Environmental Impact Assessment

October 2018

India: Assam Power Sector Investment Program Tranche 3

Supplementary EIA Volume 3

Prepared by Assam Power Generation Corporation Limited (APGCL), Government of Assam for the Asian Development Bank. This is an updated version of the draft originally posted in April 2018 available on https://www.adb.org/projects/documents/ind-47101-004-eia

Ensuring Safeguards Compliance

LOAN 3327 IND

ASSAM POWER SECTOR INVESTMENT PROGRAM – TRANCHE 2

Consulting Services for Supplemental Environmental Assessment for Lower Kopili Hydropower Project

Final Report

(Volume 3 - Integrated Water Resources Management Plan Report)

Submitted to:

Assam Power Generation Corporation Limited

INDIA

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ABBREVIATIONS

ADB	Asian Development Bank
AMD	acid mine drainage
AIFRERM	Assam Integrated Flood & River Erosion Risk Management
APGCL	Assam Power Generation Company Limited
APDCL	Assam Power Distribution Company Limited
APSIP	Assam Power Sector Investment Program
ASDMA	Assam State Disaster Management Authority
ASEB	Assam State Electricity Board
AWRMI	Assam Water Resources Management Institute
BB	Brahmaputra Board
CAT	catchment area treatment
CEA	Central Electricity Authority
CGWB	Central Ground Water Board
CIA	cumulative impacts assessment
CWC	Central Water Commission
DEM	digital elevation model
DPR	detailed project report
EIA	environmental impact assessment
EMP	environmental management plan
FREMAA	Flood & Riverbank Erosion Management Authority of Assam
GoA	Government of Assam
GoI	Government of India
IMD	India Meteorological Department
IPCC	Inter-governmental Panel on Climate Change
IWRMP	integrated water resources management plan
LKHEP	Lower Kopili Hydroelectric Project
MDoNER	Ministry for the Development of the North Eastern Region
MES	Ministry of Earth Sciences
MoEFCC	Ministry of Environment, Forest and Climate Change
MPGCL	Meghalaya Power Generation Corporation Limited
MWR	Ministry of Water Resources
NABARD	National Bank of Agriculture and Rural Development
NDMA	National Disaster Management Authority
NEC	North Eastern Council
NEEPCO	North Eastern Electric Power Corporation
NEHARI	North Eastern Hydraulic and Allied Research Institute
NER	North Eastern Region
NESAC	North East Space Application Center
NRSA	National Remote Sensing Agency
NWP	National Water Policy
PMKSY	pradhan mantri krashi sichai yojna
RBA	Rastriya Barh Ayog
RBO	River Basin Organization

SEA	supplemental environmental assessment
SHP	small hydropower policy
SRTM	Suttle Radar Topographic Mission
TAC	Technical Advisory Committee
WRD	Water Resources Department

1. INTRODUCTION

1.1 Background

1. On July 03, 2014 ADB Board approved a Multi-tranche Financing Facility (MFF) to the Government of Assam (through Government of India) for the Assam Power Sector Investment Program (APSIP). The APSIP aimed to finance a portion of the power sector investment plan for generation and distribution of the Government of Assam (GoA). The APSIP objectives are to increase capacity and efficiency of power generation and distribution systems in the State of Assam and to reduce load shedding while meeting growing demand for power in the region. The investment program's impact will be to increase availability of electricity in Assam. The outcome will be increased capacity and efficiency of energy generation and distribution systems in Assam.

2. The investment program is estimated to cost US$430 million. On Government request, ADB provided MFF in an amount up to US$300 million from ADB's ordinary capital resources to help finance a part of the investment program. The MFF comprise three tranches. Tranche 1 for US$ 50 million (Loan 3140-IND) was approved on 11 July 2014 and became effective on 12 May 2015; it includes replacement of an aging, inefficient gas plant, and project implementation support and capacity development support to Assam Power Generation Corporation Limited (APGCL). Tranche 2 for US$ 48 million (Loan 3327-IND) was approved on 23 November 2015 and the loan was signed on 07 November 2016; it includes expansion and upgrading of the power distribution system in the state of Assam, and strengthening institutional capacity of Assam Power Distribution Company Limited (APDCL). The Government is planning to submit PFR 3 for Tranche 3; it includes financing for the 120 megawatt (MW) Lower Kopili Hydroelectric Project (LHEP).

3. The detailed project report (DPR) for the Lower Kopili HEP has been prepared by APGCL including an EIA as per Government of India requirements. The draft EIA report has been reviewed by ADB and existing issues were identified which require action by APGCL before the project can be funded under the Investment Program.

4. Draft EIA prepared by WAPCOS (October 2016) requires three additional components in order to be finalized: a Cumulative Impacts Assessment (CIA), an Integrated Water Resources Management Plan (IWRMP) and a Water Quality Restoration Plan including a mitigation strategy.

5. This document is part of the main report on supplemental environmental assessment for the Lower Kopili Hydropower project, which focuses on the Integrated Water Resources Management Plan (IWRMP).

6. An additional Terms of Reference (ToR) was issued by the Ministry of Environment, Forest and Climate Change (MoEF&CC) of India for the EIA, which included cumulative impact of operation of the LKHEP and existing HEP development. The EIA is also required to fulfill ADB requirements for sustainable hydropower. Following review of WAPCOS EIA, ADB and APDCL/APGCL identified additional studies required to complete the EIA to meet GoI and ADB's requirements. APDCL invited consulting services proposals for Supplemental Environmental Assessment (SEA). Subsequently, ES Safeguards Compliance Services Private Limited, India was retained by APDCL/APGCL as Consultant to undertake 'Consulting Services for Supplemental Environmental Assessment for Lower Kopili Hydropower Project'. The consultant worked with APGCL and other assisting consultants and conducted the Supplemental Environmental Assessment as detailed in the consultant's ToR. The

supplemental environmental assessment consulting services is being financed under Tranche 2 of the MFF. Lower Kopili Hydropower Project is proposed for financing under Tranche 3 of the Assam Power Sector Investment Program.

1.2 Objective of the IWRMP component

7. The main objectives of the assignment are (i) to provide further inputs to incorporate IWRMP consideration into the LKHEP environmental impact assessment (EIA) and environmental management plan (EMP) so that any downstream impacts on water uses and water users are adequately mitigated; inputs to the EIA and EMP should include (i) recommendations for mitigating and/or adapting to the possible effects of climate change and other potential threats to water availability, and (ii) to provide advisory services to the Government of India and Government of Assam agencies in updating the current master plan of the Kopili River to incorporate IWRMP considerations in order to provide a robust direction for sustainably managing and developing the Kopili River for multisectoral needs. The updated IWRMP will provide a framework for improving the livelihoods of the people living in the Kopili River basin through equitable, environmentally and socially sound options for management and development of water resources for maximum economic benefit.

1.3 Scope of the IWRMP Study

8. The updated IWRMP will cover development of the Kopili River for multiple purposes including hydropower, irrigation, drinking water supply, etc., through the assessment of water supply and demand within the basin with due consideration of downstream flow requirements and overall sustainability. The IWRMP will outline appropriate mechanisms to manage and maintain the Kopili River system for multiple purposes in a sustainable manner. The consultants will assist the Brahmaputra Board, the Assam Water Resources Department, and other relevant agencies in document review, data analysis, and stakeholder consultations to facilitate IWRMP development, and provide inputs to the EIA and EMP as noted above.

1.4 Major Tasks

9. The major tasks stipulated in the ToR related to the IWRMP components are:

- Review available Kopili River basin plans including sub-basin and sectoral plans prepared by the Brahmaputra Board, Assam Department of Water Resources, other government agencies, non-government organizations (NGOs), and other entities as provided by GoA/APGCL/APDCL;
- Examine the existing institutional and regulatory arrangements on river basin management;
- Review the existing plans on natural resources conservation in Assam and identify any gaps in relation to sustainable management of Kopili River basin;
- Review the Government of India National Water Policy 2012, state-level policies, legislations, and the current institutional framework on water resources development and management, to confirm that the LKHEP project is being implemented in accordance with IWRM principles;
- Review available information and data on existing, identified potential and planned irrigation, water supply, flood control, and hydropower including all sites licensed for hydropower development, and other water use systems prepared and proposed by different government agencies, NGOs, private sector, etc. for Kopili River system or other adjacent river basin that may affect the Kopili River basin;

- Study and analyze the power development plans of Assam, and hydropower- related policy principles and programs such as the Assam Small Hydropower Development Policy 2007;
- Review irrigation plans and all available documents related to irrigation policy, irrigation development options, water requirements and water use efficiency improvements, water conservation initiatives, to determine the potential impacts that LKHEP may have on future irrigation activities;
- Analyze the water supply plans, policies, and programs, prepared by the Government of Assam, Government of India, NGOs, and other relevant agencies provided by GoA/APGCL/APDCL;
- Identify and assess current land use and development in the Kopili River basin, map the areas of soil erosion, deforestation, and other types of land degradation; and areas suitable for agriculture;
- Assess current use and potential water development in the Kopili River basin in relation to existing, planned, or estimated water use based on at least 20-year planning horizon. Include potential water uses such as domestic, industry, hydropower projects, agriculture and irrigation, religious, cultural, recreation or tourism, environmental use, and other existing and/or potential beneficial uses.
- Identify and assess the water development and management options for the Kopili River basin;
- Review any policies or legal requirements on environment, biodiversity conservation or climate change requiring water from the Kopili River basin;
- Review the current and future water balance of the Kopili River and major tributaries (or perennial feeders) at every confluence to another river and at other appropriate locations such as water diversion point; and,
- Provide recommendations on the management, regulatory, monitoring requirements, and essential actions such as capacity-building needs for the sustainable implementation of the updated IWRMP.

1.5 Project Description

10. The proposed LKHEP will receive water from (i) tail race outlet from the existing Kopili power plant, (ii) incremental flow from the river catchment area between Khandong dam and the proposed LKHEP dam near Longku, and (iii) any reservoir releases (“spill”) from Khandong and Umrong reservoirs. LKHEP is designed as a hybrid run-of-river and storage design. During high flow season it will operate on a run-of-river basis, but in low flow season it will store water during the day and then release flow and generate power during the evening peak demand period. This design and variations thereof are common in India, and are generally referred to there as run-of-river with daily storage.

11. LKHEP is designed to have a total capacity of 120 MW in two power plants: the main power plant is rated at 110 MW and the auxiliary power plant is rated at 10 MW. The main power plant will receive water diverted at the dam, while the auxiliary power plant is located at the toe of the dam harnessing the environmental flow. The main power plant is expected to operate at full capacity (base load) during the high-flow season, and operate in peaking mode during the low-flow season. The auxiliary power plant will operate throughout the day, when water is released from the bottom of the dam to maintain the environmental flow. Power output will be evacuated to the existing Sankardevnagar substation (Figure 1-1). Figure 1-2 shows the LKHEP Layout map.

1.6 Organization of Report

12. The remainder of this report includes:

- The Kopili River Basin (Chapter 2)
- Water Resources Development & Flooding Issues (Chapter 3)
- Review of Kopili River Basin Plans (Chapter 4)
- Data Collection & Review (Chapter 5)
- Land Use analysis & watershed Restoration (Chapter 6)
- Review of Policy & Legislation (Chapter 7)
- Review of Institutions (Chapter 8)
- Water Resources systems analysis (Chapter 9)
- Integrated Water Resources Management Plan (Chapter 10)
- References
- Appendices

Figure 1-1: LKHEP Location Map

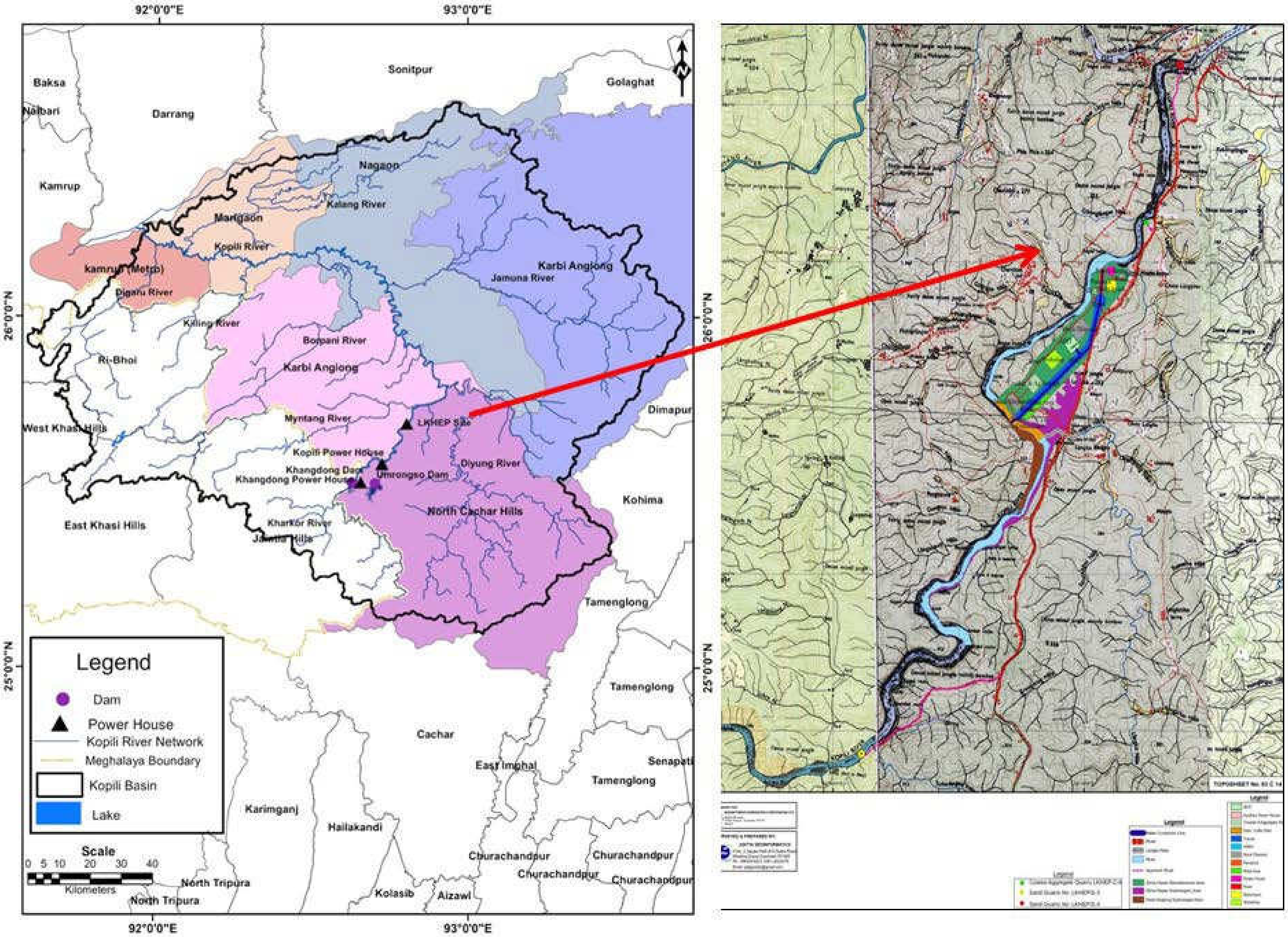
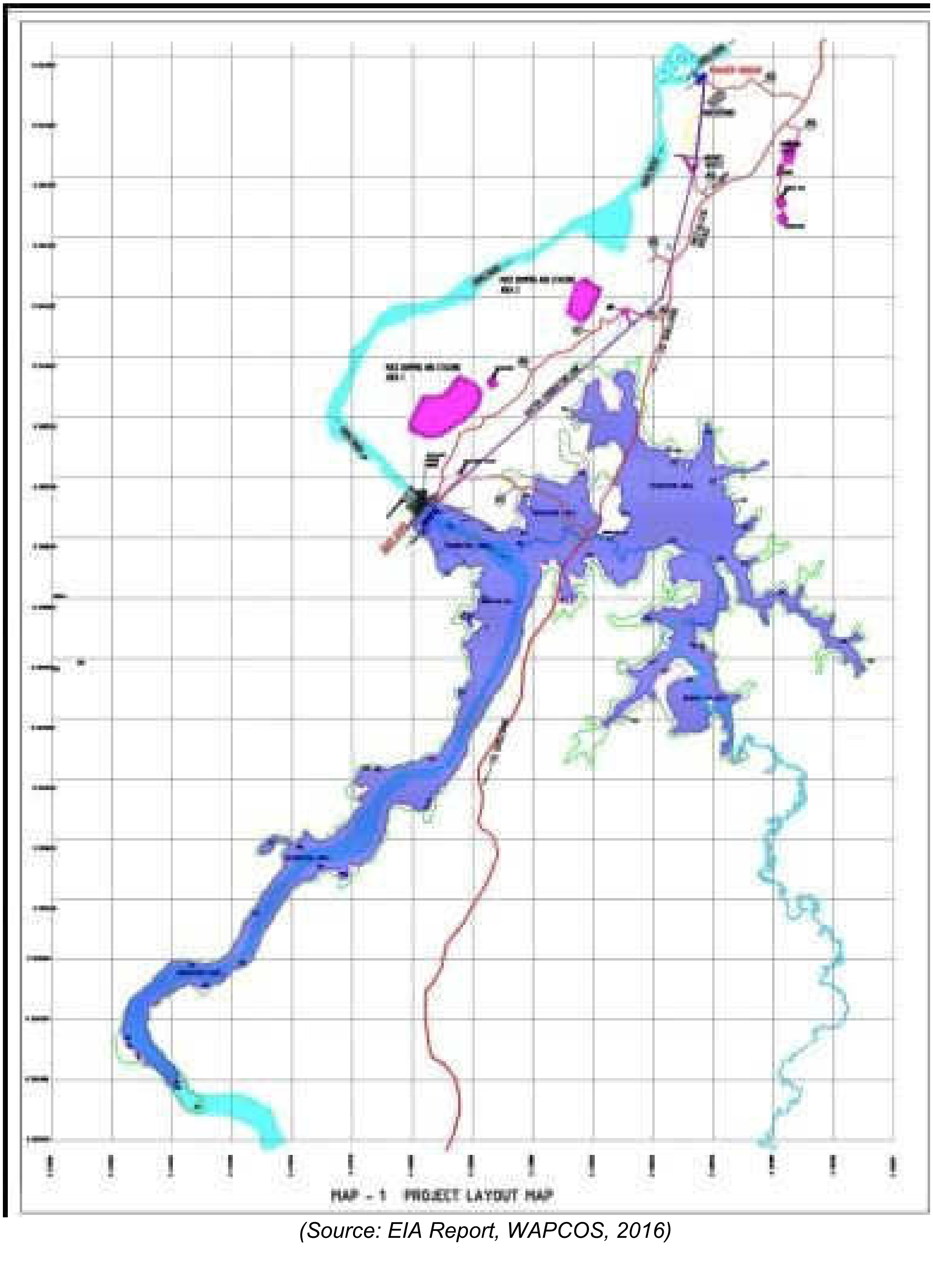


Figure 1-2: Project Layout Map



(Source: EIA Report, WAPCOS, 2016)

2. THE KOPILI RIVER BASIN

2.1 Physical Context

13. The Kopili River is one of the major river systems of the Brahmaputra. About three fourth of the basin area lies in the hills and balance is in the plains. The hill catchment is mostly covered by dense forest. The plains catchment is a fertile agricultural land with elevation ranging from 150m to 50m to the confluence of the Brahmaputra.

14. Kopili is a south bank tributary of Brahmaputra which originates in the Borail range mountains in Meghalaya at an altitude of about 1600 m and has a total length of 290 km up to its confluence with Brahmaputra. Its basin is bound by the Jaintia Hills in the west and the South Cachar and Mikir Hills in the east. Kharkor, Mynriang, Dinar, Longsom, Amring, Umrong, Longku and Langkri are its major tributaries in its upper reaches.

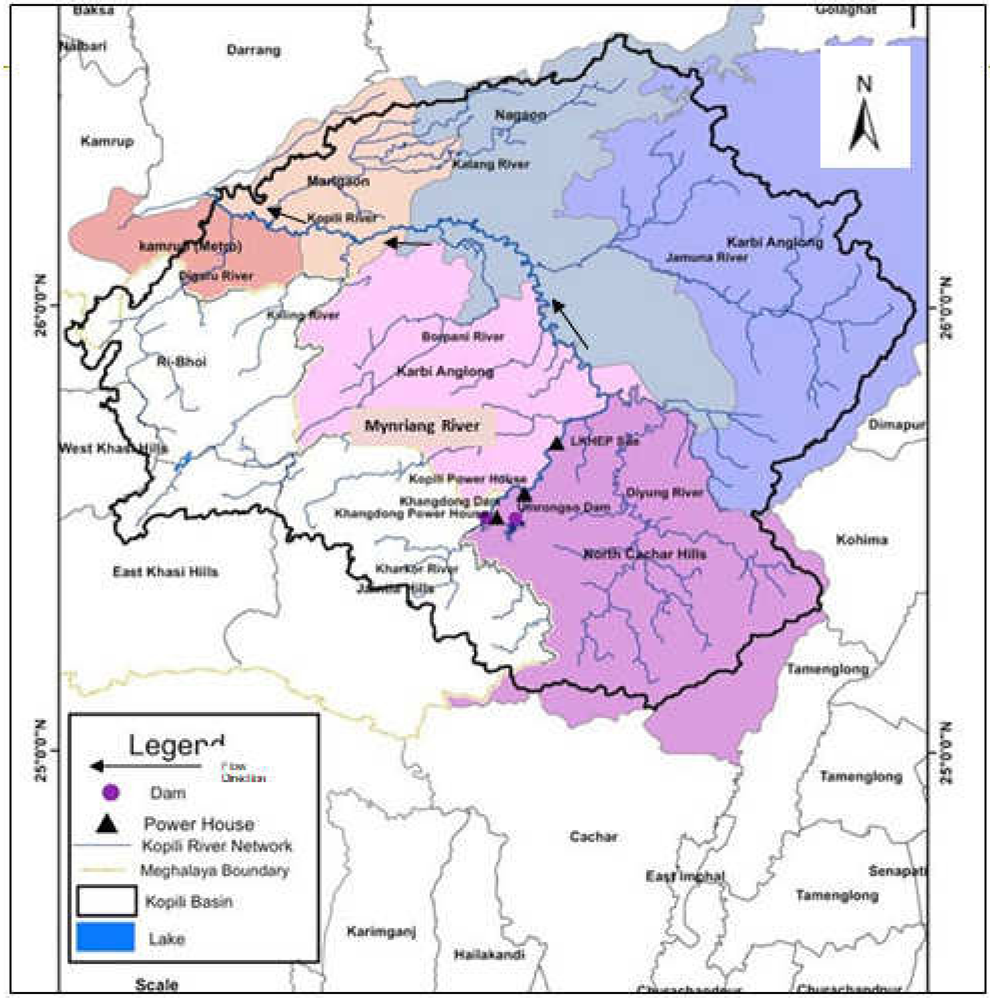
15. After entering Assam the Kopili separates the Karbi Anglong district from the Dima Hasao (North Cachar Hills) district up to its confluence with Diyung River on its right at 135 km. After the confluence with Diyung, Kopili flows into the Nagaon district in a north- westerly direction. The Jamuna River with a catchment of 3946 km^2 flows to the Kopili at Jamunamukh. The river then flows in western direction, and further downstream, the Umkhen-Borapani River which rises in the Shillong plateau and drains an area of 1821 km^2 joins Kopili at a distance of 220 km from the left in the east. The Killing River, known as Umiam in its upper reaches draining an area of about 1355 km^2, flows into Kopili from the left at about 234 km. The Kopili River finally flows to Kallang, a spill channel of Brahmaputra, near Hatimukh after traversing a distance of 290 km. The total catchment of Kopili River is about 20,997 km^2.

16. The major tributaries of the Kopili River are, as shown in Figure 2-1: Diyung, Jamuna, Mynriang, Borpani, Killing and Kallang. The basin covers four districts of Assam, namely Dima Hasao (North Cachar hills), Krabi Anglong, Nagaon and Morigaon. The river originates from Jaintia hills and its tributaries drain the West Khasi hills of Meghalaya. Table 2.1 shows the area distribution of the tributaries.

Table 2-1: Catchment area of the Kopili River basin (tributaries and key locations)

Sub-catchment / tributary	Distance from origin (km)	Area (sq.km)	Cumulative Area (sq.km)
Head water catchment	0	403	403
Kharkar River	70	509	912
local nalas and catchment up to Khandong dam	0-80	341	1253
LKHEP dam site	90	757	2010
Mynriang River	125	898	2908
Diyung River	135	3887	6795
Jamuna River	165	3946	10741
Borpani River	220	1821	12562
Killing River	234	1355	13917
Kallang River	243	1891	15808
Digaru, Titamari channel & lower floodplain	243-287	1709	17517
Kopili River channel	290	3480	20997
TOTAL	**290**	**20,997 km^2**	**20,997 km^2**

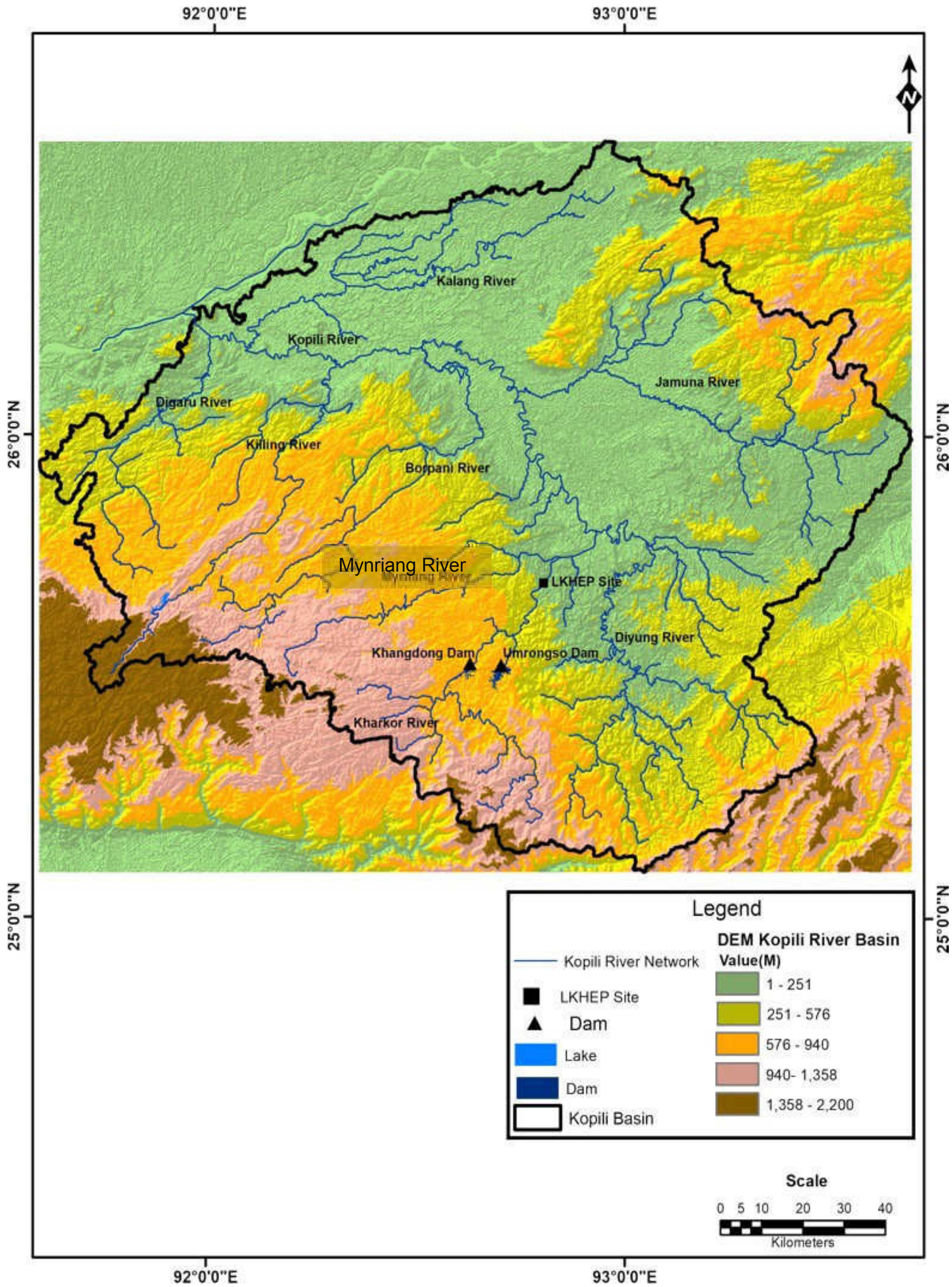
Figure 2-1: The Kopili River basin showing major tributaries and districts of Assam



17. Figure 2-2 shows the topographic map of the Kopili River basin based on the downloaded Digital Elevation Model (DEM) provided by at the Suttle Radar Topographic Mission (SRTM) of NASA– https://www2.jpl.nasa.gov/srtm/

18. A detailed analysis of the basin drainage system was carried out using GIS to delineate the sub-catchments and drainage system of the basin as shown in Figures 2-3 and 2-4 respectively.

Figure 2-2: The Kopili River Basin Digital Elevation Model



(Source:https://www2.jpl.nasa.gov/srtm/)

Figure 2-3: Sub-watersheds of the Kopili River basin

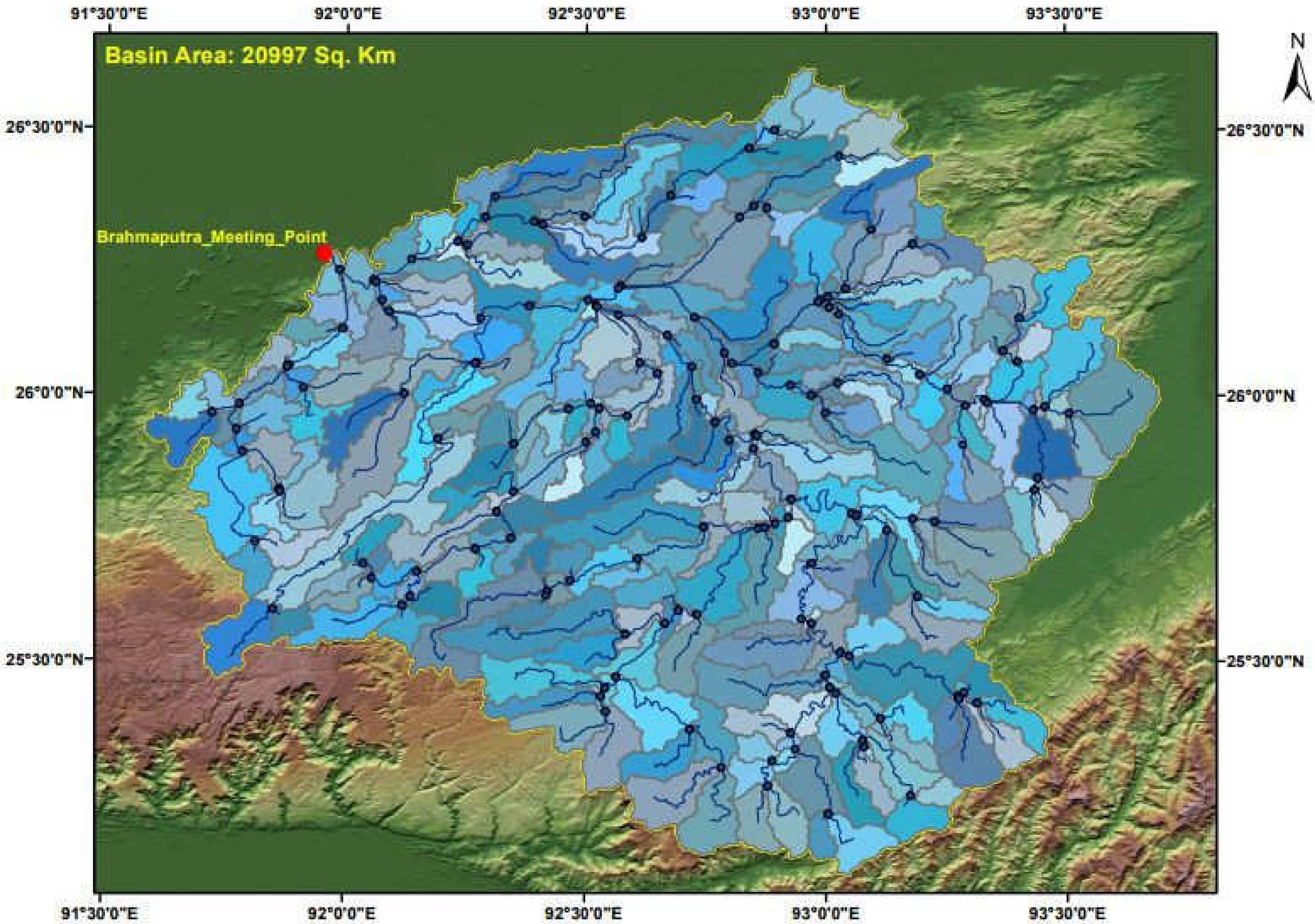
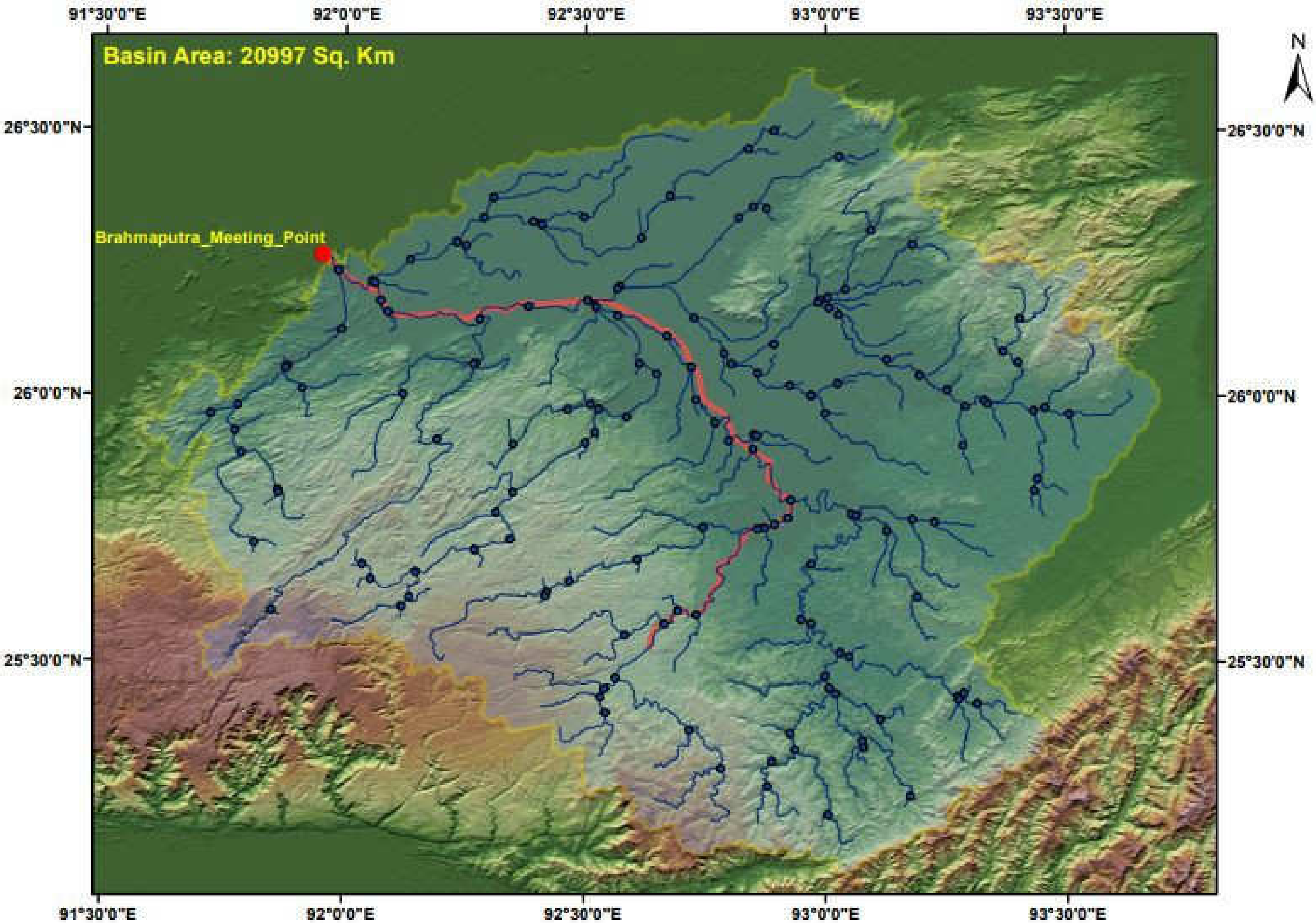
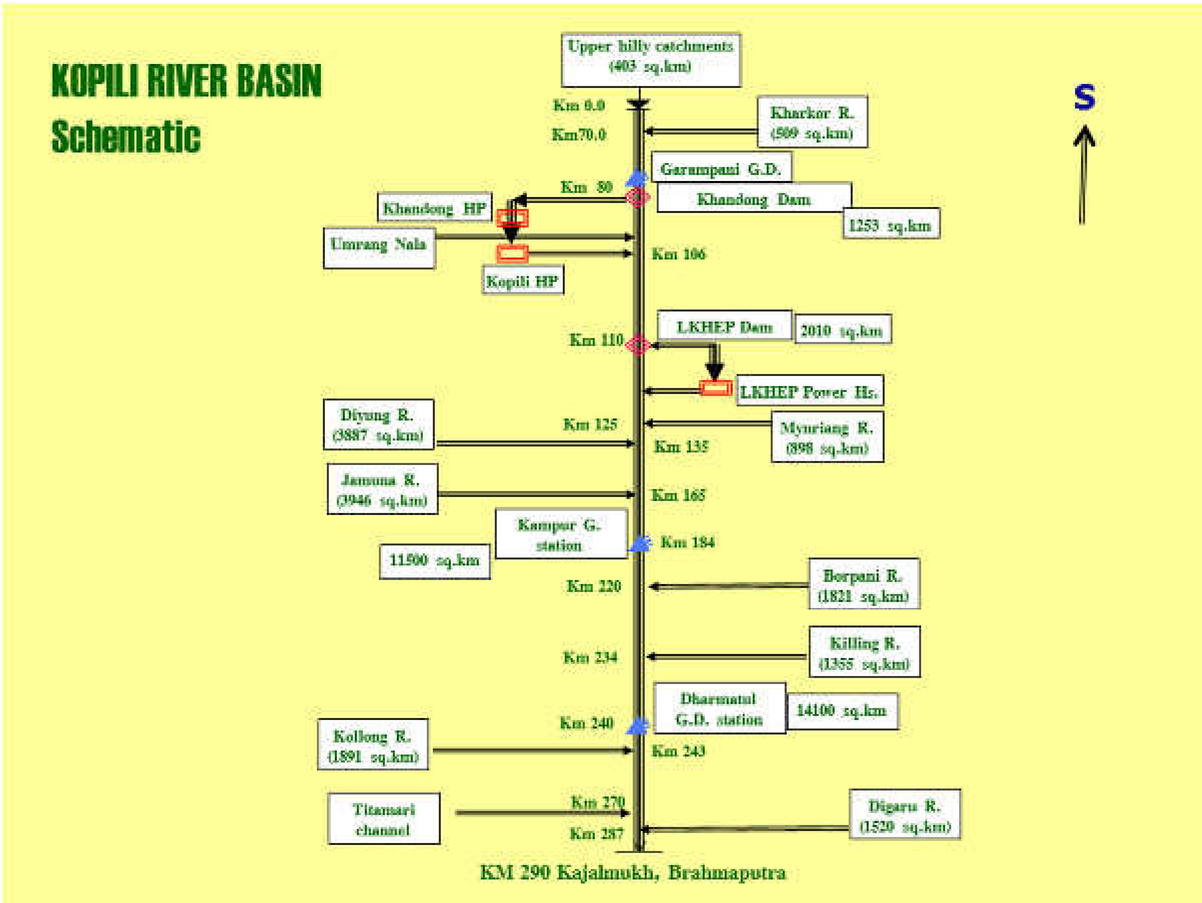


Figure 2-4: Drainage system of the Kopili River Basin



19. Based on GIS analysis, a schematic of the Kopili river system has been developed as shown in Figure 2-5.

Figure 2-5: Kopili River Basin Schematic



2.2 The Socio-economic Context

2.2.1 Population

20. The sub basin population has been calculated by the proportionate area basis. As per 2011 census, population of the sub basin has been estimated to be about 4,488,061 persons against the 3,080,841 persons estimated in year 1991. The district wise distribution of the population in the sub basin is shown in the Table 2.2. Plain area has a high density of population while hilly area is sparsely populated, for example, population densities in the Nagaon and Morigaon districts are 664 and 901 persons per sq.km., respectively. These figures are much higher than the overall average of Assam which is about 398 persons per sq.km. The overall average density of population in the Kopili basin is estimated as 422 persons per sq.km. Table 2.3 and Figure xx shows population of important towns in the basin.

21. The total urban population in the year 2011 was only 480,344 against the 391,625 estimated in year 1991 which is approximately 10.7% of the total population of the sub basin. The rural population constitutes about 89.30% of the total population in the sub basin.

Table 2-2: Population of districts within the Kopili Basin

State	District and Area (sq.km)	Percentage of District falling in the sub basin	Population of District (In No.)	Population of the sub basin for the year 2011 (In No.)	Population Density
Assam	1- Nagaon & Marigaon (5535)	70.65%	3781191	2671411	664
	2-Kamrup (4345)	14.95%	2771480	414336	901
	3-Karbi Anglong (10434)	69.96%	956313	669037	92
	4-NC hills (4888)	77.94%	214102	166871	44
Meghalaya	5-East Khasi Hills (5196)	44.84%	824059	369508	300
	6-West Khasi Hills (5247)	1.27%	385601	4897	73
	7-Jaintia Hills (3819)	52.36%	366694	192001	160
Total Population in Sub Basin				4488061	

(Source: census of 2011- Statistical handbooks of Assam and Meghalaya).

Table 2-3: Population of towns located in the Sub Basin

S.No	Town	Population as per 2011 census
1.	Nagaon (M.B.)	117722
2.	Lumding (C.T)	22658
3.	Hojai (M.B.)	36638
4.	Lanka (T.C.)	36805
5.	Jagiroad (C.T.)	17739
6.	Dipu (T.C.)	61797
7.	Haflong (T.C.)	43756
8.	Shillong (M.B.)	143229
	Total	**480344**

22. Population projection has been done to estimate the basin population in year 2021, 2031, 2041, and 2050. Geometrical increase method of population projection has been adopted for population projection. Due to non-availability of district wise population data prior to 1971, census data of 1971, 1981, 1991, 2001 and 2011 have been considered for projection. Detailed estimation of projected population of the basin is summarized in Table 2.4 and illustrated in Figure 2-6, while Table 2.5 (Figure 2.7) shows the project population in the districts.

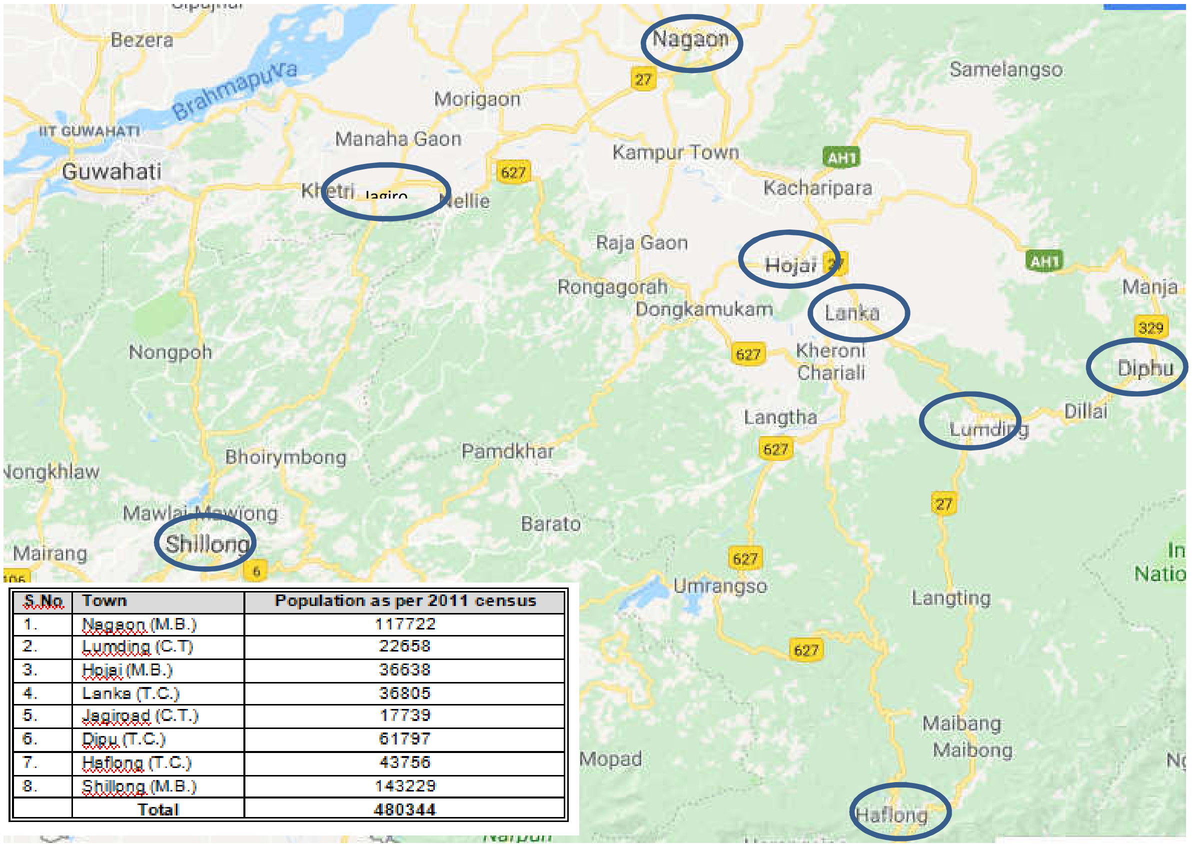
Table 2-4: Projected population in Kopili Sub basin

Year	Population	Decadal Increase	% Increase in Population	Remarks
1971	1591258	-		Geometrical Increase method is used for projects
1981	2489943	898685	56.48	
1991	3081844	591901	23.77	
2001	3710528	628684	20.4	
2011	4488062	777534	21.0	
		Avg. Decadal Growth %	**30.40**	

Table 2-5: District Population projections

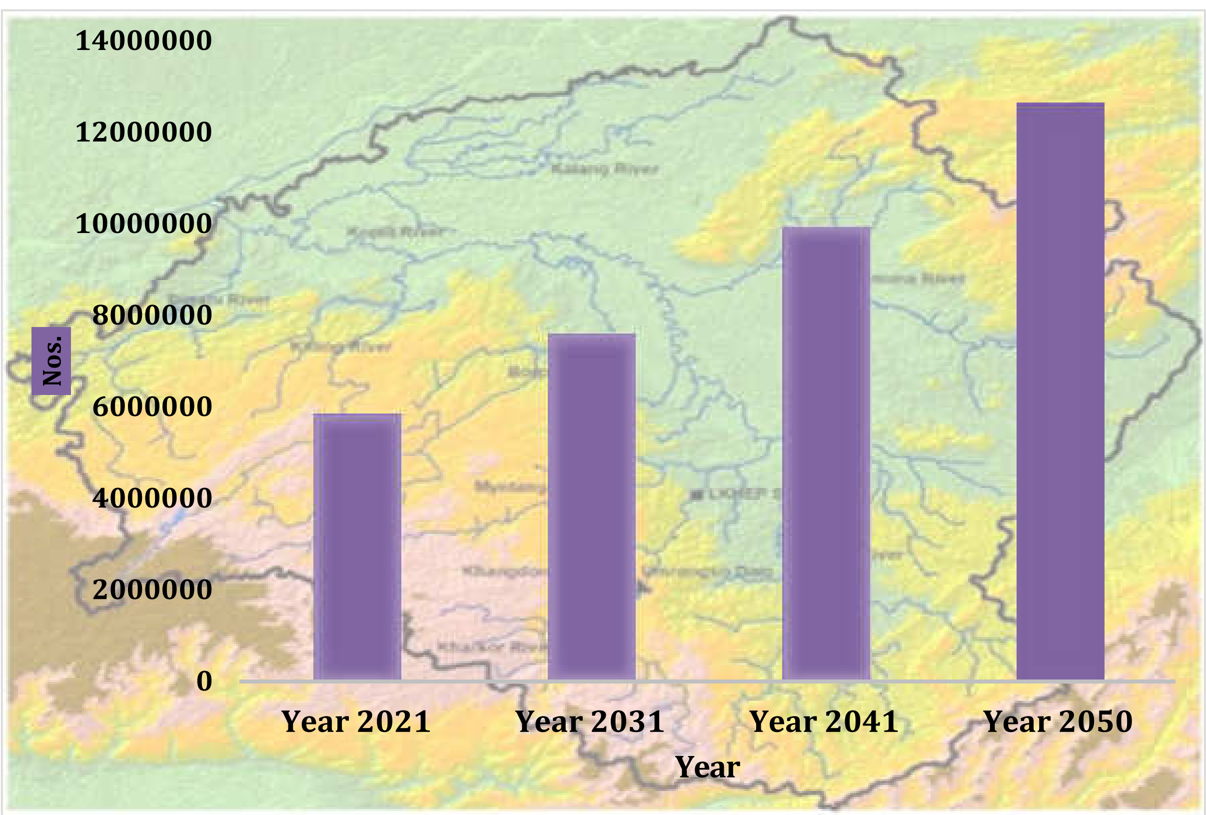
State	District and Area (sq.km)	Projected Population			
		2021	**2031**	**2041**	**2050**
Assam	1- Nagaon & Marigaon (5535)	3483550	4542587	5923584	7544335
	2-Kamrup (4345)	540299	704556	918749	1170127
	3-Karbi Anglong (10434)	872431	1137660	1483521	1889427
	4-Dima Hasao (NC hills) (4888)	217602	283755	370020	471261
Meghalaya	5-East Khasi Hills (5196)	481843	628328	819347	1043528
	6-West Khasi Hills (5247)	6386	8327	10859	13830
	7-Jaintia Hills (3819)	250371	326487	425743	542230
Total (in No.)		**5852482**	**7631700**	**9951821**	**12674738**

Figure 2-6: Population of important towns in the Kopili Basin



S.No	Town	Population as per 2011 census
1.	Nagaon (M.B.)	117722
2.	Lumding (C.T)	22658
3.	Hojai (M.B.)	36638
4.	Lanka (T.C.)	36805
5.	Jagiroad (C.T.)	17739
6.	Dipu (T.C.)	61797
7.	Haflong (T.C.)	43756
8.	Shillong (M.B.)	143229
	Total	480344

Figure 2-7: Population Projection in the Kopili River Basin (based on Census of 2011)



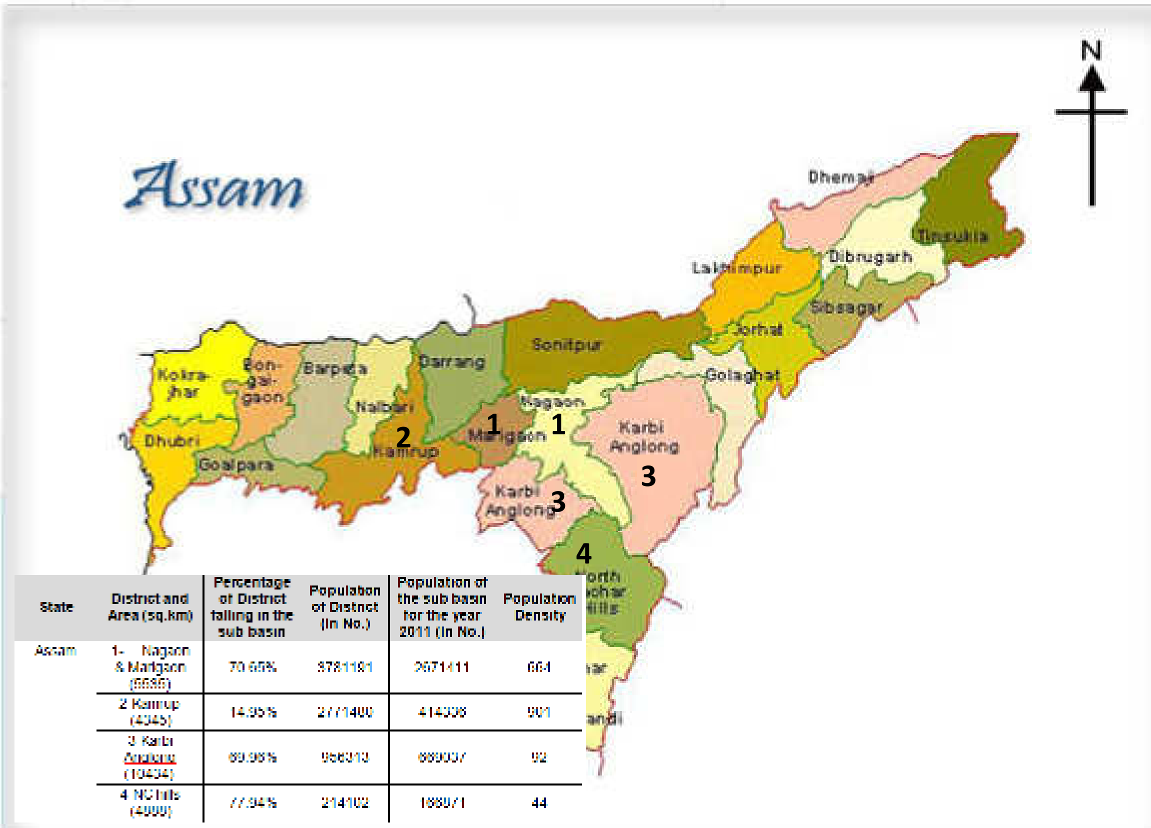
2.2.2 Agriculture

23. Agriculture provides the main means of livelihood to the people of the Kopili basin. Forest also provides livelihood to the people in the hilly areas of the basin. The district wise agricultural areas are shown in Table 2.6 (Figure 2.8 and Figure 2.9). The main crops grown are rice, jute and mustard. Other crops like sugarcane, wheat, maize, potato, gram, arhar are also grown in the area. Apart from these, horticultural crop like pineapples, citrus fruits, banana, papaya, and cash crops like coffee, rubber and cashew area also grown in the hilly areas.

Table 2-6: Agriculture Areas of the Districts in the Basin (Source: Kopili-Kallang basin Master Plan, Brahmaputra Board, 1995)

S.No	State	District and Area (Sq.Km)	Percentage of District falling in the sub basin	Total Agricultural Area (Gross Cropped Area) in the district (in Sq.Km)	Agricultural Area of the basin in (Sq. Km.)
1	Assam	1- Nagaon & Marigaon (5535)	3911 / 5535 =70.65%	4247	3001
		2-Kamrup (4345)	650 / 4345 =14.95%	2252	337
		3-Karbi Anglong (10434)	7300 / 10434 =69.96%	2103	1471
		4-NC hills (Now Dima-Hasao) (4888)	3810 / 4888 =77.94%	543	423
2	Meghalaya	5-East Khasi Hills (5196)	2330 / 5196 =44.84%	456	204
		6-West Khasi Hills (5247)	67 / 5247 =1.27%	367	5
		7-Jaintia Hills (3819)	2000 / 3819 =52.36%	355	186
Total					**5627 (sq.km)**

Figure 2-8: Agriculture Areas of the Districts (Assma) in the Kopili Basin



State	District and Area (sq.km)	Percentage of District falling in the sub basin	Population of District (In No.)	Population of the sub basin for the year 2011 (In No.)	Population Density
Assam	1- Nagaon & Marigaon (6696)	70.65%	3781191	2671411	664
	2 Kamrup (4345)	14.95%	2771400	414336	901
	3 Karbi Anglong (10434)	89.96%	956313	869007	92
	4 NC hills (4888)	77.94%	214102	166871	44

Figure 2-9: Agriculture Areas of the Districts (Meghalaya) in the Kopili Basin

State	District and Area (sq.km)	Percentage of District falling in the sub basin	Population of District (In No.)	Population of the sub basin for the year 2011 (In No.)	Population Density
Meghalaya	5-East Khasi Hills (5196)	44.84%	824059	369508	300
	6-West Khasi Hills (5247)	1.27%	385601	4897	73
	7-Jaintia Hills (3819)	52.36%	366694	192001	160

24. *Jhum* cultivation which is a form shifting cultivation is being practiced in the hilly portions of the basin. This is very unscientific and wasteful method of cultivation since it denudes the area of vegetation cover and washes down the humus-rich top soil rendering the area infertile. The governments of Assam and Meghalaya are now trying to educate farmers and encourage them to take more permanent form of cultivation like terracing on the hills instead of *Jhum*. The shifting cultivation practice has socio-economic relevance for production of agricultural crops in Meghalaya sub basin area. There is no other alternative means of livelihood for the ethnic peoples of the area because of their poor economic condition, which compels them to still practice this system. The people who follow the *Jhum* cultivation are called *Jhummias*. Table 2-7 gives an idea of shifting cultivation in Assam and Meghalaya states.

