Terms of Reference
for
Consultancy for Surface Water Assessment and Water Balance Studies for Kiul-Harohar and Mahananda Basin

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1.0 Background

Bihar is one of the most flood-prone states in India, with 76 percent of the population living under the recurring threat of flood devastation. With geographical area of 94,163 sq. km, 73.06 % of the state is flood prone. The recurrent floods are devastating Bihar's economy and undermine poverty alleviation efforts. Not only they affect lives, livelihoods, productivity and security of existing investments, but are also a disincentive for additional investments in Bihar. While North Bihar (area lying north of river Ganga) is flood prone, South Bihar (area south of Ganges) is vulnerable to both drought & flood. Records show that in the recent years, frequency of occurrence of these extreme eventshave increased.

Based on the successful outcome of the past two phases of the Hydrology Project, the Government of India with World Bank assistance initiated a follow up project – National Hydrology Project (NHP) - Approach towards Integrated Water Resources Management (www.indiawrm.org).

The National Hydrology Project (NHP) will be implemented in eight years (2017-2024) with the funding of USD 350 million. The project aims to improve the extent, quality, and accessibility of water resources information and strengthen the capacity of targeted water resources management institutions in India. One of the key outcomes of the project to enable the States to manage floods and dry season operation by using River Basin approach.

2.0 Need for Conducting Water Balance studies

With the increasing imbalance between water supply and water demand in the state of Bihar, water availability and water scarcity has progressively emerged as a key issue in the state, as illustrated in the policy objectives of various national directives and communications. This is potentially exacerbated by changes in climate during the past few decades.

'Water Balance', as referred in the current ToR can be described as an accounting for the inputs, outputs and changes in the volume of water in the various components&other water bodiesat specified hydrological unit and time interval, occurring both naturally and as a result of human induced water abstractions and returns. The Water Balance assessmentcan help support the development of River Basin Management Plans by providing a coherent framework to cross-evaluate the information on water quantity (including the coherence between water abstraction and water recharge, water flow between water bodies/catchments, storage changes over time, etc.) and provide a sound basis to the quantitative management of water resources. Some of the relevant benefits for assessment of water balances in the river basin are but not limited to:

- Have a better understanding whether water resources are at quantitative &qualitativerisk
- Support the identification of drought and water scarcity situations.
- Have good overview of the spatial and temporal variability of water resources, under current and future scenarios.

- Identify “where best to target efforts” (for instance, identifying areas of existing or future water stress, reducing abstraction from a given sector, increase storage, develop reuse etc.) when selecting measures for improving the quantitative state of water resources.
- Water resource assessment and management at various scales to quantify runoff estimation, groundwater recharge potential, water-energy nexus, e-flows, real-time analysis, operation and forecasting.
- Provide a coherent framework for combining and structuring hydrological and socio-economic information on climate, water resources in different compartments, water uses (abstraction, discharge…), etc.
- Facilitate the identification of priority area and identify possible “data gaps”.
- Provide a common platform for building a shared understanding of issues amongstakeholders.
- Provide sound arguments as part of communication and awareness raising.

In view of the above, Water Resources Department, Govt. of Bihar (WRD) proposes to develop “Surface Water Assessment and Water Balance in Kiul-Harohar and Mahananda River Basins” under the World Bank National Hydrology Project. The assessment is expected to provide a Decision Support tool for strategic water planning and sustainability of long-term water resource planning for various water usesfor the river basins.

The other aim is to integrate environmental and economic information in a common, comprehensive and coherent way to measure the contribution of environment in the economy and the impact that economic activities may have on the environment.

3.0 Objectives of the Consultancy

The overall objective of the study is to assess water balance and long termsurface water availabilityto identify imminent and long-term water security related challenges and opportunities in Kiul-Harohar and Mahananda basins in the state of Bihar. The assessment will support the decision makers in planning and management of water in consideration of existing as well as futuristic water resource development. It will determine the extent to whichchallenges (upstream development and climate) hinder water resource development and explore prospects for sustainable socio-economic and environmental security. This development must include a dashboard for query-based generation for display of results including display of water balance in the basins and inter-sectoral water allocation system for all stakeholders. The specific objectives include but not limited to: -

(i) Review and verify the currently used hydro-meteorological data. Correct, validate and process the required hydro-meteorological data of the basins.

(ii) Assess and promote irrigation and other water use potentials in the Kiul-Harohar and Mahananda basins within the territorial area of the state.

(iii) Conduct basin modelling for assessment of water availability and balances in the Kiul-Harohar and Mahananda River basins. Determine water balance at the sub-basin level based on the current land use pattern and historical hydro-meteorological data available.

(iv) Identify areas that are likely to be under water stress and measures to mitigate stress through efficient use and water management. Recommend efficient and economic use of water in the Kiul-Harohar and Mahananda basins and to measure socio-economic and environmental scenarios/impacts for the suggested water use.

(v) Inflow forecast to determine the optimal time to operate various schemes and manage. Suggest measures for maintaining the sustainability of water availability in the Kiul-Harohar and Mahananda Basins.

(vi) Decision Support System that would provide support to the decision makers/ policy planners in taking informed decisions on issues pertaining to water resource management within the ambit of seasonal planning for wet, dry and normal years;

4.0 Scope of Consultancy

The scope of this consultancy will cover Kiul-Harohar and Mahananda rivers and their tributaries starting from Khajuri in Chotanagpur and Indo-Nepal Border respectively (entrance point of Kiul-Harohar and Mahananda River in Bihar) upto their confluence point with river Ganga. The Salient details of the basins are provided in **Annexure 1**. The consultant specific services towards estimating surface water resource and water balance studies in the Kiul-Harohar and Mahanandabasins should comprise of following tasks and deliverables, but not limited to:

Task-1: Development of rainfall-runoff and river basin model for Kiul-Harohar and Mahananda River basins for assessing water resource availability and water balance. The model will be used as a planning tool and will include optimization and development of scenarios. The task will include:

A. Collection and preparation of inventory of primary hydro-meteorological data for the two basins in alignment with India-WRIS database system. The task will include data geo-tagging, collection of maps, information and relevant report. Water resources assessment across the study area should also incorporate data on remote sensing-based precipitation, land use, cropping pattern, evapotranspiration, soil type, water bodies capacity and other features as required.
B. Quality checking, validation and analysis of data;
C. Delineation of the Kiul-Harohar and Mahananda Basin, Sub-basins and their major drainage system;
D. Setting-up of suitable Hydrological model for the basins;

Task 1 - Deliverables

The Consultant will provide following deliverables for Task 1.

Inventory on hydro-meteorological data for the basins in alignment with India-WRIS database system, Report detailing Review on model studies undertaken for the basins in the past, existing hydro-meteorological network in the basins, data validation and analysis, methodology adopted for rainfall runoff modeling/basin modeling including a general assessment of the reliability of all data sources. The features of the basin will include:

- A basin, sub-basin displaying administrative unit system schematics with network paths and nodes to represent flow channels, supply inflow and demand outflow points, storage and control points, linkages to other systems, water bodies etc.
- Basin maps containing sub-basins and administrative units of relevant themes.

