AGENDA AND AGENDA NOTES

74th MEETING OF THE TECHNICAL ADVISORY COMMITTEE (TAC) OF NIH

APPENDICES

(Vol.-II)

December 15, 2020
AT 1100 HRS
NIH, ROORKEE

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NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE-247667

APPENDIX – 74.2.1

MINUTES OF THE 73rd MEETING OF TAC OF NIH

APPROVED MINUTES OF THE 73rd MEETING OF TECHNICAL ADVISORY COMMITTEE OF NATIONAL INSTITUTE OF HYDROLOGY Held on 17 December 2019 at Roorkee

The 73rd meeting of the Technical Advisory Committee (TAC) of the National Institute of Hydrology, Roorkee was held at NIH, Roorkee on 17 December 2019. The meeting was chaired by Er. R.K. Jain, Chairman, CWC. The list of the participants is given in Appendix -I.

At the outset, the Chairman in his opening remarks welcomed the members and the invitees. He appreciated the research being carried out by NIH, and desired that the Institute should try to align the research outcome with the activities of the Ministry of Jal Shakti, Deptt. of WR, RD & GR and the overall water sector in India. Also, he advised NIH to formulate its research programme based on extensive need assessment and share the results of studies with field experts.

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

ITEM NO. 73.2: Confirmation of the Minutes of 72nd Meeting of TAC

The Member-Secretary informed that minutes of the 72nd meeting of TAC, held on June 3, 2019, were circulated to all the members and invitees vide email dated July 25, 2019. Since no comments were received from the members, the Minutes were confirmed by the TAC.

ITEM NO. 73.3: 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. He informed that the suggestions offered during the previous meeting have been noted for compliance, and actions initiated accordingly.

Shri Rajeev Baboota mentioned that a study for Teesta basin, i.e. 'Snow and glacier contribution and impact of climate change in Teesta basin, Eastern Himalaya' is under progress in NIH. He desired that NHPC may be associated as one of the partners in the study. He also said that the data available with NHPC can be shared to carry out this study.

Shri Baboota stated that they are facing difficulties in discharge measurement in Himalayan basins by use of AWLR. There is no foolproof method for the measurement of velocity in Himalayana region. He requested that a robust method can be suggested for measurement of velocity in such conditions. Director, NIH informed that one such study is proposed by NIH and IITR under NHP.

Shri Baboota wanted to know about any study on the water availability under climate change in Himalayan basins because changes in water availability will affect power generation. He said that NIH has already carried out one such study for Chenab basin to see the impact of climate change. Similar type of studies can be carried out for other basins.

ITEM NO. 73.4: Status of the Work Programme for the Year 2019-20

The Member-Secretary briefed about the studies carried out by the Institute during the year 2019-2020. 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 2019-2020 were presented during the meeting:

i. Improving our understanding of aquifer systems of Sunderban (Dr. Gopal Krishan, GWH Div.)
ii. Water quality assessment of Southwest Punjab emphasizing carcinogenic contaminants and their possible remedial measures (Dr. Rajesh Singh, EH Div.)

TAC noted the status of work programme for the year 2019-2020.

ITEM NO. 73.5: Report Proceedings of the Working Group and Regional Coordination Committee (RCC) Meetings

The Member-Secretary briefed about the 49th meeting of the Working Group of NIH, which was held at NIH, Roorkee, during 4-5 Nov., 2019, and 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 2019-2020.

ITEM NO. 73.6: Major projects and activities of national importance

(i) **ROORKEE WATER CONCLAVE-2020**

National Institute of Hydrology Roorkee (NIH) and Indian Institute of Technology Roorkee (IITR) jointly decided to organize regular international conference every 2 years in the area of various facets of water, to be known as “Roorkee Water Conclave”. The first Roorkee Water Conclave is being organized during 26-28 February, 2020 at Roorkee broadly focusing on “Hydrological Aspects of Climate Change”. Detailed information about the conference is available on the conference website (https://www.iitr.ac.in/rwc2020/index.html) as well as www.nihroorkee.gov.in .

(ii) **6th National Water Symposium**

The sixth National Water Symposium (in Hindi) on the focal theme of “Water and Environment” organized by the Institute during 16-17 Dec., 2019.

ITEM NO. 73.7: Reporting Items

Details of the consultancy projects carried out by NIH during the year 2019-2020 were noted by the TAC.

ITEM NO. 73.8: Additional items with permission of the Chair

No such items were discussed.

The meeting ended with a vote of thanks to the Chair.

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Appendix-I

LIST OF PARTICIPANTS IN THE 73rd MEETING OF TAC OF NIH

1.	Er R K Jain, Chairman, CWC, New Delhi	In-chair
2.	Dr. Goverdhan Prasad, Director, Hydrology (N), CWC, New Delhi	Member
3.	Dr Sharad K Jain, Director, NIH, Roorkee	Member
4.	Dr A K Das, IMD, New Delhi	Rep. DDG(H)
5.	Prof M K Jain, IIT-Roorkee	Rep. IIT Roorkee
6.	Dr. Man Singh, Project Director, WTC, New Delhi	Member
7.	Shri Rajeev Baboota, Chief Engineer, NHPC, Faridabad	Member
8.	Dr V C Goyal, Sc. G, NIH, Roorkee	Member-Secretary

INVITEES

1. Dr Rakesh Kumar, Sc. G & Head, SWH Division, NIH, Roorkee
2. Dr J V Tyagi, Sc. G & Head, EH Division, NIH, Roorkee
3. Dr Sudhir Kumar, Sc. G & Head, HI Division, NIH, Roorkee
4. Er C.P. Kumar, Sc.G & Head, GWH Division, NIH, Roorkee
5. Dr Sanjay Jain, Sc. G & Head, WRS Division, NIH, Roorkee
6. Dr M K Goel, Sc. G, NIH, Roorkee
7. Smt Deepa Chalisgoankar, Sc.G , NIH, Roorkee
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 M Someshwar Rao, Sc.F, NIH, Roorkee
13. Dr Renoj Thayyen, Sc.E, NIH, Roorkee
14. Dr Archana Sarkar, Sc.E, Roorkee
15. Dr Rajesh Singh, Sc.D, NIH, Roorkee
16. Dr Gopal Krishan, Sc.C, NIH, Roorkee
17. Dr Ashwini Ranade, Sc.C, NIH, Roorkee
18. Dr Sunil Gurrapu, Sc.C, NIH, Roorkee

Appendix-II

APPROVED WORK PROGRAMME FOR THE YEAR 2019-2020

ENVIRONMENTAL HYDROLOGY DIVISION

Work Program for 2019-20

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

Training Programs During 2019-20

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

GROUND WATER HYDROLOGY DIVISION

Work Program for 2019-20

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GWH/ NIH/19-21	Application of Satellite Data Products for Water Resources Assessment	Suman Gurjar (PI), Vishal Singh, Surjeet Singh, C. P. Kumar, P. K. Singh	2 years (05/19 - 04/21) *Status: In progress*	Internal Study
2. NIH/GWH/ NIH/19-20	The Regional Hydrological Impact of Farm-Scale Water Saving Measures in the Gangetic Plains	Sumant Kumar (PI), C. P. Kumar, Archana Sarkar, Surjeet Singh, P. K. Mishra	1 year (08/19 – 07/20) *Status: In progress*	Internal Study (in collaboration with CSIRO, Australia)
Sponsored Projects				
3. NIH/GWH/ NIH/15-19	Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply	Surjeet Singh (Lead), B. Chakravorty, Y. R. S. Rao, Anupma Sharma, Sumant Kumar, Gopal Krishan, Suman Gurjar, Anju Chaudhary, Sanjay Mittal	2.5 years (11/15–12/19) Ext. approved until March 2020 *Status: In progress*	Sponsored by MoWR, RD & GR under Plan Fund
4. NIH/GWH/ NMSHE/16-20	Study of River - Aquifer Interactions and Groundwater Potential at Selected Sites in the Upper Ganga Basin up to Dabrani	Surjeet Singh (PI), C. P. Kumar, R. J. Thayyen, Sudhir Kumar, Manohar Arora, Gopal Krishan, Nitesh Patidar, Anjali	5 years (01/16 - 12/20) *Status: In progress*	Sponsored by DST under NMSHE SP-8
5. NIH/GWH/ BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency Groundwater Level and Salinity Measurements	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar, M. S. Rao *From: BGS, UK* Dr. Dan Lapworth (PI) Prof. Alan MacDonald	3 years (12/17-11/20) *Status: In progress*	Sponsored by BGS, UK
6. NIH/GWH/ PDS/17-20	Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin	Sumant Kumar (PI), Sudhir Kumar, Rajesh Singh, Gopal Krishan, Anju Chaudhary *Partner Organization:* MWRD, Bihar *Collaborator:* Brijesh Yadav, IIT Roorkee and N.S Maurya, NIT Patna	3 years (12/17-11/20) *Status: In progress*	Sponsored by NHP under PDS

7. NIH/GWH/ PDS/17-21	Assessment of Impacts of Groundwater Salinity on Regional Groundwater Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar, S. K. Verma *IIT-Roorkee:* M. L. Kansal, Brijesh Yadav (PI) *Sehgal Foundation, Gurgaon:* Lalit Mohan Sharma	4 years (12/17-11/21) *Status: In progress*	Sponsored by NHP under PDS
8. NIH/GWH/ PDS/17-21	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Surjeet Singh (PI), C. P. Kumar, Sudhir Kumar, Suman Gurjar, Gopal Krishan	4 years (12/17-11/22) *Status: In progress*	Sponsored by NHP under PDS
9. NIH/GWH/ DST/18-20	Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA	B. Chakravorty (India Lead), Surjeet Singh (Dy. Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar *Other India Partners:* IITR, IITKg, MCS, Patna *UK Partners:* Univ. of Manchester, BGS, Salford University, Univ. of Birmingham	3 years (01/18 - 12/20) *Status: In progress*	DST-Newton Bhabha-NERC- India-UK Water Quality Research Programme
10. NIH/GWH/ DST/18-20	Impact of Rainwater Harvesting on Groundwater Quality in India with Specific Reference to Fluoride and Micro-pollutants	Anupma Sharma (India Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar, M. K. Sharma *Other Indian Partners:* IIT Ropar, IIT Jodhpur *UK Partner:* School of Water, Energy and Environment, Cranfield University *Project Partners:* Water Harvest, Excellent Development (UK based NGOs)	3 years (01/18 - 12/20) *Status: In progress*	DST-Newton Bhabha-NERC- India-UK Water Quality Research Programme
11. NIH/GWH/ CEHM/18-22	Integrated Management of Water Resources for Quantity and Quality in Upper Yamuna Basin upto Delhi	Anupma Sharma (PI) Sanjay K. Jain, Archana Sarkar, M. K. Sharma, L. N. Thakural, Sumant Kumar, Suman Gurjar, Vishal Singh, Nitesh Patidar *Partner Organizations:* Water Resources & Irrigation Dept. Haryana, Groundwater Dept. UP, Yamuna Basin Organization, CWC, New Delhi	4 years (04/18-03/22) *Status: In progress*	Special Project under "Centre of Excellence" (NHP)

12. NIH/GWH/ DST/19-23	Enhancing Food and Water Security in Arid Region through Improved Understanding of Quantity, Quality and Management of Blue, Green and Grey Water	Anupma Sharma (Lead NIH), C.P. Kumar, Nitesh Patidar (Lead: CAZRI Jodhpur, Partners: NIH Roorkee, IISWC Dehradun, CSWRI Bikaner, CIAH Bikaner, NIAM Jaipur)	5 years (03/19 - 02/24) *Status: In progress*	Sponsored by DST
13. NIH/GWH/ NMCG/19-20	Environmental Flow Assessment for Yamuna River from Hathnikund Barrage to Okhla Barrage	Anupma Sharma (PI), Sharad K. Jain, Manohar Arora, Pradeep Kumar, Rajesh Singh, Vishal Singh	1 year (04/19 - 03/20) *Status: In progress*	Sponsored by NMCG
14. NIH/GWH/ MoES/19-19	Improving our Understanding of the Aquifer Systems in Sunderbans	Gopal Krishan (PI), C. P. Kumar (Co-PI)	6 months (06/19 - 11/19) *Status: Completed*	Sponsored by India-UK Water Centre (MoES & NERC)
Other R & D Projects				
15. NIH/GWH/ CEHM/18-21	Development of Groundwater Module for Integrated Hydrologic Model	Anupma Sharma (PI), B. Chakravorty, Surjeet Singh, Suman Gurjar, Sumant Kumar, Nitesh Patidar	3 years (08/18 -07/21) *Status: In progress*	CEHM, NHP
Consultancy Projects				
1.	Assessment of Saline and Freshwater Zone in Faridkot, Fazilka and Muktsar Districts of Malwa Region of Punjab	Gopal Krishan (PI)	10 months (03/19-12/19) *Status: In progress*	Punjab Government
2.	Expansion of Salinization in Aquifers in Punjab	Gopal Krishan (PI)	1.5 year (03/19-09/20) *Status: In progress*	Punjab Government
3.	Water Availability Study based on Hydrological Investigations and Rainfall-Runoff Modeling of Upper Hindon Basin	Anupma Sharma (PI)	12 months (04/19-03/19) *Status: In progress*	Irrigation Deptt., Saharanpur
4.	Hydro-geological Study of Goindwal Sahib Area of Tarn Taran District, Punjab	Surjeet Singh (PI)	6 months (09/19-02/20) *Status: In progress*	GVK Power Ltd., Tarn Taran (Punjab)

HYDROLOGICAL INVESTIGATIONS DIVISION

Work Program for 2019-20

SN.	Project Title	Study Team	Duration	Remarks
INTERNAL STUDIES:				
1	Integrated hydrological investigations of natural water springs in lesser Himalaya, Uttarakhand	S M Pingale (PI), Sudhir Kumar, S. D. Khobragade, Soban Singh Rawat, Rajeev Gupta	3 years (04/19-03/22)	Continuing Study
2	Isotope fingerprinting of precipitation over Indian Region	Nidhi Kalyani (PI) Sudhir Kumar, MS Rao, Scientists from RC's	3 years (04/19-03/22)	Continuing Study
SPONSORED PROJECTS:				
1.	Understanding of hydrological processes in Upper Ganga basin by using isotopic techniques	Suhas Khobragade (PI) Sudhir Kumar, Rajesh Singh M. Arora, R. J. Thayyen, S.K. Verma	5 Years (04/16-03/21)	Continuing Study under NMSHE Project
2.	Rejuvenation of Springs and Spring-fed Streams in Mid-Himalayan Basin using Spring Sanctuary concept	Sudhir Kumar (PI) S.K. Verma	3 Years (06/16 -05/19) Ext. approved until Mar 2020	Continuing Study Project with GBPIHE
3.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	MS Rao (PI) Sudhir Kumar, C.K. Jain, S.K. Verma	3 Years (06/16 -05/19) Ext. approved until May2020	Continuing Study IAEA under CRP
4.	Chemical & Isotopic Characterization of Deep Aquifer Groundwater of Middle Ganga Basin	Sudhir Kumar (PI) C.K. Jain, M. Someshwar Rao, S.K. Verma	3 ½ year (1/18 – 6/21)	Continuing Study PDS under NHP
5.	Integrated Study on groundwater dynamics in the coastal aquifers of West Bengal for sustainable groundwater management	M. Someshwar (PI), Sudhir Kumar, S.K. Verma A. R. Senthil Kumar V. S. Jeyakanthan	3 ½year (1/18 – 6/21)	Continuing Study PDS under NHP
6.	Development of a comprehensive plan for conservation and sustainable management of Bhimtal and Naukuchiatal lakes, Uttarakhand	Suhas Khobragade Sudhir Kumar	3 Years (1/18 – 12/20)	Continuing Study PDS under NHP
7.	Unravelling Submarine Discharge (SGD) zones along the Indian subcontinent and its islands (Mission SGD) – Pilot Study	Sudhir Kumar MS Rao, SM Pingale, BK Purandra, YRS Rao	1 year (04/19 – 03/20)	MoES through NCESS
8.	Groundwater Rejuvenation As Climate changE Resilience for marginalized and gender sensitive GangeS (GRACERS)	Sudhir kumar MS Rao SM Pingale	2 years (06/19 – 5/21)	IIT Bombay, Mumbai

SURFACE WATER HYDROLOGY DIVISION

Work Program for 2019-20

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

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

WATER RESOURCES SYSTEMS DIVISION

Work Program for 2019-20

S N	**Title**	**Study Team**	**Duration**	**Funding (Rs. Lakhs)**
	Completed Internal Studies			
	Development of window based software for hydrological data processing and Unit Hydrograph Analysis	D. Chalisgaonkar A. K. Lohani, M. K. Goel	1 year (04/18-03/19)	
	Ongoing Internal Studies			
1.	Hydrological process and characterization of Lesser Himalayan Catchments	M. K. Nema Sharad K. Jain, Sanjay K. Jain, Renoj J.Thayyen, P. K. Mishra	5 years (12/14-12/19)	
2.	Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework	P. K. Singh P. K. Mishra, M. K. Goel, Suman Gurjar	2 years 2018-2020	
3.	Real time flood modelling using HEC-RTS modelling framework	Vishal Kumar A. K. Lohani, Sanjay K. Jain	2 years 2018-2020	
4.	Development of window based software for Flood Estimation	D. Chalisgaonkar A. K. Lohani, M. K. Goel	1 year (04/19-03/20)	
	Ongoing Sponsored Studies			
1.	Mass and Energy balance of Phuche and Khardung glaciers, Ladakh range	Renoj J. Thayyen Farooq Azam, P.G. Jose, A.P. Dimri	3 years (03/16-02/19) Ext. until March 2020	SERB (65.14)
2.	Development of a project website and hydrological database in Upper Ganga Basin **(Sub-project – 1)**	M. K. Goel M. Arora, A. K. Lohani, D. S. Rathore, D. Chalisgaonkar, A. R. S. Kumar, S. Singh, P. Mani, A. Sarkar, M. K. Nema, P. K. Mishra	5 years (01/16-12/20)	DST-NMSHE (52.15)
3.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore D. Chalisgaonkar, V. S. Jeyakanthan, L. N. Thakural	5 years (01/16-12/20)	DST-NMSHE (48.83)
4.	Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3)**	Sanjay K. Jain A. K. Lohani, Sudhir Kumar, P. Thakur (IIRS)	5 years (01/16-12/20)	DST-NMSHE (36.79)
5.	Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios **(Sub-project – 4)**	Renoj J.Thayyen Sanjay K. Jain, Sharad K. Jain, P. K. Mishra, M. Arora, AP Dimri (JNU)	5 years (01/16-12/20)	DST-NMSHE 51.43 (NIH) + 28.29 (JNU)
6.	Observation and modelling of various hydrological processes in a small watershed in Upper Ganga basin **(Sub-project – 5)**	Sharad K. Jain Renoj J.Thayyen, Sanjay K. Jain, Surjeet Singh, M. K. Nema; P. K. Mishra; P. K. Agarwal, AP Dimri (JNU)	5 years (01/16-12/20)	DST-NMSHE (54.07)
7.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin	P. K. Mishra M. K. Nema, Renoj J.	5 years (01/16-12/20)	DST-NMSHE

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

RESEARCH MANAGEMENT AND OUTREACH DIVISION

Work Program for 2019-20

SN	Title of Project/Study	Funding	Study Team	Duration	Status
	Internal Study				
1	Study on effect of climate change on sediment yield to Pong reservoir	NIH	A R Senthil kumar (PI) J V Tyagi, S D Khobragade, Manohar Arora	Apr 2015- Jun 2019)	Completed
2	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system	NIH, CEH-UK	**NIH**: Omkar Singh (PI) V C Goyal, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka **CEH-UK**: Prof. Laurence Carvalho & Team	Apr 2018- Mar 2020 Ext. approved until Mar 2021	On-going
3	Bathymetric survey of identified ponds in the districts of Muzaffarnagar, Meerut, Ghaziabad and Baghpat (UP) for development of water management plan	NIH	Digambar Singh (PI), Omkar Singh, Rohit Sampatrao Sambare, N R Allaka	Apr 2018- Mar 2020 Deferred due to technical snag with e-Boat	On-going
	Sponsored Projects				
1	Vulnerability assessment of identified watersheds in Neeranchal Project States	Shifted from NNWP to Plan	Jyoti P Patil (PI)	Jul 2017- Jun 2019	Completed
2	Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact	DST-NMSHE	A R Senthil Kumar (PI) J. V. Tyagi, M. K. Goel, S. D. Khobragade, P. C. Nayak, Manohar Arora	Mar 2016- Mar 2021	On-going
3	Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts of UP	MoJS-sponsored project-Through INCSW	V C Goyal (PI) Omkar Singh, Digambar Singh, Rajesh Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka	Apr 2017- Mar 2020	On-going
4	Rejuvenation of village ponds in identified villages of Baghpat, Ghaziabad and Meerut districts of Uttar Pradesh	MoJS-sponsored project (through Plan Budget)	Omkar Singh (PI), Rajesh Singh, V C Goyal, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka	Jan. 2018- Dec. 2020	On-going
5	Development of water allocation plan for identified watersheds in Kanker district (Chhattisgarh)	Shifted from NNWP to Plan	A R Senthil kumar (PI) T R Nayak, Jyoti P Patil, Rohit Sampatrao Sambare, Rajesh Agarwal	Apr 2018- Mar 2020	On-going
6	Innovation Centre for Eco-	DST (GoI),	V.C. Goyal (PI),	Apr 2019-Mar	On-going

	Prudent Wastewater Solutions (IC-EcoWS)	Cost: Rs. 5.1 Crore	Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sampatrao Sambare **Partners:** NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Ahmedabad	2024	

Proposed Trainings/Workshop/Activities:

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

Expected Outreach Activities:

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

Proposed activities under INC-IHP during 2019-20

Meetings to be organised/ attended

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

Thematic Trainings:

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

Brainstorming sessions/ exhibitions during conferences/ summits

S. N.	INC-IHP event	Conference/ Summit	Host Organisation	Location	Date
1.	Exhibition on R&D in Hydrology, Wastewater treatment	3rd World Water Summit 2019	Energy and Environment foundation	New Delhi	21-23 Aug, 2019
2.	Brainstorming session on Theme-V 'Ecohydrology-Engineering Harmony for a Sustainable World'	Water future Conference	IISc, Bengaluru	Bengaluru	24-27 Sep, 2019
3.	Session on 'Enhancing sustainable groundwater resources management'	8th Int. Groundwater Conference on Sustainable Management of Soil-Water Resources	IIT- Roorkee	Roorkee	21-24 Oct, 2019
4.	Theme- Water-related Disasters and Hydrological Changes	Int. Conference on Soil and Water Resources Management for Climate Smart Agriculture, Global Food and Livelihood Security	Soil Conservation Society of India (SCSI), New Delhi	New Delhi	5-9 Nov, 2019
5.	Theme- Game-changing approaches and technologies	Int. Conference on Future Cities	IIT- Roorkee	Roorkee	11-13 Dec, 2019
6.	Theme- Promoting innovative tools for safety of water supplies and controlling pollution	HYDRO-2019 (Hydraulics, Water Resources and Coastal Engineering)	Osmania University, Hyderabad	Hyderabad	18-20 Dec, 2019
7.	Theme- Water Education- Key for Water Security	Roorkee Water Conclave 2020	IIT- Roorkee and NIH	Roorkee	26-28 Feb, 2020
8.	Celebration of World Water Day		NIH with UNESCO, New Delhi	New Delhi	22 Mar 2020

REGIONAL CENTRE, BELAGAVI

Approved Work Program for 2019-20

S N	Title of the Study	Study Group	Duration	Funding
ON-GOING STUDIES	Impact of Land use/Land cover Changes on Ground water – A Case	BKP & BV	3 years (April 17- March 20)	*MoES*
	Studies on Occurrence, Distribution and Sustainability of Natural Springs for Rural Water Supply in parts of Western Ghats, India	BKP (PI), SK, NV, Abhilash, & Ujwal,	3 years (4/17-3/20)	PDS under NHP
	Climate Change Impact assessment for Jayakwadi Reservoir	BV (PI), and officers from WRD, Govt. Maharashtra)	3 years (05/18-3/21)	Internal
	Development of prediction tools for Assessment of Water Resources in Ungagued catchments of West Flowing Rivers of Western Ghat Region	CMT(PI), BV and CK & Officer from WRDO	3 years (4/18-3/21)	Internal
NEW STUDIES	Estimation of Submarine Groundwater Discharge in parts of Karnataka	BKP, SK, JVT and NV	2 year (2019 to 2021)	NCESS (MoES)
	Groundwater Model Development In Micro Basin Of Hard Rock In Krishna And Godavari River Basins Of Telangana	BV, MKJ, Anupama Sharma and Abhilash, and Officials form TSGWD	3 years (2019 to 2022)	PDS under NHP (submitted for approval)
	Flood Vulnerability Assessment and developing mitigation plan for Thiruvananthapuram City, Kerala	CM, BV, MKJ and CS	2 years (2019 to 2021)	Internal
	Study on the impact of extensive sand extraction on the river environment and aquifer regime in Godavari basin	MKJ, BV, CMT NV Abhilash and Officials form TSGWD	2 years (2019 to 2021)	Internal
CONSULTANCY	view 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	Karnataka Power Corporation Limited, Govt. of Karnataka
	Preparation of Emergency Action Plan (EAP) and Study of Tail Channel Design Flood Carrying Capacity of Ambazari Lake, Nagpur	BV (PI)	1 year	Irrigation Department, Nagpur Go Maharashtra

JVT : J.V. Tyagi, Scientist G
BV : B.Venkatesh, Scientist F
CMT : Chandramohan T., Scientist D
NV : N Varadarajan,PRA
SK : Sudhir Kumar, Scientist G
BKP : Purandara, Scientist F
MKJ : Mathew K. Jose, Scientist D
CK : Chandra Kumar S., SRA

REGIONAL CENTRE, JAMMU

Approved Work Program for 2019-20

S. No.	Title of Study	Team	Duration	Remarks
Internal Studies				
1.	Assessment of Hydrological Characteristics of a Western Himalayan river	D. Khurana P. G. Jose S. S. Rawat R. V. Kale	24 months (June 2018 to May 2020)	Ongoing
2	Hydrologic and hydraulic modeling for floodplain inundation mapping under future climate change scenarios: A case study of Tawi River, India.	R. V. Kale P. G. Jose S. S. Rawat	03 years (August 2018 to March 2021)	Ongoing
3.	Statistical evaluation of global precipitation estimates over data scarce Western Himalayan Region of India	D. S. Bisht V. Singh, S. S. Rawat, P. G. Jose, D. Khurana	02 Years (Sept. 2019 to Sept. 2021)	New Proposal (revised)
PDS under National Hydrology Project (NHP) at NIH				
1.	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 P. G. Jose S. P. Rai S. Gurjar R. V. Kale	04 years (Apr 2017 to Mar 2021)	Ongoing PDS under NHP
2.	Entropy based discharge monitoring technique application for Himalayan rivers [New Study under PDS]	**NIH Team** R. V. Kale M. K. Goel P. G. Jose D. S. Bisht **CWC Team** Bhopal Singh A. K. Singhal	04 years	Yet to start [recommended proposal, pending final approval at DoWR, RD & GR]
Externally funded R & D Studies				
1.	Integrated Studies of Himalayan Cryosphere using Space Based Inputs (ISHC)	P. G. Jose R.J. Thayyen	02 years Sept 2017 to Sept 2019	Ongoing Funded by SAC/ISRO Ext. up to Mar. 2020
2.	"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 19 to March 22)	Ongoing
Consultancy Projects				
1	Establishment of Silt Observation Post (SOP) in the Baglihar HEP catchment	P. Kumar P. G. Jose S. S. Rawat	06 months (Mar 2016 to Oct 2016)	Ongoing/ Ext. upto Sep 2017

REGIONAL CENTRE, BHOPAL

Approved Work Program for 2019-20

S.N.	Name of the project	Duration	Study Group	Status
1.	Evaluation of impacts of Rabi irrigation in Ganga river sub basin of Madhya Pradesh	3 years	**PI-** Er. R.V.Galkate, **Co-PI** Er. R. K. Jaiswal Dr. T.R. Nayak Dr. T. Thomas Ms.S.P. Indwar	Started in Oct 2017 to Sept 2020
2.	Impacts of Upcoming Irrigation Projects and Climate Change on the Droughts and Desertification Scenario for Chambal Basin in Western Madhya Pradesh.	4 years	**PI-** Dr. T. Thomas **Co-PI** Dr. P.C. Nayak Dr. Surjeet Singh Dr. B. Venkatesh Er. R.V. Galkate Dr. R. K. Jaiswal Ms. S.P. Indwar	Started in Dec, 2017 to Nov 2021
3.	Integrated Assessment of the Impacts of Climate Change and Land use Change on the Hydrology of the Narmada basin through Hydrological Modelling Approaches	5 Years	**PI-** Dr. T. Thomas **Co-PI** Dr. Surjeet Singh, Dr. B. Venkatesh, Dr. P. C. Nayak, Dr. ArchanaSarkar, Er. Manish Nema, Dr. Prabhash Mishra, Er. S. P. Indwar Dr. Sharad Jain, Dr. N.C. Ghosh, Dr. J. V. Tyagi, Dr. Sanjay K. Jain, Dr. M. K. Goel,	Started in Feb 2018 to Jan 2023)
4.	Modelling of Narmada using GWAVA	4 years	Dr. Sanjay Jain (PI) **Co-PI** Dr. T. Thomas, Dr. P K Mishra, Er. Manish Nema Dr. Sharad Jain	Started in April 2015 to March 2019)
5.	Revival of Village Ponds through Scientific Interventions in Sagar District (Sponsored R&D Project by Department of Science & Technology, Govt. of India)	2 years	**PI-** Dr. T. Thomas **Co-PI** Dr. Sandeep Goyal, MPCST, Bhopal Dr. Vivek Bhatt, WALMI, Bhopal. Dr. Jyoti Patil, NIH, Delhi	Started in July-2017 to December 2019
6.	Modelling of Tawa Reservoir Catchment and Development of Tawa Reservoir Operation Policy	3 Years	**PI-** Er. S. P. Indwar **Co-PI** Dr. T.Thomas Dr. T.R. Nayak Er. R.V. Galkate Er. R. K. Jaiswal	Started in September 2017-August 2020
7.	Estimation of Revised Capacities in Reservoirs of Chhattisgarh State using	1 Year	**PI-** Dr. R. K. Jaiswal **Co-PI**	Started in April 2019 to

	Digital Image Processing technique: Part-III (Sikasar, Pipariya, Miniyarim Chhirpani and Khutaghat reservoirs)		Dr. T.R. Nayak Er. R.V. Galkate Er. S. P. Indwar Sh. Akhilesh Verma WRD Raipur	March 2020
8.	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	4 Years	**PI-** Er. R. K. Jaiswal **Co-PI** Er. R.V. Galkate Dr. T.R. Nayak Dr. T.Thomas Er. S. P. Indwar Dr. D.S. Rathore Dr. A.K. Lohani Dr. Sudheer Kumar Dr. Surjeet Singh	Started in April 2019 to March 2023
9.	Development of Decision Tool for Efficient Utilization of Water Resource in Parwati Canal & Dholpur Piped irrigation Project of Rajasthan.	3 Years	**PI-** Dr. R. K. Jaiswal **Co-PI** Er. R.V. Galkate Dr. T.R. Nayak Dr. A.K. Lohani Er. S. P. Indwar	Started in Started in April 2019 to March 2022

REGIONAL CENTRE, KAKINADA

Approved Work Program 2019-20

S.No	Title of the Project	Team	Duration (Start date and End date)	Funding
I.	**Internal Studies**			
1	Sedimentation Study of Hirakud Reservoir, Odisha using Optic and Microwave Remote Sensing Technology	V.S. Jeyakanthan (PI) J.V. Tyagi Y.R. Satyaji Rao S.V. Vijaya Kumar R. Venkata Ramana P.C. Nayak	July 2017-June 2020	Approved by NHP PDS (Rs.51.19 lakhs) (SP-28/2017-18/PDS-3)
2	Groundwater salinity source identification in Godavari delta, Andhra Pradesh	Y R Satyaji Rao(PI) T Vijay, R V Ramana S V Vijaya Kumar	Dec.2017-Nov. 2020	Approved by NHP PDS (Rs 61.09 lakhs) (SP-28/2017-2018/PDS-13)
3	Forecasting of Flash flood and Management for east flowing rivers of India's Subzone 4(a)	R. V. Ramana (PI) Y.R. Satyaji Rao V.S. Jeyakanthan S.V. Vijaya Kumar T.Vijay	Dec 2017-Nov 2020	Internal (NIH)
4	Study of the behavior 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 J.V.Tyagi Y R Satyaji Rao T Vijay	April 2018-March 2021	Approved under NHP as PDS (partnership With AP SGW &WA Dept.
5	Dam break studies of Somasila, Kandaleru and Pulichintala dams in Andhra Pradesh	P.C.Nayak Y.R.Satyaji Rao	2019-20 to 2021-22	Uunder NHP-PDS
II.	**Sponsored Projects**			
6	River bank Filtration (RBF) studies in coastal alluvium of A.P	Y R Satyaji Rao T Vijay	April 2016 – December 2019	Under Peya Jal Suraksha Project
7	High Performance Advanced Septic System for Villages and Roadside Restaurants	Y R Satyaji Rao T Vijay	April 2018 - March 2020	Funded by IC-IMPACT, Canada
8	Unravelling Submarine Groundwater Discharge (SGD) Zones along A.P and Odisha States (Mission SGD)-Pilot Study	Y R Satyaji Rao T Vijay	April 2019 to March 2020	Funded by MoES through NCESS SP-35/2018-20/HID

CFMS-GUWAHATI

Approved Work program for 2019-20

S.N.	Title	Study Group	Duration (Month/Year)	Remarks
1.	Flood Inundation Mapping of Beki River Basin of Assam	S.K Sharma, Rakesh Kumar, Pankaj Mani, J P Patra, G. Arun	3 years (4/18 to 3/21)	On-going

2.	Development of regional methods for design flood estimation in North Brahmaputra subzone 2 (a).	S.K Sharma, Rakesh Kumar, Pankaj Mani, J P Patra, G. Arun	3 years (4/18 to 3/21)	On-going
3.	Linear Hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin	Gulshan Tirkey, S. K. Sharma, P. Mani, G.Arun	3 years (4/18 to 3/21)	On-going
4.	Impact of Climate Change on Runoff and Sediment Yield for a Major Tributary of River Brahmaputra	Swapnali Barman, J.V. Tyagi, R.K. Bhattacharya, Waikhom Rahul Singh	3 years (11/18 to 10/21)	On-going
5.	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 (4/19 to 3/21)	New Study
6.	Comparison of Hydrological Behaviour of two mid-sized Mountainous Catchments under the influence of Climate and Land Use Changes	Waikhom Rahul Singh, A.K. Lohani, A. Bandyopahdyay Swapnali Barman Nitesh Patidar	3 years (7/19-3/22)	New Study

CFMS-PATNA

Approved Work program for 2019-2020

S N	Title	Study Team	Duration
Internal Studies			
1.	Demonstration scheme on Riverbank Filtration in Gangetic plain of Bihar	B. Chakravorty (PI) N. G. Pandey	On going (02/16-03/20)
2.	River shifting analysis and flow modelling study of Ganga river from Rishikesh to Anupshahar	Pankaj Mani (PI) Rakesh Kumar, J. P. Patra	On going (04/16-03/20)
3	Drought Studies for Selected Districts in South Bihar.	SR Kumar (PI)	3 year (4/19 – 3/22)
4	Bank erosion of river Bhagirathy-Hoogly upto Bujbuj and its morphological changes	NG Pandey (PI)	2 year (04/19-03/21).
Sponsored Study (PDS/NHP)			
5.	Modelling and management of erosion and sedimentation processes in alluvial river using morphodynamic modeling	Pankaj Mani (PI) Rakesh Kumar, J. P. Patra, B. Chakravorty & WRD Bihar	New study proposed under PDS (04/19-03/22)

APPENDIX – 74.6.1

WORK PROGRAMME OF THE DIVISIONS AT THE H.Q. AND RC’s/CFMS OF THE INSTITUTE FOR THE YEAR 2020-2021

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	Sh. Rajesh K. Nema	Scientist B
6	Ms. Anjali	Scientist B
7	Smt. Babita Sharma	RA
8	Smt. Bina Prasad	RA

Recommended Work Programme for the Year 2020-21

SN	Study	Study Team	Duration/Status
Sponsored Projects (Ongoing)			
1.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	M. K. Sharma(PI) Manohar Arora Pradeep Kumar Rajesh Singh D. S. Malik (GKU)	5 Years (04/16-03/21) **Sponsored by**: DST (NMSHE) **Project Cost**: Rs. 2.25 Crore **Status:** In-progress
2.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures	M. K. Sharma (PI) Surjeet Singh Pradeep Kumar **Partner:** WRD, Raipur, CGWB, Raipur	3 Years (09/17-08/20) **Sponsored by**: NHP-PDS **Project Cost**: Rs. 25.4 Lakh **Status:** In-progress *Request Extension upto 03/21*
3.	Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures	Rajesh Singh (PI) Pradeep Kumar M. K. Sharma Sumant Kumar **Partner:** Irrigation Department, Punjab	3 Years (09/17-08/20) **Sponsored by**: NHP-PDS **Project Cost**: Rs. 65.6 Lakh **Status:** In-progress *Request Extension upto 03/21*
4.	Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures	Anjali (PI) Sudhir Kumar, J. V. Tyagi, M. K. Sharma, Nitesh Patidar **Partner:** CGWB (Delhi unit)	3 Years (11/19 – 10/22) **Project cost:** Rs. 76.10 Lakh **Sponsored by**: NHP-PDS **Status:** In-progress
Internal Study (Ongoing)			
5.	Water quality assessment of Haridwar District	R.K. Nema (PI) Rajesh Singh J. V. Tyagi Pradeep Kumar	3 years (05/19-12/20) **Project cost:** 17.10 lakh **Status:** In-progress
6.	Simulation of Non-Point Source Pollution Processes in Song River	Pradeep Kumar (PI) J. V. Tyagi M. K. Sharma Rajesh Singh R. K. Nema	4 years (11/19-10/23) **Project cost:**43.02 lakh **Status:** In-progress
Internal Study (New)			
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 Nitesh Patidar Surjeet Singh Rajesh Singh	3 Years (07/20-06/23) **Project cost:** Rs. 20.24 Lakh **Sponsored by**: Internal **Status:** New Project
8.	Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar	Rajesh Singh (PI) J. V. Tyagi R.K. Nema Pradeep Kumar	2 Years (06/20-05/22) **Project cost:** Rs. 23.71 Lakh **Sponsored by**: Internal

		M. K. Sharma	**Status:** New Project
Consultancy Projects (New Project)			
9.	Estimation of Economic Losses in Real Terms per Hectare Basis due to Forest Fire in Uttarakhand and Madhya Pradesh	J. V. Tyagi (PI) Pradeep Kumar (Co-PI) T. Thomas (Co-PI) L. N. Thakural, P. K. Singh, M. K. Sharma, Rajesh Singh, R. K. Nema	2 Years (03/20-02/22) **Sponsored by:** ICFRE **Project Cost**: Rs. 1.1033 Crore **Status:** New Project

Training Programmes

SN	Topic	Duration	Place
1.	Water Quality Management under NHP-PDS (Coordinator: Dr. M. K. Sharma)	5 Days	Roorkee
2.	Water Quality Assessment & Management under NHP-PDS (Coordinator: Dr. Rajesh Singh)	5 Days	Roorkee
3.	Water Quality: Concepts and Analysis under NHP (Coordinator: Dr. Pradeep Kumar)	5 Days	Roorkee
4.	Contaminant Transport Modeling under NHP-PDS (Coordinator: Ms. Anjali)	5 Days	Roorkee

Study - 1 (Sponsored Project)

1. **Title of the Study:** Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin (Subproject-10).

2. **Study Group:**

Project Investigator/Co-Project Investigator
Dr. M. K. Sharma, Sc. 'E' Dr. Manohar Arora,Sc. 'E'
Co-Investigator
Dr. Pradeep Kumar, Sc. 'D' Dr. Rajesh Singh, Sc 'D'
Scientific/Technical Staff
Smt. Babita Sharma, RA Smt. Beena Prasad, RA Sri. Rakesh Goyal, Tech. Gr. I
Collaborating Agency
Prof. D. S. Malik, Professor, GKU, Haridwar

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

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

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

6. **Scheduled date of completion:** March 2021

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

8. **Study Objectives:**

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

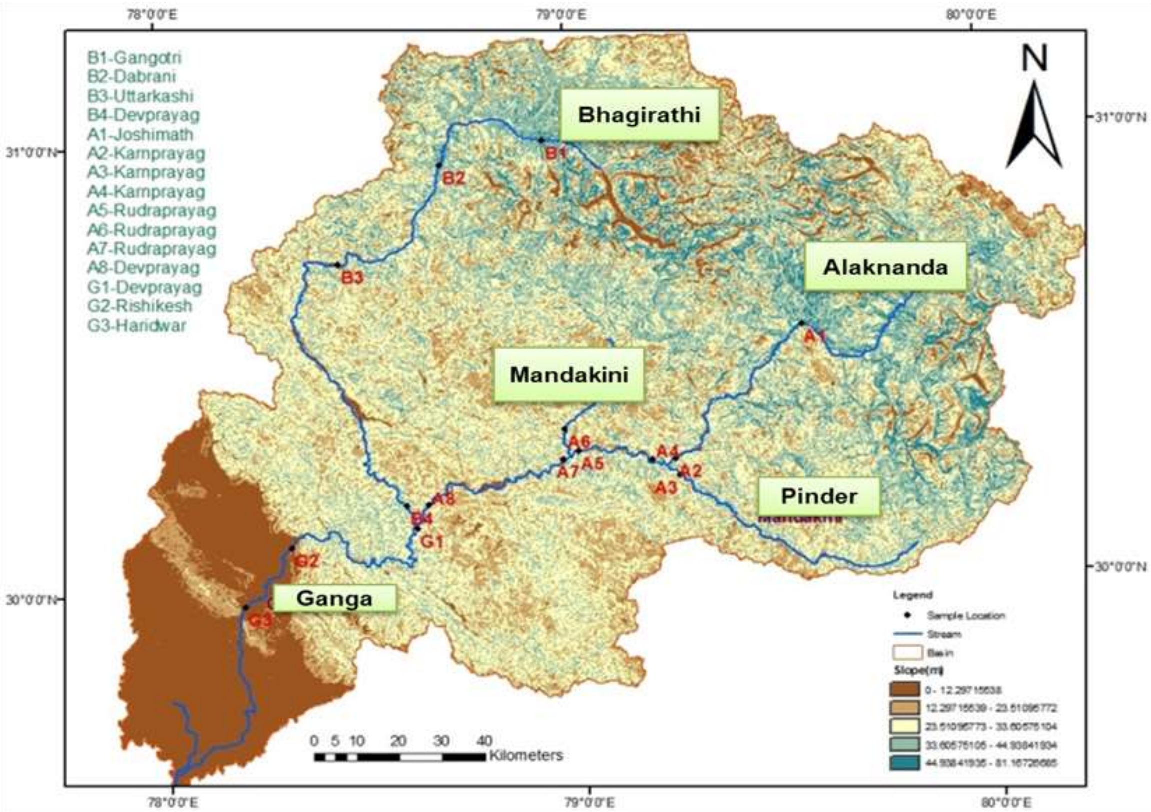
9. **Statement of the Problem:**

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

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

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

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



Study area: Upper Ganga Basin

10. Approved Action Plan/Methodology:

i) Water quality assessment through comprehensive field and laboratory investigations.

ii) Monitoring point and non-point source pollution

iii) Adsorption characteristics through laboratory scale model studies.

iv) Kinetics and thermodynamics of adsorption process through experiment approaches.

v) Monitoring temporal abundance of different aquatic species at selected locations

vi) Monitoring aquatic habitat parameters (depth, velocity, slope, gradient, substrate, pH, conductance, water temperature, DO, BOD, COD, TDS, salinity, etc.) at selected locations

vii) Assessment of aquatic biodiversity: Phytoplankton, zooplankton, benthos and piscine fauna (distribution, species richness and abundance as per their habitat)

viii) Impact assessment of environmental flows in relation to productivity of River Ganga

ix) Estimating environmental flows in critical reaches

11. Timeline:

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

12. Objectives and achievement during last six months:

Objectives	Achievements
Processing of Hydro-chemical data	• Spatial and temporal variation of hydro-chemical parameters completed. • NPS contribution for Alaknanda Stretch completed.
Adsorption characteristics	• Experiments of Adsorption of metal Cd on bed sediment of Bhagirathi, Alaknanda and Ganga for different operating variables completed. • Experiments of Adsorption of Nickel are under progress.
Habitat characteristics	• Habitat characteristics data of 8 selected zones completed.
Aquatic biodiversity	• Relative abundant species of aquatic biodiversity completed. • Biodiversity indices (Shanon – Weiner Index, Simpson Index, Evenness Index) for 8 zones completed.
Environmental flow estimations	• Keystone species in the study area identified • Habitat suitability curves for the keystone species were developed. • Habitat Simulation Modelling using SEFA software completed for maintaining environmental flow for sustenance of keystone aquatic species for Joshimath, Rudraprayag, Devprayag and Rishikesh sites.

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
No comments	-

14. Analysis & Results:

i) Spatial and temporal variation of hydro-chemical parameters for River Bhagiarthi, Alaknanda and Ganga completed. High values of COD indicate anthropogenic pollution. TSS is high at all the locations and decreases from higher elevation to lower elevation because sediments gets deposited due to geomorphology of the river.

ii) Processed hydro-chemical data for NPS contribution in Alaknanda Stretch using chemical mass balance approach.

iii) Experiments of Adsorption of metal Cd on bed sediment of Bhagirathi, Alaknanda and Ganga for different operating variables completed and data is being processed for thermodynamic parameters and adsorption kinetics.

iv) Relative abundant species of aquatic biodiversity completed.

v) Aquatic habitat parameters were monitored at eight selected zones on quarterly basis for development of habitat suitability curves. Higher BOD observed during summer season in upper ganga basin due to high temperature that favours microbial activity. Seasonal variation observed in abiotic parameters during the whole study. Physico-chemical parameters concentration of water showed that river water was under good quality condition i.e. good for aquatic biodiversity growth and survival.

vi) The keystone species for upper (>1500m), middle (500-1500m) and lower (< 500m) zones are Brown Trout, Snow Trout and Golden Mahseer respectively. The habitat suitability curves for the keystone species were developed which may be used for the habitat simulation modelling with more detailed data.

vii) Habitat Simulation Modelling provides a number of optional scenarios for the maintenance of different levels of habitat sustenance whereas in case of hydrodynamic modelling, the flows optimum for maintaining a certain depth of water are recommended.

viii) The final modelling output of the habitat simulation modelling is the Area Weighted Suitability (m^2/m of reach length) which indicates the suitability of a particular discharge for the habitat sustenance. Based on the variability of AWS for the historical flow variability, AWS duration analysis may be carried out in the SEFA software which may further be used for selecting a particular level of AWS for providing reasonable habitat for different seasons.

ix) Assuming that the environmental flows may be kept for maintaining the median or higher values of AWS for sustenance of keystone aquatic species, e-flows are recommended at Joshimath site, Rudraprayag site, Devprayag site (after confluence) and Rishikesh sites.

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

16. Deliverables: Technical report and research papers:

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

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

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

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

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

20. Study Benefits / Impacts:

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

21. Involvement of end users / beneficiaries:

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

23. Shortcoming/Difficulties: No

24. Future Plan:

- Processing of hydro-chemical data.
- Experiments of Adsorption on bed sediments and processing data for thermodynamic parameters and adsorption kinetics.
- Processing of habitat parameter data for Habitat Suitability Curve.
- Assessment of Environmental flow requirement using SEFA Software.
- Write up of the Project Report.

Study - 2 (Sponsored Project)

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

2. **Study Group:**

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

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

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

5. **Date of start:**1 September, 2017

6. **Scheduled date of completion:** 31 August 2020 (Extension till March 2021 required)

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

8. **Study Objectives:**

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

9. **Statement of the Problem:**

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

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

10. Approved Action Plan/Methodology:

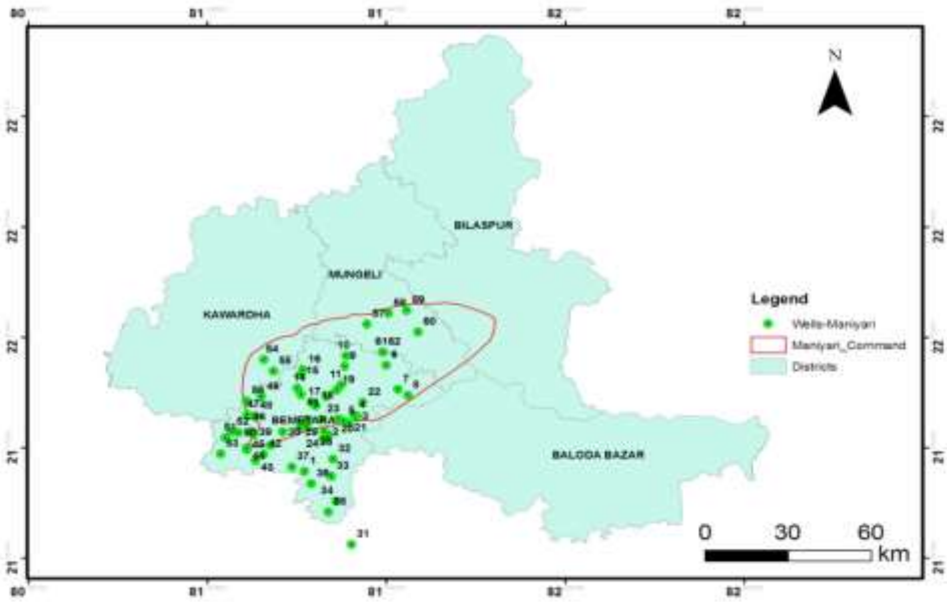
i) Literature survey on assessment of groundwater quality and issues in the region.

ii) Analysis of groundwater resources in the Bemetara district.

iii) Collection of existing meteorological and groundwater quality data of various locations of the Bemtara district and analysis.

iv) Collection of groundwater levels and lithological data from State Groundwater Department.

v) Hydrogeological characterization of the study area and establish specific linkages of groundwater quality with hydrogeology.



Study area: Maniyari Shale Formation

vi) Collection of groundwater samples from selected sources in pre-monsoon (April-May) and post-monsoon (October-November) season at identified locations.

vii) Analysis on flow and movement of groundwater.

viii) Analysis for physico-chemical parameters: pH, EC, TDS, Alkalinity, Hardness, Major Cations (Na, K, Ca, Mg), Major Anions (HCO_3, Cl, SO_4, NO_3), Minor Ions (F, PO_4,) and Toxic (Heavy) Metals: As, Cd, Cr, Pb, Cu, Ni, Fe, Zn, Mn in the collected water samples.

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

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

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

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

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

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

11. Timeline:

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

12. Objectives and achievement during last six months:

Objectives	**Achievements**
Field visit, Sampling, Data Collection and processing of the data	• A field visit was made during 23-27 December 2019 for post-monsoon sampling and rainfall data, aquifer parameter data from WRD, Raipur.
Sample Analysis and processing of the data	• Hydro-chemical analysis completed and processed the data.
Modelling flow and transport of sulphate using MODFLOW & MT3D	• Prepared the input database for simulation of groundwater flow using MODFLOW & MT3D.

13. Recommendation / Suggestion: No Comments

Recommendation / Suggestion	**Action Taken**
Dr. Man Singh enquired about the sources of nitrate in the study area. Dr. Sharma replied that the analysis of ammonia will also be carried out in collected samples in future to confirm the source of nitrate.	• Collected samples were analysed for ammonia concentration.

14. Analysis & Results:

i) Hydro-chemical analysis of collected groundwater sample completed.

ii) Processed hydro-chemical data for water type, classification, hydrogeochemical analysis and calculating Water Quality Index.

iii) Prepared the following database for simulation of groundwater flow using MODFLOW model:
- Contour maps for ground water level (2014-2018)
- River shape files in study area
- Shape for Soil map and landuse data
- River stage Data

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

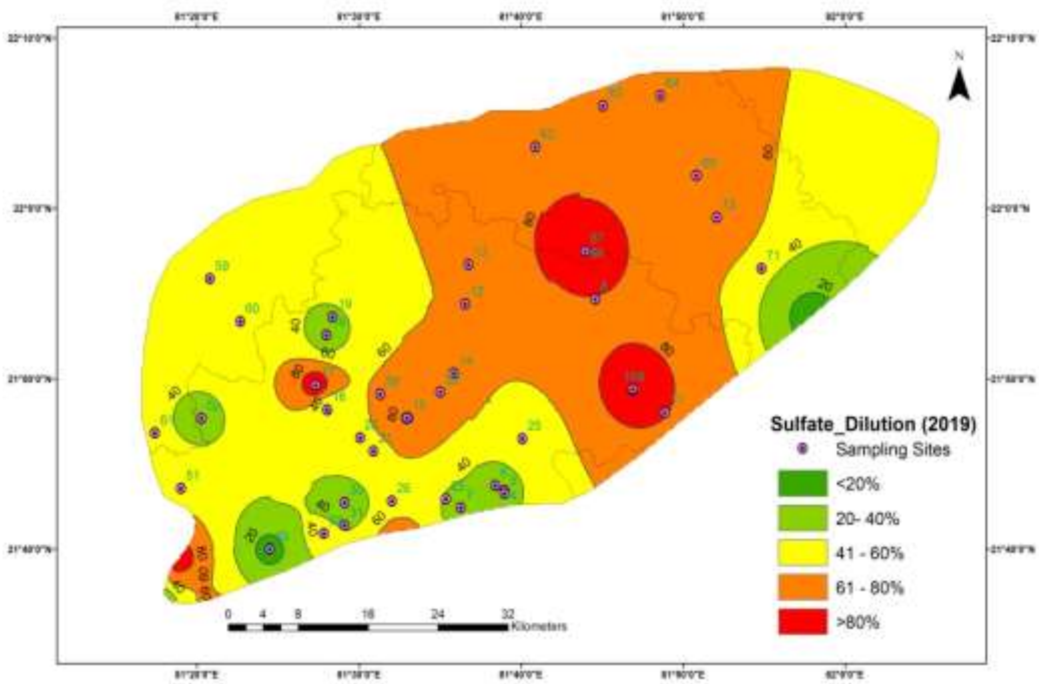
16. **Deliverables:** Technical report and research papers:

Research papers – 3 Nos.

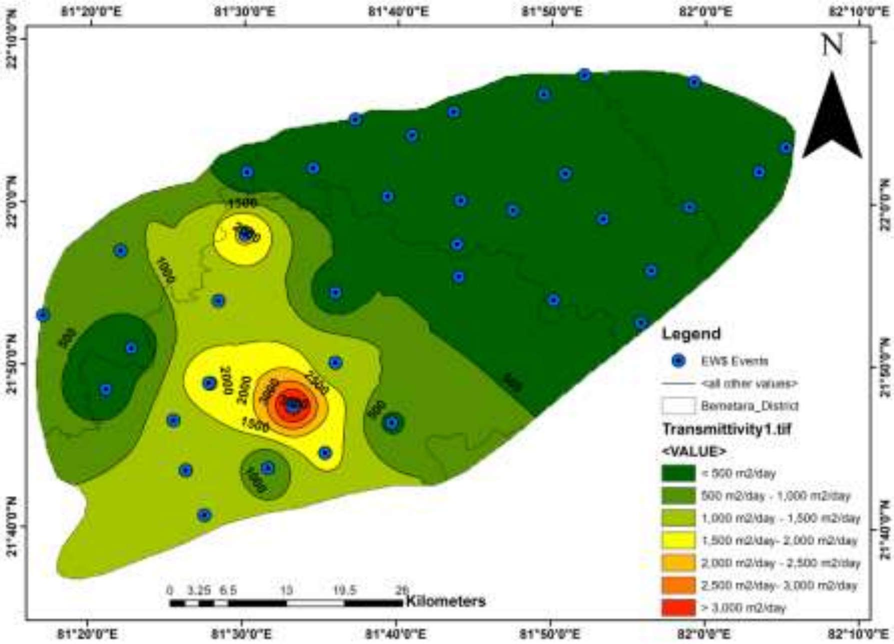
i) Sharma, M.K. and Kumar, Mohit (2020) Sulphate contamination in groundwater and its remediation: An overview, Env. Monit. Assess., 192, 74, 1-10.

ii) Sharma, M.K., Kumar, Pradeep, Singh, Surjeet, Kumar, Mohit and Shukla, A. K. (2019) Source Identification of Sulphate Contamination using Hydrogeochemical Investigation: A Case Study of District Bemetara, Chhattisgarh, India, Submitted for Int. Conf. IGWC-2019 at IIT, Roorke during 21-25 Oct. 2019.

iii) मुकेश कुमार शर्मा, प्रदीप कुमार, राकेश गोयल एवं मोहित कुमार (2019) "बेमेतरा जिले, छत्तीसगढ़ में भूजल गुणवत्ता का मूल्यांकन", राष्ट्रीय जल संगोष्ठी -२०१९, प्रपत्र 8.6



Location of Sulphate Dilution in Maniyari Region



Transmissivity in Maniyari Region

17. Major items of equipment procured:

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

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

20. Study Benefits / Impacts:

For any scheme of water supply in an area, it is mandatory to have the status of water quality of the water resources being used for supply. An extensive survey of groundwater quality monitoring of district Bemetara will provide the knowledge about degraded ground water quality zones and possible sources of pollution and specific parameters not conforming to drinking/ & irrigation water quality standards, which will help the policy makers and society. Further, present PDS will suggest ameliorative measures to restore the quality and sustainable use of groundwater for drinking and irrigation purpose by investigating the hydro-geology of the area.

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

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

23. Shortcoming/Difficulties: No

24. Future Plan:

- Processing of ground water data and water quality data.
- Preparation of Groundwater flow model in Modflow.
- Collection of ground water data, aquifer parameter data and hystorical ground water quality data from CGWB, Raipur and PHED.
- Modelling flow and transport of sulphate contamination using MODFLOW & MT3D.
- Identification of Artificial Recharge sites and quantification of Artificial Recharge using modeling.

Study - 3 (Sponsored Project)

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

2. **Study Group:**

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

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

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

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

6. **Scheduled date of completion:** September 2020 (Extension till March 2021 required)

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

8. **Study Objectives:**

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

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

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

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

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

9. **Statement of the Problem:**

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

10. Approved Action Plan/Methodology:

i) Upgradation of literature and data collection

ii) Delineation of villages and finalization of sampling locations

iii) Sampling & analysis of water samples

iv) Statistical analysis of the contaminant data and cancer incidences

v) Mutagenicity of water resources

vi) Contaminant remediation

11. Timeline:

S. No.	Activities	YEAR 1				YEAR 2				YEAR 3			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1.	Hiring of manpower & training												
2.	Purchase of equipment & consumables												
3.	Upgrading literature and data collection												
4.	Delineation of villages and finalization of sampling location												
5.	Collection and analysis of samples												
6.	Statistical analysis of data and Carcinogenicity test												
7.	Contaminant remediation												
8.	Training & capacity building												
9.	Scientific publications												
10.	Final technical report												

12. Objectives and achievement during last twelve months:

S. No.	Activity	Achievements
1.	Purchase of equipment & consumables	• Laptop & Multiparameter analyzed has been purchased. • For syringe pump, the procurement process is in final stage. • Purchase of software is in the final stage. • Standards and consumable planned for the period 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- and post-monsoon sampling for the delineated villages has been completed. • Analysis of organoleptic and major ions has been completed. • Analysis of trace metals has been completed for pre-monsoon samples. • Processing of samples for pesticide and PAHs analysis has been completed for pre monsoon samples and analysis work will be continue whenever IIT-R will allow to do work. • Analysis of Radon in the drinking water samples has been completed.
4.	Statistical analysis of data and Carcinogenicity test	• The health risk assessment for Bathinda district was done. The same will be replicated for other districts once the analytical results are available. • The infrastructure required for carcinogenicity test is ready and procurement of bacterial strains has been done.
5.	Training & capacity building	A training course for the government officials was organized during June 17-21, 2019 and other will organized in Sept. 2020.
6.	Scientific publications	A research paper titled 'An overview of carcinogenic pollutants in groundwater of India' is published in *Biocatalysis and Agricultural Biotechnology*, https://doi.org/10.1016/j.bcab.2019.101288. Three manuscripts are under writing stage.

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
Dr. Bhism Kumar (Ex. Scientist, NIH & IAEA) suggested to carry out the analysis of Radon in the samples.	Radon concentration in the groundwater of the study area was analyzed.

14. Analysis & Results:

Purchase of equipment & consumables:

- Multiparameter Ion Analyzer with Electrodes: Purchased
- Laptop & Peripherals: Purchased.
- Syringe Pump along with accessories: The purchase process was completed; however, the procurement was not made due to low response from the vendors. The procurement has again reinitiated and is in final stage.
- Software: Procurement of software is in final stage.
- Required planned glassware, plasticware, filter paper and chemical purchased for sample collection and analysis.

Upgrading literature and data collection:

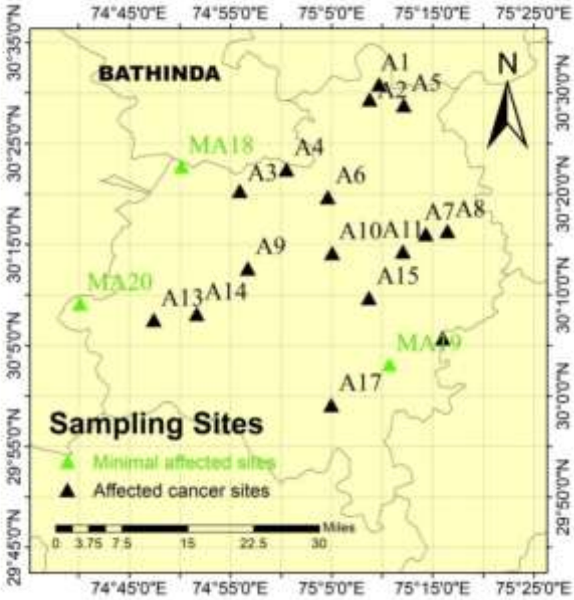
- The recently published literature related to carcinogens in the water and their assessment was reviewed and a review paper titled 'An overview of carcinogenic pollutants in groundwater of India' is published in "Biocatalysis and Agricultural Biotechnology", published https://doi.org/10.1016/j.bcab.2019.101288. 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.

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 & 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, and trace metals analysis has been completed and analysis of pesticides and polyaromatic hydrocarbons are being analyzed following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017).
- Onsite Radon measurement in groundwater from different locations in SW Punjab has been completed from five districts. Radon analysis in groundwater of Fazilka is pending.



Sampling Sites of Bathinda District

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

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

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

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

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

20. **Study Benefits / Impacts:**

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

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

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

23. **Shortcoming/Difficulties:**NA

24. **Future Plan:**

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

Study -4 (Sponsored Project)

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

2. **Study Group:**

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

3. **Type of Study:** Sponsored project by NHP (PDS), Budget: Rs 76,10,000/-
4. **Nature of Study:** Applied Research
5. **Date of start:** 1 November, 2019
6. **Scheduled date of completion:** 31 October, 2022
7. **Duration of the Study:** 3 Years
8. **Study Objectives:**

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

9. **Statement of the Problem:**

The growth in population, urbanization and industrialization has led to the increase in the generation of solid waste all over the world. It is believed that the rate of waste generation is an index of socio-economic development and an economic prosperity of a country. This is evident from the fact that the rate of waste generation is more prominent in the developing countries where there is an increased rate of unplanned urbanization of the cities. In India, the total Indian urban population amounts to approximately 377 million (Census of India 2011). The cities which have more than 100,000 populations contribute to more than 72 percent of the total municipal solid waste. The growth rate of population in urban India is much higher than that in rural India. The Census figures also show Delhi to be the most urbanised State in India. Since waste generated by the city depends on its population and per capita income, it is estimated that the quantity of Municipal Solid Waste (MSW) would reach 17,000 – 25,000 MT/day by 2021 (Talyan et al.,2007). For solid waste management in Delhi, twenty landfill sites were identified and developed since 1975, and of which 15 have already been closed and two were suspended. At present only three landfill sites are in operation. They are namely, Bhalaswa catering the needs of northern part of Delhi, Okhala in the southern part and Gazipur in the eastern part of Delhi. The dumping of waste in these non-engineered landfill sites contributes to percolation of leachate in the groundwater. These percolating liquids have high concentration of hazardous chemicals. The harmful constituents of leachate then move along the groundwater in the surrounding region rendering it unfit for human consumption and pose various health risk.

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

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:

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

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

S. N.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared.
2.	Decolourization of samples	• Samples colour removal was undertaken • Reasons for coloured samples was identified.
3.	Literature survey	• Literature on Microplastics, leachate characterization and isotopes in landfill was extensively surveyed.

13. **Recommendation / Suggestion:**

Recommendation / Suggestion	Action Taken
Dr. Bhishm Kumar suggested to go for dilution instead of removing colour from the sample or monitor the changes in parameters.	Dilution was also tried.

14. **Analysis & Results:**

- Field Survey was undertaken for selecting sites for Leachate sampling.
- For understanding the basic characteristics of leachate, preliminary samples were collected in order to find out the suitability of various experiments and to identify the procedures need to be followed in future.
- The physico-chemical, metal contents and isotopic parameters of Leachate was identified.
- Reasons for coloured samples which hinders various experiments is being identified.
- Decolouration of samples were carried out through $FeCl_3$ and Fenton.
- Risk on human health because of consumption groundwater is evaluated.

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

16. **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.

17. **Major items of equipment procured:** Procurement procedure for FTIR imaging, MODFLOW and TLC meter initiated.

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

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

20. **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.

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

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 Dr. J. V. Tyagi, Sc. G & Head, EHD Dr. Pradeep Kumar, Sc. C, EHD
Scientific Staff	Mrs. Anju Chaudhary, PRA Mr. Rakesh Goyal, Tech. Gr. 1

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

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

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

6. **Scheduled date of completion:** Rescheduled to be December 2020

7. **Duration of the Study:** 1.5 year

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 analyzingthe water samples for organoleptic parameters, major ions, trace metals, and pesticides to understand the suitability of water for different usage and to understand the weathering processes controlling the water quality.

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

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

11. Timeline:

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

12. Objectives and achievement during last six months:

S. No.	Activity	Achievements
1.	Field Investigation and sampling plan	• The sample locations and sampling plan prepared
2.	Sample Collection and Analysis	• Pre- and post-monsoon samples were collected from 68 locations. • Analysis for organoleptic, major ions, and coliforms in the collected samples completed. • Analysis of trace metals in pre-monsoon samples completed and pending for post-monsoon samples. • Samples were processed for pesticides analysis and analysis will be completed after the facilities in IITR starts functioning.
3.	Data Processing and Interpretation	• Data processing is under progress.
4.	Interim Report	• 1st interim report prepared and submitted.

13. Recommendation / Suggestion:

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

14. Analysis & Results:

Field Investigation and sampling plan

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

Sampling & Analysis

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

The organoleptic parameters, major ion, and bacteriological analysis completed for both pre- and post-monsoon samples. Trace metals analyzed for pre-monsoon samples and pending for post-monsoon samples. Pesticides are being analyzed following APHA's Standard Methods for the Examination of Water and Wastewater (APHA, 2017).

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

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

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

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

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

20. **Study Benefits / Impacts:**

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

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

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

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

24. **Future Plan:**

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

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 Dr. M. K. Sharma, Sc. 'E', EHD Dr. Rajesh Singh, Sc. 'D', EHD Er. R. K. Nema, Sc. 'B', EHD
Scientific Staff	Mrs. Babita Sharma, RA Mrs. Beena Prasad, RA Mr. Rakesh Goyal, Tech. Gr. I

3. **Type of Study:** Internal Study**, Budget:** Rs 43.02 lacs
4. **Nature of Study:** Applied Research
5. **Date of start:** Nov 2019
6. **Scheduled date of completion:** Oct 2023
7. **Duration of the Study:** 4 Years
8. **Study Objectives**

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

9. **Statement of the Problem:**

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 was been prepared starting from Apr 2020, but, due to lockdown, the same will be started as the situations normalize.
(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).
(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	--

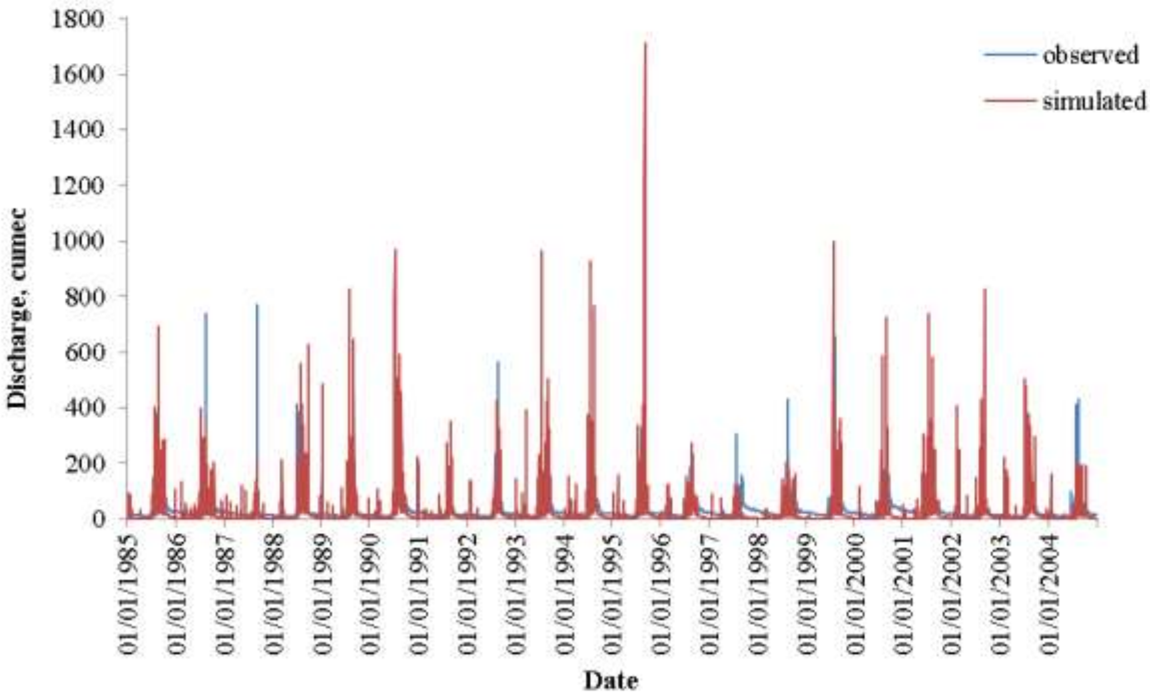
14. Analysis & Results:

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 Suswa river 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.

SWAT Model setup

Although sampling was planned to be started in April 2020, but, due to Corona pandemic, the same will be started when the situations normalize. In the meantime, 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.

Study – 1 (Internal Study - New)

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

2. Study Group:

Study Team
Dr. M. K. Sharma, Sc. E– Principal Investigator Dr. Sudhir Kumar, Sc. 'G'- Project Coordinator Dr. R. P. Pandey, Sc. 'G' & Head Dr. Anupma Sharma, Sc. 'F' Ms. Anjali, Sc. 'B' Dr. Vishal Singh, Sc. 'C' Dr. Pradeep Kuamr, Sc. 'D' Dr. Nitesh Patidar, Sc. 'B' Dr. Surjeet Singh, Sc. 'F' Dr. Rajesh Singh, Sc. 'D'
Supporting Staff
Mrs. Babita Sharma, RA Mrs. Beena Prasad, RA Mr. Rakesh Goyal, Tech. Gr. I

3. Type of Study: Internal

4. Nature of Study: Applied Research

5. Date of Start: July 2020

6. Scheduled date of Completion: June 2023

7. Duration of the Study: 3 years

8. Study Objectives

i) Understanding the river basin system through historical data analysis of surface and groundwater sources
ii) To study the water balance of Hindon River basin
iii) Identification of major contaminant zones and sources of river pollution
iv) Identification of affluent and effluent sections of River Hindon
v) Prepare the river rejuvenation plan for River Hindon

9. Statement of the Problem

River Hindon, an important tributary of river Yamuna flowing through the districts of Western Uttar Pradesh, is subjected to varying degree of pollution caused by numerous untreated and/or partially treated waste inputs of municipal and industrial effluents. The toxic pollutants from these wastes will ultimately reach the ground water and enter in the food chain posing a threat to human health because of their carcinogenic nature. 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. 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

S. No.	**Major Activities**	**2020-21**				**2021-22**				**2022-23**				**2023-24**			
		Q 1	**Q 2**	**Q 3**	**Q 4**	**Q 1**	**Q 2**	**Q 3**	**Q 4**	**Q 1**	**Q 2**	**Q 3**	**Q 4**	**Q 1**	**Q 2**	**Q 3**	**Q 4**
1	Reconnaissance visit and sampling plan																
2	Data collection																
3	Field surveys																
4	Inventory Plan																
5	Sample collection/Analysis/Experiment																
6	Preparation of database																
7	Identification of affluent and effluent sections																
8	MODFLOW Model: Calibration & Validation																
9	SWAT Model: Calibration, Validation & Simulation of river water and groundwater interaction																
10	Reach-wise Recharge augmentation plan																
11	Interim Report																
12	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	258000	258000	258000	774000
2.	Travelling expenditure	100000	300000	100000	500000
3.	Infrastructure /Equipment /Consumable	100000	100000	100000	300000
4.	Experimental charges/Analytical charges	100000	100000	100000	300000
5.	Misc. Expenditure	50000	50000	50000	150000
6.	Grand Total	608000	808000	608000	2024000

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

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

S. No.	Manpower Category	Nos.	Gross Salary per month	1st year	2nd year	3rd year	Total
1.	Resource Person (Junior)	1	21500	258000	258000	258000	774000

- Travelling expenditure: For visit to study area, attending conferences, data collection, surveys etc. (one visit per month for sampling/Field survey)
- Equipment/Consumables: Purchase of chemicals, glasswares, plasticwares etc.
- Experimental/Analytical charges: Towards analysis of samples in outside laboratories and in NIH water quality lab

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

a) Identification of major contaminant zones and Inventory of pollution sources contributing to the River
b) Identification of affluent and effluent sections
c) Reach-wise Recharge augmentation plan to rejuvenate the river
d) Technical report and papers

14. **End Users/Beneficiaries of the study**: Deptt. of Irrigation, UP, Ground Water Department, UP, and UPSPCB

Study – 2 (Internal Study - New)

1. Title of the Project	**:**	Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar
2. Project Team		
a. Project Investigator	**:**	Dr. Rajesh Singh, Sc. D, EHD
b. Project Co-investigator	**:**	Dr. J. V. Tyagi, Sc. G & Head, EHD Er. Rajesh K. Nema, Sc. B, EHD Dr. Pradeep Kumar, Sc. D, EHD Dr. M. K. Sharma, Sc. E, EHD

3. Objectives

- Improvement in river water quality due to covid-19 lockdown and deterioration due to anthropogenic activities over time and space.
- Self-purifying capability of river Ganga and factors responsible for it.
- Statistical analysis and water quality indexing.

4. Present state-of-art

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.

Our main interest is to analyze the river Ganga water sample for different physico-chemical and bacteriological parameters in a stretch from Rishikesh to Haridwar, on fortnightly 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.

5. Methodology:

a. Collection of surface and groundwater 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.

6. Research Outcome from the Project:

a. Impact of anthropogenic (religious) activities on the water quality of river Ganga.
b. Processes/reasons responsible for non-putrefying nature of river.
c. Technical report and papers

7. Cost Estimate

a. Total cost of the project **:** Rs. 2371200.00

b. Source of funding **:** NIH (Internal)

c. Sub headwise abstract of the cost **:**

Sr. No.	**Sub-Head**	**I Year**	**II Year**	**Total**
1	Manpower (Resource Person (Junior)	4 09 200	4 62 000	**8 71 200**
2	Travelling expenditure	2 50 000	1 50 000	**4 00 000**
3	Infrastructure / Equipment / Consumable	7 00 000	2 00 000	**9 00 000**
4	Experimental charges	50 000	50 000	**1 00 000**
5	Misc. Expenditure	50 000	50 000	**1 00 000**
	Grand Total	1459200	912 000	**2371200**

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

- Travelling expenditure: For visit to study area, attending conferences, data collection, surveys etc.
- Equipment/Consumables: Purcahse of chemicals, glasswares, plastics, electrodes, etc.
- Experimental charges: Towards analysis of samples in outside laboratories

8. Work Schedule

a. **Probable date of commencement of the project** **:** June 2020

b. **Duration of the project** **:** 2 Years

c. **Stages of work & milestone**

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

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	Er. Sumant Kumar	Scientist D
5	Mrs. Suman Gurjar	Scientist C
6	Dr. Gopal Krishan	Scientist C
7	Sh. Nitesh Patidar	Scientist B
8	Mrs. Anju Choudhary	PRA
9	Sri Sanjay Mittal	SRA
10	Sri S.L. Srivastava	SRA
11	Sri Ram Chandra	RA

Recommended Work Programme for the Year 2020-21

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GWH/NIH/19-21	Application of Satellite Data Products for Water Resources Assessment	Suman Gurjar (PI), Vishal Singh, Surjeet Singh, C. P. Kumar, P. K. Singh	2 years (05/19 - 04/21) *Status: In progress*	Internal Study
2. NIH/GWH/NIH/19-20	The Regional Hydrological Impact of Agricultural Water Saving Measures in the Gangetic Plains	Sumant Kumar (PI), C. P. Kumar, Archana Sarkar, Surjeet Singh, P. K. Mishra	1 year 8 months (08/19 – 03/21) *Status: In progress*	Internal Study (in collaboration with CSIRO, Australia)
3. 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	5 months (07/20 – 11/20) *Status: New Study*	Referred by DoWR (MoJS)
4. 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: New Study*	Internal Study
Sponsored Projects				
5. NIH/GWH/NMSHE/16-20	Study of River - Aquifer Interactions and Groundwater Potential at Selected Sites in the Upper Ganga Basin up to Dabrani	Surjeet Singh (PI), C. P. Kumar, R. J. Thayyen, Sudhir Kumar, Manohar Arora, Gopal Krishan, Nitesh Patidar, Anjali	5 years (01/16 - 12/20) *Status: In progress*	Sponsored by DST under NMSHE SP-8
6. NIH/GWH/BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency Groundwater Level and Salinity Measurements	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar, M. S. Rao *From: BGS, UK* Dr. Dan Lapworth (PI) Prof. Alan MacDonald	3.5 years (12/17-06/21) *Status: In progress*	Sponsored byBGS, UK
7. NIH/GWH/PDS/17-20	Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin	Sumant Kumar (PI), Sudhir Kumar, Rajesh Singh, Gopal Krishan, Anju Chaudhary *Partner Organization:* MWRD, Bihar *Collaborator:* Brijesh Yadav, IIT Roorkee and N.S Maurya, NIT Patna	3.5 years (12/17-06/21) *Status: In progress*	Sponsored by NHP under PDS

8. 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	4 years (12/17-11/21) *Status: In progress*	Sponsored by NHP under PDS
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, Sudhir Kumar, Suman Gurjar, Gopal Krishan	4 years (12/17-11/21) *Status: In progress*	Sponsored by 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 (India Lead), Surjeet Singh (Dy. Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar *Other India Partners:* IITR, IITKg, MCS, Patna *UK Partners:* Univ. of Manchester, BGS, Salford University, Univ. of Birmingham	3 years (01/18 - 12/20) *Status: In progress*	DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme
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 (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)	3 years (01/18 - 12/20) *Status: In progress*	DST-Newton Bhabha-NERC-India-UK Water Quality Research Programme
12. 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	4 years (04/18-03/22) *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 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)	5 years (03/19 - 02/24) *Status: In progress*	Sponsored by DST
14. NIH/GWH/CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Coordinator)	3 years (07/20 – 06/23) *Status: New Study*	Sponsored by Federal Ministry of Education and Research, Germany
Consultancy Projects				
1.	Assessment of Saline and Freshwater Zone in Faridkot, Fazilka and Muktsar Districts of Malwa Region of Punjab	Gopal Krishan (PI)	1.5 year (03/19-09/20) Cost: 17.70 lakh *Status: In progress*	Punjab Government
2.	Expansion of Salinization in Aquifers in Punjab	Gopal Krishan (PI)	1.5 year (03/19-09/20) Cost: 1.18 crore *Status: In progress*	Punjab Government
3.	Water Availability Study based on Hydrological Investigations and Rainfall-Runoff Modeling of Upper Hindon Basin	Anupma Sharma (PI)	1.5 year (04/19-09/20) Cost: 11.80 lakh *Status: In progress*	Irrigation Deptt., Saharanpur

Laboratory and Centre:

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

Trainings organized/ planned:

The division has organized one online training during July 2020 and shall organize two training courses under NHP during 2020-21 in the groundwater domain.

Outreach activities since previous WG meeting:

1. Scientists published/accepted **31** papers in international/national journals & conferences.
2. Scientists delivered **14** lectures in different training courses and workshops.
3. Scientists guided/guiding **7** M.Tech./Ph.D. students for their thesis work.

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

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

Project team

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

Type of study: Internal

Duration: May 2019 - April 2021

Objectives:

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

Study area:

The study area is Ganga basin. The Ganga basin outspreads in India, Tibet (China), Nepal and Bangladesh over the total area of 10,86,000 Sq.km. The major part of the geographical area of the Ganga basin lies in India and it is the biggest river basin in the country draining an area of 8,61,452 Sq.km. The Ganges is the most populated river basin of the country and is home to half the population of India including two-thirds of the nation's poor people. The basin provides over one-third of the available surface water in India and is the focus of over half the national water use – 90 percent of this being in irrigation. Ganga basin is facing many challenges in terms of its flow regime due to water resources infrastructure, high level of water abstraction and ecological health of Ganga and its tributaries.

Methodology:

The methodology involves collection of available recent and historical hydrological and satellite data related to the basin area. This includes data on precipitation, evaporation, river flow, surface storage, soil moisture, groundwater levels etc. The various spatial and temporal data would be converted to uniform scale and duration by downscaling/upscaling. Water balance for the basin will be estimated. For assessment of surface water and groundwater, hydrological models such as SWAT-MODFLOW will be used. The results will be calibrated and validated using the observed data at certain locations of the basin, to verify the accuracy of the generated results.

Objectives & Achievements:

Objectives	Achievements
• Assess the applicability of using multi satellite data approach for water resource assessment. • To analyze the accuracy of the satellite data product by calibrating it with the observed data and use the satellite data at places where there is scarcity of observed data. • To explore the suitability of re-scaled satellite data for the purpose of water resources management.	• Preparation of raster maps of the entire study is completed. • Gridded data of hydro meteorological parameters is downloaded. • Data is processed for Yamuna basin. • For remaining sub-basins, data is being processed. • Objective 2 & 3 will be accomplished after the completion of objective 1.

Progress made so far:

- The satellite data for meteorological parameters is being prepared sub-basin wise due to huge size and processing time of data. Presently, the data is prepared for the Yamuna basin. For the remaining sub-basins, the data is downloaded and being processed for final input to the model. After the completion of the data preparation of all sub-basins, the data will be used for water resource assessment of the complete basin using SWAT-MODFLOW.

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

Title of the Project: ***The Regional Hydrological Impact of Farm-Scale Water Saving Measures in the Gangetic Plains***

Project team

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

Collaborator **:** CSIRO, Australia

Type of study **:** Internal (On-going)

Duration **:** August 2019 - July 2020 (extension of 5 months is required)

Budget **:** Rs. 5 Lakh

Objectives:

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

Study area: Bhojpur district of Bihar

Statement of the problem:

Many farm-scale water saving measures have been in practice such as improved irrigation delivery technologies viz. drip irrigation; stopping seepage from water delivery canals; agronomic practices like alternative wetting and drying and other conservation practices (zero tillage, minimum tillage, etc.). Farm conservation practices affect the water accounting of watersheds. Water accounting is required to assess the relative contribution of components of water balance. For water accounting of large aquifers, we need to identify and quantify all the gains and losses from the aquifer. There are some research questions such as what is the likely impact of conservation agriculture and a plough pan/ puddled layer on recharge in the monsoon season? Can natural recharge to groundwater be enhanced by deep ploughing and breaking the plough pan in the monsoon season? What is the likely regional hydrological impact of farm-scale water saving measures? The proposed scoping study will be mainly based on available literature and hydrological data of water saving measures. The scoping study, therefore would provide a broad understanding of impact of the farm saving measures on groundwater resources in the selected watersheds of Bhojpur district of Bihar, lying in the Gangetic plains.

End Users/ Beneficiaries: Minor Water Resources Dept., Govt. of Bihar; Ministry of Agriculture and Farmers' Welfare, Govt. of India; Ministry of Jal Shakti, Govt. of India; NGOs; Local Community etc.

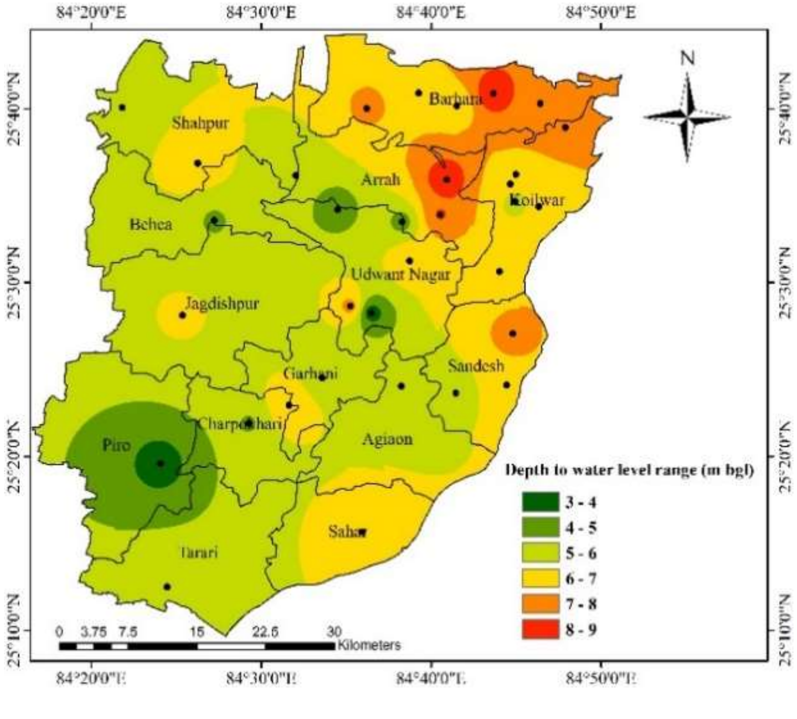
Objectives & Achievements:

A review of agriculture practices and agricultural water saving measures and their impact on groundwater resources.	Data on agricultural practices have been collected from Department of Agriculture, Govt. of Bihar and analyzed. Literature review has been completed.

Trend analysis of groundwater level data to understand recharge and discharge processes.	The groundwater level data of 33 monitoring stations in the district have been collected from CGWB, Faridabad and has been analyzed.
To study surface water and groundwater interaction based on the available and monitored data.	A coarse groundwater modeling would be attempted to study the surface water and groundwater interaction.