Table 2-7: Jhum Cultivation areas in Meghalaya and Assam

S.No	State	Total Geographical Area of the State (Sq.Km.)	Annual Area under Shifting Cultivation (Sq.Km.)	Jhuming Cycle (Year)	Minimum Area under shifting cultivation one time or other (Sq.Km)
1	Assam	78520	696	2-10	1392
2	Meghalaya	22490	530	5-7	2650

2.2.3 Plantation & Horticulture

25. The topography, agro-climatic conditions, prevalence of fertile soil and long tradition of growing plantation and horticulture crops have enabled commercial cultivation of several crop varieties. Besides these crops, the sub basin districts produces various types of horticultural fruits like banana, papaya, litchi, pineapple, lemon etc. and other plantation crops such as coconut, areca nut etc. Tea cultivation is also done mostly in the organized sector. Sericulture is also an important activity practiced widely in the district. The three main varieties of silk produced are Eri, Mulberry, Muga and Pat. The Muga culture is found nowhere in the world except in Assam and to a limited extent in Meghalaya. It is an important source of supplementary income and employment particularly to the rural womenfolk of tribal areas. Horticulture could be one of the strongest features of the economy of some districts located in the basin because of its congenial agro-climatic and soil conditions. Bamboo, a large species of grass, grows abundantly in all parts of the basin. It is an excellent substitute for timber in house building and for innumerable other purposes including handicraft industries

2.2.4 Livestock and Dairy

26. Livestock rearing provides supplementary income to a large number of rural households. Poultry, Duckery, Goatery and Piggery are major backyard activities of the rural households for food and nutrition. Pig rearing is taken as a subsidiary occupation by the small and marginal farmers and the agricultural laborers of the tribal community.

27. Pisci-culture is a major allied agro-enterprise in the basin. The main river, its tributaries as well as water bodies like beels and low-lying swamps are the natural breeding places for a variety of fishes and provide large capture for markets both within and outside the basin. The basin has also large number of culture fisheries in ponds.

2.2.5 Mineral resources

28. Major minerals of the basin are coal, lime, granite, and quartz. Stones used as railway ballast, road metal are abundant in the basin. Sand and brick clays are also found in the districts located in the basin. For example, granites and gneisses found near Jagiroad are being quarried for railway ballast and road metal. Clay found extensively in the alluvial tracts of the basin is quite suitable for the manufacture of bricks and earthenware. Some of the areas fall in Karbi Anglong district in the floodplains of Jamuna and Kopili rivers. The thickness of sediments in these valleys is found to be more than 250 m.

29. The Assam coal belongs to a tertiary coal belt. In the Kopili basin, coal occurs at Koiljan (26^0 N 8' N, 93^0 34' E), Sheel Bhetta (26^0 N , 93^0 8' 34" E) Kumba man, Longloi and Daigrung river bed of Karbi Anglong district and at Arda of North Cachar Hills district in Assam, East Khasi hills, West Khasi hills and Jaintia Hills in Meghalaya. The total possible reserve of coal at Koilajan and Sheelbheta is estimated to be 0.5 Million tonnes and 0.15 Million tonnes respectively. However, Koilajan is slightly outside of the Kopili- Kallang sub basin and comes under Dhansiri sub basin.

30. Lime stone deposits are found in Karbi Anglong and Dima Hasao (NC hills) district of Assam and East Khasi Hills of Meghalaya. In Karbi Anglong district, lime stone deposits are located at Koilajan area, Dilai Parbat, Saini-langso and Sheel Bheta. In Dima Hasao district the lime stone deposits are located at Panimur, Garampani, Umrangshu at 11km post and Umrangshu at 16km post. The limestone deposits in Karbi Anglong district are cement grade and total reserve is estimated at 64.36 million tonnes. In Dima Hasao, the total reserve of

cement grade lime stone is 53.7 million tonnes. Apart from this, low-grade lime stone is also found in some of the basin areas which have less economic importance.

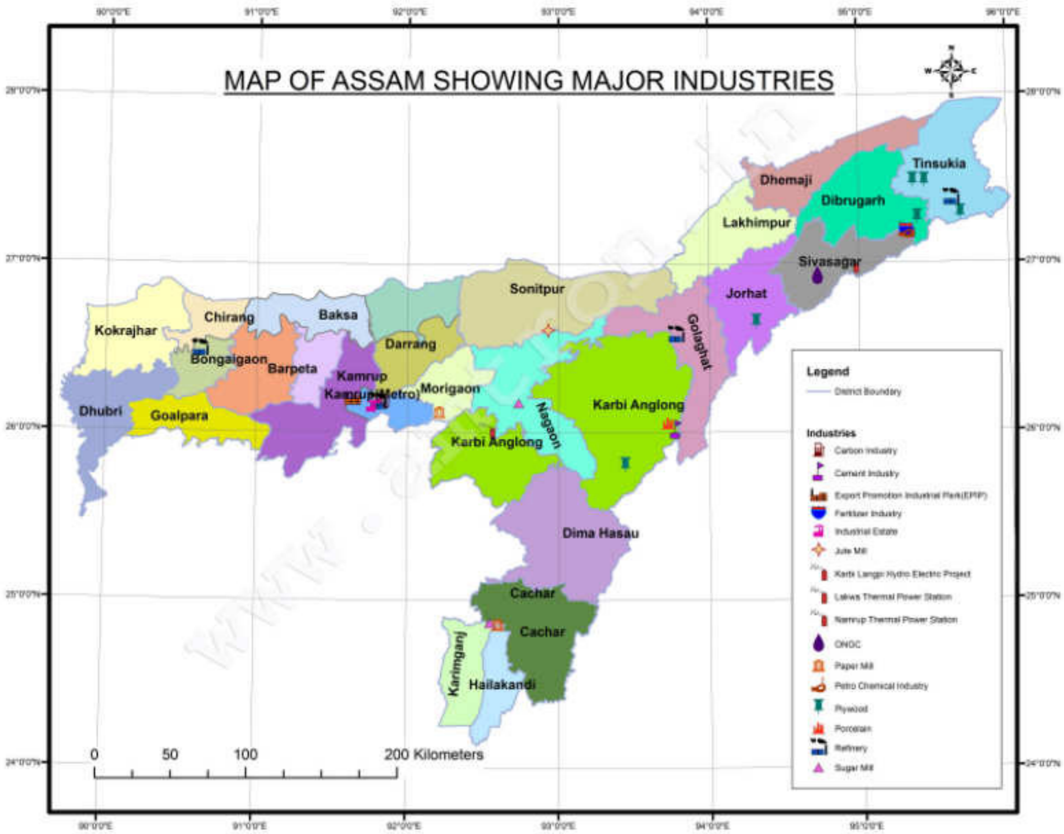
31. Other mineral that occurs in the sub basin are fire clay, pottery clay, Kaolin and Feldspar. Pottery clay occurs in the alluvial tracts and fire clay, Kaoline and Feldspar are found in Karbi Anglong district.

2.2.6 Industries

32. The industries in the basin are mainly located in the plain district of Nagaon (Figure 2.10). Tea manufacturing is the predominant industry in Nagaon. In addition to the tea industry, there are three large scale industries, two medium scale industries in the co-operative sector. In the private sector, one medium scale industry is presently in operation. Important industrial units of the district are as follows.

- ***Hindustan Paper Corporation***: This is mainly a forest product based unit, the main raw material being bamboo. The items and inputs required in the production of paper can be ancillaries, and also downstream industries can be established with HPC's surplus caustic soda and industrial waste like lime, coal ash, etc.
- ***The Assam Spun Silk Mill:*** This was set up to consume the locally available Eri and Muga and also to supply the weavers with Spun Silk yarns. Ancillary and downstream industry can be developed in small scales. As regards downstream unit, carpet making unit may be encouraged. Small carpentry unit for production of stick and bobbin may be encouraged.
- ***Assam Co-operative Jute Mill:*** Nagaon is one of major jute growing areas of the country. A few cottage and household industries for producing jute bags, jute carpet and wall hangings can be set up for encouraging local prospective artisans with definite marketing arrangements. Highest concentration of agro- based industries found in and around Nagaon town. Forest based units are also mainly concentrated in and around Nagaon town. Among the forest based units, saw mills have their dominance. Other forest based industries are Agarbatti, wooden furniture, cane and bamboo products manufacturing units.
- ***Handloom and handicraft industries-*** Jute and tea are two important export items of the district. Timber and cotton are the principal exports of this important trade centre. Hojai is a principal wholesale market for rice and known as the granary of Assam. Agor industry of Hojai is another important one. Dry fish is one of the important items going out from Jagiroad to number of places of this region.

Figure 2-10: Major industrial in Assam



- ***Tea industry-***The tea industry in the sub basin is in existence from early part of the last century. Most of the tea gardens are situated in the Nagoan districts (Figure 2.11). There are 643 small tea growers registered with Assam Tea with total registered tea gardens covering an area of 8086 ha (2013-14) in this district. Most of the tea gardens are situated in the foot hill areas along both banks of Nonoi, the Chapanalla, and the Kallang. The total tea production in the Nagoan district is 17029 tonnes. A few numbers of tea gardens are also located in Karbi Anglong and Dima Hasao districts.

Figure 2-11: Team Gardens in Assam

2.2.7 Transport & communication

33. The transport system in plain areas of the Kopili basin is generally good, important places being connected by both roads and railways. The National Highway No 37 passes through Nagoan district and it connects Nagaon with Guwahati, Jorhat, Sibsagar, Dibrugarh etc. The National Highway No 36 passes through Nagaon and Karbi Anglong districts and connects Nagaon with Dimapur, Imphal etc. The National Highway 40 No passes through Meghalaya.

34. The broad-gauge railway line passes through the basin and connects Guwahati with Lumding. Beyond Lumbding the railway line is of meter gauge. A branch line connects Nagaon town with Chaparamukh on the main line. Another branch line connects Lumding with Silchar.

35. The existing road transport in the hilly areas is poor and not in very good condition except highways as comparison to the plain.

2.2.8 Hydropower Development

36. The CIA Report (Volume 2 of Final Report) submitted by the Consultant provides a detailed description of the power sector development in Assam and in the Kopili basin. Therefore, it is not repeated in this report. However, a summary of Assam power generation capacity under development is provided in Table 2-8.

Table 2-8: Assam Power Generation Capacity under Development

Project	Capacity	Status
Bongaigon Thermal Power Station (Coal) – NTPC Ltd.	500 MW	250 MW to be commissioned in October 2015, of which 130 MW is dedicated to APGCL under power purchase agreement; additional 500 MW is expected to be sold to other states outside of Northeast Region.
Revival of Chandrapur Thermal	60 MW	JV with private sector. Environmental clearance received. Coal linkage awaited.
Margherita Supercritical mine-mouth coal	660 MW	Proposed as Joint Venture with NEEPCO (51%) and APGCL (49%). Coal linkage awaited. DPR under preparation.
Total Coal	***1220 MW***	No other coal-fired power plants have been identified
Namrup Replacement Plant Combined Cycle gas turbine	100 MW	65% complete; open cycle commissioning expected by year-end 2015
Lakwa Replacement Plant – internal combustion engine natural gas	70 MW	Contract award for principle equipment by year-end 2015; funded by ADB (MFF-083, Tranche 1)
40 MW Titabor Power Project	40 MW	Further development pending confirmation of gas allocation.
30 MW Cachar Power project	30 MW	APGCL awarded gas supply on open tender for ONGCL. Gas linkage confirmation awaited.
Total Natural Gas	***70 MW***	Net addition of 70 MW of capacity due to lack of available gas supplies
Myntriang Stage-1 (3x3 MW); Enhancement of Stage II (1.5 MW)	10.5 MW	Approximately 57% project work is completed. Commissioning is expected by December 2015.
Borpani Middle Stage II HEP	24 MW	DPR approved by APGCL Board in December 2014.
Borpani Middle Stage I (Amring) HEP	21 MW	DPR under preparation
Borpani Middle Stage I – barrage toe powerhouse	12 MW	DPR under preparation
Upper Karbi Longpi	60 MW	n/a
Lower Kopili HEP	120 MW	Environmental clearance expected in Q2 2016.
Total Hydropower	***268.5 MW***	LKHEP represents 45% of hydro capacity under development
Namrup Solar	2 MW	Co-located with Namrup thermal plant. To be proposed under JNNSM. DPR under preparation.
Lakwa Solar	2 MW	Co-located with Lakwa thermal plant. To be proposed under JNNSM. DPR under preparation.
Amguri Solar PV	60 MW	n/a [JNNSM – not APGCL]
Suryataap Solar	5 MW	Off-take tariff set in September 2015; commissioning date unknown
Total Solar	***69 MW***	
GRAND TOTAL	**1627.5 MW**	LKHEP represents 8.7% of total capacity under development

Notes: Projects by APGCL except as noted. Status details from APGCL Tariff Order dated 24 July 2015.

2.2.9 Overall Development

37. According to the Assam Planning Department's Approach to the 12th Five Year Plan, in general, Assam has been growing at a slower rate than the rest of the country (6.1% during the first 3 years of the 11th Plan period). The hill area of Assam had an even slower rate of growth. According to the North Eastern Council's (NEC's) Annual Plan 2012- 13, the region's basic economic strengths and weaknesses are listed below.

A. The region's basic economic strengths are:

- Large natural resources and potential for growth in the agro-forestry and horticultural sectors including expansive and extensive bamboo plantation, exotic flora
- Large mineral deposits (particularly in Assam and Meghalaya)
- A vast bio-diversity hot spot
- Vast water resources including tremendous hydel power potential
- Great promise for tourism development
- Proximity to one of world's fastest – growing economies, those of the Southeast Asia
- A highly literate population
- Rich heritage of handicrafts/handloom/tribal artefacts
- Strong community spirit and traditional democratic system of local self-governance

B. The region's economic weaknesses are:

- Inadequate development of basic infrastructure
- Geographical isolation and difficult terrain that reduces mobility: high rainfall and recurring flood in the Brahmaputra valley
- Lack of capital formation and proper enterprise-climate
- Slow spread of technology
- Absence of a supporting market structure and adequate institutional finance structure
- Low level of private sector investment
- Lack of local agricultural surplus
- Insurgency problems
- Late start in the development process

2.3 Climate Change Issues

38. Climate change has drawn wide concerns across the world since it has wider implications on food, water, livelihood and energy security of the populations. It also affects domestic and international policies, trading patterns, resource use and food security. Inter-governmental Panel on Climate Change (IPCC) pointed out serious damage to natural resources, socioeconomic conditions and livelihood of the people due to climate change. Therefore, Climate change is the greatest global challenge and a serious environmental threat to humanity and has implications for sustainable development and society. It is a known fact that climate is already changing. Along with continued warming of the atmosphere, erratic rainfall pattern is emerging and as a result new patterns of droughts and floods are being observed, which are likely to get more frequent and severe in future given the warming of the earth because of the anthropogenic emissions of greenhouse gases.

39. The North East Region (NER) is one of the highly vulnerable regions in the India in

terms of climate change. Assam and Meghalaya have reasons to be concerned about climate change, as they have a large population dependent on agriculture and forests for livelihood. The States' economies are also dependent on natural resources and any adverse impact on these and allied sectors will negate the governments' efforts to alleviate poverty and ensure sustainable livelihoods for the population.

40. The Government of Assam has prepared a "State Action Plan of Climate Change" in 2015. In this plan, state level climate data for the period 1951 to 2010 has been analyzed by the India Meteorological Department. According to IMD's analysis the mean temperature in the State has increased by +0.01ºC/year. There is also an increase in seasonal temperatures across seasons with pronounced warming in post monsoon and winter temperatures. IMD also found a decrease in annual rainfall by -2.96 mm/year during the same period. Additionally, when station wise data were analyzed for a period of 25-30 years at least, significant variations are seen across seasons in number of rainy days and in 24 hour maximum rainfall.

41. Apart from trend analysis, climate projections are also available and discussed in the State Action Plan for Climate Change for the period 2021–2050 using regional climate model PRECIS, a model developed by the Hadley Centre, UK Met office. Projected changes reveal that temperatures continue to rise and may increase by 1.7-2.0ºC with respect to baseline. Only the western part of the State will experience slight decrease in rainfall while the rest of Assam is projected to have increase in rainfall. There is likely to be increase in extreme rainfall event by 5 to 38% with respect to baseline. Drought weeks are going to rise, with southern districts showing marginal reduction in drought weeks but rest of the districts show an increase by more than 75% with respect to baseline. About floods, they are going to rise by more than 25% in the southern parts of Assam.

42. Meghalaya is also highly prone to the effects of climate change because of its geo-ecological fragility, humid monsoon climate, and socio-economic conditions. Demographically, the State harbors over 2.96 million population (source: 2011 population census), of this approximately 80% of the population is rural. Majority of the districts of Meghalaya have experienced variation in precipitation (i.e. West and East Garo hills districts showed decrease in precipitation, West Khasi hills district has the highest increase in precipitation) and temperature (increase in minimum temperature was found in the western part of the state as compared to the eastern part; central parts have witnessed increase in maximum temperature source: State Action Plan of Climate Change). The IMD analysis has shown that Meghalaya is showing a trend of declining annual rainfall since 2005-06. However, climate models predict 2-3.5°C temperature increase and 250-500 mm increase in precipitation (the rainfall increase is predicted to be higher in forest covered areas). Furthermore, the rainfall variability and occurrence of extreme events have increased and is expected to increase further, with monsoon rains already having increased since 2001 and shifted towards the "post-monsoon" period.

2.3.1 Climate Risk Screening with Special reference to Lower Kopili Hydroelectric Project

43. Based on the Climate Risk Screening Report (Dec.2015) of Lower Kopili Hydroelectric Project, following projections and probable impacts were made:

A. Climate Projection

44. ***Temperature:*** By 2050s, annual mean temperature in the project area is projected to increase by 2.480 degrees Celsius under the RCP8.5 emissions scenario. The highest

temperature rise is projected to occur in December (>2.75^{0}C) and the lowest in July (<2.19^{0}C).

45. ***Precipitation***: Under the same scenario, annual total precipitation is projected to increase by 206mm or 7.6% by 2050s. The increase is projected to occur overwhelmingly during the May-October monsoon season (190mm, 8.8%). Precipitation during dry season (January to April) is projected to decrease slightly.

B. Climate Impact

46. **Reduced Reliability of Power Generation in Dry Season**-Climate change may result in serious adverse impacts on water resources by significantly increasing the intra-annual as well as seasonal variability of river flow. Changing hydrological flows due to increased and more variable precipitation will impact hydropower generation and the run-of-river type of hydropower generation is more susceptible to the impact of climate change. Power generation during the monsoon season will not be significantly affected as there will be sufficient river run-off. Variability in river run-off should be adequately accounted for by using the diurnal storage. For the dry season, power generation will be less reliable. Since LKHEP will only be used as peaking station during the dry season, the diurnal storage may also help reduce the climate vulnerability.

47. **Storage Capacity and Sediment Flushing-**The projected increase in monsoon precipitation is likely to result in exacerbated soil erosion within the watershed. Increased sediment load entering the storage will not only result in reduced water storage requiring more frequent flushing of sediment, but also damages to turbines, and exacerbated flood risks.

48. **Damages to Equipment** -The rivers in the Himalayan region often transport sand with the highest Quartz content. Quartz is very detrimental to the turbines. Increased sediment load due to increased precipitation intensity may accelerate the wearing of equipment.

49. **Effluents from opencast coal mining** sites in the upstream areas are highly acidic. Increased precipitation during the monsoon season may result in more effluents from the mining sites. Acid effluents are highly erosive and corrosive which will damage the turbines. The wear and tear due to erosion/corrosion caused by acid mine discharge reduces the efficiency and the lifespan of the equipment leading ultimately to economic loss.

3. WATER RESOURCES DEVELOPMENT AND FLOODING ISSUES

50. Surface water generated by rainfall is the main source of water in the Kopili basin. Ground water is also available and used in the plain areas of the basin.

51. Water resources development in the Kopili Basin is for the following purposes:

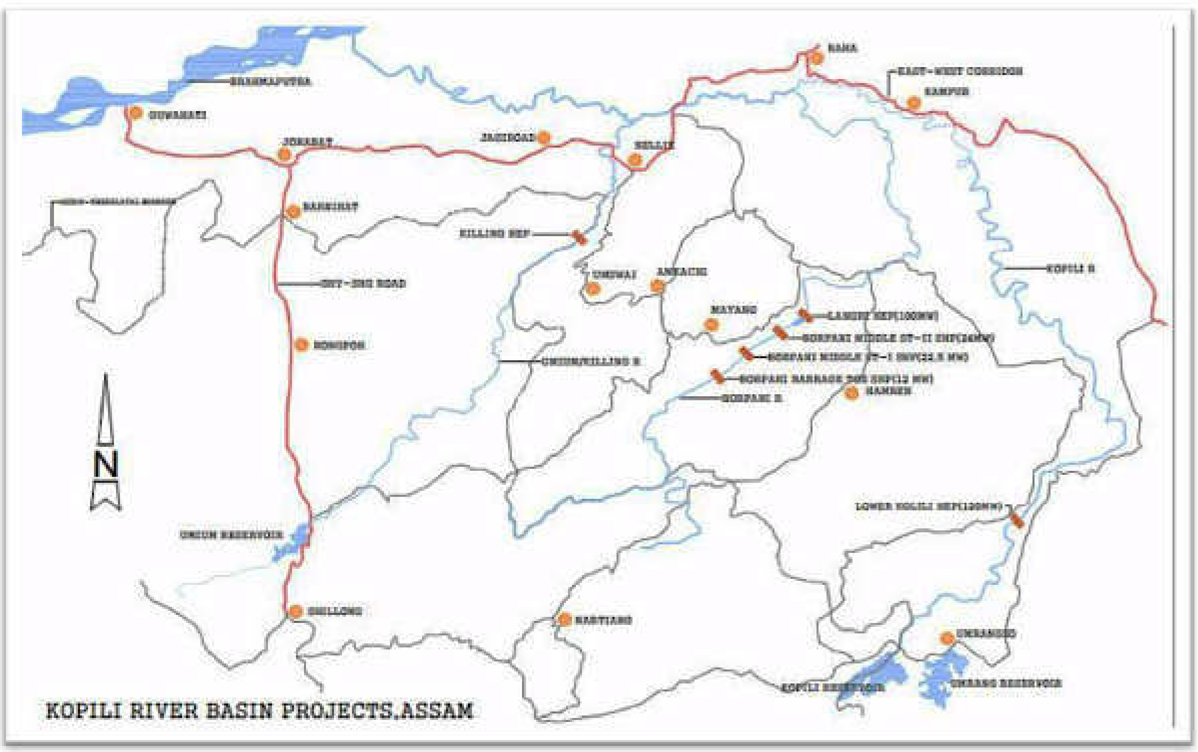
- Hydropower
- Domestic water supply
- Irrigation
- Fisheries
- Navigation
- Improvement of water quality and pollution abatement
- Maintenance of environmental flows in the river reaches
- Flood Management

3.1 Hydropower Development

52. The DPR (APGCL/Lahmeyer, 2015) and other power sector planning documents provide an adequate overview of other the hydropower development situation in Assam and in the Kopili basin. APGCL operates about 378 MW of generation capacity in the state. About 1628 MW of new capacity is at different stages of development, of which about 40% is from the proposed supercritical coal project at Margherita in eastern Assam (Table 2-8, Chapter 2).

53. Further details on existing hydropower development are provided in the CIA Report (Volume 2). Figure 3.1 show power generation in Kopili Basin.

Figure 3-1: Map showing power generation projects in Kopili River Basin, Assam



3.2 Domestic Water Supply

54. Domestic water demand in the basin is estimated based on per capita water consumption and population residing in various villages and towns. The basin population has been calculated by the proportionate areas of the districts within the basin. As described in Chapter 2, the geometrical increase method of population projection has been adopted. Due to non-availability of district wise population data prior to 1971, five census years data of 1971, 1981, 1991, 2001 and 2011 have been considered for projection (Table 3-1 and Table 3-2). It has also been assumed that per capita daily water requirement of people residing in the basin is approximately 135 litres. Using the same norms, domestic water supply demand in million

cubic meter(MCM) has been worked out for the basin area which is summarized in Table 3-1 and Figure 3-2.

Table 3-1: Estimation of Population as per 2011 Census

State	District and Area (sq.km)	Percentage of District falling in the sub basin	Population of District (In No.)	Population of the sub basin for the year 2011 (In No.)
Assam	1- Nagaon & Marigaon (5535)	70.65%	3781191	2671411
	2-Kamrup (4345)	14.95%	2771480	414336
	3-Karbi Anglong	69.96%	956313	669037
	(10434)			
	4- Dima Hasao (NC hills) (4888)	77.94%	214102	166871
Meghalaya	5-East Khasi Hills (5196)	44.84%	824059	369508
	6-West Khasi Hills (5247)	1.27%	385601	4897
	7-Jaintia Hills (3819)	52.36%	366694	192001
Total Population in Sub Basin				**4488061**

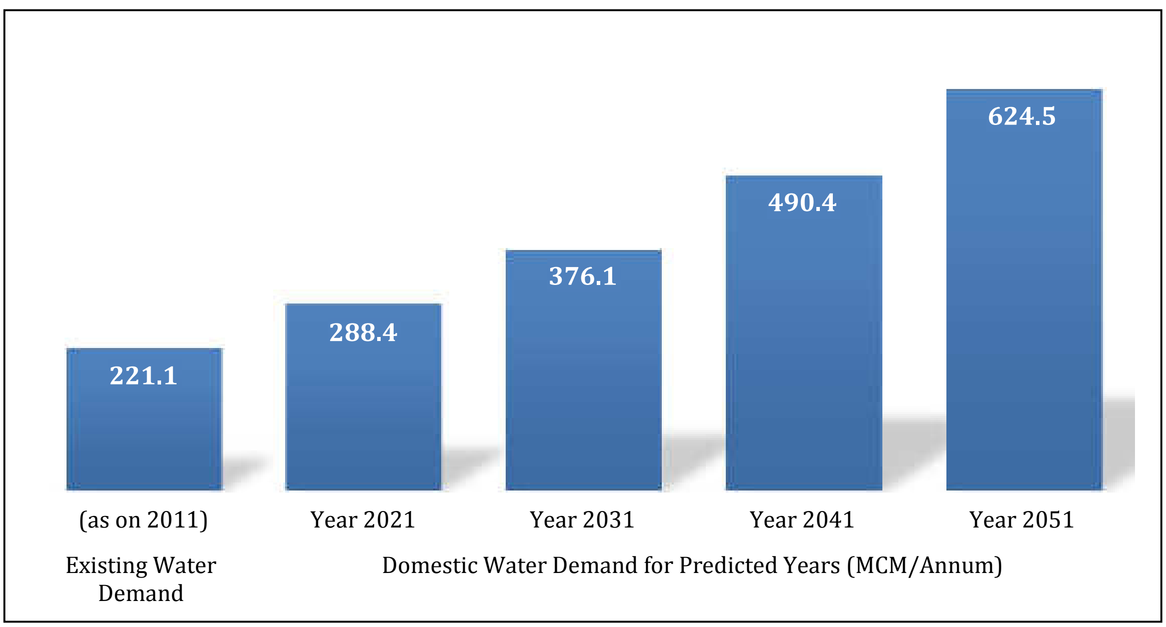
Table 3-2: Population Projection

State	District and Area (sq.km)	Predicted Population			
		2021	**2031**	**2041`**	**2051**
Assam	1- Nagaon & Marigaon (5535)	3483550	4542587	5923584	7544335
	2-Kamrup (4345)	540299	704556	918749	1170127
	3-Karbi Anglong (10434)	872431	1137660	1483521	1889427
	4-Dima hasao (NC hills) (4888)	217602	283755	370020	471261
Meghalaya	5-East Khasi Hills (5196)	481843	628328	819347	1043528
	6-West Khasi Hills (5247)	6386	8327	10859	13830
	7-Jaintia Hills (3819)	250371	326487	425743	542230
Total (in No.)		**5852482**	**7631700**	**9951821**	**12674738**

Table 3-3: Estimation of Domestic Water Demand of Sub- Basin Area (MCM/Annum)

State	District and Area (sq.km)	Existing Water Demand (Year 2011)	Domestic Water Demand for Predicted Years (MCM/Annum)			
			2021	2031	2041`	2051
Assam	1- Nagaon & Marigaon (5535)	131.6	171.7	223.8	291.9	371.7
	2-Kamrup (4345)	20.4	26.6	34.7	45.3	57.7
	3-Karbi Anglong (10434)	33.0	43.0	56.1	73.1	93.1
	4-DIma Hasao (NC hills) (4888)	8.2	10.7	14.0	18.2	23.2
Meghalaya	5-East Khasi Hills (5196)	18.2	23.7	31.0	40.4	51.4
	6-West Khasi Hills (5247)	0.2	0.31	0.41	0.54	0.68
	7-Jaintia Hills (3819)	9.5	12.34	16.09	20.98	26.72
Total Domestic Water Demand of Kopili Basin (MCM/annum)		**221.1**	**288.4**	**376.1**	**490.4**	**624.5**

Figure 3-2: Domestic Water Demand for Sub-Basin (MCM/Annum)



55. It can be inferred from the above tables and figure that, the quantity of water required in year 2021 would be 288.4 MCM/annum for domestic consumption. This demand will further increase up to 624.5 MCM/annum in the year 2051, which is approximately three times of the water demand of year 2011.

3.3 Irrigation

56. During the pre-independence period, no worthwhile efforts were made for irrigation development in the NE region. In fact, with low density of population, abundant rainfall and fertile soils, enough food grains were produced to meet the requirement even with traditional cropping and agricultural practices in the basin. Rice, pulse, oil seeds and grams were the major crops. Therefore, the need for any sizable and planned irrigation system was hardly felt. The condition now has radically changed. The population in the plain areas in the basin has been growing at very fast rate, which has more than doubled in last few decades. Also with the improved standard of living per capita requirement of food and fiber has risen. The demand for food has also increase a with setting of some industrial ventures in the basin. Therefore, the need for producing more food to meet the ever-increasing demand is obvious. The traditional cropping pattern (where the source of water is either rain or flood and where a plot of land is generally used for single crop only) is totally inadequate to meet this growing food demand. The introduction of multiple cropping along with some assured source of water for irrigation has become inevitable.

57. The cultivators living in the basin, especially in the plain areas of Nagaon and Morigaon districts, are very hard working and endeavoring. By providing adequate irrigation facilities and imparting proper training on modern technique of cultivation, encouraging results can be expected from them.

58. Table 3-4 shows the potential agricultural area in the districts of the basin. Table 3-5 shows the irrigation potential created in the basin.

Table 3-4: Potential Agricultural Areas in the Kopili Basin

S.No	State	District and Area (sq.km)	Percentage of District falling in the sub basin	Total Agricultural Area (Gross Cropped Area) in the district (in sq.km)	Agricultural Area of the Sub basin in (sq. km.)
1	Assam	1. Nagaon & Marigaon (5535)	3911 5535 =70.65%	4247	3001
		2. Kamrup (4345)	650 4345 =14.95%	2252	337
		3. Karbi Anglong (10434)	7300 10434 =69.96%	2103	1471
		4. NC hills (Dima-Hasao) (4888)	3810 4888 =77.94%	543	423
2	Meghalaya	1. East Khasi Hills (5196)	2330 5196 =44.84%	456	204
		2. West Khasi Hills (5247)	67 5247 =1.27%	367	5
		3. Jaintia Hills (3819)	2000 3819 =52.36%	355	186
Total					**5627 (sq.km)**

Source: Assam Statistical hand-book 2015.

Table 3-5: Irrigation Potential in the Kopili Basin (as of March 2015, Source: Assam Statistical hand-book 2015)

S.No	State	Districts Undivided		Irrigation Potential created by Govt. schemes		Total (Ha)
				Minor	Major/Medium	
1	Assam	1-Nagaon	Nagaon	16953	-	16953
			Marigaon	18893	85842	104735
		2-Kamrup	Kamrup	25076	-	25076
			Kamrup Metro	5407	-	5407
		3-Karbi Anglong		60910	9637	70547
		4-NC hills (Now Dima-Hasao)		7290	-	7290
2	Meghalaya	5-East Khasi Hills				
		6-West Khasi Hills				
		7-Jaintia Hills				
Total						

59. On the Kopili basin as a whole, major irrigation schemes are implemented only in the plains. As per the Brahmaputra Board's Master plan (1995), of the total agricultural area of 4,658 sq.km only 1,027 sq. km is irrigated, that is only about 22%. The irrigation area in the plains is 716 sq. km, while that in the hills it is 310 sq.km. Since rice is the main irrigated crop and it is grown during the monsoon season, there is enough surface water available for expanding irrigation areas in the plains.

3.4 Fisheries

60. Fisheries in the basin are commonly seen in the *beels* and along rivers. While adequate water is available in the river channels in the plains, river fisheries in the hilly region suffer from lack of water during the dry season (December to May). Traditional fishery is a livelihood for many tribal people in the hills of Assam and Meghalaya. In the plain districts of Assam (Nagaon, Morigaon), commercial pond fisheries are growing due to attractive markets. Table 3-6 shows a summary of water area available for fish farming in the basin, as provided in the Master Plan of Brahmaputra Board (1995).

Table 3-6: Water Area for Fish Farming (Source: Kopili-Kallang Basin Master Plan, 1995, Brahmaputra Board)

State	Area of state	Area under the Kopili basin km^2 (%)	Water area available for fisheries in ha (excluding river area)	
			In states	In Kopili basin
Assam	78,438 km^2	15,671 km^2 (19.98%)	133,690 ha	26,708 ha
Meghalaya	22,429 km^2	4,379 km^2 (19.60)	391 ha	77 ha

61. Assuming an average width of the Kopili River at 70 m along its plain reach of 132.50 km, the total river area comes out to be 927.50 ha for fisheries. Therefore, the total water area for fisheries is computes as 27,713 ha. It is estimated that total annual fish production is about 254 million tonnes in this area (Kopili-Kallang Basin Master Plan, Brahmaputra Board, 1995).

62. In addition, indigenous lotic (fast water) fish species are found along the Kopili River and its hilly tributaries. The many hydropower schemes that are constructed and are in planning will affect these indigenous fisheries by reducing the lean season flows downstream of the dams.

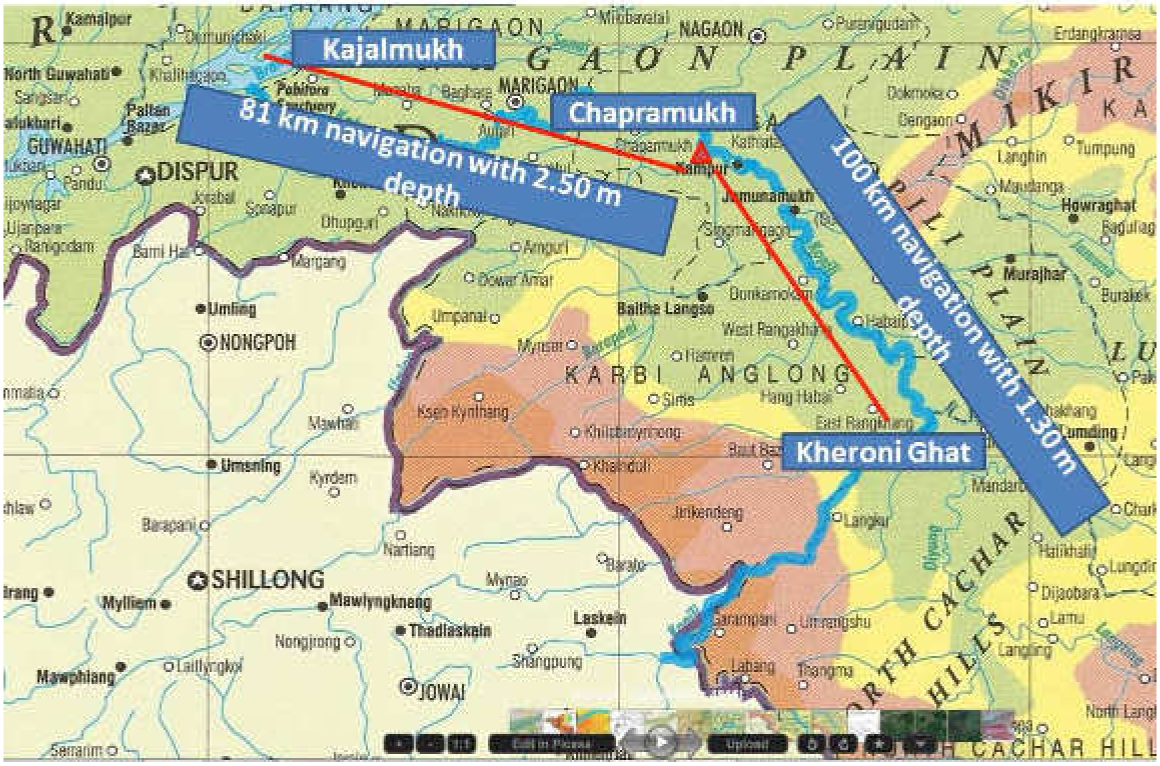
63. The environmental flow rates to be maintained at the downstream of the hydropower dams has been calculated to support the indigenous lotic fish species. However, as mentioned above, the ultimate success of reintroducing the indigenous lotic fish species may depend on there being a more continuous and integrated river system than one interrupted by multiple dams and reservoirs. Therefore, lotic fish species should be selected that are likely to be the most robust and tolerant regarding variations in river flow rate and/or length of fast flow stretches. In addition to reintroducing lotic fish species, the creation of slow moving reservoirs presents the opportunity to introduce lentic (slow water) fish species to provide an additional ecosystem service and livelihood to local residents.

64. Design and implement a comprehensive fisheries reintroduction plan in the hilly reaches, including specifications of lotic and lentic species, and timing and locations of reintroduction, as well as implementation budget and responsibilities. The plan should provide for long-term regular monitoring and evaluation of plan implementation and effectiveness with contingencies for restocking to maintain population levels and to achieve a balanced gene pool through transfers from other stream stretches, as necessary.

3.5 Navigation

65. The Kopili river is navigable along its lower reach of 81 km from its mouth at Kajalmukh to Chapramukh (Figure 3-3). The average water depth is more than 2.50 m in this reach, which is adequate for reasonable size of cargo boats. Beyond Chapramukh, an average depth of 1.30 m available for navigation for a length of about 100 km up to Kheronighat. Only small boats can ply in this route. In order to maintain a year-round navigation (2.50 m depth), one way is to create a storage in the upstream sub-basins to regulate the flow in dry season. However, such a scheme is not found feasible. Therefore, only limited navigation is possible in the river.

Figure 3-3: Navigational reaches of Kopili River



3.6 Water Quality

66. Water quality of a river is a critical factor for determining its utility and ecological significance. The qualitative and quantitative data of various physico-chemical and biological parameters are significant for characterization of river ecosystem and any changes and alterations due to any unsystematic developmental activities influence the river water quality. Water quality data in the Kopili River has been assembled and evaluated from various sources primarily from WAPCOS EIA (2016) and the APGCL Design Project Report (2015). Additionally, pH data was obtained from NEEPCO for the Khandong and Umrong Reservoirs.

67. Water quality issues have been described in details in the CIA Report (July 2017). This issue is being reported in details under the component: Water Quality Restoration and Mitigation Strategy. Water quality in the lower Kopili River is influenced predominately by low-pH surface water draining from mining areas in West Assam and Meghalaya. The Acid Mine Drainage (AMD) flows into the Kharkar River. The mineral pyrite (FeS_2) contained in the coal deposits produces sulphuric acid upon exposure to air and water. A study conducted by the Central Soil and Materials Research Station (CSMRS), New Delhi (2010) reported pH levels at 2.8 to 3.3 in the Kharkar River. This was confirmed that samples collected by Consultant team during a site visit in January 2017, where pH in the Kharkar was measured at 3.3 and 3.8 below the confluence with the Kharkar River, as shown in Table 3-7. Figure 3-4 shows pH profile of Kopili basin and Figure 3-5 show the low pH reaches of the Kopili River up to the confluence with Mynriang River. Figure 3-6 shows a general water quality trend in the Kopili River. Figure 3.7 show water quality trends.

Table 3-7: **Water Quality Sample Locations and Field Parameters, January 2017**

Tributary	Field pH	Field EC (µs/cm)
Umrongso East Bank	4.2	120
Lower Kopili Damsite	4.1	140
Longku Nala	7.4	60
Kharkar River upstream	3.3	480
Kopili River upstream	7.4	40
Kopili River downstream	3.8	440

Figure 3-4: pH profile of Kopili River Basin

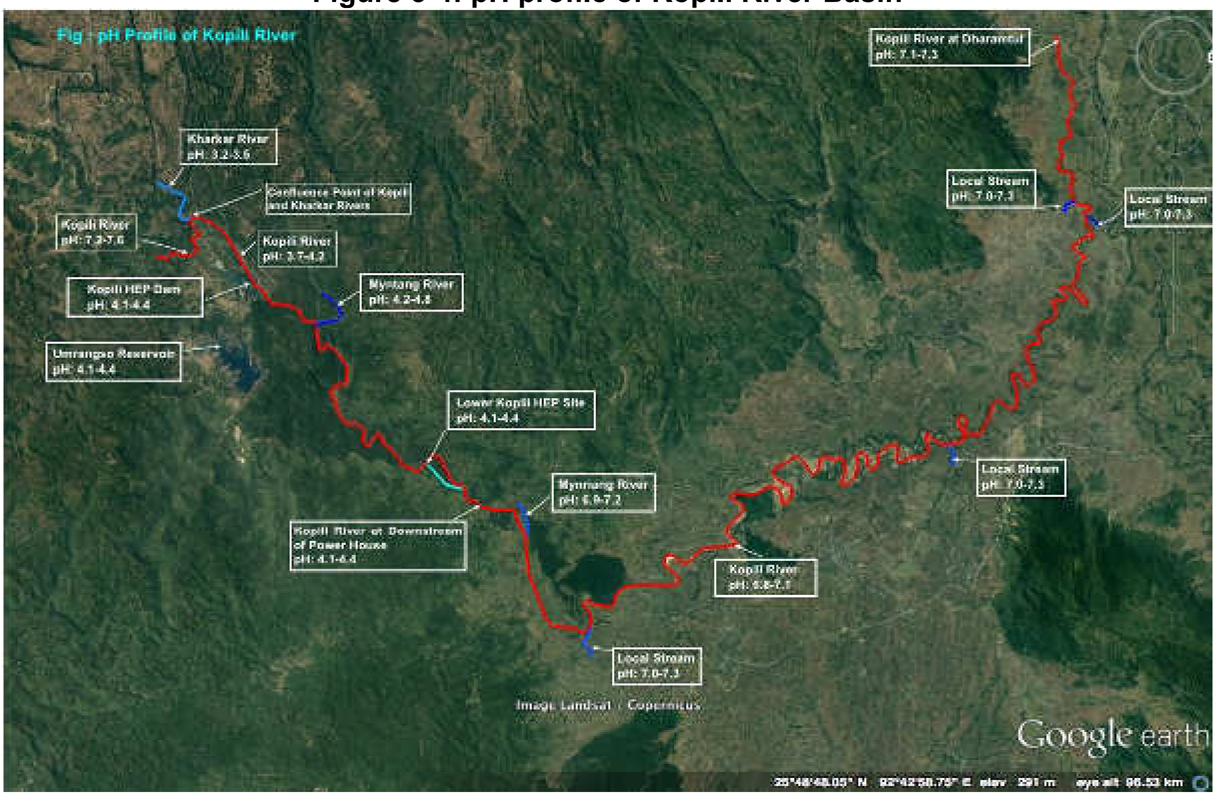


Figure 3-5: Water Sampling location and existing reservoirs

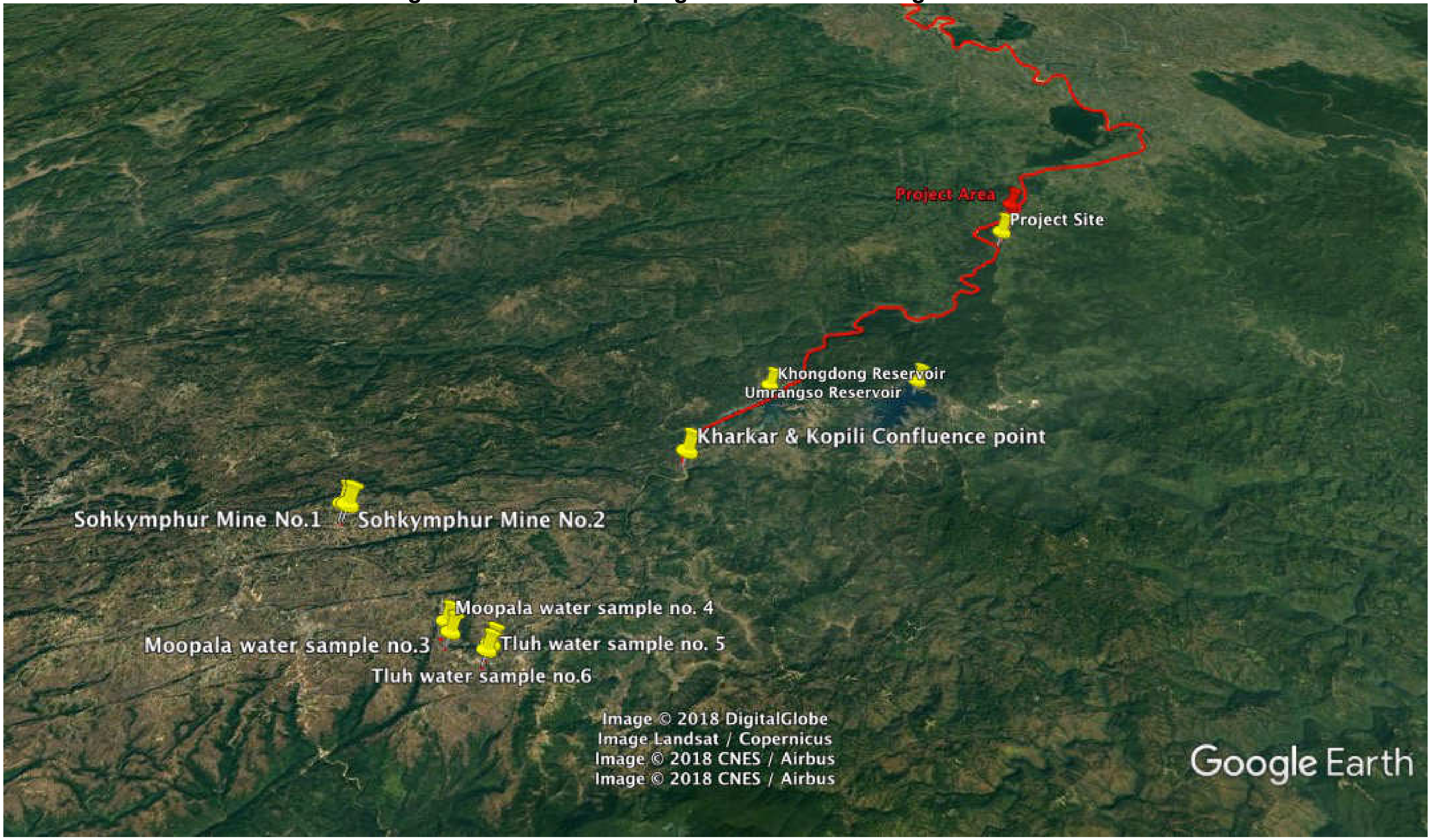


Figure 3-6: Low pH reaches of Kopili River

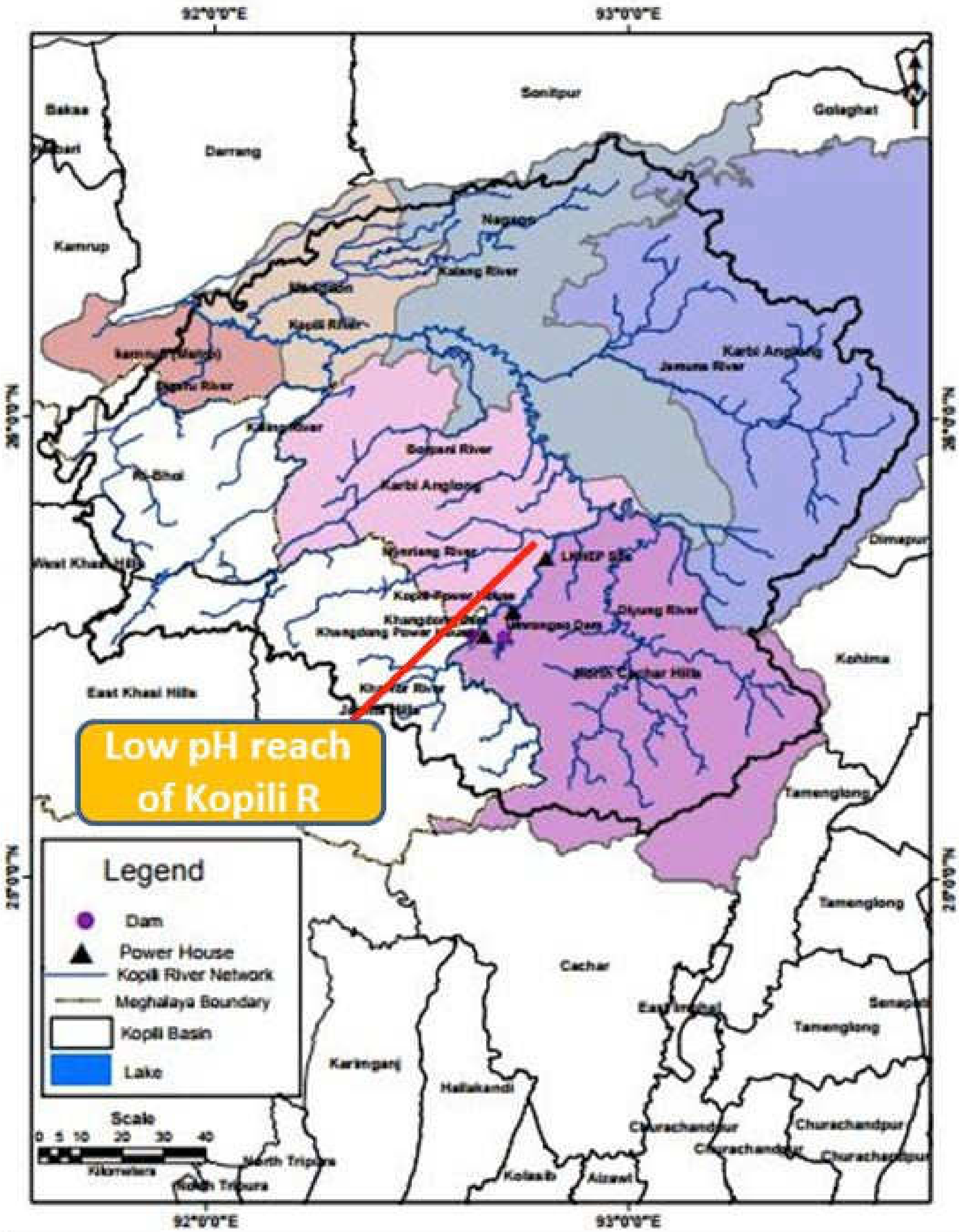
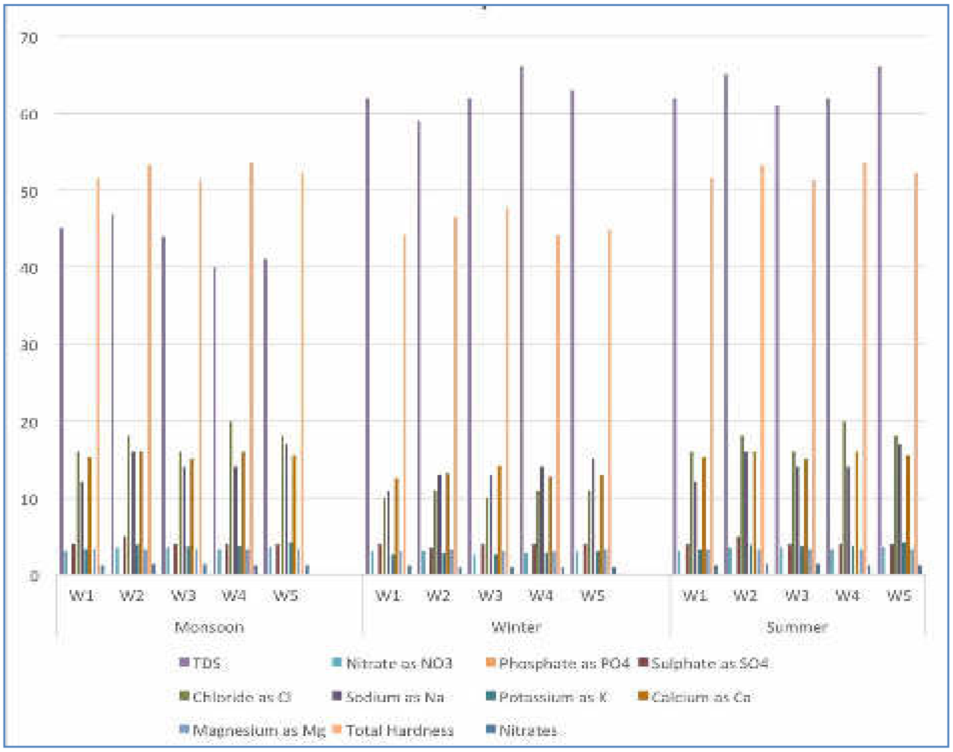


Figure 3-7: General Water Quality Trends Lower Kopili



68. Other than low pH, there are no major sources of pollution loading in the basin. The catchment has low population density and little agricultural activity. Other than illegal mining there are no other industrial sources of contaminant discharge into the Kopili drainage system. The BOD values are well within the permissible limits, indicating the absence of organic contaminants. This is mainly due to the low population density and absence of industries in the area. The low COD values also indicate the absence of chemical pollution loading in the area. Dissolved oxygen ranged from 4.2 to 4.9 mg/l at various sampling locations monitored for three seasons as a part of the study. Due to low pH, water quality of river Kopili is unfit for domestic, irrigation, bathing or industrial use.

3.7 Maintenance of environmental flows in the river reaches

69. Environmental flows describe the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and wellbeing that depend on these ecosystems. Most of the hydropower projects built or under planning are expected to alter the hydrography and hydrology of the river system and thus adversely affect and change the aquatic ecosystem, at least to short reaches immediately downstream of dams. More specifically, in the case of the LKHEP Project or any HPP in the Kopili River Basin, the dams and reservoirs limit the potential to restore the past lotic ecosystem, even if water quality issues are resolved. When considering that there are already two dams and reservoirs upstream supporting the KHP, and that there have been several other small hydropower projects proposed for elsewhere in the basin or in the two autonomous districts in the basin, it is necessary to maintain environmental flows downstream of the dams.

70. The LKHEP project is a “run-of-river” type hydropower project, with a diurnal storage designed for peaking power generation during limited hours. As such, during the lean season, it will store water only for short durations and discharge to at the base of the dam as “environmental flow”. According to the WAPCOS EIA, to mitigate the adverse impacts of the LKHEP dam and reservoir on Kopili River water quality and aquatic and riparian ecology, an environmental flow requirement has been set, as follows:

- Monsoon Season - May to September - the cumulative flow releases including spillage during monsoon period should be about 30% of the average flows during the 90% dependable year
- Non-monsoon / Non-lean Season - October and April - 25% of the average flows during the 90% dependable year
- Lean Season - November to March - 20% of the average flows during the 90% dependable year

71. The environmental flow requirements are based on release data provided by the DPR and approved by the Expert Environmental Appraisal Committee of the MoEFCC, as well as the Central Electricity Authority and Central Water Commission of India.

72. In addition, the implementation and effectiveness of the environmental flow rates should be monitored and evaluated on a regular basis during project start-up and operation.

3.8 Ground Water

73. According to the central Ground Water Board (CGWB), there is abundance of ground water resources in Assam and Meghalaya, with a large potential to utilize for domestic use as well as for irrigation. Table 3-8 shows a summary of ground water availability and utilization as reported in the Kopili-Kallang basin Master Plan (Brahmaputra Board, 1995).

