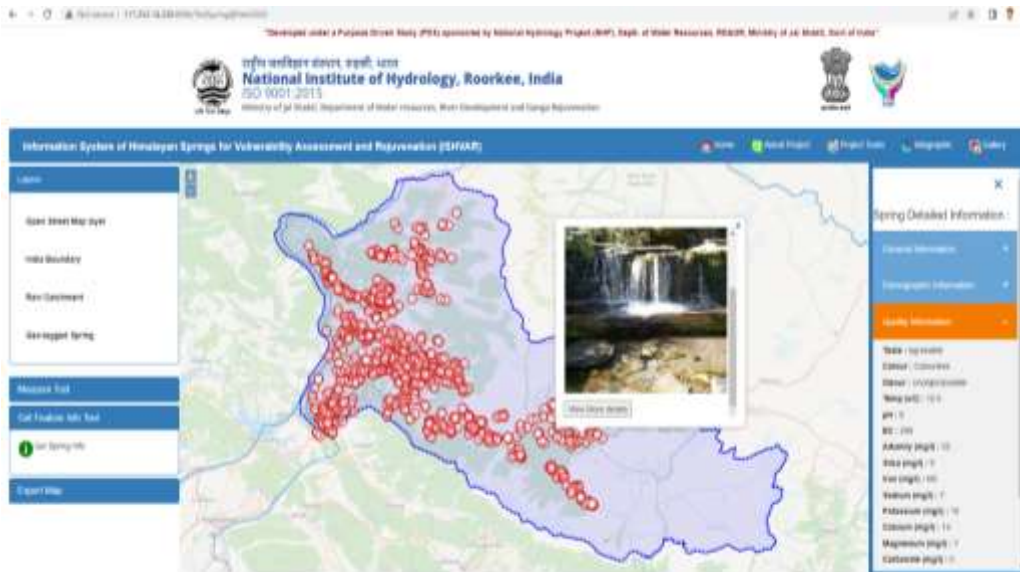
Fig. 2: Developed GIS based Web-Portal (ISHVAR) under NHP-PDS.

- Daily Rainfall data at 07 different locations (Sherpur, Dherog, Sahu, Mahela, Gera, Holi and Bharmaur) of the catchment are being observed and rainfall samples for isotopic analysis are being collected since July, 2021.
- Daily discharge of twelve springs of the catchment are being monitored and isotopic samples are also collected since July, 2021 for understanding the hydrological behaviour of the springs in different parts of the catchment.
- Field investigation was conducted during 18-24 November, 2021 with the geologist hired for geological investigation in Ravi river catchment. During the field visits in-situ water quality investigations of selected springs and nearby water bodies were performed (Fig. 3). Geological investigation was performed for identification of typology of 35 vulnerable springs in the area (Fig 4).



Fig 3: Field investigation for in-situ water quality analysis and geological investigation in Ravi River catchment.

Fig 4. Geological map with selected spring location map of the Ravi river basin. Modified after Webb, (2013); Thakur et al., 2019; Srikantia, and Bhargava, (2021).

**Future Work:**
- ➢ To identify the recharge area of selected springs.
- ➢ To develop the adaptive measures for revival of the springs.

**9.0** *PROJECT* REFERENCE CODE*: SP/38/2019-22/RCJ*

| | |
|---|---|
| **Title of the Study:** | **WEB-ENABLED INVENTORY OF NATURAL WATER SPRINGS OF TAWI RIVER CATCHMENT OF JAMMU AND KASHMIR STATE OF INDIA FOR VULNERABILITY ANALYSIS AND DEVELOPING ADAPTIVE MEASURES FOR SUSTAINING TAWI RIVER** |
| **Study Team:** | S S Rawat (P.I.), P G Jose, Suman Gurjar, and D S Bisht |
| **Collaborating agencies:** | Dept. of Soil and Water Conservation, Govt. of Jammu & Kashmir |
| **Type of Study:** | Sponsored (under NMHS) |
| **Funding Agency:** | Ministry of Environment, Forest & Climate Change, Govt. of India |
| **Budget:** | Rs. 38.04 lakh |
| **Duration of Study:** | 03 Years (January 2019 to September 2022) |

**Study Area:**

The present study is focused on the Tawi River Catchment (Fig. 1). Tawi River is a major river that flows from Jammu division of Jammu and Kashmir. Tawi River, also called the lifeline of the two major district (Jammu and Udhampur) of Jammu region, is the left bank tributary of river Chenab originating from the lapse of Kali Kundi spring area southwest of Bhadarwah in Doda district. After originating from the Doda district of Jammu region it enters into the Udhampur district where it flows for its maximum length and enters Jammu district and finally merges with river Chenab in Pakistan. The length of River from its originating point to Jammu is about 150 km. Total catchment area of the river Tawi is about 2168 km$^2$ up to Jammu region. Catchment area of the Tawi River lies in the four most populous districts of Jammu divison i.e. Jammu (21.56% area of Tawi catchment), Udhampur (71.6%), Reasi (4.8%) and Samba (1.7%). The Tawi River has a very high social impact as it is the only major source of water for drinking, agricultural and industrial needs, and it serves to the almost 20% population of the whole J&K state. About 250 villages of these four districts fall in the Tawi catchment directly depend on Tawi River or nearby springs for their drinking as well domestic water needs. Since, there is no glacier present in the Tawi catchment, springs are the only available sources that maintain the flow of the river Tawi in lean season. The average altitude of the catchment is about 2200 m above mean sea level (amsl). The catchment elevation varied from 4000 m amsl in the upstream to about 300 m amsl in the plains.

**Objectives:**

➤ Creation of GIS based web-enabled database of the springs emerging in Tawi River catchment based on extensive inventory of physical and hydro-chemical characteristics.
➤ Identification of vulnerable springs using hot-spot analysis.
➤ Hydro-geological investigation of some selected springs, which are vulnerable and having high societal importance for identification of their spring-shed area and potential.
➤ To suggest adaptive strategies for selected hot-spot springs for spring sanctuary development to sustain the local water demand.
➤ To build capacity among the local stakeholders through creating para-hydrogeologists.
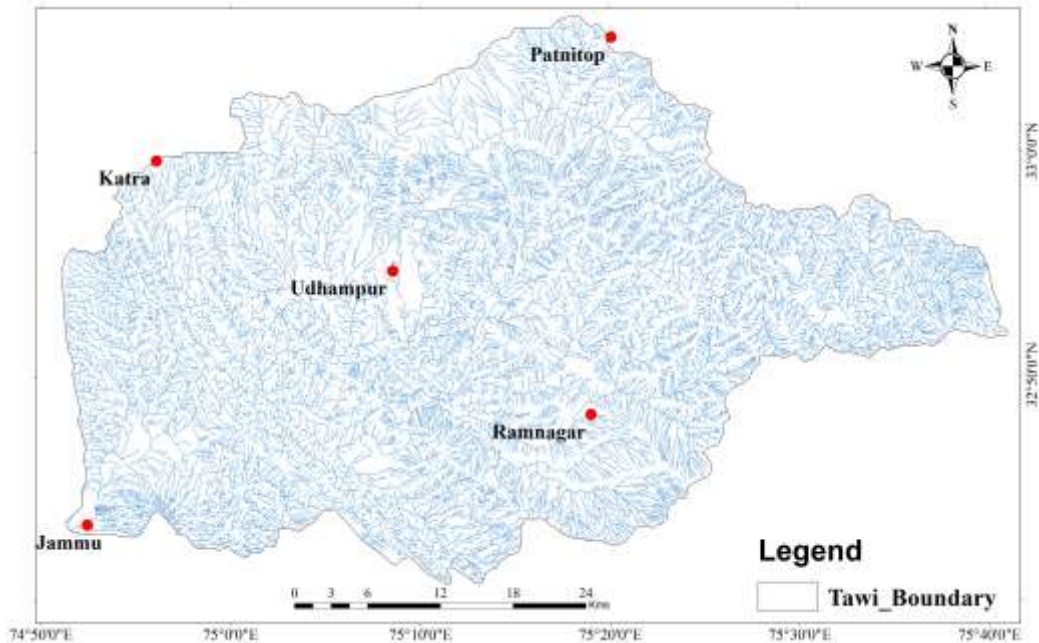
**Fig. 1: Tawi River catchment of Jammu and Kashmir and its drainage network**

**Statement of the Problem:**

River Tawi is the major river in Jammu region and its importance for sustaining the most populous cities in the region, Jammu and Udhampur, has been considered while selecting the basin. About 250 villages of four districts Jammu, Udhampur, Riasi and Samba fall in the Tawi catchment and depend upon Tawi River and springs in its catchment for their drinking as well domestic water demand. As per SOI toposheets more than 350 major springs are emerging from Tawi catchment and are responsible for maintaining the base flow of the River, which also is important for sustaining the artificial lake and Tawi Riverfront Development Project, which are under construction. There is hardly any water flowing in River Tawi during lean season and the people of the area face acute shortage of water impacting their very livelihoods. A previous study carried out by National Institute of Hydrology (NIH), Roorkee indicates that the discharge flux in Tawi is declining at the rate of 23 MCM per year. Water demand in the catchment is on the rise due to rapid urbanization and high population growth (20% per decade). In view of cultural, social and hydrological importance of Tawi catchment and lack of base data on springs, the proposed project has immense significance for the sustainable water resource management in the catchment wherein revival of drying springs will play a vital role.

**Brief Methodology:**

➢ Conducting the Survey using mobile app
➢ Preparation of GIS layers and Base line data collection
➢ Development of Web-GIS Information System using open source technologies such as Geo-Server, Post-GIS, HTML, Java etc.
➢ Identify the vulnerable springs through Hot-spot analysis
➢ Identification of recharge area using the integration of Hydro-geo-chemical and isotopic analysis.

**Progress of Work/Results and Analysis:**

➢ For collecting the data for creating spring inventory a survey form covering questionnaire to various parameters related to the springs has been created in KoBo tool box (Fig. 1). These parameters have been monitored during field visits and the spring photos have been geo-

170

tagged. A total of 47 parameters have been recorded in the field which cover all the general, spatial, social and demographic factors related to the spring.

➢ Spring survey work for Tawi river catchment up to Jammu (2168 sq. km) has completed. Total of 500 springs have been geotagged and surveyed.
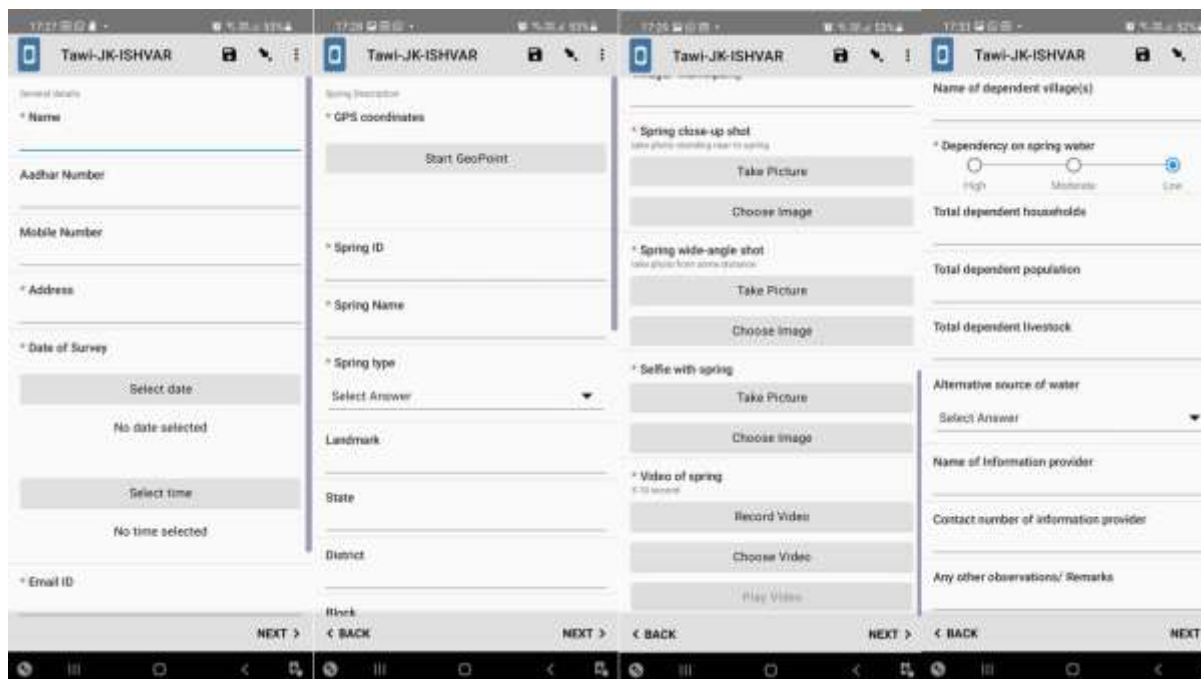


Fig. 1: Spring data collection app in KoBo tool box.

➢ Samples for water quality analysis for all surveyed springs are being conducted in the lab.

➢ Spring web-portal for Tawi catchment having the information of 300 surveyed springs on 47 parameters have been created with all supporting GIS layers and geotagged spring photographs (Fig 2). However, data compilation for the remaining springs are in progress.

➢ Seven raingauge stations i.e. Jammu (282 m, amsl), Udhampur (750 m, amsl), Pangara Jagir (766 m amsl) Chennani (1210 m, amsl), Jagir (1488 m amsl) and Mantalai (1650 m, amsl) have been established and daily rainfall data is being measured since July, 2021.

➢ 08 springs, representing the different parts of the catchment, have been selected for detailed study. Daily discharge data for these springs have been recorded since July 2021.

➢ Two days' online training workshop on 'Tools and Techniques for Springshed Management' was organized for the stakeholders of the Tawi catchment during 06-07. 01.2022 at WHRC, Jammu (Fig. 3)

**Future Work:**

➢ To compile the data of springs on the developed web-portal for complete inventory of springs of Tawi catchment.

➢ To prepare local geological maps and demarcation of recharge area of selected springs.

➢ To develop the adaptive measures for revival of the selected springs.
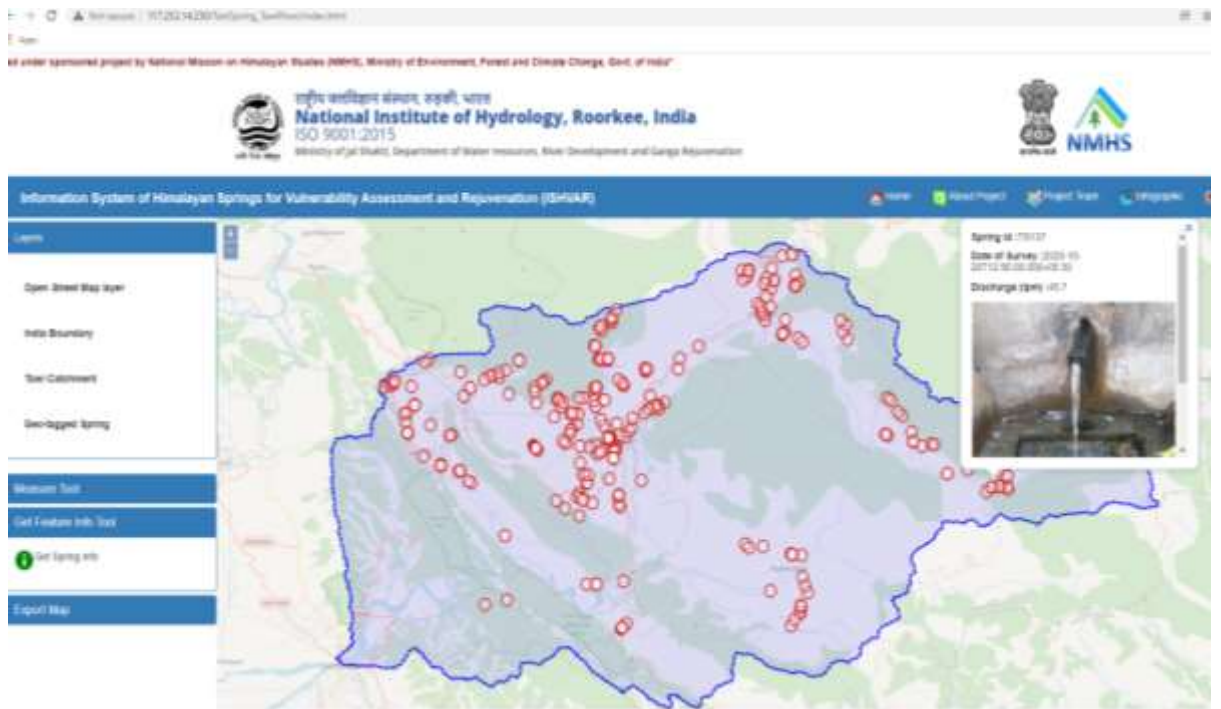
Fig. 2: Web-GIS based spring portal for Tawi catchment of Jammu & Kashmir.
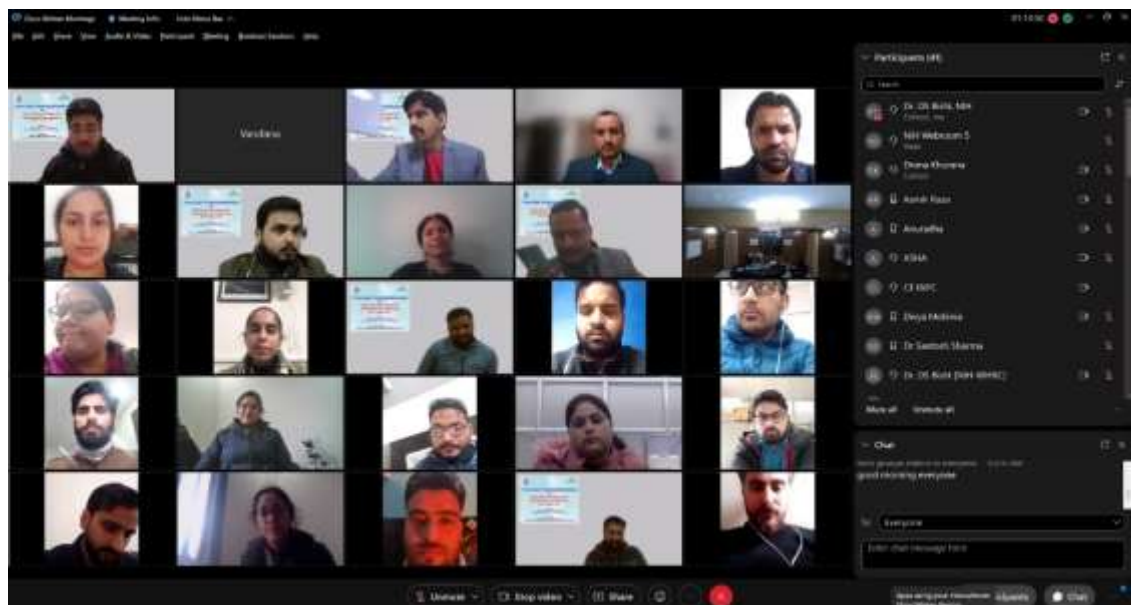


Fig. 3: Training workshop for the stakeholders of the Tawi catchment.

**NEW STUDIES PROPOSED FOR 2022-23**


**INTERNAL STUDIES**


*1. PROJECT REFERENCE CODE:  NIH/HID/R&D/2022/1*


| | |
|---|---|
| **Study Title:** | **ASSESSMENT OF THE POSSIBLE IMPACT OF CLIMATE CHANGE ON EVAPOTRANSPIRATION FOR DIFFERENT CLIMATIC REGIONS OF INDIA** |
| **Study Team:** | SD Khobragade (PI), Dr. Vishal Singh, Scientist-C, Dr. Sudhir Kumar, Sc-G; |
| **Type of Study:** | Institute Funded R & D Study |
| **Duration:** | 3 years |
| **Date of Start:** | April, 2022 |
| **Date of Completion:** | March, 2025 |
| **Budget:** | 10 Lakh |

**Statement of Problem:**
Evapotranspiration is one of the key components of the hydrologic cycle. Precipitation which falls on the land is subjected to evaporation and evapotranspiration before it reaches back to the oceans, causing a significant loss of the available water. Increasing scarcity of water due to increased ET losses may lead to difficulties in meeting the various demands of the growing population and its development needs. Most of the water bodies in the warm tropical regions undergo heavy evaporation losses. As per the CWC (2006) report, average annual evaporation loss from reservoirs/water bodies in India is about 27,000 MCM.  As such, any change in evapotranspiration is likely to significantly affect the global hydrologic as well as energy cycle (IPCC, 2013). Being a cause of significant water loss, evapotranspiration plays a major role in determining the stream flow regime. Therefore, understanding the impact of temperature rise or climate change on evapotranspiration is essential for a proper understanding of the impact of climate change on the hydrological regime of the stream and water availability in the basin or water body.  It shall provide a proper assessment of how much more or less water shall be available and, if less water is available, then how much additional water shall be required to meet the various demands. Unfortunately, not many studies have been reported on assessment of impact of climate change on evaporation and Evapotranspiration, more so for India.


**Objectives:**
The major objectives of the proposed study are: ·
  i)   To assess the present ET regime of some selected climatic regions of India
  ii)  To assess the impact of rising temperature on various hydro-meteorological parameters used for ET assessment
  iii) To predict and compare the possible impact of climate change on ET regimes of the selected climatic regions of India


**Study Area**
The study is proposed to be carried out for different climatic regions of India. About five areas shall be identified to represent different climatic regions. The selection of the study area shall be based on the availability of required data vis-à-vis the identified methodology.


**Present state-of-art**
A plethora of literature is available on the possible impacts of temperature rise and climate change on the hydrologic cycle.  Unfortunately, only a limited number of these studies are related to the assessment of the impact specifically on the process of evapotranspiration.  It can be illustrated from 5th assessment report of IPCC also.  Many of the reported studies related to climate change impact are based on trend analysis of the evaporation data, particularly the pan evaporation data. These studies report mixed findings with increase predicted for some regions and decrease for some other. Few

studies have also been reported using the output from the global or regional circulation models and coupling it with the hydrological models. As far as India is concerned, although one of the initial studies on climate change impact on evaporation using GCM simulations was reported in the last decade of the previous millennium by Chattopadhyay and Hulme (1997), which projected a decrease in the potential evapotranspiration, not may studies using GCM or RCM data have been reported since then. Most impact studies related to evaporation or evapotranspiration for different regions of India deal with analysis of trends in pan evaporation or reference evaporation data ( Verma et al.,2008; Jaswal et al., Jhajharia et al.,2009; Bandopadhyay et al., 2009, Padmakumari et al.,2013; ; Annu priya et al., 2014, Goroshi et al. , 2017). The reported studies clearly indicate that evaporation paradox has been observed in most parts of India. However, more and more studies using the projected outputs from the atmospheric circulation models and using them as input in the Penman-Monteith model are required for the picture to become clearer.

## Justification for the study

Climate change and the associated temperature rise is expected to significantly affect the hydrologic cycle in general and its various components in particular, necessarily including evapotranspiration. The knowledge of the possible impact of climate change on evaporation and evapotranspiration is particularly important because in water stressed regions of the world, like India, any increase in future ET losses may play a significant or even a deciding role in the water availability and management of such regions. As such, knowledge about the impact of climate change on ET is one of the most essential aspect of preparedness for future water management in view of climate change. Unfortunately, not many studies have been reported on assessment of possible impact of climate change on evaporation or ET in India. The proposed study intends to fill the gap.

## Brief Methodology

i)      The present average ET rates for selected climatic regions of India shall be estimated from the present hydro-meteorological data of last few decades, using the Penman-Monteith model

ii)     All temperature dependent hydro-meteorological paramours shall be identified.

iii)    Projected climatic data variables such as minimum and maximum temperature from the latest GCMs developed under CMIP6 project shall be obtained to analyze the impact of climate change on ET factors.

iv)     For this purpose, the evaluation of four best GCMs with SSP245 and SSP585 scenarios

v)      (total eight scenarios) will be done for selected climatic regions and then the bias correction and spatial downscaling of the GCM variables will be performed for selected climatic regions of India.

vi)     The downscaled and bias corrected GCM variables shall be used as input to the Penman-Monteith model and future changes in ET rates will be estimated by performing probabilistic linear and non-linear trends analysis (e.g. Quantile regression, Q-Q plots, and CDF).

vii)    The present and projected ET rates shall be compared to assess the impact of climate change on ET variability (in terms of magnitude of change) for different regions.

viii)   The present and predicted rates of different climatic regions shall be compared and factors responsible variation shall be identified

## Research outcome/Deliverable from the project

i)   Comprehensive Project Report including all data, maps, information, analysis and results. The report would contain comparative impact of climate change on ET for different climatic regions of India.

ii)  Research Publications

**Beneficiary/End User**
The outcome of the study shall be useful for all the state and central government agencies dealing with water management. It would also be useful for the researchers working in the area of impact of climate change on hydrology and water resources.

**Budget Justification:**
The budget is required for procurement/collection of data.

**Work Plan/Activity Chart:**

As given in activity schedule below. :

## ACTIVITY SCHEDULE

| SN | Activity | Year- I | | | | Year- II | | | | Year- III | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| **1.0** | **PREPARATORY WORK** | | | | | | | | | | | | |
| 1.1 | Collection & Review of all available data/information/literature | √ | √ | √ | √ | √ | √ | | | | | | |
| 1.2 | Selection of study area representing different climatic regions of India | √ | √ | | | | | | | | | | |
| 1.3 | Preparation of study area maps | | √ | √ | | | | | | | | | |
| 1.4 | Procurement & compilation of meteorological data of different selected climatic regions of India | √ | √ | √ | | | | | | | | | |
| 1.4 | Downloading and processing of meteorological and GCM datasets | √ | √ | √ | √ | √ | | | | | | | |
| **2.0** | **DATA PROCESSING & ANALYSIS** | | | | | | | | | | | | |
| 2.1 | Estimation of present ET rates for selected climatic regions of India | | | | | √ | √ | | | | | | |
| 2.2 | Assessment of the impact of temperature rise on different temperature dependent hydro-meteorological parameters & their inter-comparison for the selected climatic regions | | | √ | √ | √ | √ | √ | √ | | | | |
| 2.3 | Prediction of the possible impact of climate change on future ET using GCMs for the selected climatic regions of India & their inter-comparison | | | | | √ | √ | √ | √ | √ | √ | √ | |
| **3.0** | **PREPERATION OF REPORT** | | | | | | | | | | | | |
| 3.1 | Interim report -1 | | | | | | √ | | | | | | |
| 3.2 | Interim Report-2 | | | | | | | | | | √ | | |
| 3.3 | Draft final report | | | | | | | | | | | | √ |

**Thrust Area:** Sustainable water systems management: Adaptation of hydro-system to climate change

**Title of the Project:** Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions

**Study group**

Dr. Soban Singh Rawat, Scientist 'E' **(Project Investigator)**
Dr. Sudhir Kumar, Scientist 'G', and Head, HID
Dr. Santosh M. Pingale, Scientist 'C', HID
Dr. P K Mishra, Scientist 'D', WRS
Dr. D. S. Bisht, Scientist 'B', WHRC, Jammu
Dr Rajesh Singh, Scientist 'D', EHD

**Type of Study:**      Internal funding

**Objectives:** The present study will be carried out with the following objectives:

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

**Study area**

The present study will be carried out Bilangana and Pratapnagar CD blocks of Tehri Garhwal district and Ukhimath CD block of Rudraprayag district of Uttarakhand state of India (Fig. 1).
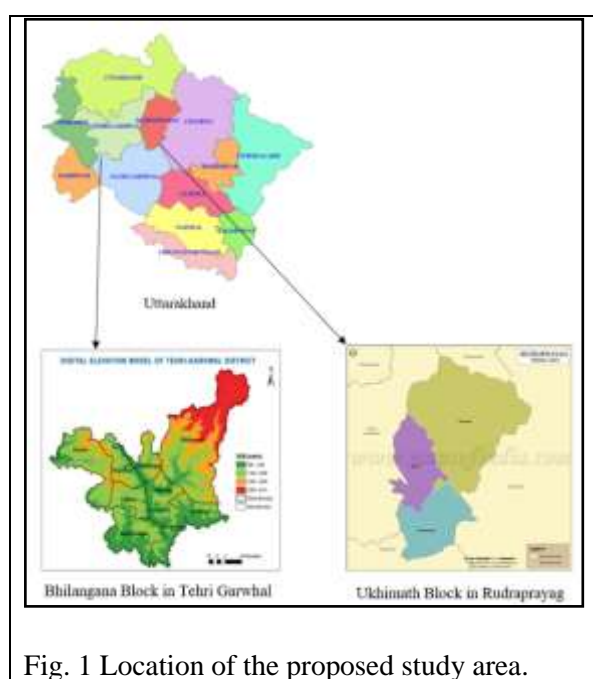


Fig. 1 Location of the proposed study area.

**Present state-of-art**

The springshed project was taken up at the instance of a decision taken in the meeting of Secretary, MoWR on 20.03.2019 that CGWB & Survey of India (SoI) may prepare a proposal for pilot project in some districts of Uttarakhand through which Ganga is flowing. CGWB, UR recommended that the pilot project can be taken up in one of the three districts Uttarkashi, Tehri Garhwal & Almora. Survey of India has submitted the timeline & cost estimate for drone based systematic mapping of spring, 100% inventory of all springs & their ground-truthing, delineating springsheds, creation of 3-D model of springsheds and preparation of Atlas for Tehri Garhwal District under the guidance of CGWB. As NMCG was already carrying out project with SoI, another project was also taken up for drone study in Tehri Garhwal District & CGWB was advised to take up a pilot study in one area in the district. Accordingly, Pratpnagar Block (about 439 Sq Km), Tehri Garhwal District was identified for pilot study. Due to various procurement related issues, there has been a delay in 3 the drone survey of Tehri Garhwal district by SoI. Consequently, Ministry has accorded approval for taking up management & restorative initiatives for spring rejuvenation activity in Bhilangana C.D block of Tehri Garhwal (about 1093 sq Km.) & Ukhimath C.D. block (about 1081 sqkm), of Rudraprayag district for which the LiDAR DEM is already available with SoI. By using DEM, point cloud and ORI of Manu Project in Bilangana CD block of Tehri Garhwal District and Ukhimath CD block of Rudraprayag District & drone mounted LiDAR data of Pratpnagar Block, Tehri Garhwal District, spring identification and demarcation of spring shed will be carried out by SoI and shared with CGWB. District Administrations will be approached for carrying out the preparation of DPR for spring rejuvenation structures by MGNREGS & execution of DPR through MGNREGS fund in Bhilangana & Pratapnagar blocks of Tehri Garhwal district & Ukhimath block of Rudraprayag district. In view of the man power constraints, it was decided to take up the study through outsourcing work. As NIH has already completed spring study in parts of Himachal Pradesh & has also prepared a web based application for spring data storage (ISHVAR - Information System of Himalayan Springs for Vulnerability Assessment and Rejuvenation), it was felt prudent to utilize the expertise of NIH in springshed work.

**Scope of Work**

In order to achieve the objective, the scope of work for the project in three blocks with timeline is detailed as under:

➢ SoI will provide spring inventory, i.e. Spatial attributes (lat long/ Easting Northing) of Springs, along with DEM and Topographical features such as Roads, Water bodies, Buildings, Contours etc. SoI will carry out springshed atlas and share it with CGWB.

➢ The initiation of the project duration will be considered from the day of receiving the information from SoI for each of the three blocks.

➢ The project will be taken up one block at a time with a broad time line as given below:

| Project | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 | M10 | M11 | M12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bhilangana C.D block, Tehri Garhwal District | | | | | | | | | | | | |

| Project | M13 | M14 | M15 | M16 | M17 | M18 | M19 | M20 | M21 | M22 | M23 | M24 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ukhimath C.D. block, Rudraprayag District | | | | | | | | | | | | |

| Project | M25 | M26 | M27 | M28 | M29 | M30 | M31 | M32 | M33 | M34 | M35 | M36 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pratapnagar block, Tehri Garhwal district | | | | | | | | | | | | |

Detailed month wise timeline for different activities in a block

- Detailed month wise timeline for each activity in a particular block is prepared and the entire duration for one block is kept one year. However, the duration of the activity "Validation of spring map, creation of spring inventory and updation of spring atlas" will vary for different blocks as geographical area and topography of three block as selected in this study are significantly differ and the spring population is yet not given by the SoI. However, total duration of the project will not be affected. Blocks selected for this study will be taken one by one and the activities and month wise timeline for one block is as follows:

| Sl. No. | Activity | Agency-Responsible | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 | M10 | M11 | M12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Validation & Ground truthing of the spring maps prepared by SoI* | NIH | ▨ | ▨ | ▨ | ▨ | ▨ | ▨ | | | | | | |
| 2 | Web-GIS Spring Inventory/Atlas creation and updation | NIH | | | | | ▨ | ▨ | | | | | | |
| 3 | Identification of Vulnerable Spring & field validation based on the list provided by stakeholders & SoI** | NIH & CGWB | | | ▨ | ▨ | ▨ | ▨ | | | | | | |
| 4 | Springshed mapping & identification of Recharge areas for springs | CGWB | | | | ▨ | ▨ | ▨ | ▨ | | | | | |
| 6 | Identification of Type & No of AR Structures for sustainability of | CGWB | | | | | ▨ | ▨ | ▨ | ▨ | | | | |

178

| Sl. No. | Activity | Agency-Responsible | M1 | M2 | M3 | M4 | M5 | M6 | M7 | M8 | M9 | M10 | M11 | M12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spring | | | | | | ▓ | ▓ | ▓ | ▓ | | | | |
| 7 | Capacity Building of Stake Holders | NIH | | | | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ |
| 8 | Preparation of DPR*** | State Agency dealing with execution of MGNERGS | | | | | | ▓ | ▓ | ▓ | | | | |
| 9 | Monitoring of work | CGWB | | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ |
| 10 | Execution of Work through MGNREGS Fund by State Government*** | District Administration | | | | | | | | ▓ | ▓ | ▓ | | |
| 11 | Continued Monitoring for Impact assessment | CGWB | | | | | | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ |
| 12 | Final Report on Project Outcome | CGWB & NIH | | | | | | | | ▓ | ▓ | ▓ | ▓ | ▓ |

**Methodology**

(i) **Validation/Geotagging of Springs**:

Springs identified by the SOI will validate through their geographical coordinates. In addition to this springs which are nearby settlement will be geotagged and surveyed through mobile App developed in KoBo tool.

**(ii) Information collection through field survey**:

The following information will be collected through mobile-app based survey:
 (a) General information (latitude, longitude, elevation, village, gram panchayat, tehsil, district, Spring type & Nature, Purpose of use, discharge, people perception about discharge, lean and peak month of discharge, month of muddy water, name and telephone of information provider, name and mobile number of gram pradhan);
 (b) Demographic information (dependent villages, household, population, livestock, dependency, land ownership at spring point and upstream side, land use at spring point and upstream side), and
 (c) Water quality information (taste, colour, odour, pH, EC, TDS, ORP, DO)

**(iii) Springs Water Quality Analysis**

The spring water is the sole source of drinking water and other domestic applications inthe villages of the study area, therefore, necessitating the water quality evaluation of these springs, for identifying

sources of contamination and implementation of corrective actions, to ensure the safety of drinking water and in turn the human health. In addition, a baseline water quality inventory will be developed for the policy makers. Department of Drinking Water & Sanitation, GOI has recommended monitoring of at least thirteen basic minimum parameters (pH, turbidity, TDS, Total Hardness, alkalinity, fluoride, chloride, sulphate, nitrate, arsenic, iron) in drinking water samples. Apart from these parameters, other parameters as per geology and local conditions (some heavy metals for some representative springs and some bacteriological parameters such as TC & FC) that may hamper the human health should be analyzed.

**(iv)      Development of Web-GIS Information System and Infographic tool**

A Web-GIS application will be configured using ArcGIS Web App-builder. The Web-GIS application will be able to respond to Spatial and Attribute based queries, and generation of report, chart, summary etc. It will allow viewer to click on spatial feature to retrieve all information on screen. A configurable operation dashboard will also be developed using ESRI application. The dashboard will provide status of key performance indicator in the form of graphs/charts/maps to users and policy makers.

**(v)      Identification of vulnerable springs**

Vulnerable springs will be identified based on "Hardship Ranking System" in which springs are ranked in term of the information collected during spring survey on their importance for users and their present status.  A spring with high scores will be declared as vulnerable, while those with less scores will be treated as 'sensitive' which may become vulnerable in future. Identified vulnerable springs will be treated as priority for various rejuvenation or revival programme to be taken by concerned departments of the district.

**(vi)      Capacity building programme**

Need base training programme will be organized for the personnel of Himachal Pradesh Jal Shakti Vibhag and local stakeholder for understanding the hydro-geology and chemistry of springs so that they can themselves formulate the Spring revival programme in future.

**6.      Final Outcome**

- Efficacy of use of modern technologies for spring mapping.

- Identification of vulnerable springs and ensure the sustainability of these springs through construction of artificial recharge/water conservation structures.

- Creation of detailed spring map of Pratapnagar & Bhilangana blocks of Tehri Garhwal District & Ukhimath block of Rudraprayag district.

- Updation of database of springs of the project area, in web portal (ISHVAR) developed by NIH

- Impact assessment study would lead to formulation of guideline for future projects on spring rejuvenation.

- The capacity building program will make the stakeholders aware about the necessity of water conservation and artificial recharge for sustainability and management of springs/aquifers in hilly region.

**Budget estimates**

a. The total cost of the project (03 Years duration): **Rs 39.55 lakh**

b. Source of funding: Internal funding from NIH

c. Sub Head wise abstract of the cost

| S. No. | Head | Amount (Rs) |
|---|---|---|
| 1 | Salary (01 JRF @31000/month + HRA and 01 Field Worker@ 18000/month + HRA) | 19,05,120 |
| 2 | Travelling expenditure | 6,00,000 |
| 3 | Infrastructure/Equipment (Multi parameter water quality kit) | 1,00,000 |
| 4 | Consumables (Chemicals and plastic wares) | 9,00,000 |
| 5 | Capacity building (training & Workshop for stakeholders & implementing agencies) | 3,00,000 |
| 5 | Contingency | 1,50,000 |
| | **Total** | **39,55,120** |

**SPONSORED PROJECT**

| | |
|---|---|
| **Title of the Study:** | **Changing the fate of the Hindon river by evaluating the impact of agriculture on the water balance: Developing a template for a cleaner Ganga river** |
| **Study Team:** | Dr. Sudhir Kumar, (Project Coordinator), Dr. M. K. Sharma, (Principal Investigator), Dr. R. P. Pandey, Dr. Suhas Khobragade, Dr.Anupma Sharma, Ms. Anjali, Dr. Vishal Singh, Dr. SM Pingale, Dr.Pradeep Kumar, Dr.Nitesh Patidar, Dr.Surjeet Singh. |
| **Collaborating agencies:** | IIT Kanpur |
| **Type of Study:** | Sponsored by DST (under DST-NOW call) |
| **Funding Agency:** | Department of Science and Technology, GoI |
| **Budget:** | Rs. 240 lakh |
| **Duration of Study:** | 05 Years (April 2022 to March 2027 |

**Study Objectives**

This research aims at providing scientific understanding on the hydrological functioning and the impact of agricultural water management of the Hindon subbasin of the Ganges river. Three areas of research are distinguished:

1) 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.
2) Interventions to improve agricultural water management and reduce negative impacts on water quantity and quality.
3) Develop recommendations for improvements in Hindon basin water quantity and quality, food production and economic revenues.

**Statement of the Problem**

River Hindon, an important tributary of river Yamuna flowing through the districts of Western Uttar Pradesh, is subjected to varying degree of pollution caused by numerous untreated and/or partially treated waste inputs of municipal and industrial effluents. The toxic pollutants from these wastes will ultimately reach the ground water and enter in the food chain posing a threat to human health because of their carcinogenic nature. The pollution matrix in some stretches of the river becomes so complicated that anaerobic and septic condition prevails during the lean period due to discharge of effluents to the river from various industries and municipal areas. Though a large number of studies, to understand the pollution aspects of river Hindon, have been carried out by different workers (Verma and Mathur, 1971; Verma and Dalela, 1975; Verma et al., 1980; Patel et al., 1985; Singhal et al., 1987; Joshi et al., 1987; Seth, 1991; Seth and Singhal, 1994; Khare, 1994; Kumar, 1994; Lokesh, 1996; Jain, 1996, 2000; Kumar, 1997; Jain and Ali, 2000; Jain and Ram, 1997a, 1997b; Jain and Sharma, 2001a, 2002, 2006; Jain et al., 1997, 1998a, 1998b, 2002, 2003, 2004a, 2004b, 2005, 2007; Sharma, 2001; Sharma et al., 2009a, 2009b), but no comprehensive and holistic plan for rejuvenation of river has been attempted. This requires monitoring of water resources and pollutants within the river basin through data collection, modeling of river water and groundwater interaction and interpretation. Further hydrological study of the basin is important to understand the surface and groundwater interaction. Water Balance in Hindon River Basin will provide water allocation for different sectors for better

water management in the basin. Reach-wise recharge augmentation plan may be implemented by identification of affluent and effluent sections in the river.

**10.     Approved Action Plan/Methodology**

i)      Literature review and collection of data from published reports and papers.
ii)     Procurement of secondary data required for the analysis from various govt. agencies (discharge, rainfall, landuse/landcover, lithology, ground water level, aquifer parameters, sediment concentration, other water quality parameters, soil map etc.)
iii)    Monitoring of water quality of River Hindon monthly basis for one year
iv)     Study the relationships between different hydrological parameters
v)      An inventory of pollution sources contributing to the River will be prepared from the collected information and Major Contaminant zones will be identified.
vi)     Identification of affluent and effluent sections of River Hindon.
vii)    Water Balance of Hindon River Basin using SWAT-MODFLOW model
viii)   Reach-wise Recharge augmentation plan will be suggested

**11.     Work schedule / Timeline**

| Year | Month | Consortium Activity | NIH action plan |
|---|---|---|---|
| 2022-23 | Apr - Jun, 2022 | Preparatory activities like approvals etc. | • Hiring of Project staff<br>• Meetings with IIT K for formulating plans for field Visits<br>• Forwarding request to state govt. for data<br>• Literature Review |
|  | Jul - Sep, 2022 | Start of the project Kick of Meeting Hiring of Staff, PhD Creation of Advisory Board | • Administrative Approval for Equipment<br>• Kick off Meeting and formal introduction of the members involved, role and responsibilities allocation.<br>• Combined field visit of IIT K and NIH for G&D site and piezo-site locations. |
|  | Oct - Dec, 2022 | • Designing Observational Network<br>• Identification of farms, urban and industry locations | • Installation of Piezometers and G&D sites<br>• Inventory of pollution sources<br>• Survey for morphometric analysis of river Hindon<br>• Health, Agricultural and drinking issues identification. |
|  | Jan - Mar 2023 | Stakeholders Identification Installation of Base network and bathymetry Measurement | • Creation of Pollution Inventory<br>• Stakeholders Identification<br>• Groundwater level trend analasys<br>• Water quality over years inventory |
| Year-2<br><br>2023-24 | Apr - Jun, 2023 | Field investigations | • Soil, Groundwater and river water quality sample collection and analysis |

| | Jul - Sep, 2023 | Data preparation for IHE-FEWS | • Contribute to FEWS data platform |
|---|---|---|---|
| | Oct - Dec, 2023 | • Stakeholders Meeting<br>• Field investigations | • Stakeholders Meeting<br>• River discharge and water quality,<br>• Groundwater levels and water quality |
| | Jan - Mar 2024 | Report writing | • Preparation of Interim report<br>• Scientific paper writing |
| Year-3<br><br>2024-25 | Apr - Jun, 2024 | Data collection | • Groundwater and river water quality sample collection and analysis |
| | Jul - Sep, 2024 | Groundwater Investigation | • Recharge Estimation for Hindon river Basin<br>• Estimation of Parameters for Groundwater Model Development. |
| | Oct - Dec, 2024 | Mid- Project stakeholders meetings | • Stakeholders Meeting |
| | Jan - Mar 2025 | Data interpretation and Report writing | • Preparation of Interim report<br>• Scientific paper writing |
| Year-4<br><br>2025-26 | Apr - Jun, 2025 | Data collection | Groundwater and river water quality sample collection |
| | Jul - Sep, 2025 | Sample analysis | Groundwater and river water analysis |
| | Oct - Dec, 2025 | Scientific Advisory Board Meetings | Final Groundwater-surface water interaction Model |
| | Jan - Mar 2026 | Stakeholders Workshop<br><br>Result sharing and analysis | Effluent and affluent zone identification.<br>And integration of individual developed models |
| Year-5<br><br>2026-27 | Apr - Jun, 2026 | Development of GW Model | Development of GW Model |
| | Jul - Sep, 2026 | Calibration and Validation of the model | Calibration and Validation of the model |
| | Oct - Dec, 2026 | Data analysis and interpretation | Suggestions and measures for Hindon rejuvenation |
| | Jan – Mar, 2027 | Advisory Board Meetings for project finalization | Working on finalization of results with Dutch Partners. |

# SURFACE WATER HYDROLOGY DIVISION

**Scientific Manpower**

| S N | Name | Designation |
|---|---|---|
| 1 | Dr. A K Lohani | Scientist G & Head |
| 2 | Dr. S K Singh | Scientist F |
| 3 | Dr. P C Nayak | Scientist F |
| 4 | Dr. Sanjay Kumar | Scientist F |
| 5 | Dr. Archana Sarkar | Scientist F |
| 6 | Dr. L N Thakural | Scientist D |
| 7 | Er. J P Patra | Scientist D |
| 8 | Dr. Ashwini A. Ranade | Scientist C |
| 9 | Dr. Sunil Gurrapu | Scientist C |
| 10 | Sri N K Bhatnagar | Scientist B |
| 11 | Sri Om Prakash | PRA |
| 12 | Sri Jatin Malhotra | SRA |

| COMPLETED STUDIES (SPONSORED) | | | |
|---|---|---|---|
| **S. No. & Ref. Code** | **Title** | **Study Team** | **Duration** |
| 1.NIH/SWHD/16-21 | Hydrological modelling in Alaknanda basin and assessment of climate change impact (NMSHE) | A.K. Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakanthan L.N. Thakural | Proposed for 5 years (April 2016 to March 2021) **Completed in time and report submitted** |
| 2.NIH/SWHD/19-22 | Rainfall-Runoff Modelling of Selected Basin based on LULC pattern and development of Correlation (NHP) | A.K. Lohani R.K. Jaiswal Sushant Jain WRD Rajasthan Sanjay Agarwal Shailendra Kumar | Proposed for 2.5 years (Oct. 2019 to April 2022) **Completed in Time** |

| ONGOING STUDIES (SPONSORED) | | | |
|---|---|---|---|
| **S. No. & Ref. Code** | **Title** | **Study Team** | **Duration** |
| 1. NIH/SWHD/19-23 | Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh (NHP) | P C Nayak Y.R.Satyaji Rao A.K. Lohani B. Venkatesh A. R. S. Senthil Kumar T. Thomas | 3 year (Sept 2019 to April 2023) |

| COMPLETED STUDIES (INTERNAL) | | | |
|---|---|---|---|
| **S. No. & Ref. Code** | **Title** | **Study Team** | **Duration** |
| 1.NIH/SWHD/21-22 | Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Mahi & Sabermati subzone – 3a (2) Upper Narmada - 3e. | S.K. Singh | Proposed for One year (April 2021 to March 2022) **Completed in Time** |
| 2.NIH/SWHD/18-20 | Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin | Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu | Initially proposed for 2 years (Nov. 2018 to October 2020) **Further extended to 2.5 years more and report not yet submitted** |

| | | | i.e. total duration Oct 2018 to March 2022 (4.5 Years) |
|---|---|---|---|
| 3.NIH/SWHD/18-21 | Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario. | Ashwini Ranade Archana Sarkar | 3 years (April 2018 to March 2021) Extended upto September 2021 **Completed in 3.5 Years** |
| 4.NIH/SWHD/18-21 | Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent | Sunil Gurrapu Ashwini Ranade J.P. Patra | Proposed for 3 years (Nov 2018 to October 2021) **Completed in Time** |


| ONGOING STUDIES (INTERNAL) | | | |
|---|---|---|---|
| **S. No. & Ref. Code** | **Title** | **Study Team** | **Duration** |
| 1.NIH/SWHD/20-22 | Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan. | J.P. Patra Rakesh Kumar Pankaj Mani Sunil Gurrapu | 2 years (July 2020 to August 2022 |
| 2.NIH/SWHD/21-23 | Uncertainty in rating curves and discharge estimation | Sanjay Kumar L. N. Thakural Sunil Gurrapu N.K. Bhatnagar J P Patra | 2 Years (April 2021 to March 2023) |

**Recommended Work Programme for the year 2022-23**

| ONGOING STUDIES (SPONSORED) | | | |
|---|---|---|---|
| **S. No. & Ref. Code** | **Title** | **Study Team** | **Duration** |
| 1. NIH/SWHD/19-23 | Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh (NHP) | P C Nayak<br>Y.R.Satyaji Rao<br>A.K. Lohani<br>B. Venkatesh<br>A. R. S. Senthil Kumar<br>T. Thomas | 3 year (Sept 2019 to April 2023) |

| ONGOING STUDIES (INTERNAL) | | | |
|---|---|---|---|
| **S. No. & Ref. Code** | **Title** | **Study Team** | **Duration** |
| 1.NIH/SWHD/ 20- 22 | Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan. | J.P. Patra<br>Rakesh Kumar<br>Pankaj Mani<br>Sunil Gurrapu | 2 years (July 2020 to August 2022 |
| 2.NIH/SWHD/ 21-23 | Uncertainty in rating curves and discharge estimation | Sanjay Kumar<br>L. N. Thakural<br>Sunil Gurrapu<br>N.K. Bhatnagar<br>J P Patra | 2 Years (April 2021 to March 2023) |

| NEW STUDIES (INTERNAL) | | | |
|---|---|---|---|
| **S. No. & Ref. Code** | **Title** | **Study Team** | **Duration** |
| 1.NIH/SWHD/ 22-22 | Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Operation of Reservoirs | A. K. Lohani, (PI)<br>R. K. Jaiswal<br>J. C. Patra<br>P. C. Nayak<br>Vishal Singh | Two Years April 2022 – March 2024 |
| 2.NIH/SWHD/ 22-23 | Application of unified-extreme-value (UEV) distribution for flood frequency: selected rivers of U.S.A. | S.K. Singh | Six month (April 2022 to Sept. 2022) |
| 3.NIH/SWHD/ 22-25 | Application of unified-extreme-value (UEV) distribution for flood frequency: Comparison of results using GEV distribution | S.K. Singh | Six month (Oct. 2022 to March 2023) |
| 4.NIH/SWHD/ 22-24 | Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model | P. C. Nayak<br>A. K. Lohani<br>J. P. Patra<br>Sunil Gurrapu<br>T. Thomas<br>Om Prakash<br>Jatin Malhotra | 3 Year (July 2022 to June 2025) |
| 5.NIH/SWHD/ 22-25 | Hydrological Study to conserve the water resources of Bikaner, Rajasthan | L. N. Thakural<br>M. K. Sharma<br>R. K. Jaiswal<br>J. P. Patra | 2 Year (July 2022 to June 2024) |

| | | P. K. Mishra Nitesh Patidaar N. K. Bhatnagar Jatin Malhotra Anil Kumar Chhangani | |
|---|---|---|---|
| 6.NIH/SWHD/ 22-24 | Review of design flood and dam break analysis of Khadakhai Dam in Odisha | J.P.Patra A. K. Lohani Pankaj Mani P. C. Nayak Sanjay Kumar | 3 Year (April 2022 to March 2025) |
| 7.NIH/SWHD/ 22-25 | Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin | Sunil Gurrapu Y R S Rao Nitesh Patidar R Venkat Raman | 2 Year (April 2022 to March 2024) |
| 8.NIH/SWHD/ 22-23 | Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes | Ashwini Ranade P.K. Mishra Sunil Gurrapu | 3 years (April 2022 to March 2025) |
| 9.NIH/SWHD/ 22-23 | Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics | Archana Sarkar Jyoti Patil Rohit Sambare Charu Pandey | 1.5 Year (May 2022 to Oct 2023) |

**1. PROJECT REFERENCE CODE: NIH/SWHD/16-21**

1. Project Title:
   Hydrological modelling in Alaknanda basin and assessment of climate change impact
   (DST Sanction  No: SP-06)

2. PI (Name & Address):
   Dr. A.K. Lohani, Scientist-G, Surface Water Hydrology Division, NIH Roorkee

3. Co-PI (Name & Address): Dr Sanjay Kumar Jain, Scientist G, Head WRS Div. NIH Roorkee

4. Approved Objectives of the Proposal
   - To model stream flow/snow melt runoff in Alaknanda Basin.

   - To investigate the impact of likely future changes in climate on stream flow in the study area using future climate scenarios.

   - To estimate seasonally varying Temperature Lapse Rate (TLR) using LST data estimated from thermal satellite image in Alaknanda basin.

Date of Start: January, 2016
Total cost of Project: 42.296 (Rs. in Lakh)

Date of completion: Sept 2021(**Completed**)

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

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

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

191

## 6. Salient Research Achievements (summary of progress):

Variable Infiltration Capacity Model (VIC) and WinSRM models have been applied for the study area. VIC is a grid-based macro-scale hydrological model with sub-grid variability in land surface vegetation classes and soil moisture storage capacity. In VIC model, drainage from the lower soil moisture zone (base flow) as a nonlinear recession. While, SRM is a degree-day based, conceptual and deterministic model and can simulate the runoff from snowmelt in basins. Further, it was decided to extend the study upto Rishikesh. Both VIC and WinSRM models were again setup for the extended study area i.e. upto Rishikesh. Both the models were calibrated and validated at Rishikesh gauging site. The INCCC (Model - CCCma_CanESM2) for climate change were applied under RCP 4.5 scenario, to examine climate influences on precipitation and temperature in the basin. Temperature and precipitation were determined for this scenario for three periods of 2006-2040, 2041-2070 and 2071-2099. After calibration and validation on the present time (2000-2015), the VIC and SRM models were used to study the impact of climate variability on the Upper Ganga basin runoff. The future climate scenario for mean temperature, precipitation and snow cover area were used to estimate the relative stream flow in the future for water resources management. Results of the VIC model are presented in Figure 1.
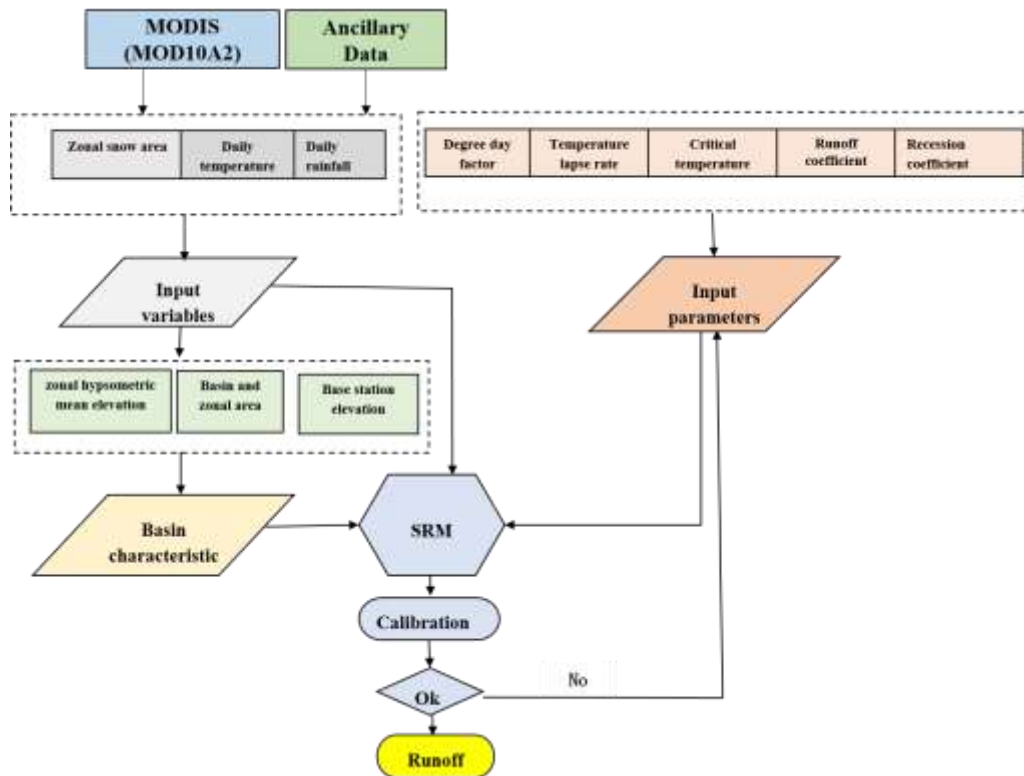


Figure 1: Workflow of SRM Model

## Studying impact of climate variability

Climate change is an important environmental issue, as progression of melting glaciers and snow cover is sensitive to climate alteration. The snow depletion starts from March from zones 4 and moves to higher elevation zone. The analysis of snow-covered area depletion during 2000 to 2015, that in zone 1,2 and 3 the snow was almost free from snow cover, in zone 4, the snow was melted completely during July to Aug. After calibration and validation on the present time (2000-2015), the SRM and VIC models were used to study the impact of climate variability. The impact of climate variability on the Upper Ganga basin runoff was studied using the SRM and VIC models under the INCCC (Model - CCCma_CanESM2) rcp 4.5 future climate scenario and discharges simulated under different snow cover area scenarios are presented in Fig. 2 & 3. The future data from 2016 to 2099 is classified into three different time periods to represent the near

future (2016-2040), middle future (2041-2070) and far future (2071-2099). From these above figures it can be observed that the monthly discharge during the monsoon period (July to August) are increasing from the near future to far future and for the non-monsoon months the monthly discharges are decreasing from near future to far future.
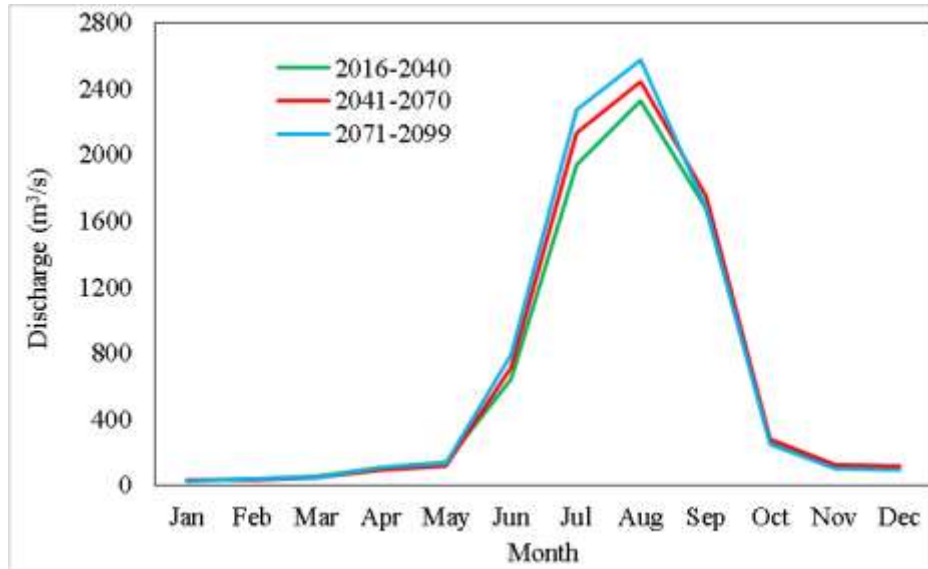


Figure 2: INCCC (Model - CCCma_CanESM2) rcp 4.5 Monthly Discharge at Rishikesh by SRM Model Data
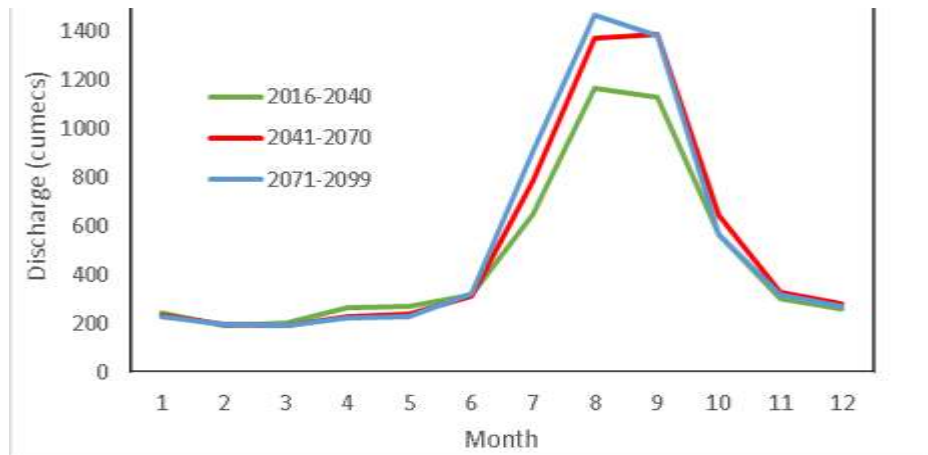


Fig 3: INCCC (Model - CCCma_CanESM2) rcp 4.5 Monthly Discharge at Rishikesh by VIC Model

**Project Title:**
Rainfall-Runoff Modelling of Selected Basin based on LULC pattern and development of Correlation

**Study Group**
    **NIH**
    A.K. Lohani, Scientist G
    R.K. Jaiswal, Scientist D
    Sushant Jain, Research Scientist

    **WRD Rajasthan**
    Sanjay Agarwal, Executive Engineer
    Shailendra Kumar, Executive Engineer

**Sponsored Agency:** NHP

**Project Duration:** Oct 2019-April 2022. (**Completed**)

**Project Cost:** Rs 15 Lakh (NIH:12 Lakh, WRD Rajasthan: 3 Lakh)
**OBJECTIVES**
- To understand the rainfall-runoff process by carrying out analysis of long-term hydrological data, land use/ land cover etc.
- Developing a rainfall-runoff model for the selected basin and to analysis the impact of land use/ land cover on runoff.
- To carryout sensitivity analysis of model parameters.

**Progress:**
The assessment of Land use and Landcover (LULC) changes on hydrological processes within the basin is conducive for optimal water resource management and assess the impact of extreme events like floods and drought. The modeling approach of basin enables us to understand the influence of each LULC class on hydrological components that greatly improve the predictability of hydrological consequences and thus can help water resource managers to make better and informed decisions. Water Resources Department, Rajasthan has requested for the rainfall-runoff modelling based on the LULC pattern for the selected basins under NHP. Out of 15 river river basins of Rajasthan, 5 basins are selected for this study namely Gambhiri, Parbati, Sabi, Shekhawati, and West Banas as sown in figure 1. Three decadal LULC were prepared for the years 1985, 1995, and 2005 and the year 2015, LULC map is going to be prepared. LULC of West Banas Basin is shown in Figure 2. SWAT model is being setup for the study basins. Further, request has been sent to WRD, Rajasthan for the supply of gauge & discharge data for the selected basins. In absence of G&D data for model calibration attempt were made to calibrate the model with satellite ET data.
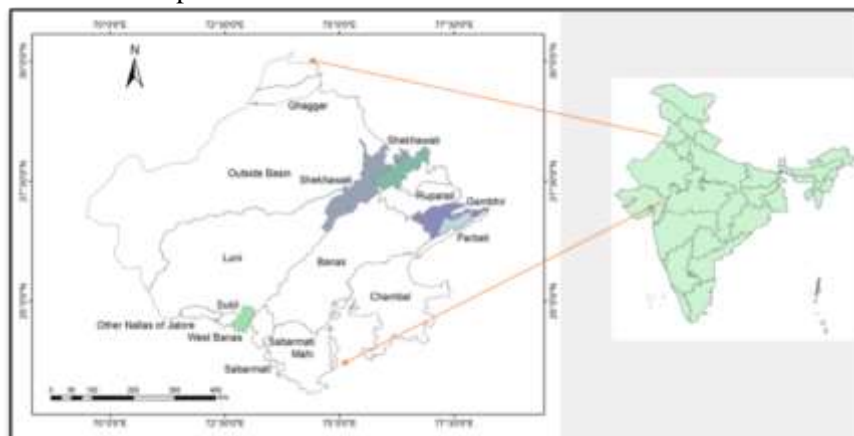


**Figure 2 Selected Basin for the study**
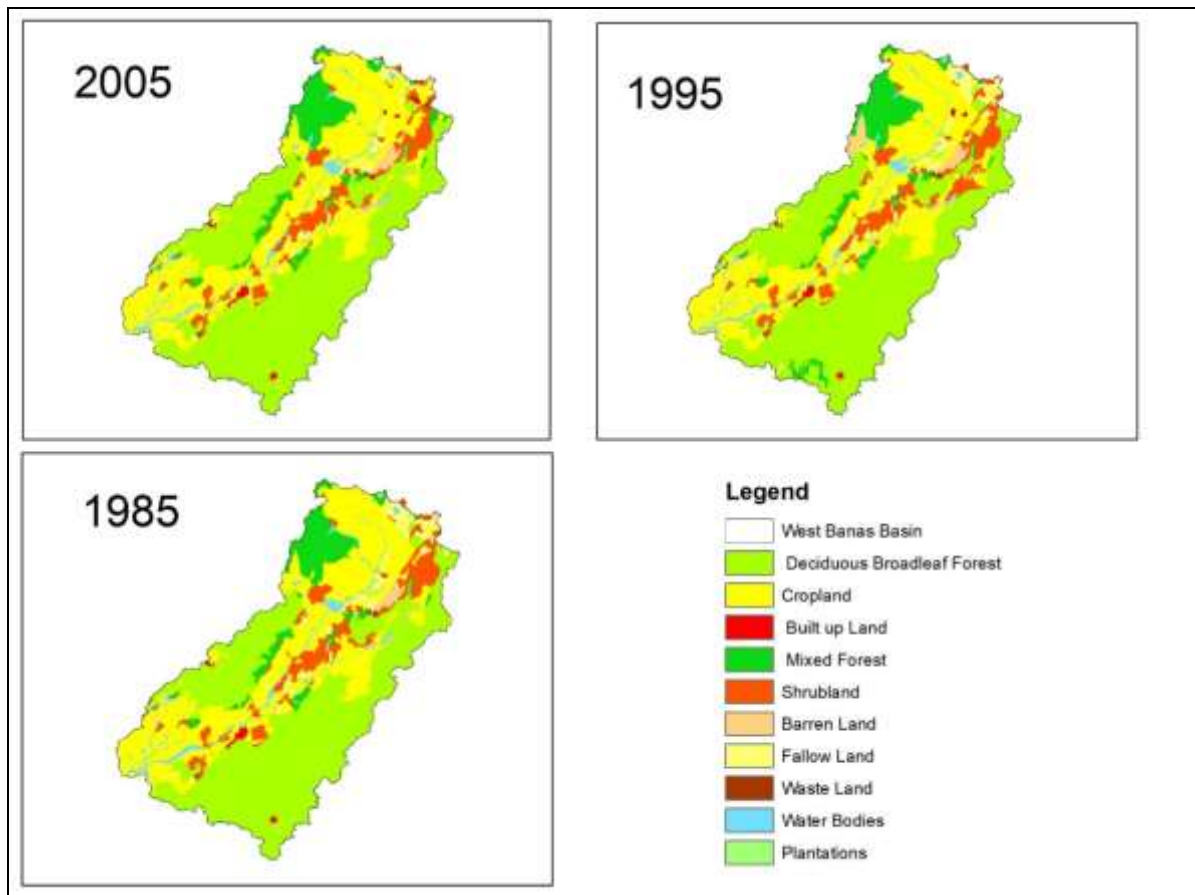
Fig 2.: LULC of West Banas
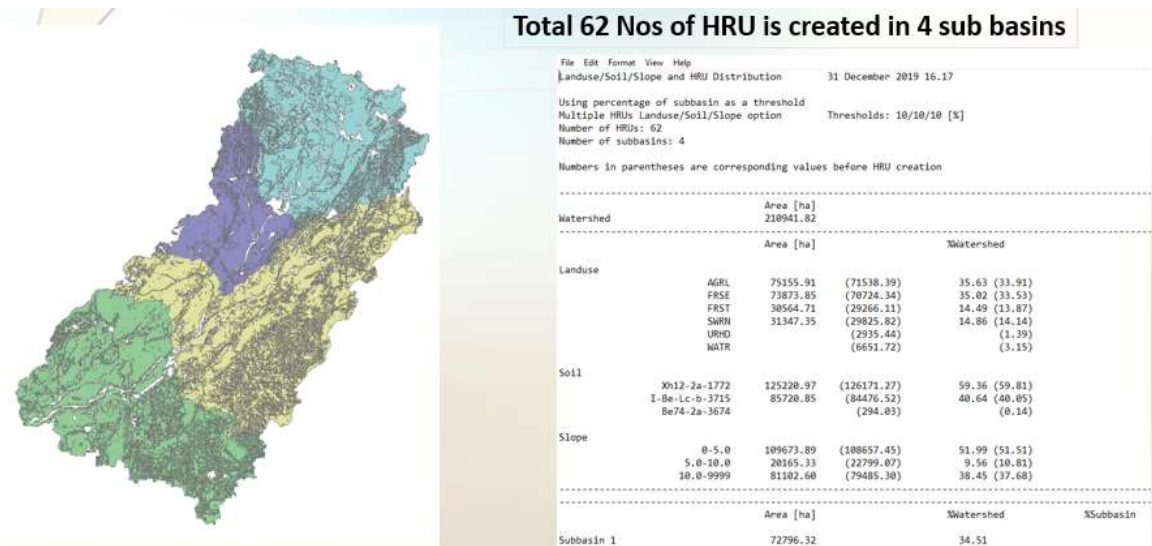


Figure 3. Hydrologic Response Unit

In the absence of discharge data, satellite based evapotranspiration data (GLEAM) was used to calibrate SWAT model. The model was calibrated and validated for Sabi basin and then the parameters were used to determine runoff from all other basins. The Global Land Evaporation

Amsterdam Model (GLEAM) is a monthly global ET dataset spanning the 18-year period from 2003 (January 1st) to 2018 (July 31st). Inititally, the model was setup in SWAT and imported in SWAT-CUP for sensitivity, calibration and validation. The GLEAM data was extracted for the Sabi sub basins and used as an input in SWAT Cup calibration model. Initially, sensitivity analysis was carried out and found that curve number (CN2), base flow alpha factor (ALPHA_BF) and soil evaporation compensation coefficient (ESCO) were found the most sensitive parameters for modeling the evaporation in the basins. After selecting the sensitive parameters, data from 2003 to 2010 is used for calibration and from 2011 to 2018 for validation (Figure 4).
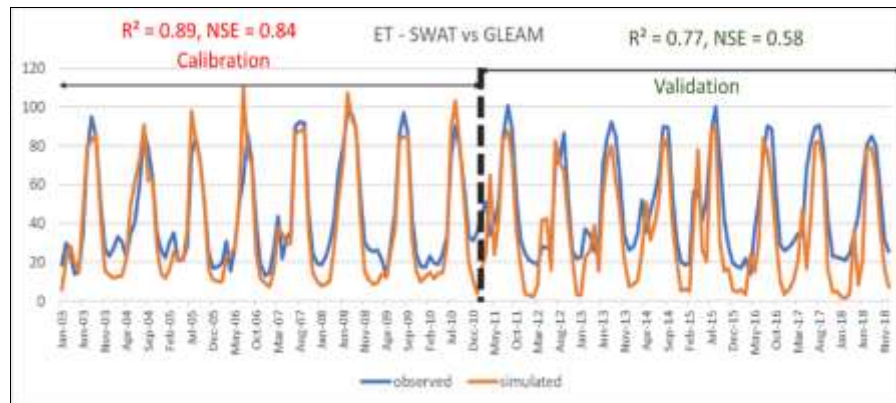


**Figure** 4 Chart represeting calibration and validation results

In the present study, an attempt was made to model hydrological processes in Banganga, Gambhiri, Parbati, Sabi and Sekhabati basins of Rajasthan state. The GIS database of the study area was prepared where, it has been found some misconception in TAHAL report about outlets that have been corrected based on recent digtial elevation model of the study area. The decadal landuse of 1985, 1995, 2005 and 2015 was prepared using supervised classification in google earth engine. It may be concluded that all the basins are agragrian basins where barren land has increased all basins from 1985 to 2015. There is considerable increases in agriculture land was found in Parbati basin.

Due to non availability of long-term discharge data, large intervention due to reservoirs and non availability of reservoir releases, it was not possible to model the hydroligcal processes using observed runoff. Therfore, in the study, cloud based evapotranspiration data from GLEEM was used to calibrated the model at Sabi basin. The SWAT model was prepared and exproted to SWAT CUP, where SUFI 2 technique was used to model evaporation. The sensitivity analysis suggested that curve number (CNII), soil evaporation compensation factor (ESCO) and base flow alpha factor (ALPHA_BF) are the most sensitive factors to model hydrolgical processes. The model was calibrated for the period of 2003 to 2010 with nash-sutcliffe efficiency (NSE) of 0.84 respectively and validated for 2011 to 1018 with NSE of 0.58. The calibrated parameters were used to determine runoff from all other sub-basins and basins considering no significant change of ET in the region.

Cloud data are being used increasingly in hydrolgical modeling and assessment and in the study, a GEE based SCS CN model was developd where cloud based landuse, soil and rainfall data were used to model runoff processes in any medium size catchment in the world. The model uses dynamic land use for computation of curve number. The model was applied in Sabi basin with coefficient of determination of 0.81 on monthly scale with SWAT results. The water availability are prerequisite for plaaning water resource projects and from different in sub-basins of Banganga, Gambhiri, Parabati, Sabi and Sekhabati basins from SWAT model were used to devlop a database and das board in Excel. The developed dashboard can be used by WR managers to determine the monthly runoff from any sub basins of these basins for any selected LULC.

## 1. PROJECT REFERENCE CODE: NIH/SWHD/19-23

**Project Title:**

Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh

**Study Group**

Principal Investigator : P C Nayak, Y.R.Satyaji Rao, A.K. Lohani, B. Venkatesh, A. R. S. Senthil Kumar, T. Thomas

Budget and Funding : Rs. 55.6 lakhs
Period : 3 year (Sept 2019 to April 2023)
Funding Agency : NHP
Status : Ongoing

**Objectives:**

- Dam break analysis of Kandaleru and Pulichintala dam using HEC-RAS. The study includes the sensitivity analysis for dam breach parameters.

- Computation of flood hydrograph and water level at different cross-sections.

- Assessment of flood inundation extent and water depth at different places in the downstream of dam.

**Overall progress of the Study:**

In the preliminary investigation, dam break modeling is performed using 1D HEC-RAS software for Kandaleru dam. Kandaleru dam is an irrigation project built on Kandaleru river in Nellore district of Andhra Pradesh. The project is a part of the Telugu Ganga project which supplies drinking water to Chennai city from the Srisailam reservoir in Krishna river. Kandaleru reservoir is mainly fed by a link canal from the Somasila dam. Kandaleru dam is an earthen dam of 10.752 Km length with a height 49.00m. The Gross Storage Capacity of reservoir at Full Reservoir Level (FRL) is 68.03TMC with a FRL value 85.00m and Top Bund Level (TBL) of dam is 89.00m. In this work, modeling is performed up to 10km downstream of dam with 1km interval. The dam breach is assumed as overtopping failure and the result are analyzed for it. The study of Kandaleru dam break is performed upto 10km downstream distance from dam. It may be noted that maximum flow at dam site is $59209.70 m^3/sec$ and 10km away from dam the value of discharge is $56175.51 m^3/sec$ and Peak flow travel time from dam site to last cross-section is 1hour. A graph showing flood hydrograph at different location is presented in Figure.
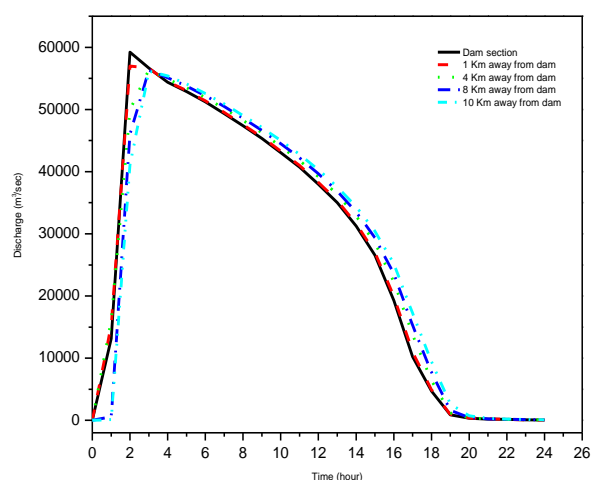


**Figure: Flood Discharge at different locations from dam site**

A sensitivity analysis has been carried out changing the breach width. In the analysis, the model is simulated with variation of breach width from 200m, 300m, 400m, 500m, 600m. In the analysis, it is noticed that as the breach width increases the discharge and water surface elevation at the dam section and all downstream sections also increases. The effect of roughness corresponding to river bed and flood plains are considered on the present study with four sets of manning's coefficient values. As the river roughness increases from 0.035, 0.040, 0.045 and 0.050 the discharge value decreases and water surface elevation increases

**Objective vis-a-vis Achievement**
As mentioned in the objectives, dam break analysis using HEC-RAS model has been carried for Kandaleru dam. Flow hydrograph has been generated at different location downstream of the dam up 10 km. Sensitivity analysis has been carried out for breach widths, changing breach formation time, changing roughness coefficient.

**Progress since last meeting**
The required hydrological and hydraulic data pertains to Kandaleru dam has been collected from A.P State irrigation department. Analysis is under progress

**Future work for the next year**
Flood inundation mapping for Kandaleru dam

## 1. PROJECT REFERENCE CODE: NIH/SWHD/21-22

**Title of the Study**

Application of generalized unified-extreme-value (UEV) distribution for flood frequency: (1) Mahi & Sabermati subzone – 3a (2) Upper Narmada -3e

| | |
|---|---|
| **Study group** | Sushil K. Singh**,** Scientist F |
| **Date of start of study** | 01 April 2021 |
| **Duration and scheduled** | One year |
| **Date of completion of study** | 31 March 2022 |
| **Type of study** | Internal (without/no funding) |

Study has been completed and report will be placed on table.

**Results & Findings**

An innovative unified-extreme-value (UEV) distribution by Singh (2016, 2017, 2019) for analyzing extreme events is further extended and applied to the annual peak-flows at the respective outlets of several catchments in (1) *Mahi and Sabermati subzone-3a*, and (2) *Upper Godavari subzone 3e*. The author has previously applied successfully this new UEV-distribution to the peak-flows observed for several catchments in Indian *subzone-3f* (Singh 2021), *subzone-3b* (Singh 2021), *subzone-3c* (Singh 2020), *subzone-3h* (Singh 2019), and *subzone-3d* (Singh 2018). The UEV-distribution closely reproduces the observed peak-flow similarly outperforming the prior other methods and procedures, and has been appropriately generalized in report as generalized extreme-value-distribution (GUEV). The GUEV-distribution encompasses seven extreme-value distributions additionally including four new extreme-value distributions besides the widely used existing three extreme-value distributions. The additional new extreme-value distributions that it represents can also been identified from the series of annual peak-flows at a gauging site using the proposed methods.

The GUEV-distribution and the proposed computationally simple methods for its parameter-determination enable data-driven implicit identification of the appropriate member-distribution of the GUEV-distribution that is followed by the data, which do away with the repetitive separate fitting of different extre-value distributions to arrive at the appropriate extreme-value distribution for the observed data. The new deterministic confidence interval/band (within which the predicted peak-flows are supposed to lie) initially proposed by Singh (2017), which replaces the existing and widely used probabilistic confidence limit initially introduced by Neyman and Pearson (1932), has also been found to work well on the peak-flow data analyzed herein. The fitting of the GUEV-distribution to observed series of peak-flow using the proposed methods is simple and easy and can even be performed on a hand-held calculator or a computer spreadsheet, and hence is of help to field engineers and practitioners.

