

CUMULATIVE IMPACT AND CARRYING CAPACITY STUDY OF SIANG SUB-BASIN INCLUDING DOWNSTREAM IMPACTS



Volume-I
December 2013

Prepared for:
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PREFACE

The State of Arunachal Pradesh, popularly known as the "Land of the Rising Sun", is located in the easternmost part of the country. The topography of the state provide for a very ideal conditions for development of hydropower projects and this coupled with large geographical area makes it the state with maximum hydropower potential in the country, which is largely distributed over 6 major river sub-basins viz. Siang, Subansiri, Dibang, Lohit, Kameng and Tawang. Siang sub-basin with estimated hydropower potential of over 18000 MW, to be harnessed by setting up of 44 hydropower projects, is the basin with the highest hydropower potential.

Large-scale development of hydropower projects through out the country has received substantial attention from environmentalists. Concerns have been raised about development of several projects in cascade in otherwise pristine, ecologically and geologically fragile regions; vanishing of rivers in tunnels without adequate assessment of environmental flows; downstream impacts due to peaking power generation by large projects, etc.

Ministry of Water Resources (MoWR) had constituted an Inter-Ministerial Group (IMG) in Feb., 2010 on the directions of Prime Minister's Office (PMO) with a view to evolve a suitable framework to guide and accelerate the development of hydropower in the North East and also to assess the impact of the massive hydropower development in Arunachal Pradesh on downstream areas in Assam. On IMG's recommendation, Central Water Commission (CWC), Government of India undertook the task of conducting Environmental Impact Assessment (EIA) Study for Siang river sub basin and Subansiri river sub basin in Brahmaputra river valley as a first step, to be followed by more such studies to cover all the river sub-basins of Arunachal Pradesh. The studies have been initiated with an objective to assess the cumulative impacts of hydropower development and carrying capacity of the sub-basin and prepare the framework for sustainable development in each sub-basin.

RS Envirolink Technologies Pvt. Ltd., Gurgaon (RSET) has been selected to undertake EIA study of Siang basin, based on techno-economic bidding. The study initiated during December 2011 involved extensive field data collection in different seasons to establish baseline status, data analysis and cumulative impact assessment, followed by recommendations for sustainable hydropower development in the basin.

An interim report was submitted during May 2012 on completion of first 5 months of the study period. Technical Advisory Committee (TAC) reviewed the report in the same month and Expert Appraisal Committee of Ministry of Environment & Forests (MoEF) reviewed the interim report for mid-course correction during its 62nd meeting held in November 2012. On completion of field data collection and analysis, and after incorporating suggestions and observations of TAC and EAC, draft final report was submitted to CWC in August 2013. TAC reviewed the report during September 2013 and after addressing their observations final version has been prepared.

The report has mapped the entire Siang sub-basin referred to as Siang basin in the report and describes the basin characteristics in detail with a view to give physiography of the basin. Data on hydropower projects planned in the basin is sourced from Central Electricity Authority & Department of Hydro Power Development, Government of Arunachal Pradesh and discussed in detail in the Report. Project features are analysed to assess direct impacts such as river length and forest area affected, reservoir creation and free flowing stretches, etc.

Extensive baseline primary and secondary data collection exercise has been undertaken based on a well-defined scientific methodology, which is described in a separate chapter in the report. Due to sheer volume of the data, a separate data volume has been created and compiled and given in Volume-II of the report. Detailed data analysis is undertaken to describe the baseline status, separately for terrestrial and aquatic ecology. Terrestrial ecology covered forest types, floristic, faunal resources and protected areas whereas aquatic ecology covered physico-chemical and biological water quality and detailed description of fish and fisheries in the basin. Further, for comprehensive data analyses of vast area like Siang basin, which extends to 14965 sq km, biodiversity value assessment has been carried out at sub basin level.

Environmental Flow Assessment is a significant component of the scope and has been addressed in separate section in the report. Various flow assessment methodologies have been described and “Hydraulic Modeling and Habitat Simulation” has been selected for detailed assessment of environmental flow requirement for various projects. Discharge data have been provided by CWC and a flow simulation study has been carried out using one-dimensional mathematical model, HEC RAS ver. 4.1.0 developed by Hydrologic Engineering Centre of US Army Corps of Engineers. Habitat assessment is based on baseline setting as described under Aquatic Ecology and project wise output is discussed for environmental flow requirement in lean, monsoon and pre/post monsoon seasons.

Operations of the large hydropower projects on main Siang river and Siyom river have been studied to assess the impacts of peaking power generation in downstream reach which extends from downstream of Siang Lower HEP till Guwahati in Assam. Hydrodynamic routing is carried out using MIKE 11 model, where lean season typical hourly releases were simulated to assess diurnal variation. Output is given in terms of fluctuation in water level during 24-hour cycle at selected downstream locations.

A combination of baseline data and proposed development activity has provided the basis of cumulative impact assessment where cumulative impacts on terrestrial and aquatic ecology along with impacts of modification of flow regime and downstream impacts have been discussed.

Recommendations have been provided in the last section of the report for sustainable hydropower development in the basin.

During the study period, we have received tremendous support and inputs from various organizations and individuals. We would like to thank officers of Central Water Commission in particular Shri C. K. Agrawal, Chief Engineer, CWC, B&B Basin Organisation, Shillong for providing Hydrological data in Siang sub-basin; Shri Pramod Narayan, Director, Morphology Directorate, CWC for providing cross-sectional data of the Brahmaputra river in different reaches. We are grateful to Shri N.N. Rai, Director, Hydrology (NE) Directorate, CWC & Member TAC who had helped in finalising the water availability series for various hydropower project sites in the Siang sub basin and provided valuable suggestions for carrying out simulation studies.

We would specially like to thank Shri W. M. Tembhurney, Chief Engineer (EMO), Chairman, TAC & PMC with whom we have had regular interactions and have received tremendous support to execute the task and Shri G. Naga Mohan, Director (EIA), Member Secretary TAC & PMC for timely convening the TAC/PMC meetings and also provide valuable suggestions for improvement/finalisation of the Report.

We would like to thank all the members of TAC and EAC with special thanks to Shri B. B. Barman, Director (MoEF) Member Secretary (EAC) & Member (TAC) who had critically reviewed the report and gave valuable inputs/suggestions.

We would also like to thank Shri H. K. Paliwal, Chief Secretary, Government of Arunachal Pradesh; Shri M. Bhattacharjee, SE (Monitoring), Department of Hydro Power Development and their officers for promptly providing the required information to undertake the study. Department of Environment & Forest has also been very helpful in providing required information promptly and extending their support.

Last but not the least, a special thank to all our scientists and engineers who have put in their best efforts to complete the extensive data collection, analysis and report preparation task.

Arun Bhaskar
Managing Director

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EXECUTIVE SUMMARY

1.0 INTRODUCTION

Central Water Commission (CWC), Government of India has undertaken the task of conducting “Cumulative Impact and Carrying Capacity Study of Siang sub-basin including Downstream Impacts” with an objective to assess the cumulative impacts of hydropower development in the Siang river sub basin in Brahmaputra river valley basin. RS Envirolink Technologies Pvt. Ltd., Gurgaon (RSET) has been awarded the study based on techno-commercial bidding. Expert Appraisal Committee (EAC) for River Valley and Hydroelectric Projects of MoEF has provided the Terms of Reference (TOR) for the study. The study initiated in December 2011 involved extensive field data collection in different seasons to establish baseline status, data analysis and cumulative impact assessment, followed by recommendations for long term sustainable hydropower development in the basin. EIA study of Siang Basin has been prepared with a view to provide optimum support for various natural processes and allowing sustainable activities. The study covers the following:

- Inventorisation and analysis of the existing resource base
- Determination of regional ecological fragility/sensitivity
- Review of hydropower development plans
- Evaluation of cumulative impacts on various facets of environment due to hydropower development
- Broad framework of environmental action plan to mitigate the adverse impacts on environment, in the form of:
 - Preclusion of an activity
 - Modification in the planned activity
 - Implementation of set of measures for amelioration of adverse impacts.

The basin study is a step beyond the EIA, as it incorporates an integrated approach to assess the impacts due to various developmental projects. The key outcomes of the study are:

- Sustainable and optimal ways of hydropower development of Siang river, keeping in view of the environmental setting of the basin
- Requirement of environmental flow throughout the year with actual flow, depth and velocity at different level
- Downstream impacts on Assam due to hydropower development in Siang basin in Arunachal Pradesh

2.0 BASIN CHARACTERISTICS

Siang river originates as Tsangpo river from Mansarovar near Mt. Kailash in the Himalaya, flows via Tibet, China, India and Bangladesh into Bay of Bengal. After traversing about 2057 km in Tibet, the Tsangpo enters Arunachal Pradesh where it is also known as the Dihang River. The upper catchment area of Siang is mountainous with deep and narrow valleys. The part of Siang basin in India is bounded on the north by eastern Himalaya, on west by Subansiri basin and on east by Dibang basin. Length of Siang river in India up to the confluence of Siyom river is approximately 197.0 km and travels further 96.9 km to join Brahmaputra in Assam with a total length in India as 293.9 km. From this point forward it flows as Brahmaputra river in Assam and traverses a distance of about 195 km up to the confluence of Subansiri river on its right bank. Further downstream it is joined by Kameng near Tezpur after another 123 km. Siang River up to its confluence with Lohit

and Dibang rivers is 251,521 sq km. Large part of the catchment is in Tibet; the total catchment of Siang river in India up to its confluence with Lohit and Dibang rivers is 14965.30 sq km.

Siang basin in India is comprised mainly of two major tributary sub-basins i.e. Siang river Sub-basin and Siyom river Sub-basin which is the largest tributary of Siang in India and joins Siang river near Pangin. Other major tributaries of the Siang river are Yamne river, Simang river, Sigong river, Ringong Asi and Yang Sang Chhu.

For the convenience of study and analysis of various physical and biological parameters and their interpretation, entire Siang basin in India has been delineated into 11 sub-basins comprised of major tributaries and covering varied domains as well as proposed hydroelectric projects. These are Siang sub-basin-I, Siang sub-basin-I, Siang sub-basin-II, Siang sub-basin-III, Siang sub-basin-IV, Siyom sub-basin-I, Siyom sub-basin-II, Siyom sub-basin-III, Hirit sub-basin, Yamne sub-basin, Simang sub-basin and Yargyap sub-basin.

3.0 HYDROPOWER PROJECTS IN SIANG BASIN

Siang basin is considered the largest basin in terms of hydropower potential in Arunachal Pradesh, the present estimated potential is 18293 MW. Apart from the projects on the main river, 44 hydropower projects are planned on all major tributaries and sub-tributaries with installed capacity ranging from 4 MW to 6000 MW. A comprehensive list of all the allotted/potential projects is given in table below.

Sl.No.	Name of Project	Installed Capacity (MW)
1	Siang Upper Stage-I	6000
2	Siang Upper Stage-II	3750
3	Siang Lower	2700
4	Siyom Middle	1000
5	Naying	1000
6	Tato-II	700
7	Hirong	500
8	Jarong	90
9	Taiyong	56
10	Tato-I	186
11	Heo	240
12	Pauk	145
13	Rapum	66
14	Rego	80
15	Kangtangshiri	80
16	Pemashelpu	90
17	Sangoshi	12.5
18	SaeChhu	15
19	Tagurshit	84
20	Tagurshit Stage-II	27.5
21	Kaying	14
22	Pitgong	14
23	Hirit	9
24	Hirit Korong	42
25	Soying Korong	48
26	Siri Korong	58
27	Sibu	4
28	Sittin	24
29	Gameng	37
30	Yemsing	38

Sl.No.	Name of Project	Installed Capacity (MW)
31	Simang-I	67
32	Simang-II	66
33	Nyikong	13
34	Pango/ Minniying	96
35	Mirak	141
36	Palsi	24
37	Sippi	96
38	Ringong	150
39	Jidu/ Yangsang	92
40	Sipit Upper	45
41	Yamne Stage-I	135
42	Yamne Stage-II	96
43	Lower Yamne Stage - I	75
44	Lower Yamne Stage - II	87
TOTAL		18293

A summary of all the 44 projects along with their present status vis-à-vis environmental clearance is given in table below.

Summary of the projects status with respect to environment clearance is given below:

Projects identified but yet to be allotted	4
Projects less than 25 MW	9
Projects accorded Scoping Clearance (Public Hearing yet to be conducted)	8
Public Hearing Conducted but EC not accorded (Hirong, Naying, Tato-I, Pauk, Heo, Simang-I, Simang-II and Kantangshiri HEPs)	8
Project accorded EC under EIA notification 2006 (Tato II HEP)	1
Project accorded EC under EIA notification 1994 (Siyom Middle HEP)	1
Projects yet to apply for Scoping	12
Projects cancelled/dropped	1
Total Number of Planned HEPs	44

4.0 BIODIVERSITY PROFILE OF SIANG BASIN

4.1 Terrestrial Ecology

4.1.1 Forest Cover

Total forest cover in the three districts (West Siang, East Siang and Upper Siang) comprising Siang basin is 15,232 sq km (82.26%) as compared to state's average forest cover of 80.50%. The three districts have 82.26% of area under forests of which Very Dense forest covers 26.99% of total area as compared state average of 24.92% of Very Dense Forest. The Siang basin study area however has 80.61% area under forests of which Very Dense forests constitute 27.08% of the total area. West Siang district has highest area under forests among the three districts i.e. 86.83%. Non-forest constitutes only 18% which mainly comprised of *jhummed* area and wide river bed in the lower reaches i.e. snow covered area, in and around Pasighat town and floodplain of Siang river in D'Ering Memorial Wildlife Sanctuary.

4.1.2 Forest Types

The forests in Siang basin fall under Central Circle with headquarters at Pasighat whereas the Protected Areas in the basin are under the administrative control of Addl. Principal Chief Conservator Forests (Wildlife & Biodiversity), Itanagar. The basin area under Central Circle is further administered by three Forest Divisions viz. Yingkiong, Along and Pasighat Forest Divisions with headquarters at Yingkiong, Along and Pasighat, respectively. In addition there are Mouling National Park and D'Ering Memorial Forest Divisions under the Central Circle. Yingkiong Forest

division is comprised of Yingkiong, Karko and Boleng Ranges, Along Forest Division is comprised of Along, Mechuka, Basar and Liromoba Ranges and Pasighat Forest Division has Mebo, Pasighat, Ruksin and Nari Ranges. The three Protected Areas in the basin are D'Ering Memorial Wildlife Sanctuary, Yordi Rabe Supse Wildlife Sanctuary and Mouling National Park. The major forest types encountered in the area have been described based on the classification of Champion and Seth (1968).

Each sub-basin of entire Siang basin harbours various forest types depending upon the altitudinal range and the same is given at **Table 1**.

Table 1: Forest types found in Siang basin and their distribution in different sub-basins

S.No.	Forest Type	Sub-Basins
1	2B/C1a Tropical Semi-Evergreen forest/ Assam Alluvial Plains semi-evergreen forest	SSb I to II, YSb, SmSb, HSb, SYSb I, BSb
2	1B/2S Secondary Bamboo brakes	SSb II to IV, YSb, SmSb, HSb, SYSb I to III, YGSb
3	3/1S2 (b) Eastern <i>Terminalia</i> - <i>Duabanga</i> forest	SSb I to IV, YSb, SmSb, HSb, SYSb I to II, YGSb
4	8B/ C I East Himalayan Sub-tropical wet hill forest	SSb III and IV, YSb, SmSb, HSb, SYSb I to II, YGSb
5	9/C2 Assam sub-tropical pine forest	SSb1, YSb
6	11b/C1 East Himalayan wet temperate forest	SYSb III, YGSb
7	12/1S1 Alder forest	SYSbIII
8	12/C3 East Himalayan mixed coniferous forest	SySb III, YGSb
9	13/C6 East Himalayan dry temperate coniferous forest	YGSb
10	15/C1 Birch-rhododendron alpine scrub forest	YGSb
11	15/C2 Deciduous alpine scrub	SYSb III, SSbIV, YGSb
12	15/C3 Alpine pastures	SYSb III, YGSb

SSBI-IV= Siang Sub-Basins; YSB= Yamne Sub-Basin; SMSB=Simang Sub-Basin; HSb= Hirit Sub-Basin; SYSBI-III=Siyoum Sub-Basins; YGSB=Yargyap Sub-Basin

4.1.3 Floristics

In all 1349 higher plant species belonging to 138 families have been documented which include 1250 Angiosperms, 11 Gymnosperms and 88 Pteridophytes. Among the lower plants bryophytes are represented by 51 species and lichens are represented by 32 species (see **Table 2**). Amongst angiosperms orchids, bamboos, canes and rhododendrons are the important plant groups that are predominantly found in the basin. Orchidaceae is represented by 102 species, rhododendrons by 16 species and bamboos and canes together are represented by 29 species.

Angiosperms is the largest group wherein the dominant family in the basin is Orchidaceae with 102 species followed by Poaceae with 91 species, Asteraceae with 64 species, and Ericaceae with 31 species. Among Gymnosperms Pinaceae is the largest family with 6 species and amongst Pteridophytes Polypodiaceae is the largest family with 17 species followed by Pteridaceae with 16 species while Mniaceae is the largest family among Bryophytes with 9 species.

Table 2: Summary of number plants species in Siang basin

VASCULAR PLANTS				
Group	Angiosperms	Gymnosperms	Pteridophytes	Total
Species	1250	11	88	1349
Families	138	2	22	162
LOWER PLANTS				
Group	Bryophytes	Lichens		
Species	51	41	-	-
Families	22	17	-	-

4.1.4 Dominant Plant Groups in Siang Basin

Orchids

In Siang basin 102 species of orchids are found. Out of this, 79 are epiphytes and only 22 are terrestrial orchids while there is only one species which is mycotrophic (living in association with mycorrhiza).

Paphiopedilum fairrieianum is under Endangered Category as per IUCN Redlist while *Cymbidium eburneum* is under Vulnerable category. There are 7 endemic species which are found in Siang basin. These are *Calanthe densiflora*, *Cymbidium eburneum*, *Dendrobium cathcartii*, *D. hookerianum*, *Galeola falconeri*, *Stichorkis plantagenia* (= *Liparis plantaginea*) and *Paphiopedilum fairrieianum*.

In the Siang basin most of the orchid species are reported from main Siang valley, Simang valey, Yamne valley and in the Mouling National Park as well as Yorde Rabe Supse Wildlife sanctuary.

Rhododendrons

Rhododendron is one of the important dominant plant taxa found in the temperate, subalpine and alpine regions of Arunachal Pradesh and the state harbours 90 species of *Rhododendron*. In Siang basin 16 species of *Rhododendron* are found. They are found between 1500 and 4000m elevations and majority of the species have been found between 1500 and 3000m elevations in the basin. Two endemic species viz. *Rhododendron dalhousiae* var. *rhabdotum* and *Rhododendron falconeri* ssp. *eximium* are found in the basin. There are 6 species which fall under Red Data List of BSI viz. *Rhododendron arizelum* (Rare), *R. boothii* (Threatened), *R. dalhousiae* var. *rhabdotum* (Rare), *R. edgeworthii* (Rare), *R. falconeri* ssp. *eximium* (Endangered) and *R. kenderickii* (Rare). Recently a new species of rhododendron *Rhododendron mechukae* has been discovered from Yargyap Chhu catchment in area between Mechuka and Yarlung by Mao et al. (2013) and has been kept under Critically Endangered category by IUCN Redlist. It found in association with *Rhododendron arboreum*, *R. arizelum* and *Taxus wallichiana*.

Bamboos and Canes

In Siang basin 15 species of bamboos have been found based upon the available data of which 5 belong to genus *Bambusa*, 5 species belong to *Schizostachyum*, 2 each belong to *Dendracalamus* and *Thamnocalamus* and one species each of *Phyllostachys* and *Sinarundinaria*.

Canes form important resource of Arunachal Pradesh. Canes (Rattans - climbing palms) belong to genus *Calamus* of family Arecaceae. Out of 20 species of canes found in the state, 14 species have been reported from Siang basin. *Calamus leptospadix* is an endemic species.

Threatened & Endemic Plant Species

Nayar and Sastry (1987-1990) have reported 35 species of rare and endangered plant species from Arunachal Pradesh. In Siang basin all there are 27 plant species that are either under different threat categories as per IUCN or under Red Data Book categories. The Siang basin as discussed above is also very rich in floristic resources and there are still number of areas in the basin which are either under-explored or yet to be explored like Yomcha area in Yordi Rabe Supse Wildlife Sanctuary, Sike river catchment and upstream catchments of Sigong and Ringong rivers. There is a probability of discovery of new species in some of these areas.

Begonia burkilli was found in Hirit valley and *Cephalotaxus griffithii* was recored from Yargyap Chhu valley.

According to Conservation Assessment and Management Plan (CAMP) 2003 of the 44 medicinal plant species were assigned the Regional Level status of Near Threatened (NT) in Arunachal Pradesh 17 are reported from Siang basin.

Endemic Plant Species

Forty six plant species that are endemic to Arunachal Pradesh have been recorded from various regions in the Siang basin. These belong to 24 families and 38 genera. These species predominantly attributed to six plant families (i.e., Orchidaceae - 8 species; Rubiaceae - 5 species, Mangnoliaceae 4 sepcies; and Arecaceae, Balsaminaceae and Begoniaceae represented by 3 species each). Majority of endemic species are found in Tropical semi-evergreen forest followed by subtropical evergreen forest, temperate broad-leaved evergreen forest, abandoned *jhum* land, degraded forest, temperate/sub-alpine coniferous and sub-tropical pine forest. Only one endemic species recorded in alpine/sub-alpine region i.e *Rhododendron dalhousiae* var. *rhabdotum*.

In addition there are 55 species which are endemic to Northeast India are reported from Siang basin. Most of these species are reported from main Siang valley and Yamne catchment.

Medicinal Plants

The people of Arunachal Pradesh collect a large number of wild edible plants in the form of tubers, rhizomes, shoots, flowers, fruits, berries, seeds, etc. as the natural supplement for their diet. These wild edible species are very rich in carbohydrates, starch, protein, sugar and oil. Among the wild edible plants consumed are the leaves and young twigs of *Aconogonum molle*, *Amaranthus spinosus*, *Cardamine hirsuta*, *Chenopodium album*, *Fagopyrum esculentum*, *Girardinia diversifolia* and *Rumex nepalensis*. The rhizomes and tubers of *Alpinia allughas*, *Alocasia indica*, *Colocasia esculenta* and *Dioscorea* spp. are commonly consumed as vegetables. Young shoots of *Bambusa tulda* and *Dendrocalamus hamiltonii* are used as food ingredients. Flower buds of *Bauhinia purpurea* and *Oroxylum indicum* are used as vegetables. Fruits of *Garcinia pedunculata*, *Elaeagnus* sp., *Rubus ellipticus*, *Ficus semicordata*, *Prunus cerasoides*, *Musa* sp., *Syzygium formosum* and *Tetradium fraxinifolium* are eaten raw or cooked as vegetables.

4.1.5 Faunal Elements

Mammals & Birds

Mammalian fauna of the basin comprises of about 143 species belonging to 32 families and 11 Orders. There are 25 species of mammals (18%) which are Schedule-I species according to WPA

(1972) whereas 26 are Schedule-II species. According to IUCN Red List Ver. 3.1 there are 8 mammals under Endangered species category viz. *Uncia uncia*, *Cuon alpinus*, *Moschus chrysogaster*, *Manis pentadactyla*, *Prionailurus viverrinus*, *Panthera tigris*, *Elephas maximus* and *Caprolagus hispidus*. While first three species are found at higher elevations, *Elephas maximus* and *Caprolagus hispidus* (Hispid hare) are found only in D'Ering Memorial Wildlife Sanctuary in Siang basin. In addition there are 12 species which are under Vulnerable category viz. *Trachypithecus pileatus*, *Melursus ursinus*, *Nycticebus coucang*, *Lutrogale perspicillata*, *Aonyx cinerea*, *Arctictis binturong*, *Pardofelis marmorata*, *Neofelis nebulosa*, *Ursus thibetanus*, *Capricornis sumatraensis*, *Cervus unicolor* and *Budorcas taxicolor*. In the assessment done by C.A.M.P. 4 species are under Endangered category which are *Panthera tigris*, *Uncia uncia*, *Caprolagus hispidus* and *Bubalus bubalis* while 4 are under Vulnerable category like *Panthera pardus*, *Nemorhaedus sumatraensis*, *Hystrix indica* and *Moschus chrysogaster*.

Based upon the information compiled from secondary sources as well field surveys 447 species of bird species belonging to 19 orders and 80 families inhabit Siang basin. However during the surveys only 102 species of birds were sighted.

Out of 447 bird species 31 species belong to Schedule-I as per Wildlife (Protection) Act, 1972. However no species is under Schedules -II & III whereas 373 species are under Schedule-IV. Prominent Schedule-I species are two species of hornbills i.e. Great Indian Hornbill, and Oriental Pied Hornbill. On the other hand 7 species of eagles are under Schedule-I and 7 other species of harriers, kites and buzzards belonging to the same family Accipitridae are under Schedule-I.

Owing to rich avi-faunal diversity 5 International Birding Areas (IBA) have been identified in Siang basin by Birdlife International.

The Siang basin is home to 3 Protected Areas i.e. two Sanctuaries (D'Ering Memorial Wildlife Sanctuary and Yordi Rabe Supse WLS) and one Mouling National Park. In addition Dibang Dihang Biosphere Reserve covers parts of three districts i.e. East Siang, West Siang and Upper Siang.

Butterflies

From Siang basin total 111 species of butterflies are found. These species belong to six families - Papilionidae, Pieridae, Lycaenidae, Hesperidae, Nymphalidae and Riodinidae. Nymphalidae was most dominant family represented by 74 species. Of all the species 8 species, viz. Common rose (*Pachliopta aristolochia*), Common sailer (*Neptis hylas varmona*), Common grass yellow (*Eurema hecabe*) and Indian cabbage white (*Pieris canidia*) are abundantly found. They were recorded in large numbers from various sampling sites. Common earl (*Tanaecia julii appiades*), Blue duchess (*Euthalia duda*), Grey count (*Tanaecia lepidea lepidea*), Common maplet (*Chersonesia risa*), Redbase jezebel (*Delias aglaidas*) are recorded quite regularly from different areas. Variegated sailer and Crimson rose are categorised as Schedule I species (WPA 1972).

Herpetofauna

Herpetofauna comprise of amphibians that include frogs, toads, newts, salamanders, etc. and reptiles which include snakes, lizards, turtles, terrapins, tortoises, etc. An inventory of herpetofauna comprising reptiles and amphibians was prepared from the Forest Working Plans, management plans of Protected Area and published literature. Total 116 species are reported from the Siang basin of which 31 species are of amphibians and 85 species are of reptiles.

Reptiles

Reptilian fauna is comprised of 85 species belonging to 14 families. Colubridae is the largest family represented by 41 species followed by Viperidae with 13 species. Sun skink, Forest skink, Khasi lizard, house lizard, common krait, Indian monitor, pit viper, rat snake are most common in the basin. Python and Indian monitor lizard have been categorized as ‘endangered’ species (ZSI, 1994). Indian egg-eating snake (*Elachistodon westermanni*) and Yellow monitor lizard (*Varanus flavescens*) are the Schedule I species while Common Asian monitor (*Varanus bengalensis*), Water monitor (*Varanus salvator*), Rat snake (*Ptyas mucosus*), Russels' viper (*Vipera russelli*), Monocellate cobra (*Naja kaouthia*), Cobra (*Naja naja*) and King cobra (*Ophiophagus hannah*) are categorized as Schedule II species. IUCN Red List has kept Assam roofed terrapin (*Pangshura sylhetensis*) under Endangered category while King cobra (*Ophiophagus hannah*), Southeast Asian box turtle (*Cuora amboinensis*) and Spotted pond turtle (*Geoclemys hamiltonii*) have been kept under Vulnerable category.

Amphibia

From the Siang basin 31 species of Amphibians are reported which belong to 4 families, which comprises of toads and frogs. Ranidae is the largest family with 14 species followed by Rhacophoridae with 8 species. *Rana* spp. and *Bufo melanostictus* are very common in the basin. There is only one species of frog i.e. Pied tree frog (*Theloderma moloch*) which falls in IUCN Red List Vulnerable category and is known from very few locations found between 300 and 1500m while two species viz. Tuberculate tree frog (*Rhacophorus tuberculatus*) and Large toad (*Xenophrys robusta*) has been kept in Data Deficient category while rest all of the species are under Least Concern category. Tuberculate tree frog is known from bamboo forests, where it hides in the stems of the bamboo during the day.