Table 3-8: Summary of Ground Water Availability and utilization in the Kopili basin

District (state)	Utilizable Ground Water in million Cubic Meter (MCM)	Used volume (MCM	Balance ground water resource for future use (MCM)
Nagaon (Assam)	1159.569	168.861	990.708
Dima Hasao (Assam)	515.561	0.189	515.372
Kamrup (Assam)	1565.916	118.307	1487.600
Karbi Anglong (Assam)	933.885	0.441	933.444
Khasi Hills (Meghalaya)	121.98	-	121.98
Jaintia Hills (Meghalaya)	57.12	-	57.12
Total (MCM	**4354.031**	**287.789**	**4106.224**
%	**100 %**	**6.61 %**	**93.39 %**

(Source: CGWB)

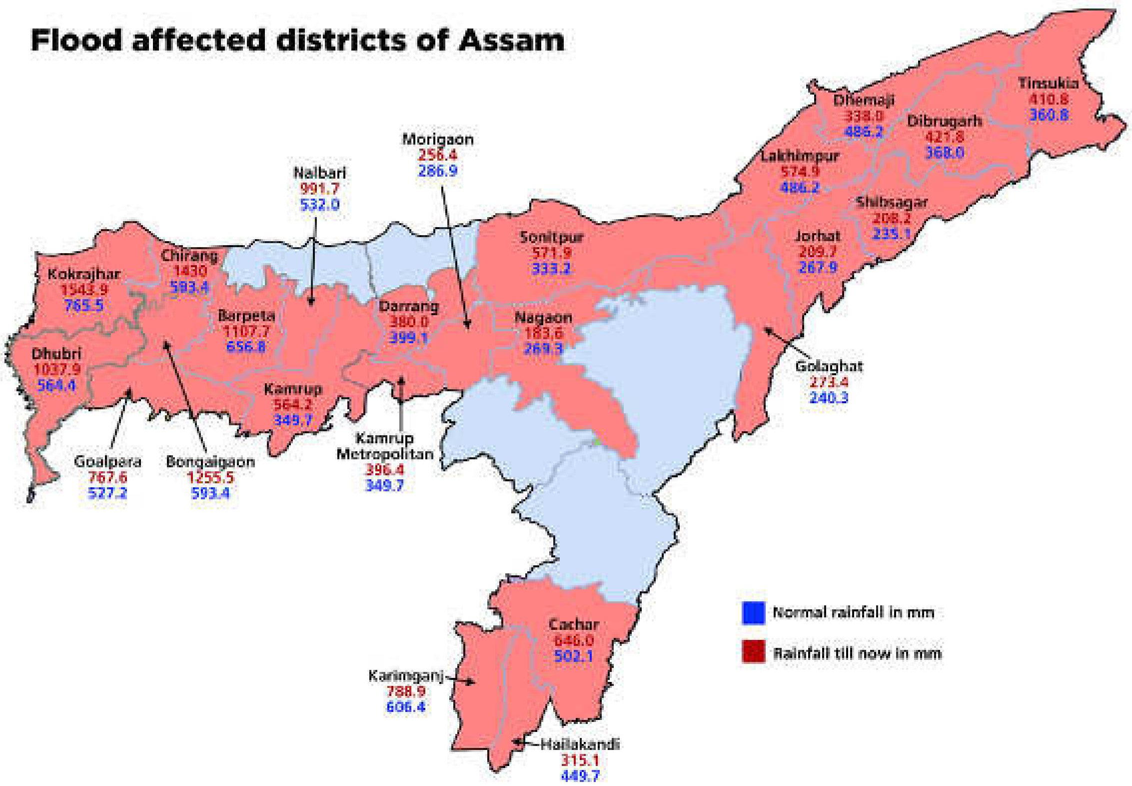
3.9 Flooding Issues

74. Flood is an annual feature in the areas of the lower Kopili river reaches. Severe floods have occurred in the past. The floods of the years 1931, 1934, 1946, 1948, 1954, 1955, 1962, 1966, 1972, 1979, 1986, 1987, 1988, 1998, 2004, 2008, 2012 have been very large and devastating (Brahmaputra Board). The floods of July 2017 are also very large inundating large areas of Nagaon and Morigaon.

75. The floods of 2012 were very large due to the Kopili River crossing its danger level (DL) at Kampur gauge site consecutively for a period of three days from 27 June 2012 to 29 June 2012 and at Dharamtul gauge site during 30 June 2012 – 1 July 2012. It caused severe damage to live stock and property. Nagaon district which is drained by Kopili River and its tributaries was the worst flood affected during 2012 unprecedented floods affecting more than 312 villages for a period of five days. Figure 3-8 show the flood affected districts of Assam.

76. The main reason of flooding in the plain areas of Nagaon and Morigaon is due to spills from the Kopili and other channels which are aggravated by drainage congestions in the towns and villages. Jamuna is the main tributary flooding districts of Karbi Anglong and Nagaon. Titamari channel, which connects Kopili from Chapramukh to Raha floods the national highways NH-37 frequently.

Figure 3-8: Flood Affected Districts of Assam



77. According to Brahmaputra Board, the total flood prone area of the basin is 2,495 sq.km. Out of 3,969 total number of villages in the basin, 1,394 villages are located in the floodplains of Kopili and its tributaries, of which 781 numbers are always flooded. The duration of flood ranges from 5 to 63 days, while the depth of flood varies from 0.46 m to 2.28 m.

78. In the catastrophic floods of 2004, out of 140 revenue villages of Kampur circle of Nagaon district 132 were affected by floods with an area of 217 km^2. Due to these floods about 192,000 people were temporarily displaced. These floods also took the lives of 4 people.

79. Out of a total agricultural area of 465,800 ha, 262,900 are in the floodplains, of which 117,500 are highly flood affected and 44,600 ha are affected annually in an average. 16,000 ha are in low lying area and are severely flood affected. The total annual average flood damage in the basin has been calculated by the Brahmaputra Board as INR 10,345.34 lakhs based on 1994-95 price level. The order of flood damages can be projected to be about INR 1,000 crores in current year's price index.

80. The lower plain areas of Kopili around Kampur town and downstream experience

regular floods mainly in August and September.

81. The hydrological information related to floods is available at Kampur and Dharamtul gauge discharge sites. The Water Resources Department (WRD), Government of Assam considers these records as representative flows out of the basin. The recoded maximum gauge level was 61.87 m in 2004 at Kampur, while it was 58.09 in 1987 in Dharamtul. An analysis for finding out the highest flood level (HFL) carried by WRD shows that flood of 25 year return period occurred in 2004 at Kampur attained a level of 61.87m whereas flood of the order of 50 year return period occurred in 2004 at Dharamtul attained a level of 58.09 m The maximum discharge recorded in 1986 is 2257.74 m3/s. The discharge of 2408.08 m3/s is adopted for the design of protection works, which is the discharge of 25 year return period of flood at Dharamtul.

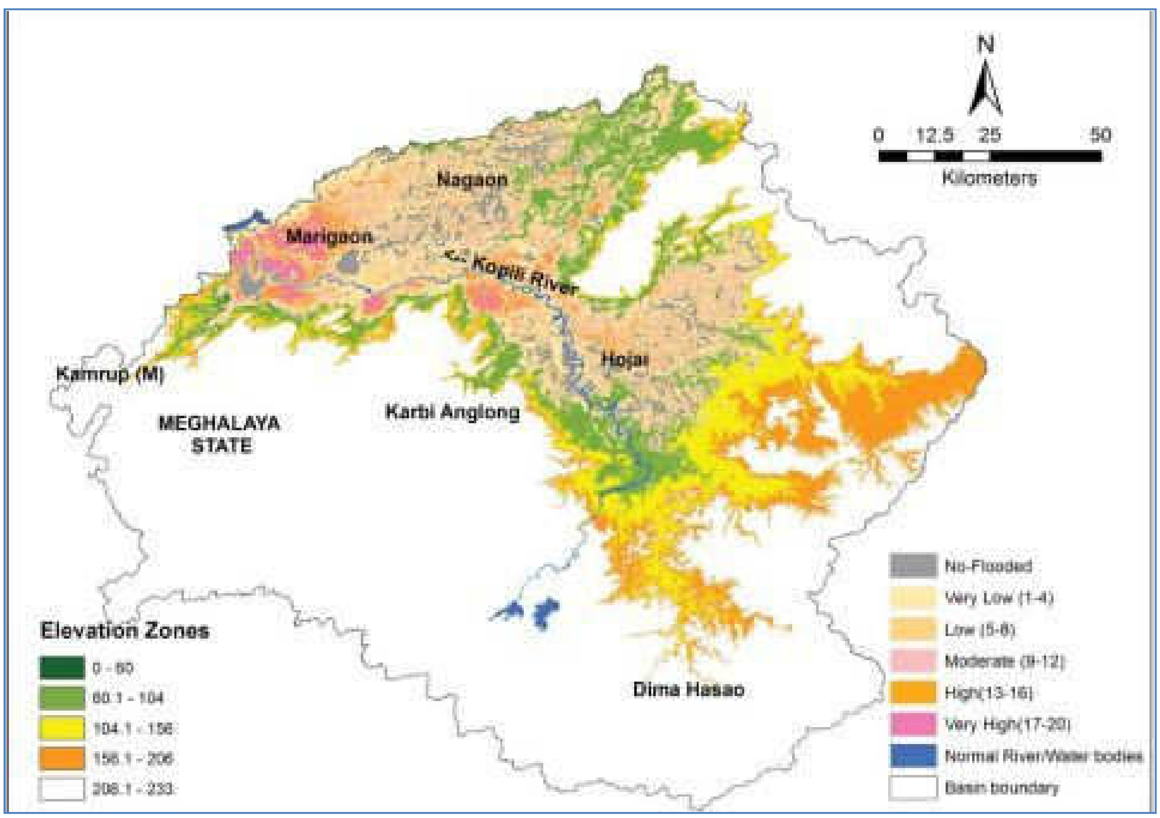
3.9.1 Remote sensing studies on flooding

82. Shivprasad Sharma et al (2016) carried out a study of flooding in the Kopili Basin using a large number of multi-temporal and multi-sensor satellite data-sets comprising of both Indian Remote Sensing (IRS) series and Synthetic Aperture Radar (SAR) RADARSAT satellite data of Canada acquired during the flood seasons of 1977, 1988 and 1998-2015.

83. Based on satellite data analysis, Shivprasad Sharma et al (2016) prepared a flood hazard map as shown in Figure 3-9, which was derived by overlaying flood hazard on elevation zones.

Figure 3-9: Flood Hazard zones in the Kopili Basin derived from satellite image analysis

The figures in brackets are number of times floods have occurred.



(Source: Sivprasad et at, 2016)

84. Figure 3-10 shows a flood inundation map of the lower Kopili area on 24th September 2012. This information was extracted by NRSA from RADARSAT data.

Figure 3-10: Flood Inundation on 24 September 2012

(Source: www.nrsc.gv.in)

85. **Flood Hazard Zones:** A detailed analysis of flooding in Assam has been carried out by Assam State Disaster Management Authority (ASDMA) in 2011. ASDMA used satellite data acquired during the floods of 1998 to 2007 to extract flood inundation. These layers based on about 90 satellite datasets, were integrated to generate a flood hazard layer, which provides the details on how frequently a given area is subjected to floods. The frequency of inundation is further classified into different categories based on the frequency of flood indentation for a particular area. (VERY LOW: for 1-2 times; LOW: for 3-4 times; MODERATE: for 5-6 times; HIGH: for 7-8 times; and VERY HIGH: for 9-10 times or higher.)

86. Table 3-9 shows the cropped areas in Nagaon, Morigaon, Karbi Anglong and Dima Hasao districts under different flood hazard zones as computed by ASDMA (2011).

Table 3-9: Cropped areas (ha) in Flood Hazard Zones (Source: ASDMA, 2011)

District	Very High (ha)	High (ha)	Moderate (ha)	Low (ha)	Very Low (ha)	Total (ha)
Morigaon	9103	12702	20125	13178	13104	68210
Nagaon	4835	20446	28610	31168	48935	133994
Dima Hasao	0	0	0	6	2	8
Karbi Anglong	86	3847	8335	10972	18577	41817

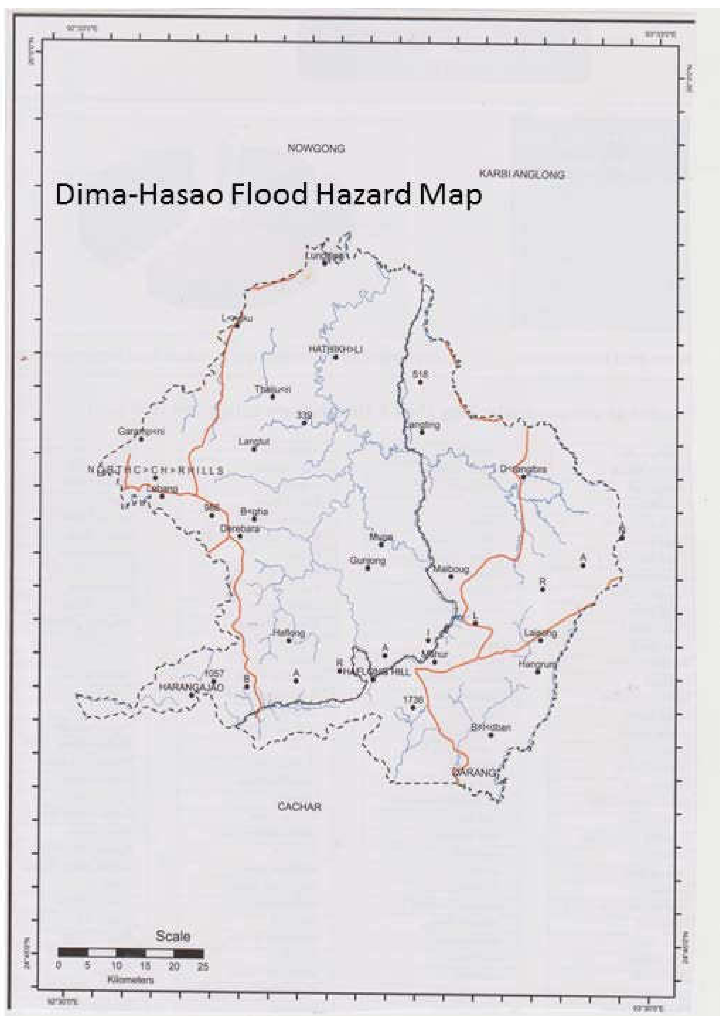
87. Table 3-10 shows the district flood hazard index in the four districts.

Table 3-10: District Flood Hazard Index (Source: ASDMA, 2011)

District	District Area (ha)	Flood Hazard Area (ha)	Hazard Index (%)
Morigaon	149300	107834	72.23
Nagaon	400002	191193	47.80
Dima Hasao	486293	462	0.10
Karbi Anglong	1042757	46337	4.44

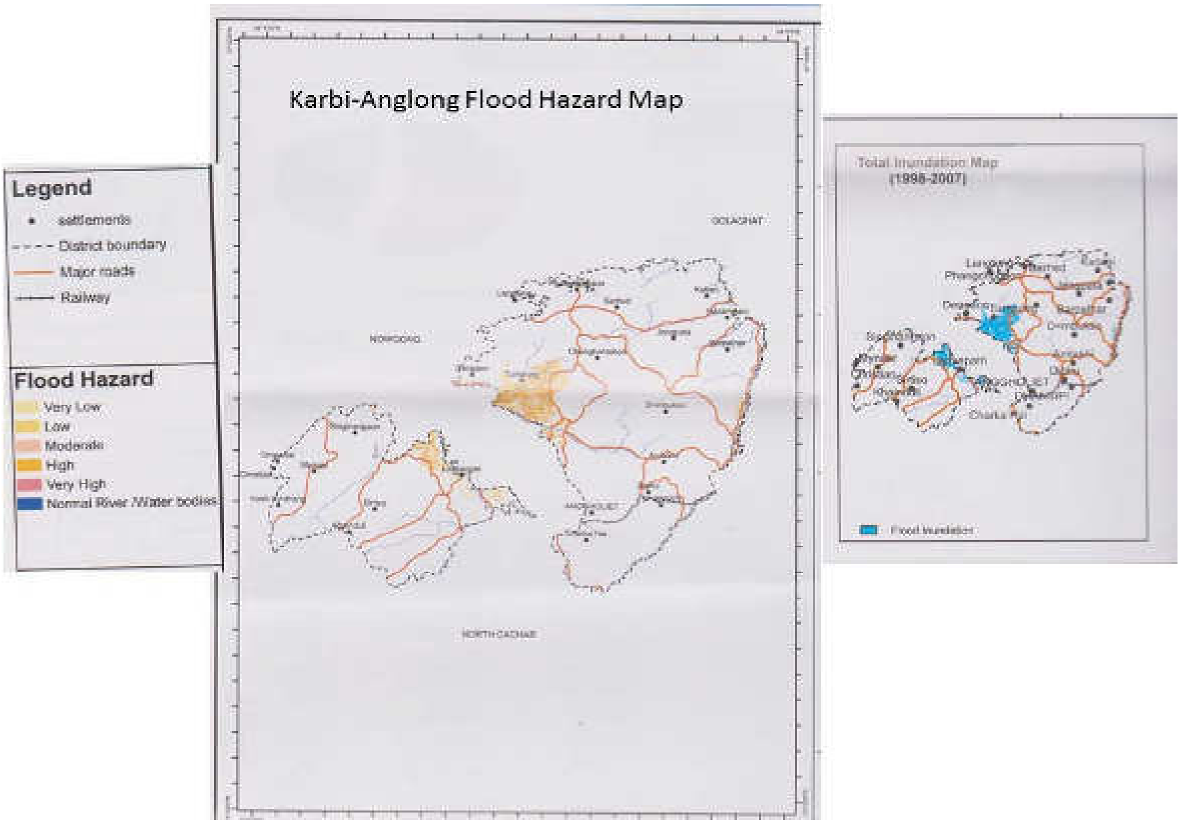
88. Some of the details of flood hazards in reference to the districts under Kopili basin are given below in Figures 3-11 to 3-14.

Figure 3-11: Flood Hazard map of Dima Hasao (only rivers are shown as no area is under flood hazard)-



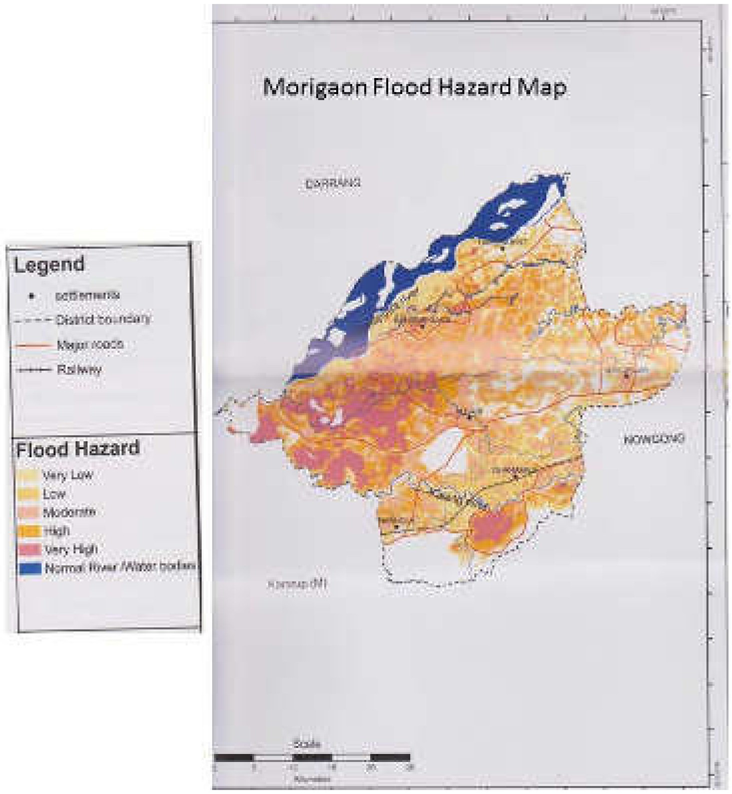
(Source: ASDMA Flood Atlas, 2011)

Figure 3-12: Flood Hazard map of Karbi-Anglong



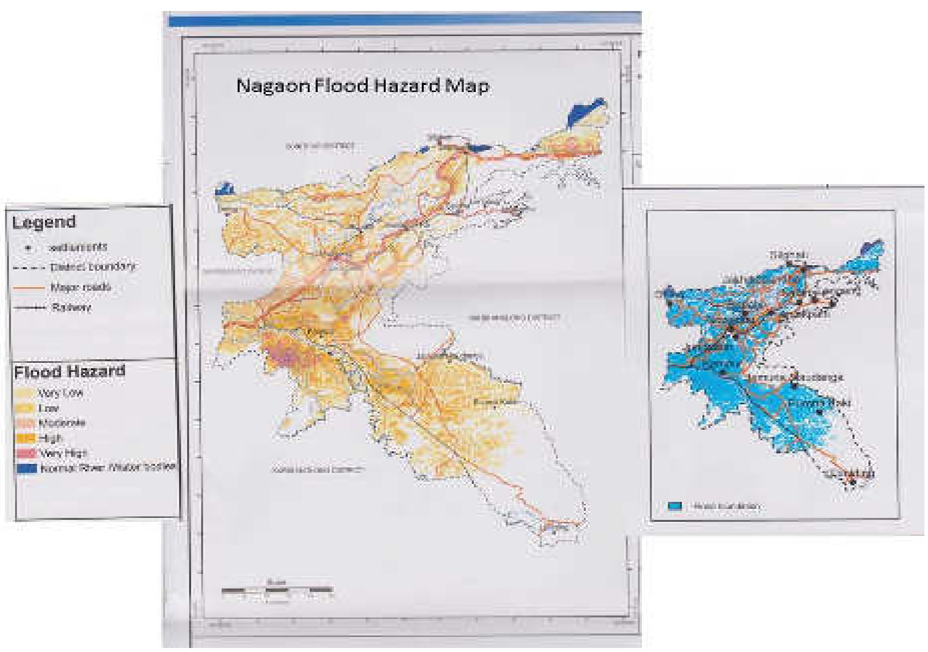
(Source: ASDMA Flood Atlas, 2011)

Figure 3-13: Flood Hazard map of Morigaon



(Source: ASDMA Flood Atlas, 2011)

Figure 3-14: Flood Hazard map of Morigaon



(Source: ASDMA Flood Atlas, 2011)

4. REVIEW OF KOPILI RIVER BASIN PLANS

89. In this Chapter, reviews are made of the following major sectoral development plans:

- Kopili-Kallang River sub-basin Master Plan prepared by the Brahmaputra Board in 1995
- Hydropower Development Plans
- Flood Mitigation Plan of Water Resources Development
- Irrigation Development Plans

4.1 The Kopili-Kallang Basin Master Plan, 1995

90. The only master plan for the development of the Kopili-Kallang Sub-basin was prepared by Brahmaputra Board, Ministry of Water Resources in 1995. As mandated by the central Ministry of Water Resources, the Brahmaputra Board started preparing Master Plans for the Brahmaputra Basin as a whole from 1986, dealing with sub basins of major tributaries. The Board has identified 38 such tributaries joining the mighty Brahmaputra from north and south sides. The draft Master Plan for Kopili-Kallang sub-basin was originally prepared in 1990. The 1995 version is an outcome of revision based on suggestions from the Ministry and other state level agencies.

91. The Kopili-Kallang sub-basin Master Plan has not been updated so far, except that a base paper in year 2012-13 on implementation of recommendations has been issued by the Brahmaputra Board. This base paper, which contains only two pages, does not update the Plan itself except providing a revised cost of the earlier schemes recommended in the Master Plan with the 2012 price level.

92. According to Brahmaputra Board, development of an updated master plan is in discussion and is expected to take some more time for its revision and upgradation of existing plan with new schemes.

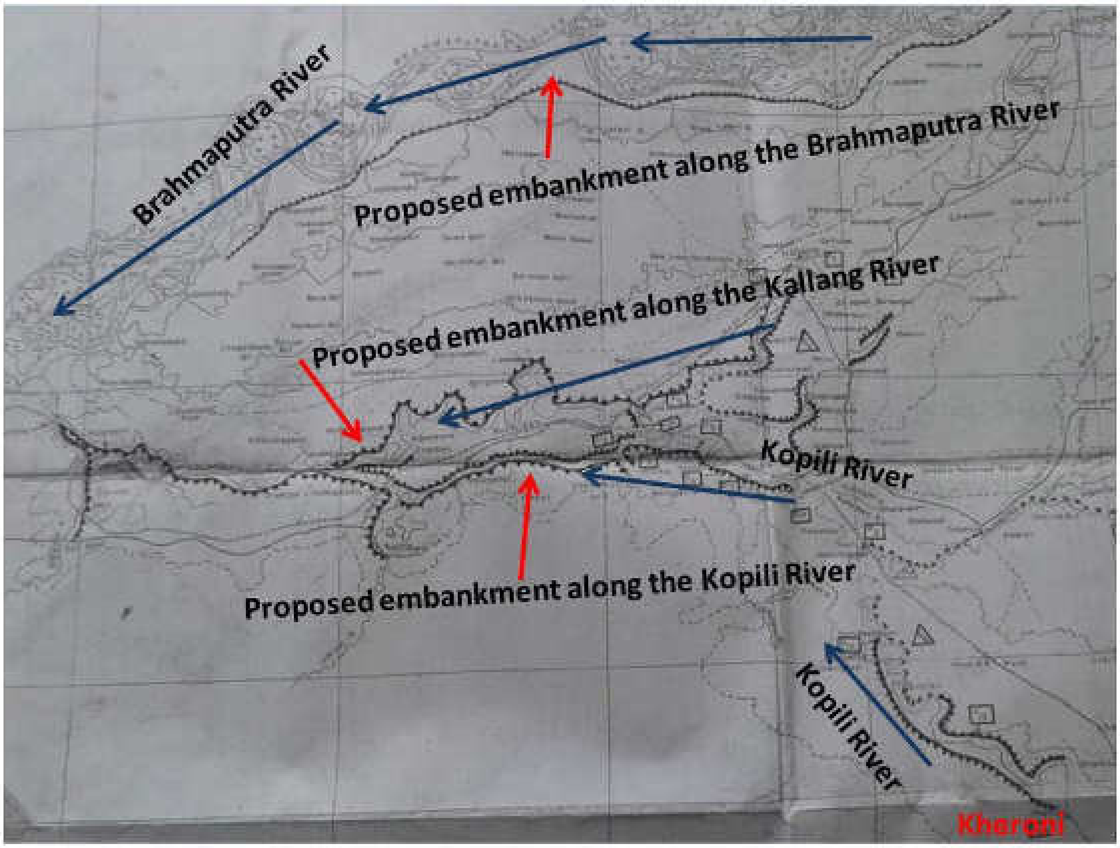
93. The Master Plan of 1995 identifies various issues related to multipurpose water resources development in the Kopili-Kallang sub-basin. However it focuses on providing detailed cost estimates of flood control schemes. In addition to the flood control schemes, hydropower, navigation and irrigation development projects were also described in the Plan. The salient features of the schemes included in the Master Plan are:

- Construction of new embankment: 59.30 km
- Raising & strengthening of embankment: 143.78 km
- Closing of existing gaps in the embankment: 60 m
- Closing of the Titamari Channel
- Construction of sluice: 5 numbers
- Anti-erosion measure: 13 sites (protection of towns, villages and embankments)
- Construction of raised platforms in low lying villages: 122 numbers
- Other non-structural measures like floodplain zoning, improvement in flood forecasting & warning systems, expansion of hydro-met network, disaster mitigation systems, preparedness, regular maintenance of embankments, watershed management etc, have also been suggested.
- Total cost of the schemes (at 1990-91 schedule of rates): Rs. 5,109.00 Lakhs
- Estimated benefits from the proposed schemes: Rs. 12,033.00 Lakhs

94. Figure 4-1 shows the location of the proposed flood control embankments in the Master Plan of the Brahmaputra Board. It can be seen that, most of the embankments are

proposed along the Brahmaputra river and Kallang river. Flood control embankments are also proposed along the flood plains of the Lower Kopili river downstream from Kheroni.

Figure 4-1: Location of flood control embankments in the Master Plan



(Source: Brahmaputra Board, 1995)

95. Analysis of problems related to floods and drainage congestion was carried out before designing the above new schemes. It was identified that 4,200 sq.km of the Kopili- Kallang sub-basin area was in the floodplain out of which 2,495 sq.km was prone to a 25 year return period flood, affecting 781 number of villages. 44,600 ha of agricultural land was affected during a normal flood, while the area affected in a high flood was 117,500 ha. The estimated average annual flood damage was Rs. 6,308.66 Lakhs.

96. The Master Plan also identified flood control schemes constructed prior to 1994. There were 331.87 km of embankments, 59.31 km of drainage channels, 39 numbers of sluices and anti-erosion measures taken at 18 sites.

97. It was pointed out that indiscriminate deforestation and practicing of shifting cultivation in the hilly part of the catchment has led to extensive soil degradation in the sub basin. This in turn perpetually adds to the intensity and severity of floods in downstream areas besides loading the rivers with substantial silt from eroded top soil cover in the hills. Soil conservation measures in the form of integrated watershed treatment/ management was recommended in the Master plan.

4.1.1 Financial Implications for Implementation of Recommended Measures

98. The estimated cost for implementation of the schemes recommended in the Kopili -

Kallang sub-basin Master plan was Rs.5,109.00 Lakhs at the price level of 1990-91. The projected estimated cost amounted to Rs.13,940.00 Lakhs at price level for the year 2012, which was provided by the Brahmaputra Board in its base Paper of 2012. A broad break up and increased cost of implementation is summarized in Table 4-1.

Table 4-1: Updated (2012 price level) Cost of Master Plan Implementation

No	Measures Proposed	Cost (Lakh Rs.)
1	Flood Management & Flood Proofing Measures	6,590
2	Irrigation	2,544
3	Agriculture including change of cropping pattern, Pisci-culture	2,185
4	Watershed Management	2,160
5	Miscellaneous including upgradation of hydro-meteorological networks, Evaluation & Monitoring	460
	Total Cost of Implementation of the recommended Measures	**13,940 Lakhs (Rs 139.4 Cr)**

4.2 Hydropower Development Plans

99. The North Eastern Region is blessed with immense amount of hydro-electric potential, consisting of almost 40% of the country's total hydropower potential. Despite such enormous potential, the Region ranks lowest in the country in terms of per capita energy consumption. This has been mainly due to inhospitable climatic conditions, remote location and inaccessibility of geographical locations. However, with continual improvement of infrastructure and communication facilities, the North East region stands to become the Power House of India by utilizing its surplus power potential, especially in the hydro sector as surface water resource of the region is near to 652.3 billion cubic meters that shares 34% of country's total water wealth (Central Electricity Authority - CEA Report, 2009-10). The Brahmaputra basin of the region has abundant hydropower potential which is estimated at 66,065 MW. As on 31/05/2017 total installed capacity of 3701 MW is in operation and with a total installed capacity of 4284 MW is under construction. This accounts for only 12.21% of the assessed potential. Therefore, a large chunk of the hydropower potential (87.79%) of the basin remains to be tapped. A list of hydroelectric projects in Brahmaputra basin is summarized as Table 4-2.

Table 4-2: Major Hydro Electric Projects in Brahmaputra Basin

Sl.No.	Project Name	River	State
1	Chuzachen Hydroelectric Project	Rangpo & Rongli	Sikkim
2	Doyang Hydroelectric Project	Doyang	Nagaland
3	Karbi Langpi Hydroelectric Project	Borpani	Assam
4	Kopili Hydroelectric Project	Kopili	Assam
5	Myntdu Leshka Stage-I	Myntdu	Meghalaya
6	Pagladia (Kamrup)	Pagladiha	Assam
7	Ranganadi Hydroelectric Project	Ranganadi	Northeast India
8	Rangit - III Hydroelectric Project	Greater Rangit	Sikkim
9	Subansiri Lower Hydroelectric Project	Subansiri	Assam
10	Teesta - V Hydroelectric Project	Teesta	Sikkim
11	Teesta Low Dam III Hydroelectric Project	Teesta	West Bengal
12	Teesta Low Dam IV Hydroelectric Project	Teesta	West Bengal
13	Umiam Hydroelectric Project	Umiam	Meghalaya

Sl.No.	Project Name	River	State
14	Umiam-Umtru Hydroelectric Project	Umtru	Meghalaya
15	Umtru Hydroelectric Project	Umtru	Meghalaya

(Source: http://india-wris.nrsc.gov.in/)

4.2.1 Power Scenario of Assam

100. The per capita electricity supply of 228 kWhr/person/year in Assam is only a quarter of the national per capita generation of 720 kWhr/person/year. As a result, Assam has one of the lowest per capita electricity consumption in the India. The remarkably low per capita electricity consumption in Assam affects both the quality of life and level of economic activity in the state.

101. The power scenario in Assam is not only bad but uncertain. Today, Assam Power Generation Corporation Limited (APGCL); (formerly Assam State Electricity Board or ASEB) has a total installed capacity is about 380.0 MW and with the state share of about 751 MW in central generating stations of North-East region, the total capacity or availability works out to about 1085 MW. This compares well with the peak demand of about 1250 MW but problems such as high pilferage, poor liquidity, solvency and escrow- ability, poor quality of T&D system (loss of the order of 50%), inadequate transformation capacity, mean that the state is perpetually in an acute power shortage condition. Assam also faces a huge hydro - thermal imbalance as a large portion of total power generation comes from thermal sources. Even the thermal power Projects are not in good shape. As a result, Assam's peaking shortage is about 12.5 percent while the energy shortage stands at 4.5 percent and the gap between the average cost of supply and the average tariff comes out to be more than Rs. 4.00 per unit.

102. Furthermore, there is vast scope for rapid industrial growth. However, availability of power shall be vital for future industrial activities. In this situation the state has to exploit its hydro power potential to the best possible extent.

103. Therefore, commissioning of the proposed HEPs in the Kopili Basin, including the Borpani River will be a major step forward in improving the power scenario in Assam.

104. Investigations carried out so far reveal that the proven power potential through hydroelectric Projects in Assam is of the order of 498 MW installed capacity with annual generation to the order of 2482 Million Units (MU) as shown in Table 4-3.

Table 4-3: Hydropower Potential in Assam (Source: Lahmeyer/APDCL, 2014)

No	Name of the Project	Capacity (MW)
1	Lower Kopili HEP	(2 x 55)+(2 x 2.5+1 x 5)=120
2	Borpani lower stage HEP	2 x 50=100
3	Borpani Upper stage HEP	2 x 30=60
4	Borpani Intermediate Stage HEP	
	Stage-I	22.5

	Stage-II	24
5	Borpani Barrage Toe Project	12
6	Amring HEP	2 x 10 =20
7	Dhansiri HEP	20
8	Small, Mini & Micro Hydel Projects	111
9	Bordikharu Micro Hydel Project	2
	TOTAL	491.5 MW

105. A Yearly demand projection was also made by Lahmeyer/APDCL in 2014, which is given in Table 4-4.

Table 4-4: Yearly projected demand position till 2019-20 (Source: Lahmeyer/APDCL, 2014)

Year	Demand (MW)	Availability (MW)	Shortfall		Rise Demand
			(MW)	(%)	(%)
2007-08	869	742	127	15	15
2008-09	915	810	105	11	11
2009-10	984	947	37	4	4
2010-11	1066	847	119	11	11
2011-12	1257	966	291	23	23
2012-13	1428	909	519	36	36
2013-14	1526	1148	378	25	25
2014-15	1618	1608	10	1	1
2015-16	1715	1644	71	4	4
2016-17	1817	1644	173	10	10
2017-18	1946	1706	240	12	12
2018-19	2080	1706	374	18	18
2019-20	222	1706	516	23	23

106. The state needs to speedily exploit its available potential to meet its growing energy demand. It is encouraging to note that the Kopili Basin has ample potential to meet the energy demand of Assam.

4.2.2 Kopili Basin

107. As a part of the Brahmaputra basin, hydropower potential in the Kopili basin was assessed by the Central Electricity Authority which is summarized in the Kopili-Kallang Master Plan prepared by the Brahmaputra Board in 1995. As stated in the Master Plan, which is summarized in Table 4-5, a gross potential of 509.9 MW was estimated at 60% load factor. However, as on 31/05/2017, total installed capacity in the Kopili basin is 541 MW which is higher than the estimated potential assessed in the old master plan. Apart from the installed capacity, 120 MW lower Kopili hydro-power project is also cleared and appraised by Central Electricity Authority in 2015 and is likely to be commenced in a year's time. A list of existing hydropower plants in the Kopili Basin is shown in Table 4-6. The oldest major project in the basin is the Umium lake project in the upper most reach of Killing developed in 1965 with a total installed capacity of 200 MW, including the cascade plants.

Table 4-5: Potential of hydropower generation in Kopili Basin estimated in Kopili-Kallang Master Plan

S. No	Name of the Scheme	River	Type of Scheme	Gross Head (m)	Live Storage (cum)	Potential at 60% load factor (MW)	Status mentioned in Master Plan, (1995)
1	Kopili-I (Khandong)	Kopili	Storage	104	129.5	21.80	E
2	Kopili (Umrong)	Kopili	Storage	347.5	55.5	91.0	E
3	Amring	Amring	Storage	79.0	357.0	26.50	P
4	Diyung Dam PH	Diyung	Storage	34.8	820.0	31.50	P
5	Jamuna Dam	Jamuna	Storage	37.8	450	19.0	P
6	Upper Borpani	Borpani	Storage	150	185	37.7	P
7	Longey	Borpani	ROR	90.0	-	24.30	P
8	Lower Borpani	Borpani	ROR	208	-	57.50	O
9	Umlamphang	Umium	ROR	280	-	14.20	P
10	Sumer PH -I	Umium	Storage	165	141.8	7.50	E
11	Sumer PH-II	Umtru	ROR	81.0	-	3.70	E
12	Umium- Umtru St-III	Umtru	ROR	160.0	-	27.0	E
13	Umium- Umtru St-IV	Umtru	ROR	146.0	-	25.20	E
14	Umium- Umtru St-V	Umtru	ROR	65.7	-	18.0	P
15	Umium- Umtru St-VI (Umling)	Umtru	Storage	207.5	234.0	95.70	P
16	Umtru PH (Existing)	Umtru	ROR	61.0	61.0	9.30	E
	Potential of hydropower generation in Kopili-Kallang basin					509.9 MW	

Note- E-Existing, O-Ongoing or Under Construction, P-Proposed

Source: Kopili-Kallang Master Plan (Brahmaputra Board, 1995)

Table 4-6: Hydropower Generation in Kopili-Kallang Basin

S.No	Basin-State	Name of Hydropower Project	Installed Capacity (MW)	Year of Commissioning
1	Assam	Karbi Langpi (L. Borpani)	100	2006-07
2		Kopili Extension	100	1996-97
3		Kopili	100	1988
4		Khandong	75	1984
5	Meghalaya	Kyrdemkulai	60	1979
6		Umiam st-I	36	1965
7		Umiam-Umtru st-IV	60	2011
	Total installed Capacity in the basin		**541 MW**	

Source: CEA, 2017

108. Figure 4-2 shows the planned hydropower stations in the Kopili Basin (NEEPCO, 2017). In the meantime, Brahmaputra Board is preparing a DPR for the development of a hydropower project in the Killing river, as shown in Figure 4-2.

Figure 4-2: Location of planned hydropower projects in the Kopili Basin

(Source: NEEPCO, 2017)

109. **Killing HEP:** The Brahmaputra Board is preparing a DPR for the Killing Hydropower Project. The dam site is located 3km upstream of Karbihidi village in Karbi angling district of Assam, It will have an installed capacity of 85 MW. Brahmaputra Board started survey and

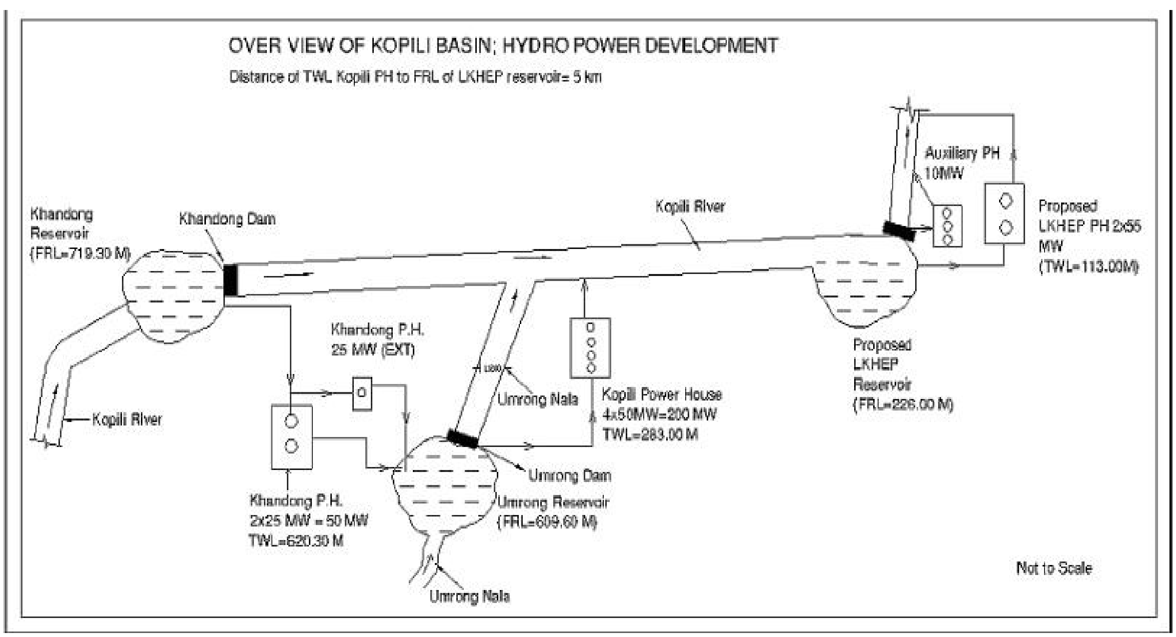
investigation of this project in 2002 and it is targeted to complete the DPR by the end of 2017. The Ministry of Power, GOI has decided to handover the project to NEEPCO for implementation. At present, hydrological studies for the DPR are in progress and layout plan of the project is under finalization.

110. The Brahmaputra Board is also carrying out survey & investigation of a 20MW mini hydropower project in the Myntang river.

4.2.3 Kopili Hydro-Electric Power Plants (KHEP)

111. The Kopili Hydro Electric Project (KHEP) has two dams, one on the Kopili River and one on its tributary Umrong nala. This project was developed by NEEPCO (Northeast Electric Power Corporation Ltd.). The first dam with 66 m height on the Kopili River is known as Khandong dam and the second one with 30 m height is known as Kopili dam located at Umranso. Water from the Khandong reservoir is utilized in the Khandong power station through a 2852 m long tunnel to generate 50 MW (2 X 25 MW) of power. The tail water from this powerhouse is led to the Umrong reservoir. The water from Umrong reservoir is taken through a 5473 m long tunnel to the Kopili power station to generate 200 MW (4 X 50 MW) power. An additional 25 MW was added to the Khandong dam in the Stage-II of the Kopili HEP, making the total power generation 275 MW. Both Khandong and Kopili dams are concrete gravity dams. The first unit of this Kopili HEP was commissioned in March 1984. The additional unit under stage two was commissioned in July, 2004. A line diagram of the KHEP along with the proposed LKHEP system is shown in Figure 4-3.

Figure 4-3: Line Diagram of existing Kopili HEP



4.2.4 Proposed Lower Kopili HEP (LKHEP)

112. The proposed Lower Kopili HEP is coming up in Boro Longku village in Dima Hasao district. The project is proposed on right bank of river Kopili and located at downstream of existing Kopili hydroelectric power plant. The project is being developed by Assam Power Generation Corporation Limited (APGCL) which is based on a run-of-river scheme. The project envisages utilization of the regulated discharge from Kopili HEP, spills of Khandong and

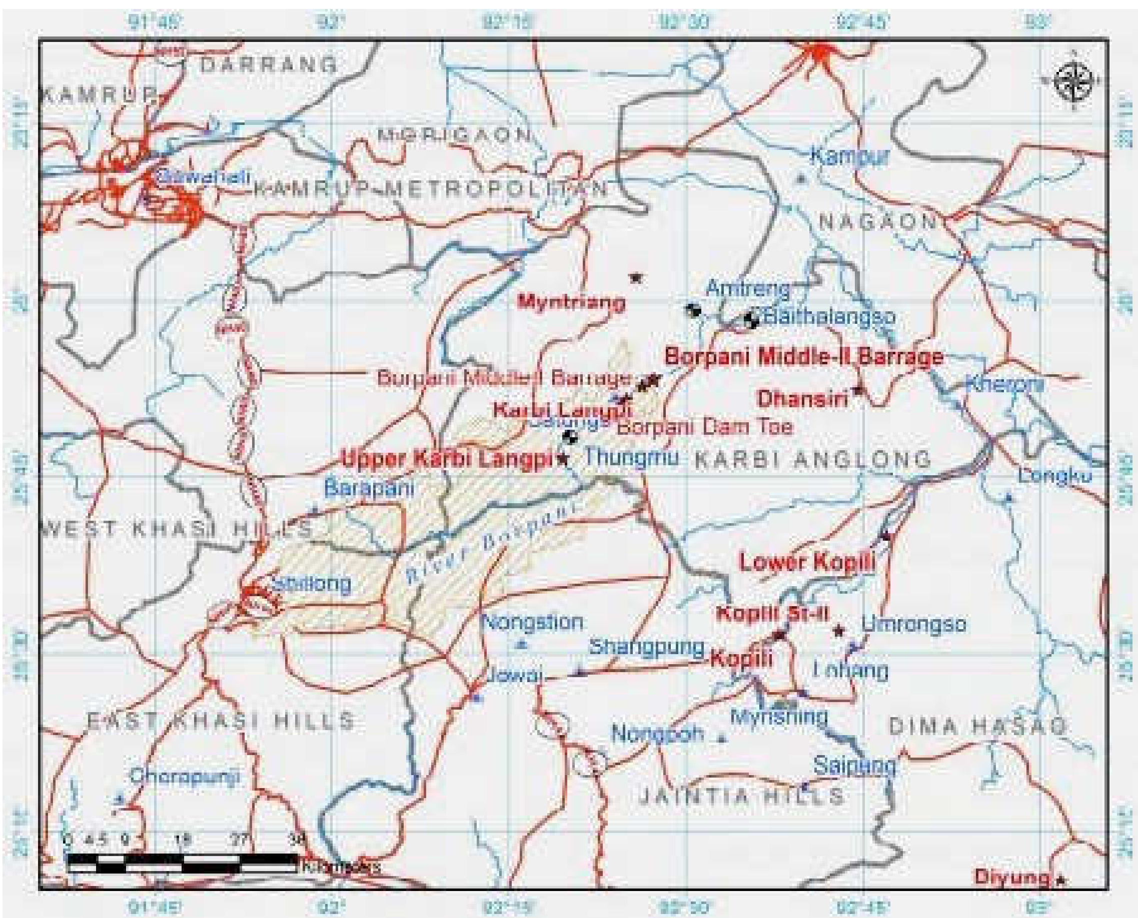
Umrong dams and the discharge from intermediate catchment by creating of a reservoir and utilizing a gross head of about 114 meters. This project will have two power houses. The first power house, or the main power house will have an installed capacity of 110 MW (2X55MW). An auxiliary power house with an installed capacity of 10MW with two units of 2.5MW each and one unit of 5MW, is planned at the toe of the dam for utilizing the mandatory releases for ecological purposes, making the total installed capacity 120 MW. LKHEP will be the third and last in a cascade of dams on the river Kopili.

4.2.5 Proposed Middle Borpani Hydropower Project (24 MW)

113. The Middle Borpani Hydropower Project one of the project identified and studied in the Borpani river. Three numbers of hydro power projects between existing Lower Langpi HEP (100 MW) and Upper Borpani HEP have been conceived following the valley optimization study on Um Khen/ Borpani river, which are: 1. Borpani Barrage Toe HEP (2 × 6.0 MW); 2. Borpani Middle I HEP (3 × 7.5 MW) 3. Borpani Middle II HEP (3 × 8.0 MW). Lahmeyer International (India) Pvt. Ltd has prepared DPRs for these projects for APGCL.

114. Borpani Middle II HEP is a run-of-the-river scheme conceived to run at full potential in monsoon season and operate as per the water availability in non-monsoon season. The Borpani Middle II HEP is located in Karbi Anglong district of Assam. Borpani river is a major tributary of Kopili river. Figure 4-4 shows the locations of the Borpani HEPs.

Figure 4-4: Location Map of Borpani HEPs



4.3 Small Hydropower Projects

115. In Assam, hydropower projects up to a capacity of 25 MW are termed "Small Hydropower Project (SHP)." Assam State Electricity Board (ASEB) in the Assam Small Hydropower Policy has identified 90 potential SHP sites with a total installed capacity 117 MW. Out of this, a total capacity of 94.75 MW is identified at 75 sites in the Kopili Basin within the three districts of Dima Hasao, Karbi Anglong and Nagaon. A list of the identified SHPs are given in Table 4-7. Only one SHP of 2 MW capacity was developed at Bordikharu in the district of Karbi Anglong. However, this plant is not operational since 1999 due to technical snag.

Table 4-7: List of Identified Small Hydropower Projects in the Kopili River Basin

S. No.	District	Name of Scheme	Stream (tributary of Kopili)	Proposed Installed Capacity (MW)
1	Karbi Anglong	Bordikharu	Bordikharu	2.00
2	Karbi Anglong	Lungit-1	Lungit	3.00
3	Karbi Anglong	Lungit-2	Lungit	3.0
4	Karbi Anglong	Dalaima	Dilaim	6.00
5	Karbi Anglong	Jamnua	Jamuna	2.00
6	Karbi Anglong	Myntriang-1	Myntriang	6.00
7	Karbi Anglong	Myntriang-2	Myntriang	3.00
8	Karbi Anglong	Kallanga	Kallanga	4.00
9	Karbi Anglong	Jangharni	Jangharni	2.00
10	Karbi Anglong	Klarang	Lungit	4.00
11	Karbi Anglong	Patradisa	Patradisa	1.00
12	Karbi Anglong	Um-mat	Um-mat	1.00
13	Karbi Anglong	Amphi	Amphi	6.00
14	Karbi Anglong	Sunani	Sunani	2.00
15	Karbi Anglong	Kaliani	Kaliani	1.50
16	Karbi Anglong	Amring	Amring	2.00
17	Karbi Anglong	Dinar	Dinar nala	0.50
18	Karbi Anglong	Khora	Khora nala	0.75
20	Karbi Anglong	Umjaring	Umjaring	2.85
21	Karbi Anglong	Dinar	Dinar nala	0.50
22	Karbi Anglong	Kohra	Kohra nala	0.75
23	Karbi Anglong	Bagijan	Bagijan	0.75
24	Karbi Anglong	Chelabour	Chelabour	0.40
25	Karbi Anglong	Danglangso	Danglangso	0.40
26	Karbi Anglong	Diphu (1-3)	Diphu nala	0.60
27	Karbi Anglong	Dirick chiring	Dirick chiring	0.20
28	Karbi Anglong	Horu horgati	Horu horgati	0.40
29	Karbi Anglong	Horu	Horu nala	0.30
30	Karbi Anglong	Kagironga	Bodiphlunadi	0.40
31	Karbi Anglong	Kuliteranggha	Kuliteranggha	0.20
32	Karbi Anglong	Langchailit	Langchailit	0.20
33	Karbi Anglong	Langsomepi	Langsomepi	0.10
34	Karbi Anglong	Lankhipam	Lankhipam	0.75
35	Karbi Anglong	Morjengnala	Morjengnala	0.30
36	Karbi Anglong	Paklangso	Paklangso	0.10
37	Karbi Anglong	Patradisa	Patradisa	0.30
38	Karbi Anglong	Thedong	Thedong	0.20
39	Karbi Anglong	Un ju	Un ju	0.20
40	Karbi Anglong	Um pani	Um pani	0.30
41	Karbi Anglong	Um sares	Um sares	0.40
42	Karbi Anglong	Um ser	Um ser	0.30
43	Karbi Anglong	Killing valley	Killing	1.00
44	Karbi Anglong	Kakachang	Kakachang	0.50
Total in Karbi Anglong district				**62.15**
45	Dima Hasao	Jenum-1	Jenum	4.00

S. No.	District	Name of Scheme	Stream (tributary of Kopili)	Proposed Installed Capacity (MW)
46	Dima Hasao	Jenum-2	Jenum	4.00
47	Dima Hasao	Jiri	Jiri	1.50
48	Dima Hasao	Dere	Dere	1.00
49	Dima Hasao	Dalaima	Dilaim	6.00
50	Dima Hasao	Thar nala	Thar nala	1.50
51	Dima Hasao	Paisa nala	Paisa nala	1.50
52	Dima Hasao	Chikhu nala	Chikhu nala	1.50
53	Dima Hasao	Riambatari	Riambatari	0.55
54	Dima Hasao	Dere nala	Dere nala	0.50
55	Dima Hasao	Dijung	Dijung	0.40
56	Dima Hasao	Dikrambi	Dikrambi	0.20
57	Dima Hasao	Diyung	Diyung R	0.30
58	Dima Hasao	Dolong	Dolong nala	0.60
59	Dima Hasao	Harangthal	Harangthal nala	0.75
60	Dima Hasao	Induki	Induk nalai	0.60
61	Dima Hasao	Laisong	Jenum R	0.40
62	Dima Hasao	Langku	Langku nala	0.45
63	Dima Hasao	Langpher	Langpher	0.20
64	Dima Hasao	Langting	Lahungdisa	0.30
65	Dima Hasao	Mahu-1	Barasanarang	0.50
66	Dima Hasao	Mahu-2	Mahu R	0.50
67	Dima Hasao	Mabong	Singplong	0.20
68	Dima Hasao	Subojal	Subojal nala	0.20
	Total in Dima Hasao district			**27.65**
69	Nagaon	Chapa nala	Chapa nala	0.75
70	Nagaon	Upper borjuri	Upper borjuri	1.50
71	Nagaon	Selohi dung	Ddigun nala	2.00
72	Nagaon	Langkidang	Langkidang	0.30
73	Nagaon	Hasna	Hasna pani	0.10
74	Nagaon	Bajuri	Bajuri	0.15
75	Nagaon	Kaipani	Kaipani nala	0.15
	Total in Nagaon district			**4.95**
	Total in three districts			**94.75**

(Source: Small Hydropower Policy, 2007)

4.4 Irrigation Development

116. The Irrigation Department categorizes irrigation schemes based on their area in ha:

- Minor Irrigation schemes: up to 2,000 ha
- Medium irrigation schemes: above 2000 ha up to 10,000 ha.

- Major Irrigation schemes: above 10,000 ha.

117. Types of Irrigation Schemes are also considered from the way the source of water is drawn:

- Gravity/Flow Irrigation Scheme: Water diverted from head works through a canal system and is conveyed to the field by gravity. Although the capital cost is high, a gravity scheme is sustainable as it requires low maintenance cost and no power supply is necessary; rather, some schemes generate power.
- Lift Irrigation Scheme: In this system water is lifted by pumps from river/reservoir and then diverted to canal network. Such schemes may be electrically operated or diesel driven.
- Ground water Scheme: Tube well irrigation schemes can also be operated either by electricity by diesel engines. Out of a total ground water potential of 22,478 MCM in the state of Assam, 19,106 MCM have been allocated to be utilized for irrigation. The irrigation department has utilized about 11% of the ground water by developing over 210,00 shallow and 1500 deep tube wells is Assam. No data is available specific to the Kopili basin.

118. Table 4-8 presents a list of irrigation schemes completed by the Irrigation Department in the Koplili River Basin.

Table 4-8: List of Completed Irrigation Projects in Kopili River Basin

Name of Scheme	River (Source)	Irrigation Area (ha)	Year of Completion
Jamuna Irr. Project	Kopili / Jamuna	25,698	1968-69
Modernization of Jamuna Irr. Project	Jamuna	8,960	2008-09
Horguti Irr. Project	Horguti	2,600	1976-77
Dikhari Irr. Project	Jamuna/Dikhari	2,360	1985-86
Hawaipur Irr. Project	Kopili	2,430	2006-07
Amreng irr. project	Amreng	6,120	ongoing
Minor irrigation Projects	Surface flow from local rivers, lifting from local rivers, deep tube wells, shallow tube wells	36,617	2014
Minor irrigation projects	Surface flow from local rivers, lifting from local rivers, deep tube wells, shallow tube wells	6,232	2014

(Source: Irrigation Department)

119. The Kopili-Kallang Basin Master Plan (1995) of the Brahmaputra Board provided details of the irrigation projects in the basin. The document states that up to the 1990s, only about 22% of the potential area for irrigation was developed. It was also stated that there is enough water resource, both surface and ground water for irrigation development in the basin.

120. A large agricultural area in the lower plains of the Kopili basin is flood prone, due to which providing irrigation facility during the monsoon is difficult. Therefore, the Master Plan emphasized in flood protection and drainage improvement in this area to increase the irrigation potential. With proper implementation of the flood management schemes (as contemplated in the Master Plan) a substantial area could be protected from floods and brought under irrigation during the monsoon season. In addition to rain-fed irrigation, ample scope exits for lift irrigation and shallow tube well irrigation. Two varieties of paddy, *Boro* and

Ahu, can be grown there for early harvesting.

4.5 Flood Mitigation by Water Resources Development

121. The low lying areas of the Kopili basin suffer from floods for a long duration during monsoon period causing hindrance to the agricultural activities as people rely on mainly paddy and jute cultivation during the period. Large scale devastation also occurs frequently during heavy floods.

122. The Government of Assam has constructed embankments on both banks of Kopili river and its tributaries in the plains. However, spills from these embankments as well as blockage of land side drainage have aggravated flooding in the low-lying areas.

123. On the other hand, the embankment system constructed long back in 60s and 70s is now in a dilapidated condition and become weak to resist the flood of 25 years return period. Erosion of river banks and the embankments has also occurred at many locations both due to natural (meandering river) and man-made (lack of proper maintenance) factors. The reach of Kopili from Kheroni to Chaparmukh, which is nearly 100 km is affected by erosion.
The Water Resources Department (WRD) has identified the weak portions of the embankment and planned to strengthen 56.50 km length of the embankment. In addition, it is also identified that eight reaches of the river are critically affected by erosion on both banks. WRD has planned to take up anti-erosion measures at those affected reaches, with a total length of 3.50. Figures 4-5 to 4-7 show the locations of flood control works of WRD.

124. Most of the strengthening works have been carried out under the flood management programme during the XI Five Year Plan (years 2007-12). However, it is learnt that the maintenance work is still on-going at some locations, using state government funds.