- Capabilities to process interactive queries and produce clear reports.
- Extensive use of graphics (e.g. charts, schematics, maps) in presenting knowledge base information.
- Display of time-series, statistical analysis and spatial point and non-point information (e.g. climate, hydrology, infrastructure, reservoir data, etc.).

The spatial and temporal resolution should be flexible and user selectable. It should allow use of different time steps and time horizons, as these differ greatly depending upon whether the requirement is for water resources strategic planning or flood management. The database should integrate the existing and future hydro-met stations into the database in order to provide access to both historic and real time data.

Task-2: Baseline study by reviewing the current situation of river flow, navigation and flood conditions; by assessing the status of present water resources development and pertaining challenges; by conducting stakeholder consultation for the right interpretation of challenges and knowledge gaps with following assignments.

A. Preparation of inventory of water resources development projects which include salient features of existing infrastructures and geo tagged water abstraction points;
B. Preparation of inventory with geo-reference of hydro-meteorological network in the basin and their data availability list;
C. Mapping of Agro-climatic zones and preparation of Aridity Index;
D. Diagnosis of water scarcity in the basin and its sector-wise distribution under water-use classes (domestic, industrial, irrigation, ecological, etc.) in the basin and sub-basins.
E. Challenges and Issues for the study

Task 2 - Deliverables

The Consultant will provide following deliverables for Task 2.

The Report shall have inventory of water resource development projects with their salient details and water abstraction points. The basin map will include review of current situation of river flow, navigation and flood conditions, Map of agro-climatic zones, aridity index, and distribution of water use in the basin with sector-wise classification. The inventory of hydro-meteorological network and infrastructure details should be developed in alignment with India-WRIS database framework for possible integration in future.

Task-3: Water balance accounting for various abstraction/losses in the basin and sub basinin alignment with target-setting on:

A. Area wise categorization of the basin as water surplus and deficit and sector-wise water use;
B. Development of Hydrological model with calibration and validation with setting-up and integration of hydrologic relation (rainfall-runoff), water demand and river basin utilization in the Hydrological models for the Kiul-Harohar and Mahananda basins.
C. Set modeling scenarios on river planning for sustainable and equitable water use with optimization. The Scenarios should be provided on a dashboard as a desktop application that will communicate with the Model Database and upload of the model results.

D. Ranking and selection of strategy for implementation with cost benefit analysis.
E. Determining the climate change impact on water use pattern and future water resources potential in the basin, etc.

Task 3 - Deliverables

The Consultant will provide following deliverables for Task 3.

Report will include categorization of the sub-catchment into water-surplus or –deficit; sector wise water usage in the basin for domestic, industrial, irrigation, navigation, and environmental purpose and their trends. Development of Hydrological model with calibration and validation and assessment of water availability in the Kiul-Harohar and Mahananda River at specified temporal and spatial scale; Scenario analyses for various combinations of demand projection, consumption trends: for identified area and sector; water resources infrastructure development, various strategies on river planning and basin management, possible climate change scenarios etc. for various timeframes (2025, 2050 etc.). Preparation of model development report comprising chapters on study area, methodology/approach for model development, data (both geospatial and non-spatial) used, analysis of various scenarios, projections for future and assumptions made for the study, output of the modeling work in the form of analysis, digital maps, GIS layers, uncertainty analysis in model development, shortcomings/limitations in the models, results, discussion, conclusions and recommendations, etc. The model output, scenarios, alternatives and ranking of strategies for selection should be provided as a dashboard on desktop application that will communicate with the Model Database and upload of model results, so as to support decision making for planning. The dashboard will be developed in alignment with the Decision Support System (Planning & Management) which is currently in the process of being undertaken to be developed by NIH.

Task-4: Study of socio-economic and environmental scenarios/impacts for the suggested water use pattern and assessment of likely future situation with changes in demand, land use, precipitation and evaporation.

A. Study the socio-economic and environmental impact/foot-print of the suggested water use pattern and trade-offs with the current water use (area wise and sector wise).
B. Suggest measures for sustainable and equitable water use considering long-term sustainability of water availability in Kiul-Harohar and Mahananda basins.
C. Suggest measures for improving the water availability situation, that has depleted in the past in the above-mentioned basins. i.e. measures for replenishing the depleted resource and management of water resource potential in the Kiul-Harohar and Mahananda basins.

Task 4 - Deliverables

The Consultant will provide following deliverables for Task 4.

The Report will include scenarios for various model development, cost-benefit analysis and socio-economic impact. It will have recommendations for sustainable and equitable water use at specified sub-basin area/hydrological unit. The model should be able to build scenarios to enable a decision maker to understand and view the system evolving over time, in different socio-economic setting and proposed alternatives. It should be able to address ‘what if’ questions on all the components of DSS for River Basin Planning.

5.0 Responsibilities of Client (Water Resource Department, Patna)

A. Facilitate access to the Consultant for procuring data and for needful works.

B. Provide access to available office data on embankment and hydrologic/hydraulic data, and satellite imagery and thematic GIS data.

C. Facilitate access to FMC (Flood Monitoring Circle) and field offices for data collection and field visits.

D. The cooperation of existing FMISC professionals will be available as and when required

E. Facilitate access to other consultancies on topographic, river and embankment surveys, flood forecast modeling, Hydrological Information System, etc. and connected databases.

6.0 Responsibilities of the Consultant

The Consultant shall conduct and complete the consultancy in a professional manner as per the agreed ToR and scope of the consultancy. He will have his own hardware (Laptop) and required software.

A. Collecting all source data from different agencies, facilitated by WRD as needed for this consultancy.

B. The Consultant shall deploy necessary resources to collect all the relevant data proposed in this work.

C. Conduct field visits for data collection and ground verification. The consultant has to provide the vehicle to the client if required to visit field.

D. The consultant shall use the restricted data available in WRD such as topographic data, satellite imagery provided by WRD in secure environment required for classified category data.

E. The Consultant shall carry out the services as detailed in “Scope of Consulting Services” in the best interest of the Client for successful realization of the project with reasonable care, skill and diligence with sound technical, administrative and financial practices and shall be responsible to WRD for the discharge of responsibilities. The Team Leader will be responsible to the Joint Director, Hydrology Directorate, WRD for proper and timely execution of all the activities and submission of outputs/reports.

F. In performing their duties, the Consultant will work in a coordinated manner with all other consultants working under NHP.

G. The Consultant shall use appropriate modeling software for obtaining satisfactory results. The requirement of all input data for the model, the consistency of data, including primary or secondary validation should be analyzed in the initial phase.

H. After the completion of the consultancy the Consultant has to provide software, hardware, data, and source code of all applications to the Client.

