Template/Pro forma for Submission

NMHS-Himalayan Institutional Project Grant

NMHS-FINAL TECHNICAL REPORT (FTR)

Demand-Driven Action Research and Demonstrations

NMHS Reference No.:	NMHS-2017-18/MG-02/478

Date of Submission:	3	0	1	1	2	0	2	1
	d	**d**	**m**	**m**	**y**	**y**	**y**	**y**

PROJECT TITLE (IN CAPITAL)

INTEGRATED SYSTEM DYNAMICAL MODEL TO DESIGN AND TESTING ALTERNATIVE INTERVENTION STRATEGIES FOR EFFECTIVE REMEDIATION & SUSTAINABLE WATER MANAGEMENT FOR TWO SELECTED RIVER BASINS OF INDIAN HIMALAYA

Project Duration: *from* (**22.12.2017**) *to* (**30.11.2021**).

***Submitted to*:**
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GENERAL INSTRUCTIONS:

1. The Final Technical Report (FTR) has to commence from the start date of the Project (as mentioned in the Sanction Order issued by NMHS-PMU) till completion of the project duration. Each detail has to comply with the NMHS Sanction Order.
2. The FTR should be neatly typed (in Arial with font size 11 with 1.5 spacing between the lines) with all details as per the enclosed format for direct reproduction by photo-offset printing. Colored Photographs (high resolution photographs), tables and graphs should be accommodated within the report or annexed with captions. Sketches and diagrammatic illustrations may also be given detailing about the step-by-step methodology adopted for technology development/ transfer and/ or dissemination. Any correction or rewriting should be avoided. Please provide all information under each head in serial order.
3. Any supporting materials like Training/ Capacity Building Manuals (with detailed contents about training programme, technical details and techniques involved) or any such display material related to project activities along with slides, charts, photographs should be brought at the venue of the Annual Monitoring & Evaluation (M&E) Workshop and submitted to the NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora 263643, Uttarakhand. In all Knowledge Products, the Grant/ Fund support of the NMHS should be duly acknowledged.
4. The FTR Format is in sync with many other essential requirements and norms desired by the Govt. of India time-to-time, so each section of the NMHS-FTR needs to be duly filled by the proponent and verified by the Head of the Lead Implementing Organization/ Institution/ University.
5. Five (5) hard-bound copies of the Project Final Technical Report (FTR) and a soft copy of the same should be submitted to the **Nodal Officer, NMHS-PMU, GBP NIHE HQs, Kosi-Katarmal, Almora, Uttarakhand**.

The FTR is to be submitted into following two (02) parts:

Part A – Project Summary Report

Part B –Detailed Project Report

In addition, the Financial and other necessary documents/certificates need to be submitted along with the Final Technical Report (FTR) as follows:

Annexure I	**Consolidated and Audited Utilization Certificate (UC) & Statement of Expenditure (SE)**, including the interest earned for the last Fiscal year and the duly filled GFR-19A (with year-wise break-up).
Annexure II	**Consolidated Interest Earned Certificate**
Annexure III	**Consolidated Assets Certificate** showing the cost of the equipment in Foreign/ Indian currency, Date of Purchase, etc. (with break-up as per the NMHS Sanction Order and year wise).
Annexure IV	**List of all the equipment, assets and peripherals** purchased through the NMHS grant with current status of use, including location of deployment.
Annexure V	**Transfer of Equipment** through Letter of Head of Institution/Department confirming the final status of equipment purchased under the Project.
Annexure VI	**Details, Declaration and Refund of any Unspent Balance transferred through Real-Time Gross System (RTGS)/ PFMS in favor of NMHS GIA General**

NMHS-Final Technical Report (FTR) *template*

Demand-Driven Action Research Project

DSL: Date of Sanction Letter

2	2	1	2	**2**	**0**	**1**	**7**
d	d	m	m	y	y	y	y

DPC: Date of Project Completion

3	0	1	1	**2**	**0**	**2**	**1**
d	d	m	m	y	y	y	y

Part A: Project Summary Report

1. Project Description

i.	Project Grant Ref. No.:								
ii.	Project Category:	Small Grant		Medium Grant	✓	Large Grant			
iii.	Project Title:	**Integrated System dynamical model to design and Testing Alternative intervention strategies for Effective Remediation & Sustainable water Management for two selected river basins of Indian Himalaya**							
iv.	Project Sites (IHR States/ UTs covered) *(Location Maps attached):*	**Upper Jhelum watershed (Jammu and Kashmir), Kosi watershed (Kumaun Region, Uttarakhand)**							
v.	Scale of Project Operation:	Local		Regional	✓	Pan-Himalayan			
vi.	Total Budget:	2.47 Cr (2,47,15,680/-)							
vii.	Lead Agency:	Department of Earth Science, University of Kashmir, Srinagar							
	Lead PI/ Proponent:	Prof. Shakil Ahmad Romshoo, Department of Earth Sciences, University of Kashmir, Hazratbal, Srinagar Kashmir, India-190006							
	Co-PI/ Proponent:	Co-PI: Dr. KV Ramesh, Principal scientist, CSIR 4PI, Bangalore Co-PI: Dr. V Rakesh, Senior scientist, CSIR 4PI, Bangalore Co-PI: Dr Sandipan Mukherjee, GBPNIHESD, Almora, Uttrakhand							
viii.	Implementing Partners:	Department of Earth Sciences, Hazratbal, Srinagar, Kashmir Jammu and Kashmir. CSIR-Fourth Paradigm Institute (CSIR 4PI), NAL Belur Campus, Bangalore. G.B. Pant National Institute of Himalayan Environment & Sustainable Development (GBPNIHESD).							