# COMPLETED STUDIES (INTERNAL)

## 2. PROJECT REFERENCE CODE: NIH/SWHD/18-20

**Title of the Study**

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

**Study Team**

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

**Type of Study**

Internal

**Date of Start**

1 Nov. 2018
**Scheduled date of completion: August 2021 (Total duration 2 years)**

**Two extension were taken and after extension the study was completed in 4.5 years**

**Report is not yet submitted**

**Study Area:**

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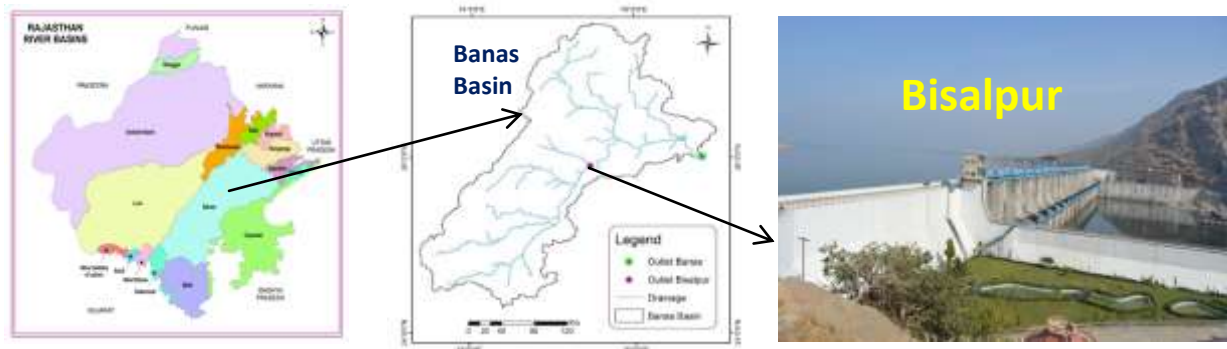


River Banas is located in east-central part of Rajasthan State in India. It originates in the Khamnor hills of the Aravali range and flows in Rajasthan. Banas is a major tributary of the River Chambal, which is again a tributary of River Ganga. The total catchment area is about 51,779 km2 with a length of about 512 km. The Banas River passes through the 13districts namely, Sawai Madhopur, Jaipur, Ajmer, Tonk, Rajsamand, Banswara, Chittaurgarh, Udaipur, Bhilwara, Dausa, Sikar, Nagaur and Karauli. The Banas Basin may be classified as tropical grassy plains, semi-arid and hot, on the basis of Koppen's classification of climatic patterns. Orographically, the western part of the Basin is marked by hilly terrain belonging to the Aravali chain. East of the hills lies an alluvial plain with a gentle eastward slope. Ground elevations in the western hilly part range approximately 900 meters, while the alluvial plain elevations range approximately from 650 meters. The mean annual rainfall over Banas Basin is around 585 mm of which about 95% falls during the four Monsoon months (June-September). The average temperature in the basin varies from 19°C to 33°C with the maximum going above 45°C during summers.

**Study Objectives:**

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

**Statement of the problem**

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

**Approved Action plan and timeline**

| S. No | Work Element | First Year | | | | Second Year | | | | Third Year | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 |
| 1 | Collection of information and Hydro-meteorological data from field, Preparation of base maps | ▓ | ▓ | | | | | | | | | |
| 2 | Trend analysis of historical data | ▓ | ▓ | | | | | | | | | |
| 3 | Downloading and bias correction of GCM data | ▓ | ▓ | ▓ | | | | | | | | |
| 4 | Development of Climate Impact Indicators | | | | ▓ | ▓ | | | | | | |
| 6 | Input data preparation for Rainfall runoff model | | | | | ▓ | ▓ | | | | | |
| 7 | Preparation of Interim Report | | | | | ▓ | | | | | | |
| 8 | Calibration and Validation of rainfall runoff model | | | | | | | ▓ | ▓ | ▓ | | |
| 9 | Preparation of Interim Report | | | | | | | | | ▓ | | |
| 10 | Inflow Outflow Analysis for the Bisalpur Dam | | | | | | | | ▓ | ▓ | | |
| 11 | Climate change scenario analysis for future water availability | | | | | | | | | ▓ | ▓ | ▓ |
| 12 | Preparation of Final report | | | | | | | | | | ▓ | ▓ |

**Progress (after last working group meeting)**

| Objectives/work elements | Achievements |
|---|---|
| **July 2021- March 2022** | |
| Trend analysis of bias corrected GCM data of ECVs for future period | Completed |
| Input data preparation for Rainfall runoff model | Completed |
| SWAT model runs and inflow outflow analysis | Completed |
| Development of Climate Impact Indicators for future Water Availability, Drought and Agriculture Productivity | Completed |

**Analysis and Results**

**Data Used**

Essential climate variables of 16 GCMs (Table below) at 0.5 degree grid have been extracted from the Climate data store of COPERNICUS. These ECVs have been processed and bias corrected on daily time interval for a period up to year 2100 for two climate change scenarios, i.e., RCP4.5 and RCP 8.5.

| S.No | Institute | GCM Name | Scenario | Resolution: Grid Lat | Resolution: Grid Long |
|---|---|---|---|---|---|
| 1 | CSIRO-BOM | ACCESS1-0 | historical, rcp4.5, rcp8.5 | 1.25 | 1.875 |
| 2 | CSIRO-BOM | ACCESS1-3 | historical, rcp4.5, rcp8.5 | 1.25 | 1.875 |
| 3 | BNU | BNU-ESM | historical, rcp4.5, rcp8.5 | 2.7906 | 2.8125 |
| 4 | IPSL | IPSL-CM5A-MR | historical, rcp4.5, rcp8.5 | 1.2676 | 2.5 |
| 5 | IPSL | IPSL-CM5A-LR | historical, rcp4.5, rcp8.5 | 1.8947 | 3.75 |
| 6 | IPSL | IPSL-CM5B-LR | historical, rcp4.5, rcp8.5 | 1.8947 | 3.75 |
| 7 | MPI-M | MPI-ESM-MR | historical, rcp4.5, rcp8.5 | 1.8653 | 1.875 |
| 8 | MPI-M | MPI-ESM-LR | historical, rcp4.5, rcp8.5 | 1.8653 | 1.875 |
| 9 | NCC | NorESM1-M | historical, rcp4.5, rcp8.5 | 1.8947 | 2.5 |
| 10 | NOAA-GFDL | GFDL-ESM2G | historical, rcp4.5, rcp8.5 | 2.0225 | 2.5 |
| 11 | GFDL-ESM2M | GFDL-ESM2M | historical, rcp4.5, | 2.0225 | 2.5 |

| S.No | Institute | GCM Name | Scenario | Resolution: Grid Lat | Resolution: Grid Long |
|------|-----------|----------|----------|------------------|-------------------|
| | | | rcp8.5 | | |
| 12 | NOAA-GFDL | GFDL-CM3 | historical, rcp4.5, rcp8.5 | 2 | 2.5 |
| 13 | CNRM-CERFACS | CNRM-CM5 | historical, rcp4.5, rcp8.5 | 1.4008 | 1.40625 |
| 14 | BCC | BCC-CSM1.1 | historical, rcp4.5, rcp8.5 | 2.7906 | 2.8125 |
| 15 | BCC | BCC-CSM1.1(m) | historical, rcp4.5, rcp8.5 | 2.7906 | 2.8125 |
| 16 | ICHEC | EC-EARTH | historical, rcp4.5, rcp8.5 | 1.1215 | 1.1215 |

For calibration of SWAT model for the Banas basin upto the Bisalpur reservoir, observed data of rainfall at 30 stations and runoff at 1 intermediate station have been used. For temperature data, IMD one-degree gridded data was used. +Other data required for SWAT simulation has been used from SWAT Tamu.

**Results**

Relevant climate impact indicators for the basin have been calculated and variability in future periods has been studied.

Simulation runs of SWAT model using default data as well as observed data of intermediate station have been carried out. Following maps depict properties of the basin:
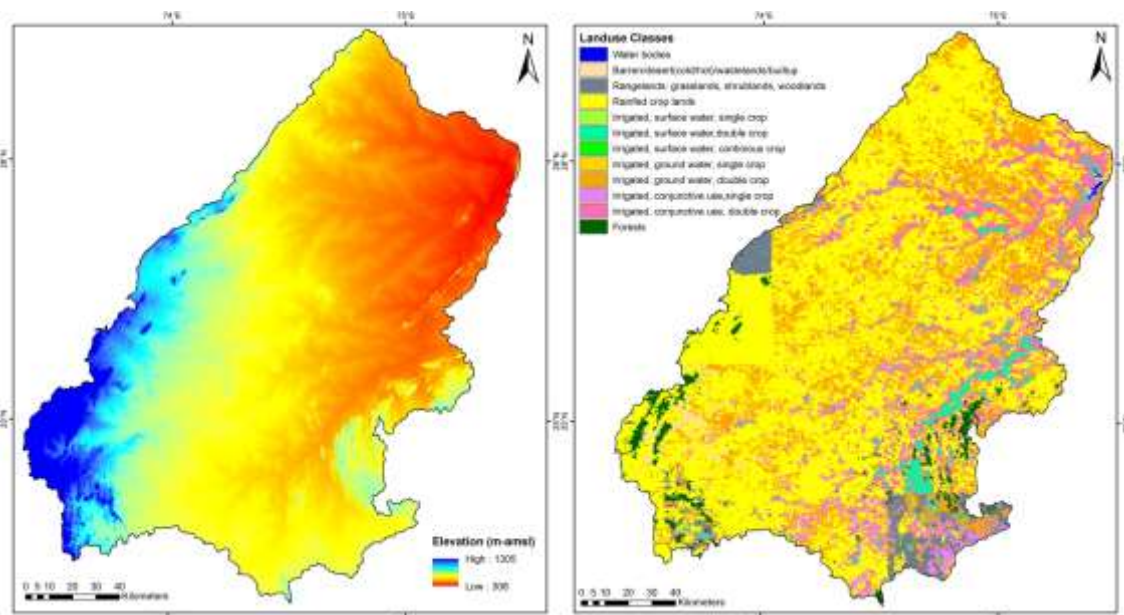


(a) **DEM of Study area**          (b) **LULC of Study area**
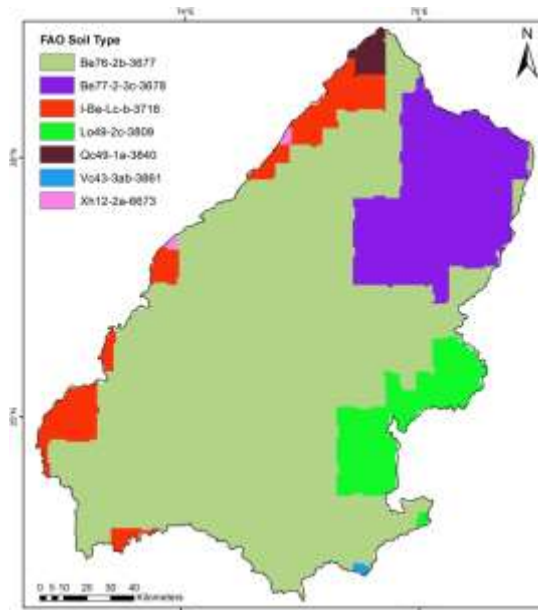
**(c) Soil Classification of Study area**    **(d) Sub-basin division in Study area**
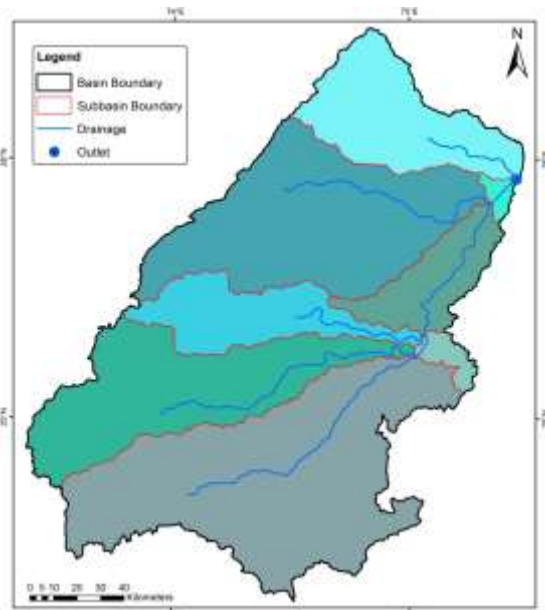
Following graphs show the rainfall runoff simulation results of SWAT runs:
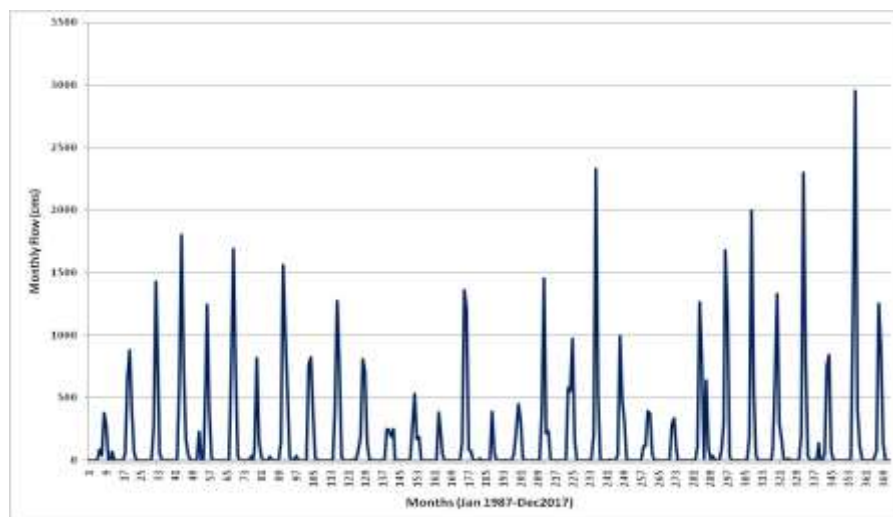

Simulation of Monthly Flows at Bisalpur Reservoir (upstream)
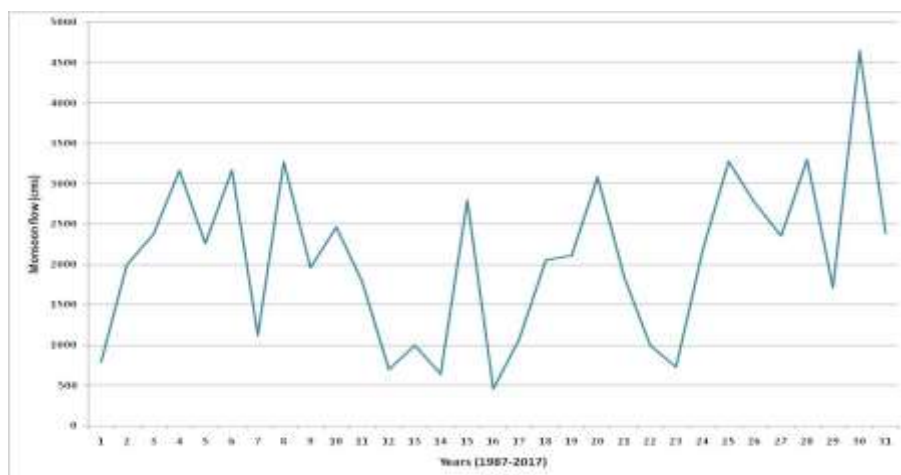

Simulation of Monsoon Flows at Bisalpur Reservoir (upstream)

204

**Expected Adopters**

Water Resources Department, Agriculture Department, Govt of Rajasthan.

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

**Deliverables**
Research papers, report, stakeholder engagement

**Data Procured and/Generated during the Study**
Daily rainfall data of 30 raingauge stations in the Bisalpur River basin for a period of 30 years (1990-2019). Gridded temperature data at $1^oX1^o$ for the Banas basin from IMD (previously procured for other study), Essential climate variables (precipitation, temperature) at 0.5deg resolution from ECMWF. DEM, Soil and LULC maps of Banas River basin upto Bisalpur reservoir.

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

**Thrust area under XII<sup>th</sup> Plan:** Impact of climate change on water resources and hydrology of xtremes

**Project team:**      Dr. Ashwini Ranade, Scientist 'D' (PI)

     Dr. Archana Sarkar. Scientist 'E' (Co-PI)

**Type of Study:**      Internal

**Status:**      completed

**Duration:**      **3 years**

**Date of Start:**      1 April 2018

**Scheduled date of completion**: 31<sup>st</sup> Dec 2021

**After Extension the study was completed in 3.5 years**

**Report submitted**

**Objectives**

| Sr. No | Objectives | Status |
|---|---|---|
| 1. | Updation of longest instrumental area-averaged monthly rainfall series (1813-2000) of 11 major and 9 independent minor river basins of India and to document climatological and Fluctuation features of annual, seasonal and monthly rainfall | Completed |
| 2. | Identification of different types of seasonal extreme rain events concerning rainfall amount, rainfall intensity and duration over seven homogenous rainfall zones of India from 1951to 2020. | Completed |
| 3. | Evaluation of 3D global atmospheric parameter changes conducive to the occurrence of large-scale extreme rain events over seven homogeneous rainfall zones during different seasons. | Completed |
| 4. | Time series modelling of the longest instrumental monthly rainfall series (1813-2020) of major and independent minor river basins for their extrapolation for 2 to 10 years | Completed |

**1. Statement of the problem**

Uneven warming of the global troposphere in last few decades are observed to make changes in spatio-temporal characteristics of rainfall across the country. The IPCC 6<sup>th</sup> assessment report projected that South Asian summer monsoon precipitation decreased over several areas since the mid-20th century (high confidence) but is likely to increase during the 21st century, with enhanced inter-annual variability and Extreme rainfall are projected to be intensified by 7% for each additional 1ºC due to acceleration of hydrological cycle in warmer climate across the globe. After general acceptance of global warming as a reality, numerous studies have been undertaken to generate information useful for the assessment of water resources and hydro-meteorological disasters to comprehend the impact of climate change. It has been seen that annual, seasonal, and monthly rainfall across India shows strong spatiotemporal variation and large departures from normal. Many of the studies show an overall decreasing trend in monsoonal rainfall over a major part of the country. Earlier we have studied climatological and fluctuation features of parameters of the hydrological wet season in 11 major and 36 minor river basins in India. We did not find any significant long term trends in wet season parameters for any basin but noticed a declining tendency in wet season rainfall in some major basins of Central India. Numerous studies have reported the rising frequency in short period extremes, especially in Central India and attributed to the significant increase in synoptic activities, convective instabilities' etc. We found that small-scale, short-duration EREs are embedded in large-scale, long-

period intense wet spells, and rainwater generated during the main monsoon wet period is highly correlated with the Asia-Pacific monsoon intensity. Few intense rain spells, consequently heavy flooding and disasters occur across the country even in dry monsoons. Locations of warming and cooling across the globe are the determinant of the plausible locations for the origin of various types of weather systems. There is a pressing need to understand the climatic changes in the 3-D structure of global temperature. Keeping in mind, recent changes in global atmospheric thermal structure, monsoon circulation pattern, and occurrence of EREs, we have studied the rainfall variability in annual and seasonal rainfall of 11 major basins, 9 independent minor basins and 7 homogeneous zones across India and associated 3-D structure of global temperature.

**2. Dataset used and Study area:**
- The global daily reanalysis product of the atmospheric temperature, geopotential height, wind speed at(1000-100hPa), mean sea level pressure and precipitable water available at 2.5° grid resolution from 1979 to 2020 from 'The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR & CFSv2) are used.
- The longest instrumental area-averaged monthly rainfall series for 11 major basins, 9 independent minor basins and 7 homogeneous subzones) earliest available from 1813 to 2000.
- IMD gridded 1° X 1° and 0.5° X 0.5° degree rainfall data from 1951-2020 to update the rainfall series from 2001 to 2020.

**3. Analysis and results:**
**3.1 Updation of monthly rainfall series:**
    Longest instrumental area-averaged monthly rainfall sequence of major river basins (Indus, Ganga, Brahmaputra, Sabarmati, Mahi, Narmada, Tapi, Godavari, Krishna, Mahanadi, Cauvery); independent minor basins ( Luni, Surma, Kasai, Damodar, Subarnarekha, Brahmani, Penner, Palar & Ponnaiyar, Vagai); The West Coast Drainage System (WCDS), All India and 7 homogeneous zones : (i) South Peninsular India (SPI);  ii) West peninsular India (WPI); iii) East Peninsular India (EPI); iv) Northwest India; v) North Central India (NCI); vi) North East India (NEI); and North Mountainous India (NMI); have been developed and updated in three phases. In the first phase, for the period 1901 to 2000, simple arithmetic mean of all available gauges in the basin/zone from a fixed well spread instrumental network of 316 rain gauge stations were used. In the second phase, the dataset has been extended backwards from 1900 to 1813 (starting year is different for each basin) when a lesser number of observations were available, by applying a theoretically vindicated numerical method on limited available observations; and in the third phase, river dataset has been updated with the ratio method, by extracting each station value from the corresponding value of the grid from the 1° X 1° gridded rainfall dataset of IMD. While homogenous zone dataset has been updated by developing area-averaged daily rainfall series from 0.5-deg gridded rainfall data from IMD

**3.2 Chief Statistical Features and Interannual variations**
    Area-averaged monthly, seasonal and annual rainfall series for all basins and zones have been developed and analyzed. Climatological and fluctuation features of all the time series have been calculated and documented. Normal (1901-2000) annual rainfall of the river basins across the country varies from 487.7mm (Luni) to 2519.5mm (Surma). The normal annual rainfall of the country is 1165.9mm, the highest rainfall of 1435.3mm occurred during the year 1917 and lowest of 895.7mm during year 1918. Normal (1901-2000) monsoon rainfall of the river basins across the country varies from 445.4mm (Luni) to 1706.6mm (Surma). For the country as a whole, the normal monsoon rainfall is 906.5mm, highest rainfall of 1088.8mm occurred during year 1961 and 661.3mm during year 1918.

For independent minor basins, the mean annual rainfall varies from 487.7mm over Luni to 2519.5mm over Surma. The coefficient of variation varies from 12.1% (Surma) to 37.4% (Luni).

Normal annual rainfall of seven homogeneous zones varies from 775.2mm over NWI to 2159.6mm over NEI. The year-wise highest rainfall varies between 1181.9 mm (NWI) and 2490.8mm (NEI), while that of lowest from 367.8mm (NWI) to 1725.1mm (NEI). Normal monsoon rainfall of seven homogeneous zones varies from 685.2mm over NWI to 1509.9mm over NEI. The year-wise highest rainfall varies between 950.9mm (NWI) and 1930.8mm (NEI), while that of lowest from 327.3mm (NWI) to 1242.5mm (NEI). Seasonal and annual rainfall time series are categorized as *very dry, moderately dry, normal, moderately wet and very wet* by using quintiles as a threshold calculated from the dataset of 1901-2000. Categorized rainfall time series for all regions have been prepared and analyzed. The inter-annual variation in the categorized monsoonal rainfall from 1813 to 2020 for the country as a whole is shown in fig.1.
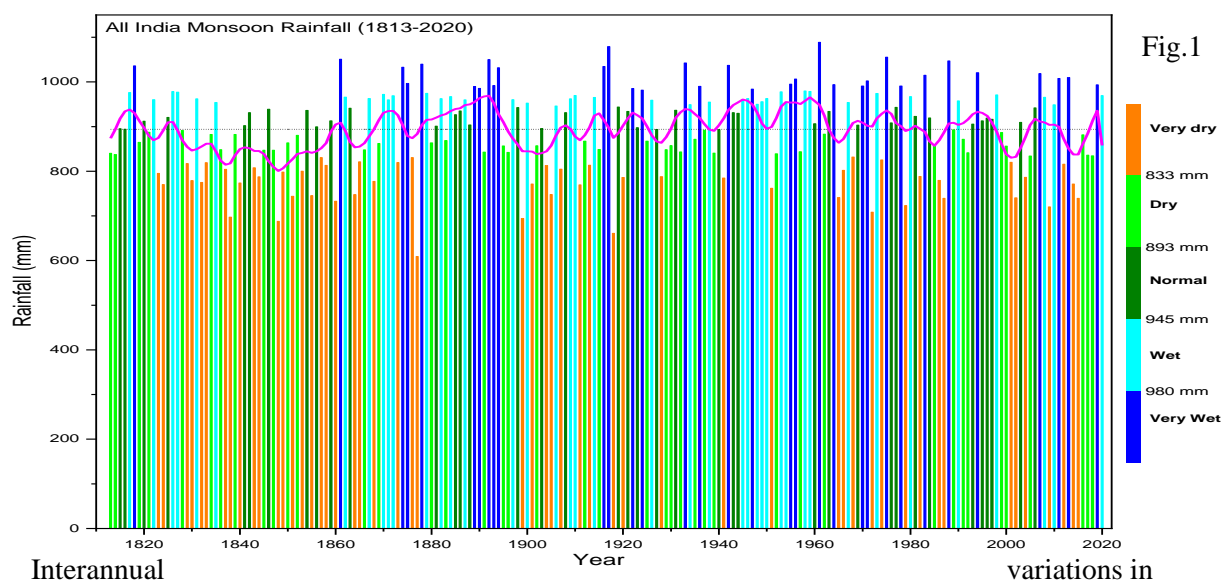


Interannual variations in categorized rainfall distribution of All India from 1813-2020

### 3.3 Short-term and Long-term rainfall fluctuations in basin rainfall series

The Cramer's $t_k$ statistics have been applied to moving averages of each of the time series of river basins to determine the broad nature of (+ve and –ve) short-term tendencies (15-year), medium-term fluctuations (31-year), long-term trend (51-year), and secular trend (101-year). The $t_k$ is calculated and significance is tested for times series. Visual examination reveals that the monthly, seasonal and annual rainfall is found to exhibit a wide range of fluctuation characteristics across the country.

Significant increasing trend is noticed in recent 101 years in monsoon rainfall over Krishna major (2.9%), Tapi (4.2%), WCDS (2.9%), Surma (2.1%), Pennar (2.8%) and the whole country (1.3%) compare to preceding instrumental period. While significant decreasing trend is noticed in Brahmaputra (-1.8%) and Brahmani (-1.4%). During recent 20 years (2001-2020) compare to last century (1901-2000), the significant decrease is noticed over Ganga major (-6.6%), Brahmaputra major (-7.6%), Cauvery (18.7%), Brahmani (-12.9%) and Pallar and Ponniyar (-19.7%). While significant increase is seen over Surma basin (7.9%). Compare to 20th century (1901-2000) monsoon rainfall over basins in northeast India, central northeast India, northwest India, and south peninsular India has been lesser while that over central northwest India, north peninsular India and north India has higher in recent 20 years.

### 3.4 Fluctuation characteristics of rainfall of homogenous zones

Inter-annual variations in annual and seasonal rainfall are filtered with 9-point filtering technique. Visual examination reveals that the monthly, seasonal and annual rainfall is found to exhibit wide range of fluctuation characteristics across the country. But over a longer period, the time series of all zones is appear to be approximately homogenous and random.

Changes in annual and seasonal rainfall of seven zones during 2001-2020 have been tested in relation to more reliable instrumental monthly rainfall records of last 100 years (1901-2000). The significance of the changes have been tested by using students' t-test for the difference between the two sub-period means. In recent 20 years, the monsoon rainfall of NCI and NEI have been significantly decreased by -9.7% and -7.3% respectively, while that of WPI and NWI increased significantly by 7.5% and 4.5 % respectively. The annual rainfall of NCI, NMI and NEI are decreased significantly by -9.6%, -12.9% and -9.4% respectively and SPI and WPI are increased significantly by 1.1% and 5.5% respectively.

### 3.5 Interannual variations in Precipitation Concentration Index(PCI) of homogenous zones

Changes in seasonal precipitation can be quantitatively assessed using this index. PCI characterizes monthly precipitation on a scale that ranges from 8.3 to 100. Year-wise annual and seasonal PCI for each zone have been calculated using monthly rainfall data. The average annual PCI for an individual homogeneous zones varies form 14.1 over SPI to 25.1 over NWI. It Indicates that, the rainfall is more uniformly distributed over SPI while more concentrated over NWI. The monsoonal PCI varies from 8.6 over NEI to 10.4 over NWI, indicating uniformly distributed rainfall during monsoon season. No considerable significant long-term trend is observed in annual and seasonal rainfall time distribution across India. However, in recent 20 years, annual rainfall of NMI, NEI and EPI and monsoonal rainfall of NEI are more concentrated in few spells.

### 3.6 Spectral Analysis:

We observe that the longest instrumental rainfall series across the country does not show any significant long-term trend however inter-annual variations at different time scales (annual, seasonal and monthly) does show a mixture of various periodic and random oscillations. Classical harmonic analysis has been used to understand the relative strength of periodic cycles in longest rainfall series. The Interannual variability of rainfall series of all time-series are is highly dominated by short-term fluctuations (~75%), followed by decadal changes (15%) and long-term variability (~10%). Simple classical harmonic analysis doesn't serve the purpose of extrapolation of rainfall time series

### 3.7 Fluctuation characteristics of 1- to 10-day Large-scale Extreme rain events over seven homogenous
### zones of India

The large-scale extreme rain events (EREs) of 1-to 10-days duration are intended to quantify severity of persisting intense rains over particular area. 1- to 10- EREs concerning rainfall amount and rainfall intensity are identified for each year. 1 The mean RI of 1-day ERE-RI varies from 20.3mm over Northwest India (NWI) to 45.2mm over Northeast India (NEI) while that of 10-day ERE-RI varies from 9.8 mm over North mountainous India (NMI) to 24.5mm over NEI. The mean cumulative rainfall of 10-day ERE-RA varies from 97.8 mm over NMI to 245.1mm over NEI. The rainfall amount of ERE-RA increases with duration overall subzones. Significant increasing trend is noticed in rainfall of 1-day EREs over WPI (16.2mm/year), EPI (22.8mm/year) and NMI (32.4mm/year) while significant decreasing trend is noticed in RI (9.1-12mm/year) and RA (10.8-12mm/year) of 7- to 10-day EREs over NCI. In recent 20 years (2001-2020) the WPI experiences, significant increase in rainfall during  1- 2-day EREs (16.9% and 18.3% respectively). The EPI experiences significant increase during 1-. 2- and 5-day EREs (15.7% , 13.1% and 12.2% respectively).

**3.8 Global Climatic Changes in 3-D structure of Atmospheric temperature**

The column-area mean monthly temperature of the lower troposphere (LTT: 1000-600hPa), upper troposphere (UTT: 550-250hPa), tropopause (TPS: 200-100hPa), whole troposphere (TT: 1000-250hPa) and stratosphere (STT: 70-1 hPa) have been area averaged at global, hemispheric, zonal and regional scale. Based upon geographical, astronomical and meteorological characteristics and climatic conditions, the whole globe (GLB) is divided into nine climatic zones: north polar (NP), north mid-latitudes (NMLAT), north subtropic (NSBT), north tropic (NTP), equator (EQ), south tropic (STP), south subtropic (SSBT), south mid-latitudes (SMLAT), south polar (SP). Each climatic zone is further subdivided into 6 macro geodomains, so the whole globe is divided into 54 geodomains.

The calendar month-year temperature data of the period 1979-2018 has been homogenized (standardized with respective monthly mean and standard deviation and multiply with annual standard deviation) in order to make the monthly temperature variations comparable before plotting. Fig. 2 shows the homogenized month-year TT variation during 1979-2018 over nine climatic zones, the two hemispheres and the globe. It also shows the 37-month (~3 years) running mean as well as the linear trend. Significant increasing trend is noticed in TT across the globe. Since 1979, TT has been increased at the rate of 0.25°C/decade over the globe. NH is warming at a faster rate (0.30°C/decade) than SH (0.20°C/decade). Stratosphere of the GLB, NH and SH shows cooling trend (approx. -0.55°C/decade). During 2009-2018, compare to base period of 30 years (1979-2008), the annual mean TT of the globe has been increased by 0.50°C, NH (0.57°C) and SH (0.42°C). The highest change is observed over NP (0.80°C) while lowest over SP (0.07°C). Across 54 geodomains, the highest positive anomaly in LTT is seen over eastern NP (+1.22°C), followed by eastern NSBT (+0.69°C) in NH and southern and equatorial Indian Ocean (+0.59°C & 0.55°C respectively). The upper troposphere of oceanic regions are warming at higher rate than that over land areas across the globe. The tropopause of tropical and subtropical regions are warming while mid-latitude regions are cooling.

in 
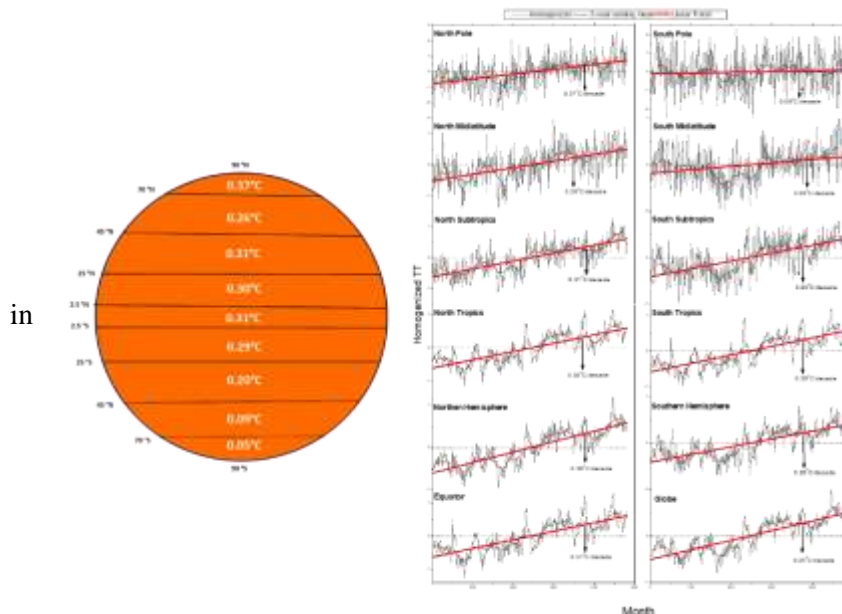
Fig.2 Linear trend (°C/10-yr) Tropospheric Temperature (TT) during 1979-2018

**3.9 Global Temperature conditions associated with Wet/Dry monsoon months**

An attempt has been made to understand the meteorological changes associated with the most extreme wet and dry monsoon months (June to September) in the recent 37 years (1979-2015) over India. Composite anomalies in the temperature, geopotential height at 12 isobaric levels and mean sea level pressure across the globe during most extreme four wet and dry years for India have been

constructed. Further the anomalies are averaged for 11 subzones and 54 geo-domains across the globe to comprehend the result.

During extreme wet years, although significant changes in departure field have not been noticed across the globe, NSBT and TBT show comparatively more intense departure field than other subzones. Tibet is warmer by 1.1° and thicker by 43.9m than normal in June, 0.54°C/23.6m in July, 0.2°C/7.9m in Aug and 0.04°C/7.8m in Sept. During extreme dry years, majority of the subzones show negative departure field compare to normal. Tibet is cooler by -0.22°C and thinner by 10m in June, -0.32°/-19.7m in July, -0.25°C/-7.3m in Aug and -0.54°C/-24.8m in Sept as compare to its normal values. It has been seen that even small changes on terrestrial scale may produce vigorous changes on local scale. In short, during wet months of the season, subtropical Asia especially Tibet-Himalaya is warmer and thicker and entire equatorial-tropical Pacific and Asian landmass is under negative pressure anomaly extends up to north pole. During driest months, the subtropical Asia is cooler and thinner while entire Asia-Pacific region is under positive pressure anomaly.

## 4. Important Results:

1. Significant decrease in monsoon rainfall is noticed over Ganga major (-6.6%), Brahmaputra major (-7.6%), Cauvery (-18.7%), Brahmani (-12.9%) and Pallar and Ponniyar (-19.7%) in recent 20 years (2001-2020) compare to last century (1901-2000), while significant increase is seen over Surma basin (7.9%).

2. On zonal scale, the monsoon rainfall of NCI and NEI have been significantly decreased by -9.7% and -7.3% respectively in recent 20 years, while that of WPI and NWI increased significantly by 7.5% and 4.5 % respectively.

3. No considerable significant long-term trend is observed in annual and seasonal rainfall time distribution across India. However in recent 20 years, annual rainfall of NMI, NEI and EPI and monsoonal rainfall of NEI are more concentrated in few spells.

4. The Interannual variability of rainfall series of all basins and homogeneous zones are highly dominated by short-term fluctuations (~75%), followed by decadal changes (15%) and long-term variability (~10%). Simple classical harmonic analysis doesn't serve the purpose of extrapolation of rainfall time series

5. Significant increasing trend is noticed in rainfall of 1-day EREs over WPI (16.2mm/year), EPI (22.8mm/year) and NMI (32.4mm/year) while significant decreasing trend is noticed in RI (9.1-12mm/year) and RA (10.8-12mm/year) of 7- to 10-day EREs over NCI during 1951-2020.

6. In recent 20 years, the WPI experiences, significant increase in rainfall of 1- 2-day EREs (16.9% and 18.3% respectively). The EPI experiences significant increase for 1-. 2- and 5-day EREs (15.7%, 13.1% and 12.2% respectively).

7. The tropospheric temperature across the globe has been increased significantly, from 1979-to 2018 at the rate of 0.25°C/decade. NH is warming at a faster rate (0.30°C/decade) than SH (0.20°C/decade).

## 8. Major Conclusion:

Due to faster warming of the troposphere of northern hemisphere compares to southern hemisphere, the monsoon circulation is intense but its 3D structure is highly distorted. Consequently, rainfall space-time distribution is heterogeneous, and extreme rain events (EREs) are highly varying type. Few selected case studies of most extreme rain events reveal that persistence in tropospheric warming and circulation anomalies over different parts of the globe drastically modulates the monsoon circulation and intensify the associated weather systems causing occurrences of severe rain events over a wide-ranging scale from small-scale short-period heavy rain events to large-scale long-period

extreme wet spells. Anomalous and abrupt warming of the upper troposphere of Tibet and Turkey sector favors the formation of deep troughs and strengthened ridges in subtropical westerlies and seen to be associated with sudden intensification of the monsoon circulation. However, detailed features of the EREs in relation to Monsoon circulation yet to be investigated.

**Deliverables:** It is expected that the results from this study will be useful to understand the effect of global warming on rainfall pattern across India. The results are beneficial for water resources planning and management of different river basins for next few years.

**Adopters of the results of the study and their feedback:** From hydrology and water resources sectors

**Major items of equipment procured:** None

**Lab facilities during the study:** None

**Specific linkages with Institutions/beneficiaries:** None

**Shortcomings/Difficulties:** Shortage of manpower

**Future Plan:** To understand the role of global temperature change in modulation of monsoon circulation and to extreme rain events across the country.

## 4. PROJECT REFERENCE CODE: NIH/SWHD/NIH/18-21

| | |
|---|---|
| **Title of the Project:** | Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the Godavari and Narmada River watersheds |
| **Project team:** | Dr. Sunil Gurrapu, Scientist C (PI)<br>Dr. Ashwini Ranade, Scientist D<br>Er. Jagadish P. Patra, Scientist D |

**Type of Study:** Internal

**Status:** Completed

**Duration:** 3 years

**Date of Start:** 1$^{st}$ November 2018

**Scheduled date of completion**: 31$^{st}$ October 2021

**The study is completed in time**

**Statement of the problem:**

Globally, floods are ranked among the largest and costliest natural disasters having major impact on various economic sectors. In India, flooding is one of the three prominent climate extremes, other two being droughts and cyclones. Majority of flooding in Indian watersheds occurs during summer monsoon months due to uneven distribution of rainfall. For example, recent devastating floods in Kerala were in response to the abnormally high rainfall received within a short period of 3 days, i.e. during 15$^{th}$ to 17$^{th}$ August 2018. Summer monsoon rainfall being the major source of water input to the Indian subcontinent, optimal design and operation of water resources infrastructure (e.g. major dams) is very much essential. Planning and design of such structures require a great depth of knowledge on the magnitude and frequency of extreme floods. Traditionally, the frequency of extreme floods is derived based on the analysis of historically observed annual maximum flows assuming they are independent and identically distributed (*i.i.d*) and the system fluctuates within a fixed envelope of variability, i.e. stationarity assumption. However, several studies across the globe highlight the potential inadequacy of traditional flood frequency analysis (FFA) and argue that the *i.i.d.* assumption can no longer be considered valid. Moreover, Indian summer monsoon is influenced by several low-frequency atmosphere-ocean oscillations including Atlantic Multi-Decadal Oscillation (AMO), Pacific Decadal Oscillation (PDO), El Niño-Southern Oscillation (ENSO) etc.

The failure probability of large hydraulic structures such as large dams and spillways, should be as low as possible. BIS specifies that the design flood for a large structure (i.e. gross storage > 60 MCM) is the probable maximum flood (PMF). The design flood for such structure is estimated based on the probable maximum precipitation (PMP). PMP is the maximum precipitation that is physically possible over a region for a given duration. PMP can be estimated either from meteorological or statistical methods. However, the changing climate across the globe is said to modify the precipitation characteristics, i.e. intensity, frequency and magnitude, which will influence the PMP estimates, and its further use in the design and analysis of flood related studies becomes questionable. In this study, we propose to first analyze the annual floods (i.e. maximum flows) with the hypothesis that they are

influenced by the low-frequency atmosphere oscillations originating in the equatorial Pacific and Indian Oceans. Secondly, we propose to evaluate the impact of climate change on PMP and prepare a status report.

The study was carried out on several sub-basins of Rivers Godavari and Narmada. We chose several streamflow gauging stations with a minimum 30 years of observed daily streamflow data. The maximum length of the available data among the chosen gauging stations is 50 years. The observed daily streamflow data for the selected gauging stations is obtained from India-WRIS website. Pacific Decadal Oscillation (PDO) indices is obtained from Joint Institute for the study of Atmosphere and Ocean (JISAO), University of Washington. And the El Niño-Southern Oscillation (ENSO) indices, quantified as Southern Oscillation Index (SOI) is obtained from Climate Research Unit, University of Eastern Anglia.

**Current Status**:

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

From the daily streamflow data collected from India-WRIS, annual peaks were extracted for the water year (1st June to 31st May of the following year), with a condition that at least 200 days of flow data is available during both southwest (June – September) and northeast (October – December) monsoon seasons, i.e. a maximum of 14 days of missing data is allowed during the water year. Despite the risk of missing out on few peaks, we adopted this condition to include as many stations as possible in the study. Annual Mean flow in majority of the gauging stations of the Godavari River basin are influenced by ENSO. The correlations between ENSO index and annual mean streamflow show statistically significant correlations (Spearman's $\rho \leq 0.54$). In addition, we observed that the annual peaks are also significantly influenced by the ENSO. Similarly, annual mean streamflow showed statistically significant correlations with the PDO index. Which indicate that up to 50% of the variability in annual streamflow at these stations can be explained by the PDO variability.

In contrast to the Godavari watershed, only a few stations in the Narmada watershed showed statistically significant correlations with both ENSO and PDO indices. Although the correlations are significant for majority of the selected gauging stations, they are not evident at all the stations. One major shortcoming is the length of the available data, because the periodicity of PDO is approximately 20–30 years, although it is nearly 10 years for ENSO. So, we have identified a few stations, with no significant regulations upstream (as per the watershed Atlas of India). Among these, we have Chosen those stations with at least 15 years of water year peak flow data (with not more than 14 days of missing data during monsoon season). We also evaluated various probability distributions used in flood frequency analysis to propose a suitable distribution that can address the issue of non-stationarity. Details of all the methods of analysis along with the results are described in the final report, a first draft of which is prepared and will be circulated for review to selected reviewers after addressing the feedback (comments from the committee members) received from the WG meeting.

**Status of the Deliverables:**

| # | OBJECTIVE | STATUS |
|---|---|---|
| 1. | Propose an appropriate probability distribution to address all the concerns over non-stationarity in the streamflow datasets. | Analysis completed and the first draft of the report is prepared |
| 2. | Research papers based on the established relations between low-frequency climate oscillations and flood magnitude and frequency. | One manuscript is drafted and is to be submitted for a publication |
| 3. | Status report on the impact of climate change on probable maximum precipitation (PMP) in India. | First draft is ready. |

1.      **PROJECT REFERENCE CODE: NIH/SWHD/20-22**


2.      **Title of the study:**
Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan.


3.      **Study group:**
   a.  Project Investigator:            J.P.Patra, Sc. – D, SWHD
   b.  Project Co-Investigator:         Pankaj Mani, Sc. – F, CFMS Patna
                                        Sunil Gurrapu, Sc. – C, SWHD
                                        Rakesh Kumar, Ex-Sc. – G & Head SWHD

4.      **Duration of study:**      2 Years (Aug 2020 to Jul 2022) : Ongoing

5.      **Type of study:  Internal.**

6.      **Location map**
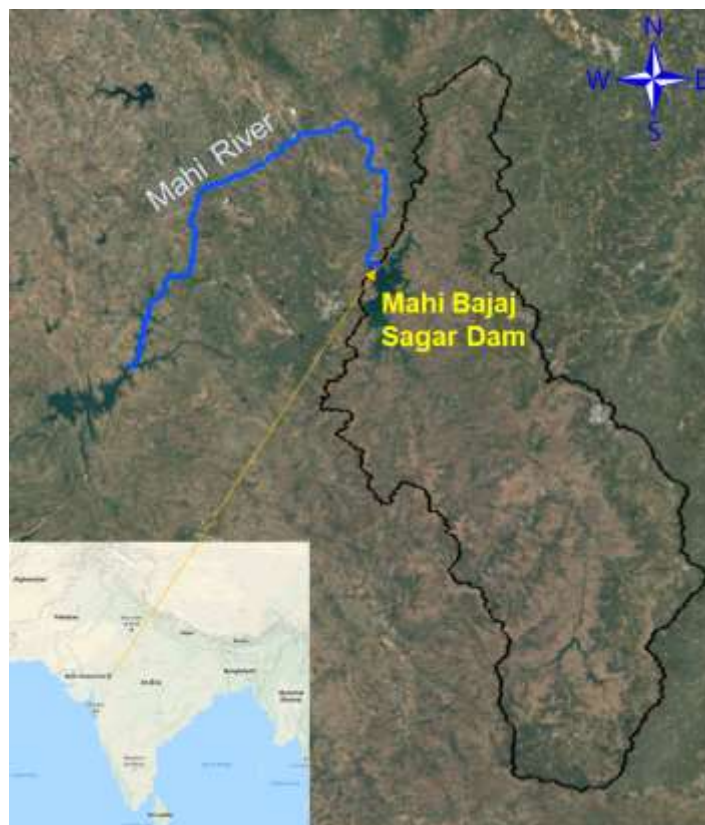


Figure 1: Location map of the study area

7.      **Study Objectives**
   a.  Estimation of probabilistic dam breach outflow hydrograph.
   b.  Preparation of Exceedance Probability Inundation (EPI) Maps.
   c.  Comparison outflow hydrographs due to level pool and dynamic routing of flows through the reservoir.
   d.  Flood hazard and flood risk assessment due to Mahi Bajaj Sagar dam breach.

8.    **Statement of the problem**

Dams have played a key role in fostering rapid and sustained agricultural and rural growth and development in India. Over the last fifty years, India has invested substantially in dams and related infrastructure. In India about 5254 large dams have been completed and another 447 under construction (NRLD 2017). However, failure of these structures may lead to catastrophic losses. In India there are 36 reported failures cases so far. The first such failure was recorded in Madhya Pradesh during 1917 when the Tigra Dam failed due to overtopping. The worst dam disaster was the failure of Machu dam (Gujarat) in 1979 in which about 2000 people have died. With increasing number of dams becoming older and older, the likelihood of dam failures in India is expected to be an ascending path. Considering these aspects India has undertaken the Dam Rehabilitation and Improvement Project (DRIP) to improve the safety and operational performance of selected existing dams in the territory of the participating states. Emergency Action Plan and flood inundation mas for the Dam are under preparation.

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. However, instead of mapping a large zone with equal probability of occurrence (either "in" or "out" of the flooding zone), modelling a full range of breach scenarios – from partial to complete, correlating the downstream impacts with a likelihood or probability of an area actually flooding would be of practical importance for dam owners. This risk-based approach arms decision makers with a probability based analysis map, would help them to visualize and prioritize actions in areas that are more likely to flood first. Such analysis would lead to smarter emergency action planning, allowing first responders and other agencies to stage critical resources such as disaster response team in key places to allow for systematic evacuation.

A flood hazard is an indication of the possible source of danger due to flooding. It, however, does not imply any risk unless persons or objects that are vulnerable to damage are exposed to it. The various hazards to be mapped include themes like the flood inundation areas, water depths and velocities, and arrival times of flood waves. Various guidelines and recommendations have been prepared under the DRIP for classifying hazard to people, vehicle, buildings etc. Moreover, combined flood hazard maps can be developed from the relationships of flood depth and velocity. Traditionally, floodplain management in India is dominated by the hazard-based method. The severity of the risks is directly proportional to the significance of the impacts of flooding i.e., the consequences of flooding. Limiting the flood hazards and reducing the degree of vulnerability to the flood impacts (such as proneness to water and velocity damage) may significantly reduce the consequences of flooding. Better management of future flood risk aims at reducing potential losses.

9.  **Approved action plan and timeline**

| S.N. | Work Element | 1st Year | | 2nd Year | |
|---|---|---|---|---|---|
| 1 | Collection of basic data, topography, cross-section, satellite images, thematic maps etc. | ▓ | | ▓ | |
| 2 | 1-D level pool dam breach model setup. | ▓ | ▓ | | |
| 3 | Quantification difference between level pool routing and full unsteady flow routing. | | ▓ ▓ | | |
| 4 | Generation of probabilistic breach parameters | | ▓ | | |
| 5 | Estimation of probabilistic dam breach outflow hydrograph. | | ▓ | | |
| 6 | Preparation of Exceedance Probability Inundation (EPI) Maps. | | | ▓ | |
| 7 | Combined general flood hazard classification and preparation of Flood Hazard Maps. | | | | ▓ |
| 8 | Risk identification. | | | | ▓ |
| 9 | Estimation of Population at risk and potential loss of life. | | | | ▓ |
| 10 | Workshop/ Training. | | | ▓ | |
| 11 | Report. | | ▓ | | ▓ |

10.  **Brief Methodology**

Dam breach models are commonly used to predict outflow hydrographs of potentially failing dams and are key ingredients for evaluating flood risk. The standard practise deterministic approach with assumption of various breach parameters viz. breach size, shape, formation time etc. Such approaches are generally conservative and there is no communication of risk and uncertainty. In this study it is proposed to apply a dam breach modelling framework to improve the reliability of hydrograph predictions. The EP will be determined by using Monte Carlo simulation technique: (i) Realization: "A Single Modelled Event in a Probabilistic Simulation", (ii) For each Realization, randomly sample uncertain input parameters (breach parameters) about pre-defined probability distributions, (iii) Run a large number of Realizations (10,000?) – large enough to demonstrate convergence of statistical moments (mean, variance, skewness, kurtosis, (iv) sort the results and select percentiles = EP discharges. Finally, routing of the chosen EP hydrograph downstream to determine its associated inundation and damages using a hydrodynamic model (HRC-RAS). This would help to answer-given a dam failure, what is the probability of any discrete location being in the flood zone?

The storage reservoir area upstream of the dam is modelled as storage area i.e. level pool routing through the lake. However, full unsteady flow routing through the reservoir pool can be carried out in 1-D with cross-sections or with bathymetry in 2-D. In general, full unsteady flow routing (1D or 2D) would be more accurate for both with and without breach scenario. However, availability of cross-section / bathymetry data in the reservoir area is often problematic. In this study the difference between level pool routing and full unsteady flow routing through the Mahi Bajaj Sagar dam reservoir will be estimated for peak flow and routed outflow hydrograph. Classified flood hazard vulnerability maps will be developed from the relationships of flood depth and velocity for various categories viz. Generally safe for vehicles, people and buildings; Unsafe for small vehicles; Unsafe for vehicles, children and the elderly; Unsafe for vehicles and people; Unsafe for vehicles and people, all buildings vulnerable to structural damage, some less robust buildings subject to failure; Unsafe for

vehicles and people, all building types considered vulnerable to failure. Risk analysis has brought a paradigm shift that has allowed advancement in the evaluation and management of flood risks, which may affect people, the environment, and human development. For estimating the efficiency of the measures targeting risk reduction, the estimation of the potential life loss and the economic loss are of great importance. Various method for estimation of potential life loss are given by Graham (1988) Sustainable Strategies of Urban Flood Risk Management (SUFRI) tool, Life Safety Model (LSM, Lumbroso et. al. 2011), LIFESim model. Synthetic damage assessment will be carried out by compiling detailed average inventories of property contents for different structure types using depth-damage curves.

11.  **Results achieved with progress/present status**

The salient features of Mahi Banswara project is obtained from the project authority and literatures. The contour map for the reservoir spread area is obtained from Gujarat Engineering Research Institute (GERI). The river cross-section at some of the locations are collected and openly available DEM for the area is also collected. The dam break analysis of Mahi Bajaj Sagar dam projects has been carried out to estimate the breach outflow from the reservoir storage. The reservoir is assumed to be at MWL and breach parameters are estimated based on the physical characteristics of dam and its construction material. The breach parameters have been estimated using regression equations and has been verified for their upper and lower bound from table suggested by Federal Agency guidelines. The breach in dam is considered when the inflow in Mahi Bajaj Sagar raises the reservoir level above the MWL of RL 281.5 m. The computed breach parameters from various methods are summarized in Table 1. The Mahi dam being earth rock fill dam, a trapezoidal breach section with is considered. The maximum water level for MBS dam is RL 281.5 m. The length of the earthen portion of the dam is 2627.07 m. The time of failure computed by Xu and Zhang is excessively high. At the start of breach, the reservoir is considered at FRL (RL 281.5 m) and the breach continues till water in reservoir lowers down to minimum reservoir level. The resulting dam breach flood hydrograph is shown in Figure 2.

Table 1: Description of breach parameters.

| SN | Method | Average Breach width (m) | Time of failure (hour) | Side slope of breach section |
|----|--------|--------------------------|------------------------|------------------------------|
| 1 | MacDonald | 461 | 4.96 | 0.5 |
| 2 | Froehlich (1995) | 307 | 10.75 | 0.9 |
| 3 | Froehlich (2008) | 280 | 8.87 | 0.7 |
| 4 | Von Thun & Gillete | 106 | 0.78 | 0.5 |
| 5 | Xu & Zhang | 174 | 12.97 | 0.5 |

The recently developed guideline in DRIP, advocate for use of the equations given by Froehlich (2016) for estimation of breach parameters. However, it has also associated uncertainty in estimation of various parameters viz. breach width (B), side slope, formation time etc. More over these parameters are also limited by the design section of dam. The outflow hydrograph with breach parameters at different statistical level in a deterministic approach are shown in Figure 2. It is evident that there is large variation in the estimated values of peak flood using various methods.
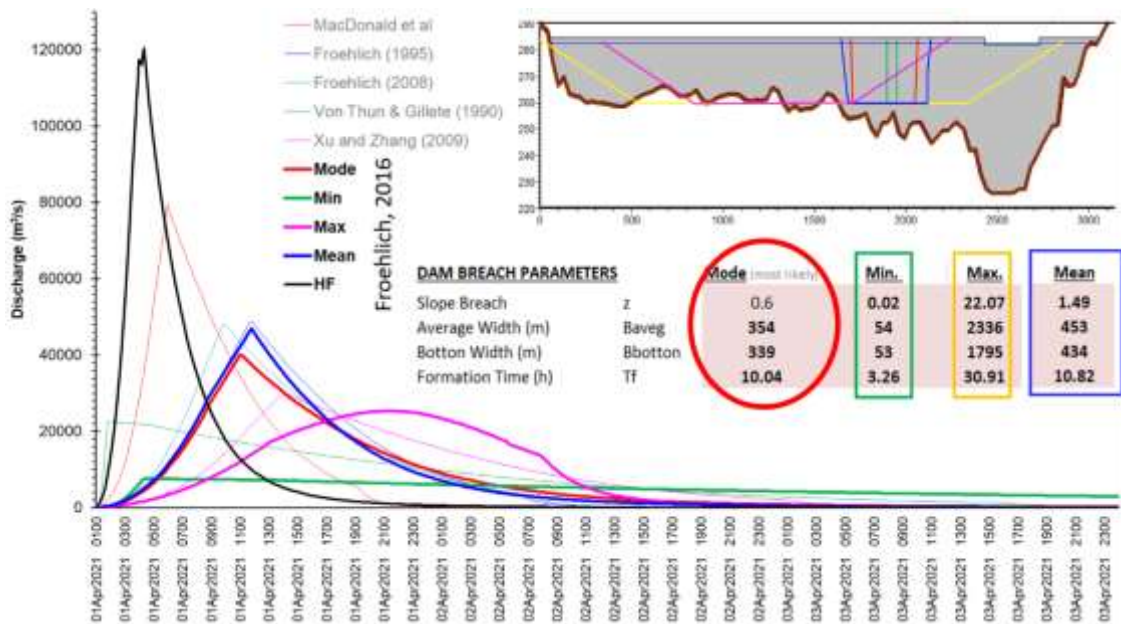
Figure 2: Dam breach flood hydrographs

However, such approaches are generally conservative and there is no communication of risk and uncertainty. In this study it is proposed to apply a dam breach modelling framework to improve the reliability of hydrograph predictions. The Exceedance Probability (EP) of hydrograph is determined by using Monte Carlo simulation technique, where each breach parameter is randomly sampled about pre-defined probability distributions. This require a large number of realizations to demonstrate convergence of statistical moments (mean, variance, skewness, kurtosis) as shown in Figure 3. It may be notes that with 100,000 realizations is quite adequate for this case (Figure 4). The estimated peak discharge at 1%, 5%, 10% and 50% EP are 74100 $m^3$/s, 61183 $m^3$/s, 55221 $m^3$/s and 37612 $m^3$/s respectively. The Map showing different hazard vulnerability classes due to PMF is shown in Figure 5.
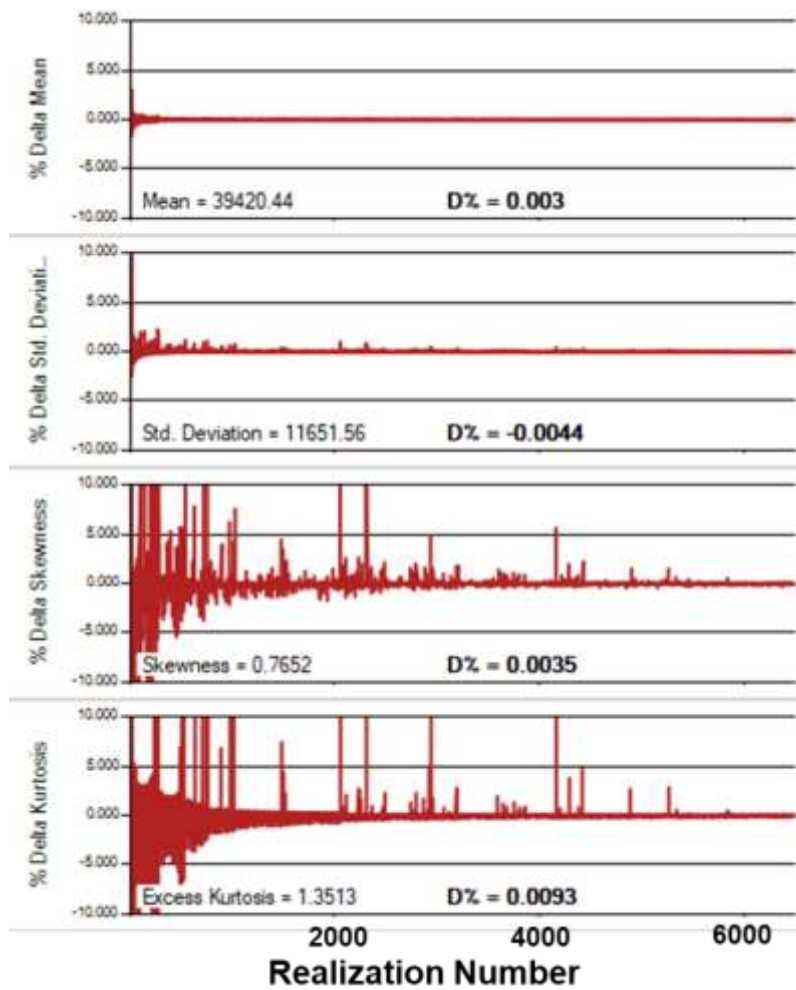
Figure 3: convergence of statistical moments
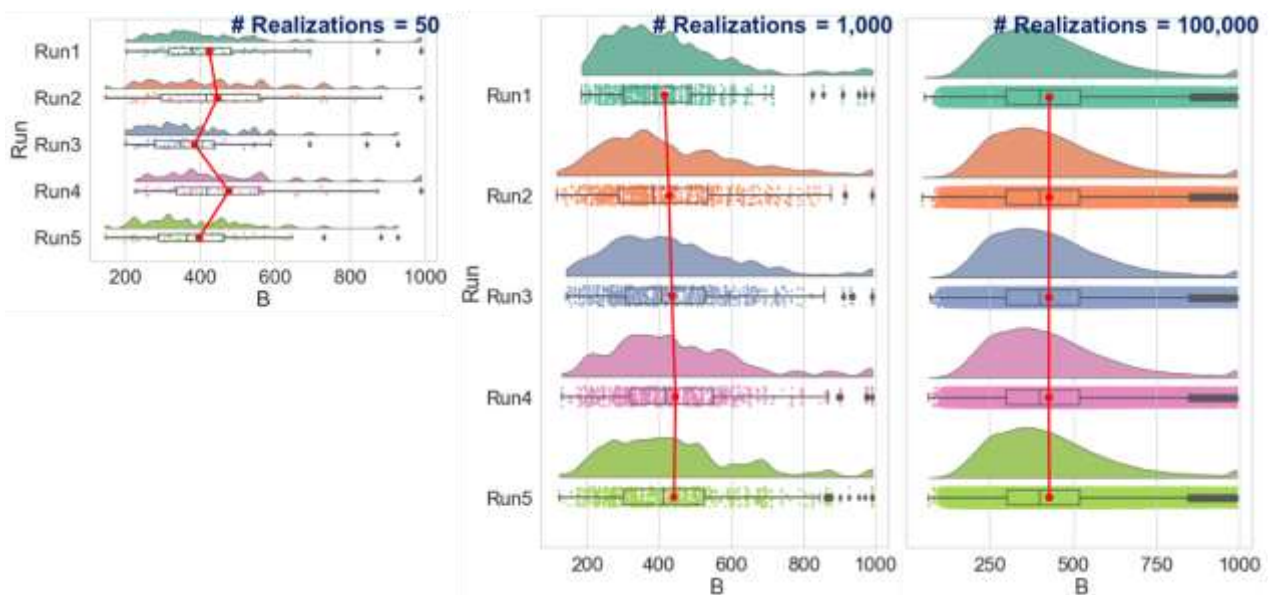


Figure 4: Distribution breach bottom width for different size of realizations.
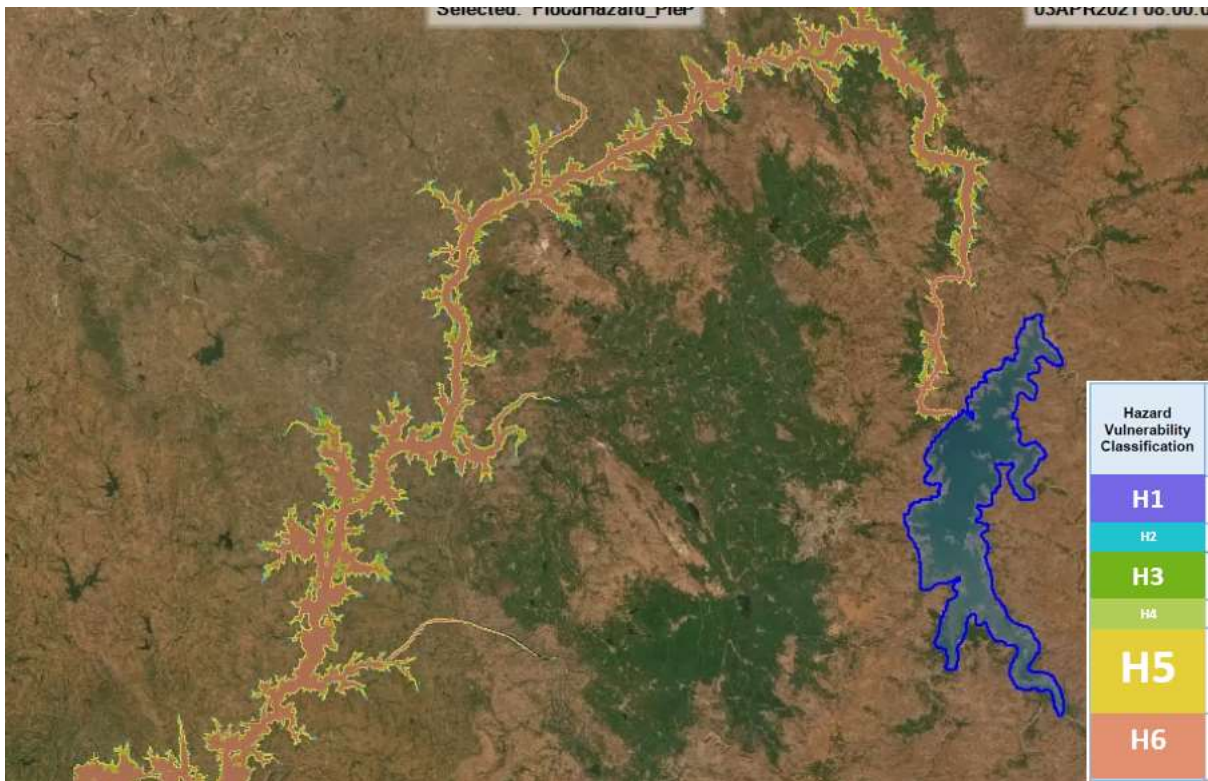
Figure 5: Map showing different Hazard Vulnerability classes

9. **Action taken on comments of previous working group meeting**
   There were no specific comments.

10. **List of deliverables**
   - Exceedance Probability Inundation (EPI) maps for Mahi Bajaj Sagar dam breach condition.
   - Quantification of difference between level pool routing and full unsteady flow routing through the Mahi Bajaj Sagar dam reservoir.
   - Maps showing depth, velocity, time of flood arrival, vulnerability due to large controlled release and dam break of Mahi Bajaj Sagar dam.
   - Capacity building for assessing and mapping risks associated with dams.

**2. PROJECT REFERENCE CODE: NIH/SWHD/NIH/21-22**

1. **Title of Study:**    **Uncertainty in rating curves and discharge estimation**

2. **Study Group:**                                          Sanjay Kumar,  Sc-E, PI
                                                            L. N. Thakural   Sc-D, Co-PI
                                                            Sunil Gurrapu    Sc C, Co-PI
                                                            J. P Patra Sc 'D' Co-PI
                                                            N. K. Bhatnagar Sc 'B' Co-PI

3. **Study Period:**                                         **Two Years** (April 2021 to March 2023)

4. **Objectives of the Study:** The objectives of the study are:

    1. To estimate uncertainty in stage discharge relationship.
    2. To estimate uncertainty in river discharge estimation.

5. **Statement of the Problem:**

The uncertainty in the river discharge measurement and estimation is caused by different sources of errors. These mainly includes uncertainty in (a) observations of river stage and discharge used to parameterize the rating curve, (b) presence of unsteady flow conditions, and (c) interpolation and extrapolation errors of the rating curves. The study will provide a framework for analyzing and quantifying the uncertainty in the (i) river flow data (ii) stage-discharge relationship The study will also examine various hydraulic factors controlling the flow at a cross section in the river and provides an understanding of independent variables that describes relations among stage, discharge and other parameters. specifically discharge measurement under steady flow conditions.

6. **Methodology:**

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

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

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

$X_{rd}=\pm( X_\alpha{}^2 + \beta^2 X^2\,H)^{1/2}$

In practice, $X_\alpha$ is the standard error of the mean relation ($S_{mr}$) and $XH_{h0}$ is the standard error of measured gauge.

## 7. Progress:

Observed and estimated discharge data of gauging sites in the subzone 1f has been collected. The observed stage and discharge data of these sites has been used to determine the Stage-Discharge relationships and their variation. The relevant literature has also been referred for uncertainty in the discharge estimation. A framework is being developed for the estimation of uncertainty in the stage-discharge relationships. The stage-discharge relationships for various sites has been shown graphically and preliminary analysis has been conducted for the observed stage and discharge data for evaluation of uncertainty.

## 8. Action Plan and Timeline:

| S.N. | Major Activities | 1st Year | | 2nd Year | |
|------|------------------|----------|---|----------|---|
| 1 | Literature review | ░ | | | |
| 2 | Development of a framework for quantifying the uncertainty | | ░ | | |
| 3 | Uncertainty in discharge measurements (Interim Report -1 in progress) | | ░ | | |
| 4 | Estimation of uncertainty in stage-discharge (rating curve) relationship. | | | ░ | |
| 5 | Uncertainty in discharge estimation and Final Report | | | | ░ |

## 9. End users/beneficiaries of the Study: Central and State government departments, academicians, BIS etc.

## 10. Deliverables: Report/Manual, Publications

**NEW STUDIES (INTERNAL)**

**1. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-22**

1. **Thrust Area under XII five year Plan:**
   Surface Water/Flood Forecasting

2. **Project team:**
   a. **Project Coordinator:**           Dr. A. K. Lohani, Sc-G **(PI)**
                                          Dr. R. K. Jaiswal, Sc-E **(PI)**

   **Project Investigator(s)**
                                          Dr. J. C. Patra, Sc-E  **(Co-PI)**
                                          Dr. P. C. Nayak, Sc-F **(Co-PI)**
                                          Dr. Vishal Singh, Sc-D **(Co-PI)**

3. **Title of the Project**
   Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Flood Management

4. **Objectives**

   - To collect and analyse  rainfall and runoff for selected reservoirs
   - Water balance of reservoirs for computation of runoff
   - Development of real time rainfall-runoff model for the catchment of reservoirs
   - Development of integrated framework for real time flood forecasting using cloud based climatic data for early warning and efficient flood management
   - Development of hydrodynamic model for assessment of flood impact downstream of dam

5. **Present state-of-art**

Flooding is an overflowing of water onto land that is normally dry. floods can happen during heavy rains, when ocean waves come on shore, when snow melts too fast, or when dams or levees break. flooding may happen with only a few inches of water, or it may cover a house to the rooftop. Floods are the catastrophic events cause damage to lives and properties. Due to impact of climate change, high intensity rainfalls are being observed in the most part of world and India. These extreme precipitations may cause unprecedented runoffs and resulting higher floods in the catchment. The recent change in climate pattern and land use in the catchment further aggravate the situation especially downstream of dams and reservoirs. The old formulae used to compute routed flood and flood protection works need to be evaluated and reformulated under changing climate situation.

Generally, regression based equations are commonly used for flood forecasting at reservoirs. In this method, water levels in the upstream and future forecast conditions from IMD are used to determine inflow in the reservoirs and according operation of gates are made during flood season. Nowdays, several sirce of forecast data for cliamate variables on grid levels are available which can be used in well calibrated rainfall-runoff model to determine pssible inflows to the reservoir through an integrated system. The gatherd knowledge of future inflows can be used for efficient reservoir operation and assessment of downstream flood and issue apporoprite preparedness for evacuation in the event of high flood. In the present study, Tawa dam of Madhya Pradesh, RaviShankar Sagar dam from Chhattisgarh, Dharoi dam from Gujarat and Beesalpur dam from Rajasthan in India.

**Tawa Dam**
Tawa dam is situated on Tawa River in Itarsi of Narmadapuram District of Madhya Pradesh state. The construction of Tawa dam was began in 1958 and was completed in 1978. The dam provides

for irrigation to several thousand hectares of farming land in Hoshangabad and Harda districts. The gross storage of Tawa reservoir is about 2311 MCM.



**Tawa Dam**

**Ravishankar Sagar Dam**

Ravishankar Sagar Project (RSP) dam was constructed in 1978 on river Mahandi in Chhattisgarh state. It is a multipurpose reservoir that serves municipal and industrial demands, irrigation demand, and hydel-power generation. The gross capacity of Ravishankar Sagar reservoir is 910.50 MCM designed to supply water for irrigation, power generation, domestic and industrial uses.



**Ravishankar Sagar Reservoir**

**Dharoi Dam**

Dharoi Dam is a gravity dam on the Sabarmati river near Dharoi, Satlasana Taluka, Mehsana district of Gujarat. The dam is constructed in 1978 and designed for irrigation, power generation and flood control. THe gross storage capacity of Dharoi reservoir is approximately 813 MCM.



**Dharoi dam**

**Bisalpur Dam**

Bisalpur Dam is a gravity dam situated on the river Banas in Tonk district, Rajasthan, India. The dam was completed in 1999 for the purpose of irrigation and water supply. The gross storage capacity of the dam is 1100 MCM.



**Bisalpur dam**

**Thokarwadi dam**

Thokarwadi dam is situated near Maval, Pune district in the state of Maharashtra. The dam is situated on river Indiravati. The gross storage capacity of Thokarwadi reservoir is 363 MCM.

**Thokarwadi dam**

These are the tentative selection of the dams and can be changed on the basis of data availabilityu and discussion with WRD officials of respectrive states.

## 6. Methodology

### Development of GIS Based data base of catchments

The GIS database of all the dam catchment consisting of topography, land use, soil, draininage, downstream structures etc. will be craeated foe all the dams selected for the study. The GIS database will work as base information for modeling the rainfall-runoff processes.

### Collection and analysis of climatological data and past catastrophic events

The climate data, rainfall, runoff, reservoir levels, releases, and supplies etc. if any will be collected and analyse with special referenc of catestrophic events in the reservoirs

### Water balance of reservoirs for computation of inflows

Non-availability of runoff data is one of the major problems in India. The runoff records upstrem of dams are generally not avaialble and under this situation a water balance of reservoir considering all inflows and outfloe components, reservoir levels, losses will be used to compute reservoir inflows in the reservoir

### Development of hydrological model for the catchments of dam

Rainfall-runoff models can be used to assess the production of water from cathment under given hydrological condition. In the study, suitable rainfall-runoff model on daily or event basis will be developed for catchments of reservoir. The developed model will be able to accommodate future forecast climate data for forecast of runoff with acceptable accuracy.

### Hydrodynamic model for risk assessment downstrem of dam

Hydrodynamic models in MIKE 1D or HEC RAS will be developed for downstream of dams to determine vulnearabvle spots under regulated flows from dams.

### Development of integrted system for early warning and downstream alert

An integrated system for all the dams will be developed under the study in which hydrological and hydrodynamic models will be integrated for efficient reservoir operation and planning for systematic reduction of flood using forecast data.

### Development of awareness and technology transfer

Series of mass awareness in the officers of WRD departments and general public will be organized for utilization of results and operate reservoir to avoid flood with efficient management

**7. Research outcome from the project**

The catastrophic events are more and more common in all over the world and India. The proposed integrated system for forecasting reservoir inflows will be useful to water resource Departments of respective states for efficient reservoir opearion and issue emergency warning well in advance to evacuate the people. The general public will be benefitted by getting timely information in the event of catestropic flood situation.

**8. Cost estimate**

      a.   Total cost of the project      :        Rs. 34,80,000
      b.   Source of funding          :          NIH internal funds
      c.   Sub Headwise abstract of the cost

| S.No. | Sub-head | Amount (in Rupees) |
|---|---|---|
| 1. | Salary | 16,80,000 |
| 2. | Travelling expenditure | 10,00,000 |
| 3. | Infrastructure/Equipment including a desktop, remote sensing data, etc. | 2,00,000 |
| 4. | Experimental charges/consumables | 2,00,000 |
| 5. | Misc. expenditure and Trainings | 4,00,000 |
| | **Grand Total:** | **34,80,000** |

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

(1)    **Salary** for one Junior Recourse Person @ 35,000 per month to support in various activities  like collection of data, GIS database development, analysis, etc.

(2)    **Travelling expenditure:** Field visits will be made in the catchment and downstream of dam sites in MP, Chhattisgarh, Rajasthan and Gujarat  for collection of data, from different agencies, ground truth and discussions regarding the study.

(3)    **Infrastructure/Equipment including a desktop, remote sensing data, etc.:** Remote sensing data for assessment of land use / land cover of the strudy area will be purchaed, a desktop will be purchased for analysis and data processing

(4)    **Experimental charges/consumables:** Field soil tests will be conducted to determine the infiltration rate and textural properties. Consumeable item like hard disk, pen drive, etc. may be purchased for data storage and transfer.

(5)    **Misc. expenditure:** Procurement of hydro-meteorological data, Stationary charges and Other miscellaneous field expenditure

**10.  Work Schedule:**

      a.   Probable date of commencement of the project:    April 2022
      b.   Duration of the project:    2 Years (April 2022 to March 2024)
      c.   Stages of work and milestone:

| S. No. | Work Element | First Year | | | | Second Year | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| 1. | Literature survey and Data collection | ▨ | ▨ | ▨ | | | | | |

| S. No. | Work Element | First Year | | | | Second Year | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| 2. | Discussion with field officers and dmas | ■ | ■ | | | | | | |
| 3. | Processing and analysis of hydrometereological data, GIS database development, Water sample collection, Spatial Database creation, | | ■ | ■ | | | | | |
| 4. | Water balance of reservoirs | | | ■ | ■ | | | | |
| 5. | Development of hydrological model for the catchments of dam | | | | ■ | ■ | ■ | | |
| 6. | Hydrodynamic model for risk assessment downstrem of dam | | | | | ■ | ■ | | |
| 7. | Development of integrted system for early warning and downstream alert | | | | | | ■ | ■ | |
| 8. | Development of awareness and technology transfer | ■ | | | ■ | | | ■ | ■ |
| 9. | Publication of reports | | | | ■ | | | | ■ |

230

**2. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-22**

**Title of Study: Application of unified-extreme-value (UEV) distribution for flood frequency: selected rivers of U.S.A.**

| | |
|---|---|
| **Study group** | Sushil K. Singh**,** Scientist F |
| **Date of start of study** | 01 April 2022 |
| **Duration and scheduled** | Six months |
| **Date of completion of study** | 30 September 2022 |
| **Type of study** | Internal (without/no funding) |

**Objectives of study**

This study is undertaken as an extension of the prior approved projects "*Generalization and parameter estimation of GEV distribution for flood analysis: Specific application on Indian data-*2016" and "*Application of unified extreme value distribution for flood frequency to different subzone-basins of India-*2018," to practically demonstrate the wider applicability of the proposed GUEV distribution.

To illustrate and demonstrate the practical application of previously developed generalized GUEV (unified extreme-value) distribution for analyzing the flood frequency of peak flows in basins falling under different subzones of India. The internal studies (without/no funding) completed for different subzones are:

1. Mahanadi subzone-3d – "Singh, S. K. (2017-18). *Generalization and parameter estimation of UEV distribution for flood analysis: Specific application on Indian data*." [This report considers Mahanadi sunzone-3d]
2. Krishna & Pennar subzone-3h – "Singh, S. K. (2018-19). *Application of unified-extreme-value distribution for flood frequency: Krishna & Pennar subzone-3h*."
3. Narmada & Tapi subzone-3c – "Singh, S. K. (2019-20). *Application of unified-extreme-value (UEV) distribution for flood frequency: Narmada & Tapi subzone-3c*."
4. LowerGodavari-3f – "Singh, S. K. (2020-21). *Application of unified-extreme-value (UEV) distribution for flood frequency: Upper Godavari-3e*."
5. Lower Narmada & Tapi subzone-3b – "Singh, S. K. (2020-21). *Application of unified-extreme-value (UEV) distribution for flood frequency: Lower Narmada & Tapi subzone-3b*."
6. Mahi & Sabermati subzone 3a – "Singh, S. K. (2021-22). *Application of unified-extreme-value (UEV) distribution for flood frequency:* (1) Mahi & Sabermati subzone 3a."
7. Mahi & Sabermati subzone 3a – "Singh, S. K. (2021-22). *Application of unified-extreme-value (UEV) distribution for flood frequency:* (2) Upper Godavari subzone 3e."

The current year study is intended for the rivers of U.S.A. to practically assess the wider applicability of the proposed GUEV distribution

**Statement of problem and brief methodology**

In an earlier report, the innovative model of UEV distribution for analyzing extreme events has been developed by the author, which is a true mathematical unification of the three extreme value

(EV-1, EV-2, and EV-3) distributions and better substitutes the GEV (generalized extreme-value distribution), is intended to be applied to the peak flows observed in the basins falling under two above mentioned subzones of zone-3 of India. Also, proposed therein to quantify the deterministic confidence limit and interval applicable for predicting the flood peaks.

**Adopters of the results of study and their feedback**

Practitioners, field engineers, and academic personals.

**Deliverables**

Research report detailing the application for flood frequency analysis of peakflows and research papers in International Journals with illustrative application on the published international data and the Indian data available/collected at NIH.

**3. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-23**

**Title of Study: Application of unified-extreme-value (UEV) distribution for flood frequency: Comparison of results using GEV distribution.**

| | |
|---|---|
| **Study group** | Sushil K. Singh**,** Scientist F |
| **Date of start of study** | 01 October 2022 |
| **Duration and scheduled** | Six months |
| **Date of completion of study** | 31 March 2023 |
| **Type of study** | Internal (without/no funding) |

**Statement of problem and brief methodology**

**In this report, the comparison of results using GEV distribution and that using the proposed GUEV distribution is intended, for a couple of Indian subzones.**

**Adopters of the results of study and their feedback**

Practitioners, field engineers, and academic personals.