Insects

From the Siang basin 31 species of insects are reported. The important groups are Diptera, Coleoptera, Hymenoptera, Lepidoptera, Hemiptera, Odonata, Ephemeroptera, Plecoptera and Trichoptera. Lepidoptera is largest group followed by Diptera.

4.1.6 Protected Areas

In Siang basin there are two Sanctuaries i.e. D'Ering Memorial Wildlife Sanctuary and Yordi Rabe Supse WLS and one Mouling National Park. In addition Dibang Dihang Biosphere Reserve covers parts of three districts i.e. East Siang, West Siang and Upper Siang.

Protected Area	Area (Sq km)
D'Ering Memorial Wildlife Sanctuary	190.00
Mouling National Park	483.00
Yordi-Rabe Supse Wildlife Sanctuary	397.00
Dibang Dihang Biosphere Reserve	5112.50; Core Area = 4094.80; Buffer Area = 1016.70

4.2 Aquatic Ecology

4.2.1 Physico-Chemical Water Quality

In order to assess the overall water quality of Siang and Siyom rivers along with their tributary streams a Water Quality Index was used which has been developed at Washington State Department of Ecology, Environmental assessment Programme. The water quality of various

streams of Siang basin i.e. Siang river, Siyom river, Yamne river, Simang river, Hirit river, and Yargyap Chhu during winter season sampling is excellent in general as it remained above 90. During monsoon only the water quality degraded a little bit but still remained under Good category. Water Quality Index (WQI) is Good to Excellent wherein WQI varied from 87 to 92 on a scale of 1-100 Siang river and all its tributaries.

4.2.2 Biological Water Quality

Phytoplankton

Siang River and its tributaries are rich in all biotic components. In all total 116 species of Phytoplankton were recorded from all the locations during surveys conducted in different months of three seasons. The genus *Achnanthes* was the most dominant genus represented by 33 species followed by *Gomphonema* with 23 species. *Achnanthes affinis* and *Achnanthes austriaca* are most common and abundant species as they were recorded with highest Proportionately Relative Abundance from Siang basin. *Achnanthes lapidosa* and *Navicula cryptocephala* are the other two most abundantly found species in the basin.

Phytobenthos

In all total 79 species of Phytobenthos were recorded from all the locations during surveys conducted in different months of three seasons. The genus *Achnanthes* was the most dominant genus represented by 21 species followed by *Gomphonema* with 13 species. *Achnanthes austriaca* are most common and abundant species as they were recorded with highest Proportionately Relative Abundance from Siang basin and it was recorded from all the sites during all samplings.

Zooplankton

Zooplanktons are represented by protozoa, rotifer and crustacean (copepods and cladoceran). Among protozoans *Arcella*, *Peridinium*, *Actinophrys*, *Paramecium* and *Ceratium* genera were observed at most of the sites in Siang basin, however their occurrence is low at sampling sites located in the lower reaches. The Rotifers are represented by *Keratella*, *Brachionus*, *Epiphanes*, *Philodina*, and *Asplanchna* sp. Among Copepods moina, bosmina, and daphnia species were found, whereas cladocerans were represented by cyclopes and diaptomus only.

Macro-invertebrates

Macro-invertebrates are widely used to determine biological conditions and acts as an in-line monitoring system for pollution. They are important part of food chain especially for fish. During the study, macro-invertebrate fauna comprised of 41 species falling under 7 Orders belonging to 29 families like Heptageniidae, Baetidae, Ephemerellidae, Leptophlebiidae, Hydropsychidae, Psychomyidae, Perlidae, Perlodidae and Chironomidae. *Cinygmula* was the most abundant genus and was recorded from all the sampling sites in all the seasons. *Hydropsyche* was next most dominant macro-invertebrate genus recorded from Siang river and its tributaries in different seasons. The Heptageniidae was most dominant family and found to be present during all the seasons. The number of species recorded from different sampling sites during different seasons varied from lowest in Siyom sub-basin at some sites where only one species was recorded during monsoon season and highest 21 at one site in Yargyap Chhu sub-basin during winters.

Biological Water Quality

For the assessment and analysis of Biological Water Quality an index named **Biological Monitoring Working Party (BMWP)** procedure was employed using species of macro-invertebrates as biological indicators (<http://www.nethan-valley.co.uk/insectgroups.doc>).

The Siang river and its tributaries are rich in aquatic biodiversity also as indicated by its quality assessed through BMWP score which reveals that river is very rich in aquatic microflora and fauna. It is also evident from vast diversity of fishes (116 species) reported from the basin.

4.3 Fish and Fisheries

Nath & Dey, 2000 had reported 74 species of fishes from Siang river system. However more information and data was collected from different secondary sources to prepare a checklist of fishes found in Siang. According to it Siang basin harbours 114 species of fishes belonging to 27 families. Cyprinidae is largest family with 42 species accounting for 37% of total fish fauna.

Following C.A.M.P. guidelines all the 116 fish species were assessed for their conservation status, of which 31 are under 'Least Concern' category. *Schistura kangjupkhulensis* and *Tor putitora* are categorized as 'Endangered' species and *Schizothorax richardsonii* has been placed under 'vulnerable' category. The category of 'Near Threatened' includes *Tor tor*, *Bagarius bagarius*, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Wallago attu*, *Ompok bimaculatus*, *Ompok pabda* and *Schistura manipurensis*.

According to IUCN 2011.2 criterion *Tor putitora*, *Lepidocephalichthys arunachalensis* (= *Nemacheilus arunachalensis*) and *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*) are under Endangered category whereas 7 species are under Vulnerable category. These are *Cyprinus carpio*, *Schizothorax richardsonii*, *Bagarius bagarius*, *Pseudecheneis sirenica*, *Botia rostrata* and *Aborichthys garoensis* (= *Nemacheilus garonesis*). Twelve species are under Near Threatened category viz. *Balitora brucei*, *Labeo pangusia*, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Tor tor*, *Syncrossus berdmorei* (= *Botia berdmorei*), *Aborichthys kempfi* (= *Nemacheilus kempfi*), *Nemacheilus devdevi*, *Schistura manipurensis* (= *Nemacheilus manipurensis*), *Ompok pabda*, *Ompok pabo*, *Ompok bimaculatus* and *Wallago attu*.

The fish communities of a particular river system largely depend on the kind of available aquatic habitat conditions and other river characteristics in which they dwell, grow, move around, complete their life cycle and survive. Likewise other Himalayan rivers in Siang basin too, two distinct fish communities/ zones can be demarcated such as Golden mahseer (*Tor putitora*) and its associated species, and Snow trout (*Schizothorax richardsonii*) and its associated species. While Mahseer (*Tor putitora*) is the most common and dominant fish species found in Siang river at lower elevations, it is *Schizothorax richardsonii* which is the most dominant species in the upper reaches of the basin and it can exist in certain elevations with and without mahseer species i.e. the overlapping elevations. Accordingly in the present the entire Siang basin was classified into three zones/categories such as Mahseer zone, Snow trout zone and 'No-fish zone'. No fish zone has been demarcated in the higher altitudes i.e. 1800 m and above. Hardly any fish could be caught in this zone despite persistent efforts and moreover, there has no published report/ literature or documentation of fish species reported from this zone. Even the locals deny the existence of fishes in this zone. Immediately below the 'no fish zone', is the snow trout zone where water temperature is always low whereas in the mahseer zone, which falls in the lower altitude rivers and streams, water is relatively warm.

4.3.1 Fish Migration & Breeding/Spawning Grounds in Siang basin

Similar to the behaviour of Himalayan fish species, in Siang river too Mahseer (*Tor putitora* and *T. Tor*) ascend long distances for breeding purpose, and then move from main stream to the tributaries. Other species like *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Labeo dero*, *Anguilla bengalensis* and snow trout species traverse relatively short distances. Mahseer and *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*) start their migration during the onset of monsoon and perform triphased migration. All 'schizothoracines' show variable migration. They descend in monsoon towards warmer places and spawn in the main streams or tributaries. *Labeo* spp. Also migrates into the nearby tributaries for breeding.

The fish species mentioned above like fast flowing, rocky bottom waters and are seen frequently around the foothills. Though mahseer was landed during surveys is found in the lower stretches of river Siang downstream of Siang Lower HEP site near Bodak it was also found upstream of Bodak but in much lesser numbers. According to fishermen the main breeding zone for mahseer in river Siang and its tributary streams upstream of Bodak village like Yamne, Hirit and manin Siang channel and also streams that join Siang downstream of Bodak village, where water flow (0.6-1.2 m/s), water depth (0.5-1.5 m), Dissolved Oxygen (>8 mg/l) and temperature (16-19°C) and substratum is gravelly.

4.3.2 Other Migratory Fish Species

Schizothorax richardsonii and *Garra naganensis* are column feeders, thus, considered to move relatively longer distance as compared to other species dwelling the river bed. *Schizothorax richardsonii* is considered to perform migration within same river. To cope with the low temperature in peak winter season it moves downwards. It finds a tributary to spawn from May to September. In the region migratory pattern of *Schizothorax richardsonii* is not well studied but other studies in Himalayan river show that they do not have specific breeding grounds. The ova of fish species (probably of *Schizothorax richardsonii*) from Siyom river and tributaries.

A few other species like *Labeo pangusia*, *L. goni* and *Anguilla bengalensis* ascend comparatively for short distance. Among catfishes *Aorichthys seenghala* does migrate for breeding and spawning purposes. The fry of *Labeo pangusia* were found in Hirit river.

Mahseer

Mahseer is a column feeder and mid-water dweller where optimum depth cannot be defined. Mahseer ascends upstream in the month of April and May for the purpose of spawning. After spawning, they descend in the months of September and October.

Snow trout

Snow trout includes two species - *Schizothorax richardsonii* and *Schizothorax progastus* in Siang basin. *Schizothorax richardsonii* is categorized as 'vulnerable' species. They are widely distributed in the basin (400 to 2300 m) and constitute an important part of capture fishery in the middle part of the basin. In the peak winter they move towards the lower elevation to cope the low temperature. Snow trout finds relatively warmer waters for the spawning in monsoon season, thus, prefer tributaries to spawn.

Snow trout is most vulnerable due to cascade development because they are widely distributed in the basin. The cascade development would lead to the habitat fragmentation, therefore, it would be difficult for snow trout to undertake migration and find suitable tributaries to spawn.

Chocolate/Copper Mahseer

Neolissochilus hexagonolepis (= *Acrossocheilus hexagonolepis*) has been categorized as 'near threatened' species and is distributed up to 1000 m in Siang basin. The species is restricted to the Eastern Himalaya. It constitutes important capture fishery in lower stretch of Siyom river, Hirit river, and lower and middle stretch of Siang river and lower stretch of Simang river. *Neolissochilus hexagonolepis* also is considered as migratory species, which finds tributaries for spawning. Due to its migratory habit, it would be affected adversely due to cascade development.

Common Carps

Common carp comprises *Labeo pangusia* and *L. gonius* in Siang basin. These species are distributed up to 1000 m in Siang basin and constitute important fishery in lower stretches of the basin. All species are considered as 'Least Concern'. Being under the Least Concern conservation status and migratory phenomenon of these major carps, they might also be affected by cascade development. However, they are widely used in cultural fishery.

Minor Carps

Minor carp comprises *Puntius* spp. and *Barilius* spp. They are predominant in tributaries like Hirit, Yamne rivers, and Yargyap Chhu, etc. Minor carp are not of any fishery interest. All minor carp in Siang basin belong to 'least concern' category.

Garra species

Garra comprises of *Garra naganensis* and occurs over a wide elevational range and is common in tributaries like Hirit, Yargyap Chhu, Ringong, Simang, etc. and also in main Siyom river. It is endemic to north-eastern region and belongs to 'least concern' category. This species neither are nor of fisheries importance but come in the catch executed by cast net.

Loaches and Catfish

Fish species belonging to Bagaridae, Sisoridae, Cobitidae and Balitoridae represent the loaches and catfish in Siang basin. Generally these species are bottom dwellers and prefer rivulets in the basin.

Loaches are dorso-laterally compressed fishes with cylindrical bodies and well known as water cleaner, sweeper and scavengers. Most of these are found in shallow water of small streams or in the shallow and slow flowing water riffles of main Siang river

The famous sport cat fish in the river water is Gounch, *Bagarius bagarius* found in the rapids, riffle and deep perennial pools of the Siang river. It performs the long distance migration. The fish may move downstream area of dam site due to submergence of upstream area and further deterioration of water quality. Other cat fish like *Glyptothorax* sp. Also prefer fast water current with rocky sub-stratum with comparatively lesser depth. Other species from Bagaridae and Siluridae, which are common in occurrence in the Ranaghat area where river is having mix habitat of hill streams and floodplains are present. River is having an average bank width of 1000 m where flowing water is 600 m wide with 0.45-1.2 m/s water flow and gradient less than 0.5%. The depth varies from 1m to 5m with gravels at meander and sandy beds. Bagaridae group makes nests during breeding season and prefers slow moving waters of 0.2-0.4 m/s with depth 1.0m and grow better with water depth more than 3m.

The famous giant river cat fish *Aeorichthys seenghala*, *A. aor*, *Mystus* spp., *Wallago attu* and *Ompok* spp. are present in this stretch. However, these fishes are widely distributed in India i.e. floodplains, rivers, lakes, ponds, beels and wetlands. Among Claridae, Magur is common in occurrence that is due to favourable habitat of sandy beds and downstream area of swamps, marshes, and wetlands of Dihang and Dibang rivers.

4.3.3 *Miscellaneous species*

Fish species like *Xenotodon cancila* and *Chanda ranga* are exclusively restricted to the lower reaches (up to 250 m) of the basin. None of the species is 'vulnerable' or 'endangered'. Since they are restricted to the lower part, therefore, cascade development in the basin may not have major impact on these species.

4.4 *Biodiversity Values in Sub-Basins*

In order to make an overall assessment of biodiversity values in different sub-basins a summary of different biodiversity components was made and is given at **Table 3**.

The overall assessment of biodiversity values in different sub-basins of Siang basin made on the basis of comparative richness, it can be concluded that Siang sub-basin-II is highest in terms of total biodiversity values followed closely by Siyom sub-basin-I, Yamne, Siang sub-basin-I, Hirit, and Siang sub-basin-III. Three major projects i.e. Siang Lower, Siang Upper Stage-II and Siang Upper Stage-I are located in these sub-basins. These three projects alone would involve direct loss of 18174 ha of forest which is about 76% of total forest land required for all 44 projects in the basin. In addition 242.6 km of Siang river (including 24.56 km of Siyom river) will be affected due to formation of reservoir.

Similarly Yamne and Hirit sub-basins too are rich in biodiversity values. This is more important in case of Hirit which happens to be a suitable habitat for migratory fishes like mahseer, and Labeo pangusia. The upper catchment of Hirit sub-basin is comprised of Yorde Rabe Supse WLS in which the forests are in pristine condition due to its remoteness. Once the projects are taken up in this sub-basin it will provide access to otherwise inaccessible areas leading to degradation of its flora and fauna. Therefore it is recommended no activity in this sub-basin is allowed.

In case of Yamne sub-basin most its biodiversity is found in its upper reaches whereas lower catchment is comparatively degraded due to *jhumming*, therefore activities in its upper catchment need to be taken up with caution taking into consideration its biodiversity richness.

In the case of Siyom sub-basins-I, II, and III it is of great concern the loss of longitudinal as well as lateral connectivity due to the proposed projects like Siyom Middle, Naying, Tato-II and Hirong HEPs planned in cascade. It is recommended that longitudinal of the riparian habitats in this 58 km of riverine stretch is maintained by leaving few free flowing stretches of Siyom river as most of the time in this stretch river will be either be travelling through tunnels or would be converted into reservoirs. This will ensure longitudinal as well as lateral connectivity also which is important for riparian vegetation.

5.0 ENVIRONMENTAL FLOWS

The environmental flow is an important aspect in the development of hydropower projects. Release of environmental flow is to be ensured immediately downstream of the diversion structure at all times to sustain the ecology and environment of project area.

For assessment of environmental flow focus is on the characteristic features of the natural flow regime of the river. The most important of these are degree of perenniality; magnitude of base flows in the dry and wet season; magnitude, timing and duration of floods in the wet season; and small pulses of higher flow, that occur between dry and wet months. Attention is then given to which flow features are considered most important for maintaining or achieving the desired future condition of the river, and thus should not be eradicated during development of the river's water resources.

Fish assemblages often include a range of species and reflect the integrated effects of environmental changes. Their presence is used to infer the presence of other aquatic organisms, since the adult fish occupy the top of the food chain in most aquatic systems. Fish species in river can guide to prepare specification of the flows necessary to meet their needs, and be useful in the monitoring and management of those flows. It is often surmised that if management of flows for fish maintenance is successful, then flow requirements for aquatic invertebrates will also be satisfied. This is because of the larger scale of fish habitat.

Therefore, the approach adopted for environmental flow assessment is based on meeting the needs of dominant fish species with larger habitat requirement. Entire Siang basin has been divided in two predominant fish zones viz. Mahseer Zone and Trout Zone. Mahseer being a large fish requires more flow in all the seasons and this aspect has been kept in mind while recommending environment flow for projects in Mahseer zone. Mahseer zone covers the entire main Siang river, Siyom river up to the powerhouse of Naying HEP, Yamne river up to the power house of Lower Yamne Stage II, Simang river up to the power house of Simang II and Hirit river. Projects fall in Mahseer zone are Siang Lower, Siang Upper Stage I and II, Siyom Middle, Lower Yamne Stage II, Simang I and Hirit HEPs. Rest of the river stretch in the basin falls in trout zone where remaining HEPs are located.

The most critical reach for assessing release of environmental flow is immediately downstream of diversion structure till first significant tributary meets river. To assess environmental flow requirements, a flow simulation study has been carried out using one dimensional mathematical model **HEC-RAS ver. 4.1.0** developed by Hydrologic Engineering Center of U.S. Army Corps of Engineers.

Table 3: Summary of biodiversity profile of sub-basins in Siang basin

	Siang Sub-basin-I	Siang Sub-basin-II	Siang Sub-basin-III	Siang Sub-basin-IV	Yamne	Simang	Hirit	Siyom Sub-basin-I	Siyom Sub-basin-II	Siyom Sub-basin-III	Yargyap	TOTAL SIANG BASIN
TOTAL GEOGRAPHIC AREA (SQ KM)	1716.89	1806.49	2018.83	1754.47	1257.10	557.51	581.33	1472.19	1203.17	1356.12	1241.58	14965.68
FOREST COVER (%)	65	95	61	88	95	96	97	91	75	69	64	81
FLORISTIC DIVERSITY												
No. of species	254	277	245	194	210	220	214	248	298	388	356	1349
No. of RET species	6	4	5	5	6	2	7	12	12	9	11	27
Endemic to Arunachal Pradesh	5	8	9	9	11	8	11	16	21	8	10	46
Endemic to North-east India	16	29	36	34	38	28	37	28	28	18	15	55
FAUNAL DIVERSITY												
Mammals												
No. of species	64	58	54	50	54	52	98	88	54	35	36	142
RET -IUCN	9	6	5	5	8	8	6	6	6	4	8	20
RET-WPA	14	20	10	10	13	13	12	12	8	11	16	50
Avi-fauna												
No. of species	156	300	280	300	224	211	205	194	165	98	95	447
RET-IUCN	19	8	2	2	8	3	8	7	2	7	7	33
RET-WPA	31	5	5	5	5	4	5	5	5	5	5	30
Fishes												
No. of species	74	59	55	36	62	41	42	43	32	24	19	116
RET-IUCN	13	15	15	11	17	11	14	13	10	7	7	22
RET-CAMP	27	29	32	21	27	10	7	22	20	9	9	47
No. of Endemic species	8	8	8	5	10	3	5	8	2	2	2	14

Cells highlighted in Red and Bold letter indicates maximum value of that particular biodiversity component in a sub-basin

There are 44 hydro projects being planned in the Siang river basin on different tributaries and their details and status is discussed in Chapter 3. None of the projects have started construction; many of the projects are at various stages of survey and investigation and quite a few of projects have yet to start the survey and investigation work as well and therefore data availability of such projects is very limited. 23 projects have been selected for simulation modelling based on data availability and to ensure that major tributaries of Siang river are covered in this modelling exercise. Out of the full year flow series (90% DY), three average values have been calculated viz. four leanest months, four monsoon months and remaining four months (pre and post monsoon).

Flow simulations have been carried out for 10%, 15%, 20%, 25%, 30%, 40%, 50% and 100% releases of the average discharge for each of above three scenarios for the identified 23 projects. Various key parameters for establishing habitat requirement have been calculated which include water depth, flow velocity and top width of waterway.

Initial 1-2 Km or the length up to which first major tributary meets the river is considered critical as for the rest of the stretch tributaries will add to the environment flow released from the diversion structure. Keeping this in view, 8-10 cross sections were taken immediate downstream of the diversion structure for each project and used in the modelling exercise. These sections have been represented in HEC-RAS model set up.

5.1 Environment Flow Assessment in Lean Season

To assess the minimum environment flow requirement in lean season a criteria has been defined that projects in the Mahseer zone needs to provide a minimum 0.5 m average depth in the initial reach studied, and for projects in the trout zone this depth is considered as 0.4m. Keeping in view that there are streams of various sizes in Siang basin, a further check is made that reduction in water depth and flow width should not be more than 50% of pre-project levels. Pre-project water depth, flow width and flow velocity is assessed by reviewing the results of 100% release scenario. Table 4 gives reduced depth under three different scenarios along with pre-project values and 50% of pre-project values for comparison.

Table 4: Average Flow Depth under different release Scenarios during Lean Season

Project	Average Flow Depth (cm)				
	15% release	20% release	25% release	Pre-project	50% of Pre-project
Hirong	70.71	79.07	85.93	146.93	73.47
Tato II	90.80	101.20	110.20	187.40	93.70
Naying	71.17	79.72	87.17	154.11	77.06
Pemashelpu	32.45	36.36	39.45	67.82	33.91
Kangtangshiri	39.73	44.55	48.64	84.55	42.28
Rapum	34.34	38.61	39.67	75.08	37.54
Pauk	52.33	58.33	63.50	107.17	53.58
Heo	60.87	67.94	74.00	126.25	63.12
Tato I	62.30	69.65	99.10	130.00	65.00
Hirit Korong	44.69	50.15	54.54	94.23	47.12
Siri Korong	37.56	42.00	45.78	79.00	39.50
Gameng	28.69	32.31	35.00	60.00	30.00
Ringong	43.55	48.55	53.18	91.73	45.87
Pango	41.56	46.39	50.56	86.11	43.06
Mirak	45.91	51.18	55.91	96.36	48.18

Project	Average Flow Depth (cm)				
	15% release	20% release	25% release	Pre-project	50% of Pre-project
Palsi	21.25	24.08	26.50	45.83	22.92
Yamne Stage I	46.58	51.92	56.58	96.00	48.00
Yamne Stage II	58.48	65.24	70.86	119.48	59.74
Lower Yamne Stage I	52.89	59.05	64.26	109.58	54.79
Lower Yamne Stage II	49.00	54.60	59.44	100.68	50.34
Simang I	45.68	50.92	55.67	94.28	47.14
Simang II	39.00	44.00	48.00	86.10	43.05

Following can be concluded from the above analysis:

- More than 50% of the pre-project flow depth is achieved under the 20% release scenario for all the projects.
- Projects in Mahseer zone viz. Naying, Lower Yamne Stage I and II and Simang I will have more than 50 cm of average flow depth under 20% release scenarios
- In the trout zone, four projects viz. Rapum, Pemashelpu, Gameng and Palsi are showing less than 40 cm of depth under 20% release scenarios
- Rapum and Pemashelpu can achieve close to 40 cm depth under 25% release scenario
- Gameng HEP can meet 40 cm depth criteria, only if it releases 35% of the average discharge in lean season, as pre-project depth is only 60 cm
- Palsi HEP can meet 40 cm depth criteria at over 70% of release in lean season as the pre-project flow depth is only 45.83 cm; this would certainly make the project unviable
- Reduction in flow velocity is observed of the order 30-35% for 15% and 20% release scenarios, which meets the habitat requirement criteria for trout as well as Mahseer.

5.2 Environment Flow Assessment in Monsoon Season

Environment flow requirement in monsoon season is different from that of lean season. Lean season flow is mainly base flow and therefore, an average value and constant release can meet the lean season flow requirement. Whereas in monsoon, apart from base flow, flood peaks are critical for various functions of the river. These flood peaks provide connectivity and wetting of side channels, opening up new habitat, gravel movement, and flushing sediment into side channels. These flows also add organic matter and nutrients through riparian vegetation into the main stream thus providing food to aquatic species. Newly connected side channels provide spawning and rearing habitat for aquatic life. Resident trout, macro-invertebrates, and other species also benefit by increased habitat diversity and clean, un-armored substrates.

Requirement for base flow in monsoon can be established from the modelling output in terms of flow required to meet the habitat requirement i.e. water width, depth and velocity. No specific criteria can be established to exactly fix the minimum habitat requirement due to adaptability of the species to varied conditions in the rivers. Habitat requirements have been summarised in Chapter 7; from where it can be concluded that projects in trout zone should not reduce water depth below 1 m in monsoon and to meet the higher requirement in Mahseer Zone such project should provide about 1.2-1.4 m depth. Further, reduced flow depth and width of the river due to diversion of water should be of the order of 50% or more as compared to that of pre-project status.

Another important characteristic of the monsoon flow is flood peaks; this should also be mimicked in post project scenario. Sufficient flood peaks should be released through out the monsoon

period. Limitation is in evaluation of the available flood pulses in monsoon because the discharge data available is ten daily series, which average out the flood peaks in most of the cases. For flood peak analysis twice daily/daily discharge data is considered most suitable. Wherever, daily data is available, data analysis is carried out for flood peak assessment and recommendations are made accordingly. In the absence of such data, higher release recommendations are made than what is assessed to meet base flow requirement to ensure flood peaks are released.

Table 5 below gives flow depth in monsoon season for 15%, 20%, 25% and 30% release scenarios along with pre-project depth or 100% release scenario. Cells have been highlighted against each project where the adequate habitat is available in terms of flow depth to meet the base flow requirement only. Highlighted release requirement for base flow needs is compared with the pre-project depth and last column gives the % of depth available with respect to pre-project depth.

Table 5: Model Output for different Release Scenario during Monsoon

Project	Average Flow Depth (cm)					% of Pre-project Depth (corresponding to highlighted release scenario)
	15% release	20% release	25% release	30% release	Pre-project	
Hirong	144.29	161.43	175.86	188.64	299.07	48.25
Tato II	184.4	205.9	224.3	240.1	377.9	48.8
Naying	151.28	170.72	187.5	202.22	339.06	50.35
Pemashelpu	79.45	89.09	97.09	104.36	167.55	62.29
Kangtangshiri	99.55	111.64	121	131.27	212.73	46.8
Rapum	83	94	103.11	111.78	192.44	53.58
Pauk	123.5	137.17	148.83	159.5	257	48.05
Heo	146.44	163.37	178.19	191.06	303.31	48.28
Tato I	151.95	170.1	185.8	199.85	323.4	46.99
Hirit Korong	92.69	103.85	113.15	121.69	194.46	53.4
Siri Korong	77.67	87.11	95.22	102.11	164.89	61.93
Gameng	58.85	65.92	71.77	77.23	124.69	
Ringong	90.18	101.27	110.36	118.73	191.91	52.77
Pango	84.61	94.67	103.11	110.5	176.61	58.38
Mirak	94.91	106.18	115.91	124.91	201.18	52.78
Palsi	45.17	50.75	55.58	59.75	96.75	
Yamne Stage I	94.75	105.5	115.08	123.42	197.42	53.44
Yamne Stage II	117.67	131	142.62	152.57	240.1	49.01
Lower Yamne Stage I	107.79	120.32	131.11	140.58	224.16	53.68
Lower Yamne Stage II	98.92	110.52	120.32	129.28	209.36	57.47
Simang I	95.68	106.13	115.47	124.03	201.23	61.63
Simang II	92.43	102.74	111.52	119.39	187.52	54.78

Naying HEP is meeting the depth requirement even under 15% release scenario, however, the depth was reduced to 44% of the pre-project level and therefore next higher level (20%) is considered where depth is 50.35% of the pre-project depth. Gameng and Palsi don't meet the criteria even under 30% release scenario as pre-project depth is only 124.7 cm and 96.7 cm for Gameng and Palsi respectively. Reduction in flow width was also checked and reduced width was found to vary from 47.5% to 76.8% under the selected scenarios (not shown in Table), which is found to be adequate for all the projects. Current velocity is found to be high and is comparable with the pre-project current velocity.