Figure 4-5: Location of flood control works of WRD

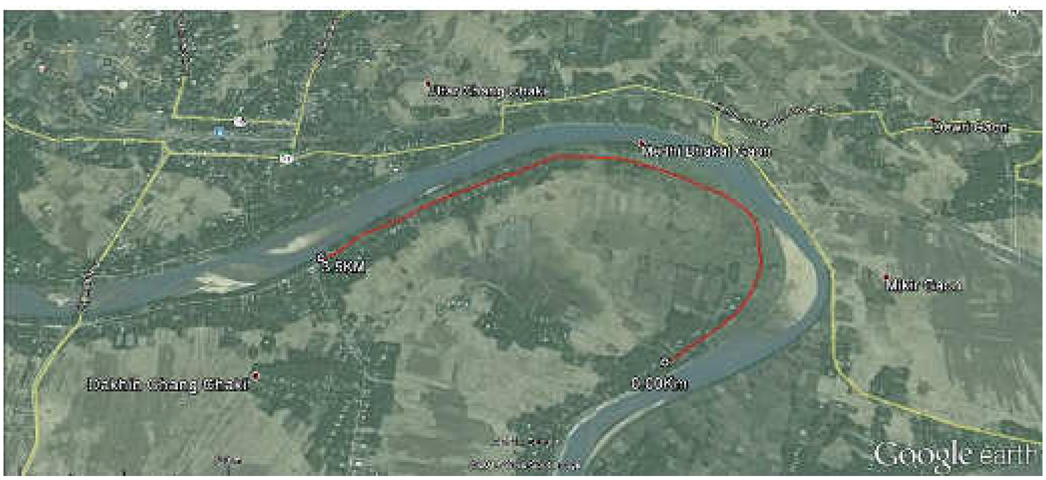
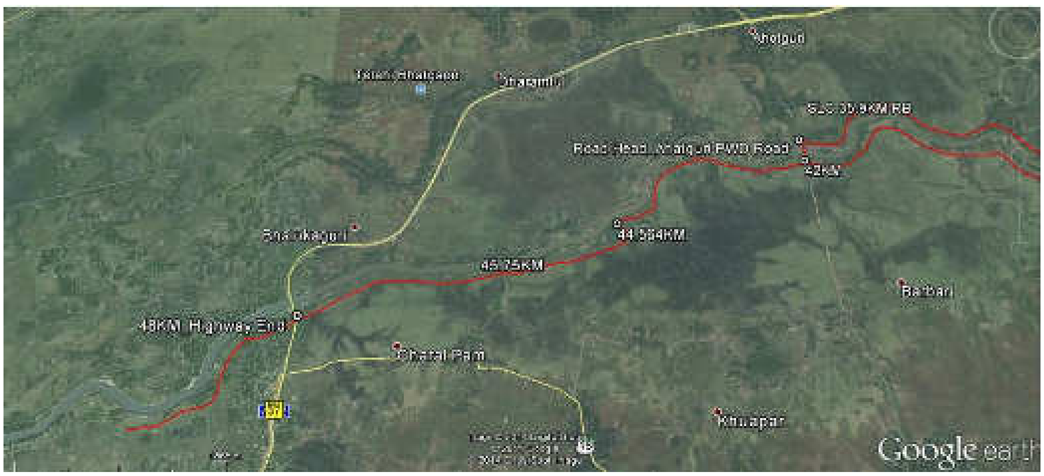


Figure 4-6: Location of flood control works of WRD

Figure 4-7: Location of flood control works of WRD



5. DATA COLLECTION & REVIEW

5.1 Data Availability & Sources

125. Data collected and analyzed in this study include:

- Secondary and primary data reported in the DPR of the LKHEP,
- WAPCOS EIA study
- Kopili-Kallang Basin Master Plan

126. Since data provided in these reports were old and not found sufficient, attempts have been made to collect additional data from the following sources: (Table 5-1 summarizes the data availability and collected for this study).

- Water Resources Department (WRD), Government of Assam
- Assam Water Research & Management Institute (AWRMI),
- Irrigation Department, Government of Assam
- Brahmaputra Board,
- NABARD
- NEEPCO Hydro Power Site Office.

Table 5-1: Summary of Data collected and Sources

S.No	Particulars	Data Used in Master Plan (1995)	Data Used in DPR of LKHEP (2012-13)	Data collected during SEA assignment (2016-17)
1	Rainfall Data	Rainfall data of 34 Stations were used from 1971-1992	Rainfall data of 12 stations for varying length from 1962-2006	Rainfall Record of LKHE P at Longku, (Jan 2011-Nov 2016)
2	Discharge Data	Discharge data of Kopili at Dharamtul from 1955-1992	Discharge data of 4 stations were available for varying lengths from 1955-2010	Daily Discharge data of Lower Kopili at Longku,(Dam site) May 2010- Nov. 2016 with three observation in each day (8AM, 12 Noon & 4.00 PM)
3	Flood Data	Water level data at Dharamtul from 1947-1989 , Flood Data from 1955-1989	Annual Peak Flood for Periods 1955-56 to 1968-69, 1979-80 to 1992-93 and 1998-99 to 2009-10	Maximum water level data of Dharamatul (1947 to 2014)
4	Basin Map	Kopili-Kallang Basin Map is provided in Master plan report	Basin map of Kopili River up to proposed dam site is given	GIS based Kopili-Kallang basin map is prepared for SEA assignment
5	LUCL Map	N/A	N/A	GIS based LULC map of Kopili basin developed
6	Water Demand/Uses Data	Proportionate water use/demand data is derived	Limited information is provided	District wise water use data collected for the basin in Assam State

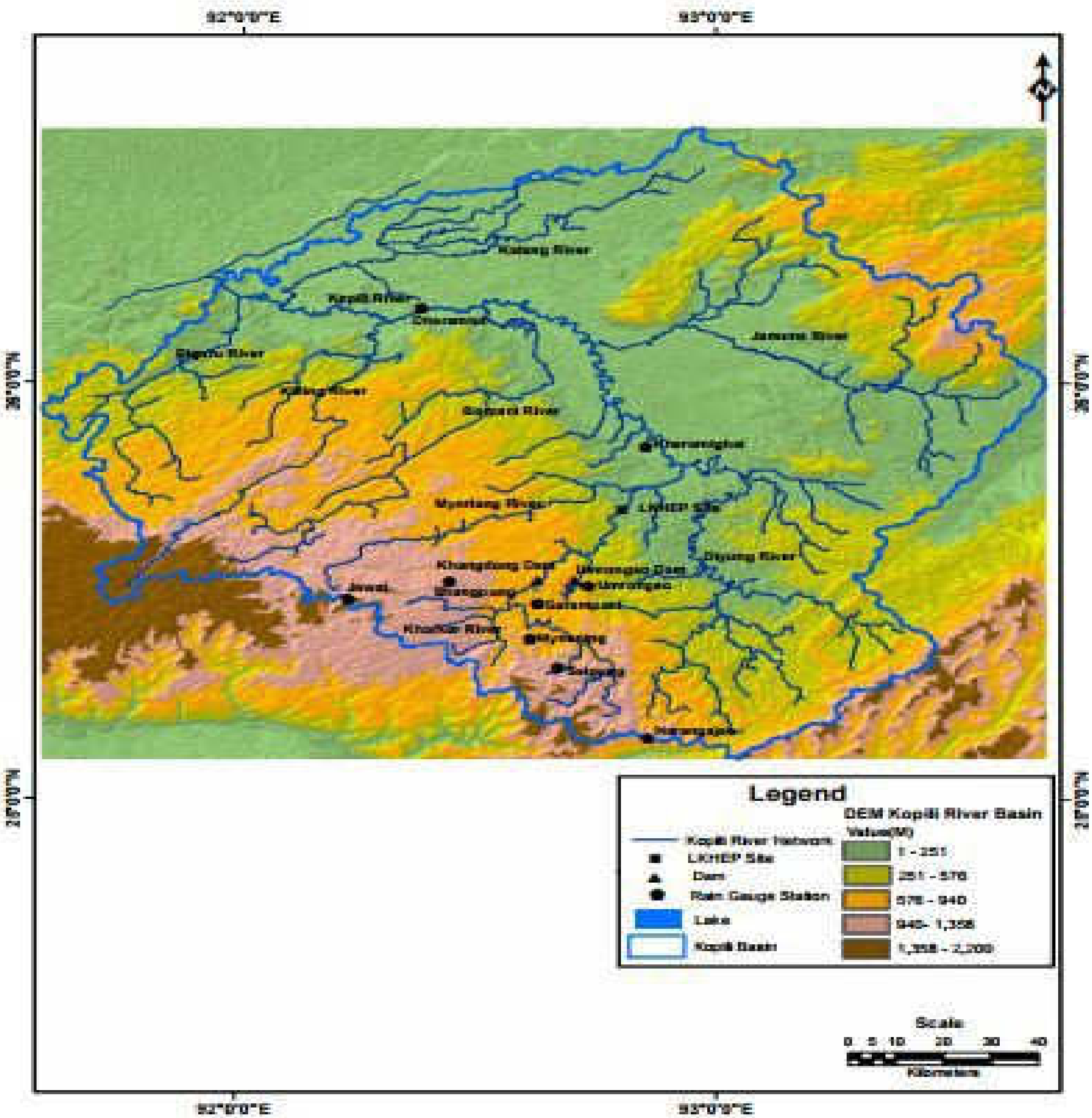
5.2 Meteorological Data

5.2.1 Rainfall

127. Heavy rainfall occurs over the entire north-east India and this is one of the main causes of floods in the Brahmaputra and Baraak Valleys. The passage of cyclonic storms originating in the Bay of Bengal also causes increased precipitation in the entire Kopili basin. These events generally occur in the late May or June and continued till late September or middle of October. Sometimes, land-based depressions in Assam, Meghalaya or it adjoining area also influence heavy precipitation over the entire basin.

128. There are number of rain gauge stations installed in the basin and available data was collected from the concerned departments. In the Kopili-Kallang master plan and in the detailed project report prepared for LKHP Project, rainfall data of the different rain gauge stations were collected from 1962-2006 and were used for different hydrological analysis. During Supplementary Environmental Assessment, rainfall data of Lower Kopili HE Project at Longku was also collected from January 2011 to November 2016. Figure 5-1 shows the location of rain gauge stations in the basin map.

Figure 5-1: Location of Rain Gauge stations in the Kopili basin



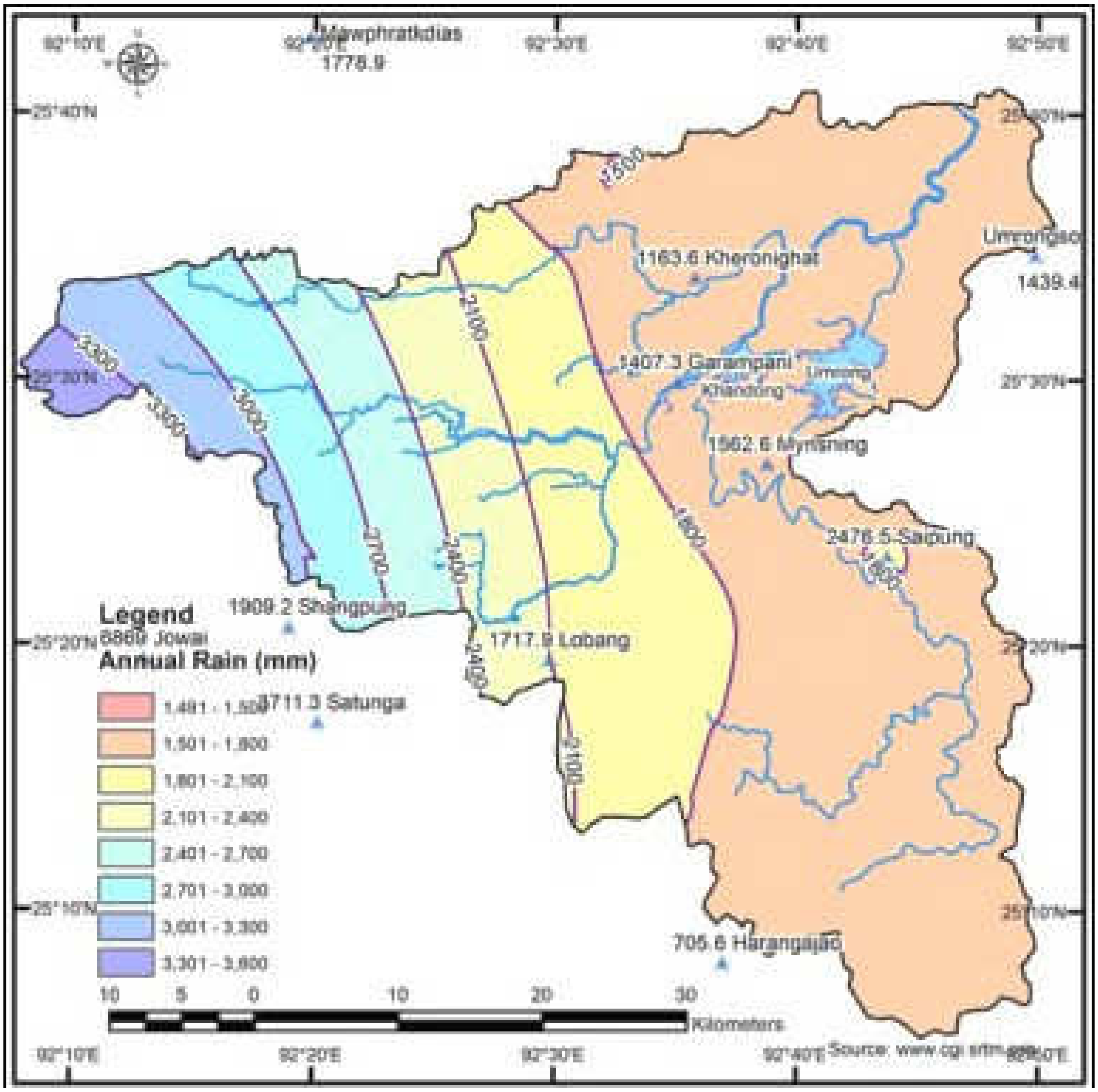
129. In the upper catchment of Kopili up to Khandong Dam site, there are seven ordinary Rain Gauge (R.G.) stations, more or less evenly distributed over the catchment at (1) Shangpung, (2) Satunga (3) Mawphratkdias (4) Saipung (5) Garampani (6) Lobong (7) Mynsning. In the same reach immediately below the Khandong reservoir, there is another ordinary rain gauge station at Umrongso in the Umrong Nallah subcatchment. Monthly rainfall data of these stations for varying length of period from 1962 to 2006 have since been available with NEEPCO as detailed below. In the intervening lower catchment, one ordinary rain gauge station was set up by the Assam State Electricity Board (ASEB) in 1980 at LKHEP dam site at Longku. Daily and monthly rainfall data of this station is available from March to May 1980 and from Jan 1981 to Dec 1986. In addition, daily rainfall data of three other rain gauge stations (Harangajao, Kheronighat and Jowai) maintained by IMD was also available for varying length of period from 1977 to 2006 as summarized in Table 5-2.

Table 5-2: Availability of rainfall data in Kopili Basin

S.No	Rain Gauge Station	Available of Rainfall Data
1.	Garamapani	Jan 1963 to Dec 1967, Jan 1970 to Dec 1974, Jan 1977 to Dec 1986 & Jan 1999 to Dec 2006
2.	Harangajao	Jan 1991 to Dec 1999
3.	Jowai	Jan 1983 to Dec 2005
4.	Kheronighat	Jan 1977 to Jan 1996 & Jan 1998 to Nov 2006
5.	Lobang	Jan 1963 to Dec 1967, Jan 1970 to Dec 1974 & Jan 1977 to Dec 1986
6.	Longku	Jan 1963 to Dec 1967, Jan 1970 to Dec 1974 & Jan 1977 to Dec 1986
7.	Mawphratkdias	Jan 1963 to Dec 1967, Jan 1970 to Dec 1974 & Jan 1977 to Dec 1986
8.	Mynsning	Jan 1963 to Dec 1967, Jan 1970 to Dec 1974 & Jan 1977 to Dec 1986
9.	Saipung	Jan 1962 to Dec 1967, Jan 1970 to Dec 1974 & Jan 1977 to Dec 1986
10.	Satunga	Jan 1963 to Dec 1967, Jan 1970 to Dec 1974 & Jan 1977 to Dec 1986
11.	Shangpung	Jan 1962 to Dec 1967, Jan 1970 to Dec 1974 & Jan 1977 to Dec 1986
12.	Umrongso	Jan 1963 to Dec 1967, Jan 1970 to Dec 1974 & Jan 1977 to Dec 1986

130. Mean annual rainfall over the catchment has been computed as 1946 mm, using interpolation considering average annual rainfall for all the stations. Figure 5-2 shows a distribution of rainfall over the Kopili basin.

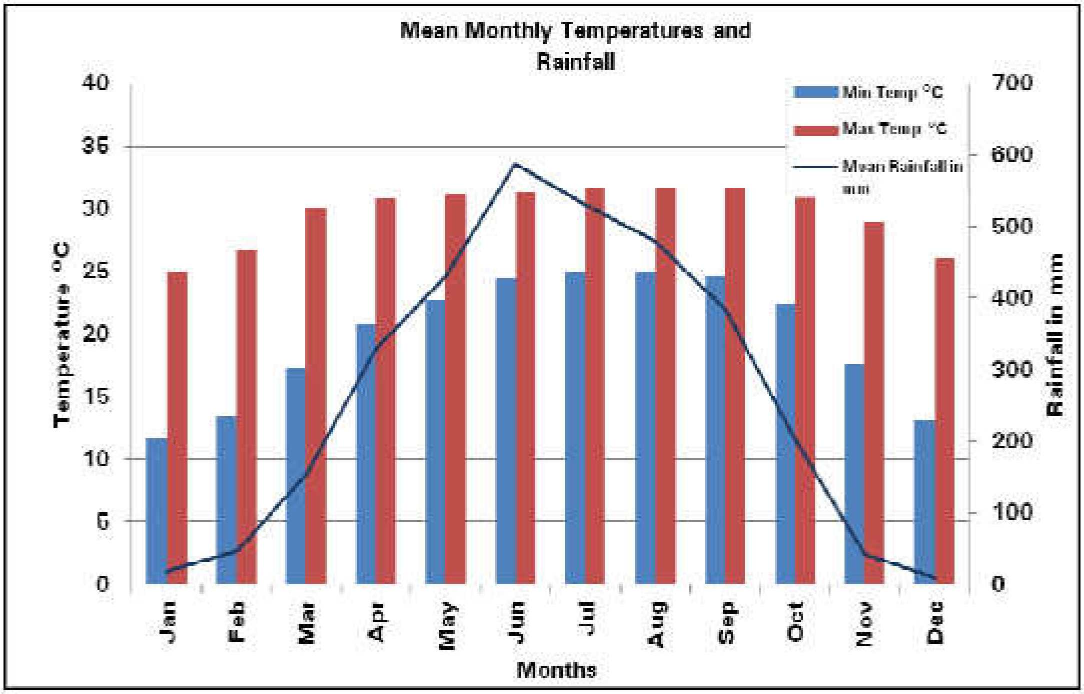
Figure 5-2: Distribution of rainfall over Kopili basin



5.2.2 Temperature

131. The high hills in the basin belong to temperate zone while lower hills and valleys are in the sub tropical agro climate zone. The region experiences four seasons viz., the winter (starting from late November and continuing up to March), the Pre-Monsoon (April and May), South-West Monsoon (end of May to September) and Post Monsoon (October to beginning of November). Temperature in the region varies generally from a maximum of 23°C to 32°C in summer to a minimum of 6°C to 14°C in winter. The average relative humidity varies between 73% and 84%. Mean monthly minimum and maximum temperatures recorded by IMD at Silchar are shown in Figure 5-3. Mean monthly rainfalls have also been shown on the same figure.

Figure 5-3: Mean Monthly Temperature & rainfall at Silchar

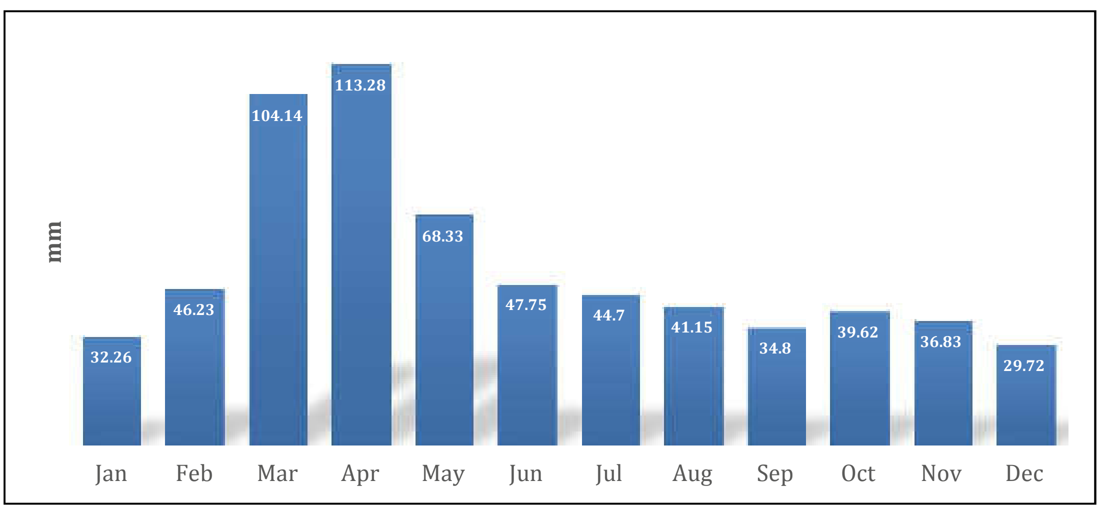


(Source: IMD)

5.2.3 Evaporation

132. There is no pan evaporation data available at the proposed site or in its vicinity. The evaporation loss rate adopted for the upper stage of the same river, only 20 km upstream of the Lower Kopili project, derived with the help of pan evaporation data provided by IMD for Guwahati, Shillong and Silchar are considered as valid for Lower Kopili Project and adopted with annual evaporation loss 638.81 mm (Figure 5-4).

Figure 5-4: Evaporation Data used in LKHEP



(Source: LKHEP DPR)

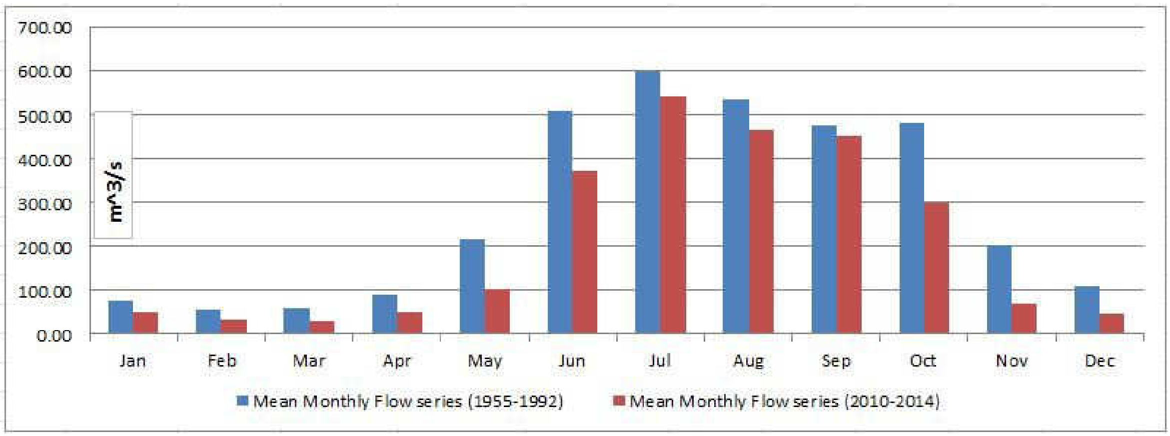
5.2.4 Discharge Data

133. The discharge data of Kopili at Dharamtul CWC gauge site are available from the

hydrological year 1955-56 to 1981-82 (in MCM per month, Master Plan, 1995). Recent years' daily discharge have been computed from the water level records from 2010 to 2014, using the gauge-discharge relation provided by the Brahmaputra Board in their Master Plan of 1995. Based on these discharge data mean monthly flows at Dharmatul

have been computed as sown in Figure 5-5. It can be seen from the two flow series that the gauge-discharge relation, developed during the Master Plan study (1990-94) has changed. There is a need to re-derive the relation by CWC.

Figure 5-5: Mean Monthly Flow at Dharmatul



(Source: CWC/Brahmaputra Board/AWRMI)

134. Data of Haria, Nonoi, Jamuna, Kallang, Borpani and Digaru are available only for a few years. For the existing Kopili HEP, a Gauge and Discharge (G & D) site was established at Garampani in 1955 by the Central Water & Power Commission (CWPC). Records of discharge at this site, intercepting a catchment area of 1256 km², mostly in the form of monthly yield have been available with NEEPCO, from Jan 1955 to Dec 1969 and from Sept 1976 to Dec 1978. Catchment area for G & D site at Garampani is 1256 km².

135. Discharge data at Longku dam site has been generated from discharge data at Garampani using catchment area proportion. Homogeneity of hydro-meteorology and catchment characteristics has been assumed, in the absence of sufficient information to consider otherwise. In 1979 another G & D. site was established by ASEB at Longku, about 1.5 km upstream of proposed dam site, 2.5 km downstream of Kopili powerhouse. Daily discharge data observed at this site is available from June 1979 to Dec 1992 with some data gaps. After 1992, this G & D station at Longku dam site was discontinued. There is another G & D site maintained by NEEPCO on Kopili River 3 km downstream of Kopili powerhouse (Longku G & D site). Data from Longku G & D site was made available for the period May 1998 to April 2004. Since discharge data for this period at the Lower Kopili dam site is not available, data from the Longku G & D site was transferred to the Lower Kopili dam site, using catchment area proportion, as the catchment area up to the dam site is 2010 km². From 2004 to 2010, discharge measurement was done by APGCL at Lower Kopili Dam site itself. Latest data for the same site from year 2011 to 2016 were also collected during SEA assignment. Summary of available discharge data is given in Table 5-3.

Table 5-3: Availability of Discharge Data for LKHEP

Site	Agency	Data Availability Period
Garampani	NEEPCO	Jan 1955 to December 1969, Sept 1976 to December 1978
Lonku, 2.5 Km Downstream of Kopili Power House	ASEB	June 1979 to Dec 1992
Longku, 3 km Downstream of Kopili Power House	NEEPCO	May 1998 to April 2004
Lower Kopili Dam Site	APGCL	2004-2010 (used in DPR), 2011-2016 collected during SEA assignment

136. In addition to the discharge data at LKHEP, discharge data for the Borpani River are also available at the proposed Borpani Middle site (DPR of Borpani Middle HEP 24 MW, 2014).

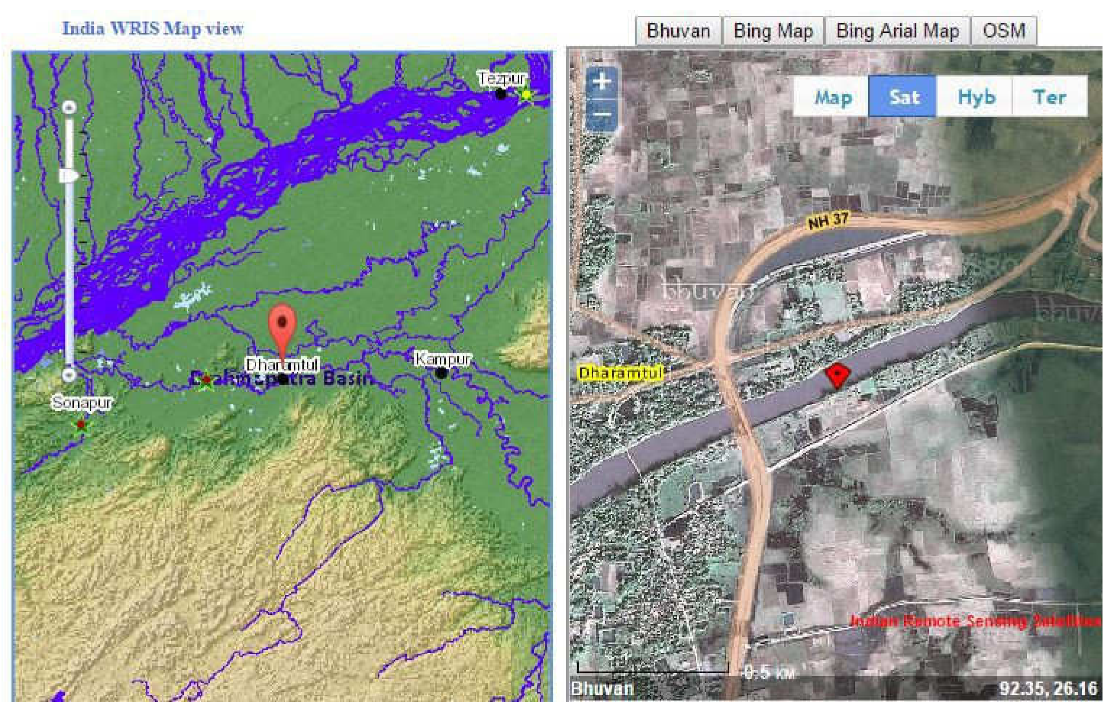
137. Long term daily discharge series of Kopili River is available at the Lower Kopili dam site from 1955 to 1969; 1979 to 1992 and then from May 1998 to April 2010 and continued from 2011- November 2016. Data gaps were present for some months and some years. In the DPR study, they were filled up using monthly average discharge values adjusted into daily data. This was adopted in place of long term average to maintain the variability of flow from year to year. Data for May 1979 was derived as average flow for each day of the month over 1979-1980 to 1992-1993.

138. Daily Discharge Record of Kopili River at Garampani Ferry Ghat is available from year 1955 to 1969 which is upstream of the proposed dam site while discharge data at Longku dam site is available from 1979-1992 & from 1999 to 2016. Looking at the continuity of data, existing/ongoing water flow trends and future years' projections were established by recent discharge data from 1999-2016. To assess the impact of the Kopili dam on river flow and to establish before and after the dam scenario, the period from 1959 to 1983 was considered as pre-dam era while period from 1999 to 2016 was considered post-dam era.

5.2.5 Flood Data

139. The CWC gauge site of Kopili at Dharmatul (Figure 5-6) has a long term time series data regularly observed by CWC. During the SEA assignment, maximum water level data of Dharamatul gauge site has been collected from Year 1947 to 2014.

Figure 5-6: CWC gauge site at Dharmatul



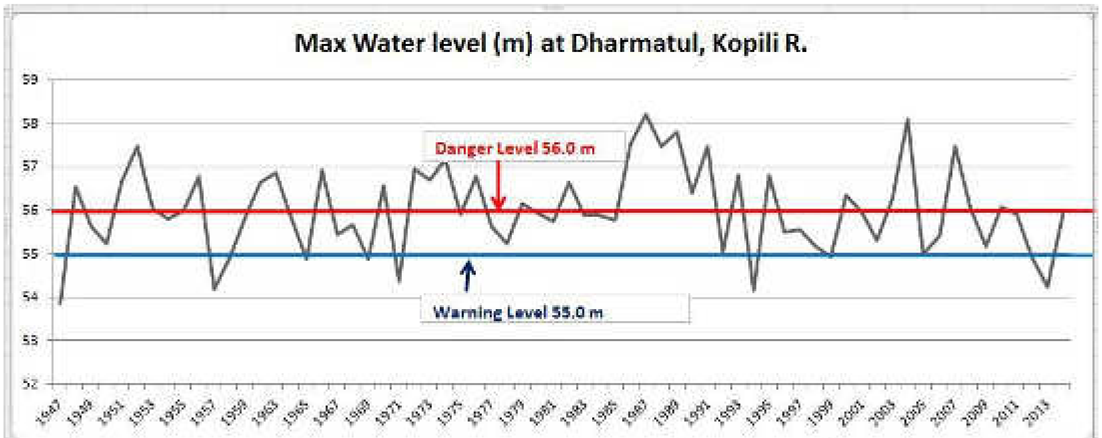
140. Danger level of Kopili at Dharmatul was fixed at 56 m by State Flood Control Department and Revenue authorities. The highest flood level of 58.19 m at Dharmtul was observed on 31.08.1987 while lowest water level of 47 m was recorded on 31.01.75.

141. Figure 5-7 shows a plot of maximum daily water level at Dharmatul. The number of

times the danger level was exceeded at this gauging site can also be seen in the figure. The highest water level at Dharmatul was recorded on 30.06.2012 while minimum water level was recoded on 01.04.2012. Similar plot for the Kampur gauging site is provided in Figure 5-8. At this site, the data after 2006 were found to be inconsistent, probably due to shifting of the gauge.

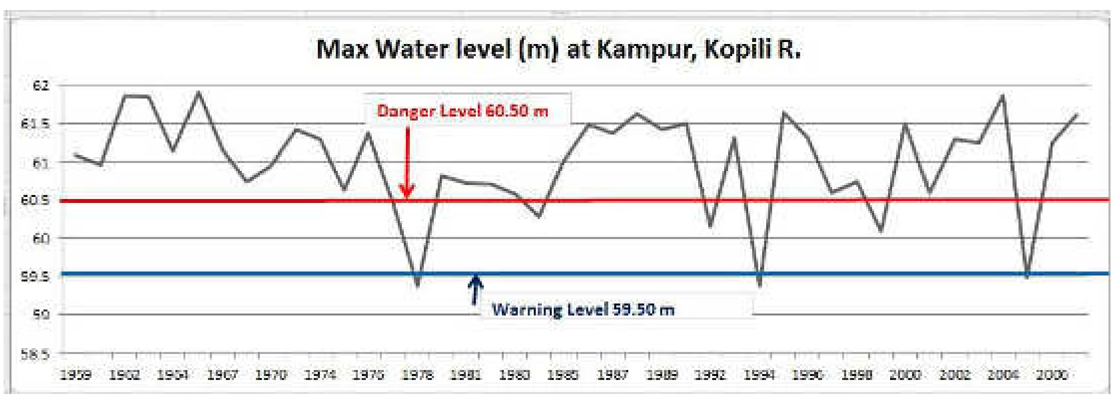
142. It can be seen from Figure 5-9 that the flood data of the CWC gauging site at Dharmatul is consistent. A comparison of the annual maximum water level at Dharamtul during from 1947-75 match well with the recent flood data. Therefore, the flood data at Dharmatul is used for further flood analysis in this study.

Figure 5-7: Maximum Annual Water Level at Dharmatul



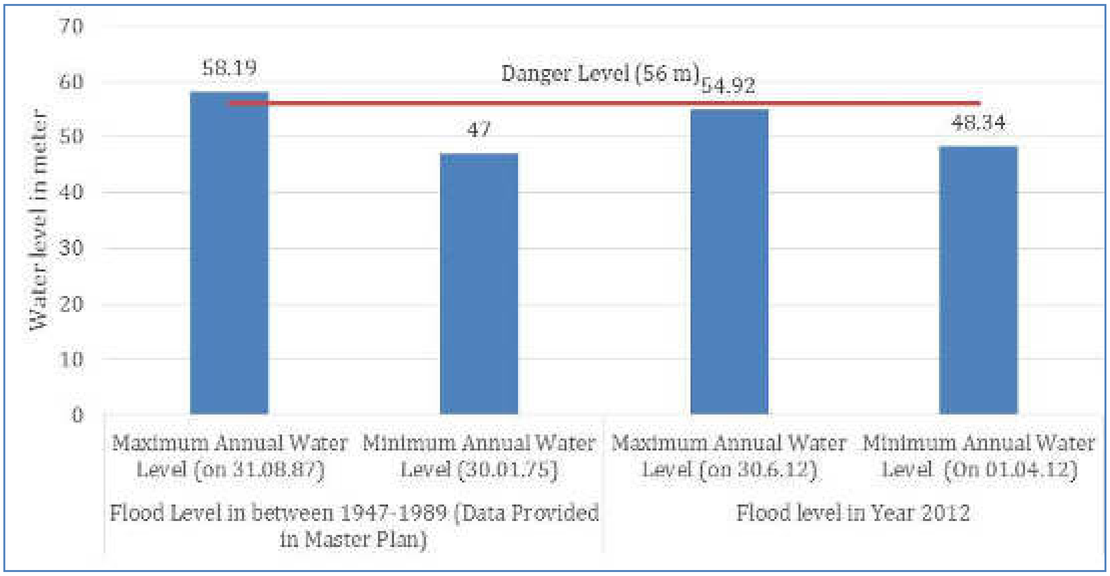
(Source: CWC/AWRMI)

Figure 5-8: Annual Maximum Water Level at Kampur Gaugung Site



(Source: CWC/AWRMI). Note: Data after 2006 not available

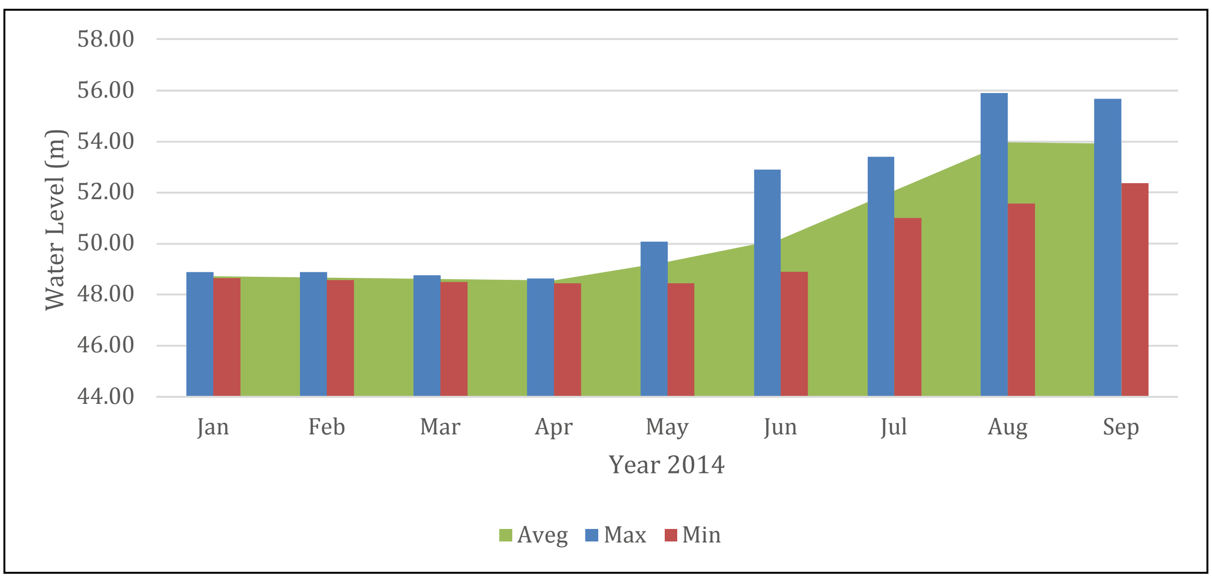
Figure 5-9: Summary of Water Level Data at Dharmatul



(Source: CWC & AWRMI)

143. Daily water levels data have also been collected for Year 2014 from January to September. Based on daily observations monthly mean have been calculated. In year 2014, maximum water level was recorded 55.89 while minimum water level is recorded 48.45 m. Monthly variation of water level of Kopili river at Dharamtul for year 2014 is depicted in Figure 5-10.

Figure 5-10: Monthly Water Level variation for 2014 at Dharmatul



(Source: CWC)

5.2.6 Assessment of recent trends of discharge:

144. Daily Discharge Record of Kopili River at Garampani Ferry Ghat is available from year 1955 to 1969 which is upstream of the proposed dam site while discharge data at Longku dam site is available from 1979-1992 & from 1999 to 2016. Looking at the continuity of data, existing/ongoing water flow trends were established by recent discharge data from 1999-2016. To assess the impact of the Kopili dam on river flow and to establish before and after the dam scenario, the period from 1959 to 1983 was considered as pre-dam era while period from 1999 to 2016 was considered post-dam era.

145. Based on the daily discharge data received from APGCL, monthly and annual mean, maximum and minimum discharge values were calculated. It is observed that in the last 18 years (1998-99 to 2015-16), annual mean discharge varied between 48.14 m^3/s (2012) to 128.77 m^3/s with annual average of 89.0 m^3/s. It is also noted that more than 66% of total discharge of Kopili River is received during monsoon months (June-October). Variation of discharge values of Kopili River at Longku from 1998-99 to 2015-16 is depicted in Figure 5-11 while monthly mean, maximum and minimum discharge observations calculated from last 18 years' data are summarized in Figure 5-12. It is seen that the variation in the monthly mean is reducing in the recent years. This may be due to improved regulations of the two upstream reservoirs (Khandong and Umrong). Figure 5-13 presents annual discharge trend of Kopili River at Longku.

Figure 5-11: Discharge variation at Longku during 1999-2016

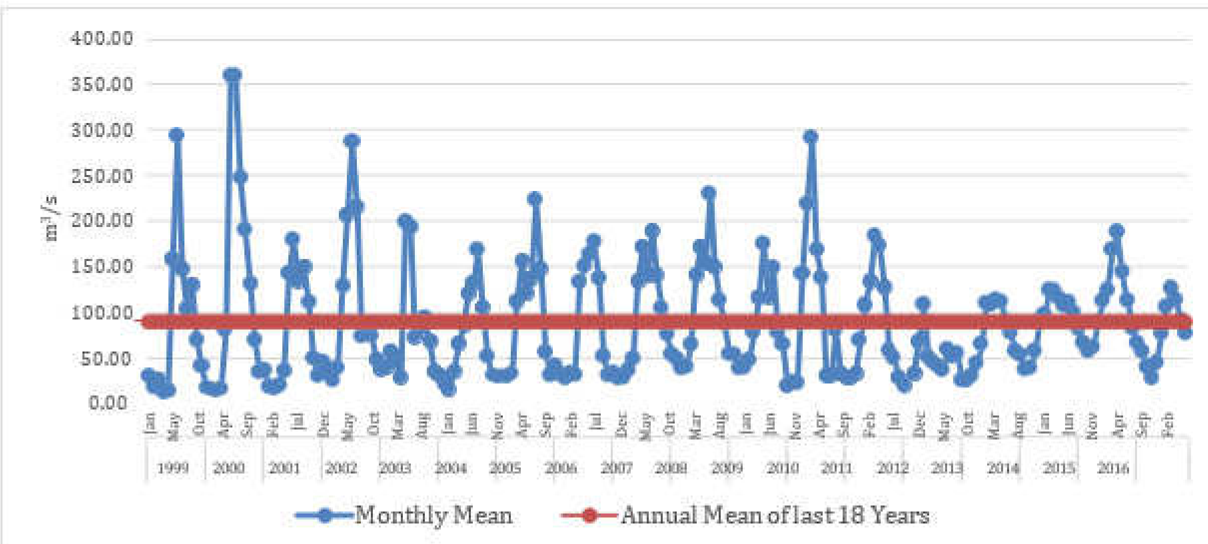


Figure 5-12: Monthly Discharge variation at Lonkhu

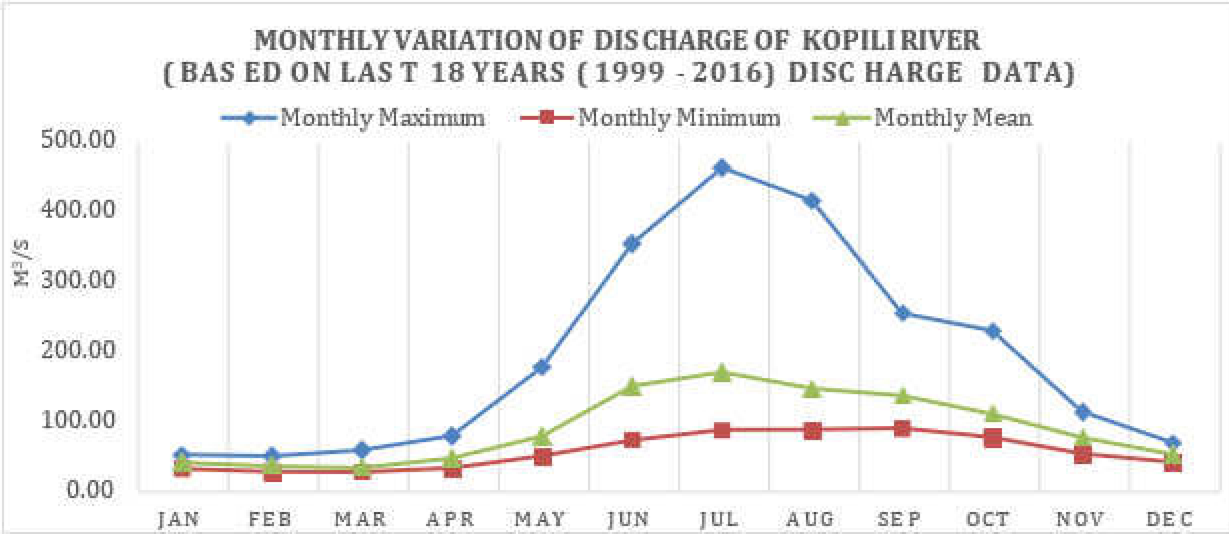
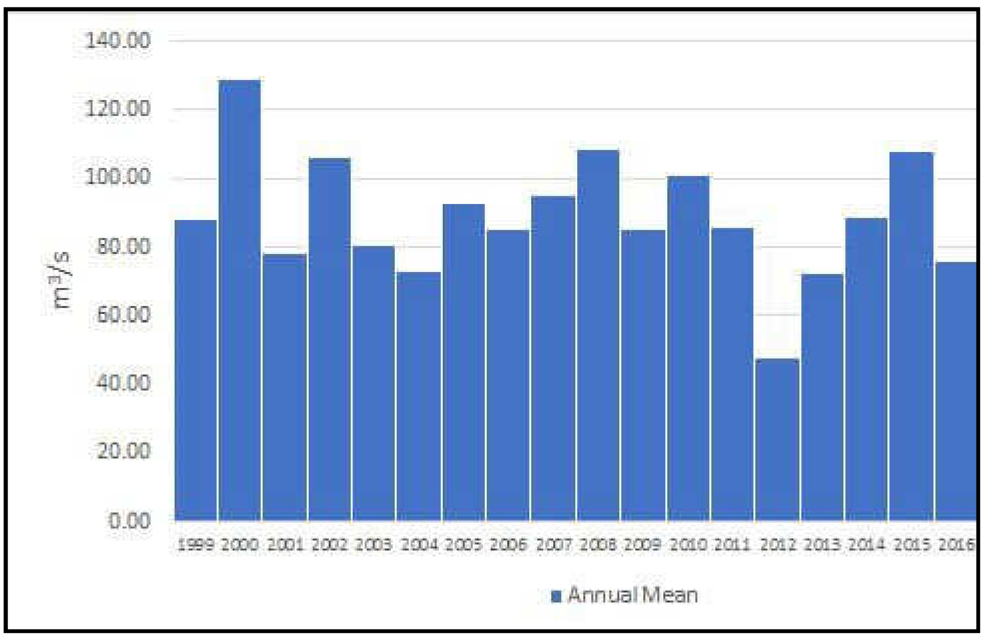


Figure 5-13: Annual Mean Discharge at Longkhu



5.2.7 Pre-and Post-dam discharge Scenarios

146. As mentioned above, to assess the impact of the Kopili dam on river flow and to establish before and after dam discharge scenario, the period from 1959 to 1983 was considered as pre-dam era while period from 1999 to 2016 was considered post-dam era. As summarized in Table 5-4, it is clearly observed that mean of monthly mean discharge was increased from 84.55 m^3/s to 89.49 m^3/s in post dam era. As far as mean of monthly maximum is concerned, it has reduced significantly from 486.20 m^3/s to 192.68 m^3/s in post dam period while mean of monthly minimum was increased significantly in post dam period from 20.72

m^3/s to 55.53 m^3/s.

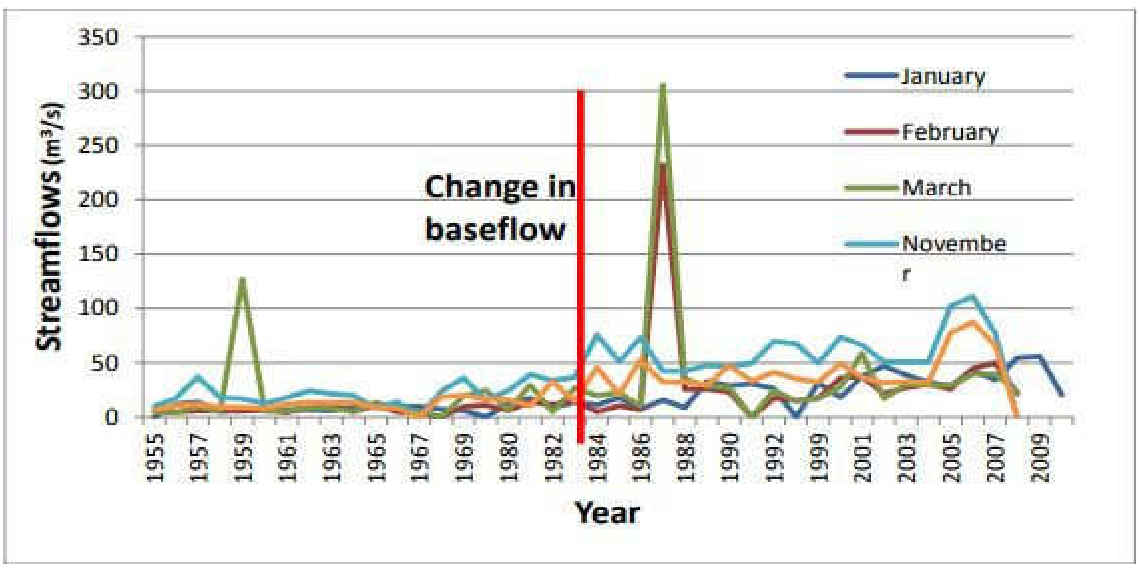
Table 5-4: Pre- and Post-dam* discharge scenario of Kopili River

Period	Mean of Monthly Mean (m^3/s)	Mean of Monthly Maximum (m^3/s	Mean of Monthly Minimum (m^3/s)
Pre -Dam Era (1959-1983)	84.55	486.20	20.72
Post-Dam Era (1999-2016)	89.49	192.68	55.53

*First unit of Kopili HEP was commissioned in Year 1984 while the second unit was established in 1997.

147. Analysis of the Kopili discharge data at Longkhu was also carried out by ADB in 2015 for a climate change impact study. The observed discharge distribution during the months of Jan, Feb, Mar, November and December is plotted as shown in Figure 5-14. Since there is no significant rainfall during these months, the flows in these months may be attributed to the base flow. As can be seen in this figure, the stream flow pattern has changed after 1984. The division of two distinct periods is shown by a thick line in Figure 5-14. This is due to the increased flow releases during base flow periods as a result of reservoir releases from Kopili Hydropower plant located upstream of the LKHEP.