**Deliverables**

Research report detailing the application for flood frequency analysis of peakflows and research papers in International Journals with illustrative application on the published international data and the Indian data available/collected at NIH.

**4. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-23**

1.  **Title of the Study:** Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model

2.  **Study Group:**

    **Study Team**
    Dr. P. C. Nayak, Sc. F– Principal Investigator
    Dr. A. K. Lohani, Sc. 'G'- Project Coordinator
    Dr. J. P. Patra, Sc. 'D'
    Dr. Sunil Gurrapu, Sc. 'C'
    Dr. T. Thomas, Sc. 'E', NIH, Bhopal

    **Supporting Staff**
    Mr. Om Prakash, PRA
    Mr. Jatin Malhotra, SRA

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 and Brahmani basin in Odisha state
    *   To predict the long lead time flood forecasting under changing climatic conditions, *i.e.,* include the GCM models output for future predictions

9.  **Statement of the Problem**

Nowadays, floods have become the widest global environmental and economic hazard in many countries, causing huge loss of lives and materials damage. It is, therefore, necessary to build an efficient flood forecasting system. The physical-based flood forecasting methods have indeed proven to be limited and ineffective. In most cases, they are only applicable under certain conditions. Indeed, some methods do not take into account all the parameters involved in the flood modelling, and these parameters can vary along a channel, which results in obtaining forecasted discharges very different from observed discharges. While using machine learning tools, especially artificial neural networks schemes appears to be an alternative. However, the performance of forecasting models, as well as a minimum error of prediction, is a very interesting and challenging issue. In this work, a comparison of deep neural networks and conceptual models are developed and compared in order to design a flood forecasting model and use discharge as input-output variables. The designed model will be tested upon intensive experiments and real case examples.

10. **Methodology**

It is proposed investigate prediction of flow statistics using conceptual/physical based model and DLNN. The river flows can be predicted using DLNN approach from mean precipitation, antecedent

flows at previous time steps, and other catchment characteristics. Future stream flow can be generated using GCM output. Flow chart of the proposed methodology is given below:
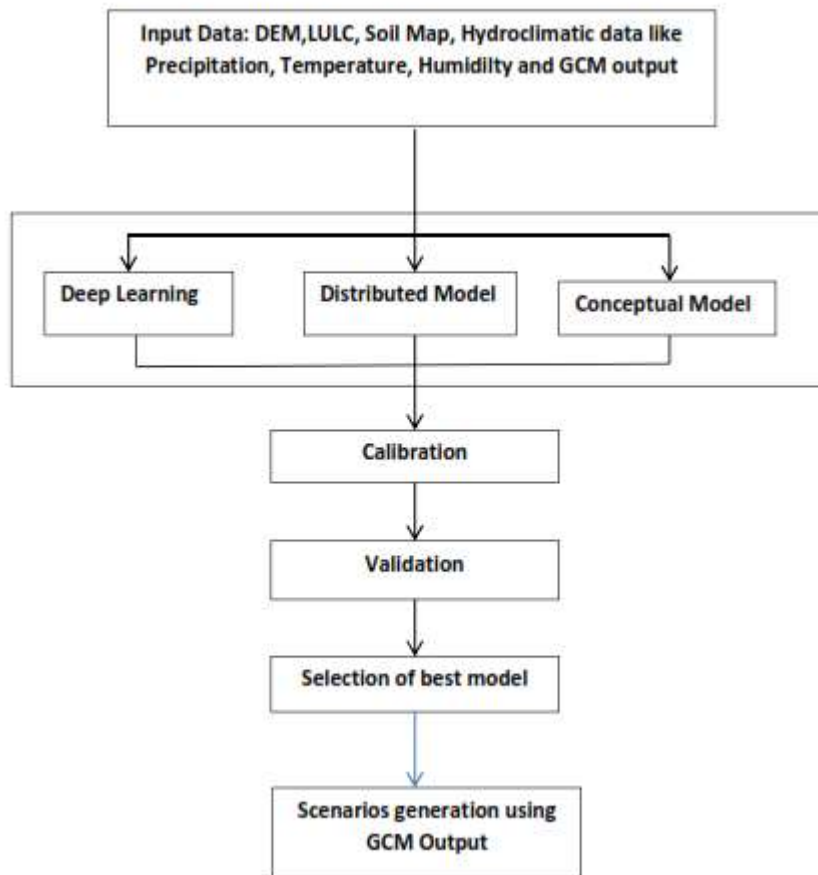
**11. Work Plan**

| S. No. | Major Activities | 2022-23 | | | | 2023-24 | | | | 2024-25 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| 1 | Literature survey | | ▓ | | | | | | | | | | |
| 2 | Data collection and preprocessing of data | | ▓ | ▓ | ▓ | | | | | | | | |
| 3 | Calibration & Validation of DLNN | | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ |
| 4 | Calibration, Validation of conceptual/physical based model | | | | | | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ |
| 5 | Future projection using GCM output | | | | | | | | | ▓ | ▓ | ▓ | ▓ |
| 6 | Interim Report | | | | ▓ | | | | ▓ | | | | ▓ |
| 7 | Final Report | | | | | | | | | | | | ▓ |

**12. Cost estimate:** Rs. 20,24,000 (NIH Internal Fund)

| S. No. | Sub-Head | I Year | II Year | III Year | Total |
|---|---|---|---|---|---|
| 1. | Manpower | 405480 | 405480 | 405480 | 1216440 |
| 2. | Travelling expenditure | 150000 | 100000 | 100000 | 350000 |
| 3. | Infrastructure /Equipment /Consumable | 30000 | 30000 | 30000 | 90000 |
| 4. | Experimental charges/Analytical charges | 0 | 0 | 0 | 0 |
| 5. | Misc. Expenditure | 20000 | 20000 | 20000 | 60000 |
| 6. | Grand Total | 605480 | 555480 | 555480 | 1716440 |

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

- Manpower: For timely collection of hydro-meteorological data required for thesimulation

| S. No. | Manpower Category | Nos. | Gross Salary per month including HRA | 1st year | 2nd year | 3rd year | Total |
|---|---|---|---|---|---|---|---|
| 1. | Junior Reserch Fellow | 1 | 33790 | 405480 | 405480 | 405480 | 1216440 |

- Travelling expenditure: For visit to study area, attending conferences, data collection,
-

**13.     Research outcome from the project:**

       a)   Identification of hydrological characteristics in flood estimation
       b)   Identification of rainfall variation over the basin
       c)   Future projection of flood using GCM output
       d)   Technical report and papers

**14.     End Users/Beneficiaries of the study:** Department. of Water Resources, Govt of Odisha

**15.     List the actions that will be necessary to put the results to use.**

    a)  Apprise the officials of the various departments of the findings of the study through reports, seminars, workshops etc.
    b)  Prepare and demonstrate some case studies to the user organisations showing the effect of particular developmental activities proposed/ being carried out by them in the study area.

**5. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-24**

**4. Title of the Project**: Hydrological Study to conserve the water resources of Bikaner, Rajasthan

**5. Project team:**

      **a**. Project Coordinator                                Dr. A. K. Lohni, 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

**6. Objectives:**

    a) To prepare inventory of water bodies in Bikaner and to understand the role of the water bodies in the human survival, livestock and livelihood sustainable and in biodiversity conservation.

    b) Long-term spatio-temporal analysis of rainfall, temperature and meteorological variables.

    c) Landuse land cover (LULC) change detection in the study area and selection of pilot water bodies (ponds).

    d) Trend analysis of groundwater levels and assessment of recharge to groundwater in Bikaner district

    e) Surface water availability analysis of pilot water bodies.

    f) Identification of various issues both quantitative and water quality assessment of pilot water bodies.

    g) To understand the socio-economical role of the water bodies to meet the daily requirement of community for water and other natural resources in and around water body.

    h) To understand the existing governance and management practices of water bodies by the local community or any other authorities.

    i) Suggesting ameliorative measures to restore water quality of water bodies and daptive and mitigation measures for rejuvenation and sustenance of water bodies.

**7. 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. In the last few decades, waterbodies have been under continuous and unrelenting stress, caused primarily by rapid urbanisation and unplanned growth. Encroachment of these waterbodies, often, identified as one of the causes of urban floods. Further, these waterbodies are being polluted by untreated effluents and sewage (Bindu and Mohamed (2016); Matto, 2019). 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.

## 8. Methodology:

**Present GW Scenario and trend analysis (Dr. Nitesh Patidaar)**
Land use change detection in study area for selection of pilot water bodies using remote sensing and GIS environment. The analysis of present GW status will be performed using the observed GW levels of Central Ground Water Board (CGWB). The analysis will be performed by generating spatial maps using interpolation atannual scale.GW data will be processed to check the consistency of observations. In order to derive groundwater level maps, data of observation wells will be interpolated using Kriging, a geo-statistical interpolation technique. The interpolated groundwater levels will be used in analyzing the spatial variability of groundwater in the study area.Trend analysis will be performed at annual scale using modified Mann-Kendall (M-K) test. The Mann-Kendall test is a non-parametric test for identifying trends in time series data. Being non-parametric, it allows to perform trend analysis on any distribution of data.

**Estimation of GW recharge**
Recharge to groundwater will be estimated using the integrated model developed at NIH. Remote sensing based data, such as land cover, impervious surface map, Leaf Area Index (LAI), Elevation, etc., will be utilized in the model. In addition, the well lithologs will be utilized to define aquifer geometry and parameters. The observed groundwater head will be utilized for validating the recharge.

**Trend analysis ( Dr L N Thakural)**
Trend analysis will be performed at annual scale using Mann-Kendall (M-K) and Sen's Slope of Estimator in rainfall and temperature parameter test in time series data.

**Assessment of Land use/Land Cover and its impact on runoff characteristics in the catchments of Waterbodies (Dr R. K. Jaiswal)**
The land use/land cover influences the characteristics of runoff and in turn considered as one of the important physical aspects in defining the water availability and sediment from catchment of water body. The traditional water bodies have their definite catchments which are being encroached and converted from forest to urban/agricultural land. Due to rapid growth of urbanization and population growth, land use pattern is being changed significantly during recent periods and availability of

remote sensing data from earth observation satellites has made it convenient to map and monitor land use/land cover at regional to local scales. The high as well as low resolution remote sensing data in GIS environment and Google Earth Engine using supervised classification technique for assessment of change in land use in different decades (1985 to 2015) and its impact on inflows in these lakes using SCS-CN or other suitable models in GEE using dynamic land use.

### Assessment of Soil Loss from the catchments (Dr R. K. Jaiswal)

The soil erosion modelling with Remote Sensing (RS) and Geographic Information System (GIS) is a valuable tool for studying the land degradation over a variety of spatial and temporal scales. The revised universal soil loss equation (RUSLE) model will be used using spatially distributed topographic, land use, soil, management options and conservation practices maps. The environmentally degraded hot spots in the catchments of water bodies will be identified for selection of appropriate conservation measures.

### Surface water availability analysis ( Sh. J. P. Patra)

The rainfall analysis will be carried out for estimating dependable rainfall at monthly and seasonal scale. The meteorological data will also be analysed along with rainfall for annual variation with respect to water availability in selected water bodies. The long term series of runoff generated from the catchment area of water bodies will be estimated using SCS-Curve number approach and other suitable methods. The runoff generated will also be analysed with respect to change in LULC and other interventions in the catchment area.

### Water Quality Assessment from water bodies (Dr. Mukesh Sharma)

Water quality assessment by collecting water samples from water bodies during pre- and post-monsoon season and analyzing these for physico-chemical parameters, demand parameters, heavy metals and pesticides. Metal pollution assessment of aquatic bed sediments of water bodies. Suggesting ameliorative measures to restore water quality of water bodies.

### Site-specific approaches for revival and restoration (Dr. P. K. Mishra)

Water harvesting and its utilization is one of the major components of the watershed development programs which is realized through: (a) in-situ rain water harvesting measures, (b) surface water development measures, such as ponds, earthen reservoirs, small harvesting tanks, gully control structures and, drainage line treatments (c) sub-surface or ground water development measures such as percolation tanks, ponds, sub-surface dams, barriers, and, diaphragm dams (d) roof top collection and runoff water cistern and, (e) improved water management practices including micro-irrigation and on-farm water management (Pandey et al, 2003; Samra, 1997). In the present study, the traditional waterbodies in and around the Bikaner city will be studied followed by broad recommendations on site-specific approaches for revival and restoration and suggest adaptive and mitigation measures for rejuvenation and sustenance of water sources mainly ponds spread over in the Bikaner district, Rajasthan

### True repositories of biodiversity ( Professor A K Chhangani)

Inventory of different types of water bodies and GIS mapping of various water bodies in Bikaner district will be prepared using digital toposheets of survey of India and Global Positioning System (GPS). Further, selection of various types water bodies in the study area for the detailed ecological and socioeconomic studies. The record of the vegetations including trees, shrubs and grasses of the study area will be compiled. For this a center point will be identified randomly, using the transect method, 500 m area to cover for the availability of plant species in and around each types of after bodies after identification. Moreover, attempts will be made to prepare inventory of all the faunal (including mammals, birds and reptiles) diversity encountered in and around different water bodies of the study area. Direct observation as well as interviews to collect information on the present management practice of the water bodies at community level will be carried out. Also, detailed inventory of the extracted resources by neighboring communities like collection of fallen wood for

fuel, coppicing of trees for food and fodder, collection of fodder grasses, and type of grazing. The existing governance and management practices of water bodies by the local community or any other authorities will be documented. Recommendations will be provided on site-specific approaches for revival and restoration of identified ponds.

## 9. Research outcome from the project

The outcome of the study will help in revival and restoration of ponds in water bodies.

## 10. Cost estimate:

a. Total cost of the project    :    Rs. 33,80,000
b. Source of funding    :    NIH internal funds
c. Sub Headwise abstract of the cost

| S.No. | Sub-head | Amount (in Rupees) |
|---|---|---|
| 1. | Salary | 16,80,000 |
| 2. | Travelling expenditure | 7,00,000 |
| 3. | Infrastructure/Equipment | Nil |
| 4. | Experimental charges/consumables | 5,00,000 |
| 5. | Misc. expenditure | 5,00,000 |
| 6. | Training/ Workshop | 5,00,000 |
| | **Grand Total:** | **38,80,000** |

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

(1) **Salary** for one Junior Resource Person @ 35,000 per month to support in various activities (GIS, Creation of data base, water sampling and analysis).
(2) **Travelling expenditure:** Field visits for data collection of water samples,GW & metrological data from different agencies, ground truth and discussions regarding the study.
(3) **Experimental charges:** Cosumables, chemicals / standards / Reagent glassware / plasticwares / filter papers/gases
(5) **Misc. expenditure**
   - Procurement of hydro-meteorological data
   - Stationary charges etc.
   - Other miscellaneous field expenditure

## 11. Quarterly Break up of cost estimate for each year

**Year: 2022-23**

| S.No. | Sub-head | Amount (in Rupees) | | | |
|---|---|---|---|---|---|
| | | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter |
| 1. | **Salary** | 2,10,000 | 2,10,000 | 2,10,000 | 2,10,000 |
| 2. | **Travelling expenditure** | 87,500 | 87,500 | 87,500 | 87,500 |

| S.No. | Sub-head | | | | |
|---|---|---|---|---|---|
| 3. | **Experimental charges** | 75000 | 75000 | 75000 | 75000 |
| 4. | **Misc. expenditure** Hydro-meteorological Data and Satellite Data Miscellaneous | 2,00,000 | | 1,00,000 | - |
| 5. | Training/ Workshop | | | 2,50,000 | |
| | **Sub- Total:** | 5,72,500 | 3,72,500 | 7,22,500 | 3,72,500 |
| | **Grand Total** | **20,40,000** | | | |

**Year: 2023-24**

| S.No. | Sub-head | Amount (in Rupees) | | | |
|---|---|---|---|---|---|
| | | 1$^{st}$ Quarter | 2$^{nd}$ Quarter | 3$^{rd}$ Quarter | 4$^{th}$ Quarter |
| 1. | **Salary** | 2,10,000 | 2,10,000 | 2,10,000 | 2,10,000 |
| 2. | **Travelling expenditure** | 87,500 | 87,500 | 87,500 | 87,500 |
| 3. | **Infrastructure/Equipment** | - | - | - | - |
| 4. | **Experimental charges** | 75000 | 75000 | 50000 | - |
| 5. | **Misc. expenditure** Hydro-meteorological Data and Satellite Data | - | - | - | - |
| | Miscellaneous, Report Printing etc. | - 50,000 | - 50,000 | - 50,000 | - 50,000 |
| 6. | Training/ Workshop | | | 2,50,000 | |
| | **Sub- Total:** | 4,22,500 | 4,22,500 | 6,47,500 | 3,47,500 |
| | **Grand Total** | **18,40,000** | | | |

Note:

(i)     The above table has to be prepared for each year of the project period

(ii)    PI  has to submit the revised table to the Finance Officer for the subsequent year (on or before 15$^{th}$ March of current year) considering the actual expenditure incurred during the current year

**12.    Work Schedule:**

d.  Probable date of commencement of the project:    April 2022
e.  Duration of the project:              2 Years (April 2022 to March 2024)
f.  Stages of work and milestone:

| S. No. | Work Element | First Year | | | | Second Year | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| 1. | Literature survey and Data collection, selection of waterbodies , Field visits | ▓ | ▓ | ▓ | ▓ | ▓ | | | |

| S. No. | Work Element | First Year | | | | Second Year | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| 2. | Processing and analysis of hydro-meteorological data, GIS database development, Water sample collection, Spatial Database creation, | ▓ | ▓ | | | ▓ | ▓ | | |
| 3. | Surface water availability, groundwater levels and assessment of recharge to groundwater | | ▓ | ▓ | ▓ | | | | |
| 4. | Identification of various issues both qualitative and quantitative bodies | | | ▓ | ▓ | ▓ | | | |
| 5. | Understand the existing governance and management practices of water bodies by the local community or any other authorities. | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ |
| 6. | Suggesting ameliorative measures to restore water quality of water bodies.  Suggest adaptive and mitigation measures for rejuvenation and sustenance of water | | | | | | | ▓ | ▓ |
| 7. | Training/ Workshop | | | ▓ | | | | ▓ | |
| 8. | Preparation of Interim/ Final report | | | | ▓ | | | | ▓ |

## 6. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-25

1. **Title of the Study:**

Review of design flood and dam break analysis of Khadakhai Dam in Odisha

2. **Project team**
   a. Project Investigator:  J.P.Patra, Sc. – D, SWHD
   b. Project Co-Investigator:  A. K. Lohani,, Sc. – G & Head SWHD
      Pankaj Mani, Sc. – F, CFMS Patna
      P. C. Nayak, Sc. – F, SWHD
      Sanjay Kumar, Sc. – E, SWHD
   c. WRD Odisha:  Tapas Pattanaik, Damsaftey
      Tareni Sen Dhala, CE & BM Subarnarekha

3. Type of Study: Internal Study

4. Nature of Study: Basic and Applied Research

5. Date of Start: April 2022

6. Scheduled date of Completion: March 2025

7. Duration of the Study: 3 years

8. 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.

9. Present state-of-art

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.

10. 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.

11. Research outcome of the project
   - Revised design flood for the Khadakhai Dam.
   - Flood inundation maps along with depth, velocity, time of flood arrival, combined flood hazard due to large controlled release and dam break of Khadakhai Dam.
   - Capacity building in line with DRIP.
   - Application of DSS (PM) developed under NHP

12. Work Schedule:

| S.N. | Work Element | 1st Year | 2nd Year | 3rd Year |
|------|--------------|----------|----------|----------|
| 12 | Collection of basic data, topography, cross-section, satellite images, thematic maps etc. | ▓ | ▓ | |
| 13 | HEC-HMS model setup, review & estimate design flood | ▓ | | |
| 14 | Uncertainty analysis for design floods with future climate projections. | | ▓ | |
| 15 | Analysis of operation rule curve | | | ▓ ▓ |
| 16 | HEC RAS model setup for dam beach modelling | ▓ | | |
| 17 | Dam breach flood inundation modelling and combined general flood hazard classification | | | ▓ ▓ |
| 18 | Review and analysis of reservoir sedimentation and updating of EAC table | | | ▓ |
| 19 | Sensitivity of the flood inundation maps | | | ▓ |
| 20 | Workshop/ Training | ▓ | ▓ | |
| 21 | Report | ▓ | ▓ | ▓ |

13. Cost estimate: Rs. 10,20,000 (NIH Internal Fund)

| S. No. | Sub-Head | Amount (Rs) |
|--------|----------|-------------|
| 1. | Travelling expenditure | 3,50,000 |
| 2. | Data/ Equipment/ Consumable | 1,10,000 |
| 3. | Training/ Workshop | 5,00,000 |
| 4. | Misc. Expenditure | 60,000 |
| | **Total** | 10,20,000 |

14. End Users/Beneficiaries of the study:
Department of Water Resources, Govt. of Odisha

## 7. PROJECT REFERENCE CODE: NIH/SWHD/NIH/22-24

| | |
|---|---|
| **Title of the Project:** | Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin |
| | |
| **Project Team:** | Dr. Sunil Gurrapu, Scientist 'C' (PI), NIH Roorkee |
| | Dr. Y R S Rao, Scientist 'G', NIH Kakinada |
| | Dr. Nitesh Patidar, Scientist 'B', NIH Roorkee |
| | Dr. R Venkat Raman, Scientist 'D', NIH Kakinada |

| | |
|---|---|
| **Type of Study:** | Internal |
| **Status:** | New |
| **Duration:** | 2 years |
| **Date of Start:** | 1$^{st}$ April 2022 |
| **Scheduled Completion Date:** | 31$^{st}$ March 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 for 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 (e.g. Liu et al., 2021; Tabari, 2020; Manfreda et al., 2018; Wang et al., 2016; Gossain et al., 2006). 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 (Manfreda et al., 2018). 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 (ICHARM 2009; Vogel et al. 2011). Therefore, information on the impacts of climate change on the basin's hydrology and the basin's hydrological projections of the 21$^{st}$ 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

## TENTATIVE SCHEDULE

| # | ACTIVITIES | YEAR 1 | | | | | | | | | | | | YEAR 2 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| 1 | Formation and mobilization of work team | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | Review of Literature | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | Collection of land use/land cover maps of the study basin | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | Collection of hydro-meteorological data (observed and gridded) | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | Collection of CMIP6 data for the study area | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | Pre-processing of CMIP6 data and bias-correction of the projected climate | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | Generating multi-model climate change scenarios | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | Reconnaissance survey in the field | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | Collection of the details of regulation works on the River network | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | Fieldwork and collection of soil samples | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | Laboratory analysis of soil samples | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | Set-up a hydrological model for the study basin | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | Hydrological model calibration and validation | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | Evaluation of the model performance | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | Preparation of CMIP6 data for generating hydrological scenarios | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | Hydrological model simulation and generation of hydrological scenarios | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | Analyse impacts of climate change on water availability and hydrological extreme events | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | Evaluate the characteristics of historical and projected hydrological extremes | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | Interpretation of results | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | Preparation of final report and submission | | | | | | | | | | | | | | | | | | | | | | | | |

## DELIVERABLES

1. Multi-model climate change scenarios for the state of Andhra Pradesh.
2. Calibrated and validated hydrological model for the Pennar River basin, ready to be used in the future studies on the assessment of climate change impacts.
3. Multi-model hydrological scenarios generated for the Pennar River Basin, ready to be used by the officials of Water Resources Department, Andhra Pradesh to make decisions on effective management of available water.

## BIBLIOGRAPHY

1. ICHARM Report, 2009. Global trends in water related disasters: an insight for policymakers. International Centre for Water Hazard and Risk Management (UNESCO), Tsukuba, Japan. http://www.icharm.pwri.go.jp.
2. Gossain A K, Rao S, Basuray D. 2006. Climate change impact assessment on hydrology of Indian river basins. *Current Science* 90 (3), 346 – 353.
3. Liu X, Attarod P, Li Z, (eds). 2021. *Understanding Hydrological Extremes and their Impact in a Changing Climate: Observations, Modeling and Attribution*. Lausanne: Frontiers Media SA. DOI: 10.3389/978-2-88966-594-5
4. Manfreda S, Iacobellis V, Gioia A, Fiorentino M, and Kochanek K (eds.). 2018. Special Issue "Impact of climate on hydrological extremes". *Water* 10.
5. Tabari H. 2020. Climate change impact on flood and extreme precipitation increases with water

availability. *Scientific Reports* 10 (1), 13768. DOI: 10.1038/s41598-020-70816-2.

6.  Vogel R M, Yaindl C, and Walter M. 2011. Nonstationarity: flood magnification and recurrence reduction factors in the United States. *Journal of American Water Resources Association* 47(3), 464 – 474. DOI: 10.1111/j.1752-1688.2011.00541.

7.  Wang J, Liang Z, Wang D, Liu T, Yang J. 2016. Impact of climate change on hydrologic extremes in the upper basin of the Yellow River Basin in China. *Advances in Meteorology*, 1404290. DOI: 10.1155/2016/1404290.

**8. PROJECT REFERENCE CODE: NIH/SWD/NIH/22-25**

**Title of the Project:** Investigation on occurrences of seasonal extremes across Northwest Himalaya in relation to global atmospheric thermal and circulation changes

**Thrust area under XII<sup>th</sup> Plan:** Impact of climate change on water resources and hydrology of extreme

| | |
|---|---|
| **Project team:** | Dr. Ashwini Ranade, Scientist 'D' (PI) |
| | Dr. P.K. Mishra, Scientist 'D' (Co-PI) |
| | Dr. Sunil Gurrapu, Scientist 'C' (Co-PI) |
| **Type of Study:** | Internal |
| **Status:** | New Study |
| **Duration:** | 3 years |
| **Date of Start:** | 1 April 2022 |

**Scheduled date of completion**: 31<sup>st</sup> Mar 2025

**Objectives:**

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

**Statement of the problem:**

Heavy rain events over the northwest Himalayan region are becoming ferocious in recent years causing catastrophic disasters. Colloquially termed as the cloudburst has a potential to downpour over a smaller region in very short duration. International disaster database (http://www.emdat.be) has reported the substantial increase in the extreme rain events over the western Himalayas in recent 30-40 years. It is one of the most studied but less understood phenomena so far. Under the influence of highly complex terrain and tropical-extratropical interactive atmosphere, the northwest part of Himalaya becomes more prone to such types of extreme events, especially during the monsoon season. Other parts of the country also experiencing extreme rain events each year surprisingly even during large-scale droughts also. In addition, there is a widespread belief that, in a recent global warming period, due to the intensification of the hydrological cycle, extreme rain events are increasing (Senior et al. 2002, IPCC 2007). The sixth assessment report (IPCC, 2021) projected that, extreme rainfall are projected to be intensifies by 7% for each additional 1 °C due to acceleration of hydrological cycle in warmer climate across the globe and become more frequent mostly in Africa and Asia.

Many more studies also supported this fact. In most of the studies, the rising frequency of extreme rain events in India has mostly attributed to the following conditions: i) a significant increase in synoptic activities over the Bay of Bengal and Arabian sea; ii) anomalous convective instability; iii) atmospheric conditions over the equatorial Indian Ocean; etc. Their conclusions are especially based upon, synoptic observations, satellite-radar output as well as numerical model simulations. Recently we have studied the

heaviest monsoon rainstorm that occurred during 16-17 June 2013 over western slopes of Himalaya and concluded that, combined five factors: cool-low and warm-low regime contrast; squeezing of three different type of flows (deep warm-moist, cool-dry and warm-dry); orographic lifting; and pumping and suction effects produced unprecedented rains over Kedarnath range. In our earlier studies concerning about the variations in spatio-temporal extreme rainfall fields over the Indian region, we observe that the point/local, short-duration extreme rain events (EREs) are embedded in large-scale, long-period intense heavy to very wet spells, and rainwater generated during the main monsoon wet period is highly correlated with the Asia-Pacific monsoon intensity.

Since 2010, about 17 noticeable extreme events have been observed over Indian Himalayan region of Leh, Uttarakhand, Jammu and Kashmir and Himachal Pradesh, about 5 over subtropical Pakistan and 2 each over Nepal and China. Studies shows that, multiple visualizable factors operated in accord to produce extreme weather/rain events across subtropical Asia. Unprecedented interactions between deep westerly trough and cross-equatorial Indian Ocean south-westerlies as well as Pacific easterlies results in evolution of large and intense monsoon trough extending from Philippine through Indus basin. Arabian sea and Bay of Bengal provides the excessive moisture and numerous synoptic scales, mesoscale and microscale weather systems are evolved and interconnected in the anomalous monsoon trough along with topographical features results in increase in the severity of the events. Formation and intensification of troughs in the temperate westerlies is a short period phenomenon. Therefore, condensation and intense rainfall in subtropical mountainous terrain that involving confluence and convergence of huge airmasses of contrasting characteristics are short lived

Various studies have documented the precipitation characteristics in the Himalayan region during rainstorm periods, while the detailed understanding of the evolution and intensification of the rain-producing weather systems at the boundary of the tropical (barotropic) and extratropical (baroclinic) regime is missing. It has been observed that the circulation dynamics of monsoonal and non-monsoon weather systems are completely different from each other. Within monsoon season itself, early monsoon phase rainstorm dynamics are different than that during the established phase and withdrawal phase. So, it is a very challenging task to comprehend the common atmospheric pattern for all Himalayan extremes and reach any generalized conclusion. We, therefore, propose to study each type of extreme rain event that has occurred in different seasons of the year over NW Himalaya as a separate case study. In this study, we propose a detailed systematic analysis of various heavy rainstorm events over northwest Himalaya during winter, pre-monsoon, monsoon and post-monsoon seasons of a year on case by case basis by using the available station (hourly) and gridded (daily) rainfall observations and reanalysis atmospheric parameters (temperature, pressure, geopotential height, precipitable water, wind, absolute vorticity, cloud cover, vertical velocity, freezing level, OLR etc.)

**Dataset used:**

- Rainfall Data: Gridded rainfall products from IMD;  hourly rainfall data of selected stations across NW Himalaya
- NCEP-CFSR dataset (2.5 degree): Temperature, geopotential height and wind at 12 isobaric levels, PPW, MSLP, OLR, Freezing level, lapse rate
- ERA-5 Reanalysis (0.25 deg): Divergence at all levels, Vertical Velocity, Vorticity, CAPE, Low, medium, high and total cloud cover, moisture convergence,


**Deliverables**

Our results are expected to provide in-depth information about the nature and types of EREs and location, shape, size, and intensity of the various rain-producing weather systems that are formed over

the northwest Himalaya during different seasons of a year. The study also provides more information about the large-scale circulation dynamics, tropical-extratropical interaction mechanisms at different levels of the atmosphere, thermodynamical processes and the role of orography in the evolution and genesis of heavy rainstorms over Northern Himalaya. The results are helpful for the assessment and prediction of the rainstorms over northwest Himalaya well in advance.

**Cost estimates**

| S. No. | Head | Amount |
|--------|------|--------|
| 2 | Travelling Expenditure | 2,00,000 |
| 3 | Consumables/contingency/Misc. expenditure | 1,00,000 |
| 4 | Capacity building/Technology transfer | 3,00,000 |
| 5 | Dataset purchase/software/hardware | 4,00,000 |
|  | **Total** | 10,00,000 |

a. **Justification for traveling expenditure**

Investigators may required to travel to collect station rainfall dataset and other meteorological dataset across study region. Fund will also be utilizing for presentation of project work in different conferences across India.

b. **Justification for contingency**

Funds will be required in order to purchase external hard drives in order to store the dataset collected and generated maps through project work. Some funds will also be used for the purchase of necessary furniture, stationary items, reference books, and preparation of research reports and training material.

c. **Justification for Capacity building/Technology transfer**

The results and knowledge gained from the project will be disseminated/exchanged with stakeholders and government officials and research students by organizing trainings/Workshops (2 nos) in the field of hydrometeorology and weather analysis.

d. **Justification for Dataset purchase/software**

It will be required to purchase hourly rainfall data and metrological parameters over selected stations across India in order to study extreme rain events in details. Funds will also be used to purchase necessary statistical and graphical analysis software as per requirement.

**Work Schedule:**

| S.N. | Work Element | 1st Year | 2nd Year | 3rd Year |
|------|--------------|----------|----------|----------|
| 1 | Identification of heavy rainstorms/snowstorms and associated weather systems | ▓ | | |
| 2 | Study of relationship of Global atmospheric thermal changes with monsoon circulation and EREs | | ▓ | ▓ |
| 3 | Study of thermo-dynamical and hydro-dynamical processes for the weather systems occurrences | | ▓ | ▓ |
| 4 | Report preparation | | | ▓ |

## 9. PROJECT REFERENCE CODE: NIH/SWD/NIH/22-23

**1. Title of the Study**

Investigating gap areas, current trends and future directions of research in Climate Change Impact on Hydrology and water Resources in India through Scientometrics

**2. Study Team**

Dr. Archana Sarkar, Sc E, SWHD (PI)

Dr Jyoti Patil, Sc D, NIH New Delhi office (Co-PI)

Mr. Rohit Sambare, Sc B, RMOD (Co-I)

Mrs Charu Pandey, A.L.I.O., Library (Co-I)

**3. Type of Study**

Internal

**4. Date of Start**

1 May 2022

**5. Scheduled date of completion**

31 Oct 2023

**6. Nature of Study**

Scientific Analysis

**7. Study Objectives:**

- To study and analyze the growth and direction of research in the field of climate change impacts on hydrology and water resources in India during 1992-2021
- Identification of gap areas and emerging areas in the research on climate change impact on hydrology and water resources to address the water security issues in India
- Evaluation of research productivity of institutions engaged in research on climate change impact on hydrology and water resources in India through scientometrics
- Dissemination of study findings through workshop/training course, scientific documentation and other outreach means.

**8. Background**

Scientometrics is considered a powerful tool of tracing the development of a given scientific field, thereby revealing the gap areas and emerging research problems, and evaluation of scientific contributions and research productivity of research community, institutions, regions, countries, etc. As technological advancements occur, there is a paradigm shift in the working trends in any field. So it is recommended to look for emerging trends and propose new developments when the current trends of any research domain are studied. Bibilometric analysis and scientometric mapping can show the change in mindset of researchers by studying the research works over a time period. Also by identifying the research questions in the water sector today, one can have insight into the future of research in the field. As Boyack et al. (2005) stated that a correctly constructed science map help to understand the inputs, associations, flows and output of science and technology: "Just like in physical world, maps help us to understand our environment- where we are, what is around us and the relationships between

neighbouring things". In recent years, scientometrics has come to play a major role in the measurement and evaluation of research performance.

Potential climate change and its unfavourable impacts on hydrologic systems pose a threat to water resources throughout the world. As per the latest report of IPCC (AR6) released in August 2021, it is unequivocal that human influence has warmed the atmosphere, ocean and land. Widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere have occurred. The scale of recent changes across the climate system as a whole and the present state of many aspects of the climate system are unprecedented over many centuries to many thousands of years. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and, in particular, their attribution to human influence, has strengthened since AR5. Many changes in the climate system become larger in direct relation to increasing global warming. They include increases in the frequency and intensity of hot extremes, marine heatwaves, and heavy precipitation, agricultural and ecological droughts in some regions, and proportion of intense tropical cyclones, as well as reductions in Arctic sea ice, snow cover and permafrost.

The effect of climate change on hydrology in tropical Asia has many facets. The Himalayas, which act as a mountain barrier on the earth, where polar, tropical and Mediterranean influences interact, play an important role in maintaining and controlling the monsoon system over the Asian continent. In the Himalayas, the storage of precipitation in the form of snow and ice (in glaciers) over a long period provides a large water reservoir that regulates annual water distribution. As a populous, tropical developing country, India faces a bigger challenge in coping with the consequences of Climate Change than most other countries. It is now clear that enhanced climate variability and climate change due to continued emission of greenhouse gases in the Earth's atmosphere will alter the key characteristics of summer monsoon rainfall and could significantly impact water supply and demand throughout the Indian subcontinent. Continued global warming is projected to further intensify the global water cycle, including its variability, and the severity of wet and dry events. Natural drivers and internal variability will modulate human-caused changes, especially at regional scales and in the near term, with little effect on centennial global warming. These modulations are important to consider in planning for the full range of possible changes. There is a strong need to reconnect climate science and policy development with the local context to generate relevant knowledge supporting future climate change adaptation and disaster risk reduction strategies on a local to national to international level. The ability to undertake policy action requires information, knowledge, tools, and skills.

## 9. Statement of the problem

Many researchers/academicians/policy makers in India have studied and published various aspects of climate change impact on hydrology vis-à-vis water resources and policy implications. However, such studies have been carried out in isolation focusing on specific region/river basin and specific aspect of climate change impact (floods/droughts/water availability/etc). As such, a scientometric analysis of research on climate change impact on hydrology and water resources by Indian scientists has not yet been carried out. The proposed study is expected to highlight the gap areas, emerging trends, and potential opportunities in taking forward the research on climate change impact on hydrology and water resources, which is gaining momentum in view of the looming water scarcity. The study will provide an insight into the dynamics of research on climate change impact on hydrology and water resources and also provide a roadmap to the policy planners in India to address the Sustainable Development Goals (SDG).

## 10. End users/beneficiaries of the study

Research Organisations, Academic Institutes, Central and State Government Agencies, Policy Makers, NGOs.

## 11. Methodology

1) Target population and sample size to be covered
   Research publications by Indian authors in hydrology journals covered under Scopus, 'Indian Citation Index', 'Indian Science Abstracts' and IWA's 'Water Intelligence Online' will be scouted for this study. Estimated sample size for the proposed 30-year period is 8,000-10,000 records.

2) Method of data collection
   The data element to be downloaded for the study include author(s), affiliation of authors, title of the paper, year of publication, source title (Journal title), citations received, keywords, publisher, language, and document type like research article, review, conference paper, editorial, meeting abstract, book review, letter and notes. Of these, only research articles, reviews, letters and notes will be subjected to detailed analysis.

3) Sources of the data
   The publication data on hydrologic climate change research by Indian researchers for the last 30 years (1992 to 2021) will be downloaded from 'Scopus' database of the Elsevier. Scopus's ability to manage bibliographic references and quantify citations makes it an essential instrument for analysis of any discipline. For expanded coverage of publications in Indian journals, efforts will also be made to explore availability of relevant publications in the 'Indian Citation Index', 'Indian Science Abstracts' and IWA's 'Water Intelligence Online'.

4) Reference period of the data to be covered
   The publication data on hydrologic research by Indian researchers for the last 30 years (1992 to 2021), which covers a significant period of the evolution of hydrologic research in India, is proposed to be used in the study.

5) Method of processing and analysing
   The publication data on climate change impact on hydrology and water resources by Indian researchers for the last 30 years (1992 to 2021) will be downloaded from 'Scopus' database of the Elsevier. Advanced search strategy available in Scopus database will be used to download the data. By using analytical functions available in the Scopus database, publications data will be further refined to get data distributed by subject, collaborating institutions, journal-wise, author-wise, organization-wise, State-wise etc. Complete counting method will be used wherein every contributing author or organization covered in multiple authorship papers will be fully counted. In order to address the issue of consistency of records, a standardization procedure will be
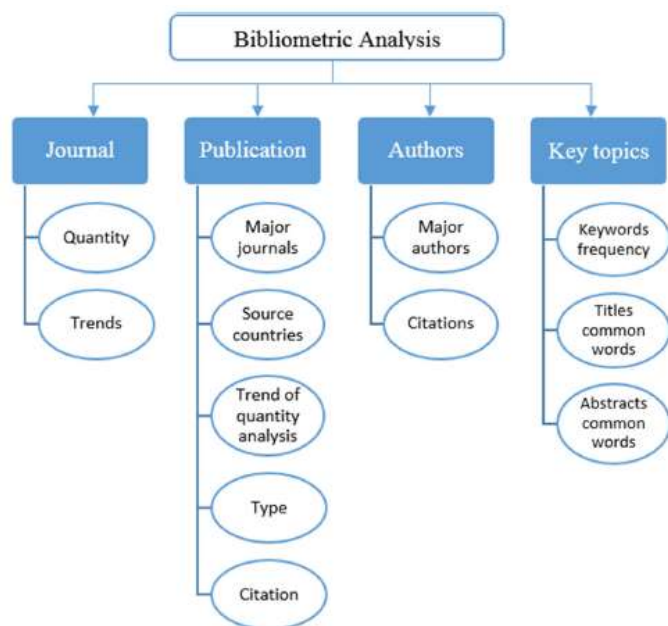
applied. As an example, for the case of authors' names, the standardization criterion will address the coincidence in the affiliation of the institutional signatures associated with the different variants of names and surnames.

After applying appropriate quality control procedures, the downloaded data from databases will be enriched through text enrichment techniques, which help to obtain better clustering that represent the fields in the relevant topic. The downloaded articles considered irrelevant for the study shall be deleted from the database. Relevant data mining techniques, such as decision-tree and apriori algorithm, shall be used to analyze the data. There is a wide range of useful bibliometric methods to analyze the bibliographic data. The main bibliometric indicators proposed to be used in the study are described below:

- Total Number of Publications (TNP);
- Total Number of Citations (TNC);
- Citations Per Paper (CPP);
- Relative Citation Impact (RCI)

## 12. Action plan and timeline

| S. No. | Work Element | First Year | | | | Second Year | |
|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 |
| 1 | Identification of computational tools | ▓ | | | | | |
| 2 | Identification of search strings relevant to research on climate change impact on hydrology and water resources in India | ▓ | ▓ | | | | |
| 3 | Data collection from various sources | ▓ | ▓ | ▓ | ▓ | | |
| 4 | Bibliometric analysis using bibliographic databases | | | ▓ | ▓ | ▓ | |
| 5 | Manual analysis by searching and analyzing data from websites | | | ▓ | ▓ | | |
| 6 | Scientometric mapping | | | | ▓ | ▓ | ▓ |
| 7 | Interpretation of bibliometric analysis | | | | | ▓ | ▓ |
| 8 | Preparation of research publications, outreach material, and synthesis report | | | | ▓ | ▓ | ▓ |

## 13. Data requirements

The publication data on hydrologic climate change research by Indian researchers for the last 30 years (1992 to 2021) from 'Scopus' database and other relevant sources

## 14. Deliverables

Research papers, synthesis report, policy brief

## 15. Cost Estimate
   I.   Total cost of the project: Rs. 18,04,000/-
   II.  Source of funding:  Internal funding from NIH
   III. Sub Head wise abstract of the cost

| S. No. | Head | Amount (Rs.) |
|---|---|---|
| 1 | Salary (Sr. Proj. Officer @Rs 28,000 p.m.) | 5,04,000 |
| 2 | Travelling Expenditure | 3,00,000 |
| 3 | Consumables | 4,00,000 |
| 4 | Technology transfer | 2,00,000 |
| 5 | Contingency and other costs | 4,00,000 |
| | **Total** | 18,04,000 |

e. **Salary**

Full time one personnel (**Sr Project Officer**) for the project will be required for assistance in the data processing and technical analysis. A qualified person will be recruited as per the guidelines of Ministry of Water Resources on temporary basis (Sr. Proj. Officer @Rs 28,000 p.m. (01))

f. **Justification for traveling expenditure**

Investigators may require to travel to collect data, carry out academic discussions, interviews and a part of analytical work and reporting. Funds will also be utilized for presentation of project work in different conferences across India.

g. **Justification for contingency**

Funds will be required for: Stationary, printer cartridge, pen drives, books and journals, procurement of computation tools, preparation of research reports and training material etc.

h. **Justification for /Technology transfer**

The results and knowledge gained from the project will be disseminated/exchanged with stakeholders, government officials, researchers and policy makers by organizing trainings/Workshops.

i. **Justification for Contingency and other costs**

Funds will be required for: Fee for access of databases; thematic training of manpower; documentation and printing; payment of honorarium to experts; other contingent expenses

# WATER RESOURCES SYSTEM DIVISION

**Scientific Manpower**

| S N | Name | Designation |
|---|---|---|
| 1 | Dr. Sanjay K Jain | Scientist G & Head |
| 2 | Dr. Manohar Arora | Scientist F |
| 3 | Dr. P K Singh | Scientist D |
| 4 | Dr. Manish Nema | Scientist D |
| 5 | Dr. P K Mishra | Scientist D |
| 6 | Dr. Vishal Singh | Scientist C |
| 7 | Sri P K Agarwal | Scientist B |
| 8 | Sri Yatveer Singh | Scientist B |

# APPROVED WORK PROGRAMME FOR THE YEAR 2021-2022

| SN | Title | Study Team | Duration | Funding (Rs. Lakhs) |
|---|---|---|---|---|
| **Completed Sponsored/ Internal Studies** | | | |
| 1. | Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework | P. K. Singh; P. K. Mishra; M. K. Goel; Suman Gurjar | 2 years (12/18-12/20) | NIH |
| 2. | Real time flood modelling using HEC-RTS modelling framework | Vishal Singh; A. K. Lohani | 2 years (12/18-12/20) | NIH |
| **Ongoing Sponsored/ Internal Studies** | | | |
| 1. | Development of a project website and hydrological database in Upper Ganga Basin (**Sub-project – 1**) | M. K. Goel; M. Arora; A. K. Lohani; D. S. Rathore; D. Chalisgaonkar; A. R. S. Kumar; S. Singh; P. Mani; A. Sarkar; M. K. Nema; P. K. Mishra | 5 years (01/16-03/21) (Likely to be extended till Sept., 2021) | DST (52.15) |
| 2. | Real-time snow cover information system for Upper Ganga basin (**Sub-project – 2**) | D. S. Rathore; (Now Deepa Chalisgaonkar is PI) V. S. Jeyakanthan; L. N. Thakural; | 5 years (01/16-03/21) (Likely to be extended till Sept., 2021) | DST (48.83) |
| 3. | Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region (**Sub-project – 3**) | Sanjay K. Jain; A. K. Lohani; Sudhir Kumar; Praveen Thakur (IIRS) | 5 years (01/16-03/21) (Likely to be extended till Sept., 2021) | DST (36.79) |
| 4. | Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios (**Sub-project – 4**) | ~~Renoj J.Thayyen;~~ Sanjay K. Jain; Sharad K. Jain (Retd.) P. K. Mishra; M. Arora; AP Dimri (JNU) | 5 years (01/16-03/21) (Likely to be extended till Sept., 2021) | DST 80.4 (NIH) + 73.2 (JNU) |
| 5. | Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin (**Sub-project – 5**) | M K Nema; Sharad K. Jain (Retd.); ~~Renoj J.Thayyen;~~ Sanjay K. Jain; P K Singh, P. K. Mishra; P. K. Agarwal AP Dimri (JNU) | 5 years (01/16-03/21) (Likely to be extended till Sept., 2021) | DST (54.07) |
| 6. | Water Census and Hotspot analysis in selected villages in Upper Ganga basin (**Sub-project – 11**) | P. K. Mishra; M. K. Nema; ~~Renoj J. Thayyen;~~ Pradeep Kumar | 5 years (01/16-03/21) (Likely to be extended till Sept., 2021) | DST (90.99) |
| 7. | Investigating Water Stress using Hydro-meteorological and Remote Sensing data | D. S. Rathore; (Now L. N. Thakural is PI); Sanjay Kumar; B. Venkatesh M. K. Jose; T. | 3 years 2017-2020 (Recommended for extension up to June, | PDS under NHP (50.23 Lakh) |

258

| | | Chandramohan | 2021) | |
|---|---|---|---|---|
| 8. | Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya | Sanjay K. Jain P. K. Singh; M. Arora ~~Renoj J. Thayyen;~~ A. K. Lohani; Vishal Singh; | 3 years (11/19-11/22) | NMHS-MoEF (143 Lakh) |
| 9. | Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin | ~~Renoj J. Thayyen~~ A. P. Dimri (JNU) Sanjay K. Jain Vishal Singh | 3 years (06/19-11/22) | NRDMS-DST (23.19 Lakh) |
| 10. | Permafrost mapping and characterization of Ladakh Region | ~~Renoj J. Thayyen;~~ A. P. Dimri (JNU) will lead now; G. Jeelani (KU); V. Agnihotri (GBPNI) | 3 years (11/19-11/22) | NMHS-MoEF (197.48 Lakh) |
| 11. | 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; P K Agarwal | 2 years (08/20-07/22) | NHP (14.50 Lakh) |
| 12. | Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios | M. Arora P K Mishra Vishal Singh | 3 years (04/18-03/21) (Extended for 12 months) | NIH |
| 13. | Impacts of glacier and climate change on runoff for selected basins of Himalayan region | Vishal Singh; Sanjay K. Jain; Manohar Arora | 2 years (08/20-07/22) | NIH (9.30 Lakh) |
| 14. | Henval Experimental Watershed: Observations and modelling (Phase II) | M K Nema; Sanjay K Jain; ~~Renoj J. Thayyen;~~ P K Mishra; P K Agarwal | 3 years (08/20-07/23) | NIH (10.22 Lakh) |
| 15. | Upgradation of NIH_ReSyP to .NET Platform– a Reservoir Operation Package | D. Chalisgaonkar M. K. Goel | 1 year (08/20-07/21) | NIH |
| **New Internal/ Sponsored Studies** | | | | |
| 1. | Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework. | P K Mishra; P K Singh; P K Agarwal | 2 years (04/21-03/23) | NHP (9.00 Lakh) |
| 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 sub-basins in the state of Mizoram | Vishal Singh; M K Nema; P K Singh; Vanlalpekhlua Sailo (SDO from Mizoram); Lalruatkima (JE from Mizoram) | 3 years (04/21-03/24) | NHP (25.00 Lakh) |
| 3. | Monitoring of Hydrological Processes in Glaciated and Non Glaciated Watersheds of North-West Himalaya | M K Nema; Sanjay K Jain; Manohar Arora; Vishal Singh; Praveen Thakur (IIRS) | 3 years (04/21-03/24) | IIRS (Total 701.37 Lakh) |

**Recommended Work Programme for the year 2022-2023**

| 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 | Sanjay K. Jain<br>P K Singh<br>M. Arora<br>A K Lohani<br>Vishal Singh | 3 years (11/19-11/22) | NMHS-MoEF (143) |
| 2. | Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin | Vishal Singh<br>Sanjay K. Jain<br>A P Dimri (JNU) | 3 years (06/19-11/22) | NRDMS-DST (23.19) |
| 3. | 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<br>P K Mishra<br>P K Agarwal | 2 years (08/20-07/22) | NHP (14.50) |
| 4. | Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework. | P K Mishra<br>P K Singh<br>Vishal Singh<br>P K Agarwal | 2 years (04/21-03/23) | NHP (9.00) |
| 5. | Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram | Vishal Singh<br>M K Nema<br>P K Singh<br>Vanlalpekhlua Sailo (SDO from Mizoram);<br>Lalruatkima (JE from Mizoram) | 3 years (04/21-03/24) | NHP (25.00) |
| 6. | Impacts of glacier and climate change on runoff for selected basins of Himalayan region | Vishal Singh<br>Sanjay K. Jain<br>Manohar Arora | 2 years (08/20-07/22) | NIH (9.30) |
| 7. | Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya | M K Nema<br>Sanjay K Jain<br>P K Mishra<br>P K Agarwal | 3 years (08/20-07/23) | NIH (10.22) |
| 8. | Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios | M. Arora<br>P K Mishra<br>Vishal Singh | 3 years (04/21-03/23) | NIH |
| **New Internal/ Sponsored Studies** | | | |
| 1. | Spatio-temporal Water Availability under Changing Climate and Landuse Scenarios in Wainganga River Basin | M K Nema<br>P K Mishra | 2 years (04/22-03/24) | NIH |
| 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<br>Sanjay K Jain<br>P. K. Mishra<br>Praveen Thakur (IIRS) | 3 years (04/22-03/25) | IIRS, Dehradun (30.91) |
| 3. | 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;<br>Vishal Singh<br>Sanjay K Jain | 3 years (04/22-03/25) | WRD, Karnataka (54.0) |

**COMPLETED STUDIES**
**INTERNAL RESEARCH PROJECT**: **NIH/WRS/2020-22/01**

1.      **Thrust Area under XII five Year Plan**: Integrated water resources Management (Integrated operation of reservoirs)

2. **Project Team:**
   Mrs. D. Chalisgaonkar, Scientist 'G'
   Dr. M. K. Goel, Scientist 'G'

3. **Title of the Project:** Upgradation of NIH_ReSyP – A Reservoir Systems Package

4. **Objectives:**
   a. Upgradation of NIH_ReSyP to .Net Platform
   b. To carry out a number of modifications in various modules

5. **Present state-of-art**

   In view of the importance of reservoir operation problem in Indian context and the non-availability of a generalized software for reservoir analysis, the National Institute of Hydrology (NIH), Roorkee had developed a generalized software named *"SRA – Software for Reservoir Analysis"* for reservoir analysis [Jain et. al (1996)] for carrying out various kind of reservoir analysis such as capacity computation, storage yield analysis, hydropower simulation, reservoir routing, EAC interpolation, inflow estimation using rate of rise method, initial rule curve derivation, and operation of a system of multiple reservoirs for conservation purposes. Subsequently, a WINDOWS based software named "NIH_ReSyP – Reservoir Systems Package" was developed [Goel and Chalisgaonkar (2011)]. The software was developed in Visual BASIC platform (VB6) and provided a user-friendly environment for carrying out various hydrological analyses related to reservoirs.

   However, for some years there has been a threat hanging over legacy VB6 applications because the next version of Windows may not support VB6 and the applications are being developed on VB.NET platform which offers more features for application development and user-friendliness. Further, during the last decade, various technology transfer activities on the software have been organized and a number of suggestions have been made by field engineers.

6. **Methodology**

   It is planned to upgrade the NIH_ReSyP software on the VB.NET form. Further it is planned to modify various modules as per the suggestions of field engineers. Some such modifications include:
   a) To reduce the input variables for easy preparation of data minimizing the data entry errors.
   b) Fixation of the units of different variables so as to avoid confusion and have a uniform input structure.
   c) Improvement of menu structure
   d) Modification of various programs for more detailed analysis

7. **Research Outcome from the project:**

   Development of a user-friendly software for integrated operation of reservoir systems in accordance with the Indian practices. Since the help files for different modules are provided along with the software, no separate report will be prepared and the output will be only in the form of software.

8. **Cost estimates:**
   No additional cost is envisaged.

9. **Work Schedule:**
   a. Date of commencement of the project:   01.08.2020
   b. Duration of the project:                1 year

**10. Progress till date**

Significant efforts have been made for the finalization of the revised version of NIH_ReSyP – 2022. All the 20 modules and their forms in .NET framework have been developed. Based on the inputs from the users, substantial improvements in the previous modeling system have been made, some of which include:

➢ Inputs reduced significantly. Fixed metric system being followed.

➢ Results up to accuracy of one cubic meter.

➢ Easier forms have been developed in .Net platform.

➢ Outputs also gives a detailed description of input.

➢ More time steps introduced for analysis, say daily or 10-daily.

➢ In rule curve derivation, desirable carryover storage added.

➢ Reservoir sedimentation is computed in a single step now.

➢ New modules added:

    ➢ Storage-Yield-Reliability relationship

    ➢ Instant estimation of reservoir inflow using rate of rise

    ➢ Modules added to help operator in finding actual release to be made depending on the prevalent policy.

    ➢ Instant estimation of release for flood control

    ➢ Spillway discharge rating table

    ➢ Instant spillway discharge estimation

➢ Significant modifications in Conservation Operation module:

    ➢ Daily time step introduced. Now 100 reservoirs can be simulated for 50 years at daily time step.

    ➢ Possible to revised demands in different years. Earlier, fixed demand pattern was possible

    ➢ Tail-water rating curve introduced. Earlier, only fixed outlet level could be specified.

    ➢ Reservoir sedimentation in real-time can be considered.

    ➢ Rule curves for daily/10-daily time step are interpolated.

    ➢ Total water balance is also computed annually for all projects in the system.

    ➢ Total water balance in the whole system is computed.

Help files of most modules have been completed and these modules have been finalized. A few modules of the software will be demonstrated in the WG meet.

**1. Title -** Real-time snow cover information system for Upper Ganga basin

**2. Project team**

| | | |
|---|---|---|
| a) | **Project Investigator:** | Deepa Chalisganokar |
| | | D SRathore (retd.) PI |
| b) | **Project Co- investigators:** | V. S. Jeyakanthan, Scientist 'E' |
| | | L. N. Thakural, Scientist 'D' |
| c) | **Project Staff (JRF)** | Ashish Bhandari, JRF |
| | | Atul Bhardwaj, JRF |

**3. Objectives**

The objectives of the project are:

a) Development of methodology for snow cover delineation in study basin using multispectral remotely sensed data
b) Development of web-GIS application for real-time snow cover information in study basin

**4. Sponsored by**            DST, New Delhi
**5. Project Cost**            Rs.77.992 Lakh

**6. Methodology**

Satellite remote sensing imagery will be used for the extraction of snow extent and snow cover. Various techniques e.g. NDVI-NDSI regions for snow underneath forests, comparing multi spatial- resolution images for fraction snow cover determination etc. will be employed. Snow extent and its statistics will be published using Web GIS software such as Geoserver, Open layers, GeoExt etc. In addition, the available web services of spatial data e.g. Open Street Maps, Google maps etc. will also be utilized.

**7. Location map/ study area**
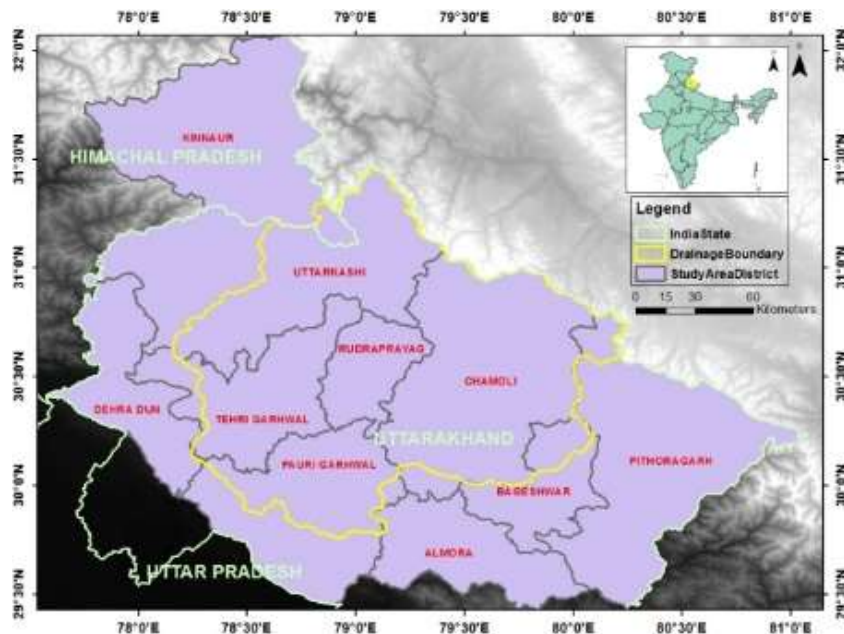


**Figure 1: Upper Ganga basin**

**8. Approved action plan and time line**

| Activity | 1st year | | 2nd year | | 3rd year | | 4th year | | 5th year | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | I | II | I | II | I | II | I | II |
| Processing of satellite data and GIS layers for delineation of snow | ←——————————————————————————————→ | | | | | | | | | |
| Development of web GIS application for snow | ←——————————————————————————————→ | | | | | | | | | |
| Field visit for ground truth and observations | ←——————————————————————————————→ | | | | | | | | | |
| Preparation of interim/ final reports | | ←→ | | ←→ | | ←→ | | ←→ | | ←→ |

**9. Recommendations/ suggestions in previous WG**

Snow area should be displayed in the web application.

**10. Achievements**

| Year | Objectives | Achievements |
|---|---|---|
| 2020-21 | Snow extent methodology | Post-processing of MODIS snow cover and computation of 8-day composite from MOD10A1 NDSI data was implemented in R and snow cover data were processed for Upper Ganga basin. Trend in seasonal maximum snow extent were not significant. Trend of seasonal average maximum snow extent was negative for autumn, early winter and spring and positive for summer in most altitudes. Autumn 2016 had large negative anomaly in the maximum snow extent. For snow survey, a Mt. Rose or Federal type snow sampler was fabricated. The survey was done at elevations between 1900 and 3200 m in Deorial Tal, Chopta, Tungnath and Dhanaulti/ Lal Tibba during January and February 2020. Snow water equivalent varied from one to 18 cm and increased with elevation. Observed densities for fresh and old snow were 0.07- 0.09 and 0.13- 0.29 respectively. A rule based classification is being developed utilizing NDSI, NDVI, B1, B2 and B4 of Landsat data for classification of snow, snow with vegetation, snow in shadows and discriminating snow from water and cloud. |
| 2020-21 | Web GIS application | More snow extent maps were added along with snow area table in the web application. |

**Final report has been prepared and submitted.**

**1. Title -** Glacial Lakes and Glacial Lake Outburst Flood (GLOF) in Western Himalayan region

**2. Study team**

1. Dr. Sanjay K. Jain, Scientist 'G'
2. Dr. A. K. Lohani, Scientist 'G'
3. Dr. Sudhir Kumar, Scientist 'G'
4. Dr. P. Thakur, Scientist 'E', IIRS, Dehradun

**Project Staff (JRF)** Mr. Manish Rawat, JRF

**3. Objectives**

The objectives of the project are:

1. To generate data base with regard to glaciers and glacial lakes in basins located in Western Himalayan region.
2. To define conditions of glacial lakes, moraine dams associated with mother glaciers attributing those with topographic features around lakes/moraine dams.
3. Analysis of the data to identify the potentially dangerous and vulnerable glacial lakes susceptible to outburst.
4. To define geometrical parameters (spread area, depth and volume of water etc.) of the vulnerable lakes and their further examination.
5. GLOF modeling using the hydro-dynamic mathematical modeling.
6. To disseminate the results and outputs among relevant oragnisations in the region that could make use of this information for GLOF hazard prevention and mitigation planning.

**4. Sponsored by**                          DST, New Delhi

**5. Project Cost**                          Rs. 41.796 Lakh

**6. Methodology**

The studies for outlined focused area would involve following work items:

(i)   Collation of literature & reference documents, procurement Remote Sensing Data from appropriate agencies-national and though on line sources.

(ii)  Formulation of data on Glacial Inventory of the Basins defining snow line, different glaciers, their attributes and classification.

(iii) Establishing Glacial Lake and Moraine Dam Inventory in the Basins and defining geometric parameters of lakes, possibility of their inter-connectivity, and geomorphic classification to work out their vulnerability status.

(iv)  Analysis of Glacial Lake database to identify the vulnerable lakes and their possibility of outburst under different causative modes. Defining breach parameters to estimate the scale of hazard on incidence of the GLOF.

(v)   Defining slope attributes of the river from vulnerable lake/lakes to project sites and cross sections of the river-valley which would carry the flood on incidence of GLOF; the parameters would be defined based on remote sensing data.

(vi)  Hydrological studies on GLOF/ Moraine Dam Break Simulation and consequent lake breach flood using the hydro-dynamic mathematical modeling.

(vii) Recommendation for the establishment of a system for monitoring potential risk lakes.

(viii) Information to be given to relevant institutions regarding the results and potential risks, thereby increasing the capability to plan for and prevent or mitigate the risks.

## 7. Present progress

This project includes four study basins: Sutlej, Beas, Chenab and Ganga. Landsat imagery has been used for delineate the glacier boundary for the basin and Glacier maps have been prepared. The inventory of glacial lakes in the basins i.e. Satluj, Beas, Upper Ganga and Chenab have been prepared. The lakes have been categorised into Glacial-erosion, Moraine-Dammed and Ice-dammed lakes. These lakes were further classified on the basis of number frequency of lakes of different areas and different elevation. The Glacier lake inventory map and different bar chart figures of lakes type have been prepared. The vulnerable lakes in the basins have been identified. Vulnerable lakes in the basins have been identified on the basis of area change, location and other conditions.

The Geodatabase for hydrodynamic modelling for these lakes have been prepared. The geodatabase contain all the information related to river cross-sectional, bank stations, elevation, flow paths and lake information. Application of HEC-RAS 1D unsteady flow hydrodynamic model has been used for GLOF Simulation. Evaluation of the GLOF impacts has been analysed by flow depth, flow velocity, peak discharge and water surface elevation for all the affected locations The simulation of GLOF for all the four basin have been carried. The example of Chenab basins is given in Figures 1,2 and 3.

**Objectives vs achievements**

| Sr.no | Activity | Status |
|---|---|---|
| 1 | Data base with regard to glaciers and glacial lakes in basins located in Western Himalayan region.<br>Acquisition of Landsat data covering the study basin for the years 1990, 2000, 2008 and 2014 Preparation of glaciers and glacier lake inventory | Completed |
| 2 | Identification of potentially dangerous lake for GLOF simulation | Completed |
| 3 | Creation of Geodatabase for GLOF simulation<br>Preparation of cross section, bank stations, flow paths along the river<br>Preparation of lake information | Completed |
| 4 | GLOF modeling using the hydro-dynamic mathematical modeling<br>Preparation of breach hydrograph for GLOF scenario based on the different parameter like breach width and breach formation time Application of HEC-RAS 1D unsteady flow hydrodynamic model for GLOF simulation | Completed |
| 5 | Evaluation of the GLOF impacts has been analysed by flow depth, flow velocity, peak discharge and water surface elevation for all the affected locations. | Completed |
| 6 | Preparation of Inundation maps for GLOF | Completed |

**Final Report has been prepared and submitted.**

**SPONSORED RESEARCH PROJECT**: NIH/WRS/2016-21/03
**NMSHE STUDIES**

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change

2. **Project Team:**

    1. Dr. M. Arora, Scientist 'E'
    2. Dr. Sanjay K. Jain, Scientist 'G'
    3. Dr. Sharad K. Jain, Retd.
    4. Dr. P. K. Mishra, Scientist 'D'
    5. Collaborator: Dr. A. P. Dimri, Professor, SES, JNU, New Delhi

3. **Title of the Project:** Assessment of downstream impact of Gangotri glacier system at Maneri and Future runoff variations under climate change scenarios

4. **Objectives:**

    1. Modelling Glacier, Snow and Rainfall components in the stream flow at Maneri
    2. Assess the role of glaciers in regulating the inter-annual runoff variations at Maneri
    3. To establish Cryosphere response to climate variables through climate downscaling and runoff modelling.
    4. Assessment of future runoff variations at Dabrani/Harsil in response to the climate change.

5. **Methodology**

A) Discharge data of Maneri will be collected from the state agencies and interannual variations and long-term trends will be assessed.

B) Weather monitoring near Harsil: Weather data at the high altitude Himalayan region is very sparse. Hence orographic processes of the Himalayan slopes are poorly understood. Recent studies have shown that the orography is a key factor controlling the weather variables in the Himalaya. A full-fledged automatic weather station with four component radiometer, precipitation gauge and soil heat flux sensors is installed at Jhala near Harsil. Data from this weather station will be used for refining the runoff model.

C) Climate of the region is dominated by Indian winter monsoon and Indian summer Monsoon. Keeping such broad scale flow in mind climate downscaling will be done in conjuncture with the study of interaction of large scale monsoonal flow with existing variable topography and to study land surface processes in association with hydrological balance over the region of study with existing CORDEX simulation (from IITM, Pune), downscaling over the catchment region and modelling experiments. As it is understood that the region of study is of complex topography and hence such topography will not be truly represented within the model domain and hence dynamical downscaling will be used to established the atmospheric-topographic interaction in defining primarily precipitation forming processes. Statistical downscaling methods will be used to overcome the coarser horizontal model resolution problem and establish moisture-temperature interplay processes. Historical and future climate scenarios will be bias corrected and tested.

D) Runoff modelling: Runoff modelling will be carried out by SPHY model as well with a temperature index model using snow cover depletion information. Using the SHPY model snow, glacier, rainfall and base flow components will be assessed. Using Climate downscaling and future predictions future runoff scenario will be generated.

**6. Research Outcome from the project:**

Understanding of the downstream impact of Gangotri glacier system with glacier, snow & rainfall component and its probable future variability.

**7. Cost Estimate:**

a. Total cost of the project:    Rs. 153.716 lakhs
        NIH                        Rs. 80.42
        JNU                        Rs.73.296
b. Source of funding:           NMSHE-DST

**8. Progress of the project**

During the reporting period focus of the project was on runoff modelling at Maneri using the bias corrected temperature and precipitation data received from JNU collaborator. Initial simulation done for the period of 30 years (1990-2020) using SPHY hydrological model has been improved.

Completed work:

1. Estimated snow cover change in the basin since 2001-2018 by developing a new cloud removal algorithm. Reducing snow cover in the lower elevations and slightly increasing snow cover during July/ August months at higher elevations were observed.
2. Runoff modelling by SPHY using CWC/ IMD ground data are carried out for 1980- 2018. Further, modelling is carried out for 1980-2100 using bias corrected REMO, Bias corrected RegCM.4.5, Various runoff/ water balance components such as rainfall, snow melt, glacier melt, base flow and evaporation are estimated. It is observed that high spatial variability of input variables in the complex mountain terrain is forcing significant uncertainty in the model output especially in the sub- basin scale.

3. Identification and characterization of Topoclimatic zone of Upper Ganga basin

4. Progress during the reporting period: Implemented the runoff model (SPHY) till Rishikesh and tried to achieve multi station calibration from basin outlet to glacier catchment. Runoff time series developed for 15 sub-catchments to assess the glacier catchment critical for runoff stability. Additionally, the catastrophic debris flow disaster event in the Rishiganga/ Dhauliganga river on 7th February is studied and role of recent warming of the area and related weather changes in the event is being established.

| Objectives | Status |
|---|---|
| 1. Modelling Glacier, Snow and Rainfall components in the stream flow at Maneri | Completed |
| 2. Assess the role of glaciers in regulating the inter-annual runoff variations at Maneri | Completed |
| 3. To establish Cryosphere response to climate variables through climate downscaling and runoff modelling. | Completed |
| 4. Assessment of future runoff variations at Dabrani/Harsil in response to the climate change. | Completed |

1.    **Thrust Area:** Himalayan Hydrology

2.    **Project Team**
      **Project Investigator**        :        Dr. M. K. Nema, Scientist 'D'
      **Co-Project Investigator**     :        Dr. Sharad K. Jain, Retd.
      **Project Co-Investigators**    :
                                       :        Dr. Sanjay K. Jain, Scientist 'G'
                                       :        Dr. Surjeet Singh, Scientist 'F'
                                       :        Dr. P. K. Singh, Scientist 'D'
                                       :        Dr. P. K. Mishra, Scientist 'D'
                                       :        Mr. P. K. Agarwal, Scientist 'B'
                                       :        Dr. A. P. Dimri, Professor, JNU
                                       :        Dr. (Mrs.) Sangeeta Verma, RA

3.    **Title of the Project:** Observation and Modelling of Various Hydrological Processes in a Small Watershed in Upper Ganga Basin

4.    **Objectives:**

      1. To establish relationship between climatic and hydrologic variables and their seasonal variations in Himalayan environment.
      2. To study the atmospheric dynamics including seasonal variations in atmospheric water budget, land-surface flux, orographic interactions during Indian summer and winter monsoon.
      3. To develop the understanding of the hydrological processes in the watershed though isotope geochemistry.
      4. To study the ground water dynamics in a lesser Himalayan watershed.
      5. To study the soil erosion characteristics and sediment routing of the watershed.
      6. To model various water balance components for a small watershed.

5.    **Methodology**

      Study Area: The small Himalayan watersheds (Henval & Jijali) in the upper Ganga basin in Tehri Garhwal district of the state of Uttarakhand are proposed for the study.

      i.    Analysis of factors influencing local weather, land surface flux including soil temperature and diurnal & seasonal forcing at AWS site.

      ii.   Application of updated Regional Climate Model-RegCM4 (Giorgi et al. 2012) for atmospheric modelling along with CORDEX and subgrid land surface parameterization using mosaic-type scheme of the RegCM 3 (Giorgi et al. 2003).

      iii.  Water and sediment sampling for water quality investigations and modelling with advance use of isotopes.

      iv.   Develop understanding of the groundwater dynamics or interactions and recharge through installation of piezometer's longitudinally along the river, modeling and isotopic analysis.

      v.    Water balance modelling using field experiment based input data to understand the components of the hydrological cycle.

      vi.   Quantitative assessment of soil erosion and spatial distribution using USLE, RUSLE and MMF, RSSYM, WERM, SWAT Models with GIS and Remote Sensing in order to plan soil conservation measures.

6.  **Research Outcome from the Project:** Enhanced understanding of the Lesser Himalayan hydrology-atmospheric interactions and climate change forcing aiding water resources management.

7.  **Cost Estimate: 134.32 lakhs**

      Total cost of the project        :        Rs. 134.32 lakhs
      Source of funding             :        NMSHE-DST

8.  **Work schedule:**

| Activity | 1st year | | 2nd year | | 3rd year | | 4th year | | 5th year | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | I | II | I | II | I | II | I | II |
| **Development of procedure for scientific work** | ↔ | | | | | | | | | |
| **Recruitment and deployment of Project Personnel** | ←——→ | | | | | | | | | |
| **Purchase of instruments and experimental setup** | ←————→ | | | | | | | | | |
| **Data generation and acquisition** | | | ←————————————————→ | | | | | | | |
| **Data analysis and modelling (Isotopic analysis / Sediment Modelling)** | | | ←————————————→ | | | | | | | |
| **Atmospheric Dynamics (water budgeting / Land Surface Flux)** | | | ←————————————→ | | | | | | | |
| **Watershed water balance and budgeting** | | | | | | | ←————————→ | | | |
| **Ground Water Dynamics** | | | | | ←————————————→ | | | | | |
| **Final Reporting** | | | | | | | | | ←→ | |

9.  **Progress of Work:**

During the period roughness length for momentum ($Z_{0m}$) is estimated using wind speeds for a valley bottom and a mountain ridge site in a lesser Himalayan experimental catchment. Results indicated that $Z_{0m}$ is comparatively higher at the valley bottom site (Nagini) in the range of (0.010 – 0.497) than the values observed (0 - 0.069) for the ridge site (Kumargaon). Seasonal variations are observed at both the stations indicating its higher value for high LAI in the leaf-on season and lower values for low LAI in the leaf-off season. At valley bottom site, the seasonal increase is higher during kharif cropping as compared to the rabi cropping whereas, at Kumargaon, this increase is visible only in the rainy season due to natural vegetation growth. The changing height of vegetation and consequently LAI in different seasons is the most important factor for seasonal variations in $Z_{0m}$. On diurnal basis, $Z_{0m}$ varies differently in different season due to changing wind speed and direction. Heterogeneity of the terrain causing fluctuations in $Z_{0m}$ is more evident at Kumargaon. Atmospheric stratification and instability is another factor responsible for diurnal variation of $Z_{0m}$.

**Final report has been prepared and submitted.**

**1. Title -** Water Census and Hotspot analysis in selected villages in Upper Ganga basin

**2. Study team**

1. Dr. P. K. Mishra, Scientist 'D'
2. Dr. M. K. Nema, Scientist 'D'
3. Dr. Pradeep Kumar, Scientist 'D'
4. Swagatam Das, JRF; Hemant Singh (JRF); Sanjay Kumar (PA); Pankaj Kumar (PA); Vishal (PA)

**3. Objectives**

The objectives of the project are:

a) To map water use pattern and livelihood linkages
b) To map potential water hazard zones in the catchment
c) To identify hotspot matrix components, hotspots analysis and adaptation strategies

**4. Sponsored by**        DST, New Delhi

**5. Project Cost** Rs. 90.99 Lakh

**6. Brief Background**

Water accounting, otherwise known as 'water census' is as important as other census activities for population, livestock, etc. carried out by the Government every decade. The Water Census is an emerging concept vital for creating Decision Support Capacity for water management agencies and policy makers. This provide a detailed accounting of water availability and use in a region. Water census can be an umbrella platform in the hands of the stakeholders working in the field of water resources with information on water availability, water uses, potential water hazards, and most importantly the livelihood linkages. Livelihood- water linkage is core to sustaining the Himalayan ecosystem for the mountain people. Water disasters are increasingly become a threat to the mountain habitat and economic development under changing climate. Identification and management of potential water disaster zones are also key to sustaining Himalayan eco-system. Considering these issues, this project is aimed to map and develop the water census (preliminary) for the Upper Ganga basin with information at micro (village) level on water availability, water use pattern and livelihood linkage, potential water threat, etc. It is also envisaged to identify the hot spot matrix components and its analysis to identify the most vulnerable sites (villages). This can only be accomplished by extensive survey at micro-level (village). The project could become a platform to integrate input from all other studies and information aiding policy formulation and strategic planning. Methodology developed and refined through this project can be replicated across the Himalayan region in subsequent stages of this mission.

An inter-linked approach to water resources management is envisaged in this project with following key components of water governance: (i) Consider all water resources; (ii) Address water demand as well as water supply; (iii) Address wastewater management as well as water supply; (iv) Involve all sectors and civil society stakeholders; (v) Promote access and gender equality: (vi) Recognize the economic (livelihood), social, and environmental value of water; (vii) Recognize the water related threat and hazards for preventive measures (adaptation and mitigation strategies)

**7. Methodology**

The project is executed as per the following roadmap:

**Sampling**

The upper Ganga is divided into two major zones comprising of Alaknanda basin and Bhagirathi basin. Each of this major zones are sub-divided into five sub-zones based on the elevation (altitude), climate etc. At least 10 villages have been screened from each sub-zones through scientific assessment and field visit as well as with discussion with other stakeholders.

Water census has been carried out by developing an elaborative matrix to capture various WRM components. A structured questionnaire and field mapping is used to gather the information.

**Road map/ work components:**

1. Preparation of GIS layers and Base line data collection
2. Selection of villages
3. Training of Resource Persons
4. Launch workshop - Stage I survey - Attributes for water census
5. Mid-term Workshop
6. Diagnostics report
7. Stage II survey
8. Finalization of Hotspot analysis
9. Development of adaptive strategies
10. Concluding workshop
11. Report preparation and submission

**Activity chart**

| Activity | 1st year | | 2nd year | | 3rd year | | 4th year | | 5th year | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I | II | I | II | I | II | I | II | I | II |
| Selection of project personnel | ■ | | | | | | | | | |
| Preparation of GIS layers and Base line data collection | ■ | ■ | | | | | | | | |
| Selection of villages | | ■ | ■ | | | | | | | |
| Training of Resource Persons | | | | ■ | ■ | | | | | |
| Stage I survey | | | | ■ | ■ | | | | | |
| Mid-term workshop | | | | | | ■ | | | | |
| Diagnostics report | | | | | ■ | ■ | ■ | | | |
| Stage II survey | | | | | | | ■ | ■ | | |
| Finalization of Hotspot Analysis | | | | | | | | ■ | ■ | |
| Development of adaptive strategies | | | | | | | | | ■ | ■ |
| Concluding workshop | | | | | | | | | | ■ |
| Report preparation and submission | | | | | | | | | | ■ |

**9. Present progress**

| Sr.no | Activity | Status |
|---|---|---|
| 1 | To map water use pattern and livelihood linkages.<br>• 231 villages surveyed (5 districts)<br>• 526 households (5 districts)<br>• GIS layers (maps) generated | Completed |
| 2 | To map potential water hazard zones in the catchment.<br>• Reported cloud bursts (57 nos.) identified since 2010<br>• Potential hazard zones due to CBs identified and mapped | Completed |
| 3 | To identify hotspot matrix components, hotspots analysis and adaptation strategies.<br>• IPCC's Livelihood Vulnerability Index based critical blocks identification for Uttarkashi, Tehri Garhwal, Pauri Garhwal, Chamoli and Rudraprayag districts. | Completed |
| 4 | Report preparation | Completed |

**1. Title -** Snow and glacier contribution and impact of climate change in Teesta basin in Eastern Himalaya

**2. Study Team**
**NIH Roorkee:**
>    Dr. Sanjay K Jain, Scientist 'G'
>    Dr. P K Singh, Scientist 'D'
>    Dr. Manohar Arora, Scientist 'E'
>    Dr. A K Lohani, Scientist 'G'
>    Dr. Vishal Singh, Scientist 'C'

**JNU, New Delhi:**
>    Dr. A P Dimri, Professor

**CAU Sikkim:**
>    Dr. S R Yadav, Assistant Professor (SWCE)

**IITM Pune**
>    Dr. (Mrs) Nayana Deshpande, Scientist D

**3. Objectives**
The proposed project will adopt an inter-disciplinary approach to address the following objectives, in particular for the Teesta basin within the eastern Himalayas:
The objectives of this study are:

- Assessment of recent changes in snow, glacier, rainfall and its impact on the hydrology of the Teesta basin through Hydrologic modelling.
- To understand the influence of glacier size, debris cover, topographic (i.e., altitude, aspect, and slope) and climatic variables on recent glacier changes?
- Sediment transfer characteristics of Teesta River at selected sites and identification of major drivers.
- Assessing climate change in the basin and future scenarios and resultant hydrological responses
- To understand and simulate the magnitude of the GLOF hazard of glacial lakes formed due to glacier recession using MIKE-II breach modeling.
- Identification of key change indicators for water resources of the region and their impact on local communities
- To develop a comprehensive and interactive web-enabled database repository of the hydro-met database and modelling spatial outputs with basic GIS functionalities.