Availability of flood pulses can be captured from daily/twice daily discharge data. Considering that daily flow time series carry much more information about flow variability and that monthly flow data can naturally be calculated from daily values, the daily flow time series are always the preferred data type for such type of analysis.

Hydro-developers who are in the process of survey and investigation have set up their own G&D sites at/near diversion sites. If 4-5 years period reliable data is available from such sites, potential releases in the monsoon can be assessed more realistically. Developers were contacted and self recorded G&D data was sought for review and analysis. Following projects developers have promptly responded and shared the data for the study, while others have not responded.

- Naying HEP on Siyom river
- Pemashelpu, Pauk, Heo and Tato I HEPs on Yargyap Chhu
- Simang I and Simang II HEPs on Simang river (June 2010-May 2012)
- Lower Yamne Stage I, Lower Yamne Stage II, Yamne Stage I and Yamne Stage II on Yamne River

Only data supplied for Naying, Pauk, Heo and Tato I HEPs was found reliable and consistent with respect to rainfall in the region and CWC approved series for corresponding projects. These data sets are for a period of more than five years; certain corrections were also applied during detailed consistency checks to ensure reliability of data.

For projects on Yargyap Chhu, analysis of corrected daily data show the peaks and flow available in the river during monsoon is adequate for these three projects i.e. Tato I, Heo and Pauk HEPs; even without any specific release restriction during monsoon. Base flow requirement is adequate at 15% release scenario in monsoon, where flow depth is 123.50 cm, 146.44 cm and 151.95 cm for Pauk, Heo and Tato I respectively. Therefore, for these projects, monsoon release of 15% is considered adequate. Whereas for Naying, daily-observed data did not show many flood peaks, in the absence of regulation on release of environment flow during monsoon. Base flow requirement for Naying HEP, can be met with 15% release in monsoon, however, 20% is considered adequate to ensure depth reduction is not less than 50% of pre-project depth and to ensure availability of flood peaks in river even during dry period.

5.3 Environmental Flow in Non-monsoon Non-Lean Season

Intervening months between monsoon and lean season or pre-monsoon and post monsoon period have their own characteristic flows which are equally important in a river's annual flow cycle. These flows also need to be retained in post project scenario as they define the fundamental difference between wet season and dry season base flows; and small pulses of higher flow, that occur in the these months. Depending upon water temperature, migratory species such as Mahseer and Trout start upward migration during pre-monsoon period and migrate back to lower reaches during post monsoon period.

Requirement for base flow in pre-monsoon and post monsoon period can be established from the modelling output in terms of flow required to meet the habitat requirement i.e. water width, depth and velocity. With a view to follow the natural flow regime, this should be higher than that of lean season and moderately less than that of monsoon therefore, needs to be separately assessed. Keeping it slightly lower than monsoon requirement, modelling output is assessed against the water depth of 65-70 cm for Trout Zone projects and 90-100 cm for Mahseer Zone

projects. Further, reduced flow depth and width of the river due to diversion of water should be of the order of 50% or more as compared to that of pre-project status.

Additionally, flow variability during this period or small floods needs to be captured in environment flow during this period as these are the indicators of migration for breeding/spawning. Such flood pulses should also be mimicked in post project scenario and this evaluation can best be done with daily flow data. Such data analysis is carried out on limited basis due to non-availability of reliable daily discharge data for most of the projects. In the absence of such data, higher release recommendations are made than what is assessed to meet base flow requirement to ensure flood pulses are spilled in the post project scenario.

Table 6 below gives flow depth in pre and post monsoon season for 15%, 20%, 25% and 30% release scenarios along with pre-project depth or 100% release scenario. Cells have been highlighted against each project, under different release scenarios, where the habitat is considered adequate to meet base flow requirement only in terms of flow depth. Highlighted cells are compared with the pre-project depth and last column gives the % of depth available with respect to pre-project depth. Naying HEP was meeting the depth requirement even under 15% release scenario, however, the depth was reduced to 45.1% of the pre-project level and therefore next higher level (20%) is considered where depth is 50.8% of the pre-project depth. Simang I is showing about 88.5 cm depth under 20% release scenario and 91.90 cm under 25% release scenario; later is 63.7% of the pre-project depth. Therefore, 25% release is considered to include the flood pulse requirement. Gameng and Palsi don't meet the criteria even under 30% release scenario as pre-project depth is only 101.77 cm and 78.58 cm for Gameng and Palsi respectively. Reduction in flow width was also checked and reduced width was found to vary from 47.4% to 70.0% under the selected scenarios (not shown in Table), which is found to be adequate for all the projects. Current velocity is found to be high and is comparable with the pre-project current velocity.

Table 6: Model Output for Different Release Scenario during Pre/Post Monsoon

Project	Average Flow Depth (cm)					% of Pre-project Depth (corresponding to highlighted release)
	15% release	20% release	25% release	30% release	Pre-project	
Hirong	118.43	132.07	144.07	154.43	245.21	48.3
Tato II	151.4	169	183.9	197.4	310.8	48.71
Naying	122.28	137.61	151	162.67	270.89	50.8
Pemashelpu	57.64	64.55	70.27	75.64	121.18	53.27
Kangtangshiri	71.55	80.27	88	94.73	153.18	52.4
Rapum	58.78	66.22	72.67	78.67	132.33	50.04
Pauk	91	101.5	110	117.83	185	49.19
Heo	107	119.31	130.13	139.56	221.19	48.37
Tato I	109.75	123	134.25	144.4	232.85	47.13
Hirit Korong	75.46	84.38	92.31	99.23	158.92	47.48
Siri Korong	63.22	70.89	77.33	83.33	134.22	52.82
Gameng	48.38	54	58.69	63.08	101.77	
Ringong	73.45	82.45	89.91	96.64	155.73	47.2
Pango	69.44	77.39	84.39	90.67	144	53.74
Mirak	77.18	86.45	94.45	101.64	164	47.06
Palsi	36.5	41.25	45	48.33	78.58	
Yamne Stage I	77.33	86.33	94	101.17	161	48.03
Yamne Stage II	96.76	107.76	117.33	125.62	197.76	48.93

Lower Yamne Stage I	88.11	98.63	107.32	115.26	182.79	53.96
Lower Yamne Stage II	81.32	90.68	98.68	105.92	169.44	58.24
Simang I	70.82	88.51	91.9	92.87	144.23	63.7
Simang II	67.26	76.3	83	88.91	138.78	48.46

Flood pulse analysis was carried out based on the corrected observed data for Pauk, Heo and Tato I which showed that adequate flood peaks higher than that of design discharge is available during pre and post monsoon period, even after the proportionate 15% releases are maintained. Therefore, for projects like Tato I, Heo and Pauk 15% of release will be adequate during non-monsoon and non-lean period.

6.0 DOWNSTREAM IMPACTS

6.1 Introduction

There are 44 HE projects proposed in Siang basin. During the monsoon period there will be significant discharge in Brahmaputra river. The peaking discharges of these hydroelectric projects are quite less in comparison to Brahmaputra discharge will hardly have any impact on Brahmaputra. Some impact in form of flow regulation can be expected during the Lean season peaking from these projects. In Siang basin, Siang Lower is the lowermost project on Siang river. The peaking discharge of Siang Lower HEP is about 4970 cumec. The other major projects are Siang Upper Stage-I and Siang Upper Stage-II with Siang Upper Stage-II proposed downstream of Siang Upper Stage-I. For Lean season peaking of 7 hours, the peaking discharge of Siang Upper Stage-II is about 4500 cumec. One of the major tributary of Siang river is Siyom River. The peaking discharge of about 709 cumec corresponding to Siyom Middle HE Project will be available from this river. Considering the reservoir of Siang lower is maintained at FRL during the lean season the net inflow should be equal to net outflow. Further, Siang Upper projects are proposed as storage projects and their peaking volume of water is more than the Siang Lower project due to more peaking hours. Hence, after Siang Upper HE projects in place the peaking discharge of 4970 cumec at Siang lower will be available for a longer duration.

The peaking release from the Siang Upper Stage-I will be re regulated from Siang Upper Stage-II. Hence, for the Siang upper projects, the peaking release from Siang Upper Stage-II only need to be considered for impact study. Hence For the downstream impact study the typical hourly Lean season releases during 24 hour from Siang Upper, Siang Lower and Siyom Middle HE Projects have been estimated. Accordingly, the impact study has been carried out for following three scenarios:

- Peaking and environmental flow releases from Siang Lower and Siyom Middle HE Projects without Siang Upper HE Projects in place
- Peaking and environmental flow releases from Siang Lower and Siyom Middle HE Projects with Siang Upper HE Projects in place
- Peaking and environmental flow releases from Siang Upper and Siyom Middle HE Projects without Siang Lower HE Project in place

Case-1: Impact study for peaking release from Siang Lower HE Project and Siyom Middle HE Project without Siang Upper HE Projects in place

In this scenario, it has been assumed that in the absence of Siang Upper HE projects the lean season peaking release from Siang Lower HE Project will be about 4970.30 cumec for 4 hours apart from the environmental release of 178.33 cumec for rest of 20 hours for each lean season

day. The lean season peaking release from Siyom Middle HE Project will be about 709.10 cumec for 4 hours apart from the environmental flow release of 20.78 cumec for rest of 20 hours.

Case-2: Impact study for peaking release from Siang Lower HE Project and Siyom Middle HE Project with Siang Upper HE projects in place

From Siang Upper projects, assuming a lean season peaking discharge of 4500 cumec, the volume of water released during 7 hours of peaking will be about 113.40 MCM. Similarly the volume of water released from Siyom Middle HE Project during 4 hours of peaking discharge of 709.10 cumec will be about 10.21MCM. Hence total 123.61 MCM water will be available at Siang lower HE Project which can be utilized at Siang Lower HE Project for about 7 hours peaking for its peaking discharge of 4970.30 cumec. In this case, hydro-dynamic routing has been carried out using lean season peaking release of about 4970.30 cumec for 7 hours apart from the environmental release of 178.33 cumec for rest of 17 hours from Siang Lower HE Project and Environmental release of 20.78 cumec from Siyom Middle HE Project.

Case-3: Impact study for peaking release from Siang Upper HE Projects and Siyom Middle HE Project without Siang Lower HE Project in place

In this case, hydro-dynamic routing has been carried out using lean season peaking release of 4500 cumec for 7 hours apart from the environmental release of 171.13 cumec for rest of 17 hours for each from Siang Upper HE Project and lean season peaking release of 709.10 cumec for 4 hours apart from the environmental flow release of 20.78 cumec for rest of 20 hours from Siyom Middle HE Project.

Hydro-dynamic modelling has been carried out on MIKE 11 model which is simulating steady, quasi-unsteady and unsteady flows in a network of open channels. Model has been set up to 484 km downstream of Siang Lower H. E. Project i.e. Pandu G&D site (Guwahati) with the help of surveyed river cross sections. The chainage of some of the important locations from Siang Lower HE Project as per MIKE11 model set up where discharge pattern and water level has been estimated are as follows:

D'Ering Memorial WLS - 20140 m to 33260 m

Dibrugarh - 102020 m

Bokaghat (near Kaziranga National Park) -269280 m

Tezpur - 355460 m

Guwahati - 462580 m

6.2 Flow Simulation Results in Natural Condition of River & Different Scenarios considered

In the natural condition of river and different cases as described above, the water levels at different locations of the study reach as simulated are given in following tables.

Water level at different locations in natural condition of river for average Lean season discharge

Place	Chainage from Siang Lower HEP (m)	Average non-monsoon discharge (cumec)	Bed level of river (m)	Simulated water level (m)
D'Ering Memorial WLS	20140	1428	145.67	150.09
D'Ering Memorial WLS	25090	1428	138.19	144.29
D'Ering Memorial WLS	33260	1428	137.66	140.51

Dibrugarh	102020	2641	92.38	96.68
Bokaghat-Kaziranga	269280	2951	86.77	94.46
Tezpur	355460	4475	67.22	74.21
Guwahati	462580	5377	30.96	39.89

Stabilized water levels computed through simulation for peaking release from Siang Lower HEP and Siyom middle HEP without Siang Upper HEPs in place

Time	At ch 20140 m of Siang river near D'Ering Memorial WLS	At ch 25090 m of Siang river near D'Ering Memorial WLS	At ch 33260 m of Siang river near D'Ering Memorial WLS	Near Dibrugarh	Near Bokaghat	Near Tezpur	Near Guwahati
[hr]	[cumec]	[cumec]	[cumec]	[m]	[m]	[m]	[m]
1	148.44	141.71	139.10	96.50	94.22	74.02	39.70
2	148.59	141.98	139.25	96.56	94.22	74.02	39.70
3	148.52	142.13	139.42	96.60	94.22	74.02	39.70
4	148.37	142.15	139.53	96.64	94.22	74.02	39.70
5	148.21	142.09	139.56	96.65	94.22	74.02	39.70
6	148.10	142.00	139.53	96.64	94.22	74.02	39.70
7	147.99	141.91	139.46	96.62	94.22	74.02	39.70
8	147.90	141.82	139.40	96.59	94.22	74.02	39.70
9	147.83	141.74	139.34	96.56	94.22	74.01	39.70
10	147.77	141.67	139.29	96.52	94.22	74.02	39.70
11	148.26	141.37	139.36	96.48	94.23	74.02	39.71
12	150.05	141.93	139.44	96.44	94.23	74.03	39.71
13	152.70	145.18	140.16	96.41	94.23	74.03	39.71
14	153.09	147.79	141.56	96.38	94.23	74.03	39.71
15	153.03	147.93	142.38	96.35	94.21	74.02	39.69
16	151.95	147.04	142.47	96.33	94.21	74.01	39.69
17	150.37	145.71	141.95	96.32	94.21	74.01	39.69
18	149.01	144.15	140.98	96.31	94.21	74.00	39.69
19	148.20	142.99	140.10	96.31	94.22	74.01	39.69
20	147.77	142.29	139.58	96.31	94.22	74.01	39.69
21	147.54	141.84	139.30	96.33	94.22	74.01	39.69
22	147.51	141.57	139.13	96.35	94.22	74.01	39.70
23	147.67	141.46	139.03	96.40	94.22	74.02	39.70
24	148.01	141.51	139.01	96.45	94.22	74.02	39.70

Stabilized water levels computed through simulation for peaking release from Siang Lower HEP and Siyom middle HEP with Siang Upper HEPs in place

Time	At ch 20140 m of Siang river near D'Ering Memorial WLS	At ch 25090 m of Siang river near D'Ering Memorial WLS	At ch 33260 m of Siang river near D'Ering Memorial WLS	Near Dibrugarh	Near Bokaghat	Near Tezpur	Near Guwahati
[hr]	[cumec]	[cumec]	[cumec]	[m]	[m]	[m]	[m]
1	147.19	141.17	138.93	96.58	94.59	74.27	39.95
2	147.20	141.09	138.90	96.58	94.60	74.27	39.95
3	147.21	141.06	138.90	96.58	94.60	74.28	39.95
4	147.22	141.04	138.91	96.61	94.60	74.28	39.96
5	147.23	141.04	138.93	96.65	94.60	74.28	39.96
6	147.23	141.04	138.95	96.71	94.60	74.29	39.96
7	147.24	141.04	138.96	96.79	94.59	74.29	39.96
8	147.24	141.04	138.97	96.88	94.59	74.29	39.96
9	147.78	140.85	139.05	96.96	94.58	74.29	39.96
10	149.92	141.4	139.13	97.03	94.58	74.29	39.96
11	152.69	144.72	139.96	97.06	94.58	74.29	39.96
12	153.08	147.72	141.42	97.07	94.58	74.29	39.96

13	153.09	148.05	142.34	97.05	94.58	74.29	39.97
14	153.09	147.93	142.61	97.01	94.58	74.29	39.97
15	153.09	147.90	142.51	96.97	94.59	74.28	39.97
16	153.02	147.85	142.29	96.92	94.59	74.29	39.98
17	151.95	147.09	142.05	96.87	94.59	74.30	39.98
18	150.36	145.77	141.55	96.82	94.59	74.30	39.98
19	148.99	144.16	140.77	96.76	94.59	74.30	39.98
20	148.18	142.98	140.06	96.72	94.59	74.29	39.98
21	147.73	142.28	139.59	96.68	94.59	74.29	39.98
22	147.45	141.82	139.32	96.64	94.59	74.29	39.97
23	147.29	141.51	139.14	96.62	94.59	74.29	39.96
24	147.21	141.30	139.01	96.59	94.59	74.28	39.96

Stabilized water levels computed through simulation for peaking release from Siang Upper HEPs and Siyom middle HEP without Siang Lower HEP in place

Time	At ch 20140 m of Siang river near D'Ering Memorial WLS	At ch 25090 m of Siang river near D'Ering Memorial WLS	At ch 33260 m of Siang river near D'Ering Memorial WLS	Near Dibrugarh	Near Bokaghat	Near Tezpur	Near Guwahati
[hr]	[cumec]	[cumec]	[cumec]	[m]	[m]	[m]	[m]
1	147.60	141.35	139.15	96.6	94.56	74.28	39.95
2	147.61	141.43	139.43	96.61	94.56	74.28	39.95
3	148.64	143.01	140.46	96.62	94.56	74.28	39.95
4	150.67	145.27	141.47	96.65	94.56	74.28	39.95
5	151.91	146.61	142.04	96.69	94.56	74.28	39.95
6	152.53	147.23	142.25	96.74	94.56	74.28	39.95
7	152.75	147.36	142.17	96.81	94.56	74.28	39.95
8	152.73	147.13	141.9	96.87	94.56	74.28	39.95
9	152.42	146.70	141.55	96.93	94.57	74.28	39.95
10	151.92	146.14	141.19	96.96	94.57	74.28	39.95
11	151.31	145.51	140.85	96.97	94.57	74.28	39.95
12	150.73	144.92	140.59	96.97	94.57	74.28	39.95
13	150.27	144.38	140.36	96.95	94.57	74.28	39.95
14	149.87	143.87	140.15	96.92	94.57	74.28	39.95
15	149.52	143.41	139.95	96.88	94.57	74.28	39.95
16	149.25	143.02	139.79	96.85	94.57	74.28	39.95
17	149.07	142.71	139.67	96.81	94.57	74.28	39.95
18	148.88	142.47	139.56	96.77	94.57	74.28	39.95
19	148.58	142.23	139.46	96.74	94.57	74.28	39.95
20	148.31	142.02	139.38	96.71	94.57	74.28	39.95
21	148.12	141.84	139.31	96.68	94.57	74.28	39.95
22	147.96	141.69	139.25	96.65	94.57	74.28	39.95
23	147.82	141.56	139.21	96.63	94.57	74.28	39.95
24	147.70	141.44	139.17	96.61	94.57	74.28	39.95

6.3 Comparison of Discharge and Water Level Pattern of Different Simulations

A comparison of discharge and water level pattern at salient locations for different simulations is given in following table.

Comparison of discharge and water level pattern at salient location for different simulations

D'Ering Wildlife Sanctuary located about 25 km d/s of Siang Lower HE Project (River bed EL 138.19 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	1428
Water level in natural condition of river (m)	144.29
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (cumec)	250-5000
Water level pattern due to peaking release from HE Projects in Siang basin	141.37-147.93

without Siang Upper HE projects in place (m)	
Discharge pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (cumec)	200-5000
Water level pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (m)	140.85-148.05
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (cumec)	248-4276
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (m)	141.35-147.36
Dibrugarh located about 102 km d/s of Siang Lower HE Project (River bed EL 92.68 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	2641
Water level in natural condition of river (m)	96.68
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (cumec)	1615-3338
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (m)	96.31-96.65
Discharge pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (cumec)	1529-4581
Water level pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (m)	96.58-97.07
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (cumec)	1791-4025
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (m)	96.60-96.97
Bokaghat (Kaziranga) located about 269 km d/s of Siang Lower HE Project (River bed EL 86.77 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	2951
Water level in natural condition of river (m)	94.46
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (cumec)	2622-2661
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (m)	94.21-94.23
Discharge pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (cumec)	3097-3147
Water level pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (m)	94.58-94.60
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (cumec)	3088-3098
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (m)	94.56-94.57
Tezpur located about 355 km d/s of Siang Lower HE Project (River bed EL 67.22 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	4475
Water level in natural condition of river (m)	74.21
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (cumec)	4138-4189
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (m)	74.00-74.03
Discharge pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (cumec)	4616-4675
Water level pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (cumec)	74.27-74.30
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (cumec)	4616-4618
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (m)	74.28
Guwahati located about 462 km d/s of Siang Lower HE Project (River bed EL 30.96 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	5377
Water level in natural condition of river (m)	39.89
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (cumec)	5042-5097
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (cumec)	39.69-39.71

Discharge pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (cumec)	5511-5586
Water level pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (m)	39.95-39.98
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (cumec)	5519
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (m)	39.95

6.4 Conclusions

It can be concluded that in general the impact of peaking of hydroelectric projects of Siang basin on Brahmaputra river is almost NIL in terms of discharge and water level fluctuations from Bokaghat up to Guwahati. This is due to very wide reach and large discharge carrying capacity of Brahmaputra river. In this reach of the Brahmaputra river the discharge and water level pattern will be approximately close to the natural condition discharge and water level pattern. In absence of Siang Upper HE projects the Lean season peaking discharge releases of projects in Siang basin ultimately being re-regulated by Siang lower HE Project will result a stabilized discharge/water level series from Bokaghat onward resulting a discharge of about 2600 cumec at Bokaghat with water level about at EL 94.20 m, and a discharge of about 5000 cumec at Guwahati with water level about at EL 39.70 m. The stabilized discharge at Bokaghat with Siang Upper HE projects in place will be of the order of 3300 cumec with water level about at EL 94.5 m, while at Guwahati the same will be about 5700 cumec with water level at EL 40.10 m. For the peaking releases from Siang Upper and Siyom Middle HE Project without Siang Lower HE project in place, the stabilized discharge at Bokaghat will be of the order of 3090 cumec with water level about at EL 94.5 m, while at Guwahati the same will be about 5500 cumec with water level at EL 39.95 m. All the above patterns are approximately same to the natural condition discharge and water level pattern.

Further, from Siang lower HE Project location at Bodak and up to Dibrugarh there will be daily fluctuations in discharge and water level due to peaking. These fluctuations will be of the order of 250 to 5000 cumec with water level variation from EL 141.46-147.93 m near D'Ering Wildlife sanctuary and 1600-3300 cumec with water level variation from EL 96.31-96.65 m near Dibrugarh, without the upper Siang HE Project in place. The same with Siang Upper HE projects in place will be of the order of 200 to 5000 cumec with water level variation from EL 140.05-148.05 m near D'Ering Memorial WLS and 1530-4580 cumec with water level variation from EL 96.58-97.07 m near Dibrugarh. For the peaking releases from Siang upper and Siyom Middle HE Projects without Siang lower HE Project in place the discharge and water level fluctuations will be of the order of 250 to 4300 cumec with water level variation from EL 141.4-147.4 m near D'Ering Wildlife sanctuary and 1800-4000 cumec with water level variation from EL 96.60-96.97 m near Dibrugarh.

7.0 CUMULATIVE IMPACT ASSESSMENT

The objective of cumulative environment impact assessment is to assess stress/ load due to hydropower development in the basin and envisage a broad framework of environmental action plan to mitigate the adverse impacts.

7.1 Impacts on Terrestrial Ecology

Cumulative impacts on terrestrial ecology have been discussed under the following heads:

- Direct Forest Cover Loss

- Forest Cover Loss due to Nibbling effect/ loss
- Impact of Spatial and Temporal crowding
- Impact on Biodiversity Values
- Impacts on Wildlife
- Impact on RET & Endemic Species
- Loss of Riparian Habitats

In order to make a comparative assessment of biodiversity richness of each sub-basin, percentage richness of each of the 15 biodiversity components (listed in Table 3) is calculated w.r.t. to the biodiversity value of that component in the entire Siang basin. These values were added up to rank the sub-basins according to biodiversity richness and the same is given in table below.

Sub-basin	Rank
Yamne	1
Siang Sub-basin-II	2
Siang Sub-basin-I	2
Siyom Sub-basin-I	3
Hirit	4
Siang Sub-basin-III	5
Siang Sub-basin-IV	6
Siyom Sub-basin-II	7
Simang	8
Yargyap	9
Siyom Sub-basin-III	10

As can be seen from the above ranking, Yamne ranks at number one in terms of total biodiversity values i.e. the richest basin in terms of biodiversity values, followed closely by Siang sub-basin-I and Siang sub-basin-II (both have similar values). Thereafter these are followed by Siyom sub-basin-I, Hirit, and Siang sub-basin-III.

Yamne sub-basin harbours 38 plant species endemic to north-east, out of 55 reported from entire Arunachal Pradesh. More than 95% of sub-basin area is under forests. Most of its biodiversity is found in its upper reaches in and around village Mariyang whereas lower catchment is comparatively degraded due to *jhumming*, therefore activities in its upper catchment (Yamne Stage I HEP) need to be taken up with a caution taking into consideration its biodiversity richness.

Next in ranking are Sang sub basin I and II, where three major projects i.e. Siang Lower, Siang Upper Stage-II and Siang Upper Stage-I are planned. These three projects alone would involve direct loss of 18174 ha of forest, which is about 76% of total forestland required for all 44 projects in the basin. In addition 208.5 km of Siang river will be affected due to formation of reservoir of these projects. Reservoir spread in Siyom, Simang and other tributaries is in addition to this. Other projects falling in these biodiversity rich sub-basins are Yemsing, Sipit and Nyikong. These projects together have the potential of seriously impacting the biodiversity in these rich areas.

Siyom sub basin I and Hirit sub basin are also very rich in terms of overall biodiversity values. Impacts are more pronounced in Hirit sub basin, which happens to be a suitable habitat for migratory fishes like mahseer, and *Labeo pangusia*. The upper catchment of Hirit sub-basin comprises of Yorde Rabe Supse WLS where forests are in pristine condition due to its remoteness.

Once the projects are taken up in this sub-basin it will provide access to otherwise inaccessible areas leading to degradation of its flora and fauna.

7.2 Impacts on Aquatic Ecology

The impacts on aquatic ecology happen in following ways:

- Reduced flows in downstream stretches
- Altered flow regime in different seasons viz. lean, monsoon, pre and post monsoon
- Discontinuity of river flow i.e. conversion of free flowing river into alternating small stretches of free flowing lotic ecosystem to lentic ecosystems of reservoirs and deprived stretches of river (run-of-the-river with long head race tunnels).
- Submergence
 - Alteration of river system from lotic to lentic environment
 - Loss of forest land
 - Alteration of landscape/aesthetics of area
- Alteration of river flow pattern downstream resulting due to variation in energy generation requirements in different periods.
 - Alteration of local ecosystem/ increased moisture conditions
 - Disruption of migration behaviour of fishes and other migratory animals
 - Health risks/Increased incidence/ proneness to unknown diseases
 - Downstream flooding due to sudden peaking

As discussed above, planned 44 projects in Siang basin will affect 513.8 km of the river length - 353 km will be converted to reservoirs and 160.8 km will be travelling through tunnels leading to significant alteration of free flowing fresh water ecosystem of Siang basin. Projects with lower generation capacity or smaller projects are affecting more river length per MW. Top four projects affecting more than 400 m of river stretch per MW are all less than 14 MW. Therefore, there is a need to plan the development in the basin in such a manner so that direct impact on the aquatic ecology due to altering/diminishing the river stretches can be reduced/ minimized.

7.3 Downstream Impacts

A cumulative impact study has been carried out to quantify the downstream impacts due to peaking power generation by the projects on main Siang River viz. Siang Lower HEP and Siang Upper Stage I and Stage II HEPs and also by Siyom Middle HEP, which is a large project planned on Siyom river upstream of confluence of Siyom with Siang river. Hydrodynamic routing was carried out using MIKE 11 model, where different combinations of operations were simulated and flow variation was studied in the extended downstream reach upto Guwahati.

Downstream impacts include loss of fisheries; changes in *beel* (wetland) ecology in the floodplains; impacts on agriculture on the chapories (riverine islands and tracts); impacts on various other livelihoods due to the blockage of rivers by dams (e.g. driftwood collection, sand and gravel mining); increased flood vulnerability due to massive boulder extraction from river beds for dam construction.