7.0 Handling Restricted Data:

The Consultants, their sub-consultants, and the personnel of either of them shall not, either during the term or even after the expiration of this Contract, disclose any proprietary or confidential information relating to the Project, the Services, this Contract, or the Client's business or operations without prior written consent of the Client. Certain data (such as topographic maps in 1:50,000 scale with heights and contour information, river discharge data for Ganga river system and DEM with 50 cm contour interval) which may be used in project may be considered 'restricted' as per Ministry of Defense and Ministry of Water Resource guidelines. Keeping in view security guidelines for data secrecy and to provide optimum functionality and to enable sharing data with the consultants, a secure data handling environment has been proposed. FMISC will maintain all classified/ secret data in this Secure Data Centre (SDC). Confidentiality and non-disclosure agreements are to be signed by the Consultant firm, as well as the individual Consultants deputed for working in Secure Data Centre (SDC). Technical data brought by the Consultant may be allowed to be loaded on the server after approval of the officer not below the rank of Deputy Director. A detailed record of all the data transferred from confidential unit will be maintained in register and data will be transferred only after approval. No original data kept on server will be modified or changed. Change/ modification required if any will be done only after having a backup of the existing data and with prior permission of the client.

8.0 Reporting and Review:

The activities described earlier and the outputs described below shall be completed within a period **nine months**. Key reporting requirements follow:

Submission of Reports	Covering	Time /Month due
Inception Report	Including overall approach & methodology	1 month from the date of commencement
Interim Report-1	Report will cover Task-1 & Task-2 incorporating all assignments under these tasks.	4 months from the date of commencement
Interim Report-2	Report will cover Task-3 & 4 incorporating all assignments under these tasks.	6 months from the date of commencement
Draft Final report	The Report will incorporate the deliverables mentioned under all the tasks.	8 months from the date of commencement
Final Report after acceptance of Draft Final Report by WRD, Bihar	Report will incorporate the suggestions on Draft Final Report to achieve the objective under this consultancy.	9 months from the date of commencement

The Reports shall be submitted in5 copies (Hard copy) and electronic version

The reports will be reviewed by a NHP Standing Review Committee (NHP-SRC) set up by WRD and consisting of members from Flood Management Improvement Support System (FMISC), officers from WRD and external experts well acquainted in this field. The committee will provide review report within 15 days after report submission by the Consultant. The consultant will be liable to complyallthe observations and comments provided by the committee.

9.0 Professional Key Staff Requirements

The indicative list of Key Staff and man months are listed below. The Consultant may propose alternative team composition and skill mix in order to carry out its roles and responsibilities efficiently for successful completion of the assignment.

	Position	Qualification & Experience	Tasks and responsibility	Man Months
1	**2**	**3**	**4**	**5**
A	Key Staff			
1	Team Leader- Water Resources expert	Master degree in Civil Engineering/ Water Resources Engineering/Hydrology/Hydraulic with minimum 10 years of experience in design, planning and management of water resource project. He /She should have extensive knowledge of hydrological and hydrodynamic modeling tools used in water surface assessment. He/ She should have working experience in multi-disciplinary teams.	Will be responsible for overall output delivery as required in Terms of Reference He / She shall ensure that all the works are done as per the scope and objective mentioned in the ToR. He shall liaise between the various stakeholders of the project. He shall also be responsible for mobilization/demobilization and scheduling of the consultant's team.	7
2	GIS Specialist	Bachelor in Engineering/ MCA/ Master degree in geography/ geo-informatics with post-graduate diploma in Remote Sensing and GIS with 5 years of experience in water resource engineering. or Bachelor in Engineering/ MCA / Master degree in geography/ geo-informatics with 10 years of experience of GIS application in Water resources sectors including Geo-data base management.	Shall assist Team Leader in review of all the survey and other GIS data. Shall assist Team leader in finding the gaps of available data and support in collection of missing data. Shall assist Team Leader in technical studies of the expected outputs of this consultancy assignment	4
3	Environmental	Master's degree in Environmental Sciences/	The Environmental expert	2

	Position	Qualification & Experience	Tasks and responsibility	Man Months
	expert	Engineering or closely related field. At least 05 years of experience of working in the field of environment management/ Environmental Impact Assessment Good Knowledge of Government procedures/ policies for environment safeguards is a prerequisite.	will be responsible for preparing the environmental checklist, EIA appraisal of the activities under the project; Shall assist the team leader in Environmental issues.	
4	Hydrologist	Master degree in Hydrology; Hydraulics or Water Resource Engineering At least 5 years working experience in designing/ managing water resources project including working experience in Basin and water Resources Planning Knowledge of hydrological modeling tools used in Basin Planning Desirable: Experience in application Software Development/design/scripting in Water resources sector.	Shall assist Team Leader in review of all the hydrological, Meteorological & other data. Shall assist Team leader in finding the gaps of available data and support in collection of missing data. Shall assist Team Leader in technical studies of the expected outputs of this consultancy assignment.	6
5	River Engineering Expert	Master Degree in Water Resources/ River Engineering/Hydraulic/ Hydrology with 5 years relevant experience in Flood management, Planning & Designing as Water Resources/ River Engineer. Preferable Knowledge of hydraulic modeling tools used in river Planning.	Shall assist Team Leader in technical studies related to river planning of the expected outputs of this consultancy assignment.	3
6	Database Specialist and programmer	Graduate in Engineering in Computer Science/IT /Civil Engineer 05 years' experience in development IT software with at least 03 years in Water Resource field etc. Extensive experience in scripting.	Experience in management of data and its depiction as useful information on which policy decision could be taken. Write scripts for exchange of data between various formats and models. Development of	6

	Position	Qualification & Experience	Tasks and responsibility	Man Months
			dashboard to support Decision Support System.	
7	System Analyst	Graduate in Engineering in Computer Science/IT /Civil Engineer/ MCA with 05 years' experience in development of IT software with at least 03 years in Water Resource field, System Analysis, etc.	Developing functional & technical specifications of the system. Prepare detailed flow charts & diagrams outlining systems capabilities & processes, Hardware specifications and system documentation. Developing plan & procedures for testing, debugging, installation, Technical support etc.	3
B	Support Staff			
8	Technical Support Staff	Bachelor's Degree in Civil Engineering/ Agricultural Engineering He/ She should have at least 3 years' experience in terrain survey/ Hydrological and Meteorological data collection/ analysis using modern techniques with experience in the use of GIS technology	Collection and inventory of primary hydrological and meteorological data, maps, information, and relevant available study report with geo-tagging. Check for data accuracy and completeness before entry.	4

10.0 <u>Duration and payment schedule under this project is given at Annexure 2.of the consultancy-</u>

The duration of the Consultancy shall be 09 (Nine) months.

Payment schedule under this project is given at Annexure 2

Annexure 1

PROJECT BACKGROUND

11.0 Kiul-Harohar River Characteristics

11.1 Description of Basin

The main river Kiul of the Kiul-Harohar system originates from an elevation of 605m east of Khajuri in Chotanagpur plateau at a Latitude of 24^0 23' N and Longitude of 86^0 10' E and flows in east direction close to the southern base of Gidheswari Hills. After that it flows taking north-easterly direction towards Lakhisarai and joins the river Harohar near Surajgarha in the district of Munger. The river basin consists of a number of small rivers like the Mohane, Dhanyan, Sukhna, Barnar, Damar, Nakti, Bajan, Ajan, Falgu etc. besides the rivers Kiul-Harohar. This river system is bounded by the Badua-Chandan system of the east, the Ganga on the North, the Chotanagpur plateau on the south and the Punpun river on the West.