**4. Sponsored by**                      NMHS, MOEF & CC
**5. Project Cost**                        Rs. 143 Lakhs

**6. Methodology**
In the present study, modelling of snow/glacier melt runoff, sediment sampling and modelling, climate change studies, impact of climate change and glacier lake outburst flood are proposed to achieve the objectives.

- Snow/glacier melt runoff modelling will be done using SNOWMOD and VIC models. Landuse/landcover, snow/glacier maps etc. will be prepared for the study basin using standard RS and GIS techniques. Hydro-meteorological data will be collected from different sources such as CWC, IMD, NHPC and state agencies.
- Sediment yield modelling and assessment will be done using Delivery Ratio and GIS coupled empirical models, SWAT model and conceptual SCS-CN based sediment yield models.

- Many methods have been developed for generating climate scenarios for the assessment of hydrologic impacts of climate change, which include downscaled general circulation model (GCM) simulations. Data and knowledge generated will be used to implement a sub-grid scale parameter scheme for Regional Climate Model using RegCM4 model with sub-grid parameterization and refined future projections for climatic variables.
- The satellite data along with field investigations will be used to assess glaciers and glacial lakes. MIKE 11 model will be used for GLOF simulations.
- A comprehensive web enabled database repository will be developed based on information from the field data collection and modelling results.

## 7. Time-Line and Activities

| | Activities | 1st Year | | 2nd Year | | 3rd year | |
|---|---|---|---|---|---|---|---|
| **NH** | Hiring Manpower | ■ | | | | | |
| | Procurement of the instruments | ■ | ■ | | | | |
| | Data collection and database preparation | | ■ | ■ | | | |
| | Model data need and requirement by other PIs | | | ■ | ■ | | |
| | Model simulations and sensitivity analysis | | | ■ | ■ | | |
| | Study of impact of climate change | | | ■ | ■ | | |
| | Sediment studies | | | | ■ | ■ | |
| | GLOF studies | | | ■ | ■ | ■ | |
| | Development of a comprehensive and interactive web-enabled database repository | | | ■ | ■ | ■ | |
| | Workshops/Trainings | | | | ■ | ■ | ■ |
| | Report writing | | | | | ■ | ■ |
| **CAU** | Hiring Manpower | ■ | | | | | |
| | Procurement &installation of Met. stations | ■ | ■ | ■ | | | |
| | Data collection and Data synthesis | | ■ | ■ | ■ | ■ | |
| | Sediment studies | | | ■ | ■ | ■ | |
| | Report writing | | | | | | ■ |
| **JNU & IITM** | Hiring of manpower | ■ | ■ | | | | |
| | Climate modelling work | | ■ | ■ | ■ | ■ | |
| | Report writing | | | | | ■ | ■ |

## 8. Progress till-the-Date

Following two tasks have been completed:

1: SWAT model for streamflow simulation up to Teesta Lower Dam Stage-IV gauging site.

2: RUSLE model in GIS environment for assessing the soil erosion severity using the IMD, TRMM and CHIRPS datasets.

### Streamflow simulation using SWAT model:
The Soil & Water Assessment Tool (SWAT) 2012 model is used to simulate the streamflow up to Teesta Lower Dam Stage-IV gauging site Teesta River basin for the period of 2004-2019. For single-site model calibration and validation at daily time steps, SWATCUP's Sequential Uncertainty Fitting 2 (SUFI-2) approach is used in this study. The calibration findings for daily simulation for the period

(2004–2016) revealed a very good model performance for flow rates, with an $R^2$ of 0.76, a PBIAS of 20.3, and a Nash–Sutcliffe efficiency (NSE) of 0.70. The validation findings for daily simulation for the period (2017–2019) revealed good model performance for flow rates, with $R^2$ values of 0.69, PBIAS of 23.3, and NSE of 0.64. In the calibration process a total of seventeen parameters were optimized. Snowfall temperature (SMTMP), Temperature lapse rate (TLAPS), melt factor for snow (SFTMP), and initial SCS curve number value (CN2) were found to be the most sensitive parameters in this work.

**<u>Soil erosion using RUSLE and Satellite precipitation datasets:</u>**
Quantitative assessment of soil erosion and its spatial variation is very important for designing effective erosion control measures for any basin. In this study, the popular erosion prediction model i.e., Revised Universal Soil Loss Equation (RUSLE) have been applied to the Teesta basin using two satellite datasets, i.e., CHIRPS and TRMM along with the latest IMDAA dataset for quantifying the average annual soil loss and its spatial variation. Thematic maps of land use land cover (LULC), soil map, slope map and other maps were developed to generate input maps of various parameters of RUSLE model for quantifying soil erosion and its spatial distribution for the period of 2000-2018. The erosion severity maps are also prepared along with the area under each class. The results show the area under extremely severe erosion class (>80 t/ha/year) due to CHIRPS, TRMM and IMD is found to be 38.17%, 41.81% and 39.52%, respectively. The results show that both the CHIRPS and TRMM datasets perform equally well across the Teesta basin and these satellite precipitation datasets can be effectively utilised for erosion modelling in the Teesta basin.

# ONGOING STUDIES
## SPONSORED RESEARCH PROJECT: NIH/WRS/2019-22/02

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change

2. **Project Team:**

   Dr. Vishal Singh, Scientist 'C'
   Dr. Sanjay K. Jain, Scientist 'G'
   Collaborator: Dr. A. P. Dimri, Professor, SES, JNU, New Delhi

3. **Title of the Project:** Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin

4. **Objectives:**

   a. Seasonal Snow loading and unloading estimation from GRACE and comparison with other RS products
   b. Seasonal mass fluctuation of glacier regime and regional mass balance assessment
   c. Seasonal soil moisture fluctuation in the basin with an emphasis to ISM (JJAS) and IWM (DJF)
   d. Inter-comparison between seasonal river runoff and basin scale mass anomaly from GRACE

5. **Methodology**

In the high mountain regions of the Himalaya, winter time water fluxes are minimum for stream discharge, Groundwater (base flow) and evaporation (low temperature). This condition ensures a high amplitude GRACE- TWS anomaly due to seasonal snowfall (Snow loading) which sustain and build up through winter months till March. Building on this opportunity, the assessment will focus on the time period from the start date ($t_0$) of snow accumulation to the breakup date ($t_b$) snowfall. The first snowfall precipitation event is determined by the daily snow cover assessment. Total basin water storage ($TWS_o$) at start date of accumulation at $t_0$ and $TWS_b$ at breakup date of accumulation $t_b$ will be estimated by the GRACE TWS data. From winter peak (March) to summer low (October) cryospheric mass changes will be resulted in marked depletion in TWS detected by GRACE over the glacier area specific region. The TWS change will be represented the integrated change of soil moisture, Snow water equivalent (SWE), and glacier mass change in the region. The remotely sensed data will be used such as MODIS snow cover product (SCA) (https://reverb.echo.nasa.gov/). These snow data (SCA and SWE) will be used to provide information regarding the distribution of snow in the basin. The runoff modelling will be carried out up to Rishikesh and various water balance components will be estimated which together force the change in GRACE-TWS on a monthly basis. The GRACE data will be downscaled for snow/glacier regions and snow/glacier water equivalent changes will be estimated the total monthly GRACE anomaly.

6. **Research Outcome from the project:** A) Development of expertise in GRACE –TWS data analysis and manpower development B) Regional assessment of snow water equivalent/ glacier change assessment through the monthly variation of TWS.

7. **Cost Estimate:**

   Total cost of the project:        Rs. 23.19 lakhs

   Source of funding:                NRDMS-DST

8. **Progress till date**

276

### a.Snowmelt-glacier melt induced runoff modelling using SPHY model

### 8.1.1 Brief on SPHY model and its methodology

SPHY is a spatially distributed leaky bucket type of model, and is applied on a cell-by-cell basis. SPHY is written in the Python programming language using the PCRaster dynamic modeling framework. For glaciers, sub-grid variability is taken into account: a cell can be glacier free, partially glacierized, or completely covered by glaciers. The cell fraction not covered by glaciers consists of either land covered with snow or land that is free of snow. Land that is free of snow can consist of vegetation, bare soil, or open water. The dynamic vegetation module accounts for a time-varying fractional vegetation coverage, which affects processes such as interception, effective precipitation, and potential evapotranspiration. SPHY simulates for each cell precipitation in the form of rain or snow, depending on the temperature. The snow storage is updated with snow accumulation and/or snowmelt.
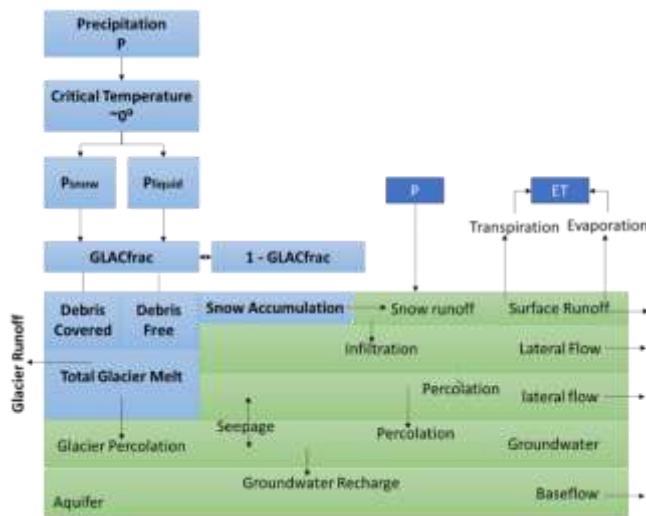


**Figure 1:** Water balance and snow-glacier runoff computation in SPHY model.

A part of the liquid precipitation is transformed in surface runoff, whereas the remainder infiltrates into the soil. Melting of glacier ice contributes to the river discharge by means of a slow and fast component, being (i) percolation to the groundwater layer that eventually becomes baseflow, and (ii) direct runoff. The cell-specific runoff, which becomes available for routing, is the sum of surface runoff, lateral flow, baseflow, snowmelt and glacier melt. Figure 1.2 represents an overview of the six modules available: glaciers, snow, groundwater, dynamic vegetation, simple routing, and lake/reservoir routing. All modules can run independently of each other, except for the glacier module. As input, SPHY requires static data as well as dynamic data. For the static data, the most relevant are digital elevation model (DEM), land use type, glacier cover, lakes/reservoirs and soil characteristics. The main dynamic data consist of climate data, such as precipitation, temperature, and reference evapotranspiration. Since SPHY is grid based, optimal use of remote sensing data and global data sources have been utilized. To undertake a proper calibration and validation procedure, observed flow data has been used at the outlet and other few locations in the upstream.

### 8.2 Works Done

1. Downloading and processing of hydro-meteorological datasets such as precipitation, temperature, discharge, soil moisture, evapotranspiration
2. Preparation of thematic datasets (e.g. DEM, LULC and SOIL maps) to setup the hydrological model for the assessment of snow-glacier induced melt runoff.
3. Preparation of decadal glacier change maps and their validation and comparison with RGI 06 glacier inventory (reference standard data)

4. Downloading of GRACE data i.e. Total water storage anomalies (TWSA) has been done for the year 2002-2020 at 25km$^2$ grid scale.
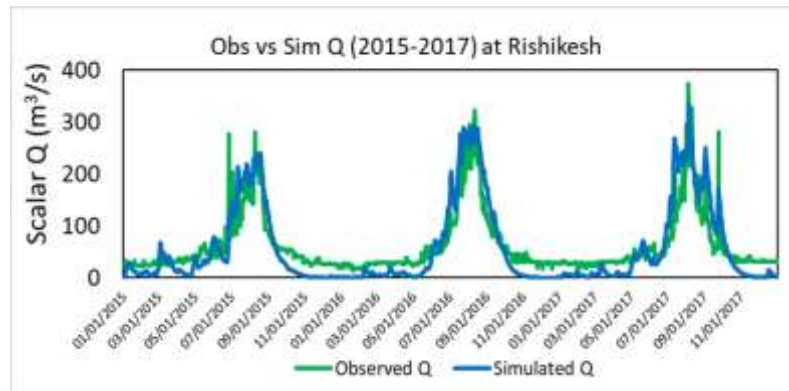


**Figure 1:** Comparison of observed vs simulate runoff at Rishikesh.
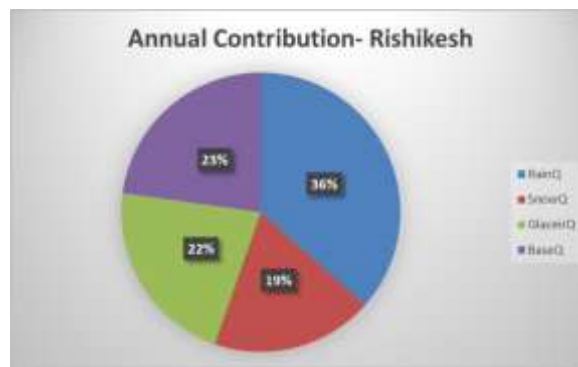


**Figure 2.** Annual contribution of runoff components at Rishikesh in the terms of percentage for base, rain, snow and glacier.

**Table 1:** GRACE Data Resolution.

| Spatial Resolution | 300 -400 km grids (~150,000km$^2$) |
|---|---|
| Gridded Resolution | $0.5^{o}$X$0.5^{o}$ |
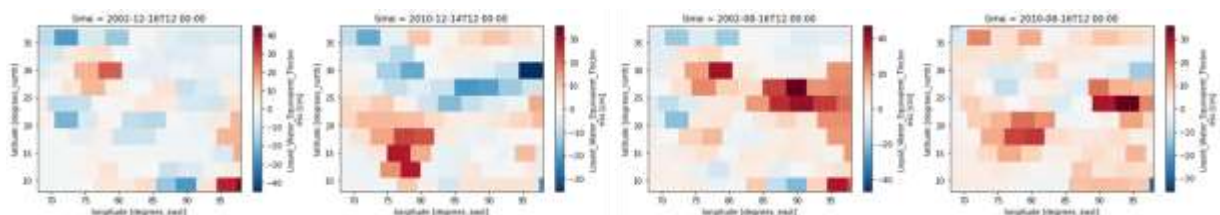


**Figure 3**: Showing variations in GRACE TWSA in different times.

**8.3 Work in Progress**

- Downscaling of Grace data and its validation with other relevant parameters to compute the snow water equivalent
- Modeling of snowmelt and glacier melt using GRACE
- Refinement of snowmelt and glacier melt runoff modelling using SPHY
- Processing of soil moisture and its utilization in snowmelt and glacier melt runoff modelling

**ONGOING STUDIES**

**SPONSORED RESEARCH PROJECT: NIH/WRS/2020-22/3**

1.　　**Title:** Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.

2. **Project Team:**

Dr P. K. Singh, Scientist 'D'
Dr P. K. Mishra, Scientist 'D'
Er P. K. Agarwal, Scientist 'B'

3. **Project Duration: 02 Years (08/20 – 07/22)**

4. **Objectives**

The major objective of this study is to apply newly developed WA+ framework for sub-basins of Brahmaputra and Barak basins in the state of Meghalaya.

a)　To develop water accounts for the study basins/sub-basins.
b)　To estimate ET consumption patterns and beneficial and non-beneficial water consumptions.
c)　To develop accounts for agricultural services (i.e., land productivity and water productivity).
d)　To prepare the detailed WA+ report for study basins/sub-basins.
e)　To impart training on WA+ to the state officials of Water Resources, Agricultural and other related Depts.

5. **Present state-of-the-art**

Water accounting (WA) can provide a coherent and consistent solution to the spatial & temporal assessment of WP and the allocation of water across various competing sectors to avert the looming water crisis. WA also considers the consumption of water and the benefits and services - including ecosystem services - that result from that consumption, including the return flow of non-consumed water. Various efforts have been made by United Nations (UN), Food and Agricultural Organisation (FAO), International Water Management Institute (IWMI) and the Australian government to develop standard WA frameworks. FAO's global information system on water and agriculture (AQUASTAT) is an important source of data, however, it does not distinguish between consumptive use and non-consumptive use. The System of Environmental Economic Accounting for Water (SEEA-WATER) of the United Nations Statistics Division (UNSD) (UN, 2012) requires a variety of data from numerous sources, which are unlikely to be available at many times (Dimova et al., 2014; Perry, 2012). It does not distinguish between the green and blue water resources (Falkenmark and Rockstr̈om, 2006; Rockstr̈om and Gordon, 2001). The Australian Water Accounting Standard (AWAS) developed by the Water Accounting Standards Board (WASB) of the Australian Bureau of Meteorology (BOM) accounts for water withdrawals rather than consumptive use. However, AWAS does not provide any information on rainfed systems and natural evapotranspiration (ET) processes.

The International Water Management Institute (IWMI) developed a WA procedure (Molden, 1997) with the aim of tracking water depletion rather than withdrawals to avoid errors when neglecting recycling, and to account for ET. The IWMI WA framework has been applied by IWMI in many irrigation system studies (e.g., Bhakra system in India (Molden, 1997); Zhanghe Irrigation System in China (Dong et al., 2004)) and at the national scale (e.g., India: Amarasinghe et al., 2007; SriLanka: Bastiaanssen and Chandrapala, 2003). However, only a few countries have adopted these WA mechanisms usually due to the lack of data needed to implement these approaches.

## 6. Methodology

The Water Accounting Plus (WA+) Framework is based on open access remote sensing data -in conjunction with open access GIS data and hydrological model output. WA+ communicates information on water storage, flows and fluxes for a variety of land use systems using eight intuitive fact sheets, tables and maps that are designed to be understood by people with technical and non-technical backgrounds alike.

The WA+ framework is developed by IHE-Delft in partnership with IWMI, FAO, and the World Water Assessment Program (WWAP). WA+ is based on a mass water balance approach (at the pixel level) and uses Budyko theory (Budyko, 1974) (Figure 1) and WATERPIX model (IHE, 2016) for this purpose. The basis of this water balance approach is that outflow from a certain area of interest (e.g., river basin) are explicitly related to the net inflow and depletion through a measurable ET processes.

WA+ framework classifies land use land cover (LULC) in to 80 classes. These 80 LULC classes are further grouped under four main Water Management Classes (WMC), i.e., Protected Land Use (PLU), Utilized Land Use (ULU), Modified Land Use (MLU), and Managed Water Use (MWU) (Figure 2). WA+ framework uses the Budyko theory (Budyko, 1974) for measurable ET separation in to ETgreen and ETblue. The Budyko theory is based on the coupling of (a) Water Balance approach and (b) Energy Balance approach. The water balance is performed individually for green and blue pixels, respectively.
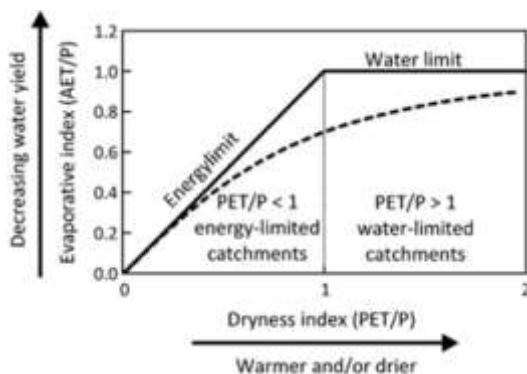


**Figure 1: Budyko Framework**          **Figure 2: WA+ Based WMC**

### 6.1 Study Area and Major Input Data

The state of Meghalaya is the north eastern part of India and is bounded in the north and east by Assam plains and in the south and west by Bangladesh plains. In the north, it is bounded by Kamrup and Goalpara districts of Assam and on the east by Karbi Anglong and North Cachar. The southern border is the international border with Bangladesh which is about 496 km long. Meghalaya is located between 25º01'51.58" N to 26º07'10.31" N latitude and 89º49'10" E to 92º48'04" E longitude with altitude ranging from 50 to 1966 meters. The State covers geographical area 22,429 km$^2$. Figure 3 shows the basin map of the Meghalaya state.

The WA+ framework makes use of open source remote sensing data in an effort to maintain a high level of transparency. Remote sensing is a reliable and objective source of data. Data products from the National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) are provided free of charge for all users regardless of nationality or intended application. Following datasets will be used for WA+ analysis in this study:
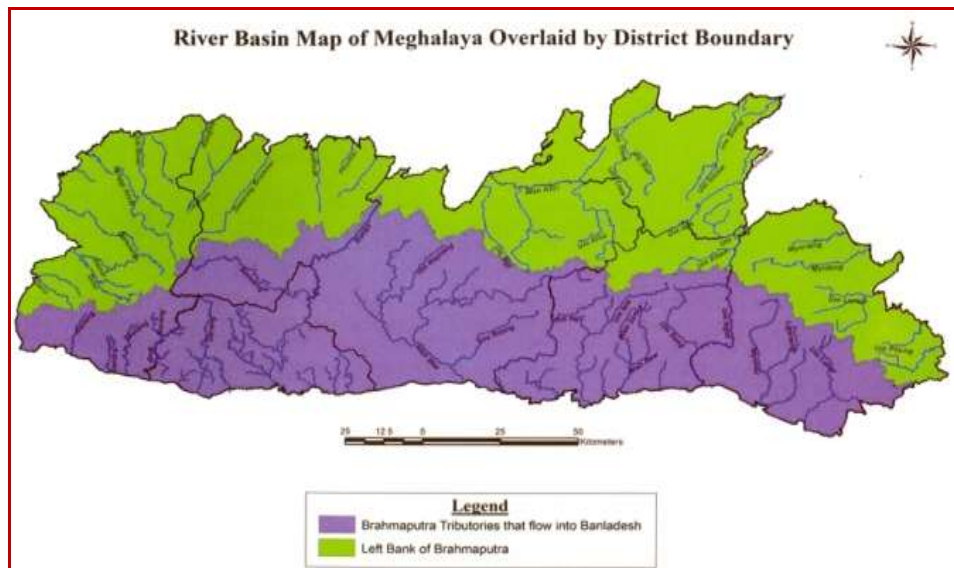
**Figure 3: River basin map of Meghalaya overlaid by district boundary**
(Source: WRD, Meghalaya)

- Precipitation (CHIRPS - or TRMM rainfall)
- Evapotranspiration (MODIS/ ETensV1.0/GLDAS)
- Meteorological data (GLDAS-Noah)
- WA+ system based Land Use / Land Cover (WALU using GlobCover, IWMI crop maps, MODIS, FAO, etc.)
- Soil moisture (EUMETSAT-ASCAT: Advanced SCATterometer (ASCAT)/GLDAS
- Vegetation, leaf area index (MODIS)
- Net primary production (NPP) and gross primary production (GPP) (MODIS)
- Crop types and crop calendar
- Basin DEM, boundary, drainage network map, etc.
- GRACE (Gravity Recovery and Climate Experiment) dataset
- GMIA (Global Map of Irrigated Areas) dataset
- MIRCA (Monthly Irrigated and Rainfed Crop Areas) dataset
- Grey Water Footprint/WPL datasets

## 7. Research Outcome from the Project:

- Water Accounts: Supply-Demand and Consumptions and Water Availability
- Water Consumption Patterns and beneficial non-beneficial consumptions.
- Accounts for Land Productivity and Water Productivity.
- LULC map, soil maps, and river networks.
- WA+ Report and Recommendations.
- Training modules on WA+ Framework.

## 8. Cost Estimates:

The total cost of the project: **₹ 14.50 Lakh**
   a. Source of funding: NHP
   b. Sub-head wise abstract of the cost:

| Head | Amount (in Lakh) | | |
|---|---|---|---|
| | 1st Year | 2nd year | Total |
| 1: Manpower: JRF @31,000/ + HRA and others | 5.00 | 5.00 | 10.00 |
| 2: Others (Hiring of services, field visits, consumables, stationary, printing of reports & brochures, and sample analysis, etc. ) | 1.00 | 1.00 | 2.00 |
| 3: Travel Expenditure | 1.00 | 1.00 | 2.00 |
| 4: Contingency | 0.25 | 0.25 | 0.50 |
| Grand Total | | | 14.50 |
| | Rs. Fourteen Lakhs Fifty Thousand Only | | |

## 9. Work Schedule

   a. Probable date of commencement of the project:
   b. Duration of the project:   02 Years
   c. Stages of work and milestone: Shown below

| Project Year | Aug. 2020-July 2021 | | | | Aug. 2021-July 2022 | | | |
|---|---|---|---|---|---|---|---|---|
| **Project Quarter** | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 |
| **a.** Data downloading, processing, and generation of data base | ←→ | → | | | | | | |
| **b.** Basic data analysis in WA+ framework, Ground truthing surveys for LULC and data collection from CWC, and state govt. departments | | ←→ | → | | | | | |
| **c.** WA+ Framework Application and Testing | | | ←→ | → | | | | |
| **d.** Development of Water Accounts | | | | | ←→ | → | | |
| **e.** Detailed Analysis of Water Accounts and Validation and research paper publications | | | | | | ←→ | → | → |
| **f.** Final report writing recommendations and Training | | | | | | | ←→ | → |

## 10. Progress till date:

The estimates of the water and land productivity were refined based on the discussions held during the second WA+ training to the WRD state officials of the North-Eastern states including Meghalaya. Green and blue water consumptions were estimated for all the districts of the Meghalaya using Budyko theory. The results show that the Garo Hills districts have more blue water consumptions than the other districts such Khasi Hills in the Meghalaya. A comparison was also made between various gridded precipitation datasets such as IMD, APHRODITE, CHIRPS, and TRMM. The goodness-of-fit statistics was evaluated in terms of RMSE, R2, MAE and Mean Bias. The results show that the TRMM datasets have lower bias as compared to CHIRPS and APHRODITE datasets with IMD. CDD and CWD were also evaluated in comparison to the IMD datasets. The work is under progress for generating supply-demand statistics and water availability in the different sub-basins of the Meghalaya. A stakeholder workshop/meeting is also planned during the month of April-May, 2022 to discuss the major findings with this study.

**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 'D'

**3. Project Duration: 02 Years (04/21 – 03/23)**

**4. Objective of the Study**

The major objective of this study is to apply the newly developed WA+ framework for the selected sub-basins of Brahmaputra, Barak and Irrawady-Chindwin basins in the state of Nagaland for estimating the status of the water resources. This will generate useful base data to help development of proper water management strategies and decision processes. The specific objectives are:

1. To set-up WA+ Framework for the selected study basins/sub-basins.
2. To estimate ET consumption patterns for the selected basins/sub-basins.
3. To estimate land and water productivity for the selected basins/sub-basins.
4. To develop Resource Base (Surface water & Groundwater) for the selected basins/sub-basins.
5. To develop capacity on WA+ to the State Govt. officials from WRD, Nagaland through training programmes

**5. Scope of the Study:**

The scope of this study is as follows:

a. To estimate ET consumption patterns and beneficial and non-beneficial water consumptions.
b. To develop accounts for agricultural services (i.e., land productivity and water productivity).
c. To collect hydrological and meteorological data.
d. To collect data on topography, soils, river networks, drainage networks and land-use & land-cover.
e. To validate, analyze and process the data collected and give necessary inputs.
f. To develop water accounts for the study basins/sub-basins.
g. To prepare the detailed WA+ report for study basins/sub-basins.
h. To impart training on WA+ to the state officials of Water Resources, Agricultural and other related Depts.

**6. Study Area and Input Data**

The state of Nagaland is a north eastern state of India and is surrounded by the states of Assam, Manipur, Arunachal Pradesh and also by Myanmar in the East. The state covers a geographical area of approximately 16580 km$^2$. The major part of the State is drained by the Brahmaputra basin (~10881 km$^2$, 65.6%) followed by Barak basin (~814 km$^2$, 4.9%) and by Irrawady-Chindwin basin (~4884 km$^2$, 29.5%). The state of Nagaland is divided into three river basins viz, rivers flowing to Brahmaputra, rivers flowing to Barak and the rivers flowing to the Irrawady-Chindwin basin.

**Input Data**

The WA+ framework focuses on the use of open source and remote sensing satellite datasets in an effort to maintain a high level of transparency and applicability in ungauged basins. Remote sensing is a reliable and objective source of data. Data products from the National Aeronautics and Space Administration (NASA), European Space Agency (ESA) and many other agencies are provided free of charge for all users regardless of nationality or intended application. Following datasets will be used for WA+ analysis in this study. 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** | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 |
| a. Data downloading and processing, and generation of data bases and maps; data collection from CWC, and state govt. departments | ← | → | | | | | | |
| b. Data analysis in WA+ Framework, 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:**

| Particulars | Work Done |
|---|---|
| Procurement of High Configuration System | Completed |
| Generation of GIS layers for 3 basins and 9 sub-basins in Nagaland | Completed |
| Data downloading and processing from open sources viz. CHIRPS, GMIA, LAI, GPP, NPP, Globcover, MIRCA (Rainfed and Irrigated), WDPA, Population, etc. | Completed |
| Development of Water Accounting based Land use (WALU) | Completed. |
| Setting up of WA+ model for Sheet 2 (Evapotranspiration) and Sheet 3 (Agricultural Services including Land and Water Productivity) Generation | Ongoing |
| Setting up of Water Pix model for Supply Generation | Ongoing |
| Generation of Sheet 4 (Utilized flow), Sheet 5 (Surface water), Sheet 6 (Groundwater), Sheet 1 (Resource base) | Yet to be done |
| Training on WA+ to selected WRD officials | Planned during the month of April/ May 2022. |

1. **Project 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 sub-basins in the state of Mizoram.

2. **Duration of the project** : **3 years (04/21-03/24)**

3. **PI and Co-PI from Lead** : PI: Dr. Vishal Singh, Scientist- C

   **Organization** Co-PI: Dr. M.K. Nema, Scientist- D

   Dr. P. K. Singh, Scientist-

4. **Investigators from Partner** : 1. Mr.K. Hamlet, Sr.E.E

   **Organization** 2. Mr. Vanlalpekhlua Sailo, AE

5. **Objective of the Study**

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) sub-basins 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 area 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.

## 6. Study area

Mizoram, with an area of 21,087 km$^2$ is largely divided into three major river basins: one is the Barak basin (8,935 km$^2$) in the central to northern part of the state, the second is Kolodyne basin (8,144 km$^2$) in

the southeastern part, and the third is Karnaphuli basin (3,999 km$^2$) in the southwestern part, as shown in Figure 1.
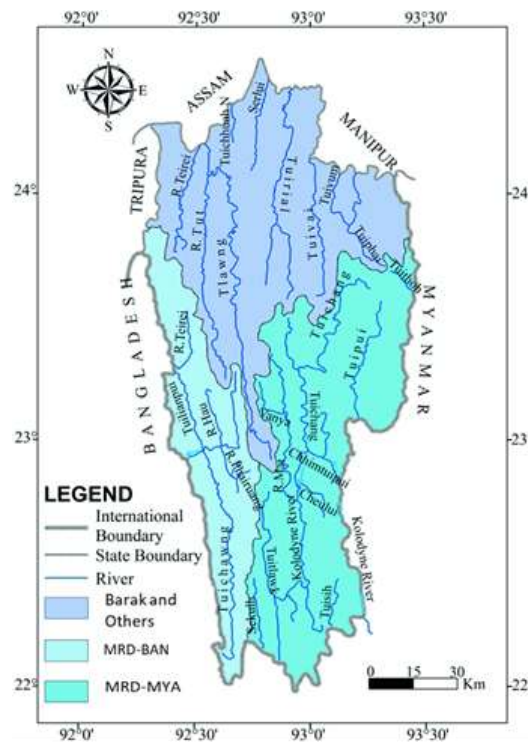


**Figure 1:** River basin map of the Mizoram showing river basins namely Barak and Other, Minor rivers draining into Bangladesh (MRD-BAN) and Minor rivers draining into Myanmar (MRD-MYA).

## 7. Brief Methodology

### 7.1 Processing of meteorological datasets
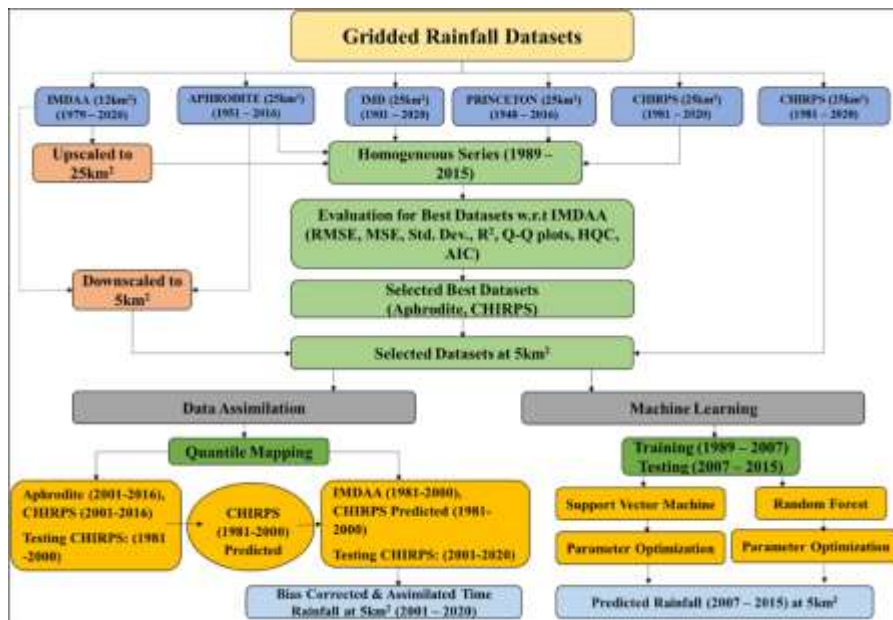


**Figure 2:** Processing of meteorological datasets and generation of new hybrid gridded rainfall.

**7.2 Climate projections and rainfall indices**
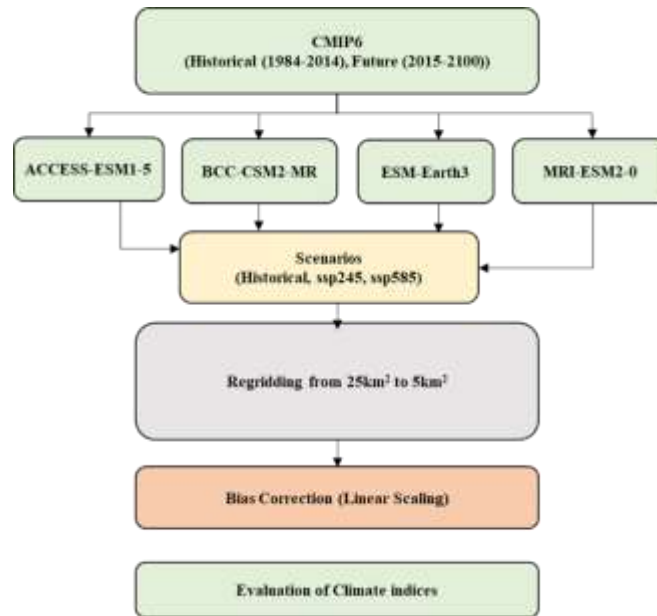


**Figure 3:** Analysis of rainfall indices to analyse changes in rainfall.

**7.3 Overall modeling methodology**
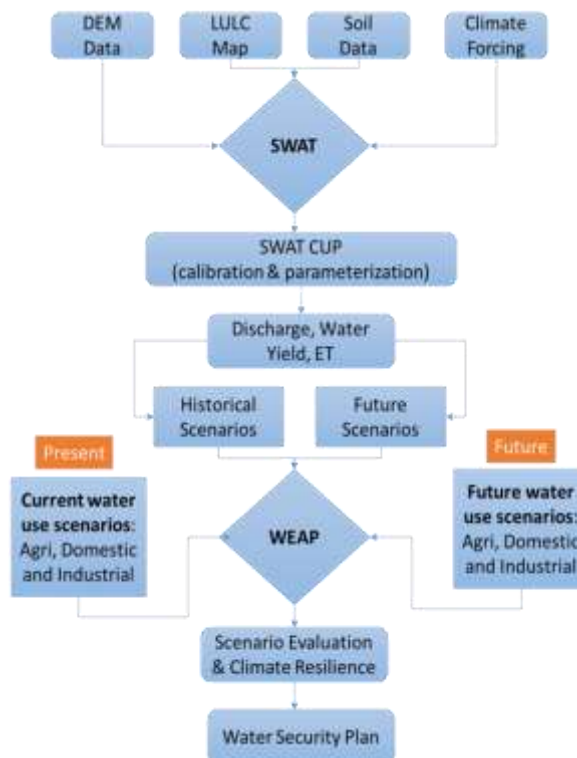


**Figure 4:** Overall modeling methods.

**8. Expected Deliverables**

- A detailed outcome of water balance components including surface and groundwater.
- Rainfall extreme trends discharge scenarios (up to 2050), with possible plans and thresholds for resilience with and without structural interventions under the anticipated conditions and combinations thereof.

- Basin/sub-basin wise water availability: Supply-Demand and Consumptions and Water Availability, considering a development period of 5 years and a planning horizon of 30 years.
- LULC change maps, soil maps and river networks.
- Guidelines and schema of water security plan, with particular reference to identified locations with significant demand. Planned developments will be taken into consideration.
- Report and Recommendations of best practices suitable for the catchments
- Trainings on hydrological models to the officers from Mizoram IWRD and other Implementing Agencies of the NHP.

## 9. Expected Timeline against the Deliverables

| Project Year | Mar 2021-Feb 2022 | | Mar 2022-Feb 2023 | | Mar 2022-Aug 2024 | |
|---|---|---|---|---|---|---|
| **Project Quarter** | M 1-6 | M 7-12 | M 13-18 | M 19-24 | M 25-30 | |
| **a.** Data downloading and processing, and generation of data bases and maps; data collection from CWC, and state govt. departments | ←———→ | | | | | |
| **b.** Data analysis, Trend generation, SWAT setup | | ←———→ | | | | |
| **c.** Hydrological Assessment & Calibration | | ←——→ | | | | |
| **d.** Projected Scenarios using GCMs and Climate Resilience Analysis | | ←————————→ | | | | |
| **e.** WEAP setup and water availability and demand assessment | | | ←—————————→ | | | |
| **f.** Report and Recommendations of best practices suitable for the catchments | | | | | ←——→ | |
| **g.** Training modules on Hydrological Model | | | | ←————————→ | | |

## 10. Progress till date

## 10.1. Generation of new gridded high resolution rainfall datasets
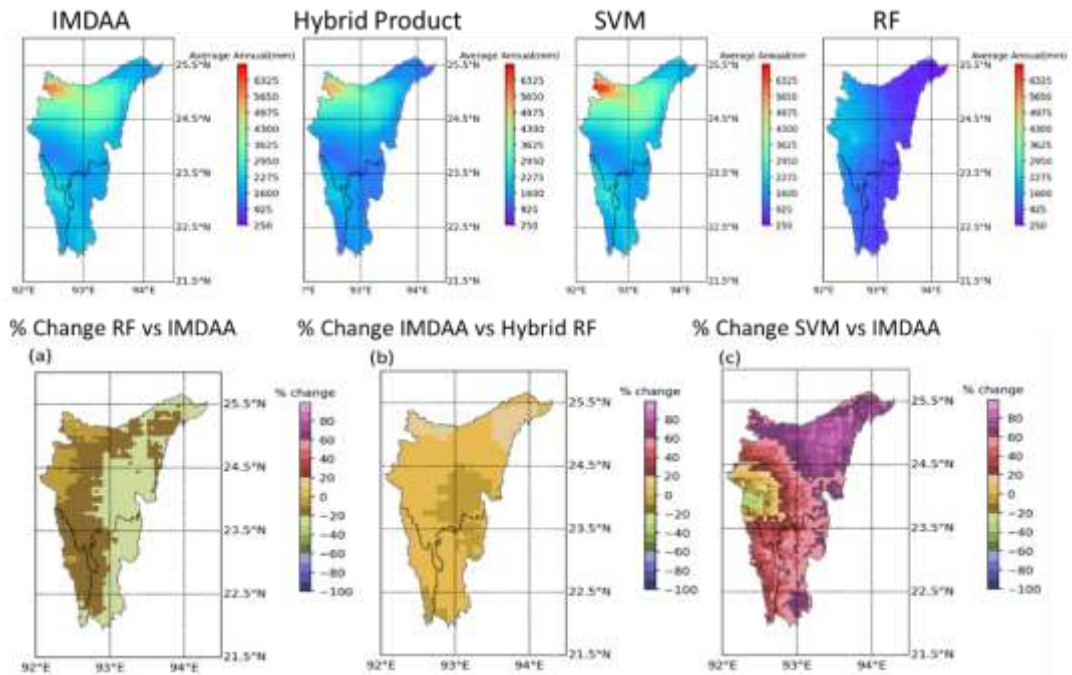
**Figure 5:** Hybrid rainfall datasets.

## 10.2. Preliminary SWAT Modeling Water Balance outcome

Water Balance Ratios
- Streamflow/Precip = 0.62
- Baseflow/Total flow = 0.40
- Surface Runoff/Total Flow = 0.60
- Perc/Precip = 0.17
- Deep Recharge/Precip = 0.01
- ET/ Precipitation = 0.36

## 10.3 Evaluation of SWAT modeling outcome (prior to calibration)

| Site | Lon | Lat | Observed discharge Duration (days) | Annual Mean Discharge | | | Standard Deviation | | | Maximum Discharge | | | $R^2$ ($Q_{obs}$ vs $Q_{sim}$) |
|------|-----|-----|------|------|------|------|------|------|------|------|------|------|------|
| | | | | $Q_{obs}$ | $Q_{sim}$ | % change | | $Q_{sim}$ | % change | $Q_{obs}$ | $Q_{sim}$ | % change | 0.27 |
| Tlabung site at River Karnaphuli | 92.47 | 22.89 | 2014 - 2018 (441) | 179.15 | 141.80 | 20.85 | 0.27 | 213.26 | 10.04 | 1303.935 | 1585 | -21.55 | 0.41 |
| Tlawng (near Lunglang village) | 92.66 | 23.62 | 2015 - 2017 (348) | 60.96 | 47.43 | 22.19 | 0.41 | 49.54 | -4.15 | 160.721 | 346.7 | -115.71 | 0.15 |
| Tuipui D Site at River Kolodyne | 92.93 | 22.90 | 2015- 2017 (593) | 403.72 | 297.10 | 26.40 | 0.15 | 465.84 | 42.68 | 8701 | 6430 | 26.10 | 0.22 |
| Mateswari Site at River De | 92.52 | 22.94 | 2015 - 2017 (629) | 39.00 | 43.33 | -11.11 | 0.22 | 62.74 | -5.49 | 333.33 | 480.8 | -44.24 | 0.27 |

$Q_{obs}$ = Observed Discharge, $Q_{sim}$ = Simulated Discharge

## 11. Work in Progress
- Calibration and Validation using Stochastic Modeling and Optimization Methods
- Generation of Projected Scenarios of Various Watershed Components to Setup WEAP model

290

1.　　**Title:** Impacts of Glacier and Climate Change on Runoff for Selected Basins of Himalayan Region

2. **Project Team:**

> Dr Vishal Singh, Scientist 'C'
> Dr Sanjay K Jain, Scientist 'G'
> Dr Manohar Arora, Scientist 'E'

3. **Project Duration: 02 Years (08/20 – 07/22)**

4. **Objectives**

1. To apply a data assimilation technique and bias correction methods for constructing more accurate high resolution gridded (i.e. approximately at $0.05^0 \times 0.05^0$) hydro-meteorological data sets (e.g. precipitation) over the selected river basins.

2. To develop a novel Integrated approach for snowmelt and glacier melt runoff modeling by incorporating SWAT and SPHY hydrological models with special emphasis on uncertainty estimation utilizing real time remote sensing and hydro-observation datasets.

3. To study the impact of snow and glacier changes on the runoff.

4. To analyze the impact of climate change and the long-term (21st century) variability in snow and glacier melt runoff utilizing latest CMIP6 GCMs datasets.

5. **Present state-of-art**

A limited number of studies have been carried out related to the separation of snow and glacier melt contributions, especially in the Himalayan region under glacier and climate changing conditions. The computation of snowmelt induced runoff from the glaciered catchment has always been a key hydrological issue, especially over high mountainous regions like Himalaya. Climate change studies resulted that around 1ºC temperature has been increased in Himalayan regions, which have been identified as one of the most vulnerable glaciated regions to climate change. The conservation of Himalayan freshwater reserves is necessary for the design and management of hydropower plants, supply of drinking water, agricultural management practices and flash flood risk assessment. This study has been proposed to carry out a research analysis over Himalayas to assess the impact of glacier and climate change in the long-term time frame (e.g. 21st century). For snow and glacier modelling, a novel approach based on snow-glacier hydrological model such as SPHY will be incorporated. SPHY model is a grid-based model and uses multiple thematic and meteorological datasets. In this study, we will use a temperature index model utilizing variable degree-day factors (uses separate factor for snow, clean ice glacier and debris glacier) in SPHY at each grid scale for analyzing snow and glacier melt runoff, especially designed for the Himalayan conditions. No such variable degree-days factors have not been applied for each grid. For climate change analysis, latest CMIP5/CMIP6 GCMs coupled with SWAT model will be utilized. SWAT model has been widely utilized in the simulation and projection of various hydro-meteorological components.

**6. Methodology:** In the present study four Himalayan river basins such as Baspa, Parbati, Lachung and Subanshiri will be taken up.

**6.1 Data assimilation and bias correction**

For meteorological datasets, a high resolution gridded daily precipitation dataset (0.05°×0.05°) 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).

**6.2 Integrated Hydrologic Modelling:**

The Soil and Water Assessment Tool (SWAT) and SPHY model, will be used for the estimation of snowmelt and glacier runoff over the selected Himalayan river basin such as Parbati, Baspa, Lachung and Subansiri.

**6.3 Snow and Glacier runoff changes**

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

**6.4 Validation of Satellite-based Snow Covers with SPHY model derive Snow Covers and Model calibration**

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

**7. Progress till date:**

7.1 Preparation and processing of hydro-meteorological datasets and thematic datasets such as LULC maps, DEM derived maps, Soil map, Glacier change maps and snow cover area maps.

7.2 Snow and glacier melt runoff modeling using SPHY and results have been calibrated and validated.

7.3. Assessment of snowmelt and glacier melt runoff changes at subbasin and seasonal scales in the Baspa river basin.

7.4 SPHY Model based simulation of snow-glacier melt induced discharge at the outlet gauge i.e. Sangla.

7.5 SPHY Model based simulation of snow-glacier melt induced discharge for Upper Ganga River Basin (up to Devprayag)

7.6 Modeling of snow/glacier induced runoff and glacier changes for Upper Ganga River Basin (up to Devprayag)

For the assessment of glacier changes and corresponding melt runoff from high (upstream) to moderate (downstream) elevation ranges, decadal glacier-change maps (1990, 2000, 2010, 2020) have been prepared utilizing the RGI glacier inventory (RGI06) data and by processing the LANDSAT satellite images.

**Table 2:** Showing changes in snow and glacier runoff components in intra-decadal (mean) scenarios

| Components | Scenarios | Bhagirithi | Alaknanda | Devprayag |
|---|---|---|---|---|
| **Glacier Q (Mean)** | 1986-1995 | 58.685230 | 75.612448 | 134.297651 |
| | 1996-2005 | 62.754126 | 78.616867 | 141.370997 |
| | 2006-2015 | 62.590482 | 78.385543 | 140.976009 |
| | 2011-2020 | 63.382801 | 79.230132 | 142.612946 |
| **Snow Q (Mean)** | 1986-1995 | 97.273781 | 139.561971 | 236.839060 |
| | 1996-2005 | 86.398220 | 121.692763 | 208.094795 |
| | 2006-2015 | 88.486988 | 121.914880 | 210.404877 |
| | 2011-2020 | 87.844005 | 122.330329 | 210.177880 |
| **Rain Q (Mean)** | 1986-1995 | 154.073537 | 274.432808 | 429.439567 |
| | 1996-2005 | 160.544640 | 295.227510 | 456.819414 |
| | 2006-2015 | 176.990498 | 317.926959 | 496.026979 |
| | 2011-2020 | 160.918805 | 287.552351 | 449.425606 |
| **Base Q (Mean)** | 1986-1995 | 34.453273 | 54.367486 | 88.909510 |
| | 1996-2005 | 36.502612 | 58.057554 | 94.666650 |
| | 2006-2015 | 38.769161 | 60.974558 | 99.855288 |
| | 2011-2020 | 37.305955 | 57.664187 | 95.064272 |
| **Total Q (Mean)** | 1986-1995 | 344.485716 | 543.974540 | 889.485507 |
| | 1996-2005 | 346.199598 | 553.594693 | 900.951855 |
| | 2006-2015 | 366.837033 | 579.201771 | 947.263023 |
| | 2011-2020 | 349.451474 | 546.776835 | 897.280474 |

## 8. Work in Progress

- Assessment of snowmelt and glacier melt runoff changes at subbasin and seasonal scales in the Teesta river basin.
- SPHY Model based simulation of snow-glacier melt induced discharge at Teesta river basin

**INTERNAL RESEARCH PROJECT: NIH/WRS/2020-23/2**

1.  **Title:** Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya

2.  **Project Team:**

    Dr Manish Kumar Nema, Scientist 'D'
    Dr Sanjay K Jain, Scientist 'G'
    Dr P. K. Mishra, Scientist 'D'
    Er. P. K. Agarwal, Scientist 'B'

3.  **Project Duration: 03 Years (08/20 – 07/23)**

4.  **Objectives**

    a.  To develop a baseline runoff and meteorological data of Henval watershed with the established experimental setup.
    b.  To carry out Hydrological modelling of Henval river
    c.  To model the spatial-temporal variability and temporal-stability of the soil moisture
    d.  To compare and validate the satellite soil moisture data with the in-situ observations

5.  **Present state-of-art**

    Watershed is supposed to be the basic unit at which the hydrologic processes are studied and is central to most of the concepts in hydrology. Experimental hydrology still has a unique place with no alternative for testing and developing new research hypotheses and models. Given the importance of experimental hydrology, NIH has initiated an experimental hydrologic project for a small lesser Himalayan watershed, namely, Henval. In the first phase of the project, a state-of-art field observatory was established with various instruments and sensors during 2016-2019. Preliminary data analysis on the estimation of evapotranspiration by various methods and water balancing of the watershed was performed. The field station developed at Henval watershed is envisaged to operate for long-term monitoring of different hydro-climatic variables. This study is supposed to be the second phase of the project.

    The field monitoring of the various variables and development of baseline datasets for the Henval watershed shall be a continuous process in this study. Hydrological modeling of the stream is planned to understand the catchment characteristics and runoff behaviour of the watershed. Soil moisture is the crucial variable for partitioning rainfall into infiltration and runoff, thus playing a fundamental role in runoff modelling and flood forecasting. Recently, the scientific community is making an excellent effort to address soil moisture estimation over large areas through in situ sensors, remote sensing, and modelling approaches. There is sizeable spatial-temporal variability of soil moisture that exists in field conditions. Currently, we are able to estimate soil moisture accurately at the point scale through in-situ sensors.

    Moreover, satellite sensors can obtain less accurate measurements at a coarse scale (~20 km). Finally, spatial downscaling/upscaling approaches can be used to integrate the different techniques and observations with modelling. Data assimilation and merging methods can also be considered to integrate in-situ, satellite and modelled data optimally.

6.  **Methodology**

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

**Hydrologic modelling:**

Several models are available for runoff modelling. In the proposal work, a semi-distributed model with proven capabilities, namely the Soil and Water Assessment Tool (SWAT) model, will be used for the estimation of streamflow in the basin.

**Soil moisture modeling**

The SWAT, Soil Water Balance Model, etc. shall be applied to carry out soil moisture modelling. The observed soil moisture data shall do the calibration and validation of soil moisture model. Study of the effects of static factors such as land-use, topography, soil texture, etc. on the spatial variability of soil moisture also envisaged in this study.

**Validation of Satellite-based Soil moisture products**

Various satellite-based soil moisture products such as ASCAT, SMAP, SMOS, etc. with different resolution shall be validated and compared against the in-situ soil moisture sensor. The interrelation of soil moisture and surface runoff shall be performed.

7. **Research Outcome from the project:**

   - Validation of the SWAT model for a lesser Himalayan watershed.
   - Assessment of the spatial-temporal variability and temporal-stability the soil moisture
   - Validation of satellite-based soil moisture product for Himalayan watershed.
   - The error characterization of the satellite-based soil moisture products.

8. **Cost estimates:**

The total cost of the project: **₹ 10.2236 Lakh**
   a. Source of funding: NIH

   b. Sub-head wise abstract of the cost:

| SN | Sub-head | Amount (₹) | | | |
|---|---|---|---|---|---|
| | | Year - I | Year - II | Year - III | Total |
| 1 | Salary (Part-Time Field Staff) | 156000 | 171600 | 188760 | 516360 |
| 2 | Travelling expenditure | 78000 | 78000 | 78000 | 234000 |
| 3 | Experimental/ Rental Charges | 66000 | 76000 | 76000 | 218000 |
| 4 | Misc. expenditure | 18000 | 18000 | 18000 | 54000 |
| | Sub- Total: | 318000 | 343600 | 360760 | |
| | Grand Total: | | | | 1022360/- |

9. **Work Schedule:**

| S N | Description of Activity | 2020-21 | | | 2021-22 | | | | 2022-23 | | | | 2023-24 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 |
| 1 | Data Collection and up-keeping of the instruments | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| 2 | Hydrological modelling | | ■ | ■ | ■ | ■ | | | | | | | | |
| 3 | Soil Moisture modelling | | | | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| 4 | Satellite data acquisition, assimilation and | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | processing | | | | | | | | | | | | |
| 5 | Validation and comparison of satellite and in-situ data | | | | | | | | | | | | |
| 6 | Report writing | | | | | | | | | | | | |

## 10. Progress till date:

The PI has visited the various instrumented sites in the experimental catchment during the last six months to collect the data and maintain the systems. In the previous working group meeting, the results related to hydrological modelling were shared with the members. In pursuance of the study's second objective, an empirical model is formulated using available parameters in this study, i.e., rainfall, wind speed, air temperature, and near soil surface temperature. This model was calibrated and validated using the Kumargaon, Kanataal and Nagini sites in the lesser Himalayan region. The results indicated the best performance of the model at Kumargaon with high $R^2$ in calibration and validation. These results are further supported by lower values of RMSE, ubRMSE, MAE and Pearson's correlation coefficient for this site. The model performed good at the other two sites of Kanataal and Nagini, but the results are comparatively inferior to Kumargaon. Furthermore, this model is simplified using the averaged values of optimized parameters and tested using the data used for validation. The results indicate that the simplified model also performed best at Kumargaon for all the soil depths with high $R^2$ values which are obtained as 0.86 for 2 cm, 0.83 for 6 cm and 0.64 for 25 cm depths, respectively. Whereas for the similar soil depths at Kanataal, the performance was good only for the topmost layer of 2 cm with a high $R^2$ value of 0.82. For the deeper soil layers at Kanataal, lower values of $R^2$ (0.50 for 6 cm and 0.33 for 25 cm) indicates relatively average performance. Once again, the simplified model performed well at the site of Nagini with high $R^2$ (0.81) value for the soil depth of 6 cm. It is also found that the model's performance decreases with increasing soil depth which indicates that the effect of meteorological variables decreases with the increasing soil depth. Yet, no ideal model would precisely predict soil moisture; hence, this quest emergence of deep learning models makes the process efficient and reliable. In the later part of the study's second objective, two deep learning hybrid models based on long-short term memory, namely, CNN-LSTM and RNN-LSTM, were developed and tested to model the sub-surface soil moisture at three stations located in a Lesser Himalayan catchment. The work is still ongoing, and findings will be shared in future working group meetings.

INTERNAL RESEARCH PROJECT: NIH/WRS/2021-23/3

**1. Title of the Study:**      Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios.

**2. Study Group:**      Dr Manohar Arora, Scientist 'E'
Dr P K Mishra, Scientist D
Dr. Vishal Singh, Scientist C

**3. Type of Study:**      Internal Project

**Date of start:**      01.04.2018
**Scheduled date of completion:**  31.03.2023

**4. Location Map:**
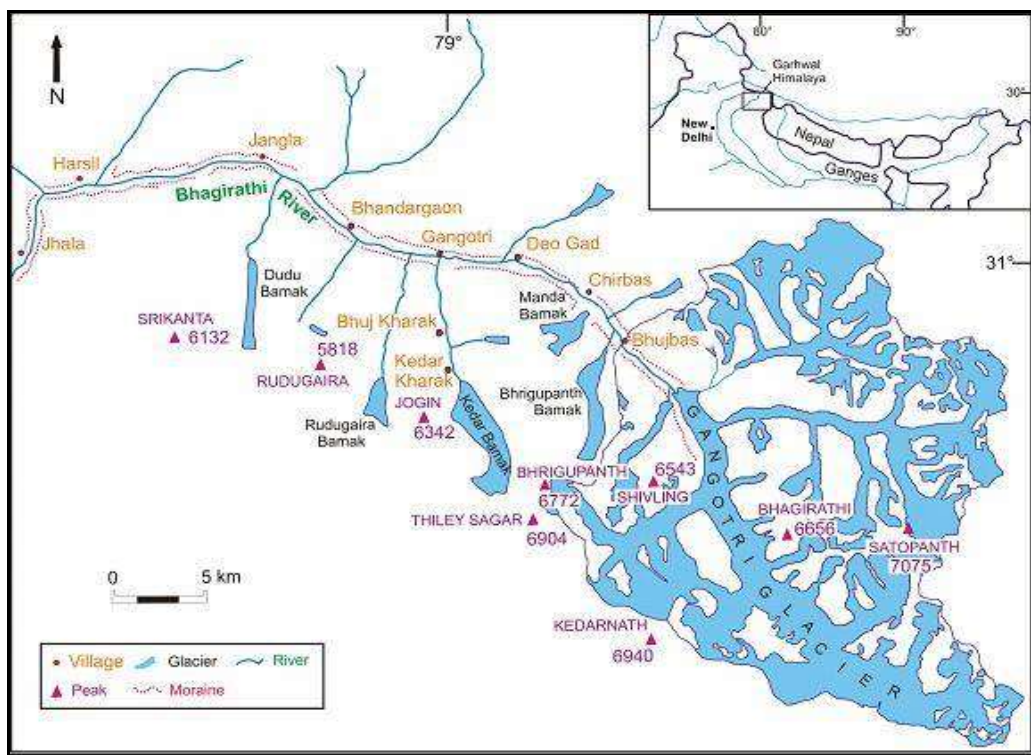


**5. Objectives:**  The objective of this study includes:

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

- Seasonal characterization of the glacier melt.

- Estimation of suspended sediment yield from the Glacier.

- Modeling the catchment runoff variation under different climatic scenarios.

**6. Statement of the problem:**

The study involves collection and analysis of hydro-meteorological and discharge data of the glacier site. The second step is to use a snow melt model for streamflow generation and identification of different runoff components. The third step is to simulate catchment runoff variation under different scenarios.

**7. Action Plan**

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

**9.     Objectives vis-à-vis Achievements**

| Objectives | Achèvements |
|---|---|
| Continuous monitoring of meteorological and hydrological data for monthly and seasonal specific water yield and its variability from the year to year | Due to Covid 19 no field investigations was carried out for ablation season 2021. The field investigations for 2022 will be started in the first week of May 2022. |
| Characterization of Suspended sediment in the Gangotri Glacier Melt Stream | Particle size analysis was carried out from the samples collected. The results indicate a clear dominance of silt size particles (65–78%) in suspended sediment throughout the melting season followed by sand (15–30%) and clay (4–7%). These results were further sub-classified into six size categories for more detailed analysis of the silt and sand particles. These sub-classification results indicate that, in the case of silt particles, medium (25–30%) and coarse (27–34%) silt provided the maximum contribution; whereas in the case of sand particles, fine sand (14–20%) dominated the suspended-sediment concentration. between 2% and 7% with an exception in the case of medium sand (10%), which happens to be the coarsest particle size of our study. |
| Seasonal Distribution of Cold Katabatic and Warm Anabatic Wind. | The percentage of Cold katabatic and Warm anabatic wind in the years 2016-2019 is 56% and 44% respectively. |
| Simulation of Streamflow for the Gangotri Glacier Melt Stream. | HBV model was used for the simulation of streamflow. The model was calibrated for the years 2016-17 and validated for the year 2018-19. Different functionalities, such as an automatic calibration using a genetic algorithm or a Monte Carlo approach, as well as the possibility to perform batch runs with predefined model parameters make the HBV model interesting especially for estimating streamflow. The coefficient of determination $R^2$ for the calibration period and validation period were 0.77 and 0.71 respectively. |

1. **Title:** Spatio-temporal Water Availability under Changing Climate and Land-use Scenarios in Wainganga River Basin

2. **Project Team:**

   Dr Manish Kumar Nema, Scientist 'D'
   Dr P. K. Mishra, Scientist 'D'

3. **Project Duration: 02 Years (04/22 – 03/24)**

4. **Objectives**

   Wide-scale interventions and other water-related activities have occurred in the Wainganga River Basin (WRB), which sustain 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 of climate and landuse on the Wainganga river basin's water balance. The specific objectives of the study are as follows:

   a. To study the historical climate change, morphological properties and land use/land cover change pattern over the Wainganga river basin
   b. To calibrate and validate a hydrological model at different spatial scales for the river basin using current land use and observed climatic conditions
   c. To develop future expected land-use change and climate change scenarios (CMIP6) for the base period and compare them with the observed period
   d. To model spatial and temporal future water availability using climate and land-use change scenarios
   e. To quantify the uncertainty in modeling analysis arising from model parameters and input conditions
   f. To prepare adaptation/management strategies under changing climate and land-use scenarios

5. **Present state-of-art**

   Presently, the total water availability of the Wainganga basin is 9225 MCM (325.89 TMC). The various sectoral demands such as domestic, industrial and agricultural for the basins water resources have grown steadily over the years, leading to an intensification of competition and conflicts for the limited water resources. Therefore, the study aims to assess the basin's water resources availability and, further, to evaluate the impact of existing and other prospective water resources developmental initiatives on the overall water balance of WRB. It is an interstate river, and the water is being shared based on the Water Dispute Tribunal Award for the Godavari Basin (Eastern Godavari Basin (EGB)). The majority of the inhabitants in this basin depend on farming, fisheries, and forest-dependent livelihood activities. The WRB fall under the parts of the Eastern Vidarbha region of Maharashtra has been in the news for many farmer suicides for more than a decade due to crop failures and increasing debts. While most districts in Vidarbha are known for cotton and soybean cultivation, eastern-Vidarbha, through which Wainganga flows, is historically known for its paddy cultivation. Bhandara and Gondia districts are known as the 'rice bowls' of Maharashtra. The rice and sugarcane production in the region was supported by the Maji-Malguzari (MM) tanks, which needs to be rejuvenated. The MM tank system, albeit feudal, was a well-designed decentralized system for irrigation and could have served as a hallmark of development in eastern Vidarbha.

## 6. Methodology

*Study Basin:*

The Wainganga rises in the Seoni District of Madhya Pradesh at an elevation of 640 m above M.S.L. Wainganga basin extends over approximately 50,000 square kilometres up to the Ashti gauging site, which spreads across the States of Madhya Pradesh and Maharashtra. The total length of this river is ~638 km up to the Ashti gauging site just before the confluence with the Wardha River. In the beginning, it flows eastward for a distance of about 175 km and then Southward for a length of about 100 km in Seoni and Balaghat District of Madhya Pradesh. It also serves as a border between Madhya Pradesh and Maharashtra state for 32km. Before joining the Godavari, it flows about 479 km in the Bhandara, Chandrapur, and Gadchiroli District of Maharashtra. The Wainganga basin lies in the medium rainfall zone, situated between 900 mm and 1600 mm. Most of the rainfall is received during the southwest monsoon from June to October. In the winter, the minimum temperature varies from $7^0$ C to $13^0$ C. Maximum temperature ranges from $39^0$ C to $47^0$ C. Month of May is the hottest month, and December is the coldest month.
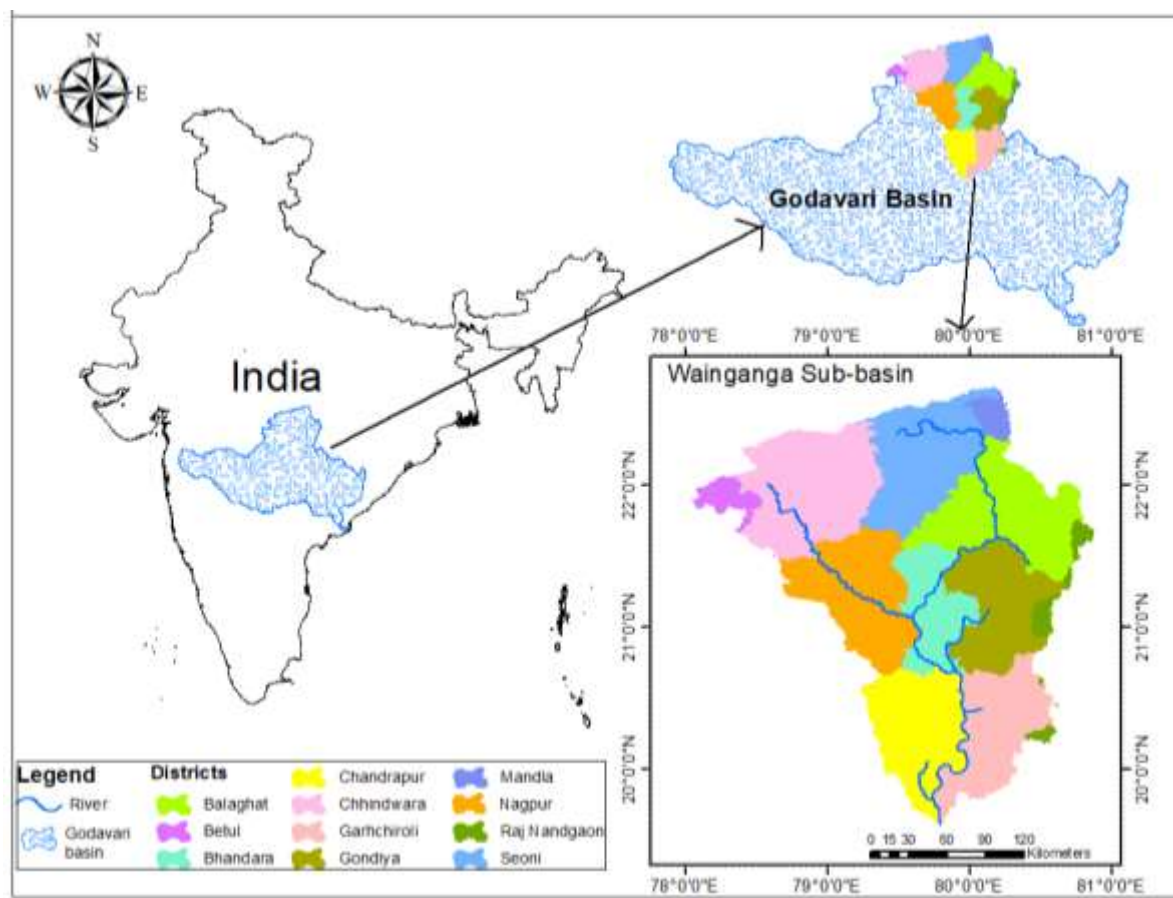


**Fig. 1 Location Map of Wainganga River sub-basin of Godavari Basin in India**

*Research Approach:*

A few activities/tasks have been defined to accomplish the study's research objectives, including collecting the data sets, field visits, surveys, analysis of collected data, model setup, scenario-based analysis, assessment of water availability, etc. The task-wise methodology proposed for analyzing the impact of climate change on the hydrology of Wainganga Basin is described below:

**Task 1:** Data collection, pre-processing and development of digital database including DEM, LULC, SOIL, Climatic time series, etc.

**Task 2:** Analysis of Trends for the climatic and hydrological extremes

**Task 3:** Modeling of surface hydrology and assessment of climate change impacts. In the proposal work, a semi-distributed model with proven capabilities, namely the Soil and Water Assessment Tool (SWAT) model, will be used to estimate streamflow in the basin.

300

*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: **₹ 10.2236 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 | | | |
|----|-------------------------|----|----|----|----|----|----|----|----|
| | | 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 | | | | | ■ | | | ■ |

1.      **Title:** 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

2. **Project Team:**

   Dr. Sanjay K. Jain, Scientist 'G'
   Dr Manish Kumar Nema, Scientist 'D'
   Dr P. K. Mishra, Scientist 'D'
   Dr. Praveen Thakur (IIRS)

3. **Project Duration: 03 Years (04/22 – 03/25)**

4. **Scope of the Work**

The scope of the work to be carried out in the project includes:

   a. Characterizing spatial extent and patterns of hydrological cycle components in selected watersheds in Western Himalaya (Uttarakhand) using multi-scale EO data;
   b. Assessment of watershed's topographical, morphological and hydro-meteorological spatio-temporal dynamics using a systematic and multi-site sampling using ground observations and EO inputs;
   c. Determining the EO-based land surface parameters and hydrological cycle variables of the watersheds and its dynamics;
   d. Developing hydrological models for multi-scale assessment of hydrological cycle components and water availability linking natural hydrological processes and anthropogenic water use under present and future climate scenarios;
   g. Developing a web-based hydrological information system, supporting hydrological and spatial database, web analytics and data/information dissemination for water resources planning and management.

5. **Deliverables**

   • Establishment of long term, experimental watershed monitoring sites with field instrumentation for understanding various hydrological and snow/glacier processes which are important in overall water balance studies.
   • The updated geospatial-database on hydrological sources and water resources of the selected watersheds.
   • Quantification of hydrological response of the selected watersheds and assessment of basin level water availability in the Upper Ganga Basin of NWH region under present and future climate change scenarios.

6. **Cost estimates:**

   The total cost of the project: **₹ 30.91 Lakh**

   a. Source of funding: IIRS

   b. Sub-head wise abstract of the cost:

| Head | Total grant (Lakh) |
|---|---|
| **Recurring** | |
| (i) Salary + HRA: 01 JRF or Project Fellow | **10.88** |
| (ii) Field work and Travel (Domestic) | **6.5** |
| (iii) Services (Field activities & other project costs: Field sampling for hydrological data collection and lab analysis of soil/water samples; contingency/consumables, skilled/non-skilled labor hiring for watersheds data collection), data, printing of project report/outputs and other charges. | **9.5** |
| (vi) Institutional charges/ Overhead | **4.03** |
| Grand Total* | **30.91*** |

Say **Rupees Thirty Lakh Ninety-One Thousand and Two Hundred only** from IIRS. *This is the maximum amount, which can be transferred during project duration. Actual budget transfer to be as per actual funds availability from ISRO, progress of work and utilization of given funds by the collaborating institute.

**8. Project Schedule**

Duration of project shall be **Three (03)** years from the date the project has been sanctioned by ISRO and approval of budgetary provisions.

| Activity | Year I | Year II | Year III |
|---|---|---|---|
| Project initiation, Inception workshop | ■ | | |
| Recruitment of project personnel | ■ | | |
| Permission for field studies | ■ | | |
| Workshop for field training | ■ | | |
| Field instrumentation/sampling | ■ | ■ | ■ |
| Acquisition of Satellite based Earth Observation data | ■ | ■ | |
| Progress review/workshop | ■ | ■ | ■ |
| Hydrological data collection, development of web based data repository and information system | ■ | ■ | ■ |
| Development of hydrological models for multi-scale water resources availability | | ■ | ■ |
| Generation of spatial layers on hydrological fluxes for present and future climate scenarios | ■ | ■ | ■ |
| Progress review and stakeholder workshop | | | ■ |
| Final Report generation | | | ■ |

## 1. Title of the Project

Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka

## 2. Objectives of the Study

The major objective of this study are as follows:

1. To collect, prepare and evaluate various thematic datasets such as DEM, land use/Land cover (LULC) map, soil map, and hydro-meteorological data-sets such as precipitation, temperature, discharge (if available) etc.
2. To analyze long-term hydro-meteorological variables such as precipitation, evapotranspiration, and water consumption patterns in the basin and assessment of their possible impacts on water management in the basins.
3. To estimate water potential of the west-flowing rivers, i.e., Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins using hydrological models and Frameworks.
4. To assess the effects of climate and landuse changes on the water yield using Budyko conceptual framework.
5. To analyze the hydrological sensitivity and resilience capacity of the basins under adverse climatic impacts.
6. To impart training on the hydrological models to the state officials of the water resources department including IAs of NHP.
7. To prepare the detailed sub-basin wise project report for the state water resources department for planning purposes.

## 3: Research Team:

PI:               Dr P K Singh, Scientist D, WRS Division, NIH Roorkee

Co-PI:          Dr Vishal Singh, Scientist C, WRS Division, NIH Roorkee

Co-PI:          Dr Sanjay K Jain, Scientist G and Head, WRS Division, NIH Roorkee

## 4: Project Duration: 03 Years (04/22 – 03/25)

## 5: The Study Area and Input Data

Figure 1 shows the map of the west flowing rivers in the state of the Karnataka. As discussed above, this study is aimed to assess the water potential yields and other hydro-meteorological analysis of the six sub-basins, e.g., Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins.

Figure 1: West-flowing Rivers in Karnataka (Source: IndiaWRIS).

## 6: Input Data

Looking into the un-availability of the measured/monitored hydro-meteorological datasets in these basins, it is planned to utilize the earth observation and satellite datasets for calibration and validation purposes and yield estimation in this study. Following datasets (not limited to) will be used in this study:

| SI. No. | Data-sets/Name | Availability/Source/Resolution | Time-Period |
|---------|----------------|-------------------------------|-------------|
| 1 | DEM | SRTM/CARTOSAT – 30 m/ALOS-PALSAR 12.5 m. | |
| 2 | Daily Rainfall and Temperature Gridded (Observed) | IMDAA –12 km$^2$ | 1979-2020 |
| 3 | Daily Rainfall Gridded (Satellite based-open sources) | CHIRPS – 5 km$^2$; TRMM+GPM -25 km2; | 1991-2020 |
| 4 | Other Hydro-Meteorological Datasets | NOAA/NASA/ ESA/ISRO | 1991-2020 |
| 5 | Population Data and population growth Data | As per census | 2011 and older |
| 6 | LULC maps | Glob cover, NRSC, IWMI, ESRI | For different time periods |
| 7 | SOIL Maps | FAO, USGS, Water Base, Future Water Group Netherlands | As per availability |

A detailed information about the data sources and their resolution can be had from their respective sources.

## 7: Methodology

The modelling tools/framework such as SWAT, HEC-HMS, WA+ and Budyko based approach will be applied for quantifying the water yield potential of these basins. The study will also assess the effects of climate and landuse changes on the water yield. Along with this, the hydrological sensitivity and

resilience capacity of these basins will also be assessed using the Budyko framework. For climate change analysis CMIP5/CMIP6 projections will be used in this study. For LULC change and impact assessment, decadal and projected LULC maps will be prepared and analyzed accordingly. For future projection of LULC change Markov chain based approach will be applied in this study. Figure 2 shows the flow chart of the methodology.
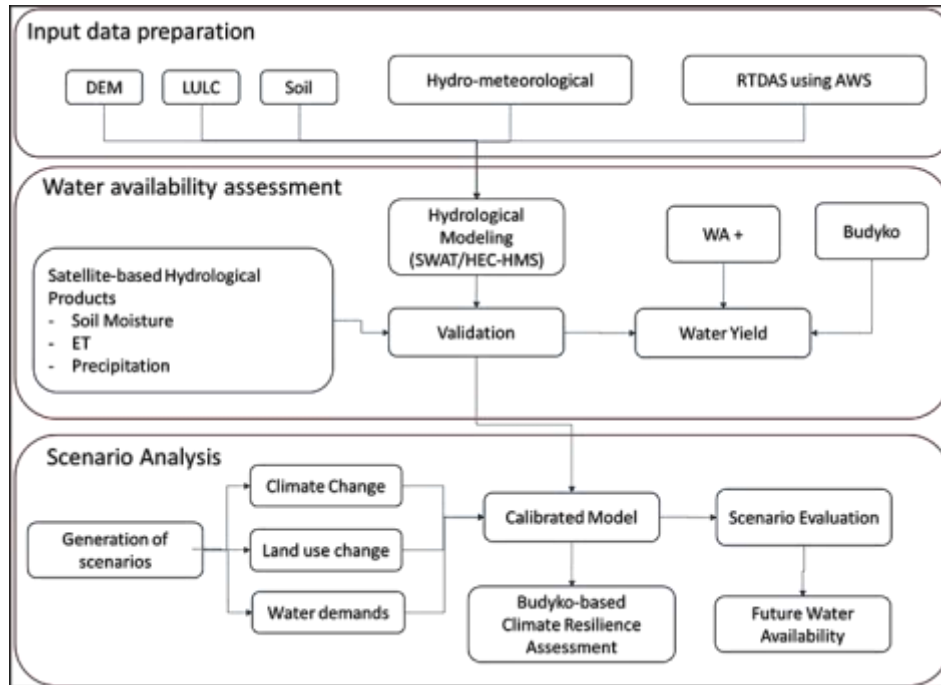


**Figure 2: Modelling Steps**

**8. Project Budget: Year-wise breakup of the budget:**

| Sl. No. | Head | Amount (in Lakh) | | | |
|---|---|---|---|---|---|
| **1:** | **Manpower (Salaries/ wages of project staff)** | **1st Year** | **2nd Year** | **3rd Year** | **Total** |
| | JRF (02 nos.) as per DST Norms | 8.50 | 8.50 | 8.50 | 25.50 |
| **2:** | Travel Expenditure | 2.00 | 2.00 | 2.00 | 06.00 |
| **3:** | Meetings/Workshop | 1.50 | 1.50 | 1.50 | 04.50 |
| **4:** | Others (Hiring of services, field works, consumables, stationary, printing of reports & brochures, and sample analysis, etc.) | 3.00 | 5.00 | 5.00 | 13.00 |
| **5:** | Contingency | 2.00 | 2.00 | 1.00 | 5.00 |
| | **GRAND TOTAL** | **17.00** | **19.00** | **18.00** | **54.00** |

**9. Expected Deliverables**
- Thematic maps: DEM, soil and LULC, stream network maps
- Improved and bias free high resolution gridded precipitation and ET datasets
- Basin wise water availability estimates: Historical (BAU)
- Revised basin-wise water availability estimates: CC with no LU change
- Revised basin-wise water availability estimates: LU change with no CC
- Revised basin-wise water availability estimates: both CC and LU change
- Resilience and Non-resilience basins under changing climates
- Sub-basin wise project report for the state water resources department for planning

306

- Training on the modelling frameworks to the state officials of the water resources department and other Implementing Agencies of the NHP.

## 10. Advantages, Challenges and Limitations
- The proposed modelling frameworks/tools will be very useful for estimating the water yield potential for ungauged basins using satellite and open data sources including the datasets obtained from the field.
- All satellite data products have some level of uncertainty and error which will be effectively taken care of in this study for generating error free and bias corrected datasets for future use.
- The hydrological resilience analysis will be an effective criterion to understand the historical as well as future changes in the basin to ensure the sustainability of the water resources.
- The main challenge of this study is that the study basins are ungauged hence the dependability on the satellite datasets will be on the larger side. Therefore, the alternative hydrological calibration strategies can be accounted utilizing the relevant hydrological variables such as ET and soil moisture which can be measured/estimated in the absence of the observed discharge datasets.