Based on the modeling exercise (refer Chapter 10), peaking releases from projects on main Siang river have been studied to understand the change in water level at D'Ering Memorial WLS on daily basis in lean season and also up to Guwahati in Assam. Increase in water level on three different locations in D'Ering Memorial WLS is given below.

Location	Variation in Levels (m)		
	Case 1	Case 2	Case 3
D'Ering Memorial WLS (20 Km d/s)	5.58	5.90	5.15
D'Ering Memorial WLS (20 Km d/s)	6.56	7.20	6.01
D'Ering Memorial WLS (20 Km d/s)	3.46	3.71	3.10
Dibrugarh	0.34	0.49	0.37
Bokaghat	0.02	0.02	0.01
Tezpur	0.03	0.03	0.00
Guwahati	0.02	0.03	0.00

Case 1: Operation of Siang Lower and Siyom Middle without Siang Upper

Case 2: Operation of Siang Lower and Siyom Middle with Siang Upper

Case 3: Operation of Siang Upper and Siyom Middle without Siang Lower

It can be seen from the above table, peaking power generation by projects on main Siang River in lean season will result in substantial diurnal variation of water level in D'Ering Memorial WLS. Life cycle of avian and aquatic flora and fauna of D'Ering Memorial WLS is closely linked to floods and dry periods and with alteration of their habitat due to peaking discharge, there will be serious impact on entire D'Ering Memorial Wildlife sanctuary. Further, downstream in Brahmaputra river, there will be small diurnal variation in levels up to Dibrugarh (102 Km downstream from Siang Lower HEP), however, beyond that variation is very small and almost nil at Guwahati. Therefore, downstream impacts due to peaking power generation by various projects on Siang river are not observed at Guwahati.

7.4 Construction Phase Impacts

Construction phase impacts are generally dealt in detail during individual project EIA study with respect to local environment setting. For cumulative environment impact assessment, it is important to visualize the cumulative impacts of several projects under construction, simultaneously. 44 hydropower projects are considered as part of this cumulative EIA study of Siang basin and none of the projects have started construction. Many of the projects are at various stages of survey and investigation and some are still in preliminary stages without any investigation work on ground. It is expected that it may take another few years before a medium to large size project will start construction in the basin, followed by another and so on. Thereafter there will be a peak period when several projects will be under construction at the same time. This construction phase might last for 10-15 years before large part of construction work will be over in the basin and many of the projects will be under operation.

Though environmental impacts attributed to construction phase of hydropower projects are considered temporary in nature, lasting mainly during the construction phase and often do not extend much beyond the construction period, their impacts however need to be minimised during this phase. The construction phase of Hydroelectric Projects is fairly large; therefore these impacts are required to be managed by strict implementation of pollution control and environment management measures.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Recommendations are made under three major heads, keeping in view the outcome of the study as per scope of work, and are discussed in the ensuing text.

8.1 Sustainable and Optimal Ways of Hydropower Development

8.1.1 Preclusion of projects

Extensive exploitation of the basins resources have been planned by way of developing hydropower projects at almost all possible locations in the basin. For sustainable and optimal ways of hydropower development in the basin, projects which are not found to be ecological viable, are located in highly fragile areas, located on tributaries but are restricting the natural of the main channels, etc. have been recommended to be dropped. These are listed in Table 7. It can be seen from the table that by dropping 15 projects, only 473.5 MW of installed capacity will be sacrificed as against the total installed capacity of 18293 MW; which is about 2.6% reduction but would save about 59.5 Km of the river length in ecologically sensitive area. This would mitigate not only direct impact on forest and river reach but also substantial indirect impact on ecologically sensitive surroundings and would also help in preserving the habitat of main channels.

Table 7: List of Projects Recommended to be precluded

Sl. No.	Name of Project	Capacity (MW)	River/ Tributary	Main River	River Length Saved (Km)	Forest Area Saved (Ha)
1	Jarong	90	Siyom	Siang	5.1	65
2	Sangoshi	12.5	Sangoshi	Yargyap	0.7	10
3	Sae Chhu	15	Sae Chhu	Yargyap	3.6	10
4	Sittin	24	Sittin	Siyom	1.2	15
5	Kaying	14	Pitgong	Siyom	5.7	10
6	Hirit	9	Hirit	Siyom	4	5
7	Hirit Korong	42	Hirit	Siyom	2.7	20
8	Soying Korong	48	Soying Korong	Hirit	2.5	45
9	Siri Korong	58	Siri Korong	Hirit	3.1	42
10	Sibu	4	Sibu	Hirit	2.1	5
11	Nyikong	13	Nyikong	Siang	8.7	5
12	Palsi	24	Palsi	Siang	5.8	20
13	Sipit Upper	45	Sipit	Siang	1.5	32
14	Gameng	37	Sike	Siyom	4	25
15	Yemsing	38	Yembung	Siang	8.8	25
Total		473.5			59.5	334

It is strongly recommended that after dropping these projects, these river reaches should be kept free. These projects should not be re-allotted by altering their features, locations, names, etc. Also on other free stretches/tributaries no further hydropower projects should be planned/allotted in the entire Siang basin even if they are small (less than 25 MW) and do not fall under the purview of EIA notification.

Environmental impacts are not directly proportion to installed capacity of the project; they are to be assessed with respect to project location, surrounding and project features. Therefore, it is recommended that Government of India should review the matter and consider bringing smaller i.e. less than 25 MW hydropower projects also under the purview of the EIA notification so that their impacts are adequately addressed and mitigated/managed.

8.1.2 Modification of Projects' Configurations

On main Siyom River, four projects in cascade taking about 55 Km of the river stretch will impact the river ecosystem. There should be at least 1 Km of free flowing river stretch between adjacent

projects when river can flow in natural conditions with full flow in all the seasons to ensure habitat connectivity and preventing landscape fragmentation. All these four projects viz. Hiron, Tato II, Naying and Siyom Middle are in advance stages of Survey and Investigation.

Instead of dropping a project and increase the inter-project riverine reach, it is recommended that FRL of three projects viz. Tato II, Naying and Siyom Middle should be slightly reduced so that free flowing river stretches of 1 Km can be maintained between FRL and TWL of these four projects in cascade.

8.1.3 Development of Projects in Proximity to Protected Areas

Simang -II, Gameng, Siyom Middle HEPs are located within 10 km radius of Mouling National Park. Siang Upper Stage - I is a large project and is located at a distance, little more than 10 km radius of Mouling National Park. Tagurshit-II HEPs on Tagurshit Nala and Pitgong on Pitgong Nala are located within 10 km radius of Yordi Rabe Supse Wildlife sanctuary. During individual project assessment, references has to be taken from biodiversity assessment of these project areas as is done in this report so that comprehensive management plans can be prepared for impact mitigation.

8.1.4 Integrated Biodiversity Conservation Plan

To conserve the rich biodiversity of the basin, it is recommended that the State Wildlife Division under Department of Forests prepares an Integrated Biodiversity Conservation plan for the Siang basin rather than having individual project based conservation plans in consultation with State Forest Research Institute, Itanagar and Wildlife Institute of India, Dehradun. The database on biodiversity generated under this basin study should be maintained at SFRI, Itanagar which need to be further updated continuously for use by the stakeholders and policy makers for taking informed decisions.

8.2 Environmental Flows

There are 44 planned hydropower projects in Siang basin. Three planned projects on Siang River viz. Siang Upper Stage I and II and Siang Lower HEPs, are in cascade without any free flowing stretch between adjacent projects. These three projects and Siyom Middle HEP on Siyom River are planned as dam toe projects with large storage reservoirs; without any significant intermediate stretch. These projects are designed to run for 24 hours at full capacity for large part of monsoon. During non-monsoon months, water will not be sufficient to do peaking round the clock; therefore during this period to ensure that intermediate stretch, if any, and downstream river reach is not dry for large part of the day, it is recommended that one turbine should be running round the clock during non-monsoon period.

Dam toe projects, depending upon the project layout, can have significant river reach before the tail water outfall locations, which can run dry if no provisions are made for release of environment flow. Therefore, depending upon the project layout environment flow release arrangements are to be made so that water is released immediate downstream of the dam/plunge pool either through the turbine or separately as environment flow.

Out of remaining 40 projects, 15 have been recommended to be dropped. Rego HEP is a tailrace development scheme linked to Kangtangshiri HEP, therefore, does not require specific flow release recommendation. Environmental flow release recommendations for remaining 24 projects

have been made in the Table 8 below based on the detailed assessment carried out and discussed in Chapter 9, “Environmental Flow”.

Table 8: Environmental Flow release Recommendation

Sl. No.	Name of Project	Capacity (MW)	Lean Season	Pre and Post Monsoon	Monsoon
1	Naying	1000	20%	20%	20%
2	Tato-II	700	20%	20%	20%
3	Hirong	500	20%	20%	20%
4	Taiyong	56	20%	20%	20%
5	Tato-I	186	20%	15%	15%
6	Heo	240	20%	15%	15%
7	Pauk	145	20%	15%	15%
8	Rapum	66	25%	25%	30%
9	Kangtangshiri	80	20%	20%	20%
10	Pema Shelpu	90	25%	25%	30%
11	Tagurshit	84	20%	25%	30%
12	Tagurshit Stage-II	27.5	20%	25%	30%
13	Pitgong	14	20%	25%	30%
14	Simang-I	67	20%	25%	30%
15	Simang-II	66	20%	20%	25%
16	Pango/ Minnying	96	20%	20%	30%
17	Mirak	141	20%	20%	25%
18	Sippi	96	20%	20%	25%
19	Ringong	150	20%	20%	25%
20	Jidu	92	20%	25%	30%
21	Yamne Stage-I	135	20%	20%	25%
22	Yamne Stage-II	96	20%	20%	20%
23	Lower Yamne Stage - I	75	20%	25%	25%
24	Lower Yamne Stage - II	87	20%	25%	30%
25	Rego HEP	80	No specific recommendation - Tailrace development scheme with Kangtangshiri		
26	Siang Upper Stage-I	6000	Directly draining into lower projects reservoir, without any free flowing stretch		
27	Siang Upper Stage-II	3750			
28	Siang Lower	2700	Dam toe projects needs to run one unit continuously through out the year*		
29	Siyom Middle	1000			

*Downstream impacts in lean season are studied, keeping in view the lean season environment flow and peaking discharge available (chapter 10); running of one unit continuously by Siang Lower HEP and Siyom Middle HEP will slightly alter the scenario resulting in minor variation in levels in the downstream reaches. Such scenarios were also simulated and results are shown in Annexure IX.

8.3 Downstream Impacts

Downstream impacts extended up to Guwahati of three major projects on Siang river viz. Siang Upper Stage I, Siang Upper Stage II and Siang Lower; and also Siyom Middle on Siyom river have been assessed by Hydrodynamic routing carried out using Mike 11 model for different combinations of operations of these projects.

To mitigate the peaking impacts with respect to diurnal flooding at D’Ering Memorial WLS in lean season, mitigation measures need to be studied in detail separately including their technical and financial viability. Among other alternatives, a compensation basin can be considered, which is a way of reducing the impact of peaking. It is generally implemented directly downstream of the turbine outlet(s). The water is temporarily stored in the basin and then released to the river by a guided system, respecting ecologically defined operation rules. It is recommended that a

comprehensive study be conducted to explore various alternatives and work out techno-economic feasibility for regulation of the peaking discharge downstream of Lower Siang HEP.

As discussed earlier, Siang basin I and II have rich biodiversity and three large projects viz. Siang Lower HEP (2700 MW), Siang Upper Stage II (3750 MW) and Siang Upper Stage I (6000 MW) are planned to cover almost entire length of Siang river in India. 208.5 Km of the Siang river will be converted into one continuous reservoir as all the three projects (Siang Upper Stage I and II and Lower Siang HEPs) are planned back to back without any free flowing intermediate river stretch.

On the other hand, the large storage dams on Siang river are considered essential for flood moderation in Assam during monsoon and contributing to the flow in Brahmaputra in lean season. During the monsoon season (June-October), floods are a common occurrence in Brahmaputra and its tributaries almost every year and hit more than one lakh people inundating human habitations and farmland in several districts of Assam and Arunachal Pradesh. A substantial storage in Siang, is being considered for overall flood management of Brahmaputra and other downstream non-monsoon requirements.

CHAPTER-1

INTRODUCTION

1.1 BACKGROUND

Central Water Commission (CWC), Government of India has undertaken the task of conducting Environmental Impact Assessment (EIA) Study for Siang river sub basin in Brahmaputra river valley with an objective to assess the cumulative impacts of hydropower development in the basin. RS Envirolink Technologies Pvt. Ltd., Gurgaon (RSET) was awarded the study based on techno-commercial bidding. Expert Appraisal Committee (EAC) for River Valley and Hydroelectric Projects of MoEF has provided the Terms of Reference (TOR) for the study. The study initiated during December 2011 involved extensive field data collection in different seasons to establish baseline status, data analysis and cumulative impact assessment, followed by recommendations for long term sustainable hydropower development in the basin.

The Siang sub-basin, the study area, has been referred to as Siang basin in the report and it is significant in terms of hydropower power potential as it has over 18000 MW of power potential, which is planned to be harnessed by setting up about 44 hydropower projects spread throughout the basin. Department of Hydro Power Development, Government of Arunachal Pradesh has allotted 39 projects, which are at various stages of survey and investigation. Five projects are yet to be allotted which includes two major projects viz. Siang Upper Stage I (6000 MW) and Siang Upper Stage II (3750 MW), which are in investigation stage.

Such a large-scale development expected to take place over a period of next 10-15 years in otherwise pristine area, can cause serious environmental impacts and will exert tremendous pressure on carrying capacity of Siang basin. EIA notification of September 2006, issued under Environmental Protection Act, 1986, has the provision of evaluating the impacts of individual projects of capacities 25 MW or more by SEAC/EAC before issuing environmental clearances. However, in a situation in Siang basin where several projects are planned in cascade utilising the same natural resource; assessment of cumulative impacts and carrying capacity study of the entire basin including downstream impacts up to Guwahati in Assam is essential to plan development in environmental friendly manner and to mitigate and manage the impact comprehensively. Therefore, the present study “Cumulative Impact and Carrying Capacity Study of Siang sub-basin including Downstream Impacts” has been prepared with a view to provide optimum support for various natural processes and allowing sustainable activities within carrying capacity of Siang sub-basin.

The study covers the following:

- Inventorisation and analysis of the existing resource base
- Determination of regional ecological fragility/sensitivity
- Review of hydropower development plans
- Evaluation of cumulative impacts on various facets of environment due to hydropower development
- Broad framework of environmental action plan to mitigate the adverse impacts on environment, in the form of:
 - Preclusion of an activity
 - Modification in the planned activity
 - Implementation of set of measures for amelioration of adverse impacts.

The basin study is a step beyond the EIA, as it incorporates an integrated approach to assess the impacts due to various developmental projects.

1.2 SCOPE OF WORK

The scope of work has been defined by CWC based on Terms of Reference provided by EAC and same was followed for the study. The study area is entire Siang Basin in India up to the confluence of Siang, Dibang and Lohit to form Brahmaputra.

Refer **Annexure-I** in this volume for detailed scope of work for the study.

1.3 OUTCOME OF THE STUDY

The key outcomes of the study are:

- Sustainable and optimal ways of hydropower development of Siang river, keeping in view of the carrying capacity and environmental setting of the basin
- Requirement of environmental flow throughout the year with actual flow, depth and velocity at different level
- Downstream impacts on Assam up to Guwahati due to hydropower development in Siang basin in Arunachal Pradesh

CHAPTER-2

BASIN CHARACTERISTICS

2.1 INTRODUCTION

Arunachal Pradesh, the land first to greet sunrise in the country, is a thinly populated hilly terrain on the extreme northeast part of India. It is situated between latitude 26° 40'N and 29° 25'N and longitude 91° 35'E and 97° 25'E. The state shares international borders with Bhutan in west, China in north and northeast and Myanmar (Burma) in east; and interstate borders with Nagaland in southwest and Assam in south. It covers an area of about 83,743 sq km extending along south slope of Eastern Himalaya and the western slope of the Patkoi hills around the Brahmaputra Valley. In terms of area, Arunachal Pradesh is the largest state in the North Eastern Region.

The state was known as North-East-Frontier Agency (NEFA) since British days. It was awarded the status of Union Territory on 21st January, 1972 when it was renamed as Arunachal Pradesh. Subsequently, on 20th February 1987 it was elevated to the status of a full-fledged state. The capital of the state is Itanagar, which falls in Papum Pare district. The state is administratively divided into 17 districts viz. Tawang, West Kameng, East Kameng, Papum Pare, Lower Subansiri, Kurung Kumey, Upper Subansiri, West Siang, East Siang, Upper Siang, Lower Dibang Valley, Dibang Valley, Lohit, Anjaw, Changlang, Tirap and newly created Longding district. The Siang basin is covered in three districts viz. Upper Siang, West Siang and East Siang districts.

Siang river originates as Tsangpo river in Tibet (see **Figure 2.1**) and is the largest river traversing through Arunachal Pradesh. There are six major river sub-basins in Arunachal Pradesh viz. Kameng, Subansiri, Siang (Dihang), Dibang, Lohit and Tirap with large number of their tributaries drain the waters of vast catchment area into the mighty Brahmaputra (see **Figure 2.2**).

2.2 BRAHMAPUTRA RIVER

Siang river originates as Tsangpo river from Mansarovar near Mt. Kailash in the Himalaya, flows via Tibet, China, India and Bangladesh into Bay of Bengal. The total length of the river is 2900 km. The three headstreams that arise there are the Kubi, the Angsi, and the Chemayungdung. From its source the river runs for nearly 1,100 km in a generally easterly direction between the main range of the Himalaya to the south and the Mt. Kailash Range to the north. Throughout its upper course the river is commonly known as the Tsangpo; it is also known by its Chinese name (Yarlung Zangbo) and by several other local Tibetan names.

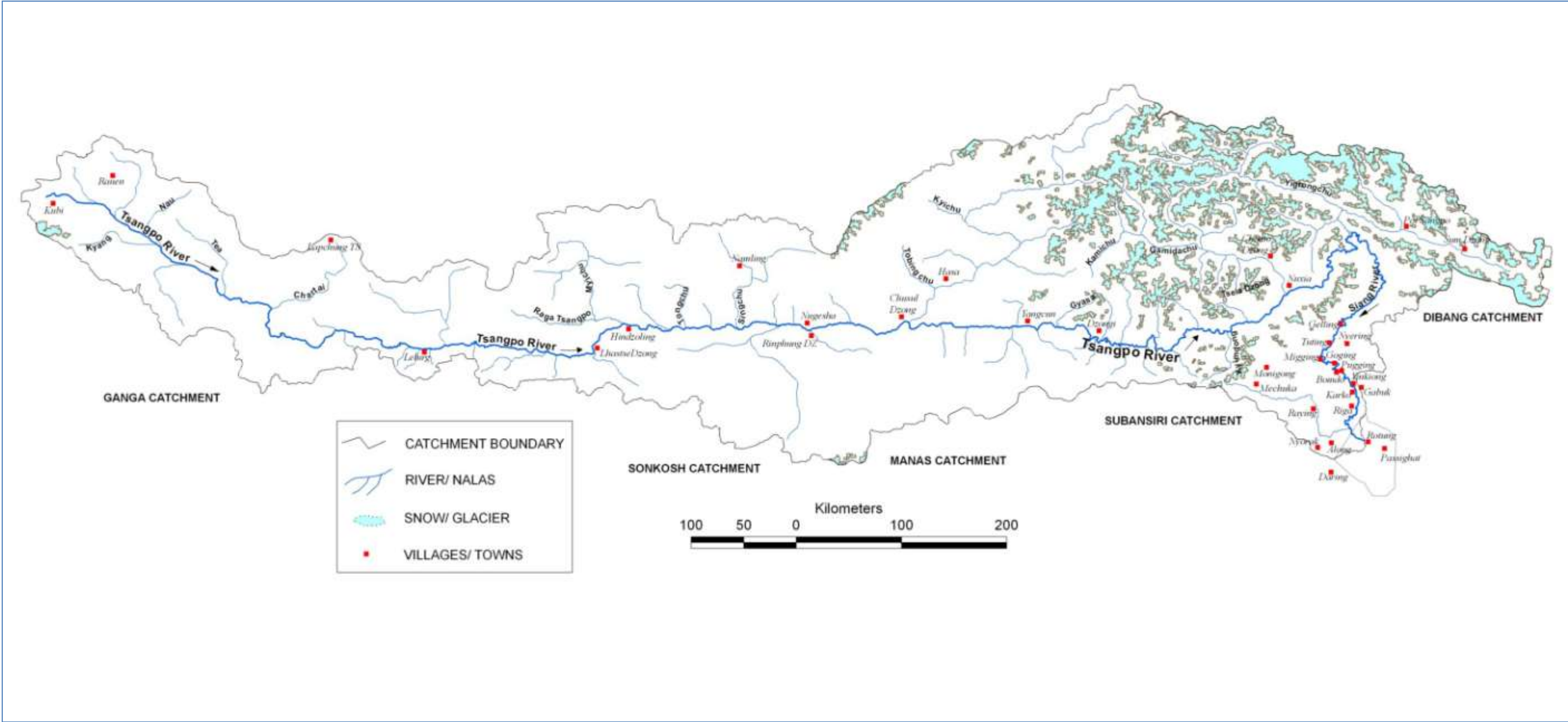


Figure 2.1: Drainage map of Siang river from its origin in Tibet up to Arunachal Pradesh



Figure 2.2: Administrative map of Arunachal Pradesh showing districts and different river sub-basins

In Tibet the Tsangpo receives a number of tributaries. The most important left-bank tributaries are the Raka Zangbo (Raka Tsangpo), which joins the river west of Shigatse, and the Lhasa, which flows past the Tibetan capital of Lhasa and joins the Tsangpo at Qüxü. The Nyang Qu (Gyamda) River joins from the north at Zela (Tsela Dzong). On the right bank a river called the Nyang Qu (Nyang Chhu) meets the Tsangpo at Shigatse.

After passing Pi (Pe) in Tibet, the river turns suddenly to the north and northeast and cuts a course through a succession of great, narrow gorges between the mountainous massifs of Gyala Peri and Namjagbarwa (Namcha Barwa) in a series of rapids and cascades. Thereafter, the river turns south and southwest and flows through a deep gorge (the “Grand Canyon” of the Tsangpo) across the eastern extremity of the Himalaya with canyon walls that extend upward for 5,000 m and more on each side before entering India as the Siang River. After traversing about 2057 km in Tibet, the Tsangpo enters Arunachal Pradesh where it is also known as the Dihang River.

Just west of the town of Sadiya in Assam, Siang (Dihang) turns to the southwest direction and is joined by two major rivers, the Lohit and the Dibang. Thereafter from the confluence during its 1,450 km course up to the Bay of Bengal, the river is known as the Brahmaputra (“Son of Brahma”). In Assam the river is mighty even in the dry season, and during the rains its banks are more than 8 km apart. As the river follows its braided 700 km course through the valley, it receives several rapidly rushing Himalayan streams, including the Subansiri, Kameng (Jia Bhareli), Dhansiri, Manas, Champamati, Saralbhanga, and Sankosh rivers. The main tributaries from the hills and from the plateau to the south are the Burhi Dihing, the Disang, the Dikhu, and the Kopili.

The upper catchment area of Siang is mountainous with deep and narrow valleys. The part of Siang basin in India is bounded on the north by eastern Himalaya, on west by Subansiri basin and on east by Dibang basin.

According to Goswami and Das (2003) the length of Brahmaputra is 2880 km (Tibet-China = 1625 km; India - 918 km; Bangladesh - 337 km) and Catchment area is 580,000 sq km (50.5% in China, 33.6% in India, 8.1% in Bangladesh and 7.8% in Bhutan). In India, its basin is shared by Arunachal Pradesh (41.9%), Assam (36.3%), Meghalaya (6.1%), Nagaland (5.6%), Sikkim (3.8%) and West Bengal (6.3%).

2.3 SIANG RIVER

The headwater region streams draining into the Siang river after it enters India near Gelling town in Arunachal Pradesh is characterized by snow clad peaks of the Eastern Himalaya. Length of Siang river in India up to the confluence of Siyom river is approximately 197.0 km and travels further 86.3 km to Assam border and further 10.6 km join Brahmaputra in Assam with total length in India as 293.9 km. From this point forward it flows as Brahmaputra river in Assam and traverses a distance of about 195 km up to the confluence of Subansiri river on its right bank. Further downstream it is joined by Kameng at Jamugurihat near Tezpur after another 123 km. From here it travels for another 134 km up to Guwahati.

The headwater region of Siang in Arunachal Pradesh is in different elevation range, viz. in the west, the river originates from peaks of 4007 to 5003 m elevation and in the east it originates from 4000 to 4003 m elevation.

The catchment area of Siang river up to its confluence with Lohit and Dibang rivers is 251,521 sq km. Large part of the catchment lies in Tibet; the total catchment of Siang river in India up to its

confluence with Lohit and Dibang rivers is 14965.30 sq km. The drainage map of the Siang river in India is given in **Figure 2.3**.

2.3.1 Siang River System

Siang sub-basin in India referred to as Siang basin in the report is comprised mainly of two major tributary sub-basins i.e. Siang river Sub-basin and Siyom river Sub-basin which is the largest tributary of Siang in India and joins Siang river near Pangin. Other major tributaries of the Siang river are Yang Sang Chhu (left bank), Ringong Asi (right bank), Pali Si (right bank), Sigong river (right bank), Niyikong River (right bank), Angong river (right bank), Yamne river (left bank), and Simang river (right bank).

2.3.1.1 Siang River

An overview of Siang river system is given in **Table 2.1**. A brief description of each of the major tributaries listed in the table is given in the following paragraphs.

a. Yang Sang Chhu

This tributary flows for about 60 km from southeast to northwest to meet the Siang river. It originates from mountain range located in its south-eastern part. Some of these mountain peaks are Mt. Ekunji (4204 m), Mt. Anno (4114 m), Mt. Mahango (4344 m), Mt. Aonkoloka (4266 m), Mt. Ibrimbo (3813 m), and Mt. Amarundi (3710 m). The drainage network is characterized by combination of rectangular and dendritic pattern. Landslide scars are dominant near the confluence with the Siang river. Mixed dense Semi-evergreen forest and degraded secondary forest occupy the Yang Sang Chhu catchment. The river is joined by many tributaries on both the banks, viz. Advor Machi, Chiri Machi, Eliya Marchi, Emasha Machi, Eshapa Machi, Alolombo Machi and Moshapongo Machi joins on right bank, while Amma Machi, Khalden Machi, Menon Machi, Enu Machi and Hudu Machi join on the left bank.

b. Ringong Asi

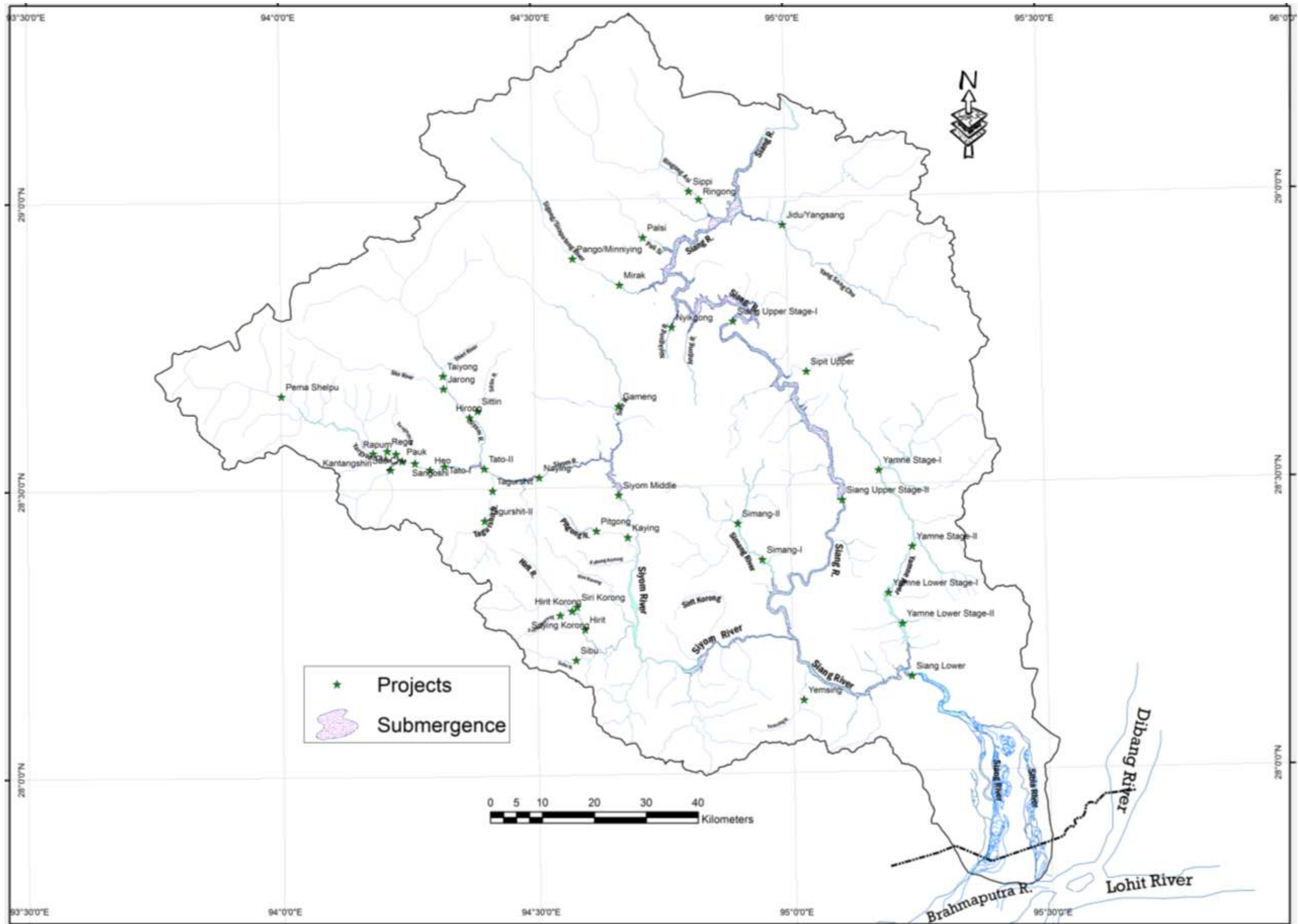
The river flows in the northern part of the Siang catchment area. It flows in northwest-southeast direction to join the Siang river near Ningguing village. The river is originated from nearby snow-clad Pari mountain range located in its northwest part. The drainage network flows through mixed semi-dense forest.