Analysis and Results:

The geographical area of the Bhojpur district is 233729 Ha, out of which 188134 Ha is net cultivable area. The net irrigation area in Kharif season is 100407 Ha and in Rabi season, it becomes 68781 Ha. The groundwater level data has been collected from the Central Ground Water Board (CGWB) and spatial behavior of water levels along with flow direction has been studied for the study area. The depth to water level in pre-monsoon season (year 2018) varies from 3.0 to 9.0 m bgl with minimum and maximum values observed in south-western part and north-eastern part. The hydraulic gradient indicated groundwater movement towards the Ganga river. The land use land cover (LULC) map of year 2018 at 30 m spatial resolution was developed using Landsat-8 satellite imagery downloaded from United States Geological Survey (USGS) website. The LULC classification showed that vegetation (46.13 %) followed by built-up area (21.64 %), fallow (16.52 %), barren land (7.37 %), sand bank (6.08 %), water (2.26 %) are the major types of land uses. Based on the available and generated data, a coarse groundwater modeling would be attempted to study the surface water-groundwater interaction.



Groundwater level variations in the study area (Bhojpur district, Bihar)

3. 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-C
		Mrs. Suman Gurjar, Scientist-C

Type of study: Internal (New)

Duration: Two years (August 2020 – July 2022)

Objectives

1. Development of the integrated GEE-MODFLOW model to estimate groundwater recharge and to disseminate model outputs.
2. Evaluation of the estimated recharge using in-situ observations.
3. Assessment of the impacts of various recharge/abstraction scenarios on groundwater system of Hindon river basin.

Statement of the problem

Groundwater resource had a significant contribution to meet societal needs and development objectives in India. In many parts of the country, groundwater is often the sole source of water and thus plays an important role in socio-economic development of the country. However, the excessive groundwater withdrawal led by growing water demands has imposed additional pressure on groundwater resources which has resulted in rapid and widespread groundwater declines. An assessment of country's groundwater by Central Groundwater Board (CGWB) reveals that out of the total 6881 blocks of the country, 17% are over-exploited, 5% are critical and 14% are semi-critical (CGWB 2017). Further, the declining groundwater levels due to over-exploitation has raised several queries about the changes in river water availability due to adverse impacts of aquifer depletion, vulnerability of groundwater contamination, and availability of surface water and subsurface water resources in the future. Therefore, to answer these queries and 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 the 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 (GRAS), 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 GRAS 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.

Methodology

The proposed GRAS will utilize various packages of MODFLOW (version 6) to assess groundwater recharge by simulating infiltration, evapotranspiration and unsaturated-saturated flows. A cloud-based data processing and visualization tool, named Google Earth Engine (GEE), will be utilized to extract information from remote sensing data at high spatio-temporal resolution for modelling and to disseminate model outputs. The GRAS will be developed into five modules, including (i) GEE-based data preparation module, (ii) infiltration and evapotranspiration module, (iii) MODFLOW-based unsaturated and saturated flow module, (iv) scenario analysis module, and (v) interactive output visualization module. It will be tested to assess groundwater recharge and investigate impacts of various hypothetical scenarios on groundwater regime in the Hindon river basin.

- *GEE-based data preparation module*. Google Earth Engine (GEE) is a free cloud-based platform that makes it easy to access high-performance computing resources for processing very large geospatial datasets. Moreover, it allows to access and analyze various remote sensing data available from various organizations throughout the world. In the data preparation module, GEE will be utilized to derive information that are important for groundwater recharge estimation, such as surface imperviousness, vegetation cover and phenology, soil moisture, precipitation and temperature.
- *Infiltration and evapotranspiration module*. A variety of infiltration and evapotranspiration approaches are available. Suitable methods will be selected based on their accuracy and compatibility with MODFLOW (version 6). Soil moisture data available from satellite remote sensing will be utilized to start the simulation of infiltration model.
- *MODFLOW-based unsaturated and saturated flow module*. MODFLOW is a U.S. Geological Survey modular finite-difference flow model which has widely been used to simulate groundwater flow. In the GRAS, MODFLOW will be used to simulate unsaturated and saturated flow through the subsurface. The impact of groundwater extraction through pumping will also be simulated using the MODFLOW.
- *Scenario analysis module.* This module will include various options to analyze 'what-if' scenarios. For example, prediction of future groundwater availability considering a groundwater pumping scenario, prediction of rise in groundwater table if some artificial recharge measures are adapted or a canal is constructed.
- *Interactive output visualization module.* This module will be designed to help researchers easily disseminate their results to other researchers, policy makers, NGOs, and even the general public. The Google Earth Engine will be utilized to develop this module which will allow to display and analyze the model outputs through an online web-based GEE application.

Data requirements

- Groundwater levels, pumping rates and lithologs.

- In-situ observations of soil moisture at different depths, hydraulic conductivity, infiltration rates, etc.
- Hydro-meteorological data.
- Land use, elevation, surface imperviousness, etc.

Deliverables

- Integrated GEE-MODFLOW model
- GEE-based web application for groundwater recharge assessment in Hindon river basin
- Model manual, research papers and reports

Beneficiaries of the study

The results and findings of the proposed study will be useful to policy makers for managing groundwater. The results could also be useful to the Water Resources Departments and the local community. The proposed system will involve remote sensing data and an interactive data dissemination tool which can be adapted for any region and thus the GRAS can easily be replicated for any region of the country by simply changing the groundwater data.

Action plan and timeline (quarter-wise from Aug 2020 to Jul 2022)

Work element	1	2	3	4	5	6	7	8
Data collection and preliminary analysis								
Development of GEE-MODFLOW model								
Measurement of soil moisture at different depths, infiltration, hydraulic conductivity, etc.								
Development and testing of GEE-based data dissemination system								
Model calibration and validation								
Simulation runs for investigating various recharge/abstraction scenarios								
Preparation and submission of research paper								
Preparation and submission of reports, model manuals and research papers								

Budget breakup

Sr. No.	**Budget head**	**Amount**
1	Travelling expenditure	2,16,800.00
2	Infrastructure/equipment	4,50,000.00
3	Experimental charges/field work/consumables	1,00,000.00
4	Contingency	50,000.00
	Total	**8,16,800.00**

Budget justification

Travelling expenditure: Field visits will be performed to measure soil moisture, infiltration, hydraulic conductivity, etc. Travel by road and stay of PI: 6 visits @ 3 visits per year @ Rs. 28800/=per visit (for 7 days), total expenditure: 1,72,800/-. Travel by road and stay of Co-PI: 2 visits @ Rs. 22000/=per visit (for 5 days), total expenditure: 44,000/-.

Infrastructure/equipment: Soil moisture measuring instrument at multiple locations will be installed in the field to observe soil moisture at different depths for calibration and validation of MODFLOW simulated unsaturated flow.

Experimental charges/field work/consumables: Required for buying the material for field investigations, installing instruments in the field and soil sample collection and laboratory investigations.

Contingency: This fund will be utilized for various expenditures in the field, such as the labor cost at the time of experiment and other miscellaneous expenditures.

4. PROJECT REFERENCE CODE: NIH/GWH/NIH/15-20

Title of the Project: ***Peya Jal Suraksha - Development of Six Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply***

Project duration: 30 months (November 2015 – March 2020
Type of study: Sponsored by DoWR, RD & GR, MoJS under NIH's Plan Fund
Nature of study: Demonstration and applied research

Methodology

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

Deliverables

Schemes demonstrating effectiveness of 'Riverbank Filtration' technique for sustainable drinking water supply in different hydrogeological settings, river hydraulic and groundwater conditions are the planned deliverables and these schemes after thorough investigations will be handed over to the respective state 'Jal Sansthan' to use them as the guiding scheme towards attaining drinking water security, particularly in rural areas.

Progress

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

Location-wise progress is given below:

(i) Laksar Site, Uttarakhand

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

(ii) Mathura and Agra Sites

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

Developed pilot demonstration RBF scheme at Agra: (a) Pump House, and (b) Stand Post.

Developed pilot demonstration RBF scheme at Mathura: (a) Pump House, and (b) Stand Post.

(iii) Ara site in Bihar

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

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

Most of the villages in Ara district along the Ganga river have groundwater arsenic contamination and villagers have no organized safe drinking water supply. The aquifer at a depth below 30/35 m has generally been reported as arsenic affected. The pilot RBF scheme at Ara was elected as an alternate to provide safe drinking water supply in the rural arsenic affected areas. Phase-I works have been completed. The performance evaluation of the RBF water quality was assessed and in general found suitable with minor issues which shall improve when in continuous operation and induce more water from river. For the RBF site in Barhara village (Ara), the exploratory drilling well development, water quality analysis, finalization of the tapping zone, etc. were completed. Phase-II works comprising of installation of pumps, construction of pump houses, electrical connections and fittings, pipeline laying and hydrant points installation, etc. will be completed by PHED, Govt. of Bihar from their own funds and they do not require any funding from NIH.

(iv) Vishakapattanam, A.P.

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

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

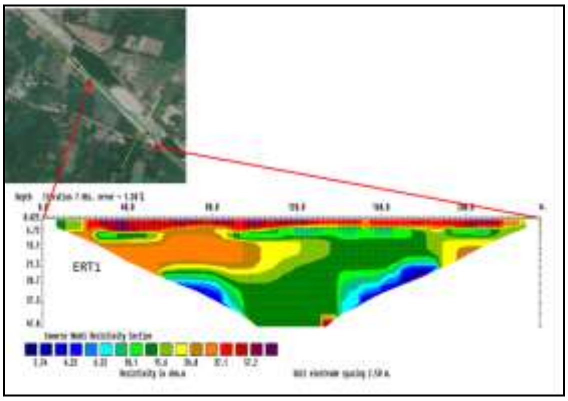


Figure showing result of geophysical survey for a section, and a snapshot of in-field water quality analysis.

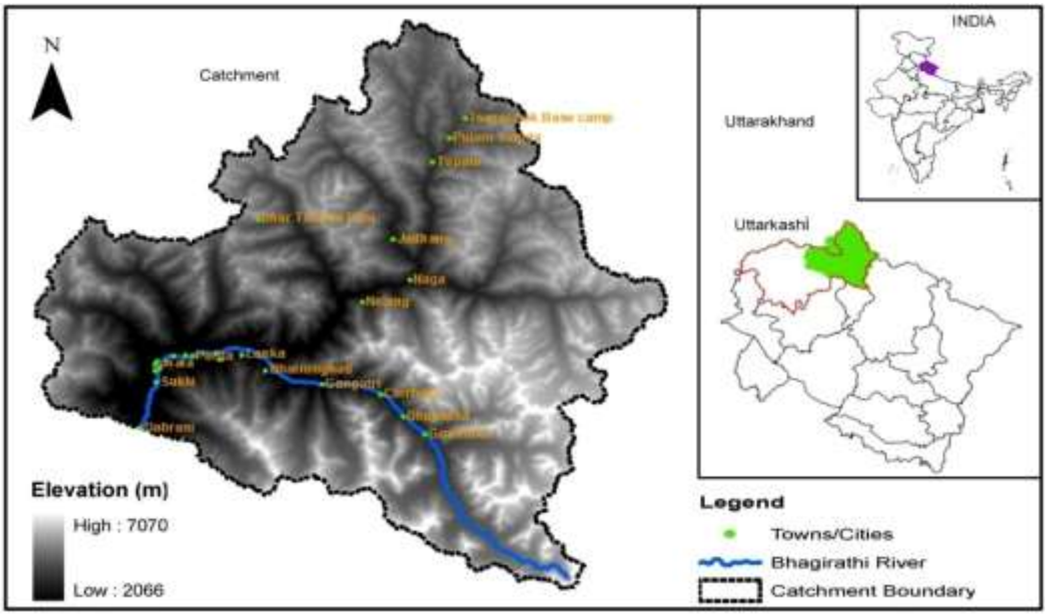
Phographs showing stages of drilling work in progress

Phase-I works were already completed. For Phase-II works, fifty percent of total approved amount of Rs.7.80 lakhs was transferred to RWS & S, Govt. of AP and execution of works was interupted due to COVID-19 and likely to be completed soon. Balance 50% amount shall be transferred after completion of phase-II works. Thereafter, this RBF scheme will also be handed over to the RWS & S, Govt. of AP for pulic water supply. The performance evaluation of the RBF water quality was assessed and found suitable with minor salinity in RBF water which shall improve when in continuous operation and induce more water from river.

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

Title of the study : ***Study of River - Aquifer Interactions and Groundwater Potential at Selected Sites in the Upper Ganga Basin up to Dabrani***

Type of study : Sponsored by DST under NMSHE SP-8
Date of start (DOS) : January 2016
Scheduled date of completion: December 2020
Study Area : Bhagirathi Basin up to Dabrani (Uttarkashi)



Study objectives:

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

Action Plan:

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

Objectives vis-à-vis Achievements:

Part of Objectives	Achievements
Understanding of river-aquifer interaction and dynamic processes in Himalayan environment	Completed
Groundwater potential assessment and availability prospects resulting from snow and glacier melt recharge	In progress

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

Analysis of Results:

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

Two piezometers were developed through the UJS, Uttarkashi; one at Jhala and one at Harsil. Groundwater levels are being continuously monitored in both these piezometers, and groundwater samples were also collected. Water samples were being continuously collected at ten daily frequency from springs, river, stream and hand pump as well as rainwater on event-basis for the isotopic and water chemistry analysis. The results indicated that water type is Mg-HCO_3, or, Mg-Ca-HCO_3 for most of the sampling sites except for Jhala hand pump where the groundwater is Na-HCO_3 type. Durov's diagram indicates shallow fresh groundwater in aquifers composed of dolomite. However, the Jhala hand pump indicated that shallow portions of regional confined aquifers have ion-exchanged waters where Na^+ is dominant. A preliminary interpretation based on the data collected so far indicated that most of the river water and groundwater samples fall close to the LMWL (Local Meteoric Water Line), which indicate mixing of surface water and groundwater having significant interaction. SWAT model was calibrated and validated up to Maneri GD site. Groundwater recharge is estimated for various sub-basins using the water balance approach. Assessment of groundwater potential in Harsil and Jhala is in progress.

List of Deliverables:

- Reports; Research papers.

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

Lab Facility used during the Study:

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

Data Procured/ Generated during the Study:

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

Study Benefits /Impact:

Process understanding of groundwater recharge due to glacier / snow melt recharge.

Specific linkages with Institutions: DST, UJS

Future Plan:

- Continue monitoring of groundwater levels
- Testing of water samples from surface and groundwater for quality and isotopic analysis (groundwater, spring, rainfall and river samples)
- Estimation of groundwater potential.

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

Title of the study: ***Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency Groundwater Level and Salinity Measurements***

Name of PI and members	:	NIH, Roorkee, India- Dr. Gopal Krishan (PI) Dr. Surjeet Singh (co-PI) Er. C.P. Kumar (co-PI) Dr. M.S. Rao (co-PI) **BGS, UK** Dr. Dan Lapworth (PI) Prof. Alan MacDonald (project coordinator)
Type of study	**:**	Sponsored**,** BGS, UK.
Date of start (DOS)	**:**	December 2017
Scheduled date of completion	**:**	November 2020 (extension required upto Nov, 2021)
Location	**:**	Bist- Doab Punjab

Study objectives:

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

Statement of the problem:

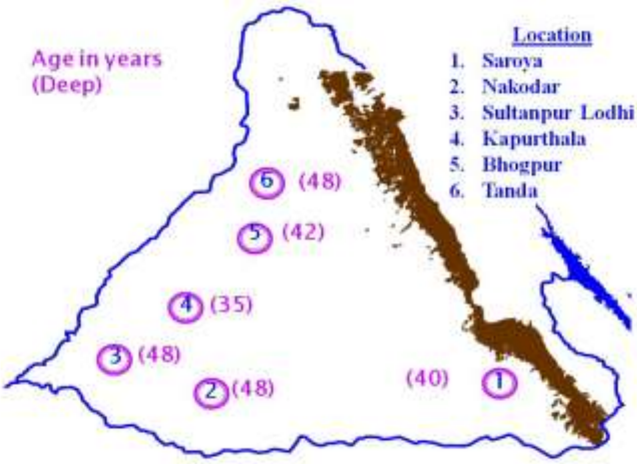
Higher rate of withdrawals are observed in the state of Punjab where the annual rate of groundwater level decline is increasing by about 80% and projected to fall by about 21 meter in 2/3rd area of central Punjab during next two decades. The large drop in groundwater levels can be due to several reasons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

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

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

Methodology:

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



Study area, Bist Doab, Punjab

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

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

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

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

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

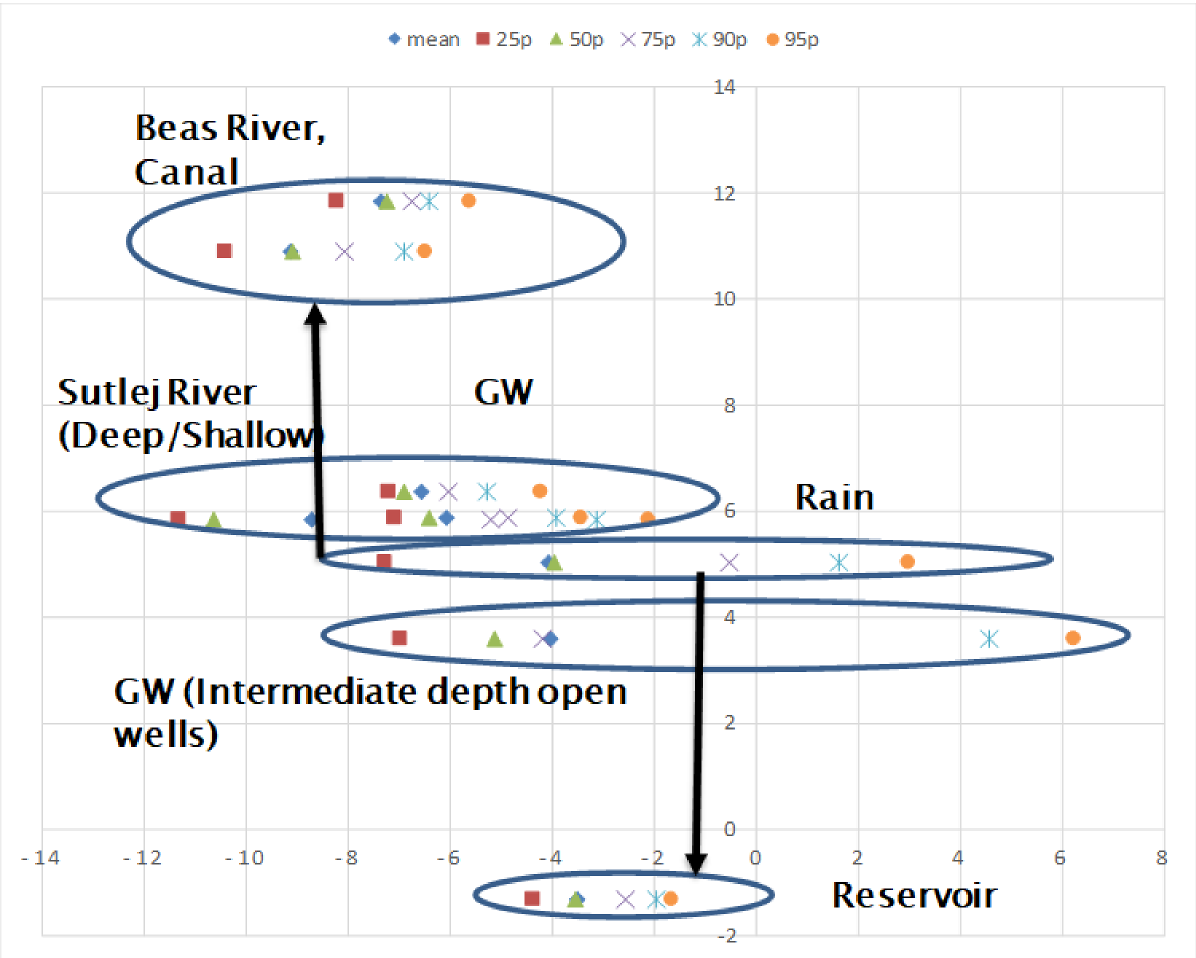
Water level responses:

- Average depth of groundwater level below ground surface: Sultanpur Lodhi (12m) < Bhogpur (17m) < Kapurthala (23m) < Saroya (32m)
- Max seasonal variation in groundwater level : Sultanpur Lodhi (±1.5m) < Kapurthala (2.5m) < Bhogpur (±3.5m) < Saroya (±6m)

The large scale trend is due to the onset of pumping for irrigation during the Kharif season and a part of which is in the monsoon season also.

New insights/evidences

- Stable isotopes patterns observations of both oxygen ($\delta^{18}O$) and hydrogen (δD) are frequently under-constrained, resulting in non-unique interpretations. Therefore, their combination as deuterium excess (d-excess) is useful due to its exceptional sensitivity during moisture source and falling precipitation generally under unsaturated columns to relative humidity and is affected by kinetic fractionation (diffusion) during phase changes within the hydrologic cycle.
- Comparison of data series of river water isotopes with data series reservoir/groundwater isotopes provide valuable insights into the river-groundwater interaction and can also be helpful in acquiring the travel times of the filtered water to groundwater.
- For finding the recharge source, a plot between $\delta^{18}O$ and δD was drawn. Long-term data on isotopes of > 2000 samples from different sources such as rain, rivers, canals, reservoirs and groundwater in the study area was plotted as $\delta\,^{18}O$ v/s D-excess.
- This data indicated that there is inter-relation between various source waters. There are some commonalities in isotope values at a certain percentile. Reservoir samples are highly enriched. High d-excess was observed in Beas river water and canal water.



$\delta\,^{18}O$ v/s D-excess data

Some unanswered questions are:

- What is the synchronisity between deep and shallow groundwater?

- 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?
- Interpreting groundwater level changes and potentially mis-interpreting recharge process water table fluctuation method is used.

Objectives and Achievements:

Study objectives	Achievements
To characterise multi-year variability in groundwater level and SEC using high frequency groundwater measurements within nested shallow and deep piezometers	Achieved - but still more data is required to understand the variability. The large scale trend is due to the onset of pumping for irrigation during the Kharif season and a part of which is in the monsoon season also. So the contribution of pumping could easily far exceed the 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 groundwater sustainability in Northwestern India, currently experiencing depletion for supporting irrigated agriculture
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 (70%) - Some data analysis is in progress. Long-term data on isotopes of > 2000 samples from different sources such as rain, rivers, canals, reservoirs and groundwater in the study area was plotted as $\delta^{18}O$ v/s D-excess. This data indicated that there is inter-relation between various source waters. There are some commonalities in isotope values at a certain percentile. Reservoir samples are highly enriched. High d-excess was observed in Beas river water and canal water.
To prepare a status report on groundwater issues in Punjab	Interim report prepared and submitted.

Action plan:

Year	December 2017 to November 2021	Remark
Dec. 2017 to Nov. 2021	➢ Literature review on available groundwater studies including water table, water quality and other hydrogeological aspects in Punjab ➢ Monitoring of water level and conductivity fluctuations in Bist-Doab, Punjab ➢ Water sampling and analysis for isotopes ➢ Prepare a status report on groundwater issues in Punjab ➢ Presentation of work progress in a workshop/review meeting under the project	Report preparation as per activity schedule

Study Benefits /Impact:

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

Specific linkages with Institutions: BGS, UK

Activity Schedule (Quarter Wise from Dec. 2017 to Nov. 2021)

Activity	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th - 14th *	15th - 16th *
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)											♦	♦		

* Some of the activities will be shifted to 13th - 14th and 15th – 16th (as per extension granted)

Progress

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

Future plan

- Downloading data from water level loggers 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.

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

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

Type of study : Sponsored (NHP)
Date of Start : December 2017
Scheduled Date of Completion : November 2020 (3 years) (6 months extension required)
Budget : Rs.70 lakh

Location : Bhojpur District, Bihar (Figure 1)

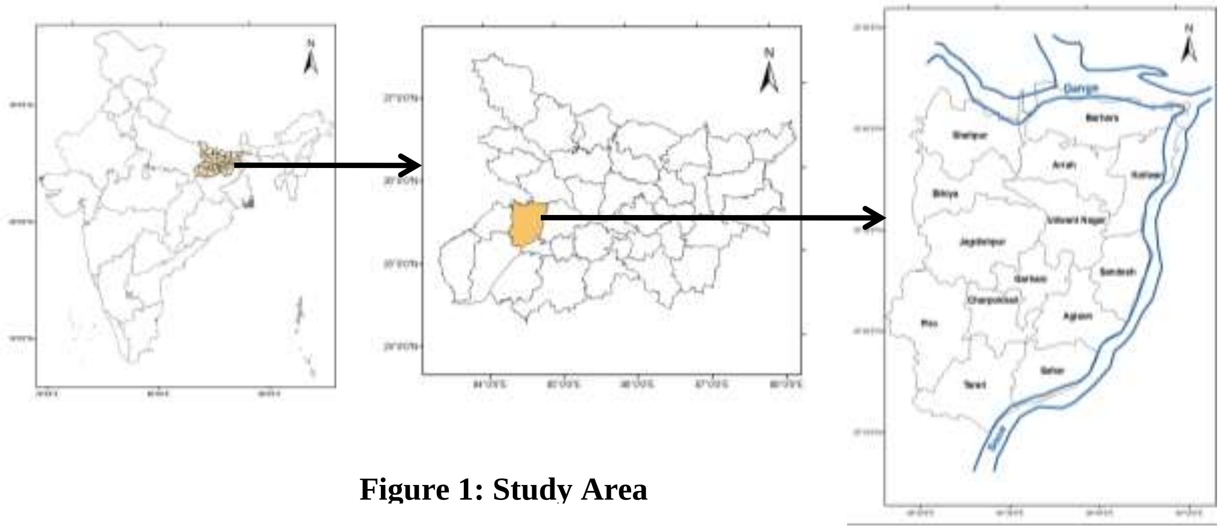


Figure 1: Study Area

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 regions of India. In recent few decades, the increasing demand of groundwater for domestic, irrigation (round the year for food production) and industrial with the growing population rate led the extensive exploitations of fresh and potable groundwater.

In last decades, few investigators reported the elevated arsenic concentration and the process of the contamination in central Gangetic basin, but none seems to study 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 modellng. Column experiments 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.

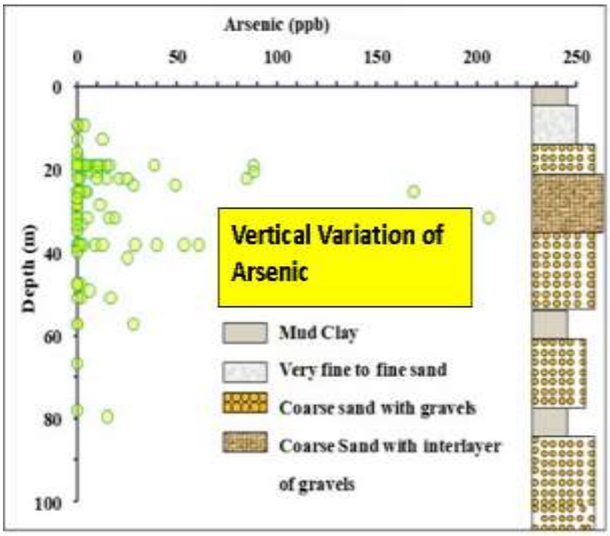
End Users/ Beneficiaries: Minor Water Resources Dept., Govt. of Bihar; Public Health Engineering Department, Govt. of Bihar; Ministry of Drinking Water and Sanitation, Govt. of India; NGOs; Local Community etc.

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 contaminated aquifer.	Eight piezometers have been constructed in the study area. Monitoring of water quality is under progress. However, no field work or samples could be collected after February 2020 due to pandemic situation occurred in the country.
Evaluation of the mechanism of transport of arsenic in geo-environmental through a column experiment.	Column experimental set-up is designed and fabricated and now it is established in the lab. Experiment would be performed on the sediment to study the leaching of arsenic.

Analysis and Results:

Based on the water sampling and analysis, the chemical results revealed that high arsenic concentration is found in the Holocene newer alluvium (northern part of district) and it is more concentrated in the depth range of 15-40 meter below ground surface. The relationship of As with other water quality parameters were studied and it was observed that strong positive correlation between arsenic and iron exist which indicates that reduction of iron oxide adsorbed with arsenic is responsible for arsenic mobilization in the groundwater. A weak or no correlation exists between arsenic and bicarbonate, chloride in the water samples. All other trace metals viz. nickel, lead, zinc, cadmium and aluminum are found in low concentration except iron and manganese. The geochemical analyses suggest that rock-water interaction is controlling the geochemistry and chemical constituent of the groundwater is mainly controlled by carbonate weathering with limited contribution from silicate weathering. The isotopic signatures revealed that the Son river is recharging groundwater while groundwater is contributing towards Ganga river. Eight piezometers have been constructed (in November 2019) in the study area to monitor the contaminated aquifer. The continuous monitoring of contaminated aquifer will help in understanding geo-chemical processes that are controlling As mobilization. Sediment analysis is under progress. Column experimental set-up is established in the laboratory and leaching experiment would be performed.


Arsenic (ppb)
0
50
100
150
200
250
0
20
40
60
80
100
Depth (m)
Vertical Variation of Arsenic
Mud Clay
Very fine to fine sand
Coarse sand with gravels
Coarse Sand with interlayer of gravels


Manual drilling for piezometer installation

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

Title of the study: ***Assessment of Impacts of Groundwater Salinity on Regional Groundwater Resources, Current and Future Situation in Mewat, Haryana – Possible Remedy and Resilience Building Measures***

Name of PI and members:	NIH, Roorkee, India- Dr. Gopal Krishan (PI) Mr. C. P. Kumar (co-PI) Dr. Surjeet Singh (co-PI) Mr. S. K. Verma (co-PI) **Haryana Irrigation Department** EE**,** Mewat **Consultants: IIT-Roorkee** Prof. M. L. Kansal Dr. Brijesh Yadav **Sehgal Foundation, Gurgaon** Mr. Lalit Mohan Sharma

Type of study	:	Applied Research
Date of start (DOS)	:	December 2017 (NHP-PDS)
Scheduled date of completion	:	November 2021
Location	:	Mewat district, Haryana

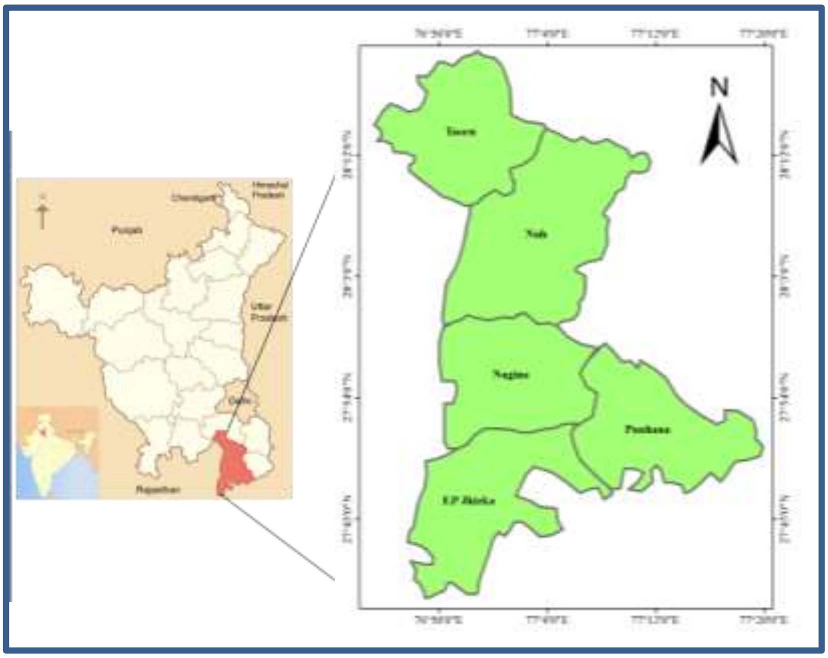
Study objectives:

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

Statement of the problem:

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

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



Map of Mewat District

Methodology:

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

In *Phase 1*, socio-economic based survey has been 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 has employed both qualitative and quantitative methods. Under the quantitative method, a well structured coded interview schedule was used. Focus Group Discussions (FGD), as a qualitative method, were administered to collect information on the above socio-economic characteristics of the farmers.

Phase 2 of the study deals with developing 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 includes 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 waste water 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.

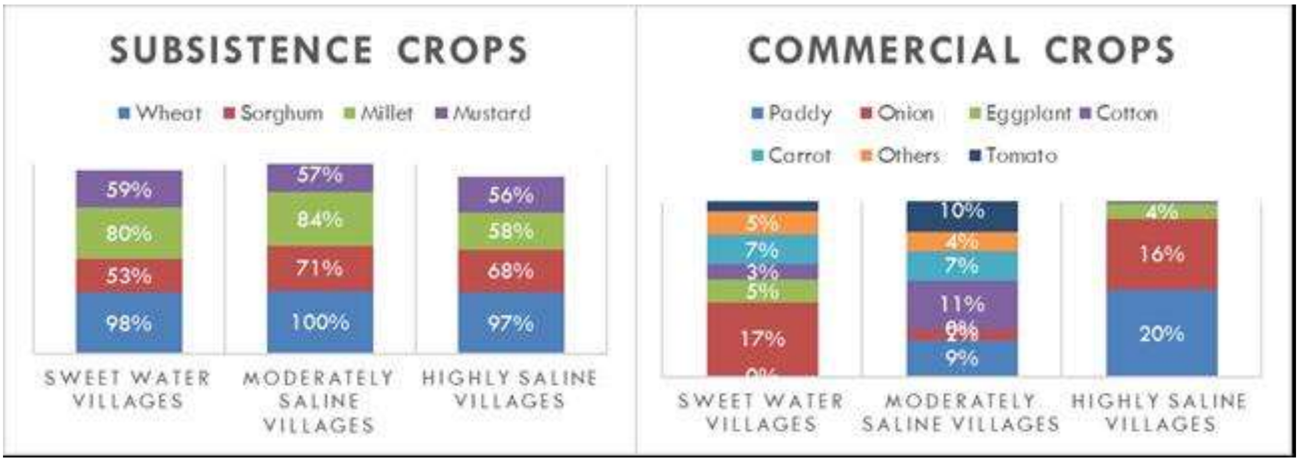
Objectives and Achievements:

Objectives	Achievements
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 are decreasing while no such observations are for salinity affected areas in Nagina block.
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.
To monitor influx of saline groundwater into fresh water zone.	Work is in progress, piezometers have been constructed to monitor influx.
To assess the impact of groundwater salinity on socio-economic aspects.	Achieved - Work is completed.
To develop and demonstrate management and resilience building measures	Achieved (50%) - Work is in progress, experimental model developed and tested for development of fresh water bubble and recovery efficiency. The same will be tested under field conditions.

Progress:

Socio-economic survey work was outsourced to Sehgal Foundation, Gurgaon and completed in the month of January 2020. Based on their survey, some of the results are explained below.

Impact of salinity on crop productivity



Cropping pattern in study region (Source: Sehgal Foundation)

The cropping pattern is another choice variable that could be affected with underground water salinity. With the limited land resources available, it is crucial for farmers to choose crops wisely for maximum returns. However, one of the crucial points of consideration is the availability and sufficiency of water for irrigation. Farmers have options between different subsistence and commercial crops. In the study region, it was 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. Onion and carrot is grown in villages in Firozpur Jhirkha block. In moderately saline villages and highly saline villages, cotton is grown because of its salt-tolerant features. Tomato growers in the region have articulated that the fruit of the plant with saline water is smaller and less juicy and therefore has to be sold at lower prices in the market. 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.

Another concern caused by salinity is its adverse effect on fertility of soil, hence affecting the crop productivity. The crop productivity is largely affected for the ones who are providing saline groundwater for irrigation because of lack of freshwater alternatives. The average yield figures for different crops show a declining trend with increasing salinity levels. For subsistence crops like wheat, mustard, and millet, the difference in yield is approximately one and two quintals per acre respectively.

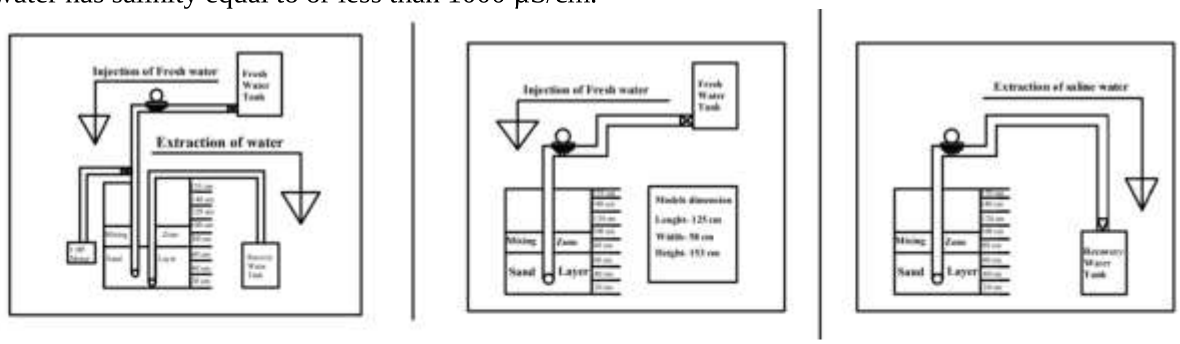
For commercial crops, the yield dynamics are varied. For a salt-tolerant crop like cotton, the yield difference is not much across all three regions. Since saline water is usually shallow and available in abundance, sufficient irrigation cycles are provided. For crops like onion, carrot, paddy, and tomato, increasing salinity levels have reduced the productivity. For tomato, farmers say that the tomato fruit is small and less juicy with saline water irrigation, which has low produce and market value. Therefore, in high-saline regions, people do not cultivate tomato.

The findings on crop productivity reveal that except for salt-tolerant crops like cotton, yield is affected negatively with saline water irrigation. A majority of crops like wheat, mustard, tomato, and onion have shown higher yield in non-saline regions. The scarcity of quality and enough water has limited the irrigation potential owing to the risk of soil salinity and is one of the reasons for low yields in high-saline zones.

Experiment on Aquifer Storage and Recovery

Aquifer storage and recovery (ASR) is a relatively new concept in management of both fresh and saline water systems. ASR avoids the construction of large and expensive reservoirs, prevents easy loss of freshwater resources and provides a cost-effective solution to water resources management. ASR can be explained by the injection of fresh water into the saline aquifers which forms the freshwater pocket. The water now is pumped out from the adjacent well and recovery of the well is done from the adjacent wells which induce the mixing of saline water in the aquifer and the freshwater injected.

An experiment was carried out in an experimental model fabricated under this PDS. After a cumulative time of 735.30 hours, an average recovery efficiency of 63% was observed. Recovered water has salinity equal to or less than 1000 µS/cm.



Aquifer Storage and Recovery Model

Adaptability/ Remediation

In the moderately and high-saline villages, the households understanding the effect of salinity is observed to be different. 39 percent in the moderate saline group and 73 percent in high-saline group consider it to be a cause of concern. Due to high salinity, the crop-diversification possibilities are also limited. Farmers have also shared concern about land degradation, as land is not able to absorb rainwater post-saline-water irrigation. In general, the land takes 15–20 days to absorb the rainwater. In the saline region, only four farmers have taken the necessary mitigation measures to tackle salinity.

In a nutshell, in high-saline regions, saline water is used for irrigation except by those who have access to canal water or pockets of freshwater. Except for cotton, all crop yields are adversely affected by salinity. This is primarily due to availability of saline-tolerant variety of cotton. In general, the crop choice is limited for farmers in saline regions. Overall, the salinity has adversely affected the economic condition of the region and could be one of the contributing causes for impoverishment in the region.

Description of work planned:

- Experiment on salinity under field conditions.
- Development of piezometers and installation of loggers.

Action plan:

Year	December 2017 to November 2021	Remark
2018 to 2021	➢ Data collection on available groundwater studies including water table, water quality and other hydro-geological aspects in Mewat district. ➢ Collection of water and soil samples to assess the salinity conditions. ➢ Dissemination of outputs in a workshop/review meeting under the project.	Report preparation as per Activity Schedule

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 (Quarterwise from December 2017 to November 2021)

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

Data Requirement and Expected Source: Hydro-meteorological data is being collected from the state departments.

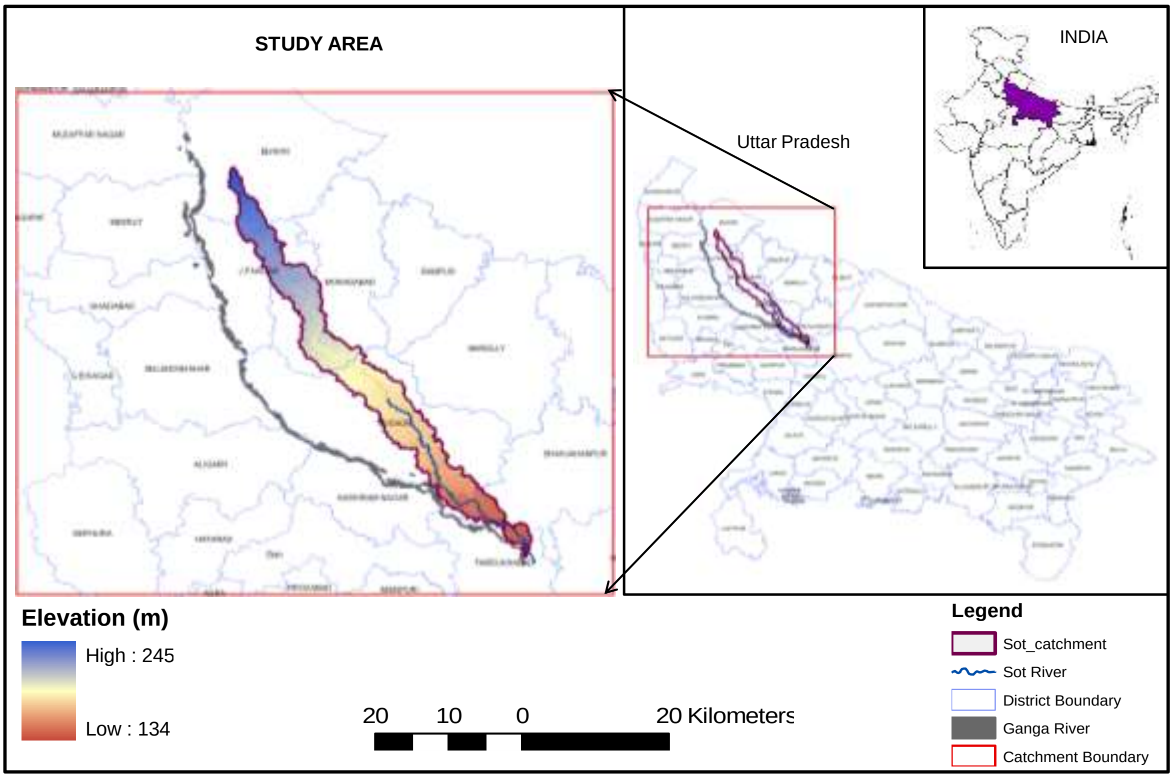
IPR Potential and Issues: Filed a patent vide no. UCS&T/PIC/PATENT-33/2018-19 but it has been suggested to show the success of work in the field.

Major Items of Equipment: EC-probe for soil salinity; water level and conductivity loggers; rain gauges and drilling of piezometers.

9. 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: November 2021 (Four Years)
Location : Sot River Catchment (Uttar Pradesh)



Study objectives:

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

Statement of the problem:

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

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

Methodology:

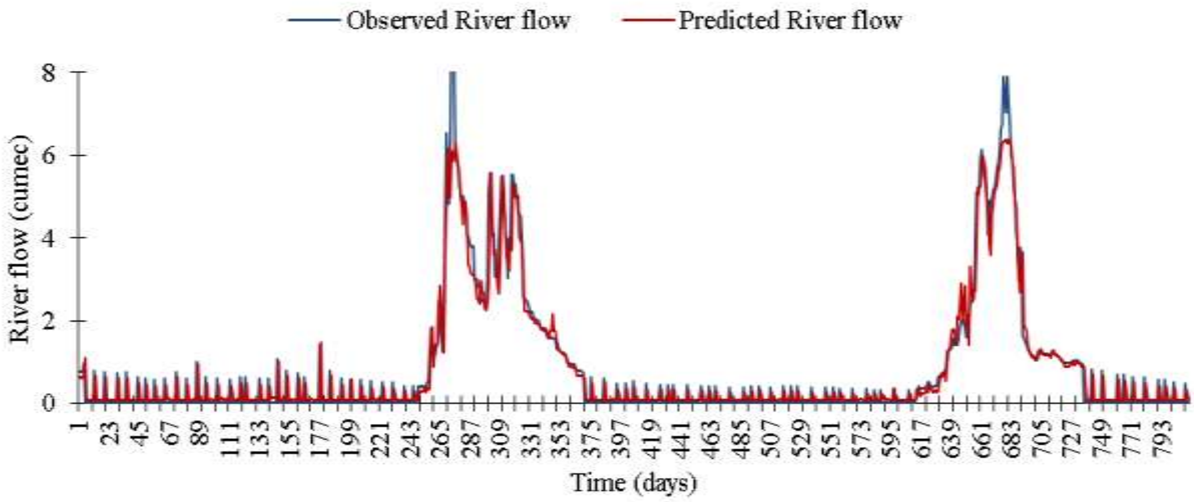
- Delineation of aquifers using litholog/ borelog data by developing fence diagram, cross-sections, profiles and 3D model in the Rockworks software.
- Time series analysis by synchronizing various temporal data (rainfall and groundwater) to study the variation in river flows and the cessation of river 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 Pettitt 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 a management plan for the enhancement of water resources both surface and underground.

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.	In progress
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. Quarterly water samples were collected from 48 locations from groundwater for isotopic and hydro-geochemical analysis for studying the river-aquifer interactions. ANN model was applied to model the river flow for the period 2009 to 2016. SWAT model was applied for extending the river flow records beyond the historical period 1985 to 2008, as river flow data for this period is not available. These data and information shall be used in the surface water and groundwater modeling.



Observed and computed river flow during validation period 2015-16 in the Sot catchment using ANN

It was observed from the results of the study that ANN model with maximum R values (0.94 and 0.97), MNSE values (0.77 and 0.78), MIA values (0.88 and 0.89), and minimum RMSE values (0.39 and 0.45) during the calibration and validation period performed well for predicting river flow of the Sot river catchment.

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
- Economic benefits through livelihood upliftment
- Climate resilience

Future Plan:

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

10. 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 (01/2018-12/2020)
India Project Partners: NIH (India Lead); IIT Kharagpur; IIT Roorkee; and Mahavir Cancer Sansthan, Patna.
UK Project Partner: University of Manchester (UK Lead); British Geological Survey; Salford University; and 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;
- 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.

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.	In-progress
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.	In-progress

Progress

[1] Progress made in geostatistical groundwater modelling for the spatial distribution of arsenic in India. Arsenic vulnerability mapping attempted by IITR employing Multi-Criteria Decision Making (MCDM) methods for twelve arsenic affected districts of Bihar, based on the secondary arsenic data of 2015 yielded satisfactory result while comparing with arsenic concentration maps of the respective districts. For gathering current arsenic scenario in the state, 93 water samples from hand pumps of Saran, Samastipur and Vaishali districts were collected in December 2019 and analyzed. Groundwater arsenic mapping across Ballia and across all 38 districts of Bihar was completed.

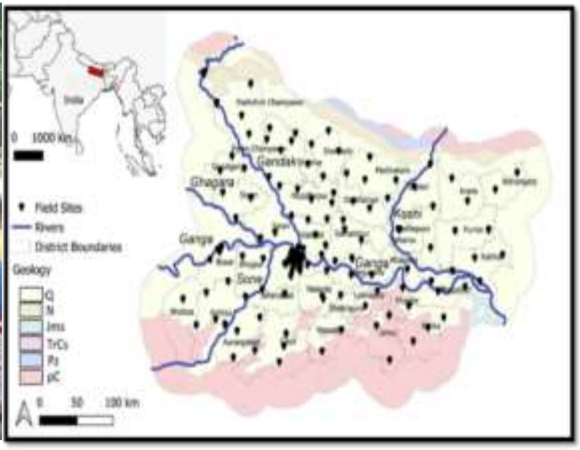
[2] Review of various arsenic remediation technologies. The technical and socio-economic analysis of Arsenic removal technologies were based on reliability, operational ease/simplicity, plant performance, affordability and social acceptability. Further, Life Cycle Analysis (LCA) was also conducted for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

For arsenic remediation, nano material for injection is being 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 have been worked out.

For arsenic remediation using permeable reactive barrier (PRB), Pumice supported nZVI particles and maghemite (γ-Fe_2O_3) nanoparticles with 20 % iron loading have been developed by IITR for PRB.

[3] Completion of stage 2 sampling across Patna and Ballia districts (November 2019) to study the urban and rural organics responsible for mobilization of arsenic in groundwater. Higher-resolution sampling was undertaken in Patna district (n = 62) due to ongoing research in this area by the UoM and MCS. The total number of samples (n = 273) were spread over 38 districts of Bihar with an average of two depths collected in and around a particular location. Progress made in the installation of field monitoring (river/groundwater) stations along the length of the Ganga by IITKgp. Field samples in the upper, middle and lower Ganga particularly focused on organic, including emerging organic contaminants (November-December 2019).

FAR- Ganga team discussing the problems with Villagers during September 2019



Groundwater Sampling Sites in Bihar

[4] Initially, seventy-two (72) water samples were collected from Ballia and Bahraich district of Uttar Pradesh by NIH team and analysed to study the variation of arsenic in the districts. Based on the water quality results, clusters of arsenic contaminated areas were identified. Sampling was made in Murli Chhapra block of Ballia where elevated concentration of arsenic (641 ppb) was found, to select the MAR site to study positive/negative impacts of MAR. Continuous quarterly groundwater samples monitoring at 32 locations in Murli Chhapra block of Ballia for chemical/isotopic analysis is being done. Surface water quality also is being monitored. Ten out of 32 samples (31%) were found above the acceptable limit of As. Installation of four piezometers in and around the MAR site is yet to be done.

[5] For potential natural Hyporheic zone experimental sites, NIH has carried-out groundwater and surface water sampling in Bijnor and Moradabad area. Groundwater of both Bijnor and Moradabad area indicated arsenic concentration below permissible limit except few locations. Laksar (Uttarakhand) was decided as a reference stretch and two sections were identified in Ballia, one on the Ganga river and another on the Ghagra river. Groundwater sampling is being done from 8 locations on each section including one sample from river on quarterly basis. Sediments samples were collected from river bed at Ballia and Laksar and analyzed for arsenic and metals. Strong correlation exists between As & (Fe and Mn); Fe & Mn; Ca^{2+} & Cl^-; Mg^{2+} & Cl^-; Mg^{2+} & SO_4^{2-}; As & Cd.

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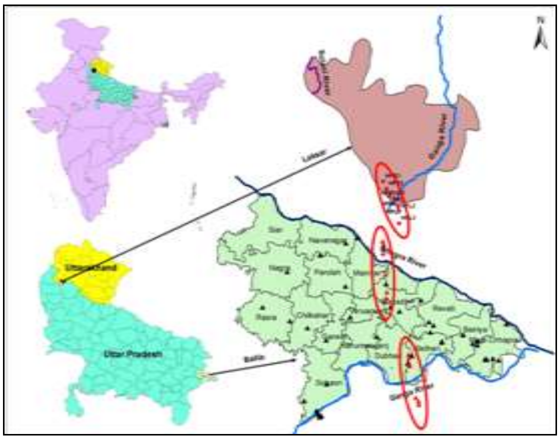
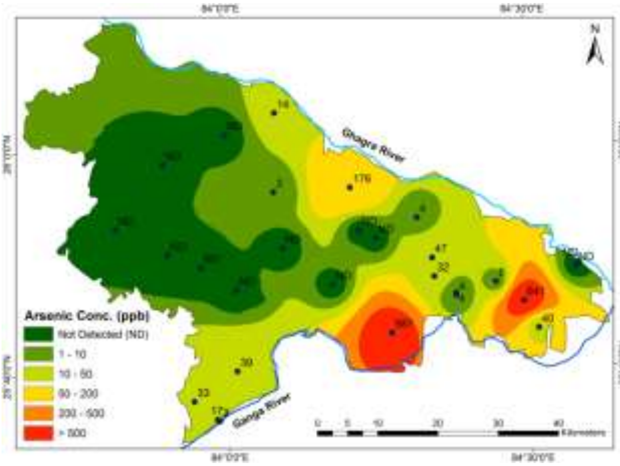


Hyporheic zone experimental sites in Laksar (Uttarakhand) and Ballia District (UP)



Arsenic Concentration Map of Ballia District (UP)

[6] IITKgp has done detailed sampling of surface water and groundwater, and sediment sampling has been done across West Bengal. For arsenic mapping, extending from the ongoing work, arsenic concentration information is being integrated to develop hydro-geochemical maps of the study area and whole of India (>1.7 Million data points). Final data integration, culling, statistics have been achieved and various thematic layers have been prepared (Geology, Geomorphology, Hydroclimatic, Hydrology etc.).

For studying urban organics by IITkgp, as a part of an ongoing work, also overlapping with FAR-GANGA, detailed sampling of surface water and groundwater, and sediment sampling has been done across West Bengal. Outcome of these studies have recently been come out in the form of three publications in the International journal.

For contaminant transport, installation of piezometer nests is completed for 6 sites at Varanasi, Patna, Bhagalpur, Behrampur, Nadia, South 24 Parganas (headwater of Sunderbans) to study contaminant transport and river-groundwater interactions. Each nest contains two sampling wells and two observation wells. Real-time piezometric loggers are awaiting to be deployed.

Field laboratory for detailed hydrogeochemical studies and reactive transport modelling has been installed in Nadia. Single and multiple tracer injection experiments have been performed in the site for tracking, multi-depth, conservative and reactive flow. Real-time and passive geophysics (ERT, EM and borehole geophysics) have been conducted to image the transport phenomenon. High-resolution (hourly to daily) sampling and in-situ analyses of tracers were done continuously for 10 months. Laboratory analyses of the tracers and water quality parameters including arsenic are being done.

[7] Successful running of a series of stakeholder events in Roorkee, Varanasi and Patna. MCS organized stakeholder meetings, attended by multiple India/UK partners, at the Bihar State Pollution Control Board. The input of stakeholders at these and other meetings has been invaluable in guiding the FAR-GANGA project. Outreach activities have been undertaken in high schools/colleges in and around Patna, including citizen science projects.

[8] Publication of papers in the International Journal, National Journal and International and National Conferences. Project Management Board Meetings (PMB) were successfully organized in India and UK.

3rd Joint Meeting of FAR-GANGA, held at the University of Manchester on 15th May 2019

4th Joint Meeting of FAR-GANGA, held at the National Institute of Hydrology, Roorkee on 14th November 2019

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

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

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 03/2021
India Project Partners: NIH Roorkee (India Lead); IIT Ropar; IIT Jodhpur
UK Project Partner: Cranfield University

Location Map

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.	Water levels and water quality monitored at regular intervals.
Assess the proportion of recharged groundwater attributable to MAR systems at selected sites.	Groundwater recharge assessment in progress for chauka system in Laporiya. Field and laboratory experiments conducted for saturated hydraulic conductivity, infiltration, grain size analysis, ICW and soil moisture retention curves. Soil parameters analyzed, and other meteorological and soil moisture data being monitored.
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.	Column experiments in progress to understand the transport of pollutants. Piezometers constructed at two sites in Laporiya and at one site in Bayana. Geological samples collected and pumping tests conducted. Dissolution experiments in progress to generate parameters to develop simulation model for mobilization and transport of fluoride in subsurface.
Develop analytical protocols to facilitate the detection of micropollutants in water bodies.	In progress.
Understand the interactions of local users with the MAR structure and also their role in water management.	Socio-economic survey conducted at Laporiya field site. Project website developed.
Interaction with project partners.	Webex Meetings held in Apr. 2019; June 2019; Aug. 2019; March 2020; Brain storming Session Dec. 2019; Joint Review Meeting July 9-10, 2019; Indo-UK Consortium Workshop Oct 8-11, 2019 at Cranfield University; Online workshop May 14-15, 2020.

Laboratory Facility used during the Study:

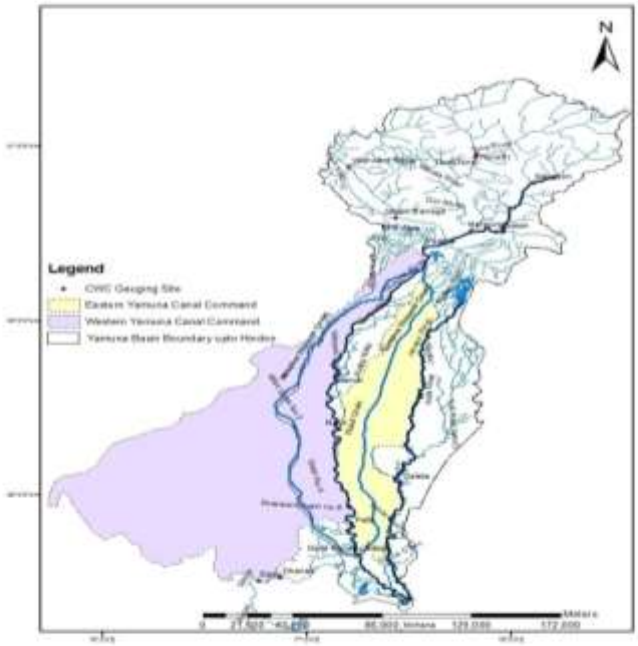
- Centre of Excellence for Advanced Groundwater Research
- Soil Water Laboratory
- Water Quality Laboratory

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

12. PROJECT REFERENCE CODE: NIH/GWH/CEHM/18-22

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

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



Study Area showing the Upper Yamuna Basin and the command areas of EYC and WYC

Study objectives:

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

Objectives vis-à-vis Achievements:

Objectives	Achievements/ Activities
Application and performance evaluation of selected hydrological models for the simulation of the surface water, groundwater, and water quality.	Application of hydrological models completed for SWAT, HEC-RAS, VIC, QUAL2K. Application ongoing for MODFLOW, MIKE HYDRO. Includes data collection from various agencies, field visits, data processing and analysis.
Quantification of the contribution of snow and glacier melt to surface water resources through snowmelt runoff modelling for the Tons river.	Data processing and work on snowmelt runoff model WinSRM in progress.
Assessment of changes in baseflow contribution to river Yamuna.	Assessment of changes in baseflow contribution to Yamuna river completed.
Assessment of present and future water availability under alternate scenarios of climate change.	Extracted data for study area, processing of downscaled meteorological data for climate projections - statistical analysis between IMD data and NEX-GDDP data, bias correction, preparation of monthly time series.
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 MIKE HYDRO and MODFLOW. Database buildup for WA+ tool to process spatial information on water depletion and net withdrawal using satellite measurements.
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 in progress 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 groundwater resources.	Modelling in progress using GIS based WetSpass distributed model. Initial results obtained. Field and laboratory experiments for soil parameters for selected sites in progress.
Roll out of technical know-how through training workshops for partner organizations	To be taken up.

Deliverables:

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

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

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

Type of study (sponsored/consultancy/referred/internal): Sponsored by DST
Nature of study: Applied research
Duration: 03/2019 to 02/2024
Lead agency and project partners: CAZRI Jodhpur (Lead agency), NIH Roorkee, IISWC Dehradun, CSWRI Bikaner, CIAH Bikaner, NIAM Jaipur

Aims

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

Objectives

I. To enhance water productivity in farming systems/regional level (Jodhpur, Jaisalmer, Barmer and Bikaner).
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 visits to two sites in Barmer Dist. for survey and characterization of sites for water resources intervention. Field visit to Bikaner district to carry out study on selected distributaries of Indira Gandhi Nahar Project (IGNP). Buildup of database in progress for development of model for better management of water in selected distributaries of IGNP in Bikaner district. Field experiments undertaken.
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 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.

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

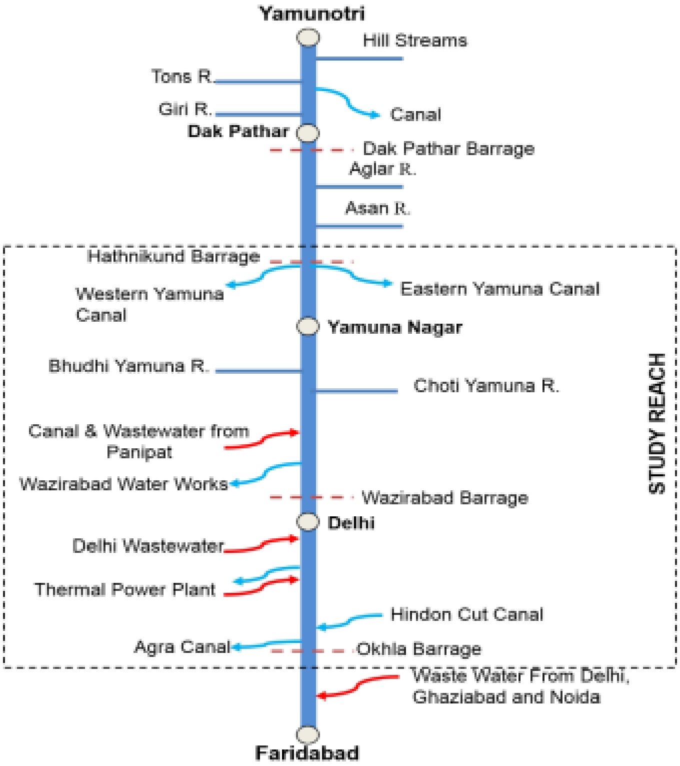
Title of the study : ***Environmental Flow Assessment for Yamuna River from Hathnikund Barrage to Okhla Barrage***

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

Objectives

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

Location Map



Study Reach on Yamuna River from Hathnikund Barrage to Okhla Barrage

Objectives vis-à-vis Achievements:

Objectives	Achievements/ Activities
Assessment of environmental flow for Yamuna River from Hathnikund Barrage to Okhla Barrage.	Completed integrated hydrologic and hydrodynamic modelling to assess the e-flows in the study reach between Hathnikund and Okhla barrage. Computed the releases required from Hathnikund barrage for maintaining the e-flows. Includes field surveys and field visits.
To suggest the management options for maintaining the recommended e-flows.	Completed.
Report preparation.	Draft final report submitted to NMCG and four presentations made before stakeholders committee.

Laboratory Facility used during the Study:

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

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

15. PROJECT REFERENCE CODE: NIH/GWH/MoES/19-19

Title of the study: ***Improving our Understanding of the Aquifer Systems in Sunderbans***

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

Statement of the problem:

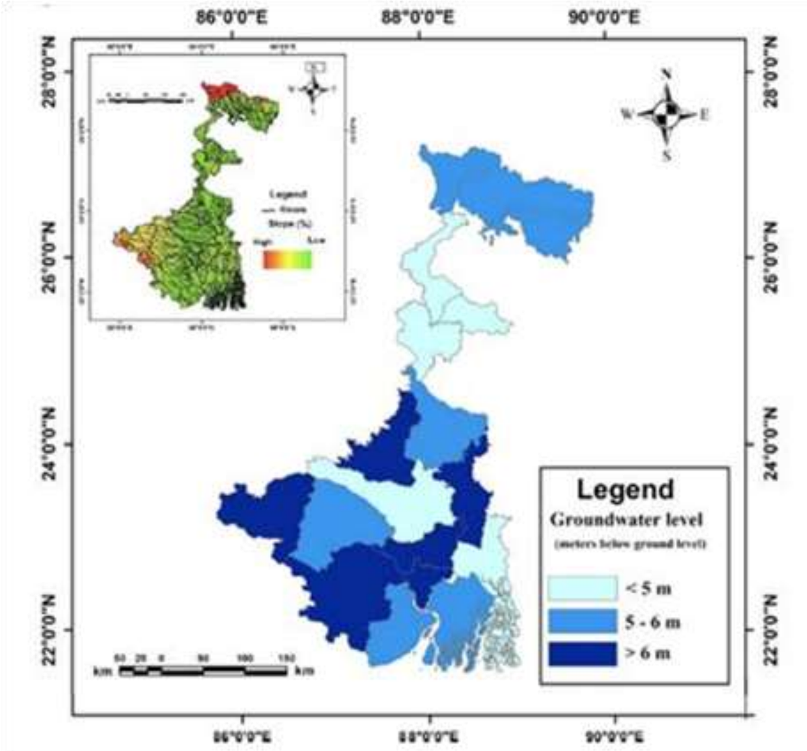
Deltaic coastal areas face challenges in dry season water availability, with brackish rivers and limited reservoir constructing opportunities. Water supplies and irrigation may depend on groundwater. In aquifers where confined saline layers are present, aquifer storage and recovery can be developed to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

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

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

Methodology:

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



Study area, Sunderbans, West Bengal

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

Action plan:

Period	June 2019 to November 2019	Remark
June 2019 to Nov. 2019	➢ Literature review on available groundwater studies including water table, water quality and other hydrogeological aspects ➢ Collection of data from hydro-meteorologists ➢ Prepare a status report and proposal for Aquifer Storage & Recovery	Study completed and report prepared.

Objectives vis-à-vis Achievements:

S. No.	Study objectives	Achievements
1	Develop a conceptual model of the island aquifer systems and collate	**Achieved** – A conceptual model was developed and applied in the field.

	available evidence on aquifer extent; that is through Aquifer Storage and Recovery System.	
2	Collate aquifer property data on the aquifer systems, including data on the shallow saline aquifers.	**Achieved –** Aquifer data was collected with the help of para-hydrogeologists; three major aquifers have been mapped which are confined in nature and providing fresh water.
3	Assess the potential and feasibility of aquifer recharge and aquifer storage and recovery.	There is huge gap between potential aquifer storage and probable aquifer storage, which can be fulfilled through more groundwater augmenting programs. Potential of cost benefit ratio was worked out and recovered reasonably higher amount of water.

Conclusions:

As a result of the participatory nature of the research, it is revealed that ensuring participation is very crucial for successful understanding of the groundwater dynamics and planning activities for the same. In this connection, a participatory data repository along with community data sharing platform need to be created with water users to regulate and maximize optimal use of fresh water. Simulated model on artificial recharge in this regard will be very useful to generate alternative water source option in the Indian Sunderbans. Aquifer storage and recovery (ASR) can be tried but some of the advantages and issues of the aquifer storage and recovery are:

- Drought and cyclone resistant water resource.
- Reduces agricultural demand and competition for the ‘sweet’ water.
- Filtration may be needed – adding costs.
- Untested longevity.
- Depends on detailed lithology – small volume ‘bubble’ will have high surface area to volume in a thick aquifer.

Study Benefits /Impact:

- Characterization of saline aquifers.
- Developed groundwater model to assess feasibility of small scale ASR.

Specific linkages with Institutions: BGS, UK and PRASARI

Future plan:

- Work has been started on small scale ASR schemes under Dwipanjali of West Bengal State Government.

16. PROJECT REFERENCE CODE: NIH/GWH/DoWR/20-20

Title of the study: ***Impact on Salinity of River Mahadayi due to Proposed Dams on River Mahadayi***

Name of PI and members	:	Mr. C.P. Kumar (Coordinator) Dr. Gopal Krishan (PI) Dr. B. Venkatesh (co-PI) Dr. Nitesh Patidar (co-PI)
Type of study	:	**Reference DoWR RD GR, MoJS**.
Date of start (DOS)	:	July 2020
Scheduled date of completion	:	September 2020
Location	:	Mahadayai river (Goa, Maharashtra, Karnataka)

Study objectives:

1. To assess present status of salinity in the Mahadayi river
2. To assess extent of increase/decrease in the salinity of Mahadayi river during last 10 years and the main causes thereof.
3. To determine the probable impact on the salinity of Mahadayi river on account of proposed diversion of water due to Kalasa and Bhandura dam on the Mahadayi river.

Statement of the problem:

Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti directed National Institute of Hydrology, Roorkee to take up a study on *Impact on Salinity of River Mahadayi due to Proposed Dams on River Mahadayi* and submit the findings in the form of report within 3 months.

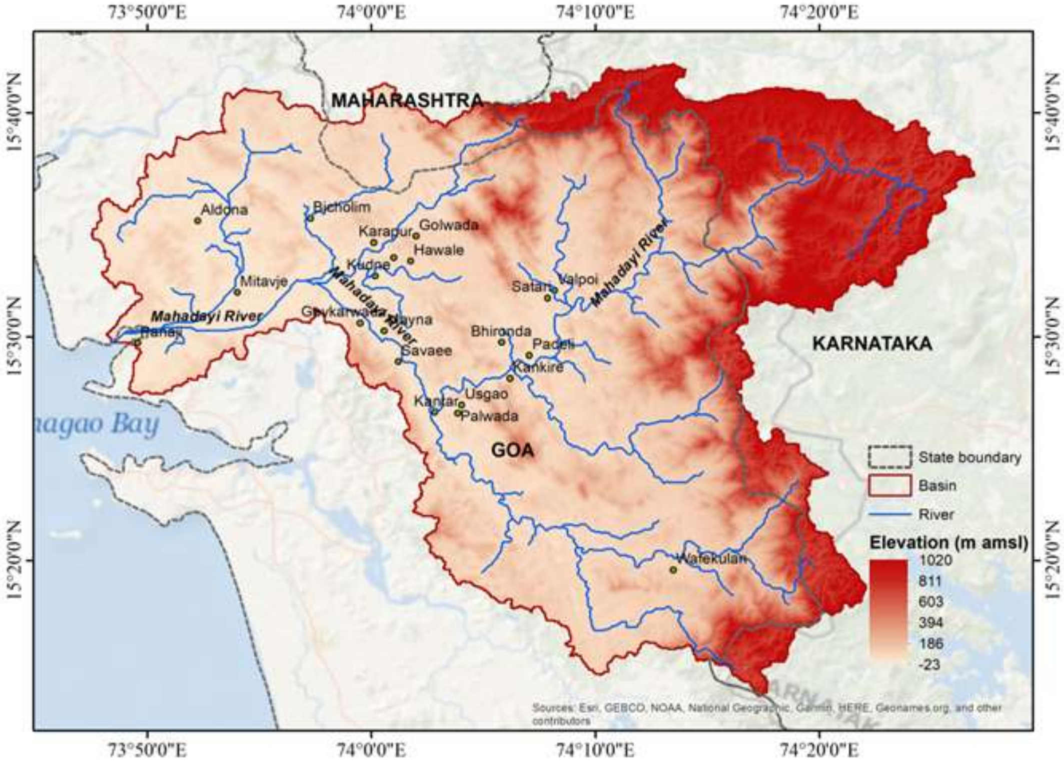
The Mahadayi river is also known as Mandovi river originating from cluster of 30 springs at Bhimgad in western ghats in Belagavi district of Karnataka and has a length of 81 kms traversing in the states of Karnataka (35 kms), Maharashtra 1 (km) and Goa (45 km) and an average depth of 5 m. Mandovi joins with the another river Zuari at a common creek at Cabo Aguada connected by a common Cumbarjua canal, forming the Mormugao harbour- Panaji, the state capital and Old Goa. The Mandovi and Zuari are exclusively used for the transportation of iron and manganese ores from the mining places located along their banks to the nearest Mormugao Port.

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

Methodology:

Collection of data and maps: 10 years salinity and discharge data will be required and for the data CWC, New Delhi and NIO, Goa and state departments will be contacted for maps. Freshwater influx data at Ganjem site will be taken from CWC, New Delhi.
Salinity data: For wet season, data will be collected in the month of August 2020 and measurements will be recorded to study the longitudinal and the intra-seasonal variations of salinity.
Numerical models:
2-Dimensional model: to simulate tidal currents or use of salinity gradient terms in momentum equation at downstream. Momentum, continuity and advection diffusion equation.
1-Dimensional model: In upstreams for area averaged momentum and continuity equations
Water balance model
To model the salinity evolution along the river, a one-dimensional modelling approach will be employed. The HEC-RAS, a hydrodynamic model, will be used to predict salinity under different scenarios. The model will simulate hydrodynamic regime, sediment transport, and water quality along the river.

Calibration and validation of the HEC-RAS model will be performed using in-situ observations of river discharge and salinity.



Mahadayai River

Tides in the estuary are of the mixed semi-diurnal type and the tidal ranges are about 2.3 and 1.5 m during the spring and neap tides respectively. It is believed that this river receives fresh water discharge during the southwest monsoon. Many researchers have reported that during a tidal cycle, the salinity remains almost constant (35 psu) from February to May and varies from 8 to 22 psu from June to September. Heavy precipitation and land runoff from June to September bring about large changes in temperature, salinity, flow pattern, dissolved oxygen and nutrients when the estuary becomes freshwater-dominated (Qasim & Sen Gupta, 1981). By the end of September, the effect of freshwater influx is reduced and saline water intrudes further toward upstream regions. By February, these estuaries become an extension of the sea. Longitudinal distribution of salinity may be variable in the river during the year. Therefore, work will be commenced to see changes in salinity with water availability in the river.

Action plan:

Period	**July 2020 to Sep., 2020** (Annexure 1)	**Remark**
July 2020 to Sep. 2020	➢ Collection of available data on Mahadayai river. ➢ Data analysis and interpretation. ➢ Prepare a status report and submit to DoWR RD & GR, Ministry of Jal Shakti.	Report preparation as per Activity Schedule

Study Benefits /Impact:

- Simulation of salinity distribution.
- Longitudinal distribution of salinity for varying river discharges.
- Long term (10 years) variations in salinity.

Specific linkages with Institutions: Referred work of Ministry of Jal Shakti

Activity Schedule (Month Wise From July 2020 To September 2020)

Activity	Jul	Aug	Sep
Collecting data.	♦	♦	♦
Field survey/Data interpretation.		♦	♦
Report preparation.			♦

Progress

- Discharge data has been collected from CWC.
- Efforts are going to collect historical salinity data.

Future plan

- Field visit.
- Data interpretation.

17. PROJECT REFERENCE CODE: NIH/GWH/CCRBF/20-23

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) **HTWD, Germany** Prof. T. Grischek (Project Leader) Dr. C Sandhu (Project Coordinator)
Type of study	**:**	Sponsored**,** Federal Ministry of Education and Research, Germany
Date of start (DOS)	**:**	July 2020
Scheduled date of completion	**:**	June 2023
Location	**:**	Agra, Uttar Pradesh

Study objectives:

1. Determination of the upper limit for removal of "emerging pollutants" by RBF.
2. Investigate the inclusion of RBF as a "smart water infrastructure concept" within the "Smart City" project of the city of Agra.
3. Synthesis of information for inclusion in the RBF Master Plan and guidelines.

Statement of the problem:

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 impartially to partially treated domestic and industrial wastewater are discharged into the Yamuna river 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 in the 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 with the benefit of an improvement in water quality due to natural processes occurring during aquifer passage. Field investigations at various locations across India including in the Yamuna floodplain (Delhi and Mathura) have confirmed that there is a large potential to use RBF as an alternative to directly abstracted surface water 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).

Agra is located in the state of Uttar Pradesh in the northern part of India at a distance of 200 km from the capital city New Delhi. The region features a semi-arid climate that borders on a humid subtropical climate with mild winters, hot and dry summers and a monsoon season. However the monsoons, though substantial, are not quite as heavy as the monsoon in other parts of India. This is the primary factor in the Agra region that characterises it as a semi-arid climate as opposed to a humid subtropical climate.

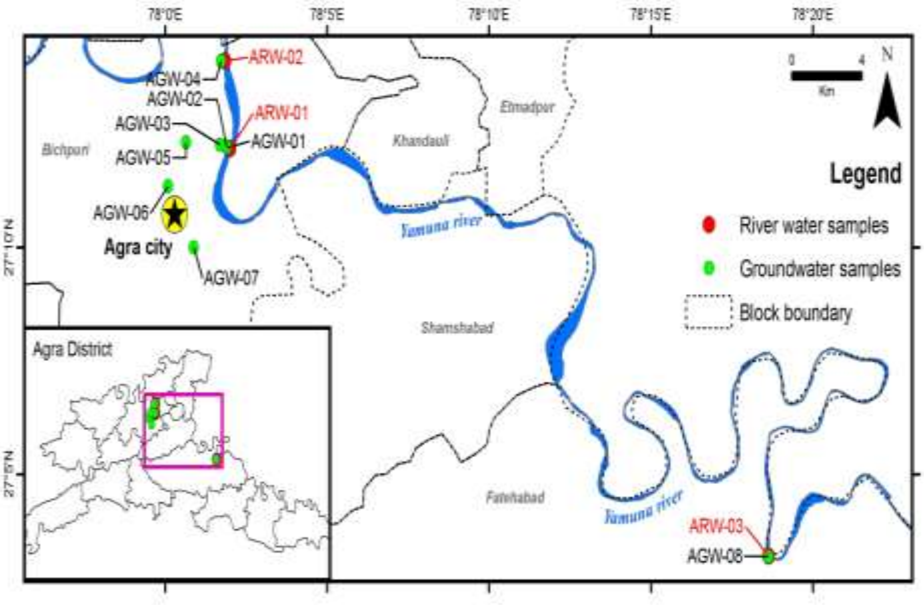
Main advantages of RBF in Agra are found with effective pre-treatment of drinking water by RBF and low risk of formation of disinfection by-products. The main positive observation is that while river water DOC concentrations are high and show a large seasonal fluctuation of around 9 mg/L (3 mg/L in monsoon – 12 mg/L in non-monsoon), RBF can serve as an important pre-treatment step and provide cost-savings for post-treatment.

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

Methodology:

NIH has already established a RBF site at Agra. Samples will be collected from river, adjoining drainages and groundwater to assess the emerging pollutants. So the main focus of this project will be:

- 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.



Study Site

Action plan:

Period	July 2020 to June 2023	Remark
July 2020 to June 2023	➢ Monitoring of the site regularly. ➢ Establishing the site with more infrastructure. ➢ Prepare a status report.	Report preparation as per Activity Schedule.

Study Benefits /Impact:

- The result will be the creation of a road map consisting of these implementation phases:
- informing and collating experience/knowledge;
- evaluating existing work bases and sharing or making them known within the network.

Specific linkages with Institutions:

- German partners: TZWD, TUD, FHP, AUT, AKUT
- Indian partners: UJS, BHU, CSIR_CMERI, BBEC, AU, IITM, TERI

Activity Schedule (Quarterwise 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.

Future plan

- Use of synergies from the competence-pool of RBF/CW/MAR through training and thematic cooperation between partners and stake holders.

HYDROLOGICAL INVESTIGATION DIVISION

Scientific Manpower

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

Recommended Work Programme for the Year 2020-2021

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)	Continuing Study
2	Groundwater Recharge estimation in a part of Sabarmati basin	**M. Someshwar Rao**(PI) Sudhir Kumar Vipin Aggarwal	2 years (9/20 – 8/22)	***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.	3 years (9/20-8/23)	***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 (04/16-03/21)	Continuing Study under NMSHE Project
2.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	**M. Someshwar Rao** (PI) Sudhir Kumar	3 Years (06/16 -05/19) **Ext. upto 03/21**	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 (1/18 – 6/21)	Continuing Study PDS under NHP
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 (1/18 – 6/21)	Continuing Study PDS under NHP
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)	Continuing Study PDS under NHP
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	1 year (04/19 – 03/20) Extended till 03/21	Continuing Study under NCESS, MoES
7.	Groundwater Rejuvenation As Climate changeE Resilience for marginalized and gender sensitive GangeS (GRACERS)	**Sudhir Kumar (PI)** M. Someshwar Rao SM Pingale	2 years (06/19 – 5/21)	IIT Bombay, Mumbai

Institute Funded R & D Studies

REFERENCE CODE:	***NIH/HID/INT/19-22***
Title of the Study:	**HYDROLOGICAL INVESTIGATIONS OF SELECTED SPRINGS IN TEHRI-GARHWAL DISTRICT OF UTTARAKHAND**

(Previously titled as "Integrated hydrological investigations of natural water springs in lesser Himalaya, Uttarakhand)

Study Team:	Santosh M. Pingale (PI), Sudhir Kumar, S.D. Khobragade, Soban Singh Rawat, Rajeev Gupta, Padam Singh
Collaborating agencies:	Veer Chandra Singh Garhwali Uttarakhand University of Horticulture and Forestry, Ranichauri
Type of Study:	Internal study
Funding Agency:	NIH
Duration:	3 years
Budget:	Rs. 31.82 Lakh
Date of Start:	April 2019
Date of Completion:	March 2022

Objectives

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

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 can not be facilitated unless one has basic understanding physical and climatic characteristics of the watershed/springshed. Otherwise, spring rejuvenation measures can not 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).

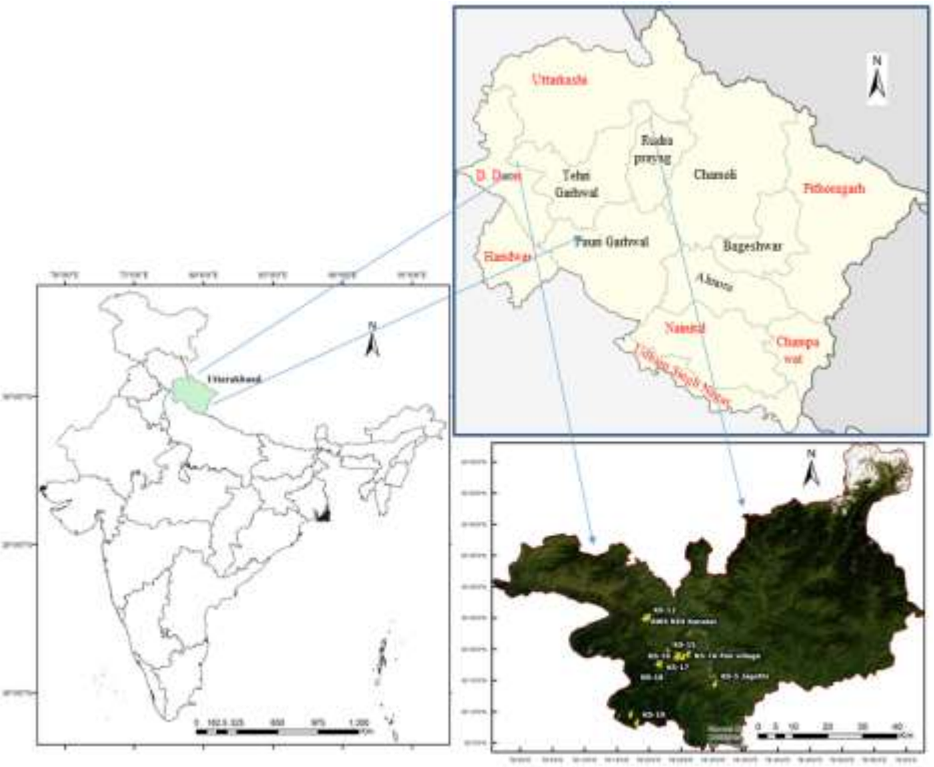


Fig. 1 Location of the study area.

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 sources/springsheds/watersheds.
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 and geo-tag the springs in the study area.	• Field visit has been made and inventorise 20 number of springs in the study area.
To characterize springs with respect to different lithological and physiographical units.	• Local Meteoric Water Line (LMWL) has been established using $\delta^{18}O$ and $\delta^{2}H$ of spring water. • Temporal plots of the isotopic composition of spring water ($\delta^{18}O$ and $\delta^{2}H$) have been prepared. • The collection of the samples for isotopic composition of precipitation is in progress. • Analysis of the altitude and local factors effect on

	stable isotopes of precipitation and spring water are in progress. • The hydrometeorological analysis is in progress.
To develop IDF curves for different return periods of rainfall and characterization of FDC for sustainability analysis of the springs.	• The IDF curves for rainfall and FDC for spring flow is in progress.
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 visit, 20 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, water samples for isotopic analysis). It was found that all spring water are slightly in alkaline nature (pH: 6.8 to 8.5; EC: 40 to 1440 µs/cm).

Isotopic analysis of spring water: The LMWL was developed for identified springs using the monthly weighted average isotopic values of precipitation (Fig.2). The equation for LMWL is given by $\delta D = 6.5316 \times \delta^{18}O + 1.2907$ (R^2=0.956, n=20). Isotopic values of the springs fall on the LMWL. Further, precipitation sampling at different altitudes will be carried out see the altitude effect. Also, the relationship between δ^2H and $\delta^{18}O$ for spring water and precipitation will be explored to identify recharge source/s of the springs.

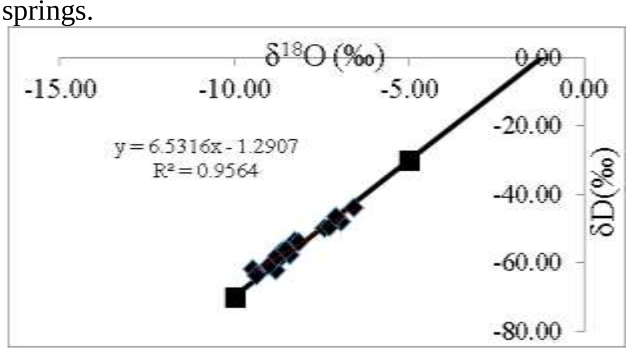


Fig. 2 Plot of isotopic values of different springs along with LMWL.

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.

Future work plan: As per activity schedule

- Additional field visits for spring inventory and collection of rainwater and spring water for chemical and isotopic analysis from the study area.
- Establishment of Rain gauge Stations for measurement of rainfall at different altitudes
- The location of map of springs along with isotopic values of spring water and rainfall will be prepared in the study area.
- Identification of recharge sources and zones of selected springs will be undertaken based on isotopic characterization of precipitation and spring water source.
- The different maps will be prepared for the study area (e.g. DEM, Slope, Drainage).
- Trends and shifts detection will be carried out for the archival data of springs and meteorological parameters using different statistical techniques for the Ranichauri campus and Fakua springs.
- The IDF curves for rainfall and FD curves of the springs flow will be prepared for the regularly monitored identified springs.

The title of the Study has been modified "Hydrological investigations of selected springs in Tehri-Garhwal district of Uttarakhand" based on the suggestion of the Chairman. The originally proposed titled was "Integrated hydrological investigations of natural water springs in lesser Himalaya, Uttarakhand. Working Group may kindly approve.

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

Title of the Project:	**ISOTOPE FINGERPRINTING OF PRECIPITATION OVER INDIAN REGION**
Study team:	Nidhi Kalyani**(PI)**, Sudhir Kumar, M.S. Rao, Swapnali Burman, N.G. Pandey, S.S. Rawat, R.K. Jaiswal, M.K. Jose, T. Vijay
Type of Study:	Internal R&D study
Duration:	3 years
Date of Start:	1stApril, 2019
Date of Completion:	31stMarch, 2022
Budget:	Rs. 39.24 lakh

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

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

The specific objectives shall be

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

Methodology: The envisaged objectives will be achieved through establishing of precipitation isotope monitoring stations at Roorkee, all regional centre of NIH and various other locations across India such as Kolkata, Srinagar, Bangalore, Mumbai, Thiruvanatpuram, and Mangalore etc. The methodology shall involve:

a. Sampling of precipitation isotopes and laboratory analysis for investigations of deuterium and ^{18}O content in precipitation.
b. Spatiotemporal mapping of D and ^{18}O values in precipitation samples for hydrological investigation studies.
c. Identification of the role of geographic, meteorological and atmospheric circulation /Indian monsoon in the space-time variations of isotopic composition of precipitation over Indian region.
d. Application of available data on isotopic composition of precipitation for parameterization of processes in Global Circulation Models, which influence isotope composition in precipitation.
e. Continuation of collection and analysis of stable isotope data over established networks.

f. Identification of climate signals in isotopic composition of precipitation (Climatic variables such as temperature have shown good correlation with isotopic composition of precipitation) to improve interpretation of paleo-climatic archives.