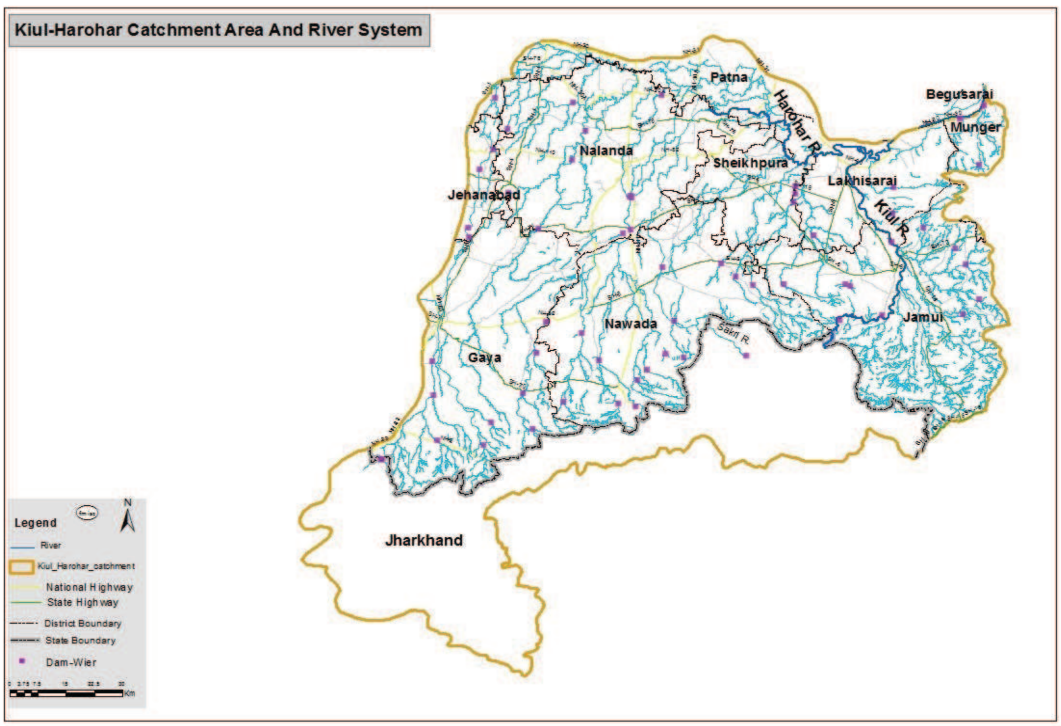

Figure 1: Kiul-Harohar catchment area

The Kiul-Harohar river system drains an area of 17,223 sq.km. The upper catchment of the river system lies in Chotanagpur Plateau area which is characterized by low hills and slopes with depression and valleys. Hills of these areas form a number of ranges. Country's general area south of Gaya rises gradually to a height of 600m and ultimately there is a rise of 1260m known as Parasnath. Formation of these is of Archean quartzite's and schists. Alluvial deposit of the Gangetic plain with maximum depth upto 1000m, forms the upper layer of the region beyond which lies the rocky basement. The deposits are clay either of sandy or calcareous grade of sand (1.25-0.125 mm), silt (0.06-0.0002 mm) and clay less than 0.0002 mm. Gravel and pebble deposits are found near the northern foot hills of the region.

Annexure 1

The Kiul-Harohar river system consists of a number of small rivers which during the course of flow bifurcate and rejoin meeting each other a number of times making it difficult to ascertain their exact length. River wise description of this river system as available from the previous records is given below.

11.1.1 Lilajan and Mohane (Falgu): - The river Mohane originates from the hills of Chatra district at an altitude of 914 m above MSL. After traversing through hills and forests for about 64 km, it crosses NH-2 (Grand Trunk Road) and enters the plains of Gaya district. After travelling a length of 40 km it receives Lilajan, a major tributary which originates in the hills of Chatra district at Latitude 24^0 11' N and Longitude 84^0 45' E at an elevation of 534 m above MSL and after traversing a distance of 85 km through hills and forests, crosses NH-2 (Grand Trunk Road) near Dobhi and travels a distance of about 29 km before joining the river Mohane. The combined river is known as the Falgu after the confluence of the Lilajan and the Mohane and travels in north ward direction up to Khizirsarai where it again bifurcates into two channels. The right channel is again known as the Mohane and the left channel is known as the Falgu. This river Falgu runs in northward direction where it is known as the Mahatmain and the Likain, ultimately as the Dhowa. Another right bifurcated channel from Ghosi is known by local names of the Jalwa and the Nona which again reunite with the Dhowa. The right branch of the Mohane river Joins the Bagahi river near Islampur and is again known as the Mohane in the downstream. The left branch of the Mohane joins the Jalwa river taking off from Falgu. This right channel known as the Mohane flowing further down for about 51 km embraces the river Paimar another important river of the basin, which originates from the foot hills of Hazaribagh near Paharpur Railway Station of Grand-chord section of the Eastern Railway before it enters the Bakhtiyarpur Tal and the combined river meets the Dhowa near Bakhtiyarpur. After this point, the combined river is again known as the Mohane.

11.1.2 A number of small streams mainly Manpur, Dhadhar, Tilaiya, Dhanarji and Khurji taking off from north of the Barakar valley in the micasive hills of Kodarma range in Girdih/ Hazaribagh district join together to form the Panchane. This Panchaneriver bifurcates into a number of channels a few km upstream of Biharsharif town known as the Goithawa, the Charsua and the old Panchane. The Charsua course again meets the old Panchane after flowing about 26 km below and joins the river Mohane in the middle reach.

11.1.3 The river Goithawa after flowing in the northward direction for about 29 km in a very flat country takes a turn in eastern direction and meets the two branches (the Jirain and the Kumbhari) of the river Sakri and the combined river below village Chhatarpur is known as the Dhanayan. The river Dhanayan flowing in the east for about 16 km meets the river Mohane at Trimohani and the combined river is known as the river Harohar.

11.1.4 Sakri-The river Sakri originates from the hills of Hazaribagh district at an elevation 365 m above MSL near village Tisri and after flowing for about 64 km in the thick forest and hilly tracts of Hazaribagh district, enters the plains of Gaya district near village Dumri. It crosses the Kiul-Gaya section of the Eastern Railway near village Paura which is about 9.6 km east of Nawada town. After flowing further down for about 19 km in the north, it branches off into the Jirain and the Kumbhari below village Dewaspur. As mentioned above, these two branches meet the river Goithawa and the combined river is known as Dhanayan.

11.1.5 Harohar- The Harohar is the biggest and the most important tributary of the Kiul Which joins it on the left bank, downstream of Lakhisarai. Its formation has already been described above. In the tail reach, the river Harohar flowing for about 16 km below Trimohani in a serpentine course, is joined by the river Tati. The river Tati originates from near Marui just on the east of Sakri valley and traverses adistance of about 51 km before it meets the river Harohar. The rivers Kaurihari, Baghel and Nata, taking off from Kauakol hills meet each other and the combined river below east of Sirari Railway Station of the Kiul-Gaya section of the Eastern Railway is known as the same. It flows further down for about 11 km in the north and meets the river Harohar near village Rapura in the tail reach.