Figure 5-14: Flow variation in Kopili at LKHEP site during base flow months



(Source: ADB Climate Change Impact Study, 2016)

148. Monthly variation of discharge before and after dam era is depicted in Figures 5-15 to 5-26.

Figure 5-15: Pre & Post Dam Variation of Discharge recorded in January

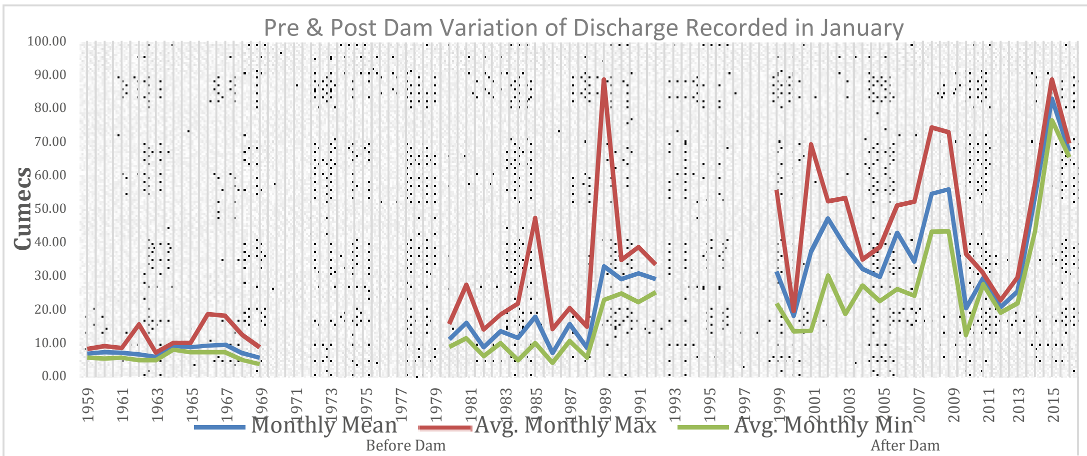


Figure 5-16: Pre & Post Dam Variation of Discharge recorded in February

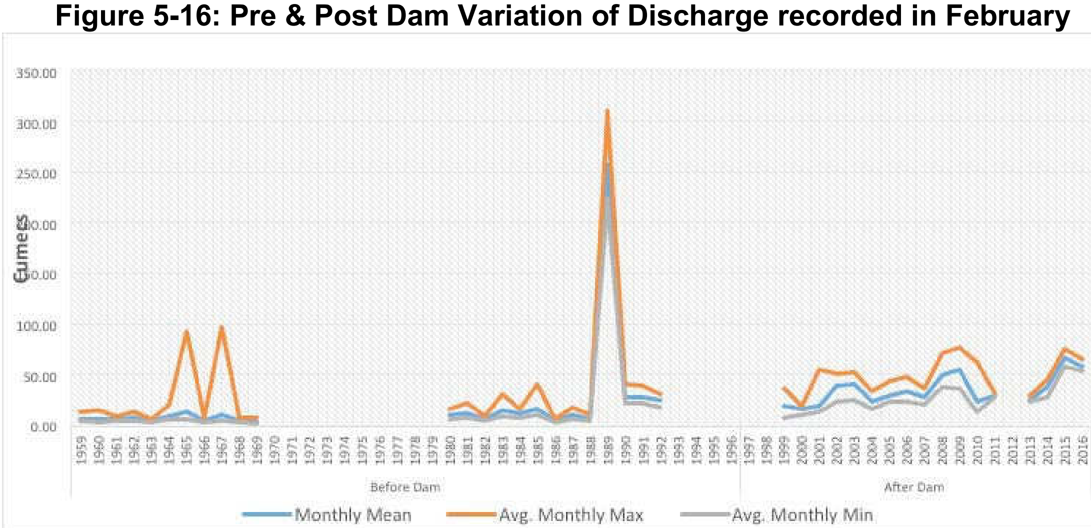


Figure 5-17: Pre & Post Dam Variation of Discharge recorded in March

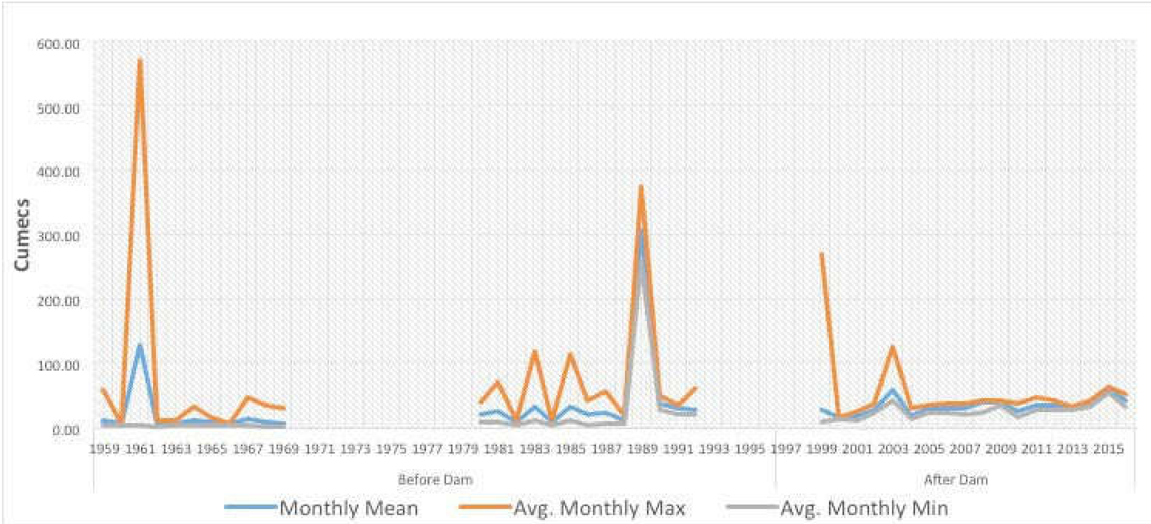


Figure 5-18: Pre & Post Dam Variation of Discharge recorded in April

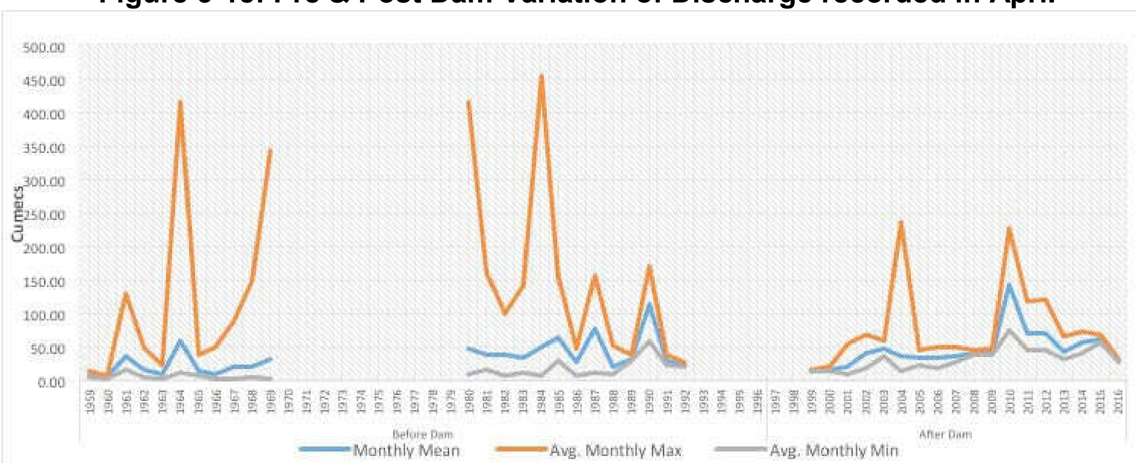


Figure 5-19: Pre & Post Dam Variation of Discharge recorded in May

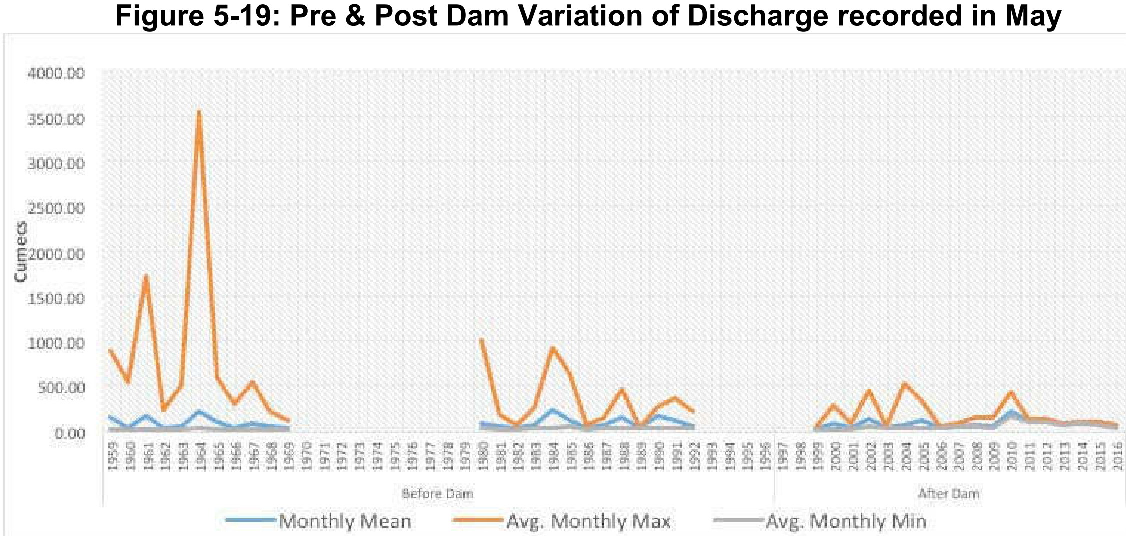


Figure 5-20: Pre & Post Dam Variation of Discharge recorded in June

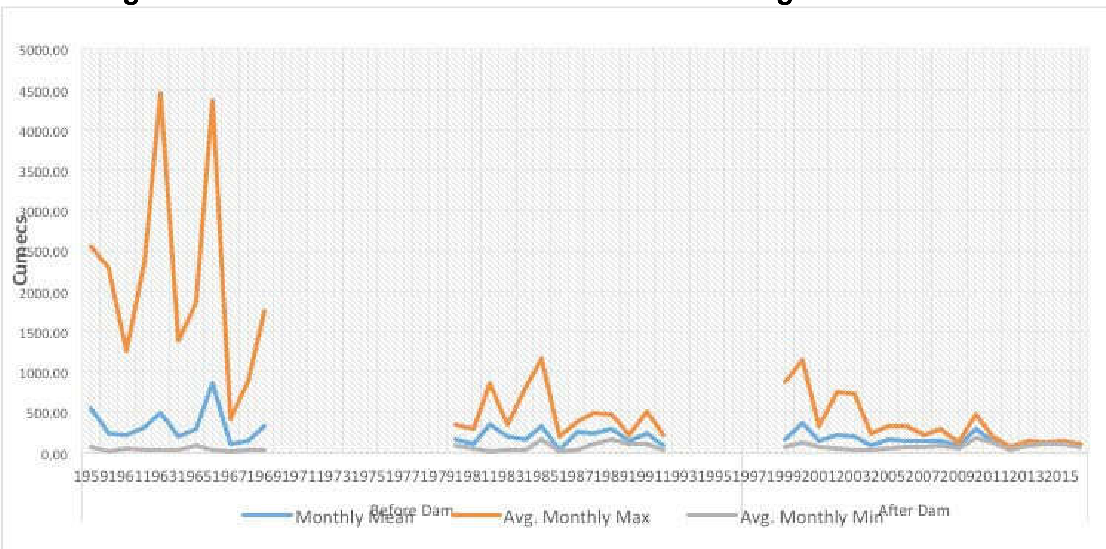


Figure 5-21: Pre & Post Dam Variation of Discharge recorded in July

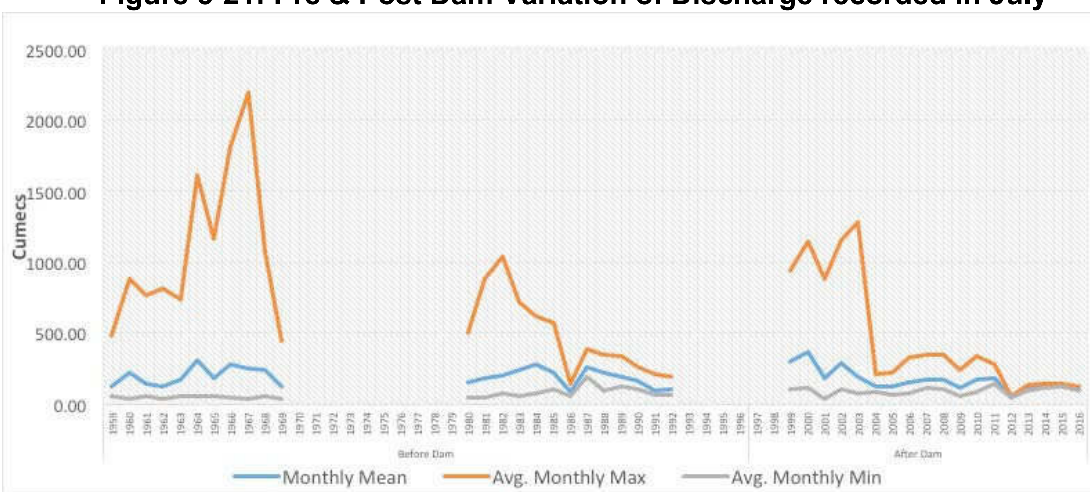


Figure 5-22: Pre & Post Dam Variation of Discharge recorded in August

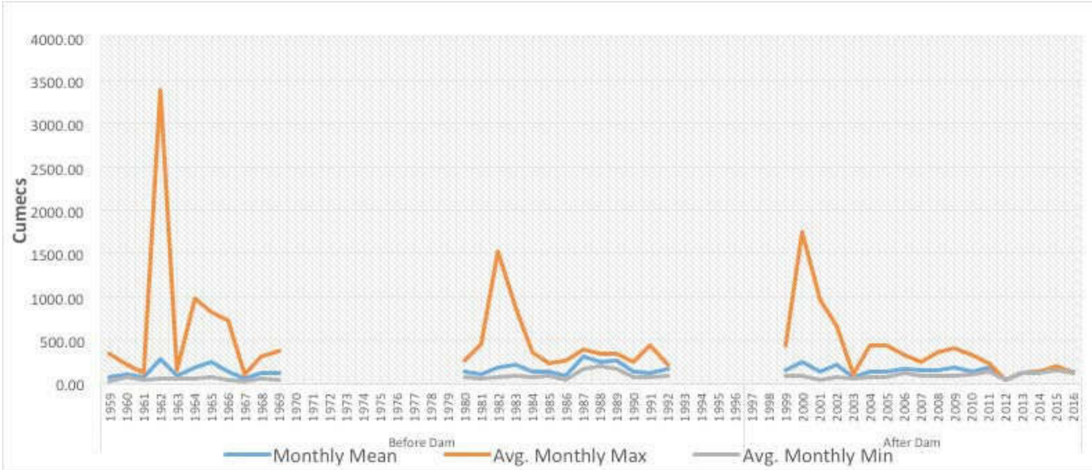


Figure 5-23: Pre & Post Dam Variation of Discharge recorded in September

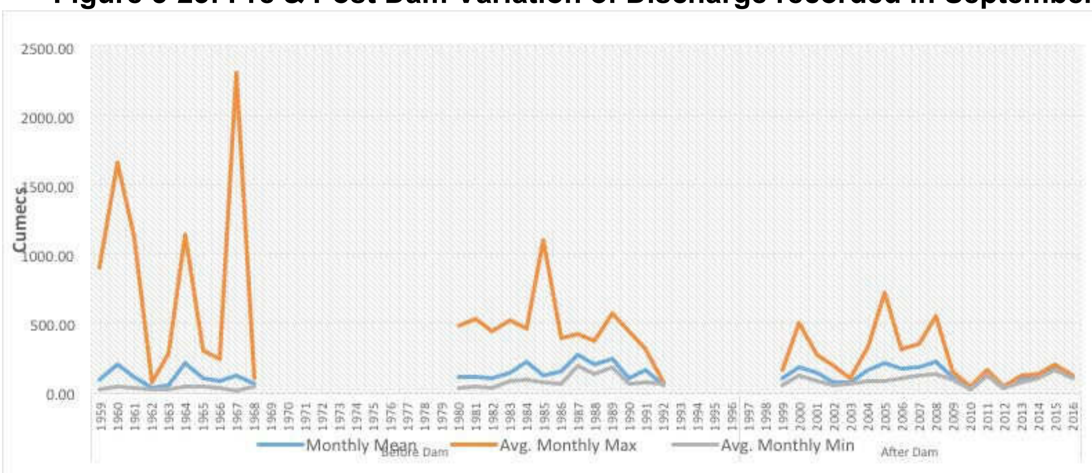


Figure 5-24: Pre & Post Dam Variation of Discharge recorded in October

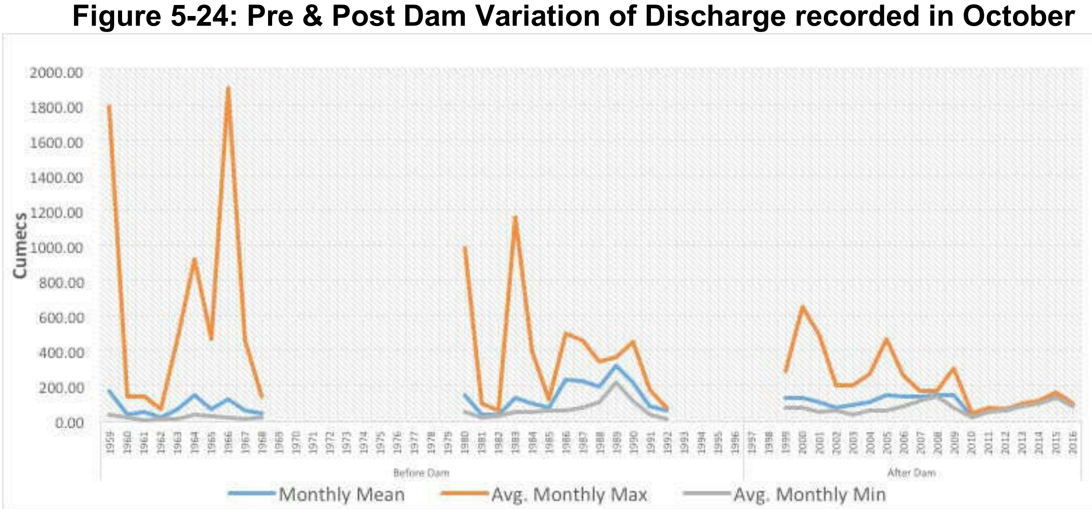


Figure 5-25: Pre & Post Dam Variation of Discharge recorded in November

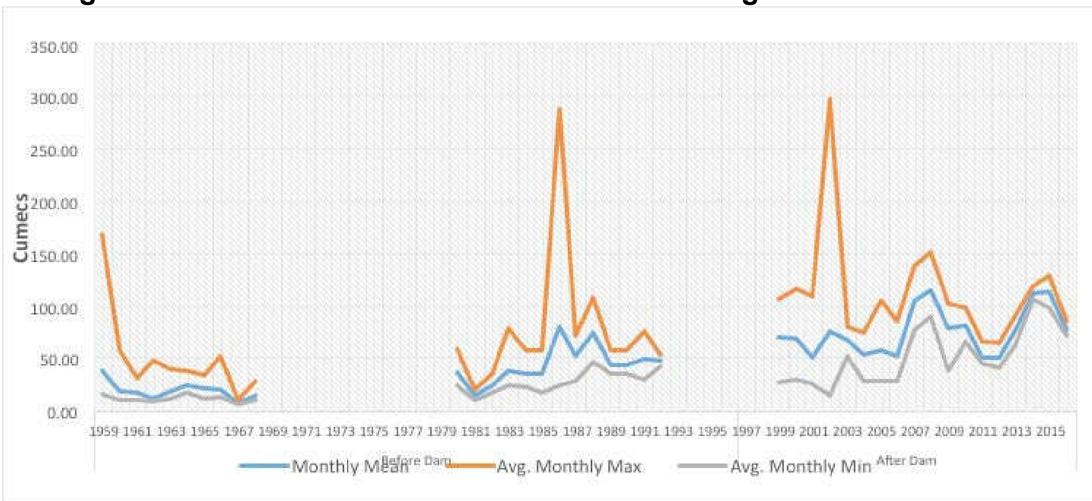
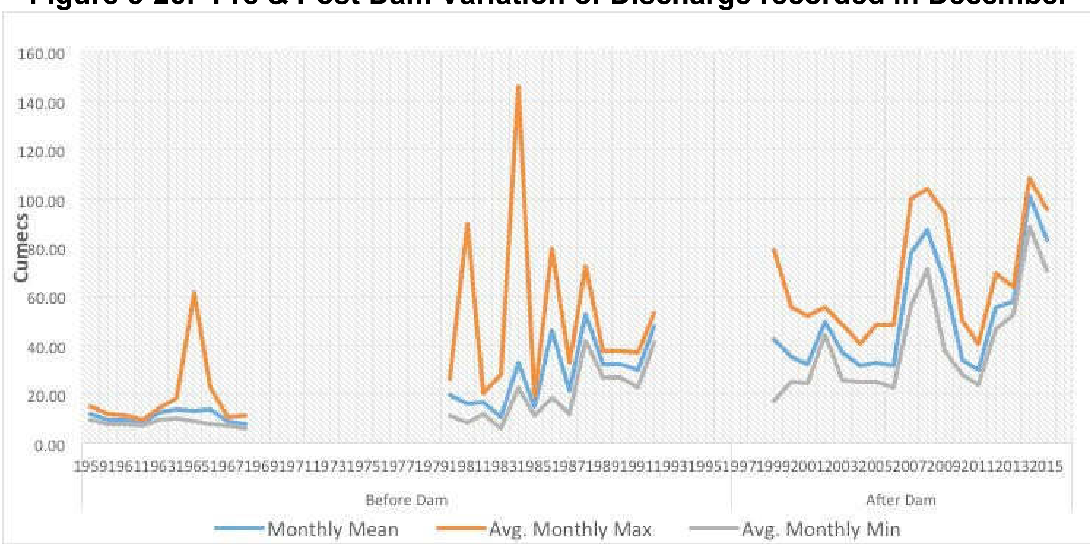
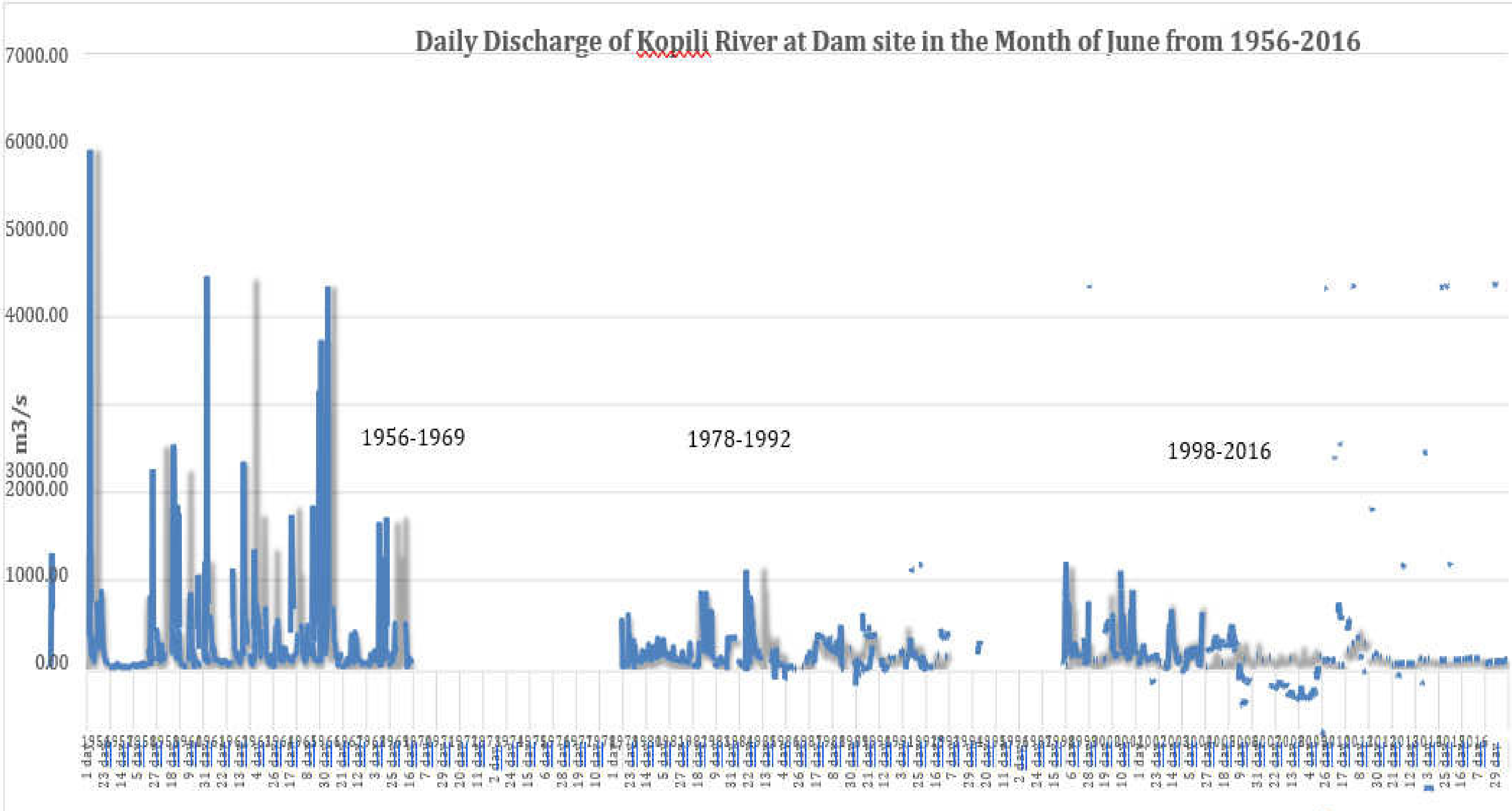


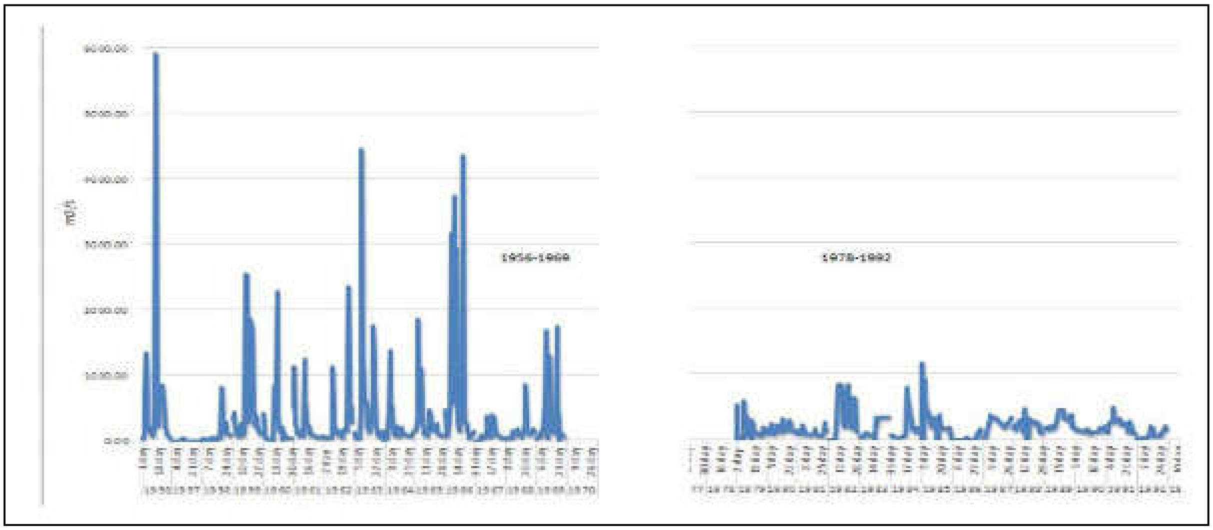
Figure 5-26: Pre & Post Dam Variation of Discharge recorded in December



149. In order to assess an impact KHEP to monsoon flows, an analysis was also carried out on the daily flow data. It can clearly be seen from Figures 5-27 to 5-29, that the peak daily flows have reduced in the post-dam period compared to the pre-dam period.

Figure 5-27: Daily Discharge at LKHEP Dam site in June (1956-1969)




m3/s
1956-1969
1978-1992

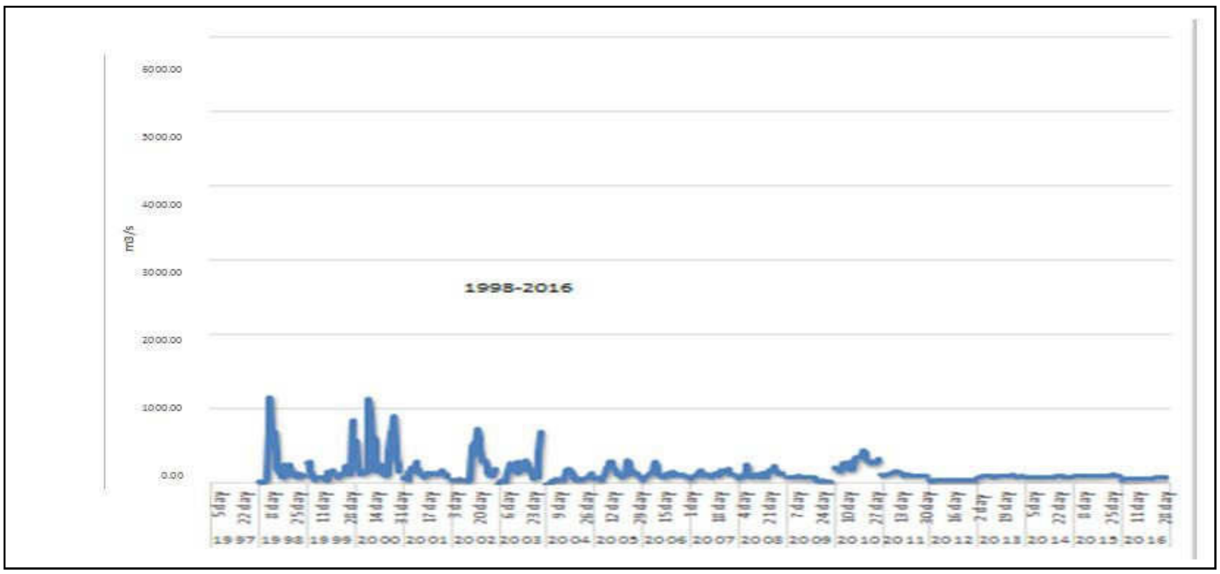
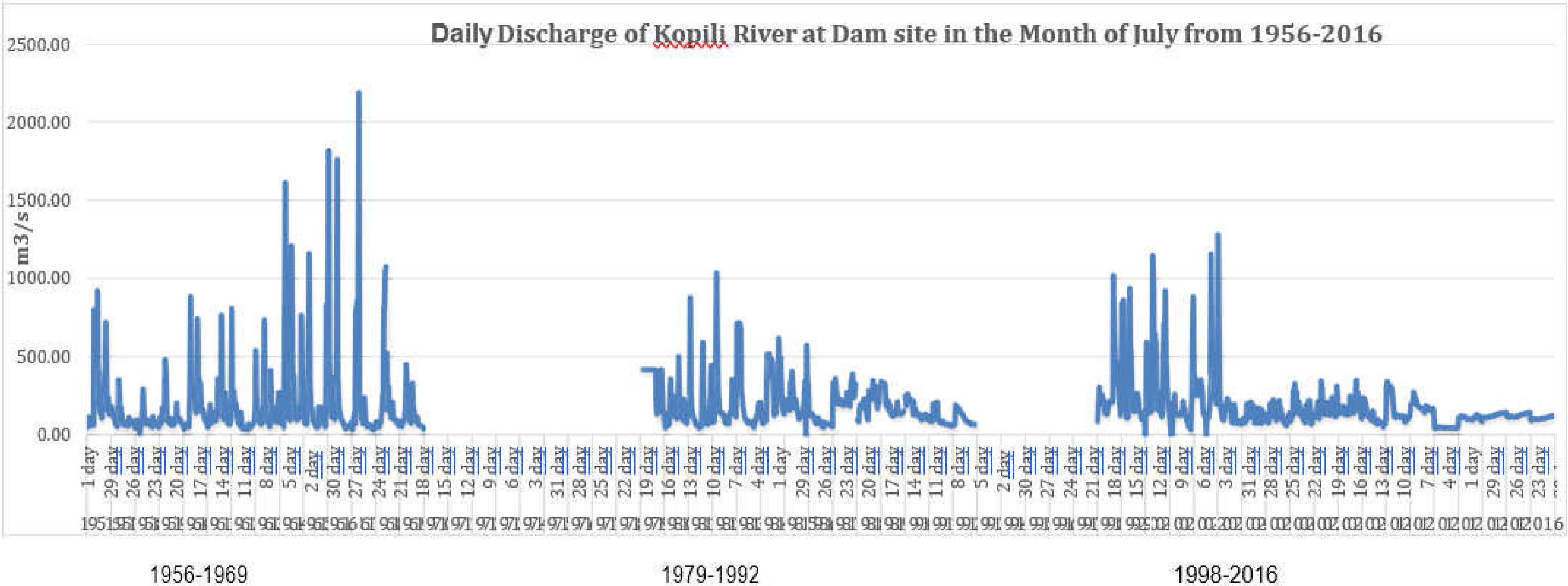

6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
m3/s
1998-2016
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016

Figure 5-28: Daily Discharge at LKHEP Dam site in July (1956-2016)



Details of Figure 5-28:

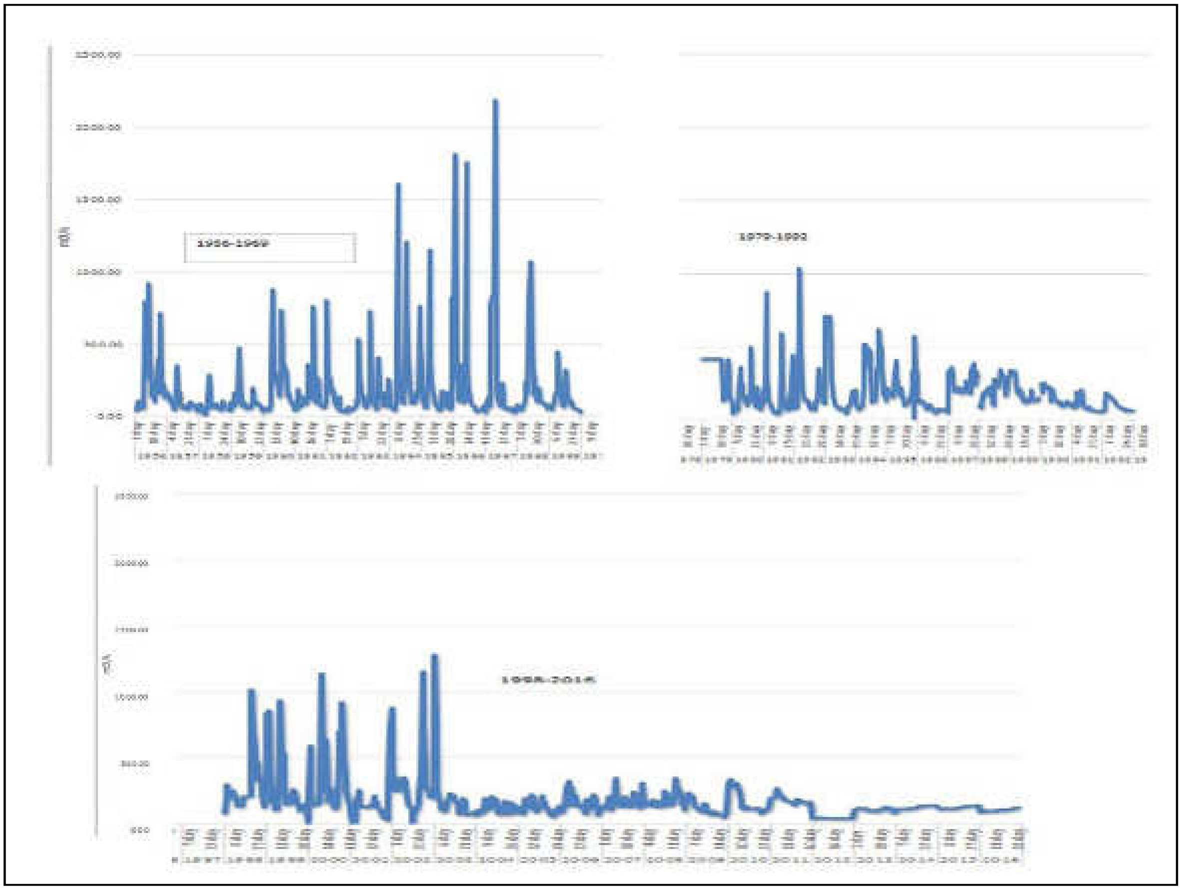
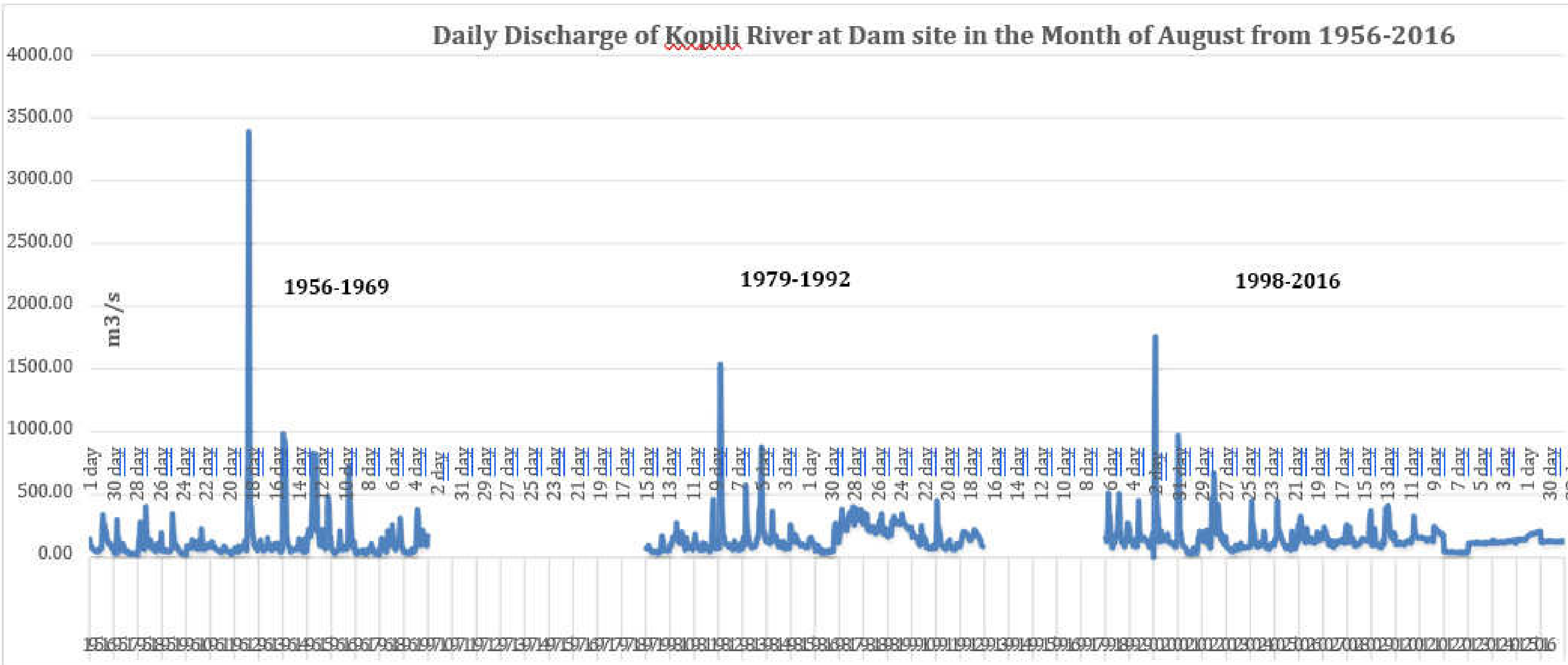
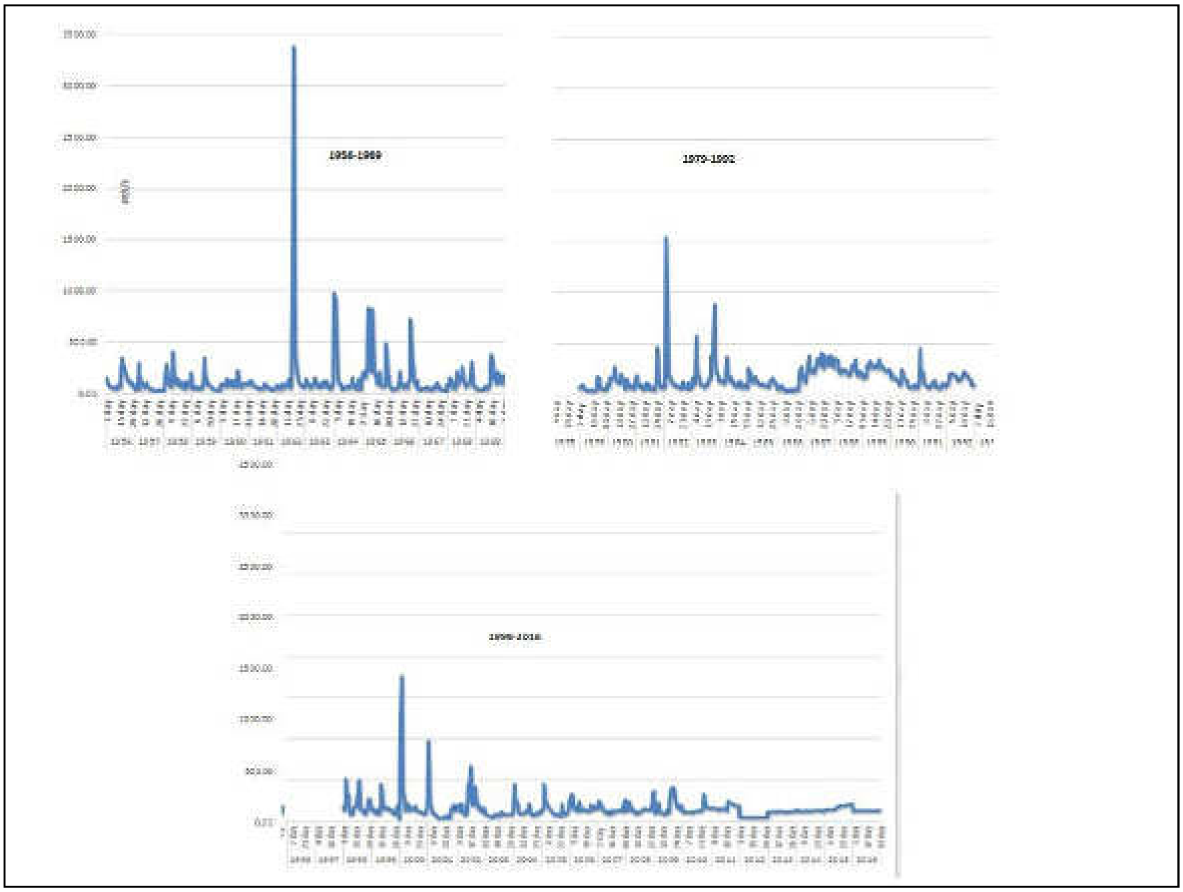


Figure 5-29: Daily discharge at LKHEP dam site in August (1956-2016)



Details of Figure 5-29



6. LAND USE ANALYSIS AND WATERSHED RESTORATION

6.1 Past studies

150. Land use describes how a patch of land is used (e.g. for agriculture, settlement, forest), whereas land cover describes the materials (such as vegetation, rocks or buildings) that are present on the surface. Accurate land use and land cover identification is the key to most of the planning processes.

151. An analysis of land use in the Kopili Basin was carried out by Assam Remote Sensing Center in 1994 using the satellite imageries of 1993, as reported by Brahmaputra Board in their Master Plan of Kopili-Kallang sub-basin. No land use maps were provided, but the land use patterns in the districts were summarized as given in Table 6-1. The largest type of land use was forest with 35.19 % followed by agricultural land with 18.65%. It was also reported that *jhum* cultivation was being practiced in hilly districts of Assam and Meghalaya.

Table 6-1: Land Use Pattern in Kopili-Kallang sub-basin

Land use type	Geographical area	Built up land	Agric. land	Forest	Waste land	Water bodies	Others (undefined)
District	(km^2)	(km^2)	(km^2)	(km^2)	(km^2)	(km^2)	(km^2)
Nagaon	5,535	8	4,106	607	159	146	509
Karbi Anglong	10,434	1	1,397	4,365			4,671
NC Hills (Dima Hasao)	4,888	2	63	1,888		22	2,913
East Khasi Hills	5,196		401	1,900			2895
West Khasi Hills	5,247		254	2076			2917
Jaintia Hills	3,819		329	1522			1968
Total area	35,119	11	6,550	12,358	159	168	15,873
% of land type	100	0.03	18.65	35.19	0.45	0.48	45.2

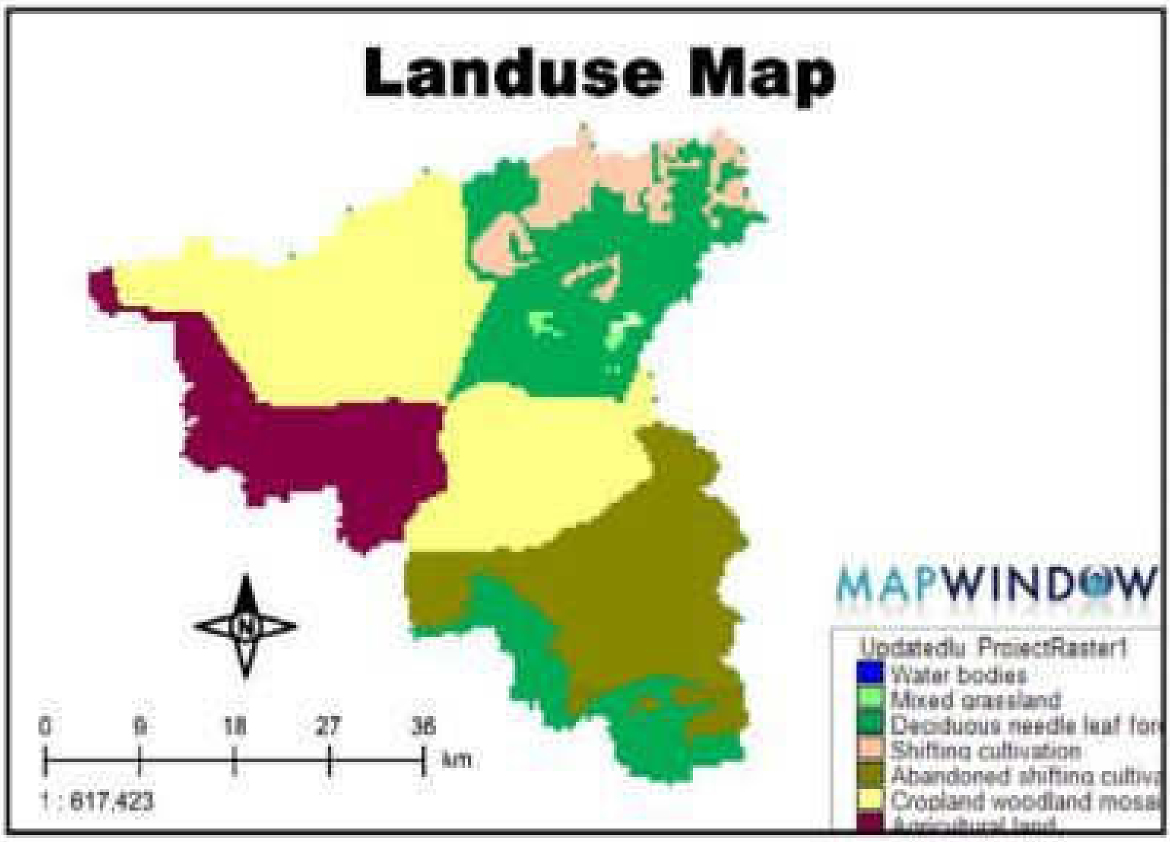
(Source: Brahmaputra Board, Master Plan, 1995)

152. As per the Statistical Year Book of Assam (2015), the forest areas of the three districts are given as: Nagaon (1,037 km2), Karbi Anglong: (2,933 km2)and Dima-Hasao: (638 km2). This data shows that forest areas of Nagaon have increased while those in Karbi Anglong and Dima Hasao, they have decreased from 1993 to 2015.

153. As part of the study on “Effect of climate change on the hydrology and sediments loadings of LKHEP” carried out by ADB (2015), a land use map obtained from the India SWAT dataset was derived (Figure 6-1). Seven divisions of land use were used in the

study: Deciduous needle leaf forest, Abandoned shifting cultivation, Shifting cultivation, Cropland woodland mosaic, Agricultural land, Rangeland - shrubs and Water bodies.

Figure 6-1: Land use Map of Kopili watershed



(Source: ADB Climate change study, 2015)

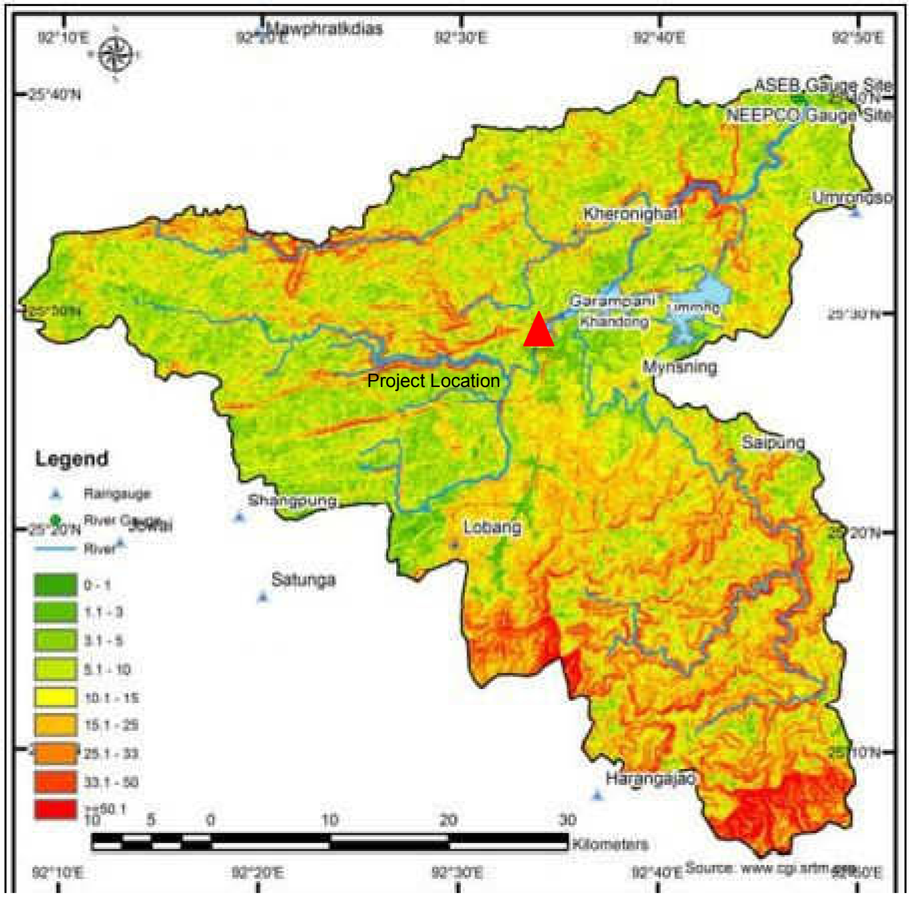
154. According to the DPR of LKHEP (Lahmeyer/AGPCL, 2015), nearly 95% of the catchment area up to the proposed dam site is covered with forest and about 5% is under cultivation. Quoting various Government websites, the DPR also provided the following information on land use and land cover as of 2011, in the Kopili basin.

- *A major portion (35.48%) of the state of Assam is under forest cover. Out of a total geographical area of 4980 km², Dima Hasao district has 1791.32 km² under evergreen/semi-evergreen forest, with 79.38 km² under degraded land. Shifting or jhum cultivation is the traditional way of cultivation with more than 2,900 km² already affected. For Karbi-Anglong district, out of a total geographical area of 10,434 km², about 4,922 km² is under forest cover. About 2476 km² is under evergreen/semi-evergreen forest, 1696 km² under deciduous forest, 68 km² under degraded land and 267 km² under forest plantation. About 4378 km² has been affected by practice of shifting cultivation.*

155. A slope map of the basin was produced in the DPR as shown in Figure 6-2.

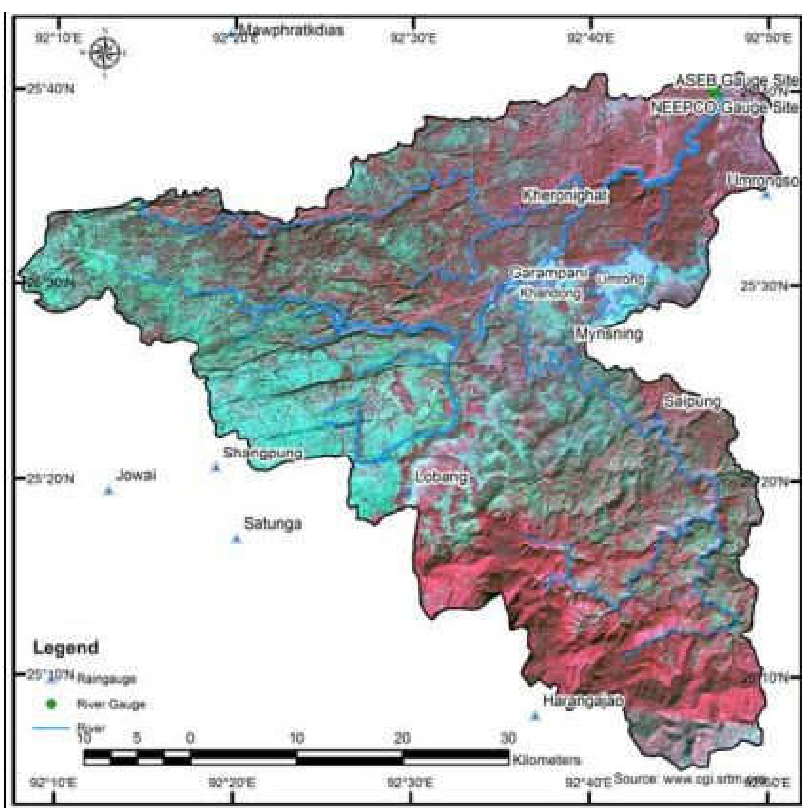
156. Using a standard false colour composite map prepared from Landsat TM data (dated 19th December 1999) it was shown that dense forest (reddish tone) was present in the southern corner of the catchment, which is the zone with steep hills (Figure 6-3).

Figure 6-2: Slope Map of Kopili Basin



(Source: LKHEP DPR, 2015)

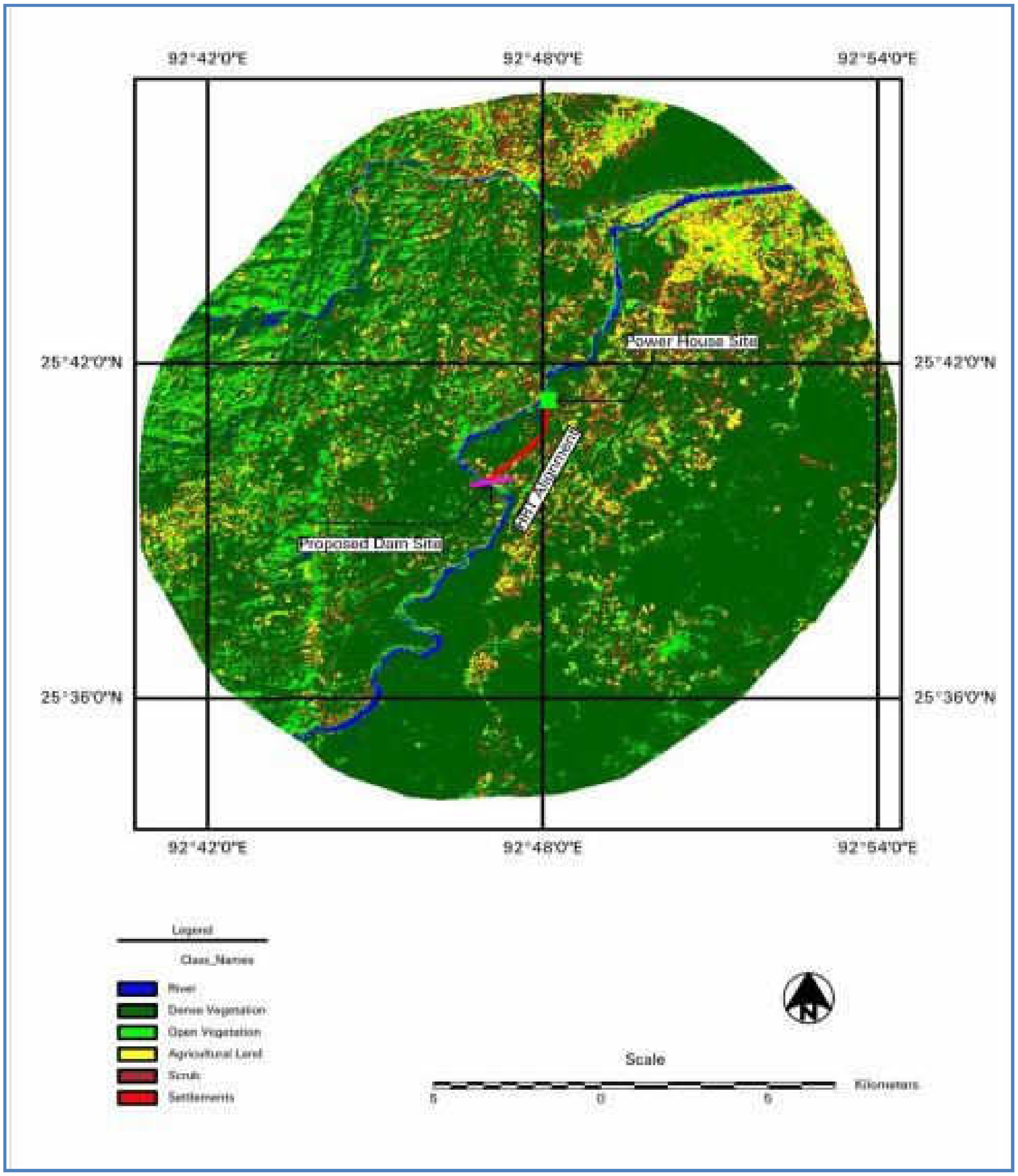
Figure 6-3: Land cover Map of Kopili Basin



(Source: LKHEP DPR, 2015, Landsat Image 1999)

157. The CEIA study carried out by WAPCOS (October 2016) presents further analysis of land use and land cover in the Kopili Basin area. The land use pattern has been studied through satellite imagery data. Remote sensing satellite data of Resource Sat-2 Satellite (LISS-IV, Sensor, path 111, row 53 C & D). Data (date is not stated) was procured from National Remote Sensing Agency (NRSA). Ground truth studies were conducted in the area to validate various signals in the satellite images and correlate them with different land use domains. The classified imagery of the study area is given in Figure 6-4. However, the area covered under the WAPCOS study includes only the catchment above the LKHEP site.

Figure 6-4: Classified Imagery of LKHEP Catchment Area



(Source: WAPCOS CEIA Study, October 2016, NRSA LISS-IV imagery)

158. The land use pattern of the study area is given in Table 6-2. The major land use categories in the study area are dense vegetation and scrubs, as they account for about 67.07% and 12.07% of the total study area. The area under open vegetation is 11.22%. Settlements account for about 0.16% of the study area. The area under water bodies and Agricultural Land is 0.18% and 7.97% of the study area.

Table 6-2: Land Use Pattern in the Kopili Basin

S. No.	Land Use Category	Area (ha.)	Area (%)
1	River /Water bodies	7,486	1.50
2	Dense Vegetation	334,972	67.07
3	Open Vegetation	56,048	11.22
4	Agricultural Land	39,976	7.97
5	Scrubs	60,287	12.07
6	Settlements	814	0.16
	Total	**499,402**	**100**

(Source: WAPCOS, CEIA Study Report, October 2016)

159. Since; the above analysis and data on land use land cover are old, based on low resolution satellite imageries, and cover only part of the basin, analysis of land use and land cover has been carried out using the latest high resolution satellite imageries (LISS- III). Details are presented in the following section.

6.2 Latest Land Use – Land Cover (LULC) Analysis

160. Using the LISS –III, satellite imageries (NRSA) of January – March 2015, LULC analysis was carried out for the entire Kopili basin. A large categories of LULC was identified, the major types being: build up area, agricultural, forest, shifting cultivation, water bodies, wasteland etc. Land cover types have also been identified separately for the two states, Meghalaya and Assam. Figure 6-5 presents the LULC map of the entire Kopili Basin.