Work Schedule

SN	Work Element	1st Year				2nd year				3rd year			
		1-Qtr	**2-Qtr**	**3-Qtr**	**4-Qtr**	**1-Qtr**	**2-Qtr**	**3-Qtr**	**4-Qtr**	**1-Qtr**	**2-Qtr**	**3-Qtr**	**4-Qtr**
1.	Recruitment of project staff	√	√										
2.	Literature Review	√	√			√				√			
3.	Collection and compilation of all available data/ information	√	√										
4.	Establishing of network of station for precipitation isotope sampling	√	√	√	√								
5.	Sample Collection and transportation	√	√	√	√	√	√	√	√	√	√		
6.	Laboratory Analysis of samples for isotopic composition			√	√	√	√	√	√	√	√	√	
7.	Space-time mapping of isotope composition in precipitation samples				√	√	√	√	√	√	√	√	
8.	Application of data/maps for study of Indian monsoon and hydrologic cycle					√	√	√	√	√	√	√	
9.	Assessment of climate change signals in isotope composition								√	√	√	√	
10.	Preparation of interim report				√				√				
11.	Preparation of final report												√

<u>Progress of Work</u>

Due to certain technical issues, much progress could not be done.

Further, it is proposed to change the PI of the project. Working Group may kind approve the change of PI.

<u>Sponsored Projects:</u>

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

Title of the Study:	**UNDERSTANDING OF 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, R. J. Thayyen 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:	March 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 along with latitude has led to prevalence of different types of climate within the study area. The upper part of the catchment, extending between the elevations of ~4000 m to ~7000 m, experiences an alpine environment, while the region lying below ~4000 m exhibits characteristics of the sub-humid tropical climate.

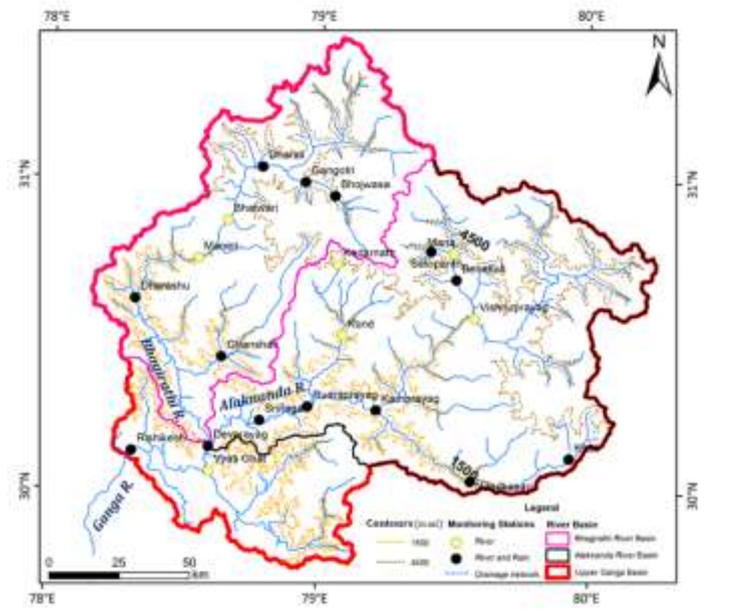


Figure 1 Study area map showing rain and river monitoring stations

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

Statement of the Problem

The Himalayan mountain system is the source of one of the world's largest supplies of fresh water. However, these sources are under threat due to serious environmental degradation and climate change. These changes are likely to dramatically affect 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 upto 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	√	√								
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	• Local meteoric water line and Altitude effect for upper Ganga basin has been established. • Spatial, temporal, and altitude wise variation in isotopic composition of rain has been established to understand the local and regional influence during precipitation events.
Runoff generation processes in headwater region of Ganga using isotope and modeling	• A two-component analysis is completed for the confluence point (5) of rivers in the study area. • Correlation between estimated and observed fraction contribution to the river discharge has been completed for the confluence point of 2 rivers. • Snow cover variation in different months during 2005-2016 using MODIS data for the study area and a

	research paper has been published.
Spatial and temporal variation of snow and glacier melt in Ganga and its major tributaries	• A three-component model has been used to calculate snow/ice melt contribution in the Ganga and its tributaries. • Detailed spatial and temporal variation of stable isotopes and tritium characteristics of Satopanth Glacier (i.e., snow and ice) has been carried out.
The contribution of transient groundwater and its role in the sustainable flow of Ganga	• A three-component approach has been used to estimate the groundwater contribution in the Ganga and its tributaries.
Groundwater dynamics in the mountainous area including identification of recharge sources and zones of major springs	• Isotopic characterization of spring and groundwater has been completed, and further analysis for identification of the recharge altitudes is under progress.

Progress of Work/Results and Analysis

A total of about 9000 samples have been collected so far from various sources such as rain, river, snow/ice, Satopanth Glacier, springs and hand pumps and analysed for stable isotopes (8367 samples), tritium (374) and chemistry (439). The geologic and geomorphic maps have been prepared for the study area

Important results obtained so far:

- The isotopic composition of rain in the Alaknanda basin is slightly depleted compared to the Bhagirathi basin, which may be indicative of relatively more local influences in the Bhagirathi basin.
- Rainfall at Dharasu shows a significant influence of local climate compared to the other stations in the Bhagirathi basin, because of close location of the Tehri dam.
- No clear amount effect has been observed for any station in the basin, even in the monsoon season. This indicates that local moisture recycling may be significant in some rainfall events, even in a monsoon while some impact of western disturbance may be also be present, particularly in July month.
- Isotopic characteristics of rain at Nandkesari are significantly different than other stations.
- Isotopic composition of snow/ice shows wide variation at higher altitude region such as, Satopanth and Gangotri glacier.
- Springs and groundwater samples show marked spatio-temporal variation across the study area indicating large no. of individual aquifers for the springs.
- The river contribution at different locations indicates dominant contribution from Alaknanda river basin (~74%) in comparison to the Bhagirathi river basin (~26%) in the study area.

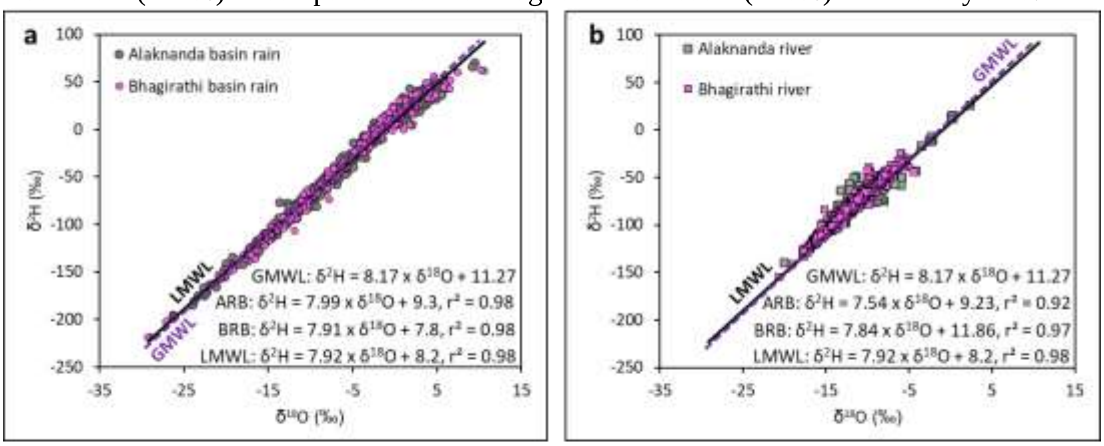


Figure 2 Cross plot of $\delta^{18}O$ and $\delta^{2}H$ values of rain (a) and river (b) in the Alaknanda and Bhagirathi river basin in the upper Ganga basin.

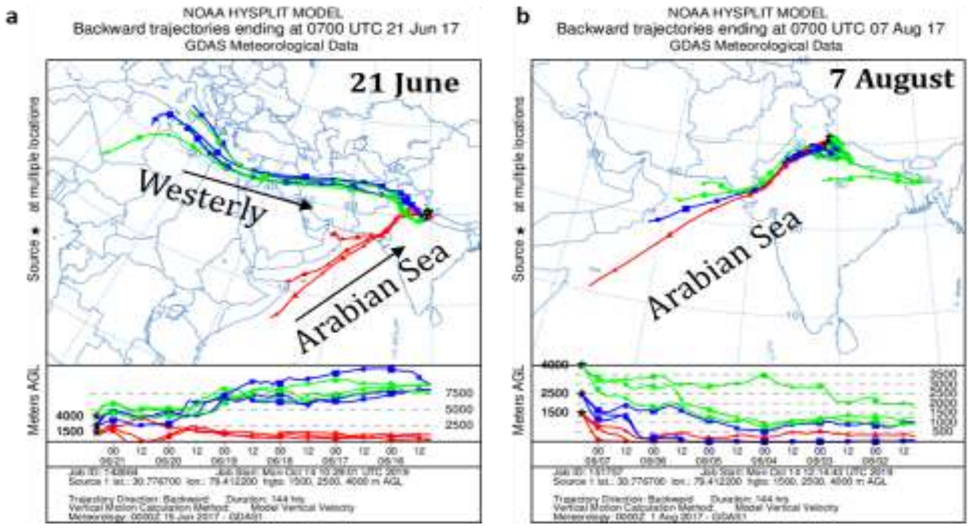


Figure 3 back tractor analysis to identify the moisture source for precipitation in the upper Ganga basin. (a) during 21 June 2017 during pre-monsoon, and (b) during 7 August 2017 during monsoon season.

Detailed results shall be presented during the working group meeting.

Future Plan: work as per activity schedule an research publications

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

Title of the Study:	**REJUVENATION OF SPRINGS AND SPRING-FED STREAMS IN MID-HIMALAYAN BASIN USING SPRING SANCTUARY CONCEPT**
Study Team:	Sudhir Kumar (PI) and S.K. Verma
Type of Study	Sponsored
Funding Agency	G B Pant National Institute of Himalayan Environment and Sustainable Development (GBNIHESD), Almora under NMHS
Budget	Rs. 15.00 Lakhs
Duration:	3 years
Date of Start:	01.06.2016
Date of Completion	31.05.2020

Objectives and Scope of Work:

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

Study Area

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

Figure 1: Map of Study Area

Progress of Work/Analysis and Results

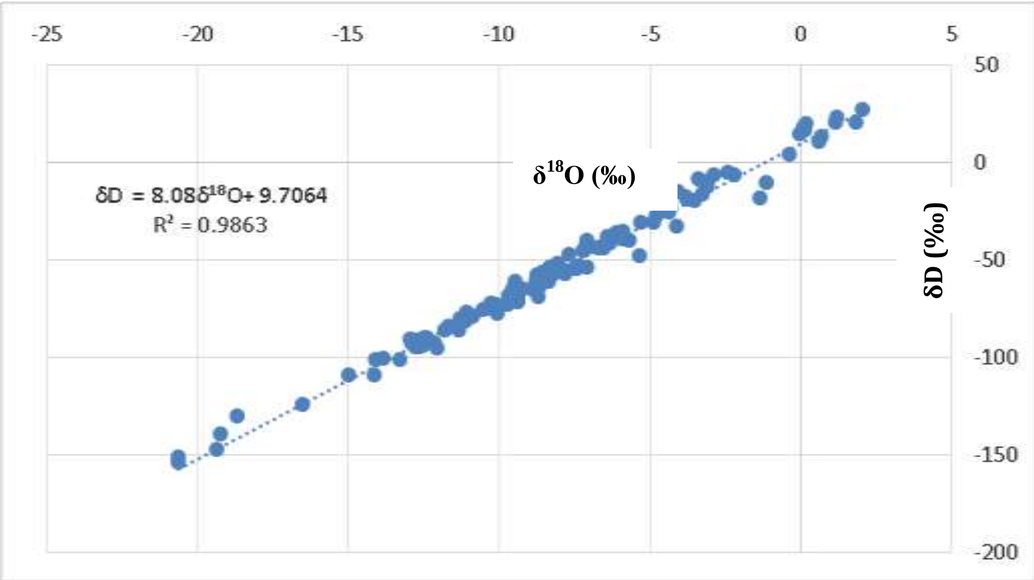
Total 800 water samples, from springs, rainfall and air moisture have been collected from a watershed in Pauri District of Uttarakhand. The plot of δD and $\delta^{18}O$ from 61 rainfall weekly-integrated samples at four different locations within the study area is presented in Figure 1. The regression line drawn between $\delta^{18}O$ - δ D defines the monsoon period local meteoric water line (LMWL) and is represented by the equation $\delta D=7.986\ \delta^{18}O +9.976$. The LMWL matches quite well with the regional meteoric water line developed for western Himalaya $\delta D=7.95\ \delta^{18}O +11.51$ by Kumar et al. 2010. The d-excess also highlights the high temporal and spatial variability and indicative of recycled/re-evaporated source. The weekly to biweekly samples from the stream (outlet location) and spring falls on the LMWL indicative of common source of origin, i.e. by rainfall recharge.

A total of 139 samples of rainfall was collected from four different elevation ranging between 1400m to 1850m to generate the local meteoric water line as well as to decipher the recharge elevation of Ayal village spring located within the study area. The LMWL (Figure 2) is represented by the equation $\delta D = 8.08\ \delta^{18}O +9.71$, $R^2 = 0.98$.

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

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

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



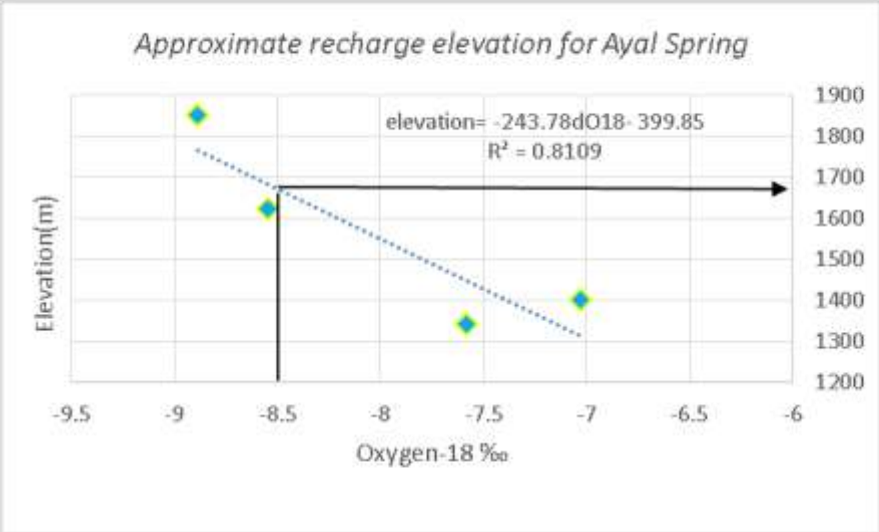


Figure 3: Altitude effect indicating an approximate recharge elevation of 1700m a.m.s.l. for Ayal village spring.

Study has been completed and final report is being prepared.

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

Title of the Study:	**DATING VARY OLD GROUND WATERS OF DEEPER AQUIFERS IN GANGA PLAINS, INDIA**
Study Team:	M. Someshwar Rao, (PI), Sudhir Kumar, S.K. Verma
Type of Study	Sponsored
Funding Agency	IAEA, Vienna (Austria)
Budget	18,000/- Euros
Duration:	3 years
Date of Start:	01.10.2016
Date of Completion	30.09.2019 (extended till March, 2021 by IAEA)

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

4. PROJECT REFERENCE CODE: NIH-26_2017_62

Title of the Study:	**CHEMICAL AND ISOTOPIC INVESTIGATION OF GROUNDWATER IN DEEP AQUIFERS OF MIDDLE GANGA BASIN, INDIA**
Study Group:	Sudhir Kumar (PI), M. Someshwar Rao
Collaborating Institution:	CGWB (MER, Patna & NER, Lucknow)
Funding Agency:	(PDS-NHP)
Budget:	Rs. 55.40 Lakhs
Nature of Study:	Applied Research
Date of start:	January 2018
Date of completion:	May, 2021
Duration of the Study:	$3^{1}/_{2}$ Years

Objectives:

i. To map aquifers Upper / Middle Ganga Plains.
ii. To identify the source of recharge to deep aquifers
iii. To assess interaction of deep aquifer with the overlying aquifers.
iv. Water quality of deep & shallow groundwater
v. Sustainability of deep aquifer for its exploration and future use

Study area: Indo-Gangetic plain encompasses a large alluvial track consisting of multi-tier aquifer system. Of this, the central Ganga plain is one of the most densely populated regions in the subcontinent. The study occupying in the Central Ganga Plains covers 21 districts of Uttar Pradesh and is spread over ~1643 km^2 area. In the study area, deep aquifer groundwater (depth > 250 m) has been sampled from piezometers developed by CGWB, GoI. Through field survey it was observed that most of these piezometers are choked or that these are located in agriculture fields and, are therefore not accessible in the presence of standing crop. After detailed survey, samples from 10 piezometers were collected and analysed for water quality and isotopic analysis. In Dec., 2019; shallow groundwater samples were collected from 49 locations. The sampled locations are shown in the figure below.

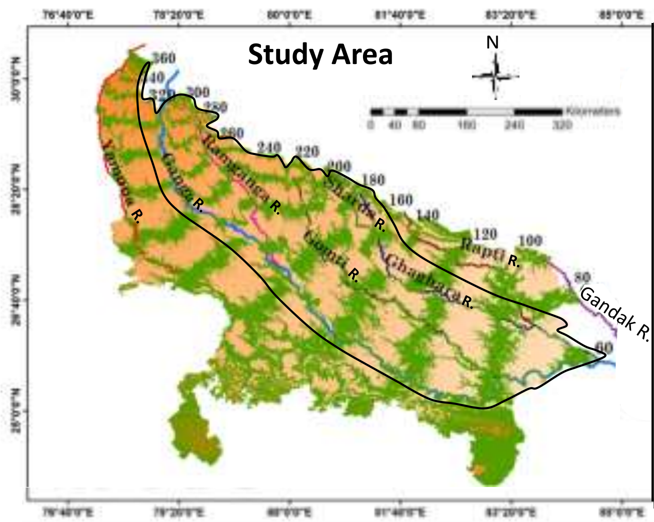


Fig: Study Area. Rivers in the state Uttar Pradesh, elevation contours and boundary of the water sampling area (closed black line)

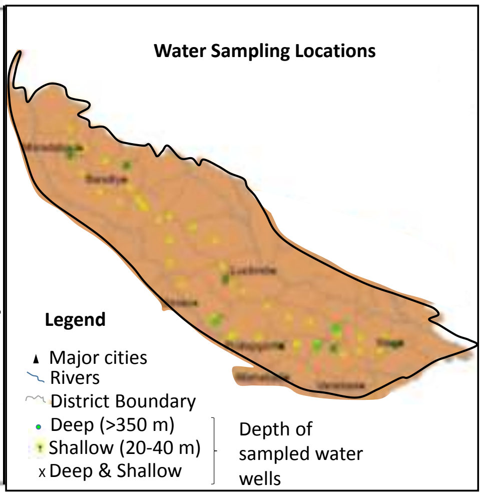
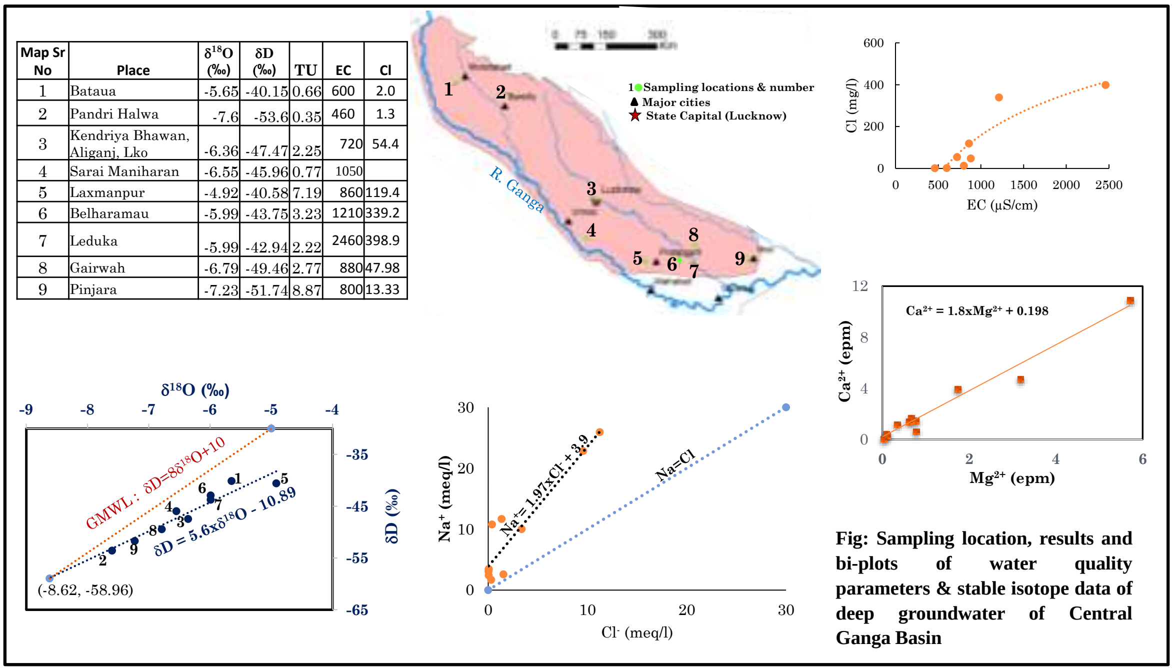


Fig.: Water sampling locations in the Central Ganga plains of Uttar Pradesh

Work accomplished (as on date)

Objectives & Analytical Method	Work components		Achievements
Investigations using RS/GIS technique	1) Rainfall-Runoff estimation using SCS-CN & GIS approach 2) Mapping of potential Groundwater recharge zones 3) Mapping of vulnerable groundwater zones	i) Digital Elevation Model ii) Land Use & Land Cover (Supervised classification) iii) Soil map iv) Surface & sub-surface mapping v) Changes in surface water & GW conditions using archival data	DEM prepared using ASTER data (30m resolution; year 2019) Sentinel (2019) images of study area is downloaded. Downloaded groundwater level and quality data Downloading/collection of the remaining data and data analysis is in progress
Investigations using isotopic & chemical analysis	Water quality & isotopic characterization of groundwater	Field Work	i) Deep GW sampling: 9 deep (depth > 200 m) GW sample collected in 3 field visits (March-2018, Oct- 2018 & Jan-2019) ii) Medium depth (30-40 m) GW sampling: 49 GW samples collected in Dec -2019
		Analysis	Deep water samples: Analysis of ^{3}H, ^{2}H, ^{18}O & major ion completed Medium depth water samples: ^{2}H, ^{18}O & major ion completed. (^{3}H analysis is in pending)



Map Sr No	Place	$\delta^{18}O$ (‰)	δD (‰)	TU	EC	Cl
1	Bataua	-5.65	-40.15	0.66	600	2.0
2	Pandri Halwa	-7.6	-53.6	0.35	460	1.3
3	Kendriya Bhawan, Aliganj, Lko	-6.36	-47.47	2.25	720	54.4
4	Sarai Maniharan	-6.55	-45.96	0.77	1050	
5	Laxmanpur	-4.92	-40.58	7.19	860	119.4
6	Belharamau	-5.99	-43.75	3.23	1210	339.2
7	Leduka	-5.99	-42.94	2.22	2460	398.9
8	Gairwah	-6.79	-49.46	2.77	880	47.98
9	Pinjara	-7.23	-51.74	8.87	800	13.33

Fig: Sampling location, results and bi-plots of water quality parameters & stable isotope data of deep groundwater of Central Ganga Basin

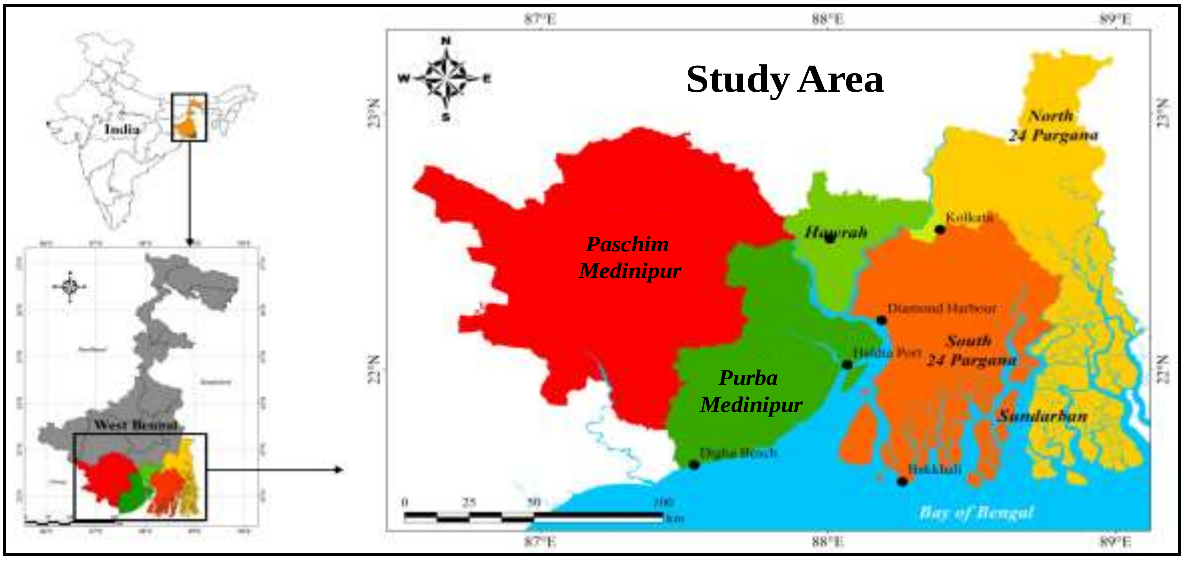
Targets & Time Line for 2020-21

Components	2020		2021	
	July-Sept	Oct-Dec	Jan-Mar	Apr-May
Rainfall- runoff				
LULC & soil map preparation	√	-		
Data integration & runoff estimation	-	√		
Groundwater vulnerability	√	√		
Mapping of potential GW recharge zones	√	√		
Isotopic & water quality characterization of deep & shallow aquifer groundwater				
Field work	√	√	--	
Sample analysis	---	√	√	
Data Interpretation	---	√	√	
Report writing & Publication			√	√

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

Title of the Study:	**INTEGRATED STUDY ON GROUNDWATER DYNAMICS IN THE COASTAL AQUIFERS OF WEST BENGAL FOR SUSTAINABLE GROUNDWATER MANAGEMENT**
Study Group:	MS Rao (PI), Sudhir Kumar, AR Senthil Kumar, VS Jeyakanthan.
Collaborating Institutions:	Er.Subrata Halder, Exe. Eng, SWID, Govt. of West Bengal
Type of Study:	Sponsored Project, NHP, MoWR, RD&GR, New Delhi,
Budget:	Rs 51.0 Lakhs
Nature of Study:	Applied Research
Date of start:	January 2018
Scheduled date of completion:	July, 2021
Duration of the Study:	$3^1/_2$ Years

Study area: Groundwater in the coastal region of West Bengal exists in unconfined to confined conditions in the multi-layered aquifer system. The groundwater quality 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.



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 data base 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:

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

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

iii) Identification of source of salinity in groundwater

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

v) Management measures for safe & sustainable coastal groundwater use

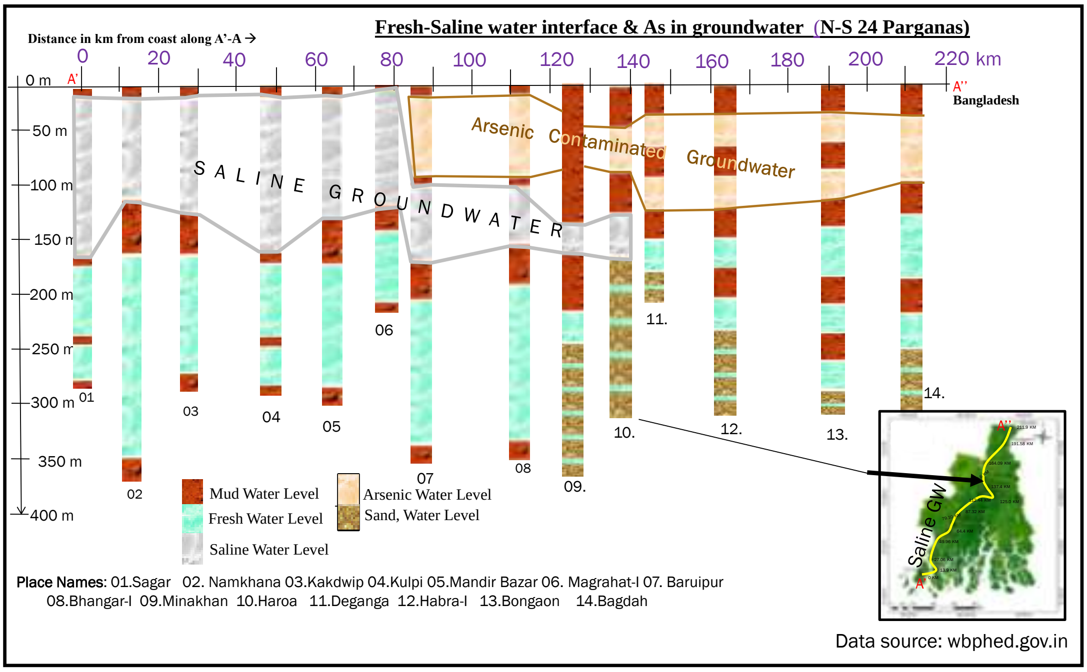


Fig : Saline-fresh groundwater interface and arsenic contamination in groundwater in 24 Parganas (south & north) of West Bengal

Scientific Work & Analytical Technique		Work Components	Achievement as on June 2020	Target: July 2020 to May 2021
Analysis using RS/GIS Techniques	Rainfall-Runoff modelling	Land Use Land Cover (Supervised classification)	LULC map of Feb 2018 prepared	Rainfall-Runoff modeling (SCS)
		Hydro-climatological Data collection	Collected archival data (2003-2013) (Precipitation, Temperature, Solar Radiation, Relative Humidity, Wind Speed)	
		Digital Elevation Model (ASTER,30m)	DEM prepared	
		Soil Map (Source: NBSS & LUP)	Completed	
	Groundwater Potential Zone Mapping	Digitization of hydrogeological & geomorphological features	Geomorphological feature digitized	Demarcation of groundwater potential zone
			Hydrogeological mapping of 70% area completed	
	SGD analysis by Thermal mapping	Source: MODIS Period: 2019 & 2020; Resolution:1km Mapping:	<u>SST</u> Maps prepared for the following dates 2019 (Apr., June, Oct., Dec.)	Interpretation of data for mapping the submarine groundwater discharge

		(i) Land Surface Temperature (LST) (ii) Sea Surface Temperature (SST)	2020 (Feb., Mar) LST Maps prepared for the following dates: 2019 (March) 2020 (March)	
Analysis using archival data	Changes in the water quality, and availability due to seawater groundwater interaction and anthropogenic effects	Changes in water quality data Changes in groundwater level (Data source: WBPCB)	Collected surface water & groundwater quality data for the period 2010-2019 Collected groundwater level data for the period…	Recent change in hydrological conditions
		Sea level fluctuation (at daily frequency)	Period: Jan 2019 to June 2020 Number of locations: 3 locations	Effect of sea level change on groundwater conditions
		Groundwater quality in multi-aquifer system of coastal zone	Prepared 2D sectional diagram of North 24 Parganas and South 24 Parganas completed Data interpretation for mapping of fresh & saline water interface and arsenic contaminated aquifer is under progress	Mapping of i)interface between seawater and fresh groundwater and, (ii) arsenic in groundwater
Primary data generation	SGD Analysis by isotopic mapping	Isotopic & chemical mapping of study area	Field work completed: June-July 2019 Samples collected: 110 Depth range: 30-350 mbgl Isotope analysis of all samples completed & $\delta^{18}O$, δD & EC maps prepared Chemical analysis of 50% samples completed	2nd field work (July-2020) & analysis of the samples that will be collected
Comprehensive report & Publications				✓

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

Title of the Project:	**DEVELOPMENT OF A COMPREHENSIVE PLAN FOR CONSERVATION AND SUSTAINABLE MANAGEMENT OF BHIMTAL AND NAUKUCHIATAL LAKES, UTTARAKHAND**
Project team:	S.D. Khobragade (PI), Sudhir Kumar, 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:	1stJanuary, 2018
Date of Completion:	31stDecember, 2020
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 Naukuchiatal 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

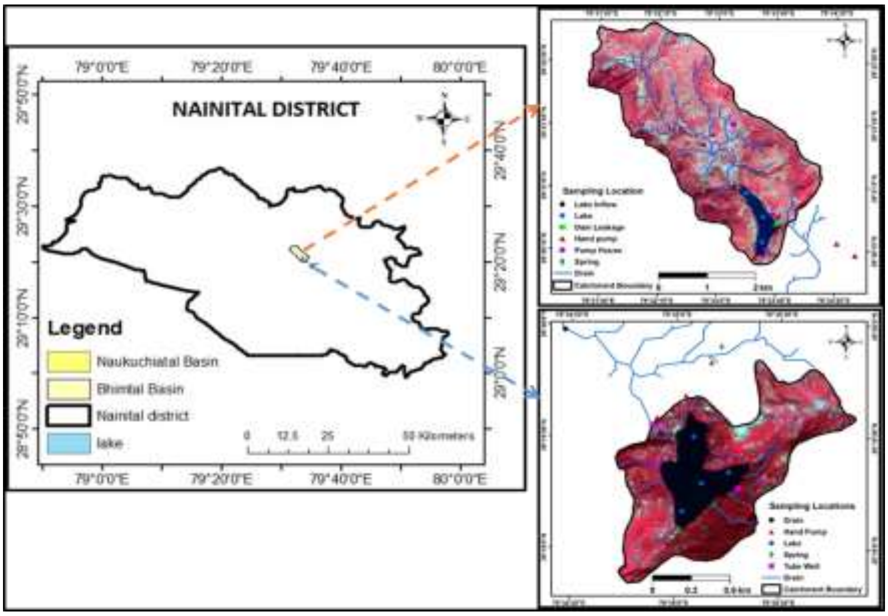


Figure 1: Study area map of Bhimtal and Naukuchiatal lakes

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.

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. The process is still to be initiated by IRI. However, based on the available data collected by NIH, water balance has been initiated. Isotopic characterization of lake water and surrounding water has been done.
To assess the water quality of the lakes and possible causes of its degradation	Water quality samples have been collected from both the lakes for pre-monsoon seasons of 2019. Analysis has been completed.
To estimate sedimentation rate and expected life of the lake	Bathymetric surveys have been completed for both the lakes and depth area capacity curves have been developed.
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

Four Field visits were undertaken during 2019-20 and samples collected for water quality and isotope analysis. Various study area maps such as catchment maps, DEM, land use land cover, drainage map, slope map etc have been prepared. Isotopic analysis of samples collected till September, 2019 has been completed. Analysis of remaining samples is under progress. The data required for water balance, which was supposed to be collected and provided by IRI, Roorkee, has not been collected and provided so far. So not much progress has been made for assessment of water balance.

Important results obtained/Analysis:

There is no declining trend in rainfall at the study area during 2004-2018. Analysis of lake water variation indicates that the 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. 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.

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.

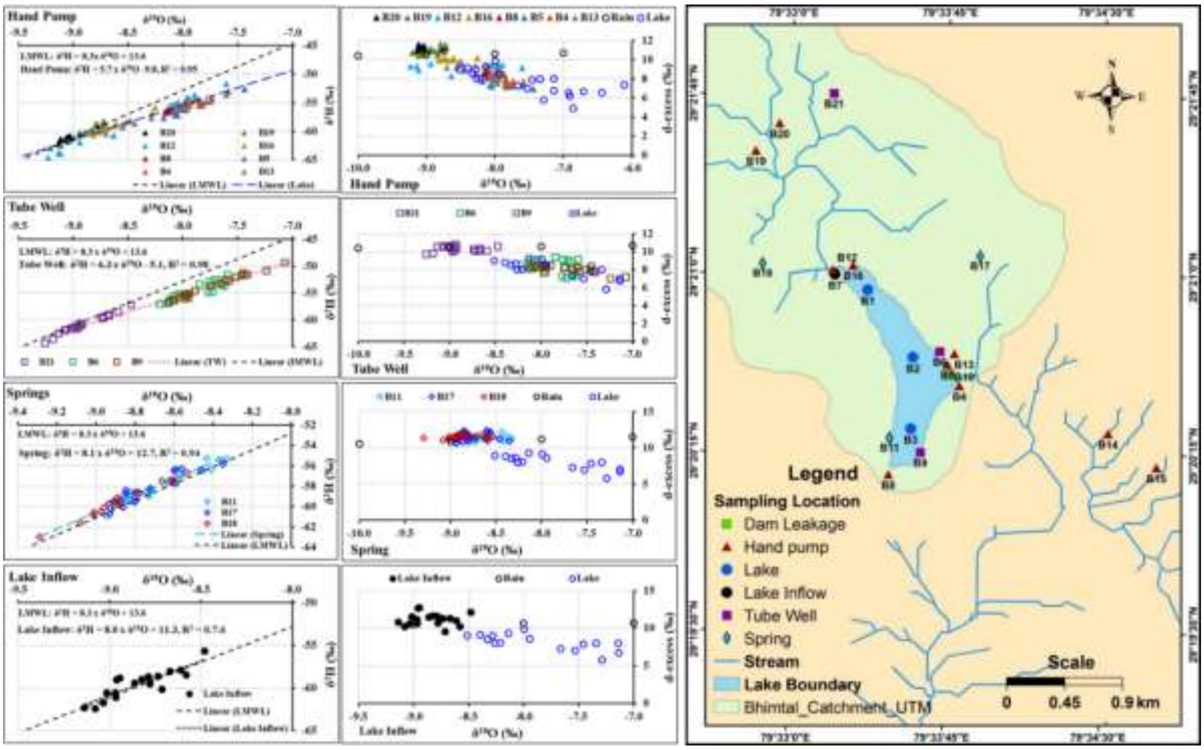


Figure 3: Isotopic variation of different source of Bhimtal Lake

Isotopic analysis of precipitation (analysis of d-excess) for the study area follows the general trend for the northern hemisphere with 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. 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. 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 Fig. 3. The recharge source for all the springs in upstream of both lake catchments are observed to be precipitation.

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.

Detailed results shall be presented in the working group meeting.

Future Plan: as per activity schedule

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 & finalization of various sampling locations	√											
1.2	Recruitment of project staff	√											
1.3	Collection & Review of all available data/information	√	√	√									
1.4	Compilation of existing data/information	√	√	√	√								
1.5	Identification of Data Gaps	√	√										
1.6	Procurement of instruments and peripherals	√	√	√									
1.7	Purchase of Remote Sensing Data and meteorological Data	√	√										
1.8	Installation of equipment in field	√	√										
1.9	Preparation of basic maps of lake and catchment		√	√									
1.10	Installation of piezometers	√	√										
1.11	Arrangement for discharge measurement	√											
2.0	**FIELD WORK**												
2.1	Generation of hydro-meteorological		√	√	√	√	√	√	√	√			
2.2	Collection of water samples for water quality & isotope analysis		√	√	√	√	√	√	√	√			
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 water levels & GW levels		√	√	√	√	√	√	√	√			
3.0	**LABORATORY ANALYSIS**												
3.1	Analysis of samples for Water Quality & isotopes		√	√	√	√	√	√	√	√			
3.2	Analysis of sediment samples		√	√	√	√	√	√	√	√			
4.0	**DATA INTERPRETATION & ANALYSIS**												
4.1	Processing of bathymetric data			√	√								
4.2	Development of depth-area-capacity curve				√								
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**												
5.3	Preparation of Interim Project Report				√				√				
5.4	Preparation of Final Project Report												√
6.0	**ORGANIZATION OF TRAINING WORKSHOP**	Post-Project											

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

Title of the Study:	**UNRAVELLING SUBMARINE GROUNDWATER DISCHARGE (SGD) ZONES ALONG THE INDIAN SUBCONTINENTS AND ITS ISLANDS**
Study Group:	Sudhir Kumar (PI), SM Pingale, MS Rao, BK Purandara, YRS Rao
Collaborating Institutions:	National Centre for Earth Science Studies, Thiruvananthapuram, RC Kakinada and Belagavi
Type of Study:	Sponsored Project, 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:	March 2020, Extended up to 03/21
Duration of the Study:	1 Year

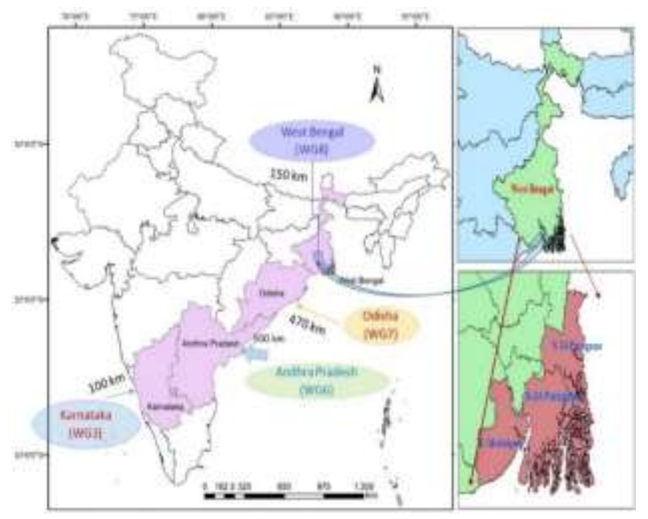


Fig. 1 Location of the study area.

Study area: The study area included the coastal districts of West Bengal (i.e. Purbha Medinipur, North & South 24 Parganas) and in some parts of Odisha (Fig.1 and 2).

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 (NH_4); and phosphate (PO_4), Oxygen and Hydrogen isotope for selected locations where SGD has been identified using thermal imaging or hydrogeological surveys.

Methodology:

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

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

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

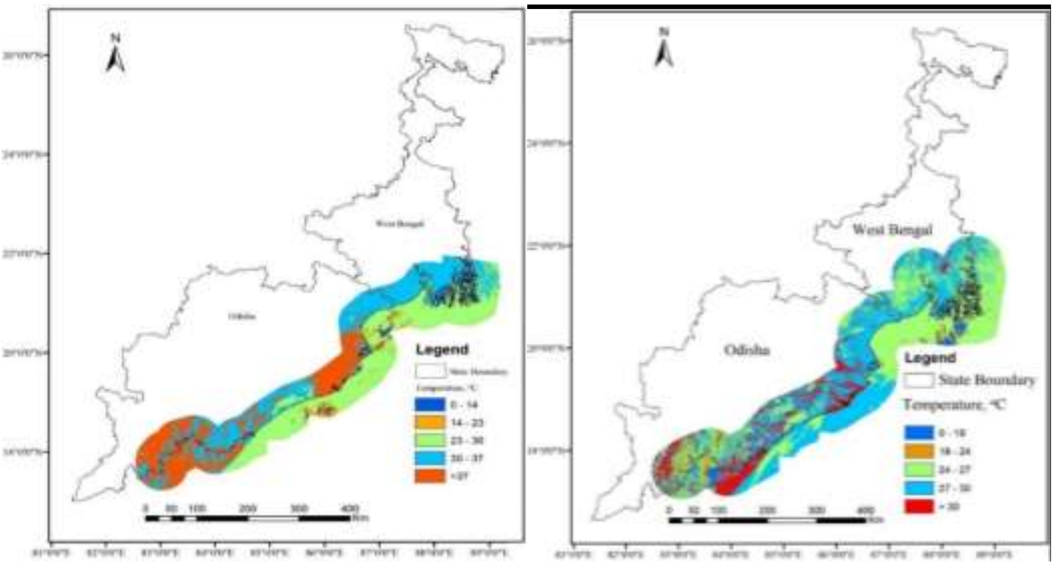
iv) **Data synthesis**: Field data and archival data will be converted into thematic layers on GIS environment. This will be used to identify the potential SGD zones in the coastal aquifers.

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

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

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 • Collected archival data related with groundwater from different sources in the potential SGD zones located the coastal aquifers. • Detail analysis is in progress.
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 (2019) for the different time period have been obtained and processed (Fig.2). • Detail analysis is in progress and the identification of the SGD zones is in progress.
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] from selected locations for chemical and stable isotope analysis have been collected in the coastal district of Purba Midinipur. • Remaining sample collections in the coastal districts of West Bengal (i.e. North 24 Parganas and South 24 Parganas) will be carried out after COVID-19 Pandemic.
To measure salinity and temperature of sediment pore water, groundwater and seawater	• The in-situ salinity and temperature of pore water, groundwater and seawater water have been carried out for the selected locations in the study area.
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.	• 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. The tritium samples are under laboratory analysis. • 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. • Detail analysis of $\delta^{18}O$, $\delta^{2}H$, Radon and water chemistry is in progress. • The linkage between the isotopic signature of water, it's chemistry and hydrogeological processes is being initiated for identification of possible SGD zones.



(a) Pre-monsoon season (b) Post-monsoon season

Fig. 2 Landsat8 thermal imageries over West Bengal and Odisha of the year 2018

(a) (b)

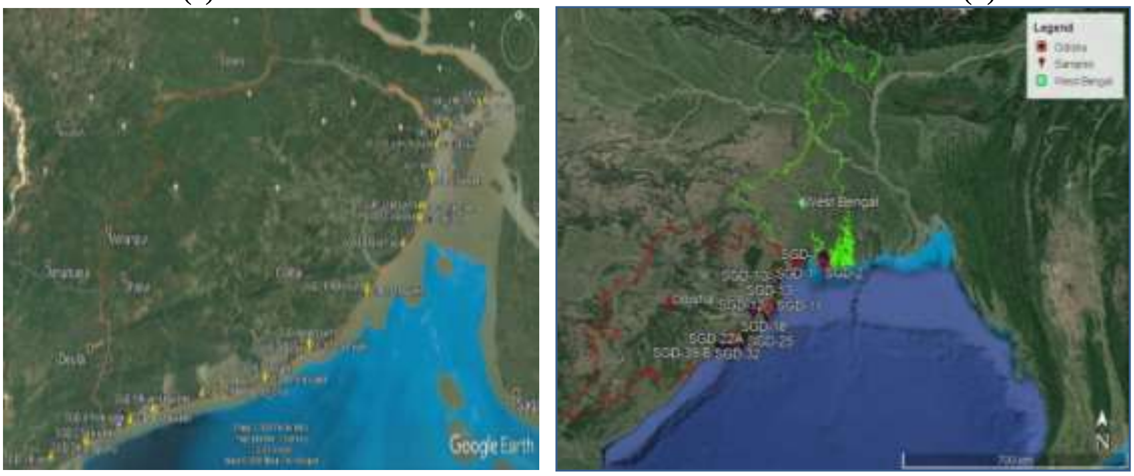


Fig. 2 SGD locations of sample water collections in (a) Purbi Medinipur district (West Bengal) and (b) Odisha

Future Plan:

- Field surveys for primary data collection for isotopic and chemical analysis of groundwater, pore water, sea water from remaining coastal districts of West Bengal (i.e. North 24 Parganas and South 24 Parganas) at specified interval.
- Procurement of rainfall and temperature data for SGD analysis.
- Analysis and preparation of thematic maps of SGD locations.

8. 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), MS Rao, 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
Duration of the Study:	3 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:

- Identify change in drinking water supply sources for rural, marginalized and women communities
- Identify socio-economic stress due to poor groundwater quality and quantity
- Identify loss of labor time and education time due to water fetching activities
- Identify health issues in consuming polluted water and long term impacts
- Identify limitations in groundwater recharge due to centralized water supply schemes
- Provide knowledge and technical support to government agencies working in the Ganges basin
- 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 (m bgl). Major Problems in the area are (i) Groundwater depletion, (ii) Water quality

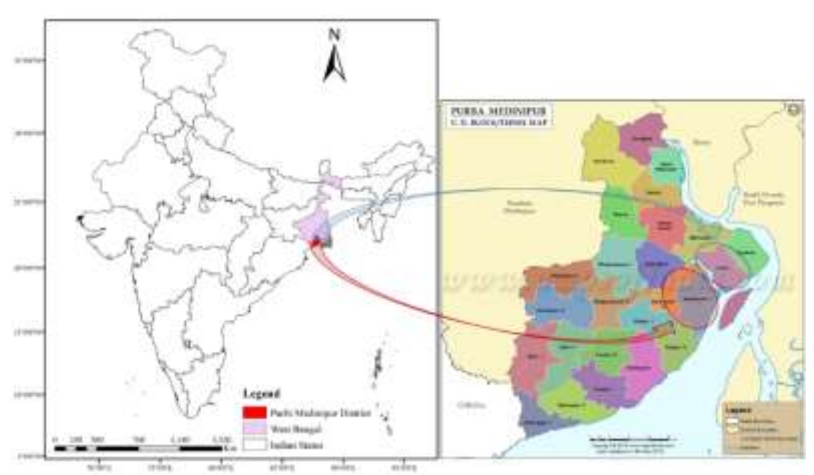


Fig. 1 Location of the study area (i.e. Nandigram & Haldia blocks)

(salinity in the upper aquifers), and (iii) Lack of proper implementation of existing legislative acts for guiding the groundwater extraction.

Methodology: The adopted methodology involves field investigations and collection of hydrological, meteorological, groundwater quality, geological, topographic and land use 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 coastal district of Purba Medinipur in West Bengal and collected water samples from some of the locations for chemical and stable isotope analysis.
- In-situ measurement of water quality parameters (e.g., salinity, temperature, EC, DO, pH) of groundwater and river water samples have been performed by using Multi-parameter water quality analyser. Water samples are mainly analysed for the seven major parameters.
- The water samples have been collected for $\delta^{18}O$ and $\delta^{2}H$ isotope for selected locations and have been analysed in the lab. 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 groundwater and river water for the study region (Fig. 2 and Table 1). Detail analysis is in progress.
- Radon concentrations in the groundwater and surface water have been directly determined in the field (Table 1). While the tritium samples are under laboratory analysis.
- Remaining sample collections in the study area (Haldia and Nandigram Block) will be carried out.
- Some of the data related with groundwater and hydrogeology have been collected from CGWB. The archival data information (i.e., groundwater, its chemistry, general aquifer properties and characteristics) have been collected from regional CGWB office at Kolkata.
- Historical groundwater level data of different groundwater observation wells in Purba Medinipur district have been collected from CGWB and India-WRIS web.
- Using the groundwater data, the hydrograph and relevant maps depicting groundwater scenario corresponding to various measurements for all the wells is under progress. These will be prepared to understand the groundwater dynamics.
- Detail analysis is in progress.

Table 1 Isotope and Radon analysis of water from different sources

S. No.	Sample Code	Source	$\delta^{18}O$	δD	Radon
			(‰)	(‰)	(pci/l)
1	WS-1	HP	-2.84	-16.20	41.00±11.5
2	WS-2	RW	-5.31	-37.08	-
3	WS-3	BW	-3.06	-20.00	9.72±7.36
4	WS-4	RW	-5.66	-40.06	4.16±1.60
5	WS-5	BW	-3.04	-18.54	63.90±15.90
6	WS-6	RW	-6.02	-43.08	4.16±2.77
7	WS-7	River	-5.90	-41.46	-
8	WS-8	HP	-3.22	-21.04	31.30±8.82

Note: WS: Water Sampling; HP: Hand pump; BW: Bore well; RW: River water

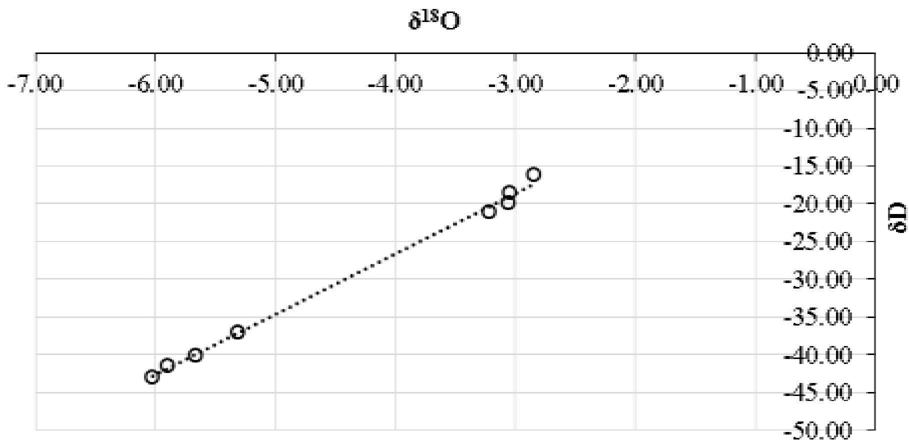


Fig. 2 Isotopic composition of collected water samples from different sources

Future Plan:

- Additional field visits are required in the study area for data collection, survey and stakeholder's discussions.
- Also, data processing and analysis as well as lab investigations will be undertaken for collected water samples from the field.
- Primary data collection for salinity measurement for dry season.
- Hydro Stratigraphic cross section across the study area to understand the flow of groundwater system.
- Procurement of hydro-climatic data for groundwater analysis.
- Conceptual model based on data collected.
- Development of groundwater vulnerability maps and potential recharge zone map of the study area.

New Internal R&D Studies

Title of the Study: AN INTEGRATED APPROACH TO THE ASSESSMENT OF GROUNDWATER RECHARGE POTENTIAL IN A PART OF SABARMATI RIVER BASIN, GUJARAT

Collaborative Institutes: Central University (CU), Gujarat

Study Team: M S Rao (PI), Sudhir Kumar, V. K. Agarwal

Dr Rina Kumari, (Sch. of Env. & Sus. Dev., CU, Gujarat)

Project Duration: 2 years [1/8/2020 to 30/7/2022]

Budget: 10.0 lakh

Objectives: The specific objectives of the project are as given below;

i) Assessment of Groundwater Recharge potential using RS/GIS approach
ii) Stable isotope characterization of groundwater and surface water sources
iii) ^{3}H dating of groundwater
iv) Estimation of vertical recharge to groundwater using tritium tagging technique
v) Identification of prospective areas for artificial recharge measures

Origin of the proposal & Statement of problem

Recharge to groundwater is crucial for waste disposal, artificial recharge measures, and groundwater resource management. Recharge to groundwater varies spatially and temporally due to an integrated effect of various attributes such as rainfall pattern, properties of surface soils, land-use/cover, vegetation type, local topography, depth to the water table etc. While, diffuse (direct) recharge occurs from irrigation or precipitation and it recharges large areas fairly uniformly; the focused recharge occurs from surface water sources such as from streams, lakes, canals, etc. The recharges from such sources is confined locally. Identification of potential recharge areas and estimation of recharge rates are non-trivial. The present study is intended to investigate potential recharge areas and vertical recharge rates from precipitation, irrigation and surface water sources using an integrated approach in the Sabarmati river Basin of Gujarat.

Methodology:

Dual approach will be used to address the objectives. In the first, using RS/GIS approach, various thematic maps to assess the factors influencing recharge to groundwater in the study area will be investigated. A conceptual framework will be prepared for mapping the likely rechargeable zones and mechanism for the recharge. In the second part, the efficiency of the identified zones for recharge to groundwater will be quantitatively examined using isotope tracer techniques. The various work Components are given in activity schedule.

Activity Schedule

Work components	Aug-Dec, 2020	Jan-Jun, 2021	Jul- Dec 2021	Jan-Jul 2022
Collection of hydrological, meteorological, agro-hydrological, surface & sub-surface soil data, irrigation data, rainfall data etc	✓			
Preparing various thematic layers: LULC, DEM, Hydrological maps	✓	✓		
Integrating and analysing thematic maps to prepare conceptual model for likely mechanism of recharge		✓	✓	
Identification of recharging water source using stable isotope technique Water sampling (for ^{2}H, ^{18}O, ^{3}H and water quality analysis)	✓	✓	✓	

Sample analysis Data interpretation	✓	✓ ✓	✓ ✓	
Estimation of recharge to groundwater ^{3}H tagging Raising the soil cores Soil analysis for 3H analysis Soil moisture & grain size analysis Data interpretation	 ✓ ✓ ✓ ✓	 ✓ ✓ ✓ ✓ ✓	 ✓ ✓ ✓ ✓ ✓	
^{3}H dating	✓	✓	✓	
Comprehensive data interpretation			✓	✓
Report and publication			✓	✓

Budget: 10.0 lakhs

Budget component	**Amount (in lakh)**
Travel	2.3
Data purchase & Consumables	2.5
Instruments	1.1
O & M	0.5
Manpower (Field cum Lab Assistant-FCLA) @Rs 18,000/- pm	3.6
Total	10.0

Justification:

1. Travel: Travel expenses is for field work and data dissemination (conference/meetings etc). It is for 3-4 field visits of 1 week each for 2 officers & manpower (FCLA). The cost includes lodging, boarding and travel.
2. Consumables: For chemicals, filters, glassware, plastic-wares, minor repairs, stationary, pen drive, hard disc etc
3. Instruments: Sieves, augers, corer or any material as required for the project etc
4. Data: Any hydro-meteorological, surface & sub-surface data
5. Field cum Lab Assistant: The person will be used for various works in the field such as for groundwater sampling for radiometric dating, soil coring, support in tritium-injection, raising soil cores, hydrologic data collection and, in laboratory for particle size analysis, soil moisture extraction, chemical analysis, tritium dating etc.

2. Title of the Project:	**INTEGRATED HYDROLOGICAL INVESTIGATIONS OF RENUKA LAKE, HIMACHAL PRADESH, FOR ITS CONSERVATION AND MANAGEMENT**
Project team:	SD Khobragade (PI), Sudhir Kumar, Hukam Singh, Rajiv Gupta, Vipin Agarwal, 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:	**1st July, 2020**
Date of Completion:	**30th June, 2023**
Budget:	**46.5 Lakh**

Statement of Problem:

Renuka lake, besides being the largest lake of Himachal Pradesh, is one of the most sacred lakes of northern India and a great tourist attraction for its picturesque location and biodiversity. 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.

The lake 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 Institute 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, 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

Present state-of-art

Only a handful of studies have been reported so far for the lake. Singh et al. (1987) reported the morphometric features of the lake. Chauhan (1993) studied the seasonal fluctuation of zooplanktons in Renuka lake. Julka and Mehta (2000) have provided details about the fauna of the lake. Das and Kaur (2001) studied the major ion chemistry and weathering processes of the lake. Mohan et al (2005) have discussed about the migratory birds of the lake. Das et al (2008) further analysed the geochemistry of the lake based on the analysis of the lake sediments. Preliminary hydrological analyses has been provided by Omkar (2009). Omkar Singh and Sharma (2012) studied the water quality and eutrophication of the lake and suggested that appropriate conservation and restoration measures are necessary for the lake. Sharma and Kumar (2015) reported the diversity of butterflies in and around Renuka Lake. The National Wetland Atlas provides some maps of the lake and its catchment prepared using the RS & GIS including vegetation cover of the lake. Thus, it is clear from the reported studies that no attempt has been made so far to systematically investigate the various hydrological processes of the lake, except for the preliminary investigations carried out earlier by NIH, Roorkee. As such, no long term conservation plan exists for the lake, although some generalized conservation measures have been suggested by some workers. Even the morphometric data as reported for the lake (Singh et al., 1987) is about three decades old.

Justification for the study

The government of India lays great emphasis on conservation of water bodies such as wetlands and lakes. The ministry of Environment and Forests runs a special scheme named National Plan for Conservation of Aquatic Eco-systems (NPCA) which aims at a holistic conservation and restoration of lakes and wetlands for achieving the desired water quality enhancement, and improvement in biodiversity and ecosystem through an integrated and multidisciplinary approach. The Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti, Govt. of India is also implementing the scheme of Repair, Renovation and Restoration (RRR) of water bodies which aims at improving catchment areas of the commands, increase in storage capacity, ground water recharge, increase availability of drinking water etc. The present proposal is very much in line with the policy of the government to conserve the lakes and wetlands. The present study aims to understand the hydrological regime of the lake by investigating the various hydrological processes. In this way, the study is not only different from the earlier work but it is also a pioneering study as far as hydrological aspects of the lake are concerned. The conservation plan to be developed under the study is to be based on sound research and as such, is expected to go a long way in conserving the Renuka lake, which is one of the important lakes of the state of Himachal Pradesh.

Methodology

For detailed hydrological investigations following methodology would be employed:

(i) Collection, processing and analysis of the available data
(ii) Generation of additional required data.
(iii) Field investigations and field surveys
(iv) Sample collection and laboratory analysis

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. Morphometric 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.

Research outcome/Deliverable from the project

i) Comprehensive Project Report including all data, maps, information, analysis and results. The report would also contain specific recommendations/ conservation plan for the conservation and management of the lake based on the analysis carried out.
ii) Research Publications
iii) Training Workshop for Concerned state government officials

Beneficiary/End User

The specific recommendation for conservation and management of the lake and the conservation plan would be used by the State Council for Science Technology & Environment, Shimla, Himachal Pradesh, who own the Renuka Lake, for development and conservation of the lake. Since the lake is of great religious significance, besides being a tourist attraction and biodiversity hotspot, its conservation shall be of immense value for the society in general.

Budget: 46.5 Lakh

The details of the budget are as follows:

S.N.	Budget Head	Amount Rs (lakh)
1	Remuneration/Emoluments for JRF @31000+HRA for 30 months	11.5
	Remuneration/Emoluments for other staff (Highly skilled worker/field assistants) for 30 months	6.0
2	Travelling Expenditure(about 10 visits)	5.0
3	Infrastructure/Instruments	10.0
4	Experimental Charges/Field Work/Consumables	7.0
5	Capacity building/Technology Transfer	2.0
6	Contingency	5.0
Total		**46.5**

Work Plan/Activity Chart:

As given in activity schedule below:

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 & identification of various sampling locations	√											
1.2	Collection & Review of all available data/information	√	√										
1.3	Compilation of existing data/information& Identification of Data Gaps	√	√	√									
1.4	Procurement of required instruments and peripherals	√	√	√									
1.6	Procurement of meteorological Data	√	√	√									
1.7	Installation of equipment in field	√	√										
1.8	Preparation of basic maps of lake and catchment	√	√										
1.9	Installation of piezometers		√	√									
1.10	Arrangement for discharge measurement		√	√									
2.0	**FIELD WORK**												
2.1	Generation of hydro-meteorological		√	√	√	√	√	√	√	√			
2.2	Collection of water samples for water quality and isotope analysis		√	√	√	√	√	√	√	√			
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 water and groundwater levels		√	√	√	√	√	√	√	√			
3.0	**LABORATORY ANALYSIS**												
3.1	Analysis of samples for Water Quality and isotopes		√	√	√	√	√	√	√	√			
3.2	Analysis of sediment samples					√	√						
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 and submission of chapter on Physical & Morphometric Characterization and Morphology of Lake catchment to NIH by HPSCCC						√	√	√				
5.2	Preparation and submission of chapter on Water Quality to NIH by HPSCCC for Project Report								√	√	√		
5.3	Preparation of Interim Project Report				√				√				
5.4	Preparation of Final Project Report												√
6.0	**ORGANIZATION OF TRAINING WORKSHOP**	Post-Project											

SURFACE WATER HYDROLOGY DIVISION

Scientific Manpower

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

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जल विज्ञान संस्थान
आपो हिष्ठा मयोभुवः

Recommended Work Program for the Year 2020-21

ONGOING STUDIES (SPONSORED)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
1.NIH/SWH D/16-21	Hydrological modeling in Alaknanda basin and assessment of climate change impact (NMSHE)	A.K.Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakanthan L.N. Thakural	5 years (April 2016 to March 2021)
2.NIH/SWH D/19-20	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	15 months (Oct. 2019 to Dec. 2020)

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
4.NIH/SWH D/17-21	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)	Sanjay Kumar Rakesh Kumar J.P. Patra Pankaj Mani	4 years (April 2017 to March 2021)
5.NIH/SWHD /18-20	Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin	Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu	2 years (Nov. 2018 to October 2020) Extended up to March 31, 2021)
6.NIH/SWH D/15-19	Study of Hydrological Changes in selected Watersheds in view of Climate Change in India	L.N. Thakural D.S. Rathore Surjeet Singh Sanjay K. Jain Sharad K. Jain	4 years (April 2015 to March 2019) Extended up to Dec., 2020
7.NIH/SWH D/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)
8.NIH/SWH D/18-21	Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent	Sunil Gurrapu Ashwini Ranade J.P. Patra	3 years (Nov 2018 to October 2021)
9.NIH/SWH D/18-20	Evaluation of water quality of Government schools in Roorkee block, District Haridwar	N.K. Bhatnagar M.K. Sharma L.N. thakural Reena Rathore	2 years (Oct 2018 to sept. 2020)

NEW STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
10.NIH/SWH D/20-21	Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Lower Narmada & Tapi subzone-3b, (2) Lower Godavari subzone-3f	S.K. Singh	One year (April 2020 to March 2021)
11.NIH/SWH D/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 (Aug 2020 to Jul 2022

PROJECT REFERENCE CODE: NIH/SWHD/16-21

1. Hydrological modeling in Alaknanda basin and assessment of climate change impact (NMSHE)

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

5. Brief Methodology/Work Plan etc:

Brief Methodology

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

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

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

6. Salient Research Achievements (summary of progress):

Variable Infiltration Capacity Model (VIC) and WinSRM models are being 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. The preliminary results of the VIC model are presented in Figure 1.

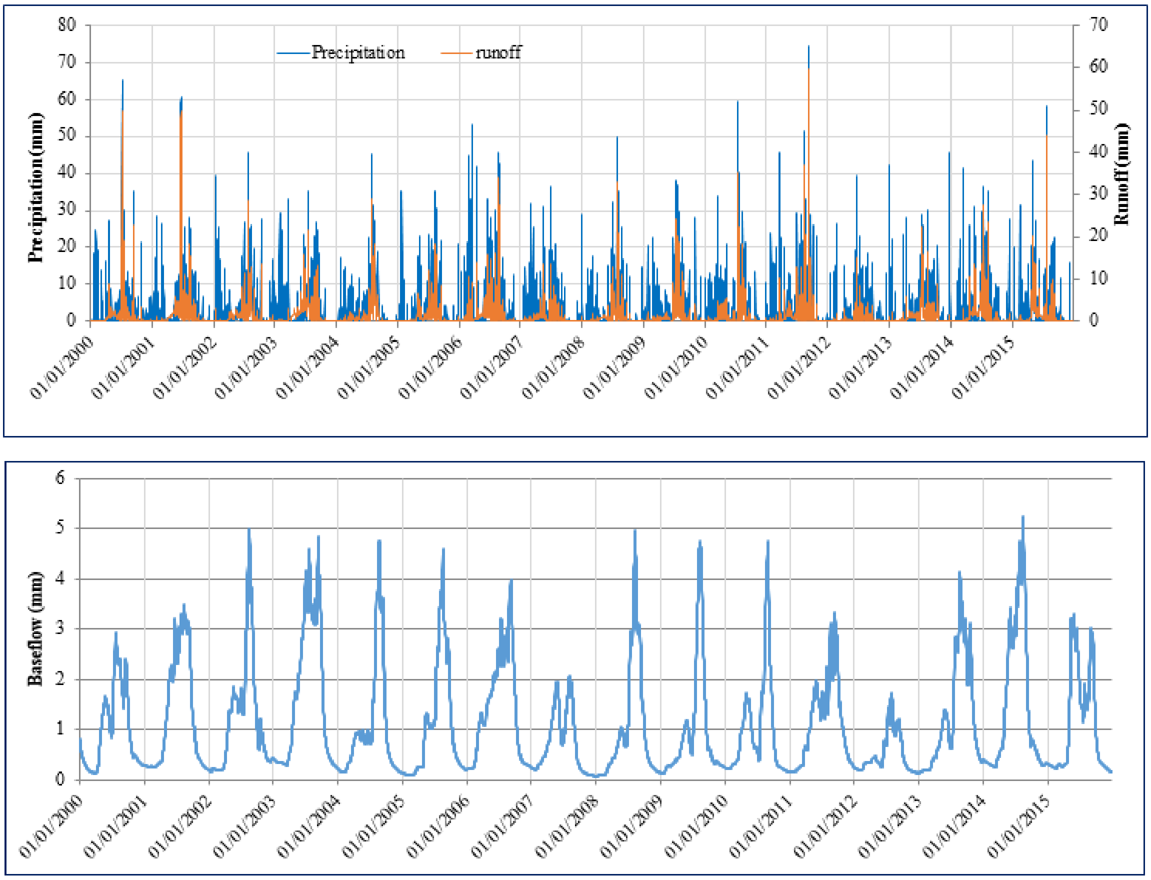


Figure 1: VIC Model results

PROJECT REFERENCE CODE: NIH/SWHD/19-20

2. Rainfall-Runoff Modelling of Selected Basin based on LULC pattern and development of Correlation

Study Group
NIH: A.K. Lohani, R.K. Jaiswal, Sushant Jain,
WRD Rajasthan: Sanjay Agarwal, Shailendra Kumar

Sponsored Agency: NHP

Project Duration: Oct 2019-Dec 2020.

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.

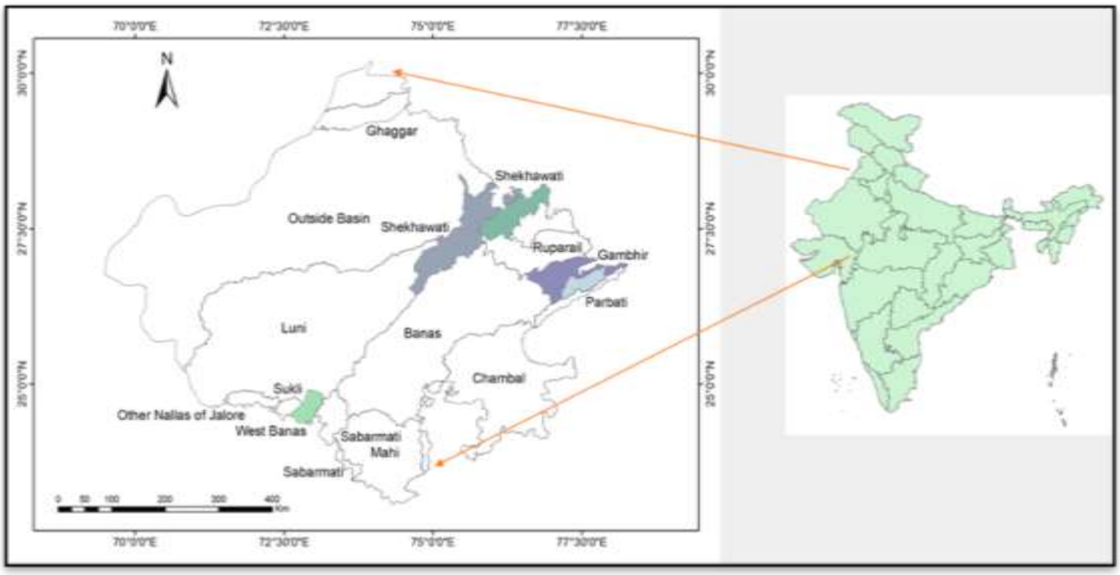
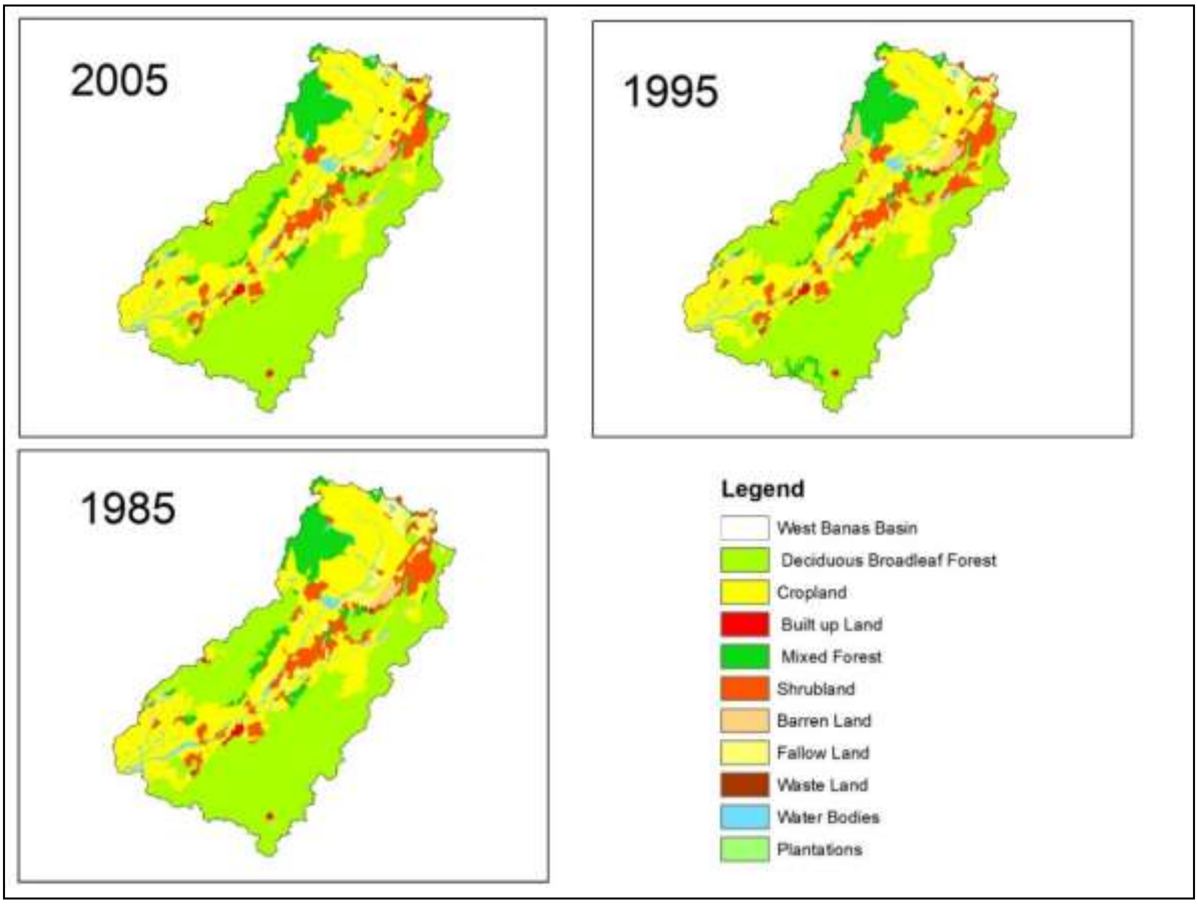


Figure 4 Selected Basin for the study



PROJECT REFERENCE CODE: NIH/SWHD/17-20

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

1. **Title of the study:** Development of regional methods for design flood estimation in Uttarakhand.
2. **Study group:** J. P. Patra, Sc. 'C'; Rakesh Kumar, Sc. 'G' & Head, Pankaj Mani, Sc. 'E', CFMS, Patna; Sanjay Kumar, Sc 'E'

   Technical assistance: T. R. Sapra, RA.
3. **Duration of study:** 3 Years (April 2017 to March 2020) : Completed
4. **Type of study:** Internal.
5. **Location map**

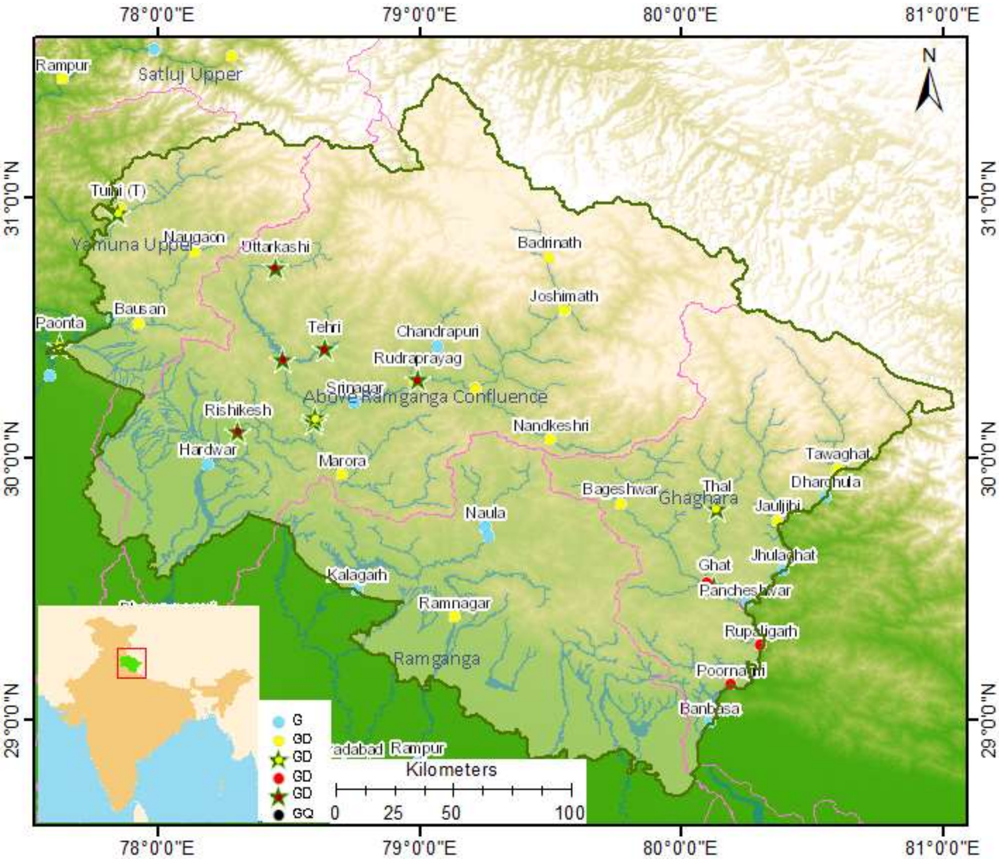


Fig. 1: Location map of study area.

6. **Study objectives:**
   a) Development of at-site flood frequency relationships using L-moments.
   b) Development of at-site and regional flood frequency relationships using L-moments.
   c) Development of regional relationships between mean annual peak floods and physiographic and climatic characteristics.
   d) Development of at-site rainfall frequency relationships using L-moments using point rainfall data.
   e) Development of at-site and regional rainfall frequency relationships using L-moments using gridded rainfall data of various sources.

f) Development of regional relationships for the Nash, Clark IUH model parameters and GIUH-based flood estimation.

g) Estimation of floods of various return periods for Ganga basin in Uttarakhand.

h) Development of flood frequency relationships under climate change scenarios.

7. Statement of the problem

The commonly used design floods estimation approaches can be categorized as: flood formulae, flood frequency analysis and hydrometeorological approach (CWC, 2010). Various empirical flood formulae have been developed for regions. These include Dicken's, Ryve's, Nawab Jung Bahadur, W P Creager's, Jarvis f, Modified Myer's etc. When long term and short term rainfall and runoff records are not available the design flood is obtained using these formulae. However, the value obtained from these can only be used for preliminary estimates for small catchments and the concept of return period flood is generally not included in this approach. The flood frequency approach can be adopted in case data of peak floods series are available for a longer period of time. In, Indian generally Gumbel or Generalized Extreme Value (GEV) distributions are fitted to the peak flood series without considering other available frequency distributions. Flood estimation reports for various sub zones have been prepared with joint efforts of Central Water Commission (CWC), India Meteorological Department (IMD) and Research Design and Standards Organisation (RDSO) of Ministry of Railways and Ministry of Surface Transport (MOST) for estimating design floods of 25, 50 and 100 year return periods for design of waterways, bridge, culverts etc having small and medium catchments where hydrological data are inadequate or totally absent. Recently, PMP atlas for various basins of India has been developed by CWC and IMD for assessment of design storm as required in the assessment of design flood for any water resources development project. The point rainfall at various raingauge stations are analysed and rainfall of various return periods have been estimated by fitting a two parameter Gumbel frequency distribution. Various new techniques of flood frequency analysis are being developed by various researchers for selecting candidate frequency distribution, parameter estimation etc. (L-Moments, PWM etc.). There is a need to use better parameter estimation technique for estimation of parameter of candidate distribution.

In India for many catchments, streamflow data are not available or the data are inadequate at the site of interest. In such cases the methods of frequency analysis using data from a single site have limited applicability because of large sampling errors, and as a result, regional flood frequency analysis is performed. The various commonly used methods of regional flood frequency analysis are: USGS method, Pooled curve method, analytical method and L-moments approach. Hosking and Wallis (1997) presented the L-Moments based regional frequency analysis approach. The authors mention that regional flood frequency analysis resolves the problem of short data records or unavailability of data by "trading space for time"; as the data from several sites are used in estimating flood frequencies at any site. Kumar et al. (2003, 2005, 2015) applied L-moments approach for development of regional flood frequency relationships for some of the regions of India. Komi et al. (2006) carried out regional frequency analysis based on L-moments and identified three homogeneous based on cluster analysis and a homogeneity test. Finally, regression models of the mean annual flood with the size of the drainage area, mean basin slope and mean annual rainfall are proposed to enable flood frequency estimation of ungauged sites within the basin. Design flood estimates in the United Kingdom are routinely obtained by using the improved Flood Estimation Handbook (FEH) statistical procedure (Kjeldsen, 2015). The author assessed uncertainty of design flood estimates at ungauged catchments for a range of return periods. The results show that the inclusion of data from nearby gauged catchments increases the reliability of the estimates when compared to an automated application of the improved FEH methods relying on catchment descriptors only. Analysis of 190 storm events in seventeen small Northern Ireland catchments, along lines developed by the UK Institute of Hydrology, shows that the time-to-peak of the instantaneous unit hydrograph can be estimated from catchment characteristics and from the time between the centroid of mass of a flood-producing rainfall event and of the resulting peak flow, but that equations calibrated on British data overestimate the time-to-peak (Gardner and Wilcock, 2003). This might be due to the distinctive hydrology of Northern Ireland. Kumar et al. (2007) developed geomorphological instantaneous unit hydrograph (GIUH) based Clark and Nash models and applied for simulation of the direct surface run-off (DSRO) hydrographs for ten rainfall-runoff events of the Ajay catchment up to the Sarath gauging site of eastern India. The GIUH is derived from the geomorphological characteristics of a catchment and it is related to the parameters of the Clark instantaneous unit hydrograph (IUH) model as well as the Nash IUH model for deriving its complete shape. Inter comparison of the performances of the GIUH based Clark and Nash models shows that the DSRO hydrographs are estimated with comparable accuracy by both the models.

Over the year, efforts have been made toward regionalisation of catchment model parameters of various complexity and scale (Seibert, 2009; Merz and Blöschl, 2004; Littlewood, 2004; Heuvelmans et al., 2006; Bastola et al., 2008; Bárdossy and Singh, 2011; Beck et al, 2016). A comparison of regionalisation methods for catchment model parameters is provided by Parajka et al., (2005). Hydrologic model parameters obtained from regional regression equations are subject to uncertainty. Consequently, hydrologic model outputs based on the stochastic parameters are random. The uncertainty associated with linear reservoirs (N) and storage coefficient (K) of Nash's IUH are assessed by various researchers. The uncertainty from regional regression equations is some time too significant to be ignored (Yeh et al., 1997). The assumption of the parameter K having the same value in all reservoirs is obviously unphysical as it results in the estimated value of N not being integral (Li, et al. 2008). Seong et al. (2007) proposed a practical approach to determining a regionalized Clark instantaneous unit hydrograph (IUH) model in limited data availability condition. The proposed model is described in terms of the synthetic time–area concentration curve, the concentration time, and a special regional similarity value that is valid in the whole basin. By introducing the regional similarity value into a Clark IUH, a statistically best estimate of IUH for given data conditions and its quantified degree of uncertainty were realized. Application of the model to Wi River basin in Korea showed a reliable estimation of hydrograph within the study area even with limited data availability. Considerable work has been done to estimate flood characteristics and long-term mean annual flow using regression relationships with catchment parameters in Indian, but most of these methods were developed a long time ago and may need to be revisited Jha and Smakhtin (2008). Goel (1998) presented the details of flood estimation procedures for Indian catchments in general and for mountainous watersheds in particular

8. Approved action plan and timeline

S.N.	Work Element	1st Year				2nd Year				3rd Year			
1	Collection of hydro meteorological data, satellite images, thematic maps etc.												
2	Compilation, statistical analysis of rainfall and river discharge												
3	At-site frequency analysis for point rainfall and gridded rainfall data												

S.N.	Work Element	1st Year				2nd Year				3rd Year			
4	Regional frequency analysis for point rainfall and gridded rainfall data												
5	Preparation of isopluvials maps for various return periods.												
6	At-site and regional flood frequency analysis for gauged catchments												
7	Estimation of catchment characteristics and parameters of UH												
8	Development of regional relationships for peak floods with catchment characteristics.												
9	Rainfall frequency relationships under climate change scenarios												
10	Report												

9. Role of team members

S. N.	Role / Action	Member/(s)
1	Collection of hydro meteorological data, satellite images, thematic maps etc.	JPP, RK, SK, TRS
2	Compilation, statistical analysis of rainfall and river discharge	JPP, SK , TRS
3	At-site frequency analysis for point rainfall and gridded rainfall data	JPP, RK
4	Regional frequency analysis for point rainfall and gridded rainfall data	RK, JPP, SK
5	Preparation of isopluvials maps for various return periods.	JPP, RK ,PM
6	At-site and regional flood frequency analysis for gauged catchments	RK, JPP,SK
7	Estimation of catchment characteristics and parameters of UH	PM, JPP, SK
8	Development of regional relationships for peak floods with catchment characteristics.	RK ,JPP,SK
9	Rainfall frequency relationships under climate change scenarios	RK ,JPP,SK
10	Report	JPP, RK, PM, SK

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

10. Brief Methodology

This study aims at development of at-site and regional flood frequency relationships using L-moments approach for Uttarakhand state (Figure 1), perticularlly in Ganga basin up to Rishikesh. For estimation of T-year return period flood at a site, the estimate for mean annual peak flood is required. For gauged catchments, such estimates can be obtained based on the at-site mean of the annual maximum peak flood data. At-site and regional flood frequency analysis will be performed using the L-Moments approach, which includes various frequency distributions: viz. Extreme value (EV1), Generalized extreme value (GEV), Logistic (LOS), Generalized logistic (GLO), Normal (NOR), Generalized normal (GNO), Uniform (UNF), Pearson Type-III (PE3), Exponential (EXP), Generalized Pareto (GPA), Kappa (KAP), and five parameter Wakeby (WAK). Screening of the data, testing of regional homogeneity and identification of distribution will be carried out. However, for ungauged catchments at-site mean cannot be computed in absence of the flow data and in such a situation, a regional relationship between the mean annual peak flood of gauged catchments in the region and their pertinent physiographic and climatic characteristics is needed for estimation of the mean annual peak flood. For example, the form of this regional relationship may be:

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

Here, ($\overline{Q}$) is the mean annual peak flood, A is the catchment area, S is the slope, D is the drainage density, R is the annual normal rainfall or rainfall for the duration of annual maximum peak flood for the catchment etc., a, b, c, d, and e are the regional coefficients. Further, relationship of various other characteristics like length of main stream (L), centroidal longest flow path (L_c) etc. with peak flood will also be evaluated. The regional coefficients will be estimated using the mean annual peak floods of the gauged catchments and their pertinent physiographic and climatic characteristics for a region. The physiographic and climatic characteristics which are considered pertinent for generation of annual maximum peak floods from a catchment and can be obtained from the observed records e.g. rainfall for the duration of occurrence of the annual maximum peak floods and derived from the toposheets/maps of the gauged catchments may be considered for development of this relationship. The lengths of historical data records are very less, particularly in hilly areas. Considering this aspect frequency analysis using L-moments will be carried out using gridded rainfall data of various sources (IMD, APHRODITE) and will be compared. Regional Nash and Clark IUH models will be developed for Uttarakhand. Floods of various return periods for selected locations of Ganga basin in Uttarakhand will be estimated. This study will also investigate the consequences of using a stationary assumption as well as the alternative: a non-stationary framework that considers temporal changes in statistics of extremes base on characteristic of time series. The estimates for various return periods using non-stationary i.e. General Extreme Value distribution with time-dependent parameters will be analysed. In addition, it is planned to analyse an ensemble of reference periods (past and future events) for rainfall frequency analysis.