	Key Persons (Contact Details, Ph. No., E-mail):	PI: Prof. Shakil Ahmad Romshoo, University of Kashmir, J&K shakilrom@uok.edu.in Co-PI: Dr. KV Ramesh, Principal scientist, CSIR 4PI, Bangalore ramesh.c4pi@nic.gov.in Co-PI: Dr. Sandipan Mukherjee, Scientist – D, G.B. Pant National Institute of Himalayan Environment. Email: sandipan@gbpihed.nic.in

2. Project Outcomes

2.1. Abstract (not more than 250-300 words) [*it should include background of the study, aim, objectives, methodology, approach, results, conclusion and recommendations*]

The project aimed to develop, test, and validate a System Dynamics Model of the Upper Jhelum and Kosi Basins in the Himalaya, focusing on the water budget, forest and agro-ecosystem under various environmental and socio-economic scenarios. A comprehensive data repository was created encompassing hydrology, meteorology, socio-economics, land use/land cover (LULC), water quality, soil quality, soil texture, present and future climate for both the upper Jhelum and Kosi basins. This data facilitated the analysis of various land surface and atmospheric variables using modeling frameworks. Climate models were used to determine plausible climate change scenarios, while LULC and socio-economics trends were studied and projected to the end of the century alongside with hydrological balance studies to assess streamflow and its components.

Key findings in the UJB reveal a decreasing trend in agriculture, forest, and glacier cover from 1981 to 2019, contrasted by increases in horticulture, built-up areas, and degraded forests. No significant changes were observed in classes, such as exposed rock, snow, scrub and pasture. Moreover, the observed and projected temperature data from the 6 CMIP3 models suggested that the GFDL CM2.1 simulations are more promising. Temperature projections indicated a rise of ~4.0oC to ~7.0oC under the three climate change scenarios by the end of 21st century varies from. The hydrological balance revealed baseflow as the largest contributor (38.39%), followed by snow-melt (31.97%), rainfall (22.79%) and glacier-melt (10.42%). Precipitation projections showed insignificant increase under climate scenarios. The updated Köppen-Geiger climate classification scheme identified 10 main climate zones in the UJB using baseline climate data. Socio-economic data analysis, showed a significant increase in the total population and population density and is projected to increase by significantly by the end of 21st century.

In the Kosi watershed, GBPNIHE focused on changes in winter wet days and forest fragmentation. Sub-watersheds were prioritized using morphometric parameters and machine

learning models were developed to predict spring high-flows. Data on hydrometeorology, spring distribution, discharge properties, and socio-economic aspects were compiled. A data-driven model for predicting spring high-flows and a Cellular Automata-based dynamical model for forest resources were also developed. Additionally, water demand and supply data for 427 households in the Suyal sub-watershed, monthly spring discharge and water quality data for six springs, and surface meteorological data for were prepared. The study suggests a significant reduction in winter wet days, emphasizing the need for community-level climate change adaptation and improved water resource management. The models provide actionable insights for targeted plantation activities and improved resource allocation.

The project made an assessment of the outcome of alternate policy and technological interventions for river conservation and associated ecosystems and stakeholder capacity building for informed water management decisions.

2.2. Objective-wise Major Achievements

S. No.	Objectives	Major achievements ***(in bullets points)***
1.	Development, Testing and validation of a System Dynamics Model of the Upper Jhelum and Kosi Basins.	1. (i) Estimated Spatiotemporal variability and change in seasonal leaf area coverage to understand the ecosystem behaviour and estimation of evapotranspiration. (ii) Crop phenology (wheat) was estimated using multispectral satellite images. (iii) Developed data models for crop production based on traditional as well as deep learning methods on past data (iv) Developed a machine learning based tool to classify High resolution satellite images from Landsat and Sentinel. 2. (i) SWAT hydrological model simulations were conducted for KOSI River basin for the period 1982-2017 with 25 sub-basins. (ii) SWAT hydrological model simulations were made for UJB River basin for the period 1982-2017 with 44 sub-basins. (iii) High resolution WRF – canopy model simulations are conducted for Kosi and upper Jhelum region. (v) DSAT and STICS Crop model was set up for Wheat in the Kosi basin (iv) Field survey cum data collection for Kosi basin was conducted during June 2019 and upper Jhelum basin in 2021. (vi) Simplified SDM has been developed in this project.