The river Ringong Asi is a perennial river and originates in the upper reaches of Indian territory, bordering China in the north. The main source of discharge in the river is snowmelt from Himalayan glaciers and small streams. Ringong Asi is a mountainous river with steep river bed slope. The water is very turbulent in this river due to presence of large size boulders and rapids as well as very frequent bends. The river has its confluence from west with the main river Siang. Total length of Ringong is about 50.2 km.

c. Sigong River

Also known as Sirapateng, it originates from snow-clad peaks of Pari mountains and flows towards east to join the Siang river near Migging village. Some of the tributaries joining in this river are Virang Asi, Viroung Korong, Nina Korong, Ugong Nala, Bibong Asi (right bank) and Une nala, Chondrak Korong, Mirak Nala, Simu Nala (left bank).

This is a perennial river and originates in the upper reaches of Indian territory bordering China in the north. The main source of flow in the river is snowmelt, glaciers and small streams. Sigong Asi is a mountainous river with steep river bed slope and having an appreciable discharge with considerable catchment area. The river has its confluence from west with the main river Siang. Total length of Sigong river is about 69 km.



d. Pali Si

Pali Si also written as Palsi originates from Orgong Adi ridge as Sate Korong at 3,929m and is joined by a stream formed by confluence of Dikong Korong and Dikuing Korong. Afterwards it flows as Pali Si which is joined by Lo Ko Korong on its left bank and later by Yusa Korong on its right bank. It joins Siang river on its right bank opposite Singing at about 400m. Total length of Pali Si is about 22.22 km.

e. Nyikgong River

This tributary joins the Siang river on its right bank near Mosing village. The stream flows for about 60 km from south to north. The drainage network is represented by dendritic pattern. Tributaries joining to the right bank are Sibit Nala, Sinach Nala, Sinam Nala. Total length of Nyikgong river is about 38.32 km.

f. Angong River

This stream flows for about 70 km from south to north to join the Siang river. The river and its tributaries flow through mixed dense forest. Its total length is about 32.91 km.

g. Simang River

This river flows from north to south to join with the Siang near Boleng village. The drainage network is well displayed by dendritic pattern. Landslide scars can be seen on the left and right bank slopes. The major tributaries joining at right bank are Kedung Korong, Yobung Korong, and Borak Korong and streams joining at the left bank are Kribung Korong, Kabung Nadi, Subbung Nadi and Dibyang Korong. Total length of Simang river is about 43 km.

h. Yamne River

It is one of the important tributary of the Siang river in the lower reaches. It flows from north to south to meet the Siang river near Bodak. The headwater region of this river is occupied by landslide scars along its bank slopes. The general drainage network is displayed by dendritic pattern. Some of the major left bank tributaries are Sapa Nala, Sidip Nadi, Sipung Korong, Sigon Korong, Siyot Korong etc., while streams joining at right bank are Yaming Nadi, Sikkam Korong, Sirang Nala, Tamil Nala, Sibya Nala and Sika Nala.

In addition, several smaller streams also joined the Siang river on its left bank. Some of them are Siki Nala, Soi kha Nala, Siri Nala, Sidi Nala, Sipat Nala, Siar Nala, Sikor Nala, Sela Nala, Ebung Nala, Poug Nala, Rebung Nala, Sieng Nala and Ribung Nala. Total length of Yamne river is about 82 km.

2.3.1.2 Siyom River

It is a major tributary of the Siang river which joins on the right bank. The river originates from the west snow-clad Pari mountains range, where elevation varies between 4472 and 5044m. The river flows northwest to southwest with sharp flow turns in west to east direction to join the Siang on the right bank. This sharp turns in the flow could be the reflection of structural control of the region. The drainage network is characterized by the dendritic and rectangular pattern. Its upper catchment is covered with fairly dense Mixed semi-evergreen forest and degraded secondary forest where a number of landslide scars along its tributaries are noticeable. Most part of the right bank slope of this tributary is covered with settlements and agricultural terraces. The length of Siyom river up to the confluence of Yargyap Chhu is about 64.4 km and travels further for another 30 km where it is joined by Sike river on its left bank near Gameng. Thereafter it travels for another 90.14 km whence it finally merges with Siang river near Pangin. The total length of Siyom from its origin up to the confluence is about 184.54 km.

A brief description of each of the major tributaries of Siyom is given below.

a. *Shiet River*

It is first major left bank tributary of Siyom river and flows east to west for about 15 km from its origin to join Siyom river near Yangrang village. The drainage network is characterized by dendritic pattern. The settlements and agricultural terraces are seen on the right bank, while landslide scars are seen along the left bank slopes of the river.

b. *Shir River*

Shir river is first major right tributary of Siyom and flows for about 39 km from its origin at about 3800m in west to east direction to join the Siyom river near Jarong village at about 1600m.

c. *Sittin N.*

Sittin N. is a left bank tributary of Siyom and flows for about 19km from north to south in general to meet Siyom river near Kate village at about 1200m.

d. *Yargyap Chhu*

The river originates from mountains of Great Himalayan range and in general flows from west to east direction to join Siyom river near Tato village. Yargyap Chhu is formed after the confluence of Barpu Sikyo and Bum Chu. The shape of the basin is like a fan and the elevation ranges from El. 4480 m to El. 1000 m. Yargyap Chhu is known by different names in different stretches such as Barpu Sikyo (at higher reaches) and Shi Chu (at lower reaches) from origin up to its confluence with Siyom river. However the name Yargyap Chhu as mentioned in different project documents has been maintained for the sake of uniformity of nomenclature. Total length of the river from its origin up to its confluence with Siyom river is about 78.80 km. The catchment area of the Yargyap Chhu up to Siyom confluence is 1222 sq km.

The settlement and agricultural terraces occupy both the river banks in the lower reaches near Tato village. Drainage network is characterized by dendritic and rectangular patterns. Its upper catchment region is covered with snow, while very dense mixed forests occupy major part of the catchment.

Major tributaries joining the right bank of the Yargyap Chhu are Bum Chu, Sagang Shuru, Shuru Phujo, Tamding Phujo, Kartesho Kong, Sae Chu, Shene Korong, Sarak Korong-I, Sarak Korong-II and Sheu N. Major left bank tributaries are Shashirong Ishi, Narsang Gongphu Chu, Gaptse Chu, Dutangphu/Dorjilingphu Chu, Songshi Bu and Pirpu Korong.

e. *Tagurshit Nadi*

It is first major tributary that joins Siyom after the confluence of Yargyap Chhu. It tributary flows for about 24 km from south to north direction and joins Siyom river on the right bank near Tado Gito village. Tributaries joining this stream are Shiyak Nadi, Shimi Nadi and Shikki Nadi.

f. *Shiyi N.*

It is a small right bank tributary that joins Siyom near Yapik village at about 750m. It flows from south to north in general.

g. *Sike River*

This tributary flows for about 110 km from north to south direction and joins Siyom river on the left bank near Bile/Gameng village. It originates from snow-clad Pari mountain range. It is the largest tributary among the streams joining at left bank. Tributaries joining left bank of this river are Sipak

Nalah, Sirang Nalah, Sito Nalah, and Iyak Nalah. Tributaries joining right bank are Rogang Nalah, Sipang Nalah, Sinyo Nalah, and Sikong Nalah. Total length of Sike river is about 61.3 km.

h. Pitgong N.

Pitgong N. is a small right bank tributary and originates at Shiakr Kamchi peak (3116m) that joins Siyom near Keak village at about 300m. It flows for distance of about 25.42 km from west to east in general.

i. Kebung Korong & Hiru Korong

Kebung Korong and Hiru Korong are the two right bank tributaries that drain forests of Yordi Rabe Supse Wildlife sanctuary and joins Siyom near Kamba village at about 250m. While Kebung Korong flows from west to east in general Hiru Korong flows in SE direction.

j. Hirit River

Hirit river is the second largest right bank tributary of Siyom and originates as Hirit Korong in forests of Yordi Rabe Supse Wildlife sanctuary at El. 3801m. It flows northwest to southeast to meet the Siyom river near Kamba village. Drainage network of this river is characterized by dendritic pattern. Drainage network is displayed by high drainage density. Headwater regions are occupied by landslide scars while settlements and agricultural terraces occupy the lower course of the river. It traverses a distance of about 45km from its origin up to the confluence. Major streams joining at the right bank of Hirit river are Yogong Korong, Sichuk Korong, Soying Korong, Kia Nala and Sibu Nala while Siri Korong is the only significant stream that joins on left bank. Sibu Nala joins Hirit near Poma Basti village. Total length of Hirit river from source up to its confluence with Siyom river is about 47 km.

k. Sirit Korong

Sirit Korong is a left bank tributary stream that flows from west to east initially and after taking a big loop southward it flows from northeast to south before it joins Siyom river downstream of Along town near Bomila Mabuk village. The drainage network is peculiarly displayed by dendritic pattern.

Sirit Korong receives drainage from number of small streams viz. Ramosubar Nalah, Ponbe Nalah, Saring Nalah, Sari Nalah, Shirum Nalah, Shipam Nalah, Shishi Nalah, Seash Nalah, Soyor Nalah, and Pebung Nalah. Total length of Sirit Korong is about 26 km.

l. Yemsing Nala

Yemsing Nala is last major right bank tributary of Siang river in its lower reaches. It merges with Siang near Kebang village. It is formed by the confluence of Jorju Korong and Kemi Nala near Yemsing village. It is also known by the name of Yembung Nala in certain stretches. Total length of Yemsing Nala is about 21.8 km.

Table 2.1: Drainage profile of Siang River System

Main Tributary	Catchment Characteristics	Right Bank/Left Bank	Confluence point with the Siang river	Major streams joining the tributary
Yang Sang Chhu	The drainage network of this catchment is represented by combination of rectangular and dendritic pattern. Most part of the catchment is covered with Semi-dense mixed subtropical, Semi-evergreen forest. Many peaks are located in the southeast part, viz. Mt. Ekunj (4204 m), Mt. Anno (4114 m), Mt. Mahango (4344 m), Mt. Aonkoloka (4266 m), and Mt. Ibrimbo (3813 m).	Left Bank	Near Jidu village	Right Bank: Arpong river, Site Che, Emasha Machi, Eshapa Machi, Alolombo Machi, Moshapong Machi; Left bank: Sikit Nala, Shirup Asi, Yeme Machi, Enu Machi, Methon Machi, Amma Machi
Ringong Asi	Snowfields and grasslands occupy in the upper reaches, while Mixed Semi-evergreen forest occupy in the lower reaches. Dendritic pattern characterizes the drainage network.	Right Bank	Upstream of Ningguing	Right Bank: Logong Korong
Sigong/ Sirapateng River	The upper part of the catchment is covered with snowclad mountains. Drainage network is characterized by rectangular and dendritic pattern. Mixed Semi-evergreen and Sub-tropical forest occupies the lower reaches part of the catchment.	Right Bank	Near Migging	Right Bank: Yinggong Korong, Ugong Nala, Nina Korong, Virbung Korong, Virang Asi, Pile Korong Left Bank: Une Nala, Chondrak Korong, Mirak Nala, Simu Nala
Pali Si	Pali Si originates from Orgong Adi ridge as Sate Korong at 3929m and is joined by a stream formed by confluence of Dikong Korong and Dikuing Korong.	Right Bank	Near Singing	Loko Korong on left bank and Yusa korong on right bank
Niyikgong River	Landslide scars are observed near Sinach Nala in the left bank. Mixed semi-evergreen, Sub-tropical and temperate forest occupies most part of the catchment.	Right Bank	Upstream of Mosing	Right Bank: Sinam Nala, Sinach Nala, Sime Nala; Left Bank: Sikir Nala, Koging Nala
Angong River	The catchment of this tributary is occupied by Mixed semi-evergreen, Sub-tropical and temperate forest. Drainage network is displayed by dendritic pattern.	Right Bank	Downstream of Mosing	Right bank: Narko Asi
Simang River	The catchment area is comparatively small. Drainage network shows dendritic pattern. Left bank slopes are dominated with landslide scars. Right bank occupies mixed subtropical and temperate forest.	Right Bank	Near Boleng	Right Bank: Butak Korong, Pabung Korong, Kebung Korong. Left Bank: Subbung Nadi, Kabung Nadi, Kibung Korong, Gobung Korong, Dibyang Korong

Main Tributary	Catchment Characteristics	Right Bank/Left Bank	Confluence point with the Siang river	Major streams joining the tributary
Yamne River	This tributary joins the main river in the upstream of the dam site. Landslide scars are present along the bank slopes of the Yaming river, the Siar Nadi, the Sapai Nala, and the Sige Nadi. The rest of the catchment area is occupied by semi-dense, semi-evergreen, subtropical and temperate forest. Overall drainage network is characterized by dendritic and rectangular patterns.	Left Bank	Downstream of Pangging, near the proposed Siang Lower HEP dam site	Right Bank: Yaming river, Salamak Nala, Sikkam Korong, Siang Nala, Siring Nala, Sirang Nala, Tamli Nala, Sibya Nala, Sika Nala; Left Bank: Sebi Nala, Sapai Nala, Sidip Nadi, Sipung Korong, Sigan Korong, Siyot Korong, Siyeng Nala, Sige Nadi, Ngerbung Korong
Siyom River	Siyom is the largest tributary in the catchment. Upper part of its catchment is covered with grass land, snowfield and wasteland. Drainage network is characterized by dendritic and rectangular pattern. Mixed semi-evergreen, subtropical and temperate forest and landslide are present in the middle part of the catchment.	Right bank	Near Koreag	Right Bank: Yargyap Chhu, Shir, Hirit Korong, Hiru Korong, Pitgong; Left Bank: Sike river, Shiet, Shing Korong.
Yargyap Chhu	The river originates from mountains of Great Himalayan Range and flows in general from west to east direction to confluence with Siyom river near Tato village. Yargyap Chhu is formed after the confluence of Barpu Sikyo river and Bum Chu. The shape of the basin is like a fan and the elevation ranges from El. 4480 m to El. 2400 m. Yargyap Chhu is known by various names as Barpu Sikyo, Yargyap Chhu and Shi Chu from origin up to confluence. The total length of the river from its origin up to its confluence with Siyom river is 78.80 km. The catchment area of the river basin up to Siyom confluence is 1222 sq km	Right Bank of Siyom	Near Tato village	Major tributaries joining the right bank of the Yargyap Chhu are Bum Chu, Sagang Shuru, Shuru Phujo, Tamding Phujo, Kamrong Sokong, Sae Chu, Shene Korong, Sarak Korong -I, Sarak Korong-II and Sheu N. Left bank tributaries of this river are Shashirong Ishi, Narsang Gongphu Chu, Lhalungphu Chhu, Dutangphu Chu, Sangshi Bu, and Pirpu Korong
Hirit River	Hirit river flows northwest to southeast to meet the Siang river. Drainage network of this river is characterized by dendritic pattern. Drainage network is displayed by high drainage density. Headwater regions are occupied by landslide scars while settlements and agricultural terraces occupy the lower course of the river.	Right Bank of Siyom		Streams joining at the right bank are Soying Korong, Kia Nala, Rijil Nala etc. while major left bank stream is Siri Korong. Other right bank streams are Yogong Korong, Kia Nala, and Sibu Nala.

2.4 GRADIENTPROFILE

Gradient profile of Siang river and its tributaries is given in Table 2.2.

a. Siang

The stream gradient of the Siang river from the point it enters India near Gelling village up to the dam site of Siang Lower HE project covering for about 293.9 km has a gradient of 1:595 within the average elevation of 150 m. In general, stream gradient is very gentle between 540 and 150 m elevations and it becomes flat between 190 m and 180 m elevations. This flat gradient covers a distance of about 90 km. There are minor knick points in the river profile which might corresponds to small cascades and rapids in the course of the Siang river. Some of the knick points are observed at 460 m, 250 m, 210 m, 180 m and 150 m elevations in the upstream of the dam site of Siang Lower HE project.

b. Siyom

The Siyom river covering for about 184.54 km from 3600m up to 190m elevation indicates, flows with a stream gradient of 1:52. The profile indicates three different types of slopes, viz. steep slope located in the headwater region between 3600 and 1500 m elevations, gentle slope between 1400 and 500 m elevations, and very gentle slope between 500 and 200 m elevations. Very gentle slope covers for a distance of about 100 km.

c. Yamne

The gradient profile of the Yamne river, covering a distance of about 82 km from 4100m to 150m show stream gradient of 1:21. As indicated by the figure, steep slope is observed in the headwater regions, between 2500 and 1400 m elevations in span of 5 km distance. Gentle slope is observed between 1400 m and 161 m elevations within the span of about 82 km. There is a knick point in the upstream of Pangi village.

d. Simang

The stream gradient of the Simang river covering a distance of about 43 km within the elevations range of 2480 and 180 m shows 1:18. The profile shows moderately steep slope in the elevation range of 2500 to 1000 m, covering for a distance of about 5 km. Also, gradual sloping is observed in the elevation range of 500 to 180 m in a span of 38 km.

Table 2.2: Gradient profile of Siang river and its tributaries

Sl. No.	Name of river	Length of the river (km)	River gradient
1.	Siang	293.9	1:858
2.	Siyom	184.54	1:52.5
3.	Yamne	82.0	1:20.9
4.	Simang	43.2	1:18.4

2.5 PHYSIOGRAPHY

Most of Arunachal Pradesh's terrain consists of deep valleys flanked by highland plateaus and ridges that rise to the peaks of the Great Himalaya. The state encompasses three broad physiographic regions. Farthest south is a series of foothills, similar in type to the Siwalik Range (a narrow sub-Himalayan belt stretching across much of northern India), that ascend from the Assam plains to elevations of 300 to 1,000 m. These hills rise rapidly northward to the Lesser Himalaya, where some ridges and spurs reach 3,000 m. Further north, along the Tibetan border, lie the main ranges of the Great Himalaya, where Kangto, the highest peak in the state, dominates the landscape at more than 7,000 m.

The Eastern Himalaya that covers 18,518 sq km area of East and West Siang districts is almost wholly a rugged mountainous terrain extending over the central region of Arunachal Pradesh. The region has been described as 'an intricate labyrinth of precipitous, rocky and high hills and mountains, with beautiful green valleys drained by innumerable rivulets and mighty rivers cascading down from upper elevations. The tangle of hills and mountains throwing a series and towering to majestic heights of eternal snow is the most imposing topographic feature of Siang basin. The elevation of the hills varies from 305 to 3050 m. The tract to the right of the Siang river is less hilly than the area lying between the Siang and Dibang, which has mountains rising from 3050 to 4572 m. There are lofty snow clad mountains in the north.

Strips of flat land are interspersed in the riverine tracts, of which the most prominent is the level area of Pasighat. The hills are covered with forests. The lower regions and the foothill areas adjacent to the plains of Assam have a luxuriant growth of vegetation with tall trees and thick undergrowth of shrubs. Major rivers and nallas in the Siang basin are characterized by the occurrence of depositional terraces. These are made of large boulders of quartzite, gneisses, schist, etc., bedded in sandy matrix. In the Yamne valley, terraces are buckled and faulted near Lagru in Yamne valley. Broad warps are also observed in the terraces near Padu. These warps reflect strong surface wave motion during an earthquake of high magnitude. There has been indication of recent ground movement by tilting of recent gravel deposit on the bank of the river Yamne. It shows suspected cracks in the deposit possibly due to severe ground shaking during an earthquake of high magnitude.

In order to understand the terrain morphology Digital Elevation Model (DEM) of the basin was prepared from ASTER G-DEM data and the same has been given at **Figure 2.4**.

2.6 RELIEF

The Siang catchment area has been divided into 11 elevation bands (**Figure 2.5**). Each of the intermediate elevation bands covers elevation range of 500 m. The southernmost part of the basin adjoining the state of Assam near its confluence with Brahmaputra ranges from about 90m to 500m. This band is also prevalent in the lower valleys of Siang and the Siyom river channels. It covers about 11% of the basin area (**Figure 2.5**). More than 55% of the basin area lies in the 90 to 2000m elevation band. Similarly area between 2000m and 3000m also covers nearly 23% of total basin area. The bands of higher elevation (3000 to 4500 m) are spread in the northwest and northeast part of the basin in the Pari Mountain range of Eastern Himalaya.

2.7 SLOPE

As can be seen from the elevation map of the Siang basin the southernmost part adjoining Assam is almost level land and there are higher mountains in the north (**Figure 2.6**). These slopes are mostly present on the western and southern part of the catchment. More than 78% of the basin lies in three categories i.e. Extremely Steep, Very steep and Steep slopes. The Extremely Steep slope category itself account for 32% of basin area. Gentle to moderate slopes cover little more than 6% of the area and such areas are uniformly distributed in the basin, particularly along the river and slopes along the stream banks. Strongly sloping areas cover 5% of the basin area and are prevalent mostly alongside the Siyom and the Siang rivers. The moderately sloping regions are characteristic of Siyom river near its confluence with the Siang river, Yargyap Chhu, and Siyom river. These slopes category occupy 3.21% of the catchment area. The gently sloping category comprises the flood plains of Siang river once it enters the plains near Pasighat. The extremely sloping category is characteristic of headwater regions of the Sigong river and Ringong Asi.

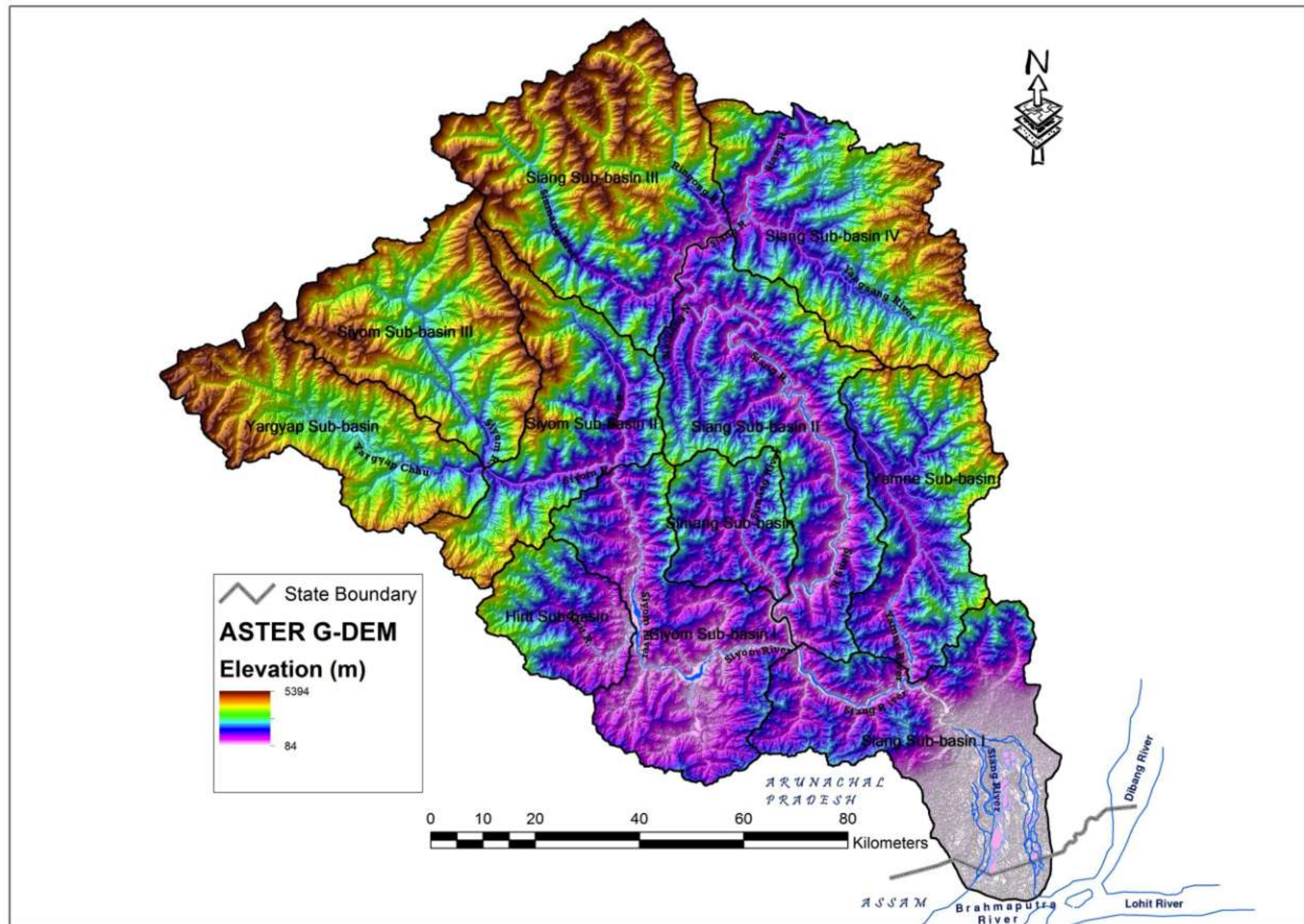


Figure 2.4: Digital Elevation Map (DEM) of Siang basin generated from ASTER G-DEM satellite data