11.1.6 Kiul- The river Kiul, which is the main outfall channel of this basin, rises in the hills of Chhotanagpur Plateau at an elevation of 605 m at Latitude 24^{0} $33^{'}$ N and Longitude 86^{0} $10^{'}$E. The river flows first in north westerly direction, then in easterly direction close to the southern face of the Gidheshwari Hills and then in a northerly direction. It then flows to north-westerly direction up to Lakhisarai. After Lakhisarai it turns in north-easterly direction and joins the river Ganga near Surajgarha in the Munger district, Bunhuni, Sukhnar, Barnar, Doharo, Nagi, Nakti, Bajan, Ajan and Morwe are the important tributaries joining the river Kiul on the right bank. The Harohar is the biggest and the most important tributary joining its left bank on the downstream of Lakhisarai. Its formation has already been dealt with earlier. The areas drained by the main rivers of the system are given below:

S.N.	Name of the river	Drainage Area(sq.km)
1	Falgu	5,281
2	Paimar	1,122
3	Sakri	5,500
4	Harohar	2,393
5	Kiul	2,927
	Total	17,223

(Source: - Second Bihar Irrigation Commission Report 1994, Volume –V, Part – II)

About 1062 sq.kmof the above area, lying in the lower zone of the system is Saucer Shaped and is commonly known as Mokama Group of Tals. It is a vast track of low lying land below a level of 45.72 m and is having width varying between 6.5 km to 17.6 km and is about 100 km long. The Mokama group of Tals comprises of seven well defined depressions namely Fatuha Tal, Bakhtiarpur Tal, Barh Tal, More Tal, Mokama Tal, Singhaul Tal and Barahiya Tal having an area of 52 sq.km, 168 sq.km, 132 sq.km, 215 sq.km, 124 sq.km and 171 sq.kmrespectively. Out of this 93 sq.kmarea consists of high lands which are submerged only during high floods. 788 sq.kmarea consists of very low land where only Rabi crop is possible and in the remaining 181 sq.kmarea it is possible to grow two crops.

The important places of Bihar & Jharkhand falling in the drainage area of the Kiul-Harohar river system are Hazaribagh, Nawada, Nalanda, Rajgir, Gaya, Barahiya, Mokama etc. The important commercial centres are Lakhisarai, Barh, Bakhtiarpur, Nawada, Hazaribagh, Gaya etc.

11.1.7 Details of the important rivers of the Kiul-Harohar river system are given below: -

	River	Bank (Left/Right)	Origin	Outfall	River Condition
	HAROHAR	Joins Kiul on left side		In the river Kiul on down stream of Lakhisarai	Functional as drainage channel
	KIUL	Right bank of the Ganga	East of Khajuri in Chotanagpur Plateau at Lat $25^{0}18^{'}10^{''}$ N & Long $86^{0}23'39^{''}$ E	In the Ganga on the downstream of Surajgarha	-do-
	MOHANE		Hills of Hazaribagh District	Meets the river Paimar near Dihra village in Bakhtiyarpur Tal	-do-
	FALGU		The river Lilajan&Mohane meet near Gaya to form the River Falgu	Known in lower reaches as the Dhowa, it ends in the Mokama Tal	-do-
	SAKRI		Near village Tesri From Chotanagpur Hills at Lat $24^{0}\,34^{'}$N Long $86^{0}8^{'}$E	It branches into river Jirain&Kumbhari which again combine with the river Goithwa to form the river Dhanayan. The river Outfalls in the river Mohane at Trimohani	-do-
	PAIMAR		It originates at Nearly 12 km south of Paharpur Rly. Station at Lat. $24^{0}29^{'}7^{''}$ N Long. $85^{0}\,14^{'}17^{''}$ E.	It outfalls in the river Mohane.	-do-

11.2 Flood Problem

Flood problem of Kiul-Harohar basin assumes a very serious nature during monsoon and inundates large area. Rivers like the Kiul, the Harohar, the Punpunetc. flow almost on the ridges in their lower reaches. The bank full capacity of these rivers is inadequate due to which they are unable to contain the flood discharges and as a result spilling takes place over their bank causing floods in the basin. At places such spills causing floods in the basin are prevented by Zamindari Embankments which are generally of inadequate section and incapable of withstanding even medium flood conditions.

Rivers of Kiul-Harohar basins are mostly in regime condition and are non-perennial in nature. Flooding in lower reaches takes place occasionally, due to spilling during monsoon season. Flood problem of the basin as identified so far are indicated below:

Annexure 1

1. The Kiul spills over its bank in the lower reaches near Lakhisarai, flooding the nearby areas.
2. The Sakri river which flows into the Harohar river is a shallow river and it carries a lot of silt. It also creates flood problem, occasionally, due to occurrence of flash floods in the river. Some local Zamindari embankments are existing on this river below Sakri Weir in which there are number of gaps and the flood water spills through these gaps.
3. The river Falgu also creates flood problem sometimes due to occurrence of flash flood.
4. The river Panchane also causes flooding sometimes due to inadequate capacity of its several bifurcated channels.