2.	Projections of water budget, Climate change, and agro-ecosystem under different environmental and socio-economic scenarios	• Generated the digital database including: Hydrology, Meteorology, Land use and Land cover, Soil and Socio-economic parameters at watershed level in the UJB. • Quantified the past and present land system changes in UJB from 1981– 2019 and future LULC projections for UJB up to 2100. • Generated Socio-economic Projections for UJB up to 2100. • Water balance assessment of UJB. • Generated present and future climate scenarios for UJB ending 21st century • Generated revised climate zonation of UJB. • Water usage and socio-economic survey in Kosi- watershed • Monthly monitoring of discharge and physico-chemical data analysis during 2019-2021 period. • Crop-vegetation survey for Rice and wheat yield, phenology, soil properties and management practices within the Kosi watershed. • Observations and data quality control of air, climate, soil and water environment in the Kosi watershed. • The particulate matter (PM10) data compilation was completed for 2020-21. • Quantifying past land and water resources changes and developing data models and digital database: • Quantified the expected changes in winter-season wet day climatological patterns for Himalayas during 2020–2099 in comparison to a baseline period of 1980–2000 under two different warming scenarios, RCP 4.5 and RCP 8.5, using CSIRO-CORDEX simulations from five GCMs. • The model ensemble predicted area-averaged reduction in the frequency of wet days by 0.3 to 1.0 day by the end of this century. • It is also observed that the Himalayan region within the range of 1000–2500 m above sea level may experience a decline in winter-season wet days by up to 0.8 to 3.2 days under the warming scenarios of both RCP 4.5 and 8.5.

- The forest fragmentation statistics, estimated using Fragstat module of Arc-GIS (v. 2014) and LULC data generated from the RGB and NIR band with 30 m resolution of Landsat indicated increase in the forest core area (i.e. forest area > 500 acre) from 201.7 km2 in 1999, 247.4 km2 in 2008 and 368.2 km2 in 2017 representing better prospect for water augmentation.
- A GIS based study was conducted to identify and prioritized the sub-watersheds of Kosi watershed based on the compound factor analysis of 10 morphological parameters related to drainage network, basin geometry, and drainage texture. The sub-watersheds were categorized into high, medium and low level of priority for conservation of natural resources leading to sustainable watershed management.
- The Cellular Automata based forest cover prediction till 2030 indicated that the forest cover area over Kosi watershed is expected to increase by 82.7 km^2 from the forest cover areas of 2017.
- A data driven model was developed for predicting spring high flows of Kosi watershed. The model development was carried out using 05 machine learning classifiers with multiple geo-climatic predictors affecting spring discharges.
- The following ecological Indicators were estimated by the CSIR:
  - Annual water yield for 2001-2019
  - Water balance
  - Baseflow
  - Surface Runoff
  - Sub-basin scale Actual evapotranspiration
  - Sediment export and deposit
  - Soil loss
  - Carbon storage
  - Nutrient transport
  - Normalized Difference Vegetation Index (NDVI)
  - Leaf Area Index (LAI)

3.	Assessment of the outcome of alternate policy and technological interventions for conservation of river and associated ecosystems.	• Model input-output data was collected in joint surveys in the Upper Jhelum and Kosi basin • Soil sample collected and analysed in UJB and Kosi basin • The problems of agriculture and horticulture etc. were identified by using pairwise rank matrix tool, for possible suggestions for enhanced human-natural resource management • Samples/ measurements on crop phenology/ plant growth, soil & grain samples from crop fields wheat/ paddy
4.	Capacity and awareness building of stakeholders for informed decision making on water management.	• A "Brain storming workshop on System Dynamic model: Livelihood and water resources" was organized at CSIR-4PI, on 12-14 March, 2020. • Workshop on "System Dynamical modelling for livelihood and river management" at CSIR 4PI, Bengaluru was organised during 13-14 Feb 2020 • One day brainstorming meeting to "Developing methodologies to characterize ecosystems in the Indian Himalayas" at CSIR 4PI, Bangalore 12th Feb 2020. • Stakeholder consultation Workshop -6 'Watershed management and livelihood enhancement' during 12-21 May, 2019 under consultative meetings titled "System Dynamic model: Livelihood and water resources of Kosi watershed" • Inception workshop & review workshop organized at the University of Kashmir 20-21 April, 2018 • Interactions and Interviews with local communities in UJB to assess the impact of climate change on horticulture and agriculture during 2018-2020 • 5 PhD and 12 Masters students were trained as part of the capacity-building efforts, contributing to informed decision-making.

Note: Further details may be summarized in DPR Part-B, Section-5. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

2.3. Outputs in terms of Quantifiable Deliverables*

S. No.	Quantifiable Deliverables*	Monitoring Indicators*	Quantified Output/ Outcome achieved	Deviations made, if any, & Reason thereof:
1.	Observation of air, climate, soil and water environment: planning, design of sampling locations and observations	Precipitation and temperature from the IMD; Streamflow from the Irrigation and Flood Control Dept. (IFC); Soil quality from SKUAST; Particulate matter	• Long term trends of precipitation, temperature, and other meteorological parameters • Soil quality • Water levels • Particulate matter	-
3.	Quantifying past land and water resources changes and developing data models	LULC of the years 1981, 1992, 2001, 2013 and 2019; Streamflow changes from 1971- 2018	Past to present LULC (1981-2019) was generated and dynamics were studied; The streamflow trend over the past five decades were studied in the UJB which shows a significant decline in streamflow at the three stations	-
4.	Development of digital database on land, water and other resources (including socio-economic) at watershed scale	Hydrology, Meteorology, Land use and Land cover, Soil and various Socio-economic parameters	Generated the digital database in GIS environment of Hydrological, Meteorological, Land use and Land cover, Soils and Socio-economic parameters at watershed level in both the both the basins	-
5.	Developing reliable high resolution past climate and future climate scenarios for the two	**UJB:** -Past-present climate and Future climate scenarios; Present and future climate zonation	**UJB:** -The most plausible climate change scenarios were developed under two climate change scenarios: RCP4.5 and RCP8.5 ending 21st Century	-