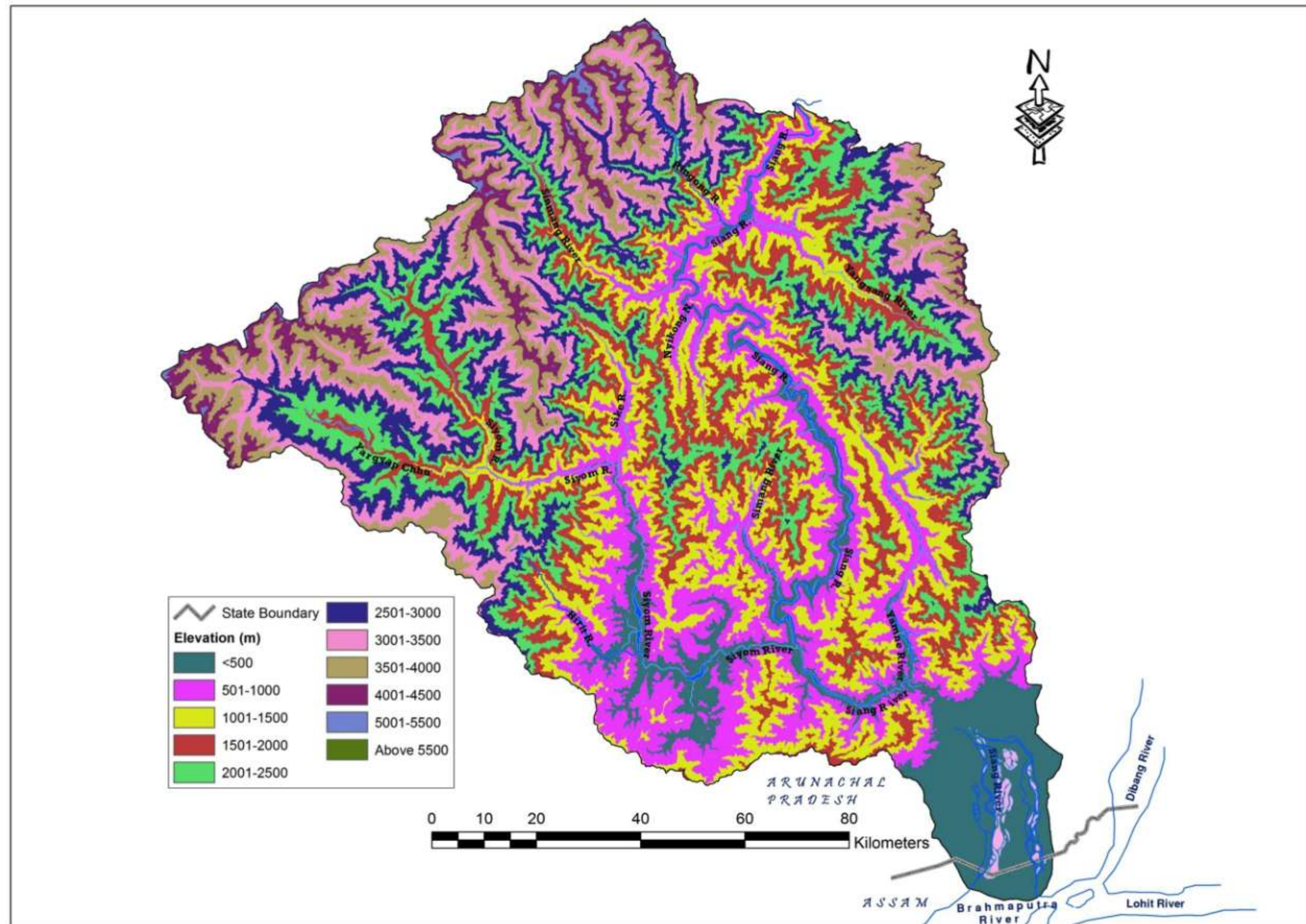


Figure 2.5: Relief map of Siang basin showing area under different elevation ranges

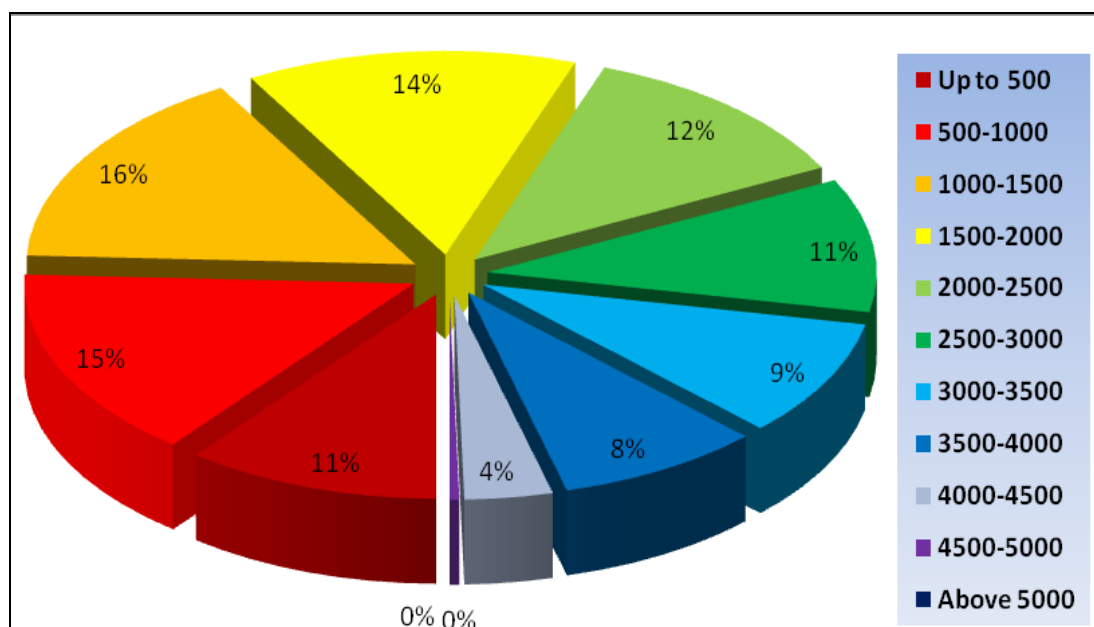


Figure 2.6: Area under different elevation bands

2.8 SIANG SUB-BASINS

For the convenience of study and analysis of various physical and biological parameters and their interpretation, entire Siang basin in India has been delineated into 11 sub-basins comprised of major tributaries and covering varied domains as well as proposed hydroelectric projects (see Figure 2.8). The characteristics of each sub-basin have been listed in Table 2.3.

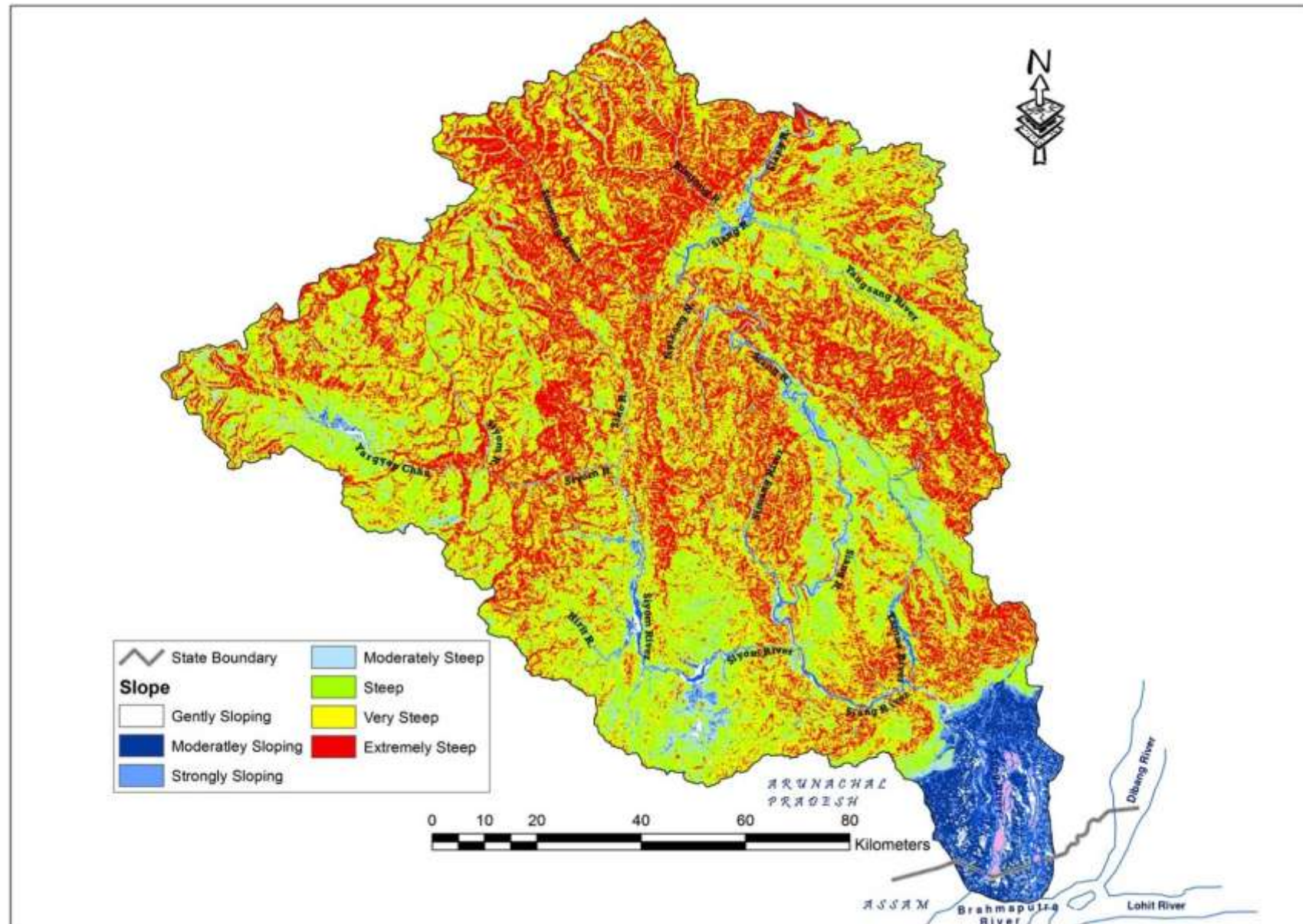


Table 2.3: Characteristics of Sub-basins of Siang river basin

S. No.	Sub-basin	Altitudinal Range (m)	Projects	River/Stream	Area (sq km)
	SIANG				
1	Siang Sub-basin - I	80 - 2000	Siang Lower	Siang	1716.89
			Yemsing	Yemsing N.	
2	Siang Sub-basin - II	400-4000	Siang Upper Stage I	Siang	1806.49
			Siang Upper Stage II	Siang	
			Nyikgong	Nyikgong	
			Sipit Upper	Sipit	
3	Siang Sub-basin -III	400-3200	Siang Upper Stage II	Siang	2018.83
			Palsi	Pali Si	
			Pango/ Minnying	Sigong R	
			Ringong	Ringong Asi	
			Mirak	Sigong R	
			Sippi	Ringong Asi	
4	Siang Sub-basin -IV	600-4000	Siang Upper Stage II	Siang	1754.47
			Jidu/ Yangsang	Yang Sang Chhu	
5	Yamne Sub-basin	600-3900	Yamne Stage-I	Yamne	1257.10
			Yamne Stage-II	Yamne	
			Lower Yamne Stage I	Yamne	
			Lower Yamne Stage II	Yamne	
6	Simang Sub-basin	800-2400	Simang-I	Simang	557.51
			Simang-II	Simang	
	SIYOM				
7	Siyom Sub-basin - I	600-4600	Siyom Middle	Siyom	1472.19
			Kaying	Pitgong	
			Pitgong	Pitgong	
8	Siyom Sub-basin - II	1400-4000	Siyom Middle	Siyom	1203.17
			Gameng	Sike	
			Naying	Siyom	
			Tato-II	Siyom	
			Tagurshit	Tagurshit	
			Tagurshit Stage II	Tagurshit	
9	Siyom Sub-basin - III	400-4000	Hirong	Siyom	1356.12
			Jarong	Siyom	
			Taiyong	Siyom	
			Sittin	Sittin	
10	Hirit Sub-basin	600-4000	Hirit	Hirit	581.33
			Soying Korong	Soying Korong	
			Siri Korong	Siri Korong	
			Hirit Korong	Hirit	
			Sibu	Sebu N.	
11	Yargyap Sub-basin	950 - 5000	Tato-I	Yargyap	1241.58
			Heo	Yargyap	
			Pauk	Yargyap	
			Rapum	Yargyap	
			Rego	Yargyap	
			Kangtangshiri	Yargyap	
			Pemashelpu	Yargyap	
			Sae Chhu	Sae Chhu	
			Sangoshi	Sangoshi Bu	



Figure 2.8: Sub-basins map of Siang basin

2.8.1 Siang Sub-basin-I

Siang Sub-basin-I is the southern-most sub-basin and is drained by Siang river which leaves Arunachal Pradesh and enters Assam to be joined by Dibang and Lohit river on its left bank to form Brahmaputra. The sub-basin is comprised of the catchment of Siang river up to its confluence with Siyom river near Pangin (**Figure 2.9**). Some of the major right bank tributaries are Yeming Nala, Siding Nala, Sireng Nala, Sibo Korong, Kemi Korong and Sille River, while the major left bank tributaries are Yumbiingi Nala, Sileng Nala, Siku River and Sibia River. Most of the habitations like Pangin, Bolek, Yembung and Pasighat are found on the right bank of river. Downstream of Pasighat Siang and Sibia rivers form a network of channels after emerging out of hills into plains then into Assam. Sille river is one of the main channels in the floodplains.

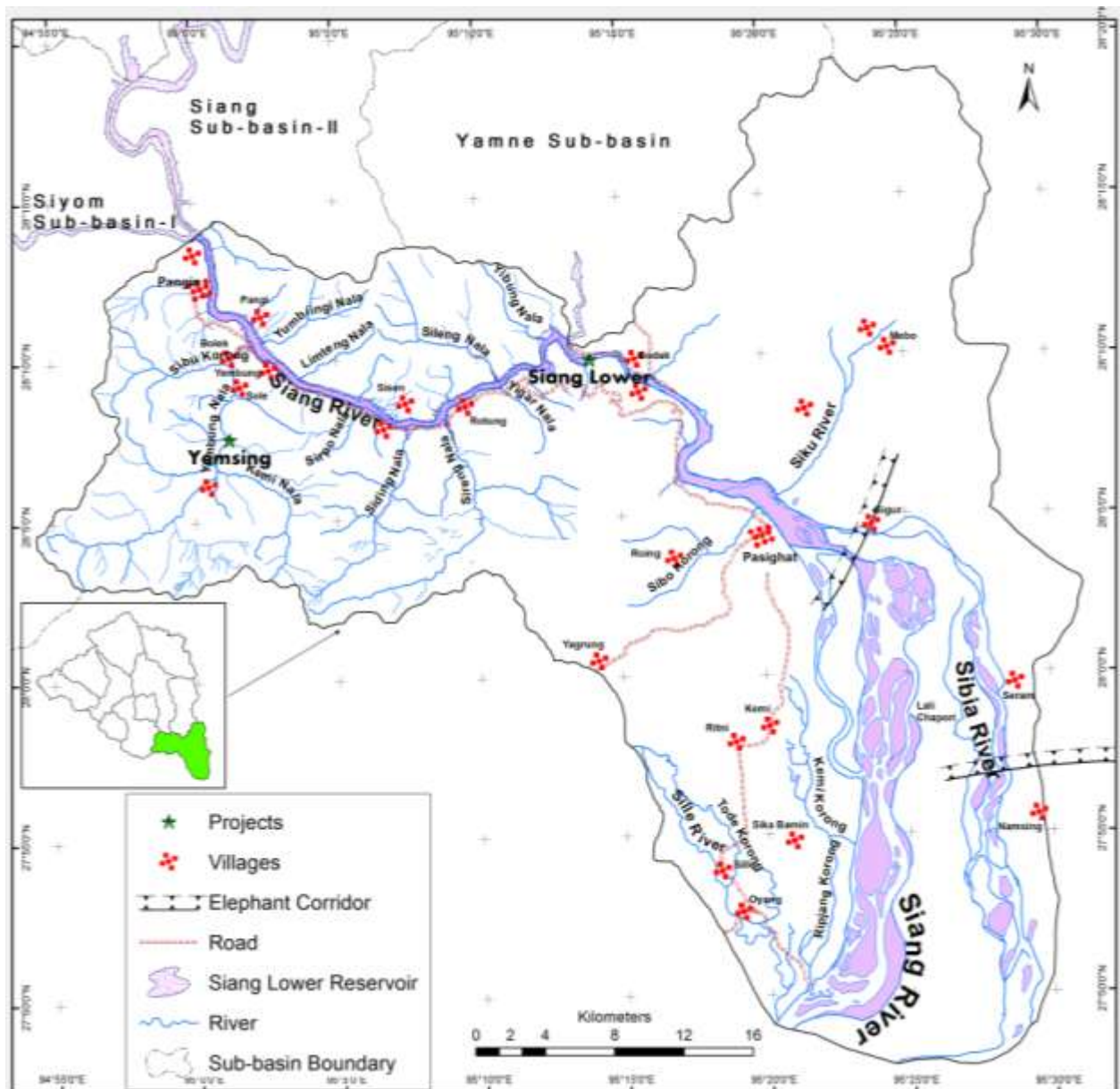


Figure 2.9: Drainage map of Siang Sub-basin-I

The elevation varies from as low as 80 m to about 3000 m (**Figure 2.10**). Majority of the sub-basin area i.e. around 55% lies in the 80 to 500 m elevation range, followed by 500 to 1000 m and 1000 to 1500 m elevation range which covers nearly 19% and 17% of the sub-basin area respectively. Elevation range from 1500 to 2000 m covers around 7% and the balance 2% of the sub-basin area is between 2000 and 3000 m elevation range.

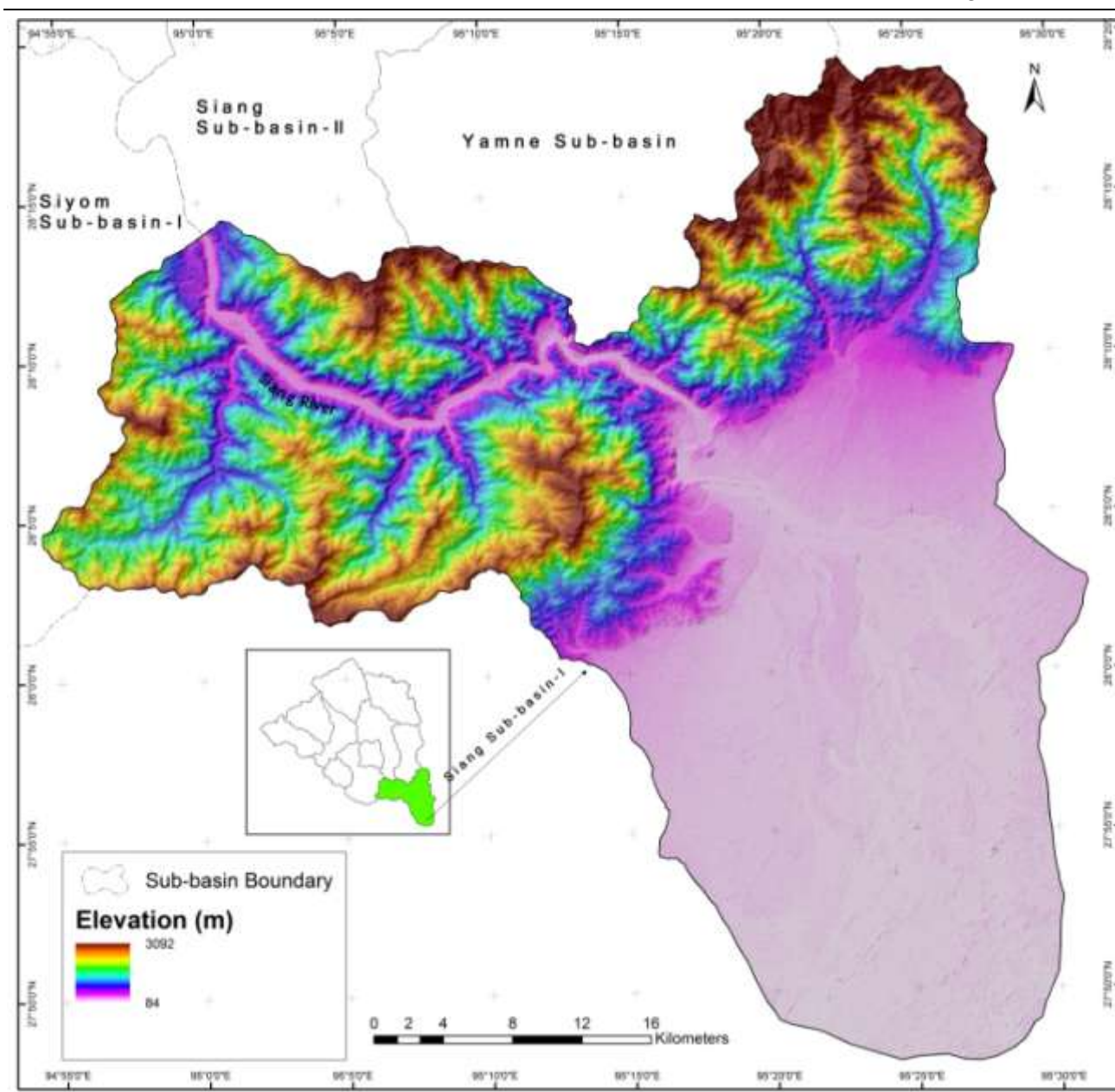
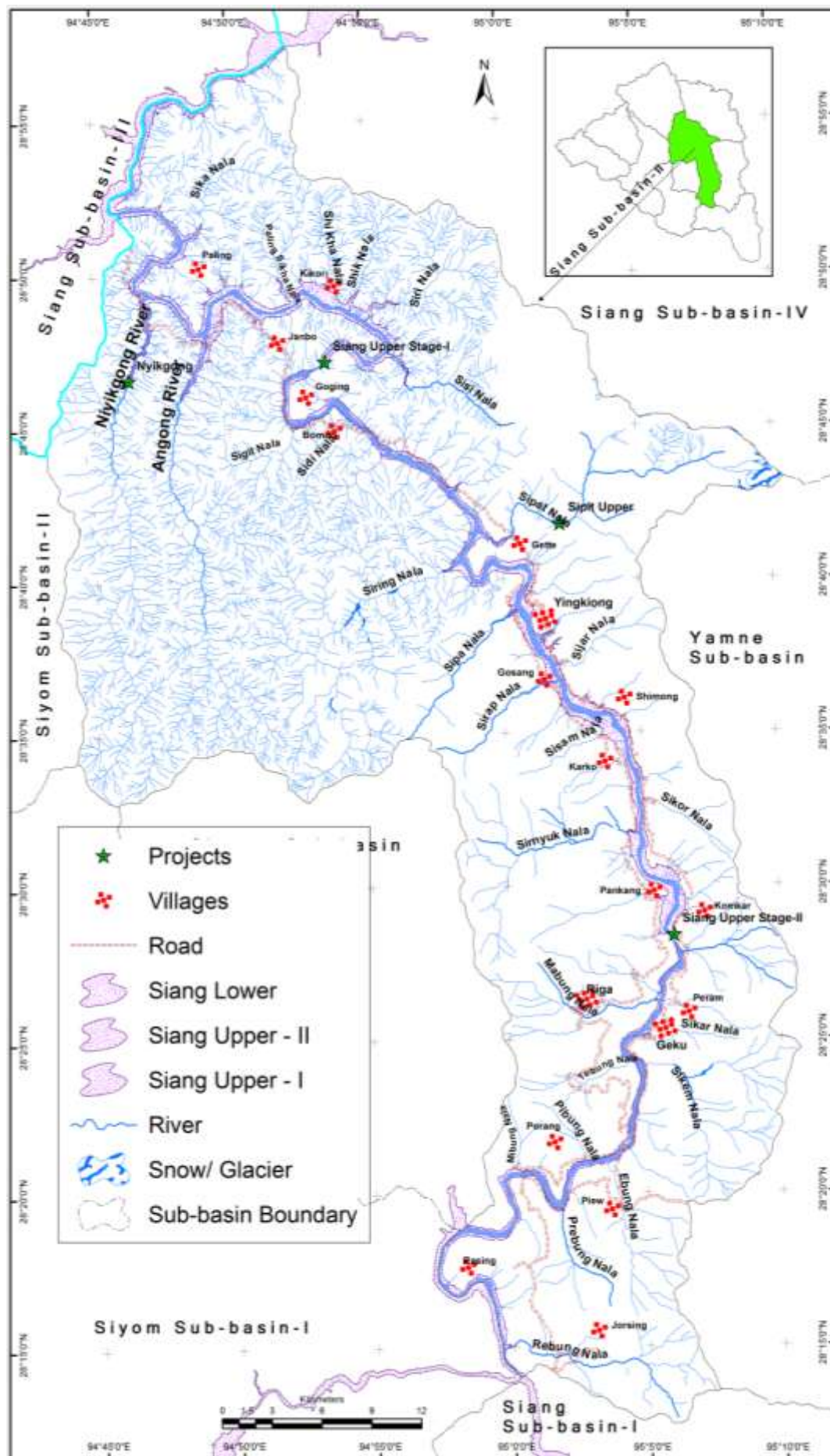


Figure 2.10: DEM of Siang Sub-basin-I

2.8.2 Siang Sub-basin-II

Siang Sub-basin-II is comprised of middle part of Siang river in Upper Siang district after its entry into India. This sub-basin is continuation of Sub-basin-I i.e. upstream of confluence with Siyom river and extending up to Paling village, excluding the catchment of Simang river (Figure 2.11). Some of the major right bank tributaries are Niyikgong River, Angong River, Siring Nala, Sipa Nala, Sirap Nala, Sirnyuk Nala, Mabung Nala and Pibung Nala, while the major left bank tributaries are Sika Nala, Sisi Nala, Sipat Nala, Sikem Nala, Prebung Nala and Rebung Nala. Group of villages on the left bank of river within the sub-basin are Paling, Kikor, Gette, Yingkiong, Shimong, Komkar, Geku, Piew, Rasing and Jorsing, while villages on the right bank are Janbo, Bomoo, Gosang, Pankang, Riga and Porang.



The elevation varies from 200 m to about 4000m (**Figure 2.12**). Elevation range of up to 500 m covers only 10% of the sub-basin area. Around 78% of the area almost falls under elevation range

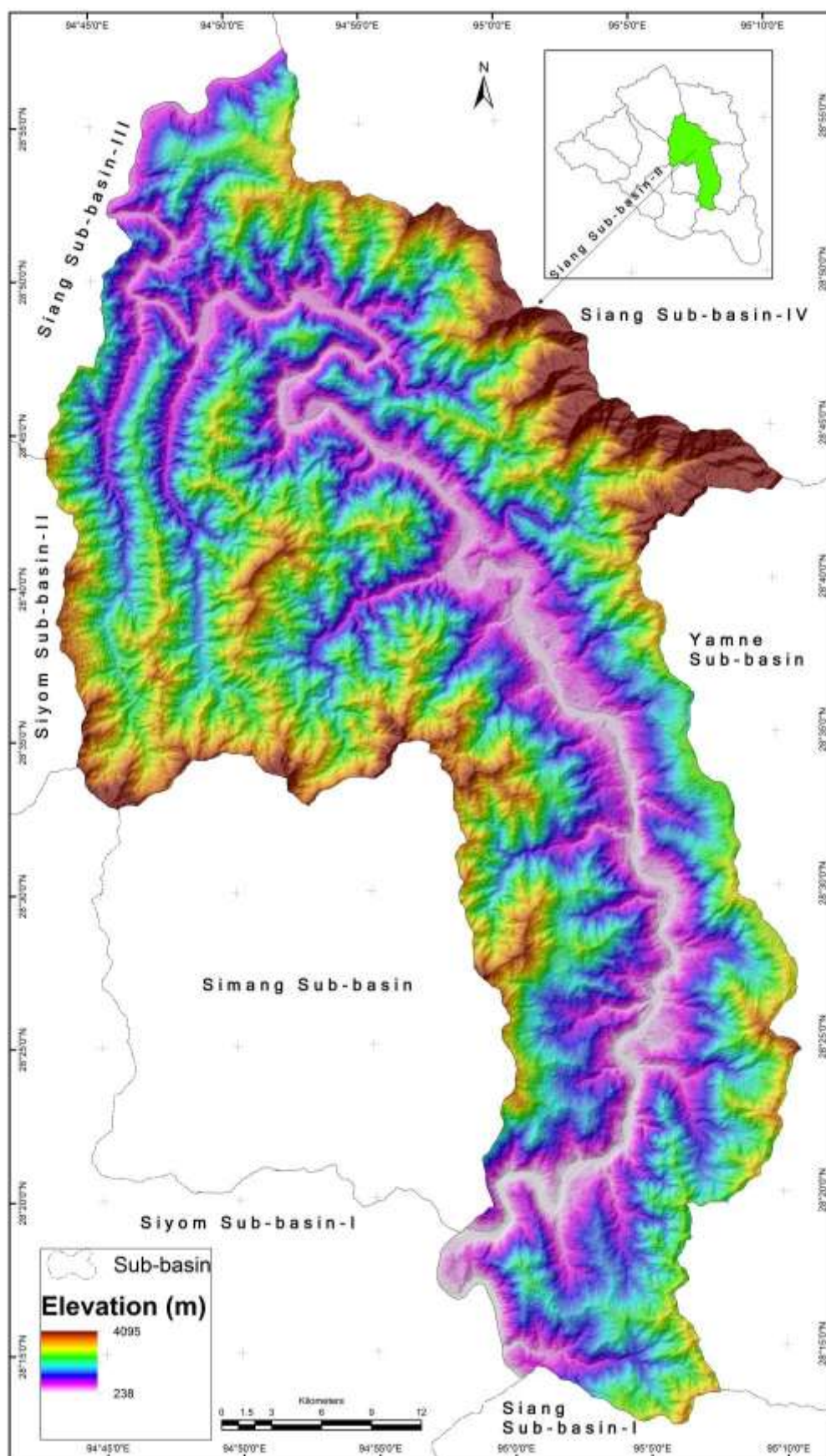


Figure 2.12: DEM of Siang Sub-basin-II

of 500 to 1000 m, 1000 to 1500 m and 1500 to 2000 m i.e. 26%, 30% and 22%, respectively. About 9% of the area falls under 2000 to 2500 m elevation range and the rest 3% of the sub-basin area is between 2500 and 4000 m elevation range.