11. Results achieved with progress/present status

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

The annual maximum discharge series are also being analysed for both Stationary and Nonstationary Extreme Value Analysis. The sample results at Rudraprayag gauging site in of Alaknanda River is shown in Figure 6. It is observed that there is a significant increasing trend in the annual maximum discharge (with or without consideration of 2013 event). Various combinations of time dependant EV1 and GEV parameters (location and scale) are estimated using Maximum Likelihood Method. The EV1 distribution with linear time dependant location parameter is select to be best model based on lower Akaike Information Criterion (AIC). The design flood corresponding to year 2050 and 2100 are estimated based using the fitted non-stationary EV1 distribution. The design flood for 25, 50, 75 and 100 year return period flood estimated using stationary assumption would become about 7, 13, 20 and 26 year return period in the year 2050 considering non-stationary. Further, in year 2100 the corresponding return periods are estimated to be 2, 3, 5 and 7 year respectively. However, it is to be noted that the 100 year return period flood estimated using L-moments approach (GLO as robust distribution) is 6030.4 m^3/s in comparison to 5937.7 m^3/s estimated in year 2100 using non-stationary EV1 distribution. The results shows that along with non-stationarity various other aspects like selection of parameter estimation method, goodness of fit criteria, uncertainty of parameter estimations, covariates etc. should be studied while estimating design flood in respect to design life of the structure. The impact of regulation due to construction of Tehri reservoir was also analysed (Fig. 7) by non-stationary flood frequency analysis using climate and reservoir indices as external covariates. How eve in this case the the impact was not significant and Stationary (GEV) is found to be best suited.

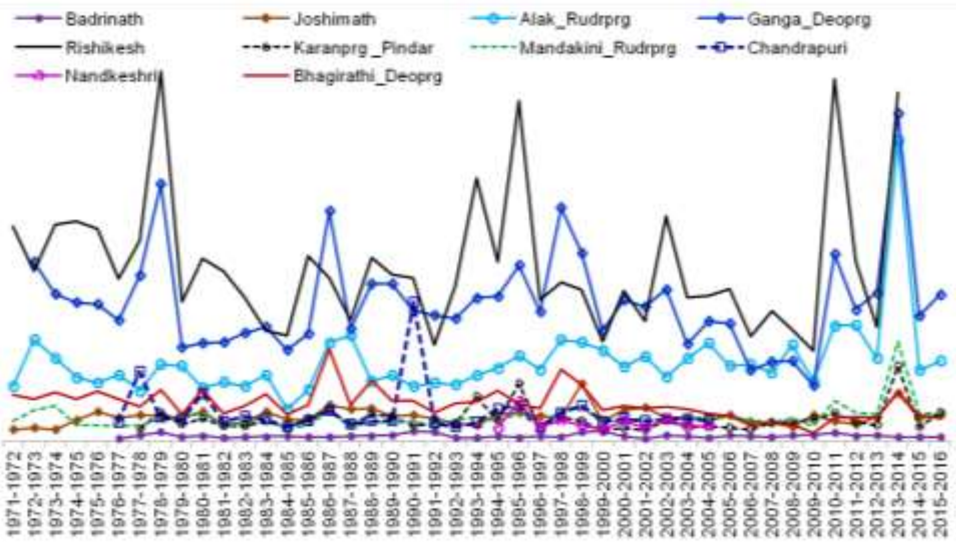
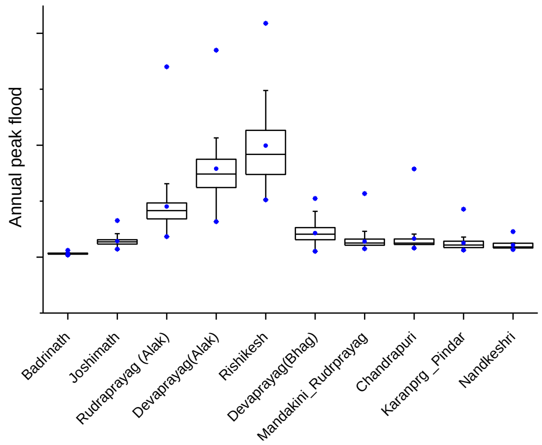


Fig. 2: Observed annual maximum flood series.



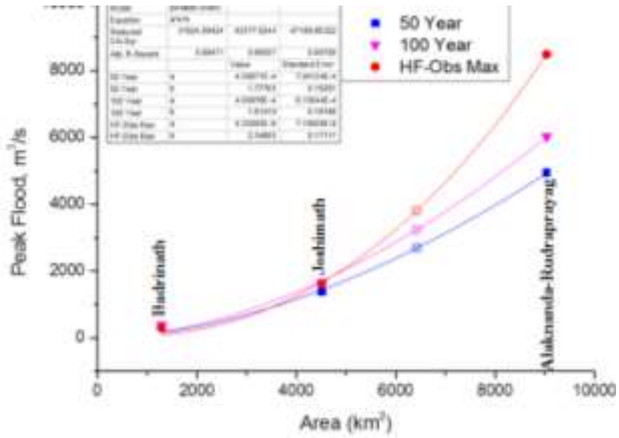


Fig. 3: Box plot of annual peak flood

Fig. 4: Floods of various return periods

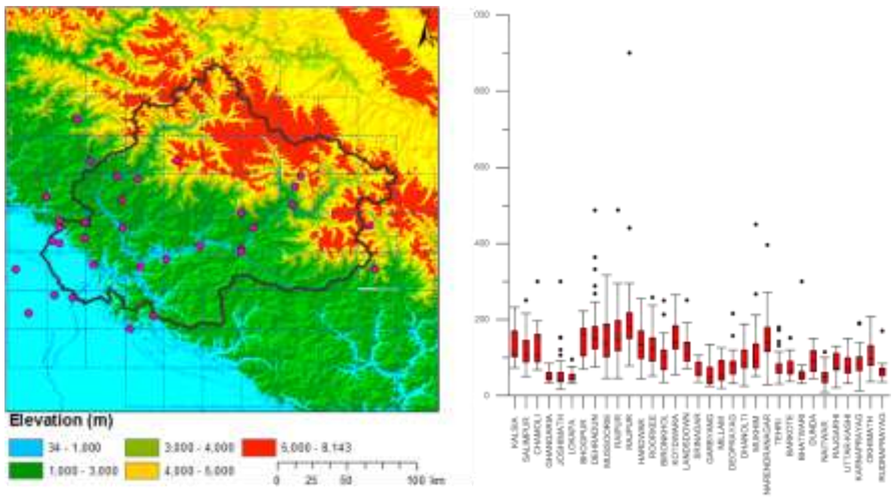


Fig. 5: Location of raingauge stations and 1 day annual maximum rainfall

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

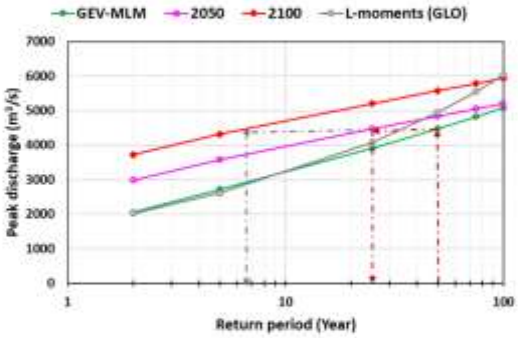


Fig. 6: Nonstationary Extreme Value Analysis using at Rudraprayag

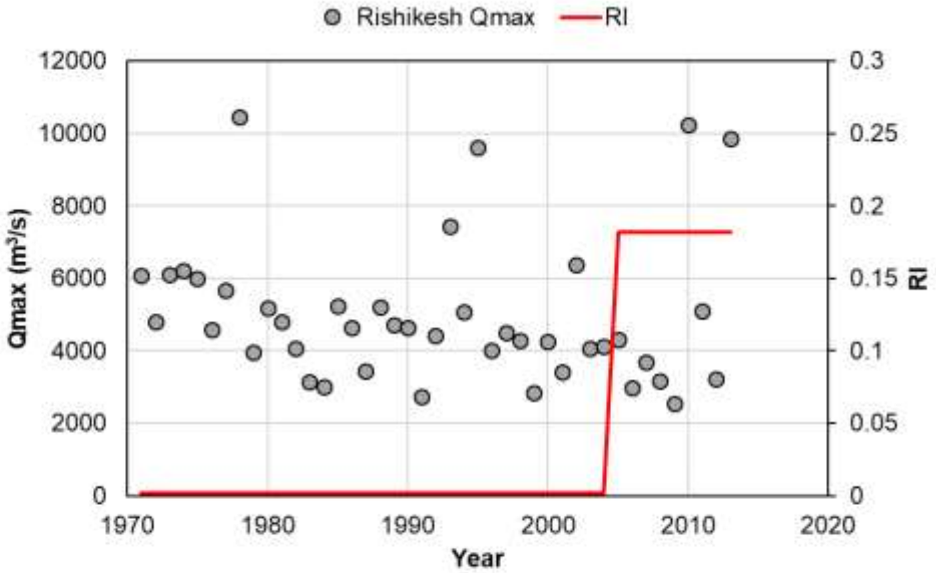


Fig. 7: Reservoir indices and maximum flood at Rishikesh

12. Action taken on comments of previous working group meeting

There were no specific comments.

13. List of deliverables

- Design floods of various return periods at river gauging locations.
- Development of relationships between mean peak floods of various return periods with catchment characteristics.
- Research papers and reports.

14. Data collected/generated

- ♦ DEM of the study area is 90 m SRTM and 30 m CartoSat.
- ♦ Peak annual maximum flood series for ten gauging sites.
- ♦ 0.25 x 0.25 deg grided daily rainfall data from 1901 to 2013 from IMD

15. Involvement of end users/beneficiaries

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

PROJECT REFERENCE CODE: NIH/SWHD/17-21

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

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

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

3. Location Map:

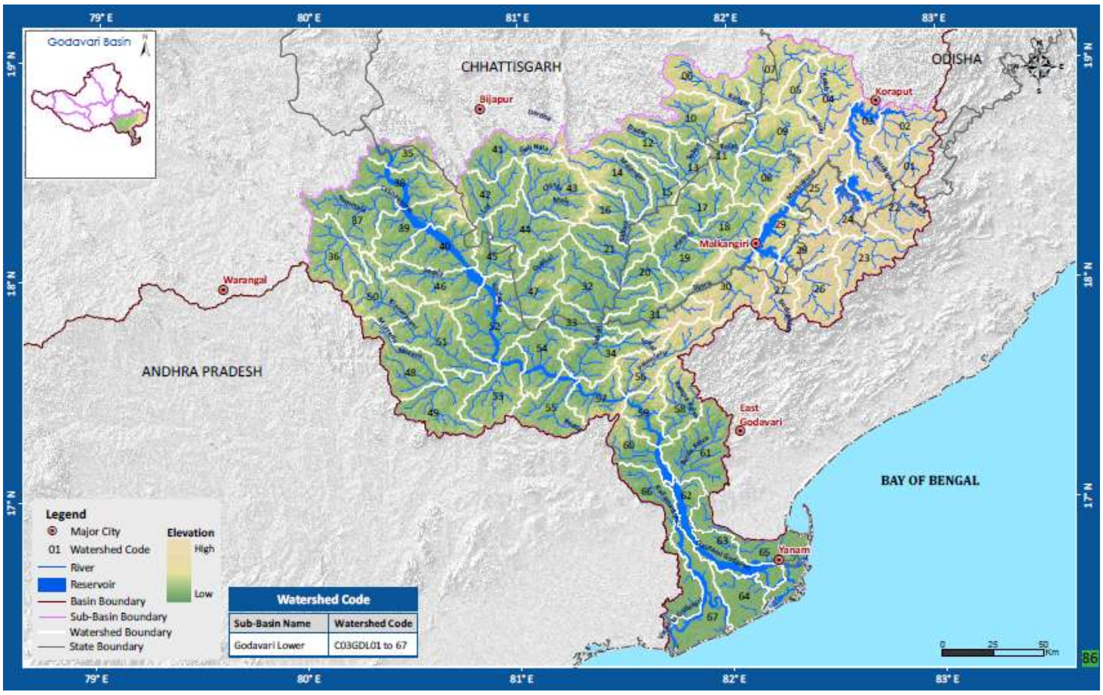


Fig 1: Location Map of the study Area

4. Objectives of the study:

The objectives of the study are:

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

5. Statement of the problem:

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

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

6. Methodology:

For estimation of T-year return period flood at a site, the estimate for mean annual peak flood is required. For gauged catchments, such estimates can be obtained based on the at-site mean of the annual maximum peak flood data. At-site and regional flood frequency analysis will be performed using the L-Moments approach, which includes various frequency distributions: viz. Extreme value (EV1), Generalized extreme value (GEV), Logistic (LOS), Generalized logistic (GLO), Normal (NOR), Generalized normal (GNO), Uniform (UNF), Pearson Type-III (PE3), Exponential (EXP), Generalized Pareto (GPA), Kappa (KAP), and five parameter Wakeby (WAK). Screening of the data, testing of regional homogeneity and identification of distribution will be carried out.

However, for ungauged catchments at-site mean cannot be computed in absence of the flow data and in such a situation, a regional relationship between the mean annual peak flood of gauged catchments in the region and their pertinent physiographic and climatic characteristics is needed for estimation of the mean annual peak flood. For example, the form of this regional relationship may be:

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

Here, ($\overline{Q}$) is the mean annual peak flood, A is the catchment area, S is the slope, D is the drainage density, R is the annual normal rainfall or rainfall for the duration of annual maximum peak flood for the catchment etc., a, b, c, d, and e are the regional coefficients. Further, relationship of various other characteristics like length of main stream (L), centroidal longest flow path (L_c) etc. with peak flood will also be evaluated. The regional coefficients will be estimated using the mean annual peak floods of the gauged catchments and their pertinent physiographic and climatic characteristics for a region. The physiographic and climatic characteristics which are considered pertinent for generation of annual maximum peak floods from a catchment and can be obtained from the observed records e.g. rainfall for the duration of occurrence of the annual maximum peak floods and derived from the toposheets/maps of the gauged catchments may be considered for development of this relationship. Downscaled climate change projections would also be used for evaluation of impact on flood estimates.

6 Deliverables

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

7 Progress

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

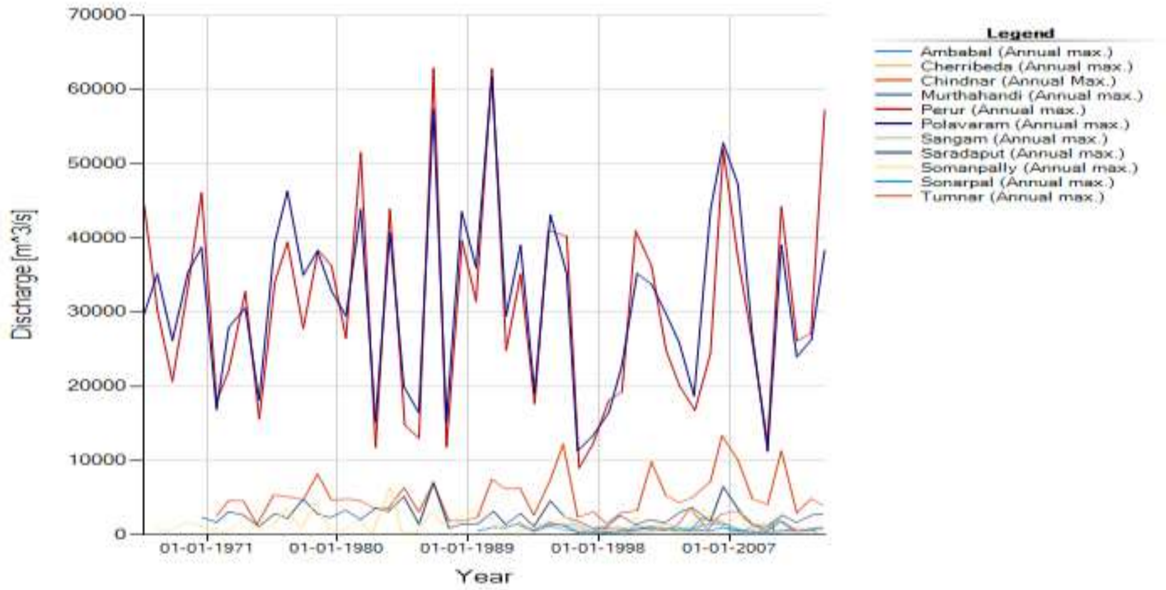


Fig 2: Observed Annual Maximum Flood Series

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

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

Table2: Parameter of GEV distribution for various sites

Site Name	Parameter of GEV Distribution		
	Location	Scale	Shape
Ambabal (Annual max.)	536.06	246.71	-0.344
Cherribeda (Annual max.)	507.58	457.7	-0.145
Chindnar (Annual Max.)	3780.31	1982.05	-0.112
Murthahandi (Annual max.)	535.26	260.73	-0.201
Perur (Annual max.)	24683.54	12577.64	-0.112

Polavaram (Annual max.)	26916.11	11795.6	0.228
Sangam (Annual max.)	213.03	100.08	-0.34
Saradaput (Annual max.)	1885.09	944.88	-0.115
Somanpally (Annual max.)	835.04	784.17	-0.22
Sonarpal (Annual max.)	567.41	335.97	-0.018
Tumnar (Annual max.)	865.21	524.59	-0.227

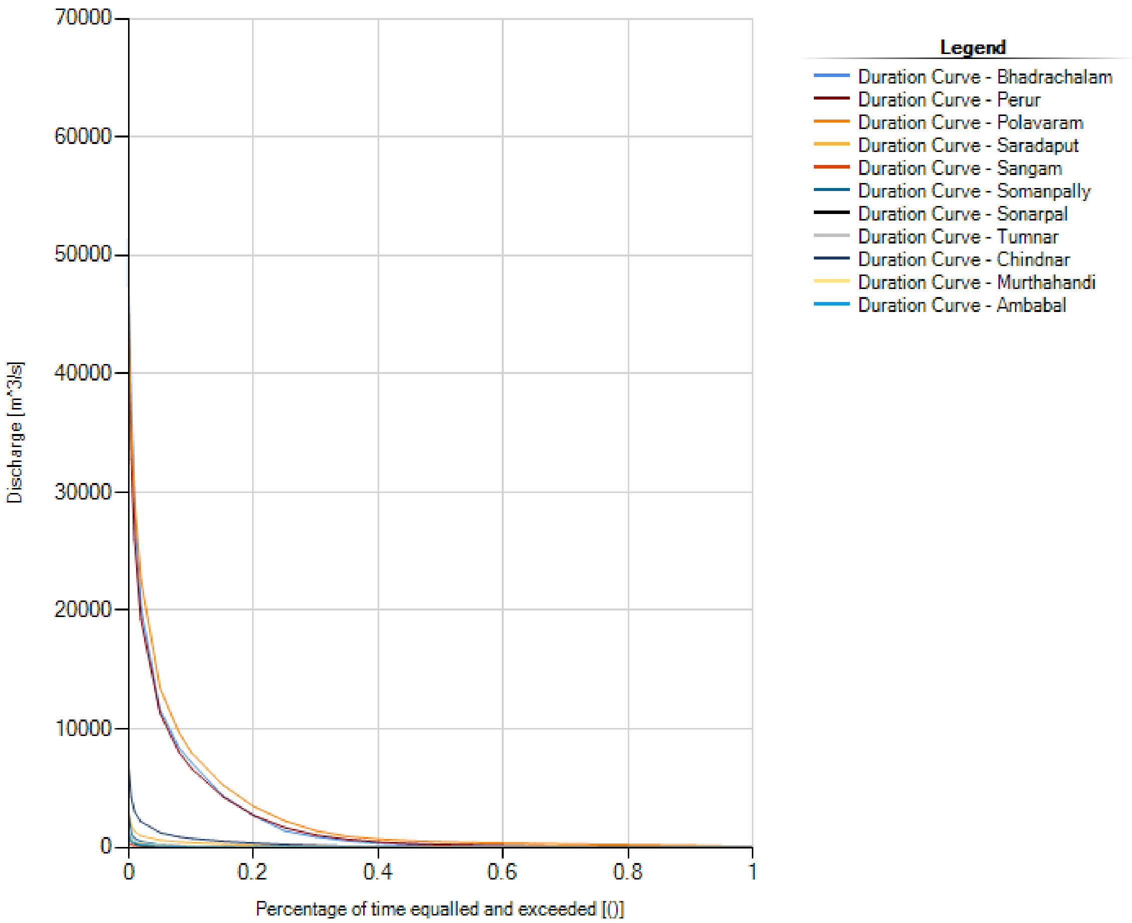


Fig: Flow duration curves at various sites

PROJECT REFERENCE CODE: NIH/SWHD/18-20

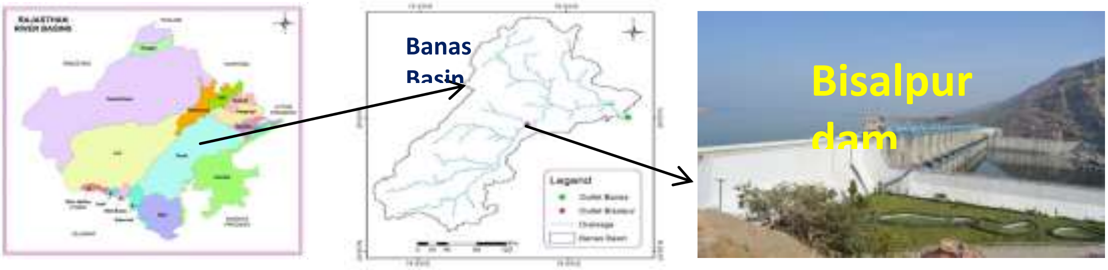
5. Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin

Study Team:

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

Type of Study: Internal
Date of Start: 1 Nov. 2018
Scheduled date of completion:
31 Oct. 2020 (old) 31, Oct. 2021 (new)
Extension sought for one year (upto 31 Oct, 2021)

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



River Banas is located in east-central part of Rajasthan State in India. It originates in the Khamnor hills of the Aravali range and flows in Rajasthan. Banas is a major tributary of the River Chambal, which is again a tributary of River Ganga. The total catchment area is about 51,779 km2 with a length of about 512 km. The Banas River passes through the 13districts namely, Sawai Madhopur, Jaipur, Ajmer, Tonk, Rajsamand, Banswara, Chittaurgarh, Udaipur, Bhilwara, Dausa, Sikar, Nagaur and Karauli. The Banas Basin may be classified as tropical grassy plains, semi-arid and hot, on the basis of Koppen's classification of climatic patterns. Orographically, the western part of the Basin is marked by hilly terrain belonging to the Aravali chain. East of the hills lies an alluvial plain with a gentle eastward slope. Ground elevations in the western hilly part range approximately 900 meters, while the alluvial plain elevations range approximately from 650 meters. The mean annual rainfall over Banas Basin is around 585 mm of which about 95% falls during the four Monsoon months (June-September). The average temperature in the basin varies from 19°C to 33°C with the maximum going above 45°C during summers.

Study Objectives:

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

Statement of the problem
The Banas River Basin is the largest river basin (45833 km^2) within the Rajasthan State of India. Banas is a seasonal river that dries up during the summer, but it is nonetheless used for irrigation. Bisalpur drinking water cum irrigation project is constructed across river Banas in 1991 with an ultimate irrigation potential of 55224 hectare (irrigation during the months of October to

March for the Rabi crop), besides providing 458.36 million m^3 of drinking water for Jaipur, Ajmer, Beawar, Kishangarh, Nasirabad and other enroute cities, towns and villages. An estimated 150 million USD of extra agriculture was produced in 2014-2015. An increase in temperature in this region has been observed from historical data. This may lead to shortening of the crop growth period, increase in crop water requirement and reduction in crop yield. The water availability in this reservoir in coming years will play a crucial role in the overall economy of the entire region including other socio-economic issues.

Approved Action plan and timeline

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

Progress

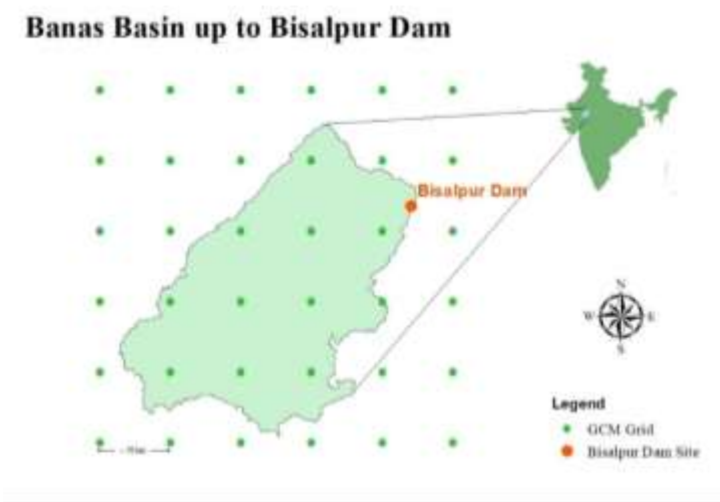
Objectives	**Achievements**
Oct 2019- May 2020	
Collection of information and Hydro-meteorological data from field, Preparation of base maps	Continued
Trend analysis of observed historical data	Completed
Downloading and bias correction of GCM data	Completed
Input data preparation for Rainfall runoff model	Initiated

Analysis and Results

Data Used

Essential climate variables of 16 GCMs (Table below) at 0.5 degrees grid (Figure below) have been extracted from the Climate data store of COPERNICUS. These ECVs are available on a daily time interval for a period up to year 2100 for two climate change scenarios, i.e., RCP4.5 and RCP 8.5.

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, rcp8.5	2.0225	2.5
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



Results

Python scripts have been written for extraction of the data available in NetCDF to CSV format. The extracted data has been downscaled for the Banas catchment. R scripts have been written for bias correction. Daily rainfall data of 19 raingauge stations for a period of 30 years similar to the historical data of GCM data has been processed and it has been used for downscaling/bias correction of the precipitation data from various GCM. Similarly, daily gridded temperature data of IMD at $1^{o}X1^{o}$ of 30 years (1986-2015) for the Banas River basin has been processed for downscaling of Temperature data from GCM.

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

Expected Adopters

Water Resources Department, Agriculture Department, Govt of Rajasthan.

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

Deliverables

Research papers, report, stakeholder engagement

Data Procured and/Generated during the Study

Daily rainfall data of 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.

Future Plan

As per the approved/proposed action plan.

6. Study of Hydrological Changes in selected Watersheds in view of Climate Change in India

PROJECT REFERENCE CODE: NIH/SWHD/15-19

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

2. Project team:

a. Project Investigator	Dr**.** L. N. Thakural, Sc-D, PI
b. Co-PI Project Co-Investigator(s)	Er. D. S. Rathore, Sc-F Dr. Surjeet Singh, Sc-F Mr. Tanvear Ahmad¸ Sc-B Dr. Sanjay Kumar Jain, Sc-G Dr. Sharad Kumar Jain, Sc-G

3. Objectives-

- Development of database related to hydro-meteorological data.
- Long-term spatio-temporal analysis of hydro-meteorological variables.
- Assessment of variation in surface water and groundwater availability.
- Spatial variation of Ground water levels.
- Drought characterization.
- Climate change scenarios/analysis.
- Inter-comparison of water resources variability in selected basins and suggestions for IWRM.

4. Present state-of-art

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

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

5. Methodology-

- Literature survey on the guidelines and pre-requisites for the selection of watersheds.
- GIS database development.
- Field visits for ground truth and data collection of exiting hydro-meteorological and groundwater related data and processing of data.
- Spatio-temporal analysis of hydro-meteorological data using parametric and non-parametric approaches.
- Application of lumped conceptual rainfall-runoff model (NAM) for assessment of surface and ground water availability.
- Computation of SPI, hydrological drought indices, analysis of change in rainy days.
- Downscaling of meteorological data, generation of climatic scenarios based on IPCC-SRES using actual data
- Impact of climate change on streamflow using statistically downscaled data for each catchment
- Inter-comparison of watersheds and suggestion for irrigation water management.

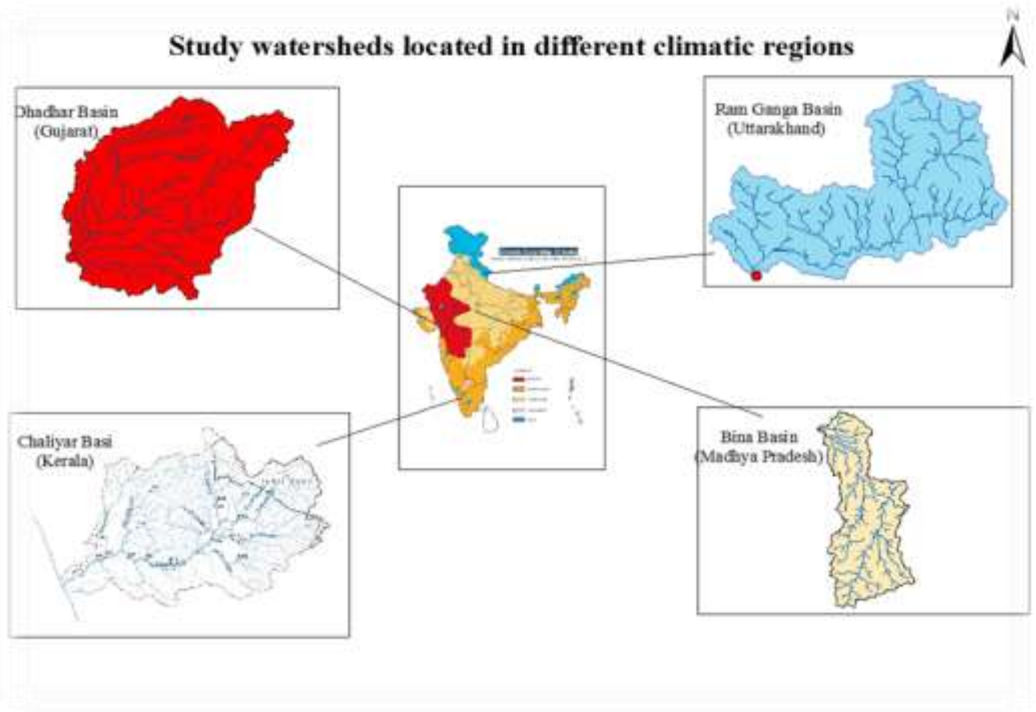
6. Research outcome from the project

The outcome of the study will help in assessment of water resources availability and impact of climate change at basin scale.

7. Progress of Work

Four different watersheds located in different climatic regions namely Dhadhar river basin (Gujarat), Ramganga up to Kalagarh (Uttarakhand), Bina River basin (M.P) and Chaliyar river basin (Kerala) as shown in Figure 1. have been selected for the present study. The hydro-meteorological data pertaining to the four river basins namely Ramganga, Bina, Chaliyar and Dhadhar have been processed to meet out different objectives of the study. The various inputs for the hydrological model such as Digital Elevation Model (Dem), landuse/landcover, soil map etc. have been prepared.

Digital elevation models (DEMs) are grid-based GIS coverages that represent elevation. Downloaded DEM was processed for removal of sinks, thereafter the filled DEM has been used to generate the flow direction, flow accumulation maps in the GIS environment for the delineation of drainage networks and watershed boundaries for the four watersheds. Moreover, land use/land cover, soil map etc. thematic maps esstential for the modeling have also been prepared for the study areas. Statistical methods for spatio-temporal temporal analysis of meteorological data using parametric and non-parametric approach have been applied to determine the trends in the rainfall time series. Moreover, spatial variation of ground water levels along with drought characterization for the river basins have been carried out. The hydrological models (NAM and SWAT) have been setup for the river basins. Input databse namely Landuse/landcover, DEM, Soil/Satellite data for the Dhadhar basin has been completed. The hydrological model have been calibrated and validated for the Dhadhar river



basin. Grided data of rainfall and temperature of IMD of four watresheds have been prepared for downscaling using SDSM. Moreover, downloaded Canadian Earth System Model (CanESM2)

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

scenarios for the study area. Statistical downscaling of meteorological data namely daily rainfall, minimum, maximum and average temperature for the Dhadhar, Bina and Rāmgangā basin using statistical downscaling model (SDSM). SDSM is based on multiple linear regression (MLR) technique. The model has been calibrated and validated based on rainfall and temperature of period 1961-1995 and 1996-2005 respectively with large-scale predictors of National centre for Environmental Prediction (NCEP) reanalysis data.

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

8. Progress since last working group

Future scenarios for Dhadhar and Chaliyar basins have been carried out to assess the impact of changing climate on runoff using SWAT model while for Bina and Ramganga is in process done. The work may be extended upto December 2020

PROJECT REFERENCE CODE: NIH/SWD/NIH/18-21

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

Thrust area under XIIth Plan: Impact of climate change on water resources and hydrology of extremes

Title of the Project:	**'Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario'**
Project team:	Dr. Ashwini Ranade, Scientist 'C'(PI) Dr. Archana Sarkar. Scientist 'D'(Co-PI)
Type of Study:	Internal
Status:	ongoing
Duration:	3 years
Date of Start:	1 April 2018
Scheduled date of completion:	31st March 2021

Objectives

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

1. Statement of the problem

The evolution of Asia-Pacific Monsoon is a very complex phenomenon. Still more complex is the issue of climate change. Since the last glacial (~11,000 years B.P.) the surface air temperature of the northern hemisphere (NH) rose from 11°C to 15°C. The NH temperature of 15°C is critical for the Indian summer monsoon. Temperature less than that would lead to drier conditions over the Indo-Gangetic Plains (IGPs). Temperature between 15°C and 15.5°C would result in a wetter monsoon (similar to the present day) over the IGPs. Temperature greater than 15.5°C would induce a westward shift in monsoon rainfall activities with relatively drier condition prevailing over the Gangetic Plains. This relationship occurs on centuries and millennia scales rather annual and decadal scales. From last 10,000 to 4,000 years, warmer and cooler epochs are of longer duration while, in later period they were shorter and less intense. From the little ice age to recent period, the warm episode is continuing. The Indian summer monsoon coherently fluctuated with the NH temperature. The Intergovernmental Panel on Climate Change (IPCC, 2007) reported that the Indian subcontinent will be adversely affected by enhanced climate variation, rising temperature, and substantial reduction in summer rainfall with water stress in some areas of the globe. According to special report of IPCC (2018) titled '*Global warming of 1.5°C'*, human activities are responsible for the 1°C of global warming. The report also concluded that, the additional 0.5°C warming could be avoided by drastically reducing greenhouse gas emissions in next 10 years.

Recent changes in global tropospheric thermal structure show that, global warming is not uniform throughout the globe. Such type of global temperature changes in last few decades are observed to make changes in rainfall pattern also. Few intense rain spells, consequently heavy flooding and disasters occur across the country even in dry monsoons. At such times sudden intensification of the monsoon circulation is seen associated with anomalous warming of the upper troposphere between Tibet and Turkey sector and development of strengthened ridge in upper tropospheric westerlies over there. Few case studies of extreme rain events carried out by us revels that, abrupt warming and cooling in the atmosphere drastically modulates the monsoon circulation and intensify the associated weather systems causing heavier rains over a region. Persistence in temperature and circulation anomalies across the globe are strongly linked to the 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. Locations of warming and cooling across the globe are the determinant of the plausible locations for the origin of various type of weather systems. We are hearby investigating the 3D changes in global atmospheric thermal structure and its role in extreme phases of monsoon.

2. Dataset used and Study area:

The global monthly reanalysis product of the atmospheric temperature at 37 vertical isobaric levels (1000-1hPa) available at 2.5º grid resolution from 1979 to 2018 from 'The National Centers for Environmental Prediction (NCEP) Climate Forecast System Reanalysis (CFSR & CFSv2) are used for global temperature changes studies. The column-area mean monthly temperature of the lower troposphere (LTT: 1000-600hPa), upper troposphere (UTT: 550-250hPa), tropopause (TPS: 200-100hPa) and stratosphere (STT: 70-1 hPa) have been area averaged at global, hemispheric, zonal and regional scale. Tropospheric mean temperature (TT: 1000-250hPa) are calculated by considering troposphere level at 250hPa. Observations show that temperature up to this height is always lower than that of the equator throughout the year.

3. Analysis and results:

3.1 Temperature Trends across the globe during 1979-2018

We have analyzed the trend in the atmospheric temperature from 1000hPa to 1 hpa atmospheric levels at global, hemispheric, zonal and regional scale. Based upon geographical, astronomical and meteorological characteristics and climatic conditions (temperature, wind pattern, precipitation etc.), the whole globe (GLB) is divided into nine climatic zones: north polar (NP: 70°-90°N), north mid-latitudes (NMLAT: 45°-70°N), north subtropic (NSBT: 25°-45°N), north tropic (NTP: 2.5°-45°N), equator (EQ: 2.5°S-2.5°N), south tropic (STP: 2.5°-25°S), south subtropic (SSBT: 25°-45°S), south mid-latitudes (SMLAT: 45°-70°S), south polar (SP: 70°-90°S). 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. 1 shows the homogenized month-year troposphere (1000−250-hPa) temperature (TT) variation during 1979-2018 over nine climatic zones, the two hemispheres and the globe. It also shows the 37-month (~3 year) running mean as well as the linear trend. The TT over the globe has been increased at the rate of 0.25° per decade. NH is warming at faster rate (0.30°/decade than SH (0.20°/decade). All climatic zones across the globe show consistent significant global warming trend for all zones except SP and SMLAT. The highest rate of increase is seen over NP (0.37°/decade) while lowest over SP (0.05°/decade).

The homogenized month-year temperature records averaged over the LTT, UTT, TPS and STT of the atmosphere are plotted. The rate of rising/declining trend in temperature over different climatic zones are also calculated. Visual examination revel that, LTT of GLB, NH, SH and all climatic zones (except SP and SMLAT) shows significant rising trend during 1979-2018. In UTT the results are consistent with LTT except SMLAT. The LTT and UTT of the globe have been increased at the rate of 0.20°C/decade and 0.32°C/decade respectively. The warming trend of LTT is higher (0.27°C/decade) in NH than SH (0.12°C/decade) while they are comparable (0.32°C/decade and 0.30°C/decade respectively) in UTT. Across 9 climatic zones, the warming trend in LTT varies from 0.08°C/decade over SP to 0.47°C/decade over NP, that of UTT from 0.20°C/decade over SMLAT to 0.40°C/decade over EQ. The LTT of SMLAT and UTT of SP both have been cooled by -0.01°C /decade. At tropopause level, no change is seen in the tropopause temperature (TPS) of the GLB while TPS of NH is warming at the rate of 0.04°C/decade and SH is cooling at the rate of -0.03°C/decade. Stratosphere of the GLB shows cooling trend of -0.55°C/decade over GLB, -0.56°C/decadeover NH and -0.54°C/decade over SH. The cooling trend in STT continues in all climatic zones as well varies from -0.51°C/decade over SMLAT to -0.80°C/decade over NP. The stratospheric cooling throughout the globe may be driven by increase in well-mixed greenhouse gases and declining stratospheric ozone levels. In general, rate of warming trend increases from south polar towards north polar throughout the troposphere, while beyond it, only EQ and tropics are warming, other climatic zones are cooling. Which could be the cause of occurrence of many unusual weather events across the globe.

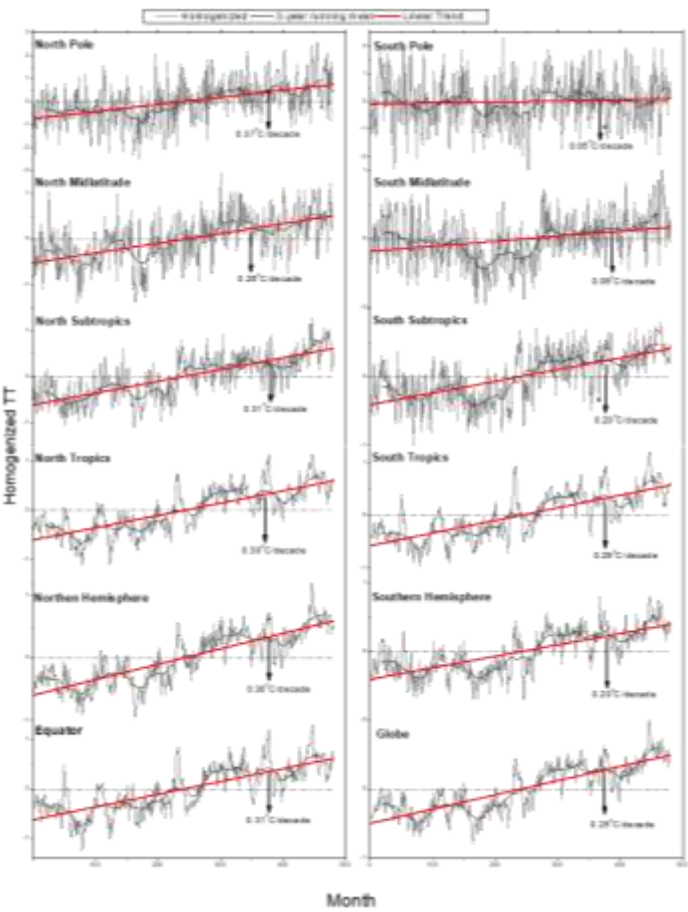


Fig 1. Homogenized (monthly mean removed and annual standard deviation equated) month-year troposphere (1000−250 hPa) temperature variation during 1979-2018 over nine climatic zones, the

two hemispheres and the globe. Thick curve is 3-year (or 36-month) running mean and straight-line linear trend

3.2 Recent 10 year changes in atmospheric temperature records

Changes in LTT, UTT, TPS, STT and TT in recent 10 years (2009-2018) compare to earlier records (1979-2008) have been calculated and significance is tested using student t-test. In recent years, the annual mean LTT, UTT, TT of the GLB, NH, SH and all climatic zones (except SP) have been increased significantly (significant at 1% level) While STT shows significant decrease. The TPS changes are significant only over NH, NTP and EQ. Over the GLB, the LTT has been increased significantly by 0.35°C, UTT 0.68°C, but not significant at TPS (0.16°C). Over NH the significant increase in LTT is 0.48°C, UTT 0.68°C and TPS 0.21°C. Over SH, the LTT and UTT shows significant increase by 0.22°C and 0.69°C respectively while not significant over TPS (0.12°C). Throughout the troposphere (TT), the NH is warming at faster rate (0.57°C) than SH (0.42°C). Across 9 climatic zones, the largest significant increase in LTT is seen over NP (0.97°C), UTT over EQ (0.82°C), TPS over EQ (0.50°C) and TT over NP (0.80°C). The rate of warming in NH climatic zones are higher compare to that of SH. For TT, the highest change is observed over NP (0.80°C) while lowest over SP (0.07°C). The significant cooling is observed in stratosphere across the globe. The STT of GLB has been significantly decreased by -0.96°C, NH -0.96 °C and SH -0.97°C. The largest (-1.11°C/decade) is observed over NTP followed by EQ (-1.11°C) and STP (-1.08°C) significant tat 1% level.

Recent 10 year changes have been analyzed for 54 geodomains and documented (fig2). It has been seen that the LTT over most of the geodomains show positive anomaly but SP and some part of SMLAT shows negative anomaly. In NH, the highest positive anomaly is seen over geodomains of NP (+1.22°C) followed by eastern NSBT (+0.69°C) and eastern NMLAT (+0.62°C). In SH, the highest positive anomaly is seen over southern Indian Ocean (+0.59°C) followed by central Pacific both in STP (+0.4°C). Over the EQ, the anomaly does not show much variation especially over oceanic areas (~+0.50°C). The largest negative anomaly is observed over SP (-0.51°C). The UTT shows consistent positive anomaly throughout the globe. In the NH, the highest value is observed over western Asia-Africa (+0.81°C), followed by south west Indian subcontinent and Arabian Sea (+0.79°C) both in NTP. In SH, the highest anomaly is over South Africa (+0.96°C) followed by south Indian Ocean (+0.91°C) both in STP belt. Over the equatorial belt, the anomaly varies from +0.76°C to +0.94°C over equatorial Indian Ocean. It has been seen that the upper troposphere of Oceanic regions are warming at higher rate than that over land areas across the globe. The TPS temperature shows mixed anomalies throughout the atmosphere. The highest positive anomaly is observed over Southeast Asian region, Indian Ocean over the equator (+0.65°C). While the largest negative anomaly is observed over geodomains of eastern SMLAT. The tropopause of tropical and subtropical regions are warming while multitude regions are cooling. The NP is warming but SP shows cooling tendency. Stratospheric cooling throughout the globe is clearly observed in recent years. In NH, maximum cooling is depicted over Arabian Sea, tropical Indian subcontinent and north tropical Southeast Asia (-1.21°C). In SH, the maximum reduction in STT is over eastern geodomains of SMLAT.

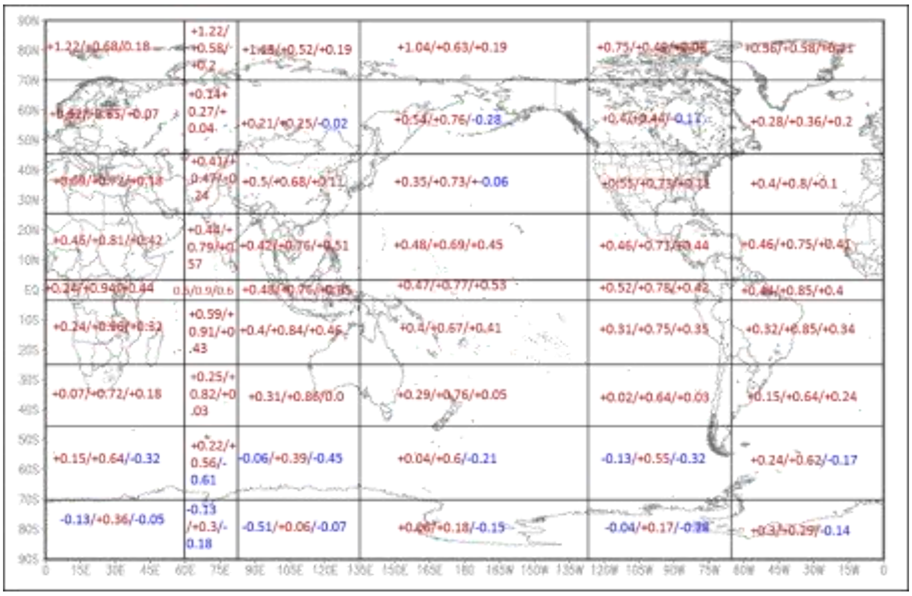


Fig. 2 Recent 10 year (2009-2018) changes in Lower tropospheric(LTT), Upper tropospheric (UTT) and Tropopause (TPS) temperatures compare to earlier record (1979-2008) over 54 geodomains across the globe

Summarized changes in column mean TT across the globe are also calculated. The largest change in TT of NH is observed over eastern NP geodomains (+0.98°C). The geodomains of NH are showing significant changes in TT in recent years as compare to those in SH. Some geodomains in SP even show cooling as well. From the dynamical perspective of Indian summer monsoon occurrence and establishment, eastern NSBT areas are of great importance. It has been seen that, In recent 10 years, the troposphere of Asia-India sector of NSBT belt was comparatively cooler (0.44°C) than the surrounded NW Asia in west (0.70°C) and Tibet-China in east (0.58°C). It leads to frequent formation of deep trough over western slopes of Himalaya. An incursion of cool-dry westerlies over Central Asia-India sector and its frequent interaction with warm-moist tropical easterlies, and its forced exit from western Himalaya itself caused the formation of cloudburst events over the NW Himalaya.

In general, rate of warming trend increases from south polar towards north polar throughout the troposphere, while beyond it, only EQ and tropics are warming, other climatic zones are cooling. This asymmetric changes in thermal structure reflected in the significant decrease in inter-hemispheric temperature contrast over most of the climatic zones and weakening of thermally directed Asia-Pacific Monsoon circulation and hence monsoon rainfall across the country and unpredictable weathers across the globe.

3.3 Conclusions:

- 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). The rate of warming in LTT is higher (0.27°C/decade) over NH than SH (0.12°C/decade) while they are comparable in UTT (~ 0.31°C/decade). At tropopause level, no change is seen in the tropopause temperature (TPS) of the GLB. Stratosphere of the GLB, NH and SH shows cooling trend (approx. -0.55°C/decade). All climatic zones across the globe show consistent significant global warming trend throughout the troposphere except SMLAT and SP.

- During 2009-2018, compare to base period of 30 years (1979-2008), the annual mean LTT, UTT, TT of the GLB, NH, SH and all climatic zones (except SP) have been increased significantly. The 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, in recent 10 years, 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 midlatitude regions are cooling.
- In recent 10 years, over Asia-pacific region, the troposphere of Asia-India sector of NSBT belt has been comparatively cooler (+0.44°C) than the surrounded NW Asia in west (+0.70°C) and Tibet-China in east (+0.58°C) responsible for the frequent formation of deep troughs over western slopes of Himalaya that casing frequent formation of extreme events over the area.

Deliverables: It is expected that the results from this study will be useful in order to understand the effect of global warming on rainfall pattern across India

Adopters of the results of the study and their feedback: From hydrology and water resources sectors

Major items of equipment procured: None

Lab facilities during the study: None

Specific linkages with Institutions/beneficiaries: None

Shortcomings/Difficulties: Shortage of manpower

Future Plan: To understand the effect of global temperature change on monsoon circulation and extreme rain spells ver seven zones of the country.

PROJECT REFERENCE CODE: NIH/SWHD/NIH/18-21

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

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

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

Type of Study: Internal

Status: On-going

Duration: 3 years

Date of Start: 1st November 2018

Scheduled date of completion: 31st October 2021

Objectives:

1. Analyze historically observed streamflow in Godavari and Narmada River basins.
2. Analyze the influence of various low-frequency atmosphere-ocean oscillations on annual peak flow (flood) magnitude and frequency.
3. Evaluate the probability distributions being used in the flood frequency analysis and propose an appropriate probability distribution to address the non-stationarity in the streamflow dataset.
4. Explore the probable maximum precipitation (PMP) estimation methods in design flood studies and prepare a status report on the impact of changing climate on PMP in India.

Statement of the problem:

Globally, floods are ranked among the largest and costliest natural disasters having major impact on various economic sectors. In India, flooding is one of the three prominent climate extremes, other two being droughts and cyclones. Majority of flooding in Indian watersheds occurs during summer monsoon months due to uneven distribution of rainfall. For example, recent devastating floods in Kerala were in response to the abnormally high rainfall received within a short period of 3 days, i.e. during 15th to 17th August 2018. Summer monsoon rainfall being the major source of water input to the Indian subcontinent, optimal design and operation of water resources infrastructure (e.g. major dams) is very much essential. Planning and design of such structures require a great depth of knowledge on the magnitude and frequency of extreme floods. Traditionally, the frequency of extreme floods is derived based on the analysis of historically observed annual maximum flows assuming they are independent and identically distributed (*i.i.d*) and the system fluctuates within a fixed envelope of variability, i.e. stationarity assumption. However, several studies across the globe highlight the potential inadequacy of traditional flood frequency analysis (FFA) and argue that the *i.i.d.* assumption can no longer be considered valid. Moreover, Indian summer monsoon is influenced by several low-frequency atmosphere-ocean oscillations including Atlantic 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, due to lack of standard approach for estimating PMP, it's use in the design and analysis of flood related studies is criticized. In this study, we propose to first analyze the annual floods (i.e. maximum flows) with the hypothesis that they are influenced by the low-frequency atmosphere oscillations originating in the equatorial Pacific and Indian Oceans. Secondly, we propose the evaluate the PMP estimation methods in flood frequency studies and prepare a status report on the impact of climate change on PMP.

Study Area:

The study is being carried out on several sub-basins of River Godavari and River Narmada. We chose several streamflow gauging stations with a minimum of 30 years observed daily streamflow data. Based on the preliminary survey of the available streamflow data, we chose 19 gauging stations from Godavari and 12 stations from Narmada watersheds, with at least 30 years of data. The maximum length of the available data is 50 years.

Datasets:

1. Observed daily streamflow data for the selected gauging stations is obtained from India-WRIS website.
2. Pacific Decadal Oscillation (PDO) indices is obtained from Joint Institute for the study of Atmosphere and Ocean (JISAO), University of Washington.
3. El Niño-Southern Oscillation (ENSO)is quantified by Southern Oscillation Index (SOI) and is obtained from Climate Research Unit, University of Eastern Anglia.

Current Status:

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

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

Annual Mean flow in 15 gauging stations out of 19 in Godavari River basin are influenced by ENSO. The correlations between ENSO index and annual mean streamflow show statistically significant correlations (Spearman's $\rho \leq 0.54$). These correlations indicate that the magnitude of annual mean streamflow in Godavari River is more during the El Niño episodes, when compared to that during the La Niña episodes. In addition, we observed that the annual peak flow in 12 gauging stations is significantly influenced by the ENSO. Similarly, annual mean streamflow in nearly 12 gauging stations 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, annual mean streamflow in the Narmada watershed did not show any significant correlations with both ENSO and PDO indices, albeit few stations (nearly 5 out of 12).

Currently, we are evaluating the spatial and temporal variability of these correlations. One crucial observation is that the majority of these gauging stations are regulated and hence the anthropogenic influence might be disturbing the natural signal of these teleconnections. Longer duration datasets and those on naturally flowing streams would help identifying the signal clearly. Currently, we are identifying more gauging stations with longer datasets and more specifically looking for stations on naturally flowing streams. Eventually, we will de-trend the streamflow datasets of anthropogenic influence (naturalization) and perform the analysis again to get a clearer picture. We are also evaluating the probability distributions used in flood frequency analysis and hope to propose a suitable distribution that can address the issue of non-stationarity.

Deliverables:

1. Propose an appropriate probability distribution to address all the concerns over non-stationarity in the streamflow datasets.
2. Research papers based on the established relations between low-frequency climate oscillations and flood magnitude and frequency.

Status report on the impact of climate change on probable maximum precipitation (PMP) in India.

PROJECT REFERENCE CODE: NIH/SWHD/NIH/16-21

9. Evaluation of water quality of Government schools in Roorkee block, District Haridwar

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

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

Role of Team Members:

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

Type of Study: Applied research
Date of start: October 2018
Scheduled date of completion: September 2020
Duration of the Study: 2 Years
Objectives of the Study: i) Groundwater quality monitoring in pre-monsoon (April-May) and post-monsoon (OctoberNovember) season at identified school locations. ii) To map degraded ground water quality zones and possible sources of pollution and identify specific parameters not conforming to drinking water quality standards. iii) To examine the suitability of ground water quality for drinking purpose using Water Quality Index. 145 iv) To suggest ameliorative measures to restore the quality and sustainable use of groundwater for drinking.

v) To organize Mass Awareness Programme for school and villagers regarding Drinking Water Quality and Water Conservation.

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

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

Timeline:

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

List of deliverables: Technical Report and Research

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

Data generated in the study: Hydro-chemical and statistical data of Roorkee block.

Study Benefits/Impact: Water quality analysis of every school will be helpful to provide pure potable drinking water to schoolchildren and they wouldn’t be bound to drink contaminated water that will be helpful them not to fall ill because of water born diseases. Directly the health of children will improve and, consequently, the attendance too.

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

Expected Budget

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

Progress after last working Group:

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

PROJECT REFERENCE CODE: NIH/SWHD/20-21

10. Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Lower Narmada & Tapi subzone-3b, (2) Lower Godavari subzone-3f

Study group	Sushil K. Singh, Scientist F
Date of start of study	01 April 2020
Duration and scheduled	One year
Date of completion of study	31 March 2021
Type of study	Internal (without funding)

Objectives of study

This study is undertaken under 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 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 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*."

The current year study is intended for the following two subzones:

- Lower Narmada & Tapi subzone-3b; and
- Lower Godavari subzone-3f

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 substitute the GEV (generalized extreme-value distribution, is intended to be applied to the peak flows observed in the basins falling under two subzones of zones-3 of India. Therein, also proposed is to quantify the deterministic confidence limit and interval applicable for predicting the flood peaks.

Achievement/progress:

The part of study dealing with *Lower Narmada & Tapi subzone-3b* is in progress, and will be completed by 30Sep2020.

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.

PROJECT REFERENCE CODE: NIH/SWHD/20-21

11. Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan.

1. Title of the Project
   Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan.

2. Project team:
   a. Project Investigator: J.P. Patra, Sc. D, SWHD
   b. Project Co-Investigator: Rakesh Kumar, Sc. G & Head SWHD
      Pankaj Mani, Sc. F, CFMS Patna
      Sunil Gurrapu, Sc. C, SWHD

3. 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.

4. Present state-of-art
   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.

Figure 1: Index map of the study area

5. 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 the 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.

6. Research outcome of the project
   - 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.

7. Work Schedule:
   a. Probable date of commencement of the project: July 2020
   b. Duration of the project: 2 Years
   c. Stages of work and milestone:

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.								

S.N.	Work Element	1^{st} Year				2^{nd} Year			
9	Estimation of Population at risk and potential loss of life.								
10	Workshop/ Training.								
11	Report.								

8. Role of team members

S. N.	Role / Action	Member/(s)
1	Collection of basic data, topography, cross-section, satellite images, thematic maps etc.	JPP, PM, TRS
2	Compilation and analysis of data, satellite images	JPP, PM
3	1-D level pool dam breach model setup	JPP, PM
4	Quantification difference between level pool routing and full unsteady flow routing.	JPP, PM, RK
5	Generation of probabilistic breach parameters	JPP, RK, SG
6	Estimation of probabilistic dam breach outflow hydrograph	JPP, RK, SG
7	Preparation of Exceedance Probability Inundation (EPI) Maps.	PM, JPP, SG
8	Combined general flood hazard classification and preparation of Flood Hazard Maps.	JPP,PM
9	Risk identification, estimation of Population at risk and potential loss of life.	JPP,PM, SG, RK
10	Report	JPP,PM, SG, TRS

JPP = J. P. Patra, RK = Rakesh Kumar, PM = Pankaj Mani, SG = Sunil Gurrapu, TRS =T. R. Sapra

WATER RESOURCES SYSTEM DIVISION

Scientific Manpower

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

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2020-2021

SN	Title	Study Team	Duration	Funding (Rs. Lakh)
Ongoing 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)	
2.	Real time flood modelling using HEC-RTS modelling framework	Vishal Singh A. K. Lohani	2 years (12/18-12/20)	
3.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora Sanjay K. Jain	3 years (04/18-03/21)	
Ongoing Sponsored Studies				
1.	Development of a project website and hydrological database in Upper Ganga Basin **(Sub-project – 1)**	M. K. Goel; M. Arora; A. K. Lohani; D. S. Rathore; D. Chalisgaonkar; A. R. S. Kumar; S. Singh; P. Mani; A. Sarkar; M. K. Nema; P. K. Mishra	5 years (01/16-12/20)	DST (52.15)
2.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore D. Chalisgaonkar, V. S. Jeyakanthan L. N. Thakural	5 years (01/16-12/20)	DST (48.83)
3.	Glacial Lakes & Glacial Lake Outburst Flood (GLOF) in Western Himalayan Region **(Sub-project – 3)**	Sanjay K. Jain A. K. Lohani Sudhir Kumar Praveen Thakur (IIRS)	5 years (01/16-12/20)	DST (36.79)
4.	Assessment of downstream impact of Gangotri glacier system at Dabrani and future runoff variations under climate change scenarios **(Sub-project – 4)**	Renoj J.Thayyen; Sanjay K. Jain; Sharad K. Jain (Retd.) P. K. Mishra; M. Arora; AP Dimri (JNU)	5 years (01/16-12/20)	DST 86.1 (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 (01/16-12/20)	DST (54.07)
6.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11)**	P. K. Mishra; M. K. Nema; Renoj J. Thayyen; Pradeep Kumar	5 years (01/16-12/20)	DST (90.99)
7.	Measurements and Modeling of Evapotranspiration and other Hydrological Processes in Lesser Himalayas	M K Nema; Renoj J. Thayyen; Sharad Jain (Retd.); Sanjay Jain;	3 years (2016-19) Extended up to Dec. 2020	MOES (Rs. 98 Lakh)

		P. K. Mishra; AP Dimri		
8.	Investigating Water Stress using Hydro-meteorological and Remote Sensing data	D. S. Rathore; L. N. Thakural; Sanjay Kumar; B. Venkatesh M. K. Jose; T. Chandramohan	3 years 2017-2020	PDS under NHP (50.23 Lakh)
9.	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; Suman Gurjar	3 years (11/19-11/22)	NMHS-MoEF (143 Lakh)
10.	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	Renoj J. Thayyen A. P. Dimri (JNU) Sanjay K. Jain	3 years (06/19-11/22)	NRDMS-DST (23.19 Lakh)
11.	Permafrost mapping and characterisation of Ladakh Region	Renoj J. Thayyen; A. P. Dimri (JNU); G. Jeelani (KU); V. Agnihotri (GBPNI)	3 years (11/19-11/22)	NMHS-MoEF (197.48 Lakh)
New Internal/ Sponsored Studies				
1.	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
2.	Henvel Experimental Watershed: Observations and modelling (Phase II)	M K Nema Renoj J. Thayyen P K Mishra	3 years (08/20-07/23)	NIH
3.	Upgradation of NIH_ReSyP to .NET Platform– a Reservoir Operation Package	D. Chalisgaonkar M. K. Goel	1 year (08/20-07/21)	NIH
4.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.	P K Singh P K Mishra	2 years (08/20-07/22)	NHP (14.50 Lakh)
5.	Preparation of Guidelines for the “Management of Glacial Hazards and Risks especially GLOFs & LLOFs”	Sanjay K. Jain A K Lohani	1 year (12/19-12/20)	NDMA (14.36 Lakh)

COMPLETED STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2019-20/01

1. **Thrust Area under XII five Year Plan**: Sustainable water systems management: Adaptation of hydro-system to climate change
2. **Project Team:**
   a. Project Investigator: Dr. Manish Kumar Nema, Scientist 'D'
   b. Project Co-Investigators: Dr. Sharad K. Jain, Retd.
   Dr. Sanjay K. Jain, Scientist 'G'
   Dr. Renoj J. Thayyen, Scientist 'E'
   Dr. P. K. Mishra, Scientist 'C'
3. **Title of the Project:** Hydrological Processes and Characterization of Lesser Himalayan Catchments
4. **Objectives:**
   a. To establish an instrumentation and experimental setup to measure various hydrological and meteorological variables in a watershed in the upper Ganga basin within the state of Uttarakhand for better understanding of their behavior and to study the dynamic linkages between the two.
   b. Analysis and comparison of estimated Evapotranspiration (ET) by different methods like RS/SEBAL, FAO56 method and actual field measurements
   c. To study the various water balance components in the watershed

5. **Methodology**

(A) Study Area:

A small Himalayan hilly watershed Hinval up to Jijli in the upper Ganga basin in the state of Uttarakhand is proposed for the study. This study area is a paired watershed of two kinds. One of them is a forested catchment (undisturbed) and other one is an agricultural watershed with anthropogenic interventions including an urban habitat at Chamba (Uttarakhand). The geographical extent of the study area is from $30^0$17'N–$30^0$26'N latitude and $78^0$16'E–$78^0$25'E longitude. This area is a typical representative of a combination of lesser Himalayan hilly temperate climatic conditions with average annual rainfall range of 1200-1800 mm. The Himalayan subtropical forests yield to a belt of temperate broad leaf and mixed forest mainly comprises of pine forest. The total area under study is of 100 km^2 approximately (20 km^2 forested catchment and 80 km^2 the other one) with an elevation range of 999-2676 m. The location map of the watershed and their digital elevation model from SRTM is given in the Figure 1 for reference. The stream in the forested sub-catchment is the source of drinking water for 87 nearby villages. This stream is being pumped 24x7 by the state authorities at its outlet at Dev Nagar. A study of the topography and land use of the proposed watershed shows that the watershed is representative of the surrounding areas.

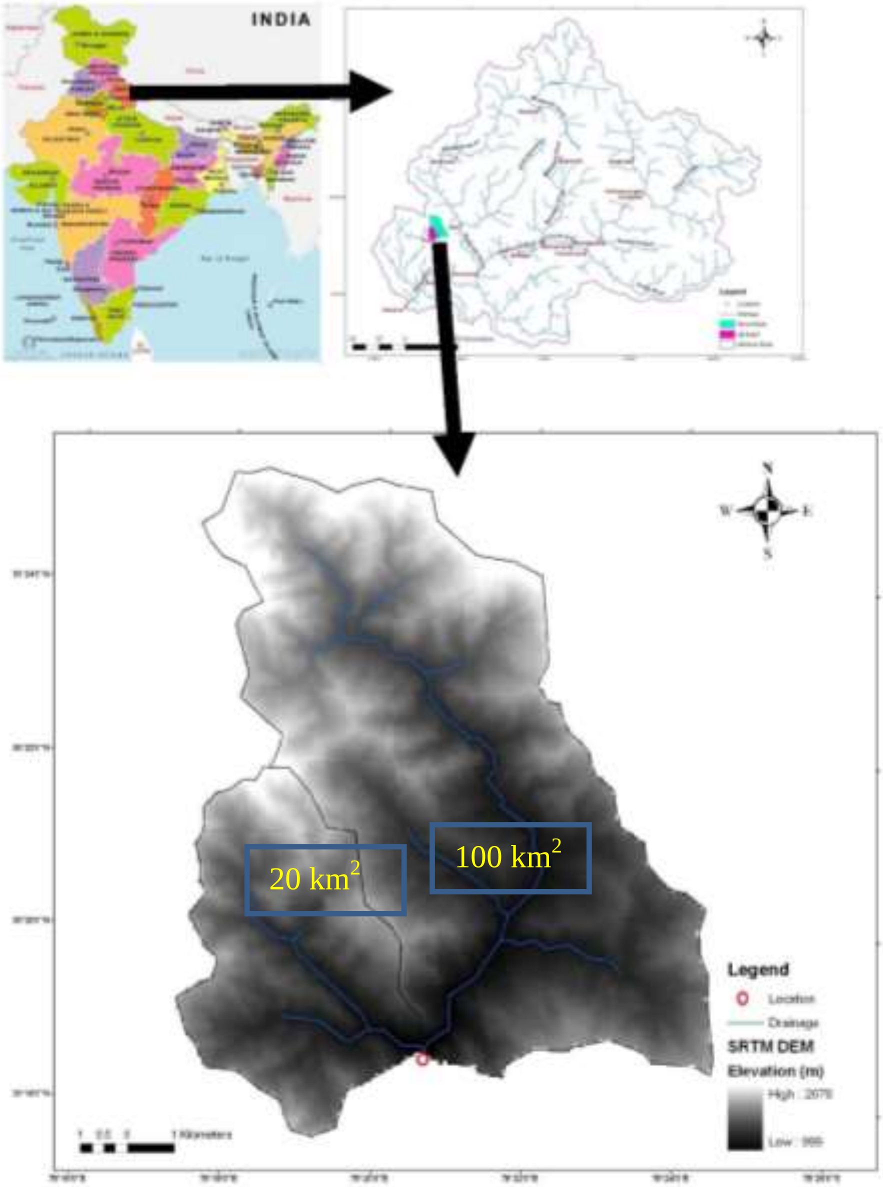


Figure 1: Location of the Henval watershed up to Jijli

(B) Experimental setup
Variables and parameters to be observed: organized in four categories, i.e., hydrological and ecological variables, atmospheric forcing variables, vegetation parameters, and soil parameters.

(C) Soil Heat Flux
Soil heat flux represents the amount of radiant energy absorbed or released at the soil surface during a given time period. Soil heat flux is a necessary input for many evaporation measurement and prediction techniques. One of the objectives of this study is to estimate soil heat flux using soil temperature collected at various soil depths. It is also intended to study the diurnal variation of soil heat flux in various seasons.

(D) Evapotranspiration (ET)
Accurate estimates of ET are needed for numerous agricultural and natural resource management tasks, hydrological modelling and to project changes in hydrological cycles due to potential climate change. In the present study, the estimates of ET from various sources will be compared with the actual field observations.

(E) Soil Moisture

Soil moisture in the uppermost 1–2 m of the earth's surface is recognized as a key variable in many environmental studies, including those related to meteorology, hydrology, agriculture and climate change. An understanding of the soil moisture variability is necessary to characterize the linkages between a region's hydrology, ecology and physiography (Jackson, 1993). The proposed objectives under this theme are to understand spatio-temporal variability of soil water potential and soil moisture content under different land covers in the temperate lesser Himalayan region and to evaluate differences, if any in spatial and temporal patterns of soil moisture content as influenced by nature of land cover. We propose to establish sampling points for measuring the soil moisture content under different land covers in selected watersheds, spread spatially to cover topographic highs and lows. Soil matric potential measurements are proposed using resistance-type probes. At each sampling point, probes will be installed at different depths. A roving instrument (handheld read-out unit) shall be used to record matric potential (kPa).

(F) Hydrologic Modelling

It is planned to apply distributed models such as the Soil and Water Assessment Tool (SWAT) and VIC Models.

6. Research Outcome from the project:

Development of a world class field hydrological laboratory in the lesser Himalaya. Development of better understanding of monsoon forcing on regional hydrology under changing climate for the end users/beneficiaries from the relevant Sectors. Research Papers and Reports.

7. Cost estimates:

a. Total cost of the project: Rs. 90, 55, 000. 00
b. Source of funding: NIH
c. Sub-head wise abstract of the cos:

S. No.	Sub-head	**Amount in Rs. (Lac)**
1.	Salaries/ wages	33.60
2.	Travelling Expenditure	10.00
3.	Infrastructure / Equipment / Data	39.45
4.	Experimental charges	7.50
5.	Misc. expenditure	0.00
	Grand Total:	90.55

d. **Justification for sub-head wise abstract of the cost**: due to lots of instrumentation involve in the project the non-recurring cost is the major component followed by the salary of the project staff.

8. Quarterly Break up of cost estimate for Year: 2017-18

SN	Sub-head	Amount (in Rupees)			
		AMJ (Q1)	OND (Q2)	JAS (Q3)	JFM (Q4)
1.	Salary	168000.00	168000.00	168000.00	168000.00
2.	Travelling expenditure	50000.00	50000.00	50000.00	50000.00
3.	Infrastructure/Equipment	320000.00	320000.00	320000.00	320000.00
4.	Experimental charges	0.00	0.00	0.00	0.00
5.	Misc. expenditure	37500.00	37500.00	37500.00	37500.00
	Sub- Total:	575500.00	575500.00	575500.00	575500.00
	Grand Total:				2302000.00

9. Work Schedule:

a. Date of commencement of the project: 01.01.2015

b. Duration of the project: 5 years
c. Stages of work and milestones:

S No.	Description of Activity	2015				2016				2017				2018				2019			
		J	A	J	O	J	A	J	O	J	A	J	O	J	A	J	O	J	A	J	O
1.	Development of Procedure for scientific work																				
2.	Recruitment and deployment of Project Personnel																				
3.	Purchase of instruments and experimental setup																				
4.	Data generation and acquisi																				
5.	Data analysis and modelling																				
6.	Final Reporting																				

10. Outcome:

National Institute of Hydrology has initiated this study in the year 2016 to develop a better understanding of climate-hydrology interaction in the lesser Himalayan catchment with an area of 102 km^2. This experimental catchment is setup in the Upper Ganga basin near Chamba town in Tehri-Garhwal (Uttarakhand). During the study various types of instruments and sensors were installed in the catchment including automatic weather stations (AWSs), automatic water level recorder (AWLR), soil moisture and temperature sensors, etc (Figure 2). A compound rectangular weir has also constructed to monitor the streamflow at the watershed outlet. All the instrumentation envisaged towards establishing a classical hydro-meteorological field observatory in the Lesser Himalayan environment has been completed in this first phase of the Project-Henval. The data collected from the AWS and other sensors have been analyzed, and results are reported. Due to the importance of the project, various sponsoring agencies, including DST and MOES, have supported the project to strengthen the monitoring facilities in the watershed.
This first phase of the study was focused on monitoring evapotranspiration (ET) by using the latest available technology of eddy covariance tower and ET modelling for the lesser Himalayan region. The ET estimated using the energy balance method from the flux tower was compared with the ET estimated by using the other methods like Penman-Monteith equation, remote sensing/ SEBAL, and Pan. The daily reference evapotranspiration for the period Mar-2016 and Dec-2019 estimated using temperature-based (Hargreaves-Samani and Blaney-Criddle) and radiation-based (Priestley-Taylor and Makkink) methods have been compared with renowned Penman-Monteith (PM) method (FAO-56). Using the statistical indices like $R^{2,}$ it has been observed that the radiation-based methods perform comparatively well than temperature-based methods. Remote sensing-based evapotranspiration estimation method Surface Energy Balance Algorithm for Land (SEBAL) is being tested for the experimental catchment. SEBAL model estimates actual ET by solving the terms of the surface energy balance derived from the visible, Near-IR, and Thermal-IR bands of the electromagnetic spectrum. LANDSAT 8 data used in determining land surface temperature (LST) and the normalized difference vegetative index (NDVI). Mapping Evapotranspiration at high Resolution with Internalized Calibration (METRIC) is a remote sensing-based model similar to SEBAL was also attempted for the Henval catchment. It estimates ET as a residual of the surface energy balance to produce ET information over a larger area of interest. One of the latest and direct measurement technique of ET, namely Eddy Covariance (EC) flux analysis was also carried out to estimate the actual ET.
The catchment response to the various hydro-climatic forcing within the lesser Himalayan catchment was evaluated by the water balance study done through the hydrological modelling using Soil and Water Assessment Tool (SWAT) model. Simulations of the stream flows at Devnagar gauging site

has been carried out by SWAT model. The modelling results show that the model is underestimating the flows; this may be attributed to the slow hydrological response of the catchment as well as fine-tuning of the model parameters (Figure 3). The results can be improved by incorporating the catchment specific data such as intensive soil parametrization. These need to be done in order to achieve better model efficacy. The main focus of the project was to establish a state-of-art field hydro-meteorological observatory and ET estimations with various empirical methods and actual field measurements. In the next phase, the main focus shall be on the hydrological modelling and studies of the interaction between the various observed variables.

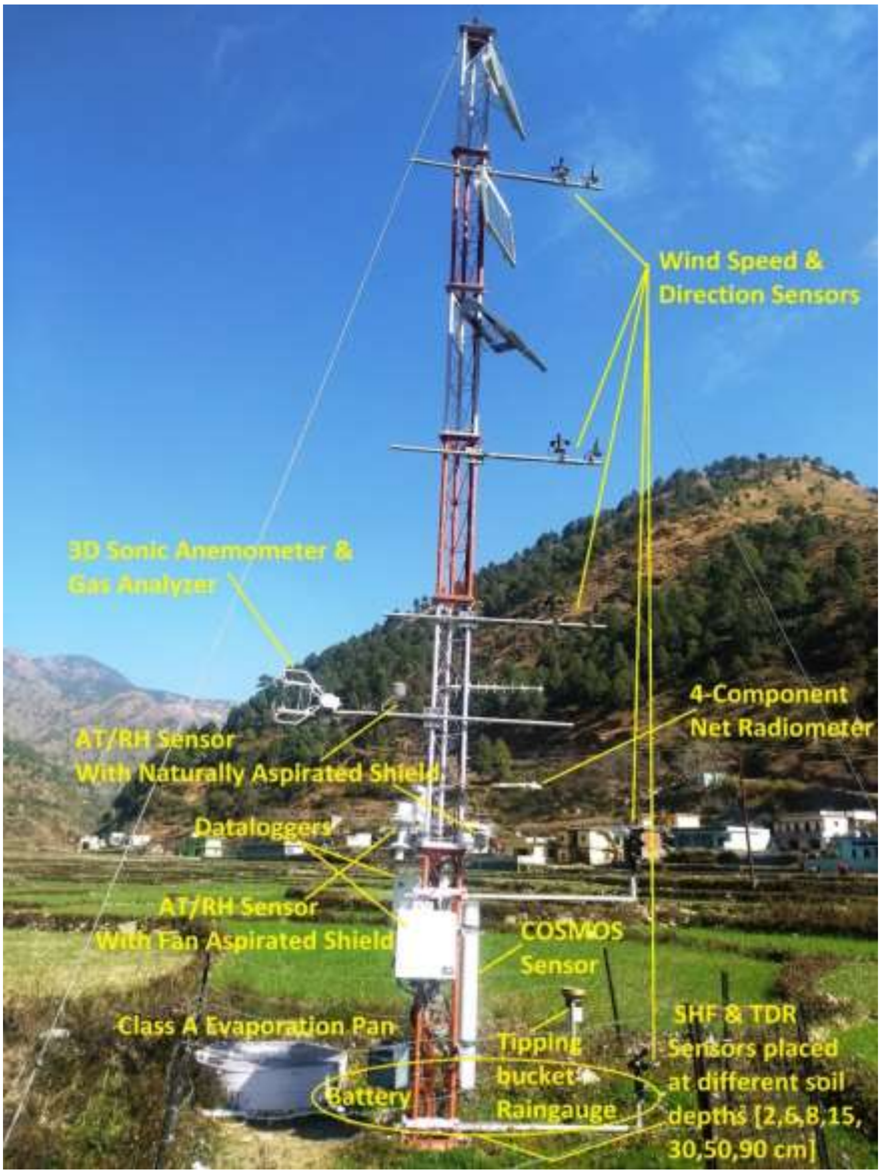


Figure 2: The automatic weather station (AWS) installed near to Chamba under Phase-I of Project-Henval

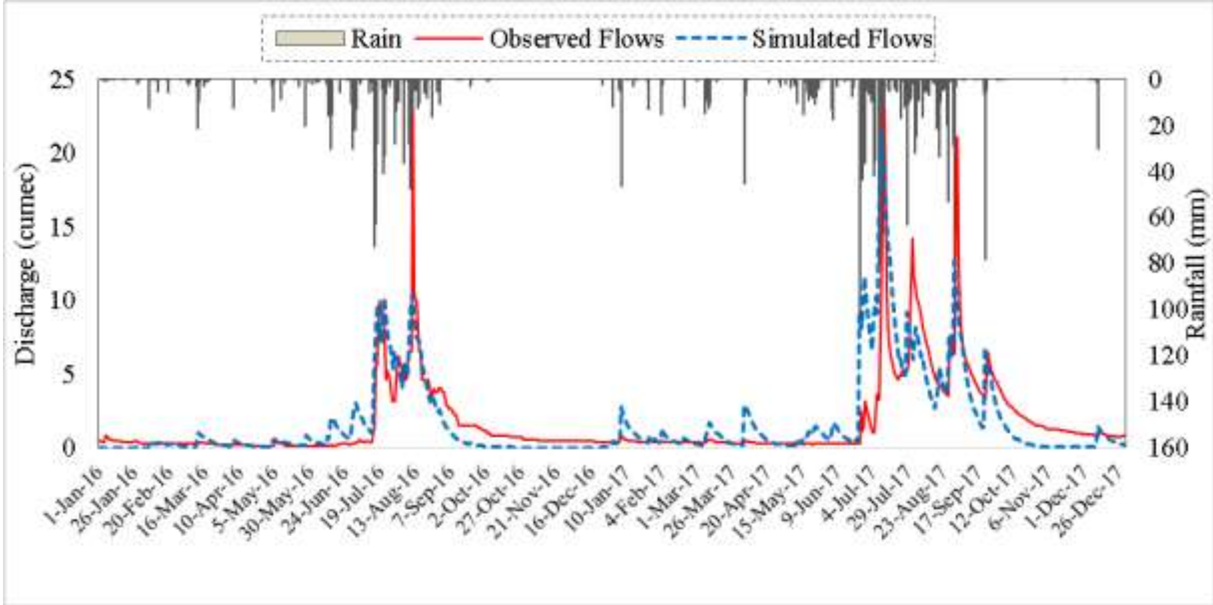


Figure 3: Time series plot of observed and simulated runoff with its rainfall for the calibration period.

COMPLETED STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2019-20/02

1. **Title:** Development of window based software for Flood Estimation
2. **Study Group:** Deepa Chaligaonkar, Scientist 'G'
   Dr. A. K. Lohani, Scientist 'G'
3. **Duration:** April 1, 2019 to March 31, 2020
4. **Objective**: To develop a WINDOWS based Software package for flood estimation.
5. **Methodology:** The software will have a user friendly environment for carrying out the various computations involved in flood estimation. The software will include following main components:
   - Channel Routing Parameters Estimation
     - Estimation of Muskingum Parameters using Graphical Method
     - Estimation of Muskingum Parameters using Method of Moments
     - Estimation of Muskingum Parameters using Optimization Technique
     - Routing of Inflow Hydrograph using Available Muskingum Parameters
     - Routing of Inflow Hydrograph using Muskingum Cunge method
   - Reservoir Routing
     - Reservoir Routing using Mass Curve Method
     - Reservoir Routing using Modified Plus Method
     - Reservoir Routing using Goodrich Method
     - Reservoir Routing using Coefficient Method
   - Unit Hydrograph Development
     - Processing and analysis of rainfall data
       - Filling up of Missing Data
       - Consistency Check of a Record using Double Mass Curve technique
       - Computation of Areal Average Rainfall
       - Computation of Variation of Depth with Area
       - Distribution of Daily Rainfall into Hourly Rainfall
     - Rating Curve Analysis and Computation of Discharge
       - Computation of Discharge from Velocity Measurements
       - Development of Rating Curve
       - Conversion of Stage Values to Corresponding Discharge Values
     - Excess Rainfall and Direct Surface Runoff Computations
       - Base flow Separation and Computation of ERH Volume
       - Separation of Base flow using Straight Line Technique
     - Unit Hydrograph Derivation
       - Unit Hydrograph for Gauged Catchments
         - ✓ Conventional Method
         - ✓ Unit Hydrograph using Collin's Method
         - ✓ Unit Hydrograph using Conventional Nash Model (Method of Moments)
         - ✓ Unit Hydrograph using Conventional Nash Model (Optimization)
         - ✓ Unit Hydrograph Given Parameters of Conventional Nash Model
         - ✓ Unit Hydrograph using Integer Nash Model
         - ✓ Unit Hydrograph using Clark Model (Optimization)
         - ✓ Unit Hydrograph using Given Parameters of Clark Model
       - Unit Hydrograph Derivation for Ungauged Catchments
         - ✓ Unit Hydrograph using Snyder's Method
         - ✓ Unit Hydrograph using Regional Formulae Developed by CWC
         - ✓ S hydrograph Computation

- ✓ Unit Hydrograph of Changed Duration using Superimposition Method
- ✓ Change of Unit Duration of Unit Hydrograph using S - Curve Method
- ✓ Development of Dimensionless Hydrograph
- ✓ Development of Unit Hydrograph from a Dimensionless Hydrograph

- UH Application on Small Catchment for Flood estimation
    - o Computation of Direct Surface Runoff Hydrograph
    - o Computation of Direct Surface Runoff (DRH) and Error Functions
    - o Computation of Design Flood
- Flood Estimation for Large Catchments

7. Outcome:

Flood estimation is one of the most important components of water resources project planning, design and operation. Unit hydrograph approach is a simple, versatile and popular technique which is being widely used for the estimation of floods for design of hydraulic structures, drainage system, small bridges, culverts etc. Flood estimation is one of the most important aspects of hydrology. In view of its importance in Indian context and due to non-availability of generalized software, a WINDOWS based software named "NIH_FLWin: A Windows based Software for Flood Estimation" has been developed. The purpose of this software is to help for the users to estimate the floods for small, medium and large catchments without facing any difficulty. There are various modules in this software. They are classified in nine different categories dealing with different aspects such as:

- ➢ <u>Processing and Analysis of Precipitation Data</u> (Estimation of Missing Rainfall Data, Consistency Check of Record using Double Mass Curve Technique, Estimation of Mean Areal Precipitation using Thiessen Polygon Method, Depth – Area Analysis using Isohyet Method and Distribution of Daily Rainfall Data into Hourly)
- ➢ <u>Computation of Discharge and Rating Curve Analysis</u> (Calculation of discharge from velocity measurements, Development of Rating Curve and Conversion of Stage Values to Corresponding Discharge Values)
- ➢ <u>Computation of Excess Rainfall and Direct Surface Runoff</u> (Calculation of Effective Rainfall from Hydrograph and Estimation of Effective Rainfall and Direct Surface Runoff using Storm Rainfall-Runoff Data)
- ➢ <u>Unit Hydrograph Derivation</u> (Derivation of Unit Hydrograph from the Discharge Hydrograph, Derivation of Unit Hydrograph from the Direct Surface Runoff Hydrograph of a Single Period Storm, Collin's Method of Unit Hydrograph Derivation, Conventional Nash Model for Unit Hydrograph Derivation, Integer Nash Model for Unit Hydrograph Derivation, Clark Model for Unit Hydrograph Derivation, Derivation of S-Curve, Change of Unit Period of a Unit Hydrograph, Superimposition Method and S-Curve Method)
- ➢ <u>Reproduction of Direct Surface Runoff and Estimation of Flood</u> (Development of direct surface runoff' hydrograph from unit hydrograph and composite storm and Reproduction of Observed Direct Surface Runoff)
- ➢ <u>Design Flood</u>
- ➢ <u>Channel Routing</u> (Estimation of Muskingum Parameters Using Graphical Method, Estimation of Muskingum Parameters Using Method of Moments and Routing of Inflow Hydrograph Using Available Muskingum Parameters)
- ➢ <u>Reservoir Routing Using Modified Pul's Method</u>
- ➢ <u>Flood Estimation for Large Catchments</u>

The software provides a user-friendly environment. It also includes on-line help to guide the user for each module. Sample data has been included in the package for easy preparation of input files. The results are in the form of tabular and graphical options facilitating efficient analysis and reporting and are subjected to the assumptions and limitations of the respective techniques on which the programmes are based. The package provides useful information regarding the flood estimation which is very much useful to the field engineers.

The main screen, sample data entry screen and sample graphical results are shown in Figures 1, 2 and 3 respectively.

Figure 1: Main Screen of NIH_FLWin Package

Figure 2: Sample Data Entry Screen

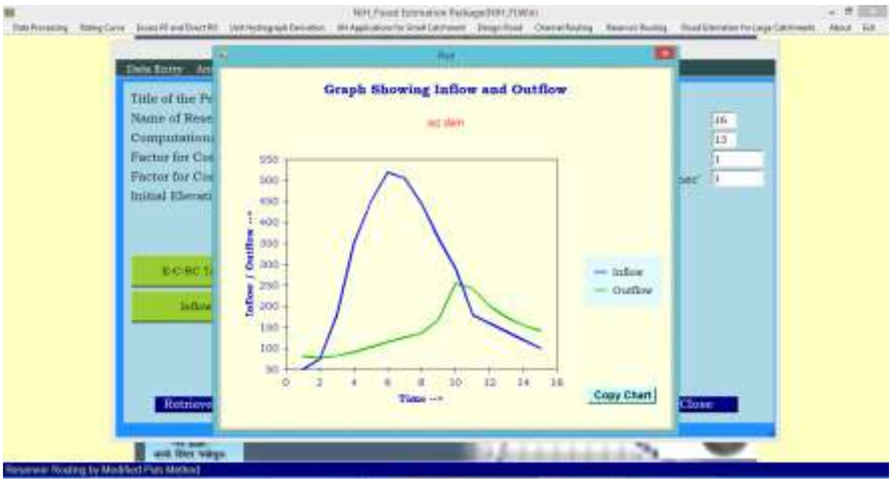


Figure 3: Sample Graphical Results

ONGOING STUDIES

INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/01

1. **Thrust Area under XII five-year Plan**
Food security and the sustainable management and use of water resources

2. **Project team:**
a. Project Investigator: Dr. P. K. Singh, Scientist 'D'
b. Co-PI Project Co-Investigator(s): Dr. P. K. Mishra, Scientist 'C'
Dr. M. K. Goel, Scientist 'G'
Er. Suman Gurjar, Scientist 'C'

3. **Title of the Project**– Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework

4. **Objectives-**The major objective of this study is to apply newly developed WA+ framework for Subarnarekha river basin in India. The objectives of this study includes assessment of:

    1. Agricultural water consumptions using green water and blue water concept
    2. Total water withdrawals and their partitioning in to surface and groundwater withdrawls
    3. Land productivity and water productivity for food security
    4. Consumed and non-consumed water along with beneficial and non-beneficial consumptions
    5. Water scarcity and develop water allocation plans from water demand and water supply statistics
    6. Available, exploitable, utilized and utilizable water resources

5. **Methodology**
The Water Accounting Plus system (WA+) is based on open access remote sensing data -in conjunction with open access GIS data and hydrological model output. WA+ communicates information on water storage, flows and fluxes for a variety of land use systems using eight intuitive fact sheets, tables and maps that are designed to be 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) 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). 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.