	selected habitats over the Indian Himalaya	**KOSI:** -2 high-resolution climate scenarios developed based on the past database/ sets; 3 high-resolution future scenario prediction/ visualization based on the data dynamics analysis.	-The Köppen-Geiger climate classification was updated and projected to the end of 21st century. **KOSI:** 06 numbers of models from CSIRO-CORDEX simulations were used for dynamical analyses of winter wet days under RCP 4.5 and 8.5 climate change scenarios ending 21st century.	
6.	Assessment of hydrological budget for two basins using numerical model that include surface, snow-ice melt, ground water and stream flow, etc.	Water balance	Water balance studies and partitioning of streamflow components into snow-ice melt, baseflow and rain in the UJB. Annually, snowmelt provides the largest contribution, while glacier melt contributes the least. Baseflow is the primary contributor during the accumulation season. During the snowmelt season, it's the snowmelt, while during the glacier-melt season, glacier melt contributes the most at higher elevations, with baseflow prevailing in lower reaches.	-
7.	Cellular automata (CA), and Socio-economic models outlook: Model Calibration	LULC projections; Socio-economic projections	Calibration of the Linear Growth Model was done for socio-economic projections; Cellular automata (CA) model was calibrated for LULC projections.	-

8.	System Dynamical models (by integrating water budget, Crop models, socio-economic models, WRF-land-canopy model and etc.) for 2 Himalayan watersheds for effective remediation & sustainable water management;	• Monitoring and comparison of the baseline information • Several System Dynamics Models tested/ customized for the Himalayan watersheds; • A number of high-resolution climate scenarios developed based on the past database; • A number of high-resolution future scenario prediction/ visualization based on the data dynamics analysis; • Outputs of Decision-support System developed, integrating SDM on GIS platform; • A number of Policy guidelines and Legislative mechanisms: prepared and/ or communicated	• Soil and crop phenology assessed for the three experimental sites for Paddy and Wheat crop. • 250m resolution 8day NDVI & EVI data generated for the period 2002-2020 • Remote sensing-based used to estimate system variables. • 500m 16-day leaf area index data generated for the period 2002-2020 • Field data collection for soil samples, springs. Leaf Area Index (LAI), plant phenology, soil Moisture and W.E.T. measurement • Input data at 4km developed for the period 2001-2016 • Crop vegetation monitoring and phenology carried out for Wheat and Apple crop for the period 2002-2019 in Kosi and UJB respectively • Hydrological model simulation is done for 1979-2019 for KOSI and upper Jhelum basin River basin. • Multivariate deep learning-based process models are developed • LULC was generated for estimating for variability and trend (both annual and seasonal timescales)	

			• Deep learning-based LAI estimation model developed
			• High resolution WRF – canopy model is customized for Kosi and upper Jhelum region simulations are complete.
			• Crop phenology estimation for 2002-2020 is complete.
			• Ecological Indicator for the period 2001-2020 has been simulated for the following parameters:
			  • Annual water yield for 2001-2019
			  • Sub-basin scale Actual evapotranspiration
			  • Sediment export and deposit
			  • Soil loss
			  • Carbon storage
			  • Nutrient transport	

9.	Developing a decision support system by integrating SDM on GIS platform.	• Sustainable water management, climate adaptation strategies, and policy interventions. • Future projections of land use, water resources, and socio-economic trends up to 2100. • Climate classification schemes and hydrological budgets	• A pilot DSS was developed for a small watershed, combining SDM and GIS to visualize and test intervention scenarios. • It integrates multiple models, including hydrological, climate, and socio-economic models, to assist in evaluating and managing water resources and land use under various scenarios.	

		• Insights for adaptive policy formulation, resource allocation, and climate-resilient strategies.	• These outputs and performance indicators demonstrate the DSS's utility in addressing water and land resource challenges in the Upper Jhelum Basin and Kosi Watershed, providing a framework that can be replicated in similar basins.	
10.	Documentation/ Publications	Climate change scenarios and climate zonation; Land surface processes (The publications are provided as annexure to this report)	**Land surface processes:** 1. Ipsita, P., Rakesh, V., Singh, R., & Mohapatra, G. N. (2023). Impact of different land use data on WRF model short range forecasts during pre-monsoon and monsoon seasons in India. *Urban Climate*, *49*, 101558. 2. Singh, R., Rakesh, V., & Varma, A. K. (2023). Association of winter vegetation activity across the indo-gangetic plain with the subsequent Indian summer monsoon rainfall. *Climate Dynamics*, *60*(7-8), 2245-2259. 3. PK, V. G., KV, R., & Rakesh, V. (2022). Improved Learning by Using a Modified Activation Function of a Convolutional Neural Network in Image	-

Classification. *Available at SSRN 4185660*.