161. Table 6-3 shows the recent LULC in the Kopili basin. In summary, the LULC in the Kopili basis is composed of:

- Agricultural land = 17.50 %
- Built up area (settlements) = 2.29 %
- Forest (different types and densities) = 58.90 %
- Shifting cultivation (current and abandoned) = 1.46 %
- Water bodies = 2.00 %
- Wasteland, scrubs, pastures and others = 17.79 %

162. Comparison with past data are presented in the following sections. Also the LULC is analyzed for Meghalaya and Assam as well as upper hilly and lower plain areas, separately

Figure 6-5: Land Use Land Cover (LULC) map of Kopili Basin (based on LISS-III satellite imagery of January-March 2015)

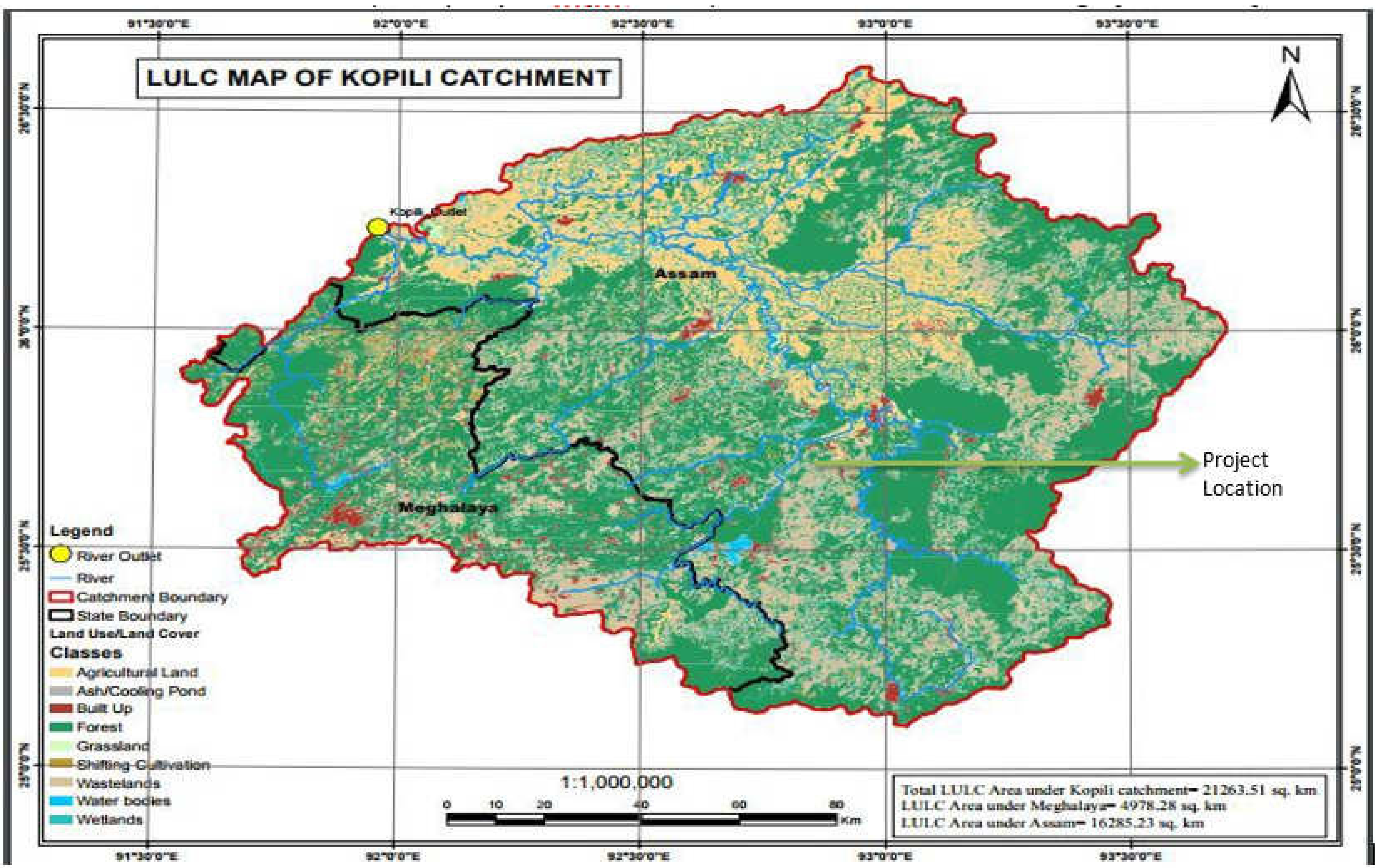


Table 6-3: Land Use Land Cover Statistics of Kopili Basin (based on LISS-III satellite imagery of January-March 2015)

Land Use Land Cover Class	in Assam		In Meghalaya		Total Area (Sq km)	% of basin Area
	Area (sq km)	%	Area (sq km)	%	Area (sq km)	%
Agricultural Land-Cropland-More than 2 seasons		0	1.45	0.03	1.45	0.01
Agricultural Land-Cropland-Double Crop	273.47	1.68	20.68	0.42	294.15	1.38
Agricultural Land-Cropland-Kharif	2482.71	15.25	299.84	6.02	2782.55	13.09
Agricultural Land-Cropland-Rabi	47.16	0.29	7.66	0.15	54.82	0.26
Agricultural Land-Cropland-Zaid	388.05	2.38		0.00	388.05	1.82
Agricultural Land-Fallow Land	17.45	0.11		0.00	17.45	0.08
Agricultural Land-Agricultural Plantation	183.41	1.13	0.28	0.01	183.69	0.86
Ash/Cooling Pond	0.97	0.01		0.00	0.97	0.00
Built Up Industrial Area	2.03	0.01	2.98	0.06	5.01	0.02
Built Up Rural	134.55	0.83	212.60	4.27	347.15	1.63
Built Up-Compact	45.95	0.28	33.40	0.67	79.35	0.37
Built Up-Quarry	8.87	0.05	0.08	0.00	8.95	0.04
Built Up-Mining Active		0.00	0.36	0.01	0.36	0.00
Built Up-Sparse	45.93	0.28		0.00	45.93	0.22
Forest-Deciduous (Dry/Moist/Thorn)-Dense/Closed	1139.1	6.99	7.07	0.14	1146.17	5.39
Forest-Deciduous (Dry/Moist/Thorn)-Open	457.48	2.81		0.00	457.48	2.15
Forest-Evergreen/Semi evergreen-Dense/Closed	776.25	4.77	273.18	5.49	1049.43	4.94
Forest-Evergreen/Semi evergreen-Open	604.42	3.71	17.85	0.36	622.27	2.93
Forest-Forest Plantation	54.98	0.34	7.28	0.15	62.26	0.29
Forest-Scrub Forest	587.22	3.61	90.59	1.82	677.81	3.19
Forest-Swamp/Mangroves-Dense/Closed	3.17	0.02		0.00	3.17	0.01
Forest-Tree Clad Area-Dense/Closed	1396.21	8.57	1088.99	21.88	2485.20	11.69
Forest-Tree Clad Area-Open	4125.72	25.33	1903.99	38.26	6029.71	28.36

Land Use Land Cover Class	in Assam		In Meghalaya		Total Area (Sq km)	% of basin Area
	Area (sq km)	%	Area (sq km)	%	Area (sq km)	%
Grass/Grazing-Temperate/Sub Tropical	47.14	0.29		0.00	47.14	0.22
Shifting Cultivation-Current	79.69	0.49	41.66	0.84	121.35	0.57
Shifting Cultivation-		0.00	135.39	2.72	135.39	0.64
Abandoned						
Shifting Cultivation-Open	54.75	0.34		0.00	54.75	0.26
Vegetated / Open Area	1.96	0.01		0.00	1.96	0.01
Wastelands-Barren Rocky	5.2	0.03	12.32	0.25	17.52	0.08
Wastelands-Ravinous	4.54	0.03		0.00	4.54	0.02
Wastelands-Salt Affected Land	0.01	0.00		0.00	0.01	0.00
Wastelands-Sandy Area-Riverine	12.97	0.08	0.82	0.02	13.79	0.06
Wastelands-Scrub land-Dense/Closed	1225.48	7.53	22.71	0.46	1248.19	5.87
Wastelands-Scrub land-Open	1696.38	10.42	754.08	15.15	2450.46	11.52
Water bodies-Lakes/Ponds-Permanent	6.68	0.04	5.45	0.11	12.13	0.06
Water bodies-Lakes/Ponds-Seasonal	4.2	0.03	0.04	0.00	4.24	0.02
Water bodies-Reservoir/Tank-Permanent	10.6	0.07	6.41	0.13	17.01	0.08
Water bodies-Reservoir/Tank-Seasonal	11.32	0.07		0.00	11.32	0.05
Water bodies-River-Non Perennial	19.02	0.12	0.00	0.00	19.02	0.09
Water bodies-River-Perennial	162.32	1.00	31.13	0.63	193.45	0.91
Wetlands-Inland-Manmade	0.1	0.00		0.00	0.10	0.00
Wetlands-Inland-Natural	167.77	1.03		0.00	167.77	0.79
Total Area in Kopili Basin	**16285.23**	**100**	**4976.83**	**100**	**21263.5**	**100**

163. Table 6-4 shows a summary comparison of LULC as seen in the 2015 satellite images and those in 1993 (as derived by the Brahmaputra Board, 1995).

Table 6-4: Comparison of major LULC observed in 2015 with those in 1993

S. No.	Land Use Category	As derived in this study using 2015 satellite images	As derived in this BB Master Plan (1995) using 1993 satellite images
		(% area)	(% area)
1	River /Water bodies	2.00	0.48
2	Forest (all types vegetation)	58.94	35.19
4	Agricultural Land	17.50	18.65
5	Shifting cultivation	1.46	Not identified
6	Settlements	2.29	0.30
7	Others (wasteland, scrubs, pastures)	17.79	23.04

164. The above comparison shows that built areas have increased over the past 20 years, while no significant increase is seen in the agricultural areas. The vegetation coverage areas including all types of forests have, perhaps remained the same, but there is no conclusive evidence due to different categorization used in the two studies.

165. A comparison of LULC in the Kopili basin parts falling in the states of Meghalaya and Assam is shown in Table 6-5. It is seen that, the basin area in Meghalaya has more rural settlements than that in Assam. Agricultural land in the Assam part is significantly larger than in Meghalaya part, which is obvious because of the large plain area falling in Assam. The area under shifting cultivation is notably more in Meghalaya than in Assam. Forest and vegetation coverage in Meghalaya is more than that in the Assam part of the basin.

Table 6-5: Comparison of major LULC in Meghalaya and Assam parts of Kopili Basin

S. No.	Land Use Category	Meghalaya part	Assam part
		(% area)	(% area)
1	River /Water bodies	0.86	2.35
2	Forest (all types vegetation)	68.09	56.15
4	Agricultural Land	6.63	20.83
5	Shifting cultivation	3.56	0.83
6	Settlements	5.01	1.46
7	Others (wasteland, scrubs, pastures)	15.87	18.09

6.3 Watershed Restoration

6.3.1 Improvement of Land Use

166. Activities related to the restoration of watershed of the Kopili River catchment play key roles in maintaining the water resources, both quality and quantity, in the river system. However, developmental activities, including hydroelectric projects, often have some impacts on this natural resource. The environmental impacts of such projects together with faulty management practices, etc., ultimately lead to environmental degradation. Accelerated soil erosion in the catchment areas and transport of detached material through the drainage network gives rise to a series of problems, notably siltation, depletion of flow capacity, steady loss of storage capacity, consistent drop in hydro- electric power generation and frequent floods. Therefore, for sustainable water resources development with least negative impact on the environment watershed management plays a pivotal role. In order to minimize the damage to the project as well as the immediate environment, the watershed management programs involving extensive soil conservation measures in the catchment have to be considered in the integrated water resources management of the Kopili river basin.

167. In order to improve the land use, a Catchment Area Treatment (CAT) plan is required is to rejuvenate various potential and degraded ecosystems in the Kopili river catchment area. Some of the elements of CAT are shown in Figure 6-6.

Figure 6-6: Major components of watershed restoration

- To facilitate the hydrological functioning of the catchment and Kopili river system
- Conservation of soil cover and to arrest the soil erosion, floods and siltation of the river and its tributaries and consequent reduction of siltation in the river especially at dam site
- Demarcation of the priority of sub watersheds of treatment based on soil erosion intensity in the catchment area
- Rehabilitation of degraded forest through afforestation
- Soil conservation through biological and engineering measures to reduce sediment load
- Ecosystem conservation resulting from increased vegetative cover and water retaining properties of soil
- Employment generation through community participation and conservation

6.3.2 Critical Areas and key threats in the Kopili Catchment

168. For the Kopili River catchment, the "critical area" is defined as that portion of the catchment that is most likely to impact on hydrological functioning, sedimentation and soil erosion. Thus, the area of land that serves as an aquatic buffer around surface water resources is the critical area. An ideal calculation of this area would be made based on soil type, slope of the land, amount of impervious surface, and type of vegetative cover present. However, it is common for catchment management efforts to use proximity to surface water as the determining factor in order to provide an easily defined boundary of the critical area. In the Kopili river basin, upper catchment located in Meghalaya state is the most critical area which is affecting river water quality due to acid mine drainage from ongoing coal mining activities. Apart from this, high slope areas mostly in upper catchment are prone to soil erosion. Shifting cultivation area in the catchment is also one of the critical areas and a reason behind degradation of Kopili River Catchment.

169. The following are the identified key threats and issues of the Kopili Catchment:

- Soil Erosion and Sedimentation
- Illegal mining in Upper Catchment
- Flooding
- Unsustainable Agricultural Practices

6.3.3 Catchment Area Treatment (CAT) Plan pertaining to LKHEP Catchment

170. The CAT Plan has been formulated in the WAPCOS EMP Report (2016) for the upper catchment up to LKHEP site. The total catchment area at proposed Lower Kopili HEP site is 2076.62 sq. km. while at the existing Kopili HEP it is 1256 sq km. Thus, the free draining catchment area proposed to be treated in the WAPCOS study is 820.62 sq.km (82062 ha). Silt Yield Index (SYI) method has been used to prioritize the watershed into various erosion categories. In this method, the terrain is subdivided into various sub-watersheds and the erodibility is determined on relative basis. SYI provides a comparative erodibility criteria of catchment (low, moderate, high, etc.).

171. In the EMP report (WAPCOS, 2016), a CAT Plan has been suggested based on the prioritization of sub watersheds using SYI method. The erosion category of various sub-watersheds in the catchment area as per SYI method was developed as shown in Table 6-6.

Table 6-6: Area under different erosion categories

Category	Area (ha)	SYI values	Area (Percentage)
Low	20984	1000-1099	25.57
Medium	27243	1100-1199	33.20
High	33836	1200-1299	41.23
Total	**82062**		**100.00**

Source WAPCOS, 2016

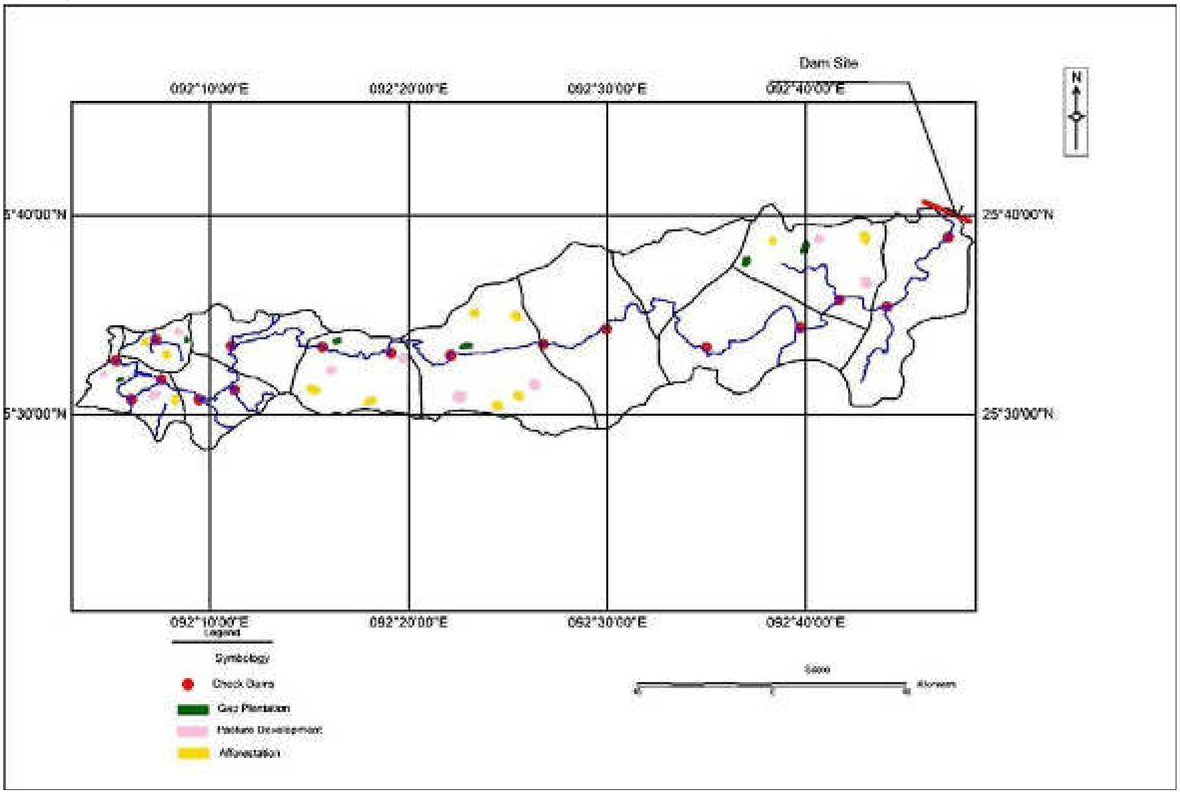
172. The area under high erosion category has to be treated by the project proponents, which accounts for about 48.84% of the total free draining catchment area. Sub- watershed wise proposed treatment measures are indicated in Figure 6-7. It is proposed that treatment measures shall be implemented over five years along with the HEP development. The proposed catchment treatment activities, which will be implemented at a total cost of 1,223.70 Lakhs rupees, are:

A. Biological Measures:

- Afforestation
- Gap Plantation
- Pasture development
- Development & maintenance of nursery
- Vegetative fencing
- Human resources for watch and ward for 5 years

B. Engineering measures: 17 numbers of check dams.

Figure 6-7: Catchment Area Treatment Measures for Lower Kopili Catchment



(Source: WAPCOS, 2016)

173. The Kopili- Kallang Master Plan of Brahmaputra Board (1995) has also suggested a number of catchment treatment measures. It was observed that deforestation in the catchment area of Kopili river has given rise to the intensity of flooding in the lower plain areas. Shifting cultivation (*Jhum*) practised in the upper catchment has aggravated the flooding and sedimentation along the Kopili river. Therefore, it is necessary to take up integrated watershed treatment in the catchment on a large scale. Jhum cultivation should be stopped and plantation like coffee, rubber, cardamom should be increased in the hilly catchment of the sub basin.

174. Afforestation and soil conservation measures are more effective in moderating relatively small and medium floods than damage-producing high floods resulting from prolonged spell of heavy rains.

175. The Master Plan has suggested the development of a detailed watershed management scheme which should include rehabilitation of Jhumia families to be taken up on priority to reduce deforestation and soil conservation.

6.3.4 Additional measures to be adopted for Catchment Area Treatment

176. In addition to the measures suggested in the WAPCOS (2016) study and the BB master Plan (1995), the following measures are suggested to be taken up as part of the integrated water resources development of the Kopili Basin.

6.3.4.1 Prevention of gully formation

177. Preventing the formation of a gully is much easier than controlling it once it has formed. If incipient gullies are not stabilized, they become longer, larger and deeper. Under certain climatic and geological conditions, vertical gully banks can easily become as high as 20-30 meters or more. This type of gully can engulf hillside farming areas, grass lands and even forest lands. In most cases, it is not possible to stabilize those gullies because of the huge landslides which occur on vertical (20-30m) gully banks after

heavy rains and alternate freezing and thawing. Prevention is also more economical because structural measures are considerably more expensive than preventive measures. Therefore, in erosion control or gully control, emphasis should be given to:

6.3.4.2 Proper land-management practices

- Prevention of forest degradation, fire and illegal wood cutting in plantations and natural forests
- Prevention of grass fires
- Control of grazing, and re-vegetation of open and grass lands
- Maintenance of soil fertility and stability on land which is under agro-forestry or agriculture
- Control of road construction and mining
- Immediate stabilization of moderate sheet and rill erosion, and incipient gullies in forest, rangeland and cultivated areas.

6.3.4.3 Retention and infiltration of surface water

178. In addition to proper land-management practices, specific slope-treatment measures, such as retention and infiltration ditches, terraces, wattles, fascines and staking, should be carried out above the gully area, and in the eroded area between the branch gullies, to reduce the rate and amount of surface run-off. These also decrease the cost of structural gully-control measures.

6.3.4.4 Diversion of surface water above the gully area

179. Diversions constructed above the gully area direct run-off away from gully heads, and discharge it either into natural waterways or vegetated water courses, or onto rock outcrops and stable areas which are not susceptible to erosion. Surface water must not be diverted over unprotected areas or it will cause new gullies.

180. The basic aim of diversions is to reduce the surface water entering into the gully through gully heads and along gully edges, and to protect critical planted areas from being washed away. Small diversion ditches constructed either alone or with other structures such as earth plugs and check dams, are commonly used in gully control. To prevent scouring along the diversion channel, the gradient of small diversion ditches must be less than one percent - preferably 0.5 percent. However, if there is a permanent plant cover in the channel, the gradient may be as high as two to three percent. The protective vegetation must be maintained during the entire rainy season, or these steeper gradients will cause channel erosion.

181. Diversion ditches should be large enough to carry all the water that is discharged from the gully catchment area during periods of maximum run-off. In regions subject to particularly heavy rains, in addition to diversions established above the gullied area, a series of check dams must be constructed along the gully channels.

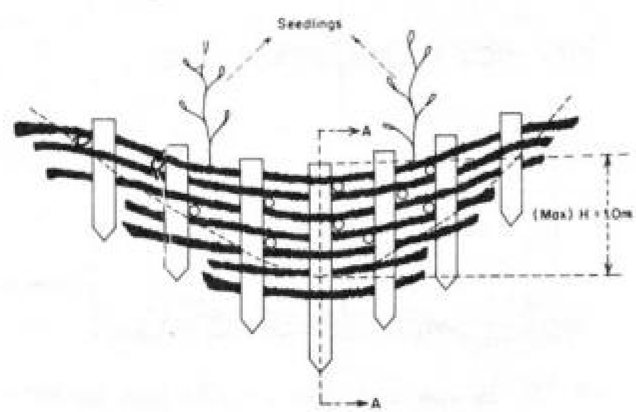
6.3.4.5 Engineering Treatment measures at specific sites

182. The engineering treatment measures require less time to be put in place and can provide quick solutions. These would comprise mainly brushwood check dams, dry stone masonry check dams, gabion check dams and contour bunding.

- **Brushwood Check Dams:** Brushwood check dams are very feasible where vegetative material for construction is abundant. Brushwood check dams can only be constructed in small gullies not deeper than 1m depth. As material required for construction of these types of dam is available locally these can be constructed faster and in very short span of time thereby effectively reducing the erosion in early phase of the project. The number of check dams are estimated using number of first order streams in an area under severe and very severe erosion intensity,

  and constructed at an interval of 100 m. An illustration of brushwood check dams recommended by FAO is given in Figure 6-8.

Figure 6-8: Brushwood check dam placed across the gully. Source: FAO (1986)



- **Dry Stone Masonry Check Dams**: Dry stone masonry check dams/walls can be made of boulder piled up across the gully and along the banks, if they are locally available. Such structures for damming a gully or a stream to reduce the flow velocity and to control bank erosion are called dry stone masonry/ loose bolder check dams/ walls.
- **Contour Bunding**: Contour bunding is used for retaining the water by creating obstruction to control erosion. It consists of constructing narrow based trapezoidal bunds on contours to improve runoff in such a manner that it percolates and recharges the root profile on either side of the bunds. Bunds are simply embankments like structures, constructed across the land slope.
- **Gabion Check Dams**: If dry stone masonry check dams are considered not to be stable in a particular reach of the stream, gabion structure can be installed.
- **Toe Walls**: Provision of toe walls is for arresting soil in the places which are prone to erosion. These short height walls keep soil from sliding and carried away with runoff. During the field trip it was observed that there are certain areas, where the land is either exposed due to tree felling or erosion with time. These toe walls would provide stability to the soil behind them and help them keep bound. Based on location, the

backfill slope of the soil behind wall would be given grass and gravel cover in order to retard erosion and hence washing of back fill soil.

- **Retaining Walls**: Provision of retaining walls is for arresting soil in the places which have significant vertical face length, and are prone to erosion. These walls are used in places where vertical stability for exposed land mass is required. During the field trip it was observed that there are certain areas, especially along the southern and western regions, where retaining walls are needed. These retaining walls would provide stability to the soil behind them and help them keep bound. In a similar fashion of toe wall design, the backfill slope of the soil behind wall would be given grass and gravel cover in order to retard erosion and hence washing of back fill soil.
- **Cascade Walls**: Cascade walls are typically used for trapping the velocity of runoff water coming out of the catchment area, which may otherwise be able to cause erosion of soil. These walls are typically provided across the cross section of natural drain with elongate flanges, so that it provides runoff with an opportunity to pound against these walls and thus assisting in settling of rolling soil particles, which may otherwise be able to escape the catchment and eventually gets deposited at the water body.

7. REVIEW OF POLICY AND LEGISLATION

183. Following severe floods, the first policy statement on floods was made in the Indian Parliament in September 1954. It set the objective, optimistically albeit unrealistically to be that "the country may be rid of the menace of floods." It stated that the floods in the country could be contained and managed and assured that the problem is capable of solution.

184. It outlined a plan to achieve this in less than a decade. It was apparently realized soon that the initial objective of getting rid of floods and solving the Flood problem was difficult to achieve. A pragmatic awareness set in and the changed objective seemed to be "to do all that is possible to save ourselves from the harm and the devastation" that the floods bring.

185. The High Level Committee on floods (1957) pointed out that absolute or permanent immunity from flood damage is not physically attainable from known methods of flood control, it was recommended that flood plain zoning, flood forecasting and warning etc. should be given due importance, particularly as they did not require large investments.

7.1 National Water Policy

186. The announcement of the National Policy for Flood in 1954 suggested that immediate relief be provided through construction of cost effective embankments using abundant local resources and man-power as a “short-term” measure.

187. The announcement of the National Programme of Flood Management resulted in wide-spread construction of flood and erosion protection schemes. In 1954 Shri Jawaharlal Nehru expressed during his visit of Dibrugarh Town on 4 September that ‘We must accept this challenge of nature’, leading to an unprecedented level of studies and investigation cumulating in the successful construction of Dibrugarh town protection.

188. The High Level Committee on Floods, 1957 already suggested measures for defining the risk environment and minimizing the risk of natural hazards through flood zoning and flood forecasting and warning. In addition, it put emphasis on flood moderation through dams.

189. The Minister’s Committee on Flood Control, 1964 suggested integrated measures ranging from combined hydropower and flood storage to flood plain zoning and insurance.

190. The Minister’s Committee on Flood and Flood Relief, 1972, apart from reiterating previous committee recommendations, expands to riverbank protection for locations with valuable properties.

191. The Rastriya Barh Ayog (RBA) or National Flood Commission, working from 1976 to 1980 addressed the problem of flooding nationwide in a scientific manner and planned and prioritized future implementation of mitigation measures. The recommendations focused on basin management aspects including dams, concentration on embankments with sufficiently large set-back distances and retirement to avoid costly riverbank protection. The RBA also emphasized the need for more research and understanding, but also includes standardized assessments of damages as well as benefits of flood protection schemes, institutional performance and requirements, and maintenance arrangements

192. The Committee on Flood Management in the North Eastern States, Ministry of Water Resources, December 1988, was formed as a response to the 1987 flood. Apart from reiterating the need for implementation of RBA recommendations, the committee mainly

outlines different solutions in response to the limited budgets, while clearly stressing the need for faster implementation, more research and development, and the limitations of permanent embankment retirements.

193. The National Water Policy, 1987 acknowledges that embankments and dykes will continue to be necessary even though flood storage is specifically emphasized. The policy adopted by the National Water Resources council, inter-alia, recommended that "adequate flood cushion should be provided in water storage projects wherever feasible to facilitate better flood management". While it recognized that "physical flood protection works like embankments and dykes will continue to be necessary", it laid emphasis "on non -structural measures such as flood forecasting and warning and flood plain zoning for the minimization of losses”.

194. The National Water Policy 2002 follows the 1987 recommendation and supports the importance of non-structural measures over structural, however also demands the reduction of land erosion. It makes a strong case for planned flood plain use and improved flood forecasting and warning and inter alia recommends the following guiding policies, such as *“While every effort should be made to avert water related disasters like floods and droughts, through structural and non-structural measures, emphasis should be on preparedness for flood / drought with coping mechanisms as an option. Greater emphasis should be placed on rehabilitation of natural drainage system.”*

195. Prime Minister Dr Manmohan Singh gave new impetus to water management during his visit to Assam on 21st & 22nd November 2004. He announced a development programme and projects to be taken up in Assam: “It is worth considering whether we need to establish a cohesive, autonomous, self-contained entity on the lines of the Tennessee Valley Authority of the USA or the Damodar Valley Corporation to address this perennial problem. It could be called the Brahmaputra Valley Authority or the North East Valley Authority. This body would develop the river areas to provide effective flood control, generate electricity, provide irrigation facilities and develop infrastructure. Given managerial and financial autonomy with top class manpower and backed by the Parliamentary sanction, such a body would be the instrument for transforming the region. It could be the instrument for providing a ‘New Deal’ for Assam”.

196. The Task Force for flood management/erosion control, 2004, formed by the central government in response to the 2004 flood provides another review and recommendations based on earlier experience.

197. Recently, The National Water Policy (NWP) 2012 was released by the President of India on April 8, 2013 during the Inauguration of India Water Week 2013. Some of the relevant highlights contained in NWP (2012) are reproduced below.

A. On capacity building: *The lack of adequate trained personnel for scientific planning, utilizing modern techniques and analytical capabilities incorporating information technology constrains good water management.*

B. On basin level: IWRM, data base

- *All the elements of the water cycle. i.e. evapo-transpiration, precipitation, runoff, river, lakes, soil moisture, and ground water, sea etc., are interdependent and the basic hydrological unit is the river basin, which should be considered as the basic hydrological unit for planning*

- *IWRM taking river basin / sub-basin as a unit should be the main principle for planning, development and management of water resources. The departments / organisations at the Centre / state Governments levels should be restructured and made multi-disciplinary accordingly.*
- *Appropriate institutional arrangements for each river basin should be developed to collect and collate all data on regular basis with regard to rainfall, river flows, area irrigated by crops and source, utilisation for various uses by both surface and ground water and to publish water budgets and water accounts based on the hydrologic balances. In addition, water budgeting and water accounting should be carried out for each aquifer.*
- *All hydrological data, other than those classified on national security consideration, should be in public domain. However, a periodic review for further declassification, of data may be carried out.*
- *A national Water Informatics Center should be established to collect, collate and process hydrological data regularly from all over the country, conduct the preliminary processing, and maintain in open and transparent manner on a GIS platform.*
- *All water related data, like rainfall, snowfall, geo-morphological, climate, geological, surface water, ground water, water quality, ecological, water extraction and use, irrigated areas, glaciers, etc., should be integrated with well defined procedures and formats to ensure online updating and transfer of data to facilitate development of database for informed decision making in the management of water.*

C. On flood management

- *In order to prevent loss of land eroded by the river, which causes permanent loss, revetments, spurs, embankments, etc., should be planned, executed, monitored and maintained on the basis of morphological studies. This will become increasingly more important, since climate change is likely to increase the rainfall intensity, and hence, soil erosion.*
- *Flood forecasting is very important for flood preparedness and should be expanded extensively across the country and modernized using the real time data acquisition system and linked to forecasting models. Efforts should be towards developing physical models for various basin sections, which should be linked to each other and to medium range weather forecasts to enhance lead times.*
- *Operating procedures of reservoirs should be evolved and implemented in such a manner to have flood cushion and to reduce trapping of sediment during flood season. The procedure should be based on sound decision support system.*
- *Protecting all areas prone to floods and droughts may not be practicable; hence methods for coping with floods and droughts have to be encouraged. Frequency based flood inundation maps should be prepared to evolve coping strategies, including preparedness to supply safe water during and immediately after floods. Communities need to be involved in preparing an action plan for dealing with flood/drought situations.*
- *To increase preparedness for sudden and unexpected flood related disasters, dam/embankment breach studies, also preparation and periodic updating of emergency action plans / disaster management plans should be evolved after involving affected communities. In hilly reaches, GLOF and land slide dam break*

flood studies with periodic monitoring along with instrumentation, etc., should be carried out.

D. On Research & training needs

- *Continued research and advancement in technology shall be promoted to address issues in the water sector in a scientific manner. Innovations in water resources sector should be encouraged, recognized and awarded.*
- *It needs to be recognized that the field practices water sector in advanced countries have been revolutionized by advances in information technology and analytical capabilities. A re-training and quality improvement programme for water planners and managers at all levels in India, both in private and public sectors, needs to be taken.*
- *To meet the need of skilled manpower in the water sector, regular training and academic courses in water management should be promoted. These training and academic institutions should be regularly updated by developing infrastructure and promoting applied research, which would help to improve the current procedures of analysis and informed decision making in the departments and by the community. A national campaign for water literacy needs to be started for capacity building of different stakeholders in the water sector.*

198. *The state water policies may need to be drafted / revised in accordance with this policy keeping in mind the basic concerns and principles as also a unified national perspective.*

7.1.1 National Water Mission

199. Ministry of Water Resources, Govt. of India launched “National Water Mission (NWM)” in 2008 as part of the National Action Plan on Climate Change (NAPCC). The main objective of the National Water Mission is “Conservation of water, minimizing wastage, and ensuring its more equitable distribution both across and within States through integrated water resources development and management”. NWM has identified five goals as below:

- Preparation of a comprehensive water data base in public domain and assessment of impact of climate change on water resources.
- Promotion of citizen and state actions for water conservation, augmentation and preservation.
- Focused attention to vulnerable areas including over-exploited areas.
- Increasing water use efficiency by 20% and
- Promotion of basin level integrated water resources management.

200. Various strategies for achieving the goals have been identified under the Mission, which would lead to integrated planning, sustainable development and efficient management of water resources with active participation of the stake holders. This is to be done after identifying and evaluating the development scenarios and management practices which would lead to better acceptability of measures to mitigate the impacts of climate change on water resources.

7.2 Assam State Water Policy

201. In 2005, the Assam State Government initiated the process of a drafting State Water Policy (SWP). Initially a theme paper was drafted by the state level officials in consultation with the Assam Science Technology Environment Centre for discussions amongst cross

section of the institutions and people. The discussions finally led to the formation of a committee headed by the retired Chairman of the Brahmaputra Board and consisting of experts and experienced people representing Government, NGOs, Research and Academic Institutions. It was expected that the SWP would be submitted to the cabinet within 2008 for its finalization.

202. A meeting was held in Assam Secretariat in respect of the guidelines of National Water Policy 2012 under the chairmanship of Additional Chief Secretary on 11th October 2012. It was decided to prepare the SWP in commensuration with the NWP.

203. The highlights of the Draft Assam Water Policy are:

- *Planning, development and management of water resources need to be governed by national perspectives. Under the constitution, water resource is primarily a 'State Subject', with legislation and administration substantially framed within the context of State boundaries. In the developmental planning of any State, water is a decisive and multifaceted component. For environmental balance, skillful and planned management for all types of developmental activities, economic use on the equitable basis and in view of the prime importance of water for all human and other living beings, an effective and sound water policy, which is responsive to the State's future needs, is necessary. The State Water Policy of Assam is prescribed in accordance to the guidelines and general directions in the National Water Policy - 2002, keeping in view the specific necessity for the State of Assam.*
- *The Policy envisages a long-term water resource management program designed to develop a critical mass of indigenous productivity with the requisite technical, economic and sociocultural means for sustainable development.*
- *The State Water Policy of Assam adopts integrated water resource management as a core strategy, based on the principles of water as a finite resource, need to use a participatory approach, the crucial role of men and women, ensuring clean water for human health and looking at water both as an economic and social good. The first priority in the strategy would, however, be development of a systematic knowledge base to examine the current understanding of integrated freshwater management quantitatively and qualitatively.*

204. The broad objectives of the State Water Policy of Assam are : (a) To ensure preservation of all water resources and to optimize the utilization of the available resources; (b) Development of all utilizable water resources, including surface water, groundwater and wastewater, to the maximum possible extent for optimal economic development and social well-being; (c) To maintain water quality, both surface and underground, to established norms and standards; (d) To bring about qualitative improvement in water resource management with inclusion of users' participation and decentralization of authority; (e) To promote formulation of integrated and multidisciplinary projects as far as and whenever and wherever possible on the concept of basin or sub- basin; (f) Judicious and economically sound allocation of water resources to different sectors, with drinking water supply as the first priority; (g) To optimize utilization of water resources to maximum production in all user sectors; (h) To emphasize and facilitate rainwater harvesting and recharging of groundwater aquifers; (i) To ensure ecological and environmental balance while developing water resources by minimizing adverse impacts of water resources development on the natural environment and on population affected by implementation of projects; (j) To ensure flood management and drainage as integral part of water resource development as well as to assure minimal supplies during drought and drought-like situations; (k) To ensure self-

sustainability in water resource development; (l) To promote beneficiaries' participation in all aspects of water planning and management;
(m) To motivate and encourage water conservation through appropriate and socially acceptable water rates, introduction of water-saving devices and practices in all sectors;
(n) To generate water literacy and awareness among all users and user sectors; (o) To advance scientific and technological level of all personnel in the water sector through intensification of applied research, technology transfer, training and education; (p) To ensure well coordinated and efficient decision making, planning, design, execution and operation and maintenance activities; (q) To facilitate private initiative in development, operation and management of water resources projects; (r) To provide a substantive legal framework for management of water resources; (s) To provide a Management Information System for effective monitoring of policy implementation; (t) To provide a mechanism for the resolution of conflicts between various users.

205. On the hydropower sector, the State Water Policy States that efforts would be made to accelerate the process of planning, development and establishment of new projects so that the available water resource are put to optimal use, especially by taking up multipurpose projects.

- *Micro-, Mini- and Small-Hydro schemes, up to 20 MW, which involve negligible storage, no considerable negative environmental impacts and no resettlement and rehabilitation problems would be encouraged.*
- *Private Sector Participation in establishing micro-, mini- and small-hydro schemes would be encouraged within the ambit of Small Hydro Power Policy of Assam.*
- *Planning of micro-, mini- and small-hydro development projects would take into account the need to provide assured drinking water and the proper approach to irrigation in nearby areas in addition to power generation.*

206. On integrated planning for maximizing water usability, some key statements in the policy are:

- *Water resources planning, development and management will be carried out adopting an integrated approach for a hydrological unit such as a river basin as a whole, or for a sub-basin, or for a watershed, multi-sectorally, planned, developed, operated and managed in an integrated manner.*
- *All individual development projects and investment proposals will be formulated and considered within the framework of river or sub-basin plan or watershed plan so that the best possible combination of options can be made and sustained for poverty alleviation, increased productivity and incomes, equity, reduced vulnerability to natural and economic risks and costs.*
- *The integrated approach of development planning will include catchment area treatment and management, environmental and ecological aspects, the rehabilitation of affected people and command area development.*

207. On flood management, some key elements of the State Water Policy are:

- *Flood protection would be considered as an essential component while planning water resources of a basin, or sub-basin, or watershed.*
- *There would be a master plan for flood control and management for each flood-prone area. In highly flood prone areas, flood management would be given overriding consideration in reservoir policy even at the cost of sacrificing some*

irrigation or power benefits.

- *While physical flood protection works like embankments and dykes may be necessary, increased emphasis would be laid on nonphysical measures such as flood forecasting and warning, floodplain zoning and flood proofing, for minimization of losses so as to reduce the recurring expenditure on flood relief.*

7.2.1 Integrated Flood & Riverbank Erosion Management (IFRERM)

208. Based on a thorough review of various policies, such as national water policy, state water policy, state disaster management plan, disaster management guidelines, Assam relief manual, etc, a strategy framework for IFRERM has been proposed which follows the overall provisions of IWRM. In order to be effective, the IFRERM strategy framework needs to be based on the well recognized three pillars of IWRM: Management instruments, enabling environment and Institutional framework.

7.3 Assam Small Hydropower Development Policy 2007

The Small Hydropower Policy (SHP) of Assam was published by the Assam State Electricity Board, Government of Assam in March 2007. All Hydropower projects/stations with an installed capacity of up to 25 MW are eligible under this policy. The identified potential for development of small hydropower projects was about 117 MW at about 88 identified locations. A large number of SHP have been identified in the Kopili basin tributaries falling under Karbi-Anglong, Dima Hasao and Nagaon districts. The policy further allows the development of any other new SHP sites identified by independent power producers (IPPs) / Users society.

209. The SHP contains the following provisions, among others:

- Process of allotment (by competitive bidding or by invitation to pre-qualified developers)
- Facilitation to be provided by Government, including allotment of land
- Sale of Power
- Wheeling Charges
- Evacuation of Power
- Royalties, duties and taxes
- Incentives by central and State Governments
- Transfer of allotment
- Time limit for execution of projects

210. SHP also states the role of the irrigation Department. The discharge available in the canals of Irrigation schemes/projects will be let out by the Irrigation Department, Government of Assam based on availability of water in irrigation canals/rivers only. The release of water in canals will be under sole control of the Irrigation Department, Government of Assam and no claims for compensation on this account will be considered.

7.4 Legal Instruments

211. In general, water law in India is largely state based (Cullet, 2007). This is due to the constitutional scheme, which since the Government of India Act, 1935 has in principle given power to the states to legislate in this area. Thus, states have the exclusive power to regulate water supplies, irrigation and canals, drainage and embankments, water storage,

hydropower and fisheries. There are nevertheless restrictions with regard to the use of inter-state rivers. Further, the Union is entitled to legislate on certain issues. These include shipping and navigation on national waterways as well as powers to regulate the use of tidal and territorial waters. The Constitution also provides that the Union can legislate with regard to the adjudication of inter-state water disputes. While no substantive clauses could be adopted at the time of the adoption of the Constitution, a specific act, the Inter-State Water Disputes Act was adopted in 1956. This introduces a procedure for addressing disputes among states concerning inter-state rivers that have not been solved through negotiations. It provides for the establishment of specific tribunals to adjudicate such conflicts and has been used in several cases.

212. The Indian Parliament also enacted the River Boards Act, which provides a framework for the setting up of river boards by the Central Government to advise state government concerning the regulation or development of an inter-state river or river valley. River boards can advise state governments on a number of issues including, conservation, control and optimum utilisation of water resources, the promotion and operation of schemes for irrigation, water supply or drainage or the promotion and operation of schemes for flood control. This act has, however, never been used in practice.

213. While the intervention of the central government in water regulation is limited by the constitutional scheme, the importance of national regulation in water has already been recognised in certain areas. Thus, with regard to water pollution, Parliament did adopt an act in 1974, the Water Act.

214. The Water act 1974, seeks to prevent and control water pollution and maintain and restore the wholesomeness of water. It gives powers to water boards to set standards and regulations for prevention and control of pollution. Besides statutory frameworks, a number of common law principles linking access to water and rights over land are still prevailing in India. These include separate rules for surface and groundwater. With regard to surface water, existing rules still derive from the early common rule of riparian rights. Thus, the basic rule was that riparian owners had a right to use the water of a stream flowing past their land equally with other riparian owners, to have the water come to them undiminished in flow, quantity or quality. In recent times, the riparian right theory has increasingly been rejected as the appropriate basis for adjudicating water claims.

215. Further, common law rights must today be read in the context of the recognition that water is a public trust. If the latter principle is effectively applied in the future, it would have important impacts on the type of rights and privileges that can be claimed over surface water. Common law standards concerning groundwater have subsisted longer. The basic principle was that access to and use of groundwater is a right of the landowner. In other words, it is one of the rights that landowners enjoy over their possessions. The inappropriateness of this legal principle has been rapidly challenged during the second half of the 20th century with new technological options permitting individual owners to appropriate not only water under their land but also the groundwater found under neighbors' lands.

216. According to the irrigation Department, a draft bill to regulate use of ground water in the state of Assam has been prepared in the line of the model bill prepared by Government of India and submitted for consideration by the Assembly and subsequent enactment.

217. Similarly, the growth of concerns over the availability of drinking water in more regions has led to the introduction of social concerns in groundwater regulation. As a result of the rapid expansion of groundwater use, the central government has tried since the 1970s to

persuade states to adopt groundwater legislation.

218. The existing legal framework concerning water is complemented by a human rights dimension. While the Constitution does not specifically recognise a fundamental right to water, court decisions deem such a right to be implied in Article 21 (right to life). The right to water can be read as being implied in the recognition of the right to a clean environment.

219. Statutory water law also includes a number of pre- and post-independence enactments in various areas. These include laws on embankments, drinking water supply, irrigation, floods, water conservation, river water pollution, rehabilitation of evacuees and displaced persons, fisheries and ferries.

220. Water law includes a number of other laws and regulations that are directly or indirectly concerned with water. One example concerns dams. Two major aspects of dam building are regulated by laws and regulations, which are only partly concerned with water. With regard to environmental impact assessment, the Environmental Impact Assessment Notification provides a framework for assessing the environmental impacts of planned big hydropower and irrigation projects. Further, there are Guidelines for Environmental Impact Assessment of River Valley Projects, which provide a general framework since 1985 for assessing the impacts of planned big dam projects.

221. The Electricity Act, 2003 is the most relevant and active Act as regards to electricity generation by central, state and private entities. It also includes national electricity policy.

222. As regards to flood management, NDMA has issued national guidelines for management of floods, 2008.

8. REVIEW OF INSTITUTIONS

8.1 Functions of Central Government Water Sector Institutions

8.1.1 Water Resources and Flood Management

223. The Union Ministry of Water Resources is primarily responsible for the formulation and implementation of policies relating to regulation, control and development of water resources and to provide technical guidance to the State Governments in implementation of various schemes relating to Irrigation, Drainage, Flood Control and Water Supply. The Ministry of Water Resources is supported by a number of organizations under its administrative control:

- Central Water Commission
- Central Ground Water Board
- Ganga Flood Control Board/Commission
- Brahmaputra Board
- Central Water & Power Research Station
- Central Soil & Material Research Station

224. The organisations directly involved in the planning and implementation of flood and river erosion mitigation measures funded by the Central Government for the Brahmaputra basin in Assam are the Central Water Commission and the Brahmaputra Board.

225. The Central Water Commission (CWC) reviews the work of the State Governments related to flood, irrigation, and multipurpose management schemes including draft master plans. Besides CWC operates hydrological observation stations and flood forecasting system, and pursues flood control, irrigation, drainage, and hydro-electric schemes in the Union Territory. The River Management Wing of the CWC is responsible for:

226. The provision of guidance in the preparation and scrutiny of (a) Flood control schemes prepared by State Governments for consideration and approval by the Technical Advisory Committee of the Union Ministry of Water Resources; (b) Draft Master Plans prepared by State Governments;(c) Irrigation and multi-purpose schemes with regard to adequacy of flood control, drainage and erosion mitigation. The main functions of CWC are:

- Planning, establishment, operation & maintenance of hydrological observation stations and flood forecasting systems in entire country,
- Coordination and acting in liaison with various authorities in processing and execution of flood control, irrigation, drainage and hydro-electric schemes in the Union Territories.
- To run the entire flood forecasting network of the Government of India as well as the hydrological observations network of the nation. The CWC through its regional/basin offices, issues stage / inflow forecast at 172 stations throughout the country, with a network consisting of 450 near-real time hydro-meteorological stations from where data are collected for formulation of forecast. In the Kopili Basin CWC operates two forecasting stations at Dharmatul and Kampur.

227. The River Management Wing has two organisations at the Headquarters namely Flood Management Organisation and Planning & Development Organisation. The Shillong office of CWC is the responsible field organisation for the Brahmaputra and Baraak basins.

228. At the national level, the overall mandate for weather forecasting and managing the country's meteorological observation network rests with the Indian Meteorological Department (IMD) under the Ministry of Earth Sciences (MES). The Central Ground Water Board (CGWB) is responsible for groundwater monitoring.

229. The National Disaster Management Authority (NDMA) at the central level provides policy guidance on minimising hydro-met related disasters.

230. Although there is no clearly stated mandate, CWC monitors and provides flood forecast along major rivers while states have to monitor the tributaries. As per Constitutional provision the subject of flood management falls within the purview of the State Governments. Therefore, project-specific planning and their implementation is to be ensured by the State Governments.

231. According to the Planning Commission, the present structure of the State level flood control departments needs to be revamped to discharge their role as prime flood managers in the State. Local level detailed flood forecasting and issuing community based warning system is seen as state Governments' responsibility.

232. Recognizing the importance of reliable and real time hydromet data for water resources planning and management, the Planning Commission recently convened a working group to assess the present system of collection and dissemination of water related data. The working group has recommended massive strengthening of the existing data collection network. India's 12th National Five Year Plan and National Water Policy (2012) recognize the importance of improving disaster preparedness as a key aspect of development and poverty reduction. The National Water Policy 2012 further emphasizes the importance of flood and drought forecasting for disaster preparedness and the need to expand it across the country using real time and modernized data acquisition systems. A Working Group constituted by the National Planning Commission for the formulation of priorities and allocations in the Twelfth Five Year Plan (2012-2017) emphasizes on strengthening hydro-met network, improve and expand the flood forecasting and warning systems, and strengthening institutional capacities of central and state agencies

8.1.2 The Brahmaputra Board

233. While the constitution does not specifically cover flood and erosion protection, Government found practical ways for the day-to-day work based on the State and Union Lists, which refer to drainage and embankments. The Central Government has bestowed responsibility for flood control on the State Governments and the Assam State Government has enacted laws in this respect. The Central Government keeps some responsibility for inter-state rivers, of which the Brahmaputra is one. The Central Government established two specialized organizations which are of special importance for the Brahmaputra:

234. **The Brahmaputra Board (BB),** an autonomous statutory body was set up under an Act of Parliament called the Brahmaputra Board Act, (Act 46 of 1980) under the Ministry of Irrigation (Now renamed as Ministry of Water Resources). The jurisdiction of the Board includes both the Brahmaputra and Baraak Valley and covers all the States of the North Eastern Region, Sikkim and part of West Bengal falling under Brahmaputra basin. The Board consists of 21 Members (4 full time Members and 17 part time Members), representing seven states of the North Eastern Region, North Eastern Council, concerned Ministries - Ministry of Water Resources, Agriculture, Finance, Power & Surface Transport
- and Departments of the Government of India - Central Water Commission, Geological

Survey of India, India Meteorological Department and the Central Electricity Authority.

235. The tasks of BB include preparatory surveys and investigations focusing on the control of floods, riverbank erosion and the improvement of drainage congestion while developing and utilization the water resources of Brahmaputra and Baraak for irrigation, hydropower, navigation etc. In addition, the BB prepares Detailed Project Reports (DPRs) for dams and other projects identified in the Master Plans as approved by the Central Government. The BB has recently completed DPRs for 5 multipurpose storage schemes now under commissioning. Presently the BB has a further 5 multipurpose storage schemes under survey and investigation. BB has also prepared the Kopili-Kallang sub- basin Master Plan in 1995, which needs a major updating. Besides, the BB is implementing drainage works which upon completion are handed over to the Assam State Water Resources Department. It is widely viewed that the Brahmaputra Board could do more in terms of managing water. However, the outcome of initiatives to convert the Brahmaputra Board into a valley authority managing the water resources is not clear as of today.

236. The North Eastern Hydraulic and Allied Research Institute (NEHARI), which is a research and investigation wing of the Board, conducts field and laboratory investigations, research and development work for hydropower, irrigation, flood control projects.

237. NEHARI was established in 1996 under BB as a follow up of the “Assam Accord” of 1985. The institute is located in sprawling campus of 44ha at Rudreswar in North Guwahati. The institute was set up to cater the needs of NER in laboratory testing of soil, rock, concrete and other construction materials for the development of water resources. It has ample facilities for physical model testing of water resources projects. NEHARI’s mandate includes, among others, associated issues for development of hydropower, irrigation and flood control projects.

238. **The North Eastern Council (NEC):** Presently NEC plays a minor role in the water sector, concentrating on road development and health for which 50% and 25% of the annual budget of more than 50 crore are spent. NEC only provides grants for studies and the development of DPRs, especially for hydropower projects, but does not finance these projects.

239. **The Ministry for the Development of the North Eastern Region (MDoNER)** is responsible for the integration of development activities in the northeast. MDoNER is a major player for development of the region encompassing this project on flood and erosion mitigation.

8.1.3 Central Electricity Authority (CEA)

240. Central Electricity Authority (CEA) of India is a central statutory organization originally constituted under Section 3(1) of the repealed Electricity (Supply) Act, 1948, since substituted by Section 70 of the Electricity Act, 2003. It was established as a part- time body in 1951 and made a full-time body in 1975. CEA’s functions are defined in the Act. Among others, CEA acts as a regulatory body to approve various stages of a hydropower development plan. While providing concurrence to a hydropower development plan, CEA evaluates them to ensure that:

- the proposed river-works will not prejudice the prospects for the best ultimate development of the river or its tributaries for power generation, consistent with the requirements of drinking water, irrigation, navigation, flood-control, or other public purposes, and for this purpose; and

- the proposed scheme meets the norms regarding dam design and safety.

241. Where a multi-purpose scheme for the development of any river in any region is in operation, CEA oversees that the State Government and the generating company shall co-ordinate their activities. CEA's assessment is also to - satisfy itself, after consultation with the State Government, the Central Government, or such other agencies as it may deem appropriate, that an adequate study has been made of the optimum location of dams and other river-works.

8.1.4 North Eastern Electric Power Corporation (NEEPCO)

242. North Eastern Electric Power Corporation Limited (NEEPCO) is a central public sector enterprise owned by the Government of India under the Ministry of Power, formed in 1976 to plan, investigate, design, construct, generate, operate and maintain power stations in the North Eastern Region of the country. Its Headquarter is in Shillong. It has 60% of total installed capacity of NER, which is 1287 MW. The Kopili hydropower plants with Umrong and Khandong reservoirs is developed and operated by NEEPCO.

8.1.5 National Disaster Management Authority (NDMA)

243. NDMA provides guidelines for a broad range of disaster management activities at national level and coordinates those with the activities of state agencies. The actual mandates and functions related to flood and erosion disasters lie in the state disaster management authority, and other departments in Assam. The NDMA's 2008 national guidelines for management of floods which aims to "minimize vulnerability to floods and consequent loss of lives, livelihood systems, property and damage to infrastructure and public utilities" through improving the awareness and preparedness of all stakeholders in flood-prone areas, introducing appropriate capacity development interventions for effective flood management (including education, training, capacity building, research & development, and documentation), and strengthening the emergency response capability in flood-prone areas.

8.1.6 North East Space Application Center (NESAC)

244. NESAC, which is a part of NRSA, provide remote sensing data and applications to the NER. Recently from 2009, at the request of Government of Assam NESAC has developed a flood warning system with support from all stake holders such as CWC, IMD, WRD, Brahmaputra Board, NEC etc with ASDMA as the major beneficiary and end user. Under this activity, effort has been made to provide flood warning in district and revenue circle level with best possible lead time in order to enable the district administration to take well in advance action for relief, rescue and other flood mitigation measures. NESAC uses hydrological models combined with geospatial tools to develop the warning system.

8.2 State of Assam Water Sector Related Institutions

8.2.1 Water Resources Department (WRD)

245. In the State of Assam flood control activities have been carried out since the announcement of the National Policy for Flood in 1954. Initially the works were performed under the Flood Control and Irrigation wing of the Public Works Department (PWD). In May 1970 the Brahmaputra Flood Control Commission was created for flood control work in Assam under a three tier system. Flood control and irrigation (FC&I) was separated from the PWD vide Notification No. ABP 135/70/10, dated 18 September 1970. In 1974 the Irrigation Department (ID) was separated from the Flood Control Department vide Notification No. ABP

74/73/Pt/17, dated 22 January 1974. In March 1987 the Brahmaputra Flood Control Commission together with the other two tiers was dissolved and another three tier system was created consisting of the Flood Control Department, the Technical Advisory Committee, and Assam State Brahmaputra Valley Flood Control Board. In 2002 the Flood Control Department was renamed Water Resources Department (WRD) vide Notification No. AR21/2001/4, dated 1 November 2002.

246. WRD is responsible for all activities relating to Flood and River Erosion Management in the State. WRD prepares flood management schemes, which are subsequently scrutinized by the State Technical Advisory Committee, and approved by the State Flood Control Board. The State has the authority to sanction four types of schemes (i) raising and strengthening of embankments, (ii) retiring embankments, (iii) flood management, drainage, and anti-erosion works, and (iv) raising of villages. The Central Government steps in if a scheme costs more than Rs. 7.5 crore. CWC clears schemes up to Rs. 15 crore for inclusion into the Plan and cleared for investment by Planning Commission. Schemes above 15 crore need the additional approval of the Advisory Committee of the Ministry of Water Resources before the investment clearance can be issued by the Planning Commission.

247. ***The Technical Advisory Committee (TAC)*** set up by GOA in 1970, and reconstituted in 2000 advises the department on the technical viability of various schemes proposed and formulated at different field levels. The TAC includes representatives of the following organisations:

- Brahmaputra Board
- Irrigation Department
- Soil Conservation Department
- Survey of India
- Geological Survey of India
- Meteorological Department
- Public Works Department (Roads)
- Fisheries Department,
- Railways (N.F. Railway)
- Inland Water Transport Authority

248. On recommendations of the TAC, detailed project reports are prepared for the consideration for funding by the Central Government via the Brahmaputra Board.

8.2.2 Irrigation Department

249. The Irrigation Department of Assam initiated its independent functioning in 1974 by bifurcating it from the erstwhile Flood Control and Irrigation Department. The Department is playing a vital role in the development of irrigation potential of Assam by harnessing the rich surface water and ground water resources of the state. The total irrigated developed by the department as of March 2015 was 882,000 ha.

250. In addition to providing irrigation facilities using both gravity and lift systems, the irrigation department also promotes generation of hydropower from canals whenever it is feasible, i.e. from canal drops. The irrigation department gives due attention to the roles of water users association in the management of irrigation systems.

8.2.3 Assam Water Mission

251. The formulation of Assam Water Mission (like other state water missions) was guided by the National water Mission for formulations of state specific action plans to manage the water sector in achieving the goals of the National Water Mission. Assam Water Mission was approved by the Cabinet in 2014.

252. Before the Assam Water Mission was established in 2014, three more institutions were created: Assam State Water Board (ASWB) in 2006, Assam State Water Resources Council (ASWRC) (Likely in2018), and Assam water Resources Management Institute in 2013.

253. The Assam Water Mission, which is being registered as a Society, is headed by a full time Director and is presently located in the premises of the Water Resources Department, Chandmari, Guwahati.

254. The Assam Water Mission recognizes that climate change could result in relatively very large temporal and spatial variations in rainfall and consequently in the river flow and ground water aquifers. Assam would be critically affected as it largely comprises of Brahmaputra and Baraak river basins and is shaped by the rainfall patterns in the NE Region as a whole. Its principal crop in Kharif Season is critically dependent upon rainfall and Rabi Crops on the Ground water sources.

8.2.4 Assam Water Resources Management Institute (AWRMI)

255. Initially the River Research Station (RRS) under WRD was established by the Government of Assam in the year 1958 as a part of the research and investigation wing of the then Flood Control & Irrigation Department. Primary objectives of this station were Soil testing and Model development and study. For this purpose, laboratories were also setup to analyze rock, soil and other building materials etc. with the technology then available. This station functioned as a laboratory in support of investigation works until the middle of the 1990s.

256. In 2013, with an aim to establish a Centre of Excellence for Knowledge and Technology in the field of Water Resources Management in North East India that would bring together various technologies and tools that could help the Government of Assam and its agencies to understand the processes that control the behavior of Brahmaputra and Baraak Rivers and their tributaries better and to take up Capacity Building in this subject, the River Research Station was converted to the Assam Water Research and Management Institute (AWRMI) vide Govt. notification No. WR(E)5/2013/16 dated 22.05.2013. The AWRMI was registered under the Societies Act XXI of 1860 on the 12th of January, 2016. It is headed by a Director General.

257. The primary objective of AWRMI is to become the Centre of Excellence, which will be the repository for all existing data, knowledge and technology relevant to the waters of the Brahmaputra and Baraak River Basins, and to carry out studies and research to originate new knowledge and expertise to manage these waters for the benefit and safety of the people of this region and of the nation.

258. The main functions of AWRMI are:

- To acquire custody (or copies) of all data and knowledge-bases relevant to the management of land, water and infrastructure in the Brahmaputra and Baraak basins.
- To acquire an independent and advanced primary and secondary data collection,

processing and testing capacity for water and related data.

- To develop and operate advanced tools for analysing, modelling and predicting and / or forecasting all processes related to flooding, river morphology and bank erosion with the objective of managing the river in a better way for the benefit of the people.
- To develop human resources (both in-house and in related agencies) to the world-class expertise for the benefit of the work of the institute.
- To gradual extend the expertise and research of the centre to allow comprehensive coverage of all subjects related to land and water management issues throughout North East India and beyond.