6. Present progress (Objective-wise):

Sl. No.	Objectives	Progress
1:	Agricultural water consumptions using green water and blue water concept.	These four objectives have been achieved and completed so far. A research paper based on the findings is ready for
2:	Total water withdrawals and their	

	partitioning in to surface and groundwater withdrawals.	submission to the Current Science Journal.
3:	Land productivity and water productivity for food security.	
4:	Consumed and non-consumed water along with beneficial and non-beneficial consumptions.	
5:	Water scarcity and develop water allocation plans from water demand and water supply statistics	The demand and supply scenario for different years have been developed using Sheets 4&6. The results will be critically analysed and the outcome will be presented.
6:	Available, exploitable, utilized and utilizable water resources	An overview of the water resources availability in the basin will be estimated (Sheet 5 and Sheet 1) and the findings will be compared with the field/secondary data sources (e.g., CWC) in the basin. This work will be completed by the end of the December 2020 and final report will be submitted.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/02

1. Thrust Area under XII five-year Plan

Flood modeling and inundation mapping

2. Project team:

Dr. Vishal Singh, Scientist C
Dr. A K Lohani, Scientist G

3. Title of the Project -
Real time flood modelling in Southern River basin using HEC-RTS modelling framework.

4. Objectives

The present research work shall explore the flood discharge and their inundation in the Southern river basin. During extreme high rainfall events, the frequency of flood events increases. The high amount of flood discharge may cause severe flood conditions in the downstream portion of the river basin. A destructive flood hazard has been recently happened in the Kerala state of India (2018) during monsoon season. Therefore, the purpose of this research work is to provide the advance research and engineering guidelines as per the adopted approaches and methodologies for the hydrological and hydrodynamic assessment of the flood discharge and inundation in the Southern river basin under extreme scenarios. Based on current research needs, following are the research objectives defined:

1) To process and accuracy assessment of the rainfall dataset over the selected river basin by utilizing satellite-based rainfalls (e.g. TRMM+GPM) and measured rainfalls (e.g. IMD gridded rainfalls).
2) Construction of the hydrological model (i.e. HEC-HMS) to generate stream flows at different sections of the river channels.
3) Climate change assessment on Periyar river flood flows utilizing GCMs/RCMs and Statistically downscaled multi-model CMIP5 GCMs datasets.
4) Generation of flood discharges at different sections of rivers and the development of flood inundation maps in a stochastic manner including multiple return periods (e.g. 20 year, 50 year, 100 year, 500 year and 1000 year).
5) Construction of the 2D Flood model by the coupling of hydrological model (i.e. HEC-
6) HMS) and hydrodynamic model (i.e. HEC-RTS) named as HEC-RTS framework.

5. Study Area

For the present research work, the Periyar river basin has been selected as shown in Figure 1.

6. Methodology

6.1 Dataset

For the proposed study, the real time time-series rainfall datasets with high spatial resolution along with other meteorological variables (e.g. temperature, humidity, radiation, wind etc.) will be utilized from different sources such as India Meteorological Department Rainfalls, APHRODITE rainfalls, TRMM rainfalls etc. Similarly, other meteorological variables will also be acquired from these organizations. The high resolution digital elevation model (DEM) and other thematic layers such as land use/land cover (LULC), Soil map will also be utilized. The hydrodynamic parameter/datasets will be collected from the nodal agencies and on the field as per their requirements. The overall methodology has been classified into three components as given below:

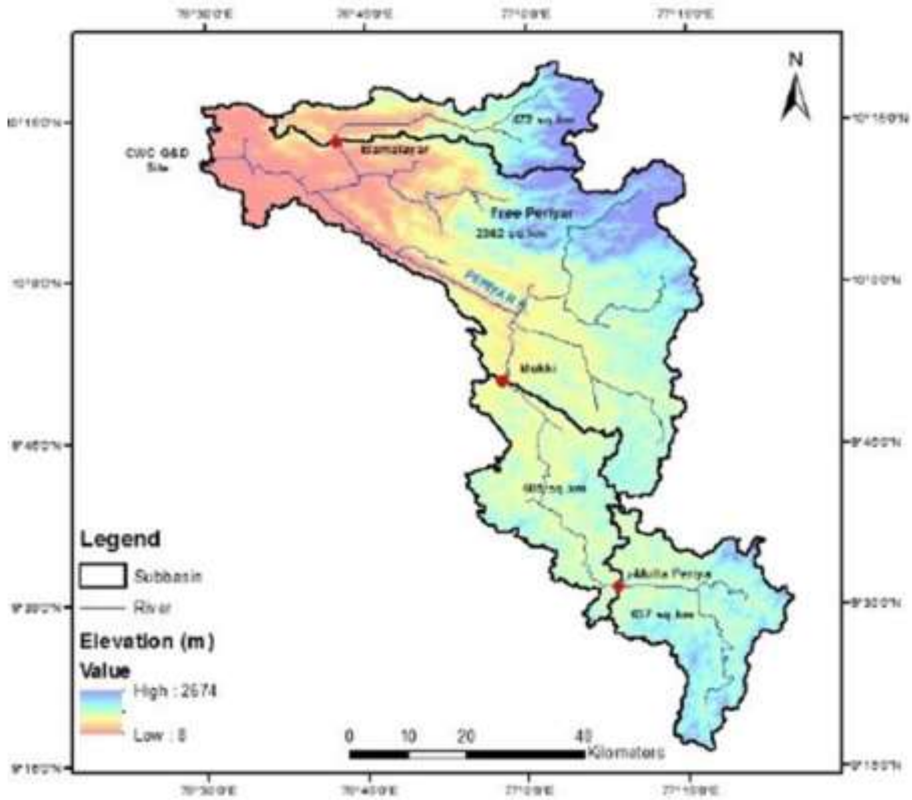
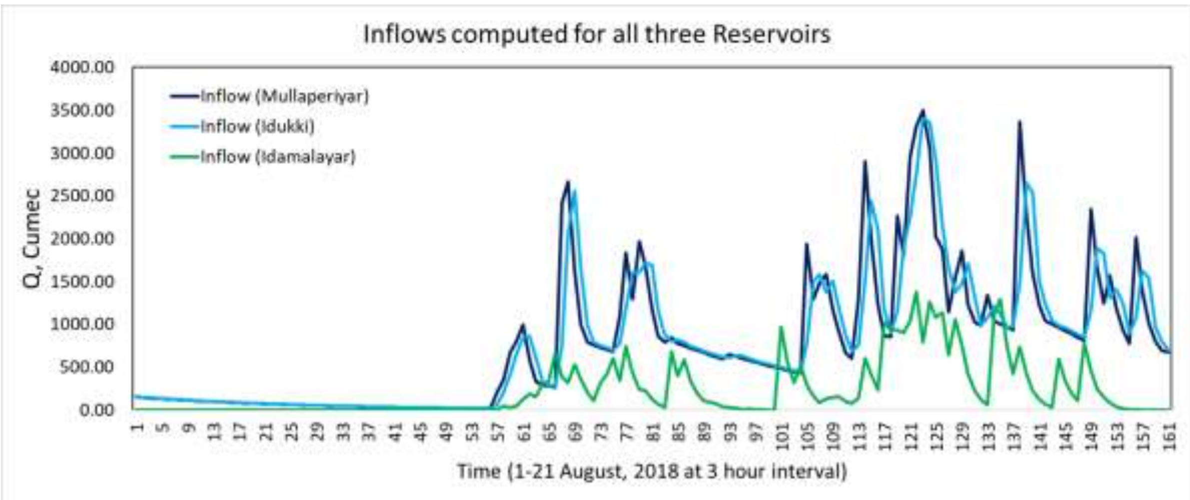


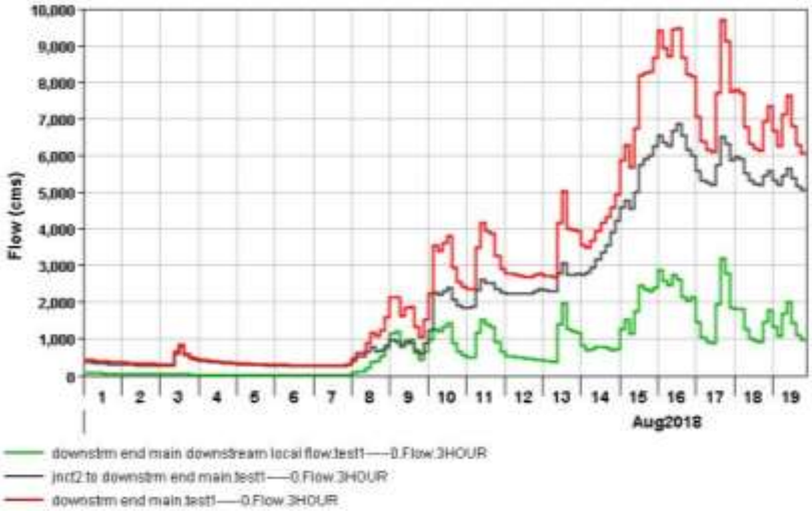
Figure 1: Periyar river basin highlighting the locations of targeted reservoirs (in red circle).

7. Progress Results (till August, 2020):

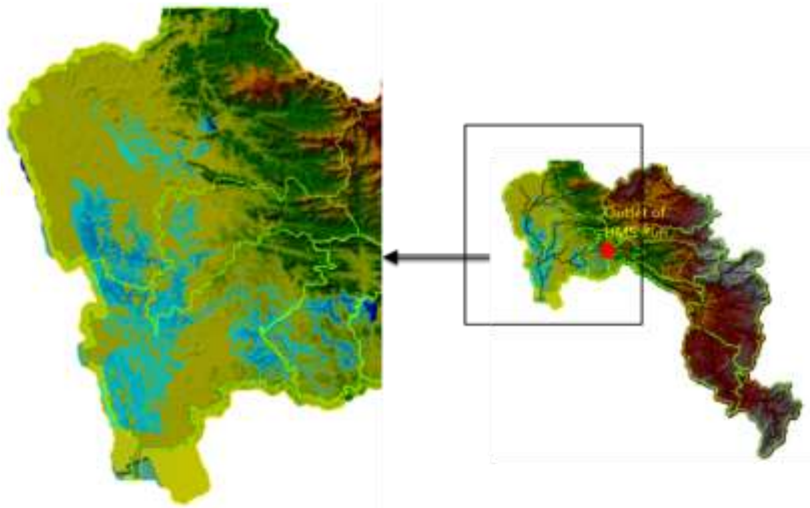
7.1. Computation of inflows to reservoir



7.2 Floods at the outlet i.e. Neeleswaram gauge during the main flood event time (1-19 August, 2018)



7.3. Flood Inundation Map as per the Flood Event "1st Aug to 18 Aug, 2018.

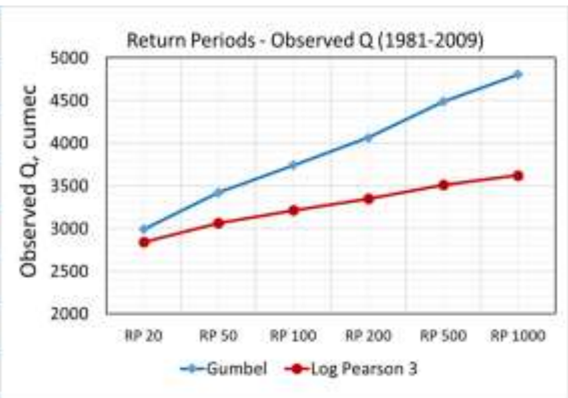


8. Flood Frequency Analysis

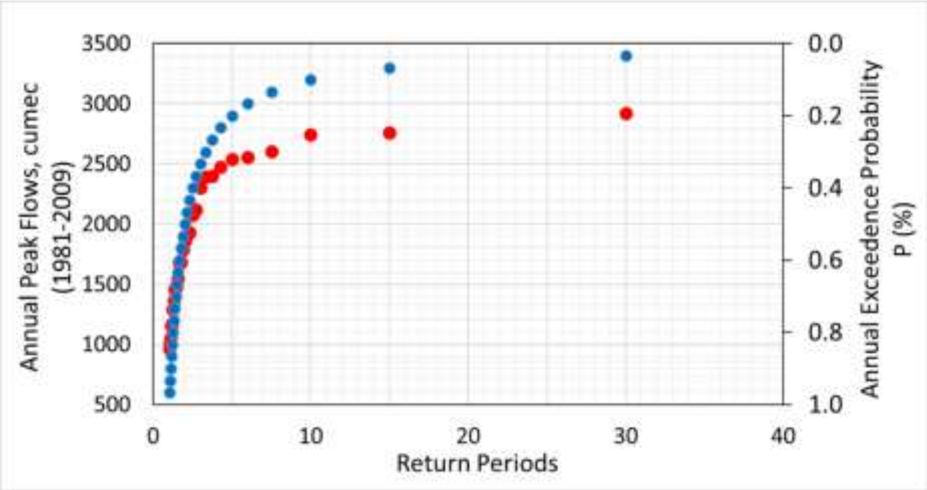
8.1 Method used: Gumbel and Log Pearson Type III

Datasets utilized: (1) Observed Daily Flows at Neeleswaram - (1981-2009)
(2) Observed Daily Rainfall (5 stations) - (1981-2009)

Return Periods	Observed Q (1981-2009)	
	Gumbel	Log Pearson 3
RP 20	2989.86	2840.20
RP 50	3419.70	3065.97
RP 100	3741.80	3214.52
RP 200	4062.73	3349.13
RP 500	4486.13	3510.54
RP 1000	4806.13	3622.65



8.2 Annual Peak Flows, Return Periods and Annual Exceedance Probability



8. Objectives vs achievement

1. To process and accuracy assessment of the rainfall dataset over the selected river basin by utilizing satellite-based rainfalls (e.g. TRMM+GPM) and measured rainfalls (e.g. IMD gridded rainfalls) – Completed.

2. Construction of the hydrological model (i.e. HEC-HMS) and reservoir simulation (using RESSIM) to generate stream flows at different sections of the river channels during Kerala flood event 2018 – Completed.

3. Climate change assessment on Periyar river flood flows utilizing GCMs/RCMs and Statistically downscaled multi-model CMIP5 GCMs datasets - On going

4. Generation of flood discharges at different sections of rivers and the development of flood inundation maps in a stochastic manner including multiple return periods (e.g. 20 year, 50 year, 100 year, 500 year and 1000 year) – Partially Completed.

5. Construction of the 1D/2D Flood model by the coupling of hydrological model (i.e. HEC-HMS) and hydrodynamic model (i.e. HEC-RTS) named as HEC-RTS framework- Partially Completed.

9. Work to be done in next step (till December 2020)

1. Simulation of final flows for the historical event (2018) at each catchment using HMS incorporating reservoir parameters and elevation-area-storage-discharge function.
2. Long term Simulation water balance components and boundary condition flows (local flows) using historical daily meteorological and GCMs based datasets by HEC HMS.
3. HEC-RAS 1D model setup and generation of flood flows, Flood Depth and inundation maps using outcomes of daily historical and GCMs based simulations from HEC-HMS.
4. Station wise flood frequency analysis (FFA) and computation of different return period flood maps.

ONGOING STUDIES
INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/03

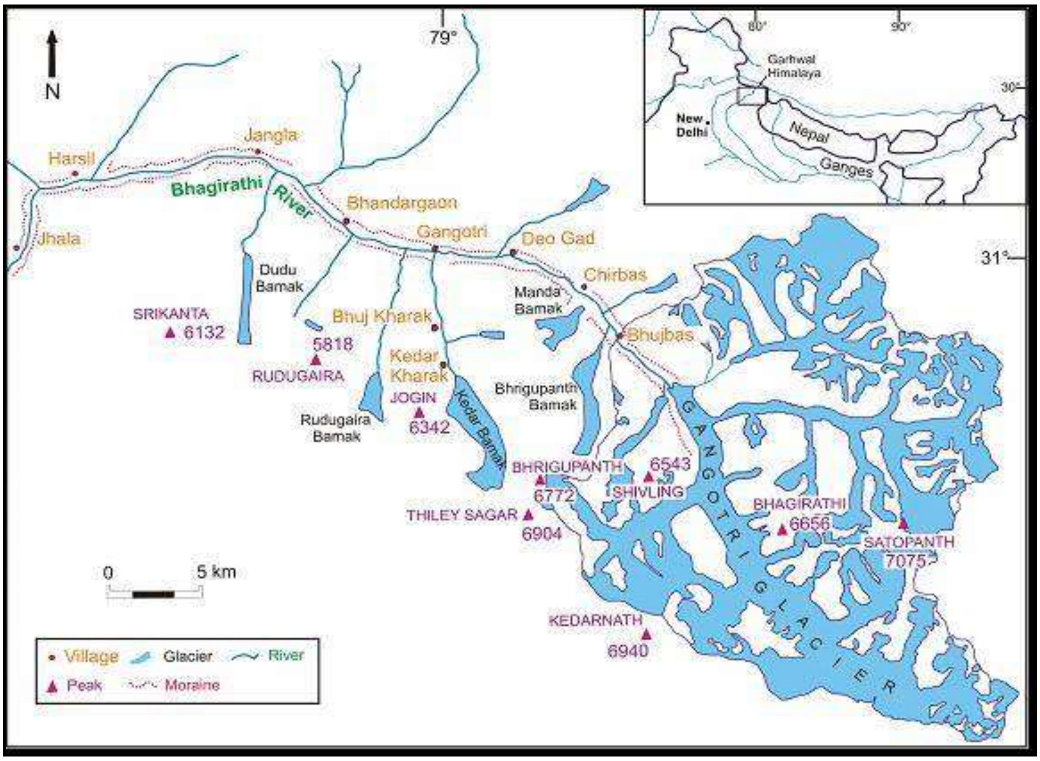
1. Title of the Study: Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios.

2. Study Group: Dr Manohar Arora, Scientist 'E'
Dr Sanjay Kumar Jain, Scientist 'G'

3. Type of Study: Internal. Project will be submitted to DST for funding.

Date of start: 01.04.2018
Scheduled date of completion: 31.03.2021.

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. Action Plan

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

7. Objectives vis-à-vis Achievements:

Objectives	Achievements
Continuous monitoring of meteorological and hydrological data for monthly and seasonal specific water yield and its variability from the year to year	The data collection and field investigations for the year 2019 commenced in the month of May 2019 and were carried out till 3rd October 2019. However, due to Covid 19 no field investigations was initiated for ablation season 2020.
To improve the hydrological model for simulating daily streamflow	The simulation of flow will be carried out after collection of three years of data.

ONGOING STUDIES

SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/01
NMSHE STUDIES

1. Title - Development of a project website and hydrological database in Upper Ganga basin

2. Study team

1. Dr. M. K. Goel, Scientist 'G'
2. Dr. M. Arora, Scientist 'E'
3. Dr. A. K. Lohani, Scientist 'G'
4. Mr. D. S. Rathore, Scientist 'F'
5. Mrs. D. Chalisgaonkar, Scientist 'G'
6. Dr. A. R. S. Kumar, Scientist 'F'
7. Dr. Surjeet Singh, Scientist 'F'
8. Mr. P. Mani, Scientist 'E'
9. Dr. A. Sarkar, Scientist 'E'
10. Dr. M. K. Nema, Scientist 'D'
11. Smt. Suman Gurjar, Scientist 'C'
12. Dr. P. K. Mishra, Scientist 'C'

3. 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.	Temperature data processing is in progress
Assessment of adequacy of hydro-meteorological network in study area.	In progress
Investigation and referencing of available spatial database from various sources.	In progress
Capacity building for use of hydrological data entry and processing software.	To be taken up after the processing of temperature data
Development of interactive project web site with hydrological information system.	Has been developed and is being continuously updated.

4. Sponsored by DST, New Delhi

5. Project Cost Rs.113.22 Lakh

6. Brief Background

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

Data collected on hydrologic variables are generally raw which may not be used directly in most hydrologic analysis work. Processing of hydrological data has two major objectives: one to evaluate the data for its accuracy and the other to prepare the data in a form valuable to the users. The rapid advance in computer technology, in speed of operation and data storage capacity as well as the capability of hydrological software has greatly simplified the management of large quantities of hydrological data. All hydrological datasets can be maintained in well-defined computerized databases using standard database management system. Surface Water Data Entry System (SWDES), developed under Hydrology Project – I, and HYMOS software can be used for entry and processing of hydrological data in standardized format. This is essential for the long-term sustainability of the datasets in proper form and their dissemination to the end users. Both, raw and processed data sets are to be properly stored and archived to specified standards so that there is no loss of information. NIH has trained manpower on SWDES and HYMOS software which can be used entry and process the hydrological database for the Upper Ganga basin up to Rishikesh and to build capacity in other organizations dealing with hydrological data for their effective utilization.

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

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

7. Present Progress

All the hydro-meteorological data (IMD and CWC) for various stations in/around the Upper Ganga basin has been imported in HYMOS data processing systems and processed using various techniques. Using the data of spatially correlated stations, the missing gaps have been gap-filled and consistency has been checked using double-mass analysis. The correction for double mass has been carried out for Nandkeshari, Uttarkashi, Badrinath, Narendranagar, and Karanprayag stations. For the corrected data, the trend analysis has been carried out for different stations. A view of the trend analysis of rainfall in Upper ganga basin is shown in Table – 1. In addition, trends of flow observations at various gauging sites has been performed which is shown in Figure 1 and the results of trend analysis at different gauging sites are presented in Table – 2. The analysis of trend of temperature in UGB and in Pan-Himalayas is in progress. The project website is also being constantly updated.

Table – 1
Trend analysis of rainfall in Upper Ganga basin

Sl No.	Station	Annual	Pre_monsoon	Monsoon	Post_monsoon	Winter
1	BHATWARI	0.50	1.60	0.42	-1.35	-0.42
2	BHOGPUR	2.22	2.69	2.27	1.01	0.75
3	BIRONKHOL	1.74	2.21	1.54	-0.33	0.21
4	CHAMOLI	2.35	-0.10	2.37	-1.41	-0.52
5	DEOPRAYAG	1.45	0.83	1.27	-1.12	0.04
6	DHANOLTI	1.71	0.06	1.94	-0.70	-1.10
7	DUNDA	0.51	1.20	0.18	-2.50	-0.67
8	GG000Y4 (Rishiikesh)	1.89	1.19	1.80	0.44	0.32
9	GG100A1 (Deoprayag)	1.93	1.56	1.96	-0.30	0.35
10	GG100K4 (Uttarkashi)	2.22	1.91	2.11	-0.54	-0.88
11	GG110A1 (Koteshwar)	1.25	1.65	0.75	-2.21	0.33
12	GG200B5 (Srinagar)	2.00	2.11	2.20	0.63	1.35
13	GG200G5 (Rudraprayag)	1.56	0.29	1.41	-0.44	-0.64
14	GG200S3 (Joshimath)	2.07	0.86	3.10	-2.49	-0.62
15	GG200V5 (Badrinath)	0.86	0.46	1.91	-1.32	-1.65
16	GG260A1 (Karanprayag)	3.17	1.74	3.54	-1.13	-0.97
17	GG260J4 (Nandkeshari)	3.41	1.06	4.20	-1.99	-2.68
18	GGZ00D3 (Marora)	0.75	0.28	2.37	-1.25	-1.19
19	JOSHIMATH	1.49	1.70	1.52	0.43	0.17
20	KEERTINAGAR	-1.03	1.34	-0.42	-1.18	-0.88
21	LANDSDOWN	0.83	1.89	0.80	-1.44	0.23
22	MUKHIM	0.73	0.84	1.21	-1.63	-1.28
23	NARENDRANAGA	1.19	0.39	1.01	0.74	-0.64
24	OKHIMATH	1.69	0.47	1.61	-0.45	-0.88
25	PAURI	1.63	2.17	1.20	0.73	0.91
26	RUDRAPRAYAG	2.37	1.58	2.35	-1.52	-1.71
27	SRINAGAR	2.57	2.25	2.97	0.72	1.39
28	TEHRI	2.18	2.20	2.11	-0.93	0.67
29	TEHRI GARHWA	1.27	2.27	0.64	-1.94	-0.17
30	UTTARKASHI	0.83	1.72	1.05	-0.55	-0.11

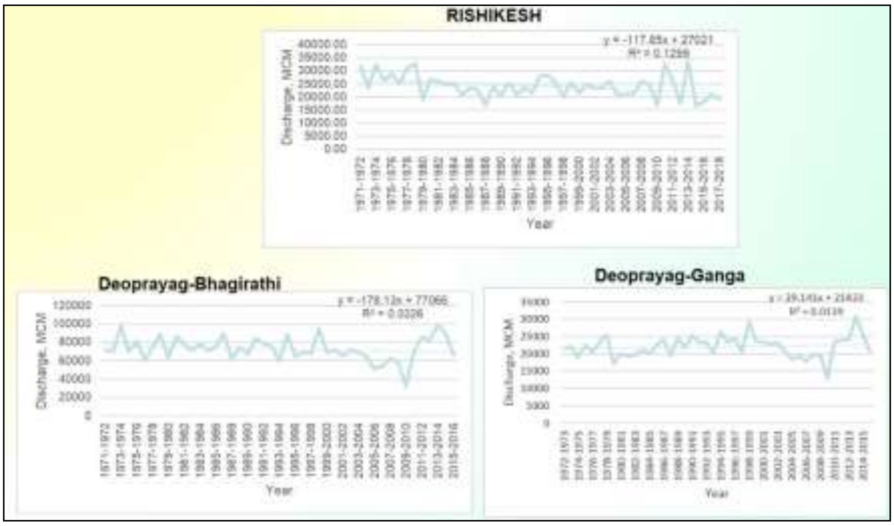


Figure 1: Trends of flow data at various G&D stations in Upper Ganga basin

Table – 2
Trend analysis of flow data at various G&D stations in Upper Ganga basin

S. No.	Station	Annual	Pre_mons.	Monsoon	Post_monsoon	Winter
1	Rishikesh	-2.53	1.01	-3.17	1.61	4.15
2	Deoprayag_Bhagirathi	-1.38	1.16	-4.42	0.13	3.08
3	Deoprayag_Ganga	1.14	0.06	-1.63	1.80	4.18
4	Rudraprayag_Alkananda	5.08	0.50	4.84	2.86	2.27
5	Rudrapraygh_Mandakani	2.04	-0.87	2.46	1.05	2.42
6	Karanprayag	0.54	-1.30	-0.22	3.10	1.73
7	Uttarkashi	-0.70	-1.94	0.28	-2.84	-3.04
8	Morara	-0.32	-0.36	-0.15	-0.15	-0.15
9	Joshimath	-0.51	-2.48	-0.64	-2.13	-1.60

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2019-20/02
NMSHE STUDIES

1. Title - Real-time snow cover information system for Upper Ganga basin

2. Project team

a)	**Project Investigator:**	D. S. Rathore, Scientist 'F'
b)	**Project Co- investigators:**	Deepa Chalisgaonkar, Scientist 'G' 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

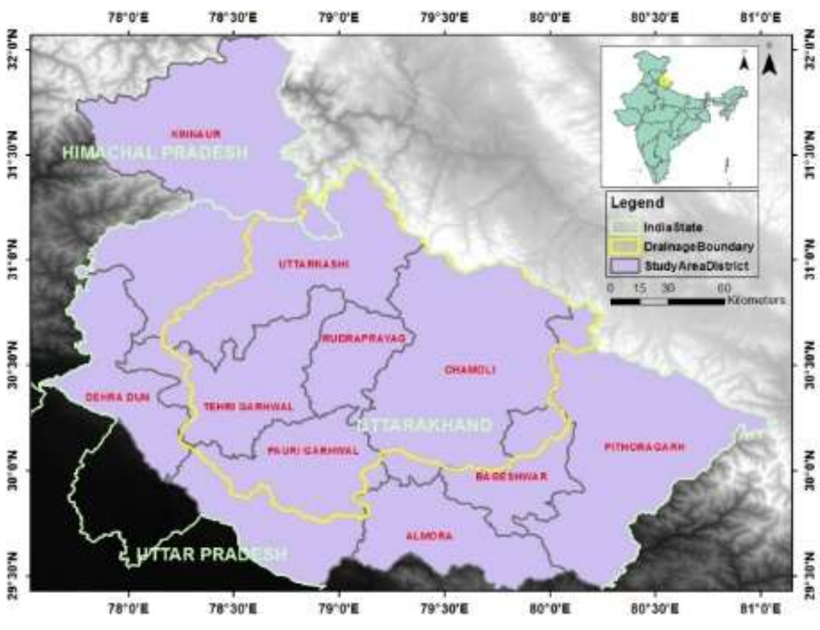


Figure 1: Upper Ganga basin

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.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/03
NMSHE STUDIES

1. Title - Glacial Lakes and Glacial Lake Outburst Flood (GLOF) in Western Himalayan region

2. Study team

1. Dr. Sanjay K. Jain, Scientist 'G'
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. 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 Preparation of cross section, bank stations, flow paths along the river Preparation of lake information	Completed
4	GLOF modeling using the hydro-dynamic mathematical modeling 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

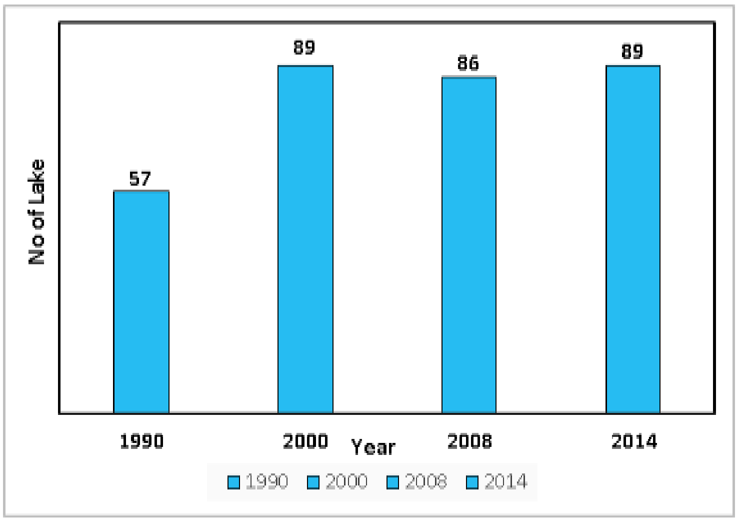


Figure 1: Number of Lakes of different years in Chenab basin

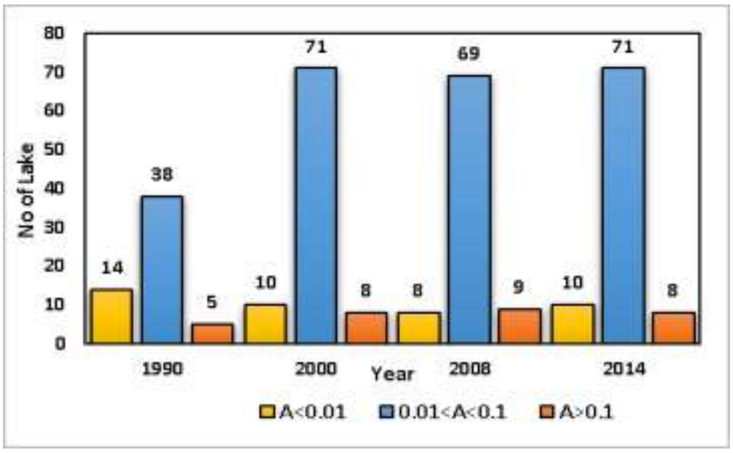


Figure 2: Number Frequency of lakes of different area ranges in Chenab basin

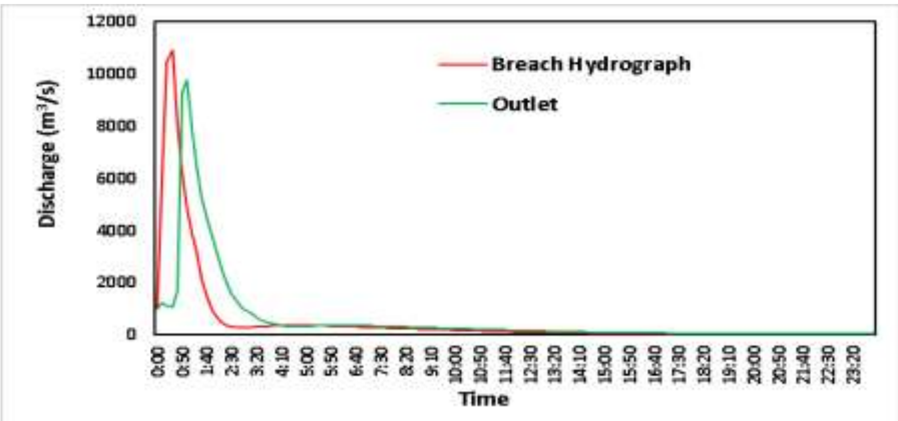


Figure 3: GLOF Hydrograph at Outlet from Lake

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/04
NMSHE STUDIES

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change
2. **Project Team:**
    1. Dr. Renoj J. Thayyen, Scientist 'E'
    2. Dr. Sanjay K. Jain, Scientist 'G'
    3. Dr. Sharad K. Jain, Retd.
    4. Dr. P. K. Mishra, Scientist 'C'
    5. Dr. M. Arora, Scientist 'E'
    6. 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 inter-annual variations and long-term trends will be assessed.

B) Weather monitoring near Harsil: Weather data at the high altitude Himalayan region is very sparse. Hence orographic processes of the Himalayan slopes are poorly understood. Recent studies have shown that the orography is a key factor controlling the weather variables in the Himalaya. A full-fledged automatic weather station with four component radiometer, precipitation gauge and soil heat flux sensors will be installed near Harsil. Data from this weather station will be used for runoff modelling and climate downscaling.

C) Runoff modelling: Runoff modelling will be carried out by snowmelt runoff model. The glacier melt component in the discharge will be derived through modelling exercise. Glacier change in the Bhagirathi catchment during the past three decades will be estimated and correlations will be established between temperature/precipitation variations in the catchment with that of glacier change with the help of reanalysis data. Future glacier area change will be determined by using the inputs from the climate downscaling exercise and future runoff and glacier component will be modelled.

D) Climate downscaling and future predictions: Climate of the region is dominated by Indian winter monsoon and Indian Summer Monsoon. Keeping such broad scale flow in mind climate downscaling will be done in conjuncture with the study of interaction of large scale monsoonal flow with existing variable topography and to study land surface processes in association with hydrological balance over the region of study with existing CORDEX simulation (from IITM, Pune), downscaling over the catchment region and modelling experiments. As it is understood that the region of study is of complex topography and hence such topography will not be truly represented within the model domain and hence dynamical downscaling will be used to established the atmospheric-topographic interaction in defining primarily precipitation forming processes. Statistical downscaling methods will be used to overcome the coarser horizontal model resolution problem and establish moisture-temperature interplay processes.

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. 159.39 lakhs
NIH	Rs. 86.1
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.

<u>Progress during the reporting period</u>:

The upper Ganga basin (UGB) constituting Bhagirathi and Alakananda basins has been considered as a single hydrological unit with comparable climate forcing across the regions and elevations. Contrary to this view, this study shows three distinct 'topoclimatic zones' in this basin having characteristically different temperature and precipitation distribution as well as differing orographic forcing due to moisture surplus and deficit, especially during summer monsoon months when discharge is high and glacier melt is at its peak. The northern region of the basin is identified as high elevation and high temperature zone (HE-HT) with monsoon moisture deficit. This monsoon deficit region is characterised by higher land surface temperature lapse rate (LSTLR) during July and August (JA) derived from MODIS-LST (11.00 °C/km) as compared to much lower LSTLR of monsoon topoclimatic zone (5.78 °C/km). The nival-glacier regimes of the monsoon dominant and monsoon deficit regions constituted the third topoclimatic zone characterised by High elevation-low temperature zone (HE-LT). This zone has comparatively lower temperature lapse rates (5.26 °C/km) than the immediately lower elevations. This insight is hugely significant as 80% of glacier area in the UGB, including the biggest glacier in the basin, Gangotri glacier is in the monsoon deficit zone. We propose that the orographic forcing in this monsoon deficit zone is regulated by the northern region processes rather than southern slopes. The work is in progress to integrate these topoclimatic zone characteristics into runoff modelling.

Objectives	Status
1. Modelling Glacier, Snow and Rainfall components in the stream flow at Maneri	Partially completed. Refinement in progress
2. Assess the role of glaciers in regulating the inter-annual runoff variations at Maneri	Partially completed. Refinement in progress
3. To establish Cryosphere response to climate variables through climate downscaling and runoff modelling.	Partially completed. Refinement in progress
4. Assessment of future runoff variations at Dabrani/Harsil in response to the climate change.	Partially completed. Refinement in progress

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/05
NMSHE STUDIES

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. R. J. Thayyen, Scientist 'E'
	:	Dr. Sanjay K. Jain, Scientist 'G'
	:	Dr. Surjeet Singh, Scientist 'F'
	:	Dr. P. K. Singh, Scientist 'D'
	:	Dr. P. K. Mishra, Scientist 'C'
	:	Mr. P. K. Agarwal, Scientist 'B'
	:	Dr. A. P. Dimri, Professor, JNU
	:	Dr. (Mrs.) Sangeeta Verma, 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	1^{st} year		2^{nd} year		3^{rd} year		4^{th} year		5^{th} 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}.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/06
NMSHE STUDIES

1. Title - Water Census and Hotspot analysis in selected villages in Upper Ganga basin

2. Study team

1. Dr. P. K. Mishra, Scientist 'C'
2. Dr. Renoj J. Thayyen, Scientist 'E'
3. Dr. M. K. Nema, Scientist 'D'
4. Dr. Pradeep Kumar, Scientist 'D'
5. 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.

<u>Road map/ work components:</u>

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

<u>Activity chart</u>

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. • 218 villages surveyed (5 districts) • 422 households (3 districts) • GIS layers (maps) generated	Completed
2	To map potential water hazard zones in the catchment. • Reported cloud bursts (54 nos.) identified since 2010 • Potential hazard zones due to CBs identified and mapped	Completed
3	To identify hotspot matrix components, hotspots analysis and adaptation strategies. • IPCC's Livelihood Vulnerability Index based critical blocks identification for Uttarkashi, Tehri Garhwal, and Rudraprayag districts. • LVI assessment for Pauri Garhwal and Chamoli district requires collection of household level data. A fifteen-day field visit is planned during 1st week of September, 2020.	Ongoing
4	Report preparation	Ongoing

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/08

1. Title of Project: Investigating water stress using hydro-meteorological and remote sensing data, Purpose Driven Study (PDS), National Hydrology Project (NHP)

2. Project team:

a) **Principal Investigator:** Mr D.S. Rathore, Scientist 'F'

b) **Project Co- investigators:** Dr L.N. Thakural, Scientist 'D'
Dr Sanjay Kumar, Scientist 'F'
Dr R. K. Jaiswal, Scientist 'D'
Dr M.K. Jose, Scientist 'E'
Dr T. Chandramohan, Scientist 'D'

Partner Organization: Water Resources Department, Rajasthan

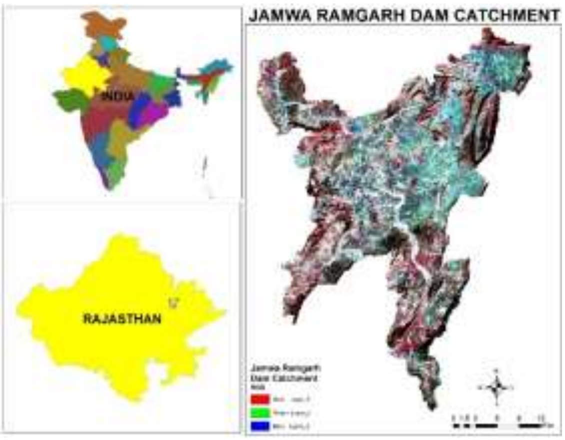
Principal Investigator: Sh Sanjay Agarwal, Deputy Director

Co- investigators: Sh Shailesh Awasthi, Assistant Engineer

3. Objectives

- Characterizing water stress using hydro meteorological, remotely sensed data and vadose zone modeling
- Analysis changes in water stress conditions due to drought response and mitigation measures
- Field level measurements of vadose zone moisture
- Forecasting and regionalizing drought indices
- Devising reservoir operating policy

4. Location map/ study area



Jamwa Ramgarh reservoir catchment is selected as study area. The dam is located on Banganga river. The study area falls in Jaipur district of Rajasthan. Area is located in East Rajasthan meteorological sub- division. Main aquifer system consists of alluvium. Quartzite, gneiss, schist and granite have localised occurrances. Catchment area is nearly 820 sq. km. The dam was built in 1903. The reservoir is dry since 2006. Mean annual rainfall is 492 mm with 36% COV. Normal annual rainy days are 110.

5. Approved action plan and time line

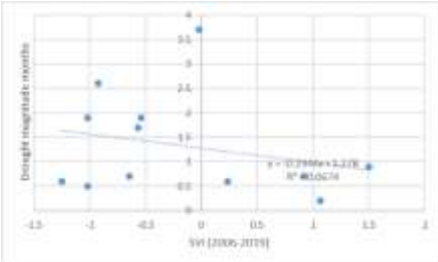
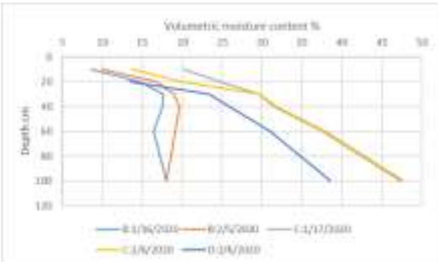
Activity	1st yr				2nd yr				3rd yr			
	I	II	III	IV	I	II	III	IV	I	II	III	IV
Data collection												
Satellite data procurement												
Field observation												
Data pre processing												
Computation of drought indices												
Regionalization of drought indices												
Forecasting												
Drought identification												
Unsaturated zone modeling												

Reservoir operation												
Scenario analysis												

8. Recommendations/ suggestions in previous WG

SAVI can be used in addition to NDVI.

9. Achievements

Year	Objectives	Achievements
2020-21	Characterizing water stress	 SPI for scale 1 to 4 and 12 months were calculated for 1974- 2017. Average drought magnitude its frequency were estimated. Drought magnitude for exceedance probability of 0.1, 0.2, 0.3 was 2.8, 2.1 and 1.9 respectively. Average SVI estimated using MOD13Q1 NDVI for a location. For SVI- drought magnitude regression, R^2 of 0.07. Variation in magnitude of drought magnitude was high for negative SVI. Vadoze zone modeling was done for sandy clay loam and wheat crop. ET was estimated to be 88% for irrigation application of 480 mm.
2020-21	Vadoze zone measurement	 Soil moisture measurements were carried out for two sites (three profiles) using PR6 profile probe during Jan and Feb 2020. Average soil moisture for flood and sprinkler irrigated fields were 30 and 18% respectively.
2020-21	Catchment modeling	Monthly reservoir inflow was estimated using water balance for period 1974- 2006. Catchment area was delineated using ALOS data to determine inland basins of 62 sq. km in extent. Mike SHE model was set up with single aquifer (fine sand), two vegetation classes, crop sequence of maize and wheat, sandy clay loam soil and groundwater pumping and irrigation (21 wells, 9.5% of precipitation). For period 1974- 1985, simulated ET and river flow were 76 and 13% respectively.

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/09

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. Renoj Thayyen, Scientist 'E'
Dr. A K Lohani, Scientist 'G'
Dr. Vishal Singh, Scientist 'C'
Er. Suman Gurjar, 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. Progress till-the-Date

- Database preparation is under progress in GIS. The satellite data have been downloaded and its processing is under progress.
- MOU with the collaborating partners have been signed and the funds have been transferred for starting the works at their end.
- The process for instrumentation procurement is under progress. The position of Research Associate has been filled under manpower in this project.

8. Time-Line and Activities

	Activities	**1st Year**		**2nd Year**		**3rd year**	
NIH	Hiring Manpower						
	Procurement of the instruments						
	Data collection and database preparation						
	Model data need and requirement by other PIs						
	Model simulations and sensitivity analysis						
	Study of impact of climate change						
	Sediment studies						
	GLOF studies						
	Development of a comprehensive and interactive web-enabled database repository						
	Workshops/Trainings						
	Report writing						
CAU	Hiring Manpower						
	Procurement &installation of Met. stations						
	Data collection and Data synthesis						
	Sediment studies						
	Report writing						
JNU & IITM	Hiring of manpower						
	Climate modelling work						
	Report writing						

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/10

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change
2. **Project Team:**
    1. Dr. Renoj. J. Thayyen, Scientist 'E'
    2. Dr. Sanjay K. Jain, Scientist 'G'
    3. Collaborator: Dr. A. P. Dimri, Professor, SES, JNU, New Delhi
4. **Title of the Project:** Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin
5. **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
6. **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.
7. **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.
8. **Cost Estimate:**

Total cost of the project:	Rs. 23.19 lakhs
Source of funding:	NRDMS-DST

9. Progress of the project

Sub-Objectives	Work Done
1. Seasonal Snow loading and unloading estimation from GRACE and comparison with other RS products	Snow cover variation in the Upper Ganga basin is carried out for 2000-2019 period and seasonal loading and unloading pattern established
2. Seasonal mass fluctuation of glacier regime and regional mass balance assessment	Not attempted as yet.
3. Seasonal soil moisture fluctuation in the basin with an emphasis to ISM (JJAS) and IWM (DJF)	Soil moisture data of three existing AWS sites in the Upper Ganga basin has been generated and various RS product is being tested, smap, SMOS etc.
4. Inter-comparison between seasonal river runoff and basin scale mass anomaly from GRACE	Preliminary run of SPHY runoff modelling completed and various Runoff/ water balance components established up to Rishikesh. Need further improvement

ONGOING STUDIES
SPONSORED RESEARCH PROJECT: NIH/WRS/2020-21/11

1. **Thrust Area under XII five Year Plan**: Himalayan Cryosphere and Climate Change

2. **Project Team:**

    1. Dr. Renoj. J. Thayyen, Scientist 'E'

    Institutional Collaborators:

    2. JNU, New Delhi: Prof. A. P. Dimri, SES
    3. GBPNIE, Almorah: Vasudha Agnihotri
    4. Kashmir University: Prof. G Jeelani

3. **Title of the Project:** Permafrost Mapping and Characterization of Ladakh District.
4. **Objectives:**

    1. Modelling of permafrost extent in Leh district of Ladakh region **(NIH).**
    2. Modelling active layer thickness of Permafrost in selected study areas **(NIH).**
    3. Assessment of regional climate and fluxes over permafrost regions (JNU).
    4. Assessment of water quality and bio-geochemistry of permafrost horizon with special emphasis to DOC, DOM, DON and DIN in active layer (GBPNIE).
    5. Assessment of Ground ice melt contribution to Regional Water resources and estimate the sources of local, and transported moisture using isotope technique (KU).

5. Methodology

1. **Modelling of Permafrost extent and active layer thickness (NIH):** Permafrost extent can be estimated only through modelling exercise. Soil temperature is the key input data required for this purpose. Number of soil temperature sensors (30 Nos) will be stablished in selected plots across the Ladakh region. Relationship between Potential Incoming Solar Radiation(PISR) and Mean Annual Ground Surface Temperature (MAGST) will be established and spatial permafrost map will be generated using the GIS. Active layer thickness will be modelled by using "GEOtop" 1D model at select sites with MAGST data.
2. **Surface flux studies based on Regional Climate Model** to integrated assessment permafrost based on the regional climate model outputs, surface fluxes coupled with atmospheric forcing over the study of the region will be analyzed. Rationale over the region of cold desert with sub-surface processes will be defined with the help of model outputs and will be verified with the proposed observations. It should be noticed that over IHR no study thus so far is taken on coupling of atmospheric and surface processes leading to permafrost. Such forcing and process at first scale will be assessed to formulate a link with existing permafrost to late link with available water storage.
3. **Estimation of Ground ice melt contribution and moisture source by isotopic method:** Water samples of precipitation, snowmelt, glacier melt, groundwater, permafrost, streams will be collected across the study area for the hydrochemistry and stable water isotopic analysis. The samples will be collected in the frozen soil region by means of the excavation of the soil profile, and then the meltwater samples will be collected underneath the soil profile. The precipitation samples (event based) will be collected as rain, except in winter when the samples will be collected as fresh snow. Samples will be also collected from melting of snow packs, groundwater, glaciers, streams, permafrost during field campaigns. The samples will be collected in 50 ml high density polyethylene bottles and were kept in laboratory for proper labelling and coding. The stable isotope ratios of oxygen and hydrogen will be measured in a selected national Laboratory. The results of the stable isotopes will be reported in the standard δ-notation, and will be defined in relation to the Vienna Standard Mean Ocean Water. The End Member Mixing Analysis (EMMA) will be used to quantify the contributions of meltwater from snow, glacier and permafrost to runoff at the basin or catchment level.

4. **Assessment of DOC, DOM, DON and DIN estimation in active layer and in permafrost horizon**

Soil cores will be collected (using augur and ice corer) at different selected sites distributed across the Indian Himalayan region, cores will be cut in 15 cm thick sections, and deep active-layer and shallow permafrost sections will be thawed and leached. Leachates will be analysed for DOC, TDN, nitrate (NO_3^-), and ammonium (NH_4^+) concentrations. On and off site physico-chemical analysis of water and soil samples will also be carried out. The analysis will be carried out continuously at the same time throughout project duration for understanding the variations of targeted parameters. Data of permafrost leachates DOC, DON and DIN will be compared with that of active layer soil in contact with permafrost top layer. (The sample will be analysed for radioactive isotopes with the help of other Co-PI).

6. **Research Outcome from the project:**

- Permafrost extend maps of the study region
- Permafrost active layer thickness information at select sites
- Model development for permafrost processes
- Contribution from permafrost to regional water resources
- Regional climate model coupled with permafrost area and surface flux
- Quantification Dissolved Organic matter (DOM), DON and DIN in permafrost soil and meltwater and water quality implications

7. **Cost Estimate:**

Total cost of the project:	Rs. 197.48 lakhs
NIH	Rs. 56.78 lakhs
Source of funding:	NMHS-MoFCC

8. **Progress of the project**

- Singed MoU with collaborating institutes
- Fund transferred
- Recruitment interview held
- Equipment procurement initiated

NEW STUDY

INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/1

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**

   (i) To apply a data assimilation technique and bias correction methods for constructing more accurate high resolution gridded (i.e. approximately at $0.05^{0}\times0.05^{0}$) hydro-meteorological data sets (e.g. precipitation) over the selected river basins.

   (ii) 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.

   (iii) To study the impact of snow and glacier changes on the runoff.

   (iv) To analyze the impact of climate change and the long-term (21^{st} 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 Collection and Analysis:

Table – 1

Details about the input datasets and their sources

Sl No.	DATASET NAME	SOURCES
1	Digital Elevation Model	SRTM/CARTOSAT - Freely available
2	Land use – Land cover Map	Waterbase/ Bhuvan - Freely available
3	Soil map – FAO Global	Waterbase - Freely available
4	Soil map – High Resolution	Future Water, Netherlands – Freely available
5	Satellite data – LISS4, LISS3	NRSC - to be procured
6	Satellite data – Landsat, MODIS, Sentinel	Earth Explorer, NASA – Freely available
7	Precipitation data and other Meteorological datasets	IMD – to be procured
8	Precipitation data and other Meteorological datasets	CHIRP, TRMM/GPM, Other Sources – Freely available
9	Observed discharge	CWC – available on request
10	Climate Models Data (CMIP5/CMIP6	IPCC – to be used/downloaded as per the availabil

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.

6.2 Data assimilation and bias correction

For meteorological datasets, a high resolution gridded daily precipitation dataset ($0.05^{o}\times0.05^{o}$) 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).

6.3 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.

6.4 Snow and Glacier runoff changes

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

6.5 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.

1. Research Outcome from the project:

- Validation of the SWAT model for the Himalayan watersheds under different parameters and variable climatological conditions.
- Assessment of the spatial-temporal variability of the snow cover and glacier areas.
- Assessment of the changes in snow and glaciers and their impacts on runoff.
- Long term simulation and projection of various hydrological components, their trends and results of magnitude of change

2. Cost estimates:

The total cost of the project: **₹ 9.30 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 (JRF/Resource Person)	3,90,000	3,90,000	7,80,000
2	Travelling expenditure	50000	50000	100000
3	Infrastructure/Equipment	0	0	0
4	Experimental /Rental Charges	0	0	0
5	Misc. expenditure	25000	25000	50000
Grand Total				**9,30,000**

3. Work Schedule:

S. No	Works - Time Schedule	2020-21			2021-22		
		8-12	1-4	5-8	8-12	1-4	5-8
1	Data Collection and Pre-Processing	■	■				
2	Integrated Hydrological Modelling		■	■	■		
3	Snow Cover Derivation and Calibration/Validation			■	■	■	
4	Future Projections and Statistical Analysis				■	■	■
5	Articles/Report Writing						■

NEW STUDY

INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/2

1. **Title:** Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya

2. **Project Team:**

   Dr Manish Kumar Nema, Scientist 'D'
   Dr Renoj J. Thayyen, Scientist 'E'
   Dr P. K. Mishra, Scientist 'C'

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**

Experimental hydrology still has a unique place with no alternative for testing and development of new research hypothesis and models. Given the importance of the 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 has been established with a variety of 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 various hydro-climatic variables. This study is planned as the second phase of the project.

The field monitoring of the various variables and development of baseline datasets for 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 the partitioning of rainfall into infiltration and runoff, thus playing a fundamental role in runoff modelling and flood forecasting. Moreover, less accurate measurements can be obtained at a coarse scale (~20 km) using satellite sensors. Finally, spatial downscaling/upscaling approaches can be used to integrate the different techniques, as well as 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:

SN	Description of Activity	2020-21			2021-22				2022-23				2023-24	
		Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2
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				■				■					■

NEW STUDY

INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/3

1. **Thrust Area under XII five Year Plan**: Integrated water resources Management (Integrated operation of reservoirs)

2. **Project Team:**
   a. Project Investigator: Mrs. D. Chalisgaonkar, Scientist 'G'
   b. Project Co-Investigator: 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

NEW STUDY

INTERNAL RESEARCH PROJECT: NIH/WRS/2020-21/4

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 'C'

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 Rockstr¨om, 2006; Rockstr¨om and Gordon, 2001). The Australian Water Accounting Standard (AWAS) developed by the Water Accounting Standards Board (WASB) of the Australian Bureau of Meteorology (BOM) accounts for water withdrawals rather than consumptive use. However, AWAS does not provide any information on rainfed systems and natural evapotranspiration (ET) processes.

The International Water Management Institute (IWMI) developed a WA procedure (Molden, 1997) with the aim of tracking water depletion rather than withdrawals to avoid errors when neglecting recycling, and to account for ET. The IWMI WA framework has been applied by IWMI in many irrigation system studies (e.g., Bhakra system in India (Molden, 1997); Zhanghe Irrigation System in China (Dong et al., 2004)) and at the national scale (e.g., India: Amarasinghe et al., 2007; SriLanka: Bastiaanssen and Chandrapala, 2003). However, only a few countries have adopted these WA mechanisms usually due to the lack of data needed to implement these approaches.

6. Methodology

The Water Accounting Plus (WA+) Framework is based on open access remote sensing data -in conjunction with open access GIS data and hydrological model output. WA+ communicates information on water storage, flows and fluxes for a variety of land use systems using eight intuitive fact sheets, tables and maps that are designed to be understood by people with technical and non-technical backgrounds alike.

The WA+ framework is developed by IHE-Delft in partnership with IWMI, FAO, and the World Water Assessment Program (WWAP). WA+ is based on a mass water balance approach (at the pixel level) and uses Budyko theory (Budyko, 1974) (Figure 1) and WATERPIX model (IHE, 2016) for this purpose. The basis of this water balance approach is that outflow from a certain area of interest (e.g., river basin) are explicitly related to the net inflow and depletion through a measurable ET processes.

WA+ framework classifies land use land cover (LULC) in to 80 classes. These 80 LULC classes are further grouped under four main Water Management Classes (WMC), i.e., Protected Land Use (PLU), Utilized Land Use (ULU), Modified Land Use (MLU), and Managed Water Use (MWU) (Figure 2). WA+ framework uses the Budyko theory (Budyko, 1974) for measurable ET separation in to ETgreen and ETblue. The Budyko theory is based on the coupling of (a) Water Balance approach and (b) Energy Balance approach. The water balance is performed individually for green and blue pixels, respectively.

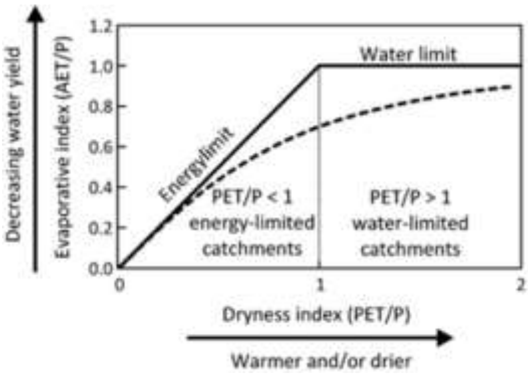


Figure 1: Budyko Framework **Figure 2: WA+ Based WMC**

6.1 Study Area and Major Input Data

The state of Meghalaya is the north eastern part of India and is bounded in the north and east by Assam plains and in the south and west by Bangladesh plains. In the north, it is bounded by Kamrup and Goalpara districts of Assam and on the east by Karbi Anglong and North Cachar. The southern border is the international border with Bangladesh which is about 496 km long. Meghalaya is located between 25º01'51.58" N to 26º07'10.31" N latitude and 89º49'10" E to 92º48'04" E longitude with altitude ranging from 50 to 1966 meters. The State covers geographical area 22,429 km^2. Figure 3 shows the basin map of the Meghalaya state.

The WA+ framework makes use of open source remote sensing data in an effort to maintain a high level of transparency. Remote sensing is a reliable and objective source of data. Data products from the National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) are provided free of charge for all users regardless of nationality or intended application. Following datasets will be used for WA+ analysis in this study:

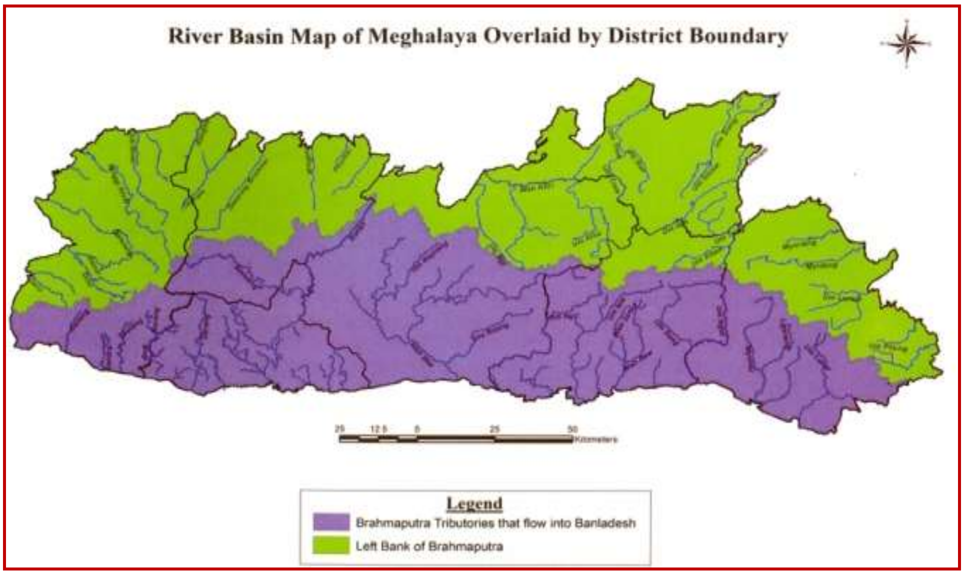


Figure 3: River basin map of Meghalaya overlaid by district boundary
(Source: WRD, Meghalaya)

- Precipitation (CHIRPS - or TRMM rainfall)
- Evapotranspiration (MODIS/ ETensV1.0/GLDAS)
- Meteorological data (GLDAS-Noah)
- WA+ system based Land Use / Land Cover (WALU using GlobCover, IWMI crop maps, MODIS, FAO, etc.)
- Soil moisture (EUMETSAT-ASCAT: Advanced SCATterometer (ASCAT)/GLDAS
- Vegetation, leaf area index (MODIS)
- Net primary production (NPP) and gross primary production (GPP) (MODIS)
- Crop types and crop calendar
- Basin DEM, boundary, drainage network map, etc.
- GRACE (Gravity Recovery and Climate Experiment) dataset
- GMIA (Global Map of Irrigated Areas) dataset
- MIRCA (Monthly Irrigated and Rainfed Crop Areas) dataset
- Grey Water Footprint/WPL datasets

7. Research Outcome from the Project:

- Water Accounts: Supply-Demand and Consumptions and Water Availability
- Water Consumption Patterns and beneficial non-beneficial consumptions.
- Accounts for Land Productivity and Water Productivity.
- LULC map, soil maps, and river networks.
- WA+ Report and Recommendations.
- Training modules on WA+ Framework.

8. Cost Estimates:

The total cost of the project: **₹ 14.50 Lakh**

a. Source of funding: NHP

b. Sub-head wise abstract of the cost:

Head	Amount (in Lakh)		
	1st Year	2nd year	Total
1: Manpower: JRF @31,000/ + HRA and others	5.00	5.00	10.00
2: Others (Hiring of services, field visits, consumables, stationary, printing of reports & brochures, and sample analysis, etc.)	1.00	1.00	2.00
3: Travel Expenditure	1.00	1.00	2.00
4: Contingency	0.25	0.25	0.50
Grand Total			14.50
	Rs. Fourteen Lakhs Fifty Thousand Only		

9. Work Schedule

a. Probable date of commencement of the project:

b. Duration of the project: 02 Years

c. Stages of work and milestone: Shown below

Project Year	**Aug. 2020-July 2021**				**Aug. 2021-July 2022**			
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							↔	↔

RESEARCH MANAGEMENT AND OUTREACH DIVISION

Scientific Manpower

S N	Name	Designation
1	Dr. V. C. Goyal	Scientist G & Head
2	Er. Omkar Singh	Scientist F
3	Dr. A. R. Senthil Kumar	Scientist F
4	Dr. (Mrs.) Jyoti P. Patil	Scientist D (LCU)
5	Er. Digambar Singh	Scientist C
6	Sri. Rohit Sampatrao Sambare	Scientist B
7	Sri Subhash Kichlu	PRA
8	Sri Rajesh Agrawal	SRA
9	Sri N. R. Allaka	RA

Recommended Work Program for the Year 2020-21

SN	Title of Project/Study	Funding	Study Team	Duration	Status
Internal Study					
1	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system	NIH, CEH-UK	NIH: Omkar Singh (PI) V C Goyal, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka; CEH-UK: Prof. Laurence Carvalho & Team	Apr 2018-Mar 2021	On-going
2	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	Jul 2020-Dec 2022	New
3	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	NIH	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Jul 2020-Jun 2022	New
4	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.	Jul 2020-Jun 2022	New
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-Mar 2021	On-going
2	Rejuvenation of village ponds in identified villages of Baghpat, Ghaziabad and Meerut districts of Uttar Pradesh	MoJS (through Scheme funds)	Omkar Singh (PI), Rajesh Singh, V C Goyal, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka	Jan. 2018-Dec. 2020	On-going
3	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/Workshops during 2020-21

S.N.	Outreach Activity	Tentative Date & Month	Place	Target Participants	Team
1	Training on ‘Water security for resilience to deal with disasters and outbreaks’, under aegis of INC-IHP (proposal approved by Director, NIH)	Nov. 2020	Virtual training	Youth and YPs associated with WR Assessment & Management	V C Goyal, Jyoti P Patil, Amrendra Bhushan, Victor Shinde (NIUA)

2	Hands-on training on 'Life Cycle Approach for rejuvenation of ponds and lakes using Nature Based Solutions', to be funded by SERB, DST, GoI (proposal approved by Director, NIH)	Dec. 2020	NIH Roorkee	PG and PhD students of Water resources management/ engineering	Jyoti P Patil, V C Goyal, Omkar Singh, T Thomas, Rajesh Singh, Rohit Sambhare
3	Three-day training program on "Hydrology of water bodies and their development under climatic uncertainty"	Jan 2021	NIH Roorkee	Engineers in Irrigation/PHE/ SWC departments	A. R. Senthil kumar, Santosh M Pingale, Rohit Sambare, N R Alakka
4	Awareness program on Ecohydrology for Wetland Conservation	Feb./ Mar. 2021	NIH Roorkee	Research scholars, and PG students	Rohit Sambare, Suhas Khobragade
5	Awareness Program for School Children	Oct/Nov 2020	5 Schools in Roorkee/ Nearby Roorkee	School Children	Digambar Singh, Omkar Singh, Subhash Kichlu, Rajesh Agarwal, N R Allaka
6	Awareness Programme on "Water quality and water budgeting in 5 sub Villages of Ibrahimpur Masahi", Dist. Haridwar	Feb/Mar, 2021 (5 days)	Vill. Ibrahimpur Masahi,	Progressive Farmers	Omkar Singh, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agarwal, NR Allaka

Proposed Outreach Activities during 2020-21

S.N.	**Activity**
1	Preparation of a guidebook on 'Role of hydrology in district level planning' (V C Goyal, Jyoti Patil)
2	Preparation of Short Videos (5-10 min) on i) CW & FW/Nature Based Solutions/ Pond Rejuvenation ii) Wetland Hydrology iii) Crop diversity, water productivity & farmer's income iv) On studies and projects of NIH Scientists
3	River Walk of Solani River (stretch to be identified)
4	Any other outreach activity on demand/assigned

Internal Study- 1 (ongoing)

1. **Title of the Study:** Conservation of ponds in Ibrahimpur-Masahi village and performance evaluation of natural treatment system.
2. **Study Group:**

Lead Organization	**Project Investigator** Er. Omkar Singh, Scientist F, RMOD
	Co-Investigators Dr. V. C. Goyal, Scientist G & Head (RMOD) Dr. Rajesh Singh, Scientist D, EHD Er. Digambar Singh, Scientist C, RMOD
	Scientific/Technical Staff Sh. Subhash Kichlu, PRA Sh. Rajesh Agarwal, SRA Sh. N.R. Allaka, RA
Partner Organization	Prof. Laurence Carvalho & Team, UK Centre for Ecology & Hydrology, Edinburgh, United Kingdom

3. **Type of Study:** Mainly Internal funded study with partial assistance by UK-CEH (under UK-India SUNRISE Scheme) to cover expenses towards O&M of CW, WQ sampling/analysis, etc.
4. **Nature of Study:** Applied
5. **Date of start:** April 2018
6. **Scheduled date of completion:** March 2021
7. **Duration of the Study:** 3 Years

8. **Study Objectives:**
   - Water quality investigations of identified ponds, village wastewater and adjacent groundwater sources (handpumps)
   - Performance evaluation of CW based Natural Treatment System and assessment of treated wastewater for fishery/agriculture
   - Societal impact assessment of NTS and Mass Awareness Activities

9. **Statement of the Problem:**

In our country, most of the traditional sources of water (i.e. ponds) in villages are on the verge of disappearing/shrinking due to encroachment, siltation and water quality deterioration and face severe eutrophication mainly due to untreated input of wastewater in the ponds. In this context, the Institute has rejuvenated a pond (Village: Ibrahimpur Masahi, Tehsil-Bhagwanpur, Dist. Haridwar) by establishing CW based Natural Treatment System (NTS). The rejuvenated ponds with treated wastewater will be used for agricultural use and other livelihood activities such as fishery. The performance evaluation of this system is necessary to establish its feasibility and replicability in other village ponds receiving continuously input of domestic wastewater into the village ponds. Therefore, it proposed to monitor important water/wastewater quality parameters at two ponds, namely Ibrahimpur Masahi (receives village wastewater through constructed wetland) and Masahi Kala (control pond/reference pond: pond without any treatment system). The UK-Centre for Ecology & Hydrology, United Kingdom is also associated in this study. The sampling locations at village pond having CW-NTS located at Ibrahimpur Masahi is given in Fig. 1.

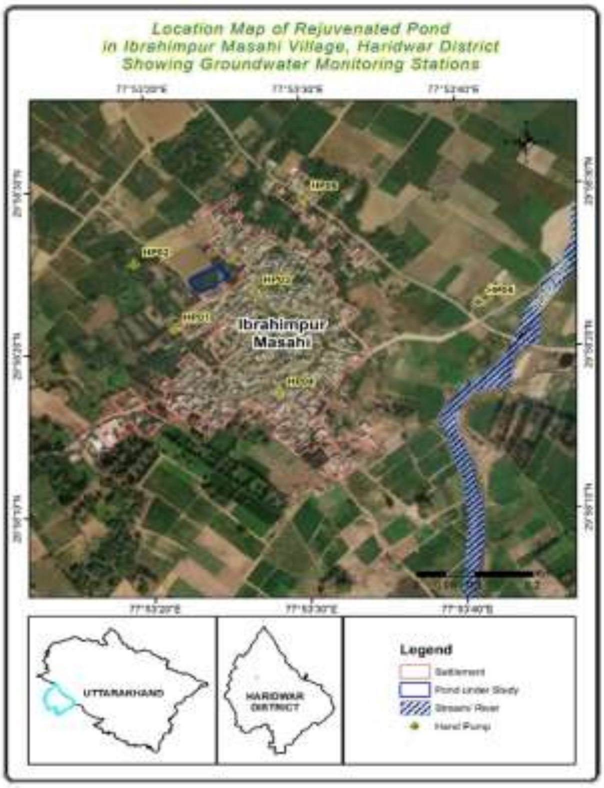


Fig.1a: Location Map of CW NTS site at Village Ibrahimpur Masahi, Dist. Haridwar

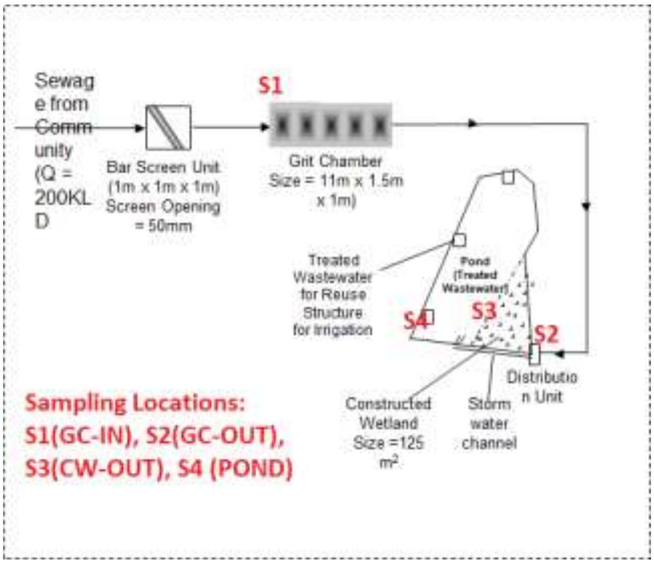


Fig.1b: Flow diagram of CW-NTS showing sampling locations at pond
(Village: Ibrahimpur Masahi, Dist. Haridwar)

10. Approved Action Plan/Methodology:

In this study, the pond, wastewater, and groundwater (hand-pumps) quality will monitored per standard procedures (APHA 2012). Along with UK-CEH team, the health of the water bodies (performance evaluation of CW-NTS pond at Ibrahimpur Masahi with a control pond at Masahi Kala) and its possible impact on society will also be assessed through social survey. Options for the use of treated wastewater will also be explored in the study. The water quality assessment for agriculture purposes (BIS-1987/2001; USDA 1954) and Fishery will be performed as per recommended procedures including development of WQ Indices. Eutrophication of ponds will be assessed using Carlson's Trophic State Index (Carlson, 1977).

11. Timeline:

S. N.	Work Element	2018-19				2019-20				2020-21			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Review of literature												
2	Water quality investigations of identified ponds, village wastewater and adjacent groundwater sources (hand pumps)												
3	Data compilation & performance evaluation of NTS												
4	Societal impact assessment												
5	Mass awareness activities/HH support for fishery cultivation in rejuvenated pond at GP level)												
6	Report Preparation												

12. Objectives and achievement during last twelve months:

Objectives	Achievements
Water quality investigations of identified ponds, village wastewater and adjacent groundwater sources (hand pumps)	• Regular WQ sampling started w.e.f. Nov. 2018 as per schedule. • CEH-UK team collected samples for specific parameters (viz. methane, biota, etc.) during Nov. 2018. • CEH-UK team collected water & WW samples for methane, plankton and benthic fauna from both the ponds and conducted social survey in the village during June, 2019. ***<u>After 49th WG:</u>*** • WQ monitoring & Analysis of key WQ Parameters (pH, EC, DO, BOD, COD, Nitrate, Phosphate & ammonia, etc.) of both identified ponds (Nov., Dec.2019 & March 2020). • GWQ and GWL monitoring and analysis of identified handpumps in Ibrahimpur Masahi.
Performance evaluation of CW based Natural Treatment System and assessment of treated wastewater for fishery/agriculture	• The performance evaluation of CW-NTS based on WQ sampling of important WQ parameters during 2019-20 has been carried out. • Interactions were made with GP & Local Administration (SDM, Bhagwanpur) alongwith UK-CEH team to sort out issues related to rearing of fishery in the rejuvenated pond (March 2020).
Societal impact assessment of NTS (social survey) and mass awareness	• Outreach activity conducted for villagers/Gram Panchayat Members and concerned local State Govt. officials at village Ibrahimpur Masahi (on dated (20/11/2018). • Transfer of CW-NTS to Gram Panchayat was done on 20.11.2018. The SOP for proper operation and maintenance of NTS was also provided to Gram Pradhan, Ibrahimpur Masahi. • Social survey in Ibrahimpur Masahi village with CEH-UK team member (Er. Elliot Hurst) during March 2020 for assessing societal impact due to pond rejuvenation.

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
Nil	-

14. Analysis & Results:

Natural treatment system i.e. constructed wetland has been established in Ibrahimpur Masahi village. I order to evaluate the performance of CW-NTS, water quality of the samples from the treatment chain/units at CW-NTS pond (Ibrahimpur Masahi) and control pond (Masahi Kala) were collected at regular interval. The samples were analyzed for indicator parameters like pH, EC, DO, BOD, COD, NO_3-N, PO_4 and NH_3-N. Detail of water samples collected and various parameters analyzed in laboratory given in Table 1. The variation of key water quality parameters (pH, BOD, COD, DO, Nitrate) is given in Fig. 2 to 6. The results of sstatistical analysis of data pertaining to BOD, Phosphate & E-coli are given Fig. 7&8, respectively. The variation of ground water levels (DTW, m bgl) are given in Fig. 9, which indicates improvement of groundwater levels as compared to pre rejuvenation period of pond (Jan. 2017) with post rejuvenation period (Nov. 2017 onwards).

Table 1: Detail of samples collected from Ibrahimpur-Masahi ponds

Month	Date	Parameter Analyzed in WQ Laboratory
November, 2018	2/11/2018	pH, EC (µS/cm), DO (mg/l), BOD (mg/l), COD (mg/l), TC (MPN/100ml), EC (MPN/100ml, Nitrate (mg/l), Phosphate (mg/l),Ammonia (mg/l), GHG(CEH-UK), etc.
	14/11/2018	Same as above
	20/11/2018	-
	28/11/2018	-
December, 2018	12/12/2018	-
	27/12/2018	-
January, 2019	15/01/2019	-
	30/01/2019	-
February,2019	13/02/2019	-
	28/02/2019	-
March, 2019	13/03/2019	-
	27/03/2019	-
April, 2019	24/04/2019	-
May, 2019	09/05/2019	-
	23/05/2019	-
June, 2019	04/06/2019	Field visit by NIH & CEH-UK team at both pond sites
July, 2019	22/07/2019	-
Sept., 2019	13/09/2019	-
October, 2019	10/10/2019	-
	25/10/2019	
November, 2019	19/11/2019	-
December, 2019	05/12/2019	With CEH-UK team
March 2020	02/03/2020 to 12/3/2020	With CEH-UK team

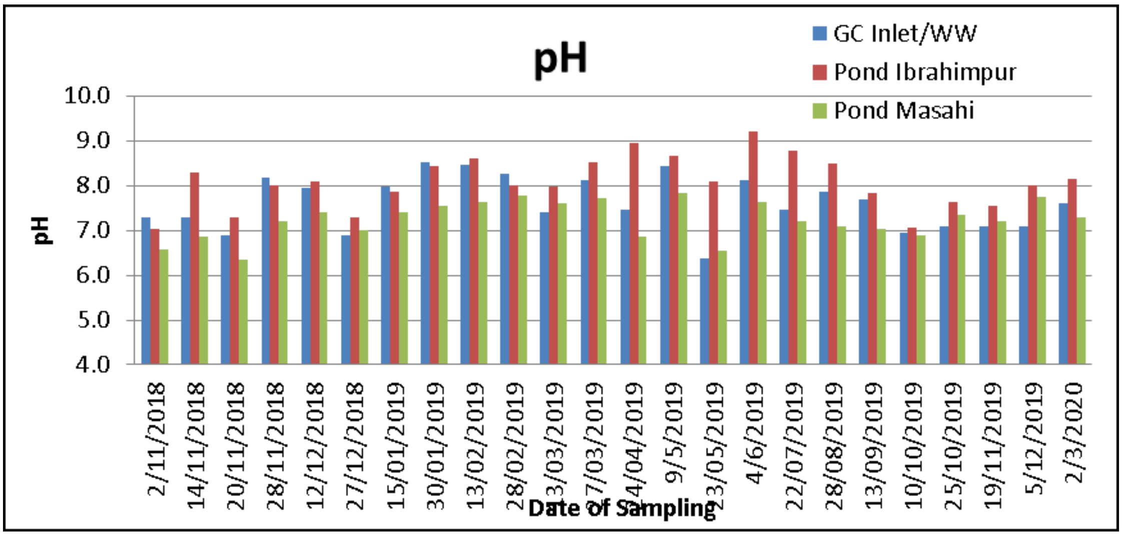


Fig. 2: pH values of ponds at Ibrahimpur Masahi (CW-NTS) and Masahi Kala

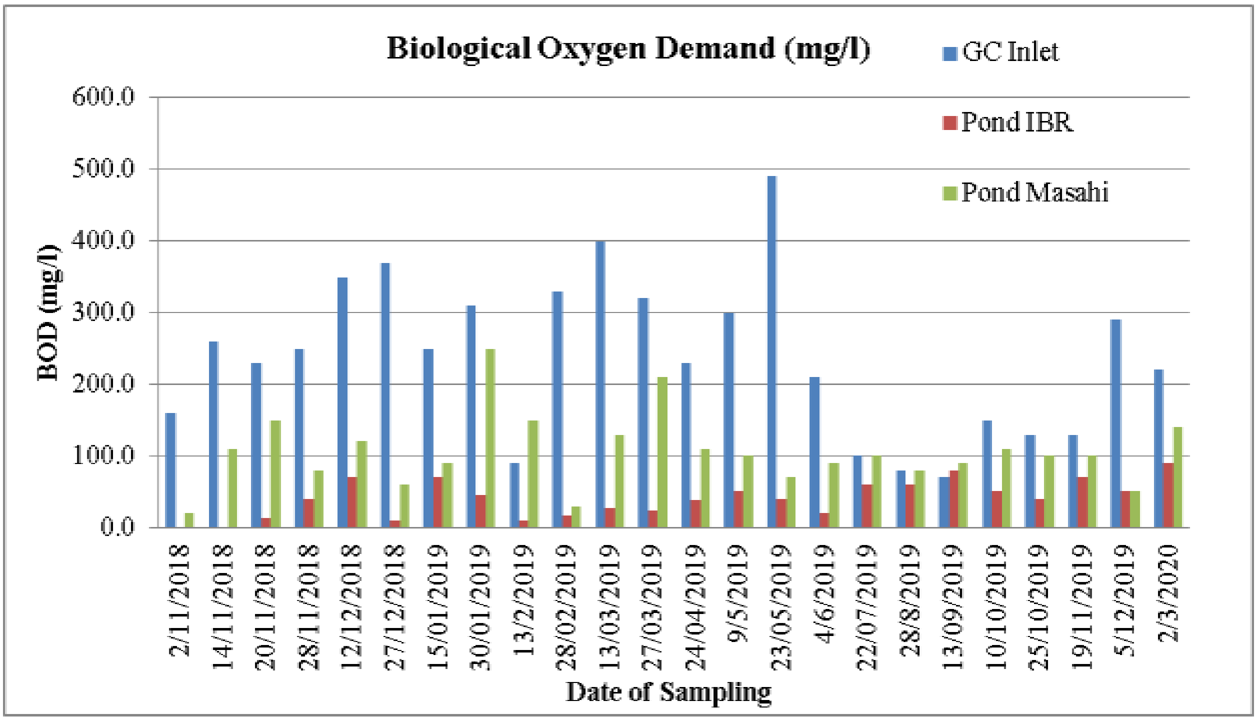


Fig. 3: Biological Oxygen Demand (mg/l) of Ibrahimpur and Masahi pond

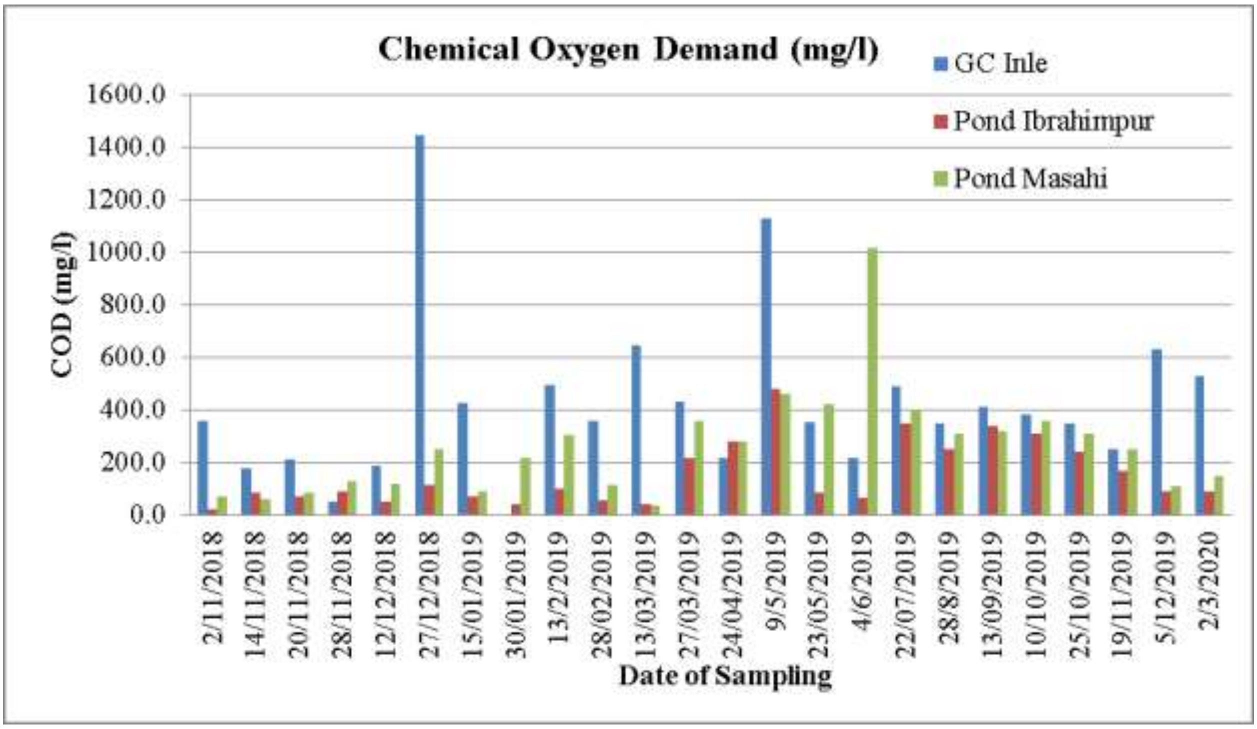


Fig. 4: Chemical Oxygen Demand (mg/l) of Ibrahimpur and Masahi pond

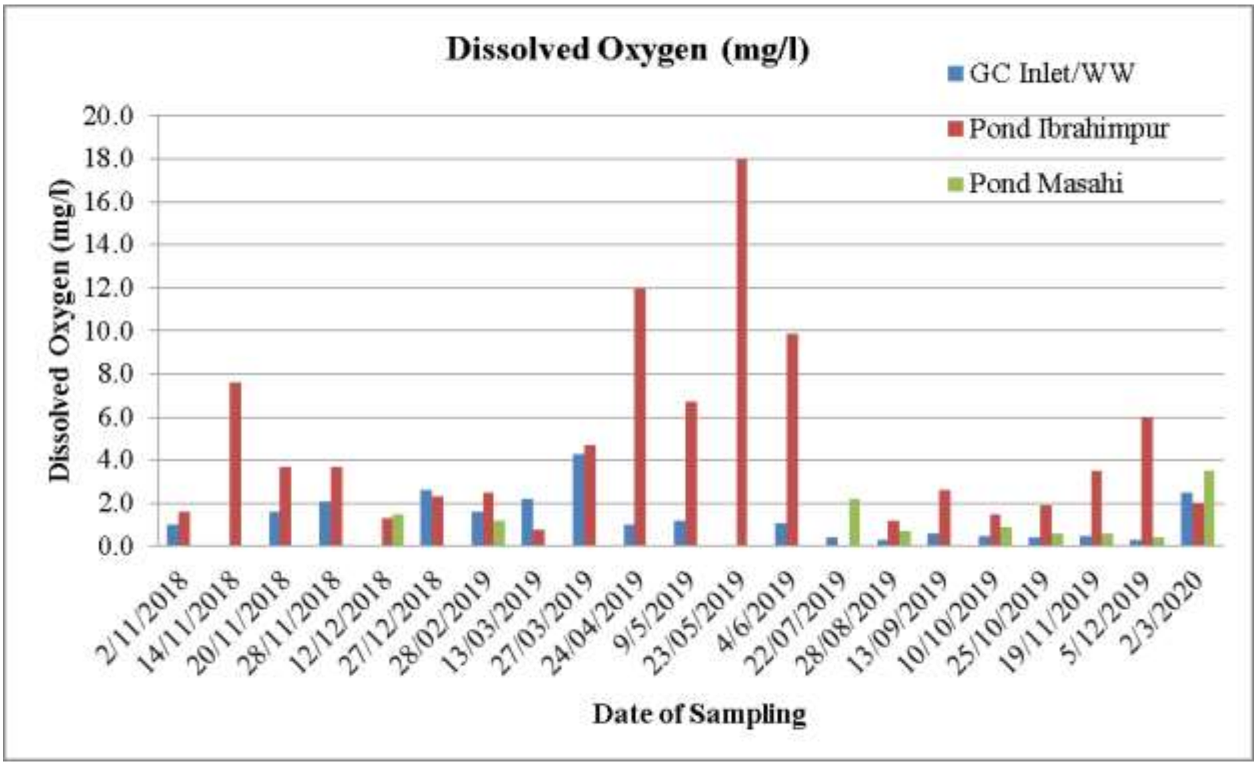


Fig. 5: Dissolved Oxygen (mg/l) of Ibrahimpur and Masahi pond

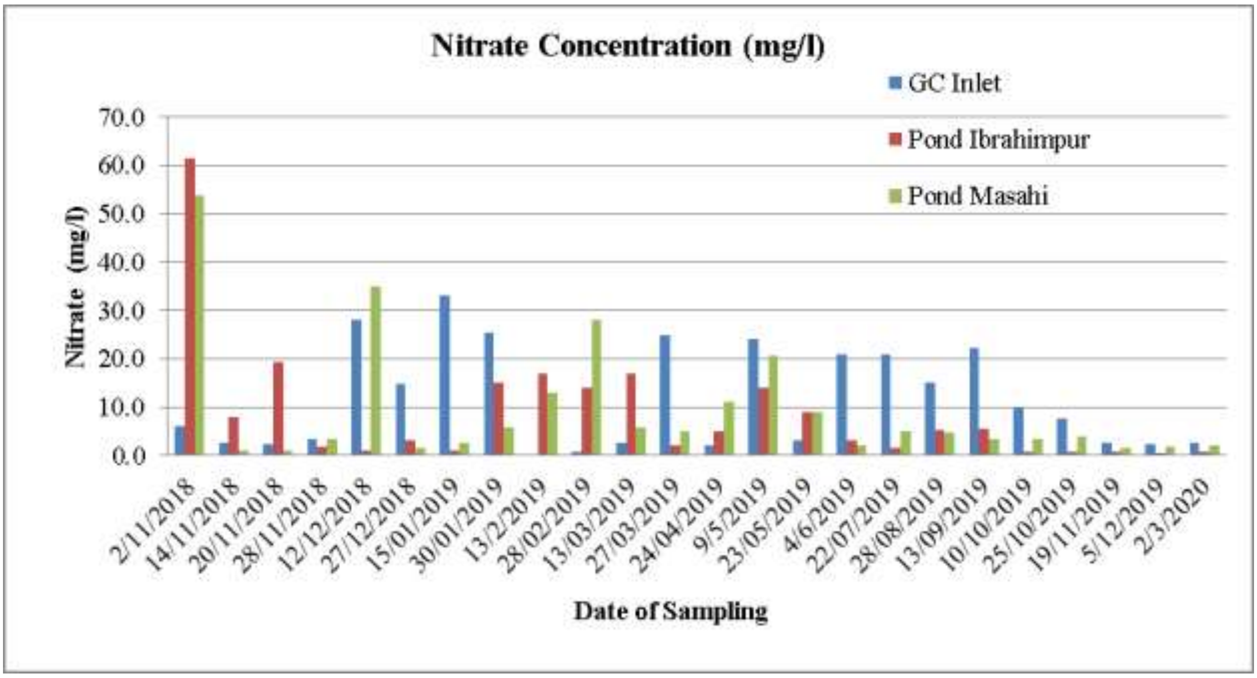


Figure 6: Variation of nitrate concentration (mg/l) at Ibrahimpur and Masahi ponds

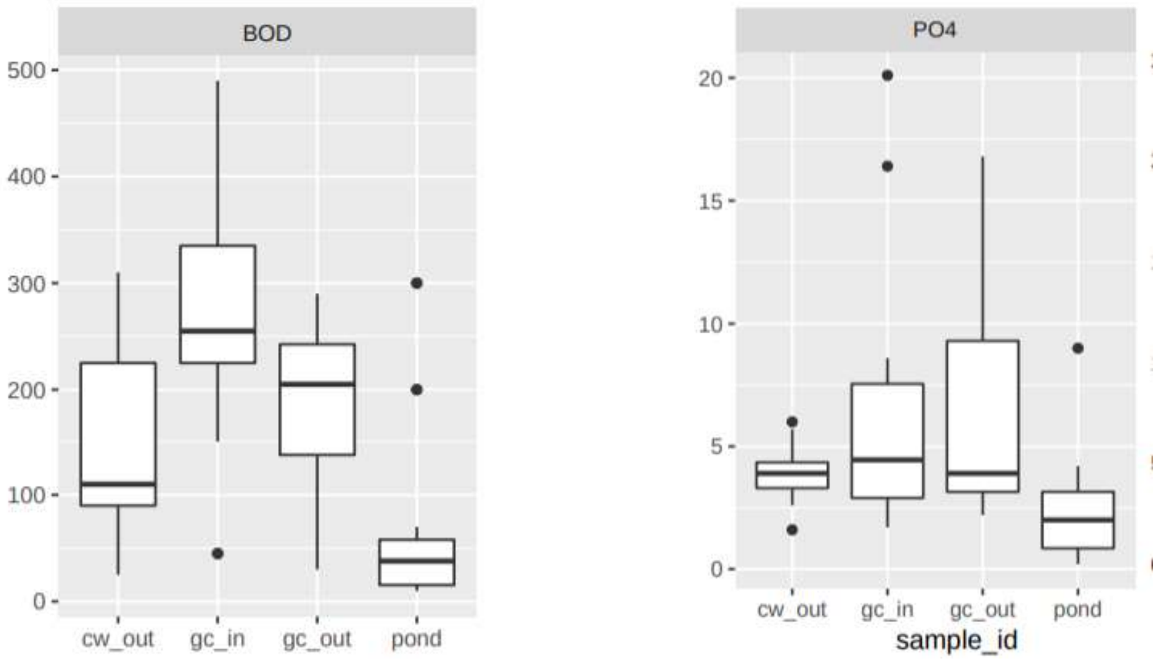


Fig. 7: Analysis of BOD and Phosphate concentrations along the treatment chain (CW-NTS site)

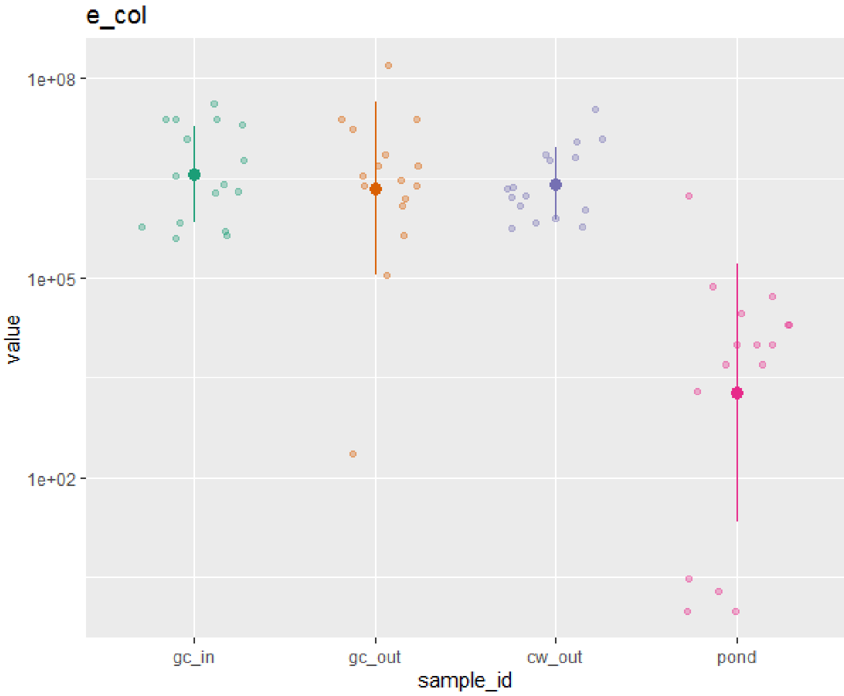


Fig. 8: E. coli concentrations along the treatment chain (log scale on y axis) at CW-NTS pond (Ibrahimpur Masahi)

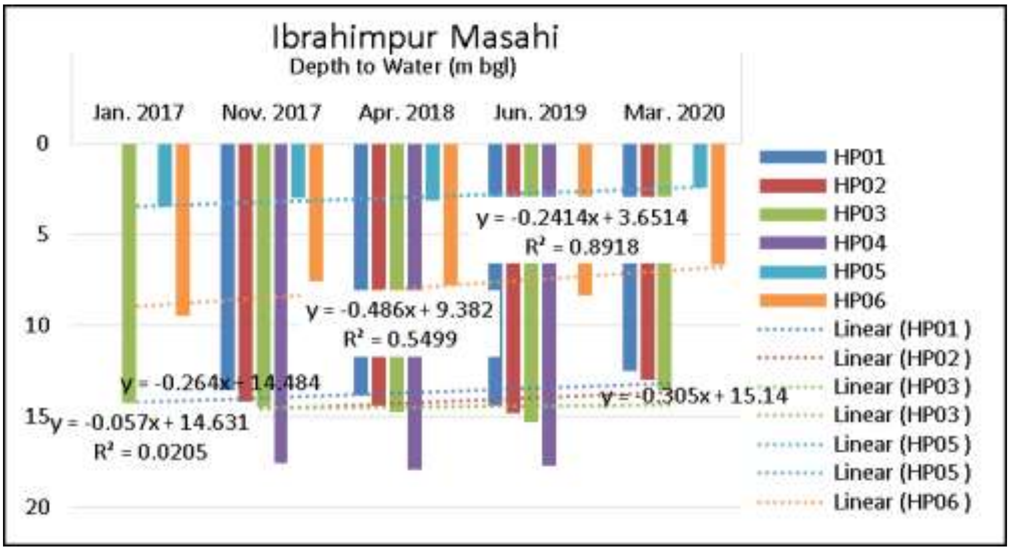


Fig. 9: Trend lines showing improvement of ground water levels (DTW, m bgl) around rejuvenated pond at Ibrahimpur Masahi (Dist. Haridwar)

15. **End Users / Beneficiaries of the Study:** Villagers & Stakeholders

16. **Deliverables:** Performance Evaluation Report of CW-NTS, Societal impact of rejuvenated water body.