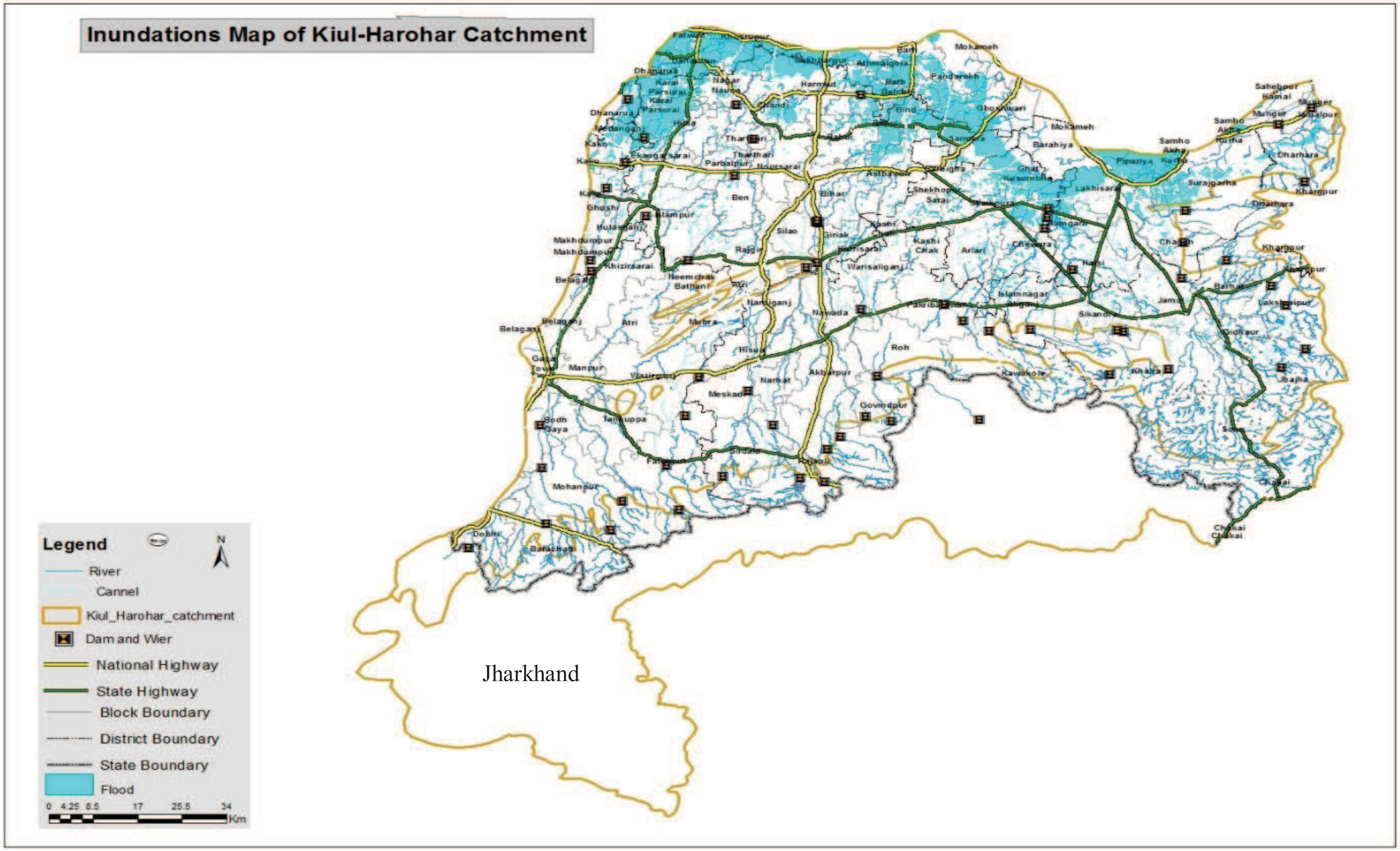

Figure 3: Flood Map of Kiul-Harohar

Annexure 1

11.2.1 Drainage Problem

The drainage problem in the Kiul-Harohar basin is confined to lower zone of the river system commonly known as Mokama group of Tals which consists of seven Tals covering an area of 1062 sq. km extending in a length of about 100 km from Fatuha in the West of the vicinity of Lakhisarai in the East. The width of the Tal varies from 6 km to 17 km. Though the Tal is continuous, it is differently named in its different reaches from west to east Tal, Bakhtiarpur Tal, Barh Tal, More Tal, Mokama Tal, Barahiya Tal and Singhaul Tal. The river Harohar is the master drain of the Tal areas. Though the main drainage slope of the Tal area is from west, it has got cross slope also from south to north up to the river Harohar. The strip of Tal on the north of Harohar cross drains from north to south. The topography indicates that the river Harohar flows in the valley of Tal areas. Several rivers that rise in the hills of South Bihar flow in the north-ward direction and join the river Harohar which is the master drain of the Tal.

During monsoon months, the Tal gets filled up with water due to inflow of rivers entering the Tal and congestion in drainage due to back water of the Ganga entering the Tal through the Kiul and Harohar rivers. Spill water of the river Punpun and the back water of the river Ganga through the river Punpun also enters the Tal from Fatuha end.

Due to submergence of the Tal area, optimum utilization of its land resources is hampered particularly during kharif season. The accumulated water of the Tal gets drained out by its natural drainage through the Harohar and the Kiul into the Ganga.

Tal areas do not get fully submerged every year. Kharif irrigation is practiced in peripherical areas of the Tal where depth of submergence is small. In fact, in some areas where irrigation facility has been created, even double crop, during both Kharif and Rabi season are being grown. Similarly, in a very limited area hot weather crop is also grown. The existing cropping pattern (on an average) for the entire Tal is given below:

Kharif	30.30 %
Rabi	65.54 %
Hot weather	4.13 %
Total	100.00 %

(Source: - Second Bihar Irrigation Commission Report 1994, Volume –V, Part – II)

More than 50% of Kharif area is reported to grow a second crop of Rabi also. Hot Weather crop is being grown in a very small area (4.16%). The cultivation of Kharif crop, second crop of Rabi in the Kharif area and the Hot Weather crops are dependent on rains, light submergence by the waters of the Tal and partially supported by State and Private tube wells. Rabi crop is grown in 65.54% of the Tal area on an average after its submergence is cleared by the 15th of October.

Due to continued submergence of most of the Tal areas, from July to September, it is not possible to grow any kharif crop in a vast area. Rabi cultivation is based on the residual moisture of the soil freed from submergence. If somehow drainage of the Tal is delayed beyond the 15th of October, the Rabi sowing is delayed and crop suffers. The above information of cropping pattern is based on the data obtained from

Annexure 1

Agriculture Department through the Chief Engineer, Master planning Organization of the Water Resources Department.

The area of Tals, ground elevation and range of highest water levels as observed between 1972 and 1991 are given below:

S.N.	Name of the Tal	Area in sq.km.	Ground Elevation in m	Highest Water levels as observed between 1972-91
1	Fatuha Tal	52.00	46.94 to 47.25	50.80
2	Bakhtiyarpur Tal	168.00	43.58 to 47.24	48.67
3	Barh Tal	132.00	42.06 to 46.02	47.30
4	More Tal	215.00	39.32 to 44.20	45.07
5	Mokama Tal	200.00	38.40 to 41.75	44.06
6	Barahiya Tal	171.00	38.70 to 41.65	43.10
7	Sighaul Tal	124.00	38.40 to 39.62	43.10
Total		1062.00		

(Source: - Second Bihar Irrigation Commission Report 1994, Volume –V, Part – II)

The difference in the lowest ground level of the Tals from west to east is 8.54 m. Similarly, the difference in highest ground levels is 7.63 m and difference in highest water levels is 7.70 m. Thus, land and water slopes are nearly the same.

The total combined capacity of the various Tals at HFL, which varies from RL 50.80 m in FatuhaTals to RL 43.10 m in Barahiya Tal (Average level of Tal during highest flood is about 46.025 m) is approximately 4.37 Lakh ham. Capacity of each Tal separately is noted below:

S.N.	Name of Tal	Capacity in ham at highest water level
1	Fatuha Tal	6562
2	Bakhtiyarpur Tal	7968
3	Barh Tal	22030
4	More Tal	85777
5	Mokama Tal	104994
6	Barahiya Tal	112025
7	Sighaul Tal	97495
Total		436851 Say 4.37 Lakh ha.m

(Source: - Second Bihar Irrigation Commission Report 1994, Volume –V, Part – II)

Annexure 1

12.0 Mahananda Basin Characteristics

12.1 Origin of River Mahananda

The river Mahananda is a major northern tributary of the river Ganga passing through Nepal, India (Bihar & West Bengal) and Bangladesh. The Mahananda originates from Mohalidram hills of the Himalayas at Chimali at an altitude of 2060 m at north latitude 26^{0} $58^{'}$ and east longitude 88^{0} 9’ and about 6.4 km north-east of Kurseong town in Darjeeling district of West Bengal. It is also known as Mahanadi river in its hilly catchment. After flowing 20 kms in the hills of Darjeeling, the river enters the plains near Siliguri. The river bifurcates into two branches near Bagdob. The right branch is known as the Phulhar Branch and outfalls into the Ganga shortly after entering into Bengal. The left branch is known as the Barsoi branch which, passing through Malda town, enters into Bangladesh to outfall in the Ganga (Padma). The Mahananda Basin is bounded on the north by the Himalayas, the ridges separating it from the Tista river system in the east, the Ganga on the south and Kosi river system in the west. Important places of Bihar falling in the drainage area of river Mahananda are Kishanganj, Barsoi, Bahadurganj, Thakurganj, Araria, Purnea and Katihar as shown in the Figure below.