## 11. Period of Project:
- Three years from the date of the start of the project

**Expected Outcome (Quantifiable Deliverables) of Key Activities with Timeline (Tentative):**

| Sl. No. | Expected Outcomes/Quantifiable Deliverables | 1st Year | | | | 2nd Year | | | | 3rd year | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| 1: | Hiring Manpower | ■ | ■ | | | | | | | | | | |
| | Data downloading and processing, and generation of data bases and maps; data collection from CWC, and state govt. departments | ■ | ■ | ■ | | | | | | | | | |
| 4: | Analyse long-term hydro-meteorological variables | | | ■ | ■ | ■ | | | | | | | |
| 5: | Hydrological Modelling: SWAT model Setup | | | ■ | ■ | ■ | | | | | | | |
| 6: | Hydrological Modelling: HEC-HMS model Setup | | | | | | | | | | | | |
| 7: | WA+ and Budyko Frameworks: | | | ■ | ■ | ■ | | | | | | | |
| 8: | Model's validation using satellite and observed (if available) datasets | | | | | ■ | ■ | ■ | ■ | | | | |
| 9: | Water potential of the west-flowing rivers | | | | | | | | ■ | ■ | ■ | | |
| 10: | Hydrological sensitivity and resilience capacity | | | | | | | | | | ■ | ■ | |
| 11: | Training on the hydrological models | | | | | | | | | | | ■ | ■ |
| 12: | Detailed basin wise project report for the state water resources department and Regional Conference with NHP | | | | | | | | | | | ■ | ■ |

# RESEARCH MANAGEMENT AND OUTREACH DIVISION

**Scientific Manpower**

| S N | Name | Designation |
|---|---|---|
| 1 | Dr. V. C. Goyal | Scientist G & Head |
| 2 | Er. Omkar Singh | Scientist G |
| 3 | Dr. A. R. Senthil Kumar | Scientist F |
| 4 | Dr. (Mrs.) Jyoti P. Patil | Scientist D (LCU) |
| 5 | Er. Digambar Singh | Scientist D |
| 6 | Sri. Rohit Sampatrao Sambare | Scientist B |
| 7 | Sri Rajesh Agrawal | SRA |
| 8 | Sri N. R. Allaka | RA |

## APPROVED WORK PROGRAM FOR THE YEAR 2021-22

| SN | Title of Project/Study | Funding | Study Team | Duration | Status |
|---|---|---|---|---|---|
| **Internal Study** | | | | | |
| 1 | Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand region | NIH | Jyoti Patil (PI) T Thomas (Co-PI), P K Mishra Rohit Sambare | Sep 2020- Feb 2023 | On-going |
| 2 | Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand) | NIH | Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade, N R Allaka; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun | Sep 2020- Aug 2023 | On-going |
| 3 | Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana | NIH | A R Senthil Kumar (PI) Omkar Singh (Co-PI) Rajesh Agarwal, N R Allaka Scientist from KVK/Agri Univ. | Sep 2020- Aug 2022 | On-going |
| **Sponsored Projects** | | | | | |
| 1 | Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact | DST-NMSHE | A R Senthil Kumar (PI) J. V. Tyagi, M. K. Goel, S. D. Khobragade, P. C. Nayak, Manohar Arora | Mar 2016-Sep 2021 | completed |
| 2 | Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS) | DST (GoI) | V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare, Project Team, HQ (IC-EcoWS) Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand | Apr 2019-Mar 2024 | On-going |

## Proposed Training/Webinar/Outreach Activities of RMOD (2021-22)

| S.N. | Outreach Activity | Tentative Date & Month | Place | Target Participants | Team |
|---|---|---|---|---|---|
| 1 | Recorded webinar on 'Water for Public Health (W4PH): Preparing for Disasters and Pandemics' (33 presentations from 35 speakers) | 26 August 2021 to 06 October 2021 | NIH Roorkee | Researchers, Professionals, Health workers, and NGOs | V.C. Goyal, J. P. Patil, Varun Goyal |
| 2 | Workshop/Webinar on rejuvenation of ponds and treatment of domestic wastewater through constructed wetlands | Sept. 2021 | NIH Roorkee | R&D Institutes/University/Govt. Organizations | NIH: Omkar Singh, V.C. Goyal, Rajesh Singh, Digambar Singh UKCEH: Laurence Carvalho & Elliot Hurst |
| 3 | Awareness Programme for School Children | July-Sep 2021 | 2 Schools in Roorkee/ Nearby Roorkee | School Children | Digambar Singh, Omkar Singh, Subhash Kichlu, Rajesh Agarwal, N R Allaka |

| 4 | 3-days training workshop on Eco-hydrology for Sustainable Development | 06-08 Oct 2021 | HRRC-NIH, Belgavi | Researchers, Professionals, Scholars | B Venkatesh, J P Patil, V C Goyal, Amrendra Bhushan |
|---|---|---|---|---|---|
| 5 | NIH-IWP joint state level workshop on 'Enhancing Capability to Address Climate Change in Integrated Water Resources Management (IWRM) in Uttarakhand State' | 07 Dec 2021 | NIH Roorkee | Officials from state departments, Researchers, NGOs | NIH: V.C. Goyal, J. P. Patil, Varun Goyal, Amrendra Bhushan IWP: Veena Khanduri, Aditi Tallu Kaul |

## Other Outreach Activities:

| S.N. | Activity |
|---|---|
| 1 | • Lecture on 'Why and how of patenting for Indian academicians and R&D Institutes', delivered by Ms Sangeeta Nagar, Scientist F, Patent Facilitating Centre, DST-TIFAC on 29-09-2021<br>• 'Guidebook on S&T interventions for ponds rejuvenation', Sponsored by DST, Government of India<br>• Brochure on 'Water for public health' released on 22nd March 2022 (World Water Day) |
| 2 | • Preparation of Short Video on Pond Rejuvenation & CW-NTS of Ibrahimur Masahi |
| 3 | • Coordination of 75 planned Activities at HQ & RCs under Azadi Ka Amrut Mahotsav @ India 75<br>• Organizing activities as per mandate of Division under Azadi Ka Amrut Mahotsav @ India 75 |
| 4 | • Any other Outreach activity on demand/assigned |

| SN | Title of Project/Study | Funding | Study Team | Duration | Status |
|----|------------------------|---------|-----------|----------|--------|
| **Internal Study** | | | | | |
| 1 | Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand region | NIH | Jyoti Patil (PI) T Thomas (Co-PI), P K Mishra Rohit Sambare | Sep 2020- Feb 2023 | On-going |
| 2 | Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand) | NIH | Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade, N R Allaka; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun | Sep 2020- Aug 2023 | On-going |
| 3 | Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana | NIH | A R Senthil Kumar (PI) Omkar Singh (Co-PI) Rajesh Agarwal, N R Allaka Scientist from KVK/Agri Univ. | Sep 2020- Aug 2022 | On-going |
| 4 | Development of Water Security Plan for Healthcare Facilities: A Pilot Study for Swami Rama Himalayan University (SRHU-HIHT), Jolly Grant, Dehradun | NIH | Omkar Singh (PI) V.C. Goyal, Rajesh Singh (Co-PI), Jyoti Patil, Rohit Sambare, N.R. Allaka; Team from SRHU-HIHT, Dehradun | April 2022- Mar 2024 | New Study |
| **Sponsored Projects** | | | | | |
| 1 | Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS) | DST (GoI) | V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare, Project Team, HQ (IC-EcoWS) Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand | Apr 2019-Mar 2024 | On-going |

## Proposed Training/Webinar/Outreach Activities of RMOD (2022-23)

| S.N. | Outreach Activity | Tentative Date & Month | Place | Target Participants | Team |
|------|-------------------|------------------------|-------|---------------------|------|
| 1 | Brainstorming session on 'Water Security in a Changing Environment-Focus on Indian Himalayan Region (IHR)', during 16th Uttarakhand Science and Tech | April 2022 | UCOST, Dehradun | Conference participants | V. C. Goyal, J P Patil, Amrendra Bhushan |
| 2 | 5-days training on 'Life Cycle Approach for Rejuvenation of Ponds and Lakes using Nature-Based | April 2022 May 2022 June 2022 July 2022 | Bhopal Belgaum Kakinada Roorkee | R&D Institutes/ University/ Govt. Organizations | Bhopal: T Thomas Belgavi: B Venkatesh Kakinada: YRS Rao Roorkee: J P Patil, Omkar |

| | | | | | Singh, Rohit Sambhare |
|---|---|---|---|---|---|
| 3 | Training on GEM | April 2022 | NIH Roorkee | Admn and finance staff of NIH | A. R. Senthil kumar Omkar Singh |
| 4 | Webinar on ecohydrological functioning of wetlands | April 2022 | NIH Roorkee | Students and researchers | Rohit Sambare V C Goyal |
| 5 | Stakeholders workshop for Upper Dhasan Basin water resources assessment | May 2022 | Bhopal | CWC, CGWB, State departments (Irrigation, WRD, Agril etc) | J P Patil, T Thomas, P K Mishra, Rohit Sambhare |
| 6 | Workshop/Webinar on rejuvenation of ponds and treatment of domestic wastewater through constructed wetlands | May/Jun 2022 | NIH Roorkee | R&D Institutes/University/Govt. Organizations | NIH: Omkar Singh, V.C. Goyal, Rajesh Singh, Digambar Singh UKCEH: Laurence Carvalho & Elliot Hurst |
| 7 | Five-day training program on "Hydrology of water bodies and their development under climatic uncertainty" | May/Jun 2022 | NIH Roorkee | Engineers in Irrigation/PHE/SWC departments | A. R. Senthil kumar, Rohit Sambare, Santosh M Pingale, N R Allaka |
| 8 | E-course on Urban hydrology | June 2022 | NIH, Roorkee NIUA, Delhi | Researchers, academicians, scholars | NIH: V C. Goyal, J. P. Patil NIUA: Victor Shinde |
| 9 | Awareness Programme for School Children | July-Sep 2022 | 3 Schools in Roorkee/ Nearby Roorkee | School Children | Digambar Singh, Omkar Singh, A. R. Senthil kumar, Rajesh Agarwal, N R Allaka |

## Other Outreach Activities:

| S.N. | Activity |
|---|---|
| 1 | • Preparation of Short Video on Pond Rejuvenation & CW-NTS of Ibrahimur Masahi<br>• River Walk of Solani River<br>• Short video on Hydrology for People @district level<br>• Short video on vulnerability assessment under Hydrology for People series |
| 2 | • Coordination of 75 planned Activities at HQ & RCs under Azadi Ka Amrut Mahotsav @ India 75<br>• Organizing activities as per mandate of Division under Azadi Ka Amrut Mahotsav @ India 75<br>• Compendium of NIH activities on the activities under Azadi Ka Amrut Mahotsav @ India 75 |
| 3 | • Any other Outreach activity on demand/assigned |

1. **Title of the Study:** Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand Region, Central India.

2. **Project team:**
   a. Project Investigator: Dr. Jyoti P. Patil
   b. Project Co-Investigator(s):

      Dr. T. Thomas (RC-Bhopal)

      Dr Prabhash K Mishra

      Er. Rohit Sambhare

3. **Type of Study:** Internal; **Budget**: 41.0 Lakhs

4. **Date of start:** 01.09.2020

5. **Scheduled date of completion:** 28.02.2023

6. **Duration of the Study:** 2.5 years (30 months)

7. **Study Objectives:**

   The major objective of the study is to assess the demand and availability of water in Upper Dhasan basin located in the drought prone Bundelkhand region in Central India, and to develop a plan for the optimal water allocation using WEAP model and WA+ framework. The following are the sub-objectives of the study:

   a. Estimation of water balance components of Upper Dhasan basin using WEAP and WA+ outputs.
   b. Estimation of water productivity and land productivity of Upper Dhasan Basin using WA+ framework.
   c. Vulnerability assessment of Upper Dhasan Basin using IPCC approach.
   d. Assessment of future water supply-demand scenario in the light of upcoming projects, inter-basin transfers and climate change.
   e. Development of water allocation plan for the optimal use of water resources in the study area.

8. **Statement of the Problem:**

   The Dhasan River is a major tributary of the Betwa river system which originates in Raisen district of Madhya Pradesh and flows through the various drought prone districts in Central India viz., Tikamgarh, Chhatarpur districts in MP and Lalitpur, Jhansi and Hamirpur districts in UP. It is one of the important rivers in Bundelkhand region which has off late become a drought prone region due to the various issues facing the region including the overexploitation of the natural resources and changes in the weather pattern. The frequency of occurrence of droughts is once in 4 years. The variability of rainfall is the main reason for the regular water stress. However, the limited groundwater availability in the hard rock region coupled with low water holding capacity soils further aggravate the water stress thereby creating livelihood issues for the local population.

   Due to the limitations of groundwater development in the basin, thrust is towards developing surface water resources in the region. Few projects have come up viz., Bansujara Multipurpose Project, the Banda Irrigation Project. The Bansujara Multipurpose Project has been completed, whereas the construction of the Banda Irrigation Project is in progress. The Banda Irrigation Project located in Banda block of Sagar district has a CCA of 80000 ha and involves providing micro-irrigation. Apart from this there is a proposal to transfer surplus water in Dhasan basin to the water deficit Bina River (Bina Complex Irrigation & Multipurpose Project) by constructing four dams for irrigating 84200 ha and generation of hydropower.

This study aims to have a holistic look into the overall water availability in the Dhasan basin, in the light of the committed storages of the planned projects and realistic assessment of the planned projects. The estimation of the water availability and water productivity using both the WEAP model and the Water Accounting+ framework in totality will help to understand the supply of available water along with the demands from various sectors in the drought prone region in Bundelkhand. The assessment of the reliability of these projects in the light of the climate change, based on scenario analysis for the estimation of the future water supply-demand and development of an optimal water allocation plan for the basin, shall provide a useful tool in the hands of the decision makers to fine-tune the water resources development and management policies accordingly. The State Government is interested in taking up such a project as this will provide them with an optimal water allocation plan in the present time as well as into the future. <u>The Chief Engineer, BODHI, MP Water Resources Department has given the consent in this regard</u>.

Very few studies related to the water resources have been carried out in Dhasan basin, viz., water balance (Thakural et al., 2009) and drought (Kar et al., 2016). The Water Evaluation and Planning System (WEAP) is one such tool which can be effectively used for devising optimum water allocation policies based on the appraisal of water management strategies at the basin scale. The model has the capability of carrying out scenario based analysis which will provide multiple options for the water resources managers and decision makers for taking effective decisions.

Increasing competition for land and water resources is expected in the coming future due to rising demands for food and bioenergy production, biodiversity conservation, and changing production conditions due to climate change. Growing competition for water in many sectors reduces its availability for irrigation. In this situation, land productivity and water productivity increment is the most efficient solution for meeting increasing food demand and climate variation. For communicating water resources related information and services obtained from consumptive use in a geographical domain to users, water accounting (WA) is the best process. WA+ is a modified and upgraded version of water accounting which has been developed by IWMI (Karmi et al., 2013) based on original initiatives taken by the Delft University of Technology (Bastiaanssen, 2009). Water accounting plus (WA+) is a framework designed to provide explicit spatial information on water depletion and the net withdrawal process from river basins. It provides the link between water balance, land use, and water use as well as management options to modify it by grouping land use classes with common management characteristics. The major landuse of Dhasan basin is agriculture. Therefore, land productivity and water productivity assessment using WA+ framework will be useful for making sound water management strategies in the Upper Dhasan basin.

The ever-growing population and a parallel increase in the demand for natural resources have left agricultural and water resources of the region susceptible to increasing climate change risks. Vulnerability assessment (VA) is, therefore, considered as a useful tool for planning of climate change adaptation and risk management strategies in water challenged areas. Assessing vulnerabilities is the process of identifying, quantifying, and prioritising the vulnerabilities in a system. Vulnerabilities from the perspective of climate change means assessing the threats from potential hazards to population, infrastructure, development goals etc. VAs can help to improve adaptation-planning, allocation of resources and raising awareness about climate change at different levels. The drought frequency has been increased in Bundelkhand region due to climate variability. Therefore, focus of this study will be on generating vulnerability index of Upper Dhasan basin, by IPCC approach, with main focus on indicators like annual rainfall, number of rainy days, number of dry days, flood frequency, drought frequency, variation in temperature (max, min) etc. The assessment would facilitate the identification of areas, which are vulnerable to climate change and need special attention towards adaptation.

The water availability needs to be assessed for multiple scenarios of new and upcoming water storage infrastructure, plans for out of the basin water transfers as well as the highly uncertain impacts of the climate change on the water availability scenario in the basin. This will provide as realistic assessment of the present and future water availability scenario in the basin based on optimal water allocation policies and plans can be devised. Such an integrated effort will go a long way in managing the available water resources in the present and future and managing the demands in tune with the availability and constraints. This will result in the development of WEAP and WA+ based water allocation plan for the optimal use of water resources in the study area, which will be useful to the line departments and stakeholders including the Agriculture Department (agriculture), Water Resources Department (better water distribution for irrigation by integrated operation of projects), Public Health Engineering Department (water supply for domestic use) and Industries that may be benefitted, ultimately leading to the development of the region resulting in improved livelihood options for the local population.

## 9.    Methodology

### Study area:

The study has been selected in Upper Dhasan basin upto Garrauli G/D site on Dhasan river falling in Chhatarpur district (Figure 1). The area of Upper Dhasan Basin is 3565 sq. km.
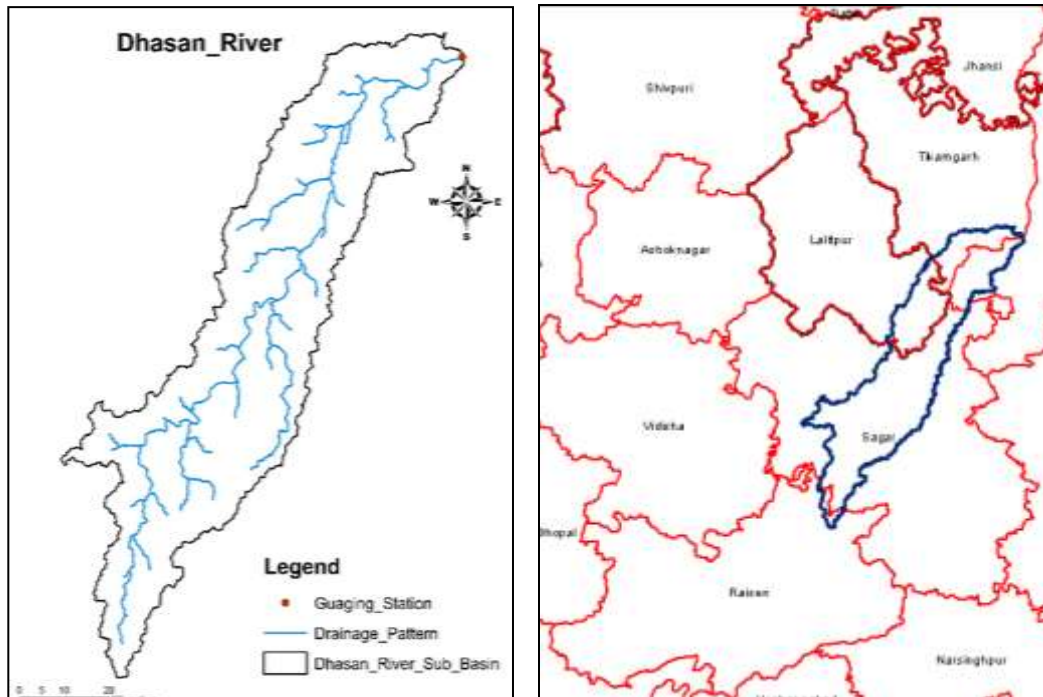


Figure 1 Location of study area (Upper Dhasan basin)

### Detailed Methodology:

1. Preparation of data inventory including climatic, hydrologic, demographic and socio-economic data.

2. Processing and analysis of data.

3. Trend analysis of meteorological and hydrological variables.

4. Customization, calibration and validation of WEAP model for runoff simulation.

5. Estimation of water productivity and land productivity using WA+ framework

6. Assessment of environmental flow requirement using established techniques and water balance and supply demand scenario using WEAP and WA+ outputs.

315

7. Vulnerability assessment using IPCC approach

8. Assessment of climate change on the future water availability.

9. Water allocation planning for the present and future under alternate scenarios of upcoming water resource infrastructure, population growth, inter-basin water transfer and climate change using WEAP.

10. Stakeholder workshop and Final Report.

**10. Approved Timeline**:

| Sr. No. | Work Component | 2020-21 | | | 2021-22 | | | | 2022-23 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | II | III | IV | I | II | III | IV | I | II | III |
| 1. | Preparation of data inventory including climatic, hydrologic, demographic and socio-economic data. | ▓ | ▓ | | | | | | | | |
| 2. | Processing and analysis of data. | ▓ | | | | | | | | | |
| 3. | Trend analysis of meteorological and hydrological variables. | ▓ | ▓ | ▓ | | | | | | | |
| 4. | Customization, calibration and validation of WEAP model for runoff simulation. | | ▓ | ▓ | ▓ | | | | | | |
| 5. | Estimation of water productivity and land productivity using WA+ framework | | ▓ | ▓ | ▓ | ▓ | | | | | |
| 6. | Assessment of environmental flow requirement using available techniques Assessment of water balance and supply demand scenario using WEAP and WA+ outputs | | ▓ | ▓ | ▓ | ▓ | ▓ | ▓ | | | |
| 7. | Vulnerability assessment | | | | ▓ | ▓ | | | | | |
| 8. | Assessment of climate change on the future water availability. | | | | | | ▓ | ▓ | ▓ | ▓ | ▓ |
| 9. | Water allocation planning for the present and future under alternate scenarios | | | | | | ▓ | ▓ | ▓ | ▓ | ▓ |
| 10. | Stakeholder interaction and Final report | | | | | | | | ▓ | ▓ | ▓ |

**11. Objective and achievement**

| Objective | Achievement |
|---|---|
| Data collection and analysis | Trend analysis of meteorological and hydrological variables is completed |
| Estimation of water balance components of Upper Dhasan basin using WEAP | WEAP model is formulated for complete Dhasan Basin and preliminary results were shared during last WG meeting |
| Estimation of water productivity and land productivity of Upper Dhasan Basin using WA+ framework | The WA+ is run for Betwa river basin. The results will be presented |
| Vulnerability assessment of Upper Dhasan Basin using IPCC approach | List of indicators is finalised. Vulnerability assessment is under progress |

**12. Recommendation / Suggestion:** NA

| Recommendation / Suggestion | Action taken |
|---|---|
| No specific comments | NA |

**13. Analysis & Results**

<u>**i. Collection of information and Hydro-meteorological Data**</u>

    a. The gauge and discharge data of Garaulli site, Madhya Pradesh was collected from Yamuna Basin Organization (YBO), Central Water Commission (CWC), Government of India from 1991-92 to 2019-20.

    b. The daily meteorological data [Rainfall, Temperature (maximum and minimum)] of 17 grid points have been collected from IMD, Pune for 50 years (1971-2020).

The details of hydro-meteorological, spatial, and agriculture data is given in the following table1.

**Table 1** Details of hydro-meteorological data

| Data | Details | Source |
|---|---|---|
| **Discharge data (Daily)** | 1991-92 to 2019-20 | CWC |
| **Rainfall (Daily)** | $0.25^o$ X $0.25^o$; 1971-2020 | IMD |
| **Temperature (Daily)** | $1^o$ X $1^o$; 1971-2019 | IMD |
| **Geospatial Maps** | Land use Land Cover (LULC) River and Water bodies Soil type | USGS earth explorer, NRSC |
| **Agriculture** | Major crops (kharif/ rabi), area under each crop, water requirements, irrigated area | Respective District Administrations, District Irrigation Plans (DIP) |
| **Demand data** | Population Livestock Industries | Census/ District Administration websites / District reports |
| **Supply information** | Water Supply, Groundwater source Tank capacity | IMD/ district authorities CGWB district reports Minor irrigation census |

<u>**ii. Spatial database**</u>

The spatial database of the basin such as Digital Elevation Map (DEM), LULC map, Drainage Network were created. The landuse of the basin is predominantly agriculture (58%). The area under each landuse is given in Table 2.
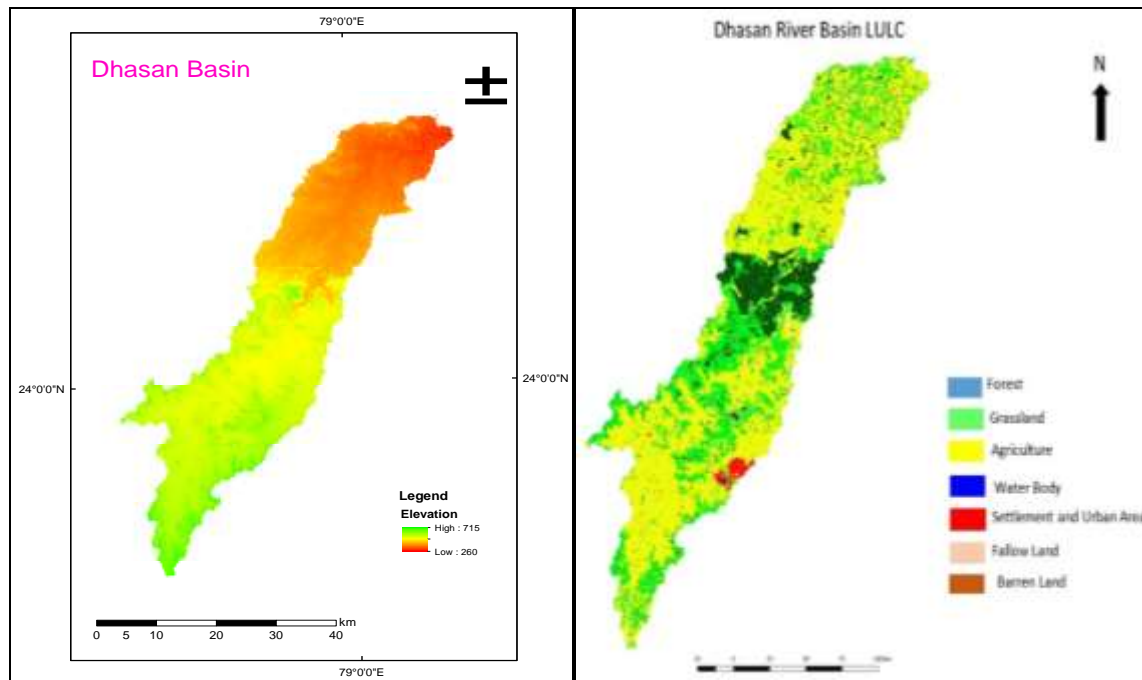
**Figure 2** DEM and LULC maps

**Table 2** Land use/land cover statistics of Dhasan river basi**n**

| Land use/cover categories | Area (km$^2$) | Percentage (%) |
|---|---|---|
| Agriculture Area | 1982.23 | 58 |
| Grassland | 959.58 | 28 |
| Forest Area | 304.91 | 9 |
| Barren land | 74.02 | 2 |
| Fallow land | 58.20 | 2 |
| Urban area | 29.41 | 1 |
| Water bodies | 18.04 | 1 |

### iii. Analysis of meteorological and hydrological variables

For modeling purpose, the basin is divided into two catchments. The sub-watershed 1 (SW1) is upto Banda Irrigation project and sub-watershed 2 (SW2) is downstream of the Banda irrigation project, upto the outlet of the basin. The Table-3 summarizes indices estimated for SW1 and SW2 alongwith their trend using Kendall-tau significance test.

**Table 3** Indices estimated for SW1 and SW2

| Index | SW1 | | SW2 | |
|---|---|---|---|---|
| | Value | Trend statistics | Value | Trend statistics |
| Mean Tmax ($^0$C) | 32.56 | 0.0226 | 32.52 | 0.0172 |
| Mean Tmin ($^0$C) | 18.43 | 0.0193 | 18.96 | 0.0161 |
| Mean Rainfall (mm/day) | 2.91 | -0.0044 | 2.78 | -0.0082 |
| No. of days RF>= 10mm | 28.96 | -0.0742 | 29.80 | -0.1205 |
| Max no. consecutive dry days (during Jun, Jul, Aug) | 15 | -0.1838 | 15 | -0.1021 |

| Max no. consecutive wet days (during Jun, Jul, Aug) | 8 | -0.0323 | 10 | -0.0249 |
|---|---|---|---|---|
| Greatest 3-day total rainfall (mm) | 183.72 | 0.3426 | 170.82 | -0.1295 |
| Greatest 5-day total rainfall (mm) | 219.28 | -0.2357 | 210.08 | -0.3429 |
| Greatest 10-day total rainfall (mm) | 301.61 | -0.5746 | 282.53 | -0.677 |
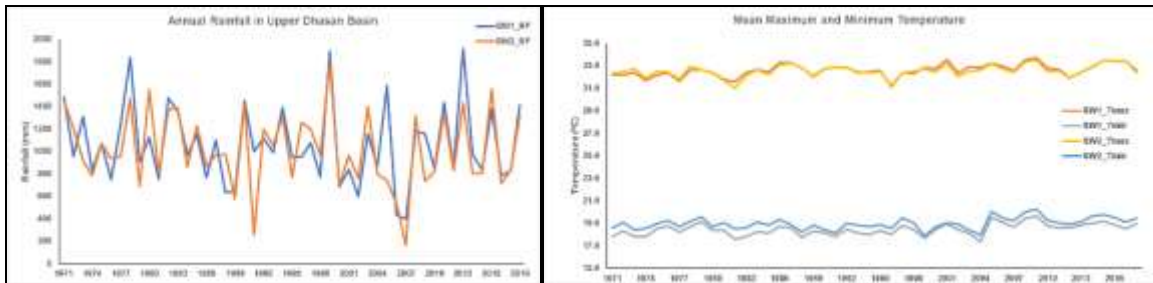


**Figure 3** Annual rainfall and mean temperature variation in basin

### iv. WEAP model formulation

The WEAP model for formulated for complete Upper Dhasan Basin for the current account year 2015 by considering demands (agriculture, forest, domestic, industrial), supply resources (rainfall, groundwater, river and major surface reservoirs). The scenarios like population growth, increased irrigation efficiency, industrial growth and incorporation of rainwater harvesting structures were run in the WEAP to observe the unmet demands of the basin during 2021-2050.
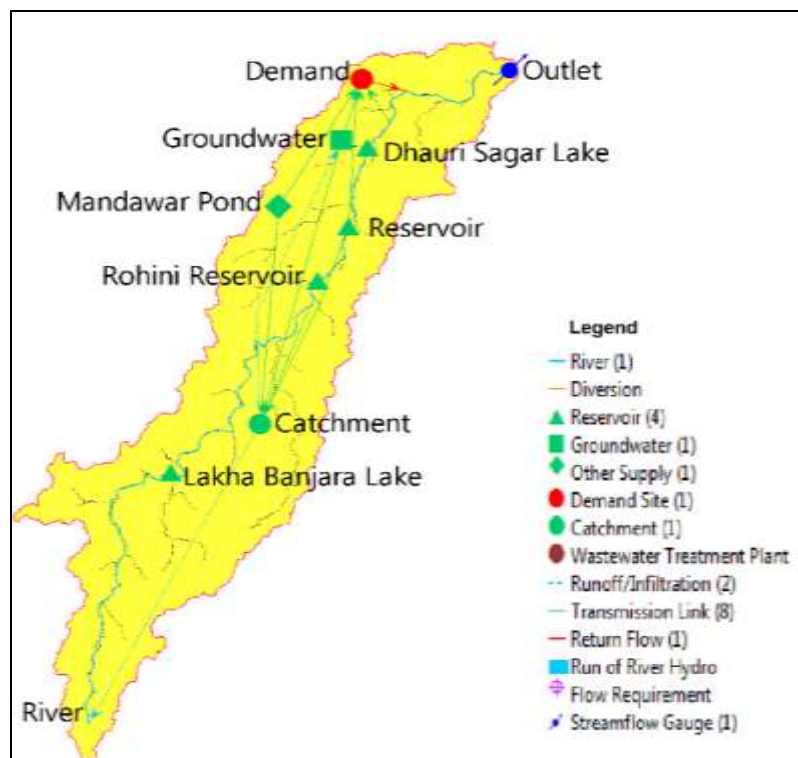


**Figure 5** WEAP model formulation for Dhasan Basin

For detail analysis of water balance components and impact of proposed dams in the basin, the WEAP model will be formulated for two sub-catchments.

## v. WA+ Framework

**Precipitation and Evapotranspiration Variability**

A preliminary analysis was carried out to understand the precipitation and evapotranspiration variability across the Betwa basin. Figures 6a shows the spatial variation of precipitation obtained from CHIRPS data (developed by the Climate Hazards Group InfraRed Precipitation with Stations) for the period of 2003-2014. It can be observed that the eastern and southern parts of the Betwa basin receives higher rainfall as compared to the rest part of the basin. Overall, the basin receives less rainfall with an annual average of 958 mm. In the contrary, the mean monthly ensemble ET is higher in the northern and central parts of the basin as shown in Figure 6b.
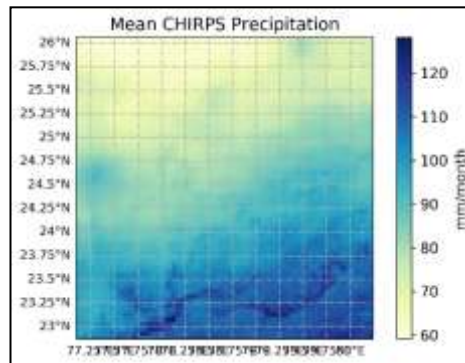


**Figure 6a Spatial variation of mean monthly CHIRPS precipitation**
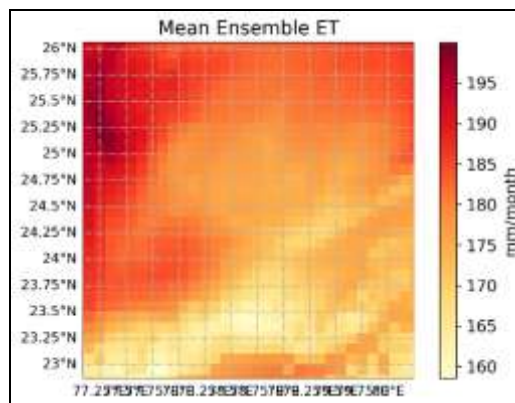


**Figure 6b: Spatial variation of mean monthly ensemble ET**

**WA+ based land use land cover (WALU)**

WA+ recognizes the influence of land use on water cycle and provides the link between water balance, land use and water use as well as management options to modify it, by grouping land use classes with common management characteristics. WA+ classifies LULC in to four major LULC classes segregated from 80 global land use classes based on the land use and water management practices as: (1) Protected Land Use (PLU); (2) Utilized Land Use (ULU); (3) Modified Land Use (MLU); and (4) Managed Water Use (MWU). PLU represents areas set aside for minimal disturbance by humans e.g. National Parks & Wildlife Sanctuaries, etc. ULU represents a land use that provides a range of ecosystem services and which has had little interference by man with less exploitation e.g., Grasslands, forest land, natural pastures, etc. MLU refers to land that is significantly modified by human activity. Here only the land use is modified e.g., Rainfed cropping systems, creation of plantation forests, etc. MWU represents the land use classes in which both the land use and water is managed with significant exploitation, e.g. Irrigated cropping systems. The WA+ based land use for the Betwa basin is shown in Figure 7. The land use distribution is presented in Table 4.

320

**Table 4:** Land use distribution for the Betwa basin generated using 8 different datasets

| LULC | Area (Km$^2$) | % area |
|---|---|---|
| Forest | 3828.25 | 10.62 |
| Grassland | 3756.81 | 10.42 |
| Waterbody | 1330.06 | 3.69 |
| Barren/waste | 2892.94 | 8.02 |
| Builtup | 6223.25 | 17.26 |
| Agriculture | 18018.44 | 49.98 |

Note: Distribution has been generated using 8 global datasets.


## Development of Evapotranspiration Sheet [Sheet 2]

Sheet 2 presents provides information on water consumption in a basin as a total value and per water sector (land use type). Major inputs for the generation of Sheet 2 are RS-based evapotranspiration maps (ET), Leaf Area Index (LAI), Net primary production (NPP), Gross primary production (GPP), daily precipitation and a LULC map. Developed Sheets for wet and dry year for the Betwa basin is shown in Figure 8a and Figure 3b, respectively. The total water consumptions of the basin for the wet year, i.e., 2013-14 is found to be 41.5 km$^3$/year with further partitioning of ET into evaporation (E) from soil and Transpiration from different LULC. The total water consumptions of the basin for the wet year, i.e., 2013-14 is found to be 25.8 km$^3$/year. Sheet 2 also shows that the non-beneficial consumptions in the basin indicating further scope for water conservation practices to be adopted in the basin to minimize non-beneficial consumptions.
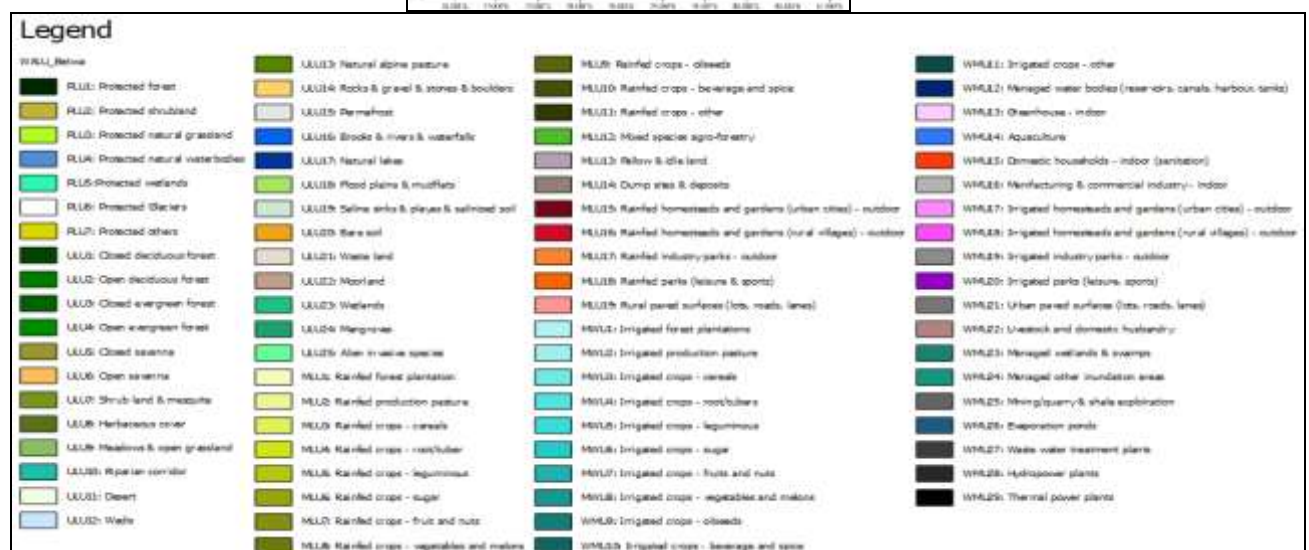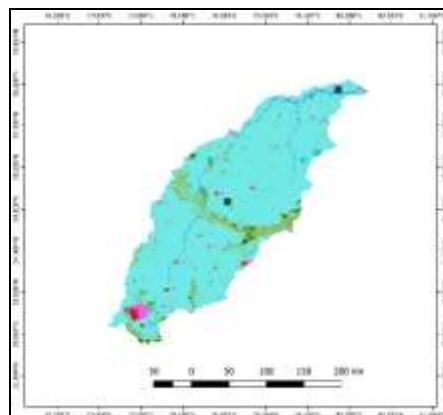


Figure 7: LULC map of Betwa basin generated using WALU
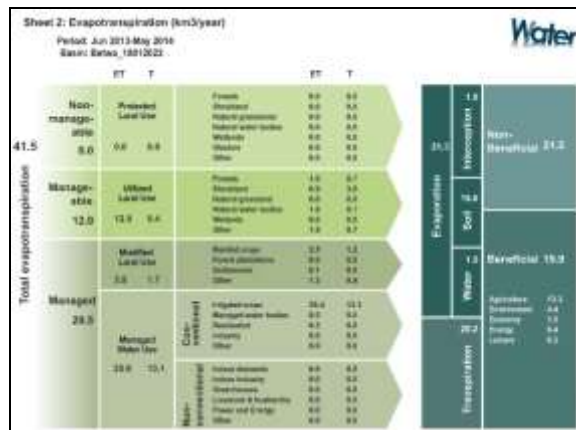
Figure 8a: Evapotranspiration Sheet: Sheet 2 for wet Year 2013-14.
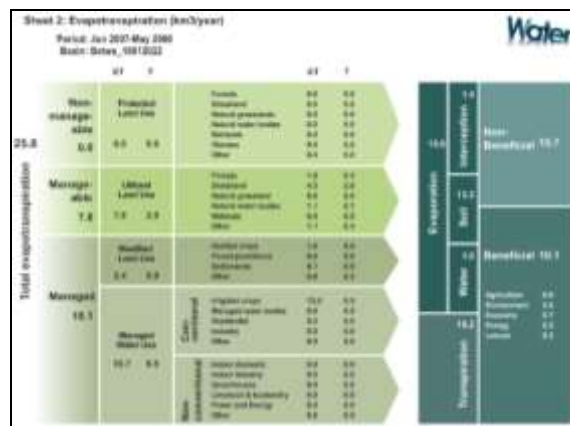


Figure 8b: Evapotranspiration Sheet: Sheet 2 for Dry Year 2007-08.

15. **End Users / Beneficiaries of the study:** Agriculture Department (agriculture), Water Resources Department (better water distribution for irrigation by integrated operation of projects), Public Health Engineering Department (water supply for domestic use) and Industries.

16. **Deliverables:** Development of Water Management Plan for Upper Dhasan Basin.

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:** Outputs of the study will be used in preparation of 'Integrated Water Management Plans at Sub-basin level and District level.

21. **Involvement of end users/beneficiaries:** Local stakeholders, District Administration of Sagar, Chhatarpur and Tikamgarh; Chief Engineer, Bodhi, Ken-Betwa Basin, WRD & Deputy Director, Agriculture of Sagar, Chhatarpur and Tikamgarh.

22. **Specific linkage with Institution and /or end users/beneficiaries:** Various line departments (KVKs, Irrigation, WRD, Agriculture, Industry).

23. **Shortcoming / Difficulties: NA**

24. **Future Plan:** Possible up-scaling to other water stressed regions/basins.

1. **Title of the study:** Establishing hydrological regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District)

2. **Study Group:**

   **Project Investigator:**
   Rohit Sambare, Scientist B, NIH, Roorkee

   **Co Project Investigators:**
   Dr. V.C. Goyal, Scientist G, NIH, Roorkee
   Dr. Suhas Khobragade, Scientist G, NIH, Roorkee
   Dr. Gajendra Singh, Scientist, USAC, Dehradun
   Sh. Nageswara Rao Allaka, RA, RMOD, NIH Roorkee
   Scientist from HESCO, Dehradun

3. **Nature of Study:** Interdisciplinary

4. **Date of start:** September 2020

5. **Expected date of completion:** August 2023

6. **Weather externally funded or not:** No

7. **Objectives:**

   - To study the hydrological regimes (e.g. water balance, water inflow-outflow, connectivity with aquifer and/or streams) and establish ecohydrological functions
   - To assess the impact of climate variability and anthropogenic activities (e.g. local Gujjar community)
   - To assess the floral diversity, invasion by invasive, temporal changes in the wasteland and establishing long term monitoring plots.
   - To support in developing the long term monitoring and management plan for conservation of Jhilmil Jheel wetland.

8. **Statement of the Problem:**

   Wetlands are facing country's ever increasing population and their economic aspirations and subsequent anthropogenic pressures. Monitoring and conservation of large wetlands such as all Ramsar sites are done regularly. But wetlands which is having relatively smaller area of influence get very little attention. There are many pristine wetlands which are needs to be monitored and should be kept from any external significant disturbances. As last inventory of wetlands in country was conducted in 2011, and it is very difficult to update all the information on regular basis. India's past forestry practices have often considered grasslands as "wastelands". The resultant plantation of exotics and other indigenous tree species in grasslands has converted several grassland habitats into woodland (Rahmani et al. 1988). The ruthless destruction of terai ecosystem for agriculture and human settlements has led to large-scale fragmentation, shrinkage, and degradation of these unique habitats. High resolution remote sensing coupling with field surveys plays important role in monitoring purpose. The regular monitoring (covering all seasons) of wetlands is very important to understand all the functions and ecological linkages of the concerned wetland. The lack of temporal and spatial extent (swath) of the satellite data can be also very problematic as wetlands are relatively very small water bodies. Wetlands are also susceptible to climate change impacts. Varying rainfall and rising temperature also affecting health of wetlands.

Jhilmil lake wetland is situated (78013'17.50" E; 29047'49" N, 240m msl) between the Haridwar–Najibabad Highway with the natural course of the Ganga to the south of it. It is surrounded by the Reserve Forest of the Chidiyapur Range. It is permanent freshwater lake spread over 148ha (WWF 2012). The catchment area of the wetland consists dry plain Sal forests and northern dry mixed deciduous forest. The temperature in summer season varies from 290C in March to 390C in May, however in winter season 6 to 100C. Annual average rainfall in the region is 1174mm with 84% precipitation occurring in monsoon season. Jhilmil lake is home of one of the most charismatic faunal species of Terai landscape Swamp Deer and also corridor for various animals of Rajaji Tiger Reserve as both shares common boundaries. It is a main source of water for animals in the surrounding forests. It also helps to stabilize micro-climate of area of the surrounding region.
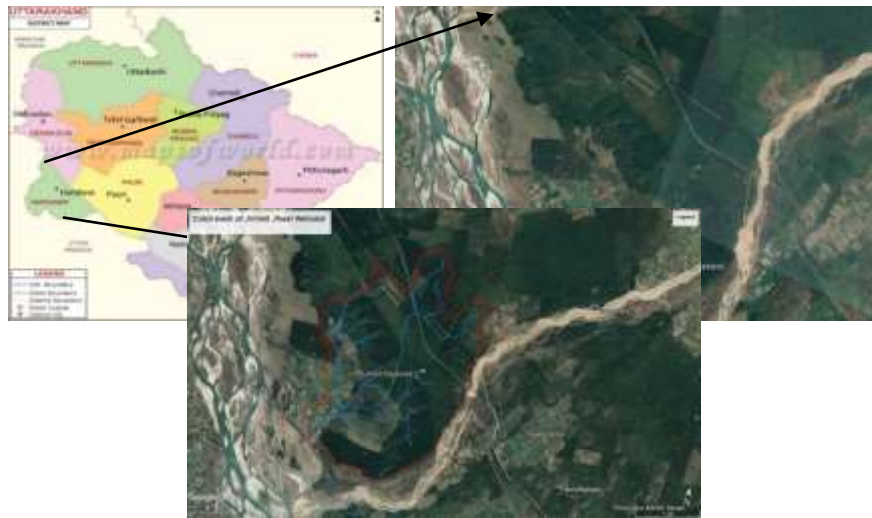


**Figure 1: Catchment of Jhilmil Jheel Wetland (Catchment derived from NRSC's high resolution CARTODEM)**

### 9.    Brief methodology:

- Mapping of the wetland will be carried out using high resolution satellite images and LULC will be generated by supervised classification. Also NDVI and NDWI maps will be generated for estimating vegetation distribution and hydroperiod of the wetland an its catchment. With the help of parameters derived from satellite images and high resolution DEM disturbance features such as crop plantation, reduction of water during various seasons, increasing tree or vegetation population in the wetland area shall be analysed. It can be vital for the deciding future conservation strategies. HGM functional assessment methods will be adopted to analyse the health score of wetland.

- SWIM (Soil and Water Integrated Model) is a semi distributed ecohydrological model, integrating hydrological processes, vegetation growth (agricultural crops and natural vegetation), nutrient cycling (nitrogen, N and phosphorus, P), and sediment transport at the river basin scale with the daily time step. SWIM will be set up for estimating ecohydrological functions of the wetland's catchment such as lateral water flows in the catchment, vegetation growth, sediment transport at desired time scales. The outputs of the model may be used in the deriving water balance of the wetland's catchment.

- Seasonal sampling of the water from the wetland, River Ganga, its two adjoining tributaries and groundwater will be done for the stable isotope analysis. Temporal hydrologic connectivity will be established between all waterbodies through laboratory analysis. Seasonal water table variations in the catchment will be analysed hence the contribution of the wetland to groundwater or vice versa can be quantified. Water quality analysis including anion, cation analysis; heavy metal analysis will be done. The graph theory will be attempted for establishing connectivity between various ecological and hydrological components of the wetland.

- RAWES (Rapid Assessment of Wetland Ecosystem Services) tool will be used to assess the wetland's ecosystem services through community surveys. Various wetland's health indicators will be developed such as Change in wetland area, Change in land cover, Wetland Stress Index, Productivity of the wetland, Hydroperiod. Floral diversity and Invasive species assessment will be done by detailed floral inventorisation (list) for various seasons from the wetland, its upstream and downstream. Lon term monitoring plots will be established for regular monitoring of the grassland and invasive species. Wetland monitoring and management plan will be generated for its conservation keeping all the aspects such as spatial extent, catchment characteristics, hydrology, biodiversity and ecosystem services of the wetland. The plan will be conveyed to state forest department and state wetland authority.

## 10.    Timeline

| Sr. No. | Work Component | FY 2020-21 | | | | FY 2021-22 | | | | FY 2022-23 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th | 1st | 2nd | 3rd | 4th |
| 1 | Hiring of project staff, identification and procurement of equipment | ■ | ■ | ■ | ■ | | | | | | | | |
| 2 | Collection of data from various sources | ■ | ■ | ■ | ■ | | | | | | | | |
| 3 | Field data collection | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| 4 | Satellite data preparation (LULC and soil data testing) | ■ | ■ | ■ | ■ | | | | | | | | |
| 5 | Finding effect of disturbance features | | ■ | ■ | ■ | | | | | | | | |
| 6 | Setting up of SWIM model and its calibration and validation. | | | ■ | ■ | ■ | ■ | ■ | ■ | | | | |
| 7 | Water sample collection from wetland and Ganga river and testing them stable isotope laboratory and water quality analysis | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | | |
| 8 | Water balance study of catchment | | | | | | | | | ■ | ■ | ■ | |
| 9 | Inventorisation of plant's diversity | | | | | ■ | ■ | ■ | ■ | | ■ | ■ | |
| 10 | Preparation of detailed vegetation map and habitat assessment (field sapling) | | | | | ■ | ■ | ■ | ■ | | ■ | | |
| 11 | Establishing long term plots and monitoring | | | | | ■ | ■ | ■ | ■ | | ■ | ■ | |
| 12 | Preparation of conservation | | | | | | | ■ | ■ | ■ | ■ | | |

| | | | | | |
|---|---|---|---|---|---|
| | strategies | | | | |
| 13 | Preparation of wetland management plan | | | | |
| 14 | Report writing | | | | |
| 15 | National workshop | | | | |

## 11. Achievements

- Several field tours have been done, sites for sample collection and water table measurement has been done.
- Collection of isotope samples for estimating the connectivity and water level measurement for post monsoon period has been done.

| Sample Code | Source | $\delta^{18}O$ (Oct 2020) | $\delta D$ (Oct 2020) | $\delta^{18}O$ (Jan 2021) | $\delta D$ (Jan 2021) |
|---|---|---|---|---|---|
| JJ-1 | Hand Pump | -7.69 | -50.14 | -7.79 | -52.20 |
| JJ-2 | Open well | -4.42 | -24.57 | --- | ---- |
| JJ-3 | Tube well | -7.79 | -50.28 | -7.85 | -48.83 |
| JJ-4 | Artesian Well | -7.21 | -47.01 | -6.99 | -47.01 |
| JJ-5 | Artesian Well | -7.11 | -47.29 | -7.12 | -46.35 |
| JJ-8 | Wetland stream | -7.84 | -50.35 | -7.92 | -54.23 |
| JJ-9 | Hand pump | -7.73 | -49.84 | -7.96 | -53.73 |
| JJ-10 | Hand pump | -7.46 | -47.61 | -7.56 | -48.03 |
| JJ-11 | Hand pump | -8.95 | -59.10 | -9.04 | -59.80 |
| JJ-13 | Hand pump | -7.61 | -49.52 | -7.21 | -48.40 |
| JJ-15 | River | -11.07 | -69.77 | -10.68 | -68.35 |
| JJ-16 | River | -7.17 | -46.60 | -9.96 | -60.05 |
| JJ-17 | Hand pump | -6.95 | -43.88 | -6.81 | -43.09 |
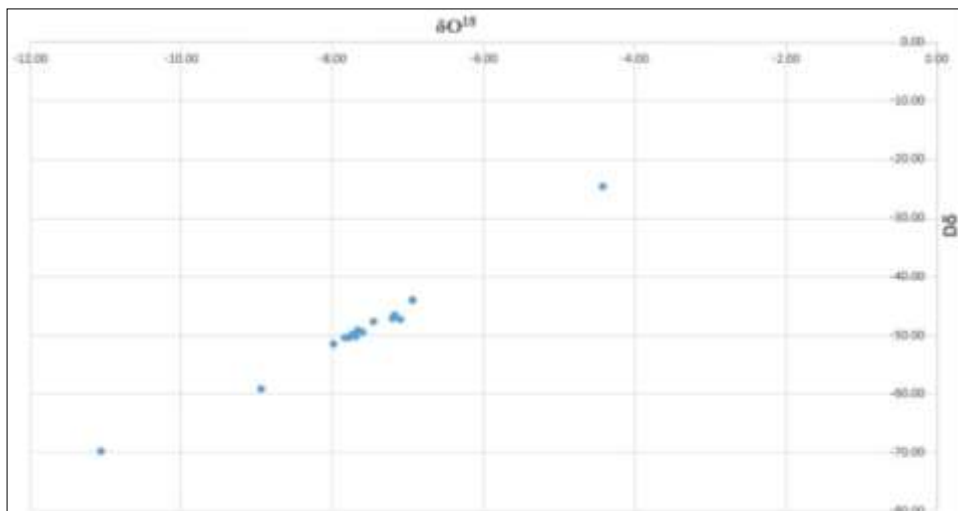


**Figure 2: Isotopic composition of collected water samples from different sources (Oct 2020)**

326
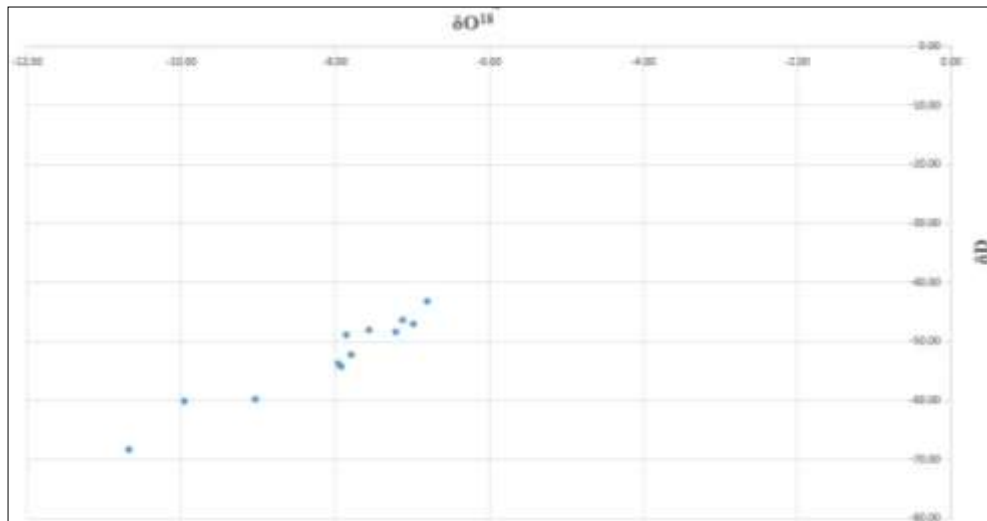
**Figure 3: Isotopic composition of collected water samples from different sources (Jan 2021)**

- Collection of water quality samples for post monsoon period has been done. Cation and anion analysis has been performed.
- High resolution Carto DEM and High Resolution Cartosat 3 image has been has been procured from NRSC Hyderabad.
- Available data from the forest department's Automatic Weather Station (AWS) has been collected.
- Analysis of season wise variations in the vegetation features and water availability has been done using satellite images of different years.
- HGM approach has been performed for the functional assessment of the wetland using field data and remote sensing products. Effects of the various disturbance features have been analysed through this approach and health of wetland has been determined. Wetland health index has been generated. Future projection of health of wetland has also been analysed with this approach.
- The study has been interrupted since last working group because, project investigator Rohit Sambare had been on the leave since September 2021 due to his health reasons. As he joined office after his recovery, this study will be continued in coming months and further achievements will be presented in next working group agenda.

1. **Title of the Study:** Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana

2. **Study group:**
   Dr  A. R. Senthil kumar, Sc "F" RMOD
   Sh. Omkar Singh,  Sc "F", RMOD
   Sh. Rajesh Agarwal,  SRA, RMOD
   Sh. Nageswara Rao Allaka, RA, RMOD

3. **Date of start: September 2020**

4. **Duration of the study: 2 Years**

5. **Whether externally funded or not: Internal**

6. **Objectives:**
   a. To evaluate the existing cropping pattern and farming practices for estimation of farmer's income

   b.  To carry out scenario analysis considering combinations of crop types and cropping pattern, land allocation, water allocation under climatic variability, etc.

   c. To develop plan for optimized income from farming practices encompassing food and water security.

7. **Statement of the problem**
   The rising population and industrial growth with climate change makes difficult to meet the demand of agricultural activities. Continuous over exploitation of ground water under uncertain occurrence of rainfall is inevitable to continue the traditional cropping pattern. Traditional cropping pattern is neither good for soil health nor for food security. Farmer's income is often below optimal. Scientific planning considering cropped area, climate smart crop types, crop productivity, cropping pattern, farming input costs, and crop revenues, will evolve optimal utilization of available water and optimize farmer's income from farming practices. Scenario analysis with projected population growth, landuse changes, climatic conditions, water-efficient irrigation technologies, etc. shall provide a canvas of options to be considered for optimal income from farming practices in future. A scientific plan is needed to guide the farming community about optimizing their income from farming practices that lead to food and water security.

8. **Methodology**
   The optimal income from agricultural for various scenarios of crop types and land resources in Mewat region, Haryana is evolved by setting up of WEAP tool with the combination of LINGO.  The inputs to WEAP tool such as water demand from various sectors, priority of the demand, catchment details, hydrologic conditions and inflows, catchment hydrology (river flow, ground water, lakes/reservoir/storage tanks, springs, other storage structures etc), supply preference (operating rules/policy), return flows, minimum flow requirements, economic variables such as cost water transmission etc are prepared from the data obtained from various sources such as irrigation department, IMD, CWC and census department.  The future climatic scenarios will be downscaled from GCM models for RCP4.5 and RCP8.5. The hydrological processes occurring in the catchment will be modeled and will be compared with the measured discharge time series. After the proper calibration of the model, the demand sites will be added into a model framework and different scenarios will be generated to assess the gaps in the water demand and supply and water availability at different locations and at the different period of time.  The optimum income for agricultural sector will be arrived by LINGO using the input variables obtained from the scenario analysis of WEAP model for crop types and land resources. The optimization functions such as maximizing the net income from agriculture, minimizing the water usage, minimizing the cost of cultivation with the constraints of land area for crops, water availability based on the scenario analysis and cost of cultivation are considered for achieving the

objectives. The scenarios such as change of cropping pattern (crop diversity) considering food security, change of cropping area with allowable limits, availability of water (normal, dry, very, wet and very wet), industrial and population growth and climate scenarios RCP4.5 and RCP8.5 from GCM models

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

Three blocks, Nuh, Nagina and Punhana of Mewat District have been selected for the setup of WEAP model based on the drainage network created from the toposheets of Survey of India. The Schematic diagram of WEAP model is given in Fig. 1. The total area of three blocks is 957.78 Sq.km. The total population by the end of 2020 is 7,71,093 (Urban- 80101 and rural - 69)based on the 2011 census and the population projection of Haryana State by National Commission on Population. The gridded data of rainfall, maximum and minimum temperature have been obtained from IMD. The evapotranspiration has been estimated by Hargreaves method using the average maximum and minimum temperature and extra terrestrial radiation obtained from https://www.engr.scu.edu/~emaurer/tools/calc_solar_cgi.pl and is given in Fig. 2
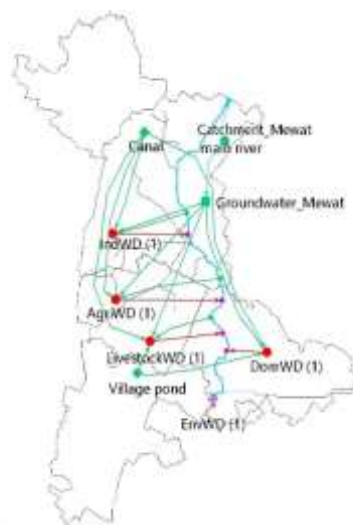


**Fig 1 Schematic diagram of WEAP model for Mewat (Nuh, Punhana, Nagina)**
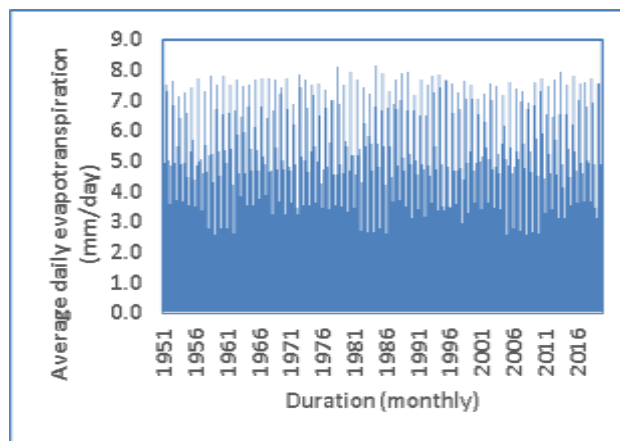


**Fig 2 Evapotranspiration by Hargreaves equation**

The study team visited district head Quarter Nuh, Agriculture department and Animal Husbandry and Dairying Department on 24.09.2021 and collected crop and livestock details and given as follows:

**Table 1. Crop area and water requirement for Kharif season**

| Crop | Area (ha) | Crop water requirement (mm) | Crop water requirement (m³/ha) |
|---|---|---|---|
| Sorghum | 4843 | 300 | 3000 |
| Millet | 18639 | 150 | 1500 |
| Cotton | 4900 | 420 | 4200 |
| Paddy | 7994 | 1200 | 12000 |
| Fodder | 19614 | 225 | 2250 |
| Sugar cane | 310 | 1500 | 15000 |
| Legumes | 49 | 200 | 2000 |
| Vegetables | 170 | 400 | 4000 |
| Garden mango | 38 | 1000 | 10000 |
| oil seed | 52 | 300 | 3000 |

**Table 2. Crop area and water requirement for Rabi season**

| Crop | Area (ha) | Crop water requirement (mm) | Crop water requirement (m3/ha) |
|---|---|---|---|
| Wheat | 56152 | 400 | 4000 |
| Mustard | 11846 | 240 | 2400 |
| Barley | 252 | 300 | 3000 |
| Chick pea | 314 | 150 | 1500 |
| Lentil | 439 | 200 | 2000 |
| Tomato | 489 | 500 | 5000 |
| Vegetables | 531 | 400 | 4000 |
| Barseem Fodder | 98 | 900 | 9000 |
| Garden mango | 17 | 1000 | 10000 |
| Sugar cane | 5 | 1500 | 15000 |
| Nursery | 15 | 1000 | 10000 |

**Table 3. Livestock population for Nuh, Nagina and Punhana blocks**

| SL No. | Block Name | Buffalo | Cattle | Goat | Rabbit | Sheep | Horses | Mules | Ponies | Pigs | Dogs | Camels | Donkey | Poultry |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Nuh | 47255 | 13704 | 9409 | 1920 | 2369 | 80 | 13 | 4 | 611 | 158 | 1 | 1 | 0 |
| 5 | Nagina | 11522 | 1152 | 1714 | 6 | 214 | 7 | 0 | 0 | 0 | 26 | 67 | 5 | 0 |
| 6 | Punhana | 54028 | 3727 | 6067 | 30 | 1191 | 15 | 7 | 0 | 107 | 53 | 6 | 1 | 0 |

The monthly water consumption urban (135 lpd) and rural (70 lpd) population and livestock palpation are given as follows:

**Table 4 Monthly water consumption for rural and urban population (m³)**

| Month | Urban | Rural |
|---|---|---|
| Jan | 4.185 | 2.17 |
| Feb | 3.915 | 2.03 |
| Mar | 4.185 | 2.17 |
| Apr | 4.05 | 2.1 |
| May | 4.185 | 2.17 |
| Jun | 4.05 | 2.1 |
| Jul | 4.185 | 2.17 |

| | | |
|---|---|---|
| Aug | 4.185 | 2.17 |
| Sep | 4.05 | 2.1 |
| Oct | 4.185 | 2.17 |
| Nov | 4.05 | 2.1 |
| Dec | 4.185 | 2.17 |

**Table 5 Monthly water consumption for livestock (m$^3$)**

| Month | Buffalo/ cattle | Goat | Rabbit | Sheep | Pig | Dog | Horse family | Camel |
|---|---|---|---|---|---|---|---|---|
| Jan | 2.635 | 0.31 | 0.0465 | 0.31 | 0.465 | 0.0372 | 1.24 | 2.325 |
| Feb | 2.465 | 0.29 | 0.0435 | 0.29 | 0.435 | 0.0348 | 1.16 | 2.175 |
| Mar | 2.635 | 0.31 | 0.0465 | 0.31 | 0.465 | 0.0372 | 1.24 | 2.325 |
| Apr | 2.55 | 0.3 | 0.045 | 0.3 | 0.45 | 0.036 | 1.2 | 2.25 |
| May | 2.635 | 0.31 | 0.0465 | 0.31 | 0.465 | 0.0372 | 1.24 | 2.325 |
| Jun | 2.55 | 0.3 | 0.045 | 0.3 | 0.45 | 0.036 | 1.2 | 2.25 |
| Jul | 2.635 | 0.31 | 0.0465 | 0.31 | 0.465 | 0.0372 | 1.24 | 2.325 |
| Aug | 2.635 | 0.31 | 0.0465 | 0.31 | 0.465 | 0.0372 | 1.24 | 2.325 |
| Sep | 2.55 | 0.3 | 0.045 | 0.3 | 0.45 | 0.036 | 1.2 | 2.25 |
| Oct | 2.635 | 0.31 | 0.0465 | 0.31 | 0.465 | 0.0372 | 1.24 | 2.325 |
| Nov | 2.55 | 0.3 | 0.045 | 0.3 | 0.45 | 0.036 | 1.2 | 2.25 |
| Dec | 2.635 | 0.31 | 0.0465 | 0.31 | 0.465 | 0.0372 | 1.24 | 2.325 |

The percentage share of landuse for agricultural land, forest land, settlement, fallow land and water bodies are 74, 8, 12, 5 and 1 respectively. The monthly crop coefficient (Kc) for different landuses and crops (FAO) and the effective precipitation for evapotranspiration are given as follows:

**Table 6 Monthly crop coefficient for Kharif and Rabi crops**

| Landuse | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agricultural Land | 0.98 | 0.41 | 0.25 | 0.36 | 0.35 | 0.79 | 0.51 | 1.09 | 1.00 | 0.53 | 0.77 | 1.12 |
| Forest land | 0.75 | 0.75 | 0.75 | 0.75 | 0.95 | 0.95 | 0.95 | 0.95 | 0.95 | 0.85 | 0.85 | 0.85 |
| Settlement | 0.08 | 0.08 | 0.08 | 0.08 | 0.12 | 0.12 | 0.12 | 0.12 | 0.12 | 0.09 | 0.09 | 0.09 |
| Fallow land | 0.15 | 0.15 | 0.15 | 0.15 | 0.19 | 0.19 | 0.19 | 0.19 | 0.19 | 0.17 | 0.17 | 0.17 |
| Water bodies | 0.90 | 0.90 | 0.90 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.00 | 1.00 | 1.00 |

**Table 7 Monthly crop coefficient for Kharif and Rabi crops**

| Crop | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sorghum (Jwar) | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 1.1 | 1 | 0.55 | 0 | 0 |
| Millet | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 1 | 1 | 0.3 | 0 | 0 |
| Cotton | 0.5 | 0 | 0 | 0.35 | 0.35 | 0.35 | 1.2 | 1.15 | 1.15 | 1.15 | 0.7 | 0.7 |
| Paddy | 0 | 0 | 0 | 0 | 0 | 1.05 | 1.2 | 1.2 | 0.9 | 0.9 | 0 | 0 |
| Fodder (Sorghum) | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 1.1 | 1 | 0.55 | 0 | 0 |
| Sugar cane | 0.75 | 0.55 | 0.4 | 0.4 | 0.4 | 1.25 | 1.3 | 1.25 | 1.25 | 0.75 | 0.75 | 0.75 |
| Vegetables (Brinjal)_kh | 0 | 0 | 0 | 0 | 0 | 0.6 | 1.1 | 1.05 | 1.05 | 0.8 | 0 | 0 |
| Wheat | 1.15 | 0.4 | 0.25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.7 | 1.15 |
| Mustard | 0.35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.35 | 1.15 | 1.15 |
| Barley | 1.15 | 1.15 | 0.4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.3 | 1.15 |

| Crop | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chickpea (Chana) | 1 | 0.35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 1 | 1 |
| Lentil (Masoor) | 1.1 | 1.1 | 0.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.4 | 1.1 |
| Tomato | 0.9 | 0.7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.6 | 1.15 | 1.15 |
| Vegetables (Cauliflower)_Rb | 0.95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.7 | 1.05 | 1.05 |
| Berseem Fodder | 0.9 | 0.9 | 0.85 | 0.85 | 0 | 0 | 0 | 0 | 0 | 0.4 | 0.4 | 0.9 |

**Table 8 Effective precipitation for evapotranspiration**

| Landuse | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agricultural land | 60 | 60 | 60 | 50 | 50 | 70 | 70 | 70 | 70 | 60 | 60 | 60 |
| Forest land | 65 | 65 | 65 | 60 | 60 | 80 | 80 | 80 | 80 | 65 | 65 | 65 |
| Settlement | 50 | 50 | 50 | 40 | 40 | 65 | 65 | 65 | 65 | 45 | 45 | 45 |
| Fallow land | 60 | 60 | 60 | 50 | 50 | 70 | 70 | 70 | 70 | 55 | 55 | 55 |
| water bodies | 18 | 18 | 18 | 15 | 15 | 25 | 25 | 25 | 25 | 20 | 20 | 20 |

The yield and market price for Kharif and Rabi crops are given as follows:

**Table 9 Yield and market price for Kahrif crop**

| Sl.no | Crop | Yield (kg/ha) | Market Price (Rs/quintal) for 2020-21 |
|---|---|---|---|
| 1 | Sorghum (Jwar) | 1890 | 2640 |
| 2 | Millet (Bajra) | 2592 | 2150 |
| 3 | Cotton | 574 | 5515 |
| 4 | Paddy | 2337 | 1868 |
| 5 | Fodder (sorghum) | 35,000 | 500 |
| 6 | Sugar Cane | 70,000 | 362 |
| 7 | Vegetable (Brinjal) | 24700 | 2000 |

**Table 10 Yield and market price for Kahrif crop**

| Sl. No. | Crop | Yield (kg/ha) | Market Price (Rs/quintal) for 2020-21 |
|---|---|---|---|
| 1 | Wheat | 3903 | 1975 |
| 2 | Mustard | 2141 | 4650 |
| 3 | Barley | 3085 | 1600 |
| 4 | Chickpea (chana) | 1666 | 5100 |
| 5 | Lentil (Masoor) | 1,800 | 5100 |
| 6 | Tomato | 21,500 | 750 |
| 7 | Vegetable (cauliflower) | 16300 | 1300 |
| 8 | Berseem Fodder | 75000 | 500 |

Initial run has been carried in WEAP model with above mentioned inputs and some of the results are given as follows:

**Fig 3. Monthly Inflows to area from 2020 to 2030**
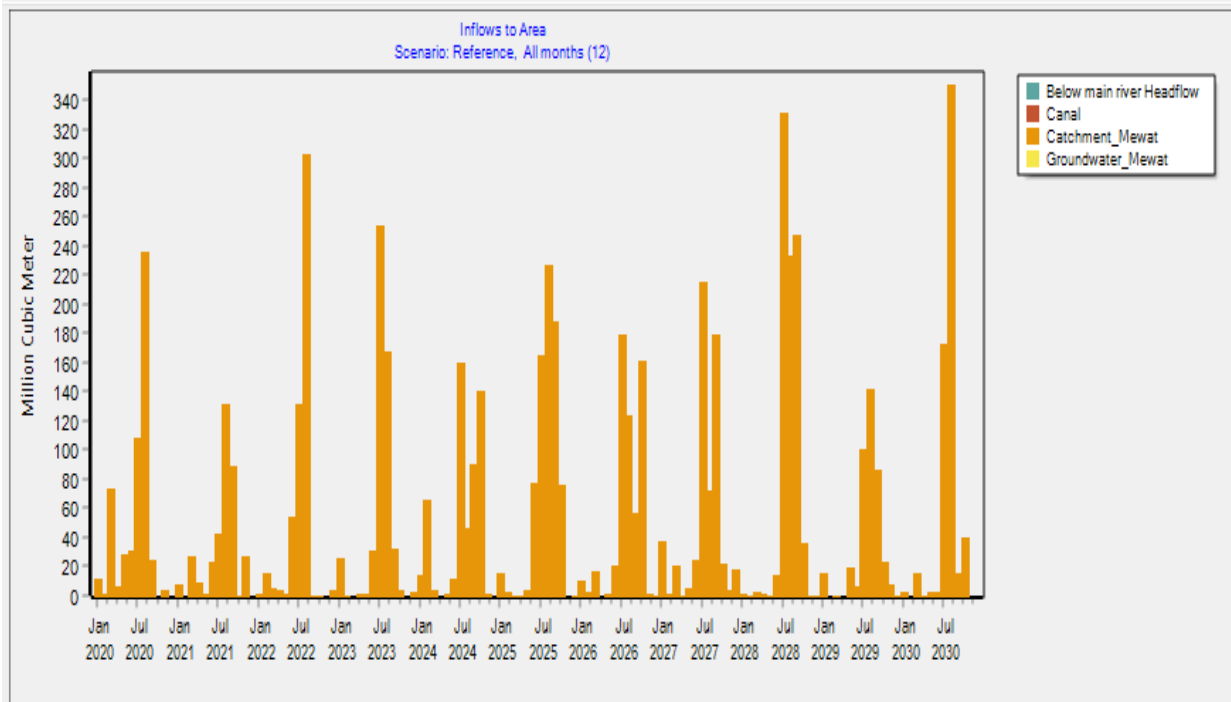


**Fig 4. Monthly ground water storage from 2020 to 2030**
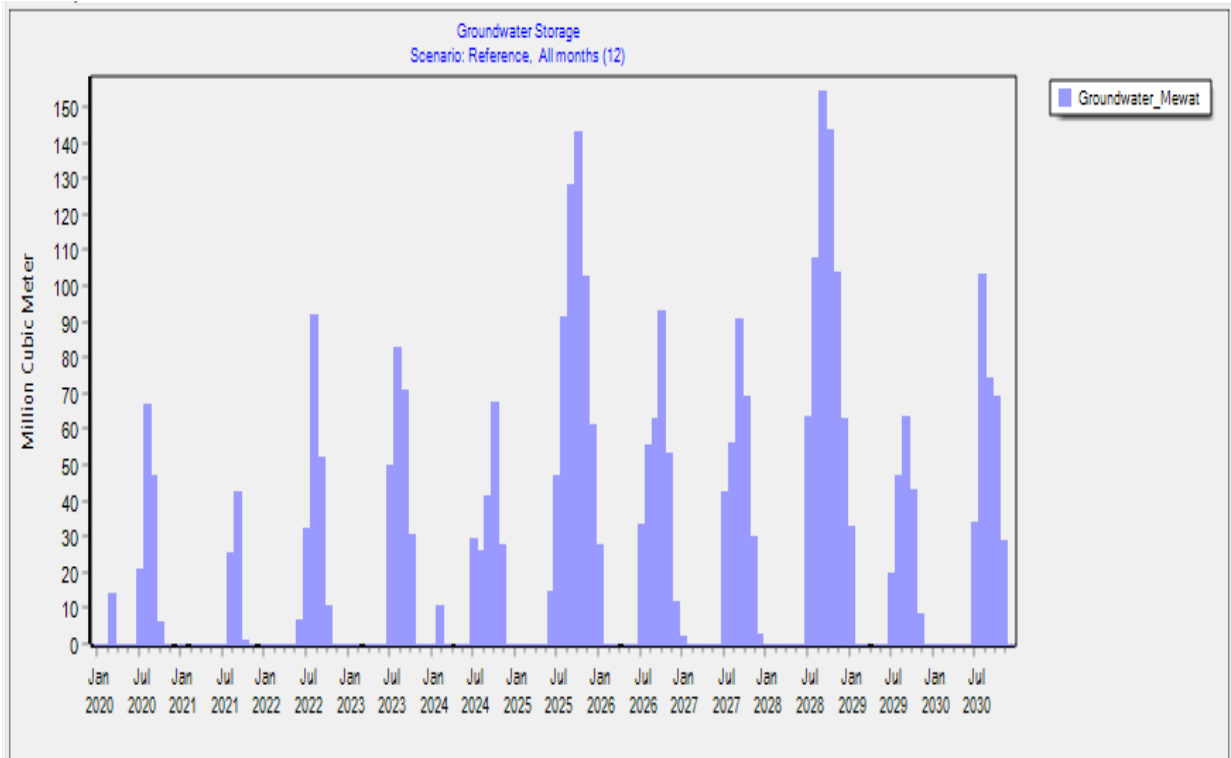
**Fig 4. Monthly unmet demand from 2020 to 2030**
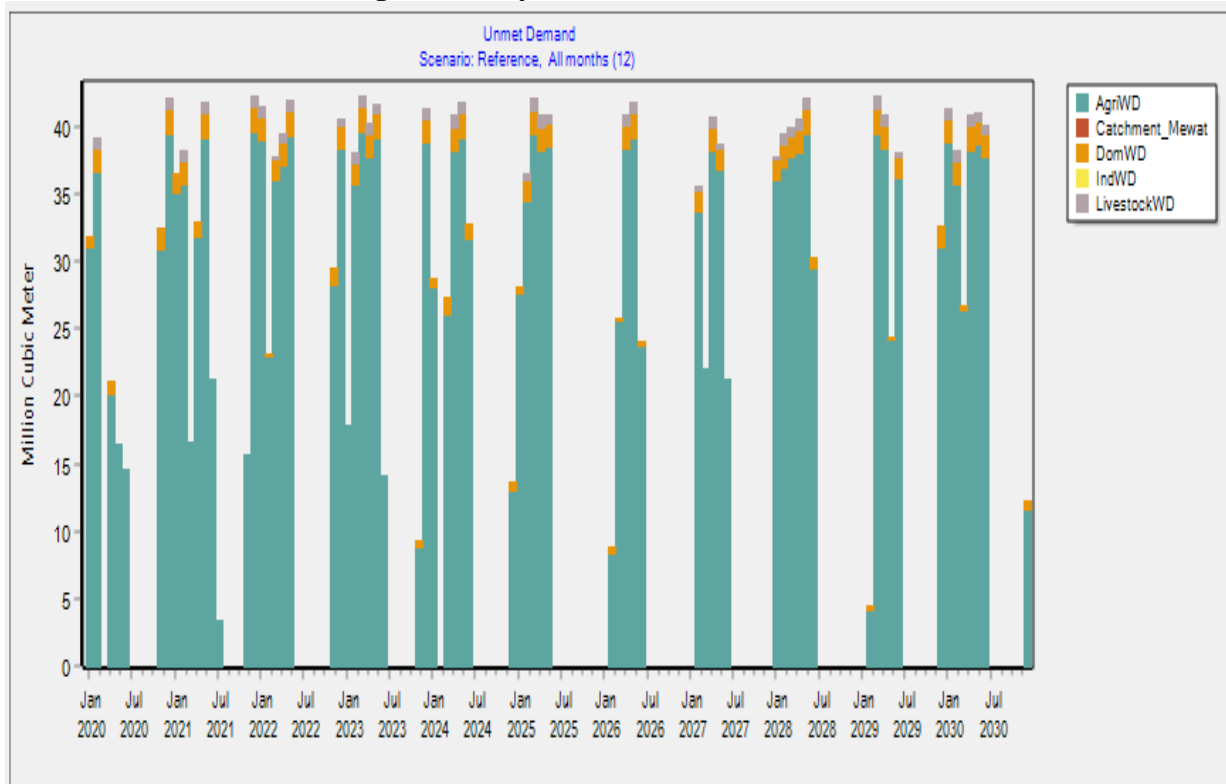


The cost of cultivation for major Kharif and Rabi has been obtained from Directorate of Economics and Statistics, Ministry of Agriculture and Farmer Welfare for the year 2018-19 and implementation of Linear Optimization model with all the inputs is under progress.