4. Altaf, S., & Romshoo, S. A. (2022). Flood vulnerability assessment of the Upper Jhelum Basin using HEC-HMS model. Geocarto International, 37(26), 14699-14720.
5. Romshoo, S. A., Yousuf, A., Altaf, S., & Amin, M. (2021). Evaluation of Various DEMs for Quantifying Soil Erosion under Changing Land Use and Land Cover in the Himalaya. Front. Earth Sci, 9, 782128.
6. Marndi, A., Ramesh, K. V., & Patra, G. K. (2021). Crop production estimation using deep learning technique. *Current Science*, *121*(8), 1073.
7. Nair, R. V., Vasanthakumar, R. K., & Rao, E. V. S. P. (2021). An Assessment of Potential Economic Gain from Weather Forecast Based Irrigation Scheduling for Marginal Farmers in Karnataka, Southern State in India. *Agricultural Sciences*, *12*(5), 503-512.
8. Ramesh, K. V., Rakesh, V., & Rao, E. V. S. (2020).

			Application of big data analytics and artificial intelligence in agronomic research. *Indian Journal of Agronomy*, *65*(4), 383-395. **Climate change scenarios and climate zonation:** 9. Purwar, S., Rakesh, V., Bankar, A., & Mohapatra, G. N. (2023). Relationship of height and intensity of low-level jet stream with Indian summer monsoon rainfall. *Theoretical and Applied Climatology*, *151*(1-2), 785-799. 10. Romshoo, S. A., & Marazi, A. (2022). Impact of climate change on snow precipitation and streamflow in the Upper Indus Basin ending twenty-first century. Climatic Change, 170(1-2), 6. 11. Kumar, V. K., KV, R., & Rakesh, V. (2022). Optimizing Lstm and Bi-Lstm Models for Multivariate Time Series Prediction and Performance Comparison with Classical Statistical Models. *Available at SSRN 4129886*.	

			12. Mohapatra, G., Rakesh, V., Purwar, S., & Dimri, A. P. (2021). Spatio-temporal rainfall variability over different meteorological subdivisions in India: analysis using different machine learning techniques. *Theoretical and Applied Climatology*, *145*(1-2), 673-686. 13. Johny, A., & Ramesh, K. V. (2020). Equatorial Indian Ocean Response during Extreme Indian Summer Monsoon Years Using Reliable CMIP5 Models. *Ocean Science Journal*, *55*, 17-31. 14. Romshoo, S. A., Bashir, J., & Rashid, I. (2020). Twenty-first century-end climate scenario of Jammu and Kashmir Himalaya, India, using ensemble climate models. Climatic change, 162, 1473-1491. 15. Johny, A., & Ramesh, K. V. (2019). Developing reliable climate projections for the continental monsoon regions. *Journal of Climate Change*, *5*(2), 51-71.	

(*) As stated in the Sanction Letter issued by the NMHS-PMU.

2.4. Strategic Steps with respect to Outcomes (in bullets)

S. No.	Particulars	Number/ Brief Details	Remarks/ Attachment
1.	New Methodology/ Technology developed, *if any:*	A new climate classification scheme developed in this research Deep learning classification algorithm; Deep learning-based model for crop yield	The details of the classification scheme are published in paper (please see Appendix 1&2)
2.	New Ground Models/ Process/ Strategy developed, *if any:*	New land surface processes were tested and simulated using the following models: • Cellular automata (CA) model for land projections • Linear Growth Model • SPHY model for streamflow partitioning • Machine learning model for predicting spring high-flows of central Himalaya • SWAT for upper Jhelum and KOSI • High resolution WRF – canopy model • LSTM and Bi-LSTM models for crop production • Ecological Indicator simulation • Watershed Scenario models	The details of the classification scheme are published in various papers (please see Appendix 1&2)
3.	New Species identified, *if any:*	-	-
4.	New Database established, *if any:*	The following high-resolution databases on various aspects of natural resources, processes and indicators were digitized and developed for analysis in GIS environment.	-

		• A time series of meteorological parameters in Upper Jhelum and Kosi basins • Land use/ land cover- UJB and Kosi basin • Watershed-wise socio-economic database- UJB and Kosi basin • Revised climate zonation in UJB • Water quality- UJB and Kosi watersheds • Spring digital database for Suyal sub watershed (Kosi). • Surface meteorological database of Kosi-Katarmal. • A time series of streamflow measurements in the UJB and Kosi basins • Apart from this, 3000+ Leaf Area Index (LAI) measurements, 124 Soil Moisture Sensor measurements and 124 W.E.T sensor measurements were taken. • Ecological Indicators are simulated at 30m resolution	
5.	New Patent, *if any:*	-	-
	I. Filed (Indian/ International)	-	-
	II. Technology Transfer, *if any:*	-	-
6.	Others, *if any*	-	-

Note: Further details may be summarized in DPR Part-B, Section-5. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

3. New Data Generated over the Baseline Data

S. No.	New Data Details	Status of Existing Baseline	Additionality and Utilisation New data

1.	LULC data from 2021-2100 for UJB	1980- 2019	Simulation modelling
2.	Watershed wise Socio-economic database from 2021-2100 for UJB	1981- 2011	For projections of population density and total population at the basin level
3.	LULC of Kosi watershed	-	Simulation modelling
5.	Streamflow data of UJB from 1971-2018	-	For past to present streamflow trend analysis
6.	Precipitation data of UJB from 1980-2018	-	Simulation modelling
7.	Soil quality data of UJB	-	Simulation modelling
8.	Soil texture data of UJB	-	Simulation modelling
9.	Water quality data of UJB and Kosi watersheds	-	Simulation modelling
10.	3000+ Leaf Area Index (LAI) measurements, 124 Soil Moisture Sensor measurements and 124 W.E.T sensor measurements	-	Simulation modelling
11.	Streamflow data of Kosi	-	Simulation modelling
12.	Particulate matter data from 2011-present	Previously not available	For determining the status of air quality
13.	Updated Koppen-Gieger zonation for UJB	Baseline data 1980-2019	New climate classification for Jammu, Kashmir and Ladakh Himalaya
14.	Future climate zonation for UJB	Projected Koppen-Gieger zonation	climate classification for Jammu, Kashmir and Ladakh Himalaya by 21st century under climate change
15.	Water usage and socio-economic data in Kosi-watershed	Water demand data for developing system dynamical model	Water Supply and Demand for SDM model
16.	Mapping of 113 springs within Kosi watershed	Geo-tagged spring data to be used for archiving in the NMHS data portal.	A digital database of geo-tagged springs was prepared.