2.8.3 Siang Sub-basin-III

Siang Sub-basin-III is on the right bank of Siang river between Paling and Tuting villages. The catchments of three major right bank tributaries namely Ringong Asi, Pali Si and Sigong River forms this sub-basin (Figure 2.13). The stream joining Ringong Asi at right bank is Logong Korong, streams joining Pali Si at left and right bank are Kobung Korong and Yusa Korong respectively. Sigong River being the largest tributary in this sub-basin is joined by many streams namely Aadrung Korong, Barak Asi, Une Nala, Chondrak Korong and Simu Nala at left bank, while stream joining at right bank are Pite Korong, Varbung Korong, Pange Lobung, Nine Korong, Ugong Korong and Yinggong Korong. Population is very less in this sub-basin as there are only three villages namely Pango, Ningguing and Tuting.

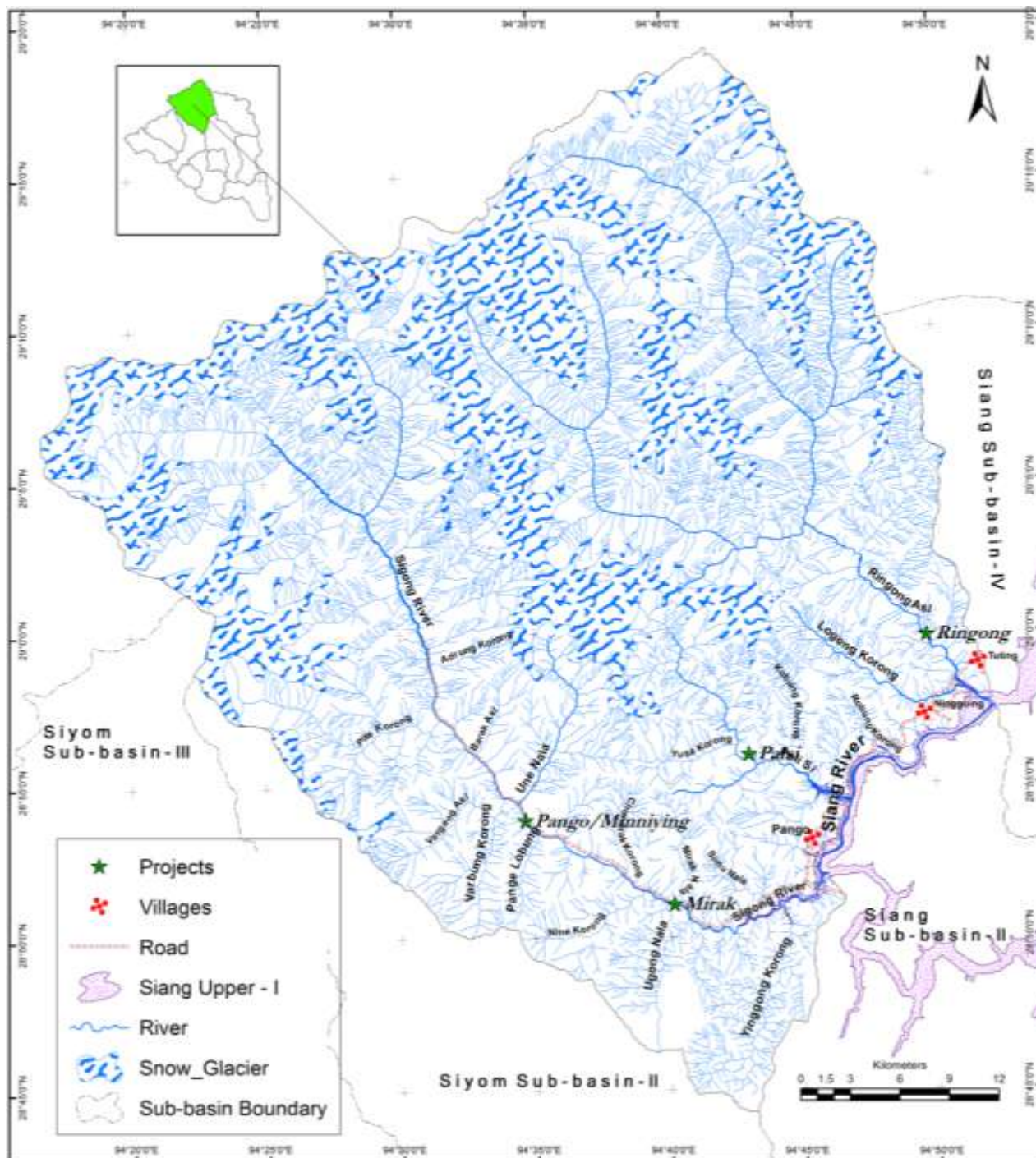


Figure 2.13: Drainage map of Siang Sub-basin-III

The elevation varies from 400 m to about 5000 m (Figure 2.14). The area between 400 to 2000 m elevation band covers nearly 21% of the sub-basin area. Elevation band between 2000 to 3000 m covers around 26% of the area. Around 51% of the area lies in the bands of higher elevation i.e. 3000 to 4500 m and the balance 2% of the sub-basin area lies between 4500 to 5000 m elevation range.

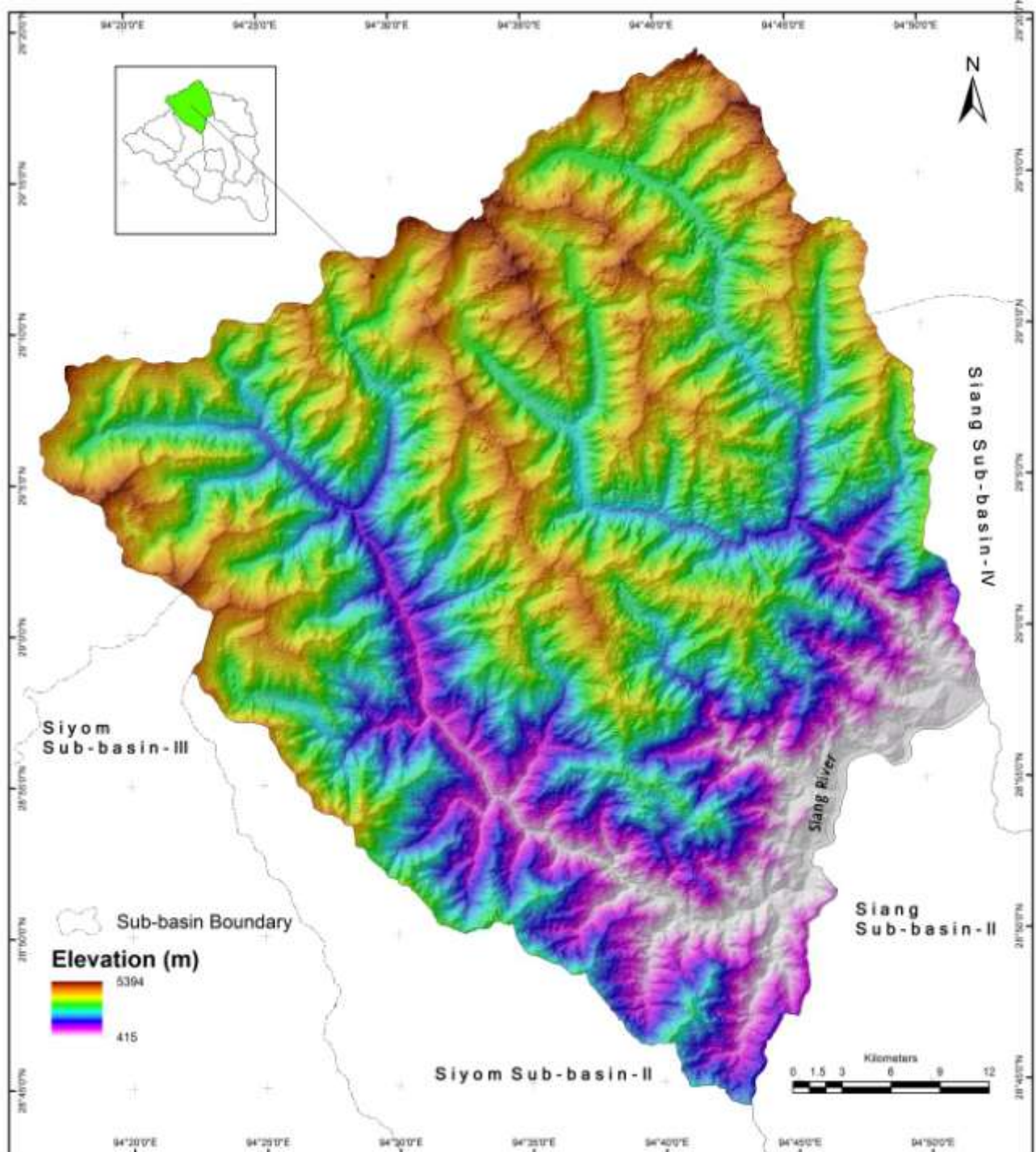


Figure 2.14: DEM of Siang Sub-basin-III

2.8.4 Siang Sub-basin-IV

Siang Sub-basin-IV is comprised of the upper most part of Siang river in Upper Siang district, between Tuting village and its entry into India. Catchment of Yangsang Chhu, a major left bank tributary of Siang river forms this sub-basin (**Figure 2.15**). The river Yang Sang Chhu is joined by many streams on both the banks viz. Moshapongo Machi, Alotombo Machi, Emasha Machi, Aduaon Machi and Arpoog River joins on right bank, while Amma Machi, Khinden Machi, Methon Machi, Hudu Machi, Shirup Asi, Sinah Nala, Sikit Nala, Hippi Asi etc. join on left bank. Again, the population is very less in this sub-basin as there are only four villages namely Tuting, Jidu, Ngamuing and Konging.

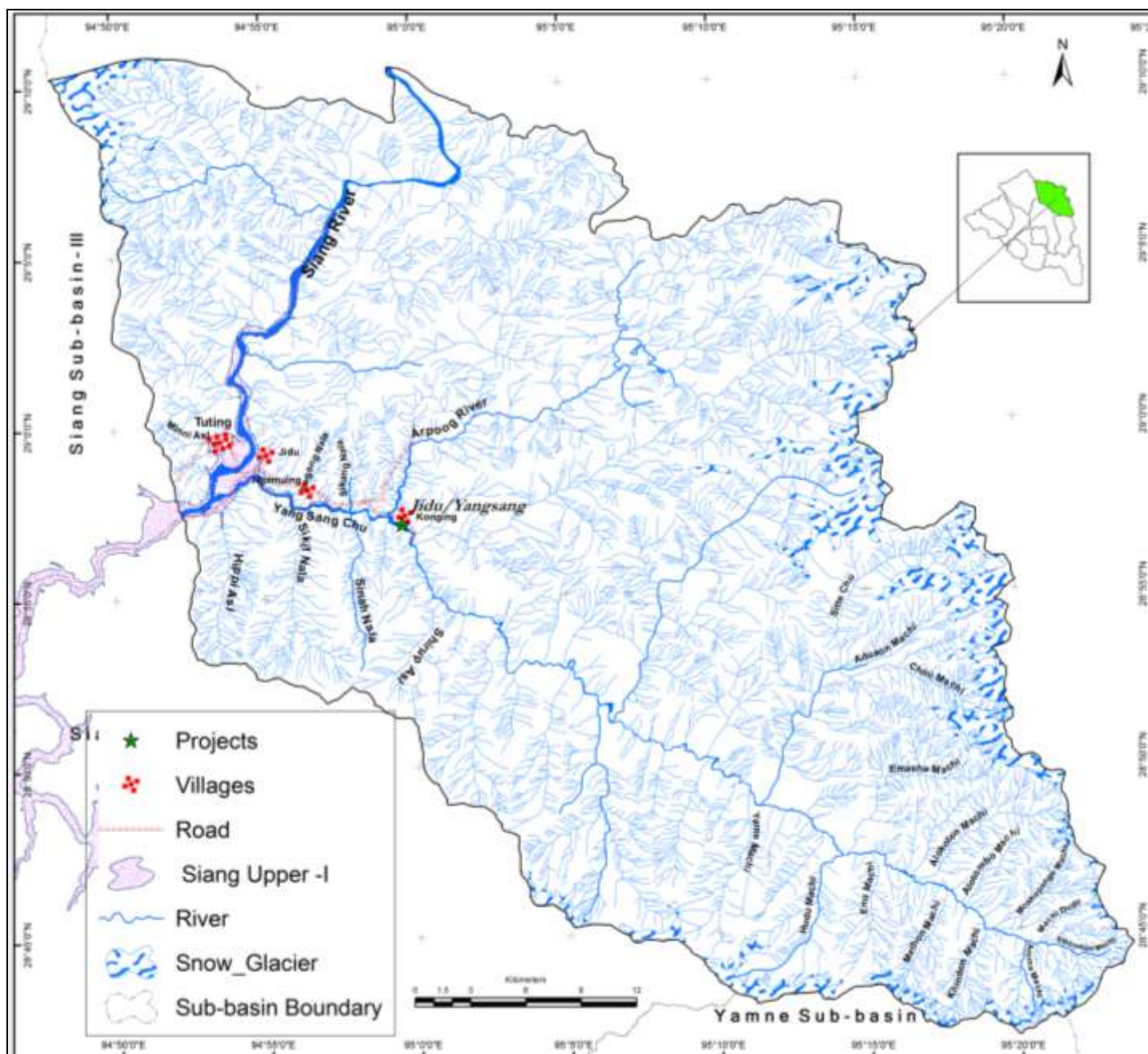


Figure 2.15: Drainage map of Siang Sub-basin-IV

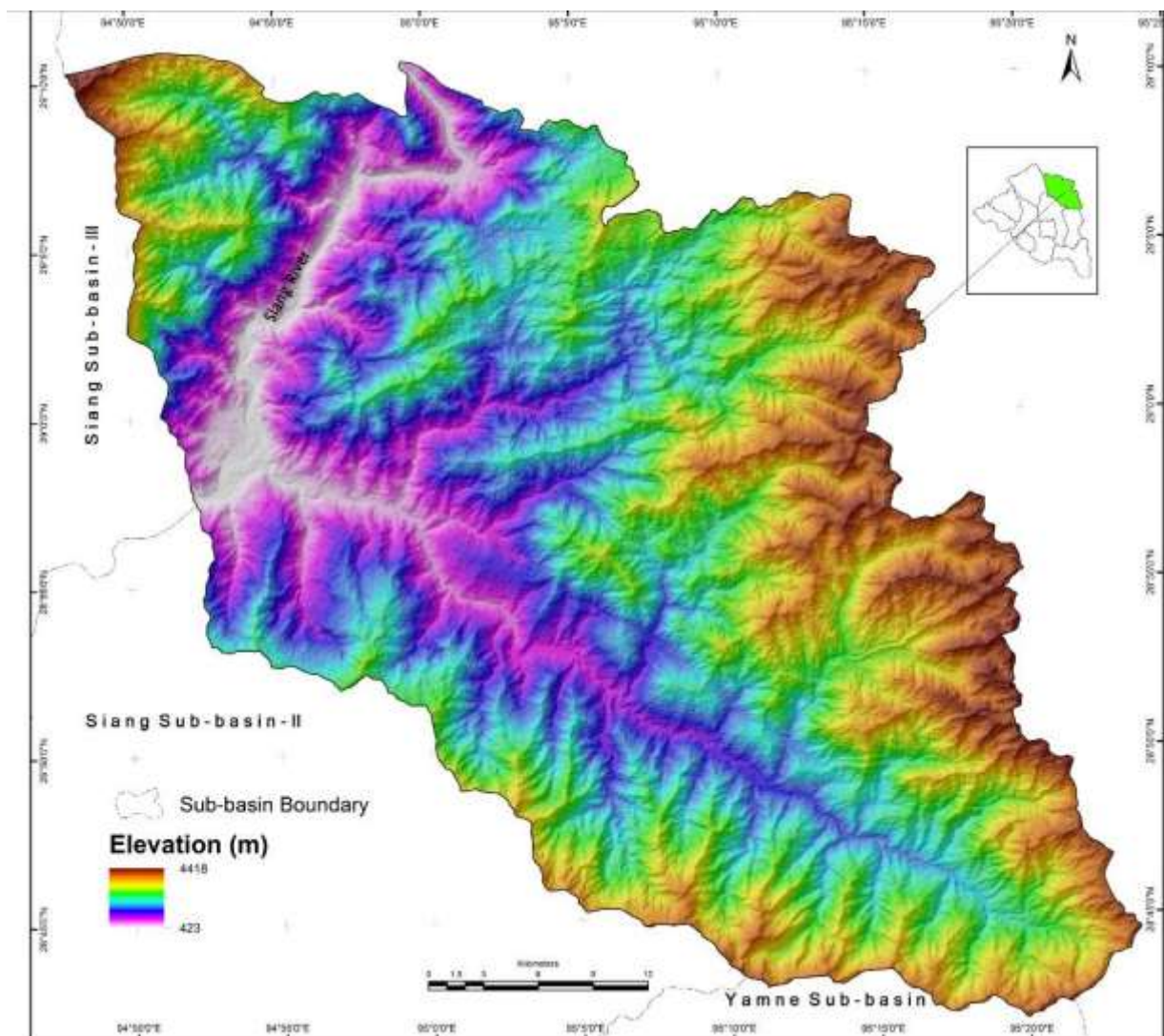


Figure 2.16: DEM of Siang Sub-basin-IV

The elevation varies from 400 m to about 4500 m (Figure 2.16). Elevation bands between 400m to 2000 m and 2000m to 3000 m cover almost equal area i.e. 39% and 36% respectively. The balance 25% of the area lies in the higher elevation band of 3000 to 4500 m.

2.8.5 Yamne Sub-basin

Yamne Sub-basin comprises of the catchment of Yamne river from its source to its confluence with Siang river near Bodak. It is one of the important tributary of the Siang river in the lower reaches. The river is also known as Yapin in the lower reaches, downstream of Silli village (Figure 2.17). The river is joined by many streams on both the banks, viz. Yamming Nadi, Sitham Korong, Sijing Nala, Siring Nala, Lamik Nala, Sibya Nala etc. joins on right bank, while Sapel Nala, Sidip Nala, Sipung Korong, Siyat Korong, Siyang Nala, Sige Nala and Nigerbung Korong join on left bank. Majority of the sub-basin area is on the left bank of river. Most of the habitations namely Silli, Padu, Dumro and Milang are found on the left bank itself, while Dalbing, Gobuk, Sibam and Jeru are on the right bank.

The river bed level varies from 200 m to about 4000 m (Figure 2.18). More than 66% of the sub-basin area lies in the 200 to 2000 m elevation band. Around 26% of the area is covered by 2000 to 3000 m elevation band. The higher elevation band between 3000 and 4000 m covers the balance 8% of the sub-basin area.

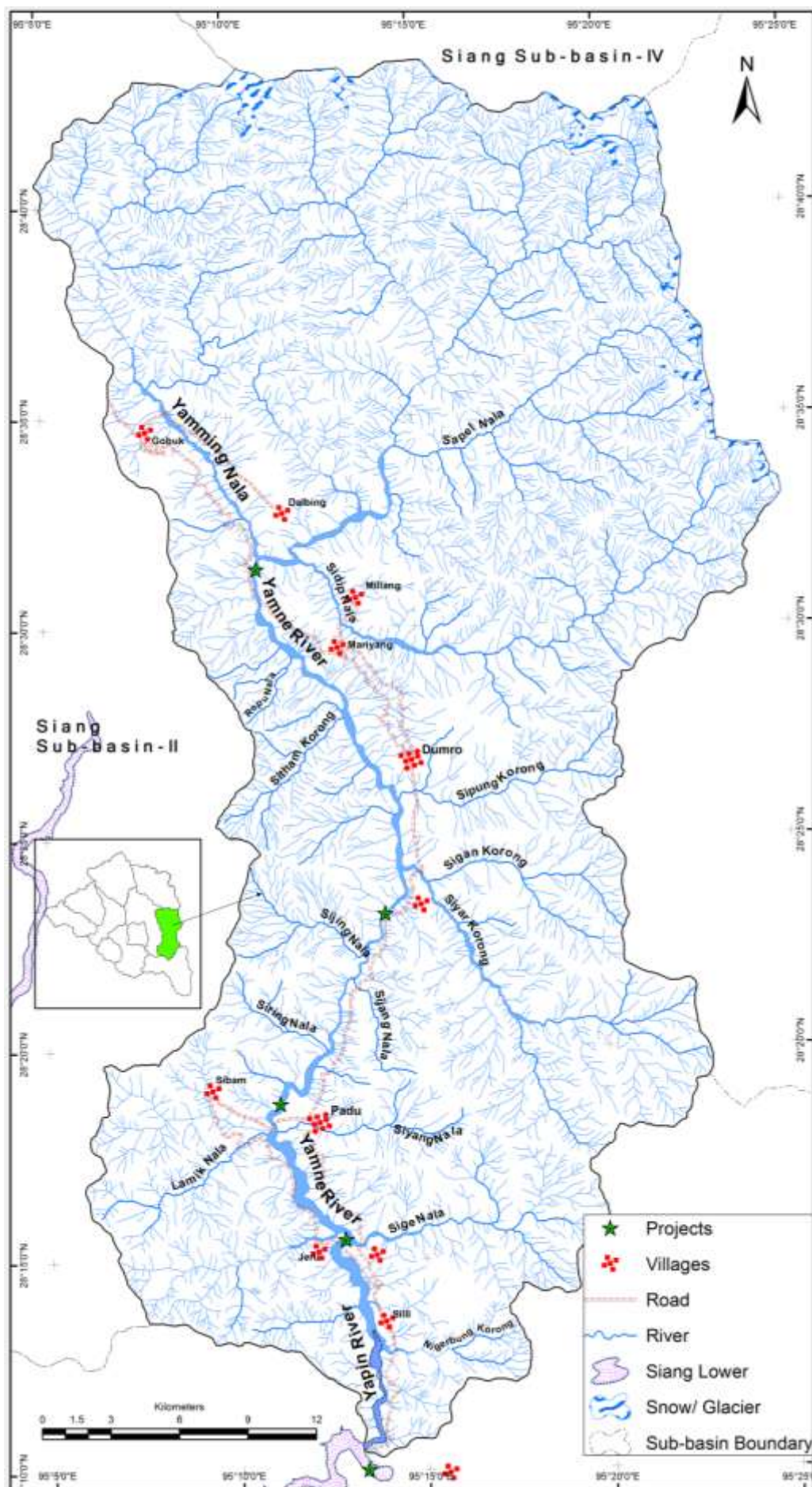


Figure 2.17: Drainage map of Yamne sub-basin

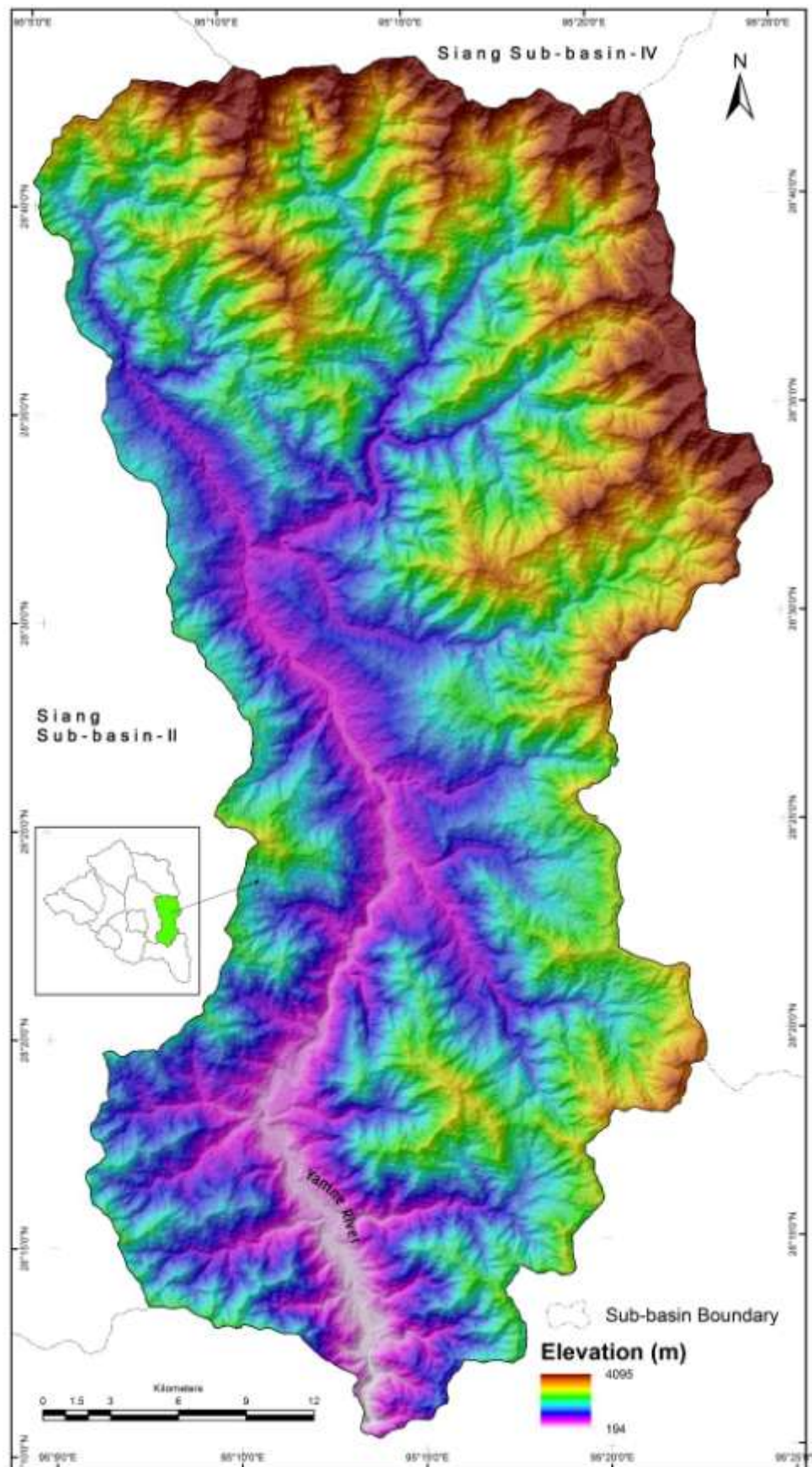


Figure 2.18: DEM of Yamne sub-basin

2.8.6 Simang Sub-basin

Simang Sub-basin comprises of the catchment of Simang river from its origin to its confluence with Siang river near Boleng village (Figure 2.19). It is the smallest sub-basin with an area of 556.43 sq km. The major streams joining at left bank are Kibung Korong, Karbung Nadi, Subung Nadi, Narobung Korong and Dibung Korong, while streams at right bank are Libung Korong, Mebung Korong, Yobung

Korong and Kebung Korong. Almost all the villages namely Lising, Yubuk, Yingku, Supting, Pareng and Libong are on the left bank of river, while Sine and Robuk Kerang are on the right bank.

The elevation varies from 200 m to about 3000 m (Figure 2.20). Around 88% of the sub-basin area lies in the 200 to 2000 m elevation band. The balance 12% of sub-basin area lies in 2000 to 3000 m elevation band.