**10.      Research outcome from the study**

The following are outcome envisaged from the study

- Maximum net profit, minimum investment cost and minimum water usage for each scenario
- Optimal land allocation for different crops (considering staple food, nutrition value), Kharif season and rabi season for each scenario

**11.      Timeline**

| Sl. No. | Work Element | First Year | | | | Second Year | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| 1 | Literature review, Collection of hydro meteorological data, preparation of base map of the catchment, population data, crop type data, water availability data, cost of cultivation | ███ | ███ | | | | | | |
| 2 | Compilation and verification of hydro-meteorological data, baseline survey data, census data and crop type data, cost of cultivation | | ███ | ███ | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | Preparation of input data for WEAP model | | ▓ | ▓ | ▓ | | | | |
| 4 | Estimation of demand and supply delivered for existing cropping pattern by WEAP | | | ▓ | ▓ | ▓ | ▓ | | |
| 5 | Estimation of demand and supply gap for different scenarios using WEAP | | | ▓ | ▓ | ▓ | ▓ | | |
| 6 | Optimization of income from agriculture sector using LINGO for inputs from the scenario analysis | | | | ▓ | ▓ | ▓ | ▓ | |
| 7 | Report writing | | | | | | | ▓ | ▓ |

**1. Title of the study:**

Development of Water Security Plan for Healthcare Facilities: A Pilot Study for Swami Rama Himalayan University (SRHU-HIHT), Jolly Grant, Dehradun

**2.      Study Group:**

| NIH, Roorkee | Swami Rama Himalayan University (SRHU-HIHT), Dehradun |
|---|---|
| Omkar Singh, V.C. Goyal, Rajesh Singh, Jyoti Patil, Rohit Sambare, N.R. Allaka, Staff from WQ lab | Er H P Uniyal, Mr Nitesh Kaushik |

**3.      Type of Study:** Internal

**4.      Nature of Study:** Development of R&D framework

**5.      Date of start:** April, 2022

**6.      Expected date of completion:** March, 2024

**7.       Duration of the study:** 2 year

**8.      Weather externally funded or not:** Internal; **NIH Budget:** 30 Lakhs

**9.      Objectives:**

- The major objective is to develop a Water Security Plan for Healthcare Facilities in India, with the help of a case study in SRHU-HIHT hospital
- The sub-objectives to attain the major objective include assessment of water demand and water availability (both freshwater and wastewater); evaluation of the quality of water and wastewater for drinking, clinical and other purposes; assessment of rainwater harvesting potential for utilization/ augmentation of groundwater recharge/disaster risk preparedness; and conducting water audit for the hospital campus
- Wastewater monitoring & characterization to develop an appropriate design of CW-NTS technology for treatment & gainful recycling of hospital wastewater
- Outreach activities toward water security/water conservation awareness for medical professionals, hospital staff, and other stakeholders

**10.      Statement of the Problem**

India is witnessing tremendous growth in healthcare infrastructure. The sector is growing at a rapid pace owing to the awareness and importance of good health and wellbeing. Hospitals and healthcare facilities (HCF) operate 24/7, with a continual stream of people working and visiting, and life-saving procedures being performed. Water plays an important role in HCF- from patient care and safety to daily operations, which causes them to use a significant amount of water. Consumption of large amount of water by the hospitals leads to the generation of large volumes of wastewater. Monitoring of water quality at HCFs is extremely important, as many functions and facilities require high-quality water. Also, since hospital wastewater (HWW) imposes a grave hazard to human health and the environment, its monitoring as well as treatment is desirable at HCF. Focusing on water efficiency and adopting better water management practices in these facilities is becoming increasingly urgent due to the volume of water they require. Another cause of concern at the HCF is extreme weather events such as storms, floods, drought, which create emergencies that damage infrastructure, compromising access to critical resources (e.g., food and water) and the safety of patients, visitors and staff. The vulnerability of HCF in disaster situations cannot be underestimated and, therefore, HCF are expected to prepare plans to deal with such emergencies. A Water Security Plan, which includes

the components of water and wastewater in terms of both quantity and quality, is considered essential to effectively deal with the water-related situations and scenarios at HCF. This plan will not only address the challenges of water scarcity and water efficiency but also lead to cost saving for the hospital management.

## 11. Brief methodology:

- Review of relevant literature
- Identification of components of water security:
Field investigation & collection of requisite data (hospital amenities/demography, etc.) for assessment of water demand, water supply and water audit (leakage & losses). In this study, the quantity of domestic water ($m^3$) per capita per month ($DWR_m$) will be estimated as follows (based on vision of Department of DW&S, MoJS, GoI): $DWR_m(m^3/month) = (P_{urban}$ x 135)x$10^{-3}$ x 30
Components of water demand in the campus- BIS standard for hospital 450L/patient/day+ residential/domestic+ other colleges etc
- Water quality monitoring, analysis and assessment for drinking purposes in the hospital based on physio-chemical, trace and bacteriological water quality parameters (as per BIS 2012). The some of the water quality parameters includes pH, BOD, COD, suspended solids, pharmaceutically active compounds (PhACs), several microorganisms including antibiotic-resistant bacteria (ARB), antibiotic-resistant genes (ARG), persistent viruses, etc.
- Collection & analysis of household/hospital roof data from Jolly Grant Hospital:
Estimation of roof top rainwater harvesting potential: The volume of rainwater that could be harvested per household per month will be estimated as per Eq. given by Ghisi et al., 2006, as below (Aladenola and Adeboye, 2010; Ishaku, et al., 2013):

$$VR = \frac{R.HRA.RC}{1000}$$

Where, VR= monthly volume of rainwater per household ($m^3$), R= monthly rainfall depth (mm), HRA= household roof area ($m^2$), and RC= runoff coefficient (dimensionless).
- Collection & analysis of rainfall data for Dehradun from various sources.
- Volume of wastewater generated
- Wastewater quality monitoring, analysis and characterization of Jolly Grant Hospital
- Designing of CW-NTS technology for treatment & gainful recycling of hospital wastewater. The HIHT, Dehradun will provide funds for CW-NTS technology in the hospital premises.

### Data Availability
Data regarding hospital amenities, demography, water supply, water demands will be taken from hospital authorities.

## 12. Mile Stones

| Sr. No. | Work Component | 2022-23 | | 2023-24 | |
|---|---|---|---|---|---|
| | | I | II | I | II |
| 1. | Review of literature | | | | |
| 2. | Field investigation & collection of requisite data (rainfall, water demands and supply, wastewater discharge); data compilation, analysis and synthesis | | | | |
| 3. | Water and wastewater quality analysis for different uses and purposes | | | | |

| SN | Activity | | | | |
|---|---|---|---|---|---|
| 4. | Estimation of roof rainwater harvesting potential and groundwater recharge potential | | 🟩 | | |
| 5. | Suggesting wastewater reuse and construction of CW-NTS in the hospital premises | | | 🟩 | 🟩 |
| 6. | Preparation of water security plan | | | 🟩 | 🟩 |
| 7. | Outreach activities: appropriate water use, water conservation, wastewater treatment and recycling | | 🟩 | 🟩 | 🟩 |
| 8. | Submission of Water Security Plan to hospital authorities | | | | 🟩 |

**13.** **Objective and achievement during last six months:** New proposal.

**14.** **Budget details**

(Rs in Lakhs)

| SN | Item | 2022-23 | 2023-24 | Total |
|---|---|---|---|---|
| 1 | Manpower at Roorkee 1 Nos Resource Person (Jr) @32,000/- | 4.0 | 4.0 | **8.0** |
| 2 | Travel ✓ Field data collection ✓ Meetings ✓ Stakeholders meetings | 5.0 | 4.0 | **9.0** |
| 3. | Contingency ✓ Flyers ✓ Capacity building and outreach activities | 4.0 | 5.0 | **9.0** |
| 4. | Consumables | 2.0 | 2.0 | **4.0** |
| | **Total** | **15.0** | **15.0** | **30.0** |

**15.** **Analysis & Results:** New proposal.

**16. End Users / Beneficiaries of the study:** Hospital authorities, Public Health Centres, Public Health Engineering Department, Line departments (fire, irrigation, etc.)

**17. Deliverables:** Implementable Water Security Plan for hospitals and healthcare centers.

**19.** **Major items of equipment procured:**

**20.** **Involvement of end users/beneficiaries:** Facilities available at SRHU will be used

1.      **Title of the project:**

**Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)**

2.      **Study Team:**

V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare,
NIH Project Team: Dr. Sandeep Kumar Malyan, Dr. Shweta Yadav, Dr. Jhalesh Kumar
 **Partners:** NIH-Roorkee, MNIT-Jaipur, IIT-Bombay, IRMA-Anand

3.      **Funding:** DST (GoI),  Cost: Rs. 5.1 Crore

4.      **Duration:** Apr 2019-Mar 2024

5.      **Objectives of the study**

The project **'Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)'** is funded by Department of Science & Technology (DST), Government of India. The National Institute of Hydrology (NIH) Roorkee is the leading institute for implementation of this project, in collaboration with the project partners from Indian Institute of Technology Bombay (IITB), Malaviya National Institute of Technology (MNIT), Jaipur and Institute of Rural Management Anand (IRMA), Ahmedabad. The objectives of the project are:

*   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,
*   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,
*   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,
*   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,
*   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.

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

The progress of the project is given below:

**Milestones achieved by NIH, Roorkee (March 2022)**

| Milestones | Activities | Target Month | NIH-Progress |
|---|---|---|---|
| Hiring of Project staff | Hiring of project staff | M6 | Completed |
| Development of Centre Portal | Development of IC-EcoWS Centre Website and social media pages for information dissemination | M12 | Completed |
| Organization of Users nteractions Workshop (annual) | 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 equipments 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 |  |  |
|  | Assessment of NTS technology – NIH Colony |  |  |
| Development and Application of Innovative ideas on NTS | Treatment of domestic wastewater by floating constructed wetland system using identified plant species at NIH Roorkee | M24 | Completed |
|  | In-situ treatment of domestic wastewater in urban drain using floating constructed wetland and Bio-Inoculum – Solanipuram Roorkee | M36 | Ongoing |
|  | Pilot-scale demonstration unit for wastewater treatment of residential building using Subsurface Constructed wetlands system at NIH Roorkee | M36 | Ongoing |
| Documentation and dissemination | Capacity building, awareness creation, and dissemination activities (Factsheets) | M36 | Ongoing |

# HARD ROCK REGIONAL CENTRE BELAGAVI

**Scientific Manpower**

| S N | Name | Designation |
|-----|------|-------------|
| 1 | Dr.B.Venkatesh | Scientist F & Head |
| 2 | Dr.M K Jose | Scientist E |
| 3 | Dr.Chandra Mohan T. | Scientist D |
| 4 | Mr. Abhilash R. | Scientist C |
| 5 | Dr.N. Varadarajan | PRA |
| 6 | Mr.Chandrakumar S | SRA |

## Approved Work Program for the Year 2021-2022

| S No. | Title of the Study | Study Group | Duration | Status |
|---|---|---|---|---|
| **Internal R & D Studies** | | | | |
| 1 | Development of prediction tools for Assessment of Water Resources in Ungauged catchments of West Flowing Rivers of Western Ghats Region | CMT(PI), BV and CK & Officer from WRDO | 3 years (4/18-3/21) | Completed |
| 2 | Climate Change Impact assessment for Jayakwadi Reservoir | BV (PI), MKJ, Ahilash and officers from WRD, Govt. Maharashtra) | 3 years (05/18-3/21) | Completed |
| 3 | Flood Vulnerability Assessment and developing mitigation plan for Thiruvananthapuram City, Kerala | CMT, BV, MKJ and CS | 2 years (9/19 - 8/21) | Completed |
| **Sponsored Projects** | | | | |
| 4 | Groundwater Model Development In Micro Basin Of Hard Rock In Krishna And Godavari River Basins Of Telangana | BV, MKJ, SK, AS , Abhilash& Officials form TSGWD | 3 years (9/19 - 8/22) (extended upto 08/23) | Ongoing PDS under NHP |
| 5 | Impact of Sand Mining on Groundwater Regime in Parts of Manjira River Basin, Telangana State | MKJ, BV, CMT Abhilash and Officials form TSGWD | 2 years (4/21-3/23) | Ongoing PDS under NHP |
| **Consultancy Projects** | | | | |
| 1 | Flood Review in Kali and Sharavathy river basin, Dam Break analysis, inundation mapping and preparation of Emergency Action Plan for Dams in Kali, Sharavathi and Varahi river basin | BV (PI) | 2 years | KPCL, Govt. of Karnataka |
| 2 | Hydrogeological Studies in and around "Redi Iron Ore Mine" (Block I) of M/S Gogte Minerals, Located at Village Redi, Taluka Vengurla, District Sindhudrug, Maharashtra | BKP (PI) | 1 year | M/s Redi Mines, Sindhudrug, Maharashtra |
| 3 | Hydrogeological Studies in and around "Redi Iron Ore Mine" (Patni Mine) of M/S Minerals & Metals, Located at Village Redi, Taluka Vengurla, District Sindhudrug, Maharashtra | BKP (PI) | 1 Year | M/s Gogte Mines, i (Belagavi) |

**Approved Work Program for the year 2021-22**

| SN | Project | Study Team | Duration | Status & Comments/ suggestions |
|---|---|---|---|---|
| **INTERNAL STUDIES** | | | | |
| 1. | Development of Prediction Tools for Assessment of Water Resources in Ungauged Catchments of West Flowing Rivers of Western Ghats Region | Chandramohan T (PI), B Venkatesh, Chandrakumar S, and officials from WRDO Karnataka | 3 years Apr 2018-Mar 2022 | The chairman suggested to validate the equations developed for estimation of various flow parameters. The CE, KGBO, suggested to develop the relationship between $q_{75}$ and basin characteristics. Dr. Sekhar, suggested to carry out a trend analysis of the precipitation and runoff of the rivers considered for analysis. The committee advised to submit the report within a month time after incorporating the suggestions of the members. |
| 2. | Climate Change Impact assessment for Jayakwadi Reservoir | B Venkatesh (PI), M K Jose, Chandrakumar S, Abhilash R and officers from WRD, Govt. Maharashtra) | 3 years May 2018 – Sep 2021 | Dr. Sekhar advised to also consider the changes in land use in the catchment as well as command area. The committee advised the PI to submit the report within a month time after incorporating the suggestions of the members |
| 3. | Flood Vulnerability Assessment and developing mitigation plan for Thiruvananthapuram City, Kerala | Chandramohan T (PI), B Venkatesh, M K Jose and Chandrakumar S | *2 years* (Sep 2019 – Aug 2021 | The PI explained that all the analysis has been completed and flood vulnerability map for the city have been developed. However, to identify the flood prone regions, a high resolution DEM is required. The PI informed that the Thiruvananthapuram City Corporation was contacted but the same is still awaited. In view of this, he expressed his inability to complete the HEC-RAS application. The Committee members advised him to complete the study and submit the report. If the high resolution map is obtained, the analyses could be done. |
| **SPONSORED PROJECTS** | | | | |
| 1. | Groundwater Model Development In Micro | B Venkatesh(PI), M K Jose, Sudhir | *3 years* | The Chairman suggested to complete the initial level modeling |

| SN | Project | Study Team | Duration | Status & Comments/ suggestions |
|---|---|---|---|---|
| | Basin Of Hard Rock In Krishna And Godavari River Basins Of Telangana | Kumar, Abhilash R & Officials from TSGWD | (Sep 2019 – Aug 2022 Extended upto August 2023 | and to also assess the impact of new development. |
| 2 | Impact Of Sand Mining On Groundwater Regime In Parts of Manjira River Basin, Telangana State | M K Jose (PI), B Venkatesh, Chandramohan T, Abhilash R and Officials form TSGWD | *2 years* Sep 2021 – Aug 2023 | This study has been initiated as in-house study by TSGWD. An initial field experiments have been completed and the status report is ready to submit |

## Recommended Work Program for the year 2022-23

| S. N. | Project Title | Study Team | Duration | Status |
|---|---|---|---|---|
| **INTERNAL STUDIES:** | | | | |
| 1. | Monitoring and Evaluation of Ground Water Quality of Belagavi City, Karnataka, India | Varadarajan N (PI), Chandra Kumar S, Abhilash R | 2 year (6/22 to 5/24) | New Study |
| **SPONSORED PROJECTS:** | | | | |
| 1. | Groundwater Model Development In Micro Basin Of Hard Rock In Krishna And Godavari River Basins Of Telangana | B Venkatesh (PI), M K Jose, Sudhir Kumar, Abhilash R & Officials form TSGWD | *3 years* (Sept 2019 – Aug 2022 Extended upto August 2023 | Special Studies under NHP |
| 2. | Impact Of Sand Mining On Groundwater Regime In Parts of Manjira River Basin, Telangana State | M K Jose (PI), B Venkatesh, Chandramohan T, Abhilash R and Officials form TSGWD | *2 years* Sept 2021 – Aug 2023 | Special Studies under NHP |
| 3 | Comprehensive Assessment of Water Availability, Use and Issues for Goa State | B Venkatesh, Chandramohan T, Abhilash R and Officials of WRD Goa | 2 years (01/22 to 12/23) | Special Studies under NHP |

# WESTERN HIMALAYAN REGIONAL CENTRE JAMMU

**Scientific Manpower**

| S N | Name | Designation |
|-----|------|-------------|
| 1 | Dr P G Jose | Scientist D |
| 2 | Dr. R V Kale | Scientist D |
| 3 | Dr. Rajeev Saran Ahluwalia | Scientist C |
| 4 | Sh. Deepak Singh Bisht | Scientist B |
| 5 | Sh. Drona Khurana | SRA |

## APPROVED WORK PROGRAM FOR THE YEAR 2021-22

| S. No. | Title of Study | Team | Duration | Remarks |
|---|---|---|---|---|
| **Internal Studies** | | | | |
| 1. | Hydrologic and hydraulic modelling for floodplain inundation mapping under future climate change scenarios: A case study of Tawi River, India. | R. V. Kale P. G. Jose | 03 years (August 2018 – Sept. 2021) | Completed; Final Report submitted. |
| 2. | Statistical evaluation of global precipitation estimates over data scarce Western Himalayan Region of India | D. S. Bisht S. S. Rawat P. G. Jose | 02 Years (Oct 2019 - Sept 2021) | Completed Final Report submitted. |
| 3. | Estimation of changes in snow cover and glacier mass balance for Upper Chenab River Basin | P. G. Jose D. S. Bisht | 02 Years (Aug. 2020 – Aug. 2022) | Ongoing (Extn. requested up to March 2023) |
| 4. | Mass Balance of Phuche and Khardung glaciers, Ladakh Range with implications for downstream water availability under changing climate. | P. G. Jose D. S. Bisht D. Khurana | 03 Years (July 2021- June 2024) | Ongoing |
| 5. | 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 D. Khurana | 03 Years (Sept. 2021- July 2024) | Ongoing |
| 6. | Early Signatures of 21st Century on Snow Cover Dynamics in Zanskar River Basin, Ladakh | D. S. Bisht P. G. Jose | 02 Years (July 2021 - June 2023) | Ongoing |
| **Externally funded R & D Studies** | | | | |
| 1. | Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River | S. S. Rawat P. G. Jose S. Gurjar D. S. Bisht | 03 years (April March 2019 to 2022) | Ongoing study funded by NMHS |
| 2. | Operational coastal flood management through short-to-medium range (real-time) flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate induced impacts | B. Sahoo, (PI, IIT-Kgp) R. V. Kale, (Co-PI) | 03 years (July, 2020 – June, 2023) | Ongoing study funded under STARS by MHRD, GoI. |
| 3. | Permafrost mapping and characterization of Western Himalayan Region | P. G. Jose A.P. Dimri (JNU) G. Jeelani (KU) V Agnihotri (GBPNIHESD) | 03 years (Aug 2019-Aug 2022) | Ongoing study under NMHS. PI revised. |

346

**Recommended Work program for the year 2022-23**

| S. No. | Title of Study | Team | Duration | Remarks |
|---|---|---|---|---|
| **Internal Studies** | | | | |
| 1. | Estimation of changes in snow cover and climate-cryosphere interaction in Upper Chenab river basin | P. G. Jose D. S. Bisht | 02 Years 07 months (Aug. 2020 – Mar. 2023) | Ongoing, Extn. up to March 2023 |
| 2. | Mass balance of Phuche and Khardung glaciers, Ladakh with implications for downstream water availability under changing climate. | P. G. Jose D. S. Bisht D. Khurana | 03 Years (July 2021- June 2024) | Ongoing |
| 3. | 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 basin | R. V. Kale D. Khurana | 03 Years (Sept. 2021- July 2024) | Ongoing |
| 4. | Early signatures of 21$^{st}$ Century on snow cover dynamics in Zanskar river basin, Ladakh | D. S. Bisht P. G. Jose | 02 Years (July 2021 - June 2023) | Ongoing |
| 5. | Comparative analysis of fine-scale satellite & reanalysis precipitation products in Upper Ganga Basin using Multi-Criterion Decision-Making | D. S. Bisht M. K. Goel | 01 Year (June 2022 – May 2023) | New Study |
| **Externally funded R & D Studies** | | | | |
| 1. | Web-enabled inventory of natural water springs of Tawi river catchment of J&K State of India for vulnerability analysis and developing adaptive measures for sustaining Tawi river | S. S. Rawat P. G. Jose S. Gurjar D. S. Bisht | 03 years (April March 2019 to 2022) | Ongoing study funded by NMHS (2 Co-PIs at WHRC) |
| 2. | Operational coastal flood management through short-to-medium range flood vulnerability mapping in the Brahmani-Baitarani River Basin integrating human and climate induced impacts | B. Sahoo, (PI, IIT-Kgp) R. V. Kale, (Co-PI) | 03 years (July, 2020 – June, 2023) | Ongoing study funded under STARS by MHRD, GoI. |
| 3. | Permafrost mapping and characterization of Western Himalayan Region | P. G. Jose A.P. Dimri (JNU) G. Jeelani (KU) V. Agnihotri (GBPNIHESD) | 03 years (Aug 2019-Aug 2022) | Ongoing study funded under NMHS. PI vide letter dtd.10.2.2022 |

**Progress of Ongoing Studies during 2021-22**


*1.    Hydrologic and hydraulic modelling for floodplain inundation mapping under future climate change scenarios: A case study of Tawi River, India.*

RVK made presentation on the completion of this research project. He explained that five freely available Digital Elevation Models (DEM) for the study area have been compared and it was found that the ALOS PALSAR 30 m DEM (AW3D30) is best suited DEM data for the Tawi river basin, especially in the lower flood plain area as compared to SRTM 30 m DEM. AW3D30 DEM data possess high accuracy in the delineation of the river basin followed by the CartoDEM, particularly in the low-lying area.

RVK informed that the event-based HEC-HMS model was set-up for the upper Tawi Basin to simulate observed discharge and stage hydrographs at Jammu (Bikram Chowk), Sidhara and Udhampur (Salmay Bridge) gauging stations. The September 2014 and August 2016 flood events were chosen to calibrate and validate the developed event-based HEC-HMS model, respectively using hourly rainfall and discharge inputs. Model performance was found satisfactory and could be confidently used for flood inundation mapping under climate change.

RVK further explained that 1D HEC-RAS steady state model was developed to generate the flood inundation map in the lower Tawi River basin downstream of the Sidhara (Jammu) gauge station up to its confluence with Chenab River basin using open sources 30 m DEM data. The high flood event of September 2014 was used to demonstrate the flood inundation mapping by HEC-RAS model. Similarly, the Landsat 8 images before flood and on 10 September 2014 were used to calibrate the output of the HEC-RAS model for the September 2014 event in absence of gauge data in lower Tawi basin. Further, LISS-III and LISS-IV images in the part of lower Tawi basin were used to verify the accuracy of the flood inundation map generated with HEC-RAS model for September 2014 flood case. The comparison of the flood inundation extent for the part of lower Tawi basin by HEC-RAS with extracted flood extent from LISS-III and LISS-IV imagery for September 2014 event suggests that error in the flood area by HEC-RAS model were -9.17 % and -4.08 %.

Based on the flood frequency analysis, it was found that the magnitude of extreme discharges at Udhampur (Salmay Bridge) gauging station ranges between approximately 900 cumec for 2-year return period and 7800 cumec for 500-year return period.  Similarly, the average magnitude of extreme flood discharge ranges from 1554 cumec for 2-year return period to 26012 cumec for 500-year return period. At the Jammu (Bikram Chowk) gauging station, average magnitude of the extreme flood discharge ranges between 2933 cumec for 2-year return period and 22153 cumec for 500-year return period. Based on flood frequency analysis, total flood inundated area ranges between 10591 ha to 26305 ha (for Indian part, it is 4063 ha to 15163 ha) for design floods of 2-year to 500-year return periods, respectively.

The climate change scenarios study has been carried out using Climate Perturbation Tool. Increasing trend in number of heavy rainy days is predicted by all the models across the basin in the range 15 to 35%. Based on climate change scenarios (CC5, CC15, CC25 and CC35), the total flood inundated area ranges between 22574 ha to 24348 ha (for the Indian part, it is 12342 ha to 13746 ha). Based on this study, future estimates about the affected agricultural and residential area and population at current conditions were made.

The Chairman and all the expert appreciated the study. The Chairman suggested to send the final draft report for its review to one of the reviewers from Irrigation & Flood Control Department,

Jammu. Er. Shiv Nandan Kumar (SNK), Chief Engineer, IBO, CWC informed that study will be useful to the CWC for flood forecasting and may be shared. In reply, the Chairman also directed to share copy of the report after its review to IBO, CWC. Further, SNK had suggested to extend application of this study to flood forecasting in Tawi River basin. Subsequently, PKG enquired about the DEM comparison carried out in the study report. In reply, RVK informed that the DEMs are compared based on various geometric parameters estimated with DEMs and some ground control points data was used to compare various DEMs.

## 2. *Statistical evaluation of global precipitation estimates over data scarce Western Himalayan Region of India*

DSB made the presentation of this completed internal study. He showed the efficacy of APHRODITE precipitation over other four Global Precipitation Estimates (GPEs) namely, IMERG, PERSIANN-CDR, CMORPH, and CHIRPS in resolving the regional precipitation in Western Himalayan Regional for the studied grids. He further apprised that the technical report categorically ranks the five GPEs while comparing them with India Meteorological Department (IMD) gridded rainfall product employing multiple performance indicator in Multiple-Criterion Decision Making (MCDM) approaches, viz., Compromise Programming (CP), Cooperative Game Theory (CGT), Weighted Average Technique (WAT), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), and Fuzzy-TOPSIS. Ranks obtained using MCDM approaches were further integrated using Group Decision Making method to obtain the robust ranking. He also mentioned that the study provides the detailed methodology for carrying-out such performance ranking and will aid hydrologists and researchers in making the informed decision while using these GPEs in Western Himalayan Region (WHR).

The Chairman asked the PI whether daily series of data was compared to which PI replied that daily observed data was compared. MKG asked whether it is possible to give a hybrid data set for the region based on this study to which DSB replied that as various data sets employ different methodologies, it would not be prudent to bring out a hybrid data set. All members were satisfied with the progress and conclusions of the project.

*3.*     *Estimation of changes in snow cover and glacier mass balance for Upper Chenab River Basin*

PGJ made a presentation of the progress achieved in the project. For estimating the extent and variability of snow cover in the Upper Chenab Basin, global MODIS snow products from TERRA satellite, viz, MOD10A2 - an eight-day composite land surface reflectance product was employed. The entire basin was divided into different zones on the basis of elevation (3 zones), slope (6 zones), and aspect (8 zones). In order to extract these features, ALOS Global Digital Surface Model available at 30 m spatial resolution was used to produce elevation, slope and aspect maps of the study area. Only snow cover imageries with less than 15% cloud cover were selected. The results reveal that almost the entire basin was snow covered between February and April through the first two decades of the 21$^{st}$ century, while the minimum snow cover was observed in the month of August. The inter-annual variability in monthly snow cover depletion over the study period was studied in relation to precipitation and air temperature variability during the study period. Highest & lowest slopes gave lowest snow cover depletion, of which lowest slopes could be glacier tongues or avalanche toes. While average annual precipitation reduced slightly and average annual air temperature increased by about 0.3 $^{\circ}$C, the peak winter precipitation shifted from March to February, while the monsoon peak has shifted from July to August, during the first two decades of 21$^{st}$ century as compared to the last five decades of 20$^{th}$ century. Estimation of specific mass balance of select glaciers in the basin was being attempted using Modified Area Accumulation Ratio (AAR) method. Initial calibration, carried out using glaciological mass balance data from Chhota Shigri Glacier, has been carried out while the development of regression equation between in-situ and modified AAR mass balances was ongoing. Temperature data analysis at daily resolution is yet to be taken up. Towards these, PI requested for extension of the project up to March 2023.

PKG commented that based on his experience in Panchinala Glacier in Lahaul valley, air temperature is the dominant factor controlling the variability of snow cover in Upper Chenab basin, with aspect playing only a very minor role. MKG queried whether any ground truthing is being carried out to verify the mass balance estimated by modified AAR method. PGJ replied that although ground truthing could not be carried out as part of the project, annual specific mass balance and AAR data between 2002 and 2019 obtained in-situ from Chhota Shigri Glacier is being used for cross verification. The Chairman directed the PI to complete the project by March 2023.

*4.*　　*Early Signatures of 21ˢᵗ Century on Snow Cover Dynamics in Zanskar River Basin, Ladakh*

DSB explained that as per the timeline proposed, the data collection for the study area is completed and further analysis is in progress. For examining the variation in maximum snow cover extent and its variability in Zanskar River basin for the first 20 years of 21ˢᵗ century, MODIS snow products from TERRA satellite, viz, MOD10A2 - an eight-day composite land surface reflectance product is downloaded. A total of 939 MOD10A2 images were downloaded for period 2000-2020 and are being analysed to study the snow cover dynamics of the basin. For investigating the influence of global warming induced due to climate change on the snow cover dynamics, ERA5-Land hourly data of total precipitation and air temperature available at 9 km x 9 km spatial resolution is procured at hourly interval. Prior to analyzing the hourly data, monthly reanalysis data from ERA5 at monthly temporal scale was analyzed.

DSB informed that good amount of precipitation occurs during months from Dec. to Feb. due to western disturbance in the region, whereas lesser precipitation occurs during the monsoon months. Mean monthly rainfall of the basin is found to be 45 mm while the mean temperature is found to be -9.9 $^0$C, and only few months show positive temperature during monsoon season. While analyzing the first 20 years of data of 21ˢᵗ century, it was found that mean temperature of the basin has increased by 0.4 $^0$C.

MKG informed that new algorithms have been developed in NMSHE to separate cloud from snow cover in MODIS data and the same may be tried. MKG will share the related inputs with DSB. DSB informed that corrected duration of study is 2 years instead of mentioned 1 year which has been corrected in minutes. The members appreciated the progress of study.

**5.** *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*

RVK made the presentation on progress of this study. He informed that from collected data in the Brahmani-Baitrani basin, it was observed that there is a frequent occurrence of floods in the coastal regions of these basins. In last 5 years, three major floods have occurred in the coastal plains creating major damages to the life and property. These basins have undergone major LULC changes (dense forest has decreased up to 56%, open forest has increased up to 200%, built-up area has increased substantially to 15%). Agricultural and barren lands have also experienced substantial changes of up to 150% and 50%, respectively.

To study the impact of climate change on the water resources of the Brahmani-Baitarani River basins under different future scenarios of the representative concentration pathways (RCPs), future climate data was downloaded from the regional climate models and analysed for change in mean monthly temperature and precipitation. The change in the frequency of dry days, wet days and the extreme precipitation due to climate change is under analysis.

The state-of-the-art numerical-wave model has been set-up for assessing the contribution of wave-current interaction to coastal flooding. Accordingly, a tightly coupled ADCIRC-SWAN model was set-up to compute the water surface elevations and simulate the combined effect of wind, astronomical tides, and waves on coastal flooding. The output of hydrodynamic ocean model was used as downstream boundary condition in the 2D HEC-RAS model to simulate the flood inundation due to "Yass" and "Fani" cyclones in BB delta region. The results of flood inundation map generated using HEC-RAS 2D model is compared with those obtained with SAR data. The progress and results of this study were appreciated by the experts. Dr. Sanjeev asked about validation of the various models used in this study. In reply, RVK informed that these models were calibrated and validated using the respective observed data.

**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-scares Western Himalayan River basin*

RVK made the presentation on progress of this study. He informed that in the previous study for the Tawi basin, the 1D steady-state HEC-RAS and HEC-HMS models were set up. However, the flood inundation and hazard mapping using two-dimensional model is most appropriate for planning flood management measures in near-real-time. A through literature review has been carried out to formulate the research approach in present study. It was mentioned that the changes in river planform and geomorphic dynamics cause ecological, hydrological and environmental impacts. These river changes can be attributed to processes occurring over multiple timescales. Accordingly, the changes in the Tawi planform during 1988 to 2022, based on the composite Landsat data, have been extracted using GEE code. It has been observed that significant changes in the planform of the Tawi river have occurred during 1988 to 2022 in the lower reaches downstream of the Sidhara gauging station. All members appreciated for the efforts and progress of the study.

**7.** *Mass Balance of Phuche and Khardung glaciers, Ladakh Range with implications for downstream water availability under changing climate*

PGJ made a presentation of the progress achieved in the project. The mass balance series of Phuche and Khardung glaciers is the longest glaciological mass balance data set in Ladakh and will gain further value addition in terms of climate-glacier-water resource linkages and future water resource availability for Leh and surrounding hamlets. As part of the project, field work was carried out in September-October 2021 and annual mass balance data was collected and data from four Automatic weather stations (AWS) and an Automatic Water Level Recorder (AWLR) from the glacier catchment were retrieved. The analysis of these data sets is going on, while mass balance data up to 2019 has been finalised. The results show significant interannual variability in summer, winter and annual mass balances as well as much more negative mass balance in case of Khardung glacier as compared to Phuche glacier.

PKG queried whether the mass balance data up to 2019 was in public domain, to which PGJ replied in the negative. PKG also queried about the stake network and snow pit data on Phuche and Khardung glaciers, to which PGJ replied that about 16 stakes on each glacier are monitored regularly and one or two snow pits are monitored for snow depth and density at the end of ablation season. PKG commented that as aspect dominates the glacier mass balance rather than air temperature in Ladakh, there is a need to increase the glacier network in the mass balance monitoring program of Ladakh to capture heterogeneity. PGJ clarified that while Khardung and Phuche glaciers have the same aspect, they have differing temperature-precipitation regimes being located in valleys with differing climate regimes. The Chairman directed the PI to fill the data gap by completing the analysis of glacier mass balances of 2019-20 and 2020-21 well before the next RCC meeting.

## 8. *Permafrost mapping and characterization of Western Himalayan Region*

PGJ made a presentation of the progress achieved in this multi-disciplinary, multi-institutional project. The project aims to model the permafrost extent and active layer thickness in Leh District, Ladakh as well as quantify the fluxes of various climatic factors in the permafrost region and ultimately the contribution of ground ice melt to the regional water resources. Additionally, it seeks to understand the water quality and biogeochemistry of the permafrost horizon. As part of the project, thirty-five ground temperature sensors were installed in 2020 and data from most of these sensors were retrieved in September 2021. Soil and water samples were collected and are being analysed for various constituents. GEOtop model has been setup for modelling of permafrost characteristics and Topographic Wetness Index (TWI) map, Emissivity map, PISR map, LST map, etc. have been prepared.

The Chairman queried whether inputs from the partner institutions have been obtained. PGJ informed that JNU report is being vetted by Co-PI, while Kashmir University and GBPIHED have informed that their inputs will be finalised and shared shortly. The project tenure needs to be extended as discussed in the last meeting of the project partners in February 2022. Also, inputs from the partners for the annual UC for 2021-22 is awaited. Regarding the equipment procurement, PGJ informed that Ice Corer could not be procured by GBPIHED due to price escalation. The Chairman directed the PI to send the requisition for Ice Corer from scheme funds of NIH, provided it can be used for cryosphere field work in future.

**Proposed Work Program for the Year 2022-23 (On-going Studies)**

*1.*      *Estimation of changes in snow cover and Climate-Cryosphere linkages for Upper Chenab river basin*

➢ Mass balance estimation of selected glaciers in U. Chenab basin.

➢ Investigation of climate-cryosphere linkages in U. Chenab basin.

*2.*      *Mass balance of Phuche and Khardung glaciers, Ladakh range with implications for downstream water availability under changing climate*

➢ Winter, Summer and Annual mass balances of Phuche and Khardung glaciers

➢ Meteorological and Hydrological data collection and analysis

*3.*      *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-scares Western Himalayan River basin*

➢ Development of codes in GEE and MATLAB

➢ Analysis of fluvial geo-morphometric planform results

➢ RRI model set-up for study area

➢ Comparison with HEC-RAS/HEC-HMS model results

*4.*      *Early signatures of 21$^{st}$ Century on snow cover dynamics in Zanskar river basin, Ladakh*

➢ Analysis of snow cover dynamics during 2001-2020.

➢ Investigation of the impact of climate change on snow cover extent

*5.*      *Web-enabled inventory of natural water springs of Tawi river catchment of Jammu and Kashmir State of India for vulnerability analysis and developing adaptive measures for sustaining Tawi river*

➢ Detailed study of selected springs

➢ To prepare local geological maps and demarcation of recharge area of selected springs

*6.*      *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 human and climate induced impacts*

➢ 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

➢ Optimization of reservoir operation with forecasted reservoir inflows and releases in real-time up to 10-days lead-time

*7.*      *Permafrost mapping and characterization of Western Himalayan Region*

➢ Field work for data retrieval and sample collection in Leh District, Ladakh.

➢ Finalization of GEOtop modelling results (active layer thickness, mean annual ground temperatures) at the selected sites

➢ Climate change scenario generation

➢ Finalization of spatial permafrost model distribution in the Tso Kar basin.

➢ Final analysis of the water and soil samples collected in the field.

➢ Stakeholders workshop


**New Proposed Studies:**

*8.*      *Comparative Analysis of Fine Scale Satellite & Reanalysis Precipitation Products in Upper Ganga Basin using Multi-criterion Decision-Making*

DSB proposed a new internal study entitled 'Comparative Analysis of Fine Scale Satellite & Reanalysis Precipitation Products in Upper Ganga Basin using Multi-Criterion Decision-Making'. He elaborated the need of study vis-a-vis upper Ganga basin (UGB) wherein precipitation data from considerable number of observatories operated by Central Water Commission (CWC) and India Meteorological Department (IMD) was collected in the recent completed NMSHE project.. The fine scale satellite products such as, Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), the Integrated Multi-satellitE Retrievals for GPM (IMERG), etc. as well as fine scale reanalysis data from ERA5 (Fifth major global reanalysis produced by European Centre for Medium-Range Weather Forecasts (ECMWF) and the Indian Monsoon Data Assimilation and Analysis (IMDAA) will be used. The Chairman approved the proposal as attached at Annexure-1 in agenda.

The approved work program for the year 2022-23 is briefly given in following table.

# CENTRAL INDIA HYDROLOGY REGIONAL CENTRE BHOPAL

**Scientific Manpower**

| S N | Name | Designation |
|---|---|---|
| 1 | Mr. R V Galkate | Scientist E & Head |
| 2 | Dr. T. Thomas | Scientist E |
| 3 | Mr. R K Jaiswal | Scientist D |
| 4 | Mrs. Shashi P.Indwar | Scientist C |
| 5 | Sh. Anoop Rai | SRA |

## APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| SN | Title of Project/Study | Study Team | Duration | Status & Comments/ suggestions | Funding |
|---|---|---|---|---|---|
| **Internal Studies** | | | | | |
| 1 | An experimental assessment oflowcostAugerHoleTechniquefor accelerating ground waterrecharge | RaviGalkate R.K. Jaiswal Vivek Bhatt (WALMI) | Sep 2020- Aug 2023 | On-going (In collaboration with WALMI Bhopal) | NIH-WALMI Bhopal |
| 2 | Impact Assessment Study at WALMI, Bhopal Demonstration Farm | R.K. Jaiswal Ravi Galkate VivekBhatt (WALMI) R. Thakur (WALMI) | Oct 2020- Jun 2021 | On-going (In collaboration with WALMI Bhopal) | NIH |
| 3 | Re-assessment of evapotranspiration (*ETo*) estimation for irrigation planning in Madhya Pradesh | Ravi Galkate, R.K. Jaiswal, A.K. Lohani, Suhas Khobragade, Shashi Indwar Ex.Engg./Dy Dir, MPWRD | July 2021 – June 2023 | New (In collaboration with MPWRD Bhopal) | NIH New study |
| 4 | Assessment of water yield in river basins of Madhya Pradesh | R.K. Jaiswal Ravi Galkate, A.K. Lohani, Shashi Indwar Ex.Engg./Dy Dir, MPWRD | July 2021 – June 2023 | New (In collaboration with MPWRD Bhopal) | NIH New study |
| **Sponsored Projects** | | | | | |
| 1 | Evaluation of impact ofRabi irrigation in GangaRiversub- basin of MadhyaPradesh | R. V. Galkate R. K. Jaiswal, T. Thomas S.P. Indwar, MPWRD | Sep 2017-Sept. 2021 | On-going (In collaboration with MPWRD Bhopal) | NHP-PDS |
| 2 | Impacts of Upcoming Irrigation Projects and Climate Changeon the Droughts and Desertification Scenario for Chambal Basin in Western MadhyaPradesh | T. Thomas P.C. Nayak, Surjeet Singh, B. Venkatesh, R.V. Galkate, R. K. Jaiswal, S. P. Indwar | Dec 2017- Nov 2021 | On-going (In collaboration with MPWRD Bhopal) | NHP-PDS |
| 3 | IntegratedAssessment ofthe Impacts of ClimateChange and Land useChangeon the Hydrology of theNarmadabasin through Hydrological Modelling Approaches | T. Thomas S. Singh, B. Venkatesh P. C. Nayak, A. Sarkar, Manish Nema, P. Mishra, S. P. Indwar | Feb 2018- Jan 2023 | On-going (In collaboration with MPWRD Bhopal) | NHP-PDS |
| 4 | Hydrological Modeling for Evaluation of Return Flow and Irrigation Planning for Optimal Utilization of WaterResourcein the Command ofSanjay Sagar | R. K. Jaiswal R. V. Galkate T. Thomas Shashi Indwar. A. K. Lohani, | April 2019- Mar 2023 | On-going (In collaboration with MPWRD Bhopal) | NHP-PDS |

| | Project in MadhyaPradesh | Sudhir Kumar, Surjeet Singh, MPWRD | | | |
|---|---|---|---|---|---|
| 5 | Development of Decision Tool for Efficient Utilization of Water Resource in Parbati Canal & Dholpur Piped Irrigation Project of Rajasthan | R. K.Jaiswal R. V. Galkate, A. K. Lohani, ShashiIndwar, RJWRD | April 2019- Mar 2022 | On-going (In collaboration with RJWRD Jaipur) | NHP-PDS |

**Recommended Work Program for the year 2022-23**

| SN | Title of Project/Study | Study Team | Duration | Status & Comments/ suggestions | Funding |
|---|---|---|---|---|---|
| | | **Internal Studies** | | | |
| 1. | An experimental assessment of low-cost Auger Hole Technique for accelerating groundwater recharge | **NIH** R.V. Galkate R.K. Jaiswal **MP-WALMI** Vivek Bhatt | 2 years (Sept 2020 – August 2022) | Ongoing In-progress in collaboration with WALMI Bhopal | Internal |
| 2. | Re-assessment of evapotranspiration (*ETo*) estimation for irrigation planning in Madhya Pradesh | **NIH** R.V. Galkate, R.K. Jaiswal A.K. Lohani Shashi Indwar **MP-WRD, Bhopal** Deepak Satpute Sayyam Jhanjari Sameer Soni | 3 years (Nov 2021 – Oct 2024) | Ongoing In-progress in collaboration with BODHI, MPWRD Bhopal | Internal |
| 3. | Water Availability Assessment for Project Formulation in Sub Basins of Ganga River in Madhya Pradesh | **NIH** R K Jaiswal, Ravi Galkate, A K Lohani. **MP-WRD, Bhopal** B Baghel | 3 years (Nov 2021 – Oct 2024) | On-going | Internal |
| 4. | Development of Reservoir Operation Plan under Climate Change scenarios for Kolar reservoir | **NIH** Shashi Indwar, T. Thomas, R. K. Jaiswal, R.V. Galkate, **MP-WRD, Bhopal** C.E, Hoshangabad, S.E Kolar, E.E Kolar. | 3 years (Oct 2021 – Sept 2024) | On-going | Internal |
| | | **Sponsored Projects** | | | |
| 5. | Impacts of Upcoming Irrigation Projects and Climate Change on the Droughts and Desertification Scenario for Chambal Basin in Western Madhya Pradesh | **NIH** T. Thomas, B. Venkatesh, R.V. Galkate, Shashi Indwar R. K. Jaiswal, P. C. Nayak, Surjeet Singh **MP-WRD, Bhopal** Director Hydromet Mahesh Paliwal, B. Baghel. | 4 years (Dec 2017- July 2022) | Ongoing | PDS under NHP |
| 6. | Integrated Assessment of the Impacts of Climate Change and Land-use Change on the Hydrology of the Narmada basin through | **NIH** T. Thomas, B. Venkatesh, P. C. Nayak, Surjeet Singh, | 5 years (Feb 2018 – Sep 2023) | Ongoing | Special PDS under NHP |

| | | Shashi Indwar **MP-WRD, Bhopal** Director Hydromet Mahesh Paliwal, B. Baghel. | | | |
|---|---|---|---|---|---|
| | Hydrological Modelling Approaches | | | | |
| 7. | Hydrological Modeling for Evaluation of Return Flow and Irrigation Planning for Optimal Utilization of Water Resource in the Command of Sanjay Sagar Project in Madhya Pradesh | **NIH** R K Jaiswal, Ravi Galkate, T Thomas Shashi Indwar, A K Lohani, Sudheer Kumar, Surjeet Singh **MP-WRD, Bhopal** Director, Hydromet, SE, GW circle, Database Admin, SE, EE, and AEs of Bah Project | 4 years (Apr 2019 – Sept 2023) | Ongoing | PDS under NHP |
| 8. | Development of Decision Tool for Efficient Utilization of Water Resource in Parbati Canal Irrigation Project of Rajasthan: | **NIH** R K Jaiswal, Ravi Galkate, Shashi Indwar, A K Lohani **WRD Rajasthan** Shailendra Kumar Sanjay Agrawal C B Garg | 3 years (Apr 2019- March 2022) *(Granted Extension up to Sept 2022 by NPMU due to Corona reason)* | On-going | PDS under NHP |
| 9. | Integrated reservoir operation studies for Mahanadi reservoir project complex in Chhattisgarh: SP-56/2021-22/NIH (CIHRC) | **NIH** R K Jaiswal, Ravi Galkate, Shashi Indwar A. K. Lohani, M. K. Goel, Vishal Singh, Sumit Saini, Dipti Rani. **WRD Chhattisgarh** A. Verma, J. K. Das, V. K. Dubey, A. Gupta, P. Awadhiya, **IGKV Raipur** S. Chandinah, | 2 years (Apr 2022-Mar 2024) | New Study | SP under NHP |

**Progress of on-going studies for 2021-22**

**1.    Evaluation of Impacts of Rabi Irrigation in Ganga River Sub Basin of Madhya Pradesh (PDS)**

Sh. Ravi Galkate, PI of the study, informed that this PDS study is completed and the final report is submitted for review in March 2022. He presented the results obtained from the baseline survey conducted in 320 villages in three irrigation projects and explained how irrigation projects had their impacts on agriculture, hydrology, economy, society, and health in those areas. The improvement in agricultural production has strengthened the economy of the region to a certain extent and improved the social status of farmers in irrigated system command. The performance evaluation analysis of eight irrigation projects based on nine comparative indicators helped to identify the best performing and lowest performing irrigation systems. The Naren and Jajon dams were found performing better having good crop, land and water productivity. He explained how the outcome of this study will useful for measuring the performance of the irrigated system and comparing it with the best practices, identifying bottlenecks, constraints, and managerial laps, and to provide direction for improvement in management practices.

**2. Impacts of Upcoming Irrigation Projects and Climate Change on the Droughts and Desertification Scenario for Chambal Basin in Western Madhya Pradesh (PDS)**

Dr. T. Thomas, P.I. informed that a SWAT model has been set up from the Chambal basin up to the Sawai Madhopur GD site and 47 dams have been incorporated into the model. The analysis indicated that the high flows are projected to increase in the future whereas the low flows are projected to decrease in the future. A drought vulnerability mapping was carried out for the baseline (1961-90) and present (1991-2015), near-term (2021-2040), mid-term (2041-2070), and end-term (2071-2100) time zones. The drought vulnerability in the Chambal basin varies from slight to moderate. The desertification vulnerability is projected to be comparatively less in the future as compared to the baseline period. The climate vulnerability is projected to be much higher in the future as compared to the baseline period. The integrated vulnerability assessment was carried out by integrating the drought, desertification, and climate vulnerability. He informed the members that an extension of 6 months has been sought from the PDS Review Committee, which is under consideration.

**3.    Integrated Assessment of the Impacts of Climate Change and Land-use Change on the Hydrology of the Narmada basin through Hydrological Modelling Approaches (Spl PDS)**

Dr. T. Thomas, P.I. presented the study for the Upper Narmada basin up to Hoshangabad. He informed that the CMIP6 data for SSP2-45 and SSP5-85 scenarios have been used for modeling. Extreme rainfall and extreme temperatures are projected to increase in the near term (2021-2040), mid-term (2041-2070), and long-term (2071-2080). As per the SWAT, VIC, WEAP, HEC-HMS, and MIKE11-NAM model simulations, high flows are expected to increase in the future, while low flows are expected to decrease. The MODFLOW and WETSPASS model projected the groundwater recharge to increase in the future under the SSP2-45 scenario. The PI presented results of the reservoir operation using NIH_ReSyp for Barna dam, drought frequency and severity, and flood frequency for various tributaries in Upper Narmada under future SSP scenarios. Dr. T. R. Nayak, Member (Civil), NCA enquired about the high values of the 1000 year return period flood in future periods and such cases how the reservoirs will be operated. In reply, Dr. T. Thomas informed that the return period floods have been estimated based on the frequency analysis using various types of distributions and the frequency of floods for various return periods has increased.

**4. Hydrological Modeling for Evaluation of Return Flow and Irrigation Planning for Optimal Utilization of Water Resource in the Command of Sanjay Sagar Project in MP (PDS)**

Dr. R. K Jaiswal, P.I. presented the progress of the PDS and explained that the NAM model for the Bah G/D site was developed and the results of soil testing in the command were used for the development of the MIKE HYDRO basin model for reservoir operation and planning. He informed about the development of an excel based dashboard for irrigation management where future forecast data can be used to determine demand and deficit in advance. In this dashboard by giving information on cropping areas, reservoir level at the start of the canal, the demand and deficit in different WUAs can be computed. This program has a option to download and use forecast climate data for futuristic inflows and irrigation planning. Dr. T. R. Nayak commented that this type of study is required for Omkareswar command of Narmada. He suggested a joint visit of NCA and NIH to look at the return flow status and formulate a study for the computation of return flow and irrigation management.

**5. Development of Decision Support Tool for Efficient Utilization of Water Resource in Parbati Canal Project of Rajasthan (PDS Under NHP)**

Dr. R. K. Jaiswal, P.I. informed that the study is based on a methodology similar to the study on return flows presented earlier. Due to time constrain, the study could not be presented in detail, however, PI highlighted the progress and main outcomes of the study achieved so far.

**6. Development of Reservoir Operation Plan under climate change scenarios for Kolar reservoir.**

Ms. Shashi P. Indwar, P.I. presented the objectives, study area, methodology, progress, and deliverables of the ongoing study. The PI informed that the Kolar reservoir provides 56.6 MCM water for the domestic water supply to Bhopal city and caters to irrigation demand in the command area of 45078 ha. Also, the Sip-Kolar interlinking project will add another 35 MCM water transfer from River Sip to Kolar. The Chairman enquired what were the change scenarios being applied in the study. The PI mentioned that the climate change scenario would only be considered for the study. As per the suggestion from the Chairman, the title of the study is modified as "Development of Reservoir Operation Plan under Climate change scenarios for Kolar reservoir".

**7. An experimental assessment of low-cost Auger Hole Technique for accelerating ground water recharge**

Sh. Ravi Galkate, PI presented the progress of this field-oriented in-house research study being carriedout jointly with WALMI, Bhopal. He explained the experimental setup carried out in WALMI Campus for testing of the technique. The field experiments were conducted including soil profiling and infiltration tests. The infiltration rate and accumulated recharge volume have increased substantially in the auger holes filled with the filter media. Sh. V. K. Bhatt, Associate Professor and PI of this study from WALMI informed that the auger hole technique is a low-cost technique that can prove to be effective for large-scale groundwater recharge. He informed that the cost of each auger hole is approximately Rs. 500 to 600 includes drilling costs and filter media costs. The Chairman suggested to complete the study and submit the report by August 2022.

**8. Impact Assessment Study of Water Harvesting Structures and Soil Water Conservation Measures in WALMI Demonstration Farm Bhopal**

Dr. R K. Jaiswal informed the members that the study has been completed and the report has been submitted for review.

**9. Water Availability Assessment for Project Formulation in Sub Basins of Ganga River in Madhya Pradesh**

Dr. R. K. Jaiswal, PI informed that this is a new study and its study area comprises of various river basins of the Ganga river system which includes Ken, Betwa, Dhasan, Parbati, Chambal etc. He informed that the rainfall and runoff data of all sub-basins of the Ganga River basin in MP were collected from MPWRD and analyzed. A GIS database of G/D sites of WRD MP was prepared by correcting the location for improvement in the website of WRD MP. Principle component analysis was carried out to group the region into three different parts. A GEE-based SCS-CN model was implemented for Bah, Shipra, and Bina River basins. The Chairman suggested to modify the title so that the tile specifically reflects the study area. The title of the study has therefore been revised as "Water Availability Assessment for Project Formulation in Sub Basins of Ganga River in Madhya Pradesh". Sri Aditya Sharma Chief Engineer, CWC commented that the study is very useful for the assessment of water and project formulation for state water resource departments and should be done for other basins also.

**10. Re-assessment of evapotranspiration (*ETo*) estimation for irrigation planning in Madhya Pradesh**

Sh. Ravi Galkate, PI presented the objectives, study area, methodology, and progress of this new study. He informed that in MP the irrigation requirement is estimated using the guideline given in Technical Circular 25 which generally overestimates the $ET_o$. He explained the Penman-Monteith method which will be used to compute the $ET_o$ in this study. The Chairman asked the PI to include more methods of $ET_o$ computation in the study and compare them. The Chairman also suggested to choose the appropriate methods which are suitable for the semi-arid area.

**Other comments and suggestions**

Sri V S Tekam, Deputy Secretary, and CE Chambal Betwa Basin informed that the MPWRD has started Mahanpura and Kundaliya project with a pressurized irrigation system. He suggested to study the impact of pressurized irrigation on the duty, delta, and other aspects through scientific techniques.

After the presentation of a work program, the Member Secretary gave details of the technology transfer, mass awareness activities, and research publications of the Centre. Member Secretary informed that the Regional Centre, Bhopal had also organized three national training programs and two mass awareness programs during 2021-22. Due to the COVID-19 pandemic situation, the training programs and mass awareness activities were organized both in online and physical modes.

# DELTAIC REGIONAL CENTRE KAKINADA

**Scientific Manpower**

| S N | Name | Designation |
|-----|------|-------------|
| 1 | Dr. YRS Rao | Scientist G & Head |
| 2 | Dr. V S Jayakanthan | Scientist E |
| 3 | Mr. R. Venkata Ramana | Scientist D |
| 4 | Mr.T.Vijay | Scientist B |
| 5 | Sh. U V N Rao | PRA |
| 6 | Sh. P R S Rao | SRA |

**APPROVED WORK PROGRAMME FOR THE YEAR 2021-22**

| S. No | Title of the Project | Team | Start date and End date | Funding |
|---|---|---|---|---|
| **Internal Study** | | | | |
| **1.** | Identification of Recharge and Discharge areas of Palar basin in Tamilnadu | V.S.Jeyakanthan (PI) J.V. Tyagi Sudhir Kumar, Y.R.Satyaji Rao, S. Raja | September 2021 to - March 2023 | Internal Funding (NIH) |
| **Sponsored Projects** | | | | |
| 1 | Groundwater salinity source identification in Godavari delta, Andhra Pradesh | Y.R.Satyaji Rao (PI) T.Vijay, Sudhir Kumar R.VenkataRamana Gopal Krishana S.V.Vijaya Kumar | March 2018 to October 2021 | NHP(PDS) (LA: DRC, NIH) (SP-28/2017-2018/PDS-13) |
| 2 | Study of the behaviour of Multi-Aquifer system & Aquifer mapping for an effective Groundwater Management in Gunderu Sub-Basin, West Godavari district, AP | S.V.Vijaya Kumar (PI) Anupama Sharma Y.R.Satyaji Rao T.Vijay Sudhir Kumar J.V.Tyagi | August 2018 to March 2022 | NHP(PDS) (LA:AP State GW&WA Dept.,) AP_1_2017_80 |
| 3 | Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh | P.C.Nayak (PI) Y.R.Satyaji Rao A.K. Lohani B. Venkatesh A. R. S. Senthil Kumar T. Thomas | April 2019 to March 2022 | NHP(PDS). (LA: DRC, NIH) SP-43/2019-21/1 |
| 4 | Urban hydrological studies of critical pilot area using of hydrological instruments in the Greater Hyderabad Municipal Corporation (GHMC) area Hyderabad. | R.VenkataRamana (PI) Y.R.Satyaji Rao V.S.Jeyakanthan T.Vijay | January 2020 to April 2023 | NHP(PDS) (LA: Hydrology and Investigations, I & CAD, Govt.,Telengana) TEL-6_2017_86 |
| 5 | High Performance Advanced Septic System for Villages and Roadside Restaurants | Y.R Satyaji Rao (PI) T.Vijay | April 2018 to March 2022 | IC-IMPACT, Canada |
| 6 | Unravelling Submarine Groundwater Discharge (SGD) Zones along A.P and Odisha States (Mission SGD)-Pilot Study | Y.R. Satyaji Rao (PI) T.Vijay | April 2019 to September 2021 | MoES,Govt., of India. |

**REVIEW OF WORK PROGRAMME FOR THE YEAR 2021-2022**

The progress of each individual study for the year 2021-2022 and the proposed activity for next year was presented by the respective principal investigator of the study. The comments / improvements suggested by the RCC members on each study are given below.

| S. N. | Project | Study Team | Duration | Status & Comments / Suggestions | Funding |
|---|---|---|---|---|---|
| **I. Internal Study** | | | | | |
| 01. | Identification of recharge and discharge areas of Palar river basin in Tamilnadu | V S Jeyakanthan,(PI) J.V.Tyagi Sudhir Kumar Y.R.Satyaji Rao | 09/21 -03/23 | **Under Progress** 1. Er. Ranga Reddy informed that there are two CWC, GDQ stations on the Palar river basin and river flow data shall be very useful for the study. 2. Chairman suggested to verify the catchment map of the Palar river basin and to delineate complete catchment boundary which is covered in other two states (Andhra Pradesh and Karnataka). He further suggested using the lithology data for understanding the aquifer geometry of Palar river basin. 3. Dr. Madhavi Ganeshan informed that the Palar river flows are more in the upstream areas of both Karnataka and Andhra Pradesh. The recharge zone identification within the Palar river basin (amilnadu) may be very useful for better groundwater resources management. 4. Mr. Gopal suggested to verify any inflow/outflow into/from the Palar river basin and to consider category of the present groundwater development as per the GEC. | Internal Funding (NIH) |
| **II. Sponsored Projects (Ongoing)** | | | | | |
| 02 | Groundwater salinity source identification in Godavari delta, | Y.R.Satyaji Rao (PI) T.Vijay, Sudhir Kumar | 03/18-10/21 | **Completed** 1. Dr. Madhavi Ganeshan expressed her happiness on | NHP (PDS) |

| S. N. | Project | Study Team | Duration | Status & Comments / Suggestions | Funding |
|---|---|---|---|---|---|
| | Andhra Pradesh | R.VenkataRamana S.V.Vijaya Kumar | | the results of the study and further suggested to focus on impact of anthropogenic activities on groundwater quality in Godavari delta.<br><br>2. Chairman suggested that the isotope data collected under the study may be further interpreted along with Tritium data for better understating.<br><br>**3.** Members suggested formulating a new study to understand the effect of backwater/freshwater through drains, creeks, and river mouth on groundwater salinity. | |
| 03 | Study of the behaviour of multi aquifer system and aquifer mapping for an effective groundwater management in Gunderu Sub-bain, West Godavari district, Andhra Pradesh | S.V. Vijay Kumar Anupama Sharma Y R Satyaji Rao T Vijay Sudhir Kumar J V Tyagi | 08/18 – 03/22 | **Completed**<br><br>No comments | NHP (PDS) |
| 04 | Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh | P C Nayak Y R Satyaji Rao A K Lohani B Venkatesh A R S Senthil Kumar T Thomas | 04/19 – 09/22 | **Under progress**<br><br>1. The PI has been transferred to NIH Roorkee and the study is under progress at NIH, Roorkee | NHP (PDS) |
| 05 | Urban Hydrological Studies of critical pilot area in the Greater Hyderabad Municipal Corporation (GHMC) | R V.Ramana (PI) Y R Satyaji Rao V S Jeyakanthan T Vijay | 01/20 - 04/23 | **Under progress**<br>1. Chairman suggested to verify the decrease in built up area in the year 1990 as compared to base year 1973.<br><br>2. Dr. Chandrashekar advised to consider same spatial resolution of satellite data and the same land use/cover classification for better comparison of changes in | NHP (PDS) |

| S. N. | Project | Study Team | Duration | Status & Comments / Suggestions | Funding |
|---|---|---|---|---|---|
| | | | | Land use/cover in the basin. | |
| | | | | 3. Dr. Madhavi Ganeshan suggested comparing SOI land use/cover and satellite data properly to avoid any ambiguity in recording the land use changes. | |
| | | | | 4. Er. Ranga Reddy suggested finding the changes in the drainage pattern and its impacts on flooding. | |
| **III. Sponsored Projects** | | | | | |
| 06 | High Performance Advanced Septic System for Villages and Roadside Restaurants | Y R Satyaji Rao (PI) T. Vijay | 04/18-12/22 | **Ongoing** 1. Chairman suggested to document HPAS efficiency in detail so that it can be implemented elsewhere. | IC-IMPACT Canada |
| 07. | Unravelling Submarine Groundwater Discharge (SGD) zones along A.P. and Odisha States (Mission SGD)-Pilot study | Y R Satyaji Rao (PI) T Vijay | 04/19 – 09/21 | **Completed** 1. Dr. Jena suggested quantifying the SGD flux using Salinity mapper called Soil Moisture and Ocean Salinity (SMOS) instrument in future studies. 2. Dr. Chandra Shekar suggested using soil moisture maps up to 1.5 m depth for further studies. | Funded by NCESS MoES |

# APROVED WORK PROGRAMME FOR THE YEAR 2022 – 2023

| S.No. | Title of the Project | Team | Duration (Start Date and End Date) | Funding |
|---|---|---|---|---|
| **I. Internal Project (ongoing)** | | | | |
| 01. | Identification of Recharge and Discharge areas of Palar river basin in Tamilnadu | V.S. Jeyakanthan (PI) J.V.Tyagi Sudhir Kumar Y.R.Satyaji Rao R.Venkata Ramana | 2 years 09/21 - 03/23 | Internal Funding (NIH) |
| **Internal Study (New project)** | | | | |
| 02 | Impact assessment of backwater through drains, creeks and river mouths on groundwater salinity in the Godavari Delta, Andhra Pradesh | Y.R.Satyaji Rao (PI) Sudhir Kumar V.S.Jeyakanthan R.Venkata Ramana | 2 years 08/22 - 08/24 | Internal Funding (NIH) |
| **II.  Sponsored Projects (Ongoing)** | | | | |
| 03 | Urban hydrological studies of critical pilot area using of hydrological instruments in the Greater Hyderabad Municipal Corporation (GHMC) area Hyderabad | R. Venkata Ramana (PI) Y.R.Satyaji Rao V.S.Jeyakanthan T.Vijay | 3 Years 01/20-04/23 | NHP (PDS) (LA: I & CAD, Govt. of Telangana) TEL-6_2017_2018 |
| 04. | High Performance Advanced Septic System for Villages and Roadside Restaurants | Y.R. Satyaji Rao (PI) T.Vijay | 3 Years 04/18 – 12/22 | IC – IMPACT Canada |
| **III.  Sponsored Project (New Project)** | | | | |
| 05 | Quantification of SGD and its quality flux along the north coastal Andhra Pradesh | Y.R. Satyaji Rao (PI) Sudhir Kumar, S.M Pingale, M.K.Sharma R.Venkata Ramana | 3 years (07/22 -07/25) | Funded by NCESS, MoES |

## PROPOSED TECHNOLOGY TRANSFER ACTIVITIES FOR THE YEAR 2022 – 2023.

The following technology transfer activities were approved by RCC members.

| Activity | Title | Venue & Course Co-ordinator |
|---|---|---|
| 1.  Five-day Training (approved and funded by NWM) | Life cycle approach for rejuvenation of ponds and lakes using nature-based solutions | Kakinada, 12-16, Sep., 2022. Dr.Y.R. Satyaji Rao and Jyoti P Patil |
| 2.  Three-day training (under Scheme) | Application of Optic and Microwave Remote Sensing Technology for Reservoir Sedimentation Analysis | Kakinada, 7-9, Nov., 2022 Dr.V.S.Jeyakanthan Dr.Y.R.Satyaji Rao |
| 3.  Three-day training (under PDS, NHP) | Urban flood modelling and mitigation measures using SWMM software | Kakinada, 5-7, Dec., 2022 R. Venkata Ramana and Dr.Y.R. Satyaji Rao |

**APPROVED WORK PROGRAMME FOR THE YEAR 2022 - 2023**

The RCC members reviewed the work programme for the year 2021 – 2022 and recommended continuation of all the ongoing studies for the year 2022 – 2023 and also recommended taking up one new internal study and one new sponsored study as given in Annexure – II. The scope, main objectives, and utility of the new proposed internal project are given below.

1. **Impact assessment of backwater through drains, creeks and river mouths on groundwater salinity in the Godavari Delta, Andhra Pradesh**

> Project Investigators:    Y.R. Satyaji Rao (PI)
>       Sudhir Kumar
>       V.S.Jeyakanthan
>       R.Venkata Ramana
>
> Budget and Funding:   Rs 23 lakhs (Internal funding)
>
> Period            :   2 years (08/22 - 08/24)
>
> Status            :   New

**Scope and objectives:** Groundwater salinity is a significant challenge to the sustainable development of coastal regions, and it plays severe implications on potable water supply in rural areas, soil fertility, and agricultural productivity. In this context, in the last two decades, paddy cultivation has been converted into fresh /brackish water aquaculture in the delta region. Further, the surface water pathways such as river mouths, drains, and creeks are well connected with the sea and recently the backwaters are widely used for marine aquaculture which affects the shallow aquifer (backwater phenomena during high tides) in the Godavari delta. The sand mining and extreme hydrological events had further aggravated backwater further inland. The proposed project aimed to understand the effect of backwater/freshwater through drains, creeks, and river mouths on groundwater salinity. To understand the behaviour and variability of interaction between surface water and groundwater, environmental tracers are very useful. The environmental isotopes represent one of the most useful tools with geochemistry to investigate geochemical evolution, recharge processes, and the origin of salinity and contaminant processes. The main objectives of the study are as follows.

**Objectives:**

1. Mapping of water pathways using high resolution satellite data and identification of locations for monitoring of salinity w.r.t tides/seasons
2. Monitoring and demarcation of salinity levels, and water flow assessment in major outfalls into the Bay of Bengal
3. Impact assessment of water path ways on groundwater salinity/contaminants using hydrochemistry and environmental isotopes.

**Work plan and Schedule**

| S.N. | Work Plan/ Schedule | 1st Year | | | | 2nd Year | | | |
|------|------|------|------|------|------|------|------|------|------|
| | | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| 1 | Review of literature on impact of water pathways in the Godavari Delta (East Godavari) | ■ | | | | | | | |
| 2 | Mapping of water pathways using high resolution satellite | | ■ | ■ | | | | | |

| S.N. | Activity | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | data and identification of locations for monitoring of salinity w.r.t tides/water cycles | | ■ | ■ | | | | | |
| 3 | Demarcation of salinity levels/water flow assessment in major outfalls into the Bay of Bengal | | ■ | ■ | ■ | | | | |
| 4 | Impact assessment of water path ways on groundwater salinity and other contaminants | | | | ■ | ■ | ■ | | |
| 5 | Publications | | | | | | | ■ | ■ |
| 6 | Preparation of final report | | | | | | | ■ | ■ |

**NIH Budget details**

| S.N. | Sub-head | Justification | Year 1 | Year 2 | Total (Rs.) |
|---|---|---|---|---|---|
| 1 | Manpower | 1 SRF (INR 38,880$_{PM}$), and 1 field assistant (INR 15,000$_{PM}$) for field assistance, data collection & analysis | 646560 | 646560 | 1293120 |
| 2 | Contingency/Fieldwork /Travel | Includes taxi hire charges, boat hire charges, accommodation, field work consumables, Porter & labour charges etc. | 100000 | 100000 | 200000 |
| 3 | Chemicals/ consumables/computer accessories | Chemicals, glassware, sample bottles, standards, servicing, calibration etc. | 200000 | 200000 | 400000 |
| 4 | Software up gradation/field instruments /outsourcing/procureme nt of field equipment | High resolution satellite images for geological, geomorphological mapping, LULC changes, salinity refractometers, etc. | 300000 | 100000 | 400000 |
| | | **TOTAL** | 1246560 | 1046560 | **2293120** |

**Deliverables:**
1. Zonation of backwater salinity in water path ways
2. Impact of water pathways salinity on shallow groundwater
3. Sources of brackish and fresh water aquaculture

**Utility of the study:**
The study outcome is useful for fisheries department, groundwater department and irrigation department. Further, these results are also useful for the people to protect their agricultural lands from ill effects of brackish water aquaculture.

# NIH-NORTH EASTERN REGIONAL CENTRE GUWAHATI

**Scientific Manpower**

| S N | Name | Designation |
|---|---|---|
| 1 | Dr. S V Vijaya Kumar | Scientist G |
| 2 | Dr. S K Sharma | Scientist C |
| 3 | Dr. Swapnali Barman | Scientist C |
| 4 | Sh. Gulshan Tirkey | Scientist B |
| 5 | Sh. Waikhom Rahul Singh | Scientist B |
| 6 | Sh. P K Sarkar | PRA |

## APPROVED WORK PROGRAMME FOR THE YEAR 2021-22

| Sl. No. | Title | Study Group | Duration (Month/Year) | Study Type | Remarks |
|---|---|---|---|---|---|
| **Internal Projects** | | | | | |
| 1. | Linear Hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin | Gulshan Tirkey, S. K. Sharma, P. Mani, | 3 years (4/18 to 3/21) | Internal | On-going Pending |
| 2. | Impact of Climate Change on Runoff and Sediment Yield for Puthimari River- A Major Tributary of River Brahmaputra | Swapnali Barman, J.V. Tyagi, R.K. Bhattacharya, Waikhom Rahul Singh | 3 years (11/18 to 10/21) | Internal | Completed |
| 3. | Groundwater Quality Assessment of Morigaon district of Assam with emphasis on Arsenic & Fluoride Contamination | S.K. Sharma Rajesh Singh G. Tirkey Waikhom Rahul Singh | 2 years (7/19 to 6/22) | Internal | Completed |
| 4. | Hydrological behavior of two mid-sized mountainous catchments under the influence of climate change | Waikhom Rahul Singh , A.K .Lohani, A. Bandyopahdyay Swapnali Barman Nitesh Patidar | 3 years (7/19-6/22) | Internal | Completed |
| 5. | Rainfall Induced Flood Hazard Risk Vulnerability Assessment in East Jaintia Hills, Meghalaya | G. Tirkey, S. K. Sharma,  A. K. Lohani, | 2 years (9/20-8/22) | Internal | On-going |
| **Sponsored Projects** | | | | | |
| 6. | River basin planning studies in Teesta basin up to confluence with Rangit River in Sikkim | Swapnali Barman M.K. Goel A.K. Lohani D.S. Rathore Deepti Raani W.R. Singh | 3 years (3/19 to 2/22) | Sponsored under NHP | On-going |
| 7. | Study on Behaviors of Flooding and Unexpected Drought like Situations in Garo Hills District of Meghalaya | S. K. Sharma R.P. Pandey GulshanTirkey Swapnali Barman W.R. Singh | 3 years (10/19 to 9/22) | Sponsored under NHP | On-going |
| 8. | A Coupled Hydrodynamic and Bank Dynamic Modeling Approach for Forensic Analysis of Bankline Erosion Process Along Majuli Island- the Largest Inhabited River Island in the World | Swapnali Barman, R.K. Bhattacharya M.K. Dutta, W.R. Singh | 3 Years (4/21-3/24) | Sponsored under DST-SERB Power grant | On-going |

# RECOMMENDED WORK PROGRAMME FOR THE YEAR 2022-23

| Sl. No. | Title | Study Group | Duration (Month/Year) | Study Type | Remarks |
|---|---|---|---|---|---|
| **Internal Projects (On-going)** | | | | | |
| 1. | Linear Hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin | *Gulshan Tirkey, S. K. Sharma, P. Mani | #3 years (4/18 to 3/21) | Internal | *PI to be Dr. S.K. Sharma #Study extended till 3/23 |
| 2. | Rainfall Induced Flood Hazard Risk Vulnerability Assessment in East Jaintia Hills, Meghalaya | *G. Tirkey, S. K. Sharma, A. K. Lohani | #2 years (9/20-8/22) | Internal | *PI to be Dr. S.K. Sharma #Study extended till 3/23 |
| **Sponsored Projects (On-going)** | | | | | |
| 3. | River basin planning studies in Teesta basin up to confluence with Rangit River in Sikkim | Swapnali Barman M.K. Goel A.K. Lohani D.S. Rathore Deepti Raani W.R. Singh | 3 years (3/19 to 2/22) | Sponsored under NHP | On-going |
| 4. | Study on Behaviors of Flooding and Unexpected Drought like Situations in Garo Hills District of Meghalaya | S. K. Sharma R.P. Pandey GulshanTirkey Swapnali Barman W.R. Singh | 3 years (10/19 to 9/22) | Sponsored under NHP | On-going |
| 5. | A Coupled Hydrodynamic and Bank Dynamic Modeling Approach for Forensic Analysis of Bankline Erosion Process Along Majuli Island- the Largest Inhabited River Island in the World | Swapnali Barman, R.K. Bhattacharya M.K. Dutta, W.R. Singh | 3 Years (4/21-3/24) | Sponsored under DST-SERB Power grant | On-going |
| **Internal Projects (New)** | | | | | |
| 6. | Impact of Climate Change on Flood Inundation in Beki River Basin | S.K. Sharma, S. Barman, W.R. Singh, S.V. Vijaya Kumar | 1 years (7/22-6/23) | Internal | New-Study |
| 7. | Drought characterization and vulnerability assessment in Assam | W.R. Singh, S. Barman, S.K. Sharma, S.V. Vijaya Kumar, A.K. Lohani | 2 years (7/22-6/24) | Internal | New-Study |

1. **Impact of Climate Change on Runoff and Sediment Yield for Puthimari River-A Major Tributary of River Brahmaputra**

Dr. Swapnali Barman, PI of the project presented the study. She informed the members that the study is completed and explained the results and the utility of the study. Dr. S.K. Singh, S.E., CWC, Guwahati asked PI on the availability of the study report. Replying to this, PI informed that the report is under review and will be distributed to stakeholders once it is ready. Chairman suggested to present the results of climate change impacts in percentage. Dr. S.P. Agarwal, Director, NESAC while appreciating the analysis done suggested to carry out climate change studies based on ensemble approach.

2. **Groundwater Quality Assessment of Morigaon district of Assam with emphasis on Arsenic & Fluoride Contamination**

Dr. S. K. Sharma, PI, presented the study. The objectives of the study are to determine the spatial and seasonal variation in groundwater quality of Morigaon District of Assam with special reference to arsenic and fluoride contamination and to suggest remedial measures. PI was asked to compare with other studies conducted by other organization, if any. Dr. P. K. Bora, Director, NERIWALM stated that co-contamination is a serious issue in Assam and has to deal with it in future studies. Chairman directed to include the suggestions and observations from members in the report.

3. **Hydrological behavior of two mid-sized mountainous catchments under the influence of climate change**

Mr. Waikhom Rahul Singh, PI presented the study. He informed the members that the study is completed and presented the results such as how the streamflow will evolve in different future eras in both Dudhnai and Pare watershed. He also presented about the difficulty encountered in employing various digital elevation model to determine cross sections of Dudhnai river which are input in HEC-RAS modelling. Ms. A. Doreen Blah, Addl. Chief Engineer, WRD, Meghalaya informed the PI as well as the members that her organization is going to carry out bathymetry in the Dudhnai river which could be shared later after completion. Director, NIH asked Mr. Waikhom Rahul Singh to coordinate with WRD, Meghalaya. Dr. R.K. Bhattacharya, Professor, IIT Guwahati also suggested to take up 2D HEC-RAS study in future.

4. **River basin planning studies in Teesta basin up to confluence with Rangit River in Sikkim**

Dr. Swapnali Barman, PI of the project briefly explained the objectives, proposed methodology and progress of the project. Dr. S.P. Agarwal, Director, NESAC mentioned that consideration of reservoir in modelling studies is a very good approach. PI talked about the difficulty in processing with no reservoir related data in which Director, NESAC advised to take advantage of remote sensing based spread area determination with inverse modelling approach in the future studies. Director, NIH asked PI to invite partner institution of the PDS project (WRD, Sikkim) in the next meet.

5. **Study on Behaviors of Flooding and Unexpected Drought like Situations in Garo Hills District of Meghalaya**

Dr. S. K. Sharma presented the study. He briefly explained about the objectives, methodology, current progress and expected deliverables of the study. Director, NIH asked PI to compare the results of flood inundation with the recent flood that occurred in June 2022.

6. **A Coupled Hydrodynamic and Bank Dynamic Modeling Approach for Forensic Analysis of Bankline Erosion Process Along Majuli Island- the Largest Inhabited River Island in the World**

Dr. Swapnali Barman, PI of the project briefly explained the objectives, proposed methodology and progress of the project. Dr. A.K. Lohani, Coordinator, NIH-NERC advised Dr. R. Deka (Director NEHARI) to coordinate with the project since his organization is collecting field survey and cross sections at the Majuli region of the Brahmapura River. Dr. Lohani also suggested the PI to take up 2D HEC-RAS modeling for this study.

7. **Linear Hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin**


8. **Rainfall Induced Flood Hazard Risk Vulnerability Assessment in East Jaintia Hills, Meghalaya**

In the absence of Mr. Gulshan Tirkey due to his medical issues, Dr. S. K. Sharma briefed the RCC members about the progress of the above two studies at (7) & (8). Dr. S. K. Sharma requested the Chairman for permission to drop these two studies. Citing the time invested in these two studies as well as a request from Ms. A. Doreen Blah, Additional Chief Engineer, WRD, Meghalaya, against dropping of the study on "Rainfall Induced Flood Hazard Risk Vulnerability Assessment in East Jaintia Hills, Meghalaya" citing the importance of study to the state of Meghalaya, the Chairman denied the request of dropping. The Chairman asked to complete the studies with the available human resources from the Centre and with Dr S. K Sharma as PI.

**PROPOSED WORK PROGRAMME FOR 2022-23**

In continuation of the ongoing studies, the following new studies were proposed to be taken-up during 2022-23.

**1.      Impact of Climate Change on Flood Inundation in Beki River Basin**

Dr. S. K. Sharma, PI of the project briefly explained the objectives, proposed methodology and expected outcomes of the study. No specific comments were received for this study.

**2.      Drought characterization and vulnerability assessment in Assam**

Mr. Waikhom Rahul Singh, PI of the project briefly explained the objectives, proposed methodology and expected outcomes of the study. Dr. P.K. Bora, Director, NERIWALM advised PI to be careful of the method to be used for estimation of evapotranspiration. He also advised to review similar works carried out by different organizations in India such as National Initiative on Climate Resilient Agriculture (NICRA), Central Research Institute for Dryland Agriculture (CRIDA), etc. so that it can be a value addition to this work.

**3.      Advances in non-structural measures for river regime management**

Dr. S. V. Vijaya Kumar, PI of the project briefly explained the importance of non-structural measures for river regime management. The Chairman asked to drop the proposal as such information is already available and not worth. The Chairman, advised take up study on evaluation of the existing practices, if required so.