17.	Monthly spring discharge and of 6 springs within Kosi-watershed are monthly monitored and compiled for January, 2019 to December, 2021.	Monthly monitored spring data used for developing spring high-flows using machine learning classifiers.	Monthly monitored spring data were used in a research publication under review.
18.	Surface meteorological variable of Kosi- katarmal	Daily meteorological data for Rainfall, air temperature, relative humidity, wind speed and net radiation observed at the 32 m profiler of GBPNIHE during 2012-2021 were compiled.	Meteorological Monograph Part I and II of the data were compiled and published by GBPNIHE.

Note: Further details may be summarized in DPR Part-B. Database files in the requisite formats (Excel) may be enclosed as annexure/ appendix separately to the soft copy of FTR.

4. Demonstrative Skill Development and Capacity Building/ Manpower Trained

S. No.	Type of Activities	Details with number	Activity Intended for	Participants/Trained			
				SC	**ST**	**Woman**	**Total**
1.	Workshops	07	• A "Brain storming workshop on System Dynamic model: Livelihood and water resources" was organized at CSIR-4PI, on 12-14 March, 2020. • Stakeholder consultation Workshop -6	7	4	28	183
2.	On Field Trainings	06	• 'Watershed management and livelihood enhancement' during 12-21 May, 2019 under consultative meetings titled "System Dynamic	4	3	13	60

			model: Livelihood and water resources of Kosi watershed" • Inception workshop & review workshop				
3.	Skill Development	--	--	--	--	--	--
4.	Academic Supports	5 12	PhD Masters	--	--	5 4	5 12
	Others (if any)	--	--	--	--	--	--

Note: Further details may be summarized in DPR Part-B. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

5. Linkages with Regional & National Priorities (SDGs, INDC, etc.)/ Collaborations

S. No.	Linkages /collaborations	Details	No. of Publications/ Events Held	Beneficiaries
1.	Sustainable Development Goals (SDGs)/ Climate Change/INDC targets addressed UJB: Climate Action (SDG 13) Life on Land (SDG 15)	• CSIR- Goal 1,2,3 • Climate Action • Life on Land Agriculture and Horticulture problems The project's climate change projections (temperature rise of 4°C to 7°C by 2100) emphasize the need for climate adaptation strategies, contributing to SDG 13 goals of mitigating climate change impacts. The study on land-use/land-cover changes reveals significant shifts in agriculture, forest areas, and urbanization, guiding better land management practices for conservation and biodiversity.	- 4 publications	Rural communities of Kosi-watershed and research and developmental organisations Policy-makers, researchers, agriculturists, horticulturists, environmental NGOs, Govt. bodies & local communities in the UJB.

	Clean Water & Sanitation (SDG 6) Zero Hunger (SDG 2)	Hydrological modelling highlighted the importance of baseflow for streamflow sustainability, supporting water management practices that ensure clean and sustainable water supplies. The project's focus on horticulture expansion contributes to agricultural diversification, which can improve food security and reduce hunger in the region.		
2.	Any other:	-		

Note: Further details may be summarized in DPR Part-B, Section-6. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

6. Project Stakeholders/ Beneficiaries and Impacts

S. No.	Stakeholders	Support Activities	Impacts
1.	Line Agencies/ Gram Panchayats:	The training programmes on "Watershed management and livelihood enhancement" were carried out in Katarmal and Balta Gram Panchayats by GBPNIHE during Stakeholder consultation at panchayat level- joined by CSIR trainers also	Capacity building and awareness about the use of technological input in natural resource management
2.	Govt Departments (Agriculture/ Forest/ Water):	Department of Agriculture; Directorate of Horticulture; Jal Shakti Department; Indian Meteorological Department; Fruit growers and farmers association;	The output from this work will aid the stake holders by providing a holistic, integrative framework for decision-making. It equips stakeholders with actionable insights to manage resources sustainably, mitigate risks, and enhance the resilience of ecosystems and communities by: • Policy Designing and Evaluation

		Forest, Ecology and Environment Department	- Governments can simulate various policy options - Stakeholders can identify the most effective use of resources based on the model outputs for sustainable development practices • Climate Change Adaptation and Mitigation • Water Resource Management to support sustainable water use • Agricultural Planning for Crop Yield Predictions and Irrigation Strategies • Cost-Benefit Analysis supporting efficient investment decisions • Livelihood Protection of local communities by forecasting resource availability and risks • Adaptive Management to enable dynamic policy adjustments to changing conditions
3.	Villagers/ Farmers:	PRA workshop at selected villages in the UJB and Kosi watersheds	Awareness of orchardists and farmers in sustainable management of agriculture and horticulture
4.	SC Community:	-	-
5.	ST Community:	-	Awareness of project outcome
6.	Women Group:	-	Awareness of project outcome
	Others (if any):		