17. **Major items of equipment procured:** Nil

18. **Lab facilities used during the study:** WQL, GWHD (NIH)/ IIC (IITR)

19. **Data procured or generated during the study:** Pond and groundwater quality and groundwater level data.

20. **Study Benefits / Impacts:** This study will address the issues related to contamination of village ponds and to find feasibility of low cost, ecofriendly and energy free solutions for treatment of village wastewater which is entering into the village ponds. The other likely impacts may be expected in the form of improvement of GWQ/GWL due to enhancement of pond storage capacity and recharge. The outcomes from the study can be utilized by the policy makers for addressing the issues in other villages.

21. **Involvement of end users/beneficiaries:** Villagers and Gram panchayats

22. **Specific linkage with Institution and /or end users / beneficiaries**: Gram panchayats & local District Administration.

23. **Shortcoming/Difficulties:** The CW-NTS was remained submerged during monsoon and post monsoon period (2019-20) which caused some hindrance in water quality samplings from CW-NTS.

24. **Future Plan:**

- To continue WQ investigations from both identified ponds (CW-NTS pond at Ibrahimpur Masahi and control pond at Masahi Kala) including wastewater characterization.
- Mass awareness activities/HH support for fishery cultivation in rejuvenated pond at GP level).

Internal Study-2 (New)

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: 01.07.2020

5. Scheduled date of completion: 30.12.2022

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 (Figure 1). 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

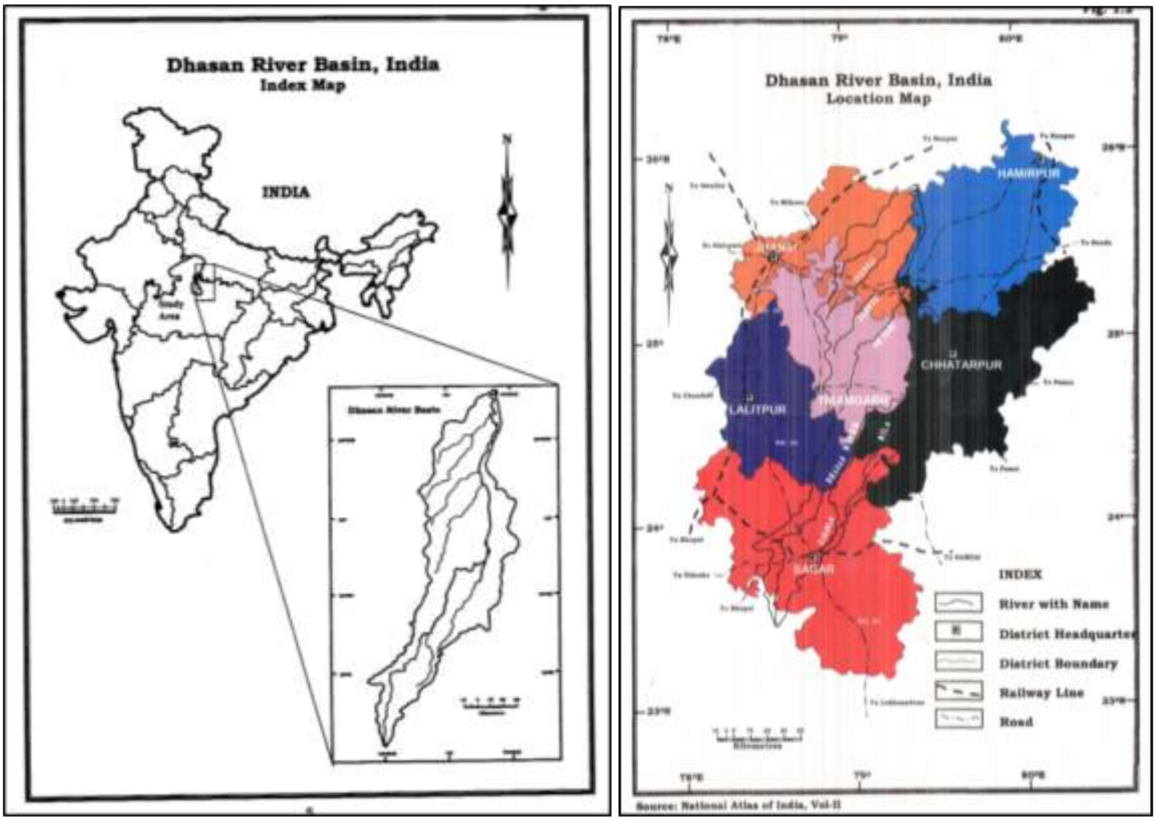


Figure 1: Index map and location map of complete Dhasan Basin

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. The Chief Engineer, BODHI, MP Water Resources Department has given the consent in this regard.

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.

<u>Previous work done in the basin</u>

Citation	Extent of work	Findings
Thakural et al (2009)	Dhasan river basin upto Patan village, Sagar (MP); A= 2049 km^2	Water balance components evaluated Basin is drought prone
Ahlawat (2011)	Betwa river catchment (including Dhasan basin)	Morphometry Prioritization of watersheds for location of gauge and discharge sites
Pareta (2015)	Dhasan river basin	Geomorphological and Hydrogeological study
Prakash et al. (2016)	Dhasan river basin	Drainage morphometry
Kar et al (2016)	Dhasan river basin upto Patan village, Sagar (MP); A= 2049 km^2	Meteorological drought (EDI) Ground water drought (GDI)

9. Methodology

<u>Study area:</u>

The study has been selected in Upper Dhasan basin upto Garrauli G/D site on Dhasan river falling in Chhatarpur district (Figure 2). The area of Upper Dhasan Basin is 3565 sq. km.

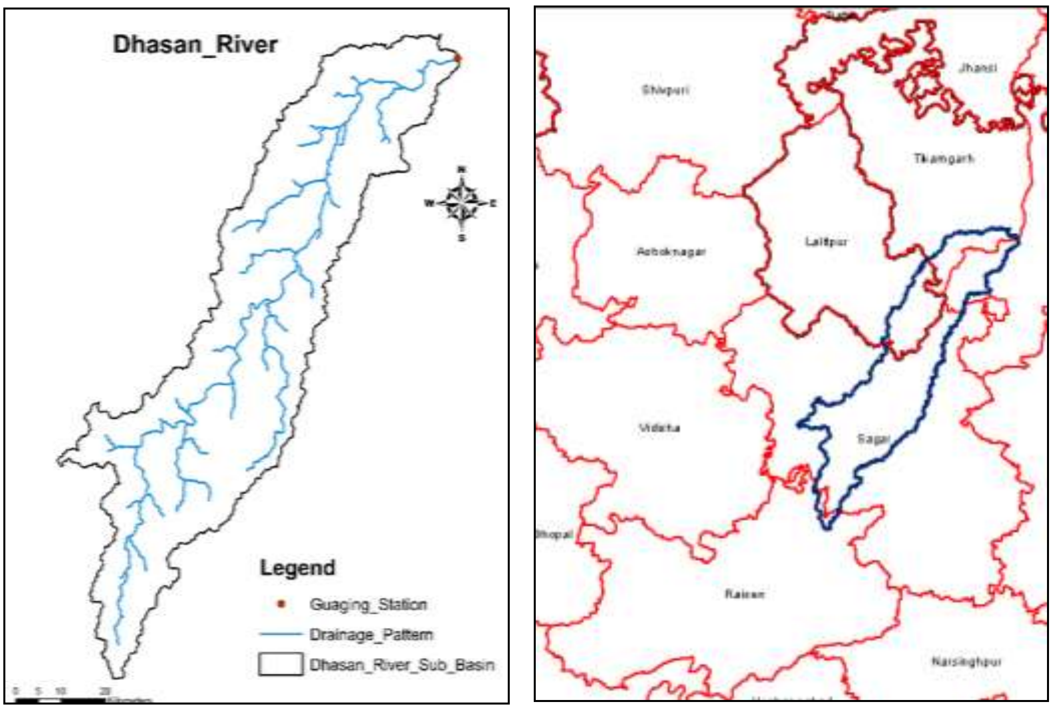


Figure 2: Location of study area (Upper Dhasan basin)

Data availability:

The available data includes India Meteorological Department (IMD) gridded daily rainfall and daily maximum, minimum and mean temperature as well as discharge data at Garrauli G/D site of Central Water Commission (CWC).

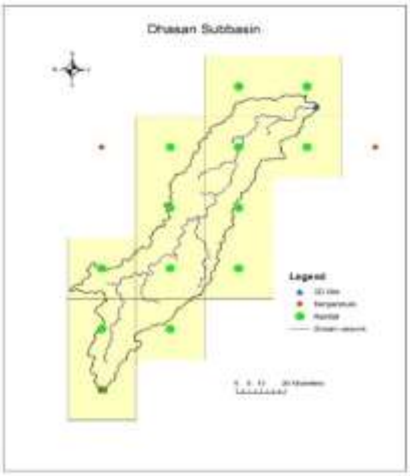


Table 1: Data requirement

Data	Details	Source
Available data		
Discharge data (Daily)	1991-92 to 2012-13	CWC
Rainfall (Daily) 13 grid points	0.25^o X 0.25^o 1901-2018	IMD
Temperature (Daily) Only one grid point	1^o X 1^o 1951-2018	IMD
Required data		
Agriculture	Major crops (kharif/ rabi), area under each crop, water requirements, irrigated area	Respective District Administrations, District Irrigation Plans (DIP)
Geospatial Maps	Land use Land Cover (LULC) River and Water bodies Canal network (optional) Soil type	To be created from readily available satellite data
Demand data	Population Livestock Industries	Census/ District Administration websites / District reports
Supply information	Rainfall, Temp, Water Supply, Groundwater source Tank capacity	IMD/ district authorities CGWB district reports Minor irrigation census

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.
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. 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 during last six months: New proposal.

12. Budget details

(Rs in Lakhs)

SN	Item	2020-21	2021-22	2022-23	Total
1	Manpower at Delhi/ Bhopal 2 Nos JRF/ Project Associate (@31,000+HRA)	7.0 (9)	9.0 (12)	7.0 (9)	**23.0**
2	Travel ✓ Field data collection ✓ Meetings ✓ Stakeholders meetings ✓ National/ Int conferences	2.0	3.0	3.0	**8.0**
3.	Contingency ✓ Registration fee for attending Nat/ Int Conf ✓ Flyers ✓ Capacity building and outreach activities	2.0	3.0	2.0	**7.0**
4.	Consumables	0.50	0.50	1.0	**2.0**
	Total	**11.2**	**15.5**	**14.2**	**40.0**

13. Recommendation / Suggestion: NA

14. Analysis & Results: New proposal.

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.

Internal Study-3 (New)

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 F, NIH, Roorkee
Dr. Gajendra Singh, Scientist, USAC, Dehradun
Scientist from Wetlands International South Asia, New Delhi
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 stream) and establish ecohydrological functions
    - To determine the indicators of wetland condition (e.g. change in wetland area, change in land cover, wetland stress index, wetland productivity, hydroperiod).
    - To assess the floral diversity, invasion by invasive, temporal changes in the wasteland and establishing long term monitoring plots.
    - To develop 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. There are many ecohydrological functions performed by the wetland but they are less studied for the Indian wetlands also there are rare studies which investigates the hydrological regimes of the wetlands and its catchment. 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. 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.

Most of the areas adjoining the course of major river systems viz., Ganges and Yamuna have remained neglected in the past due to hostile climatic conditions and frequent changes in the river courses. Jhilmil Jheel and its surrounding areas (viz., Banganga) in Haridwar Forest Division is a remnant Terai habitat which forms the western most part of Terai landscape in India. Jhilmil lake wetland is situated (78^{0}13'17.50" E; 29^{0}47'49" N, 240m asl) between the Haridwar–Najibabad Highway with the natural course of the Ganga to the south of it. It is permanent freshwater lake spread over 148ha. There are studies in the Jhilmil Jheel describing the various animal species in the wetland surroundings especially swamp deer but there is no integrated interdisciplinary study linking both hydrology and ecology for this study area. Also Jhilmil Jheel and its surrunding areas (viz., Banganga) in Haridwar Forest Division is a remnant Terai habitat which forms the western most part of Terai landscape in India. Various invasive and exotic species are invading wetlands with alarming rate. Keeping all points in mind, it is imperative to have regular monitoring of health of the wetland and its area of influence is of utmost important. The future scenarios should be estimated and long term monitoring and phase wise management strategies should be prepared.

9. Study Area: JhilMil Jheel Wetland and its catchment, Haridwar District

10. 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. 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 analyzed. It can be vital for the deciding future conservation strategies.

SWIM (Soil and Water Integrated Model) is a continuous-time 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 will be used in the deriving water balance of the wetland's catchment.

Monthly sampling of the water from the wetland, River Ganga, its two adjoining tributaries and groundwater will be done for the stable isotope analysis. Sampling will also be done for all rainfall events also. Temporal hydrologic connectivity will be established between all waterbodies through laboratory analysis. The piezometers will be installed in the wetland's catchment to monitor the water table during various seasons hence the contribution of the wetland to groundwater or vice versa can be quantified. 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. Long 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.

11. 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	■	■	■	■	■	■	■	■	■	■		
8	Water balance study of catchment							■	■	■	■		
9	Preparation of conservation strategies							■	■	■	■		
10	Preparation of wetland management plan							■	■	■	■		
11	Report writing										■	■	■
12	National workshop										■	■	■

12. Expected Outcome/Output:

- Detailed Geo-spatial vegetation map with temporal changes of the Jhilmil Jheel wetland.
- A report on wetland basin and ecohydrological functions of Jhilmil Jheel wetland.
- Assessment of impacts of anthropogenic activities on wetland connectivity and its functioning.
- Factsheet and SOP on ecohydrological functioning of Jhilmil Jheel wetland to be used by the Uttarakhand State Wetland Authority.
- Wetland Management Plan will be prepared covering aspects including hydrology and ecology with stakeholder's participation which can implemented by concerned authorities.

Internal Study-4 (New)

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
   Scientist from related KVK/Agri. Univ.

3. **Date of start:** **June 2020**
4. **Duration of the study:** **2 Years**
5. **Whether externally funded or not:** **Internal**
6. **Objectives:**

- To evaluate the existing cropping pattern and farming practices for estimation of farmer's income
- To carry out scenario analysis considering combinations of crop types and cropping pattern, land allocation, water allocation under climatic variability, etc.
- 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. **Present state-of-art**

WEAP simulates hydrologic pattern based on climatic input. WEAP uses precipitation, temperature, humidity, infiltration, and wind speed data to predict the amount of precipitation that falls into a particular area, discharge of streams, recharge of groundwater and/or evapotranspiration through vegetation. It allows to build a futuristic scenarios based on the baseline scenarios along with assumptions towards water demand, infrastructure and regulations. The assessment of the impact of all the anthropogenic activities on water resources management and livelihood issues could be possible in order to predict water shortage and water quality based on a model scenario. This software tool can be used to demonstrate the results of water demand quantity met during a month, the degree of potential water shortage, level of reservoir storage for future use and measurement of water quality. Further, it can be used to assess the adequacy of environmental flows, the level of hydropower generation capacity, the evaluation of soil moisture, evapotranspiration rates, volume of surface runoff, the rate of ground water recharge, agriculture water requirement, possible alternative to adapt cropping pattern to increase water use efficiency and maximize the income. Scenario analysis helps in finding out the demand and supply pattern by exploring "what if" questions.

LINGO is a comprehensive tool designed to make building and solving Linear, Nonlinear (convex & nonconvex/Global), Quadratic, Quadratically Constrained, Second Order Cone, Semi-Definite, Stochastic, and Integer optimization models faster, easier and more efficient. LINGO provides a completely integrated package that includes a powerful language for expressing optimization models, a full featured environment for building and editing problems, and a set of fast built-in solvers.

This study is undertaken to optimize the income from agriculture sector without compromising the supply to the increasing domestic demands and industrial requirement by combing WEAP and LINGO in Mewat region, Haryana by evaluating the available water resources and management of demand and supply requirements of different socio-economic activities using WEAP model. Suitable water allocation plan would be evolved for various stress conditions by scenario analysis studies using WEAP model. The optimum income from agricultural sector would be achieved from the results of the scenario analysis for crop types and land resources using LINGO.

9. **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.

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. Work Plan

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								

12. Responsibility

SN	Name of scientist and staff	Nature of responsibility
1	Dr. A. R. Senthil Kumar, Sc “F”	Collection and analysis of data, Setting up of WEAP and LINGO, running of the model for income optimization, analysis of results, report writing
2	Dr. V. C. Goyal, Sc “G”,	Suggestions in setting up of WEAP and LINGO, analysis of the results
3	Sh. Omkar Singh, Sc “F”,	Estimation of Crop water requirement and running of the model for income optimization
4	Sh. Rajesh Agarwal, SRA	Preparation of input data, Setting of LINGO for income optimization
5	Sh. Nageswara Rao Allaka, RA	Preparation of input data, base map of the catchment and setting up of WEAP

Sponsored Project- 1 (ongoing)

1. Title of the study:

Hydrological modelling in Bhagirathi basin up to Tehri dam and assessment of climate change impact

2. Study Group:

Dr. A. R. Senthil kumar Sc F, NIH, Roorkee
Dr. J. V. Tyagi, Scientist 'G', NIH, Roorkee
Dr. M. K. Goel, Scientist 'G', NIH, Roorkee
Dr. S. D. Khobragade, Scientist 'F', NIH, Roorkee
Dr. P. C. Nayak, Scientist 'D', Deltaic Regional Centre, NIH, Kakinada
Dr. Manohar Arora, Scientist 'D', NIH, Roorkee

Project staff: Sh. Sandeep Chourasia, JRF, Sh. Bhajan Lal, PA

Date of start: 1 January, 2016

3. Duration of the study: 5 Years

4. Whether externally funded or not: DST

5. Objectives of the study:

a. To model stream flow/snow melt runoff in Bhagirathi Basin up to Tehri dam.
b. To model sediment yield at Tehri dam.
c. To investigate the impact of likely future changes in climate on stream flow and sediment yield up to Tehri dam using future climate scenarios.
d. To assess impact of afforestation/deforestation on sediment yield in the basin.
e. To assess the operation policy of the Tehri dam in light of the climate change impact.

6. Statement of the problem

The developmental activities in the catchment area contribute high sediment load which affects the expected performance of the reservoir. Increase of anthropogenic emissions of green house gases will aggravate climate change and thus average temperature of atmosphere, no of extreme events of rainfall and intensity will increase. In Himalayan region, the increase in high intensity rainfall will contribute more sediment to the reservoir. It is important to estimate the change in sediment yield under the projected different climatic scenarios to assess the performance of the Tehri reservoir. The study on impact of afforestation/deforestation on sediment yield in the basin is also important for effective watershed management.

7. Brief methodology:

Sediment yield model

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

Streamflow simulation

The streamflow up to Tehri reservoir is modeled by SNOWMOD with the input data of elevation, rainfall, aspect, temperature and snow cover area. The performance of SWAT is compared with SNOWMOD in simulating the discharge.

Climate Scenarios

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

Computation of streamflow and sediment yield under different scenarios

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

Revision of elevation-area-capacity table

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

The impact of afforestation/deforestation on sediment yield is analyzed by the simulation of sediment yield using SWAT by increasing/decreasing the LULC.

The rule curves for operating the reservoir are modified by considering the revised elevation-area-capacity curve in light of increased/increased sediment yield.

8. Results achieved with progress/present status:

The sediment yield at Tehri reservoir is modelled by Soil and Water Assessment Tool (SWAT). The inputs such as DEM, LULC and Soil map for running the ARCSWAT have been generated using different sources available in the web sites of different organizations such as NASA, National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Indian Council of Agricultural Research, Harmonized World Soil Database (HWSD) International Institute for Applied Systems Analysis **(**IIASA) and National Remote Sensing Centre (NRSC). The daily rainfall, maximum temperature, minimum temperature, Solar radiation, wind speed, relative humidity have been obtained from IMD and SWAT.tamu website**.** Initially**,** the discharge and sediment yield at Tehri dam has been simulated using the input data from IMD and SWAT.tamu website by taking the parameters randomly with SWAT. The parameters for discharge and sediment yield have been optimized in SWAT-CUP using SUFI-2 algorithm.

The daily rainfall values at Mukhim, Tehri, Bhatwari, Dunda, Maximum and Minimum temperature at Mukhim, relative humidity and wind speed at Mukhim have been obtained from IMD. The daily discharge (1994 to 2007) and sediment yield (1994 to 2001) have been obtained from THDC, Rishikesh and are given as follows:

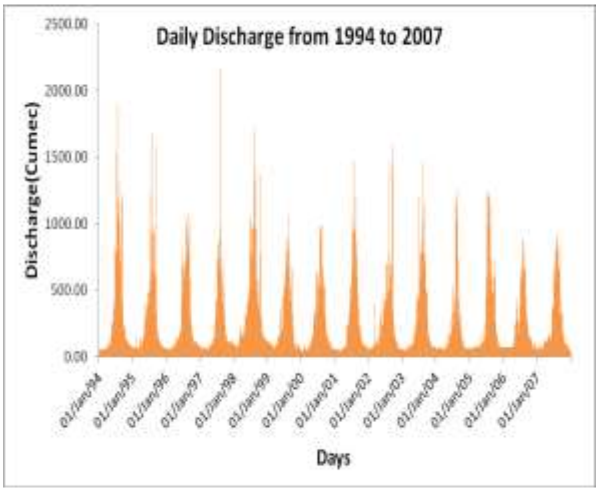


Fig.1 Daily discharge at Tehri dam from 1994 to 2007

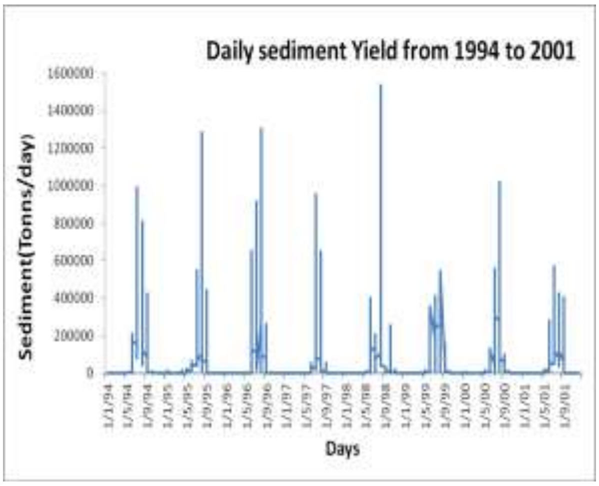


Fig.2 Daily sediment yield at Tehri dam from 1994 to 2001

The parameters of the SWAT have been calibrated for discharge and sediment yield by considering the data from IMD and THDC, Rishikesh. Sensitivity analysis of the parameters for both discharge and sediment yield has been carried in SWAT-CUP using SUFI2 and the rankings is given in flowing table 1. The best eight sensitive parameters for sediment yield have been considered for optimization. The lower, upper limits and the best fitted values of the parameters are given table 2.

Table 1 Sensitivity analysis of parameters for sediment yield

S.No	**Parameters name**	**P-value**	**t-stat**	**Rank**
1	USLE_P.mgt	0.00002	- 45.058	1
2	USLE_K.sol	0.00005	-15.59	2
3	SPEXP.bsn	0.00032	2.17	3
4	SPCON.bsn	0.00042	0.301	4
5	CH_COV2.rte	0.05126	1.16	5
6	CH_COV1.rte	0.01625	1.15	6
7	ADJ_PKR .bsn	0.21561	2.15	7
8	PRF BSN.bsn	0.415369	-0.414	8

Table 2. Lower limit, upper limit, best fitted values of parameters

Parameter	Details	Lower Limit	Upper Limit	Best Fitted Value
SPCON.bsn	Linear parameter for calculating the maximum amount of sediment that can be reentrained during channel sediment routing.	0.0001	0.01	0.004
SPEXP.bsn	Exponent parameter for calculating sediment reentrained in channel sediment routing	1	1.5	1.132
CH_COV1.rte	Channel erodability factor	0	0.2	0.0030
CH_COV2.rte	Channel cover factor	0	0.2	0.076
USLE_P.mgt	USLE equation support practice factor	0.1	1	0.02
USLE_K.sol	USLU soil factor	-0.2	0.2	0.432
ADJ_PKR	Peak rate adjustment factor for sediment	0.5	2	1.32

.bsn	routing in sub basin (tributary channels)			
PRF.bsn	Peak rate adjustment factor for sediment routing in the main channel	0.5	1	0.71
PRF.bsn	Peak rate adjustment factor for sediment routing in the main channel	0.5	1	0.71

The graphical comparison of the observed and simulated discharge and sediment yield at Tehri dam are given as follows:

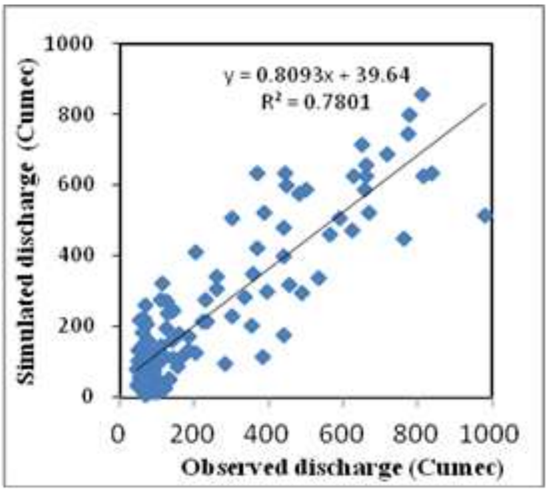


Fig. 3 Scatter plot for monthly discharge for calibration period from 1996 to 2005

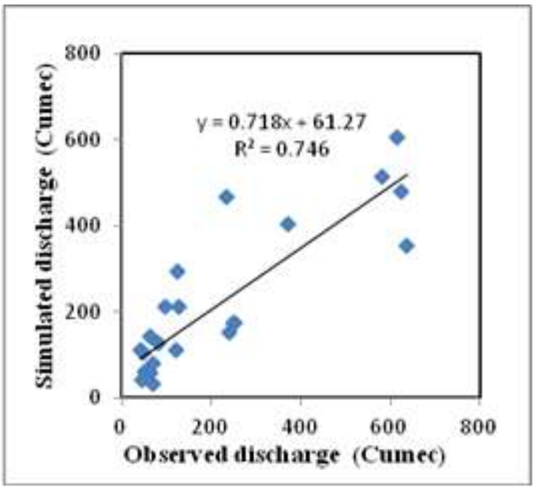


Fig 4. Scatter plot for monthly discharge for validation period from 2006 to 2007

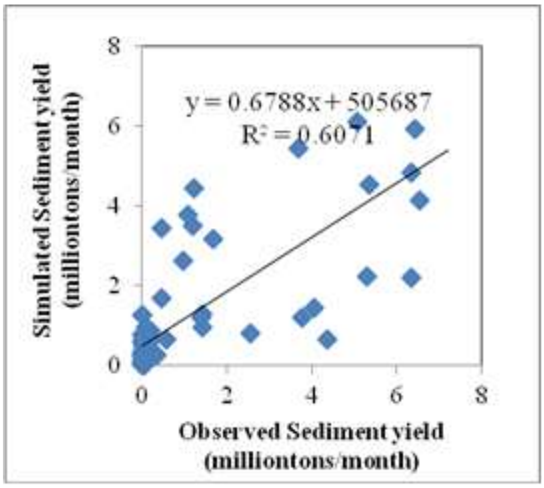


Fig. 5 Scatter plot for monthly sediment yield for calibration period from 1996 to 1999

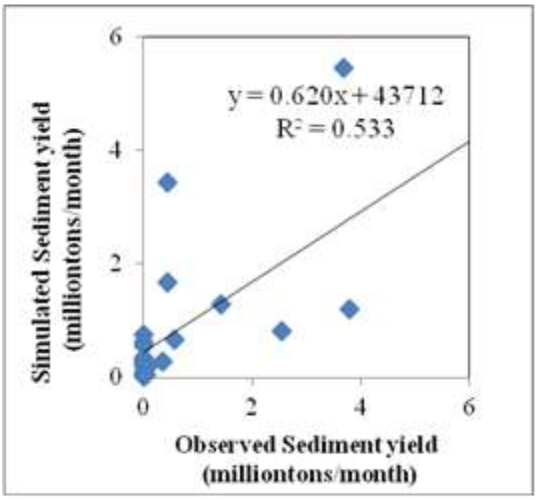


Fig. 6 Scatter plot for monthly sediment yield for validation eriod from 2000 to 2001

SRM data preparation

SRM requires basin characteristics (basin and zone areas, area-elevation curve), daily rainfall data, temperature and snow covered area to simulate the runoff components from sources such as snow, rain. The whole area is divided into 10 elevation zone and is given table 3.

Table 3 Zone wise area of the Bhagirathi basin

Zone	Elevation(M)	Area(km^2)	Percentage
1	<700	0.0603	0.001
2	700-1400	534.3911743	7.543
3	1400-2100	1240.68689	17.513
4	2100-2800	951.2783813	13.428
5	2800-3500	644.7393188	9.101
6	3500-4200	642.9959717	9.076
7	4200-4900	1113.010254	15.711
8	4900-5600	1540.567749	21.746
9	5600-6300	568.8143921	8.029
10	>6300	48.7629013	0.688

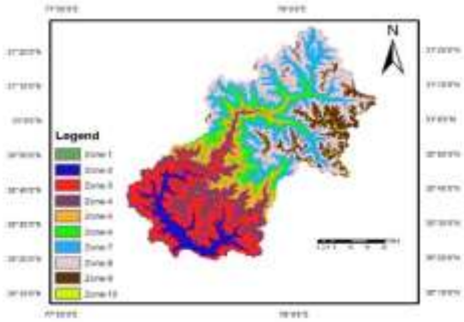


Fig. 7 Zone wise Digital elevation model of the Bhagirathi basin

The 8-day maximum snow cover data from MODIS 8-day snow cover product (MOD10A2) with spatial resolution of 500 m have been used to map and monitor SCA for the period from 2001 to 2007. In Himalayan basin the snow accumulation in Himalayas is generally from November to March, while snowmelt is from April to September. The average snow covered area at the start of ablation season is 59.74%, when the accumulation of snow is started in September, the average snow covered area at the end of ablation season is 28.67%. A comparison of the percentage snow cover for different years as extracted from image classification for ablation period (March-September) is given in table 4. The maximum snow area is given in Table 5.

Table 4 Percentage snow covered for different years

Month	Snow Covered Area (%)						
	2001	2002	2003	2004	2005	2006	2007
March	59.19	63.08	60.91	53.90	61.12	56.97	63.04
April	57.12	56.88	56.26	47.63	55.92	49.67	50.36
May	45.48	48.10	34.90	32.52	37.83	33.35	37.88
June	31.06	39.20	33.29	29.27	39.97	18.71	20.82
July	29.77	24.58	29.95	25.88	37.19	29.69	27.05
August	32.45	33.93	34.21	27.17	28.36	19.21	17.01
September	23.98	36.38	27.12	33.75	38.98	17.10	23.36

Table 5 Maximum Snow covered area in different elevation zone:

ZONE	Elevation(M)	% SCA
1	<700	0.000293
2	700-1400	0.001275
3	1400-2100	0.086006
4	2100-2800	1.618566
5	2800-3500	10.87052
6	3500-4200	14.56009
7	4200-4900	25.44261
8	4900-5600	33.91766
9	5600-6300	12.41843
10	>6300	1.08454

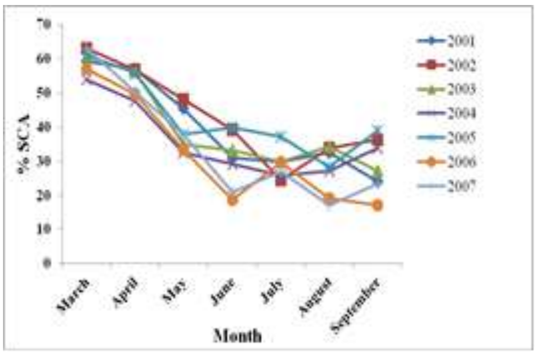


Fig 8. Snow depletion curves for years (2001-2007)

The parameters to be calibrated in Win SRM are runoff coefficient, degree-day factor, temperature lapse rate and critical temperature. The runoff is calibrated with the parameters and are given in Table 6. WinSRM uses two well-established accuracy criteria, namely the coefficient of determination (R^2) and the volume difference (D_v) , which are automatically computed and displayed after each run of WinSRM. The results of SRM- based snowmelt runoff is given in Table 7. From the table 7, it can be seen that R^2 for snowmelt season for 2001 –2003 varied from 0.73 to 0.68. Measured runoff for melt season is about 7979–7465($10^6 m^3$). Computed run-off varies between 7190-7838 ($10^6 m^3$). and computed average runoff varies between 228-228(m^3/s). Volume difference varies from 3.68% for 2002 to 0.79% for 2001. The result for the year 2001 is given in Fig 9.

Table 6 Snowmelt run-off model parameters used for the year 2001

Month	Temp. Lapse rate °C per 100 m	Critical temp (°C)	D (degree day factor)	Runoff coefficient for rain C_R
January	0.6	2	3.5	0.1
February	0.6	2	3.5	0.1
March	0.6	2	3.5	0.1
April	0.6	2	4.5	0.1
May	0.6	2	5.5	0.2
June	0.6	2	5.5	0.3
July	0.6	2	5.5	0.6
August	0.6	2	6.5	0.8
September	0.6	2	4.5	0.5
October	0.6	2	3.5	0.3
November	0.6	2	3.5	0.1
December	0.6	2	3.5	0.1

Table 7 Results of model simulation for the period 2001–2003

	2001	2002	2003
Measured run-off volume ($10^6 m^3$)	7480	7465	7979
Average measured run- off (m^3/s)	237	236	253
Computed run- off volume ($10^6 m^3$)	7420	7190	7838
Average computed run- off (m^3/s)	235	228	248
Volume difference, D_v (%)	0.79	3.68	1.76
Coefficient of determination, R^2	0.73	0.67	0.68

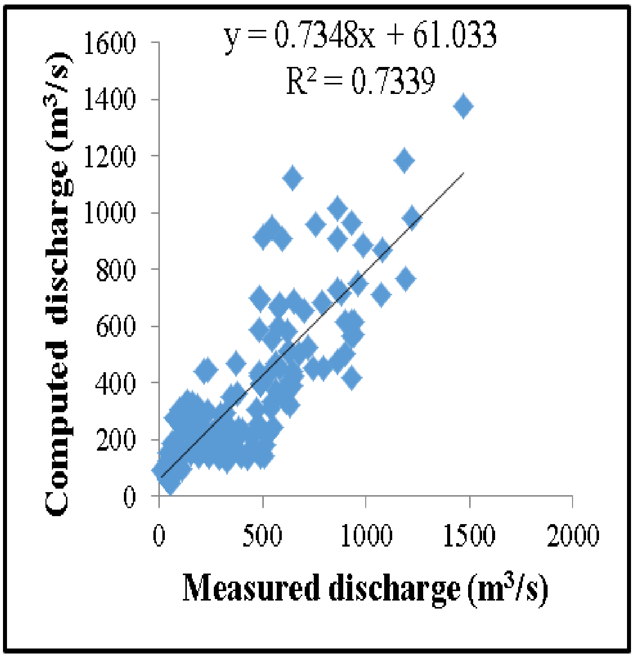


Fig 9 Measured and simulated discharge for the year 2001

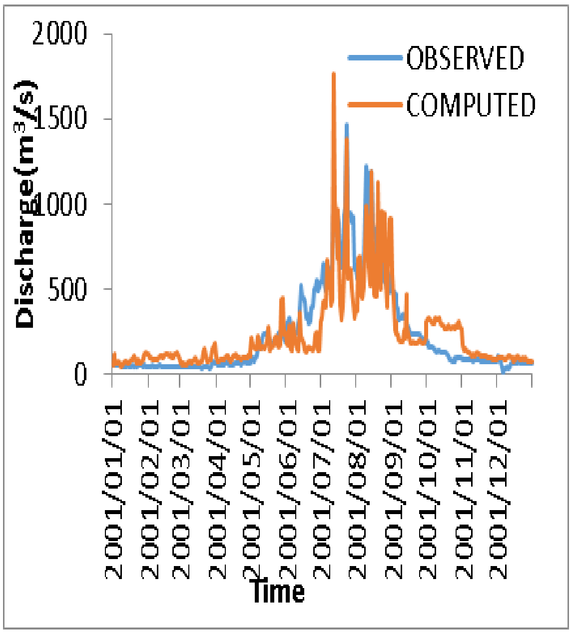


Fig 10: Measured and simulated discharge for the year 2001

Figure 10 shows that snowmelt runoff is started increasing from the (April–May) season, mainly due to increase in air temperature, whereas maximum run-off is observed in August, mainly due to monsoonal rains. Snowmelt is low from October to February. The simulation confirms snowmelt runoff as the main source of freshwater in the region throughout the year, except during monsoon, when rain on snow and normal rainfall–run-off contribution is much higher than normal snowmelt runoff because of increase in temperature.

9. Outcome of the study

The output of the study will give an idea of increased sediment yield and streamflow from the future climatic scenarios to the state department officials for managing the various demands based on the available the storage in the reservoir on priority basis. The impact of afforestation/deforestation on sediment yield will be used for planning cropping pattern to reduce the sediment yield

10. Expected date of completion: 31 January 2021

11. Timeline

Activity	**2016-17**		**2017-18**		**2018-19**		**2019-20**		**2020-21**	
	H1	**H2**	**H1**	**H2**	**H1**	**H2**	**H1**	**H2**	**H1**	**H2**
Collection and processing of Hydrometeorological data and purchase of satellite imagery										
Data preparation for SNOWMOD and SWAT										
Simulation of streamflow by SNOWMOD										
Simulation of Sediment yield by SWAT										
Downscaling of data from GCM Models										
Simulation of streamflow and sediment yield with the data from future climatic scenarios										
Revision of elevation-area-capacity table of the reservoir by using the future projected sediment yield										
Analysis of the reservoir performance with the revised elevation-area-capacity table and projected streamflow										
Writing of the final report										
Training workshop										

Sponsored Project- 2 (completed)

1. Title of the Study: Rejuvenation of village ponds for identified villages in Muzaffarnagar and Meerut districts of UP

2. Study Group:

<table>
<tr><td rowspan="3">Lead Organization</td><td>Project Investigator
Dr. V. C. Goyal, Sc. G & Head, RMOD</td></tr>
<tr><td>Co-Investigators
Er. Omkar Singh, Scientist F, RMOD
Dr. Rajesh Singh, Scientist C, EHD
Er. Digambar Singh, Scientist C, RMOD</td></tr>
<tr><td>Scientific/Technical Staff
Sh. Subhash Kichlu, PRA
Sh. Rajesh Agarwal, SRA
Sh. N. R. Allaka, RA
Dr. N. G. Shrivastava, Senior Expert
Dr. Nihal Singh, Research Scientist
Dr. Kalzang Mathus, Research Associate
Sh. Sandeep Yadav, Research Associate
Sh. Subhash Vyas, Project Assistant</td></tr>
<tr><td>Civil Work Execution Agency</td><td>NPCC Limited (A GoI Enterprise), Noida</td></tr>
</table>

3. Type of Study: INC-SW (MoWR, RD & GR) Sponsored Pond Project

4. Budget: Rs. 830 Lakh (actual cost Rs. 853.12 Lakh)

5. Nature of Study: Applied Research

6. Date of start & duration: April 2017 (3 Years)

7. Scheduled date of completion: March 2020

8. Study Objectives:

- Assessment of water situation in the identified villages and carry out water budgeting exercise with the respective Gram Panchayats.
- Rejuvenation of identified village ponds through installation of appropriate Natural Treatment System.
- Carry out awareness generation/capacity building of the local villagers.

9. Statement of the Problem:

Presently, ponds in the villages of western UP are in a very bad shape. Ponds are generally used as sink for all wastewater as well as for solid waste generated in the villages leading to the deposition of solid wastes and growth of weeds. Capacity of these ponds has been reduced drastically as removal of silt is not taken up on regular basis. Encroachment of the catchment area has added to the dismal state of such ponds in the rural and per-urban areas.

The project aims to rejuvenate of identified village ponds and to enhance storage capacity of the ponds, which will be a good age old practice to facilitate water conservation and management in the selected villages for better water security and sustainability. The CW-NTS at pilot scale in the study is expected to prove a role model for the Gram Panchayats for treating the wastewater entering into the ponds. The location map of identified village ponds is given in Fig. 1.

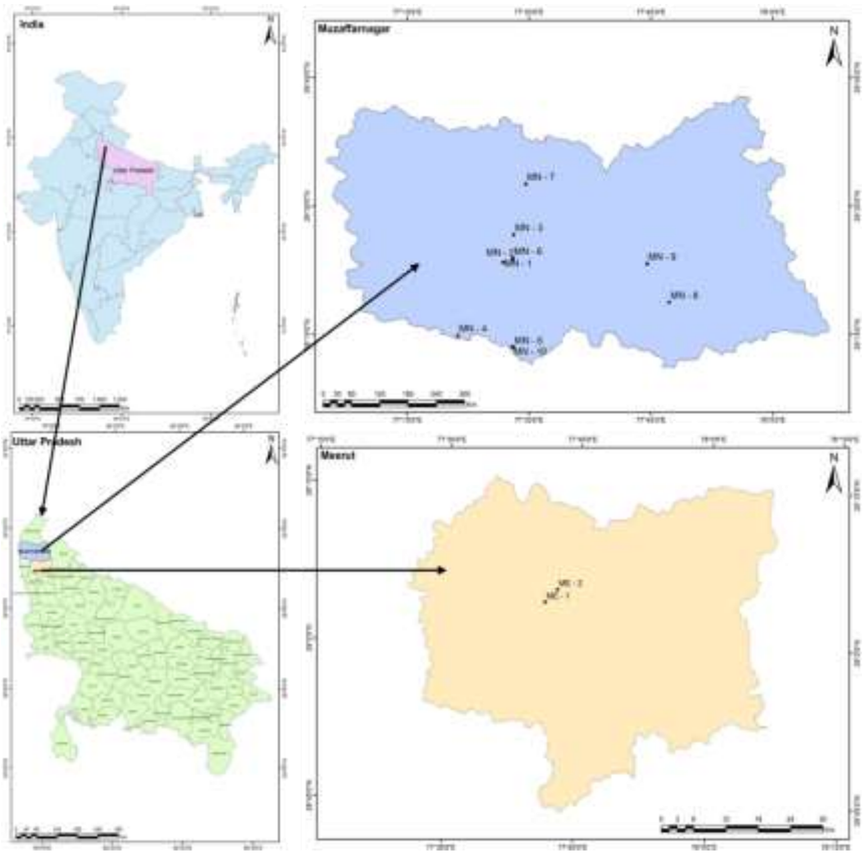


Fig. 1: Location map of identified village ponds in Muzaffarnagar & Meerut Dist.

10. Approved Action Plan/Methodology:

After field measurement of the dimensions of the ponds, DPRs were prepared for estimation of the civil works, etc. involved in the pond rejuvenation related works. Execution of the pond rejuvenation works (civil component) was carried out by NPCC Ltd. (A GoI Enterprise).

In the next phase, an appropriate NTS technology (Floating Wetland) will be established in the limited no. of identified pond/s for treatment of the wastewater entering into these ponds. In order to ensure effectiveness of NTS, Screen Chamber, Grit Chamber and Sedimentation chamber will be provided at the identified pond. The R&D activities in the field and lab were carried out as per plan.

11. Timeline:

S. N.	Work Element/ Milestone	2017-18				2018-19				2019-20			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
1	Data collection (baseline data of village/community) for existing ponds and identification of suitable natural treatment s stem	■	■	■	■	■	■	■	■				
2	Carry out water budgeting / reuse exercise/LULC mapping around pond area for respective GPs							■	■	■	■	■	■
3	Groundwater level measurement around ponds		■							■			
4	Water/wastewater sample collection and analyses		■					■	■	■	■		
5	Execution of civil works (dewatering, desilting, inlet works, outlet works, floating wetland)					■	■	■	■	■	■	■	
6	Nursery development *(plant species for floating wetland)* at NIH, Roorkee					■	■	■	■	■	■		
7	Performance evaluation of Natural Treatment System									■	■	■	■
8	Trophic State Analysis and Primary Production Capacity			■				■	■		■	■	
9	Capacity building/Mass Awareness/preparation of SOP for O&M of treatment system										■	■	■
10	Submission of reports				■				■				■

12. Achievements:

Objectives	Achievements
Assessment of water situation in the identified villages and carry out water budgeting exercise with the respective Gram Panchayats.	• Water quality assessment of pre rejuvenation stage of the pond was completed. • Infiltration test for the excavated pond bed carried out for 11 ponds. • Ground water samples and ground water level measured during the month of April & May 2019. • Total 33 samples collected and analysed for physico-chemical, microbiological & heavy metal anlaysis in the laboratory is completed. • Sludge samples collected from pond beds and analysis has been completed for trace metals (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Hg) • LU/LC map prepared for the reuse of treated water. • ***After 49th WG:*** • Field investigations (WQ of ponds and Handpumps, GWL) were collected in the month of January 2020. • Results compiled and interpretation of results has been completed. • The analysis of water quality data has been completed in light of pre-rejuvenation (2017) and post-rejuvenation (2020) stages of ponds. • Project Completion Report has been submitted to INC-SW (Jan. 2020) • Final Report has also been submitted to INC-SW (May 2020).
Rejuvenation of ponds by execution of civil works (de-weeding, dewatering, desilting, etc.)-	• As per letter from the Ministry regarding pond rejuvenation works in identified villages of Muzaffarnagar & Meerut Districts, a proposal was prepared and submitted to the Ministry. In this connection, the Ministry sanctioned Rs. 830 Lakh (under INC-SW funded Scheme) to carry out pond rejuvenation tasks & R&D works in identified village pond of Muzaffarnagr & Meerut Districts. • A revised estimate of civil work was obtained from NPCC and requisite work of pond

through NPCC	rejuvenation (12 ponds) was awarded to NPCC as per MOA. • In this connection, a formal consent was also obtained from 12 GPs to rejuvenate their identified ponds. • *The civil work component (de-weeding, de-watering, de-silting) of pond's rejuvenation been completed during Nov. 2019 at all 12 identified ponds alongwith development of NTS at one site by NPCC (Cost: Rs. 760.68 Lakh).*
Carry out awareness generation/capacity building of the local villagers.	• The nursery for developing aquatic plant saplings has been established. • Approx. 5000 Reed Plant and 1500 Canna plant saplings has been raised. • Nursery plants transported to the site/s for establishing Floating Wetland at identified pond site (Munawwarpur Kalan). • The concerned Gram Pradhans and local peoples were given necessary instructions during field investigations for proper maintenance of the rejuvenated ponds. The concerned GP (NTS pond at Munawarpur Kaka) was given necessary input for maintenance of the NTS plants and system. • Based on the request of NIH, the concerned District Authorities in Muzaffarnagar Dist. have instructed the concerned BODs to take up various maintenance works of the rejuvenated ponds under MNREGA Scheme.

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
There were no specific comments from working group members. Prof. S.S. Grewal (PAU, Ludhiana) appreciated pond rejuvenation cum wastewater treatment efforts of NIH and desired to extend the works in other states, if feasible.(viz. Punjab).	Noted for future compliance subject to availability of funds.

14. Analysis & Results:

(A) Civil Work of Pond rejuvenation: The civil work related to the rejuvenation of the ponds has been completed by the NPCC. Natural treatment system (Floating wetland) has been established in one pond located at Munnawarpur Kalan (Dist. Muzaffarnagr). The civil works carried out through NPCC is given below in Table 1:

Table 1: Status of civil works related to rejuvenation of ponds in Muzaffarnagar and Meerut

(B) **R&D Component: Pre- and post-rejuvenation Situations**

I. Water Sampling and Analysis

- Groundwater (nearby hand pumps)
- Pond water
- Wastewater (at pond inlets)

Physical: pH, EC, ORP, TDS, TSS, turbidity, alkalinity

Chemical: fluoride, nitrate, nitrite, sulphate, DO, COD, BOD; hardness, calcium, magnesium, sodium, potassium, chloride, ammonium,
Biological: TC, E.coli
Trace metals: aluminium, cadmium, copper, chromium, lead, manganese, zinc
Groundwater level ranged from 3.87m to 37.4m (June 2017), 3.81m to 34.2m (May 2019) and 3.95 to 32.13 m (March 2020), respectively. The trend lines of GWL variation of two pond sites (Munawarpur Kala and Siwaya) are given in Fig.3, which clearly shows the improvement of ground water levels after pond rejuvenation.

II. Sludge and Soil Sampling and Analysis

- Sludge at pond bed
- Pond bed soil
- Soil from nearby agricultural fields

Soil bulk density and texture
pH, EC, organic carbon, boron, zinc, copper, iron, nickle, lead, arsenic, chromium, sulphur, manganese, available nitrogen, phosphorus, potassium

III. Permeability and Infiltration Rate Analysis

IV. Trophic Status of Ponds

- TP, TN, TP/TN
- Carlson's Trophic Status Index (CTSI)
- Nygaard's Algal Index
- Shannon-Weaver Diversity Index

V. Establishment of Natural Treatment System (NTS)- Floating Wetland (FW)

VI. Reuse planning of treated wastewater

- GIS-based LULC buffer maps

Various field investigations were carried out during June 2017, May 2019 and Jan. 2020, respectively. The list of water quality samples collected before and after pond rejuvenation works are given in Table 2. The details of field investigations are given in Table-3.

Table 2: List of WQ samples collected in the study

Name of Village	Village ID	No. of Ponds	No. of Samples (June 2017)	No. of Samples (Apr/May 2019)	No. of Samples (Jan. 2020)
Munnawarpur Kalan	MK	1	04	06	03
Antwara	AT	1	04	05	03
SiwayaJamalullapur	SW	1	05	02	03
Pavli Khas	PK	1	04	03	03
Roni Hazipur	RZP	1	04	03	03
MohammadpurMadan	MM	1	06	03	-
Bhora Kalan	BKL	1	04	03	03
Bhora Khurd	BK	2	07	03	05
Biral	BR	1	04	03	03
Itawa	IT	2	06	02	-
Total		**12**	**48**	**33**	**26**

Table 3: Details of Field Investigations at Identified Ponds in M. Nagar and Meerut Dist.

Village Name	**R&D Activities**								
	Sludge Sampling	**Soil Sampling**		**Infiltration Test**	**GWL Measurement**	**Ground Water Sampling**	**Agri. soil Sampling**	**Analysis of GW Samples**	**Analysis of Soil Samples**
		Disturbed	**Un-disturbed**						
MUZAFFARNAGAR DISTRICT									
Mohammadpur Madan - 2	23/4/19	-	-	-	23/4/2019	23/4/19	23/4/2019	✔	✔
Bhora Kalan	17/10/18	17/10/2018	17/10/2018	4/12/2018	4/12/2018	4/12/18	17/10/18	✔	✔
Bhora khurd-1	11/1/19	11/1/2019	25/4/2019	25/4/2019	25/4/2019	25/4/19	11/1/2019	✔	✔
Bhora khurd-2	11/1/19	11/1/2019	11/1/2019	11/1/2019	25/4/2019	25/4/19	11/1/2019	✔	✔
Itawa-1	9/1/2019	9/1/2019	9/1/2019	9/1/2019	24/5/2019	24/5/19	9/1/2019	✔	✔
Itawa-2	8/1/2019	8/1/2019	8/1/2019	8/1/2019	24/5/2019	24/5/19	8/1/2019	✔	✔
Biral	3/1/2019	3/1/2019	3/1/2019	3/1/2019	22/5/2019	22/5/19	3/1/2019	✔	✔
Munnawarpur Kalan	17/10/18	17/10/2018	17/10/2018	17/10/2018	15/5/2019	15/5/19	17/10/18	✔	✔
Roni Hazipur	24/4/19	24/4/2019	24/4/2019	24/4/2019	24/4/2019	24/4/2019	24/4/2019	✔	✔
Antwara	7/1/2019	7/1/2019	7/1/2019	7/1/2019	15/5/2019	15/5/2019	7/1/2019	✔	✔
MEERUT DISTRICT									
Siwaya	15/10/18	15/10/018	15/10/2018	15/10/2018	23/5/2019	23/5/2019	23/5/2019	✔	✔
Pavli Khas	18/3/2019	18/3/2019	18/3/2019	18/3/2019	24/5/2019	24/5/2019	18/3/2019	✔	✔

Based on field investigations, the water quality and trophic status of identified ponds before and after rejuvenation was assessed and results are given below in Table 4&5. The results indicate that the water quality has been improved after pond rejuvenation. The benefit of the rejuvenated ponds can also be seen in the form of reduction in eutrophication levels from hyper eutrophic to eutrophic after pond rejuvenation.

Table 4: Water quality of identified Ponds Before and After Rejuvenation

Village ID	Before Rejuvenation (June, 2017)								After Rejuvenation (January, 2020)							
	pH	EC (µS/cm)	TDS (mg/l)	DO (mg/l)	COD (mg/l)	BOD (mg/l)	TC (MPN/ 100 ml)	E.coli (MPN/ 100 ml)	pH	EC (µS/cm)	TDS (mg/l)	DO (mg/l)	COD (mg/l)	BOD (mg/l)	TC (MPN/ 100ml)	E.coli (MPN/ 100 ml)
ME - 1	8.1	1647	810	Nil	180	48	$10X10^6$	$6X10^4$	7.4	2650	1696	1.0	192	70	2613000	624000
ME - 2	7.7	1675	840	2.2	150	60	$210X10^6$	$10X10^4$	7.4	2240	1433.	0.8	680	200	3649000	30000
MN- 1	9.3	1303	562	Nil	102	30	$170X10^6$	$20X10^4$	7.9	894	572.1	3.7	56	30	223000	10000
MN - 2	7.6	1660	774	Nil	220	65	$200X10^6$	$20X10^4$	7.2	663	424.3	3.0	280	50	250000	10000
MN - 3	7.5	1483	648	0.2	56	16	$220X10^6$	$6X10^4$	-	-	-	-	-	-	-	-
MN - 4	8.2	1735	1154	1.1	260	70	$7x10^6$	$5X10^4$	8.0	1296	829.4	8.9	328	47	1464000	231000
MN - 5	7.7	2170	1142	Nil	220	60	$230X10^6$	$5X10^4$	-	-	-	-	-	-	-	-
MN - 6	7.4	1770	774	Nil	68	20	$100X10^6$	$10X10^4$	7.1	656	419.8	2.8	40	9	650000	63000
MN - 7	7.6	2280	1306	Nil	380	90	$9X10^6$	$6X10^4$	8.4	1224	783.3	3.5	120	50	63000	20000
MN - 8	7.6	1909	854	3.1	200	50	$300X10^6$	$3X10^4$	8.4	1226	784.6	0	440	140	85000	20000
MN - 9	7.4	1645	954	Nil	220	54	$6X10^6$	$2X10^4$	8.1	1571	1005	3.4	152	49	960000	20000
MN -10	7.2	1540	502	Nil	160	50	$210X10^6$	$6X10^4$	-	-	-	-	-	-	-	-

Table 5: Trophic Status of Ponds Before and After Rejuvenation (Benefits of pond rejuvenation)

Village ID	Village Name	TP (mg/l) 2017	TP (mg/l) 2020	TN (mg/l) 2017	TN (mg/l) 2020	TN/TP (2017)	TN/TP (2020)	Composite TSI (CTSI) (2017)	Trophic Status as per Carlson's Index (2017)	Composite TSI (CTSI) (2020)	Trophic Status as per Carlson's Index (2020)
ME - 1	Pavli Khas	29.5	2.336	410	61.05	13.9	26.1	146	Hyper Eutrophic	73	Eutrophic
ME - 2	Siwaya Jamalullapur	1.98	1.982	502	106.3	253.5	53.6	128	Hyper Eutrophic	75	Eutrophic
MN- 1	Bhora Kalan	4.29	4.491	412	45.18	96.0	10.0	111	Hyper Eutrophic	81	Eutrophic
MN - 2	Bhora Khurd - 1	6.24	7.031	416	35.31	66.6	5.0	116	Hyper Eutrophic	85	Eutrophic
MN - 3	Mohammadpur Madan	3.2	-	474	-	148.1	-	111	Hyper Eutrophic	-	-
MN - 4	Biral	13.92	9.848	512	42.6	36.7	4.3	115	Hyper Eutrophic	91	Eutrophic
MN - 5	Itawa -2	6.98	-	432	-	61.8	-	116	Hyper Eutrophic	-	-
MN - 6	Bhora Khurd - 2	5.23	4.553	433	15.43	82.7	3.3	112	Hyper Eutrophic	73	Eutrophic
MN - 7	Roni Hazipur	28.09	8.388	452	51.74	16.0	6.1	118	Hyper Eutrophic	91	Eutrophic
MN - 8	Antwara	13.77	4.864	514	44.84	37.3	9.2	115	Hyper Eutrophic	82	Eutrophic
MN - 9	Munnawarpur Kalan	30	8.128	487	93.9	16.2	11.5	110	Hyper Eutrophic	94	Eutrophic
MN - 10	Itawa - 1	4.49	-	426	-	94.8	-	115	Hyper Eutrophic	-	-

The LULC maps of the area around pond surroundings (upto 1 km) were prepared for reuse planning of the treated pond water (Fig.2). The GWL variation in the study area during pre and post rejuvenation stages of ponds is given in Fig. 3.

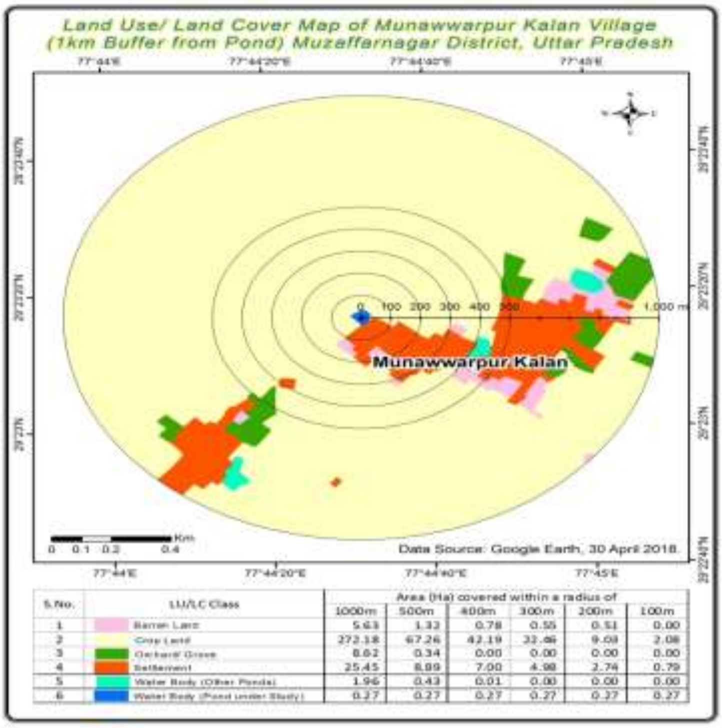
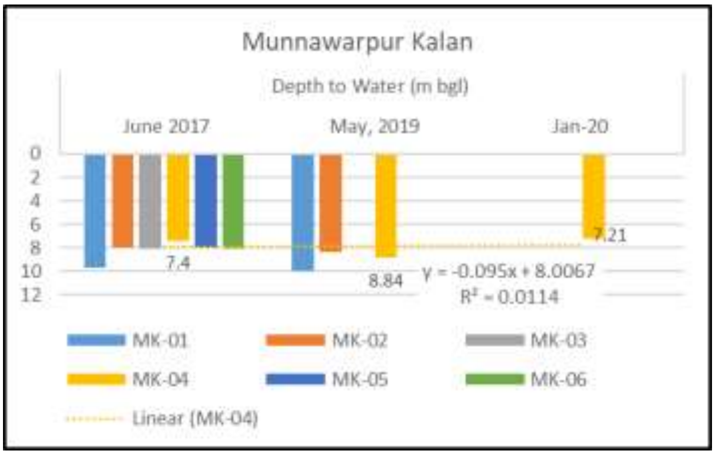


Fig. 2: LULC map of pond surroundings at village Munnawarpur Kalan



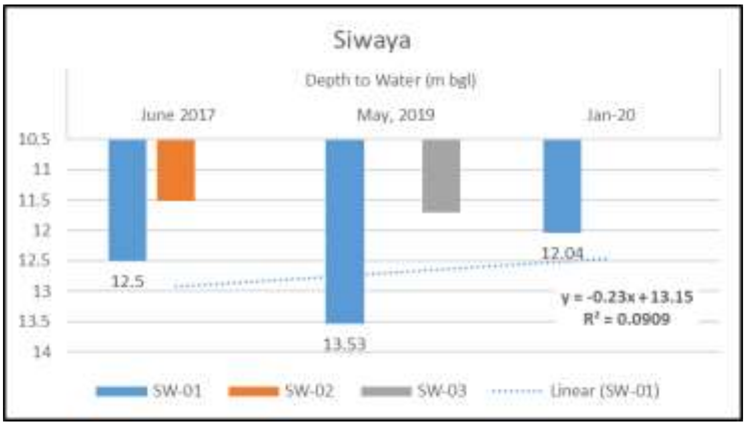


Fig. 3: Variation of ground water levels (DTW, m bgl) in the study area

15. **End Users / Beneficiaries of the Study:** Villagers and Stakeholders

16. **Deliverables:** Rejuvenated village ponds, Standard Operating Procedures (SOP) for O&M of treatment system in village pond/s, Technical report(s) and publications.

17. **Major items of equipment procured:** Nil

18. **Lab facilities used during the study:** WQL, S&W Lab, GWHD (NIH)/ IIC (IITR)

19. **Data procured or generated during the study:** Groundwater quality, Pond water Quality, Village wastewater quality, Trophic Status Index of pond, Pond productivity test, Groundwater level, Infiltration rate at pond bed, Permeability, Leachability of trace metals and nutrients in the sludge.

20. **Study Benefits / Impacts:**

The outcome of the project will be beneficial for the villagers in a sense that it has increased the groundwater recharging capacity of the pond and also enhanced the groundwater water quality of the area. This study will also help in replication of the technology in other village ponds of other districts of the country. The details are given below:

- 2 research papers, under publication in peer-reviewed reputed journals, present pre- and post-intervention results.
- 300 to 400% enhancement in pond storage capacity (village water security)
- Improved pond water quality and solved water logging problem in villages (villagers appreciated)
- Significant reduction in total phosphate (TP) and total nitrogen (TN) achieved.

- Trophic status (TSI) of rejuvenated ponds improved from Hyper-eutrophic to Eutrophic.
- Authorities in Muzaffaranagar district have instructed BDOs of respective villages to take up various maintenance works for the rejuvenated ponds under MNREGA scheme.

21. **Involvement of end users/beneficiaries:** Villagers & Gram Panchayats

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

23. **Shortcoming/Difficulties:** Local issues

24. **Future Plan:** The final project completion report has been submitted report to INC-SW, which has been approved by the Chairman, INC-SW/CWC, New Delhi (May 2020).

Sponsored Project-3 (Ongoing)

1. **Title of the Study: Rejuvenation of Village Ponds in Identified Villages of Baghpat, Ghaziabad and Meerut Districts of Uttar Pradesh**

2. **Study Group:**

Lead Organization	**Project Investigator** Er. Omkar Singh, Scientist F, RMOD
	Co-Investigator Dr. Rajesh Singh, Sc. C, EHD Dr. V. C. Goyal, Sc. G, RMOD Er. Digambar Singh, Sc. C, RMOD
	Scientific/Technical Staff Sh. Subhash Kichlu, PRA Sh. Rajesh Agarwal, SRA Sh. N. R. Allaka, RA Dr. N. G. Shrivastava, Senior Expert Dr. Nihal Singh, Research Scientist Dr. Kalzang Mathus, Research Associate Sh. Sandeep Yadav, Research Associate Sh. Subhash Vyas, Project Assistant
Civil Work Execution Agency	NPCC Limited (A GoI Enterprise), Noida

3. **Type of Study:** Invited study by MoWR, RD & GR,
4. **Budget:** Rs. 780 Lakh (through Scheme budget)
5. **Nature of Study:** Applied Research
6. **Date of start & duration:** Jan. 2018 (3 Years)
7. **Scheduled date of completion:** Dec. 2020
8. **Study Objectives:**

- Rejuvenation of identified village ponds by carrying out de-weeding, de-silting and associated civil works for development of Natural Treatment System (NTS) in the ponds for their rejuvenation.
- Establishment of appropriate phyto-remediation based Natural Treatment System (NTS) at identified pond sites for treatment of wastewater
- Performance evaluation of the NTS based rejuvenated ponds and assessment of treated wastewater for irrigation/fishery by monitoring relevant water & wastewater quality parameters, groundwater levels, etc.
- Capacity building/Mass Awareness Activities.

9. **Statement of the Problem:**

With the availability of millions of village ponds and local drains, there exists a vast potential of recycling and reuse of wastewater through simple retrofitting techniques. Such decentralized treatment of these small water bodies is an emerging need for their restoration and preservation, leading to multiple benefits of disaster resiliency, groundwater recharging, environment regeneration and livelihood generation at the local watershed level. The Ministry of WR, RD & GR (GoI) directed NIH to undertake the rejuvenation of ponds and wastewater treatment based on the natural solutions in 10 villages of Baghpat, Ghaziabad and Meerut (Fig. 1).

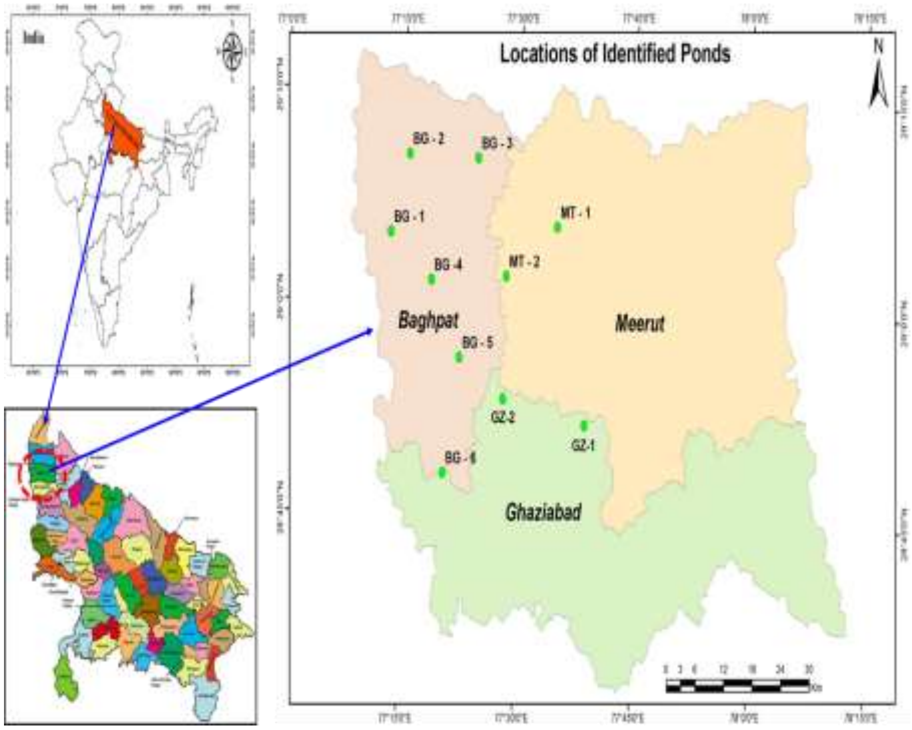


Fig. 1: Location map of identified village ponds in Baghpat, Ghaziabad and Meerut Dist.

At present, the wastewater generated from most of the villages in the country is discharged into the village ponds and leads to eutrophication of these ponds and growth of blue green algae, making the water toxic and unfit for the consumption, even by animals. Moreover, the organic laden water in the pond during recharge to the aquifer transports organics into the aquifer material enhancing the undesirable anaerobic microbial action on the aquifer media resulting in the dissolution of toxic metals like arsenic etc. into the groundwater. The polluted water resources lead to dramatic human cost. Keeping in view of the above issues related to contamination of water resources and wastewater management in the villages, the ministry directed NIH to undertake the rejuvenation of ponds and wastewater treatment based on the natural solutions in 10 villages of Bagpat, Ghaziabad and Meerut. Accordingly, the research proposal has been formulated which will address the problem related to deteriorating health of village ponds and the declining groundwater levels as well as quality in the villages of western UP on a pilot scale, the results from which can be replicated in other villages of the country.

10. Action Plan/Methodology:

- Reconnaissance survey of identified village ponds for data collection along with sampling and analysis of wastewater input to the pond
- Rejuvenation of identified village ponds & associated civil work (de-weeding, de-silting, etc.) including fabrication of suitable natural treatment system (CWT) for nutrients removal (through NPCC).
- Water and wastewater characterization and Health Assessment of Water Body.
- Monitoring of GWQ and GWL around rejuvenated ponds
- Performance evaluation of NTS based on key water quality parameters
- Reuse planning of treated pond water
- Mass Awareness/capacity building

11. Timeline:

Sr. No.	Activities	w.e.f. Jan. 2018				2019				2020			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1	Identification of study site/ponds with GPs												
2	Field investigations (sampling and analysis)												
3	Detailed engineering design/estimates from NPCC for civil works												
4	Execution of civil works (dewatering, desilting, inlet works, outlet works, floating wetland)												
5	Performance evaluation of NTS (Floating Wetlands) at two ponds												
6	Health Assessment/ Trophic Status of rejuvenated ponds												
7	LU/LC maps for Reuse planning of treated pond water												
8	Mass awareness/capacity building												
9	Technical reports												

12. Objectives and achievements:

Objectives	**Achievements**
Rejuvenation of identified village ponds by carrying out de-weeding, de-watering, de-silting and associated civil works for development of Natural Treatment System (NTS) in the identified ponds –through NPCC.	• As per letter from the Ministry regarding pond rejuvenation works in the identified villages of Baghpat, Meerut and Ghaziabad Districts, a proposal was prepared and submitted to the Ministry. • In this connection, the Ministry directed Institute to rejuvenate 10 identified village ponds through Scheme budget the Institute in this project. • A revised estimate of civil work was obtained from NPCC and requisite work of pond rejuvenation (9 ponds) was awarded to NPCC as per MOA. • In this connection, a formal consent was also obtained from 9 GPs to rejuvenate their identified ponds. • *The civil work component (de-weeding, de-watering, de-silting) of pond's rejuvenation been completed during Nov. 2019 at all 9 identified ponds alongwith development of NTS at two sites by NPCC (Cost: Rs. 502.41 Lakh).*
Establishment of appropriate phyto-remediation based Natural Treatment System (NTS) at identified pond sites for treatment of wastewater	• The nursery for developing aquatic plant saplings has been established. • Approx. 5000 Reed Plant and 1000 Canna plant saplings were grown at NIH and requisite nursery plants have been transported at identified two pond sites (Basoli & Ikari). • FW has been established at both identified pond sites (Basoli & Ikari) in this project.
Performance evaluation of the NTS based rejuvenated ponds and assessment of treated wastewater	• During May 2018, field investigations were carried out to collect water samples from all identified ponds, inlets and handpumps. • During April/May 2019, field investigations were carried out to

for irrigation/ fishery by monitoring relevant water & wastewater quality parameters, groundwater levels, etc.	collect GW samples, GWL, soil & sludge samples (for trace metals-As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn, Hg), infiltration tests at pond beds, etc. ***<u>After 49th WG Meeting:</u>*** • Field investigations (WQ of ponds & adjacent hand pumps, GWL) were collected at two NTS pond sites (Basholi & Ikari) during January 2020. • The analysis of water quality data has been completed in light of pre-rejuvenation (2018) and post-rejuvenation (2020) stages of these two ponds. • LU/LC maps (1km radius from ponds) were prepared for reuse of treated wastewater.
Capacity building/Mass Awareness Activities	• The concerned GPs (Basoli and Ikari) were given necessary input for maintenance of the NTS plants and system

13. Recommendation / Suggestion:

Recommendation / Suggestion	Action Taken
There were no specific comments from working group members.	-

14. Analysis & Results:

(A) Civil Work

The civil work related to the rejuvenation of the ponds has been completed by the NPCC. Natural treatment system (Floating wetland) has been established in pond at Basoli and Ikari as per revised scope of work. The status/ progress of the civil works by NPCC is given below in Table 1:

Table 1: Status of rejuvenation of ponds in Baghpat, Ghaziabad and Meerut

Date: 01/10/19

RENOVATION & OTHER CONSTRUCTION WORK OF POND

STATUS OF WORK UPTO SEPTEMBER- 2019

S.No.	Name of Pond and Village		Dewatering	Removal of Sludge	Periphery Drain work	Sedimentation Tank	Screening Chamber at Inlet	Compaction of embankment & periphery	Floating Wetland Work	Depth of Pond (NGL)	(Sludge)
B	Baghpat & Ghaziabad (PACKAGE-2)										
1	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	2.37m	2.07m
2	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	4.28m	4.83m
3	Basoli	[illegible]	Completed	Completed	Completed	Complete	Not required	Completed	Completed	5.56m	2.63m
4	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	3.97m	2.84m
5	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	3.20m	2.80m
6	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Complete	Completed	Dropped by NIH	4.7m	3.25m
7	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	2.89m	2.36m
8	Ikari	[illegible]	Completed	Completed	Completed	Complete	Complete	Completed		1.8m	1.48m
9	[illegible]	[illegible]	Completed	Completed	Dropped by NIH	Dropped by NIH	Non availability of Land & Dispute of villagers	Completed	Dropped by NIH	4.52m	3.7m

P.M.
Project Manager
NPCC Ltd
Meerut Unit

(B) R&D Component: Pre- and post-rejuvenation Situations

I. Water Sampling and Analysis

- Groundwater (nearby hand pumps)

- Pond water
- Wastewater (at pond inlets)

Physical: pH, EC, ORP, TDS, TSS, turbidity, alkalinity
Chemical: fluoride, nitrate, nitrite, sulphate, DO, COD, BOD; hardness, calcium, magnesium, sodium, potassium, chloride, ammonium,
Biological: TC, E.coli
Trace metals: aluminum, cadmium, copper, chromium, lead, manganese, zinc
Groundwater level ranged from 9.58m to 33.25 m (2018) and 2.3 to 33.64m (2019). The trend lines of GWL variation of two pond sites (Basoli and Ikari) are given in Fig.3, which clearly shows the improvement of ground water levels after pond rejuvenation.

II. Sludge and Soil Sampling and Analysis

- Sludge at pond bed
- Pond bed soil
- Soil from nearby agricultural fields
- Soil bulk density and texture
- pH, EC, organic carbon, boron, zinc, copper, iron, nickel, lead, arsenic, chromium, Sulphur, manganese, available nitrogen, phosphorus, potassium

III. Permeability and Infiltration Rate Analysis

IV. Establishment of Natural Treatment System (NTS)-Floating Wetland (FW) at Basoli & Ikari

V. Reuse planning of treated wastewater

- GIS-based LULC buffer maps

Various field investigations were carried out during April/May 2018, June 2019 and Jan. 2020, respectively. The list of water quality samples collected before and after pond rejuvenation works are given in Table 2. The details of field investigations are given in Table-3.

Table 2: List of WQ samples collected in the study

S.No	**Village Name**	**Village ID**	**No. of samples (Apr/May 2018)**	**No. of samples (Jun 2019)**	**No. of samples (Jan 2020)**
1	Basoli	BL	5	4	3
2	Khindora	KD	6	6	-
3	Saidpur	SR	5	3	-
4	Paldi	PD	6	3	-
5	Ikari	IK	6	4	3
6	Dhikana	DK	6	4	-
7	Dagarpur	DG	6	5	-
8	Pilana	PI	6	3	-
9	Budhera	BD	6	4	-
Total		**10**	**57**	**36**	**6**

Table 3: Field Investigations at Identified Ponds in Baghpat, Ghaziabad and Meerut Dist.

Village	Progress of R&D WORK								
	Sludge sampling	Soil sampling		Infiltration Test	Ground Water Level Measurement	Ground Water Sampling	Agri. Land-soil sampling	Analysis of GW Samples	Analysis of soil samples
		Disturbed	Un-disturbed						
BAGHPAT									
Budhera	15-03-19	15-03-2019	15-03-2019	15-03-2019	21-05-2019	21-05-2019	15-03-2019	✔	✔

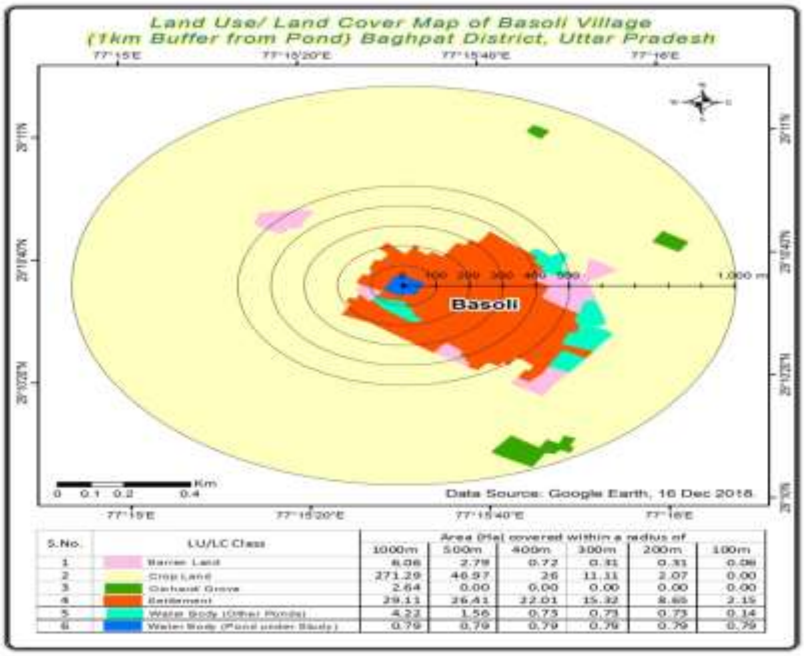
Pilana	18-03-2019	-			20-05-2019	20-05-2019	15-03-2019	✔	
Basoli	14-03-2019	14-03-2019	14-03-2019	14-03-2019	23-04-2019	23-04-2019	14-03-2019	✔	✔
Dagarpur	04-02-2019	-			20-05-2019	20-05-2019	04-02-2019	✔	✔
Dhikana	19-03-2019	-			16-05-2019	16-05-2019	19-03-2019	✔	✔
Paldi	15-10-2018	15-10-2018	15-10-2018	15-10-2018	14-05-2019	14-05-2019	04-02-2019	✔	✔
MEERUT									
Ikari	10-01-2019	10-01-2019	-	10-01-2019	14-05-2019	14-05-2019	10-01-2019	✔	✔
GHAZIABAD									
Saidpur	29-04-2019	-			29-04-2019	29-04-2019	29-04-2019	✔	✔
Khindora	28-04-2019	-			28-04-2019	28-04-2019	28-04-2019	✔	✔

Based on field investigations, the water quality of identified ponds before and after rejuvenation was assessed and results are given below in Table 4. The results indicate that the water quality has been improved after pond rejuvenation.