# CENTRE FOR FLOOD MANAGEMENT STUDIES PATNA

**Scientific Manpower**

| S N | Name | Designation |
|-----|------|-------------|
| 1 | Er.Biswajit Chakravorty | Scientist G |
| 2 | Dr.Pankaj Mani | Scientist F |
| 3 | Dr. Pravin Rangrao Patil | Scientist C |
| 4 | Sh. Suryansh Mandloi | Scienstist B |
| 5 | Sh. Uday Pratap S. Bhadoriya | Scientist B |
| 6 | Sh. Atam Prakash | SRA |

## APPROVED WORK PROGRAMME OF THE YEAR 2021-22

| Sl | Title | Study Team | Duration |
|---|---|---|---|
| **Internal Studies** | | | |
| 1 | Integrated Flood Management Plan for a stretch of Burhi Gandak River from Sikanderpur to Rosera | B Chakravorty(PI), Pankaj Mani and NG Pandey | 2 years (04/20-03/22) |
| 2 | Performance evaluation of Upper Morhor Canal System of South Bihar | NG Pandey(PI) B Chakravorty | 2 years (04/20-03/22). |
| 3 | Design flood estimation for small structures in the south Bihar area. | Pankaj Mani (PI), B Chakravorty, I C Thakur, Director WALMI | 1 years (04/21-03/22) |
| **Sponsored Project (PDS/NHP)** | | | |
| 4.* | Modelling and management of erosion and sedimentation processes in alluvial river using morphodynamic modeling* | Pankaj Mani(PI) J. P. Patra B. Chakravorty & WRD Bihar | New study proposed under PDS (05/21-04/24) |

*This study was started as an internal study in April, 2019. The proposal of this study was submitted to NHP as PDS. This study has been approved as PDS in Feb. 2021 with duration of 3 years from May, 2021 to Apr 2024 and therefore now this study has been taken up as PDS.*

The progress of the studies listed in work program of the year 2021-22 were presented by the PI of the respective studies. The summary of the discussions held during the RCC meeting are given below.

| SN | Title of Project/ Study, Study Group,Start/ Completion Dates | Status and Recommendations/ Suggestions |
|----|---|---|
| | **Internal Studies** | |
| 1. | Performance evaluation of Upper Morhor Canal System of South Bihar<br><br>**Study Group:**<br>NG Pandey(PI)<br>B Chakravorty<br><br>**DOS:** April 2020<br>**DOC:** March 2022 | The study was presented by Sh. Biswajit Chakravorty. The Upper Morhor irrigation scheme was constructed in 1958 and at present there is a wide gap in irrigation potential created and utilized. To understand the problem of the system, a performance evaluation of the project has been taken up. Analysis of crop water demand and canal supplies has been analyzed and the distributaries not getting adequate water were identified. Sh. Chakravorty informed that the study is completed and the report has been sent to the reviewer.<br><br>Director Hydrology, WRD, Bihar advised Sh. Chakravorty to share the report. |
| 2. | Integrated Flood Management Plan for a stretch of Burhi Gandak River from Sikanderpur to Rosera<br><br>**Study Group:**<br>B Chakravorty(PI),<br>Pankaj Mani and<br>NG Pandey<br>**DOS:** April 2020<br>**DOC:** March 2022 | The progress of study was presented by Sh. Biswajit Chakravorty. The background, objectives of the study, study area, data availability and the methodology for carrying out the study was explained. The design flood computation for 50 and 100 year return period for Sikanderpur and Rosera was shown. The development of river flow model using MIKE FLOOD and it performance were illustrated. The study illustrated that although the embankment does not overtop for the observed peak discharge, the spilling occurs at a few locations for 50-year flood and a number of locations in 100-year flood. Computation were done for the magnitude of raising the embankment for no spilling for the design discharge. Sh. Nagan Prasad, Reader WALMI informed that although embankment does not overtop for the observed discharge, the breach occurs in the embankment due to other reasons like rat holes or human interference. Dr. Sanjay Kumar Jain suggested to check the design flood estimation using recent flood peak data. While discussing, Dr. Jain wanted to know about the utility of landuse land class in the study to which Sri Chakravorty informed that the assessment would be to evaluate if there is any flooding in the flood plain of Burhi Gandak in the stretch. Sh. Chakravorty informed that some more time is required to complete the study. Chairman agreed to extend the study till September 2022. |
| 3. | Future Secular Changes & Remediation of Groundwater Arsenic in the Ganga River Basin – FAR GANGA, Indo-UK Newton Bhabha Water Quality Research Programme.<br><br>**Study Group:** | Sri Chakravorty briefed the study and informed that the project has been completed in January, 2022. The highlight of the project updates, publications with link has been provided in the project web site. Sri M. K. Biswas, Regional Director, CPCB, Kolkata while appreciating the project wanted to know about the suggested remediation by the experts. Sri Chakravorty briefly explained the remedial measures and informed that it is available on the web site |

| SN | Title of Project/ Study, Study Group,Start/ Completion Dates | Status and Recommendations/ Suggestions |
|---|---|---|
| | India lead: NIH (B. Chakravorty) UK Lead: Univ. of Manchester Prof David Polya) | www.farganga.org site. |
| 4. | Modelling and Management of Erosion and Sedimentation Processes in Alluvial River using Morpho-dynamicModelling **Study Group:** Pankaj Mani(PI), J. P. Patra, B. Chakravorty and WRD Bihar **DOS:** May 2021 **DOC:** April 2024 | The progress of this PDS study under NHP was presented by Dr. Pankaj Mani. The progress of partial collection of hydrological data from CWC was discussed. Sh. Mukesh Kumar, SE (Cord) CWC, Patna informed that the rest of data would be supplied shortly. Further, Dr. Mani informed the progress of river cross section survey by third party and its availability of data by May 2022. The installation of river gauge at two sites and progress of procurement of AWL was informed. NIH has also planned for some additional hydrological data (AWL and river gauge, flow velocity and silt concentration) at the Baligaon site and Fatehabad (AWL and river guage) under this PDS study.

Dr. Jain suggested to keep close liaison with WRD officials as this is purpose driven study of NHP. |
| 5. | Design flood estimation for structures in the south Bihararea.

**Study Group:** Pankaj Mani(PI), J. P. Patra, B. Chakravorty and WRD Bihar **DOS:** April 2021 **DOC:** March 2022 | The progress of the study was presented by Dr. Pankaj Mani. In the presentation, the availability of annual peak data obtained from CWC and WRD and extraction of catchment characteristics using ALOS POLSAR online DEM data was discussed. The flow data covering almost 60% of south Bihar river basins have been collected so far. Sh. Naval Kishor Singh, Joint Director Hydrology, WRD Bihar informed that they are collecting river data for 36 streams and 63 GD sites are being maintained in South Bihar and Water Year Book is published every year. Dr Mani informed that the collected data are from similar water book only, however, further data would be collected with the help of Joint Director Hydrology, WRD, Bihar. On request for time extension of study, Chairman RCC consented to extend the study till November 2022. |

## RECOMMENDED WORK PROGRAMME FOR THE YEAR 2022-2023

The work program for the year 2022-23 was finalized during the meeting as given in the table below. Two internal studies and one study (PDS) under NHP are ongoing studies from the previous year. One new study is proposed.

| Sl | Title | Study Team | Duration |
|----|-------|------------|----------|
| **Internal Studies** | | | |
| 1 | Integrated Flood Management Plan for a stretch of Burhi Gandak River from Sikanderpur to Rosera | B Chakravorty(PI), Pankaj Mani and NG Pandey, Ex. Scientist | 3 years (04/20-09/22) |
| 2 | Design flood estimation for small structures in the south Bihar area. | Pankaj Mani (PI), J. P. Patra B Chakravorty, I C Thakur, Director WALMI | 2 years (04/21-11/22) |
| **Sponsored Study (PDS/NHP)** | | | |
| 1. | Modeling and management of erosion and sedimentation processes in a reach of Gandak river using morphodynamic modeling | Pankaj Mani(PI) J. P. Patra B. Chakravorty & WRD Bihar | 3 years (05/21-04/24) |
| **New Study** | | | |
| 1. | Study of flood mitigation measures in Mahav nala using mathematical modelling study (New study) | Pankaj Mani (PI), J. P. Patra B Chakravorty with support from UP Irrigation Department and Forest Department (Maharajganj) | 1 years (04/22-03/23) |

A brief discussion about the new study is given below:

**1.      Study of flood mitigation measures in Mahav nala using mathematical modeling study**

Dr. Mani presented briefly the new proposal. He informed about the study area: Mahav nala originates from Nepal having steep gradient and enters India (Maharajganj district, UP) in comparatively smaller slope. Outfall is in Bhagel river which meets Rohini and further d/s in Rapti R. In the lower part of Mahav, reserved forest area is located on its right bank. Flash flood type situation with short duration storms (8-24 hours) occurs frequently in the area and brings heavy silt from upstream and deposits in the downstream reach. The flooding in upper reach is a frequent phenomenon in the area while in lower reach sufficient water is not available for forest area. The upper part of nala is cleared for silt and dredged soils are placed on the bank of the nala. In course of time, it has consolidated and lot of vegetation has grown up and behaving like embankment. In the lower part, within the forest area no dredging has been carried out. Vegetation encroachment on the banks and stream bed can be seen in this reach. The width of nala in upper part is about 20-22 m while in lower part it is about 10 m. The reduced carrying capacity of nala in lower stretch also restrict the flow within forested area. Forest department has approached NIH in 2018 and after site visit it was suggested to remove embankment on the left bank towards forested area so that water spills from bank and get locked in low laying area of forest cover. Again in April 2022, Forest Department and UP Irrigation Department approached NIH for some amicable solution to the recurrent flooding problem. The site was visited on 23rd April along with DFO, Maharajganj and Executive Engineer UPID. There is no change in the situation since 2018. Still flooding is occurring in the upstream reach with heavy siltation in upper reach and no water in forest area. The carrying capacity of the nala needs to be improved in its entire stretch; from international border to its confluence with Bhagel nala. Further, a comprehensive study for flooding in Mahav nala using mathematical model is proposed by UPID. Using the model study, the carrying capacity of the nala in existing condition would be evaluated; the critical locations of drainage congestion would be identified. For the design flood, suitable section would be evaluated considering the flooding condition in Bhagel nala at the downstream end. The flow characteristics like flow velocity, water level, shear stress may be computed in the stretch of nala which may be used further use for maintenance of nala section. The mathematical model may further be coupled with low laying area within forest area to compute the magnitude of flood water that may be safely absorbed and used without flooding the surrounding settlement area. Under the above background a study entitled "Flood mitigation measures in Mahav nala using mathematical modelling study" is proposed with following objectives:

1. Estimation of design flood in Mahov nala
2. Development of river flow model for the Mahav nala and computation of hydraulic characteristics for design flood.
3. Design of adequate nala section to safely pass the design flood.

# LIST OF PAPERS PUBLISHED/ ACCEPTED FOR PUBLICATION DURING AUGUST 2021- MARCH 2022 & APRIL – JUNE 2022

# LIST OF PAPERS PUBLISHED/ ACCEPTED FOR PUBLICATION

| S.No. | Item | Published (Aug.21-Mar.22) | Published (Apr.-Jun 22) |
|-------|------|---------------------------|-------------------------|
| 1. | International Journal | 49 | 17 |
| 2. | National Journal | 14 | 00 |
| 3. | International Conference/ Seminar/ Symposium | 80 | 01 |
| 4. | National Conference/ Seminar/ Symposium | 03 | 00 |
| 5. | Books/Chapters | 24 | 04 |
| | Total | **170** | **22** |

**LIST OF PUBLICATIONS PUBLISHED DURING 2021-22 (Aug. 2021- March 2022)**

| | **BOOKS** |
|---|---|
| 1. | Goyal, V.C., Patil, Jyoti P. and Goyal V. (2022). "Water for public health". Brochure released on 22nd March 2022 (World Water Day) during NIH-IITR joint event. |
| 2. | Goyal, V.C., Patil, Jyoti P. and Singh, A.K. (2022). "Guidebook on S&T Interventions for Pond Rejuvenation". NIH Roorkee (India), 1-143 pp. ISBN : 978-935620-081-4. |
| | **CHAPTERS IN BOOKS** |
| 1. | Chakravorty, B., Ramana, R.V. and Pandey, N.G. (2022). "Hydrodynamic Modeling of Urban Flooding and Its Management: A Case Study of Patna, India", In: River Hydraulics. Water Science and Technology Library (Eds. Jha, R., Singh, V.P., Singh, V., Roy, L.B., Thendiyath, R.), vol 110. Springer, Cham. https://doi.org/10.1007/978-3-030-81768-8_33. |
| 2. | Jain, S.K., Mishra, P.K. and Sharma, A. (2022). "Environmental Flows and Their Assessment", In: Riverine Systems (Eds. Mukherjee A.), Springer, Cham. https://doi.org/10.1007/978-3-030-87067-6_1. |
| 3. | Kale, R.V., Jose, P.G., Taloor, A.K. and Kumar, R. (2022). "Assessment of Digital Elevation Models Based on the Drainage Morphometric Parameters for the Tawi River Basin", In: Advanced Modelling and Innovations in Water Resources Engineering (Eds. Rao C.M., Patra K.C., Jhajharia D., Kumari S.), Lecture Notes in Civil Engineering, Vol 176. Springer, Singapore. https://doi.org/10.1007/978-981-16-4629-4_10. |
| 4. | Kant, S., Purandara, B.K., Kiran, S., Sujitha, V., Varadarajan, N. and Kumar, S. (2021). "Groundwater quality investigations with special reference to submarine groundwater discharge along the coast of Uttara Kannada district, Karnataka", In: Water Resources: Quality and Management, Wester Books, Germany, pp. 13-21. |
| 5. | Krishan, G., Sudarsan, N., Rao, M.S., Kumar, B., Ghosh, S., B.S. and Vasisth, R. (2021). "Water isotopes as tools in groundwater salinity studies in semi-arid region of northwest India", In: Groundwater Management in Arid and Semi-Arid Regions of Hard Rock Terrains (Ed. B. Venkateshwara Rao), BP Publishers, Hyderabad, 181-185. ISBN 978-93-90211-67-8. |
| 6. | Kumar, A., Tripathi, V. K., Sachan, P., Rakshit, A., Singh, R.M., Shukla, S. K., Pandey, R., Vihwakarma, A. and Panda, K.C. (2022). "Sources of ions in the river ecosystem", In: Ecological Significance of River Ecosystems: Challenges and Management Strategies (Eds. S. Madhav, S. Kanhaiya, A. L. Srivastav, V. B. Singh and P. Singh), Elsevier Publications, Amsterdam, Netherlands, pp. 187-202. |
| 7. | Mali, Shailaja C., Thabaj, Kiran A. and Purandara, B.K. (2021). "Geochemical evaluation of ground water of Ghataprabha sub basin using multivariate approaches", In: Water Resources: Quality and Management, Wester Books, Germany, pp. 1-12. |

| 8. | Mani, P., Kumar, R. and Patra, J.P. (2022). "Using CARTODEM Data for Dam Break Flood Hazard Mapping in a Hilly Terrain" , In: River Hydraulics. Water Science and Technology Library (Eds. Jha, R., Singh, V.P., Singh, V., Roy, L.B., Thendiyath, R.), vol 110. Springer, Cham. https://doi.org/10.1007/978-3-030-81768-8_38. |
|---|---|
| 9. | Mir, R. and Jain, S.K. (2021). "Trends in observed discharge (1963-2012) at Rampur hydrological station of Saltuj River Basin, Western Indian Himalaya", In: Climate change, Springer, pp 183-205, DOI:10.1007/978-3-030-92782-0_9. |
| 10. | Mishra, P.K., Behera, S., Singh, P.K. and Sambare, R. (2022). "Utility of Satellite-Based Open Access Data in Estimating Land and Water Productivity for a Canal Command", In: Geospatial Technologies for Land and Water Resources Management (Eds. Pandey A., Chowdary V.M., Behera M.D., Singh V.P.), Water Science and Technology Library, vol 103. Springer, Cham. https://doi.org/10.1007/978-3-030-90479-1_9. |
| 11. | Mishra, P.K., Singh, H., Das, S. and Chandniha, S.K. (2021). "Entropy-Based Measurement of Long-Term Precipitation Variability Across India", In: Advances in Hydrology and Climate Change (Eds. Surendra Kumar Chandniha, Anil Kumar Lohani, Gopal Krishan, Ajay Krishna Prabhakar), Apple Academic Press & CRC Press, Taylor & Francis Group. |
| 12. | Patil Jyoti P., Gupta, M. and Goyal, V.C. (2022). "Vulnerability assessment of micro-watershed for sustainable food and livelihood security", In: Managing hill resources and diversities for sustainable farming, Chapter-4, pp 27-38 ISBN 978-81-7622-515-1. |
| 13. | Patra, J.P., Kumar, R., Mani, P. (2022). "Hydrologic and Hydraulic Modelling of a Bridge", In: Hydrological Modeling. Water Science and Technology Library, vol 109. (eds) Jha, R., Singh, V.P., Singh, V., Roy, L.B., Thendiyath, R. Springer, Cham. https://doi.org/10.1007/978-3-030-81358-1_24. |
| 14. | Prakasam, C., Saravanan R., Kanwar, Varinder S., Sharma, M.K. and Sharma, M. (2021). "GI Science for Land Use Suitability Analysis in the Himalayas – A Case Study of Himachal Pradesh, India", In: Geographic Information Science for Land Resource Management (Eds. Suraj Kumar Singh, Shruti Kanga, Gowhar Meraj, Majid Farooq, and Sudhanshu), Scrivener Publishing LLC, pp. 301–318. |
| 15. | Prakasam, C., Saravanan, R. and Sharma, M.K. (2022). "Assessment of Environmental Flow Requirements through Rainfall-Runoff Modelling for Hydropower Project", In: Environmental Restoration (Eds. D. K. Ashish and J. de Brito), Lecture Notes in Civil Engineering 232, Springer Nature Switzerland AG. |
| 16. | Prakasam, C., Saravanan, R., Kanwar, Varinder, S. and Sharma, M.K. (2021). "Environmental flow monitoring system– the need of the hour". Advances In Multi-Disciplinary Sciences and Engineering Research (ICAMSER – 2021) (Eds: S. R. Sharma, Ishwar Dutt, Arun Lal Srivastav), ISBN No.: 978-81-953416-1-0, Paper No. 21, pp. 30. |
| 17. | Purandara, B.K., Ujval U., Vidya Sujitha, Abhilash R., Venkatesh, B., Kumar, S. and Tyagi, J.V. (2021). "Impact of land use/land cover changes on catchment characteristics and groundwater dynamics in parts of Western Ghats', In: Water Resources: Quality and Management, Wester Books, Germany, pp. 125-133. |
| 18. | Sambare, R., Singh, V. and Jain, S. K. (2021). "Groundwater Resources Management Using Remote Sensing and GIS, In: Groundwater Resources Development and Planning in the Semi-Arid Region (pp. 369-387). Springer, Cham. |
| 19. | Sandhu, C., Grischek T., Kimothi P.C., Sharma S.K., Kumar S., Uniyal, H.P., Ghosh, N.C., Krishan, G., Kumar, P., Mehrotra, I. (2020). "Sustainable and year-round drinking water production by bank filtration in Haridwar, India", In: Managing Aquifer Recharge: A Showcase for Resilience and Sustainability (Eds. Zheng Y, Ross A, Villholth KG, Dillon P), Paris, UNESCO 20, 261-268. |
| 20. | Ujval U., Purandara, B.K. and Abhilash R. (2021). "Influence of LULC on groundwater recharge and spring sustainability in Western Ghats in Sindhudurg district of Maharashtra", In: Water Resources: Quality and Management, Wester Books, Germany, pp. 141-147. |
| 21. | Vidya Sujitha, Purandara, B.K., Shivapur, A.V., Kumar, S. and Tyagi, J.V. (2021). "Vulnerability of coastal aquifers due to over exploitation in parts of North Goa, Southwest Coast of India", In: Water Resources: Quality and Management, Wester Books, Germany, pp. |

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|---|---|
| | 148-152n. |
| 22. | Zameerulla, M., Torvi, A., Singh, M., Rajaput, Purandara, B.K. and Shivapur, A.V. (2021). "Impact of solid and liquid wastes on surface and groundwater quality of Belagavi city", In: Water Resources: Quality and Management, Wester Books, Germany, pp. 110-118. |

## INTERNATIONAL JOURNAL

| | |
|---|---|
| 1. | Abhilash, R. Venkatesh, B., Srinivasa, V.C. and Patankar, D.B. (2022). Geospatial Approach for Integrated Command Area Management. J. Irrig. Drain Eng, 2022, 148(4), 04022003, DOI: 10.1061/(ASCE)IR.1943-4774.0001659. |
| 2. | Agarwal, A., Patil, Jyoti P., Jayakumar, K.V. and Goyal, V.C. (2021). Formulation of WEAP Based Water Allocation Plan of a Rainfed Micro-Watershed, Chhattisgarh, India. J. Agriculture and Forest Meteorology Research, 4(2): 479-488. |
| 3. | Ansari, M.I., Hasan, Q., Thakural, L.N., Alam, M. and Ahmed, S. (2021). Spatio-temporal analysis of rainfall variability for districts of NCT Delhi. The Journal Of Oriental Research Madras, ISSN : 0022-3301, August 2021, Pg 28-48. |
| 4. | Barman, S. and Dutta, M.K. (2021). River Bank Stability Assessment Based on Engineering Properties of Soil around the Majuli Island of Northeast India. SSRG International Journal of Civil Engineering, 8(10): 35-42. ISSN: 2348 – 8352 /doi:10.14445/23488352/IJCE-V8I10P106. |
| 5. | Behera, A. K., Pradhan, R. M., Kumar, S., Chakrapani, G. J. and Kumar, P. (2022). Assessment of groundwater flow dynamics using MODFLOW in shallow aquifer system of Mahanadi delta (East coast), India. Water, 14(4), 611. https://doi.org/10.3390/ w14040611. |
| 6. | Chaemiso, S. E., Kartha, S. A., and Pingale, S. M. (2021). Effect of land use/land cover changes on surface water availability in the Omo-Gibe basin, Ethiopia. Hydrological Sciences Journal, 66(13), 1936-1962. https://doi.org/10.1080/02626667.2021. 1963442. |
| 7. | Chakravorty, B. and Jha, R. (2021). Estimating waterlogged areas and its reclamation using satellite data and regression analysis for lower Gandak basins, India. Journal of Xi'an University of Architecture & Technology, Volume XIII, Issue 11, 2021, doi.org/10.37896/JXAT13.11/314112. |
| 8. | Dar, T., Rai, N., Kumar, S. and Bhat, M. A. (2022). Climate change impact on cryosphere and streamflow in the Upper Jhelum River Basin (UJRB) of north-western Himalayas. Environmental Monitoring and Assessment, 194(3), 1-21. https://doi.org/10.1007/s10661-022-09766-3. |
| 9. | Ghosh, N.C., Jaiswal R.K. and Ali, S. (2021). Normalized Antecedent Precipitation Index-Based Model for Prediction of Runoff from Un-gauged Catchments. Water Resource Management, 35, 1211–1230, https://doi.org/10.1007/s11269-021-02775-w. |
| 10. | Goyal, V.C., Singh, O., Singh, R., Chhoden, K., Kumar, J., Yadav, S., Singh, N., Srivastava, N.G. and Carvalho, L. (2021). Ecological health and water quality of village ponds in the subtropics limiting their use for water supply and groundwater recharge. Environmental Management, 277 (2021) 111450, https://doi.org/10.1016/j.jenvman. 2020.111450. |
| 11. | Gurrapu, S., Sauchyn, D.J. and Hodder, K.R. (2022). Assessment of the hydrological drought risk in Calgary, Canada using weekly river flows of the past millennium. Journal of Water and Climate Change 13 (4), 1920 – 1935. DOI: 10.2166/wcc.2022.348. |
| 12. | Horan, R., Rickards, N.J., Kaelin, A., Baron, H.E., Thomas, T., Keller, V.D.J., Mishra, P.K., Nema, M.K., Muddu, S., Garg, K.K., Pathak, R., Houghton-Carr, H.A., Dixon, H., Jain, S.K. and Rees, G. (2021). Extending a Large-Scale Model to Better Represent Water Resources without Increasing the Model's Complexity. Water, 13(21):3067, https://doi.org/10.3390/w13213067. |
| 13. | Jain, S., Jaiswal, R.K., Lohani, A.K. and Galkate, R.V. (2021). Development of Cloud based rainfall-runoff model using google earth engine. Current Science, 121(11):1433-1440. |
| 14. | Jaiswal, R.K., Lohani, A.K. and Tiwari, H.L. (2021). A decision support system framework for strategic water resources planning and management under projected climate scenarios for a reservoir complex. Journal of Hydrology, https:/doi.org/10.1016/jhydrol.2021.127051. |
| 15. | Jaiswal, R.K., Nayak, T.R., Lohani, A.K. and Galkate, R.V. (2021). Regional Flood frequency modelling for a large basin in India. Natural Hazard, |

| | http://doi.org/10.1007/511069-21-05119-4. |
|---|---|
| 16. | Khatun, A., Ganguli, P., Bisht, D. S., Chatterjee, C. and Sahoo, B. (2022). Understanding the impacts of predecessor rain events on flood hazard in a changing climate. Hydrological Processes 36(2): e14500. doi: 10.1002/hyp.14500. |
| 17. | Krishan, G., Rao, M.S., Vasisth, R., Chaudhary, A., Singh, J and Kumar, A. (2022). Isotopic assessment of Groundwater salinity: a case study of Southwest (SW) region of Punjab, India. Water, 14, 133. https://doi.org/10.3390/w14010133 |
| 18. | Krishan, G., Vasisht, R., Sudarshan., N. and Rao, M.S. (2021). Groundwater salinity and isotope characterization: a case study from South-West Punjab, India. Environmental Earth Sciences, 80:169, DOI: 10.1007/s12665-021-09419-7. |
| 19. | Kulimushi, L. C., Choudhari, P., Maniragaba, A., Elbeltagi, A., Mugabowindekwe, M., Rwanyiziri, G., Byizigiro, R.V., Pingale, S.M. & Singh, S. K. (2021). Erosion risk assessment through prioritization of sub-watersheds in Nyabarongo River catchment, Rwanda. Environmental Challenges, 5, 100260. https://doi.org/10.1016/j.envc.2021.100260 |
| 20. | Kumar, S., Kumar, M., Chandola, V.K., Kumar, V., Saini, R.K., Pant, N., Kumari, N., Srivastava, A., Singh, S., Singh, R., Krishan, G., Induwar, S.P., Kumar, S., Yadav, B.K., Maurya, N.S. and Chaudhary, A. (2021). Groundwater Quality Issues and Challenges for Drinking and Irrigation Uses in Central Ganga Basin Dominated with Rice-Wheat Cropping System. Water 13, no. 17: 2344. https://doi.org/10.3390/w13172344. |
| 21. | Kumar, S., Kumar, V., Saini, R. K., Pant, N., Singh, R., Singh, A., Kumar, S., Singh, S., Yadav, B. K., Krishan, G., Raj, A., Maurya N. S. and Kumar, M. (2021). Floodplains Landforms, Clay deposition and irrigation return flow govern arsenic occurrence, prevalence and mobilization: A geochemical and isotopic study of the Mid-Gangetic floodplains. Environmental Research, DOI: 10.1016/j.envres.2021.111516. |
| 22. | Malakar, A., Singh, R., Weber, K. A., Westrop, J., Elofson, C.N., Kumar, M. and Snow, D.D. (2021). Occurrence of arsenite in surface and groundwater associated with a perennial stream located in Western Nebraska, USA. Journal of Hazardous Materials, 126170. |
| 23. | Malyan, S.K., Singh, O., Kumar, A., Anand, G., Singh, R., Singh, S., Z. Yu, Kumar, J., Fagodiya, R.K. and Kumar, A. (2022). Greenhouse gases trade-off from ponds: An overview of emission process and their driving factors. Water, 14, 970. https://doi.org/10.3390/w14060970. |
| 24. | Malyan, S.K., Yadav, S., Sonkar V., Goyal, V.C., Singh, O. and Singh, R. (2021). Mechanistic understanding of the pollutant removal and transformation processes in the Constructed Wetland System. J. Water Env. Research, Willey, pp. 1882-1909, June 2021, https://doi.org/10.1002/wer.1599. |
| 25. | Manjunatha, S., Hiremath, C.G. and Venktesh, B. (2021). Evaluating the Impacts of Climate Change on Thunga River Basin Karnataka. SSRG International Journal of Agriculture and Environmental Science, ISSN: 2394 – 2568 /doi:10.14445/23942568/IJAES-V8I5P101. |
| 26. | Mishra, P.K., Thayyen, R. J., Singh, H., Das, S., Nema, M. K., Kumar, P. (2021). Assessment of cloudbursts, extreme rainfall and vulnerable regions in the Upper Ganga basin, Uttarakhand, India. International Journal of Disaster Risk Reduction, 102744. https://doi.org/https://doi.org/10.1016/j.ijdrr.2021. 102744. |
| 27. | Osheen, Kansal, M. L. and Bisht, D. S. (2022). Evaluation of an Urban Drainage System using Functional and Structural Resilience approach. Urban Water Journal. doi: 10.1080/1573062X.2022.2044495. |
| 28. | Panda, K.C., Singh, R.M., Thakural, L.N. and Sahoo, D.P. (2022). Representative grid location-multivariate adaptive regression spline (RGL-MARS) algorithm for downscaling dry and wet season rainfall. Journal of Hydrology, Volume 605, February 2022, 127381, https://doi.org/10.1016/j.jhydrol.2021.127381. |
| 29. | Pant, N., Semwal, P., Khobragade, S. D., Rai, S. P., Kumar, S., Dubey, R. K., ... & Ahluwalia, R. S. (2021). Tracing the isotopic signatures of cryospheric water and establishing the altitude effect in Central Himalayas: A tool for cryospheric water partitioning. Journal of Hydrology, 595, 125983, https://doi.org/10.1016/j.jhydrol.2021.125983. |
| 30. | Patidar R., Pingale S.M. and Khare D., (2021). GIS based groundwater potential mapping for |

| | Shipra river basin of India using Machine Learning Techniques. Arabian Journal of Geoscience, Springer. 14, 1645.http://dx.doi.org/10.1007/s12517-021-07871-0. |
|---|---|
| 31. | Pradhan, R. M., Behera, A. K., Kumar, S., Kumar, P., & Biswal, T. K. (2022). Recharge and Geochemical Evolution of Groundwater in Fractured Basement Aquifers (NW India): Insights from Environmental Isotopes ($\delta$18O, $\delta$2H, and 3H) and Hydrogeochemical Studies. Water, 14(3), 315. https://doi.org/10.3390/w14030315. |
| 32. | Prakasam, C., Saravanan R., Kanwar, Varinder S., Sharma, M.K. and Sharma, M. (2020). Assessment of Environmental Changes using GIS Applications. International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, 9(11), 16-20, DOI: 10.35940/ijitee.J7559.0991120. |
| 33. | Prakasam, C., Saravanan R., Sharma, M.K. and Kanwar, Varinder, S. (2021). Assessment and distribution of water quality of Pandoh river basin (PRB), Himachal Pradesh, North India. Applied Water Science, 11(137), 1-9. https://doi.org/10.1007/s13201-021-01468-4. |
| 34. | Purandara, B. K., Kumar, S., Varadarajan, N., Kant, S., & Tyagi, J. V. (2021). Hydrogeological and Hydrochemical Characterization of Coastal Aquifers with Special Reference to Submarine Groundwater Discharge in Uttara Kannada, Karnataka, India. Journal of Marine Science, 3(3). DOI: https://doi.org/10.30564/jms.v3i3.3476. |
| 35. | Richards, L. A., Kumari, R., White, D., Parashar, N., Kumar, A., Ghosh, A., Kumar, S., Chakravorty, B., Lu, C., Civil, W., Lapworth, D. J., Krause, S., Polya, D. A. and Gooddy, D. C., (2021). Emerging organic contaminants in groundwater under a rapidly developing city (Patna) in northern India dominated by high concentrations of lifestyle chemicals. Environmental Pollution, 268(A): 115765. DOI: https://doi.org/10.1016/j.envpol.2020.115765. |
| 36. | Richards, L.A., Fox, B.G., Bowes, M.J., Khamis, K., Kumar, A., Kumari, R., Kumar, S., Hazra, M., Howard, B., Thorn, R.M.S., Read, D.S., Nel, H.A., Schneidewind, U., Armstrong, L.K., Nicholls, D.J.E., Magnone, D., Ghosh, A., Chakravorty, B., Joshi, H., Dutta, T.K., Hannah, D.M., Reynolds, D.M., Krause, S., Gooddy, D. C., and Polya, D. A., (2022). A systematic approach to understand hydrogeochemical dynamics in large river systems: Development and application to the River Ganges (Ganga) in India. Water Research, Volume 211, Art No. 118054, https://doi.org/10.1016/j.watres.2022.118054. |
| 37. | Sharma, G., Thomas, T. and Singh, R.M. (2021). Comparison of contrasted in rainfall and drought characteristics in the Chambal basin in Madhya Pradesh and Rajasthan. Journal of water and climate change. 12(8), pp. 3932-3957, http://doi.org/10.2166/ wcc.2021.305. |
| 38. | Singh, D., Senthil Kumar, A.R., Goyal, V.C., Arora, M. and Allaka, N. Rao (2021). Characteristics of meteorological variables and their implications on evaporation in Roorkee (India), J. HydroResearch, Volume 4, 2021, Pages 47-60, ISSN 2589-7578, https://doi.org/10.1016/j.hydres.2021.04.002. |
| 39. | Singh, G., Senthil Kumar, A.R., Jaiswal, R.K., Singh, S. and Singh, R.M. (2021). Model coupling approach for daily runoff simulation in Hamp Pandariya catchment of Chhattisgarh state in India. Environment, Development and Sustainability, Springer. https://doi.org/10.100710668-021-01949-1. |
| 40. | Singh, L., Mishra, P.K., Pingale, S.M., Khare, D., and Thakur, H.P. (2022). Streamflow regionalisation of an ungauged catchment with machine learning approaches. Hydrological Sciences Journal, 1-12. https://doi.org/10.1080/02626667.2022.2049271. |
| 41. | Singh, S., Sharma, P., Raju, M., Chakravorty, B., Singh, A. and Sharma, S.D. (2021). Assessment of hydrogeochemistry and arsenic contamination in groundwater of Bahraich District, Uttar Pradesh, India. Arabian Journal of Geosciences (2021) 15:9. https://doi.org/10.1007/s12517-021-09222-5. |
| 42. | Singh, V. and Francisco Munoz-Arriola (2021). Improvements in Sub-Catchment Fractional Snowpack and Snowmelt Parameterizations and Hydrologic Modeling for Climate Change Assessments in the Western Himalayas. MDPI Hydrology DOI: 10.3390/hydrology8040179. |
| 43. | Singh, V., Jain, S.K. and Goyal, M.K. (2021). An assessment of snow-glacier melt runoff under climate change scenarios in the Himalayan basin. Stochastic Environmental Research and Risk Assessment, https://doi.org/10.1007/s00477-021-01987-1. |

| 44. | Singh, V., Lohani, A.K. and Jain, S.K. (2022). Reconstruction of extreme flood events by performing integrated real-time and probabilistic flood modeling in the Periyar river basin, Southern India. Natural Hazards (Springer). DOI: 10.1007/s11069-022-05272-4. |
|---|---|
| 45. | Singh, V., Singh, P.K., Jain, S. K., Jain, S.K., Cudennec, C. and Hessels, T. (2022). Examining evaporative demand and water availability in recent past for sustainable agricultural water management in India at sub-basin scale. Journal of Cleaner Production (Elsevier), DOI: 10.1016/j.jclepro.2022.130993. |
| 46. | Singh, W.R., Barman, S. and Tirkey, G. (2021). Morphometric analysis and watershed prioritization in relation to soil erosion in Dudhnai Watershed. Applied Water Science, Volume: 11; Issue: 9, https://doi.org/10.1007/s13201-021-01483-5. |
| 47. | Suryavansi, A., Nema, A.K., Jaiswal, R.K., Jain, S. and Kar, S.K. (2021). Identification of Soil Erosion Prone Areas of Madhya Pradesh using USLE/RUSLE, Journal of Agriculture Engineering, 58(2), https://doi.org/jae2021581.1744. |
| 48. | Tiwari, A., Joshi, S.K., Saxena, R. and Tripathi, S.K. (2021). Spatial pattern of groundwater recharge in Jhansi district in the Bundelkhand region, central India. Environment, Development and Sustainability. DOI:10.1007/s10668-021-01405-0. |
| 49. | Verma, S., Nema, M.K. (2021). Development of an empirical model for sub-surface soil moisture estimation and variability assessment in a lesser Himalayan watershed. Modeling Earth System Environment, https://doi.org/10.1007/s40808-021-01316-z. |

| NATIONAL JOURNAL | |
|---|---|
| 1. | Abhilash, R., Venkatesh, B., Srinivasa, V.C., and Patankar, D.B. (2021). Geospatial Approach for Integrated Command Area Management. Journal of Irrigation and Drainage Engineering, DOI: 10.1061/(ASCE)IR.1943-4774.0001659. |
| 2. | Ankita, S., Senthil Kumar, A.R., Manasa, Tata, Manickam, M. (2021). Real time flood forecasting at Kasol (Bhakra reservoir) using Artificial Neural Networks. Journal of Indian Water Resources Society, Vol. 41 no. 3&4, Jul & Oct, 2021. |
| 3. | Chakravorty, B. and Jha, R. (2022). Assessment of Spatio-Temporal Variation of Waterlogged Areas Lying between Lower Gandak and Burhi Gandak Basins, India. J. Indian Soc. Remote Sens., doi 10.1007/s12524-021-01482-8. |
| 4. | Goyal, V.C., Agarwal, R. and M. Furqan Ullah (2021). Kaleidoscopic View of Research Journey at National Institute of Hydrology, Rorkee (India), J. IWRS, Vol. 41, No. 1, pp. 54-62. |
| 5. | Jayasree, V. and Venkatesh, B. (2021). Assessment of Flood Vulnerability and Mapping using HEC-RAS- a Case study of Neersagar Reservoir, Karnataka. Environmental Sustainability, Green Growth and disaster Resilience, Knowledge Compendium, Published by NIDM, 2021 page no. 28-40. |
| 6. | Kumari, N., Srivastava, A., and Kumar, S. (2022). Hydrological Analysis Using Observed and Satellite-Based Estimates: Case Study of a Lake Catchment in Raipur, India. Journal of the Indian Society of Remote Sensing, 1-14. |
| 7. | Patil, Jyoti P., Gunther, F., Goyal, S. and Goyal, V.C. (2022). Agro-Ecological Assessment using GAEZ for Suitability and Production Potential of Selected Crops in Bundelkhand Region, India. Journal of Water Resource Research and Development; 4(2):1-19, DOI: http://doi.org/10.5281/zenodo.5044787. |
| 8. | Raina, A. G., Rawat, S.S. and Malaviya, P. (2021). Spring Water Quality Assessment using Water Quality Index in Lansi village of Udhampur, Jammu and Kashmir (India). International Journal of Environmental Sciences (ISSN: 2277-1948), Vol. 10. No.1., pp: 19-23. |
| 9. | Rawat, S.S.., Raina, G., Anuradha, & Malaviya, P. (2022). Relationship between DEM Derived Lineaments and Spring Occurrence in a Himalayan Catchment, Journal of Indian Water Resource Society. |
| 10. | Sabale, R. and Jose, M.K. (2021). Hydrological Modeling to Study Impact of Conjunctive Use on Groundwater. J. Indian Water Works Association. |
| 11. | Venkatesh, B., Thomas, T., Nayak, P.C. and Abhilash R. (2021). Comparison of 6 Reference Evapotranspiration Methods for Stations Located in Humid and Sub-Humid Regions of |

| | |
|---|---|
| | Western Ghats, IWRA (India) Journal, 10 (2), pp. 51-58. |
| 12. | अग्रवाल, पी. के. (2021). "नदियों का अंतर्योजन: केन – बेतवा लिंक परियोजना". जल चेतना पत्रिका published by राष्ट्रीय जल विज्ञान संस्थान, रूडकी, Vol. 10(2), pp: 1-3. |
| 13. | पंगले, संतोष मुरलीधर एवं सिंह, हुकुम (2021). "जलवायु के बदलते परिदृश्य में शहरी जल मांग प्रबंधन" जल चेतना पत्रिका published by राष्ट्रीय जल विज्ञान संस्थान, रूडकी, Vol 10, Issue 1, pp: 33-36. |
| 14. | रावत, सोबन सिंह, कुमार, सुधीर , एवं बिष्ट, दीपक सिंह. (2022). "क्षेत्रीय जल सुरक्षा में झरनों की उपयोगिता- भारतीय परिपेक्ष " जल चेतना पत्रिका, राष्ट्रीय जल विज्ञान संस्थान, रूडकी. 11(1): 25-29. |

| | **INTERNATIONAL CONFERENCE/SEMINAR/ WORKSHOP** |
|---|---|
| 1. | Abdelhamid, K.A., Pingale, S.M. and Khare, D. (2021). "Effect of climate change on reference evapotranspiration at the sub-national scale: Case study of Egypt". Proceedings of the Cairo Water Week, CWW 2021. |
| 2. | Ali, S., Bharti, B., Jaiswal, R.K. and Singh, H.P. (2021). "Assessment of Precipitation Trends in the Bah River Basin, Madhya Pradesh, India". Proceedings of the International Conference on Threats and Challenges to Sustainability of Natural Resources: Contemporary Remedial Tools and Techniques organized by Deptt of Soil & Water Conservation Engineering, GBPUA&T, Pantnagar during 23-24 October, 2021 (online). |
| 3. | Anjali (2021). "Rejuvenation of River Assi". Proceedings of the 2nd International Conference on "River Health: Assessment to restoration (RHAR-2021)" during 22-24 Oct. 2021. |
| 4. | Ansari, M.I., Thakural, L.N. and Hasan, Q. (2021). "Study of Meteorological Drought Using Standardized Precipitation Index in Chaliyar River Basin, Southwest India". Proceedings of the E-Conference (ICWSS) on Water Source Sustainability 2021 organized by the Indian Water Resources Society (IWRS) and Department of Water Resources Development and Management (WRD&M), Indian Institute of Technology (IIT) Roorkee, Uttarakhand during 18-20, June 2021. |
| 5. | Ansari, M.I., Thakural, L.N., Hasan, Q. and Alam, M. (2021). "Spatio-temporal analysis of rainfall variability for districts of NCT Delhi". Proceedings of the E-Conference (ICWSS) on Water Source Sustainability 2021 organized by the Indian Water Resources Society (IWRS) and Department of Water Resources Development and Management (WRD&M), Indian Institute of Technology (IIT) Roorkee, Uttarakhand during 18-20, June 2021. |
| 6. | Arora, M., Kesarwani, K., Malhotra, J. and Jain, S.K. (2022). "Modelling and Streamflow Characterization of Gangotri Glacier Melt Stream". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 7. | Bhanot, K., Sharma, M.K. and Kaushik, R.D. (2022). "Hydrochemical assessment of river Alaknanda, Uttarakhand, India using multivariate statistics". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 8. | Chandniha, S.K., Krishan, G., Lohani, A.K., Prabhakar, A., Meena, P., Shukla, R. (2021). "Investigation of groundwater level fluctuations along with trend analysis using non-parametric tests in Haryana state of India". Proceedings of the International Virtual Conference on Ground Water (ICGW-2021) organized by the Department of Geology, Mohanlal Sukhadia University, Udaipur during 28th October 2021 at Udaipur. |
| 9. | Chyne, B.L., Yadav, S.R., Singh, P.K., Singh, V., Jain, S.K., Arora, M. and Lohani, A.K. (2022). "Spatial Evolution of Soil Erosion in Teesta Basin in Eastern Himalaya, India using Geo Spatial Techniques RUSLE model, IMD, TRMM Datasets". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 10. | Debbarma, S., Barman, S., Debnath, A.C. and Nath, M. (2021). "A Coupled ANN-SCS Approach for Rainfall-Runoff Simulation in Pagladiya Watershed: A Sub-Catchment of River |

| | Brahmaputra". Proceedings of the 26<sup>th</sup> International conference on Hydraulics, Water Resources and Coastal Engineering, HYDRO 2021 International in Sardar Vallabhbhai National Institute of Technology, Surat during December 23-25, 2021. |
|---|---|
| 11. | Donald, J., Krishan, G., Bashrat, M., MacDonald, A. and Daniela, C. (2021). "Groundwater accumulation in northwest India and Pakistan in the 20th century". Proceedings of the GSA connects 2021 in Portland, Oregon October 10-13, 2021. |
| 12. | Galkate, R.V., Jain S., Jaiswal, R.K., Pandey, R.P., Lohani, A.K. and Yadava R.N. (2021). "Assessment of meteorological drought in Bundelkhand region of MP (India) using Standardized Precipitation Index (SPI) and remote sensing derived Vegetation Condition Index (VCI)". Proceedings of the Joint International Conference (virtual Mode) of IMESA & IAWEES, 17-19 November 2021, Cape Town, South Africa. |
| 13. | Galkate, R.V., Jain, S., Jaiswal, R.K., Pandey, R.P., Lohani, A.K. and Yadava, R.N. (2021). "Assessment of meteorological drought in Bundelkhand region of MP (India) using Standardized Precipitation Index (SPI) and remote sensing derived Vegetation Condition Index (VCI)". Proceedings of the Joint International Conference by Institute of Municipal Engineering of Southern Africa & International Association of Water, Environment, Energy and Society, Virtual Mode, 17-19 November 2021 at Cape Town, South Africa. |
| 14. | Galkate, R.V., Pandey, R.P. and Yadava S. (2021). "Assessment of rainfall variability and drought features in Bundelkhand region of Madhya Pradesh, India". Proceedings of the Fifth World Congress for Disaster Management, 24-27 November 2021, IIT Delhi. |
| 15. | Goel, M.K. and Chakravorty, B. (2021). "Analysis of water transfer in the proposed Sankh-South Koel – Subarnarekha link system". Proceedings of the 2<sup>nd</sup> Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 16. | Indwar, S.P., Thomas, T., Galkate, R.V and Jaiswal, R. (2022). "Crop Water Requirement and Irrigation Scheduling of Rabi Crops using CROPWAT 8.0 Model for Tawa Command in Madhya Pradesh". Proceedings of the 2<sup>nd</sup> Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 17. | Jain, S.K. and Arora, M. (2021). "A country paper on "Climate Change Impacts – Challenges and Opportunities in Water Sector". Proceedings of the BRICS WATER FORUM Session on 16<sup>th</sup> November 2021. |
| 18. | Jaiswal, R.K., Kumari C., Galkate, R.V. and Lohani, A.K. (2021). "Assessment of Productivity based Efficiencies for Optimal Utilization of Water Resources in a Command". Proceedings of the International Conference on Water Source Sustainability (ICWSS21) organized by IIT Roorkee during 18-20 June, 2021 (online). |
| 19. | Jaiswal, R.K., Lohani, A.K., Galkate, R.V. and Jain, S. (2021). "Spatial variability of Climate extreme indices over Mahanadi basin (India)". Proceedings of the 20th World Congress on Disaster Management organized by World Congress on Disaster Management, New Delhi (India) during 23-27 November 2021 at New Delhi. |
| 20. | Jeyakanthan, V.S., Venkataramana, R., Tyagi, J.V. and Satyaji Rao, Y.R. (2022). "Multi-sensor and multi-temporal satellite data analysis for reservoir water spread area estimation". Proceedings of the 2<sup>nd</sup> International Conference on Emerging Trends in Water Resources and Geo-Environmental Engineering during January 27-29, 2022, Department of Civil Engineering, MVGR College Of Engineering, Vizianagaram, Andhra Pradesh, India. |
| 21. | Jeyakanthan, V.S., Venkataramana, R., Tyagi, J.V. and Satyaji Rao, Y.R. (2022). "Reservoir water-spread area estimation using microwave satellite data". Proceedings of the International Conference on Civil Engineering, Architecture and Sustainable Infrastructure (2nd ICCEASI - 22) organized by Babu Banarasi Das University, Lucknow in association with Institute For Engineering Research and Publication (IFERP) during February 9-10, 2022. |
| 22. | Khamis, K. and the Team SAPTANADI (Chakravorty, B as one of the team members) (2021). "Using in-situ sensors to quantify spatial variability in nutrient concentrations across the Ganges river basin". Proceedings of the EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-11071, https://doi.org/10.5194/egusphere-egu21-11071, 2021. |
| 23. | Krause, S. and the Team SAPTANADI (Chakravorty, B as one of the team members) (2021). |

| | "Taking the pulse of Mother Ganga - Revealing the visible and invisible water pollution crisis along the Ganges River". Proceedings of the EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-10801, https://doi.org/10.5194/egusphere-egu21-10801 , 2021. |
|---|---|
| 24. | Krishan, G. and Rao, M.S. (2021). "Temporal and spatial isotopic variation of Satluj and Beas Rivers, Punjab". Proceedings of the 4th International conference on status and future of World large rivers sustainability" organized by Boku University, Vienna, IAHR, UNESCO-IHP at Moscow, Russia during 3-6 August, 2021. |
| 25. | Krishan, G., Bhattacharya, P., Sudarsan, N. and Polya, D. (2021). "Health risk assessment associated with arsenic in groundwater in the state of Punjab, India". Proceedings of the GSA connects 2021 in Portland, Oregon during October 10-13, 2021. |
| 26. | Krishan, G., Kumar, R., Yadav, B.K., Kansal, M.L., Bradley, A., Singh, S., Muste, M. and Sharma, L.M. (2022). "Numerical modelling of salt transport in a semi-arid region of district Mewat, Haryana, India". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 27. | Krishan, G., Rao, M.S., Chaudhary, A., Vasisht, R. and Singh, J. (2022). "Assessment and management of fresh-saline groundwater system of Southwestern parts of Punjab, India". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 28. | Krishan, G., Sejwal, P., Yadav, B.K., Kansal, M.L., Bradley, A., Singh, S., Kumar, M., Sharma, L.M. and Muste, M. (2021). "Controls of groundwater salinity using principal component analysis (PCA)- case study from Mewat (Nuh), Haryana, India. Proceedings of the International Conference on Recent Advances in Water Science and Technology (ICRAWST - 2021) organized during December 02-03,2021 at Sri Shakthi Institute of Engineering and Technology, Coimbatore, India. |
| 29. | Kumar, M., Sharma, M.K. and Malik, D.S. (2022). "Groundwater quality evaluation of a semi-arid region for irrigation using Irrigation Water Quality Index (IWQI): A case study of Bemetara district of Chhattisgarh, India". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 30. | Kumar, S., Gurrapu, S., Thakural, L.N. and Patra, J.P. (2022). "Trends in annual maximum flow series and their relationship with El Niño-Southern Oscillation". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 31. | Kumar, S., Patra, J.P., Thakural, L.N. and Gurrapu, S. (2022). "Regionalization of Flow Duration Curves". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 32. | Lohani, A.K. (2021). "Soft Computing Techniques in Water Resources Engineering". Keynote paper in HYDRO 2021 – INTERNATIONAL, 26th International Conference on Hydraulics, Water Resources and Coastal Engineering (23rd – 25th December 2021) Organized by Department of Civil Engineering, Sardar Vallabhbhai National Institute of Technology, Surat, India under the aegis of Indian Society for Hydraulics (ISH), Pune, India |
| 33. | Lohani, A.K., Jaiswal, R.K. and Jain, S.K. (2021). "Glacial Lake Outburst Flood Modelling". Proceedings of the Fifth World Congress for Disaster Management, 24-27 November 2021, IIT Delhi. |
| 34. | Lu, C., Richards, L.A., Wilson, G., Krause, S., Lapworth, D.J., Gooddy, D.C., Chakravorty, B., Polya, D.A. and Niasar, V.J. (2021). "Impacts of groundwater abstraction on Ganges river water ingress into shallow aquifers under Patna, India: Sensitivity Analysis". Proceedings of the Aqua360 (The University of Exeter), Abstract ID 182. online, 31 Aug - 2 Sep 2021. |
| 35. | Mani, P. (2021). "Flood Risk Management for an Industrial Site". Proceedings of the 3rd International Conference on Advances in Civil Engineering (ICACE 2021) during June 25th to 26th, 2021 by K L Deemed to be University, Andhra Pradesh, India (virtual mode). |
| 36. | Mani, P., Chaterjee, C., Kumar, R. and Patra, J.P. (2021). "Incorporating Climate Change Impacts in the Design of Flood Mitigation Measure". Proceedings of the International Conference on Emerging Trends in Sustainable Infrastructure Developments organised by |

| | Sharda University (virtual mode). |
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| 37. | Mani, P., Kumar, R. and Patra, J.P. (2021). "Dam Break Flood Hazard Assessment: A Case Study for a Small Dam in Eastern Himalayan Range in West Bengal, India". Proceedings of the International Conference on Emerging Trends in Sustainable Infrastructural Developments organised by Sharda University (virtual mode).. |
| 38. | Manikandan and Satyaji Rao, Y. R. (2022). "Mapping and Change detection of Water bodies in the Godavari Delta using Geospatial Technology". Proceedings of the International Conference NUclearCSE-2022 held at NIIT University (NU), Neemrana, Rajasthan during 20-22 January 2022. |
| 39. | Mohanty, A., Sahoo, S., Kale, R.V. and Sahoo, B. (2021). "Decoding the feedback relationship between recurrent flood and land use-land cover change in a deltaic river basin using remote sensing approach". Proceedings of the American Geophysical Union, Fall Meeting 2021, Paper #H43B-03, https://agu.confex.com/agu/fm21/meetingapp.cgi/Paper/960379. |
| 40. | Nayak, P.C., Ramola, M., Venkatesh, B. and Thomas, T. (2022). "Dam Break analysis using HEC-RAS model for Kandaleru dam in Andhra Pradesh". Proceedings of the 2$^{nd}$ Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 41. | Nel, H. and the Team SAPTANADI (Chakravorty, B as one of the team members) (2021). "Sediment and surface water microplastic contamination along the Ganges River, from the Himalayan foothills to the tidal reach downstream of Kolkata, India". Proceedings of the EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-13000, https://doi.org/10.5194/egusphere-egu21-13000 , 2021 |
| 42. | Nema, M.K. and Nagashree, G.E. (2022). "Evaluation of deep learning-based hybrid models for the soil moisture prediction in a Lesser Himalayan catchment". Proceedings of the 2$^{nd}$ Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 43. | Noel, D.D., St. Jacques, J. M. and Gurrapu, S. (2021). "The interacting effects of the Pacific Decadal Oscillation and Atlantic Multidecadal Oscillation on flood risk in the North American West Coast". Proceedings of the Applied Geography Conference (Virtual Conference), USA during 14–16 October, 2021. |
| 44. | Noel, D.D., St. Jacques, J.M. and Gurrapu, S. (2021). "Assessing the influence of the Pacific Decadal Oscillation and the Atlantic Multidecadal Oscillation on discharge variability in western North America". Proceedings of the AGU Fall Meeting, New Orleans, USA during 13 – 17 December, 2021. |
| 45. | Pandey, R.P. (2021). "Application of hydrologic model for assessment of vulnerability to drought". HYDRO-2021 organized by Indian Society of Hydraulics (ISH), 23-25 Dec 2021, at SVNIT Surat. |
| 46. | Pandey, R.P. (2021). "Hydrological Impacts of Climate Change on Water Resource System and its Implications for Energy and Food: A Countrywide Assessment". under Theme-1: Food-Energy-Water-Climate Security Nexus and the Challenges, XV Agricultural Science Congress, 13-16 November 2021 at BHU Varanasi. |
| 47. | Pandey, R.P. (2022). "Implications of Climate Change and Sustainable Water Resource Management in India". Key Note Paper under one of the themes "Climate Change and Sustainable Development" presented in International Seminar on Ecosystem Functioning in Anthropocene (ISEFA-2022) organised by Banaras Hindu University (BHU) during 23-25$^{th}$ February 2022. |
| 48. | Pati, A., Kale, R. and Sahoo, B. (2021). Disaggregation of daily rainfall into hourly rainfall in an Ungauged Urban Catchment, EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-9171, https://doi.org/10.5194/egusphere-egu21-9171. |
| 49. | Patidar R., Khare D., & Pingale S.M. (2021). GIS-based groundwater potential mapping using machine learning techniques. AGU Fall meeting. Paper Id: EP15H-10. https://agu.confex.com/agu/fm21/meetingapp.cgi/Paper/969287. |
| 50. | Patidar, N., Krishan, G. and Sharma, A. (2022). "Estimation of Groundwater Recharge |

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| | Utilizing Remote Sensing Inputs in Unsaturated Flow Model". Proceedings of the 2$^{nd}$ Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 51. | Patil Jyoti P., Sarkar A. and Goyal V.C. (2022). "Review of Women's Contribution in Water Research in India". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 52. | Patra, J.P., Kumar, R., Mani, P. and Kumar, S. (2022). "Flood Risk Management in Lower Reaches of Bhedan River, Odisha". Proceedings of the 2$^{nd}$ Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 53. | Polya, D. A., Chakravorty, B., Mukherjee, A., Ghosh, A., Joshi, D., Mondal, D., Gooddy, D., Krause, S. And Richards, L. A (2021). "Poor economics and arsenic: the key role of end-user & science informed co-designed policy and action, stakeholder guidance, transparancy and the proactively enhanced role of women for better interventions in India". Proceedings of the 8$^{th}$ International Congress, Wageningen, The Netherlands, online, 7-9 June 2021. |
| 54. | Prakasam, C., Saravanan, R., Kanwar, Varinder, S. and Sharma, M.K. (2021). "Environmental flow monitoring system– the need of the hour". Proceedings of International Conference on Advances In Multi-Disciplinary Sciences and Engineering Research (ICAMSER – 2021) at Dept. of Applied Sciences, Chitkara University, District Solan (H.P.) during 2-3 July 2021, Paper No. 21, pp. 30. |
| 55. | Ranade, A. (2021). "Large-scale extreme rain event analysis of seven homogeneous zones of India in relation to global thermal changes". Proceedings of the International Symposium on Tropical Meteorology (INTROMET-2021) during 23-26 November 2021 at Cochin, Kerala. |
| 56. | Ranade, A. (2022). "Time series analysis of seven homogenous rainfall zones using longest instrumental monthly rainfall records". Proceedings of the 2$^{nd}$ Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 57. | Ranade, A. (2022). "Effect of Climatic Changes on Extreme Weather Events over Subtropical Himalayan Region". Proceedings of the International Conference on Extreme weather events under changing climate in Indian-Himalayan region during 10-11 March 2022 at Kullu. |
| 58. | Rawat, S. S., Nikam, B. R., Kumar, P., & Gupta, P. K. (2022). Modeling of Sediment Yield of Tawi Catchment to Identify the Critical Sources Area. In Recent Trends in River Corridor Management: Select Proceedings of RCRM 2021 (pp. 215-234). Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-16-9933-7_14. |
| 59. | Rawat, S.S., Gurjar, S., Bisht, D.S., Raina, G., Kumar, S., Jose, P.G. and Stanzin, C. (2021). "Development of Spring Information System for Sustaining Water Demand in Indian Himalayan Region (IHR). Proceedings of the Online "5th World Water Summit" organized by Energy and Environment Foundation during August 21-22, 2021. |
| 60. | Richards, L. A. and the Team SAPTANADI (Chakravorty, B as one of the team members) (2021). "Water Quality across the River Ganga Basin in India: Trends, Dominant Geochemical Processes and Impacts". Proceedings of the EGU General Assembly 2021, online, 19–30 Apr 2021, EGU21-10642, https://doi.org/10.5194/egusphere-egu21-10642 , 2021. |
| 61. | Sabale, R. and Jose, M.K. (2021). "Comparative study between water yield and consumptive use: A Case study of Khatav Taluka". Proceedings of the ICRIPE-2021 Conference, Web of Science. |
| 62. | Sabale, R. and Jose, M.K. (2021). "Conjunctive use modeling using SWAT and GMS for sustainable irrigation in Khatav, India". Proceedings of the ACTM- 2021 Conference, Scopus, Springer, ASCE, Dec2021. |
| 63. | Sabale, R. and Jose, M.K. (2021). "Optimization of Conjunctive use by LINGO & PSO for water resources management in irrigation command of Khatav taluka". Proceedings of the ICETET 2021 (Conference), SCOPUS, May 2021. |
| 64. | Sandhu, C., Grischek, T, Krishan, G., Sharma, S.K., Patil Kavita V., Ronghang, M., Narsimhan C Lakshmai, Elango, L. and Banerjee, P. (2021). "A strategy to propagate riverbank filtration in India from state to national level". Proceedings of the 47$^{th}$ International |

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| | Association of Hydrogeologists (IAH) conference during 23 – 28 August 2021. |
| 65. | Sandhu, C., Grischek, T. and Krishan, G. (2021). "Demonstrating riverbank filtration as a nature-based solution in India – examples from project CCRBF". Proceedings of the G-STIC Dubai: Deep Dive Session Theme: Harmonizing Nature Based Solutions for Water Security organized by TERI on October 25, 2021. |
| 66. | Sarkar, A. and Gurrapu, S. (2022). "Impact of climate change on crop health/ productivity: A case study from Rajasthan state in India". Proceedings of the International e-conference" on "Environment and Health-Frontiers Ahead", organised by Adamas University, West Bengal during 26 – 26 February 2022. |
| 67. | Sarkar, A., Patil, Jyoti P., Deka, B.J., Jain, S.K., Singh, S. P. and Joshi, H. (2022). "Governance, Conflicts, and Gender Mainstreaming in Water Management". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 68. | Satyaji Rao, Y. R., Nayak, S.K., Yenagimath, G., Teeparthi, V. and Kumar, S. (2021). "Assessment of Submarine Groundwater Discharge (SGD) zones along the coastal tract of Odisha", Proceedings of the "HYDRO 2021 26th International Conference on Hydraulics, Water Resources and Coastal Engineering (online mode)",  held at SVNIT, Surat, during 23-25 December 2021. |
| 69. | Satyaji Rao, Y.R. (2022). "Urban Flood Modeling and Management" at International Conference on "Emerging Trends in Water Resources and Geo-Environmental Engineering held at MVGR College of Engineering, Vizianagaram, Andhra Pradesh during 27-29 January 2022. |
| 70. | Satyaji Rao, Y.R., Vijay, T., Sivaprasad, Y. and Kumar, S. (2022).  "Impact of Geogenic and anthropogenic sources on groundwater salinity in Godavari delta, Andhra Pradesh, India". Proceedings of the International Conference on "Emerging Trends in Water Resources and Geo-Environmental Engineering held at MVGR College of Engineering, Vizianagaram, Andhra Pradesh during 27-29 January 2022. |
| 71. | Senthil Kumar, A.R., Sambare, R., Chourasia, S.K., Arora, M., Allaka, N. Rao. (2022). "Assessment of land use and climate change effect on streamflow and sediment yield of Bhagirathi basin up to Tehri dam". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 72. | Sharma, M.K., Arora, M., Sharma, B. and Prasad, B. (2022). "Diurnal variations of hydrological and hydro-chemical parameters in the meltwater of Gangotri Glacier, Uttarakhand, India". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 73. | Singh, B., Krishan, G., Rao, M.S., Singh, P., Shad, S.A., Tripathi, S., Ojha, R., Srivastava, R. and Guha, S.  (2022). "Methodological considerations for the collection of air moisture for isotopic analysis". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 74. | Thakur, D., Sharma, A. and Goel, P. (2021). "Manganese Contamination in Alluvial Region of Saharanpur District, Uttar Pradesh, India". Proceedings of the International Conference on Recent Advances in Water Science and Technology (ICRAWST-2021), Chennai, Dec. 02-03, 2021. |
| 75. | Thomas, T., Sharma, G., Nayak P.C., Venkatesh, B. and Indwar, S.P. (2022). "Evaluation of Critical Dry Spells and Supplemental Irrigation Planning for Chambal basin in Western M.P. India". Proceedings of the 2nd Roorkee Water Conclave (RWC) jointly organized by the IIT Roorkee and NIH Roorkee during 02 – 04 March, 2022 at Roorkee. |
| 76. | Venkata Ramana, Jeyakanthan, V.S. and Satyaji Rao, Y.R. (2021). "River flood simulation using hydrological and hydrodynamic model". Proceedings of the International conference on Research & Development in Civil Engineering (RDCE'21) organized by Department of Civil Engineering, SVKM's Institute of Technology, Dhule, Maharashtra India during December 23-24, 2021. |
| 77. | Venkata Ramana, R., Jeyakanthan, V. S. and Satyaji Rao, Y.R. (2022).  "Nagavali River Basin |

| | Flash Flood Simulation Model". Proceedings of the International Conference on Civil Engineering, Architecture and Sustainable Infrastructure (2nd ICCEASI - 22) organized by Babu Banarasi Das University, Lucknow in association with Institute For Engineering Research and Publication (IFERP) during February 9-10, 2022. |
|---|---|
| 78. | Venkata Ramana, R., Satyaji Rao, Y.R. and Jeyakanthan, V.S. (2022). "Flood Forecasting of East Flowing Rivers Using Data Driven Models". Proceedings of the 2$^{nd}$ International Conference on Emerging Trends In Water Resources and Geo-Environmental Engineering during January 27-29, 2022, Department of Civil Engineering, MVGR College of Engineering (Autonomous), Vizianagaram, Andhra Pradesh, India. |
| 79. | Vijaya Kumar, S V. (2022). Locating Suitable Sites for Recharge Basins in Upland Sandstone Formations. Proceedings of the Roorkee Water Conclave March 2022 organized by IIT and NIH during 2-4 March, 2022 at Roorkee, Uttarakhand, India. |
| 80. | Vijayakumar, S.V. (2021). "Groundwater Flow Modeling for Evaluating Specific Yield Sensitivity of a Sandstone Aquifer system in Gunderu Sub-basin". Proceedings of the "Hydro 2021 International 26th International Conference on Hydraulics, Water Resources and Coastal Engineering (online mode)", held at SVNIT, Surat, during 23-25 December 2021. |

| NATIONAL CONFERENCE/SEMINAR/ WORKSHOP | |
|---|---|
| 1. | Kumar, S. V. Vijaya (2022). "Erosion and sedimentation study of Tungabhadra upper sub-using RS & GIS". Proceedings of the National Seminar on Hydrology with focal theme changing climate and extreme hydrology events organized by AHI, Visakhapatnam in virtual mode hosted by Andhra University, Visakhapatnam 25-26 Feb 2022. |
| 2. | Sabale, R. and Jose, M.K. (2021). "Reservoir sedimentation Analysis using SWAT model". Proceedings of the HYDRO-2022 Conference, ISH Journal. |
| 3. | Satyaji Rao, Y.R. and Sharma, M.K. (2022). "Water quality monitoring and management during extreme events with special reference to emerging contaminants". Proceedings of the National Seminar on Hydrology (Focal theme: Changing climate and extreme hydrological events) held during 25-26 Feb., 2022, pp.34, online by AHI, Andhra University, Visakhapatnam. |

**LIST OF PUBLICATIONS PUBLISHED DURING 2022-23 (April - June 2022)**

| INTERNATIONAL JOURNAL | |
|---|---|
| 1. | MacAllister, DJ., Krishan, G, Basharat, M., Cuba, D., MacDonald A.M. 2022. A century of groundwater accumulation in Pakistan and northwest India. Nature Geoscience. https://doi.org/10.1038/s41561-022-00926-1 |
| 2. | Singh L., Mishra P.K., Pingale S.M., Khare D., Thakur H.P. (2022) Streamflow regionalisation of an ungauged catchment with machine learning approaches. Hydrological Sciences Journal, Taylor and Francis.https://doi.org/10.1080/02626667.2022.2049271. Impact factor = 3.787. |
| 3. | Manikandan, P. and Satyaji Rao, Y.R. (2022). Mapping and Change Detection of Water Bodies in the Godavari Delta using Geospatial Technology. ADBU-Journal of Engineering Technology, ISSN: 2348-7305, Volume 11, Issue 1, May, 2022 011010032(6PP) |
| 4. | Abhilash, R., Venkatesh.B., Srinivasa, V.C., and Patankar, D.B., (2022) Geospatial Approach for Integrated Command Area Management, J. Irrig. Drain Eng., 2022, 148(4): 04022003, DOI: 10.1061/(ASCE)IR.1943-4774.0001659 |
| 5. | Thomas T., Sharma, G., Nayak P.C., Venkatesh B. (2022). "Development of a Framework for Integrated Assessment of Drought Vulnerability in Chambal Basin in Western Madhya Pradesh". International Conference on water and Environment Management (WEM_2022), CWRDM Kozhikode, 22-24 June, 2022. |
| 6. | Ankur Rajpal, Akansha Bhatia, NileshTomar, A AKazmi, Chandra Shekhar P Ojha, Vinay Kumar Tyagi (2022) Insight into a novel post-anoxic integrated biofilm process for wastewater treatment and reclamation. Journal of Water Process Engineering, 49, 102957 [IF: 5.485]. |

| 7. | Shashi Kant Bhatia, Vishal Ahuja, Neha Chandel, RanjitGurav, Ravi Kant Bhatia, MuthuswamyGovarthanan, Vinay Kumar Tyagi,Vinod Kumar,ArivalaganPugazendhi, J Rajesh Banu, Yung-Hun Yang(2022) Advances in algal biomass pretreatment and its valorisation into biochemical and bioenergy by the microbial processes. Bioresource Technology, 358, 127437[IF: 9.642]. |
|---|---|
| 8. | Sharma, M. K., Kumar, Pradeep, Bhanot, Kunarika and Prajapati, Parul, Wadhwa, Udita Wadhwa, Tomar, Garima, Goyal, Rakesh, Prasad, Beena and Sharma, Babita(2022) Study of hydrochemical and geochemical characteristics and solute fluxes in Upper Ganga Basin, India, J. Asian Earth Sciences: X, https://doi.org/10.1016/j.jaesx.2022.100108 |
| 9. | Waikhom, R.S., Patidar, N., Taggu, A. (2023). Investigation of Climate Extremes: A Study in Dudhnoi River Basin, India. In: Bhattacharjya, R.K., Talukdar, B., Katsifarakis, K.L. (eds) Sustainable Water Resources Management. Advances in Sustainability Science and Technology. Springer, Singapore. https://doi.org/10.1007/978-981-16-7535-5_6. |
| 10. | Barman, S., Tyagi, J.V. and Singh, W.R. (2023). 'Future rainfall trend analysis over Puthimari river basin: A comparative study using different CMIP5 models'. In: Bhattacharjya, R.K., Talukdar, B., Katsifarakis, K.L. (eds), Sustainable Water Resources Management, Advances in Sustainability Science and Technology, Springer, Singapore, 19-28. |
| 11. | Krishan, Gopal, Bhattacharya, Prosun, Chaudhary, A, Rao, MS,. Vashish Rajesh (2022). Groundwater contamination in SW Punjab, India. In: Frontiers in Hydrology, AGU 2022, Sanu Juan, Perto Rico June 19-24, 2022, https://agu.confex.com/agu/hydrology22/meetingapp.cgi/Paper/1034042 |
| 12. | Kumar, Puspendra, Krishan, Gopal, Nema, AK and Thankur, Aradhana ( 2022) Occurrence and Distribution of Arsenic concentrations in Ghazipur District, Uttar Pradesh, India In: Frontiers in Hydrology, AGU 2022, Sanu Juan, Perto Rico June 19-24, 2022, https://agu.confex.com/agu/hydrology22/meetingapp.cgi/Paper/1035714 |
| 13. | Choudhary S., Pingale S.M., Khare D. (2022) Delineation of groundwater potential zone of upper Godavari sub-basin using bi-variate, MCDM and advanced machine learning algorithm.*Geocarto International Journal, Taylor and Francis* . Impact factor = 4.889.https://www.tandfonline.com/doi/abs/10.1080/10106049.2022.2093992. |
| 14. | Gelebo A.H., Kasiviswanathana K.S., Khare D., Pingale S.M. (2022) Assessment of spatial and temporal distribution of surface water balance in data-scarce African transboundary river basin. Hydrological Sciences Journal, Taylor and Francis Impact factor = 3.942. https://doi.org/10.1080/02626667.2022.2094268. |
| 15. | Nema, M K, (2022). "Field hydrology and Experimental Catchment based research studies in the lesser Himalaya" in the International online workshop on Scaling Effects on Runoff Assessment/Monitoring organized by ICAR – Indian Institute of Soil and Water Conservation, RC, Udhagamandalam on May 31, 2022. |
| 16. | Dar, Tanveer, Rai, Nachiketa, Kumar, Sudhir, and Aadil Bhat. (2022) Climate change impact on cryosphere and streamflow in the Upper Jhelum River Basin (UJRB) of North-western Himalayas", Environmental Monitoring and Assessment. 194, 140 (2022). https://doi.org/10.1007/s10661-022-09766-3. |
| 17. | Ajit Kumar Behera, Rudra Mohan Pradhan, Sudhir Kumar, Govind Joseph Chakrapani, Pankaj Kumar, 2022. Groundwater dynamics in shallow aquifer system of Mahanadi delta (east coast), India. Water. 2022; 14(4).https://doi.org/10.3390/w14040611. |

| INTERNATIONAL CONFERENCE/SEMINAR/ WORKSHOP | |
|---|---|
| 1. | Kale, R.V., P. G. Jose, Drona Khurana (2022) presented research paper entitled as "Analysis of September 2014 Catastrophic flood event in the part of Tawi River, India" on 30th May 2022 at 2nd International Conference on River Corridor Research and Management (RCRM-2022) organized by IIT Guwahati and IIT Jammu during 30th May to 1st June 2022. |

| | CHAPTERS IN BOOKS |
|---|---|
| 1. | Pandey, RP (2021) Hydrological Drought in India – An institutionalized systemic hydrological management challenge (Case study 2). A policy-note contribution in FAO publication entitled "A rapid review of drought risk mitigation measures – Integrated drought management" (Author: Caroline King-Okumu; Eds: Maher Salman, FAO-UN and Daniel Tsegai, UNCCD). Rome, FAO, pp. 128-131, https://doi.org/10.4060/cb7085en. |
| 2. | Krishan, G, Prakash, J, Dasgupta, P, Mackenzie, A, Devi, Thiyam Thampasana. 2022. Groundwater Salinity—Impacts and Possible Remedial Measures and Management Solutions In: Lama et al (Eds.), Transforming Coastal Zone for Sustainable Food and Income Security. 52: Springer (Book Chapter) |
| 3. | Krishan, Gopal, Nagar, Anoop, Angurala, M L., Rana, Rakesh, Sudarsan, N. 2022. Hydrogeology, Groundwater Regimes and Quality Issues in Punjab. In: Chandniha, SK, Lohani, AK, Krishan, G and Prabhakar, A. (Eds). Advances in Hydrology and Climate Change- Historical trends and new approaches in water resources management. Apple Academic Press 419-428 |

| | BOOK |
|---|---|
| 1. | Chandniha, SK, Lohani, AK, Krishan, G and Prabhakar, A. 2022. "Advances in Hydrology and Climate Change- Historical trends and new approaches in water resources management" Apple Academic Press |

# LIST OF WORKSHOPS/ TRAINING COURSES/ SYMPOSIA ORGANISED
# DURING AUGUST 2021- JUNE 2022

## LIST OF WORKSHOPS/ TRAINING COURSES/SYMPOSIA ORGANISED DURING AUGUST 2021- MARCH 2022

| SN. | ACTIVITES | PERIOD | VENUE |
|---|---|---|---|
| **INTERNATIONAL ACTIVITIES** | | | |
| 1. | Roorkee Water Conclave – 2022 | March 2 – 4, 2022 | IIT-Roorkee |
| 2. | India-UK Workshop on 'Mobilization of Fluoride in Groundwater' | February, 1-4, 2022 | Virtual Mode |
| **NATIONAL ACTIVITIES** | | | |
| **CONFERENCES/SEMINARS/SYMPOSIA/WORKSHOPS** | | | |
| 1. | Recorded webinar on 'Water for Public Health (W4PH): Preparing for Disasters and Pandemics' | August 26 - October 06, 2021 | Virtual Mode |
| 2. | ISO 9001:2015 Internal Auditors Training | September 23-24, 2021 | NIH Roorkee |
| 3. | Three days' virtual workshop on Eco-hydrology for sustainable development | October 06-08, 2021 | HRRC, NIH, Belagavi |
| 4. | Workshop on "Climate change impact and Adaptation in the Water sector in India". | October 25, 2021 | NIH, Roorkee |
| 5. | Flood Management and Erosion Control | January 27-28, 2022 | Virtual Mode (CFMS, Patna) |
| 6. | World Water Day | March 22, 2022 | Hybrid Mode, (NIH, Roorkee) |
| **TRAINING COURSES** | | | |
| 5. | Five-day online training on "Hydrological Modeling using Soil and Water Assessment Tool (SWAT): Theory and Hands-on" sponsored by National Hydrology Project (NHP) for 23 participants from 10 state governments water resources departments and 03 central implementing agencies. | August 16-20, 2021 | NIH, Roorkee |
| 6. | Training course on "Advanced Hydrology and Modelling Tools" | August 16-20, 2021 | Virtual Mode |
| 7. | Five Days' Training on "Hydrodynamic Modeling using HEC RAS" under National Hydrology Project. | August 23-27, 2021 | Virtual Mode |
| 8. | Springshed management and rejuvenation through scientific data collection and processing techniques | August 24-25, 2021 | Divisional Forest Office, Narendranagar, Uttarakhand |
| 9. | Recorded webinar on 'Water for Public Health (W4PH): Preparing for Disasters and Pandemics' (33 presentations from 35 speakers) | August 26 - October 06, 2021 | Virtual Mode |
| 10. | ISO 9001:2015 Internal Auditors Training | September 23-24, 2021 | NIH, Roorkee |
| 11. | Why and How of patenting for Indian academicians and R&D institutes | September 29, 2021 | Virtual Mode |
| 12. | हिन्दी कार्यशाला 'प्रयोजनमूलक हिंदी' | September 29, 2021 | Virtual Mode |
| 13. | Training course on ' Impact of Climate Change, Flood Mitigation and Drought Vulnerability' for the participants of WRD, Shillong officials | October 4-7, 2021 | Shillong, Meghalaya |
| 14. | Three days' training workshop on "Eco-hydrology for Sustainable Development" | October 6-8, 2021 | Virtual Mode |

| 15. | Four Days' Mandatory Level-II training for Senior Research Assistants (SRAs) of CWC sponsored by NWA, CWC, Pune | October 20-23, 2021 | Virtual Mode |
|---|---|---|---|
| 16. | Five Days' Training on "Water Accounting Plus (WA+) for all Northeast IAs" | November 15-19, 2021 | Shillong, Meghalaya |
| 17. | Organized 5-day Online Training Course titled "Water Quality Assessment & Management" under NHP | December 6-10, 2021 | Virtual Mode |
| 18. | Five Days' training on "Climate Change and Hydrological Impact Assessment" | December 6-19, 2021 | Virtual Mode |
| 19. | Enhancing Capability to Address Climate Change in Integrated Water Resources Management (IWRM) in Uttarakhand State organized by NIH, INC-IHP, UNESCO | December 7, 2021 | Hybrid Mode (NIH Roorkee) |
| 20. | 4-days training on "Hydrological Modeling for Water Resource Management" under National Hydrology Project. | December 08-11, 2021 | Raipur |
| 21. | Training Course on "Scientific data collection and processing techniques for springshed management and rejuvenation" | December 13-17, 2021 | NEHARI, Brahmaputra Board, Guwahati, Assam |
| 22. | Online training workshop on "Life Cycle Approach for Rejuvenation of Ponds and Lakes using Nature-Based Solution" under National Water Mission. | December 13-17, 2021 | HRRC, Belgaum |
| 23. | "प्रयोजनमूलक हिन्दी " वषय पर एक दिवसीय हिन्दी कार्यशाला का आयोजन। | December 27, 2021 | Virtual Mode |
| 24. | Tools and Techniques for Springshed Management under National Mission on Himalayan Studies (NMHS), MOEF&CC | January 06-07, 2022 | Virtual Mode |
| 25. | Online National Level Training Programme on "Floods and Drought Risk Mitigation Under Climate Change" jointly Organized by NIH and NIDM, New Delhi | February 2-4, 2022 | Virtual Mode |
| 26. | Five Days' online training on "Soil and Water Assessment Tool (SWAT)" sponsored by Indian Council of Forestry Research and Education (ICFRE), Dehradun. | February 28 to March 04, 2022 | Virtual Mode (NIH, Roorkee) |
| 27. | Hands-on session on "Climate Impact Indicators for Water Security" organised during the 2nd Roorkee Water Conclave (RWC) 2022 | March 4, 2022 | IIT, Roorkee |
| 28. | Advanced Training Program cum Workshop on Groundwater Modelling | March 05-08, 2022 | Jaipur |
| 29. | Training Course on "Groundwater Modelling and Management" | March 21-25, 2022 | Virtual Mode |
| 30. | E-course on "Hydro-meteorological and Climate Data Analysis: Basics and Advanced Techniques" | March 21-25 2022 | Virtual Mode |
| 31. | Stakeholder Consultation Workshop on "GRACERS Project" | March 22, 2022 | Haldia (W.B.) |
| 32. | Three Days' online training workshop on "Flood Management and Erosion Control" organised by NEHARI, Brahmaputra Board and NIH Roorkee | March 28-30, 2022 | Virtual Mode |

**LIST OF WORKSHOPS/ TRAINING COURSES/SYMPOSIA ORGANISED DURING APRIL – JUNE 2022**

| S.No. | Name of the Course | Date | Venue | No. of Participants |
|---|---|---|---|---|
| **PLAN** | | | | |
| 1. | 5-day training workshop on "Flood Management and Erosion Control" organised by NIH and NEHARI | 9-13 May, 2022 | NEHARI, Brahmaputra Board | 22 |
| **NHP** | | | | |
| 1. | Groundwater contaminant transport monitoring & modelling (NHP – PDS – 19) | 23 to 27 May 2022 | Online | 40 |
| **Sponsored** | | | | |
| 1 | 12-days training programme on "Water Resources Planning and Management" | April 15-25, 2022 | sponsored by META Nashik for the engineers of the Water Resource Department (WRD) of the Government of Maharashtra | 19 |
| 2. | Training on "Remote Sensing and GIS" in the Induction Course for Newly Appointed AE's of WRD (Irrigation), Government of Bihar in four batches | 02 May 2022, 12 May 2022, 23 May 2022 and 30 May 2022 | | 50 |
| 3. | Training on "Approaches for Management of Groundwater Quantity and Quality with special focus on MAR" | 06-10 June, 2022 | jointly organized by NIH, Roorkee, Indian Institute of Technology, Roorkee, Kindai University Japan, and Pusan National University, South Korea | 48 |
| 4. | Training on "Remote Sensing and GIS" in the Induction Course for Newly Appointed AE's of Project and Development (P&D) Department, Government of Bihar in two batches | 06 Jun 2022 and 30 Jun 2022. | | 50 |

# PROGRESS OF LABORATORY WORK DURING THE PERIOD AUGUST 2021- JUNE 2022

**1. Water Quality Laboratory**
**2. Nuclear Hydrology Laboratory**
**3. Soil-Water Laboratory**

**Chemical and Bacteriological Analysis of Water Samples in Water Quality Laboratory for the period between August, 2021 to June, 2022**

|  | No. of samples of Division | No. of samples of Regional Centre | No. of samples of Outside Agencies on payment basis |
|---|---|---|---|
| Physico-chemical analysis | 2201 | - | - |
| Bacteriological analysis | 60 | - | - |
| Metal analysis | 71 | - | - |
| Pesticide analysis | 673 | - | - |
| **Total analysis** | 3005 | - | - |

**Details of samples analyzed by the Nuclear Hydrology Laboratory during August 2021 to June, 2022**

| Sl. No. | Parameter Analyzed | No. of Samples |
|---|---|---|
| 1. | $\delta^2$H on DI-IRMS | 5649 |
| 2. | $\delta^{18}$O on CF-IRMS | 5390 |
| 3. | Tritium | 260 |
| 4. | WQ samples on IC | 1150 |

## Soil Water Laboratory
## Laboratory Analysis carried out during the period Aug 2021 to June. 2022.

| Sl. No. | Name of the studies | No. of Samples | Parameters Measured |
|---|---|---|---|
| 1. | Hydrological modelling for evaluation of return flow and irrigation planning for optimal utilization of water resources in the command of Sanjay Sagar Project in Madhya Pradesh | 12 No. | 1.Determination of soil texture using sieve shaker and laser based particle size analyzer.<br>2 Determination of soil moisture retention characteristics by disturbed soil samples using Pressure Plate Apparatus. |
| 2. | Development of decision tool for efficient utilization of water resources in Prabati Canal & Dholpur piped irrigation project of Rajasthan. | 10 No. | 1.Determination of soil texture using sieve shaker and laser based particle size analyzer.<br>2 Determination of soil moisture retention characteristics by disturbed soil samples using Pressure Plate Apparatus. |
| 3. | Integrated Management of water resources for quantity and quality in Upper Yamuna Basin Project. | 54 No.<br><br>77 No.<br><br>19 No.<br><br>252 No. | 1.Determination of soil texture using sieve shaker and laser based particle size analyzer.( Fifty Four(54)<br><br>Determination of soil moisture retention characteristics by disturbed soil samples using Pressure Plate Apparatus. (Seventy Seven(77)<br><br>Determination of Permeability. Bulk Density,Dry Density(Ninteen(19)<br><br>Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 4. | Hydrological Study of area in the victinity of SEL Manufacturing Co.Ltd Navashahar Punjab | 15 No.<br><br>49 No. | Determination of soil texture using sieve shaker and laser based particle size analyzer.<br><br>Trace element analysis(Soil & Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 5. | Seasonal characterization of Gangotri Glacier melt runoff simulation of stream flow variation under different Climate Scenario. | 16 No. | Determination of soil texture using laser based particle size analyzer. |
| 6. | Impact of Rain Water Harvesting on Groundwater Quality in India with Specific Reference of Fluoride and Other Micro-pollutants, Laporiya, Bhadrajun,Bayana Bharatpur ( Rajasthan) | 08 No.<br><br>16No.<br><br>418 No. | 1. Determination of soil texture using sieve shaker and laser based particle size analyzer.<br><br>2.Determination of soil moisture retention characteristics by disturbed soil samples .<br><br>Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 7. | Hydrological studies conserve the water source of Bikaner | 08 No. | 1.Determination of soil texture using sieve shaker and laser based particle size analyzer. |

| | | 2.Determination of soil moisture retention characteristics by disturbed soil samples using Pressure Plate Apparatus. |
|---|---|---|
| 8. | Estimation of economic losses in real time per hectare basis due to forest fire in Uttarakhand and Madhya Pradesh | 56 No.<br><br>108 No<br><br>114 No.<br><br>326 No. | 1.Determination of soil texture using sieve shaker and laser based particle size analyzer. (56 Disturbed Samples).<br>2.Determination of soil moisture retention characteristics by disturbed soil samples (108Disturbed Samples).<br>3.Determination of Permeability using ICW Lab Permeameter Undisturbed Samples(114 Undisturbed Samples).<br>4.Determination of Carbon, Hydrogen, Nitrogen,Sulphur using CHNS analyser |
| 9. | Investigation of Chamoli disaster | 04 No. | Determination of soil texture using sieve shaker and laser based particle size analyzer . |
| 10. | Cosmos soil moisture monitoring | 02 No. | Determination of soil texture using sieve shaker and laser based particle size analyzer |
| 11. | Ground Water Investigation of Rana Sugars Ltd Buttar Seviyan area of Amritsahar, Punjab | 21 No.<br><br><br>36 No. | 1.Determination of soil texture using sieve shaker and laser based particle size analyzer.<br>2.Determination of Dry Density & Porosity.<br><br>Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 12. | Contaminant Transport modeling using HYDRUS ( Jamia Millia Islamia New Delhi) | 04 No. | 1.Determination of soil texture using sieve shaker and laser based particle size analyzer.<br>2.Determination of Permeability using ICW Lab Permeameter<br>3. Determination of soil moisture retention characteristics by disturbed soil samples using Pressure Plate Apparatus. |
| 13. | Optimisation of SBR Plants (IIT Civil Deptt Roorkee) | 03 No. | Determination of Particle size using laser based particle size analyzer. |
| 14. | Comparing the disparate impact of Oak and Chir Pine Tree spices on their local hydrological regimes. | 14 No. | 1.Determination of soil texture using sieve shaker and laser based particle size analyzer. |
| 15. | Leachate Transport Modeling for Gazipur Landfill Site for Suggesting ameliorative measures (PDS-19) | 10 No.<br><br><br>368 No. | 1.Determination of Bulk Density,Dry Density.<br>2.Determination of Permeability using ICW Lab Permeameter<br><br>Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 16. | Sample from College of Technology G.B.Pant Univ. Pantnagar | 18 No. | Determination of soil moisture retention characteristics by disturbed soil samples using Pressure Plate Apparatus. |
| 17. | Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their possible remedial measures | 151 No. | Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 18. | Enhancing Food and water Security in Arid | 9 No. | Trace element analysis(Water Samples) i.e. |

| | | | |
|---|---|---|---|
| | Region through improved understanding of Quantity, Quality and Management of Blue, Green and Gray Water | | Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 19. | Groundwater Quality Assessment of Morigaon district of Assam with emphasis on Arsenic & Fluoride Contamination | 43 No. | Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 20. | Assessment of saline and fresh water Zones in Faridkot, Fazilka and Muktsar districts of Malwa region of Punjab | 12 No. | Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 21. | Integrated Study of GW dynamics in the coastal aquifers of W. Bengal for sustainable GW management (SP-28/PDS 11/2017-18) | 40 No. | Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 22. | Chemical and Isotopic characterization of Deep aquifer G.W. of middle Ganga basin (SP-28/PDS-12) | 72 No. | Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 23. | Hydro Geological study for Tanda Thermal Power Station Stage- II (2x660 MW) | 32 No. | Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 24. | Web-enabled Inventory of Natural water springs of Tawi River catchment of Jammu & Kashmir state of India for vulnerability analysis and developing adaptive measures for sustaining Tawi River watershed in Jammu & Kashmir state | 19 No. | Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 25. | Hydro-Geological Studies in Meja in Prayagraj District of UP | 69 No. | Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 26. | Review of Hydrogeology to assess impact of NTPC Mouda on Surface water and Ground regime especially around ash dyke St-I & II and propose specific measures | 65 No. | Trace element analysis(Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 27. | Hydro Geochemical evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin (PDS-10) | 102 No.<br><br>93 No. | Trace element analysis i.e. Total Arsenic<br><br>Trace element analysis(Soil and Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |
| 28. | Indo-UK NERC Far-Ganga study- Future Secular changes and remediation of Groundwater Arsenic in Ganga River Basin | 47 No.<br><br>104 No. | Trace element analysis i.e. Total Arsenic<br><br>Trace element analysis(Soil and Water Samples) i.e. Al, As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn |

# MINUTES OF THE 51st MEETING OF THE WORKING GROUP OF NIH

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**MINUTES OF THE**
**52ND MEETING OF WORKING GROUP OF NIH**
**HELD AT NIH, ROORKEE, DURING 12-13 APRIL 2022**

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The meeting was held in hybrid mode under the Chairmanship of Dr. J V Tyagi, Director, NIH. The list of participants of the meeting is given in Annexure-I.