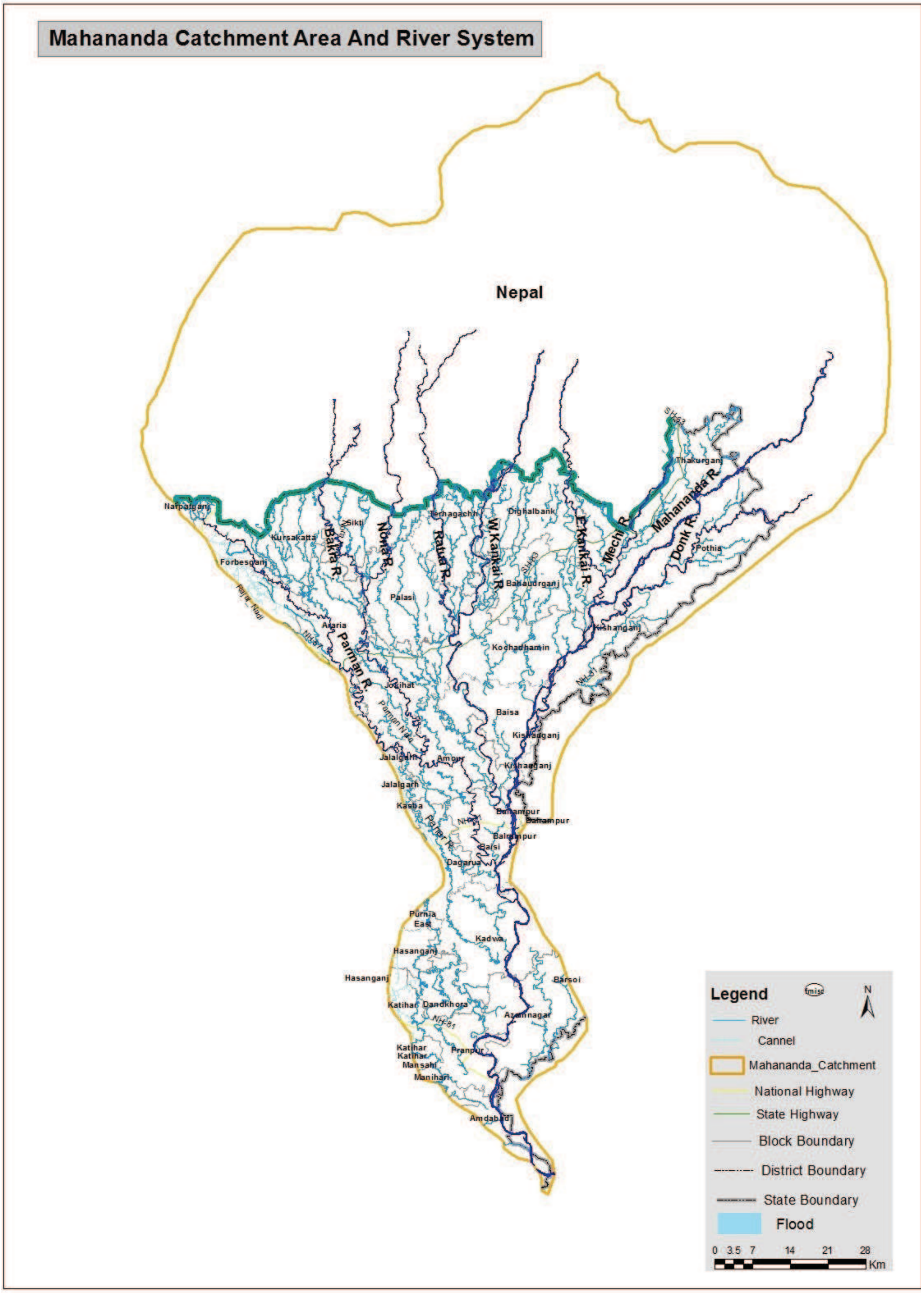

Figure 3: Mahananda River System

It drains a total catchment area of 23,700 sq. Km over a length of 376 km of which 16,100 sq.km lies in India, 4500 sq.km in Nepal and the balance 3100 sq.km in Bangladesh. In India about 6340 sq.km lies in Bihar and 9760 sq.km in West Bengal. The Catchment receives most of its rainfall during the south west monsoon season from June to September. The average rainfall in the river system in India is about 115 cms. The normal annual rainfall recorded at Kurseong close to the origin of the Mahananda is 405.23 cms and at Malda is 145.31 cms. From its origin near Chimali in the Mahalidran hills to its confluence with Ganga (Padma). The western course, known as Phulhar (Jhaua) branch, carries on an average about 75 % of the total discharge of Mahananda river. The eastern branch known as Barsoi branch carries the remaining discharge.

The river Barsoi after bifurcating from the Mahananda travels in south easterly direction through Sudhani, Barsoi, Kachna and is joined by the river Nagar at Jugiamer and travels uptoSubarnapur. The Barsoi branch also bifurcates into two channels, down-stream of Barsoi, one is the active channel eastern channel and the other is the dying western channel. Both these channels again meet on the upstream of Subarnapur. The Phulhar branch ultimately flows into the Ganga at Surmara. The Kalindri takes off from the Phulhar at short distance upstream from its outfall into the Ganga. The Kalindri which has a rather tortuous course ultimately falls into the Barsoi branch near Nimasarai R.S.

12.2 Tributaries of River Mahananda

The important right bank tributaries of the Mahananda are the Balason, the Mechi, the Eastern Kankai, the Western Kankai, the Panar (Parman), the Bakra, the Kalindri etc. and the left bank tributaries are the Nagar, the Tangon, the Punarbhaba etc. Contrary to the main Mahananda, the right bank tributaries have significant catchment in Nepal. Between Lava and Bhalika, the Phulhar branch forms the border of West Bengal and Bihar.

River Balason joins this river below Siliguri on its right bank upstream of Sonapkur hat, the Chenge joins the Mahananda on its right bank about 3.2 km upstream at Taibpur railway bridge, the river Mechi joins on its right bank near Rupadpur. Another stream Donk meets on its left bank near Belwa Village. The Eastern Kankai, a major tributary joins the Mahananda on the right bank near Kuttighat at about 0.60 km downstream of its crossing with Kishenganj-Bahadurganj PWD Road and the Western Kankai joins about 3.2 km upstream of Dhengraghat road bridge on NH 31.

The Barsoi branch is joined by Mara Mahananda at Pirganj and then it is augmented by a major tributary, the Tangon at Aiho, thereafter, the Mahananda flows into Bangladesh and joins Ganga (Padma) at Godagarighat.