259. AWRMI has provided some of the recent hydrological data of Kopili river for this study.

8.2.5 Flood and Riverbank Erosion Management Authority of Assam (FREMAA)

260. The Flood and River Erosion Management Agency of Assam (FREMAA) was set up in 2010 as an Executing Agency under Society Registration Act 1860. It is a special purpose vehicle established for implementation of the Assam Integrated River Erosion Risk Management Investment Program (AIFRERMIP), which would be able to coordinate with various agencies like the Water Resources Department, the flood warning system of Central Government, district administration and NGO's dealing with public participation. Initially, FREMAA is funded by ADB with provision of comprehensive, cost-effective and sustainable structural and non-structural measures in the Brahmaputra river at designated locations.

261. In addition to the above primary function, FREMAA is also designed to Facilitate sustainable interdepartmental cooperation, coordination and communication to integrate structural and non structural measures relevant to IFRERM projects, Implementation and maintenance, operation and management of such infrastructures. It provides an effective IFRERM funding conduit for the GOA.

262. With the establishment of FREMAA, the institutional framework for IFRERM in Assam has become relatively strong. Whilst the institutional framework of these agencies is strong on an individual basis, an effective FRERM framework is not in place to integrate and coordinate their roles and responsibilities, either across both national agency boundaries or across state agency boundaries.

263. It is required to recognize and address the technical difference between national agencies and their state counterparts; and facilitate discussion and consultation between national and state agencies and assistance by national agencies to promote the uptake of national FRERM initiatives by Assam state agencies.

264. Brief functions of other related agencies are given below:

265. The Assam State Disaster Management Authority (ASDMA) works under the Revenue and Disaster Management Department. Its functions include: prepare disaster management Policy/ Plan at state, district, village and departmental level; prevention and preparedness; mainstreaming disaster risk reduction in development activities; Flood Early Warning System (FLEWS) with the technical collaboration with NESAC; water resources and flood & erosion risk mitigation planning; and involvement of NGOs/ CBOs and voluntary groups in Flood Risk management.

266. Soil Conservation Department with a mandate to conserve the land in the state from soil erosion specially on agriculture land, wasteland, degraded forest land and in riverine land. The main activities are protection of riverine land adopting both vegetative and

engineering methods and to implement gully control works.

8.2.6 Assam Power Generation Corporation Limited (APGCL)

267. Assam Power Generation Corporation Ltd. was constituted after unbundling of Assam State Electricity Board (ASEB) in December 2004 through State Power Sector Reform Programme under the provision of Electricity Act'2003. The certificate of commencement of business was obtained with effect from 29th April 2004. The final Transfer scheme was implemented on August 2005. The company is mainly responsible for energy generation to meet up the demand in the State. The vision and mission of APGCL are stated as:

- To fulfill energy demand in Assam and in NE region by producing Electricity at lowest possible cost
- Planning and development of new projects by exploring conventional as well as non-conventional resources to meet up the increasing demand
- To establish as a consumer focused, environmentally conscious and reliable electricity supplier for the benefit of society.

9. WATER RESOURCES SYSTEMS ANALYSIS

268. This Chapter deals with water resources systems analysis, which is divided into two main sections:

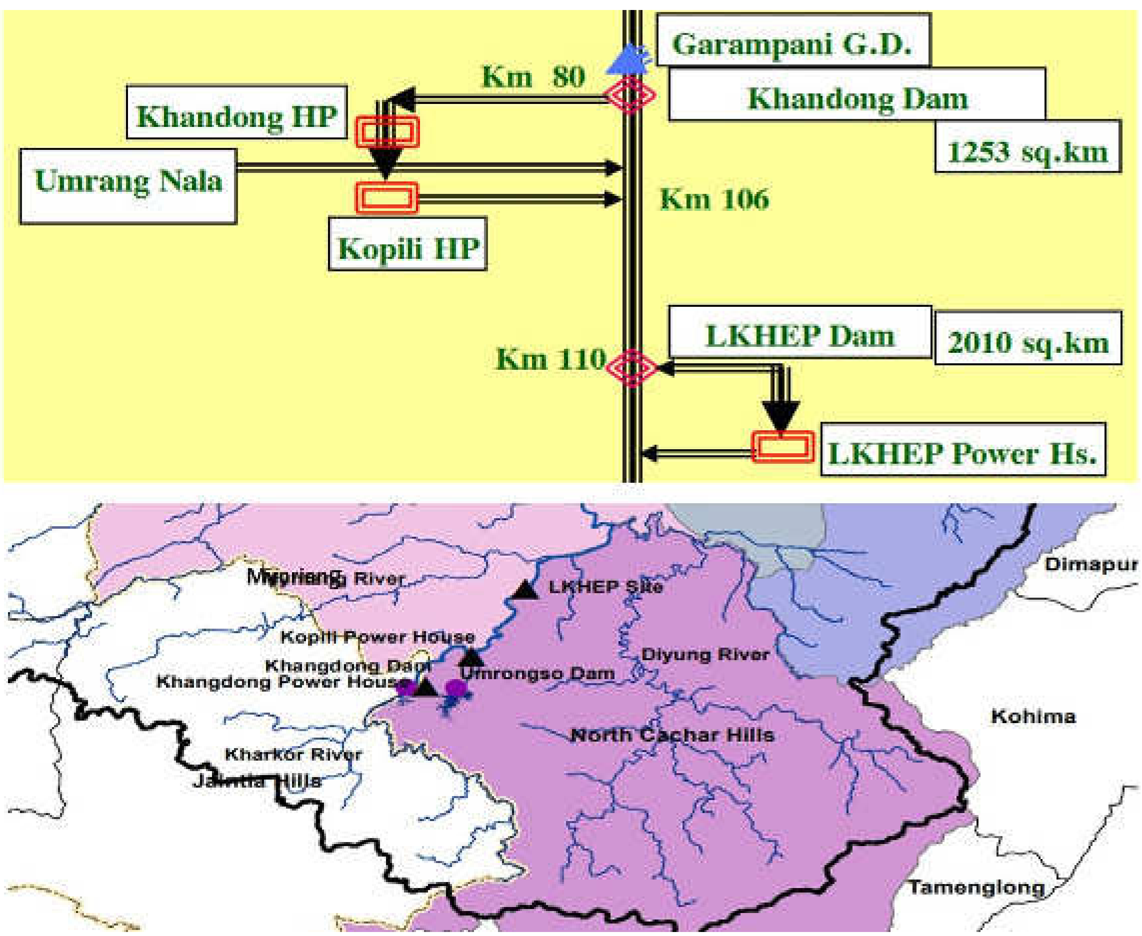
i. Review and updated analysis of the water resources system at the LKHEP site, including the provision of environmental flows
ii. Analysis of water resources for the Kopili Basin

269. In addition to the above a special section is devoted to the climate change issues.

9.1 Water Resources Analysis at the LKHEP site

270. The sources of water for the Kopili River up to the LKHEP site are rainfall in the hilly catchments in Meghalaya and Assam (Figure 9-1) with a total catchment area of 2010 km2. Chapter 5 describes the water data availability and data used in this study.

Figure 9-1: Location of LKHEP site



271. The NEEPCO owned Kopili hydropower system was commissioned in 1984 (1st unit) and 1997 (2nd unit). The proposed LKHEP will receive water from (i) tail race outlet from the existing Kopili power plant, (ii) incremental flow from the river catchment area between Khandong dam and the proposed LKHEP dam near Longku, and (iii) any spills from Khandong and Umrong reservoirs. Flow computations have been carried out using the data from 1959 to 2016 (with several years' gap in data). The computed flows at the LKHEP site have three characteristics due to the impact of the upstream Kopili HEP.

(i) Pre-Kopili HEP Period: 1959 – 1983: Natural flow
(ii) Transition Period: 1984-1996: Flows affected by the operation of the 1st one unit of KHEP
(iii) Post-Kopili HEP Period: 1997-present: Flows affected by the full operation of KHEP

272. A summary of the mean monthly flows in during the three period is given in Table 9-1. Tables 9-2 to 9-4 show mean monthly data for the above three periods. The different flow characteristics during the three periods are also depicted Figure 9-2. As expected, the impact of operation of the Kopili hydropower system, by releasing regulated flow from the Khandong and Umrang reservoirs, is positive on the down steam river flows at the LKHEP site. The mean monthly flows in the lean season are increased while the flows during the monsoon season are reduced. Therefore, further analysis of water resources in the Kopili basin is guided by the above findings. While analysis of natural catchment flows will be based the natural flows before 1984, analysis for future planning will be based on the flow data post-LKHEP period after 1994.

Table 9-1: Summary of Mean Monthly Flows (m3/s) at LKHEP during the three periods

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1959- 1983 (Prior to Kopili HEP)	8.95	8.33	18.96	26.54	77.60	301.87	194.48	135.29	112.57	83.11	22.27	12.35	83.82
1984 - 1996 (1 unit operating)	20.35	43.59	54.56	49.03	103.13	192.95	177.34	172.73	176.37	169.94	51.84	34.31	103.85
1997-2016 (Post Kopili HEP)	40.14	35.06	32.81	46.73	77.78	148.90	168.84	145.39	135.53	109.39	76.00	52.04	89.05

Table 9-2: Mean Monthly Flows at LKHEP (period-i: Pre-KHEP)

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual Mean
1959	7.03	6.51	9.39	8.15	139.83	553.27	117.77	72.39	97.74	176.13	38.23	11.81	103.19
1960	7.34	6.23	5.54	4.75	38.83	235.35	214.60	93.20	209.97	40.08	18.50	9.47	73.66
1961	7.16	5.94	126.71	37.49	163.53	219.57	144.87	62.48	122.58	49.55	17.56	9.13	80.55
1962	6.71	7.44	5.34	15.70	26.88	299.84	119.65	272.54	40.86	24.53	12.76	8.05	70.03
1963	6.07	4.88	5.54	9.69	44.75	492.78	172.85	83.31	57.02	69.40	16.84	12.17	81.44
1964	9.24	9.18	9.06	60.14	216.17	190.26	310.98	175.98	223.09	151.18	24.99	13.51	116.15
1965	8.92	13.10	8.27	14.23	94.11	296.11	181.55	238.30	104.31	67.34	22.36	13.29	88.49
1966	9.41	5.59	4.87	10.63	34.97	848.03	274.48	125.70	87.25	124.99	20.81	13.81	130.04
1967	9.61	11.40	13.06	21.63	80.65	111.65	250.24	44.99	60.85	59.38	8.57	8.92	56.75
1968	7.05	5.26	8.12	20.95	45.97	142.68	235.80	116.33	66.52	42.70	15.45	11.13	64.26
1969	5.75	4.07	5.63	31.98	28.42	328.85	124.40	116.27	107.02	80.53	19.81	11.13	71.99
1980	11.21	10.61	19.37	48.41	86.48	161.30	153.61	125.27	123.72	151.35	37.18	19.62	79.01
1981	16.13	12.45	25.58	39.90	55.87	103.18	181.90	107.15	123.15	34.88	14.30	16.09	60.88
1982	8.87	6.79	6.73	39.18	36.69	351.95	200.65	181.39	114.19	40.54	25.37	16.69	85.75
1983	13.69	15.52	31.16	35.31	70.84	193.16	233.90	213.98	150.35	133.99	39.28	10.49	95.14
Mean	**8.95**	**8.33**	**18.96**	**26.54**	**77.60**	**301.87**	**194.48**	**135.29**	**112.57**	**83.11**	**22.27**	**12.35**	**83.82**

Table 9-3: Mean Monthly Flows at LKHEP (period-ii: transition)

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual Mean
	No data during 1970-1979												
	First Unit of the Kolili HEP commissioned in 1984												
1984	11.66	12.39	7.93	50.24	221.15	167.98	275.04	129.44	224.84	102.92	36.30	32.79	106.08
1985	17.91	16.87	32.12	65.13	113.02	319.05	220.42	124.72	130.48	78.11	36.62	14.65	97.42
1986	7.18	5.04	20.50	26.59	33.57	30.74	86.63	84.73	157.90	237.76	80.16	45.83	68.05
1987	15.69	11.50	22.47	76.68	66.51	243.23	255.30	300.09	273.78	229.38	52.76	21.14	130.71
1988	8.69	7.07	10.46	21.18	138.72	234.54	214.90	251.31	209.28	200.22	75.26	52.51	118.68
1989	32.91	257.00	305.64	33.22	30.08	291.68	190.63	255.33	246.77	312.57	43.88	32.30	169.34
1990	29.17	28.33	36.35	114.24	160.86	138.60	158.08	124.91	113.42	221.15	43.88	32.30	100.11
1991	30.81	28.41	28.28	29.85	115.98	231.60	91.02	119.39	167.81	86.95	49.44	29.69	84.10
1992	29.13	25.70	27.33	24.16	48.30	79.17	104.00	164.62	63.04	60.43	48.25	47.56	60.14
Mean	20.35	43.59	54.56	49.03	103.13	192.95	177.34	172.73	176.37	169.94	51.84	34.31	103.85

Table 9-4: Mean Monthly Flows at LKHEP (period-iii: Post-KHEP)

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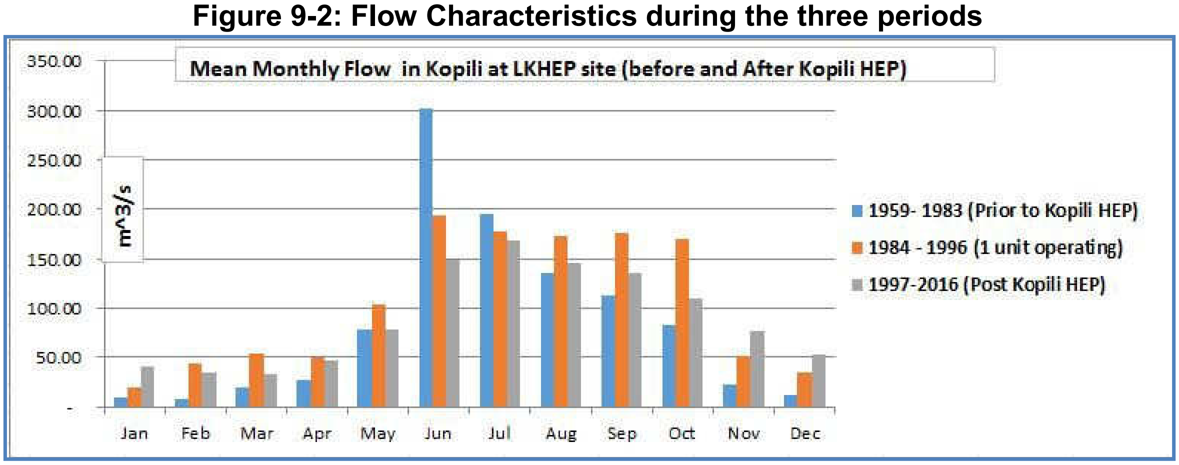
Figure 9-2: Flow Characteristics during the three periods



9.1.1 Design discharge used in LKHEP

276. LKHEP is designed as a hybrid run-of-river and storage system. During high flow season it will operate on a run-of-river basis, but in low flow season it will store water during the day and then release flow and generate power during the evening peak demand period. This design and variations thereof are common in India, and are generally referred to there as run-of-river with daily storage. In the Detailed Project Report of LKHEP, annual flow volumes for the period 1998 to 2010 have been considered to arrive at the 90% and 50% dependable hydrologic years, based on Weibull Plotting position formula, as shown in Table 9-5.

Table 9-5: Dependability of Annual Flow Volumes

S. No.	Year	Volume (MCM)			Exceed. Prob. %
1	1998	2483.6	2008	2990.8	7.7
2	1999	2553.9	2000	2958.4	15.4
3	2000	2958.4	2007	2809.6	23.1
4	2001	2506.0	2002	2792.8	30.8
5	2002	2792.8	1999	2553.9	38.5
6	2003	2440.2	2001	2506.0	46.2
7	2004	2184.4	1998	2483.6	53.8
8	2005	2434.7	2009	2450.2	61.5
9	2006	2381.0	2003	2440.2	69.2
10	2007	2809.6	2005	2434.7	76.9
11	2008	2990.8	2006	2381.0	84.6
12	2009	2450.2	2004	2184.4	92.3

(Source: LKHEP DPR, 2015)

277. The summary results of dependable flow analysis for 90% and 50% dependable years are shown in Table 9-6.

Table 9-6: Dependable Year Flow Volumes

Dependability	Dependable Water Year (June – May)	Annual Flow Volume (MCM)
90%	2004-05	2184.4
50%	1998-99	2483.6

278. Flow Duration Curves for 90% and 50% dependable years have been portrayed in Figures 9-3 and 9-4, respectively.

Figure 9-3: Flow Duration Curve for 90% Dependable Year: 2004-05

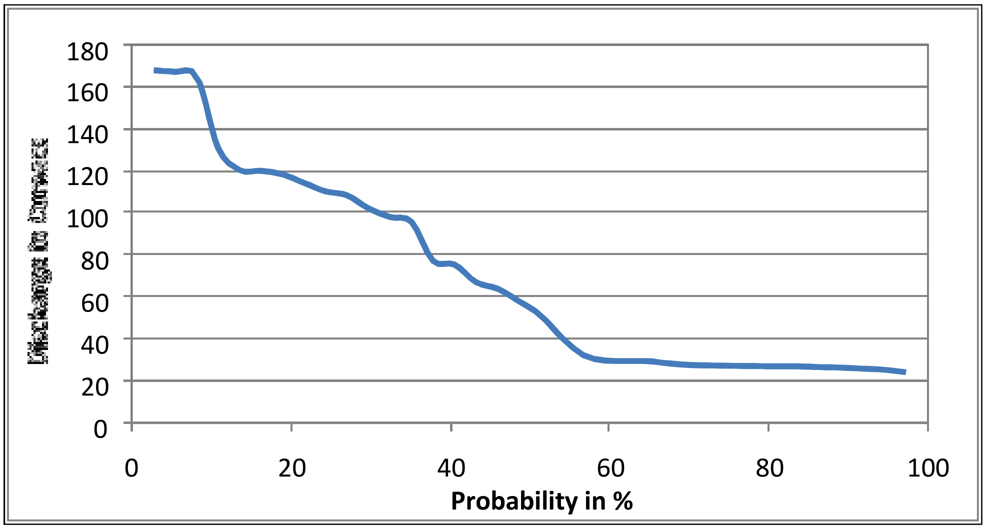
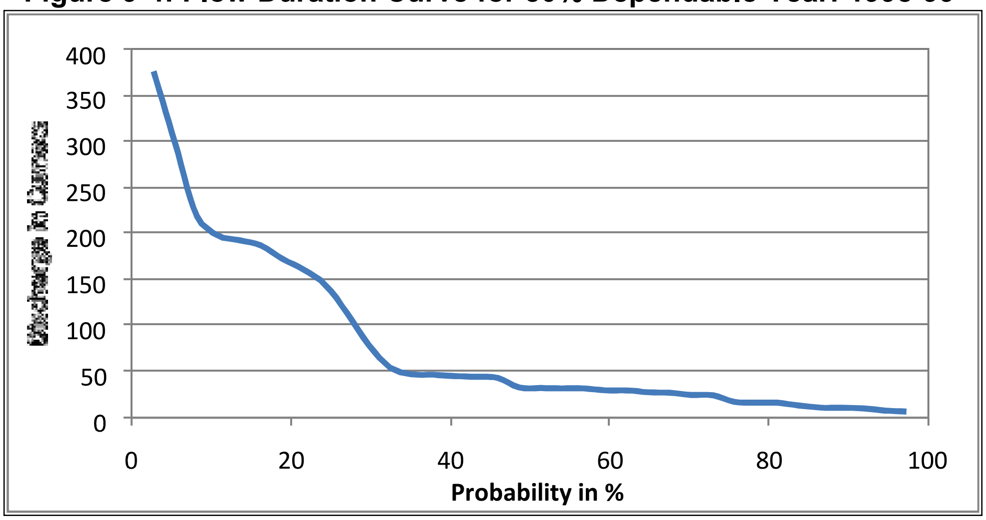


Figure 9-4: Flow Duration Curve for 50% Dependable Year: 1998-99



9.1.2 Environmental Flow / Release

279. As per the Terms of Reference for study of environmental impact assessment issued by MOEF, 20% of the average flow of four consecutive leanest months in a 90% dependable year should be maintained as environmental flow during the lean season. The recommended Environmental Flows to be released are given as follows:

- Monsoon Season- May to September - 30% of the average flows during 90 % dependable year.
- Non-monsoon Non lean Season- October & April - 25% of the average flows during 90% dependable year.
- Lean Season- November to March - 20% of the average flows during 90% dependable year.

280. The annual flow volume estimates for the period 1979-80 to 2009-2010 have been considered to arrive at the 90%, 75% and 50% dependable hydrologic years. Long term

river flow series was established in the form of ten-day discharge values; computed from the available daily discharge data. The 50% and 90% dependable years were worked out as 1998-1999 and 2004-05 with annual flow volume as 1801.2 MCM and 1715.2 MCM respectively. The design discharge for power generation is 112.71 m^3/s. The 10 daily discharge for 90% dependable year is given in Table 9-7.

Table 9-7: 10 daily flows for 90% dependable year

Month	10-daily period	Discharge (m^3/s)
June	I	6.54
	II	79.95
	III	41.28
July	I	63.76
	II	84.02
	III	74.09
August	I	130.34
	II	75.96
	III	43.02
September	I	132.54
	II	86.02
	III	133.25
October	I	106.21
	II	86.35
	III	50.32
November	I	44.38
	II	37.50
	III	18.79
December	I	22.30
	II	22.11
	III	23.07
January	I	21.83
	II	18.87
	III	21.35
February	I	21.69
	II	20.09
	III	21.94
March	I	20.61
	II	21.68
	III	21.07
April	I	16.08
	II	15.98
	III	16.31

Month	10-daily period	Discharge (m^3/s)
May	I	53.43
	II	81.94
	III	116.88

281. For the 90% dependable year 2004-05, December to March was identified as the period with lowest average flow for four consecutive months, with monthly average discharges estimated as 27.83, 26.02, 26.58 and 26.46 m3/s, respectively. The average discharge of these months is 26.72 m3/s. The environmental release for the lean period, computed as 20% of the average flow of the four leanest months, is 5.345 m3/s. During the monsoon period (considered as June to September), 30% of inflow calculated on the basis of 90% dependable year will have to be released. The average discharges for the months of June to September for the 90% dependable year 2004-05 are 76.6 m^3/s, 107.9 m^3/s, 117.2 m^3/s and 151.2 m^3/s respectively. The average monsoon flow is calculated as 113.2 m^3/s. Therefore, the environmental release during the monsoon period is 33.970 m^3/s. For the non-lean, non-monsoon period, environmental release has to be 25% of the inflow, calculated on the basis of 90% dependable year, as recommended by the Environmental Appraisal Committee. For the 90% dependable year 2004-05, the average discharge of the non-lean non-monsoon months of April, May, October and November are 29.6 m^3/s, 97.6 m^3/s, 95.1 m^3/s and 47.1 m^3/s respectively. The average discharge during the period is 67.3 m^3/s. The environmental release for this period has been considered at the rate of 25% of the average discharge, i.e. 16.835 m^3/s.

282. A computation of flow releases based on the 90% dependent 10-daily flows is shown in Table 9-8.

Table 9-8: Computation of Flow Releases

Month	Period	Inflow	EF	EF to be released	Turbine release for 24 hrs	Actual EF released through Aux.PH	Spill
		(m^3/s)	(%)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
Lean Season, 90% DY							
December	I	22.30	20	4.46	17.84	4.46	Nil
	II	22.11	20	4.42	17.69	4.42	Nil
	III	23.07	20	4.61	18.46	4.61	Nil
January	I	21.83	20	4.37	17.46	4.37	Nil
	II	18.87	20	3.77	15.10	3.77	Nil
	III	21.35	20	4.27	17.08	4.27	Nil
February	I	21.69	20	4.34	17.35	4.34	Nil
	II	20.09	20	4.02	16.07	4.02	Nil
	III	21.94	20	4.39	17.55	4.39	Nil
March	I	20.61	20	4.12	16.49	4.12	Nil
	II	21.68	20	4.34	17.34	4.34	Nil
	III	21.07	20	4.21	16.86	4.21	Nil
Avg.		**21.4**		**4.3**	**17.1**	**4.3**	
Non-Monsoon Non-Lean Season, 90% DY							
October	I	106.21	25	26.55	84.97	26.55	Nil
	II	86.35	25	21.59	69.08	21.59	Nil
	III	50.32	25	12.58	40.26	12.58	Nil
November	I	44.38	25	11.10	35.50	11.10	Nil
	II	37.50	25	9.38	30.00	9.38	Nil
	III	18.79	25	4.70	15.03	4.70	Nil
April	I	16.08	25	4.02	12.86	4.02	Nil
	II	15.98	25	4.00	12.78	4.00	Nil
	III	16.31	25	4.08	13.05	4.08	Nil
May	I	53.43	25	13.36	42.74	13.36	Nil
	II	81.94	25	20.49	65.55	20.49	Nil
	III	116.88	25	26.55	93.50	26.55	Nil
		53.7		**13.4**	**40.3**	13.4	
Monsoon Season							
June	I	6.54	30	1.96	4.58	1.96	Nil
	II	79.95	30	23.99	55.97	23.99	Nil
	III	41.28	30	12.38	28.90	12.38	Nil
July	I	63.76	30	19.13	44.63	19.13	Nil
	II	84.02	30	25.21	58.81	25.21	Nil
	III	74.09	30	22.23	51.86	22.23	Nil

Month	Period	Inflow	EF	EF to be released	Turbine release for 24 hrs	Actual EF released through Aux.PH	Spill
		(m^3/s)	(%)	(m^3/s)	(m^3/s)	(m^3/s)	(m^3/s)
August	I	130.34	30	39.10	91.24	39.10	Nil
	II	75.96	30	22.79	53.17	22.79	Nil
	III	43.02	30	12.91	30.11	12.91	Nil
September	I	132.54	30	39.76	92.78	39.76	Nil
	II	86.02	30	25.81	60.21	25.81	Nil
	III	133.25	30	39.98	93.28	39.98	Nil
		79.2	**30**	**23.8**	**55.4**	**23.8**	

(Source: DPR, 2015)

283. The minimum environmental flow release during the lean months (December to March) was adopted in the DPR is 5.345 m3/s. was The main power station of LKPH is proposed to comprise of 2 units of 55 MW each, which designed to be operated as a peaking plant for at least 3 hours a day. In the auxiliary power house below the dam, two units each of 2.5 MW and 1 unit of 5 MW will be operated to utilize the mandatory environmental flows.

9.1.3 Computation of Environmental flow from daily reservoir operation

284. A simulation model of the LKHEP reservoir was developed (using HECRes-SIM of the Hydrologic Engineering Center of US Army Corps of Engineers). The operation of the reservoir was simulated during lean months from December 2003 to March 2004, which were designated as the lean months for a 90% flow dependable year (DPR, 2015).

9.1.4 Design basis for reservoir operation

285. The basis for simulating the operation of the reservoir is its configuration the main power house is set up with a plant capacity of 110 MW comprising of 2 units with capacity of 55 MW each. During the non-monsoon season, the plant is to be operated as a peaking plant generating at full plant capacity for at least 3 hours a day. It has been proposed to utilize the environmental release for generating hydropower by passing it through turbines of a dam toe power house named as Auxiliary Power House. This auxiliary power house will have two units of 2.5 MW each and one unit of 5 MW. This will act as a base load plant, generating power.

286. In order to generate power to meet diurnal peak load, the main power house is proposed to be operated in the mode of diurnal peaking. As per the design, LKHEP can be operated at full plant capacity for most part of the monsoon months while diurnal peaking operation can be supported in the non-monsoon months. The operation as a peaking plant can be supported for at least 3 hours a day. For a few ten-daily periods during the lean flow season, the plant will have to operate with one machine running, to maintain generation for a minimum of 3 hours. Alternatively, hours of peaking can be reduced for these periods with extreme low flows. It has been envisaged to operate the reservoir at Full Reservoir Level (FRL) throughout the year, to gain maximum advantage of the head available. The live storage is just sufficient to support all the units operating at full load for about 7.94

days. Therefore, it has been planned to release all the water during the last ten daily period of the month of May, taking the reservoir water level to Minimum Draw Down Level (MDDL). It is expected to get filled up to FRL during the next two ten- daily periods. However, generation in one ten daily period has to be sacrificed; which can be made use for regular maintenance operations.

287. The design discharges adopted of the various turbines are 56.35 m^3/s for each of the 55 MW units, 6.23 m^3/s for each of the 2.5MW units and 12.46 m^3/s for the 5 MW unit. The total design discharge of the main power house is 112.71 m^3/s with an average net head of 108 m while the design discharge for the auxiliary power house is 24.94 m^3/s with a net head of 47.30 m, all at FRL.

288. Based on the simulation of the reservoir with daily inflow from upstream during the four lean months from December 2003 to March 2004, the following results are summarized.

289. Tables 9-9 to 9-12 show operation results in terms of inflows and releases during the four months: December 2003 – March 2004. Figures 9-5 shows the reservoir operation result from 2003 December 1 to 2004 March 31.

Table 9-9: Reservoir Operation Results during December 2003

Day	Reservoir Inflow	Reservoir Outflow	Operation hours		Total release to main power house	Release to Aux Power house	Storage level
			Unit-1 (55MW)	Unit-2 (55MW)		E-flow	
	m^3/s	m^3/s	hours	m^3/s	m^3/s	m^3/s	MCM
1	32.97	47.61	9	9	42.26	5.345	106.290
2	43.8	47.61	9	9	42.26	5.345	105.019
3	39	33.52	6	6	28.18	5.345	104.684
4	40.87	47.61	9	9	42.26	5.345	105.151
5	40.33	47.61	9	9	42.26	5.345	104.563
6	41.28	33.52	6	6	28.18	5.345	103.928
7	38.36	33.52	6	6	28.18	5.345	104.592
8	33.39	33.52	6	6	28.18	5.345	105.004
9	34.95	33.52	6	6	28.18	5.345	104.987
10	31.41	33.52	6	6	28.18	5.345	105.104
11	33.04	33.52	6	6	28.18	5.345	104.916
12	39.85	33.52	6	6	28.18	5.345	104.868
13	32.28	33.52	6	6	28.18	5.345	105.409
14	48.62	47.61	9	9	42.26	5.345	105.295
15	46.66	47.61	9	9	42.26	5.345	105.377
16	37.42	47.61	9	9	42.26	5.345	105.289
17	34.26	33.52	6	6	28.18	5.345	104.402
18	45.3	33.52	6	6	28.18	5.345	104.460
19	39.94	33.52	6	6	28.18	5.345	105.471
20	37.42	47.61	9	9	42.26	5.345	106.020
21	36.42	33.52	6	6	28.18	5.345	105.134
22	37.49	33.52	6	6	28.18	5.345	105.378
23	35.99	33.52	6	6	28.18	5.345	105.715
24	36.26	40.56	9	6	35.22	5.345	105.922
25	38.22	33.52	6	6	28.18	5.345	105.544
26	37.29	40.56	9	6	35.22	5.345	105.944
27	28	33.52	6	6	28.18	5.345	105.655
28	25.99	33.52	6	6	28.18	5.345	105.172
29	25.43	33.52	6	6	28.18	5.345	104.515
30	36.16	33.52	6	6	28.18	5.345	103.810
31	33.97	33.52	6	6	28.18	5.345	104.031
Minimum daily Operating hours			6	6			
Maximum daily Operating hours			9	9			
			Unit-1 (55MW)	Unit-2 (55MW)			
			Minimum Storage maintained for the month =				103.810
			Average Storage Maintained for the month =				105.085
			FRL (m)=				226.000
			Storage at FRL (MCM)=				106.29
			FRL at minimum storage for the month (m)=				225.587
			Allowed maximum reduction in FRL for the month (m)=				0.413

Table 9-10: Reservoir Operation Results during January 2004

Day	Reservoir Inflow	Reservoir Outflow	Operation hours		Total release to main power house	Release to Aux Power house	Storage level
			Unit-1 (55MW)	Unit-2 (55MW)		E-flow	
	m^3/s	m^3/s	hours	m^3/s	m^3/s	m^3/s	MCM
1	31.78	33.52	6	6	28.18	5.345	103.908
2	30.88	33.52	6	6	28.18	5.345	103.673
3	34.39	33.52	6	6	28.18	5.345	103.742
4	34.91	33.52	6	6	28.18	5.345	103.856
5	34.70	33.52	6	6	28.18	5.345	103.952
6	33.77	33.52	6	6	28.18	5.345	103.967
7	34.04	33.52	6	6	28.18	5.345	104.006
8	33.97	33.52	6	6	28.18	5.345	104.039
9	30.53	33.52	6	6	28.18	5.345	103.774
10	31.20	19.43	3	3	14.09	5.345	104.785
11	33.87	26.48	3	6	21.13	5.345	105.417
12	33.35	33.52	6	6	28.18	5.345	105.396
13	33.18	33.52	6	6	28.18	5.345	105.361
14	33.54	33.52	6	6	28.18	5.345	105.356
15	34.06	33.52	6	6	28.18	5.345	105.397
16	32.57	33.52	6	6	28.18	5.345	105.309
17	33.61	33.52	6	6	28.18	5.345	105.310
18	28.31	33.52	6	6	28.18	5.345	104.854
19	28.47	33.52	6	6	28.18	5.345	104.411
20	32.02	33.52	6	6	28.18	5.345	104.275
21	32.76	33.52	6	6	28.18	5.345	104.204
22	33.01	33.52	6	6	28.18	5.345	104.153
23	32.41	33.52	6	6	28.18	5.345	104.051
24	31.80	33.52	6	6	28.18	5.345	103.896
25	29.76	33.52	6	6	28.18	5.345	103.565
26	30.26	19.43	3	3	14.09	5.345	104.495
27	31.63	33.52	6	6	28.18	5.345	104.325
28	31.20	33.52	6	6	28.18	5.345	104.119
29	34.51	33.52	6	6	28.18	5.345	104.198
30	31.03	33.52	6	6	28.18	5.345	103.977
31	27.27	33.52	6	6	28.18	5.345	103.430
Minimum daily Operating hours			3	3			
Maximum daily Operating hours			6	6			
			Unit-1 (55MW)	Unit-2 (55MW)			
			Minimum Storage maintained for the month =				103.430
			Average Storage Maintained for the month =				104.361
					FRL (m)=		226.000
			Storage at FRL (MCM)=				106.29
			FRL at minimum storage for the month (m)=				225.553
			Allowed maximum reduction in FRL for the month (m)=				0.477

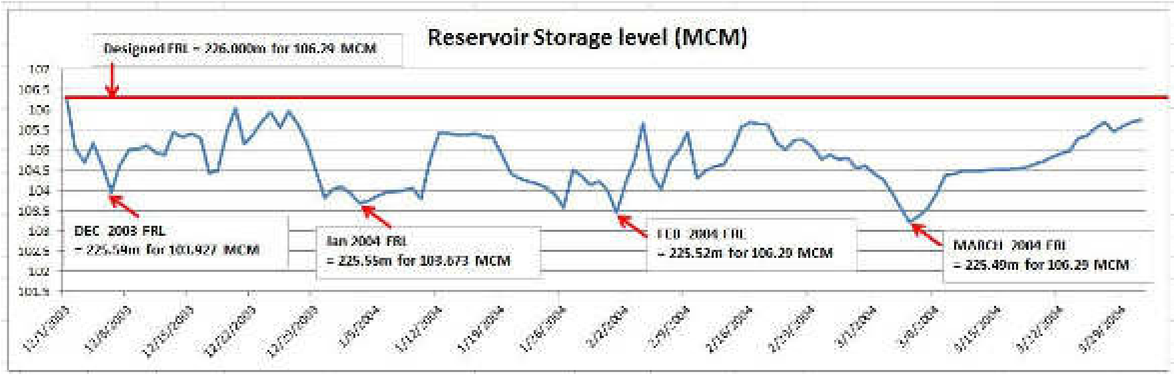
Table 9-11: Reservoir Operation Results during February 2004

Day	Reservoir Inflow	Reservoir Outflow	Operation hours		Total release to main power house	Release to Aux Power house	Storage level
			Unit-1 (55MW)	Unit-2 (55MW)		E-flow	
	m^3/s	m^3/s	hours	m^3/s	m^3/s	m^3/s	MCM
1	32.97	19.4325	3	3	14.09	5.345	103.430
2	43.8	19.4325	3	3	14.09	5.345	104.213
3	39	19.4325	3	3	14.09	5.345	104.727
4	40.87	47.6075	9	9	42.26	5.345	105.647
5	40.33	33.52	6	6	28.18	5.345	104.349
6	41.28	19.4325	3	3	14.09	5.345	104.014
7	38.36	19.4325	3	3	14.09	5.345	104.727
8	33.39	19.4325	3	3	14.09	5.345	104.990
9	34.95	33.52	6	6	28.18	5.345	105.414
10	31.41	19.4325	3	3	14.09	5.345	104.278
11	33.04	19.4325	3	3	14.09	5.345	104.457
12	39.85	19.4325	3	3	14.09	5.345	104.583
13	32.28	19.4325	3	3	14.09	5.345	104.615
14	48.62	19.4325	3	3	14.09	5.345	104.957
15	46.66	26.47625	6	3	21.13	5.345	105.542
16	37.42	19.4325	3	3	14.09	5.345	105.681
17	34.26	19.4325	3	3	14.09	5.345	105.633
18	45.3	26.47625	6	3	21.13	5.345	105.613
19	39.94	19.4325	3	3	14.09	5.345	105.139
20	37.42	19.4325	3	3	14.09	5.345	105.000
21	36.42	26.47625	6	3	21.13	5.345	105.220
22	37.49	26.47625	6	3	21.13	5.345	105.218
23	35.99	26.47625	6	3	21.13	5.345	105.082
24	36.26	19.4325	3	3	14.09	5.345	104.747
25	38.22	19.4325	3	3	14.09	5.345	104.863
26	37.29	19.4325	3	3	14.09	5.345	104.756
27	28	19.4325	3	3	14.09	5.345	104.771
28	25.99	19.4325	3	3	14.09	5.345	104.513
29	25.43	26.47625	6	3	21.13	5.345	104.593
Minimum daily Operating hours			3	3			
Maximum daily Operating hours			9	9			
			Unit-1 (55MW)	Unit-2 (55MW)			
			Minimum Storage maintained for the month =				103.430
			Average Storage Maintained for the month =				104.854
					FRL (m)=		226.000
			Storage at FRL (MCM)=				106.29
			FRL at minimum storage for the month (m)=				225.522
			Allowed maximum reduction in FRL for the month (m)=				0.478

Table 9-12: Reservoir Operation Results during March 2004

Day	Reservoir Inflow	Reservoir Outflow	Operation hours		Total release to main power house	Release to Aux Power house	Storage level
			Unit-1 (55MW)	Unit-2 (55MW)		E-flow	
	m^3/s	m^3/s	hours	m^3/s	m^3/s	m^3/s	MCM
1	31.78	28.18	6	6	42.26	5.345	104.400
2	24.33	28.18	6	6	42.26	5.345	104.244
3	24.16	28.18	6	6	28.18	5.345	103.905
4	24.16	28.18	6	6	42.26	5.345	103.552
5	23.13	21.13	6	3	42.26	5.345	103.199
6	23.27	21.13	6	3	28.18	5.345	103.365
7	18.23	14.09	3	3	28.18	5.345	103.544
8	19.62	14.09	3	3	28.18	5.345	103.896
9	14.48	14.09	3	3	28.18	5.345	104.368
10	14.97	14.09	3	3	28.18	5.345	104.395
11	14.04	14.09	3	3	28.18	5.345	104.465
12	14.3	14.09	3	3	28.18	5.345	104.455
13	14.49	14.09	3	3	28.18	5.345	104.467
14	14.04	14.09	3	3	42.26	5.345	104.496
15	14.37	14.09	3	3	42.26	5.345	104.485
16	14.45	14.09	3	3	42.26	5.345	104.504
17	14.45	14.09	3	3	28.18	5.345	104.529
18	15.09	14.09	3	3	28.18	5.345	104.554
19	14.87	14.09	3	3	28.18	5.345	104.634
20	15.52	14.09	3	3	42.26	5.345	104.696
21	14.97	14.09	3	3	28.18	5.345	104.813
22	15.21	14.09	3	3	28.18	5.345	104.883
23	17.6	14.09	3	3	28.18	5.345	104.974
24	14.9	14.09	3	3	35.22	5.345	105.271
25	16.66	14.09	3	3	28.18	5.345	105.335
26	15.59	14.09	3	3	35.22	5.345	105.551
27	18.35	21.13	6	3	28.18	5.345	105.675
28	15.79	14.09	3	3	28.18	5.345	105.429
29	15.24	14.09	3	3	28.18	5.345	105.569
30	14.89	14.09	3	3	28.18	5.345	105.663
31	15.28	14.09	3	3	28.18	5.345	105.726
Minimum daily Operating hours			3	3			
Maximum daily Operating hours			6	6			
			Unit-1 (55MW)	Unit-2 (55MW)			
			Minimum Storage maintained for the month =				103.199
			Average Storage Maintained for the month =				104.614
					FRL (m)=		226.000
			Storage at FRL (MCM)=				106.29
			FRL at minimum storage for the month (m)=				225.485
			Allowed maximum reduction in FRL for the month (m)=				0.515

Figure 9-5: Reservoir Operation Simulation during 1 Dec 2003 - 31 March 2004



290. The conditions used in the reservoir simulation are:

- The storage is at Full Reservoir Level (FRL) at the end of November 2003.
- The reservoir is kept at FRL as much as possible in order to utilize the designed head of 108 m for the two main power units (2X 55MW).
- The two power units are operated for peaking purpose and one must be operated for at least 3 hours.
- A design discharge of 56.35 m^3/s is released to one unit.

291. Table 9.13 summarizes the operation results for the four months. It is noted that it is possible to release the minimum environmental flow of 5.345 m^3/s throughout the designated lean period of December 2003 to March 2004. The two units of the main power plant will be able to operate for at least 3 hours without compromising the mandatory environmental flow. The number of days during which the units can operate for 3, 6 and 9 hours can also be counted from the Tables 9-10 to 9-12 above.

Table 9-13: Summary of Reservoir Operation during December 2003 to March 2004

Month	Minimum Environmental Flow released	Minimum (Maximum) Operation hours of Main Power Plant (2 X 55 MW)		Maximum allowed lowering from FRL
	(m^3/s)	Unit-1 (hours)	Unit-2 (hours)	(m)
December 2003	5.345	6 (9)	6 (9)	0.413
January 2004	5.345	3 (6)	3 (6)	0.477
February 2004	5.345	3 (9)	3 (9)	0.478
March 2004	5.345	3 (6)	3 (6)	0.515

9.1.5 Reservoir Operation during floods

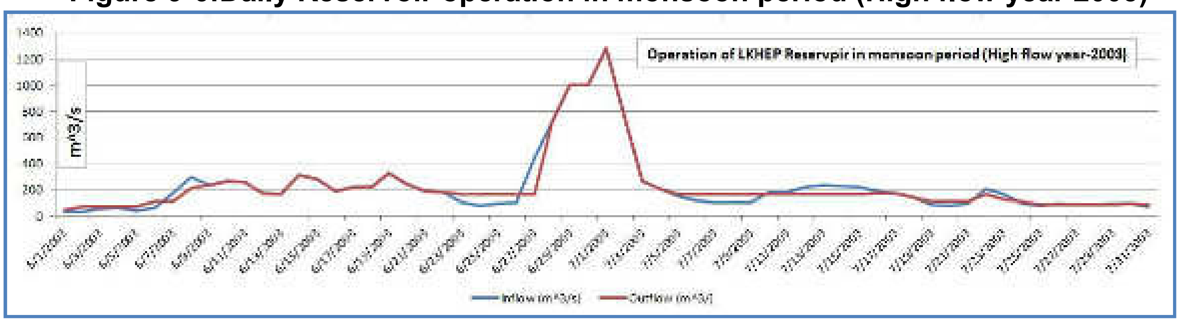
292. A simulation of reservoir operation was carried out during the monsoon period to assess its impact on flood flows. The monsoon period of the year 2003 was found to be a high flow year. The simulation results shows that the operation of the LKHEP reservoir will not increase the river flows during the monsoon season. During the high flows days from June 1 to July 31, both the power plants will be operated with the installed capacities for most of the days, except a few days. Table 9- 14 shows the summary of power plant operation hours.

Table 9-14: Summary of Daily Reservoir Operation during June-July 2003

	Main Power Plant operation		Aux Power Plant Operation		
	Uinit-1 (55 MW)	Unit-2 (55MW)	Unit-1 (2.5 MW)	Unit-2 (2.5 MW)	Unit-3 (5 MW)
Dates of 24 hour operation	June 8 – July 17; July 22		All days from 1 June-31 July		
Dates of 12 hours operation	June 6-7	June 6-7	All days from 1 June-31 July		
Dates of 9 hours operation	July 18-22	July 18-22	All days from 1 June-31 July		
Dates of 6 hours operation	July 20-31	July 20-31	All days from 1 June-31 July		
Dates of 3 hours operation	June 1-5	June 1-5	All days from 1 June-31 July		

293. Figure 9-6 shows the results of reservoir operation during the monsoon period simulated for the high flow year (2003). It can be concluded that the reservoir operation will not increase the downstream flow. This results can also be seen as the result of combined operation of the Kopili HEP (Khandong dam) and the proposed LKHEP.

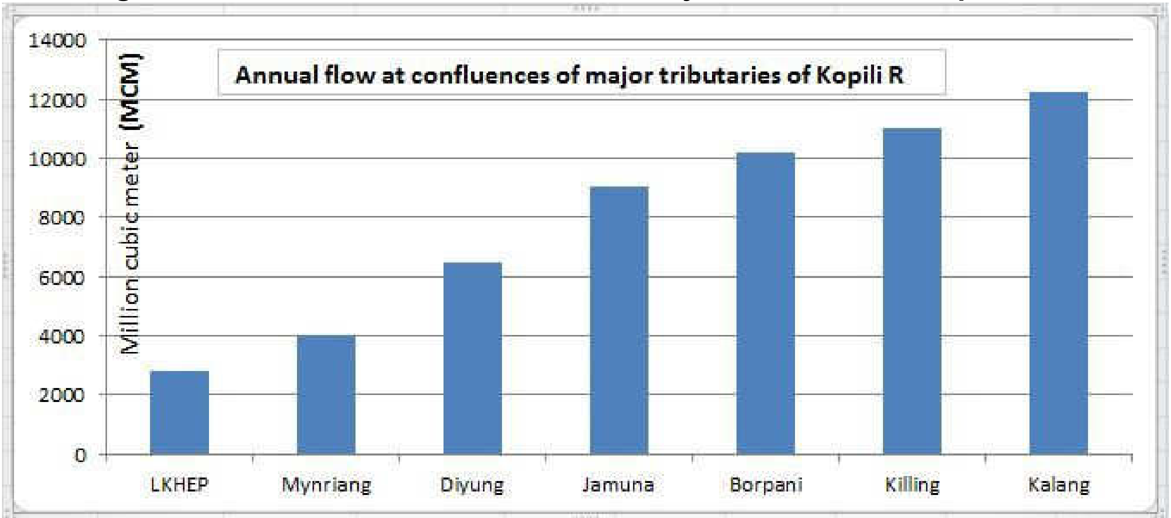
Figure 9-6:Daily Reservoir operation in monsoon period (High flow year 2003)



9.2 Water Resources Analysis for the Kopili River System

294. A simulation of water resources was carried out to find the flows at major confluences of the major tributaries of Kopili river, namely, Mynriang River, Dyung river, Jamuna River, Borpani River, Killing River and Kallang River. As water use data from the river reaches is not available, the analysed flows are natural flows at these confluences. Figure 9-7 shows the annual flows (in MCM) at the major confluences.

Figure 9-7:Annual flows at confluences major tributaries of Kopili River



295. Figure 9-8 shows the distribution of annual flows at the major confluences along with mean monthly flows at these locations. Details of monthly flows for each of the confluences are given in Figures 9-9 to 9-15.

Figure 9-8: Summary of Monthly and annual flows at confluences of major tributaries of Kopili River

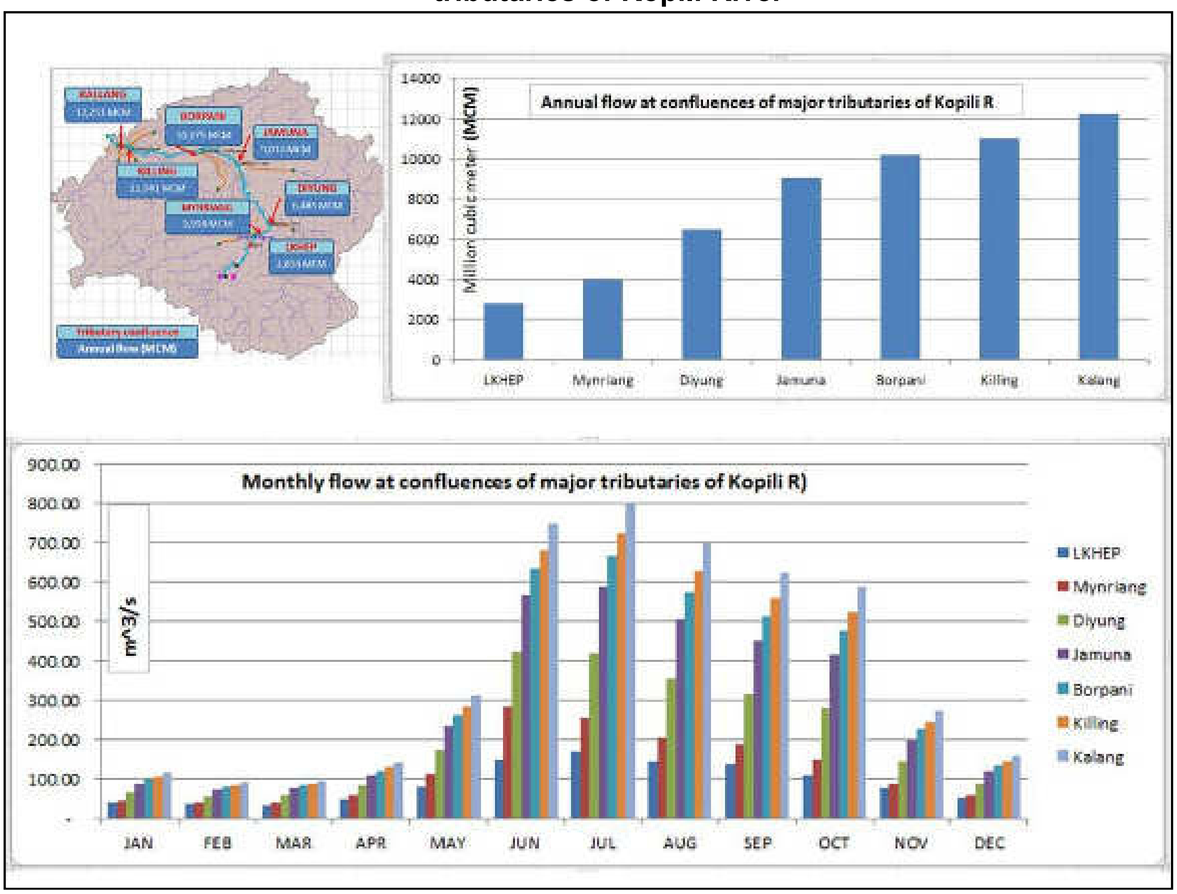


Figure 9-9: Mean monthly flows at LKHEP site

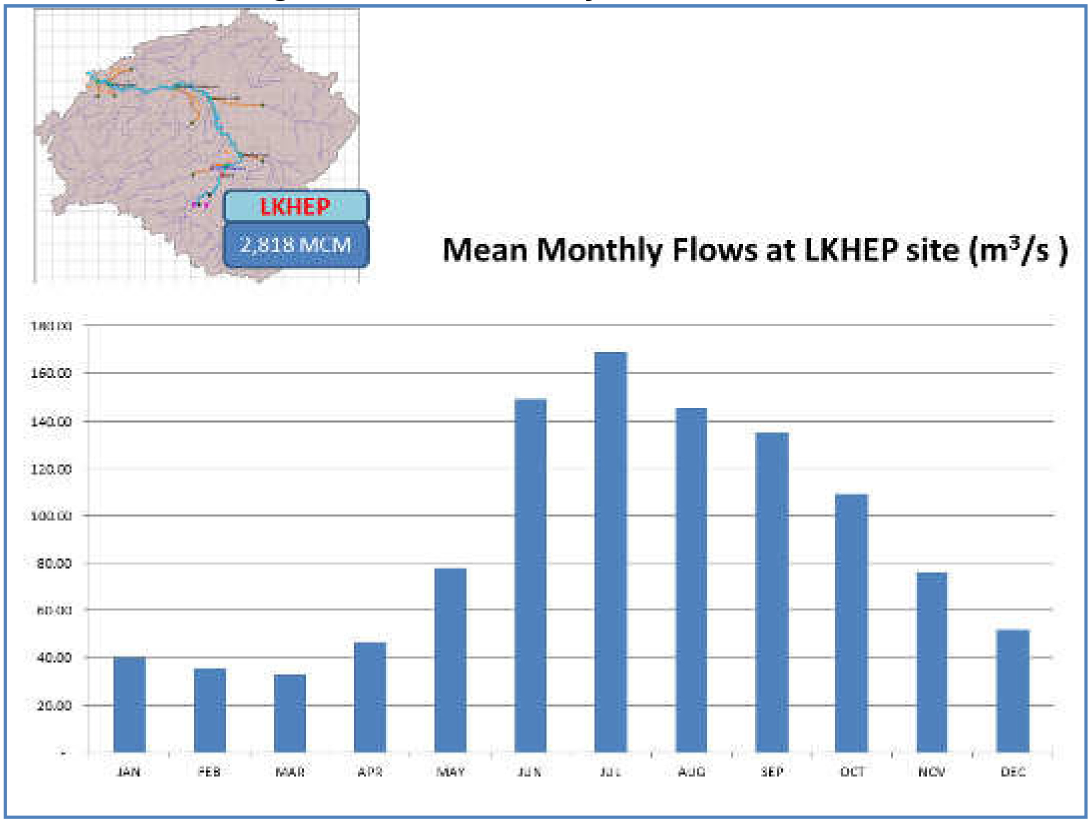


Figure 9-10: Mean Monthly flows after the confluence of Mynriang and Kopili River

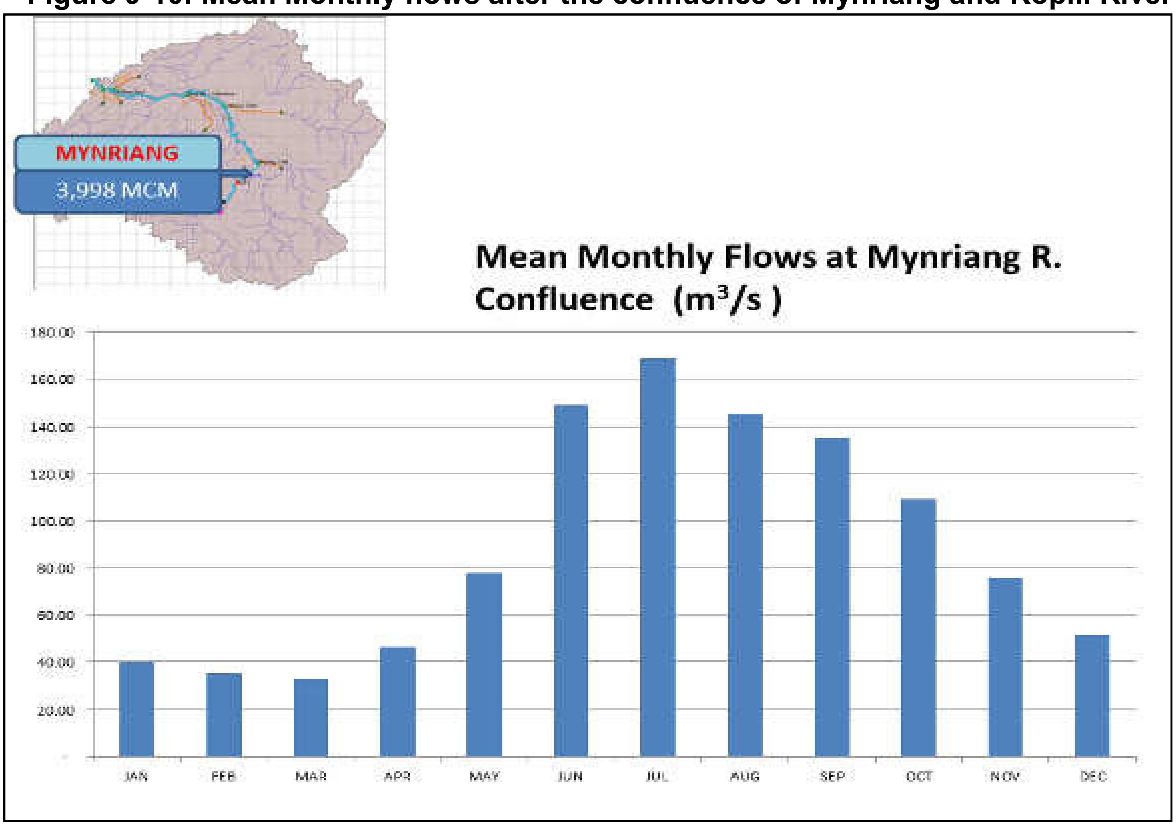


Figure 9-11: Mean Monthly flows after the confluence of Diyung and Kopili Rivers

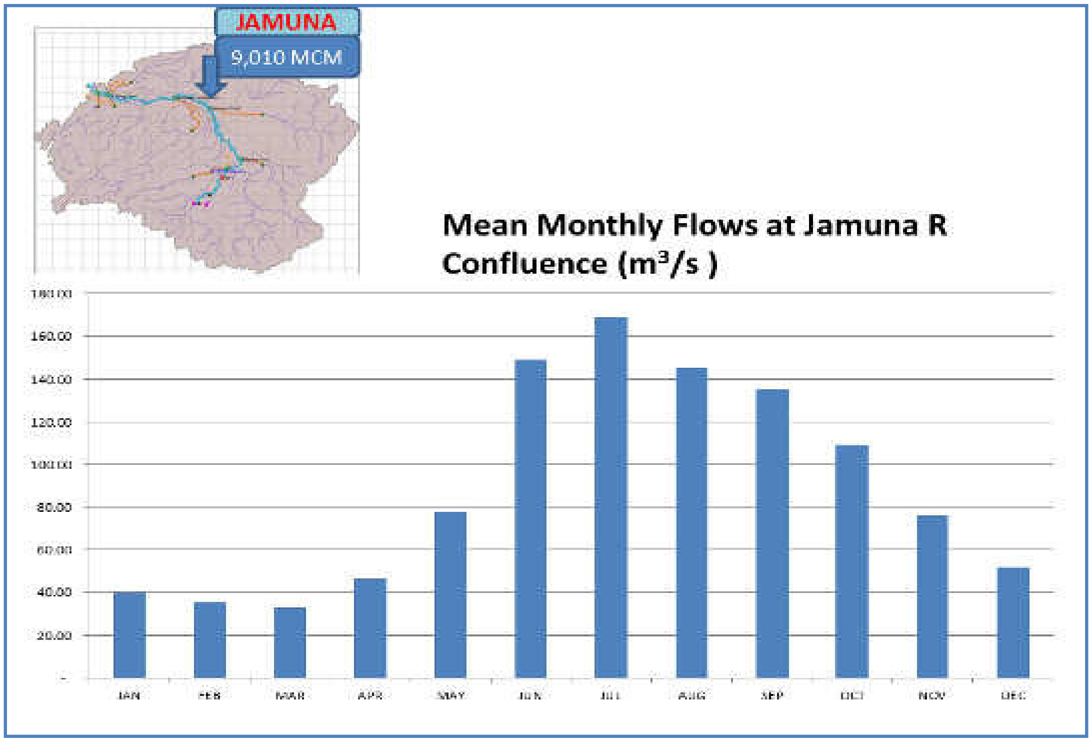


Figure 9-12: Mean Monthly flows after the confluence of Jamuna and Kopili Rivers

Figure 9-13: Mean Monthly flows after the confluence of Borpani and Kopili Rivers