Note: Further details may be summarized in DPR Part-B, Section-6. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

7. Financial Summary (Cumulative)

S. No.	Financial Position/Budget Head	Funds Received	Expenditure/ Utilized	% of Total cost

I.	Salaries/Manpower cost	5933608	5814000	98%
II.	Travel	882254	1013249	100% (excess expenditure
III.	Expendables &Consumables	662610	510660	77%
IV.	Contingencies	662260	603721	91%
V.	Activities & Other Project cost	1467758	1227328	84%
VI.	Institutional Charges	200000	200000	100%
VII.	Equipment	7120950	6989552	98%
	Total	16982665	16358510	**96%**
	Interest earned			
	Grand Total	16982665		

* Please attach the consolidated and audited Utilization Certificate (UC) and Year wise Statement of Expenditure (SE) separately, *ref*. **Annexure I.**

8. Major Equipment/ Peripherals Procured under the Project** (if any)

S. No.	Name of Equipment	Quantity	Cost (INR)	Utilization of the Equipment after project
1.	Handheld Air Temperature and Relative Humidity sensor with display logger and Disdrometer	1	577013/-	Hourly collection of precipitation-form data using disdrometer. Collection of Air Temperature and Relative Humidity data on field for future research
2.	Automatic Rain Gauges	5	733831/-	Hourly measurements of precipitation data for future research
3.	Automatic Weather Station	1	1049840/-	To be used for 30-minute measurements of meteorological parameters for use in other studies
4.	Nikon Coolpix Camera	1	27881/-	For field data collection
5.	Micro-pipette 0.5-5 Ml Thermo	1	18100/-	Water sampling for water quality assessment
6	Godrej GDR, Book Case	1	19997/-	For library usage
7	Workstations	1	223971/-	Computational Research, model simulations for other research projects
8.	AWS with data logger	1	3,68,000/-	To be used for 30-minute measurements of meteorological parameters at field scale for use in other projects

9.	Outdoor air quality sensor	1	5,23,807/-	To be used for continuous monitoring of air quality parameters at field
10.	Hobo water level recorder (SN: 20196711) and accessories	1	75,470/-	To be used for continuous monitoring of water level and temperature at field
11.	Porometer	1	7,21,740/-	Continuous data collection for future research related to the measurements of the pore size and permeability of the stomatal conductance of a leaf for use in other projects
12.	Work station	1	11,55,000/-	Data processing and model simulations
13.	Handheld GPS	1	24,990/-	Continuous data collection for future research
14.	NDVI, Chlorophyll measurement meters	1	8,80,598.82/-	Will be used for the data processing and model simulations related to the estimation of chlorophyll content in plants for other ongoing and future studies
15.	ENVI Image Processing	1	5,89,314/-	To be used for the extraction of information from the satellite data in other projects

Details should be provided in details **(*ref* **Annexure III &IV).**

9. Quantification of Overall Project Progress

S. No.	Parameters	Total (Numeric)	Remarks/ Attachments/ Soft copies of documents
1.	IHR States Covered:	*2*	Upper Jhelum basin, Jammu and Kashmir state. Kosi watershed, Kumaun region of Uttarakhand state.
2.	Project Site/ Field Stations Developed:	*5*	Kosi and upper Jhelum basin

3.	Scientific Manpower Developed (Phd/M.Sc./JRF/SRF/ RA):	14	KU: 4 (PhD); 5(JPF); 1(FA), 11 MSc projects GBPNIHE: 01 (JRF/SRF); 02 (Field Assistant) CSIR: 06 (JRF/SRF/FA), 3 PhD
4.	Livelihood Options promoted:	-	Scoping work for livelihood quality enhancement
5.	Technical/ Training Manuals prepared:	*One*	*For Rural participatory Appraisal*
6.	Processing Units established	(attach photos)	*Note applicable*
7.	No of Species Collected, *if any*	-	*Not applicable*
8.	No. of New Species identified, *if any*	-	*Not applicable*
9.	New Database generated (Types):	• 6 (KU) • 3 (GBPNIHE)	• Land use/ land cover (From 1980-2019 and 2021-2100) • Watershed-wise socio-economic database (From 1980-2019 and 2021-2100) • Streamflow data from 1971-2018 • Precipitation from 1980-2018 • Soil quality (1491 samples) • Soil texture (725 samples) • Particulate matter data from 2011-present • Revised climate zonation in UJB • Water quality (50 samples) • Meteorological data (Kosi) • Geo-tagged 113 spring database (Kosi) • Socio-economic data on water demand and availability (Kosi). • Field data collection: 26 stream measurements, collected 120 soil samples and located 8 springs. Apart from this, 3000+ Leaf Area Index (LAI) readings, 530+ leaf properties, 124 Soil Moisture

			Sensor measurements and 124 W.E.T sensor measurements were taken. • Field Experiments – Five villages- Sunoli, Dotiyal Gaon, and Mahat Gaon for wheat crop in Kosi watershed • Input data at 4km downscaled climate data for 2001-2016 • Soil and water analysis data, Satellite images, LULC maps, Agriculture and Horticulture maps
	Others (if any)		*No*