Table 4: WQ parameters of ponds before and after rejuvenation

		Before Rejuvenation (May 2018)						After Rejuvenation (Jan 2020)					
Sample ID	Source	pH	EC	TDS	DO	BOD	COD	pH	EC	TDS	DO	BOD	COD
			μs/cm	mg/L	mg/L	mg/L	mg/L		μs/cm	mg/L	mg/L	mg/L	mg/L
BD	Pond	8.7	1370	877	0	460	800	-					
KD	Pond	7.1	2026	1297	0	500	160						
DK	Pond	6	2100	1344	0	80	56						
BL (Basoli)	Pond	7.8	1561	999	0	410	216	8.74	1437	915	9.5	90	168
IK (Ikari)	Pond	6.7	1505	963	0	70	136	6.67	1687	1079	3	40	80
SR	Pond	6.32	1810	1158	0	130	160	-					
PD	Pond	7.28	1619	1036	0	80	288						
PI	Pond	9	2058	1317	0	70	160						
DG	Pond	8.12	1604	1027	0	80	176						

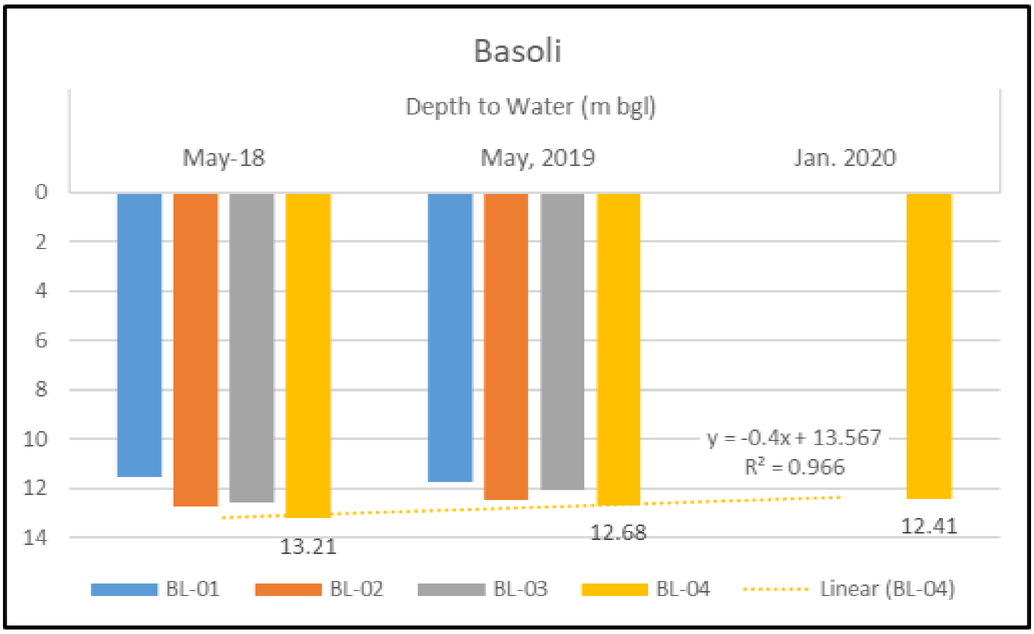
Water quality parameters of before and after rejuvenation of ponds shown in Table 4 indicates that after rejuvenation work water quality of ponds improved significantly. Initially Dissolved oxygen was nil almost in all ponds but after the installation of floating wetland DO improved from 0 to 9.5 mg/l in Basoli pond and 3 mg/l in Ikari pond. Similarly, BOD in pond reduced to 70 mg/l to 40 mg/l and COD of ponds decreased from 136 to 80 mg/l in Ikari pond. COD values also reduced to 216 to 168 mg/l in Basoli pond and 136 to 80 mg/l in Ikari pond after rejuvenation work.



S.No.	LU/LC Class	Area (Ha) covered within a radius of					
		1000m	500m	400m	300m	200m	100m
1	Barren Land	8.06	2.79	0.72	0.31	0.31	0.08
2	Crop Land	271.29	46.97	26	11.11	2.07	0.00
3	Orchard Grove	2.64	0.00	0.00	0.00	0.00	0.00
4	Settlement	29.11	26.41	22.01	15.32	8.65	2.15
5	Water Body (Other Ponds)	4.22	1.56	0.73	0.73	0.73	0.14
6	Water Body (Pond under Study)	0.79	0.79	0.79	0.79	0.79	0.79

Figure 2: LULC Map of Basoli

The LULC maps of the area around pond surroundings (upto 1 km) were prepared for reuse planning of the treated pond water (Fig.2). The GWL variation in the study area during pre (May 2018) and during rejuvenation (May 2019) stages of ponds is given in Fig. 3.



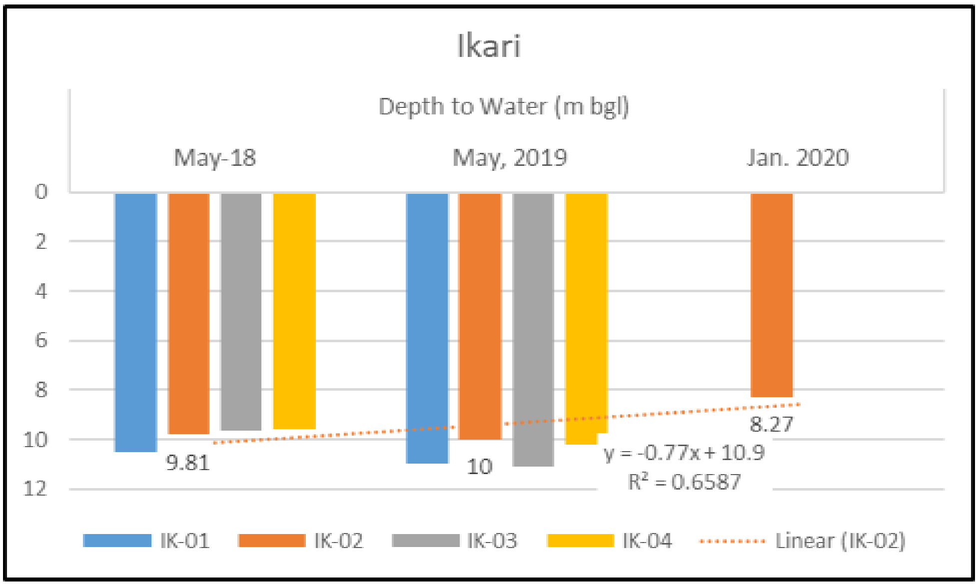


Fig. 3: Variation of ground water levels (DTW, m bgl) in the study area

15. **End Users / Beneficiaries of the Study:** Villagers and Stakeholders

16. **Deliverables:** Rejuvenated village ponds, Standard Operating Procedures (SOP) for O&M of treatment system in village pond/s, Technical report(s) and publications.

17. **Major items of equipment procured:** Nil

18. **Lab facilities used during the study:** WQL, S&W Lab, GWHD (NIH)/ IIC (IITR)

19. **Data procured or generated during the study:** Groundwater quality, Pond water Quality, Village wastewater quality, Trophic Status Index of pond, Pond productivity test, Groundwater level, Infiltration rate at pond bed, Permeability, Leachability of trace metals and nutrients in the sludge.

20. **Study Benefits / Impacts:**

The outcome of the project will be beneficial for the villagers in a sense that it will increase the groundwater recharging capacity of the pond and also enhance the groundwater water quality of the area. This study will also help in replication of the technology in other village ponds of other districts of the country.

21. **Involvement of end users/beneficiaries:** Villagers & Gram Panchayats

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

23. **Shortcoming/Difficulties:** Local societal issues

24. **Future Plan:** Field Investigations (WQ, GWL) in the project area and Mass awareness/capacity building activities with GP's**.**

Sponsored Project- 4: Shifted from NNWP to Plan (completed)

1. Title of the Study:

Development of water allocation plan of watersheds in Chhattisgarh

2. Study group:

Dr. A. R. Senthilkumar, Sc “F” RMOD
Dr. T R Nayak, Sc “F”, RC, Bhopal
Dr. Jyoti P Patil, Sc “D”, RMOD
Sh. Rohit Sambare, Sc “B”, RMOD
Sh. Rajesh Agarwal, SRA, RMOD

3. Date of start: April 2018

4. Duration of the study: 2 Years

5. Whether externally funded or not: No

6. Objectives:

a. To model the different components of hydrological process.
b. To evolve water allocation plan for various uses by scenario analysis.

7. Statement of the problem

The demand for water from agricultural, industrial and domestic uses is continuously increasing due to the development in their respective sectors. The fixed availability and uncertainty over the occurrence of water increases the complexity of allocation of water to the competing demands from various sectors. It is imperative to evolve management plans for the allocation of water in efficient way to achieve optimum crop yield without compromising the demands for domestic and industrial uses. Allocation of limited water resources among agricultural, domestic and industrial uses requires the integration of supply, demand, water quality and ecological considerations. The Conventional supply-oriented simulation models are not always adequate for exploring the full range of management options for water allocation. Water Evaluation And Planning (WEAP) tool integrates all tools in a robust way for integrated water resources planning.

8. Methodology

The water allocation plan among different uses in micro watersheds in Chhattisgarh is evolved by setting up of WEAP tool. The inputs to WEAP tool such as water demand from various sectors, priority of the demand, catchment details, hydrologic conditions and inflows, catchment hydrology (river flow, ground water, lakes/reservoir/storage tanks, springs, other storage structures etc), supply preference (operating rules/policy), return flows, minimum flow requirements, economic variables such as cost water transmission etc are prepared from the data obtained from various sources such as irrigation department, IMD, CWC, census department. The hydrological processes occurring in the catchment will be modeled and will be compared with the measured discharge time series. After the proper calibration of the model, the demand sites will be added into a model framework and different scenarios will be generated to assess the gaps in the water demand and supply and water availability at different locations and at the different period. The different water allocation plan will be evolved based on the scenario analysis to achieve optimum crop yield.

9. Results achieved with progress/present status:

The WEAP model has been setup for micro watersheds IWMP14, IWMP15 and IWMP16 using the climate data such as rainfall from IMD data, reference evapotranspiration for crops, population data and livestock details, area under different crops, priority for supply from DPR, crop coefficient, etc. The catchment area of IWMP 14, IWMP15 and IWMP 16 are 50.35, 47.56 and 39.78 sqkm respectively. The base year for current accounts (reference scenario) for IMWP14, IWMP15 and IWMP16 are 2011, 2015 and 2009 respectively. The input for IWMP16 are taken from global climate dataset attached with WEAP model. The annual demand for domestic, livestock and agricultural and unmet demand for the reference scenario for the period from 2011 to 2021 for IWMP14, 2015 to 2025 for IWMP15, 2010 to 2050 for IWMP16 are computed with the input data. The runoff computation is done using the simplified coefficient method. The schematic diagram of the model setup for IWMP 14, 15 and 16 are given as follows:

Fig. 1 Schematic diagram for IWMP 14

Fig. 2 Schematic diagram for IWMP 15

Fig. 3 Schematic diagram for IWMP 16

The annual domestic demand and unmet demand (Reference scenario) for IWMP 14, IWMP15 and IWMP16 are given as follows:

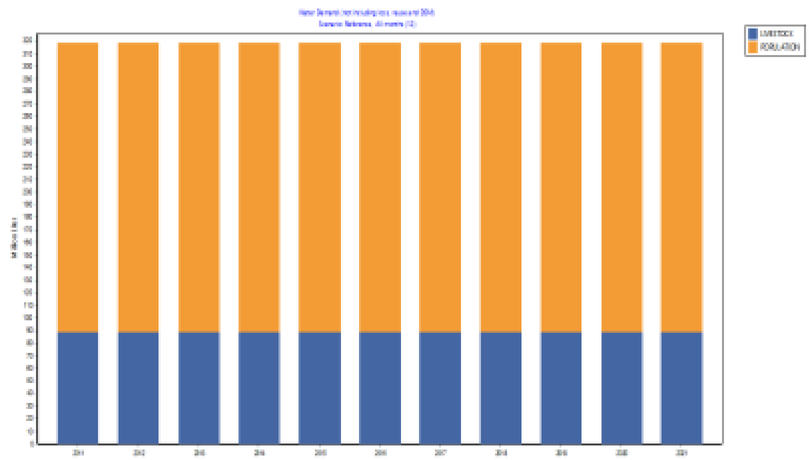


Fig. 4 Annual domestic demand (Reference Scenario) for IWMP14

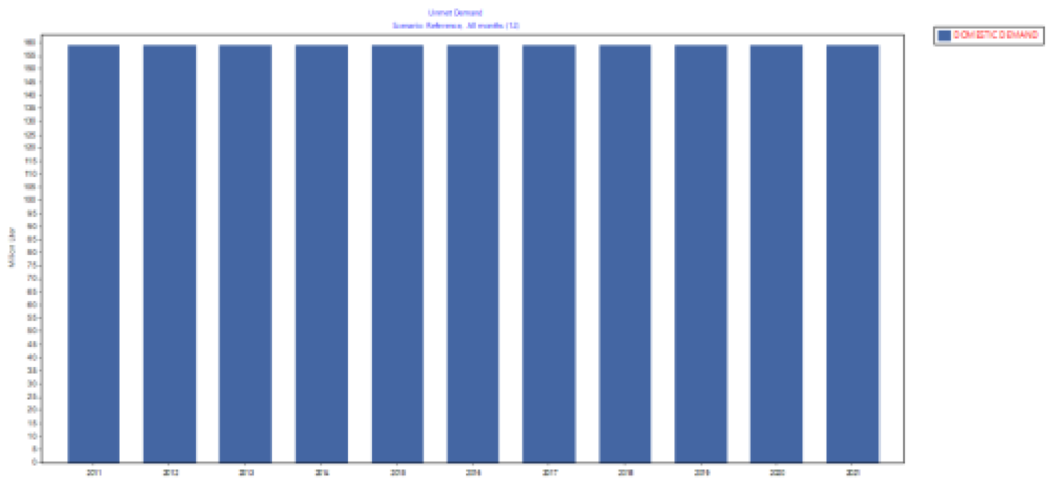


Fig. 5 Unmet water demand (Reference Scenario) IWMP14

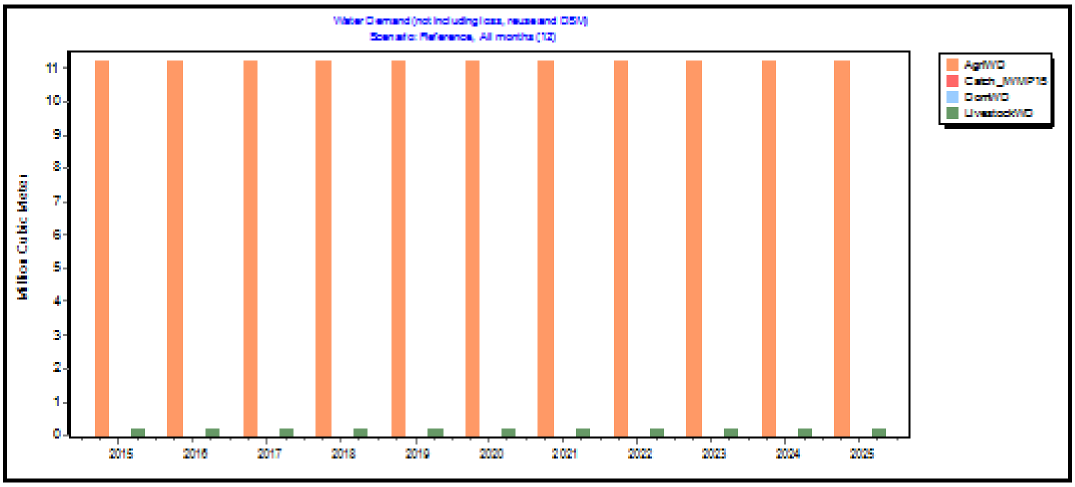


Fig. 6 Water Demand (reference scenario) IWMP15

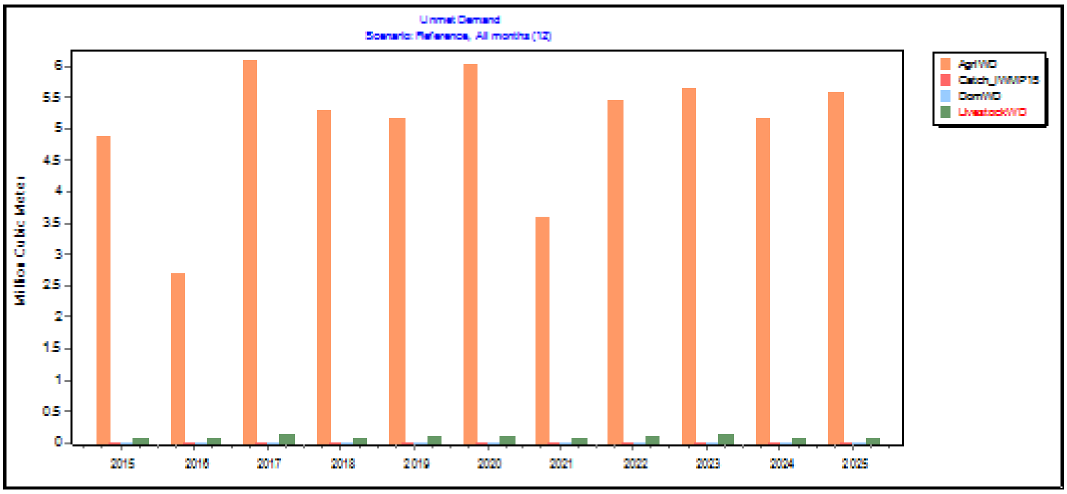


Fig. 7 Unmet Demand (reference scenario) IWMP15

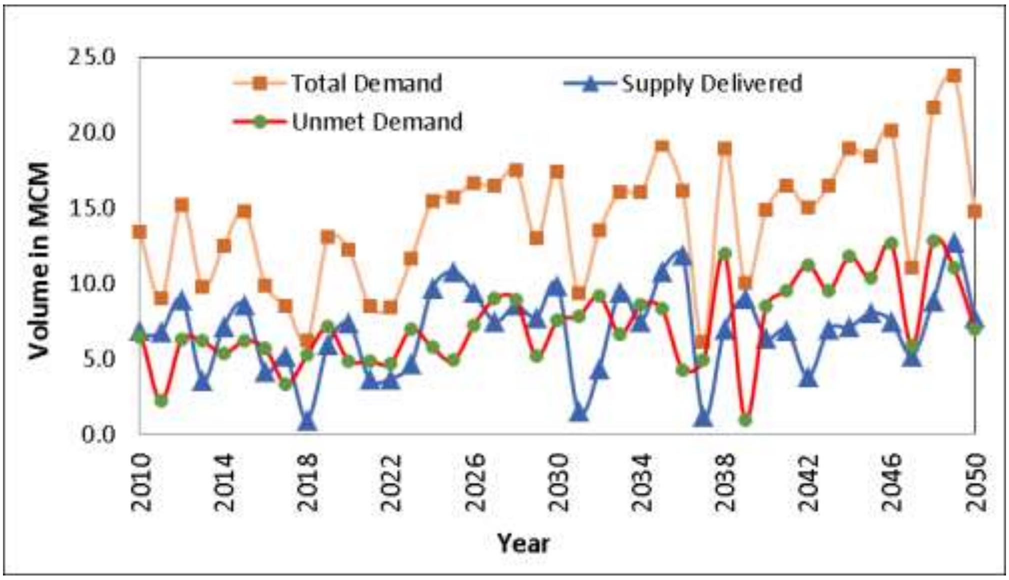


Fig. 8 Supply and demands (Refence Scenario) for IWMP16

The scenario analysis carried out for IWMP14 are low population growth, high population growth and supply augmentation. The scenario analysis carried out for IWMP15 are population growth rate with 0.9%, 1.0%, 1.1% and 1.3 %. The scenario analysis carried for IWMP16 are, decrease or increase in groundwater recharge, construction of surface water storage structures with population growth. The demand and unmet demand for the scenarios are computed and analyzed for the demand met by the way of considering the supply augmentation. The annual water demand and unmet demand for population growth scenario for IWMP 14 are given as follows:

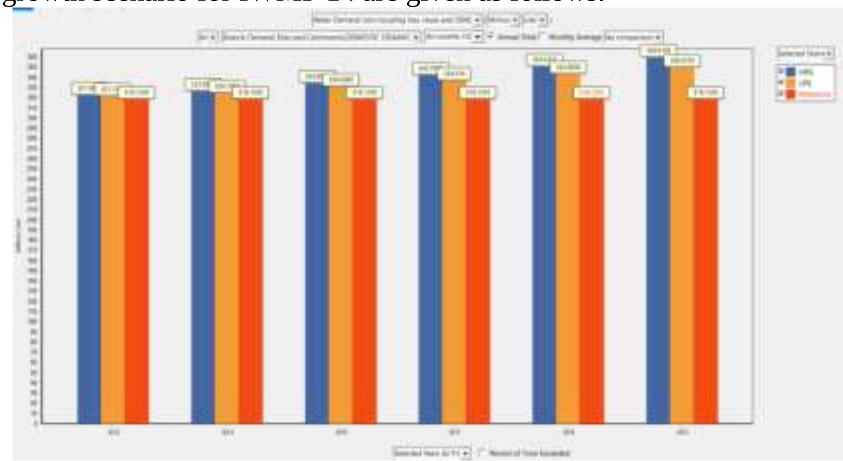


Fig. 9 Annual water demand, Population growth scenario for IWMP14

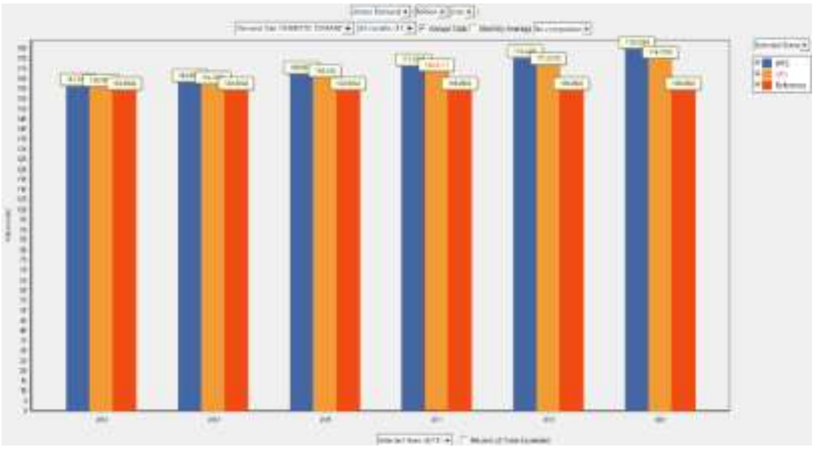


Fig. 10 Annual unmet water demand, Population growth scenario for IMP14

It can be clearly seen that population growth is going to create water stress in the region if the current water supply is not altered. The unmet water demand in this case changes by 20-30 million litres as compared to the baseline scenario. The annual water demand and unmet demand for population growth scenario at 1.3 % per for IWMP 15 given as follows:

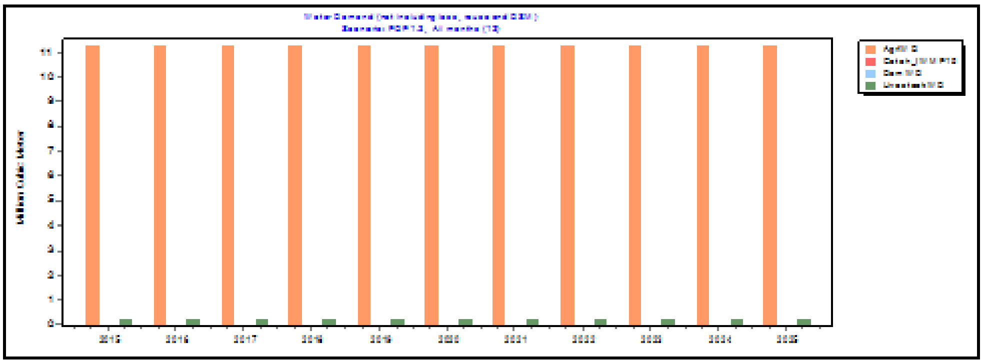


Fig. 11 Demand for the scenario of population growth rate at 1.3 % per annum

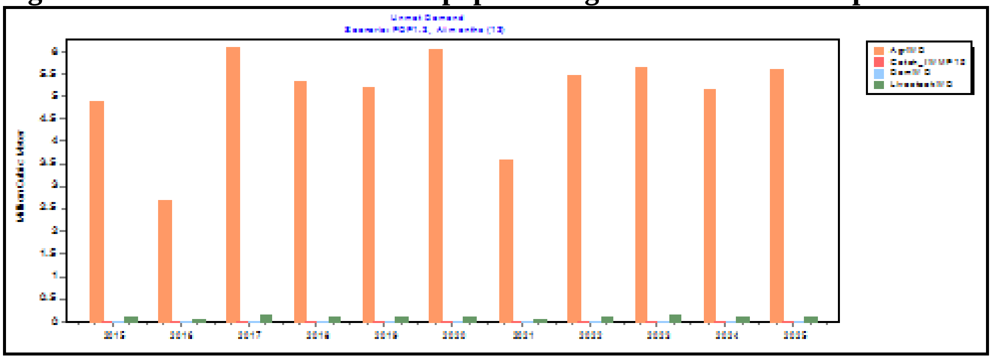


Fig. 12 Unmet demand for the scenario of population growth rate at 1.3 % per annum

It can be clearly seen that the domestic water demand is met even at the population growth rate at 1.3 % per annum. The unmet demand for agriculture varies from 2.7 Mm^3 to 6.10 Mm^3 for the period from 2015 to 2025. The unmet demand for livestock varies from 0.07 Mm^3 to 0.13 Mm^3 for the period from 2015 to 2025. The annual unmet water demand for 2 % growth rate in Groundwater recharge for IWMP 16 is given as follows:

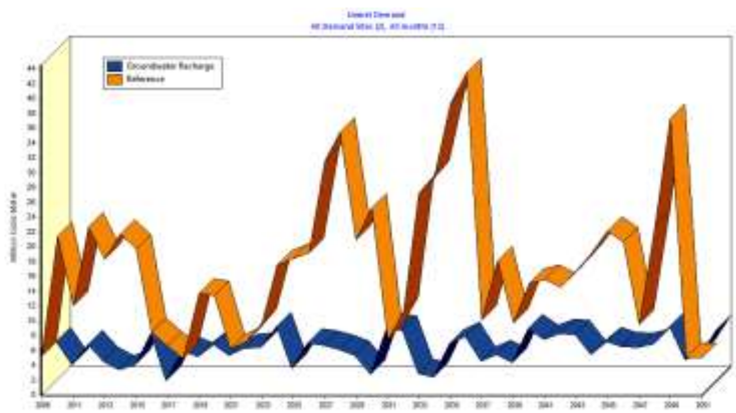


Fig. 13 Annual Variation in Unmet Water Demands (2009-2050) With 2% Growth Rate in Groundwater Recharge

It can be seen that unmet demands for IWMP16 are expected to be very less by the year 2050.

10. Expected date of completion: Draft completion report has been prepared

11. Timeline

Sl. No.	Work Element	**2018-19**				**2019-20**			
		Q1	**Q2**	**Q3**	**Q4**	**Q1**	**Q2**	**Q3**	**Q4**
1	Literature review								
2	Collection of hydro meteorological data, satellite images, thematic maps etc.								
3	Compilation and verification of hydro-meteorological data, baseline survey data, census data and other qualitative data								
4	Preparation of input data for WEAP model								
5	Simulation of components of hydrological processes using SWAT model								
6	Water allocation plan for different uses by scenario analysis by WEAP model								
7	Report writing								

Sponsored Project-5 (ongoing)

SN	Title of Project/Study	Funding	Study Team	Duration
1	Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)	DST (GoI), Cost: Rs. 5.1 Crore	V.C. Goyal (PI), Omkar Singh, Rajesh Singh, Jyoti P. Patil, Rohit Sambare, Project Team (IC-EcoWS) **Partners:** NIH, MNIT-Jaipur, IIT-Bombay, IRMA-Ahmedabad	Apr 2019-Mar 2024

The project **'Innovation Centre for Eco-Prudent Wastewater Solutions (IC-EcoWS)'** is funded by Department of Science & Technology (DST), Government of India. The National Institute of Hydrology (NIH) Roorkee is the leading institute for implementation of this project, in collaboration with the project partners from Indian Institute of Technology Bombay (IITB), Malaviya National Institute of Technology (MNIT), Jaipur and Institute of Rural Management Anand (IRMA), Ahmedabad. 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.

The progress of the project is given below:

NIH Roorkee

Milestone	**Target Month**	**NIH Progress**
Hiring of project staff	M6	Completed
Development of IC-EcoWS Centre's Website and social media pages for information dissemination and communication (Webpage http://117.252.14.242/rmod_dst/Default.aspx , Facebook page and Gmail Account)	M12	Completed
IC-EcoWS project Flyers/Brochures		Completed
IC-EcoWS Project Inception Cum Need Assessment Workshop (8-9 August, 2019)	M12	Completed

Report on First Annual Workshop- Project Inception Cum Need Assessment Workshop		Completed
Procurement of technical and scientific lab equipment for setting up the IC-EcoWS Innovative Centre at NIH	M18	Ongoing
Establishment of Live Laboratory (i.e., Online Water Quality Monitoring System) for the detailed assessment of Natural treatment System (NTS) for wastewater in the rural setting.		Ongoing
Innovative Ideas : NTS-based efficient and low-cost onsite wastewater treatment technologies for domestic and industrial wastewater; Assessment of GHG Emission from wetlands/ponds; Economically sound business model for sustainable wastewater treatment and management.	M24	Ongoing

IIT Bombay

Milestone	Target Month	Progress
Hiring of project staff	M6	Completed
Report on existing NTS installations and their performance in India	M8	Completed
Report on nutrient and energy flows through the NTSs	M18	In progress
Report on environmental performance of NTSs and relevant resource recovery technologies	M30	To be started
Report on multi-criteria assessment of NTSs	M 42	To be started
Decision Support Tool (DST)	M48	To be started

MNIT Jaipur

Milestone	Target Month	Progress
Hiring of project staff	M6	Completed
Establishment of Live Laboratory	M18	
Design of a "pilot CW" finalized (10 KLD) sewage from RBC of MNIT Jaipur		Ongoing
Demarcated space for CW for gray water treatment of a Girl's hostel (50 KLD) in MNIT		Ongoing
Sample Testing from CW receiving residential and Hospital wastewater		Ongoing
Equipment procurement (Laptop/PC)		Ongoing

IRMA Anand

Milestone	Target Month	Progress
Hiring of project staff	M6	Completed
Life Cycle Cost (LCC) estimation of identified NTS technologies	M30	In progress
Business Models for Technology Packages	M42	To be started
To organize capacity building, awareness creation, documentation and dissemination activities, and preparation of a TOT Module	M 48, M50	To be started

HARD ROCK REGIONAL CENTRE BELAGAVI

Scientific Manpower

S N	Name	Designation
1	Dr.B.Venkatesh	Scientist F & Head
2	Dr.B.K.Purandara	Scientist F
3	Dr.M K Jose	Scientist E
4	Dr.Chandra Mohan T.	Scientist D
5	Dr.N. Varadarajan	PRA
6	Mr.Chandrakumar S	SRA

NATIONAL INSTITUTE OF HYDROLOGY

राष्ट्रीय जल विज्ञान संस्थान

आपो हिष्ठा मयोभुव

Recommended Work Program for the Year 2020-2021

SNo.	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)	Ongoing
2	Climate Change Impact assessment for Jayakwadi Reservoir	BV (PI), MKJ, Ahilash and officers from WRD, Govt. Maharashtra)	3 years (05/18-9/21)	Ongoing
3	Flood Vulnerability Assessment and developing mitigation plan for Thiruvananthapuram City, Kerala	CM, BV, MKJ and CS	2 years (9/19 - 8/21)	Ongoing
4	Study on the impact of extensive sand extraction on the river environment and aquifer regime in Godavari basin	MKJ, BV, CMT Abhilash and Officials form TSGWD	2 years (9/19 - 8/21)	Ongoing
Sponsored Projects				
5	Impact of Land use/Land cover Changes on Ground water – A Case	BKP ,BV, SKJ, and CPK	3 years (4/18-3/21)	Ongoing study sponsored by MoES
6	Studies on Occurrence, Distribution and Sustainability of Natural Springs for Rural Water Supply in parts of Western Ghats, India	BKP (PI), SK, NV, Abhilash, & Ujwal,	3 years (9/17-7/20)	Ongoing PDS under NHP (Seeking an extension of 6 months upto March 2021
7	Estimation of Submarine Groundwater Discharge in parts of Karnataka	BKP, SK, JVT and NV	2 years (4/19-3/21)	Ongoing study sponsored by NCESS (MoES)
8	Groundwater Model Development In Micro Basin Of Hard Rock In Krishna And Godavari River Basins Of Telangana	BV, MKJ, AS , Abhilash & Officials form TSGWD	3 years (9/19 - 8/22)	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	Preparation of Emergency Action Plan (EAP) and Study of Tail Channel Design Flood Carrying Capacity of Ambazari Lake, Nagpur	BV (PI)	1 year	Irr. Dept. Nagpur Govt. Of Maharashtra,
3	Preparation of Report On Hydrology of Bandura Nala And Kalasanala Diversion Scheme For Drinking Water Supply	BV (PI)	1 year	KNNL, Bangalore
4	Hydrogeological Studies in and around “Redi Iron Ore Mine” (Block I) of M/S Gogte Minerals, Located at Village Redi, TalukaVengurla, District Sindhudrug, Maharashtra	BKP (PI)	1 year	M/s Redi Mines, Sindhudrug, Maharashtra
5	Hydrogeological Studies in and around “Redi Iron Ore Mine” (Patni Mine) of M/S Minerals & Metals, Located at Village Redi, TalukaVengurla, District Sindhudrug, Maharashtra	BKP (PI)	1 Year	M/s Gogte Mines, Tilakwadi (Belagavi)

Training Workshop				
1	Hydrological Modelling using SWAT	CMT (PI)	5 day	Proposed
2	Brain Storming Session on "Rejuvenation of Rivers in Hard Rock Region"	BV(PI)	1 day	Proposed

JVT : J.V. Tyagi, Scientist G
BV : B.Venkatesh, Scientist F
CMT : Chandramohan T., Scientist D
NV : N Varadarajan,PRA

SK : Sudhir Kumar, Scientist G
BKP : Purandara, Scientist F
MKJ : Mathew K. Jose, Scientist D
CK : Chandra Kumar S., SRA

PROGRESS OF STUDIES

1. Development of |Prediction Tools for Assessment of Water Resources in Ungauged Catchments of West Flowing Rivers of Western Ghats Region

Dr. Chandramohan explained the objectives of the study. He informed that 7 catchments in Karnataka and 7 catchments in Kerala have been selected with catchment area ranging from 50 km^2 to 3000 km^2. The discharge data for these catchments has been collected from the State/Central agencies. The geomorphological parameters for these catchments are being estimated using the GIS. Also SWAT rainfall-runoff model analysis has been completed for majority of the basins. While discussing the results, Dr. V.V. Rao enquired about the resolution of land use information used in the study. The PI has informed that, the land use resolution was 450mX450m. Dr Rao informed that, the NRSC host the land use data of finer resolution in their portal and may be used for analysis. Dr. Lakshman informed that several agencies such as NIT Surathkal, NIT Calicut and CWRDM have carried out the SWAT model analysis for Western Ghats catchments and the SWAT model parameters may be used as references for this analysis. Dr. Paneeraselvam enquired about the flow characteristics being considered in this analysis. The PI described the methodology and informed that the flow quantiles will be regionalized using the geomorphological characteristics of the catchments. The Chief Engineer, WRD Goa noticed that no catchment has been selected from Goa and Maharashtra. The PI informed that he would contact the CE WRD Goa for the selection of basin for this study. Chairman suggested to look at the values obtained for the Curve Number (CN) parameters of the SWAT which looks too low for the study area. Also he mention to complete the study within the stipulated time period.

2. Climate Change Impact Assessment for Jayakwadi Project

Dr. Venkatesh explained the objectives of the project and the methodology adopted in the study. He explained that 30 years of data for 79 raingauge stations and 15-20 year discharge data was collected from the WRD Nashik, Maharashtra and gridded rainfall data from 119 years (1901-2019) from IMD. The results of rainfall analysis, such as, trend, homogeneity and drought analysis for duration, intensity and persistence and discharge analysis for trend as well as homogeneity were presented. Also it was informed that, the 14 GCM model outputs from CORDEX for the basin have been downloaded and statistical analysis of data is underway. Using these data, a trail run of SWAT model was made. While discussing the results, Dr. V.V Rao opined that, while setting-up the reservoirs in the SWAT model, care should be taken to register them at the outlet of the watershed with respective reservoir characteristics in the SWAT model. Dr. Panneraselvam advised to use the RCP data for the study. The Chief Engineer, WRD Nashik advised to include the Irrigation Water Requirement in the command area with different types of crops while setting-up of model. Dr. Venkatesh requested the Chief Engineer, WRD Nashik to help in identifying the reservoirs and in obtaining the required data for the modeling. The Chief Engineer, WRD Nashik has assured the cooperation from his.

An extension of 6 months, i.e., till September 2021 was recommended by the RCC.

3. Flood Vulnerability Assessment of Thiruvananthapuram City, Kerala

Dr. Chandramohan presented the progress achieved in the study, wherein he mentioned that, the Thiruvananthapuram Corporation area has been identified as the study area. A river namely, Karamana is entering into the city with high flows and there are number of inter connected channels and water bodies in and around the city. In this study, various return period rainfall values have been estimated and are being used to generate the flood inundation map for the city using of HEC-RAS model. Dr. V.V. Rao advised to apply models such as MIKE-Flood instead of HEC-RAS in such conditions. He also advised to consider the major drains for the study. The Chairman advised the PI to look for high resolution DEM and other data from the department to generate an acceptable flood inundation and vulnerability map for the city. Further, Dr. V.V. Rao informed that, after the recent floods in Kerala, the Govt. of Kerala and IIT Madras along with other institutes have developed a large database, which may be used in this study also.

4. Study on the impact of extensive sand extraction on the river environment and aquifer regime in Godavari basin

While presenting the progress of the study, Dr. M K Jose has explained the methodology and procedure of the study proposed to be carried out in the in the Manjira river sub-basin of Godavari basin. The study was originally inducted during the previous RCC as per the initiation of the TSGW Dept., and the However, the Director TSGW Dept. informed that the department has subsequently initiated an in-house study on the topic with the approval of NPMU as part of the NHP. Responding to the situation, the Chairman suggested to explore possibility of collaborating with TSGWD in the study as they have already started the study and to explore the type of collaboration that NIH can involve with and contribute to this study.

5. Impact of Land use/Land cover Changes on Groundwater – A Case Study

Dr. Purandara, PI presented the results of the study. While discussing the results, he informed that up-scaling of the results obtained from the experimental watersheds selected at Kodgibail, will be carried out to quantify the hydrological parameters of Malaprabha sub basin which is highly dynamic. The RCC members suggested to attempt upscaling based on primary data.

6. Studies on Occurrence, Distribution and Sustainability of Natural Springs for Rural Water Supply in parts of Western Ghats, India (HP III PDS)

Dr. Purandara (PI) presented the progress achieved during the year and informed that a field visit was made to collect the information about the existence of springs in the selected districts of Maharashtra state namely, Satara, Savantwadi and Sindhudurg and in Malaprabha basin in Karnataka. An inventory of the springs is being carried out using the data collected during the filed visit. Dr. Purandara informed that, the arrangements have been made for discharge measurements from these selected springs. The samples collected from these springs are being tested for their quality. Dr. V. V. Rao advised to create a geo-tagging of these springs and add to the database created by the NIH for Himalayan Springs.

7. **Estimation of Submarine Groundwater Discharge in Parts of Karnataka**

Dr. Purandara explained the objectives of the study and informed that already 62 water samples, both foreshore and backshore area of the beach up to a depth of 1.5 m has a fresh water and with low salinity, have been collected for various locations in Uttarakannada district of Karnataka. Prof. Lakshman inquired about the results of the sample analysed at a village named Maravanthe, wherein the river and the Arabian Sea is separated by a small strip of land. The PI informed that, since he is carrying out the study of Uttarakannada district, the partners of the will be contacted for getting information on Marvanthe beach which is a part of Udupi district.

8. Groundwater Model Development in Micro Basin of Hard Rock In Krishna and Godavari River Basins of Telangana.

Dr. M.K.Jose informed that two areas have been identified namely, Dindi watershed in Krishna and Cheppur in Godavari basin. A field visit was made during December 2019 and data were collected from the TSGWD Hyderabad. The results obtained through the analysis were presented. The Director, TSGWD mentioned that, there is a need for more involvement of the officials from both the department to analyse the data and to carry out the experiments required for the study. He further informed that, they have installed number of AWLR's in the study area to augment the data and carried out some of the water quality analysis of the groundwater samples. In response to this, Dr. Venkatesh, proposed frequent virtual meeting to discuss the progress and to formulate the plans for the study until the prevailing situation subsides. Once the condition is normal, the field based experiments will be conducted. The Director, TSGWD has agreed to have virtual meeting to discuss about the study.

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	Sh. Deepak Singh Bisht	Scientist B
4	Sh. Drona Khurana	SRA

Recommended Work Program for the year 2020-21

S. No.	Title of Study	Team	Duration	Remarks
Internal Studies				
1.	Assessment of Hydrological Characteristics of a Western Himalayan river – A study of River Ujh	D. Khurana P. G. Jose S. S. Rawat R. V. Kale	24 months (June 2018 - May 2020)	Ongoing/ to be completed by October, 2020
2	Hydrologic and hydraulic modeling 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 (Aug 2018 - Mar 2021)	Ongoing
3.	Statistical evaluation of global precipitation estimates over data scarce Western Himalayan Region of India	D. S. Bisht V. Singh S. S. Rawat P. G. Jose	02 Years (Sept 2019 - Sept 2021)	Ongoing
4.	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)	New proposal
PDS under National Hydrology Project (NHP) at NIH				
1.	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 P. G. Jose S. Gurjar D. S. Bisht S. Kumar	04 years (Apr 2017 - Mar 2021)	Ongoing PDS under NHP
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 (Apr 2019 - Mar 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.

Progress of Ongoing Studies

1. Assessment of Hydrological Characteristics of a Western Himalayan River – A Case Study on River Ujh

The progress of the study was presented by Er. Drona Khurana (DK). Morphometric analysis of Ujh river basin and prioritization of the sub-watersheds has been carried out and their sediment production rates have been estimated. PI also mentioned about the challenges posed in the scientific studies due to data scarcity, observed during the work.

JVT as well as Dr. Vaibhav Gosavi (VG) asked the PI to mention in his report specific recommendations to be shared with the concerned departments or agencies, especially for soil and water conservation work for effective management of the watershed. JVT also asked to mention in the report the sediment yield from various sub-basins in this modelling study. DS Bisht (DSB), Scientist 'B' and Co-PI of the project emphasized on the requirement of the hourly discharge data as it has been observed that the time of concentration of the basin is ~5 hours and a daily scale recording will not be able to capture the peak. DSB also mentioned that availability of hourly discharge will better help in studying the basin response for individual storms. MKG pointed out the importance of data collection (sediments and discharge) at the outlet of various sub-basins to further understand the processes and suggested to include these recommendations in the reports.

The Chairman directed DK to complete the study incorporating the various suggestions by the end of October, 2020.

2. Statistical evaluation of global precipitation estimates over data scarce Western Himalayan Region of India

DSB made the presentation on progress of this internal study. One of the main findings revealed that overall, the number of total rain-gauge stations used in creating IMD gridded rainfall product has decreased over the period of time, especially during 1976-2005 in comparison to large number of rain-gauge stations used during 1950-1975. Given the need for a long-term record of rainfall in climate change studies, this period is of particular importance. DSB further told the chairman and the RCC members that in the final year of the study, the statistical evaluation of various Global Precipitation Estimates will be carried out and a suitable long-term rainfall dataset will be prepared. He also mentioned that the study was still in its first year and will be completed in the stipulated time as proposed.

All members were satisfied with the progress of the project.

3. 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"

Interim results of ongoing NHP-PDS study were presented by Dr. S.S. Rawat (SSR). He also demonstrated the ISHVAR web-portal being developed in the project to the RCC members. SSR apprised that web-GIS based spring inventory has been developed up to Chamba town and survey work for springs for rest of the Ravi River catchment of Himachal Pradesh is being carried-out by 3 field assistants and it would be completed by December, 2020. Selection of the springs for detailed study will be done after resuming of normalcy in the state.

VG appreciated the work carried-out by WHRC to inventorize the springs of Ravi catchment. He also commented that while the idea of web portal is appreciable, it needs to be tested in open access or with limited access to RCC experts/stake-holders/users for taking feedback for its improvement. He also requested that the methodological framework for hot spot analysis be presented in the next RCC meet.

4. Web-enabled Inventory of Natural Water Springs of Tawi River Catchment for Vulnerability Analysis and Developing Adaptive Measures for Sustaining Tawi River

SSR apprised the RCC that this study was sanctioned under National Mission on Himalayan Studies (NMHS) in which Deptt. of Soil and Water Conservation, Govt. of Jammu & Kashmir is collaborating as supporting agency. Spring survey work is in progress and about 200 springs have been surveyed by the staff recruited under the project.

JVT queried about the spring recharge area demarcation and recommended intervention for spring rejuvenation. SSR informed that these activities for selected vulnerable springs will be carried out as planned in the project. Dr. D. K Vatsa (DKV), while appreciating the work, requested possible collaboration with CSK-HPAU, Palampur in the area of spring studies. JVT welcomed such collaboration and suggested a proposal mentioning roles and responsibilities of university scientists/ faculty in the study. VG commented that studying springs in Himalayas is a challenging task in itself and collaboration with different Research Institutes, working in this field, is needed for improved scientific understanding and effective implementation. Er. Vineet Gupta (EVG) enquired about the spring discharge measurement and suggested that such activities can be taken up in Jal Jeevan Mission as springs are of high relevance. He further suggested to contact Public Health Engineering Department in this regard. MKG asked EVG for any possibility to extend the ongoing spring study to entire Jammu and Kashmir, to which he suggested to approach Jal Jeevan Mission and Rural Development Department. MKG suggested SSR to explore the possibility of a combined meeting with EVG and other line departments in this regard.

5. Hydrologic and hydraulic modeling for floodplain inundation mapping under future climate change scenarios: A case study of Tawi River, India.

Dr. R. V. Kale (RVK) presented the study. Regarding the input data requirement to conduct this study, the PI informed that the annual maximum and 10-daily discharge data for Sidhara station has been collected from CWC. Further, he mentioned that a fresh request has been made to CWC in requisite format to provide the hourly stage data for selected high flood events and also daily discharge data for selected months including rating curve information during these events. Further, he informed that a request has been sent to the JTFRP to provide high resolution DEM to conduct the flood inundation modelling study. MKG stressed that hourly and daily discharge and stage data at G&D sites on the Tawi river are important to carry out the flood inundation modelling study.

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

RVK briefly presented the study. As this study project has been recently initiated, no comments were offered by RCC members.

7. Integrated Studies of Himalayan Cryosphere using Space Based Inputs (ISHC)

Dr. P. G. Jose (PGJ) presented this sponsored collaborative project with SAC/ISRO. He apprised the RCC that the major goal enunciated in the project objectives was to assist ISRO in developing space based monitoring techniques with ground based measurements of glacier surface elevations for geodetic mass balance studies, ground validation of SAR data for ice velocity measurements, and glacier ice thickness measurements by Ground Penetrating Radar (GPR) for volume estimation, which were taken up through field studies carried out in September 2017 and September 2018 on Drang Drung Glacier, Zanskar Valley, Ladakh. Additional work carried out by the PI for isotopic analysis of water samples from the study area indicated that waters are sourced from snow ice melt at elevations > 4500 m asl., while one lake sample suggested evaporation from a closed basin. PI informed that the project was completed on March 31, 2020. The RCC members appreciated the work carried out in extremely challenging high altitude and remote area.

New Proposed Studies:

1. **Title of the Project:** Estimation of changes in snow cover and glacier mass balance for Upper Chenab River Basin

2. **Study Team:**

Project Investigator:	Dr. Pottakkal George Jose, Scientist 'D'
Co-Project Investigator:	Mr. Deepak Singh Bisht, Scientist 'B'

3. **Objectives:**
   a) Estimation of changes in snow cover and glaciated area in Upper Chenab River Basin
   b) Estimation of specific glacier mass balance in Upper Chenab River Basin
   c) Investigation of climate-cryosphere linkages

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

Glaciers and transient snow covers large proportion of the Himalayan landscape. The impact of these cryospheric components on the water resources of mountainous regions has been recognized globally, but not well understood in the Himalayan region in general and specifically in the Kashmir valley for various reasons. Glaciers in the Himalayas are receding at rates comparable to other glaciated regions in the world, and these include glaciers of Kashmir. A study on Kolhai Glacier conducted by remote sensing by the National Geophysical Research Institute, Hyderabad, revealed that its area has decreased from 19.34 sq. km in 1992 to 17.23 sq. km in 2001, a net decrease of 2.11 sq. km in 10 years. The longest glaciological mass balance record from India (Wagnon et al., 2007; Azam et al., 2012; Vincent et al., 2013; Azam et al., 2019; Mandal et al., 2020) gave a cumulative wastage of -7.87 m.w.e.a^{-1} for Chhota Shigri Glacier, Chandra sub-basin, Chenab basin, Himachal Himalaya. Seasonal snow covers 28% of Indus basin and accounts for 19% of Mean Annual Flow (Savoskul and Smakstin, 2013). Reportedly, Lidder and Sind basins snow cover has progressively declined over the years. Preliminary studies on the impact of deglaciation using tracer experiments has been carried out in the ablation zones of Dokriani and Gangotri glaciers (Hasnain et al., 2001; Pottakkal et al., 2014) suggesting significant role played by melt water entering the glacier body in accelerating the seasonal evolution of glacier hydrological system and influencing not only the release of meltwater at the glacier terminus, but also the glacier dynamics. Racoviteanu et al. (2011) gives an exhaustive treatment on the use of optical remote sensing techniques applied for analyzing the glacier characteristics of Himalayan region. Theyyan and Gergan (2010) conceptualized three different glacier catchments in the Himalayan region having different behavior. The relation between meteorology and glacier mass balance was studied in Chhota Shigri glacier catchment by Azam et al (2016), while a decadal scale snow and ice melt contribution was estimated for same glacier catchment (Azam et al., 2019).

Normalised Difference Snow Index (NDSI) has been used to extensively to map the extent of snow cover in various parts of the world in including the Himalayas (Immerzeel et al. 2009; Gurung et al., 2011). Moderate Resolution Imaging Spectroradiometer (MODIS) snow cover products have been used not only for snow studies, but also in Accumulation Area Ratio (AAR) delineation. Specific mass balance of glaciers has also been arrived at using the AAR technique that has been reworked over the years (Kulkarni et al., 2004; Tawde et al, 2016; Tak and Keshari, 2020). With the advancement in remote sensing and modeling capabilities coupled with longer in situ records available at select high altitude locations, we can now have the opportunity for better estimates of snow and glacier contributions to flows of Himalayan rivers.

5. **Study area**

Upper Chenab basin (~3,728 km^2) located in the Lahaul-Spiti District of Himachal Pradesh (76.87^o E to 77.80^o E and 32.08^o N to 32.99^o N), is composed of Chandra (~2,440 km^2) and Bhaga (~1,288 km^2) sub-basins, which join together near Tandi, Himachal Pradesh to form the mighty Chenab. It is one of the most glaciated basins in Western Himalayan Region, with estimates of snow and glacier contributions estimated between 50-80%. This basin is also interesting from the point of view of climatology as it falls under the monsoon-arid transition zone. Upper Chenab Basin is alternately influenced by Mid-latitude Westerlies and Indian Summer Monsoon, although most of the accumulation happens in winter months. There is also a gradual increase in aridity as we go from SE to NW. Upper Chenab has one of the longest in situ glacier mass balance series in HKH region as well as year-round meteorological observations at glacier elevations, viz. Chhota Shigri Glacier, Chandra sub-basin. Apart from this, it also has long-term meteorological observations at a few locations both in the Chandra (eg. Koksar) and Bhaga (e.g. Patseo) sub-basins. Moreover, the basin is highly Important from the point of hydropower generation, and several run-of-the-river HEPs, depend on snow and glacier melt contributions that peak in summer months for their power generation.

6. Methodology

a. Estimation of changes in snow cover and glaciated area using remote sensing images from MODIS/LANDSAT/SENTINEL datasets. Topographic details will be retrieved from CARTOSAT/ALOS PALSAR/ASTER/SRTM DEMs.
b. Estimation of glacier mass balance using modified Accumulation Area Ratio technique coupled with a temperature index melt model.
c. To investigate the climate-cryosphere linkages, air temperature from IMD gridded data and precipitation from APHRODITE data or from other suitable sources will be used.

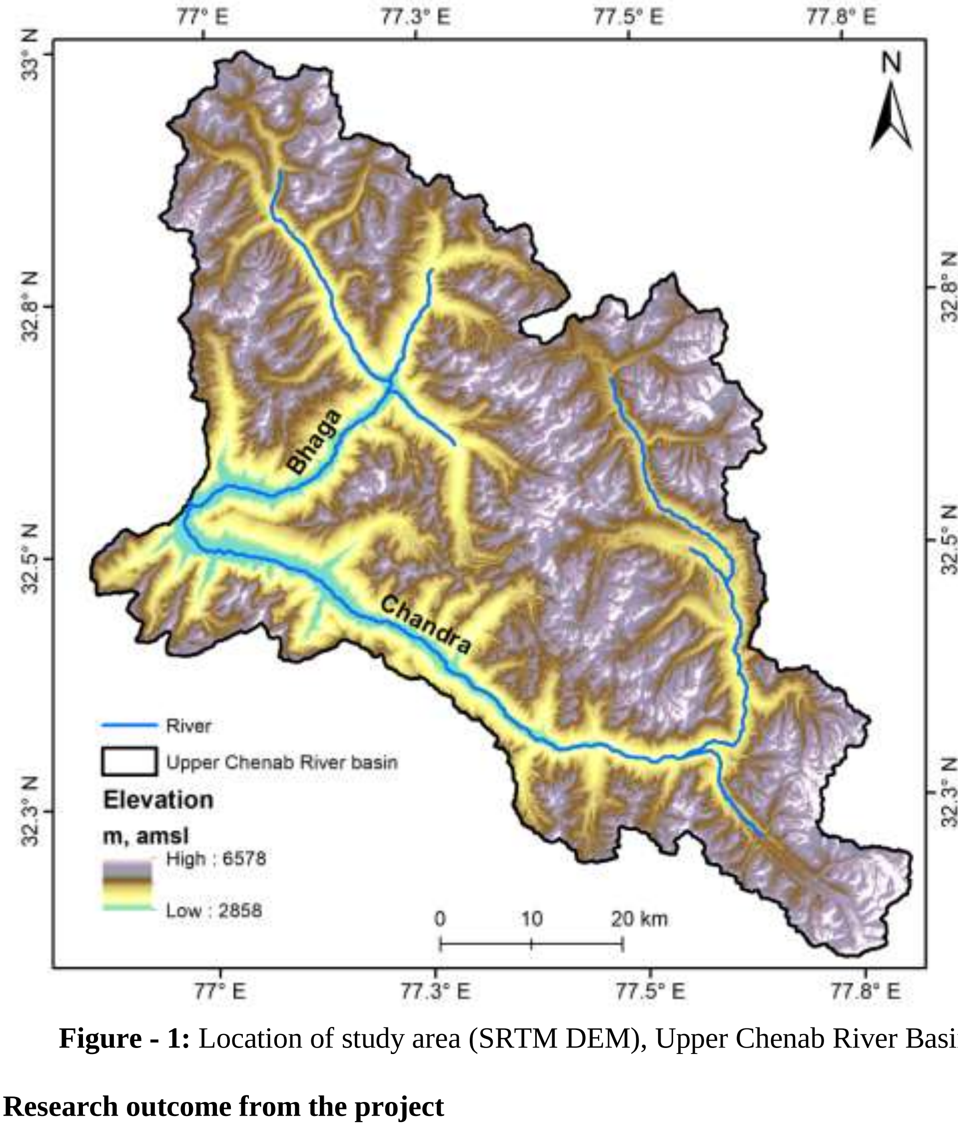


Figure - 1: Location of study area (SRTM DEM), Upper Chenab River Basin

7. Research outcome from the project

A research framework will be developed, which can be extended to other glaciated catchments of Western Himalaya. Besides, this exercise will create a knowledge base vis-à-vis the changing climate and snow cover as well as glacier dynamics in the study area. Furthermore, the information generated through this project will help in better understanding of climate-cryosphere linkages in the region that can aid in water resource management.

8. Cost estimate:

a. Total cost of the project: 2,00,000
b. Source of funding: Institutional Funding
c. Sub Head-wise abstract of the cost:

S. No.	Sub-head	Amount (in Rupees)
1.	Travel/Fieldwork expenditure	1,00,000
2	Meteorological data procurement	50,000
3.	Contingency	50,000
Grand Total		**2,00,000**

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

i. A major component is field work travel. Also travel for literature/secondary data collection and participation in seminar/symposia/conference within India.
ii. Meteorological data for climate driver correlation with cryosphere changes.
iii. High Altitude gear need to be purchased for Co-PI. Adequate high-risk insurance cover for researchers/staff will be provided for duration of field work. It will also take care of consumables like hard disk for data storage.

9. Work Schedule

a. Probable date of commencement of the project: August, 2020
b. Duration of the project: 2 years
c. Stages of work and milestone:

Work Elements	1st year				2nd year			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Literature Survey								
Data collection & procurement								
Data analysis								
Field work for ground truthing								
Synthesis of report & publications								

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

Recommended Work Program for the year 2020-21

Sl. No	Name of the project	Duration	Status (Period)	PI
Ongoing Studies				
1.	Modeling of Tawa Reservoir Catchment and Development of Tawa Reservoir Operation Policy under Climate Change	3 Years	Ongoing (09/17-08/20) To be extended for 1 year	PI: Er. S.P. Indwar
2.	Evaluation of the impact of Rabi irrigation in Ganga River sub-basin of Madhya Pradesh	3 years	Ongoing (11/17-10/20) To be extended for 1 year	PI: Er. R. V. Galkate
3.	Impacts of Upcoming Irrigation Projects and Climate Change on the Droughts and Desertification Scenario for Chambal Basin in Western Madhya Pradesh	4 years	Ongoing (12/17-11/21)	PI: Dr. T. Thomas
4.	Integrated Assessment of the Impacts of Climate Change and Land-use Change on the Hydrology of the Narmada basin through Hydrological Modelling Approaches	5 years	Ongoing (02/18-01/23)	PI: Dr. T. Thomas
5.	Modeling of Narmada using GWAVA. (International Collaborative Project with CEH Wallingford, UK)	2 years from 04/15 Extended further for 2 years. Again extended for 1 more year.	Ongoing (04/15-03/20)	PI: Dr. T. Thomas
6.	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	4 years	Ongoing (04/19-03/23)	PI: Dr. R. K. Jaiswal
7.	Development of Decision Tool for Efficient Utilization of Water Resource in Parbati Canal &Dholpur Piped Irrigation Project of Rajasthan	3 years	Ongoing (04/19-03/22)	PI: Dr. R. K. Jaiswal
Proposed New Studies				
1	An experimental assessment of low-cost Auger Hole Technique for accelerating groundwater recharge	3 year	In-house collaborative study September 2020 to August 2023	PI: Ravi Galkate Co-PI: Dr. R.K. Jaiswal

Progress on on-going Studies

1. Modeling of Tawa Reservoir Catchment and Development of Tawa Reservoir Operation Policy.

Ms. Shashi Indwar, PI presented the progress of the study. She informed that the assessment of the present supply-demand scenario has been carried out using water balance techniques and each component of water balance has been computed using CROPWAT, mathematical equations and other techniques. The irrigation water demand and supply in the Tawa command area of Hoshangabad district and the crop water requirement and irrigation scheduling of Kharif and Rabi crops using CROPWAT 8.0 in the Tawa command area were presented. Results obtained from hydrological modeling of the Tawa basin up to the Tawa Reservoir using the SCS-CN model and future supply-demand scenario of Tawa Dam were shown. Dr. T.R. Nayak member (Civil), NCA advised to re-check the additional command area calculated at 75% dependable flow. He also advised deriving rule curves very precisely which will be useful for generating the operation policy of the Tawa reservoir based on present supply-demand. Revised storage capacity (after silting) estimation would be useful for planning the powerhouse releases during the monsoon months in time, so that the power generation may be maximized without compromising the irrigation and other requirements during monsoon months. PI explained that the conservation operation of the Tawa reservoir is under progress based on present demands and it will be worked out considering future demands.

2. Evaluation of Impacts of Rabi Irrigation in Ganga River Sub Basin of Madhya Pradesh (PDS under NHP)

Sh. Ravi Galkate PI of the project briefed the objectives of the study and explained the need and importance of impact and performance evaluation of irrigation projects in Madhya Pradesh. He informed that a total of 10 dams have been taken for impact and performance evaluation analysis. The secondary data collection is almost completed. Detail data of dams and command areas, crop type, cropping area, etc. of the dams sites selected for the study have been collected, however, the data collection was the big challenge as data is not available with one agency and data availability was very limited. A baseline survey was initiated in command and non-command areas of Kotwal and Samrat Ashok Sagar dam for impact evaluation. Around sixty percent of survey work is completed and work has to be stopped at the end of March 2020 due to COVID-19 Lockdown. The performance evaluation has been carried out for four dams so far using seven comparative indicators classified in two groups, agriculture and water-use or physical performance suggested by the International Water Management Institute. The PI informed that the important aspect of this PDS is to development of a dynamic web-site application which will enable irrigation project managers to evaluate the performance of projects under their control with the use of project-related data and information as an input. Chairman advised for rechecking of groundwater analysis results for the Rabi season. Dr. T.R. Nayak, NCA opinioned that the comparative analysis will be useful to identify problems areas of irrigation project and to form strategies to improve upon.

3. Impacts of Upcoming Irrigation Projects and Climate Change on the Droughts and Desertification Scenario for Chambal Basin in Western Madhya Pradesh

Dr. T. Thomas, P.I. presented the progress of the study. He informed that the water resources development in the Chambal basin is taking place at a rapid pace with few upcoming projects, the impact of these projects on the supply-demand scenario and these extreme events seems to be interesting. He gave a brief of work done for the assessment of climate change, the study of drought characteristics using an indicator-based approach. He explained work carried out for spatiotemporal variation of drought, estimation of crop water requirement, dry spell analysis and supplemental irrigation requirement estimation for 14 blocks falling in the study area. Work was also carried out on hydrologic modeling and integrated drought vulnerability assessment. It was informed that the project duration is for 4 years and will be completed in March 2022.

4. Modeling of Narmada using GWAVA (International Collaborative Project with CEH, Wallingford, UK)

During the discussion on various studies, Dr. T.R. Nayak, NCA, gave his view on the study "Modeling of Narmada using GWAVA" that the outcome of this study, i.e. modeling of water availability in the Narmada basin should be shared with NCA so that NCA can plan its Reservoir Operations. Dr. Thomas, in reply, was agreed upon to share the results with NCA once it is finalized. However, Dr. Thomas pointed out that it may not be possible to forecast inflows based on IMD rainfall forecasts. Instead, it was informed that the results of hydrologic modeling by scenario analysis based on the percentage changes in the rainfall can be worked out and provided. Dr. T. Thomas requested a one-year extension to the GWAVA Modeling study. The Chairman asked Dr. Thomas, PI of the study to add requirements and suggestions given by NCA as an objective to be addressed during the extended period. Dr. Nayak also mentioned that the study was started in April 2015 with a duration of two years and an extension of two years has already been given to this study. He also mentioned that the outcome of the study should be thoroughly reviewed before giving a further extension.

5. 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 (PDS Under NHP)

Dr. R. K Jaiswal, P.I. presented the progress of the PDS which has been undertaken in collaboration with MPWRD. He informed that irrigation return flow is an important aspect of irrigation management and presently state govt. assumes fixed 10% of water storage as a regenerated flow from the command which needs to be verified using scientific assessment for optimal utilization. The data collection, preparation of GIS database, survey for identify discharge monitoring site of the study area, preparation of land use variation maps is in progress. Development of lumped water balance, computation of crop water requirement using Cropwat, SCS-CN model for computation of surface runoff, reservoir releases and discharge rate at downstream of command are done for determination of inflow and outflow from the system. The computed regenerated flows in different years were seen varied from 24 to 33% (2015 to 2018) which is more than the amount fixed for computation of flows to downstream reservoirs in Madhya Pradesh. Soil and water samples were collected for moisture and isotopic analysis. For the development of a mobile application, the selection of agency and development of the model is under progress. The soil testing in the command could not be carried out due to the corona pandemic.

Dr. T.R. Nayak advised to re-check the estimated regenerated flow values as it seems to be on the higher side i.e. 28.4%. Sh. Y.C. Sharma, Ex CE, WRD, commented that he had suggested this study to verify the assumption of 10 to 15 % as return flow which is used for irrigation planning and to get actual values through this field-based scientific study. The result of the study showing return flow for irrigation as 19.76% to 33.37% with an average of 28.4%, which seems okay.

6. Development of Decision Support Tool for Efficient Utilization of Water Resource in Parbati Canal & Dholpur Piped Irrigation Project of Rajasthan (PDS Under NHP)

Dr. R. K Jaiswal, P.I. presented the progress of the PDS which has been undertaken in collaboration with Rajasthan WRD. He informed that looking into the importance of irrigation efficiencies for better management and planning, different conventional and water use efficiencies will be computed by field observation for Parbati open canal and Dholpur piped irrigation project in Rajasthan state. For assessment and comparison of irrigation efficiencies in open channel systems and pressurized pipe irrigation systems, a data collection, preparation of GIS database, survey to identify the discharge measurement sites is mostly completed. A water balance of the Parbati reservoir was carried out to compute reservoir inflows and reservoir efficiency of the project. Collection of weekly data of canals, reservoir, and fields for the rabi season of 2019-20. Data regarding yield, cost, etc. could not be collected for the rabi season of 2019-20 due to the corona pandemic. The work for developing a decision support tool for demand-based irrigation using a participatory approach has been initiated. The soil testing in the command could not be carried out due to the COVID-19 pandemic. A stakeholder workshop on PDS was carried out in the month of July 2019.

7. Revival of Village Ponds through Scientific Interventions in Sagar District

Dr. T. Thomas, P.I. presented the progress of the study. He informed that this was DST funded study and work is completed. Two village ponds in Sahawan village and Cheelpahadi village in the Bundelkhand region of MP were selected for the study. He informed that a number of scientific activities were carried out for the revival of ponds like de-weeding, construction of contour trenches, desilting and stone pitching of the pond, fencing, widening of spill channel for safety and improve natural recharge through convergence. Work also carried out for the construction of large diameter recharge pits to recharge the unconfined aquifer, construction of a floating wetland to improve the pond water quality. A cell and membrane-based water purifying system have been installed at one of the dug wells to provide clean drinking water to the local villagers. Stakeholder Workshop and consultation meetings were organized in the village. Chairman appreciated the work and queried, what are basic cause for the dysfunction of the pond and who will be responsible for the maintenance of the pond. It was informed that the basic causes for the dysfunction of the pond were their age, ponds have been constructed more than 200 years ago, reduction of pond capacity due to silt, continuous negligence by the villages and no responsible agencies at the district or block level for maintenance. Chairman suggested to re-check the rate of soil erosion and subsequent deposition in the channel, the deposition rate estimated seems to be very high and the channel may get silted frequently if it is so.

Proposed Study

1. An experimental assessment of low-cost Auger Hole Technique for accelerating groundwater recharge

Sh. Ravi Galkate, PI presented the outline of the study. This is a field-oriented in-house research study and will be carried out jointly with WALMI, Bhopal with a duration of 3 years starting from August 2020. The proposal aims to test and evaluate the effectiveness of the new Auger Hole Technique for the artificial recharge of groundwater through experimental studies as well as pilot field studies. The study area and testing sites will be selective watershed or a water scare block in Bhopal or nearby districts where the historical groundwater data is being monitored by the state groundwater survey department of WRD. This will help to assess the impact of proposed techniques on the groundwater level in the area. The study aims to identify appropriate procedures, design, optimized numbers of auger holes to augment sustainable recharge, its size, materials available locally to keep its cost reasonable for its easy adaptability in the community. Developing the design of augur hole groundwater recharge structure and its optimization. Pilot testing for adaptability in different field conditions viz. point sources (Dug wells), rural catchments, and urban sprawls. Quantitative, qualitative and economic analysis of the technique. Impact assessment on groundwater regime. Preparation of Guideline, recommendations, manual for wide adaptability of the technique.

DELTAIC REGIONAL CENTRE KAKINADA

Scientific Manpower

S N	Name	Designation
1	Dr. YRS Rao	Scientist G & Head
2	Dr. S V Vijayakumar	Scientist F
3	Dr. V S Jayakanthan	Scientist E
4	Dr. P C Nayak	Scientist E
5	Mr. R. Venkata Ramana	Scientist D
6	Mr.T.Vijay	Scientist B
7	Sh. U V N Rao	PRA
8	Sh. P R S Rao	RA

Recommended Work Programme for the year 2020 – 21

S. No	Title of the Project	Team	Duration (Start date and End date)	Funding
I.	**Internal R & D Studies**			
1	Forecasting of Flash flood and Management for east flowing rivers of India's Subzone 4(a)	R.VenkataRamana (PI) Y.R. Satyaji Rao V.S.Jeyakanthan T.Vijay	3 Years (Dec'17 - Nov'20)	Internal (NIH)
II.	**Sponsored Projects (Ongoing (7))**			
2	Sedimentation Study of Hirakud Reservoir, Odisha using Optic and Microwave Remote Sensing Technology	V.S.Jeyakanthan (PI) J.V.Tyagi Y.R.Satyaji Rao R.VenkataRamana	3 Years (Nov'17 – Mar'21)	NHP(PDS) (SP-28/2017-18/PDS-3)
3	Groundwater salinity source identification in Godavari delta, Andhra Pradesh	Y.R.Satyaji Rao (PI) T.Vijay, R.VenkataRamana Gopala Krishana S.V.Vijaya Kumar	3 Years (Mar'18'-Jul' 21)	NHP(PDS) (SP-28/2017-2018/PDS-13)
4	Study of the behavior 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 J.V.Tyagi Y.R.Satyaji Rao T.Vijay	3 Years (Apr'18 - Mar'21)	NHP(PDS) (LA:AP State GW&WA Dept.,) AP_1_2017_80
5	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	3 Years (Apr'19 - Mar'22)	NHP(PDS). SP-43/2019-21/1
6	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	3 Years (Jan'20 – Apr 23)	NHP(PDS) (LA: Hydrology and Investigations, I & CAD, Govt.,Telengana) TEL-6_2017_86
7	High Performance Advanced Septic System for Villages and Roadside Restaurants	Y.R Satyaji Rao (PI) T.Vijay	2 Years (Apr'18 - Dec'20)	IC-IMPACT, Canada
8	Unravelling Submarine Groundwater Discharge (SGD) Zones along A.P and Odisha States (Mission SGD)-Pilot Study	Y.R. Satyaji Rao (PI) T.Vijay	2 Years (Apr'19 to Mar'21)	MoES, Govt., of India.

Progress of on-going studies

1. Forecasting of Flash flood and Management for east flowing rivers of India's Subzone 4(a)

Sh. R. Venkata Ramana (PI) presented the objectives and progress of the study. Dr. V. V. Rao, suggested to include the time taken to achieve the peak flood and time lag in the report. Further he suggested to share the outcome of the study with A.P Disaster Management Department. Dr. Subramanyan, suggested to make corrections in the index map units. Sh. M.K. Srinivas suggested to share the details of the study with CE, CWC Bhubaneswar. Prof. K.P. Sudheer, suggested that the study should be used for practical purposes and asked to develop spatial pattern of the floods, library of inundation areas/forecast. He further emphasised, if is not possible to include these aspects in the present report than it can be taken up as another study. Prof. Mudgal, informed that the inundation maps need to be corrected, and the units are to be mentioned on the maps. Sh. TVNAR Kumar enquired whether the data used in the Vamsadara flood study can be shared for their river morphology study, undertaken by IIT Guwahati. Chairman informed that the data used in the study have been collected from CWC with an undertaking not to share the data with other departments. He suggested that they can contact the CWC directly for getting the required data. Sh. Venkata Ramana informed that the Sarada basin is dropped due to poor data quality and its inconsistency with flash flood events. The chairman asked the PI to contact Water Resources Department and calibrate the model once again otherwise to drop the Sarada river basin and complete the study by November 2020. Dr. V.V. Rao suggested to mention reasons for dropping the Sarada basin scientifically in the report.

2. Sedimentation study of Hirakud Reservoir, Odisha using Optic and Microwave Remote Sensing technology

Dr. V.S. Jeyakanthan (PI) presented objectives and progress of the study. Dr.V.V.Rao informed that CWC/NRSC has carried out many studies on Hirakud reservoir sedimentation and these studies should be considered for the comparison purpose. He also emphasized that Odisha government has already done lots of work on Hirakud reservoir and asked him to visit the Dam authority for getting the true picture of the status of sedimentation. Dr. Rao further informed that microwave data provides good accuracy for waterbody mapping. Dr. K.P. Sudheer, IIT, Chennai, pointed out that the observations made in the earlier RCC meeting were not considered and again requested to take care of those points. The chairman advised PI to refer earlier works done by other departments and compare his study with the physical survey also. Chairman also directed to follow the member's suggestion. The PI informed that the NRSC has carried out many reservoir water spread area estimation studies using microwave data and it yields acceptable results. Therefore, in the assessment of reservoir sedimentation studies, microwave data can be substituted if cloud free data is not available in optical data. Chairman informed that the PDS sub-committee instructed to drop the sediment yield modeling approach using the SWAT model which was not informed in the forum. However, Jeyakanthan informed that most of the work to run the model has been completed and hence requested the chairman to allow the modeling part to continue as a part of the study within stipulated time.

3. Groundwater salinity source identification in Godavari Delta, Andhra Pradesh

Dr Y R Satyaji Rao (PI) briefed about the background of the study and presented the progress. Prof. Elango appreciated the study and informed that as per the remote sensing maps, the water bodies are increasing in the study area. Dr YRS Rao informed that remote sensing data are acquired during non-monsoon period and these changes are found to be due to the increase of aquaculture ponds. Prof. Elango asked the importance of isotope data in the study. Dr YRS Rao replied that this data is useful to identify the source of salinity and Dr. Sudhir Kumar also informed that the stable isotope data is yet to be interpreted in the Godavari delta. Dr.VV Rao suggested to upscale these studies to the entire East Coastal region instead of doing at the regional scale. He further suggested to consider takingup a new project proposal using Ground Penetrating Radar (GPR) data. Prof. Elango clarified that the GPR gives only 20 m depth information which may not be much of help for the large scale project. Dr. Y.R.S.Rao agreed to look into the suggestions made by the members.

4. Study of the behavior of Multi-Aquifer system & Aquifer mapping for an effective Groundwater Management in Gunderu Sub-basin, West Godavari District, A.P

Dr. S.V.Vijayakumar (PI) presented the objectives and progress of the study. Dr. Nandan, enquired whether interlinking of Polavaram canal would affect recharge in this region. Dr. Vijaykumar informed that the Polavaram canal is a lined canal and it has no impact on groundwater levels as the groundwater table is much deeper. Dr. Elango informed that the $\delta^{18}O$ contours are to be verified before finalsing the contribution of recharge based on $\delta^{18}O$. Further, he asked whether the recharge from the ponds has been considered in the groundwater modelling? He further pointed out only 40% of study area has pumping wells and the remaining area has no wells and suggested to recheck the wells data in the study area. He suggested that the Specific yield, which was considered in the sandstone formation should be in between 3-10%. Dr. S.V .Vijay Kumar agreed to look after the member suggestions. Chairman, suggested members to send their suggestions through email to Head, DRC Kakinada, if any.

5. Dam break studies of Somasila, Kandaleru and Pulichintala dams in Andhra Pradesh

Dr. P.C.Nayak (PI) presented the objectives and progress of the study. He informed that Somalsila project is not included in the present study because this reservoir has been included in other scheme of activities by A.P State Irrigation Department. Prof. Mudgal, suggested to take Manning's coefficients from present land use/land cover maps instead of using it as arbitrarily. Dr. Nayak informed that CWC norms were being followed in the study, and agreed that the HEC-RAS has the inbuilt capability of taking the Manning's coefficient automatically and he would look into it.

6. River bank Filtration (RBF) studies in coastal alluvium of Andhra Pradesh

Dr Y.R. Satyaji Rao (PI) presented the final results of the completed study under Peya Jal Suraksha project funded by the Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti with the partnership of AP State Rural Water Supply and Sanitation Dept. He informed that the RBF well shall be capable of supplying potable water to the rural people as compared to the saline groundwater being presently supplied. No Suggestions and comments were received from the members. Chairman enquired about the status of construction of the pump house. Dr. Satyaji Rao replied that the work is not yet completed due to COVID19 and laying of new pipeline and procurement of 5 HP motor has been completed and pending works by the State Department is under progress.

7. High Performance Advanced Septic Systems (HPAS) for villages and Road side Restaurants

Dr. Y.R. Satyaji Rao (PI) presented the objective and progress of the study. He explained about design aspects of High Performance Septic Sytem (HPAS) and informed that the system has been executed in the JNTU Campus. He shared the initial results of the HPAS performance and informed that due to COVID 19 the JNTU campus has been converted into quarantine center. No Suggestions and comments were received from the members.

8. **Unravelling Submarine Groundwater Discharge (SGD) zones along the A.P and Odisha (Mission-SGD) - Pilot study**

The review of this ongoing project has been conducted recently by the expert committee and found that the work is satisfactory. Due to shortage of time and as per the suggestion of the Co-Charman, the Chairman decided that the progress of the study need not be presented again and members agreed upon.

<u>Proposed new study is discussed in the RCC meeting and details of discussions are given below.</u>

1. Urban hydrological studies of critical pilot area using of hydrological instruments in the Greater Hyderabad Municipal Corporation (GHMC) area Hyderabad.

Sh. R. Venkata Ramana (PI) presented the objective and proposed methodology of the study. He further informed that the study is in collaboration with the state Irrigation Department, Govt. of Telangana and the same is approved under NHP (PDS) during October 2019. Prof. Mudgal informed that the BITS Pilani has done similar type of study on urban floods in Hyderabad and suggested to interact with them. Further, he advised to conduct physical survey for understanding the field conditions and also for setting up the instruments. Dr.VV Rao advised not to purchase ALOS Pulsar data for the DEM. The PDS study requires only Drone data of 0. 5-1m resolution. Dr. Mudgal informed that Lidar and Drone may not provide invert levels of storm water drains therefore field data is essential. Dr.V.V.Rao informed that the terrain model needs high resolution data.

CENTRE FOR FLOOD MANAGEMENT STUDIES GUWAHATI

Scientific Manpower

S N	Name	Designation
1	Dr. S K Sharma	Scientist C
2	Dr. Swapnali Barman	Scientist C
3	Sh. Gulshan Tirkey	Scientist B
4	Sh. Waikhom Rahul Singh	Scientist B

Recommended Work Programme for the year 2020-21

Sl.No.	Title	Study Group	Duration (Month/Year)	Remarks
1.	Flood Inundation Mapping of Beki River Basin of Assam	S.K Sharma, Rakesh Kumar, Pankaj Mani, Jagadish Prasad Patra, G. Arun	3 years (4/18 to 3/21)	Internal
2.	Development of regional methods for design flood estimation in North Brahmaputra subzone 2 (a).	S.K Sharma, Rakesh Kumar, Pankaj Mani, Jagadish Prasad Patra, G. Arun	3 years (4/18 to 3/21)	Internal
3.	Linear Hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin	GulshanTirkey, S. K. Sharma, P. Mani, G.Arun	3 years (4/18 to 3/21)	Internal
4.	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.R. Singh	3 years (11/18 to 10/21)	Internal
5.	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 (4/19 to 3/21)	Internal
6.	Comparison of Hydrological Behaviour of two mid-sized Mountainous Catchments under the influence of Climate and Land Use Changes	Waikhom Rahul Singh, A.K.Lohani, A. Bandyopahdyay Swapnali Barman NiteshPatidar	3 years (7/19-3/22)	Internal
7.	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 DeeptiRaani G. Arun, W.R. Singh	3 years (3/19 to 2/22)	PDS under NHP
8.	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 G. Arun, W.R. Singh	3 years (10/19 to 9/22)	PDS under NHP
9.	Rainfall Induced Flood Hazard Risk Vulnerability Assessment in East Jaintia Hills, Meghalaya	G. Tirkey, S. K. Sharma, A. K. Lohani, G. Arun,	3 years (4/20-3/23)	Internal New Study

Progress of on-going Studies

1. Flood Inundation Modelling of Beki River Basin of Assam.

Dr. S. K. Sharma (PI),presented the study. He briefly explained the objectives, methodology and achievements of the study. He also explained the preliminary modelling results of flood inundation area in Beki River Basin. Dr. BipulTalukdar enquired about the dimensions of the modelling and also suggested to consider the embankments in the study. Er. V. D. Roy asked to check whether there is any floods due to breach of embankments, which is common in Brahmaputra river basin. He also suggested locating the erosion sites and embankment breach locations for anti-erosion structures in Beki River. Dr. P. L. N. Raju suggested using 10m Carto-DEM available from NESAC to use for Flood Inundation Modelling purposes. Director asked to expedite the process of data collection so that the study can be completed within the time.

2. Development of regional methods for design flood estimation in North Brahmaputra subzone 2 (a)

Dr. Sanjay K. Sharma, PI, presented the study. The objectives of the study described followed by achievements. He also explained about the methodology and parameters which have been derived for the gauged catchments that help to assess the flood frequency relationships in the adjoining ungauged catchments. Director suggested minor corrections avoiding repetitions in the objectives. Dr. A. K. Lohani suggested for applying the classified data via new form and giving the presentation of the study to the concerned CWC officers for speeding up the data collection process.Er. V. D. Roy also guided about data selection and application for water level and discharge data form CWC Shillong. Director also asked the PI to ensure completion of the study within the stipulated time.

3. Linear hydrological routing using Satellite precipitation datasets for flood forecasting in parts of Brahmaputra Basin

Er. GulshanTirkey, PI presented the study. He explained the objectives and methodology of the study involved in flood forecasting with the usage of near real time satellite precipitation datasets. He also explained implementation of Integrated Flood Analysis System (IFAS) modelling in Brahmaputra River Basin for Flood forecasting applications. He has also stated the current progress and achievements of the study. PI has explained the data order issues due to large number of stations and longer duration of data.Er. V. D. Roy suggested to concise the required data list and contact to concerned CWC office.

4. Impact of Climate Change on Runoff and Sediment Yield for a Major Tributary of River Brahmaputra

Dr. Swapnali Barman, PI of the project presented the study. She briefly explained the objectives, methodologies and progress of the study that covered rainfall and temperature trend analysis over the Puthimari basin using different climate models, land use/land cover (LULC) change detection study using supervised classification technique and application of CA Markov model to predict the future LULC, and setting up of SWAT model for analyzing the impact of climate change on runoff and sediment yield of the river.

Dr. J.V. Tyagi, Director, NIH in the very beginning of the presentation suggested the PI to include the name of the tributary i.e. Puthimari in the title of the project. Mr. P.L.N. Raju, Director, North eastern Space Application Centre (NESAC) and other officials from his organization suggested that the LULC maps of Puthimari basin may be verified with the LULC maps prepared in NESAC. Dr. Arnab Bandyopadhyay, Associate Professor, North Eastern Regional Institute of Science and Technology (NERIST), told about the importance to determine future LULC scenario using Markov Model that facilitates to analyze its future impact on runoff and sediment yield in the basin. Mr. V.D. Roy, Superintending Engineer, CWC enquired if any other major tributary has also been considered in the study and also about the future LULC of the basin. At the end of the presentation, regarding the SWAT model, Dr. J.V. Tyagi, Director, NIH suggested to check the parameters for a better result of the model.

5. Groundwater Quality Assessment of Morigaon district of Assam with emphasis on Arsenic & Fluoride Contamination

Dr. S. K. Sharma 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. He also explained about the sampling grid size and tentative locations for collecting 50 Nos. distributed samples from the Morigaon District.Director asked about the initiation of sample collection. PI has stated that sample collection was unable to be undertaken due to Pandemic situation and the samples would be collected during pre-monsoon and post-monsoon of 2021.

6. Comparison of Hydrological Behaviour of two mid-sized Mountainous Catchments under the influence of Climate and Land Use Changes.

Er. Waikhom Rahul Singh, PI presented the study. The objectives of the study are (1) to compare the morphometric parameters of Pare and Dudhnoi river basins using Digital Elevation Model (DEM), (2) to classify and project future landuse maps of Pare and Dudhnoi catchments using Cellular Automata-Markov Model, (3) to simulate water yields for different scenarios under landuse and climate change using calibrated VIC model, and (4) to map inundation levels of Dudhnoi river basin using HEC-RAS. Various progress achieved so far such as sub-watershed prioritization, drought conditions and extreme climate extremes in the study areas has been presented. Director, NIH and few members suggested changing the title of the study by removing the word "comparison" in the title. Director, NIH also recommended reviewing various watershed characteristics reports of the Dudhnoi basin so that the quality of the results may be improved.

7. 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. The progress includes land use/land cover change detection study using LANDSAT data, trend analysis of snow cover area using MODIS snow cover data, and precipitation trend analysis over the basin using different climate models. No particular comment has been received from the members of the meeting.

8. 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. On enquiry by Director, PI explained that the study has been started during October 2019. He also explained about the procurement and recruitment progress and delay due to pandemic.

RCC members noted the progress.

Proposed New Study

1. Rainfall Induced Flood Hazard Risk Vulnerability Assessment in East Jaintia Hills, Meghalaya

Er. GulshanTirkey, PI proposed the study.He has presented the objectives, methodology and expected outcomes of the study. Er. V. D. Roy has appreciated the importance of the study in this region and suggested that an operational forecast would beneficial. He also suggested that landslide component can also be considered for study in this region.