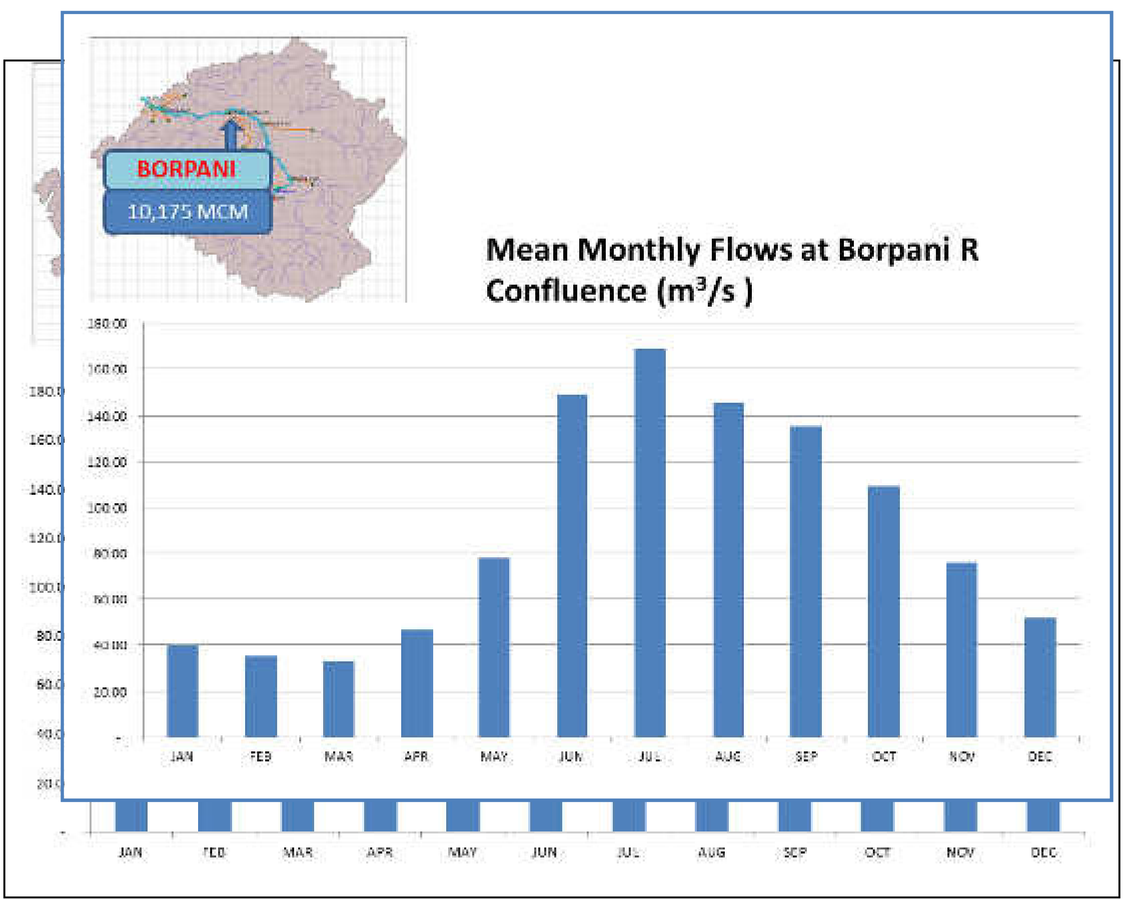


Figure 9-14: Mean Monthly flows after the confluence of Killing and Kopili Rivers

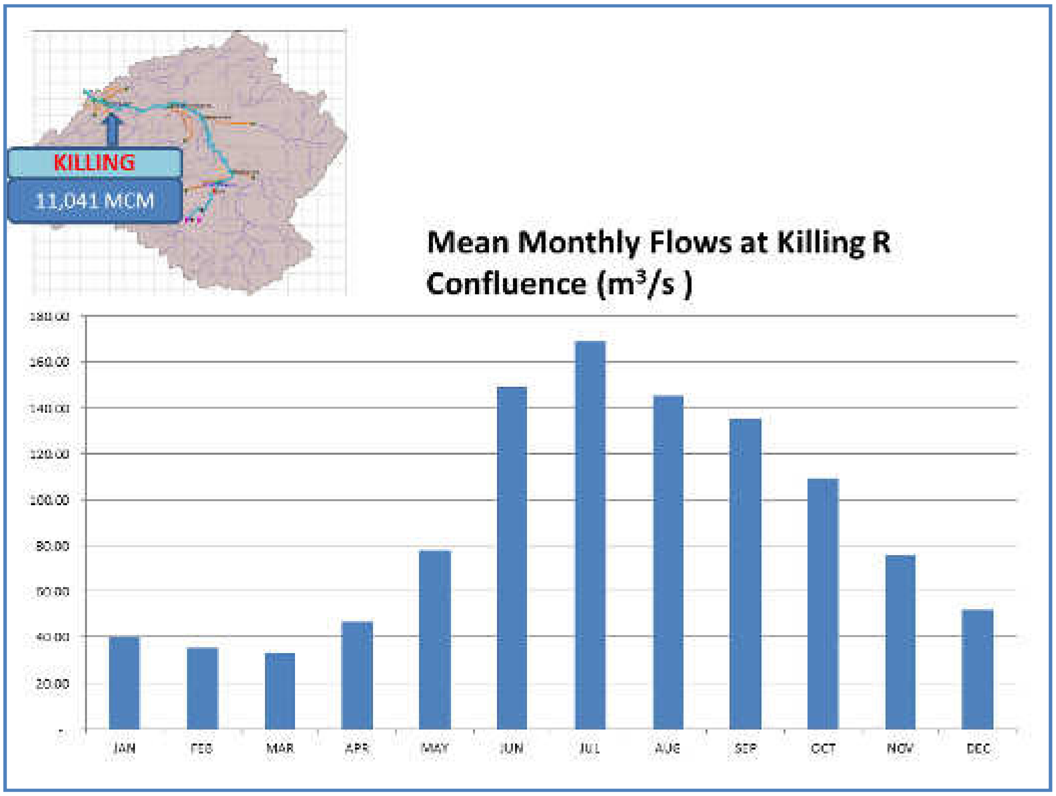
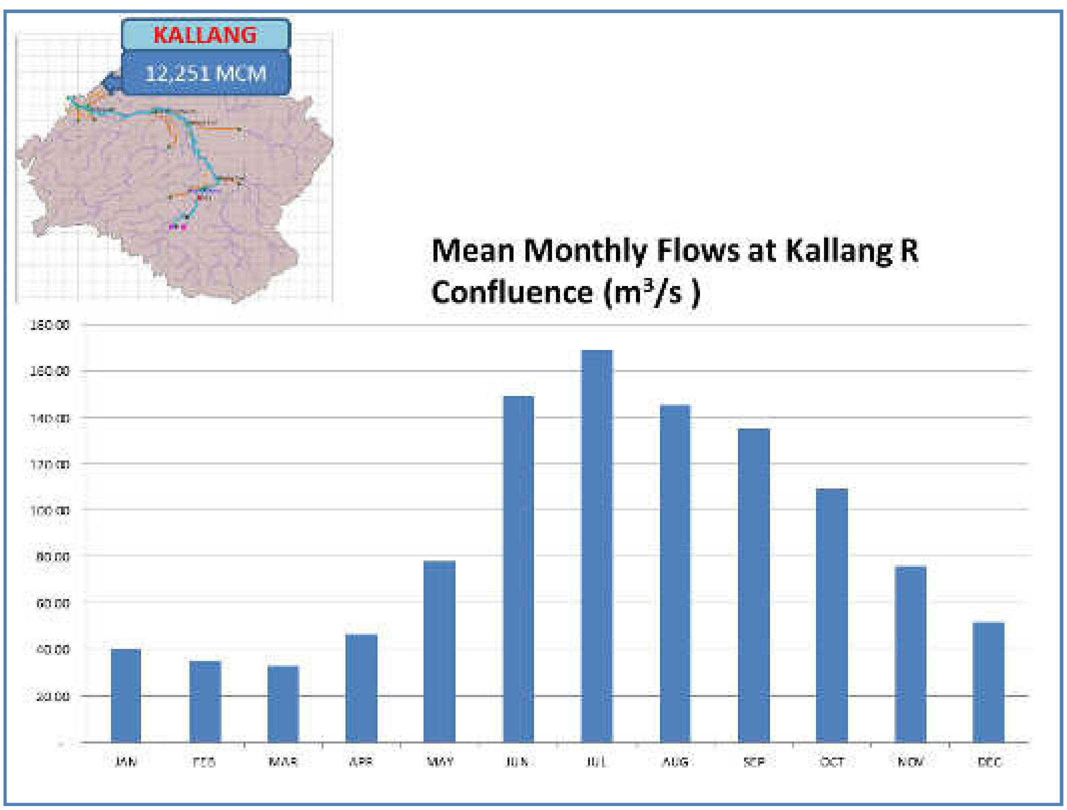


Figure 9-15: Mean Monthly flows after the confluence of Kallang and Kopili Rivers



9.3 Water Requirement and Availability for Irrigation

296. Based on the latest (year 2016) district irrigation plans submitted by NABARD under PMKVY, crop water requirements of different districts of the Kopili basin have been worked out and are summarized in Figure 9-16 and detailed out in the Tables 9-15 to 9-17.

Figure 9-16: Summary of Irrigation Demand and water resources potential in the three districts (Source: NABARD, 2016)

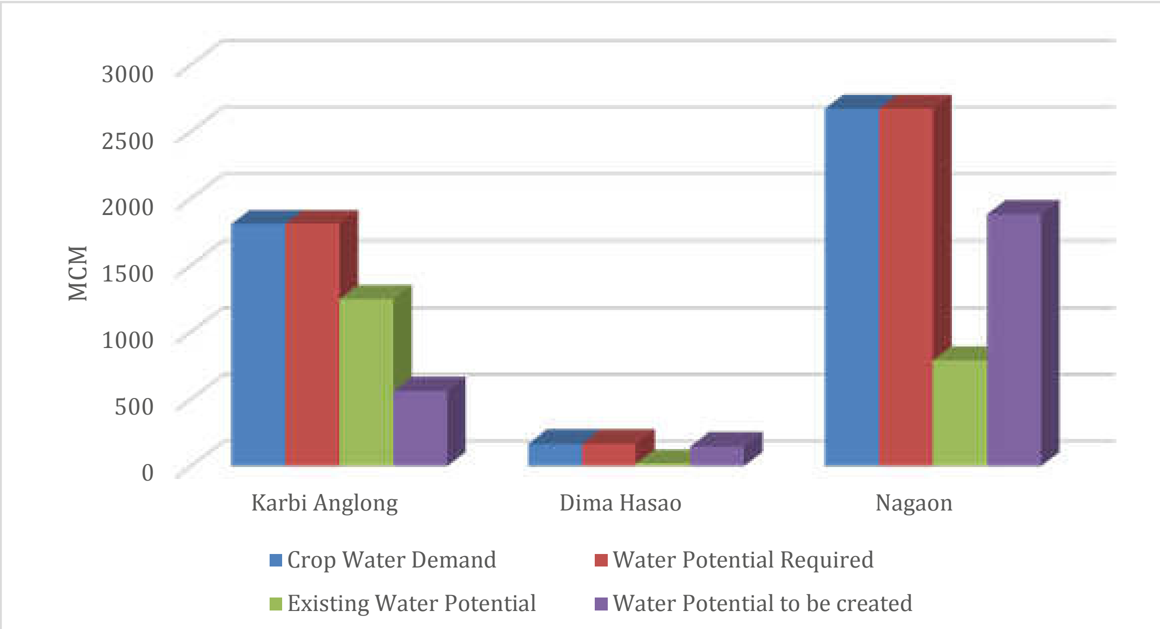


Table 9-15: Irrigation Water Demand of Dima Hasao District

Block	Area sown (Ha)	Irrigated area (Ha)	Crop Water Demand (MCM)	Water Potential Required (MCM)	Existing Water Potential (MCM)	Water Potential to be created (MCM)
New Sangbar	8270	230	24.81	24.81	0.69	24.12
Diyungbra	10902	2470	32.71	32.71	7.41	25.30
Harangajao	13006	1930	39.02	39.02	5.79	33.23
Jatinga Valley	8684	1208	26.05	26.05	3.62	22.43
Diyung Valley	14376	425	43.13	43.13	1.28	41.85
Total	55238	6263	165.714	165.714	18.789	146.925

(Source: District Irrigation Plan 2016 prepared by NABARD)

Table 9-16: Irrigation Water Demand of Karbi-Anglong District

District	Area sown (Ha)	Irrigated area (ha)	Crop Water Demand (MCM)	Water Potential Required (MCM)	Existing Water Potential (MCM)	Water Potential to be created (MCM)
Karbi Anglong	361525	249640	1808	1808	1248	559.43

Source: District Irrigation Plan 2016 prepared by NABARD

Table 9-17: Irrigation Water Demand of Nagaon District

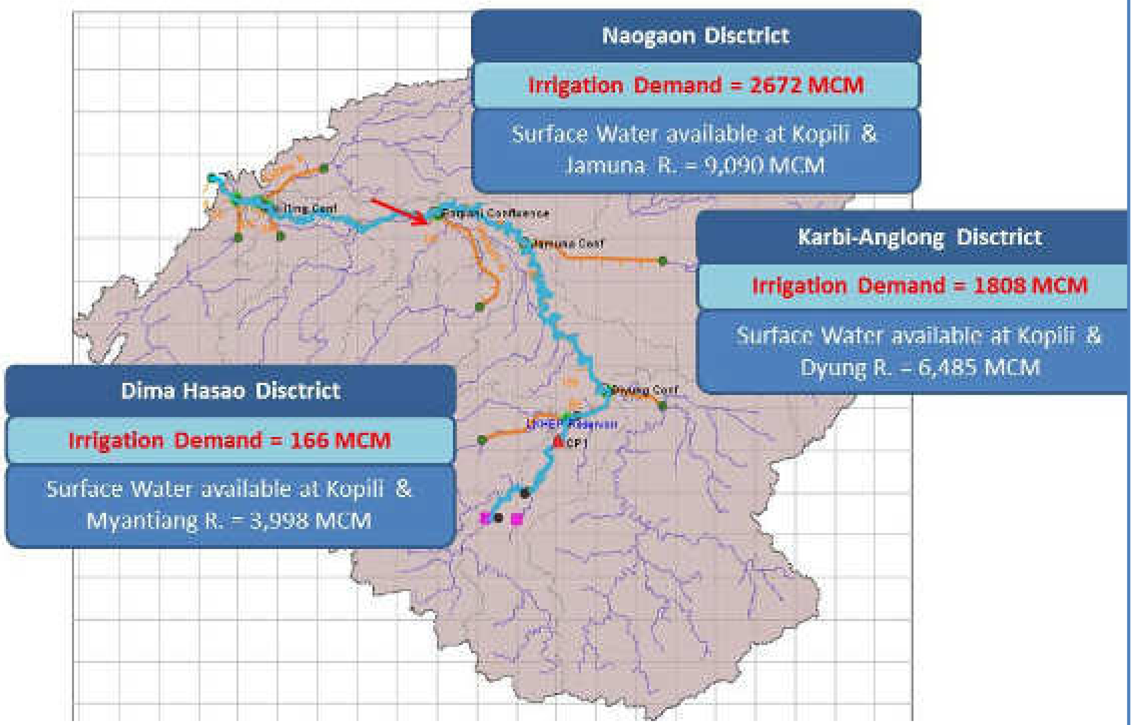
Block	Area sown (Ha)	Irrigated area (Ha)	Crop Water Demand (MCM)	Water Potential Required (MCM)	Existing Water Potential (MCM)	Water Potential to be created (MCM)
Bajiagaon	11250	4054	112.5	112.5	40.54	71.96
Barhampur	9778	2394	97.78	97.78	23.94	73.84
Batadraba	9813	10769	98.13	98.13	107.69	-9.56
Binnakandi	24831	6425	248.31	248.31	64.25	184.06
Dulongghat	9715	1407	97.15	97.15	14.07	83.08
Dhal Pukhuri	14800	1800	148	148	18	130
Jugijan	9950	1197	99.5	99.5	11.97	87.53
Juria	12050	6969	120.5	120.5	69.69	50.81
Kaliabor	10911	5012	109.11	109.11	50.12	58.99
Kathiatoli	24786	4312	247.86	247.86	43.12	204.74
Khagarijan	7364	4530	73.64	73.64	45.3	28.34
Laokhowa,	8538	2880	85.38	85.38	28.8	56.58
Lumding	4520	2200	45.2	45.2	22	23.2
Pachim Kaliabor	23079	1124	230.79	230.79	11.24	219.55
Pakhimoria	6574	1020	65.74	65.74	10.2	55.54
Raha	25465	16100	254.65	254.65	161	93.65
Rupahihat	9194	3240	91.94	91.94	32.4	59.54
Udali	44600	3540	446	446	35.4	410.6
Total	267218	78973	2672.18	2672.18	789.73	1882.45

(Source: District Irrigation Plan 2016 prepared by NABARD)

297. In the Kopili basin as a whole, major irrigation schemes are implemented in the plains. Since rice is the major crop grown in the wet season, there is ample water surface available for irrigation. Also as mentioned in Chapter 3, a large ground water potential exists in the basin, which is not utilized.

298. A comparison of irrigation water requirement with the surface water availability along the Kopili River is presented in Figure 9-17. Since details of irrigation schemes and their locations are not available, this figure may serve as a guide to future irrigation development planning in the basin. For the case of Dima Hasao, however, the problem of high acidity in the water of Kopili along the stretch falling in the district have to be investigated in detail. Alternatively the vast potential of ground water resources will be utilized.

Figure 9-17: Comparison of irrigation requirements in the districts with surface water availability in Kopili River



9.4 Water Requirement and Availability for Domestic Water Supply

299. As computed in Chapter 3, Table 9-18 shows the present and future projected domestic water supply demand in the districts. It can be seen that water availability, both surface and ground water, exceeds the future demand. However, ground water is the preferred source of domestic eater supply as there are many issues with river water quality. Also, in terms of infrastructure requirement, utilisation of ground water is more attractive from economic considerations in rural areas as well as in small towns of the Kopili basin.

Table 9-18: Projection of domestic water demand

State	District	Existing Water Demand (Year 2011)	Domestic Water Demand for Predicted Years (MCM/Annum)			
			2021	2031	2041`	2051
Assam	Nagaon & Marigaon	131.6	171.7	223.8	291.9	371.7
	Kamrup	20.4	26.6	34.7	45.3	57.7
	Karbi Anglong	33.0	43.0	56.1	73.1	93.1
	Dima Hasao	8.2	10.7	14.0	18.2	23.2
Meghalaya	East Khasi Hills	18.2	23.7	31.0	40.4	51.4
	West Khasi Hills	0.2	0.31	0.41	0.54	0.68
	7-Jaintia Hills (3819)	9.5	12.34	16.09	20.98	26.72

Total Domestic Water Demand of Kopili Basin (MCM/annum)	**221.1**	**288.4**	**376.1**	**490.4**	**624.5**

9.5 Climate Change Issues

300. Climate change has drawn wide concerns across the world since it has wider implications on food, water, livelihoods and energy security of the populations. It also affects domestic and international policies, trading patterns, resource use and food security. Inter-governmental Panel on Climate Change (IPCC) pointed out serious impacts on natural resources, socioeconomic conditions and livelihood of the people due to climate change. It is a known fact that climate is already changing. Along with continued warming of the atmosphere, erratic rainfall pattern is emerging and as a result new patterns of droughts and floods are being observed, which are likely to get more frequent and severe in future given the warming of the earth because of the anthropogenic emissions of greenhouse gases.

301. The North-East Region (NER) is one of the highly vulnerable regions in the India in terms of climate change. Assam and Meghalaya have reasons to be concerned about climate change, as they have a large population dependent on agriculture and forests for livelihood. The States' economies are also dependent on natural resources and any adverse impact on these and allied sectors will negate the governments' efforts to alleviate poverty and ensure sustainable livelihoods for the population.

302. The Government of Assam has prepared a "State Action Plan of Climate Change" in 2015. In this plan, state level climate data for the period 1951 to 2010 has been analysed by the India Meteorological Department. According to IMD's analysis the mean temperature in the State has increased by +0.01oC/year. There is also an increase in seasonal temperatures across seasons with pronounced warming in post monsoon and winter temperatures. IMD also found a decrease in annual rainfall by -2.96 mm/year during the same period. Additionally, when station wise data were analysed for a period of 25-30 years at least, significant variations are seen across seasons in number of rainy days and in 24 hour maximum rainfall.

303. Apart from trend analysis, climate projections are also available and discussed in the State Action Plan for Climate Change for the period 2021–2050 using regional climate model PRECIS, a model developed by the Hadley Centre, UK Met office. Projected changes reveal that temperatures continue to rise and may increase by 1.7-2.0^{o}C with respect to baseline. Only the western part of the State will experience slight decrease in rainfall while the rest of Assam is projected to have increase in rainfall. There is likely to be increase in extreme rainfall events by 5 to 38% with respect to baseline. Drought weeks are going to rise, with southern districts showing marginal reduction in drought weeks but rest of the districts show an increase by more than 75% with respect to baseline. About floods, they are going to rise by more than 25% in the southern parts of Assam.

304. Meghalaya is also highly prone to the effects of climate change because of its geo-ecological fragility, humid monsoon climate, and socio-economic conditions. Demographically, the State harbors over 2.96 million population (source: 2011 population census), of this approximately 80% of the population is rural. Majority of the districts of Meghalaya have experienced variation in precipitation (i.e. West and East Garo hills districts showed decrease in precipitation, West Khasi hills district has the highest increase in precipitation) and temperature (increase in minimum temperature was found in the western part of the state as compared to the eastern part; central parts have witnessed increase in maximum temperature source: State Action Plan of Climate Change). The IMD analysis has shown that Meghalaya is showing a trend of declining annual rainfall since 2005-06. However, climate models predict 2-3.5°C temperature increase and 250-500 mm increase in

precipitation (the rainfall increase is predicted to be higher in forest covered areas). Furthermore, the rainfall variability and occurrence of extreme events have increased and is expected to increase further, with monsoon rains already having increased since 2001 and shifted towards the "post-monsoon" period.

9.5.1 Climate Risk Screening with Special reference to Lower Kopili Hydroelectric Project

305. The Climate Risk Screening Report prepared by ADB in December 2015, presented the following projections and probable impacts:

A. Climate Projection

306. ***Temperature:*** By 2050s, annual mean temperature in the project area is projected to increase by 2.480 Celsius under the RCP8.5 emissions scenario. The highest temperature rise is projected to occur in December (>2.75^{0}C) and the lowest in July (<2.19^{0}C).

307. ***Precipitation***: Under the same scenario, annual total precipitation is projected to increase by 206mm or 7.6% by 2050s. The increase is projected to occur overwhelmingly during the May-October monsoon season (190mm, 8.8%). Precipitation during dry season (January to April) is projected to decrease slightly.

B. Climate Impact

- Reduced Reliability of Power Generation in Dry Season Climate change may result in serious adverse impacts on water resources by significantly increasing the intra-annual as well as seasonal variability of river flow. Changing hydrological flows due to increased and more variable precipitation will impact hydropower generation and the run-of-river type of hydropower generation is more susceptible to the impact of climate change. Power generation during the monsoon season will not be significantly affected as there will be sufficient river run-off. Variability in river run- off should be adequately accounted for by using the diurnal storage. For the dry season, power generation will be less reliable. Since LKHEP will only be used as peaking station during the dry season, the diurnal storage may also help reduce the climate vulnerability.
- Storage Capacity and Sediment Flushing-The projected increase in monsoon precipitation is likely to result in exacerbated soil erosion within the watershed. Increased sediment load entering the storage will not only result in reduced water storage requiring more frequent flushing of sediment, but also damages to turbines, and exacerbated flood risks.
- Damages to Equipment- The rivers in the Himalayan region often transport sand with the highest Quartz content. Quartz is very detrimental to the turbines. Increased sediment load due to increased precipitation intensity may accelerate the wearing of equipment.
- Effluents from opencast coal mining sites in the upstream areas are highly acidic. Increased precipitation during the monsoon season may result in more effluents from the mining sites. Acid effluents are highly erosive and corrosive which will damage the turbines. The wear and tear due to erosion/corrosion caused by acid mine discharge reduces the efficiency and the lifespan of the equipment leading ultimately to economic loss.

9.5.2 Study on effect of climate change

308. Based on a need felt for assessing the climate change impacts on the temporal variability of the water availability in LKHEP, a study on "Effect of climate change on the hydrology and sediment loadings of LKHEP" was carried out by ADB in 2015.

309. They investigated the effect of climate change on the hydropower generation capacity of LKHEP. Water availability analysis was based on a watershed simulation model to assess the hydrologic and sediment regime under current conditions and future conditions as projected by climate change models.

310. Based on climate model predictions, the findings if this study were:

- The annual average precipitations were in general projected to be increased. Of these, the monsoon precipitations were found to be significantly increasing. The monthly average precipitation during the non-monsoon period were found to have mixed response i.e., some models have predicted future precipitation to be higher and while other models predicted the reverse.
- The stream flows have followed the patterns exhibited by the precipitation. The annual average flows from two out of six models considered were found to be increasing. This increase is the result of increased precipitations during the monsoon period (March – October). This means the power generation during these months is not likely to be affected. However the low flows during the non- monsoon period were found to reduce in the case of some models. Depending the future scenario these non-monsoon period flows are likely to be reducing as predicted by three out of six climate models. Thus the power generation during the months of November to February are only likely to be affected.
- Since there is no reduction in flows during monsoon flows there is no hydrologic risk during these periods. Even during the non-monsoon period, the reduction is found to be vary between 10-50%. However, since the magnitudes of flows are very small, the percentage differences may appear large. On the positive note, the risks for the LKHEP may be offset by the adaptation strategies implemented by the upstream Umrong and Khandong dams.
- Also, since 1984, the flows in the river at LKHEP site have increased during the non-monsoon flows due to releases from the upstream reservoirs. If this trend continues, the risks for the power generation at the current project site are likely to be minimized.

10. INTEGRATED WATER RESOURCES MANAGEMENT PLAN

10.1 IWRM Principles and Planning Processes

10.1.1 Introduction

311. Assam, like many other States in India, has been practicing traditional water resources management along sectoral lines, centralized by government public departments or institutions with limited stakeholders' participation. These traditional water resources management practices have proved to be unsustainable. Integrated Water Resources Management (IWRM) is still in its embryonic stage in Assam but important steps towards a commitment have been taken by the Government through promulgation of policies and establishment of several institutions for water resources management and research.

312. IWRM is a tool for achieving the Millennium Development Goals (MDGs) which recognises the role of water to achieve development goals. The Plan of Implementation adopted at the World Summit on Sustainable Development in Johannesburg in 2002 called for countries to "develop Integrated Water Resources Management and Water Efficiency Plans by 2005". These "plans" are milestones in recurring and long-term national water strategy processes.

313. The implementation of a policy of integrated management of water resources is now a universally recognized goal. It is in this context that the Governments of India and Assam have in their water policies recognised adaptation of the IWRM approach.

314. Integrated water resource management is an essential process for promoting long term protection and sustainable use of water resources, built on a foundation of active stakeholder engagement and responsible economic and social development policies.

315. **Benefits of IWRM**: IWRM can add a substantial value to any development planning that involves water. It promotes a holistic approach by spanning across disciplines, sectors and agencies. It does not replace sector planning; rather, it provides a context, highlighting synergies and dependencies. Its orientation towards stakeholder involvement and gender mainstreaming enhances the relevance and usefulness of the planning and the prospects for implementation.

316. IWRM contributes to water security. ADB's framework for water security involves 5 key dimensions: Households, economics, urban centres, environmental health; and risk/resilience.

10.1.2 Water Demand and Availability

317. IWRM is aimed towards the 'triple bottom line' of economic, social and environmental value generated. It observes balances as listed below:

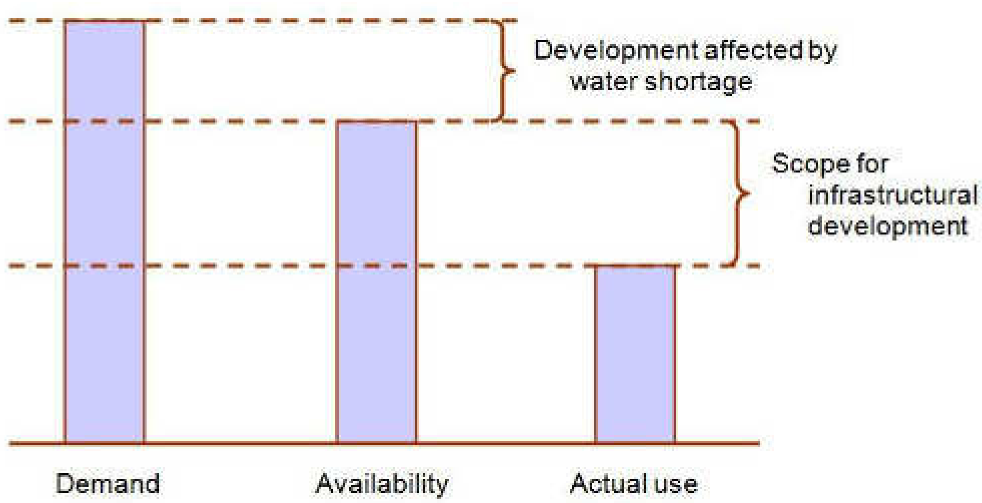
- Balance between upstream and downstream demands. This is in support of a fair and equitable water allocation and water rights within the river basin (and a main justification for basin-level management), in many cases including water-sharing between urban centres and rural areas;
- Balance between in-stream and off-stream demands. In-stream demands include aquatic habitats; navigation; tourism and recreation; and control of sea water intrusion. Off-stream demands include domestic uses; irrigated agriculture; industries; and the service sector. (Hydropower comes somewhere in between); and

- balance between immediate and long-term benefits, in support of a sustainable resource utilization

318. Balances in water allocation and water rights (between sectors, within the basin, between water uses, and between immediate and long-term benefits) provide the basis for an 'equitable' water allocation, which is, in turn, a precondition for the 'triple bottom line'. In the frequent case of a finite water availability, balances are needed to assure that benefits to one bottom line are not achieved at the cost of undue trade-offs for other bottom lines. For example, the direct economic value of water is highest for off-stream industrial uses, mainly in urban centers - while the social benefits (such as livelihoods) may be higher for irrigation uses - and the environmental benefits may depend on a certain in-stream water availability (which can also serve purposes such as fisheries, navigation and tourism). Other potential imbalances could exist between short-term profits (for example from deforestation) and long-term costs (related to biodiversity, siltation and flood risk).

319. Figure 10-1 illustrates the relation between water demand and availability and the need to infrastructure development to match the demand and supply scenarios.

Figure 10-1: Water Demand and Availability



320. The availability of water in a given area can be taken as:

=	The flow from upstream (if any)
+	the (surface and groundwater) resources generated in the area by net rainfall
-	priority allocations within the area, or downstream of the area.

321. Priority allocations can be for domestic use, for environmental preservation, or for maintaining a desired navigation depth.

322. The availability is largely determined by the rainfall. It changes slowly - from one decade to the next, due to medium-term climate variations, or due to construction of reservoirs or diversions. The availability can be measured, and/or determined by numerical modelling, with an accuracy that is determined by the coverage and quality of the basic hydrological data.

323. The demand of water is the amount required for a given purpose, for example litre per person per day, or mm per crop. The demand can be present or future, and it can be actual (i.e. related to an available infrastructure) or potential (assuming full infrastructural development and no water shortage). The serviceable (part of the) demand is limited both by infrastructure and water availability.

324. A distinction can be made between off-stream (or 'consumptive') demand (for households, industries and agriculture), and in-stream (or 'non-consumptive') demand (for hydropower, habitat preservation, fisheries, navigation, and pollution abatement). In this connection, hydropower reservoirs are somewhere in between - they 'consume' water (by storing it) in part of the year, and release it in a different part of the year. Run-of-river hydropower schemes are basically non-consumptive.

325. It must be noted that availability and demand are largely independent. Estimates of (future) water demand are normally much more uncertain than estimates of the water availability.

326. The use (or consumption, or utilisation) of water is the part of the demand that is actually served at a given time. Many uses generate a return flow, (for example sewage, or irrigation tail water). The return flow can occur at a different time or place than the withdrawal (for example a storage reservoir retaining water for release in a different part of the year). The use of water can be increased by infrastructural development and reduced by demand management.

10.1.3 Management Options

327. A distinction can be made between demand management and supply enhancement. In some cases, the choice is open between these options (or a combination). In other cases, only one of the options is feasible, at least in the short term.

328. **Demand Management**: Water demand management is a tool for achieving harmony between the demand of water and the availability of water. Demand management is applied in order to meet a water shortage, or a shortage of money for infrastructural development, or to improve the water efficiency.

329. If water (or money) is limited, such management can be required in support of important water-related development goals: (i) Economic development; (ii) food security; (iii) poverty alleviation in towns and in rural areas; (iv) rural livelihood consolidation and development; and (v) environmental protection.

330. **Supply Enhancement**: Supply enhancement is to make more water available to households, industries, farmers, and other consumers. This can be done by infrastructural development (of waterworks, distribution systems and irrigation systems), and/or by storage (in reservoirs), and/or by using new raw water sources. Supply enhancement requires water resources and funds for infrastructure development.

331. **Efficiency Improvement**: In general, efficiency is the ratio between outputs and inputs. The over-all water efficiency is the production per unit of water. The distribution efficiency is the ratio between water supplied and raw water withdrawn. Improvement of water efficiency comprises reduction of any unnecessary losses and waste (during storage, distribution or consumption). This can be achieved (for example) by appropriate operation

and maintenance (and rehabilitation if required), and/or by introduction of new technology in agriculture and industry. Often, efficiency improvement is an attractive 'win- win' solution with economic, social and environmental benefits.

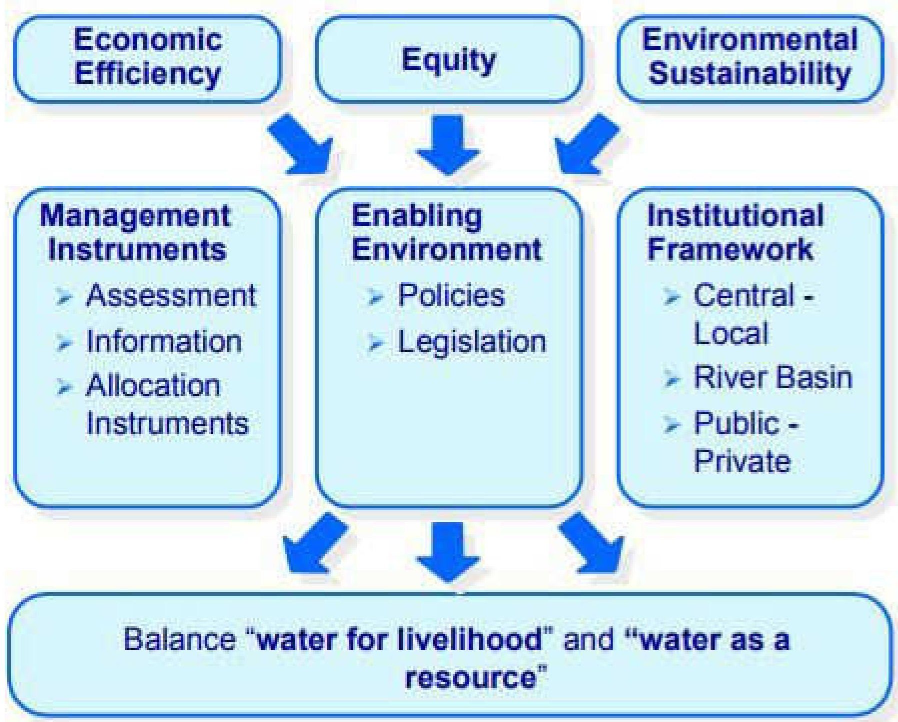
10.1.4 IWRM Principles and Planning Processes

332. According to the Global Water Partnership (GWP) and other sources, many countries are experiencing water-related problems that are proving intractable to conventional, single-sector approaches. Some possible examples: drought, flooding, groundwater overdraft, water-born diseases, land and water degradation, on-going damage to ecosystems, chronic poverty in rural areas, and escalating conflicts over water. The solutions to such problems may fall outside of the normal purview of the agencies tasked with addressing them, and usually require cooperation from multiple sectors. In such cases, an Integrated Water Resources Management (IWRM) approach makes identifying and implanting effective solutions much easier. It also avoids the all too common situation where solving one problem creates another.

333. The basis of IWRM is that different uses of water are interdependent. Additional benefits can be derived when different user groups are consulted in the planning and management of water management programs as such users are likely to apply local self-regulation in relation to issues such as water conservation and catchment protection far more effectively than central regulation and surveillance can achieve.

334. IWRM is an important instrument to address poverty reduction. Good water governance, the objective of IWRM, and the objective of any ”IWRM plan”, is to ensure wise water governance which contributes to the economic development, social equity and environmental sustainability of the society (the “three e‟s, or, the three pillars”). Implementing an IWRM process is a question of getting the “three pillars” right: (1) moving towards an enabling environment of appropriate policies, strategies and legislation for sustainable water resources development and management; (2) putting in place the institutional framework through which to implement the policies, strategies and legislation; and (3) setting up the management instruments required by these institutions to do their job, Figure 10-2. The enabling environment sets the rules, the institutional roles and functions define the players who make use of the management instruments.

Figure 10-2: The Three Pillars of IWRM

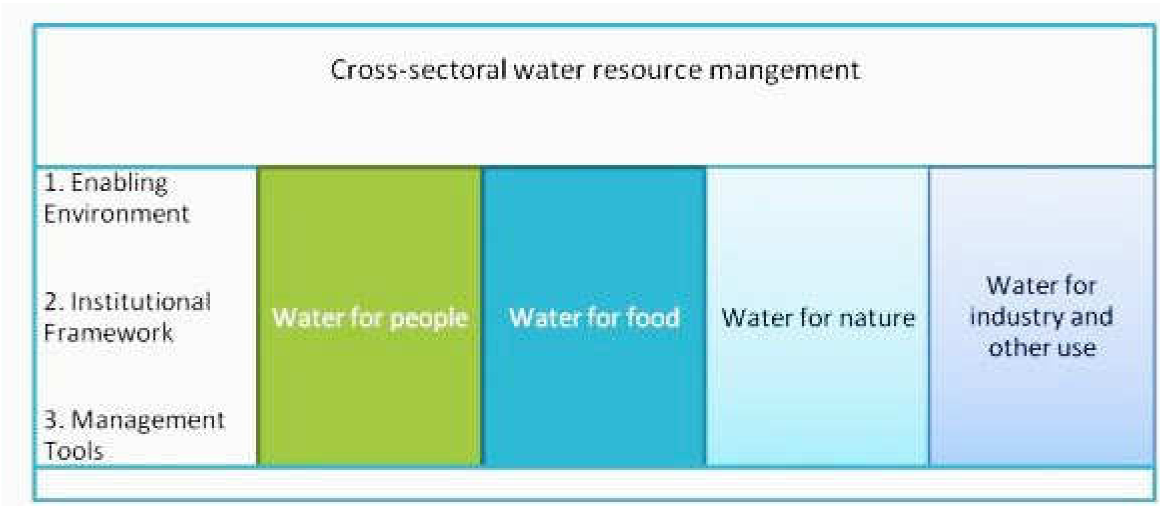


335. IWRM is the "integrating handle" leading from sub-sectoral towards cross-sectoral water resources management and at the same time providing a framework for provision of water services.

336. The following definition by GWP has proven to be a useful definition of IWRM widely supported in an international context: "IWRM is a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems". An important aspect of IWRM is to enhance cross-sectoral water resources management in order to replace what is considered to be inefficient sub-sectoral management within the different individual water use sectors.

337. IWRM is not a goal in itself. The specific goals, interest and challenges will vary from place to place depending on the specific ecological, social and economic situation. IWRM is the process of balancing and making trade-offs, in a practical scientifically sound way, between: economic efficiency in water use; social justice and equity concerns; and environmental and ecological sustainability. The specific details of these goals will have to be balanced in the IWRM process. Implementing IWRM is a political process that involves allocating resources between competing uses and users. Sometimes it is possible to come up with win-win solutions. However, more often compromises and trade-offs will have to be negotiated. Figure 10-3 illustrates a cross-sectoral management approach, often called the "IWRM Comb."

Figure 10-3: Cross-sectoral Water Resources Management



338. IWRM must not be interpreted as a universal blueprint for water resources management. Certain basic principles underlying IWRM may be commonly applicable, but they must be seen in the specific context and stage of economic or social development. The nature, character and severity of water problems, human resources, institutional capacities, the relative strengths and characteristics of the public and private sectors, the cultural setting, natural conditions and many other factors differ greatly between countries and regions. Practical implementation must reflect such variations in local conditions and should, consequently, take a variety of forms. The most appropriate mix of IWRM elements will change over time for a specific country and region due to internal or external developments.

339. IWRM involves managing water resources at the basin or watershed scale, managing demand and optimizing supply including assessments of available surface and groundwater supplies and evaluating the environmental impacts of distribution and use options. IWRM principles are based on equitable access to water resources, broad stakeholder participation, an inter-sectoral approach to decision making based on sound science and usually require establishment of adequate regulatory and institutional frameworks. The planning process should result in an IWRM plan endorsed and implemented by government, more or less detailed depending on the situation and needs of the country.

340. The institutional arrangements needed to bring IWRM into effect include:

- water resources management based on hydrological boundaries;
- a gender-balanced consortium of decision-makers representing all stakeholders, reflecting society's responsibility for water management;
- organizational structures at basin and sub-basin levels to enable decision making at the lowest appropriate level, rather than a centralized decision-making model;
- government coordinating the national or state management of water resources across water use sectors.

10.2 Integrated Approach to the Kopili River Basin Development

10.2.1 Sectoral Integration

341. The Integrated River Basin Development Plan (IRBDP) for the Kopili river basin is based on the concepts IWRM (as described above), in which water resources development and management in the basin is not done on sectoral basis but in a coordinated way encompassing all major sectors.

342. The major sectors of water resources development in the Kopili basin considered are:

- Hydropower Development in the upper hilly reaches, including small hydropower
- Irrigation development in the middle and lower plain reaches
- Flood and river bank erosion management in the lower plain reaches

343. Other sectors, which are related but not considered major from the water requirement point of view are:

- Domestic water supply
- Fisheries
- Navigation
- Catchment area treatment
- Improvement in water quality in the upper reaches

344. The above are also called “sectoral intervention.”

10.2.2 Non-structural measures

345. The non-structural measures deal with the three pillars of IWRM:

- appropriate ‘management instruments’ to assess, inform and manage water resources and mitigate floods and river bank erosion risks;
- an effective ‘enabling environment’ of relevant policies and legislation to address these risks and management actions; and
- an appropriate ‘institutional framework’ that embraces all stakeholders at the basin, state, local administration and community levels.

346. The non-structural measures included are:

- Hydro-meteorological data monitoring and information dissemination
- Provision of flood forecasting and warning
- Integrated operation of the water resources systems (hydropower plants)
- land-use and hazard zoning, flood-proofing, emergency planning, community- based risk management planning, and education and financial measure.

10.2.3 Institutional Integration

347. In order to achieve a sustainable development of the water resources and to achieve an efficient water management system in the basin, it is essential that works of the various concerned agencies are coordinated in a meaningful way. Two models are suggested in this regard:

I. A coordination mechanism in which all concerned agencies share information on water resources and management. Assam Water Resources Management Institute (AWRMI) supported by Assam Water Mission can be the apex agency to develop and implement such a coordinating mechanism among various stakeholders such as WRD, APGCL, NEEPCO and Irrigation Department.

II. A formal institutional mechanism, which might lead to the formation of a River Basin Organization (RBO) in the future, to enable water resources development and management in the basin in an unified way. Since this is a complex and sensitive issue, the options have to be analyzed in details in consultation with stakeholders. Initial discussions were carried out in the stakeholder workshop organized by the project on 7th October 2017. The participants recognized the need of an institution to manage the water resources of the basin in an integrated way. However, the decision on the form of the institution - a formal RBO with a full mandate or a coordinating institution, would only be decided by high level representatives of key agencies of both Assam and Meghalaya.

10.2.4 Strengthening of sectoral development using IWRM Pillars

348. Present sectoral development planning and of the water resources in the Kopili basin will benefit by strengthening its approach using the three pillars of IWRM, as illustrated in Figure 10-4.

Figure 10-4: Illustration Matrix for sectoral development strengthened with IWRM pillars

Primary sectoral Development	Required strengthening with IWRM Pillars		
	Management Instruments	Enabling Environment	Institutional Framework
Hydropower (HP) Development	Tools for capacity optimization	Existing policy and legislation is sufficient	An new institutional mechanism required for coordinated operation of HP in the basin
Flood & Riverbank Erosion Mitigation	Monitoring, modelling & forecasting	Existing policy and legislation is sufficient	Coordination between Brahmaputra Board & WRD essential
Irrigation Development	Tools for system optimization, modernization & efficiency Improvement.	Existing policy and legislation is sufficient	Coordination with WRD to integrate with flood control schemes
Others: Domestic water Supply, fisheries, navigation, water quality, etc.)	Tools for assessment and information dissemination	Existing policy and legislation is sufficient	Coordinated approach with other sectoral agencies

349. Table 10-1 emphasizes on the development of the major sectors as primary water resources development components, while these developments should consider other secondary sectors to achieve economic as well as social efficiency and equity, as per the WRM principles.

Table 10-1: Sectoral Integration Matrix

Sectors	Integration with other sectors	Coordination among Agencies / Institutions
1. Hydropower	Unified operation of hydropower systems considering downstream flood impacts in the Kopili basin, possibility of providing irrigation and domestic water from small hydropower plants	APGCL, NEEPCO, WRD Assam
2. Flood Management	Protection of agricultural land/ irrigation areas, designing adequate drainage, maintaining natural fish habitats, restoring connections between rivers and *beels* for fish migration	WRD, BB, Irrigation Department
3. Irrigation	Planning low lift pumps for irrigating flood protected areas. Developing hydropower from irrigation canals.	WRD, Irrigation Department, APGCL
4. Domestic water supply	Providing water supply from small hydropower plants and ground water	Municipalities, local bodies, communities, ground water board.
5. Fisheries	Maintaining natural fish habitats, restoring connections between rivers and *beels* for fish migration	Dept. of Fisheries
6. Navigation	Providing required navigational depths	Inland water transport, WRD
7. Water Quality Improvement	Implementing water quality restoration plan with treatment of the low Ph in the upper reaches of Kopili river and its tributaries.	Relevant agencies of Assam & Meghalaya, Pollution control Boards, Department of Geology and Mines.
8. Land use control	Provide flood zonation, design flood levels for infrastructure	BB, WRD, PWD, municipalities
9. Watershed restoration	Developing catchment treatment plans to reduce runoff and erosion, to control jhum cultivation.	Forest departments of Assam and Meghalaya, autonomous districts.

10.3 Non-structural components

350. For an integrated development and management of the water resources of the Kopili Basin, several non-structural measures are recommended to be adopted in addition to the structural measures listed above.

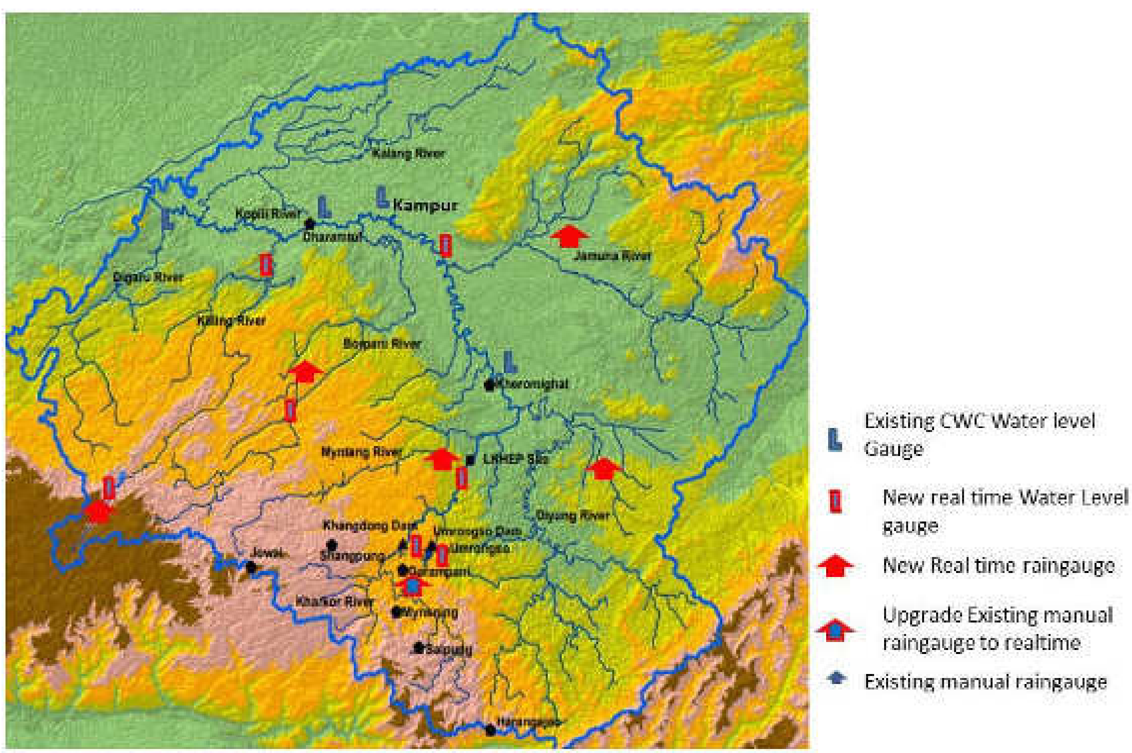
10.3.1 Hydro-meteorological Monitoring

351. In order to manage the hydropower systems in close coordination with flood management systems, it required to:

- expand the meteorological network
- upgrade some of the rain gauges to automatic real time reporting systems
- install real time water level monitoring stations at key locations along the river
- measure discharges at key locations along the river.

352. The density of rain gauges in the upper catchment of the Kopili basin is found to be adequate. However, the middle and lower parts of the basin need more rain gauges to compute rainfall representative of the respective areas. A suggested expansion and upgrading in rain gauge network is presented in Figure 10-5. A total of 7 automatic rain gauges reporting in real time are recommended to be installed. A real time rain gauge consists of a tipping bucket type of rain gauge, a data logger, a transmission system based on GPRS and solar power back up.

Figure 10-5: Proposed Real time rain gauge and water level stations



353. Monitoring of water level is required along the river in addition to the existing water level gauges of CWC at Dharmatul, Kampur and Kheronighat. New automatic water level recorders are suggested to be installed at eight locations as also shown in Figure 10-5. The suggested water level gauge locations are:

(i) upstream of Khandong dam (to monitor water level of the reservoir),
(ii) upstream of Umrong dam (to monitor water level of the reservoir),
(iii) upstream of LKHEP dam (to monitor water level of the reservoir),
(iv) downstream of Kopili-Dyung confluence,
(v) upstream of the proposed Borpani middle HEP reservoir, and
(vi) downstream of Jamuna-Kopili confluence.
(vii) upstream of Umium reservoir
(viii) upstream of proposed Killing dam site

354. It will also provide an opportunity to include sensors for some water quality parameters such as pH and DO, along with the water level sensors. In order to convert the water levels into river flows, it is suggested to measure discharge at two gauge locations (iv and v).

355. The real time data collected from the proposed stations to be assimilated in a database is a web based SCADA system, which will be available for all the authorized stakeholders. Assam Water Resources Management Institute (AWRMI) is the mandated agency to manage such a system. AWRMI is in the process of implementing real time data acquisition system (RTDAS) under the World Bank Hydrology Programme (2017- 2021). AWRMI may include the proposed RTDAS in their programme.

10.3.2 Development of a Flood Forecasting and Warning System

356. CWC has included three stations in the Kopili Basin, namely at Kheronighat, Kampur and Dharmatul for reporting daily flood levels indicating trends in water levels. In other stations of the Brahmaputra, CWC provides 24-hour flood forecasts. The method used for formulating the forecasts by the CWC is gauge to gauge correlation between the upstream (base station) and downstream (forecasting station) gauge on the river stretch.

357. An advanced flood forecasting system based on a hydrological model is proposed to be developed for the Kopili basin using real time data and meteorological forecasts. Using such a modelling system, flood forecasts can be derived up to 3 days in advance with good accuracy. In addition, inflow forecast to the hydropower reservoirs can be derived. Assam Water Resources Department (WRD) is the mandated agency to implement the proposed flood forecasting system for the Kopili river.

10.3.3 Dissemination of flood warning

358. The success of a flood forecasting system can be ensured only when flood warnings reach to flood affected communities and are effectively used by them reducing flood risks. Also the flood forecasts and warnings should be used meaningfully by revenue departments at various levels from state to districts and down to block and Panchayat levels. Disaster management agencies should be able to get access to the flood warning in time and in easily understandable forms. Similarly, flood

warning should reach to NGOs and civil societies.

10.3.4 Community Based Flood Risk Management

359. For a community, flood risk management includes diverse yet related activities and actions. Some of the key actions are dissemination and use of flood information and warning, dealing with emergencies during floods, recovery after floods and preservation of livelihoods. For people, it is always a crucial decision to decide to leave their houses and go to safer places because of the considerable effort and hardship involved. Hence many villagers try to endure the floods as long as possible. They move to other places only when it is no longer possible to stay in their own homes. People do not leave their homes in normal floods since they can survive in stilt houses or on in-house raised platforms or granaries on stilts inside the house and can travel for essentials on boats or rafts. It is only in major floods when the floors of the stilt houses or raised platforms are submerged or the house itself is seriously damaged that they leave for the nearest safe shelter.

360. People who are poor do not have boats or strongly built houses and leave early for safe places. Some people prefer to stay on raised platforms (made of bamboo) outside the house. Those who cannot make raised platforms, or do not like to stay on them, come out to the road and stay in makeshift houses. Usually people have to leave their homes when the flood is caused by embankment failure or when there is a flash flood originating from an extraordinary cloudburst or landslide. Embankment failures are largely anticipated because they happen over a few days and people are informed through the local network, as mentioned earlier. Hence people get time to plan their evacuation.

10.3.5 Unified operation of the Water Resources System

361. Using the above described monitoring and forecasting system, it is possible to operate the existing and future reservoirs to optimize power generation, and in the same time reduce incidence flood peaks downstream. Such a system may be developed by AWRMI in cooperation with WRD, NEEPCO and APGCL.

10.3.6 Institutional capacity building

362. Capacity building activities are of two types: (1) technical, and (2) management, including coordination. In the technical part, agencies involved need their capacity strengthening in database development, hydrological modelling, and optimization of reservoir operation. In the management part, the agencies need to establish and implement an effective coordination mechanism in the unified operation of the reservoirs.

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APPENDICES

(All data collected and analysed are presented in a CD.)