Details of different rivers of the Mahananda drainage basin in India are: -

Sr.No.	River	Bank (Left or Right)	Out fall river
1.	New Balason	Right	Mahananda
2	Old Balason	Right	Mahananda
3	Mechi	Right	Mahananda

Annexure 1

4	E. Kankai	Right	Mahananda
5	W. Kankai	Right	Mahananda
6	Nagar	Left	Out fall into Barsoi Branch
7	Kulik	Left	Out fall into Nagar
8	Gamari	Left	Out fall into Barsoi Branch
9	Tangon	Left	Out fall into Barsoi Branch
10	Parman	Right	Out fall into Bagdob

(Source: - Second Bihar Irrigation Commission Report 1994, Volume –V, Part – II)

12.2.1 River Morphology and River Behavior

The river Mahananda and its tributaries experience frequent shifting of their courses in the plains inherent with high silt load in these rivers. The quantitative study of the morphology of the river Mahananda viz. aggradation/degradation of river channels erosion of bank, effects of flood control works on the river regime etc. could not be made due to lack of appropriate data base. However, it can be seen that the Mahananda river and its tributaries had been subjected to vast change in their courses from the past to the present. All these rivers are gradually aggrading and there is large scale meandering and channel deviation in many reaches. Deposition of sediment in the bed is huge. The bank full capacity of the rivers is nowhere sufficient to take high flood discharges. The bank erosion is a common feature in the main Mahananda as well as in the tributaries East Kankai, the West Kankai, the Dauk and the Parman. The bifurcation of the Mahananda into the Phulhar branch & the Barsoi branch is the natural manifestation of typical morphology of the river

12.2.2 Flood and Drainage problem

The main problem in the river system is spilling over banks, shifting of river course and erosion of banks etc. during the monsoon season heavy precipitation in the Himalayan catchment of the tributaries the Parman, Bakra, the Western Kankai, the Eastern Kankai and the Mechi brings flash floods downstream in these rivers in Bihar with very high velocities. The flood waters often bring huge quantities of detritus and deposit them in the upper reach as well as in the plains reducing the bankfull capacity. The floods in excess of the bank full capacity spill over its banks and inundate vast areas. Poor outfall condition of the Mahananda into the Ganga and the back-water flow often causes prolonged drainage congestion. The flood water of the Ganga itself used to enter into the catchment in lower reaches causing wide spread damage but large-scale construction of embankments have checked this phenomenon. With the construction of flood embankment in Bihar and West Bengal along both banks of the Phulhar branch and the right bank of Barsoi branch, the areas falling behind these embankments have been protected from the flood spilling but intensive and extensive flooding in more aggressive form is often experienced along the un-embanked left bank of the Barsoi branch in Bihar as well as in West Bengal portion.

Annexure 1

Inadequate waterways under rail and road bridges lead to drainage congestion, besides causing heavy damages to the roads and railways themselves. Such inadequacies should be identified after taking up detailed surveys and investigations and further action to remove thesebottlenecks may be taken on the basis of their technical feasibility and economic viability.

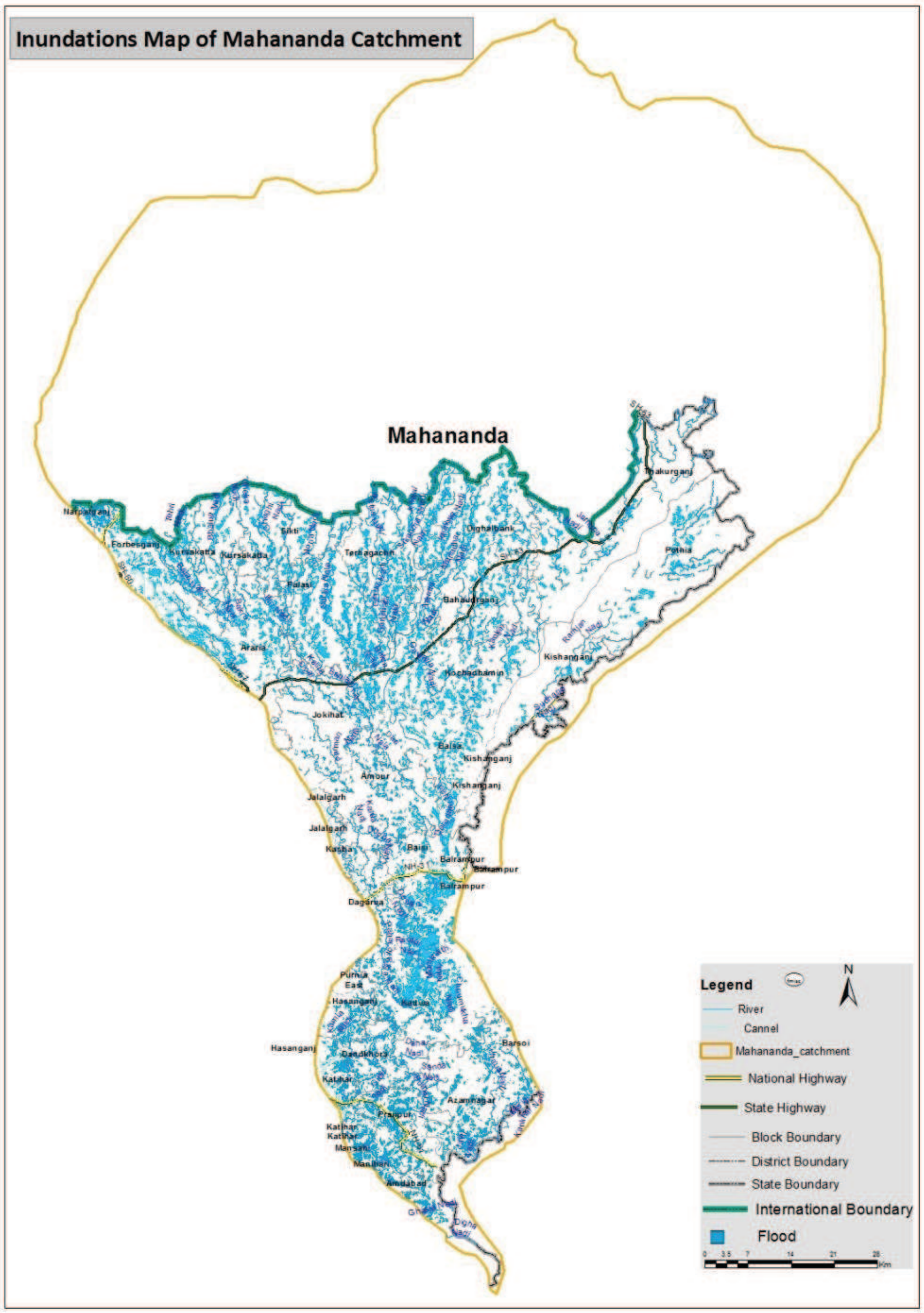

Figure 4: Inundation Map of Mahananda Catchment

Annexure 2

Payment Schedule

A. 10% after submission and approval of the Inception Report by NHP-SRC.

B. 10% after submission and approval of Interim Report 1 by NHP-SRC.

C. 30 % after submission and approval of Interim Report 2 by NHP-SRC.

D. 20% after submission and approval of the Draft Final Report by NHP-SRC.

E. 30% after submission and approval of the Final Report by NHP-SRC.

संयुक्त निदेशक
जल विज्ञान निदेशालय
जल संसाधन विभाग, अनिसाबाद, पटना।