Note: Further details may be summarized in DPR Part-B. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

11. Knowledge Products and Publications:

S. No.	Publication/ Knowledge Products	*Number*		*Total Impact Factor*	*Remarks/* Enclosures
		National	International		
1.	Journal Research Articles/ Special Issue:	04	11	30+	-
2.	Book – Chapter(s)/ Monograph/ Contributed:	02	--	--	-
3.	Technical Reports:	--	--	--	--
4.	Training Manual (Skill Development/ Capacity Building):	--	--	--	--
5.	Papers presented in Conferences/ Seminars:	02	--	--	-
6.	Policy Drafts/Papers:	--	--	--	
7.	Others, if any:	--	--	--	--

Note: Please append the list of KPs/ publications (with impact factor, DOI, and further details) with due Acknowledgement to NMHS. Supporting materials may be enclosed as annexure/ appendix separately to the FTR.

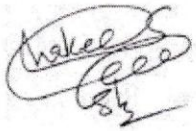
12. Recommendation on Utility of Project Findings, Replicability and Exit Strategy

Particulars	Recommendations
Utility of the Project Findings:	Potentially insightful knowledge products generated under the project by the three partners have significant application in the two Himalaya sites and beyond. Some of these are listed below. 1. A versatile digital database designed to enable seamless abstraction and assimilation of data on various resources and processes such as

	environmental, crops, soils, water, climate, demography etc. are useful for diverse purposes- and can be shared with scientific community in the country 2. The climate change projections and impact studies have potential to inform climate change adaptation studies in the Himalaya to minimize the adverse impacts of climate change on various sectors in the Himalaya 3. The knowledge generated through model development and application can be used to inform strategies for sustainable development of land and water resources in the two basin and extended Himalayan regions. 4. Application of the following models for simulation, analysis and synthesis: • SWAT-upper Jhelum and KOSI • High resolution WRF – canopy model • LSTM and Bi-LSTM models: crop production,LAI • LAI estimation-Upper Jhelum and Kosi • APSIM-WHEAT • STICS-APPLE • Watershed Scenario models • Ecological Indicators 5. Design of model-based scenarios for feedback learning from stakeholder interactions 6. One way for better management of water resources could be better prediction of spring high-flows that could be stored for lean period use. Consequently, the numerical model proposed in this study would be useful. 7. The forest fragmentation status produced in this study could be used by the state forest department for targeted plantation activities.
Replicability of Project/ Way Forward:	**Replicability of the project:** • The project generated extensive datasets, including hydrology, meteorology, LULC, water quality, socio-economics, and climate. This repository is replicable for similar studies in other Himalayan basins facing water resource and land management challenges.

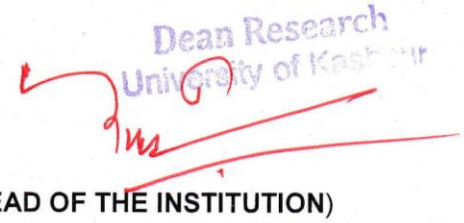
	• The utilization of SWAT, SPHY, and Cellular Automata models can be applied to other watersheds with modifications tailored to local conditions. These models can be adapted for basin-scale water and land resource management elsewhere. • The AI/ML frameworks for predicting spring flows and LULC changes are generic and can be implemented in other regions to assess ecological changes and water availability. • The outputs provide a replicable framework for climate adaptation strategies, water allocation, spring management, and forest conservation that can guide policy development in other environmentally sensitive regions. • The participatory approach involving local stakeholders offers a blueprint for enhancing community involvement in sustainable resource management. **Way Forward:** Building on the outcomes of this project, the next steps should focus on replicating the developed System Dynamics Model in other Himalayan basins to address basin-specific environmental and socio-economic challenges. Integrating real-time monitoring data and advanced climate modeling techniques can enhance the predictive accuracy of hydrological and ecological assessments. Collaborative efforts with government bodies, NGOs, and local communities are essential for implementing land and water conservation strategies, reforestation initiatives, groundwater spring rejuvenation, and ecosystem restoration strategies. Expanding carbon accounting and ecosystem service valuation into policy frameworks will bolster climate change adaptation and mitigation measures. Additionally, establishing long-term monitoring stations, creating open-access data repositories, and conducting capacity-building programs for stakeholders

	will ensure sustainable water and ecosystem management in the face of future challenges.
Exit Strategy:	The exit strategy for this project focuses on embedding its outcomes into policy frameworks, institutional mechanisms, and community-driven initiatives to ensure sustainability and long-term impact. Key findings should be integrated into regional and national water and forest management policies, supported by user-friendly decision-support tools. Collaboration with academic and research institutions can institutionalize the data repositories and modeling frameworks, while capacity-building workshops and training programs can empower stakeholders. Community engagement is critical, with actionable insights like targeted plantation activities and spring rejuvenation programs fostering local ownership. Dissemination of findings through policy briefs, journal articles, and public reports, along with presentations at national and international forums, will promote replication in similar contexts. By following the above strategy, the project outcomes can catalyze sustainable ecosystem management beyond the formal completion of the project.



(PROJECT PROPONENT/ COORDINATOR)

(Signed and Stamped)



(HEAD OF THE INSTITUTION)

(Signed and Stamped)

Place: ……**Srinagar**……..
Date: …10/12/2024