**ITEM NO. 52.1: 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 2021-22 and formulate the work program of 2022-23. The Chairman then requested the WG members to give their general observations, suggestions and remarks on the scientific activities of the Institute. These are summarized below:

| S N | Member | Suggestion(s) |
|---|---|---|
| 1. | Dr. Manoj P.Samuel | <ul><li>Avoid duplication and redundant studies</li><li>Collaboration with CWRDM</li><li>Climate change impact in coastal areas</li><li>Work on water footprint, Early Warning Systems</li><li>Explore copyright for software</li></ul> |
| 2. | Prof. A K Saraf | <ul><li>Improve presentation skills</li><li>Exhaustive literature survey needed before proposing a new study</li></ul> |
| 3. | Dr. Bhishm Kumar | <ul><li>Upload work program on NIH website</li><li>Link scientists at NIH RCs through VC</li></ul> |
| 4. | Dr. S. S. Grewal | <ul><li>Focus on groundwater in Kandi areas in Punjab and Haryana</li></ul> |
| 5. | Dr.Ramakar Jha | <ul><li>Studies should be outcome based</li><li>Any new study should address 'Why' and 'How', and must include literature survey</li><li>Explore patents, innovations; involve water industry</li></ul> |
| 6. | Dr. Sadhana Malhotra | <ul><li>Improve presentation skills- rehearsal by presenters</li><li>Bring out impact of completed studies</li></ul> |
| 7. | Sh. Sudhindra Mohan Sharma | <ul><li>Research should be society oriented/useful for society</li><li>Focus of drinking water studies</li><li>Strengthen outreach activities</li></ul> |
| 8. | Dr. M S Rathore | <ul><li>Time period of studies should not be too long</li></ul> |
| 9. | Dr. Pawan Labhasetwar | <ul><li>Reduce long study periods</li><li>Field studies addressing water quality should have suggestions for mitigation and/or adaptation</li></ul> |

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

**ITEM No. 52.2: CONFIRMATION OF MINUTES OF 51st MEETING OF WORKING GROUP**

The 51st meeting of the Working group was held during 14-15June, 2021 in VC mode. The minutes of the meeting were circulated to all the members and invitees vide letter No. **RMOD/WG/NIH-10 dated 26 July, 2021**. The members confirmed the minutes of the 51st Working Group meeting.

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412

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**ITEM No. 52.3: ACTION TAKEN ON THE DECISIONS/RECOMMENDATIONS OF THE PREVIOUS WORKING GROUP MEETING**

Dr V C Goyal gave a brief account of the actions taken on the recommendations/ decisions of the 51ST working group meeting.

**ITEM Nos. 52.4 & 52.5: PRESENTATION AND DISCUSSION ON THE STATUS AND PROGRESS OF THE WORK PROGRAMME FOR YEAR 2021-22 AND FINALIZATION OF THE WORK PROGRAMME FOR YEAR 2022-23**

The Member-Secretary requested the respective Divisional Heads to present the progress of studies carried out during 2021-22 and also to present the proposed studies for F.Y. 2022-23. Accordingly, the progress of various studies and sponsored projects, and proposal for new studies and projects during 2022-23, were presented by all Scientific Divisions during the two-day deliberations of the Working Group. The Division wise minutes of each study/project presented during the meeting are given next.

## ENVIRONMENTAL HYDROLOGY DIVISION

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

**Progress of Work Program for 2021-22 and Recommended Work Program for the year 2022-23**

| S. No. | Study | Suggestions/Comments |
|---|---|---|
| | **Sponsored Projects** | |
| 1. | Title: Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures<br>Study Group: Rajesh Singh (PI), Pradeep Kumar, M. K. Sharma, Sumant Kumar<br>Partner: Irrigation Deptt., Punjab<br>**Duration:** 3½ Years (09/17 –3/21)<br>Extension requested till 09/21<br>**Sponsored by:** NHP-PDS<br>**Project Cost:** 65.6 Lakh<br>Status: Completed | Progress of the study was reported and there were no specific suggestions/comments. |
| 2. | Title: Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures<br>**Study Group:** Anjali (PI), Sudhir Kumar, J.V. Tyagi, M.K. Sharma<br>Partner: CGWB (Delhi unit)<br>**Duration:** 3 Years (11/19 –10/22)<br>**Sponsored by:** NHP-PDS<br>**Project Cost:** 76.1 Lakh<br>Status: In-progress | Progress of the study was reported and there were no suggestions/comments. The PI of this project has been transferred from EH Division to HI Division. Therefore, this study is transferred to HI Division. |
| 3. | Title: Water Efficient Irrigation by Using SCADA System for Medium Irrigation Project | Progress of the study was reported and there were no specific suggestions/comments. |

| | | |
|---|---|---|
| | (Mip) Shahnehar<br>Study Group: R.P. Pandey, (PI), Jagdeesh Patra, Rajesh Singh, N. K. Bhatnagar<br>**Duration:** 3 Years (12/17 –12/20)<br>Extension requested till 03/22<br>**Project Cost:** 75.0 Lakh<br>Status: In-progress | |
| 4. | Title: Isotopic and geochemical approach to study vulnerable confined and unconfided drinking water aquifers in Varanasi and surrounding area<br>Study Group:<br>Rajesh Singh (PI), R. P. Pandey<br>BHU, Varanasi (Lead)<br>Other Collaborators: BARC, Mumbai, ICER, Hungary<br>**Duration:** 3 years (07/21-07/24)<br>**Project Cost:** Rs. 10.0 Lakh<br>**Sponsored by:** BHU<br>**Status:**In-progress | Progress of the study was reported and there were no specific suggestions/comments. |
| | **Internal Studies** | |
| 5. | **Title:** Water quality assessment for Haridwar District<br>**Study Group:** R.K. Nema (PI), Rajesh Singh, J. V. Tyagi, R. P. Pandey, Pradeep Kumar<br>**Duration:** 2 years (05/19-06/21)<br>**Status:** Completed | • The working group member,Dr. Bhism Kumar (Ex. Scientist, NIH & IAEA) appreciated the study and its outcomes. He suggested for further investigation to find out the causes of deterioration in next study.<br>• Sh. Prashant Rai, CGWB suggested to replace the contour maps with point maps.<br>• Prof. A. K. Saraf, IIT Roorkee suggested to check and validate the interpolation method. |
| 6. | **Title:** Simulation of Non-Point Source Pollution Processes in Song River<br>**Study Group:** Pradeep Kumar (PI), J.V. Tyagi, M.K. Sharma, Rajesh Singh<br>**Duration:**4 years (11/19-10/23)<br>**Status:** In-progress | Progress of the study was reported and there were no specific suggestions/comments. |
| 7. | **Title:** Development of rejuvenation plan for Hindon river system<br>**Study Group:** M. K. Sharma (PI), Dr. Sudhir Kumar (Project Coordinator), R. P. Panday, Anupma Sharma, Anjali, Vishal Singh, Pradeep Kuamr, Nitesh Patidar, Surjeet Singh, Rajesh Singh.<br>**Duration:**3 years (07/20 to 06/23)<br>**Status: Closed from EH Division** | Progress of the study was reported and there were nospecific suggestions/comments. T<br><br>This study has been Transferred to HI Division and merged with DST-NWO Project on River Hindon |
| 8. | **Title:** Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar<br>**Study Team:** Rajesh Singh (PI), J.V. Tyagi, R.P. Pandey, R.K. Nema, Pradeep Kumar, M.K. Sharma<br>**Duration:** 2 Years (06/20 – 05/22) | Prof. Ramakar Jha, NIT Patna suggested to consider the pollutants load in addition to their concentration for interpreting the impact. |

| | | |
|---|---|---|
| | **Status:** In-progress | |
| 9. | **Title:** Understanding Arsenic mobilization in groundwater of Haridwar and formulating remediation measures<br>**Study Team:** Rajesh Singh (PI), R.K. Nema, Sumant Kumar, Pradeep Kumar, M.K. Sharma<br>**Duration:** 3 Years (07/21 – 06/24)<br>**Status:** In-progress | Progress of the study was reported and there were no specific suggestions/comments. |
| | **Internal Studies (New Study)** | |
| 10. | **Title:** Characterisation of Groundwater Dynamics in Krishna-Godavari Delta using groundwater levels, Hydrochemistry, Isotopes and Emerging Contaminants<br>**Study Group:** M. K. Sharma (PI), Suhas Khobragade, Rajesh Singh, Y. R. S. Rao, Collaborating Agency: CGWB, Hyderabad<br>**Duration:** 2 years (04/22 to 03/24)<br>**Budget:** Rs. 17.60 lakh<br>**Status:** New Study | Dr. Sharma presented the study proposal. Dr. Prashant Rai, CGWB appreciated the proposed study and suggested that this is the right time to take up this study for the benefit of society. |

## GROUND WATER HYDROLOGY DIVISION

Dr. M. K. Goel, Scientist 'G' & Head, GWHD, presented a brief overview, status of studies and activities carried out by the division since the 51st Working Group meeting. He gave an account of scientific personnel available in the division; ongoing and completed internal, sponsored and consultancy projects; and also the future activities planned by the division for the year 2022-23. MKG informed that one in-house R&D study and nine sponsored studies were approved for the year 2021-22.

In addition to the above studies, scientists of the division have a major role in activities of the National Hydrology Project (NHP); development of DSS (Planning and Management); development of groundwater module for "*National Hydrologic Model (NHM)*" with IIT Kharagpur; Computer Centre; External Project Management Cell; and procurement related activities. 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. Three new in-house R&D studies that are planned in the year 2022-23 and two completed sponsored studies were presented. The progress of five on-going studies was also presented by the respective Principal Investigators.

A special one-hour session was dedicated to present the major outcomes of the National Mission for Sustaining Himalayan Ecosystem (NMSHE) project entitled **"Integrated Hydrological Studies for Upper Ganga Basin up to Rishikesh" which was sponsored by DST.** This project focuses on the issues of comprehensive integrated hydrological studies for upper Ganga basin up to Rishikesh and involves 11 sub-projects with different study teams. The study was completed on Sep 2021 and the final report has been completed by March 31, 2022 and the same was shared with WG members during its meeting. MKG, who worked as the Coordinator of NMSHE Project, briefly presented the work components, objectives and major achievements of all the 11 sub-projects. WG members appreciated the work done by NIH.

The details of the GWHD studies presented in the WG meet are provided in the table below.

| S. No. | Project | Project Team | Duration & Status | Funding Source |
|---|---|---|---|---|
| **Internal Studies** | | | | |
| 1. NIH/GWH/NIH /20-22 | Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System | **Nitesh Patidar (PI)**, Gopal Krishan, Suman Gurjar | 2 years (08/20 – 07/22) *Status: **In progress*** | Internal Study |
| 2. NIH/GWH/ NIH/22-25 | Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin | **Sumant Kumar (PI),** Surjeet Singh, Rajesh Singh, Gopal Krishan, M.K. Sharma, Vinay Kumar Tyagi, S.S. Rawat, Nitesh Patidar, P.K. Mishra, M.K. Goel | 3 years (04/22 – 03/25) Status: **New Study** | Internal Study |
| 3. NIH/GWH/ NIH/22-24 | Conjunctive Management of Water Resources in IGNP Command | **Nitesh Patidar (PI)**, M. K. Goel, Anupma Sharma, Gopal Krishan, Surjeet Singh, Sumant Kumar, Nidhi Kalyani | 2 years (04/22 – 03/24) Status: **New Study** | Internal Study |
| 4. NIH/GWH/ NIH/22-24 | Studying Groundwater Dynamics using Machine Learning and Numerical Modelling | **Nidhi Kalyani (PI)**, Anupma Sharma, Nitesh Patidar, Sumant Kumar | 2 years (04/22 – 03/24) Status: **New Study** | Internal Study |
| **Sponsored Projects** | | | | |
| 5. NIH/GWH/BG S/17-20 | Groundwater Fluctuations and Conductivity Monitoring in Punjab - Groundwater resilience in Punjab and adaptation to future changes in climate and water resource demands (title modified by funding agency) | **Gopal Krishan (PI)**, S. Singh, C. P. Kumar (retd.), M. S. Rao BGS, UK: Dr. Dan Lapworth Dr. Alan MacDonald Dr. Daren Goody | 5 years (12/17-11/22) Status**: In progress** | BGS, UK |
| 6. NIH/GWH/DS T/ 18-20 | Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA | **B. Chakravorty (PI)**, Surjeet Singh (Dy. Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar Other India Partners: IITR, IITKg, MCS, Patna UK Partners: Univ. of Manchester, BGS, Salford University, Univ. of Birmingham | 4 years (01/18 - 12/21) Status: **Completed** | DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme |
| 7. NIH/GWH/DS T/ 18-20 | Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micro-pollutants | **Anupma Sharma (PI)**, Sumant Kumar, Gopal Krishan, Suman Gurjar, M. K. Sharma Indian Partners: IIT Ropar, IIT Jodhpur UK Partner: Cranfield University, Water Harvest, Excellent Develop. (UK based NGO) | 4 years (01/18 - 02/22) Status: **Completed** | DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme |

| 8. NIH/GWH/DST/ 19-23 | Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water | **Anupma Sharma (PI)**, Gopal Krishan, Nitesh Patidar (Lead: CAZRI Jodhpur, Partners: NIH Roorkee, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur) | 5 years (03/19 - 02/24) Status: **In progress** | DST |
|---|---|---|---|---|
| 9. NIH/GWH/ CCRBF/20- 23 | Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF | **Gopal Krishan** (PI & Co-coordinator) | 3 years (07/20 – 06/23) Status: **In progress** | Federal Min. of Education and Research, Germany |
| 10. NIH/GWH/ DST-SERB/21-24 | Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen | **Gopal Krishan (PI)**, M.S. Rao | 3 years (04/21 – 03/24) Status: **In progress** | DST-SERB |

The suggestions emerged during the presentation of these studies are given below:

| S. No. | Title of Project | Status and Recommendations/Suggestions |
|---|---|---|
| **Internal Studies** | | |
| 1 | Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System | Dr. Nitesh Patidar (PI) presented the objective-wise progress, results, and interface of the model developed under the study. Mr. Sudhindra Mohan Sharma asked about the model inputs, such as GW extractions and lithology and PI clarified the same. Prof. Saraf asked about the estimation of irrigation requirement in the model and PI clarified the same by explaining the LAI-based method used in the model. Prof. Ramakar Jha asked about the groundwater observation inputs in the model and PI clarified that observations are required for calibration and validation. WG members appreciated the work. |
| 2 | Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin | Dr. Sumant Kumar (PI) presented the background, objectives, methodology and expected outcome of the new proposed internally funded study. The WG members appreciated and recommended to take up the study as the project outcomes would be helpful for providing safe drinking water to the community of arsenic affected areas. The WG members are of view that study area is large and hence they suggested PI to look after the resources and accordingly study area may be curtailed down, if possible. PI responded that the study area may be finalized after internal discussions. One of the WG members suggested to contact researchers working in the field of arsenic genesis and treatment. PI replied with thanks that NIH team is already in contact with few IITs. |
| 3 | Conjunctive Management of Water Resources in IGNP Command | Dr.Nitesh Patidar (PI) presented the problem statement, objectives and methodology of the new internal R&D study. WG member, Dr. Sudhir Kumar, suggested to look at an earlier study done by NIH in IGNP. WG members also suggested to review the studies done in IGNP and PI agreed on the suggestion. Dr. |

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| | | Gopal Singh Bhati appreciated the work stating that a lot of changes have happened during past 20 years in groundwater levels and cropping patterns in the area and the assessment of the current status of groundwater and water logging is needed in IGNP. |
| 4 | Studying Groundwater Dynamics using Machine Learning and Numerical Modelling | Ms. Nidhi Kalyani (PI) presented the background, objectives and methodology of the study. Prof. Ramakar Jha suggested to explore the various input layers required in the machine learning model and the PI agreed on the suggestion. |
| **Sponsored Projects** | | |
| 5 | 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) | Dr. Gopal Krishan (PI) presented the variation in water level in last 150 years, trend of groundwater depletion mainly due to the onset of pumping; correspondence between shallow and deep is notable; deep and shallow groundwater have similar isotopic compositions and seasonal groundwater response, highlighting the vertical connectivity of the aquifer system<br>Dr. S.S. Grewal (Retd. Director), PAU, Ludhiana, appreciated the work and told that work should be disseminated to the policy makers. Dr. M.K. Goel replied that the work has already been presented in Punjab Vidhan Sabha.<br>Dr. M.S. Rathore, Director CEDS, Jaipur, asked about the contribution of return flow in groundwater and effect of cropping pattern on groundwater levels to do similar study in Haryana. PI informed that component of irrigation return flow was found in groundwater but it is not quantified, for effect of cropping pattern PI replied that there was a model shown depicting the groundwater level variations due to the change in cropping pattern. Regarding the similar study in Haryana, PI replied that the NIH is already doing a PDS under NHP in Mewat region.<br>Dr. Sudhinder Mohan Sharma, Consultant ex-nodal officer MoDWS, Indore, asked about the groundwater quality status in different aquifers. PI, informed that a plot was already shown to mark changes in salinity variations. |
| 6 | Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA | Dr. Surjeet Singh (PI) presented the study in detail and reported that the study is completed and a final presentation was already made to DST. No comments were made by the WG Members. |
| 7 | Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micro-pollutants | Dr. Anupma Sharma (India Lead PI) presented the study approved under the India-UK DST-NERC-EPSRC Water Quality Research Programme (Newton Bhabha fund). The research objectives of the study, and the work packages were presented. Field investigations and data collection that were carried out at the fluoride affected field sites in Rajasthan, recharge attributable to rainwater harvesting structures, and the related laboratory experiments and results of chemical analysis were presented. Mobilization of fluoride under saturated conditions and fluoride release kinetics were presented using results of lysimeter and column experiments and geochemical modeling. |
| 8 | Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water | Dr. Anupma Sharma (PI from NIH) presented the DST sponsored WATER-IC project in which the lead agency is CAZRI, Jodhpur. The overall objectives of the study, and research objectives taken up by NIH were presented. Work being carried out in IGNP area in Rajasthan pertaining to estimation of groundwater recharge using water balance model and stable |

418

| | | isotope analysis, as well as climate variability in the area were presented. Progress regarding field experiments to study the impacts of different irrigation schedules on a selected crop was shown. It was explained that the data generated will be used for model calibration. One of the Working Group Experts, Shri Sudhindra Mohan Sharma suggested that help from local community would further facilitate the data generation. |
|---|---|---|
| 9 | Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF | Dr. Gopal Krishan (PI) presented motivation for the study, development of a demonstration site, searching for new site for RBF well and progress under the project. No comments were made by WG members |
| 10 | Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen | Dr. Gopal Krishan (PI) presented the background, statement of the problem, objectives, methodology, progress and future plans of the study with main emphasis on methodology. The presentation was well appreciated. Dr. M. Samuel, Director CWRDM, asked about the methods for measuring ET and asked about use of Lysimeter. PI told that the experiments will be conducted at IIT-Kanpur and all the results will be validated and uncertainty analysis will be carried out. |

## RECOMMENDED WORK PROGRAM FOR THE YEAR 2022-23

| S. No. | Project | Project Team | Duration & Status | Funding Source |
|---|---|---|---|---|
| | | **Internal Studies** | | |
| 1. NIH/GWH/NIH/ 20-22 | Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System | Nitesh Patidar (PI), Gopal Krishan Anupma Sharma | 2 years (08/20 – 07/22) *Status: In progress* | Internal Study |
| 2. NIH/GWH/NIH/ 22-25 | Studying arsenic genesis and developing alternate water supply management strategies in Ganga basin | Sumant Kumar (PI), S. Singh, R. Singh, G. Krishan, S. S. Rawat, M.K. Sharma, N. Patidar, P. K. Mishra, M. K. Goel | 3 years (04/22 – 03/25) Status: **New Study** | Internal Study |
| 3. NIH/GWH/NIH/ 22-24 | Conjunctive Management of Water Resources in IGNP Command | Nitesh Patidar (PI), M. K. Goel, Anupma Sharma, Gopal Krishan, Surjeet Singh, Sumant Kumar, Nidhi Kalyani | 2 years (04/22 – 03/24) Status: **New Study** | Internal Study |
| 4. NIH/GWH/NIH/ 22-24 | Studying Groundwater Dynamics using Machine Learning and Numerical Modelling | Nidhi Kalyani (PI), Anupma Sharma, Nitesh Patidar, Sumant Kumar | 2 years (04/22 – 03/24) Status: **New Study** | Internal Study |
| | | **Sponsored Projects** | | |
| 5. NIH/GWH/BGS/ 17-20 | Groundwater Fluctuations and Conductivity Monitoring in Punjab - Groundwater resilience in Punjab and adaptation to future changes in climate and water resource demands (title modified by funding agency) | Gopal Krishan (PI), S. Singh, C. P. Kumar (retd.), M. S. Rao *BGS, UK:* Dr. Dan Lapworth Dr. Alan MacDonald Dr. Daren Goody | 5 years (12/17-11/22) *Status: In progress* | BGS, UK |
| 6. | Assessment of Impacts of | Gopal Krishan (PI), | 4 years | NHP under PDS |

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|---|---|---|---|---|
| NIH/GWH/PDS/ 17-21 | Groundwater Salinity on Regional Groundwater Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures | Surjeet Singh, C. P. Kumar (Retd.), *IIT-Roorkee:* M. L. Kansal, Brijesh Yadav *Sehgal Foundation:* Lalit Mohan Sharma | (12/17-07/22) *Status: In progress* | |
| 7. NIH/GWH/PDS/ 17-21 | Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study | Surjeet Singh (PI), C. P. Kumar, Sudhir Kumar, Suman Gurjar, Gopal Krishan | 4 years (12/17-07/22) *Status: In progress* | NHP under PDS |
| 8. NIH/GWH/CEH M/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, Sumant Kumar, P.K. Mishra, V. Singh, N. Patidar, N. Kalyani *Partners* Haryana Irr. & WR Dept., UPGW Dept., UYRB, CWC | 4 years (04/18-01/24) *Status: In progress* | Special Project under "Centre of Excellence" (NHP) |
| 9. NIH/GWH/DST/ 19-23 | Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water | Anupma Sharma (PI), Gopal Krishan, Nitesh Patidar (*Lead*: CAZRI Jodhpur, *Partners*: NIH Roorkee, IISWC Dehradun, CSWRI & CIAH, Bikaner, NIAM Jaipur) | 5 years (03/19 - 02/24) *Status: In progress* | DST |
| 10. NIH/GWH/CCR BF/20-23 | Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF | Gopal Krishan (PI & Co-coordinator) | 3 years (07/20 – 06/23) *Status: In progress* | Federal Min. of Education and Research, Germany |
| 11. NIH/GWH/DST-SERB/21-24 | Partitioning Evapotranspiration into Evaporation and Transpiration fluxes using Stable Isotopes of Oxygen and Hydrogen | Gopal Krishan (PI), MS Rao | 3 years (04/21 – 03/24) *Status: In progress* | DST-SERB |
| 12. NIH/GWH/APN/ 22 | Capacity Development Program on Site Suitability Mapping for Managed Aquifer Recharge (MAR) under Varying Climatic Conditions using Remote Sensing and Machine Learning based Hydrological Modelling Tools | Nitesh Patidar (PI), S. Singh, G. Krishan *IIT Roorkee(lead):* Basant Yadav, Ashish Pandey, R D Singh, B. J. Deka *In-kind support:* KU, Japan: Yutaka Matsuno, PNU, South Korea: Sanghyun Jeong | 10 months (01/22-10/22) *Status: New Study* | Asia-Pacific Network (APN) |
| **Consultancy Projects** | | | | |
| 1. | Groundwater Investigations of Rana Sugars Ltd. Buttar Seviyan Area of | Surjeet Singh (PI) | 6 months (01/22 – 06/22) | NIT, Jalandhar (Punjab) |

| | | | Amritsar District, Punjab | | *Status: In progress* | |
|---|---|---|---|---|---|---|

## HYDROLOGICAL INVESTIGATIONS DIVISION

Dr Sudhir Kumar, Scientist-G and Head of the H. I. Division presented the brief details of the Division including the scientific staff strength and infrastructure. He briefly introduced about the scientific work of the Division and the various studies being carried by the Division, 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 2021-22.

Table 1: Details of training Courses/Workshops organised by HI Division during April 2021-March, 2022

| S. N. | Topic | Duration | Coordinator | Venue | No. of Participants |
|---|---|---|---|---|---|
| 1. | Scientific data collection and processing techniques for springshed management and rejuvenation | 05 Days (13-17 Dec 2021) | Dr S S Rawat | Guwahati | 25 |
| 2. | Tools and techniques for springshed management | Two Days (06-07.01.2022) | Dr SS Rawat | Jammu | 39 |
| 3 | Stakeholder Consultation Workshop on "GRACERS Project" | March 22, 2022 (01 day) | Dr. SM Pingale | Haldia, West Bengal | 50 |

Table 2: Details of Research Publications by HI Division during April 2021-March, 2022

| Publication | Published | Accepted | Communicated | Total |
|---|---|---|---|---|
| Books / Book Chapter | 01 | - | - | 01 |
| International Journals | 24 | - | 15 | 39 |
| National Journals | 02 | 02 | 01 | 05 |
| International Conferences | 11 | 02 | - | 13 |
| National Conferences | 02 | - | - | 02 |
| Total | 40 | 04 | 16 | 60 |

The progress of each individual study for the year 2021-22 and the proposal for a new study was presented by the respective P.I. of the study. A new study for springs of Tehri Garhwal district of Uttarakhand was proposed by Dr. M.S. Rao, Scientist-F. However, Chairman, working group observed that another study on springs of Tehri Garhwal district is already being undertaken by the division. So, the Chairman, working group suggested that instead of Tehri Garhwal, Dr. M.S. Rao may come up with a proposal on springs of North-East region.

The comments/actions suggested by the working group for various studies are as follows:

| S. N. | Project Title | Study Team | Duration | Comments |
|---|---|---|---|---|
| **INTERNAL STUDIES:** | | | | |
| 1. | Assessment of impact of land use and land cover change on | M. Someshwar Rao (PI) Sudhir Kumar | 2 years (04/21– 03/23) | Dropped |

| S. N. | Project Title | Study Team | Duration | Comments |
|---|---|---|---|---|
| | groundwater conditions in parts of Sabarmati river Basin, Gujarat | Vipin Aggarwal | | |
| 2. | Integrated Hydrological Investigations of Renuka lake, Himachal Pradesh, for its Conservation and Management | SD Khobragade (PI) Sudhir Kumar Hukam Singh Rajiv Gupta Vipin Agarwal Scientist from GoH.P. | 3 years (07/20-06/23) | Dropped |
| 3. | Assessment of dissolved radon concentration in groundwater of Uttarakhand | Hukam Singh (PI), M Someshwar Rao, Soban Singh Rawat, Vipin Agarwal | 1 ¾ years (04/21-12/22) | No Comments |
| 4. | Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions of India | SD Khobragade (PI), Dr. Vishal Singh, Sudhir Kumar | 3 years (04/22-03/25) | No Comments |
| **SPONSORED PROJECTS:** | | | | |
| 1. | Dating very old ground waters of deeper aquifers in Ganga Plains, India | M. Someshwar Rao (PI) Sudhir Kumar | 3 Years (06/16 -12/22) | Not presented |
| 2. | Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin | Sudhir Kumar (PI) M. Someshwar Rao Vipin Aggarwal | 3 ½ year (01/18 – 06/22) | Not presented |
| 3. | Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management | M. Someshwar Rao (PI), Sudhir Kumar A. R. Senthil Kumar V. S. Jeyakanthan | 3 ½ years (01/18-06/22) | Not presented |
| 4. | Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand | Suhas Khobragade (PI) Sudhir Kumar | 3 years (01/18-06/22) | Not presented |
| 5. | Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS) | Sudhir Kumar (PI) SM Pingale | 2 years (06/19 – 09/22) | Not presented |
| 6. | Web-GIS Based Spring Inventory for Vulnerability Assessment and Hydro-Geological Investigation of Selected Springs for Sustaining Local Water Demand in Ravi Catchment of Himachal Pradesh | S S Rawat (PI) Sudhir Kumar P G Jose, Suman Gurjar, D S Bisht | 4 years (08/17-09/22) | Not presented |
| 7. | Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River | S S Rawat (PI) P G Jose, Suman Gurjar, D S Bisht | 3 years (01/19-09-22) | No comments |

| S. N. | Project Title | Study Team | Duration | Comments |
|---|---|---|---|---|
| 8. | Changing the fate of the Hindon river by evaluating the impact of agriculture on the water balance: Developing a template for a cleaner Ganga river | Sudhir Kumar, (*Proj. Coordinator*), M. K. Sharma, (PI), Suhas Khobragade, Anjali, Vishal Singh, SM Pingale, Nitesh Patidar, Surjeet Singh. | 5 years (04/22-03/27) | Not presented |

**RECOMMENDED WORK PROGRAMME FOR THE YEAR 2022-23**

| S. N. | Project Title | Study Team | Duration | Status |
|---|---|---|---|---|
| **INTERNAL STUDIES:** | | | | |
| 1. | Assessment of dissolved radon concentration in groundwater of Uttarakhand | Hukam Singh (PI), M Someshwar Rao, Soban Singh Rawat, Vipin Agarwal | 1 ¾ years (04/21-12/22) | Continuing Study |
| 2.. | Assessment of the Possible Impact of Climate Change on Evapotranspiration for Different Climatic Regions Of India | SD Khobragade (PI), Dr. Vishal Singh, Sudhir Kumar | 3 years (04/22-03/25) | New Study |
| 3. | Ascertaining the efficacy of use of State of the art technologies for spring mapping and sustainability of springs through suitable interventions | Soban Singh Rawat, (PI) Sudhir Kumar, Santosh M. Pingale, P K Mishra, D. S. Bisht, Rajesh Singh | 3 years (04/22-03/25) | New Study |
| 4. | Studies for selected springs of Tehri Garhwal region, Uttarakhand | MS Rao (PI) and Team | | Chairman suggested that instead of Tehri Garhwal, a proposal on study of springs of North-East region may be formulated. |
| **SPONSORED PROJECTS:** | | | | |
| 1. | Dating very old ground waters of deeper aquifers in Ganga Plains, India | M. Someshwar Rao (PI) Sudhir Kumar | 3 Years (06/16 - 12/22) | Continuing Study IAEA under CRP |
| 2. | Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin | Sudhir Kumar (PI) M. Someshwar Rao Vipin Aggarwal | 3 ½ year (01/18 – 06/22) | Continuing Study NHP (PDS) |
| 3. | Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management | M. S. Rao (PI), Sudhir Kumar A. R. Senthil Kumar V. S. Jeyakanthan | 3 ½ years (01/18-06/22) | Continuing Study NHP (PDS) |
| 4. | Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand | Suhas Khobragade (PI) Sudhir Kumar | 3 years (01/18-06/22) | Continuing Study NHP (PDS) |

| S. N. | Project Title | Study Team | Duration | Status |
|---|---|---|---|---|
| 5. | Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS) | Sudhir Kumar (PI) SM Pingale | 2 years (06/19 – 09/22) | Continuing Study (IIT Bombay, Mumbai) |
| 6. | Web-GIS Based Spring Inventory for Vulnerability Assessment and Hydro-Geological Investigation of Selected Springs for Sustaining Local Water Demand in Ravi Catchment of Himachal Pradesh | S S Rawat (PI) Sudhir Kumar P G Jose, Suman Gurjar, D S Bisht | 4 Years 17/08)– 0922/) | Continuing Study NHP (PDS) |
| 7. | Web-enabled Inventory of Natural Water Springs of Tawi River Catchment of Jammu and Kashmir State of India for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River | S S Rawat (PI) P G Jose, Suman Gurjar, D S Bisht | 3 years (01/19- 09/22) | Continuing Study (NMHS) |
| 8. | Leachate transport modelling for Gazipur landfill site for suggesting ameliorative measures | Anjali (PI) Sudhir Kumar, J. V. Tyagi M. K. Sharma Partner: CGWB (Delhi unit) | 3½ years (11/19 – 06/23) | Continuing Study NHP (PDS) Transferred from EHD |
| 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 | Sudhir Kumar, (Proj. Coordinator), M. K. Sharma, (PI), Suhas Khobragade, Anjali, Vishal Singh, SM Pingale, Nitesh Patidar, Surjeet Singh. | 5 years (04/22- 03/27) | DST |

## SURFACE WATER HYDROLOGY DIVISION

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

**Work Program for the Year 2021-22**

| S. N. | Title | Status and Recommendations/ Suggestions |
|---|---|---|
| | **Completed Internal Studies** | |
| 1 | Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Mahi & Sabermati subzone – 3a (2) Upper Narmada -3e. **Study Group:** S.K. Singh **DOS:** April 2021 **DOC:** March 2022 | **Status:** Completed Study presented. |
| 2 | Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin **Study Group:** Archana Sarkar, Surjeet Singh, | **Status:** Completed Chairman suggested to fine tune the report including rewriting the section on key |

| | | |
|---|---|---|
| | Suman Gurjar, Sunil Gurrapu<br>**DOS:**Nov. 2018**DOC:** March 2022 | messages of the study and submit the final report for review. |
| 3 | Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario.<br>**Study Group:** Ashwini Ranade, Archana Sarkar<br>**DOS:**April 2018**DOC:**Sept. 2021 | **Status:** Completed<br>Study presented. |
| 4 | Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the Godavari and Narmada River Basins.<br>**Study Group:** Sunil Gurrapu, Ashwini Ranade, J.P. Patra<br>**DOS:**Nov 2018 **DOC:**Oct. 2021 | **Status:** Completed<br>Dr. S S Grewal, inquired on how this study could be useful to an implementing agency to plan watershed management plan. The PI of the study responded saying that the relationships established in this study could be useful to estimate water availability in the watershed, which can be useful in planning a better management plan for a watershed.<br>Dr. Ramakar Jha, NIT Patna inquired about the opposite correlations in the cane of gauges from Narmada basins. The PI of the study said that the monsoon rainfall across central India was shown to be least affected by PDO or ENSO, as studied by Krishnamurthy & Krishnamurthy, 2013. So, the opposite correlations were as expected. Dr. Jha also suggested that instead of developing linear relationships, non-linear regressions could be developed using all the indices used in this study. The PI of the study agreed with Dr. Jha and said that multi-linear or non-linear regressions may be developed based on the relationships established in this study.<br>Dr. C T Dhanya, IIT Delhi said that statistically significant correlations between annual floods and PDO, could be misleading because many of the flow gauges were regulated along the basins. The PI of the project said that the significant correlations were also seen in the natural gauges, and the reservoir operations could also be influenced indirectly by these oscillations, i.e. on the water available in the basin. Dr. Dhanya agreed that if the correlation is significant in the natural gauges also, this can be accepted.<br>Dr. Ashok Das, agreed with the PI of the project that the opposite correlations in the case of gauges from Narmada basin are because of the opposite relationships between monsoon rainfall and PDO in this region, as established by Krishnamurthy & Krishnamurthy, 2013.<br>Mr. N N Rai, CWC was asking (online) about the impact of climate change on PMP in Indian watersheds, but the question was not clearly heard because of connectivity issues. The PI of the project said that the literature review on the |

| | | same has been done and a status report was prepared. Dr. J V Tyagi suggested that the same report shall be shared with Mr. Rai and ask for a review of the report. Dr. J V Tyagi, suggested that the title of the project should be changed to show the names of the study basins, i.e. Godavari and Narmada. |
|---|---|---|
| **Completed Sponsored Studies** | | |
| 1 | Hydrological modelling in Alaknanda basin and assessment of climate change impact (NMSHE) **Study Group:** A.K. Lohani, Sanjay K. Jain, Archana Sarkar, V.S. Jeyakanthan, L.N. Thakural **DOS:** April 2016 **DOC:** March 2021 | **Status:** Completed Study not presented. |
| 2 | Rainfall-Runoff Modelling of Selected Basin based on LULC pattern and development of Correlation (NHP) **Study Group:** A.K. Lohani, R.K. Jaiswal, Sushant Jain; Sanjay Agarwal, Shailendra Kumar **DOS:**Oct. 2019**DOC:**April 2022 | **Status:** Completed Study not presented. |
| **Ongoing Sponsored Studies** | | |
| 1 | Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh (NHP) **Study Group:** P C Nayak, Y.R.Satyaji Rao, A.K. Lohani, B. Venkatesh, A. R. S. Senthil Kumar, T. Thomas **DOS:**Sept 2019 **DOC:**April 2023 | **Status:** Ongoing Study not presented. |
| **Ongoing Internal Studies** | | |
| 1 | Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan **Study Group:** J.P. Patra, Rakesh Kumar, Pankaj Mani, Sunil Gurrapu **DOS:** August 2020; **DOC:** July 2022 | **Status:** Ongoing Study not presented. |
| 2 | Uncertainty in rating curves and discharge estimation **Study Group:**Sanjay Kumar, L. N. Thakural, Sunil Gurrapu, N.K. Bhatnagar, J P Patra **DOS:**April 2021; **DOC:**March 2023 | **Status:** Ongoing Study not presented. |

**RECOMMENDED WORK PROGRAMME FOR THE YEAR 2022-23**

| ONGOING SPONSORED STUDIES | | | | |
|---|---|---|---|---|
| S. N. | Title | Study Team | Duration | Status & Comments |

| 1 | Dam break studies of Kandaleru and Pulichintala dams in Andhra Pradesh (NHP) | P C Nayak<br>Y.R.Satyaji Rao<br>A.K. Lohani<br>B. Venkatesh<br>A. R. S. Senthil Kumar<br>T. Thomas | 3 year (Sept 2019 to April 2023) | On-going |
|---|---|---|---|---|
| **ONGOING INTERNAL STUDIES** | | | | |
| 1 | Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan. | J.P. Patra<br>Rakesh Kumar<br>Pankaj Mani<br>Sunil Gurrapu | 2 years (July 2020 to August 2022 | On-going |
| 2 | Uncertainty in rating curves and discharge estimation | Sanjay Kumar<br>L. N. Thakural<br>Sunil Gurrapu<br>N.K. Bhatnagar<br>J P Patra | 2 Years (April 2021 to March 2023) | On-going |
| **NEW INTERNAL STUDIES** | | | | |
| 1 | Development of Cloud Data Based Integrated Framework to Forecast Flood for Efficient Operation of Reservoirs | Dr. A. K. Lohani, Sc-G<br>Dr. R. K. Jaiswal, Sc-E<br>Mr. J. P. Patra, Sc-D<br>Dr. P. C. Nayak, Sc-F<br>Dr. Vishal Singh, Sc-D | Two Years April 2022 – March 2024 | No specific action Suggested |
| 2 | Application of unified-extreme-value (UEV) distribution for flood frequency: selected rivers of U.S.A. | S.K. Singh | Six month (April 2022 to Sept. 2022) | No specific action Suggested |
| 3 | Application of unified-extreme-value (UEV) distribution for flood frequency: Comparison of results using GEV distribution | S.K. Singh | Six month (Oct. 2022 to March 2023) | No specific action Suggested |
| 4 | Flood Forecasting under Changing Climate Conditions - Role of Machine Learning and Conceptual/Physical based Model | P. C. Nayak<br>A. K. Lohani<br>J. P. Patra<br>Sunil Gurrapu<br>T. Thomas<br>Om Prakash<br>Jatin Malhotra | 3 Year (July2022 to June2025) | No specific action Suggested |
| 5 | Hydrological Study to conserve the water resources of Bikaner, Rajasthan | L. N. Thakural<br>M. K. Shama<br>R. K. Jaiswal<br>J. P. Patra<br>P. K. Mishra<br>Nitesh Patidaar<br>N. K. Bhatnagar<br>Jatin Malhotra<br>Anil Kumar Chhangani | 2 Year (July2022 to June2024) | Dr. A. K Saraf, working group member, suggested to modify the name of study by substituting revival and restoration instead of conservation. |
| 6 | Review of design flood and dam break analysis of Khadakhai Dam in Odisha | J.P.Patra<br>A. K. Lohani<br>Pankaj Mani<br>P. C. Nayak<br>Sanjay Kumar | 3 Year (April2022 to March2025) | No specific action Suggested |

| 7 | Climate change scenarios for Andhra Pradesh and its impact on streamflow and groundwater levels in Pennar River basin | Sunil Gurrapu<br>Y R S Rao<br>Nitesh Patidar<br>R Venkat Raman | 2 Year (April2022 to March2024) | Dr. C T Dhanya suggested that a separate objective should be added in this project to evaluate and reduce (optimize) the uncertainty in the projected hydrological scenarios. She said such analysis will be important because this project being an implementable research, the implementing agency would want to know how to handle the uncertainty. The PI of the project agreed to the same and an appropriate objective will be framed after discussing it with the other member of the team.<br>Dr. Ramakar Jha suggested that a basic literature review should have been presented either in the proposal or during the presentation. The PI of the project informed that the objectives have been framed after discussing with the Chief Engineer of the implementing agency. |
| 8 | Investigation on occurrences of extreme rain events across Northwest Himalaya in relation to global atmospheric thermal and circulation changes | Ashwini Ranade<br>P.K. Mishra<br>Sunil Gurrapu | 3 years (April2022 to March2025) | The committee members appreciated the importance of the study as well suggested minor modification in the title of the project. |
| 9 | 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<br>Jyoti Patil<br>Rohit Sambare<br>Charu Pandey | 1.5 Year (May2022 to Oct2023) | No specific action Suggested |

**Training Courses/Workshops and Research Publications Completed During 2021-22**

| Trainings/ | Research publications | | | | |
|---|---|---|---|---|---|
| Workshops Organized | International Journals | National Journals | International Conferences | National Conferences | Chapters in books |
| 13 | 3 | 1 | 7 | 4 | 2 |

**Training Courses/Workshops and Research Publications Planned During 2022-23**

| Trainings/ | Research publications | | | | |
|---|---|---|---|---|---|
| Workshops to be Organized | International Journals | National Journals | International Conferences | National Conferences | Chapters in books |
| 10 | 2 | 4 | 5 | 5 | 2 |

## <u>WATER RESOURCES SYSTEMS DIVISION</u>

Dr. Sanjay K Jain (SKJ), Sc. G and Head, presented an overview of the Division – scientific strength, the ongoing studies, sponsored & consultancy studies, technical publications and training courses organized. Thereafter, internal studies were presented by the respective PIs as given below:

| SN | Study | Status and Recommendations/ Suggestions |
|---|---|---|
| | **Completed Sponsored/ Internal Studies** | |
| 1. | **Title:** Upgradation of NIH_ReSyP to .NET Platform – a Reservoir Operation Package **Team:** D. Chalisgaonkar (DC); M. K. Goel **Duration:** 1 year (08/20-03/22) **Funding:** NIH **Status:** Completed | DC presented the progress of the completed study. She informed that significant efforts have been made for the finalization of the revised version of NIH_ReSyP – 2022. All the 20 modules and their forms in .NET framework have been developed. Based on the inputs from the users, substantial improvements in the previous modeling system have been made. She informed that the following new modules have been added: <br>• Storage-Yield-Reliability relationship <br>• Instant estimation of reservoir inflow using rate of rise <br>• Modules added to help operator in finding actual release to be made depending on the prevalent policy. <br>• Instant estimation of release for flood control <br>• Spillway discharge rating table <br>• Instant spillway discharge estimation <br>She also informed that the help files for different modules are provided along with the software, so no separate report will be prepared and the output will be only in the form of software. |
| 2. | **Title:** Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2). Team:** D. S. Rathore; (Now Deepa Chalisgaonkar is PI) V. S. Jeyakanthan; L. N. Thakural; **Duration:** 5 years (01/16-03/21) (Extended till Sept., 2021) **Funding:** DST **Status:** Completed | A special session of one-hour duration was allotted to briefly present the important outcomes of the eleven studies jointly conducted under National Mission for Sustaining the Himalayan Ecosystem (NMSHE). Dr. M. K. Goel, Project Coordinator, NMSHE presented the studies on behalf of all the Investigators. Dr Sanjay K Jain, Smt Deepa Chalisgaonkar, Dr M. K. Nema, and Dr. P. K. Mishra contributed during the presentation. Dr Goel informed that the study was completed by September, 2021 and the final report has been |

| 3. | **Title:** Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3).** **Team:** Sanjay K. Jain; A. K. Lohani; Sudhir Kumar; Praveen Thakur (IIRS) **Duration:** 5 years (01/16-03/21) (Extended till Sept., 2021) **Funding:** DST **Status:** Completed | prepared. He also shared the hard copy of the report with the members. |
|---|---|---|
| 4. | **Title:** Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios **(Sub-project – 4)** **Team:** Sanjay K. Jain; Sharad K. Jain (Retd.); P. K. Mishra; M. Arora; AP Dimri (JNU) **Duration:** 5 years (01/16-03/21) (Extended till Sept., 2021) **Funding:** DST **Status:** Completed | |
| 5. | **Title:** Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin **(Sub-project – 5)** **Team:** M K Nema; Sharad K. Jain (Retd.); Sanjay K. Jain; P K Singh, P. K. Mishra; P. K. Agarwal; AP Dimri (JNU) **Duration:** 5 years (01/16-03/21) (Extended till Sept., 2021) **Funding:** DST **Status:** Completed | |
| 6. | **Title:** Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11).** **Team:** P. K. Mishra; M. K. Nema; Pradeep Kumar **Duration:** 5 years (01/16-03/21) (Extended till Sept., 2021) **Funding:** DST **Status:** Completed | |
| **Ongoing Sponsored/ Internal Studies** | |
| 1. | **Title:**Snow and glacier contribution and impact of climate change in Teesta river basin in Eastern Himalaya **Team:** Sanjay K. Jain; P. K. Singh; M. Arora; A. K. Lohani; Vishal Singh; **Duration:** 3 years (11/19-11/22) **Funding:** NMHS-MoEF **Status:** Ongoing | Not presented. |
| 2. | **Title:**Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin **Team:** Vishal Singh (VS); A. P. Dimri | Not presented. |

| | | |
|---|---|---|
| | (JNU); Sanjay K. Jain<br>**Duration:** 3 years (06/19-11/22)<br>**Funding:**NRDMS-DST<br>**Status:** Ongoing | |
| 3. | **Title:**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.<br>**Team:** P K Singh (PKS); P K Mishra; P K Agarwal<br>**Duration:** 2 years (08/20-07/22)<br>**Funding:** NHP<br>**Status:** Ongoing | Not presented. |
| 4. | **Title:** Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework.<br>**Team:** P K Mishra (PKM); P K Singh; P K Agarwal<br>**Duration:** 2 years (06/21-05/23)<br>**Funding:** NHP<br>**Status:** New | Not presented. |
| 5. | **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 sub-basins in the state of Mizoram<br>**Team:** Vishal Singh (VS); M K Nema; P K Singh; Vanlalpekhlua Sailo (SDO from Mizoram); Lalruatkima (JE from Mizoram)<br>**Duration:** 2.5 years (06/21-05/24)<br>**Funding:** NHP<br>**Status:** New | Not presented. |
| 6. | **Title:**Impacts of glacier and climate change on runoff for selected basins of Himalayan region<br>**Team:** Vishal Singh (VS); Sanjay K. Jain (SKJ);<br>Manohar Arora<br>**Duration:** 2 years (08/20-07/22)<br>**Funding:** NIH<br>**Status:** Ongoing | VS presented the study on 'Impacts of glacier and climate change on runoff for selected basins (3 Nos) of Himalayan region'. He presented the outcome of the studies of the two catchment modelled so far. He said that the study of third catchment is under progress. The work related to impact of climate change is under progress and will be completed in next three months. He informed the work carried out for Baspa basin has already been published in Journal of Hydrology. The members asked about the validation of contribution of snow and glaciers. Dr. VS and Dr. SKJ informed that the results related to melt from snow/glacier combined have been compared with the previous works. For validation of snow and glacier melt separately. Dr. Bhism Kumar suggested to compare the results with isotope analysis based results. Chairman/Director said that the detailed analysis of isotopes for the separation of snow + glacier Q can be taken as a new study in the next phase after the submission of the present work. |

| | | Dr. M K Goel informed that isotopic analysis has been carried for upper Ganga basin under NMSHE and the outcome of the study can be considered for comparison. VS noted the suggestions. |
|---|---|---|
| 7. | **Title:**Monitoring and Hydrological Modelling of Henvel watershed in Lesser Himalaya<br>**Team:** M K Nema; Sanjay K Jain; P K Mishra; P K Agarwal;<br>**Duration:** 3 years (08/20-07/23)<br>**Funding:** NIH<br>**Status:** Ongoing | MKN presented the progress pertaining to third objective of the study, i.e., soil moisture modelling. He informed that an empirical model based on meteorological observations was already developed and presented in the previous working group meeting. In this meeting, Dr Nema explained the application of artificial intelligence (AI) in soil moisture modeling using different AI models such as MLP-ANN, DNN, SVM, MLR etc. The predicted soil moisture based on the AI model was satisfactory. The performance of the DNN model outplayed rest of the models as stated above. He further informed that a few Hybrid-AI models are also being developed and tested on the experimental catchments. The results shall be shared in the coming WG meetings. Director NIH suggested to run the SWAT model with the longest observed data likely to be generated with due course of time. The working group members made no specific suggestions or comments during the presentation. |
| 8. | **Title:**Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios<br>**Team:** M. Arora (MA); P K Mishra; Vishal Singh<br>**Duration:** 3 years (04/18-03/22)<br>**Funding:** NIH<br>**Status:** Ongoing | MA presented the progress of the study. He informed the house that the data could not be collected for the ablation period of 2020 and 2021 because of Covid 19 outbreak. The progress achieved in the characterization of suspended sediment in the Gangotri Glacier melt stream was presented before the working group. It was informed that wind also plays a crucial role in the melting of glaciers and in this particular glacier the percentage of Cold katabatic and Warm anabatic wind in the years 2016-2019 is 56% and 44% respectively. HBV model was used for the simulation of streamflow. The model was calibrated for the years 2016-17 and validated for the year 2018-19. The coefficient of determination $R2$ for the calibration period and validation period were 0.77 and 0.71 respectively. Director NIH asked as to why SNOWMOD is not used for this analysis. In its response it was informed that SNOWMOD has been used in earlier studies but now in this study the role of aspect has also been included. However, a comparison will be made between the output of two models in future. Dr A K Saraf wanted to know the role of debris cover on the glacier melting. The results obtained from small experiments carried out earlier on the debris cover were discussed. |
| **New Internal/ Sponsored Studies** | |
| 1. | **Title:** Spatio-temporal Water Availability under Changing Climate and Land use Scenarios in Wainganga River Basin<br>**Team:** M K Nema (MKN); P K Mishra;<br>**Duration:**2 years (04/22-03/24) | MKN presented proposed new study on River Wainganga with the aim to examine the basin's water resources availability and, more importantly, to estimate the influence of current and future changes in climate and land use on the basin's water balance. He |

| | **Funding:** NIH<br>**Status:** New | informed that he has already made a visit of the study area and discussed the study with stakeholders. A few specific comments made by the WG members during the presentation are as follows:<br>1. The study should include the groundwater component. The proposal has been modified with an added objective and a team member from the groundwater division has been included.<br>2. Few changes were recommended in the listed objectives of the study, which has been incorporated. Dr M K Goel suggested to modify the second objective suitably.<br>Dr. Nema said that the comments/suggestions will be incorporated in the study. |
|---|---|---|
| 2. | **Title:**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<br>**Team:** M K Nema; Sanjay K Jain (SKJ); Praveen Thakur (IIRS)<br>**Duration:**3 years (04/22-03/25)<br>**Funding:** IIRS<br>**Status:** New | SKJ presented the proposed new study which is a collaborative study with IIRS, Dehradun. He said that this project is multi institutional. He informed that the signing of MOU of the study has been already done with IIRS, Dehradun. He informed about the study areas to be considered for the study. No specific comments were received from Working Group Members. |
| 3. | **Title:**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<br>**Team:** P K Singh (PKS); Vishal Singh, Sanjay K Jain<br>**Duration:**3 years (04/22-03/25)<br>**Funding:** WRD, Karnataka<br>**Status:** New | PKS presented the New study which is referred by WRD, Karnataka under NHP. He elaborated the objectives and informed about the involvement of the Engineers of WRD. Director asked to involve one scientist from RC, Belgavi. |

## RECOMMENDED WORK PROGRAMME FOR THE YEAR 2022-2023

| 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 | Sanjay K. Jain<br>P K Singh; M. Arora<br>A K Lohani; Vishal Singh | 3 years (11/19-11/22) | NMHS-MoEF (143) |
| 2. | Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin | Vishal Singh;<br>Sanjay K. Jain;<br>A P Dimri (JNU) | 3 years (06/19-11/22) | NRDMS-DST (23.19) |
| 3. | 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;<br>P K Mishra;<br>P K Agarwal | 2 years (08/20-07/22) | NHP (14.50) |

| 4. | Development of Water Accounts for the different sub-basins in the state of Nagaland Using Water Accounting Plus (WA+) Framework. | P K Mishra; P K Singh; Vishal Singh P K Agarwal | 2 years (04/21-03/23) | NHP (9.00) |
|---|---|---|---|---|
| 5. | Long term hydrological assessment for the development of water security plan into three sub-basins namely Barak, Minor rivers draining into Bangladesh and Minor rivers draining into Myanmar sub-basins in the state of Mizoram | Vishal Singh; M K Nema; P K Singh; Vanlalpekhlua Sailo (SDO from Mizoram); Lalruatkima (JE from Mizoram) | 3 years (04/21-03/24) | NHP (25.00) |
| 6. | Impacts of glacier and climate change on runoff for selected basins of Himalayan region | Vishal Singh; Sanjay K. Jain; Manohar Arora | 2 years (08/20-07/22) | NIH (9.30) |
| 7. | Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya | M K Nema; Sanjay K Jain; P K Mishra; P K Agarwal | 3 years (08/20-07/23) | NIH (10.22) |
| 8. | Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios | M. Arora; P K Mishra; Vishal Singh | 3 years (04/21-03/23) | NIH |
| **New Internal/ Sponsored Studies** | | | | |
| 1. | Spatio-temporal Water Availability under Changing Climate and Landuse Scenarios in Wainganga River Basin | M K Nema; P K Mishra | 2 years (04/22-03/24) | NIH |
| 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; Sanjay K Jain; P. K. Mishra; Praveen Thakur (IIRS) | 3 years (04/22-03/25) | IIRS, Dehradun (30.91) |
| 3. | Hydrological Assessment of Ungauged Basins (Aghanashini, Dasanakatte, Sita Nadi, Madisala Hole, Swarna Nadi and Gurupur River Basins) of the West Flowing Rivers in the Western Ghat Region of Karnataka | P K Singh; Vishal Singh; Sanjay K Jain; | 3 years (04/22-03/25) | WRD, Karnataka (54.0) |

## DETAILS OF RESEARCH PUBLICATIONS DURING APRIL, 2021 - MARCH, 2022

| Months | Division/RC/CFMS | Research studies | Research papers | Training courses | Training of personnel |
|---|---|---|---|---|---|
| 1 | Apr, 2021 | | | | |
| 2 | May, 2021 | | | | |
| 3 | June, 2021 | | 2 | | 2 |
| 4 | July, 2021 | | 2 | | |
| 5 | August, 2021 | | | 1 | |
| 6 | September, 2021 | | | | |
| 7 | October, 2021 | | 1 | | |
| 8 | November, 2021 | | 1 | 1 | |
| 9 | December, 2021 | | 4 | | |
| 10 | January, 2022 | | | | 1 |
| 11 | February, 2022 | | | | |
| 12 | March, 2022 | 01 | 10 | 1 | 2 |

| | | Total | 01 | 20 | 3 | 5 |
|---|---|---|---|---|---|---|

## DETAILS OF TRAINING/ WORKSHOP COMPLETED

| SN | Title of Training Course/Workshop | Coordinators | Duration | Venue |
|---|---|---|---|---|
| 1. | Online training on "Hydrological Modeling using Soil and Water Assessment Tool (SWAT): Theory and Hands-on" from August 16-20, 2021, at NIH, Roorkee sponsored by National Hydrology Project (NHP) for 23 participants from 10 state governments water resources departments and 03 central implementing agencies. | Dr. M. K. Nema, Scientist 'D' Dr Vishal Singh, Scientist 'C' | 5 days | Online |
| 2. | Training on "Water Accounting Plus (WA+) for all Northeast IAs" from November 15-19, 2021, at Meghalaya, Shillong, sponsored by National Hydrology Project (NHP). | Dr P K Singh, Scientist 'D' Dr P K Mishra, Scientist 'C' | 5 days | Offline |
| 3. | Online training on "Soil and Water Assessment Tool (SWAT)" from Feb 28 to March 04, 2022, at NIH, Roorkee sponsored by Indian Council of Forestry Research and Education (ICFRE), Dehradun. | Dr. M. K. Nema, Scientist 'D' Dr Vishal Singh, Scientist 'C' | 5 days | Online |
| 4. | Stakeholders' Workshop "Snow and glacier contribution and impact of climate change in Teesta river basin, eastern Himalaya" under NMHS Project at Gangtok, Sikkim on 23/02/2022 | Dr. Sanjay K Jain, Scientist 'G' Dr P K Singh, Scientist 'D' | One day | Offline |

## RESEARCH MANAGEMENT AND OUTREACH DIVISION (RMOD)

Dr. V C Goyal, Sc. G & Head, presented an overview of the Division's activities and progress of studies during 2021-22. He also presented tables showing the studies and outreach activities proposed for the F.Y. 2022-23. Next, he invited Er. Omkar Singh, Dr. Senthil Kumar, Dr. Jyoti Patil and Er. Rohit Sambare to present the progress of studies/project as given below:

| SN | Title of Project/Study, Study Team | Status and Recommendations/Suggestions |
|---|---|---|
| 1. | Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand Region, Central India **Team:** Dr. Jyoti P Patil (PI) Dr. T. Thomas (RC-Bhopal) Dr. Prabhash K Mishra Er. Rohit Sambhare  DOS: September 2020, DOC: February 2023 | The results of trend analysis, climatic indices, and WEAP model were briefly presented as those were discussed during the last WG meeting. The preliminary findings of Water Accounting + framework for Betwa basin were presented. These findings can be confirmed only after discussions with the stakeholders in the basin. The queries of the members were answered by the PI and Co-PI. |
| 2 | Establishing hydrological regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District) | The HGM classification of wetland and its functional assessment using open source geospatial data has been presented. Sri S M |

435

| | Team: Er. Rohit Sambare (PI), Dr. V.C. Goyal, Dr. Suhas Khobragade, Dr. Gajendra Singh, Scientist (USAC, Dehradun), Shri N. R. Allaka <br><br>DOS: Jul2020, DOC: Jun 2022 <br>Extn. Sought upto August 2023 | Sharma suggested to include biodiversity component. <br>The PI requested for extension of this study upto Aug 2023 due to his illness. The working group members agreed for extension of the study. |
|---|---|---|
| 3 | Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat Region, Haryana <br>**Team:** A. R. Senthil Kumar, Omkar Singh, Rajesh Agarwal, Nageswara Rao Allaka. <br><br>DOS: Jul 2020, DOC: Jun 2022 <br>Extn. Sought upto Sep 2022 | Dr S. S. Grewal suggested to consider the pattern of the crop types with respect to quality of ground water while going for the crop diversity scenario. Dr. Ramakar Jha, Professor, NIT Patna querried about the quantum of data involved in WEAP model setup. The PI infomed about the sources of data for both WEAP and LINGO model. |
| 4. | Development of Water Security Plan for Healthcare Facilities: A Pilot Study for Swami Rama Himalayan University (SRHU-HIHT), Jolly Grant, Dehradun <br><br>**Team:** Omkar Singh (PI), V.C. Goyal, Rajesh Singh (Co-PI), Jyoti Patil, Rohit Sambare, N.R. Allaka; Team from SRHU-HIHT, Dehradun <br>DOS: Apr 2022, DOC: Mar 2024 | This is a new study in collaboration with SRHU-HIHT, Dehradun. Sh. Omkar Singh (PI)presented the proposed objectives, methodology and expected outcome. Dr. Pawan Labhasetwar, Dr. Manoj Samuel and Dr. Ramakar Jha appreciated this type of study with hospitals, and suggested to take due care with Hospital Administration about any hazardous wastes in the wastewater. |
| 5. | Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS) <br>DST (GoI), Cost: Rs. 5.1 Crore <br>V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare <br>**Partners:** NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Ahmedabad <br>DOS: Apr 2019, DOC: Mar 2024 | This is a sponsored project of DST (GoI) and reported in the WG meeting. Hence, the progress was not presented in this meeting. |

## RECOMMENDED WORK PROGRAM FOR THE YEAR 2022-23

| SN | Title of Project/Study | Funding | Study Team | Duration | Status |
|---|---|---|---|---|---|
| **Internal Study** | | | | | |
| 1 | Integrated assessment of water resources for sustainable use in Upper Dhasan basin in Bundelkhand region | NIH | Jyoti Patil (PI) <br>T Thomas (Co-PI), P K Mishra Rohit Sambare | Sep 2020- Feb 2023 | On-going |
| 2 | Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand) | NIH | Rohit Sambare (PI) <br>V C Goyal (Co-PI), Suhas Khobragade, N R Allaka; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun | Sep 2020- Aug 2023 | On-going |
| 3 | Hydrology-based scenario planning for water productivity and optimization of income from farming practices in Mewat region, Haryana | NIH | A R Senthil Kumar (PI) <br>Omkar Singh (Co-PI) <br>Rajesh Agarwal, N R Allaka Scientist from KVK/Agri Univ. | Sep 2020- Aug 2022 | On-going |

| 4 | Development of Water Security Plan for Healthcare Facilities: A Pilot Study for Swami Rama Himalayan University (SRHU-HIHT), Jolly Grant, Dehradun | NIH | Omkar Singh (PI) V.C. Goyal, Rajesh Singh (Co-PI), Jyoti Patil, Rohit Sambare, N.R. Allaka; Team from SRHU-HIHT, Dehradun | April 2022-Mar 2024 | New Study |
|---|---|---|---|---|---|
| **Sponsored Projects** | | | | | |
| 1 | Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS) | DST (GoI) | V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare, Project Team, HQ (IC-EcoWS) Partners: NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Anand | Apr 2019-Mar 2024 | On-going |

## Proposed Training/Webinar/Outreach Activities of RMOD (2022-23)

| S.N. | Outreach Activity | Tentative Date & Month | Place | Target Participants | Team |
|---|---|---|---|---|---|
| 1 | Brainstorming session on 'Water Security in a Changing Environment-Focus on Indian Himalayan Region (IHR)', during 16th Uttarakhand Science and Technology Congress | June 2022 | UCOST, Dehradun | Conference participants | V. C. Goyal, J P Patil, Amrendra Bhushan |
| 2 | 5-days training on 'Life Cycle Approach for Rejuvenation of Ponds and Lakes using Nature-Based Solutions' sponsored by National Water Mission (4Nos) | April 2022 May 2022 June 2022 July 2022 | Bhopal Belgaum Kakinada Roorkee | R&D Institutes/ University/ Govt. Organizations | Bhopal: T Thomas Belgavi: B Venkatesh Kakinada: YRS Rao Roorkee: J P Patil, Omkar Singh, Rohit Sambhare |
| 3 | Training on GEM | June 2022 | NIH Roorkee | Admn and finance staff of NIH | A. R. Senthil kumar Omkar Singh |
| 4 | Webinar on ecohydrological functioning of wetlands | Jul 2022 | NIH Roorkee | Students and researchers | Rohit Sambare V C Goyal |
| 5 | Stakeholders workshop for Upper Dhasan Basin water resources assessment | May 2022 | Bhopal | CWC, CGWB, State departments (Irrigation, WRD, Agril etc) | J P Patil, T Thomas, P K Mishra, Rohit Sambhare |
| 6 | Workshop/Webinar on rejuvenation of ponds and treatment of domestic wastewater through constructed wetlands | Jul 2022 | NIH Roorkee | R&D Institutes/University/Govt. Organizations | NIH: Omkar Singh, V.C. Goyal, Rajesh Singh, Digambar Singh UKCEH: Laurence Carvalho & Elliot Hurst |
| 7 | Five-day training program on "Hydrology of water bodies and their development under climatic uncertainty" | Jun/Jul 2022 | NIH Roorkee | Engineers in Irrigation/PHE/SWC departments | A. R. Senthil kumar, Rohit Sambare, Santosh M Pingale, N R Allaka |

| 8 | E-course on Urban hydrology | June 2022 | NIH, Roorkee NIUA, Delhi | Researchers, academicians, scholars | NIH: V C. Goyal, J. P. Patil<br>NIUA: Victor Shinde |
| 9 | Awareness Programme for School Children | July-Sep 2022 | 3 Schools in Roorkee/ Nearby Roorkee | School Children | Digambar Singh, Omkar Singh, A. R. Senthil kumar, Rajesh Agarwal, N R Allaka |

## Other Outreach Activities:

| S.N. | Activity |
| --- | --- |
| 1 | • Preparation of Short Video on Pond Rejuvenation & CW-NTS of Ibrahimur Masahi<br>• River Walk of Solani River<br>• Short video on Hydrology for People @district level<br>• Short video on vulnerability assessment under Hydrology for People series |
| 2 | • Coordination of 75 planned Activities at HQ & RCs under Azadi Ka Amrut Mahotsav @ India 75<br>• Organizing activities as per mandate of Division under Azadi Ka Amrut Mahotsav @ India 75<br>• Compendium of NIH activities on the activities under Azadi Ka Amrut Mahotsav @ India 75 |
| 3 | • Any other Outreach activity on demand/assigned |

Dr. V C Goyal thanked the members for their valuable contributions during deliberations in the Working Group meeting.The meeting ended with vote of thanks to the Chair.

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**List of Working Group Members who attended the 52ⁿᵈ WG meeting**

| | | |
|---|---|---|
| 1. | Dr. J V Tyagi, Director, NIH | Chairman |
| 2. | Dr. A. K Das, IMD, New Delhi | Member |
| 3. | Sh. Sudhindra Mohan Sharma, Ex-Nodel Officer, MoDWS, Indore | Member |
| 4. | Sh. Prashant Rai, CGWB, Dehradun | Member |
| 5. | Dr. Manoj P.Samuel, CWRDM, Kozhikode | Member |
| 6. | Dr. Sadhana Malhotra, Mindspace, Dehradun | Member |
| 7. | Prof. A K Saraf, IIT Roorkee | Member |
| 8. | Dr. Bhishm Kumar, IAEA (Retd.), Roorkee | Member |
| 9. | Prof. Ramakar Jha, NIT, Patna | Member |
| 10. | Dr. S S Grewal, Chandigarh | Member |
| 11. | Prof. Varun Joshi, GGSIPU, New Delhi | Member |
| 12. | Prof. Danya, C.T. Assistant Professor, IIT, Delhi | Member |
| 13. | Dr. Sushil Kumar Rohella, WIHG, Dehradun | Member |
| 14. | Dr. R K Goyal, CAZRI, Jodhpur | Member |
| 15. | Dr. Praveen Thakur, IIRS, Dehradun | Member |
| 16. | Dr. P R Ojasvi, ICAR-IISWC, Dehradun | Member |
| 17. | Dr. Manohar S. Rathore, CE &DS, Jaipur | Invitee |
| 18. | Sh. Gopal Singh Bhatti (Retd.), Pokhran, Rajasthan | Invitee |
| 19. | Dr. Sudhir Kumar, Sc. G & Head HI Division, NIH | Member |
| 20. | Dr. Sanjay K. Jain, Sc. G & Head WRS Division, NIH | Member |
| 21. | Dr. M. K. Goel, Sc. G & Head GWH Division, NIH | Member |
| 22. | Dr. A.K. Lohani, Sc. G & Head SWH Division, NIH | Member |
| 23. | Dr. R P Pandey, Sc.G & Head EH Division, NIH | Member |
| 24. | Dr. V C Goyal, Sc. G & Head, RMO Division, NIH | Member-Secretary |

**Scientists from NIH**

| | EH Division | | RMO Division |
|---|---|---|---|
| | **EH Division** | | **RMO Division** |
| 1 | Dr. M.K. Sharma, Sc.E | 18 | Er. Omkar Singh, Sc.F |
| 2 | Dr. Rajesh Singh, Sc.D | 19 | Dr. A R Senthil Kumar, Sc.F |
| 3 | Dr. Pradeep Kumar, Sc.D | 20 | Dr. (Mrs.) Jyoti P. Patil, Sc.D |
| 4 | Dr. Vinay K. Tyagi, Sc.D | 21 | Sh. Digamber Singh, Sc.D |
| 5 | Sh. Rajesh K. Nema, Sc.B | 22 | Sh. Rohit Sambare, Sc.B |
| | **GWH Division** | | **SWH Division** |
| 6 | Dr. Anupama Sharma, Sc.F | 23 | Dr. P C Nayak, Sc.F |
| 7 | Dr. Surjeet Singh, Sc.F | 24 | Dr. Sanjay Kumar, Sc.E |
| 8 | Dr. Sumant Kumar, Sc.D | 25 | Dr. Archana Sarkar, Sc.E |
| 9 | Dr. Gopal Krishan, Sc.D | 26 | Dr. L.N. Thakural, Sc.D |
| 10 | Sh. Nitesh Patidar, Sc.B | 27 | Dr. J.P. Patra, Sc.D |
| 11 | Ms. Nidhi Kalyani, Sc.B | 28 | Dr. Ashwini A. Ranade, Sc.D |
| | **HI Division** | 29 | Sh. Sunil Gurrapu, Sc.C |
| 12 | Dr. Suhas Khobragade, Sc.F | | **WRS Division** |
| 13 | Dr. M.S. Rao, Sc.F | 29 | Smt. Deepa Chalisgaonkar, Sc. G |
| 14 | Dr. Soban S. Rawat, Sc.D | 30 | Dr. Manohar Arora, Sc.E |
| 15 | Dr. Santosh M Pingale, Sc.C | 31 | Dr. P K Singh, Sc.D |
| 16 | Sh. Hukam Singh, Sc.B | 32 | Dr. Manish Nema, Sc.D |
| 17 | Mrs. Anjali, Sc.B | 33 | Dr. P K Mishra, Sc.D |
| | | 34 | Dr. Vishal Singh, Sc.C |
| | | 35 | Sh. P K Agarwal, Sc.B |
| | | 36 | Sh. Yatveer Singh, Sc.B |