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	Er. N G Pandey	Scientist E
4	Er. S R Kumar	Scientist E

Recommended Work Program for the year 2020-21

Sl	Title	Study Team	Duration
Internal Studies			
1	Identification and Assessment of Meteorological Drought Trends for Agro-climatic Zones of South Bihar	SR Kumar (PI), RP Pandey, Rakesh Kumar and Nitesh Patidar	3 years (4/19 – 3/22)
2	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)
3	Performance evaluation of Upper Morhor Canal System of South Bihar	NG Pandey(PI) B Chakravorty	2 years (04/20-03/22).
Sponsored Study (PDS/NHP)			
4.	Modelling and Management of Erosion and Sedimentation Processes in Alluvial River Using Morpho-dynamic Modeling	Pankaj Mani (PI), Rakesh Kumar, JP Patra, B Chakravorty and WRD Bihar	New study proposed under PDS (04/19-03/22)

Progress of Studies

1. Identification and Assessment of Meteorological Drought Trends for Agro-climatic Zones of South Bihar

Drought is one of the major natural hazards affecting the environment and economy of the regions worldwide. Rainfall is important for replenishment of groundwater resources. Meteorological drought indices may play important role in water resources planning and management. Drought is a recurring phenomenon in south Bihar and in recent years, the frequency of occurrence of drought in south Bihar region has increased. With this background, this study has been proposed with the objectives; (i) developing inventory of drought events in the study areas, (ii) to analyze the critical dry spells during the monsoon and crop growing season, (iii) analysis of meteorological and hydrological data and agricultural records for establishing regional drought indicators/indices, (iv) evaluation of proposed indicators/indices. In the present study, various types of drought like Meteorological drought, Agricultural drought, Hydrological drought, Socio-economic drought and Environmental drought will be studied. For studying these types of droughts, standard drought indices like Reservoir storage index, Groundwater drought index, Streamflow drought index, Normalized Difference Vegetation Index (NDVI) etc. will be determined for the study area. During presentation of the study, Dr. Upadhyay, Principal Scientist, ICAR, Patna and Director NIH suggested to incorporate the information related to drought hazard, drought risk and socio-economic vulnerability through template maps to enhance the quality of the results. They further suggested for close interaction with different state govt. agencies and collection of required field data and information of the study area for desired quality output. Accordingly, drought hazard, drought risk and socio-economic vulnerability will also be studied and incorporated.

2. Integrated Flood Management Plan for a stretch of Burhi Gandak River from Sikanderpur to Rosera

Rivers have been channelized, deepened and constrained by embankments for centuries to increase agricultural productivity and improve flood defences. This has restricted the hydrological connectivity between rivers and their floodplains. The present study aims to evaluate the existing embankments of Burhi Gangak river from Sikanderpur to Rosera in a stretch of 106 km. The embankment breach is a recurrent problem in the stretch. Further, the stretch has promising agricultural activity. The objectives of the study are: i) to estimate the design flood at Sikanderpur and Rosera, ii) to carry out flood simulation, compute water surface profile to evaluate the adequacy of embankment heights and identify critical locations of spilling, iii) estimate the extent, depth of inundation and flood damage, iv) estimation of safe grade elevation for buildings and infrastructures and development of emergency action plan and v) sensitivity analysis of model parameters

The catchment area of Burhi Gandak river is 12,021 km^2 in which 2,420 km^2 lies in Nepal and the rest 9,601 km^2 lies in Bihar. The average annual rainfall is 1,482mm in which 91% occurs during Monsoon. The distance between Sikanderpur to Rosera is 105.5 km. The topographical difference is from 65m to 38m. The morphology of Burhi Gandak is meandering in nature. The hydrological (daily) data at Sikanderpur and Rosera (G&D site) and Samastipur (G site) are proposed to be used in the study. Cross-sectional data at regular interval between Sikanderpur to Rosera would be used for model development. The SRTM data would be used for inundation modelling.

Dr. Upadhyaya, ICAR suggested to include the idea of integrated flood management in this study. Dr Rakesh Kumar, Scientist G and Coordinator CFMS, Patna suggested to refer the dissertation guided by Dr Chatterjee, IIT Kharagpur in this regard. Director NIH suggested to consult ICAR and WRD while conducting this study. Dr. Upadhyaya from ICAR has been consulted and the proposal has been revised. We would further consult the concerned resource persons while carrying out the study as suggested.

3. Performance evaluation of Upper Morhor Canal System of South Bihar

This study is proposed in consultation with WALMI and Irrigation Department, Govt. of Bihar. The river Morhor is an important right bank tributary of river Punpun which joins near Gourichak in Patna district. The Upper Morhor irrigation scheme was constructed in 1958 with a low diversion weir built near village Sugidhi of Gaya district at $24^0$30’ N latitude and 84^0 44’ E longitude. The purpose of the project was to provide irrigation to five drought prone CD blocks of Amas, Gurua, Paraiya, Konch of Gaya district and CD block of Rafigunj. of Aurangabad district.

The old canal system constructed in 1958, need its performance evaluation and improvement of its efficiency and crop production. The canal system of upper Morhor will be digitized from LISS3 PAN data. Landuse classification will be made using GIS software. Crop coverage in Kharif and Rabi season will be made. Crop water demand and canal supply at head reach and tail end will be analyzed. Suggestive measures to reduce gap in irrigation potential created and utilized will be shared with Sate Govt.

4. Modelling and Management of Erosion and Sedimentation Processes in Alluvial River Using Morpho-dynamic Modeling

The fluvial process is the macroscopic view and long-term consequence of sediment movement. Understanding of the fluvial process as a result of sediment deposition and erosion, is necessary for management of alluvial river. Flood, avulsion and sediment transportation and deposition are the natural processes while the water diversion, channelization, and navigation are human disturbances to rivers. The braided rivers are naturally unstable, causing frequent bank erosion in different reaches and at varying rate. If the bank is composed of finer non-cohesive material, the erosive activity could take a serious turn. Therefore, arresting the erosive activity is given high importance. Anti-erosion works are normally costly and therefore, such measures are executed mainly at critical locations. For providing dependable protection, scientific approach is required for understanding the river behaviour at the critical location. The morphodynamic modelling helps in quantitative estimation of the flow and sedimentation/ erosion characteristics of river that can be used for adopting suitable engineering measures and their design. The 2D morphodynamic models are better replica of flow conditions and velocity distribution in alluvial river to understand the river regime and flow characteristics. With this background, this study has been proposed with the objectives; (i) to develop the flow field and carrying out the flood studies of river channels and adjacent floodplains using a curvilinear grid to compute the flow characteristics like maximum flood level, flow velocity, flow direction, etc., (ii) to forecast of morphological changes over 2-3 years in the mobile braided river. The analysis would useful for planning and execution of river training works, (iii) to prepare design criteria for river training works in terms of flow velocities, flow depths, scour depths, bank line retreat rates, shoaling, etc., (iv) to analyze sediment deposition (and erosion) in the study stretch and prediction of required annual volume of silt for dredging and sand mining etc. and(v) the selection of the study area is under finalization with the consultation of WRD, Bihar. In the first year of study, river shifting analysis has been carried out using historical satellite images.

APPENDIX 74.4.2

LIST OF PAPERS PUBLISHED/ ACCEPTED FOR PUBLICATION DURING DECEMBER 2019 - SEPTEMBER, 2020

LIST OF PUBLICATIONS FROM Dec.2019-Mar. 2020 & April – Sept.2020

S.No.	Item	Published/Accepted Dec.2019-Mar.2020	Published/Accepted Apr.-Sept.2020
1	International Journal	38	26
2	National Journal	10	8
3	International Conference/ Seminar	52	8
4	National Conference/ Seminar	50	1
5	Books/Chapters	18	4
	Total	**168**	**47**

List of Publications from Dec.2019-Mar. 2020

CHAPTERS IN BOOKS	
1.	Barman, S. and Goel, M. K. (2019). "Climate Change and Riverflow", In: Climate Change and Its Impacts on Water Resources with Focus on India (Eds. Sharad K. Jain & P. K. Singh), Special Report-1/19, National Institute of Hydrology, Roorkee, India, pp. 147-157.
2.	Gurappu, S. and Singh, V. (2019). "Uncertainty in Climate Change Studies", In: Climate Change and Its Impacts on Water Resources with Focus on India (Eds. Sharad K. Jain & P. K. Singh), Special Report-1/19, National Institute of Hydrology, Roorkee, India, pp. 254-264.
3.	Humbal, C., Gautam S., Joshi, S. K., Rajput, M. S. (2020). "Spatial Variation of Airborne Allergenic Fungal Spores in the Ambient PM2.5—A Study in Rajkot City, Western Part of India", In: Measurement, Analysis and Remediation of Environmental Pollutants. Energy, Environment, and Sustainability, Springer, Singapore, pp. 199-209.
4.	Jain, S. K. and Singh, V. (2019). "Impact of Climate Change on Himalayan Cryosphere", In: Climate Change and Its Impacts on Water Resources with Focus on India (Eds. Sharad K. Jain & P. K. Singh), Special Report-1/19, National Institute of Hydrology, Roorkee, India, July 2019, pp. 125-141.
5.	Jaiswal, R. K., Galkate, R. V., Thomas, T., Nayak, T. R. and Verma, A. (2020). "Modeling Approach for Impact Assessment of Soil and Water Conservation (SWC) measures on Sediment Yields", In: Multi-disciplinary Approach towards Sustainable Development, Bookwell, Delhi (India), pp. 63-69.
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9.	Kumar, P., Nayak, J. P., and Ram, S. (2020). "Hydro-Ecological Assessment of Environmental Flows for Satluj River", In: Climate Impacts on Water Resources in India, Springer, Ch. 13.
10.	Kumar, R., Nayak, P. C., Patra, J. P. and Mani, P. (2019). "Impact of Climate Change on Floods", In: Climate Change and Its Impacts on Water Resources with Focus on India (Eds. Sharad K. Jain & P. K. Singh), Special Report-1/19, National Institute of Hydrology,

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12.	Singh, R and Kumar, S. (2019). "Impact of Climate Change on Water Quality", In: Climate Change and Its Impacts on Water Resources with Focus on India (Eds. Sharad K. Jain & P. K. Singh), Special Report-1/19, National Institute of Hydrology, Roorkee, India, pp. 178-181.
13.	Singh, V. (2019). "Downscaling of Climate Data", In: Climate Change and Its Impacts on Water Resources with Focus on India (Eds. Sharad K. Jain & P. K. Singh), Special Report-1/19, National Institute of Hydrology, Roorkee, India, pp. 21-44.
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18.	Tyagi, J. V. (2019). "Climate Change and Soil Erosion", In: Climate Change and Its Impacts on Water Resources with Focus on India (Eds. Sharad K. Jain & P. K. Singh), Special Report-1/19, National Institute of Hydrology, Roorkee, India, pp. 246-253.
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	Science and Research (IJSR), Volume 8, Issue 5.
23.	Salila, E., Sharma, M. P. and Singh, R. (2020). Climate Change Impacts on Water Quality of Water bodies - A Review. International Journal of Environment and Climate Change, 10(3), 26-37.
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जल संसाधन एवं पर्यावरण विषय पर 6th राष्ट्रीय जल संगोष्ठी-2019 दिसम्बर 16-17, 2019, राष्ट्रीय जलविज्ञान संस्थान, रूड़की

क्रम स.	लेखक	शोध पत्र का विषय
1.	राकेश कुमार, पंकज मणि, जे.पी.पात्रा, तिलक राज सपरा	एल–मोमेंटस का उपयोग करते हुए सब–हिमालयन क्षेत्र के लिए विभिन्न वापसी अवधि के लिये बाढ़ का पूर्वानुमान,
2.	पुष्पेंद्र कुमार अग्रवाल तथा डॉ. शरद कुमार जैन, राष्ट्रीय जलविज्ञान संस्थान, रुड़की।	भारतवर्ष की नदियों के नामकरण का अध्ययन।
3.	एम.के.नेमा, प्रदीप कुमार, पी.के.मिश्रा और सौरभ नेमा राष्ट्रीय जलविज्ञान संस्थान, रुड़की	दैनिक वर्षा के आकड़ों द्वारा तवी नदी बेसिन के लिए अलग–अलग प्रत्यागमन अवधियों के लिए तीव्रता–अवधि–आवृत्ति (आईडीएफ) वक्र का विकास
4.	दिगम्बर सिंह, ए.आर सैंथिल कुमार, मनोहर अरोड़ा, ओमकार सिंह, नागेश्वर अल्लका, राष्ट्रीय जलविज्ञान संस्थान, रूड़की	विभिन्न वाष्पोत्सर्जन विधियों द्वारा रूड़की क्षेत्र के लिए वाष्पोत्सर्जन दरों का तुलनात्मक अध्ययन
5.	अर्चना सरकार, कुलदीप तिवारी, नीरज भटनागर, रोहित गोयल, राष्ट्रीय जलविज्ञानं संस्थान रूड़की	भारत के रेगिस्तानी प्रदेश के एक भाग पर वर्षा के ट्रेंड विश्लेषण एवं इसके जल संसाधन प्रबंधन पर होने वाले प्रभाव
6.	एस.के. शर्मा[1], जी.तिर्की[1], एस. बर्मन[1], ए.के. लोहनी[2], 1राष्ट्रीय जलविज्ञान संस्थान क्षेत्रिय केंद्र, गुवाहाटी, 2राष्ट्रीय जलविज्ञान संस्थान, रुड़की	कुलसी नदी क्षेत्र (असम/मेघालय) के अंतर्गत बूट्स्ट्राप आधारित कृत्रिम तंत्रिका प्रसार (आर्टिफ़िशियल न्यूरल नेटवर्क्स) का प्रयोग कर अल्पावधि बाढ़ पूर्वानुमान
7.	पुष्पेंद्र कुमार अग्रवाल, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	जल के इष्टतम उपयोग हेतु आवश्यक जल प्रबंधन
8.	शीपिका सुन्द्रियाल, डॉ राजेश सिंह, राष्ट्रीय जलविज्ञान संस्थान, रूड़की	मध्य हिमालय पर पिघले पानी में ट्रेस तत्वों की सांद्रताः डोकरियानि और गंगोत्री ग्लेशियर का एक केस अध्ययन
9.	अंजली[1], आशीष मलिक[2], 1राष्ट्रीय जलविज्ञान संस्थान, रूड़की, 2लोकसभा सचिवालय, नई दिल्ली	वारंगल जिले का भूजल पुनर्भरण आकलन।
10.	एस.एस. रावत[1], प्रदीप कुमार[2], सुमन गुर्जर[2], पी.जी. जोस[1], गिरीश रैना[1], एस.पी. राय.[3], 1राष्ट्रीय जलविज्ञान संस्थान क्षेत्रीय केंद्र, जम्मू 2राष्ट्रीय जलविज्ञान संस्थान, रूड़की, उत्तराखंड, 3बनारस हिन्दू विश्वविद्यालय, वाराणसी।	बदलते मौसम में निरंतर सूखते हिमालयी जल स्रोतों (झरनों) के पुनरुद्धार हेतु वैज्ञानिक समाधान।
11.	सुजाता[1] एवं राजेश सिंह[2], 1जलविहार कॉलोनी राजसं., रूड़की, 2राष्ट्रीय जलविज्ञान संस्थान, रूड़की।	बारिश की एक–एक बूँद है बेशकीमतीः वर्षा जल संचयन।
12.	नितेश पाटीदार[1], अशोक के. केशरी[2] 1राष्ट्रीय जलविज्ञान संस्थान, रुड़की, 2भारतीय प्रौद्योगिकी संस्थान, दिल्ली।	दिल्ली में शहरीकरण के विगत 26 वर्ष–ग्राउंडवाटर रिचार्ज पर बढ़ती इम्परवियस सरफेस का प्रभाव।
13.	अनुपमा शर्मा, अंजू चौधरी, पारुल गुप्ता, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	सौराष्ट्र प्रायद्वीप के तटीय नदी बेसिन में सिंचाई अनुकूलता हेतु भूजल गुणवत्ता आंकलन
14.	दीपा चालीसगाँवकर, पुष्पेन्द्र कुमार अग्रवाल,	गंगाकोशः आधुनिक तकनीक द्वारा गंगा नदी से सम्बंधित सूचनाओं का

	प्रभाष कुमार मिश्र, मनीष कुमार नेमा, राष्ट्रीय जलविज्ञान संस्थान, रूड़की	प्रचार एवं प्रसार
15.	[1]अनिल कुमार लोहनी, [2]योगेश जोशी, [1]संजय कुमार जैन, 1राष्ट्रीय जलविज्ञान संस्थान, रुड़की, 2भारतीय प्रौद्योगिकी संस्थान, रुड़की	हाइड्रो–डाइनैमिक मॉडल तथा जीआईएस द्वारा फ्लैश फ्लड का आंकलन एवं चित्रण
16.	राहुल कुमार जैसवाल, अनूप कुमार राय, रवि गलकटे, सुकान्त जैन, राष्ट्रीय जलविज्ञान संस्थान क्षेत्रीय केंद्र, भोपाल।	सोंदूर जलाशय में डिजिटल इमेज प्रोसेसिंग तकनीक का उपयोग करके अवसादन का आकलन
17.	एल एन ठकुराल, आशीष भंडारी, अतुल भारद्वाज, वी एस जयकांथन, डी एस राठौर, दीपा चालीसगांवकर, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	ऊपरी गंगा बेसिन में हिम मानचित्रण और वेब अनुप्रयोग
18.	गोपाल कृष्ण[1], पूरनबा दास गुप्ता[2], एंड्रू मैकेंजी[3], सी.पी.कुमार[1], डी बर्मन[4], यू.के. मंडल[4], अंजू चौधरी[1] 1 राष्ट्रीय जलविज्ञान संस्थान, रुड़की 2 राजारहाट प्रसारी 3ब्रिटिश जियोलाजिकल सर्वे, यू.के. 4ICAR-CSSRI, कैनिंग टाउन कोलकाता	सुंदरबन क्षेत्र में मिट्टी–पानी के मुद्दे और संभावित प्रबंधन।
19.	मनोहर अरोडा, नरेन्द्र कुमार वार्ष्णेय, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	भारतीय प्रिंट मीडिया में जलवायु परिवर्तन कवरेजः एक लेख विश्लेषण
20.	रोहित सांबरे, वी.सी.गोयल, अर्चना सरकार, मो. फुरकान उल्लाह, चारू पाण्डेय, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	हाइड्रोलॉजी में साइंटोमेट्रिक्सः एक समीक्षा पत्र।
21.	द्रोण खुराना[1], एस.एस.रावत[1] एवं एम. के. गोयल[2], 1राजसं.क्षेत्रीय केंद्र जम्मू, 2राष्ट्रीय जलविज्ञान संस्थान, रुड़की	क्षेत्रीय जल की कमी के सतत समाधान हेतु जम्मू क्षेत्र के कंडी बेल्ट में तालाबों का जलविज्ञानीय अध्ययन–एक समीक्षा
22.	ओमकार सिंह, राजेश सिंह, वी.सी. गोयल, दिगम्बर सिंह, एवं निहाल सिंह, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	ग्रामीण तालाब के जीर्णोद्धार में सहायक रूटजोन वेटलैण्ड तकनीकीः घरेलू अपशिष्ट जल का प्राकृतिक तरीके से शुद्धीकरण
23.	जे.पी.पात्रा[1], राकेश कुमार[1], पंकज मणि[2], तिलक राज सपरा[1], 1राष्ट्रीय जलविज्ञान संस्थान, रुड़की 2राष्ट्रीय जलविज्ञान संस्थान क्षेत्रीय केंद्र, पटना	एक आयामी और दो–आयामी द्रवगतिकीय निदर्श के युग्मन के उपयोग से बांध–भंग बाढ़ आप्लावन का निदर्शन करना
24.	तिलक राज सपरा[1], राकेश कुमार[1], पंकज मणि[2], जे.पी.पात्रा, 1राष्ट्रीय जलविज्ञान संस्थान, रुड़की 2राष्ट्रीय जलविज्ञान संस्थान क्षेत्रीय केंद्र, पटना	माइक फ्लड सॉफ्टवेयर का उपयोग करके जलाशय के तटबंध की विफलता के लिए बाढ शमन योजना
25.	राजेन्द्र प्रसाद पांडेय, नीरज कुमार भटनागर, हुकम सिंह, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	प्रभावी न्यूनीकरण (Mitigation) योजना के लिए सूखा के लिए बल्नेरेबिलिटी (Vulnerability) का आकलनः भारत की केन नदी बेसिन का प्रकरण
26.	पंकज मणि[1], राकेश कुमार[2], जे.पी.पात्रा[2], तिलक राज सपरा[2], 1राष्ट्रीय जलविज्ञान संस्थान क्षेत्रीय केंद्र, पटना 2राष्ट्रीय जलविज्ञान संस्थान, रुड़की	कारटो डी ई एम आंकडो का उपयोग करते हुए एक पहाड़ी क्षेत्र में बांध भंग के कारण बाढ़ हजार्ड का मानचित्रण
27.	गुलशन तिर्की, जी. अरुण, एस. के. शर्मा और स्वप्नाली बर्मण,	उन्नत भू–स्थानिक डेटा विश्लेषण का उपयोग करके असम राज्य में ब्रह्मपुत्र नदी की जलधाराओं की बाढ़ की मैपिंग

	राष्ट्रीय जलविज्ञान संस्थान क्षेत्रीय केंद्र, गुवाहाटी	
28.	नीरज भटनागर[1], अर्चना सरकार[1], वैभव गर्ग[2], 1राष्ट्रीय जलविज्ञान संस्थान, रुड़की 2भारतीय सुंदर संवंदन संस्थान, देहरादून	उत्तराखंड हिमालय में जलवायु परिवर्तन का अध्ययनः प्राचीन वर्षा के बदलते रूझान।
29.	मनोहर अरोड़ा, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	जलवायु परिवर्तन अनुमानों में अनिश्चिततायें ।
30.	दीपक सिंह बिष्ट, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	जलवायु परिवर्तन के साथ भारत में विकराल होती संभावित सूखे की समस्या।
31.	पी.के.मिश्रा, रिनोज जे.थैय्यन, एम.के. नेमा, एच.सिंह, एस.दास, पी.कुमार, नरेश कुमार, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	ऊपरी गंगा बेसिन में बादलों के फटने की संभावना एवं संवेदनशीलता का आकलन।
32.	सुरजीत सिंह, अंजू चौधरी, सुमन गुर्जर, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	एकीकृत जल संसाधन प्रबंधन (IWRM) के संदर्भ में जल गुणवत्ता निगरानी नेटवर्क की पहचान एवं योजना।
33.	राहुल कुमार जैसवाल[1], अनिल कुमार लोहनी[2], रवि गलकटे[1] 1राष्ट्रीय जलविज्ञान संस्थान, क्षेत्रीय केंद्र भोपाल 2राष्ट्रीय जलविज्ञान संस्थान, रुड़की	जलवायु परिवर्तन का कमांड क्षेत्र (सिंचन क्षेत्र) की सिंचाई आवश्यकता पर पड़ने वाले प्रभाव का अध्ययन।
34.	संजय मित्तल, गोपाल कृष्ण, सी.पी. कुमार, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	भारत में हरियाणा राज्य के मेवात जिले में मृदा प्रदूषण के संबंध में भारी धातुओं का आंकलन।
35.	गोपाल कृष्ण, चंद्र प्रकाश कुमार, सुमन गुर्जर, बलविंदर सिंह सिद्धू, गोकुल प्रसाद, अंजू चौधरी, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	पंजाब में जलभृत लवणता की समस्या
36.	एम.के.नेमा[1], दीपक खरे[2], लवशंकर भारती[3], शरद कुमार जैन[1] 1राष्ट्रीय जलविज्ञान संस्थान, रुड़की 2आई.आई.टी. रूड़की 3पूर्व छात्र, आई.आई.टी. रूड़की	भूमि उपयोग परिवर्तन और शहरीकरण के शहरी–ऊष्मात–द्वीपीय प्रभावः लखनऊ शहर का एक अध्ययन।
37.	सुमंत कुमार, अंजू चौधरी, संजय मित्तल, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	भारत के उत्तर प्रदेश के बलिया जिले में भूजल गुणवत्ता का आकलन।
38.	मुकेश कुमार शर्मा, प्रदीप कुमार, राकेश गोयल एवं मोहित कुमार, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	बेमेतरा जिला, छत्तीसगढ़ में भूजल गुणवत्ता का मूल्यांकन
39.	मुकेश कुमार शर्मा, बबीता शर्मा एवं बीना प्रसाद, राष्ट्रीय जलविज्ञान संस्थान, रुड़की	भूजल में उभरते हुए दूषित पदार्थ और उनके निवारण।
40.	सौरभ दास[1], राजेश सिंह[3], वी.के. पाण्डेय[2], आर.पी.पांडे[3], 1MIGI भिलाई दुर्ग छत्तीसगढ़ 2IGKV, रायपुर 3राष्ट्रीय जलविज्ञान संस्थान, रुड़की	रिस्पंना नदी के सतह जल की गुणवत्ता का वर्णन।
41.	अली हैदर[1], दिगम्बर सिंह[2], ए.आर. सैंथिल कुमार[2], हुकम सिंह[2], 1देवबन्ध, सहारनपुर 2राष्ट्रीय जलविज्ञान संस्थान, रुड़की	देवबन्द (सहारनपुर) उत्तर प्रदेश, में नगरीय ठोस कचरे का प्रबन्धन।

List of Publications from April – Sept.2020

Chapters in Books	
1.	Sharma, M. K., Singh, Rajesh, Singh, Omkar and Durbude, D. G. (2020) Contamination in drinking water supply: A case study of Shimla city, Himachal Pradesh, India Book titled 'Climate Impacts on Water Resources in India' to be published by Springer (Accepted for publication).
2.	Singh, R., Kanbienaa, D. and Pandey, A. (2020) Water Quality Status of Upper Ganga Canal, Book titled 'Climate Impacts on Water Resources in India' to be published by Springer (Accepted for publication).
3.	Singh, R., Kashyap, S. and Pandey, A. (2020) Water Quality and Human Health, Book titled 'Climate Impacts on Water Resources in India' to be published by Springer (Accepted for publication).
4.	Kumar, Pradeep, Jai Prakash Nayak, and Shobha Ram (2020) Hydro-Ecological Assessment of Environmental Flows for Satluj River, Book titled 'Climate Impacts on Water Resources in India' to be published by Springer (Accepted for publication).

International Journal	
1.	Abungba J.A., Khare D., Pingale S.M., Adjei K.A., Gyamfi C., Odai S.N. (2020), Assessment of hydro-climatic trends and variability over the Black Volta Basin in Ghana. Journal of Earth Systems and Environment, Springer. https://link.springer.com/article/10.1007/ s41748-020-00171-9. Emerging SCI & Scopus indexed.
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International Conference/Seminar/ Workshop	
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2.	Singh, Gaurav, Nitin Mishra and L. N. Thakural (2020) "Statistical Downscaling and Future Scenarios of Temperature in Haridwar District, Uttarakhand, 4^{th} International Conference on Mathematical Techniques in Engineering Applications (ICMTEA2020) December 4-5, 2020 Dehradun
3.	Sharma, M. K., Prajapati, Parul, Bhanot, Kunarika, Wadhwa, Udita and Tomar, Garima (2020) Hydro-geochemical investigations in Upper Ganga Basin, India, International Web-Conference on Resource Management and Biodiversity Conservation to Achieve Sustainable Development Goals, organized by Academy of Natural Resource Conservation and Management, Lucknow (UP), India during September 11-12, 2020.
4.	Raghav, Nandani and Sharma, M. K. (2020) Proficiency of Water Purification System Against Bacterial Contamination In Water International Web-Conference on Resource Management and Biodiversity Conservation to Achieve Sustainable Development Goals, organized by Academy of Natural Resource Conservation and Management, Lucknow (UP), India during September 11-12, 2020.
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6.	Venkata Ramana, R., Y.R.Satyaji Rao and V.S. Jeykanthan (2020). Improved Neuro-Wavelet Model for Flood Forecast of Nagavali River Basin. International Web-Conference on Resource Management and Biodiversity Conservation to Achieve Sustainable Development Goals September 11-12, 2020 Organized by Academy of Natural Resource Conservation and Management, Lucknow (UP), INDIA.
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National Conference/Seminar/ Workshop	
1.	Krishan, Gopal, Sudarsan, N., Sidhu, B.S., In an online seminar on “Covid 19 effects and challenges for sustainable agriculture and water management” organized by River Water Users Association, India during June 21-22, 2020 at Prayagraj, India.

APPENDIX 74.4.3

LIST OF WORKSHOPS/ TRAINING COURSES/ SYMPOSIA ORGANISED DURING DECEMBER 2019 - SEPTEMBER, 2020

TECHNOLOGY TRANSFER ACTIVITIES

SN	ACTIVITIES	PERIOD	VENUE
1.	Training Course on "Climate Change and Hydrological Impact Assessment"	December 02-13, 2019	NIH, Roorkee
2.	Training Workshop on "Basic Hydrology", organised for AP Surface Water Department, Vijayawada	December 03-05, 2019	Vijayawada, Andhra Pradesh
3.	Workshop on "Understanding Aquifer Systems of Sunderbans- Wpecial Emphasis on ASR using Saline Aquifers to Improve Farmers' Livelihood", Sponsored by IUKWC	December 09, 2019	Salt Lake, Kolkata
4.	Training course on "Geospatial Applications in Hydrology: Theory & Practice."	December 09-13, 2019	WHRC, Jammu
5.	Sixth National Hindi Conference on "Jal Sansadhan Aur Paryavaran" (जल संसाधन एवं पर्यावरण)	December 16-17, 2019	NIH, Roorkee
6.	Training Course on "Hydrodynamic Modelling of a River System"	January 06-08, 2020	Jalandhar
7.	Training Course on "Advance Hydrology" under NHP	January 06-10, 2020	SIHFW, Jaipur (Rajasthan)
8.	Training Course on DGPS for students from Department of Civil Engg, GLA University, Mathura (UP)	January 20-23, 2020	NIH, Roorkee
9.	Brainstorming Session on Hydrologic Modelling for Water Resources Management. Under the ongoing UKCEH Project	January 30, 2020	PICU, WALMI, Bhopal
10.	International Webinar on Sunderbans-The case of Water, Water Everywhere But Not A Drop to Drink'?	February 04, 2020	NIH, Roorkee
11.	Training Course on "Hydrology for Water and Sanitation Programmes" for engineers of PHED, Rajasthan	February 11-14, 2020	NIH, Roorkee
12.	One Day Workshop on "Impact of Untreated Sewage water on Shallow groundwater Quality and its Remedies", organised at DRC, Kakinada	February 20, 2020	Kakinada
13.	Hydrology and Water Resources Management of Cascade of Tanks System Under Climatic Uncertainty (For officers of Dept. Of Irrigation and Dept. of Agrarian Development, Sri Lanka	February 17-21, 2020	New Delhi
14.	Seminar on "Application of Climate Change Science in Water Resource Management in Western Canada"	February 24, 2020	NIH, Roorkee
15.	Seminar on "Sediment and water quality modeling with HYPE: a journey around the world."	February 25, 2020	NIH, Roorkee
16.	International conference 'Roorkee Water Conclave' on "Hydrological Aspects of Climate Change", jointly organized with Indian Institute of Hydrology (IIT)	February 26–28, 2020	NIH, Roorkee
17.	Training Course on "Hydrological Modelling Using HEC RAS and HEC-HMS" under NHP	March 02-06, 2020	Hyderabad
18.	Training course on 'GW Modelling using Visual MODFLOW' (under NHP)	6-10 July, 2020	In VC mode
19.	Training course on 'Hydrological Modelling Using HEC HMS and HEC RAS' (under NHP)	13-17 July, 2020	NIH, Roorkee In VC mode
20.	Training course on 'Machine Learning for Remote Sensing Data Classification'	1 June, 2020	Conducted by IIRS, Dehradun
21.	Workshop on DSS (PM) (under NHP)	24 Aug., 2020	NIH, Roorkee
22.	Training Programme on "Remote Sensing Application in	3-7 Aug.,	Conducted by

	Agricultural Water Management"	2020	IIRS, Dehradun
23.	Online Training Programme on "Hydrological Modeling using SWAT"	August 21-25, 2020	NIH, Roorkee
24.	Webinar on "Hydrology of Upper Ganga basin in climate change perspective" organized on the occasion of Himalaya Day	9 Sept., 2020	NIH, Roorkee and IHP of UNESCO
25.	Online Training Programme on "Understanding of Coastal ocean processes using RS and Numerical Modeling"	September 21-25, 2020	IIRS Dehradun
26.	Online Google Earth Engine Workshop	Sept. 18, 2020	NIH Roorkee
27.	Online DSS(PM) workshop	Sept. 25, 2020	NIH Roorkee

APPENDIX 74.4.4

PROGRESS OF LABORATORY WORK
DURING THE PERIOD
DECEMBER 2019 - SEPTEMBER, 2020

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 December, 2019 to September, 2020

	No. of samples of Division	No. of samples of Regional Centre	No. of samples of Outside Agencies on payment basis
Physico-chemical analysis	2127	-	10
Bacteriological analysis	115	-	-
Metal analysis	-	-	-
Pesticide analysis	-	-	-
Total analysis	2242	-	10

Details of samples analysed by the Nuclear Hydrology Laboratory, HI Division during December 2019 to September, 2020:

S.N.	Parameter analysed	No. of samples
1	δ^2H on DI-IRMS	5761
2	$\delta^{18}O$ on DI-IRMS / CF-IRMS	5714
4	Tritium	162
5	WQ samples on IC	650

Soil Water Laboratory
Laboratory Analysis carried out during the period Dec 2019 to Sept. 2020.

Sl. No.	Name of the studies	No. of Samples	Parameters Measured
1.	Upper Yamuna Basin Project (Saharanpur Region)	Fourteen (14) + Six (06)	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.
2.	Impact of Rain Water Harvesting on Groundwater Quality in India with Specific Reference of Fluoride and Other Micro-pollutants, Laporiya, Bhadrajun,Bayana Bharatpur (Rajasthan)	Eight(08) + Seventeen(17) + Forty Five(45) + Forty One(41)	1. Determination of soil texture using sieve shaker and laser based particle size analyzer. 2.Determination of Bulk Density,Dry Density(17 Undisturbed Samples). 3.Determination of soil moisture (17 Undisturbed Samples). 4.Determination of Permeability using ICW Lab Permeameter Undisturbed Samples(17 samples) 5.Determination of soil moisture retention characteristics by disturbed soil samples (45 Disturbed Samples).
3.	Ganges Aquifer Management in the Context of Mansoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Forty Eight (48)	1.Determination of soil moisture retention characteristics by disturbed soil samples using Pressure Plate Apparatus.
4.	Pey Jal Suraksha-RBF Patna(Sample by RC Patna)	Thirty Six(36)	1.Determination of soil texture using sieve shaker and laser based particle size analyzer.
5.	Development of Comprehensive plan for conservation and sustainable management of Bhimtal & Naukuchiyatal Lake ,Uttrakhand	FortySix(46)	Determination of soil texture using sieve shaker and laser based particle size analyzer.
6.	Investigation of water stress using hydro meteorological and remote sensing data	Fifteen (15)	1.Determination of Bulk Density,Dry Density. 2.Determination of soil moisture 3.Determination of Permeability using ICW Lab Permeameter Undisturbed Samples.
7.	Enhancing Food & Water Security in arid region through improved understanding of Quantity,Quality and management of Blue ,Green and Gray Water	Two (02)+Five(05)	1.Determination of soil texture using sieve shaker and laser based particle size analyzer. 2.Determination of Bulk Density,Dry Density(05 Undisturbed Samples). 3.Determination of soil moisture(05 Undisturbed Samples). 4.Determination of Permeability using ICW Lab Permeameter Undisturbed Samples(05 Undisturbed Samples).

8.	Integrated Water Resources Management (IWRM) of Pond Area,(MOWR- RD&GR Sponsored Project)	Twenty	1.Determination of soil texture using sieve shaker and laser based particle size analyzer.
9.	Glacial and Glacial Lake out Brust Flood in western Himalaya(NMSHE Project)	Five (05)	1.Determination of soil texture using sieve shaker and laser based particle size analyzer.
10.	Hydro-Geological Study of Govindwal Sahib, Punjab	Ten(10)	1.Determination of soil texture using sieve shaker and laser based particle size analyzer. 2.Determination of Bulk Density,Dry Density Samples).
11.	Integrated Assessment of the Impact of climate Changeon hydrology of Narmada Basin through hydrological modeling approach	Fifty Two (52)	1.Determination of soil texture using sieve shaker and laser based particle size analyzer.

APPENDIX 74.5.1

MINUTES OF THE 50th MEETING OF THE WORKING GROUP OF NIH

APPROVED MINUTES OF THE
50TH MEETING OF WORKING GROUP OF NIH
HELD AT NIH, ROORKEE, DURING 20-21 AUGUST2020

The meeting was held in VC 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. 50.1: OPENING REMARKS BY THE CHAIRMAN

The Chairman, WG, welcomed the WG members and the Scientists of NIH. 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. Vijay Kumar	▪ Suggested use of newly developed software to verify results of studies earlier conducted by NIH
2.	Dr. S P Aggarwal	▪ Provide a link for data availability
3.	Sh. Man Singh	▪ NIH scientists should think beyond RCPs
4.	Dr. Bhishm Kumar	▪ For Henval experimental station, suggested extensive characterization using hydromet, chemical and isotopic studies
5.	Prof. A P Dimri	▪ NIH should take up urban flooding studies ▪ NIH scientists should think beyond RCPs ▪ Create databank at NIH

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

ITEM No. 50.2: CONFIRMATION OF MINUTES OF 49th MEETING OF WORKING GROUP

The 49th meeting of the Working group was held during 2-3 May, 2019. The minutes of the meeting were circulated to all the members and invitees vide letter No. **RMOD/WG/NIH-10 dated 3 Dec., 2019**. The members confirmed the minutes of the 49thWorking Group meeting.

ITEM No. 50.3: 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 49th working group meeting.

ITEM Nos. 50.4& 50.5: PRESENTATION AND DISCUSSION ON THE STATUS AND PROGRESS OF THE WORK PROGRAMME FOR YEAR 2019-20 AND FINALIZATION OF THE WORK PROGRAMME FOR YEAR 2020-21

The Member-Secretary requested the respective Divisional Heads to present the progress of studies carried out during 2019-20 and also to present the proposed studies for F.Y. 2020-21. Accordingly, the progress of various studies and sponsored projects, and proposal for new studies and projects during 2020-21, 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, and technology transfer activities. Subsequently, the scientists of the Division were invited to present the completed studies, progress of ongoing internal studies and proposed new studies. The Comments/suggestions of Working Group members are summarized below.

Progress of Work Program for 2019-20 and Work Program for 2020-21

S. No.	Study	Recommendations/Comments
	Internal Studies	
1.	**Title:** Development of Habitat Suitability Curves for the Aquatic Species of Western Himalayan Streams and Assessment of Environmental Flows **Study Group:** Pradeep Kumar (PI), C. K. Jain Duration: 3 Years (04/16-05/19) Status: Completed	Dr. Pradeep Kumar presented the study which is completed and the report has been submitted.
2.	**Title:** Water quality assessment for Haridwar District **Study Group:** R.K. Nema (PI), Rajesh Singh, J. V. Tyagi & Pradeep Kumar **Duration:**1.5 years (05/19-12/20) **Status:** Ongoing	Dr. Rajesh Singh presented the progress of the study.The members appreciated and expressed that this type of studies are very useful and should be carried out sincerely. Dr. Bhism Kumar (Ex. Scientist, NIH & IAEA) indicated that the study is very important and the results would be useful for drinking water supply & water quality management in the district. He suggested that the time duration of the study should not be reduced. Dr. Pawan Labhasetwar (Scientist, NEERI) suggested to carry out the sanitary surveillance.
3.	**Title:** Simulation of Non-Point Source Pollution Processes in Song River **Study Group:** Pradeep Kumar (PI), J. V. Tyagi, M. K. Sharma & Rajesh Singh **Duration:**4 years (11/19-10/23) **Status:** Ongoing	The members were informed about the progress of the study and the ongoing activities.
	Internal Studies (New Study)	
4.	**Title:** Identification of Causes for deterioration of River Hindon and suggestive rejuvenation plan **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. **Duration:**3 years (07/20 to 06/23)	Dr. M. K. Sharma presented the proposal. Dr. Man Singh suggested to fill the gaps in the studies conducted so far on river Hindon and to bring a holistic prespective for rejuvenating the river. Dr. Arun Kumar Saraf suggested that we should focus on small rivers for rejuvenation or Hindon section wise. Dr. Pawan Labhasetwar suggested that a thorough water quality investigation for pre-

		and post-monsoon duration should be carried out. An inventory of all the drains need to be prepared. Dr. Varun Joshi recommended to go through Ph.D. thesis of his students.
5.	**Title:** Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar **Study Team:** Rajesh Singh (PI), J. V. Tyagi, R. P. Pandey, R. K. Nema, Pradeep Kumar, M. K. Sharma **Duration:** 2 Years (06/20 – 05/22)	Dr. Rajesh Singh presented the proposal. Dr. Pawan Labhasetwar (Scientist, NEERI) suggested analysis of river water quality in the breaded segment. Dr. Deshpande suggested modification in third objective i.e. Statistical Analysis as it is the part of methodology and cannot be a standalone object.

Training Programmes organized during 2019-20

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

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2020-21

SN	Study	Study Team	Duration/Status
Sponsored Projects (Ongoing)			
1.	Environmental Assessment of Aquatic Ecosystem of Upper Ganga Basin	M. K. Sharma(PI) Manohar Arora Pradeep Kumar Rajesh Singh D. S. Malik (GKU)	5 Years (04/16-03/21) **Sponsored by**: DST (NMSHE) **Project Cost**: Rs. 2.25 Crore **Status:** In-progress
2.	Ground Water Quality Assessment with Special Reference to Sulphate Contamination in Bemetara District of Chhattisgarh State and Ameliorative Measures	M. K. Sharma (PI) Surjeet Singh Pradeep Kumar **Partner:** WRD, Raipur, CGWB, Raipur	3 Years (09/17-08/20) **Sponsored by**: NHP-PDS **Project Cost**: Rs. 25.4 Lakh **Status:** In-progress *Request Extension upto 03/21*
3.	Water Quality Assessment of Southwest Punjab Emphasizing Carcinogenic Contaminants and their Possible Remedial Measures	Rajesh Singh (PI) Pradeep Kumar M. K. Sharma Sumant Kumar **Partner:** Irrigation Department, Punjab	3 Years (09/17-08/20) **Sponsored by**: NHP-PDS **Project Cost**: Rs. 65.6 Lakh **Status:** In-progress *Request Extension upto 03/21*

4.	Leachate Transport Modeling for Gazipur landfill site for suggesting ameliorative measures	Anjali (PI) Sudhir Kumar, J. V. Tyagi, M. K. Sharma, Nitesh Patidar **Partner:** CGWB (Delhi unit)	3 Years (11/19 – 10/22) **Project cost:** Rs. 76.10 Lakh **Sponsored by**: NHP-PDS **Status:** In-progress
Internal Study (Ongoing)			
5.	Water quality assessment of Haridwar District	R.K. Nema (PI) Rajesh Singh J. V. Tyagi Pradeep Kumar	3 years (05/19-12/20) **Project cost:** 17.10 lakh **Status:** In-progress
6.	Simulation of Non-Point Source Pollution Processes in Song River	Pradeep Kumar (PI) J. V. Tyagi M. K. Sharma Rajesh Singh R. K. Nema	4 years (11/19-10/23) **Project cost:**43.02 lakh **Status:** In-progress
Internal Study (New)			
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 Nitesh Patidar Surjeet Singh Rajesh Singh	3 Years (07/20-06/23) **Project cost:** Rs. 20.24 Lakh **Sponsored by**: Internal **Status:** New Project
8.	Influence of Anthropogenic Factors on River Ganga in the stretch from Rishikesh to Haridwar	Rajesh Singh (PI) J. V. Tyagi R.K. Nema Pradeep Kumar M. K. Sharma	2 Years (06/20-05/22) **Project cost:** Rs. 23.71 Lakh **Sponsored by**: Internal **Status:** New Project
Consultancy Projects (New Project)			
9.	Estimation of Economic Losses in Real Terms per Hectare Basis due to Forest Fire in Uttarakhand and Madhya Pradesh	J. V. Tyagi (PI) Pradeep Kumar (Co-PI) T. Thomas (Co-PI) L. N. Thakural, P. K. Singh, M. K. Sharma, Rajesh Singh, R. K. Nema	2 Years (03/20-02/22) **Sponsored by:** ICFRE **Project Cost**: Rs. 1.1033 Crore **Status:** New Project

Training Programmes

SN	Topic	Duration	Place
1.	Water Quality Management under NHP-PDS (Coordinator: Dr. M. K. Sharma)	5 Days	Roorkee
2.	Water Quality Assessment & Management under NHP-PDS (Coordinator: Dr. Rajesh Singh)	5 Days	Roorkee
3.	Water Quality: Concepts and Analysis under NHP (Coordinator: Dr. Pradeep Kumar)	5 Days	Roorkee
4.	Contaminant Transport Modeling under NHP-PDS	5 Days	Roorkee

	(Coordinator: Ms. Anjali)		

GROUND WATER HYDROLOGY DIVISION

Dr. Anupma Sharma, Scientist 'F' presented a brief overview, status of studies and activities carried out by the division since the 49th Working Group meeting held in November, 2019. She gave an account of scientific personnel available in the division; internal, sponsored and consultancy projects - ongoing and completed; and also future activities planned by the division. Dr. Sharma informed that two in-house R&D studies and twelve sponsored studies were approved for the year 2019-20. In addition to the above studies, scientists of the division have a major role in activities of the National Hydrology Project (NHP), DSS planning and management in selected states, development of groundwater module for "*Integrated Hydrologic Model*" 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. The progress of following studies was presented by respective Principal Investigators:

S. No.	Project	Project Team	Duration & Status	Funding Source
Internal Studies				
1. NIH/GWH/ NIH/19-20	The Regional Hydrological Impact of Farm-Scale Water Saving Measures in the Gangetic Plains	Sumant Kumar (PI), C. P. Kumar, Archana Sarkar, Surjeet Singh, P. K. Mishra	1 year (08/19 – 07/20) *Status: In progress*	Internal Study (in collaboration with CSIRO, Australia)
2. 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	3 months (07/20 – 09/20) *Status: New Study*	Referred by DoWR (MoJS)
3. 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: New Study*	Internal Study
Sponsored Projects				
4. NIH/GWH/ NIH/15-20	Peya Jal Suraksha - Development ofSix Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply	Surjeet Singh (Lead), B. Chakravorty, Y. R. S. Rao, Anupma Sharma, Sumant Kumar, Gopal Krishan, Suman Gurjar, Anju Chaudhary, Sanjay Mittal	4.5 years (11/15–03/20) *Status: Completed*	Sponsored by MoWR, RD & GR under Plan Fund
5. NIH/GWH/ CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Coordinator)	3 years (07/20 – 06/23) *Status: New Study*	Sponsored by Federal Ministry of Education and Research, Germany

The suggestions emerged during the presentation of progress of these studies are given below:

S.No.	Title of Project/ Study, Study Group, Start/ Completion Dates	Status and Recommendations/Suggestions
	Internal Studies	
1	The Regional Hydrological Impact of Farm-Scale Water Saving Measures in the Gangetic Plains (Ongoing) **Study Group:** Sumant Kumar, C. P. Kumar, Archana Sarkar, Surjeet Singh, P. K. Mishra **DOS:** Aug. 2019 **DOC:** Jul. 2020	Dr. Sumant Kumar (PI) presented the objectives, methodology, achievements and expected outcome of the study. The PI requested for the extension of the study for seven months and it was approved by members. PI also informed that a word 'farm-scale' has been replaced with 'agricultural' in the study title and it was approved by the members. Now, the study title shall be "The regional hydrological impact of agricultural water saving measures in the Gangetic plains".
2	Impact on Salinity of River Mahadayi due to Proposed Dams on River Mahadayi (New) **Study Group:** Gopal Krishan, B. Venkatesh, Nitesh Patidar **DOS:** Jul. 2020 **DOC:** Sep. 2020	Dr. Gopal Krishan (PI) presented the background, statement of the problem, objectives, methodology and future plans and also requested for extension of time period by two months, which was agreed during the meeting.
3	Integrated GEE-MODFLOW based Groundwater Recharge Assessment System for Hindon River System (New) **Study Group:** Nitesh Patidar (PI), Gopal Krishan, Suman Gurjar **DOS:** Aug. 2020 **DOC:** Jul. 2022	Dr. Nitesh Patidar (PI) presented about the background, objectives, methodology and future plan of the study. Dr. R.D. Deshpande suggested to measure evapotranspiration in the field, if feasible.
	Sponsored Projects	
4	Peya Jal Suraksha -Development ofSix Pilot Riverbank Filtration Demonstrating Schemes in Different Hydrogeological Settings for Sustainable Drinking Water Supply (Completed) **Study Group:** Surjeet Singh, B. Chakravorty, Y. R. S. Rao, Anupma Sharma, Sumant Kumar, Gopal Krishan, Suman Gurjar, Anju Chaudhary, Sanjay Mittal **DOS:** Nov. 2015 **DOC:** Mar. 2020	Dr. Surjeet Singh (PI) presented the study in detail on the RBF sites developed in various states. He described about the selection of sites, details on drilling of RBF well, construction of pump house, performance on water quality, safety from floods, etc. and future plan. Mr. S. M. Sharma, Working Group member requested to provide the draft final report. Director NIH advised to send the report to Mr. S. M. Sharma for review in addition to the approved list of reviewers.
5	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF (New) **Study Group:** Gopal Krishan **DOS:** Jul. 2020 **DOC:** Jun. 2023	Dr. Gopal Krishan (PI) presented the background, work packages and future plan of the study.

RECOMMENDED WORK PROGRAM FOR THE YEAR 2020-21

S. No.	Project	Project Team	Duration & Status	Funding Source
		Internal Studies		

1. NIH/GWH /NIH/19-21	Application of Satellite Data Products for Water Resources Assessment	Suman Gurjar (PI), Vishal Singh, Surjeet Singh, C. P. Kumar, P. K. Singh	2 years (05/19 - 04/21) *Status: In progress*	Internal Study
2. NIH/GWH /NIH/19-20	The Regional Hydrological Impact of Agricultural Water Saving Measures in the Gangetic Plains	Sumant Kumar (PI), C. P. Kumar, Archana Sarkar, Surjeet Singh, P. K. Mishra	1 year 8 months (08/19 – 03/21) *Status: In progress*	Internal Study (in collaboration with CSIRO, Australia)
3. 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	5 months (07/20 – 11/20) *Status: New Study*	Referred by DoWR (MoJS)
4. 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: New Study*	Internal Study
Sponsored Projects				
5. NIH/GWH /NMSHE/ 16-20	Study of River - Aquifer Interactions and Groundwater Potential at Selected Sites in the Upper Ganga Basin up to Dabrani	Surjeet Singh (PI), C. P. Kumar, R. J. Thayyen, Sudhir Kumar, Manohar Arora, Gopal Krishan, Nitesh Patidar, Anjali	5 years (01/16 - 12/20) *Status: In progress*	Sponsored by DST under NMSHE SP-8
6. NIH/GWH /BGS/17-20	Groundwater Fluctuations and Conductivity Monitoring in Punjab - New Evidence of Groundwater Dynamics in Punjab from High Frequency Groundwater Level and Salinity Measurements	Gopal Krishan (PI), Surjeet Singh, C. P. Kumar, M. S. Rao *From: BGS, UK* Dr. Dan Lapworth (PI) Prof. Alan MacDonald	3.5 years (12/17-06/21) *Status: In progress*	Sponsored byBGS, UK
7. NIH/GW H/PDS/1 7-20	Hydro-geochemical Evolution and Arsenic Occurrence in Aquifer of Central Ganges Basin	Sumant Kumar (PI), Sudhir Kumar, Rajesh Singh, Gopal Krishan, Anju Chaudhary *Partner Organization:* MWRD, Bihar *Collaborator:* Brijesh Yadav, IIT Roorkee and N.S Maurya, NIT Patna	3.5 years (12/17-06/21) *Status: In progress*	Sponsored by NHP under PDS
8. NIH/GW H/PDS/1 7-21	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	4 years (12/17-11/21) *Status: In progress*	Sponsored by NHP under PDS
9. NIH/GW H/PDS/1 7-21	Ganges Aquifer Management in the Context of Monsoon Runoff Conservation for Sustainable River Ecosystem Services - A Pilot Study	Surjeet Singh (PI), C. P. Kumar, Sudhir Kumar, Suman Gurjar, Gopal Krishan	4 years (12/17-11/21) *Status: In progress*	Sponsored by NHP under PDS

10. NIH/GWH/DST/18-20	Future Secular Changes and Remediation of Groundwater Arsenic in the Ganga River Basin - FAR GANGA	B. Chakravorty (India Lead), Surjeet Singh (Dy. Lead), Sumant Kumar, Gopal Krishan, Suman Gurjar *Other India Partners:* IITR, IITKg, MCS, Patna *UK Partners:* Univ. of Manchester, BGS, Salford University, Univ. of Birmingham	3 years (01/18 - 12/20) *Status: In progress*	DST-Newton Bhabha-NERC- India-UK Water Quality Research Programme
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 (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)	3 years (01/18 - 12/20) *Status: In progress*	DST-Newton Bhabha-NERC- India-UK Water Quality Research Programme
12. 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	4 years (04/18-03/22) *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 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)	5 years (03/19 - 02/24) *Status: In progress*	Sponsored by DST
14. NIH/GWH/CCRBF/20-23	Expansion of the Indo-German Competence Centre for Riverbank Filtration – CCRBF	Gopal Krishan (PI & Coordinator)	3 years (07/20 – 06/23) *Status: New Study*	Sponsored by Federal Ministry of Education and Research, Germany
Consultancy Projects				

1.	Assessment of Saline and Freshwater Zone in Faridkot, Fazilka and Muktsar Districts of Malwa Region of Punjab	Gopal Krishan (PI)	1.5 year (03/19-09/20) Cost: 17.70 lakh *Status: In progress*	Punjab Government
2.	Expansion of Salinization in Aquifers in Punjab	Gopal Krishan (PI)	1.5 year (03/19-09/20) Cost: 1.18 crore *Status: In progress*	Punjab Government
3.	Water Availability Study based on Hydrological Investigations and Rainfall-Runoff Modeling of Upper Hindon Basin	Anupma Sharma (PI)	1.5 year (04/19-09/20) Cost: 11.80 lakh *Status: In progress*	Irrigation Deptt., Saharanpur

HYDROLOGICAL INVESTIGATIONS DIVISION

Dr Sudhir Kumar, Scientist-G and Head of the H. I. Division presented the activities of the Division including the scientific staff strength and infrastructure. He briefly introduced about the scientific work of the Division and the various studies being carried by the Division including the new proposals, along with details about the publications by the Division and analytical work carried out at the Nuclear Hydrology Laboratory. He also informed about the technology transfer activities organized/proposed by the Division during November 2019 to August 2020.

Table 1: Status of studies carried out by HI Division during Nov'19 to Aug'20

Type of study/Project	Approved Studies	Completed Studies	New studies	Total
Internal Studies	2	1*	-	1
Sponsored Projects	9	2	-	7
Consultancy Projects	5	1	5	9
Total	16	4	5	17

*Dropped

Table 2: Details of training Courses/Workshops organised by HI Division during Nov'19 to Aug'20

SN	Title of Training Course/Workshop	Duration	Venue	Co-ordinator
1.	Tools and techniques of hydrological investigations	04 - 08 Nov 2019	NIH, Roorkee	S. M. Pingale

Table 3: Details of samples analysed by HI Division Labs during Apr'19 to Mar'20

SN	Parameter analysed	No. of samples
1	δ^2H on DI-IRMS	6,707
2	δ^{18}O on DI-IRMS & CF-IRMS	6,693
3	Tritium enrichment / measurements	378
4.	WQ samples on IC	1,075

Table 4: Details of Research Publications by HI Division during Nov'19 to Aug'20

	Published	Accepted	Communicated
Books/Book Chapter	-	-	-
International Journals	2	-	6
National Journals	1	-	-
International Conferences	5	3	-
National Conferences	2	-	-

The progress for ongoing studies and proposals for new studies for the year 2020-21 was presented by the respective P.I. of the study. The comments/actions suggested by the working group for various studies are as follows:

INTERNAL STUDIES:

SN	Project	Study Team	Duration	Status	Comments/ Action(s) Suggested
1.	Hydrological investigations of selected springs in Tehri Garhwal District , Uttarakhand **Earlier title:** Integrated hydrological investigations of natural water springs in lesser Himalaya, Uttarakhand	S M Pingale (PI), Sudhir Kumar Suhas Khobragade S. S. Rawat Rajeev Gupta	3 years (04/19 to 03/22)	Continuing Study	i) Dr. Bhishm Kumar suggested (i) only important springs, i.e., which are being used by local public should be studied, (ii) tritium dating of the spring water should be carried out to understand the recharge zones. ii) Dr. RD Deshpande suggested to reformulate the first three objectives of the study. iii) Dr. Sudhindra Mohan Sharma suggested (i) to also develop the correlation of spring characteristics with geomorphology, and (ii) to suggest the guidelines for spring studies.
2.	Isotope fingerprinting of precipitation over Indian Region	Nidhi Kalyani (PI), Sudhir Kumar MS Rao Scientists from RC's	3 years (04/19 to 03/22)	Continuing Study	To be dropped as no progress is made. May be considered in future.
3.	Groundwater recharge estimation in a part of Sabarmati basin	M. Someshwar Rao (PI) Sudhir Kumar Vipin Aggarwal	2 years (09/20 to 08/22)	New Study	Dr. Bhishm Kumar suggested that (i) tritium tagging technique may be used with high precaution, and (ii) stable isotopes should be used for determination of recharge.
4.	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 (7/20-6/23)	New study	Could not be presented due to shortage of time

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2020-2021

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)	Continuing Study
2	Groundwater Recharge estimation in a part of Sabarmati basin	**M. Someshwar Rao**(PI) Sudhir Kumar Vipin Aggarwal	2 years (9/20 – 8/22)	***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.	3 years (9/20-8/23)	***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 (04/16-03/21)	Continuing Study under NMSHE Project
2.	Dating very old ground waters of deeper aquifers in Ganga Plains, India	**M. Someshwar Rao** (PI) Sudhir Kumar	3 Years (06/16 -05/19) **Ext. upto 03/21**	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 (1/18 – 6/21)	Continuing Study PDS under NHP
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 (1/18 – 6/21)	Continuing Study PDS under NHP
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)	Continuing Study PDS under NHP
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	1 year (04/19 – 03/20) Extended till 03/21	Continuing Study under NCESS, MoES
7.	Groundwater Rejuvenation As Climate changeE Resilience for marginalized and gender sensitive GangeS (GRACERS)	**Sudhir Kumar (PI)** M. Someshwar Rao SM Pingale	2 years (06/19 – 5/21)	IIT Bombay, Mumbai

Table 2: Training Courses/Workshops proposed by HI Division for the year 2020-2021

S. N.	Title of Training Course/Workshop	Duration	Venue	Co-ordinator

1.	Advanced tools and techniques for hydrological investigations	November 2020	NIH, Roorkee	S. M. Pingale
2.	Conservation and management of lakes, wetlands and springs	December 2020	NIH, Roorkee	S. D. Khobragade

SURFACE WATER HYDROLOGY DIVISION

Dr. Rakesh Kumar, Sc G & Head, Surface Water Hydrology Division presented the various activities of the division. The concerned PI of the study presented the progress of his study during the working group meeting. The record of discussions for the respective study is given below:

S.N.	Title of Project/ Study, Study Group, Start/ Completion Dates	Status and Recommendations/Suggestions
SPONSORED STUDIES		
1.	Hydrological modeling 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	VIC and WinSRM models have been setup for the study basin. Further, calibration of both VIC and WINSRM models with the available data has been carried out. The study also extended upto entire upper Ganga basin catchment up to Rishikesh and both the above mentioned models were calibrated and validated. Further climate change scenario have been downloaded and applied to generated future runoff series using the selected models. The study will be completed by December 2020.
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, WRD Rajasthan, Sanjay Agarwal, Shailendra Kumar **DOS:** Oct. 2019; **DOC:** Dec. 2020	Rainfall-runoff models e.g. SWAT and VIC have been setup for the study catchments. Request were made to WRD, Rajasthan for the G&D data for the selected basins. It was informed by the WRD, Rajasthan that the G&D data for the study are not available. Further, G&D data for the other sites available with CWC were provided by WRD, Rajasthan in the month of July 2020. Now with these data the hydrological models are being calibrated for the gauged sites. Further, using the calibrated parameters of the hydrological models runoff time series will be generated for the study basins. The progress of the study was presented in the R&D session of PDS held in Jan 2020 at New Delhi.
INTERNAL STUDIES		
3.	Development of regional methods for design flood estimation in Uttarakhand **Study Group**: J.P. Patra Rakesh Kumar, Pankaj Mani, Sanjay Kumar **DOS:** April 2017; **DOC:** March 2020	Mr. Jagadish Prasad Patra, presented the objectives, need for such study with brief methodology of the completed internal study entitled "Development of regional methods for design flood estimation in Uttarakhand". The various objectives of study and work carried out were presented. The results of rainfall and flood frequency analysis using L-moments approach are presented with detail explanation. The relationships developed to estimate design flood for various return periods with catchment area are also presented. The Nonstationary Extreme Value Analysis considering the aspect of non-stationary in data series is presented in detail for annual maximum peak flood series and 1day annual maximum rainfall series. It is presented that an unjustified assumption of stationarity could lead to an underestimation of extreme floods. However, it is highlighted that effect on such nonstationary approach may not be always very critical in terms of water level in the river viz. water surface in a bridge, over topping of embankments etc. Further, effect of Tehri dam for moderation of

		flood peaks at Rishikesh is also discussed considering reservoir index as an additional co-variate. However, the results obtained until now are not very conclusive. The experts enquire about any specific recommendation regarding the effect of climate change in flood frequency analysis. It was explained that the considering various uncertainties associated with climate change, is difficult to exactly quantify the increase in design flood value. However, with example it is explained that non-stationary frequency analysis needs to be carried out to check the resilience of various infrastructures with respect to their design life.
4.	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f) **Study Group:** Sanjay Kumar Rakesh Kumar, J.P. Patra, Pankaj Mani **DOS:** April 2017; **DOC:** March 2021	Dr. Sanjay Kumar presented the progress of the study, he mentioned that the study has five objectives and the work has been completed on three objectives. The work on other two objectives is under progress based on secondary data from various reports and manual as short interval recorded rainfall (hourly) data at CWC gauging sites has not been provided. He mentioned that based on the available secondary data and collection of the additional rainfall data of nearby sites from IMD, the study will be completed in time.
5.	Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin **Study Group:** Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu **DOS:** Nov. 2018 **DOC:** March 2021	Dr Archana Sarkar presented the background and objectives of the study. She presented the methodology adopted and detailed results of the downscaled and bias corrected climate data (precipitation, maximum temperature, minimum temperature, mean temperature) for historic as well as future time period upto 2100 from 16 GCMs under two future emission scenarios (RCP4.5 & RCP8.5). She also presented the data availability for hydrological modeling in the Banas basin upto the Bisalpur reservoir and future plan of work. She informed the house that due to the present pandemic situation, field visits for some more data collection could not be taken up and the study requires one year extension upto October 2021. The Chairman asked the PI to complete the study by March 2021. Dr Deshpande from SAC, Ahmedabad enquired about the inflow and outflow from the Bisalpur reservoir. Another member from NEERI, Nagpur also enquired about water allocation priorities from the reservoir to which Dr Sarkar presented the Dam operation data given by WRD, Rajasthan. No other specific comments were received from the committee members present.
6.	Study of hydrological changes in selected watersheds in view of climate change in India **Study Group:** L.N. Thakural D.S. Rathore, Surjeet Singh, Sanjay K. Jain Sharad K. Jain **DOS:** April 2015; **DOC:** March 2020	Dr. Laxmi Narayan Thakural presented the objectives, methodology and the status of the above ongoing study. The GIS database created to meet out the objectives of the study using Digital Elevation Model (DEM) and satellite imagery for flow accumulation, stream network, watershed boundary, Land use/Land coverthematic maps in addition to soil map for the four watersheds was presented. Spatio-temporal analysis of hydro-meteorological data using parametric and non-parametric approaches for the Ramganga, Bina, Dhadhar and Chaliyar river basins were also presented in the meeting. The outcomes/results of hydrological models calibrated and validated for the river basins i.e. Ramganga, Bina, Chaliyar and Dhadhar river basins were presented and the future simulations using future rainfall and temperature scenarios for the Dhadhar and Chaliyar basins were also presented. On the request of the PI, the study has been extended up to December 2020 to complete the future simulations under changing climate for the remaining two basins (which is under process).

7.	Evaluation of seasonal extreme rain events across river basins of India in 3D global temperature change scenario. **Study Group:** Ashwini Ranade Archana Sarkar **DOS:**April 2018; **DOC:** March 2021	Dr. Ashwini Ranade, PI of the project presented the objectives, work plan and current status of the project. She has presented important results from global temperature trend analysis (1979-2018). Committee members well appreciated the work on the changes in 3-D global atmospheric thermal structure in recent years and its association with monthly rainfall of seven homogeneous zones of the country.
8.	Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent. **Study Group:** Sunil Gurrapu Ashwini Ranade J.P. Patra **DOS:** Nov 2018; **DOC:** October 2021	PI of the study presented the objectives and the status of the study,with preliminary results of correlations analysis between low-frequency ocean-atmosphere oscillations and the streamflow at the selected gauging sites. Based on the suggestions from previous working group, an additional objective was added to the study objectives and the study will now be concentrated on 2 watersheds,Godavari and Narmada River Basins. No comments were made by the committee members. Dr. J V Tyagi, Director, NIH inquired if the study is going as per the schedule and suggested that the project be completed as scheduled, i.e. by the end of October 2021.
9.	Evaluation of water quality of Government schools in Roorkee block, District Haridwar **Study Group:** N.K. Bhatnagar M.K. Sharma, L.N. Thakural, Reena Rathore **DOS:** Oct. 2018; **DOC:** Sept. 2020	Head SWHD briefed the progress of the study on Evaluation of water quality of Government schools in Roorkee block, District Haridwar. Pre monsoon and post monsoon water sampling has been done and testing of water quality has been completed. Testing of metal ions for pre monsoon in water samples has been completed, post monsoon is under process. All GIS Maps has been completed. Report writing is under progress.The Chairman desired that the study should be completed and its report may be submitted by October,2020.
10.	Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Lower Narmada & Tapi subzone-3b, (2) Lower Godavari subzone-3f **Study Group:** S.K. Singh **DOS:** April 2020; **DOC:** March 2021	It was informed by Head SWHD that in this study the methodology developed by the PI will be applied for carrying out flood frequency analysis generalized UEV (unified extreme-value) distribution for Lower Narmada & Tapi subzone-3b; and Lower Godavari subzone-3f. The efficacy of the developed methodology will be demonstrated for flood frequency estimation.
11.	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:** July 2020; **DOC:** August 2022	Mr. Jagadish Prasad Patra, presented the current practice of dam break studies for preparation of EAP and the need for moving towards a Probabilistic dam break studies and importance of Exceedance Probability Inundation (EPI) Maps in future. The various objectives along with brief methodology was presented for the proposed study "Probabilistic dam break flood wave simulation and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan". It was explained that considering reduction in duration of the study, a truncated model approach will be used for modelling the breach outflow hydrograph rather than cloud computing or parallel processing approach. There was no specific comments on the study.

RECOMMENDED WORK PROGRAM FOR THE YEAR 2020-21

ONGOING STUDIES (SPONSORED)

S. No. & Ref. Code	Title	Study Team	Duration
1.NIH/SWHD /16-21	Hydrological modeling in Alaknanda basin and assessment of climate change impact (NMSHE)	A.K.Lohani Sanjay K. Jain Archana Sarkar V.S. Jeyakanthan L.N. Thakural	5 years (April 2016 to March 2021)
2.NIH/SWHD /19-20	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	15 months (Oct. 2019 to Dec. 2020)

ONGOING STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
4.NIH/SWHD/ 17-21	Development of regional relationships for water availability analysis and flood estimation for lower Godavari basin (3f)	Sanjay Kumar Rakesh Kumar J.P. Patra Pankaj Mani	4 years (April 2017 to March 2021)
5.NIH/SWHD/1 8-20	Assessment of Climate Change Impact on Water Availability and Agriculture in part of Banas basin	Archana Sarkar Surjeet Singh Suman Gurjar Sunil Gurrapu	2 years (Nov. 2018 to October 2020) Extended up to March 31, 2021)
6.NIH/SWHD/ 15-19	Study of Hydrological Changes in selected Watersheds in view of Climate Change in India	L.N. Thakural D.S. Rathore Surjeet Singh Sanjay K. Jain Sharad K. Jain	4 years (April 2015 to March 2019) Extended up to Dec., 2020
7.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)
8.NIH/SWHD/ 18-21	Evaluation of the influence of low-frequency atmosphere-ocean oscillations on annual floods in the watersheds of the Indian subcontinent	Sunil Gurrapu Ashwini Ranade J.P. Patra	3 years (Nov 2018 to October 2021)
9.NIH/SWHD/ 18-20	Evaluation of water quality of Government schools in Roorkee block, District Haridwar	N.K. Bhatnagar M.K. Sharma L.N. thakural Reena Rathore	2 years (Oct 2018 to sept. 2020)

NEW STUDIES (INTERNAL)			
S. No. & Ref. Code	**Title**	**Study Team**	**Duration**
10.NIH/SWH D/20-21	Application of unified-extreme-value (UEV) distribution for flood frequency: (1) Lower Narmada & Tapi subzone-3b, (2) Lower Godavari subzone-3f	S.K. Singh	One year (April 2020 to March 2021)
11.NIH/SWH	Probabilistic dam break flood wave simulation	J.P. Patra	2 years

D/20-22	and flood risk assessment for preparation of EAP for Mahi Bajaj Sagar dam in Rajasthan.	Rakesh Kumar Pankaj Mani Sunil Gurrapu	(Aug 2020 to Jul 2022

WATER RESOURCES SYSTEMS DIVISION

During the working group meeting, internal completed/ ongoing studies and proposed new studies were presented. None of the sponsored studies were presented during the WG. Accordingly, two completed studies, three ongoing studies and four new studies were presented by the respective PIs. Dr. Sanjay K Jain, Sc. G and Head, presented an overview of the division – scientific strength, the ongoing studies, sponsored & consultancy studies, technical publications and training courses organized. Thereafter, PIs of the studies as discussed above presented their studies. Following are the comments/suggestions received from working group on the presentations of the various studies.

PI: Dr. M. K. Nema (MKN), Scientist "D"

MKN presented one completed and one proposed study.

1. Hydrological Processes and Characterization of Lesser Himalayan Catchments (Completed)
MKN presented the completed study covering the study background, objective, methodology, instrumentation set up and various results. He informed that all the objectives had been accomplished. It has been explained that the first phase of the Henval study mainly dealt with the establishment of field observatory in the catchment and also time-series analysis of various meteorological, hydrological and lithological variable. The results of the evapotranspiration (ET) estimated by the various methods and their inter-comparison were presented. It was also informed that a detailed project report has been prepared and sent for technical review to external and internal experts. The WG members made no significant comments during the presentation.

2. Monitoring and hydrological modeling of Henval watershed in Lesser Himalaya (Project Henval Phase-II) (New Study)
MKN proposed a new internal research study on the Henval experimental watershed. He expressed that considerable instrumentation has been done in the Henval catchment and in continuation Henval Phase-II is being proposed. He briefed about the study objectives, methodology, budget, and project timeline to the working group members. The working group members appreciated the initiatives and made no specific suggestions or comments about the new proposed study.

PI: Deepa Chalisgaonkar, Scientist "G"

DC presented one completed study and one proposed study.

1. Development of window based software for Flood Estimation (Completed)
Mrs. Deepa presented the study. She informed WINDOWS based software named "NIH_FLWin: A Windows based Software for Flood Estimation" has been developed. The modules in the software are classified in nine different categories dealing with different aspects such as Processing and Analysis of Precipitation Data, Computation of Discharge and Rating Curve Analysis, Computation of Excess Rainfall and Direct Surface Runoff, Unit Hydrograph Derivation, Reproduction of Direct Surface Runoff and Estimation of Flood, Design Flood, Channel Routing, Reservoir Routing Using Modified Pul's Method and Flood Estimation for Large Catchments. These modules have been further sub-divided into various sub modules.
She further added that the software provides a user-friendly environment. It also includes on-line help to guide the user for each module. Sample data has been included in the package for easy preparation of input files. The results are in the form of tabular and graphical options facilitating efficient analysis and reporting and are subjected to the assumptions and limitations of the respective techniques on which the programmes are based. The package provides useful information regarding the flood estimation which is very much useful to the field engineers.

Dr S P Agrawal enquired about the validation of the software. Dr A K Lohani informed that the software has been tested with sample data and it is working fine.

2. Upgradation of NIH_ReSyP – A Reservoir Systems Package (New Study)

Mrs. Deepa presented the study. She informed that there are two objectives. (i) Upgradation of NIH_ReSyP to VB.Net Platform and (ii) To carry out a number of modifications in various modules of NIH_ReSyP software developed in the institute about a decade back. The modules of NIH_ReSyP software 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 will be upgraded from VB6 to VB.NET. It was suggested by Dr. Vijay Kumar, MoES that a number of reservoir system studies have been carried out at NIH. It would be worthwhile to demonstrate the applications of NIH_ReSyP software modules with such data. It was clarified that in the previous version of the software, sample input - out files for each module were provided with the software and the same will be provided in this version also. Dr M K Goel added that the development of a user-friendly software for integrated operation of reservoir systems in accordance with the Indian practices.

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

PKS presented one ongoing study and one proposed study.

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

PKS presented the work on the ongoing study "Developments of Water Accounts for Subarnarekha Basin Using Water Accounting Plus (WA+) Framework". During presentation, one of the experts asked whether the deep aquifers are considered in this framework. PKS informed that WA+ framework does not consider deep aquifer mechanism in developing water accounts. By the end of December, 2020, the remaining work on overall aspects of water resources availability (Sheet 5 and Sheet 1) will be completed and the final report of this project will be submitted. PKS further informed that the work has been also presented in IGWC-2019 and one research paper is ready for submission to the Current Science Journal. The presentation was appreciated by the experts.

2. Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework. (New Study)

PKS also presented a new NHP sponsored study on "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". This study was specifically requested by the implementing agency (IA) of National Hydrology Project (NHP), i.e., Water Resources Department (WRD) Meghalaya to NIH Roorkee.

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

MA presented one ongoing study.

1. Monitoring and Modeling of Gangotri Glacier melt runoff and simulation of stream flow under different climate scenarios (Ongoing study)

MA presented the progress of the study. He informed that the data could not be collected for the ablation period of 2020 because of Covid 19 outbreak. The analysis of meteorological parameters was presented. The capabilities of HBV light model were demonstrated with the help of one case study for a Himalayan catchment the difference between SNOWMOD and HBV was explained. The CORDEX outputs will be used for studying the climate response. Dr Bhishm Kumar asked about the isotope analysis in the study. It was informed that samples are collected for isotope analysis in another NMSHE study. Dr Man Singh wanted to know how the individual components of streamflow are characterized. MA explained how snowmelt and ice melt can be separated. Director, NIH was interested in knowing the beneficiaries of this study. MA informed that studies carried out were presented in PAMC of DST and project report was submitted to DST. The results of the study were also used for reply of parliament queries. Also the results are communicated to the hydropower companies, State climate departments and GSI etc.

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

VS presented one ongoing study and one proposed study.

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

VS presented study on Real time flood modelling using HEC-RTS framework in Periyar river basin. He briefly presented the different components under HEC-RTS. Dr. Dimri suggested a similar new study on urban flood modeling. Dr. Sanjay Jain informed that the study is different than urban flooding study and some studies have been carried out in the Institute on urban flooding also.
No specific comments were received from the members.

2. Impacts of glacier and climate change on runoff for selected basins of Himalayan region (New)

VS presented the proposed new study on 'Impacts of glacier and climate change on runoff for selected basins of Himalayan region'. He explained that the main purpose of the study is to know the impact of glacier change on runoff and also to see the impact of climate change on runoff. No specific comments were received from the members.

The work program of the division for the year 2020-21 is given below.

RECOMMENDED WORK PROGRAMME FOR THE YEAR 2020-2021

SN	Title	Study Team	Duration	Funding (Rs. Lakh)
Ongoing 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)	
2.	Real time flood modelling using HEC-RTS modelling framework	Vishal Singh A. K. Lohani	2 years (12/18-12/20)	
3.	Seasonal Characterization of Gangotri Glacier melt runoff and simulation of streamflow variation under different climate scenarios	M. Arora Sanjay K. Jain	3 years (04/18-03/21)	
Ongoing Sponsored Studies				
1.	Development of a project website and hydrological database in Upper Ganga Basin **(Sub-project – 1)**	M. K. Goel; M. Arora; A. K. Lohani; D. S. Rathore; D. Chalisgaonkar; A. R. S. Kumar; S. Singh; P. Mani; A. Sarkar; M. K. Nema; P. K. Mishra	5 years (01/16-12/20)	DST (52.15)
2.	Real-time snow cover information system for Upper Ganga basin **(Sub-project – 2)**	D. S. Rathore D. Chalisgaonkar, V. S. Jeyakanthan L. N. Thakural	5 years (01/16-12/20)	DST (48.83)
3.	Glacial Lakes & Glacial Lake Outburst Flood	Sanjay K. Jain	5 years	DST

	(GLOF) in Western Himalayan Region **(Sub-project – 3)**	A. K. Lohani Sudhir Kumar Praveen Thakur (IIRS)	(01/16-12/20)	(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 (01/16-12/20)	DST 86.1 (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 (01/16-12/20)	DST (54.07)
6.	Water Census and Hotspot analysis in selected villages in Upper Ganga basin **(Sub-project – 11)**	P. K. Mishra; M. K. Nema; Renoj J. Thayyen; Pradeep Kumar	5 years (01/16-12/20)	DST (90.99)
7.	Measurements and Modeling of Evapotranspiration and other Hydrological Processes in Lesser Himalayas	M K Nema; Renoj J. Thayyen; Sharad Jain (Retd.); Sanjay Jain; P. K. Mishra; AP Dimri	3 years (2016-19) Extended up to Dec. 2020	MOES (Rs. 98 Lakh)
8.	Investigating Water Stress using Hydro-meteorological and Remote Sensing data	D. S. Rathore; L. N. Thakural; Sanjay Kumar; B. Venkatesh M. K. Jose; T. Chandramohan	3 years 2017-2020	PDS under NHP (50.23 Lakh)
9.	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; Suman Gurjar	3 years (11/19-11/22)	NMHS-MoEF (143 Lakh)
10.	Assessment of seasonal variations in Hydrology and Cryosphere of upper Ganga Basin	Renoj J. Thayyen A. P. Dimri (JNU) Sanjay K. Jain	3 years (06/19-11/22)	NRDMS-DST (23.19 Lakh)
11.	Permafrost mapping and characterisation of Ladakh Region	Renoj J. Thayyen; A. P. Dimri (JNU); G. Jeelani (KU); V. Agnihotri (GBPNI)	3 years (11/19-11/22)	NMHS-MoEF (197.48 Lakh)
New Internal/ Sponsored Studies				
1.	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
2.	Henvel Experimental Watershed: Observations and modelling (Phase II)	M K Nema Renoj J. Thayyen P K Mishra	3 years (08/20-07/23)	NIH
3.	Upgradation of NIH_ReSyP to .NET Platform–	D. Chalisgaonkar	1 year	NIH

	a Reservoir Operation Package	M. K. Goel	(08/20-07/21)	
4.	Development of Water Accounts for the different sub-basins of Brahmaputra and Barak River Basins in the state of Meghalaya Using Water Accounting Plus (WA+) Framework.	P K Singh P K Mishra	2 years (08/20-07/22)	NHP (14.50 Lakh)
5.	Preparation of Guidelines for the "Management of Glacial Hazards and Risks especially GLOFs & LLOFs"	Sanjay K. Jain A K Lohani	1 year (12/19-12/20)	NDMA (14.36 Lakh)

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 2019-20. He also presented tables showing the studies and activities proposed for the F.Y. 2020-21. Next, he invited Dr Jyoti Patil, Er Rohit Sambare and Dr Senthil Kumar to present the newly proposed studies.

RECOMMENDED WORK PROGRAM FOR THE YEAR 2020-21

SN	Title of Project/Study	Funding	Study Team	Duration	Status
Internal Study					
1	Conservation of ponds in Ibrahimpur- Masahi Village and performance evaluation of natural treatment system	NIH, CEH-UK	NIH: Omkar Singh (PI) V C Goyal, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka; CEH-UK: Prof. Laurence Carvalho & Team	Apr 2018-Mar 2021	On-going
2	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	Jul 2020- Dec 2022	New
3	Establishing hydrologic regime and ecohydrological functions of Jhilmil Jheel wetland (Haridwar District, Uttarakhand)	NIH	Rohit Sambare (PI) V C Goyal (Co-PI), Suhas Khobragade; Gajendra Singh-USAC, Dehradun; WI-SA, New Delhi; HESCO, Dehradun	Jul 2020- Jun 2022	New
4	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.	Jul 2020- Jun 2022	New
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-Mar 2021	On-going
2	Rejuvenation of village ponds in identified villages of Baghpat, Ghaziabad and Meerut districts of Uttar Pradesh	MoJS (through Scheme funds)	Omkar Singh (PI), Rajesh Singh, V C Goyal, Digambar Singh, Subhash Kichlu, Rajesh Agrawal, Rakesh Goel, NR Allaka	Jan. 2018-Dec. 2020	On-going

3	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/Workshops during 2020-21

S.N.	Outreach Activity	Tentative Date & Month	Place	Target Participants	Team
1	Training on 'Water security for resilience to deal with disasters and outbreaks', under aegis of INC-IHP (proposal approved by Director, NIH)	Nov. 2020	Virtual training	Youth and YPs associated with WR Assessment & Management	V C Goyal, Jyoti P Patil, Amrendra Bhushan, Victor Shinde (NIUA)
2	Hands-on training on 'Life Cycle Approach for rejuvenation of ponds and lakes using Nature Based Solutions', to be funded by SERB, DST, GoI (proposal approved by Director, NIH)	Dec. 2020	NIH Roorkee	PG and PhD students of Water resources management/ engineering	Jyoti P Patil, V C Goyal, Omkar Singh, T Thomas, Rajesh Singh, Rohit Sambhare
3	Three-day training program on "Hydrology of water bodies and their development under climatic uncertainty"	Jan 2021	NIH Roorkee	Engineers in Irrigation/PHE/ SWC departments	A. R. Senthil kumar, Santosh M Pingale, Rohit Sambare, N R Alakka
4	Awareness program on Ecohydrology for Wetland Conservation	Feb./ Mar. 2021	NIH Roorkee	Research scholars, and PG students	Rohit Sambare, Suhas Khobragade
5	Awareness Program for School Children	Oct/Nov 2020	5 Schools in Roorkee/ Nearby Roorkee	School Children	Digambar Singh, Omkar Singh, Subhash Kichlu, Rajesh Agarwal, N R Allaka
6	Awareness Programme on "Water quality and water budgeting in 5 sub Villages of Ibrahimpur Masahi", Dist. Haridwar	Feb/Mar, 2021 (5 days)	Vill. Ibrahimpur Masahi,	Progressive Farmers	Omkar Singh, Rajesh Singh, Digambar Singh, Subhash Kichlu, Rajesh Agarwal, NR Allaka

Proposed Outreach Activities during 2020-21

S.N.	Activity
1	Preparation of a guidebook on 'Role of hydrology in district level planning' (V C Goyal, Jyoti Patil)
2	Preparation of Short Videos (5-10 min) on i) CW & FW/Nature Based Solutions/ Pond Rejuvenation ii) Wetland Hydrology iii) Crop diversity, water productivity & farmer's income iv) On studies and projects of NIH Scientists
3	River Walk of Solani River (stretch to be identified)

4	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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ANNEXURE-I

List of Working Group Members who attended the 50th WG meeting

1.	Dr. J V Tyagi, Director, NIH	Chairman
2.	Dr. B P Yadav, IMD, New Delhi	Member
3.	Er. Bhopal Singh, NWDA, New Delhi	Member
4.	Dr. Vijay Kumar, MoES, New Delhi	Member
5.	Dr. P R Ojasvi, ICAR-IISWC, Dehradun	Member
6.	Dr. Sushil Kumar, WIHG, Dehradun	Member
7.	Er. Kireet Kumar, GBPIHE&D, Almora	Member
8.	Dr. R D Deshpande, PRL, Ahmedabad	Member
9.	Dr. R K Goyal, CAZRI, Jodhpur	Member
10.	Dr. Pawan Labhasetwar, NEERI, Nagpur	Member
11.	Dr. S P Aggarwal, IIRS, Dehradun	Member
12.	Dr. Man Singh, WTC, ICAR-IARI, New Delhi	Member
13.	Dr. Varun Joshi, GGSIPU, New Delhi	Member
14.	Prof. K K Singh, Kurukshetra Univ., Kurukshetra	Member
15.	Prof. A K Saraf, IIT Roorkee	Member
16.	Dr. Bhishm Kumar, IAEA (Retd.), Roorkee	Member
17.	Prof. Ramakar Jha, NIT Patna	Member
18.	Prof. A P Dimri, JNU, New Delhi	Member
19.	Dr. Debashish Sen, PSI, Dehradun	Member
20.	Dr. Sadhana Malhotra, Mindspace, Dehradun	Member
21.	Sh. Sudhindra Mohan Sharma, Ex-Nodel Officer, MoDWS, Indore	Member
22.	Dr. Rakesh Kumar, Sc. G & Head SWH Division, NIH	Member
23.	Dr. Sudhir Kumar, Sc. G & Head HI Division, NIH	Member
24.	Dr. Sanjay K. Jain, Sc. G & Head WRS Division, NIH	Member
25.	Dr. R P Pandey, Sc.G & Head EH Division, NIH	Member
26.	Dr. V C Goyal, Sc. G & Head, RMO Division, NIH	Member-Secretary

Scientists from NIH

	EH Division		**SWH Division**
1	Dr. M.K. Sharma, Sc.E	19	Dr. A.K. Lohani, Sc.G
2	Dr. Rajesh Singh, Sc.D	20	Dr. Sanjay Kumar, Sc.E
3	Dr. Pradeep Kumar, Sc.D	21	Dr. Archana Sarkar, Sc.E
4	Sh. Rajesh K. Nema, Sc.B	22	Dr. L.N. Thakural, Sc.D
5	Ms. Anjali, Sc.B	23	Sh. J.P. Patra, Sc.D
	GWH Division	24	Dr. Ashwini A. Ranade, Sc.C
6	Dr. Anupama Sharma, Sc.F	25	Sh. Sunil Gurrapu, Sc.C
7	Dr. Surjeet Singh, Sc.F	26	Sri N K Bhatnagar, Sc.B
8	Er. Sumant Kumar, Sc.D		**WRS Division**
9	Dr. Gopal Krishan, Sc.C	27	Dr. M.K. Goel, Sc.G
10	Sh. Nitesh Patidar, Sc.B	28	Smt. Deepa Chalisgaonkar, Sc. G
	HI Division	29	Er. D.S. Rathore, Sc.F
11	Dr. M.S. Rao, Sc.F	30	Dr. Renoj J. Thayyen, Sc.E

12	Dr. Santosh M Pingale, Sc.C	31	Dr. Manohar Arora, Sc.E
13	Ms. Nidhi Kalyani, Sc.B	32	Dr. P K Singh, Sc.D
	RMO Division	33	Er. Manish Nema, Sc.D
14	Er. Omkar Singh, Sc.F	34	Dr. P K Mishra, Sc.C
15	Dr. A R Senthil Kumar, Sc.F	35	Dr. Vishal Singh, Sc.C
16	Dr. (Mrs.) Jyoti P. Patil, Sc.D	36	Sh. P K Agarwal, Sc.B
17	Sh. Digamber Singh, Sc.C		
18	Sh. Rohit S. Sambare, Sc.B		