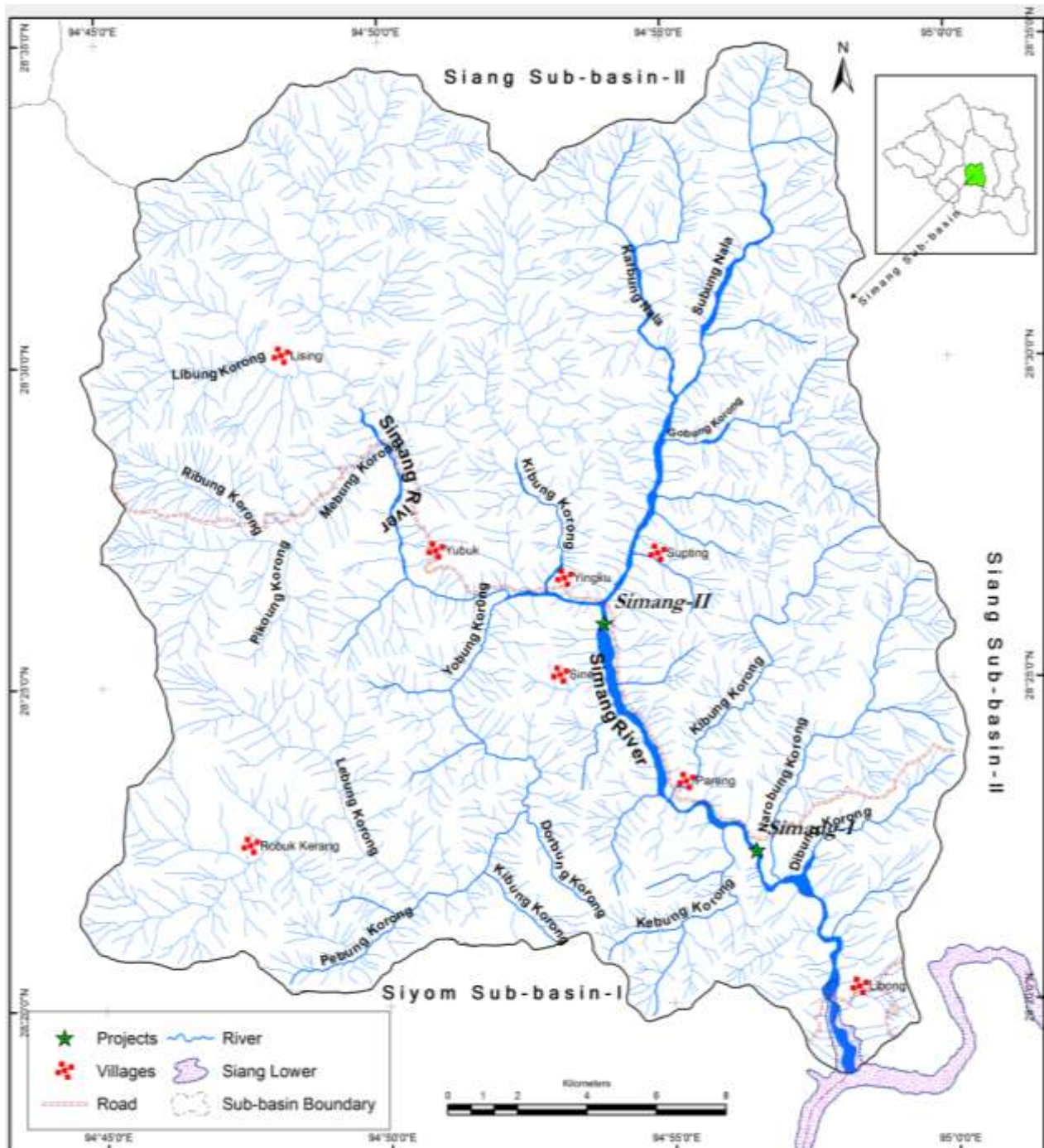


Figure 2.19: Drainage map of Simang Sub-basin

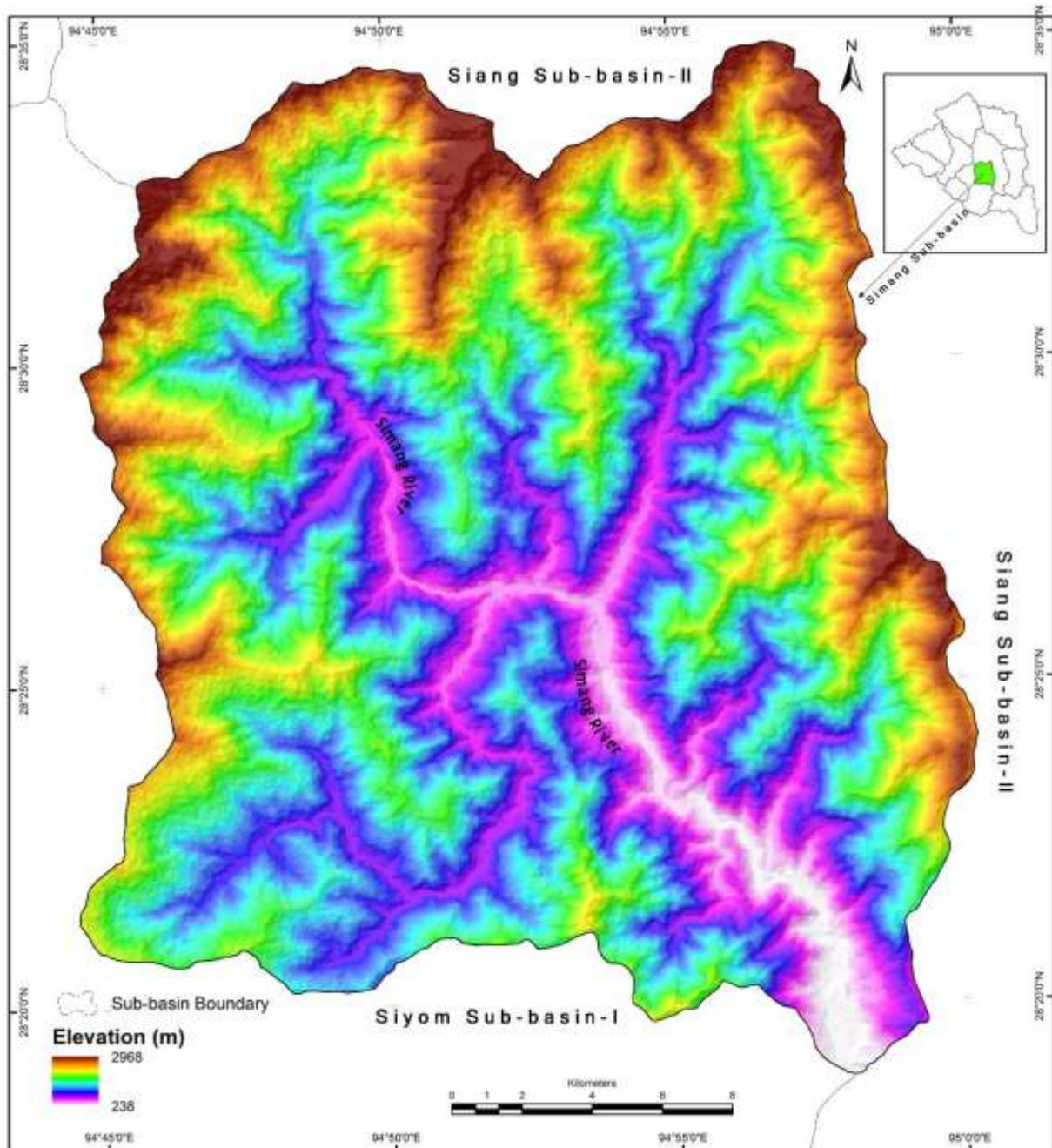


Figure 2.20: DEM of Simang Sub-basin

2.8.7 Hirit Sub-basin

Hirit Sub-basin comprises of the catchment of Hirit River from its origin to its confluence with Siyom River near Kamba village (Figure 2.21). Hirit river is the second largest right bank tributary of Siyom river. The major streams joining at right bank are Yogong Korong, Shichuk Korong, Soying Korong, Rijli nala, Sibu Nala and Himak Nala, while Siri Korong and Hiru Korong are the only significant streams that joins at left bank. Habitation is found in the lower reaches of river, most of the villages namely Poyam, Poma Basti, Damda, Larmukh, Solapotham and Baje are situated near Sibu Nala on the right bank of the river, while Boye, Kamba, Kangki Dolung and Likor Dolung are situated on the left bank of the river.

The elevation varies from 250 m to about 4000 m (Figure 2.22). Majority of the sub-basin area i.e. around 73% lies in the 200 to 2000 m elevation band. Around 24% of the area is covered by 2000 to 3000 m elevation band. The higher elevation band between 3000 to 4000 m covers the balance 3% of the sub-basin area.

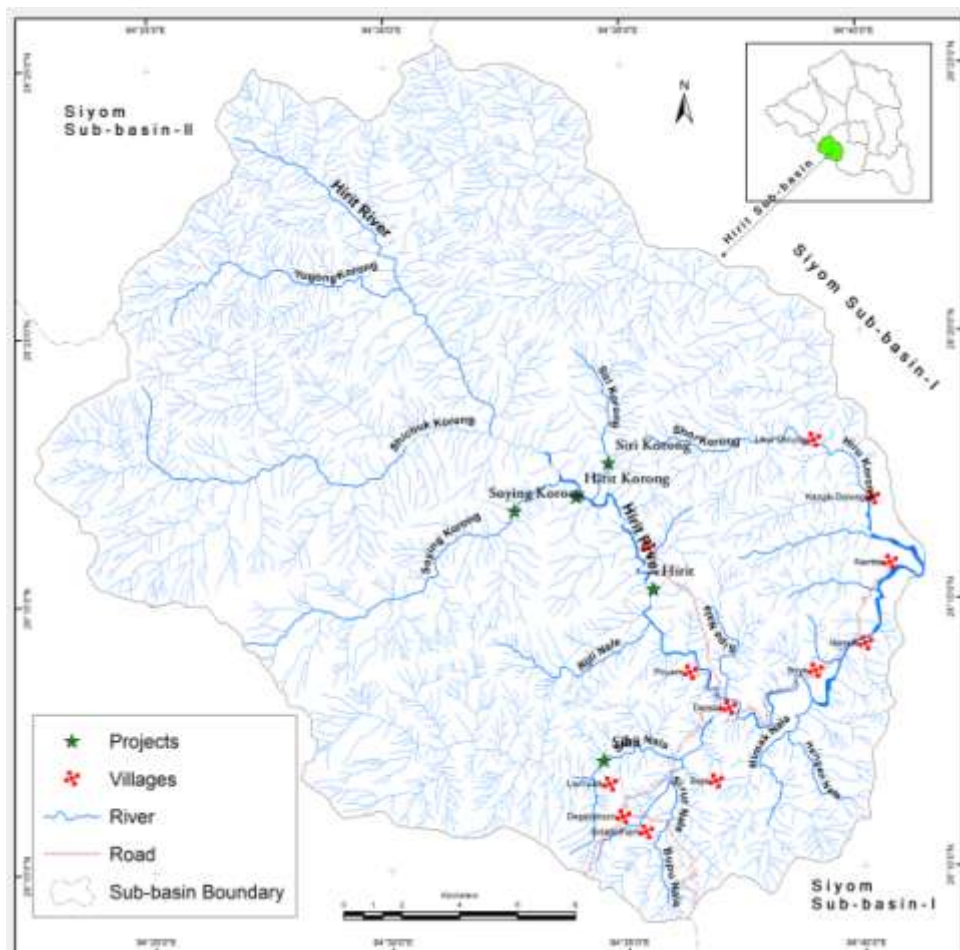


Figure 2.21: Drainage map of Hirit Sub-basin

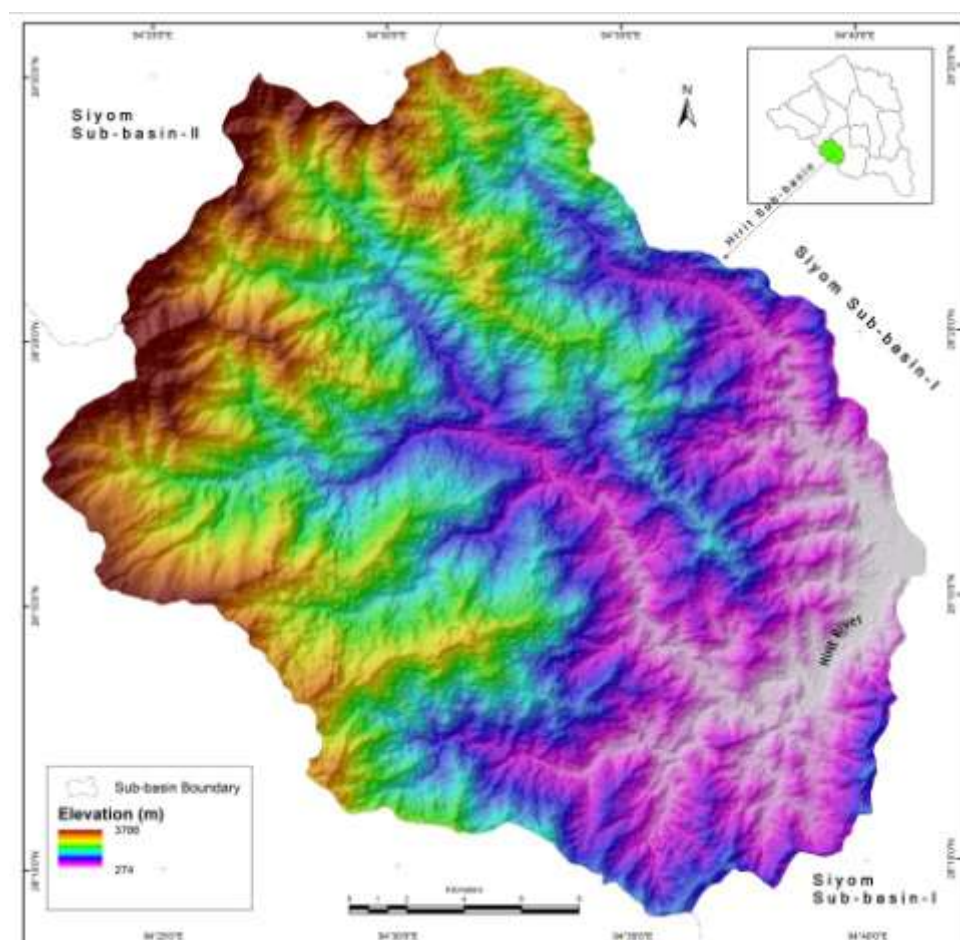


Figure 2.22: DEM of Hirit Sub-basin

2.8.8 Siyom Sub-basin-I

Siyom Sub-basin-I is the southern-most sub-basin of Siyom river, a major tributary of Siang river which joins on the right bank near Pangin. The sub-basin is comprised of the catchment of Siyom river from its confluence with Siang river on right bank near Pangin up to Baga village where it is joined by Sike river on left bank (**Figure 2.23**). The sub-basin falls partially in East Siang and partially in West Siang districts. The river is joined by many streams on both the banks, viz. Sikong Nala, Pitgong, Kebung Korong, Sijum Nala, Kano Korong, Sipu Korong, Mekbu Korong, Yumbung Korong etc. joins on right bank, while Mebung Nala, Pebung Korong, Lebung Korong, Siking Korong, Siping Korong, Sirie Korong, Abung Korong etc. join on left bank. The sub-basin is fairly populated with majority of the villages namely Kaying, Kamki, Wak, Kabu, Along, Dorkane, Lipa, Darung and Tarak. being on the right bank, while Baga, Paya, Pesing and Deku on the left bank of the river.

The elevation varies from 200 m to about 3000 m (**Figure 2.24**). Almost whole of the sub-basin area i.e. around 97% lies in the 200 to 2000 m elevation band, while the rest 3% of the area is covered by 2000 to 3000 m elevation band.

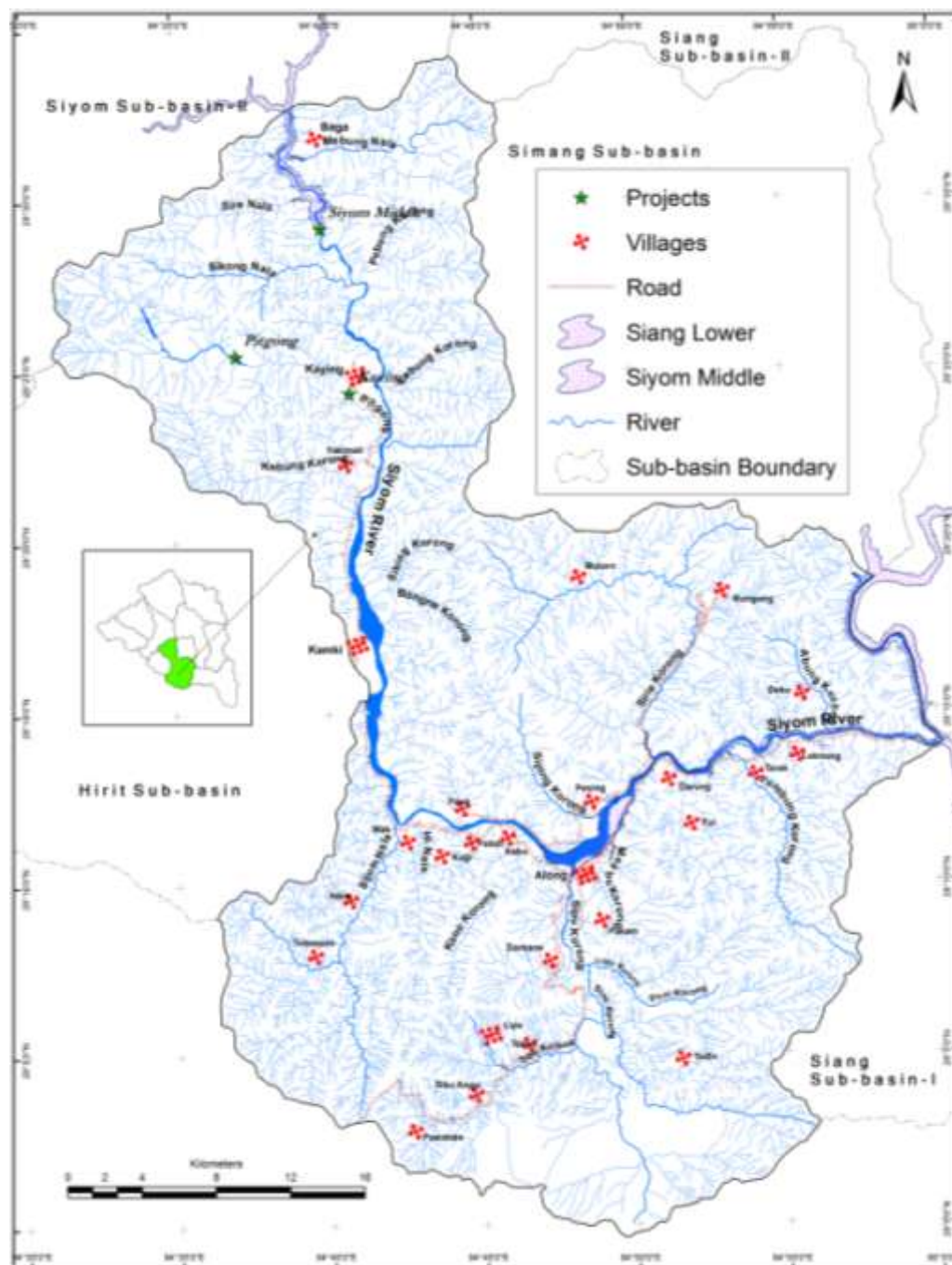


Figure 2.23: Drainage map of Siyom Sub-basin-I

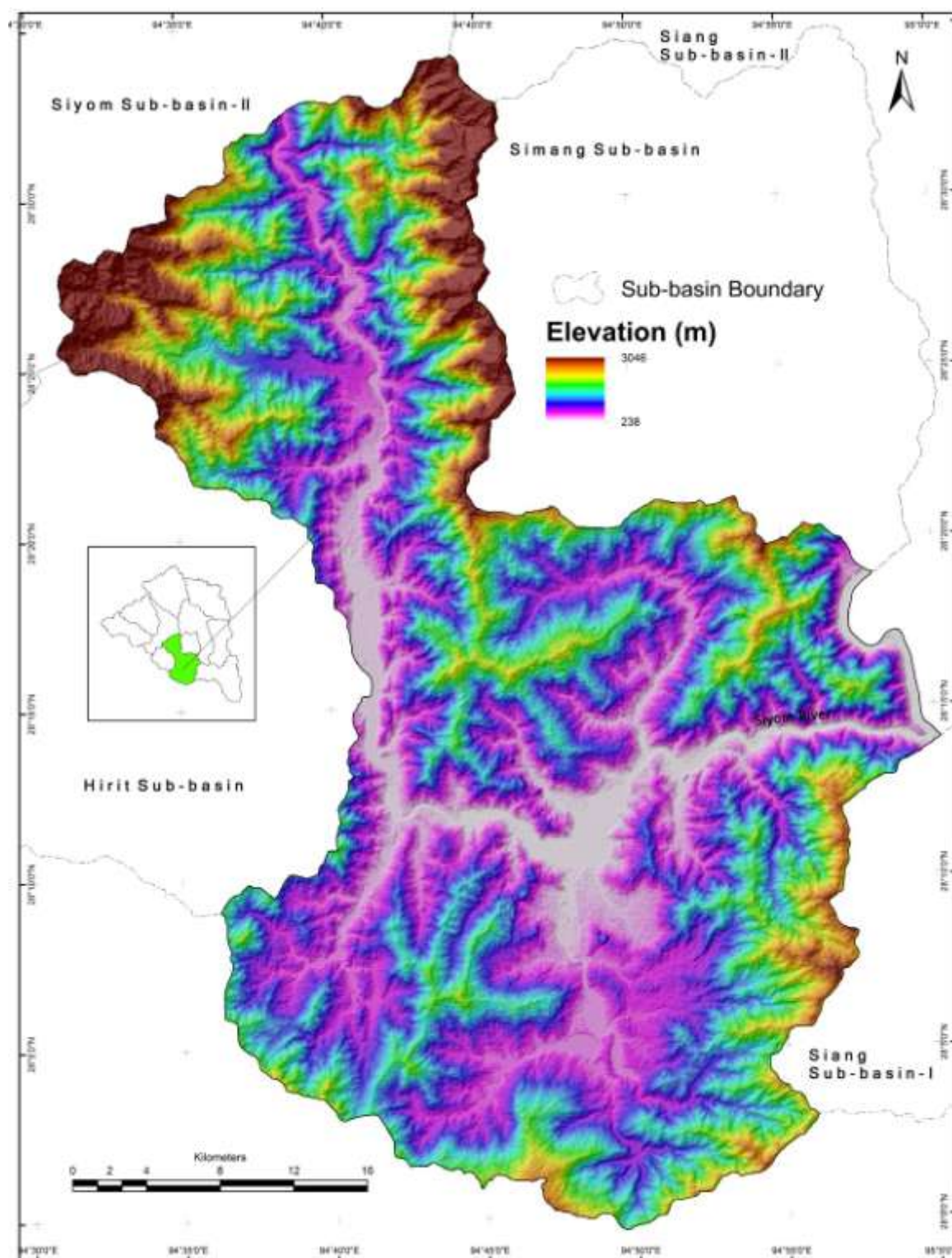


Figure 2.24: DEM of Siyom Sub-basin-I

2.8.9 Siyom Sub-basin-II

Siyom Sub-basin-II is comprised of middle part of Siyom river in West Siang district. This sub-basin is continuation of Sub-basin-I i.e. upstream of confluence with Sike river and extending up to its confluence with Yargyap Chhu river (Figure 2.25). Catchment of Sike river, largest tributary among the streams joining at left bank holds the majority of the sub-basin area. Streams joining left bank of this river are Sipak Nala, Sirang Nala, Sito Nala and Iyak Nalah, while streams joining right bank are Rungang Nala, Sipang Nala, Sinun Nala, Sinyot Nala and Sikong Nala. Apart from Sike river the other streams joining at left bank are Seath Nala, Nabung Nala and Sinyot Nala, while streams joining at right bank are Tagurshit Nadi, Shiyub Nala, Shiyi Nadi, Shikam Nala and Pong Nala. Habitation is equally spread over both the banks of Siyom river as well as on the lower reaches of Sike river. Villages on the

2.35

[illegible]

Figure 2.25: Drainage map of Siyom Sub-basin-II

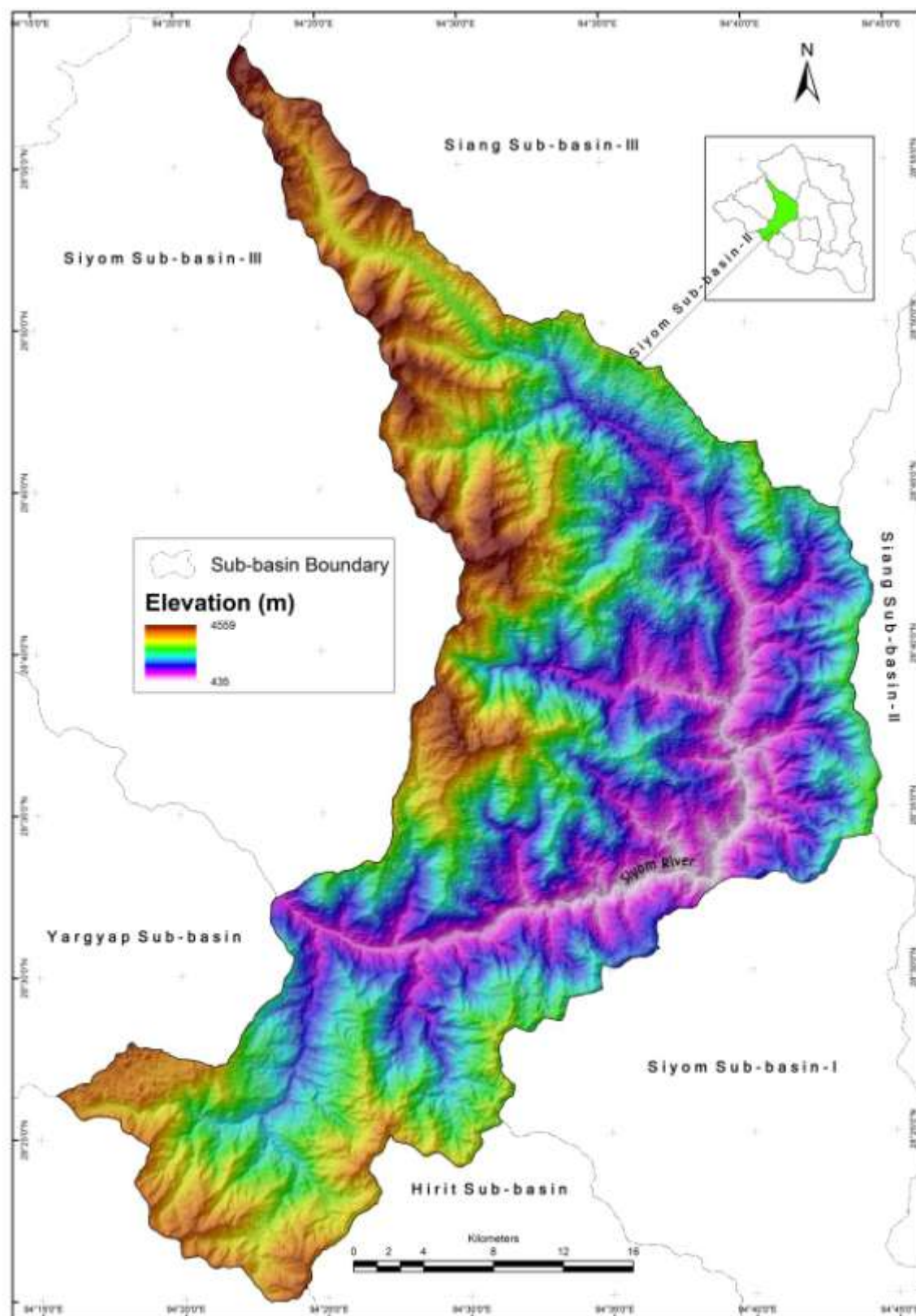


Figure 2.26: DEM of Siyom Sub-basin-II

2.8.10 Siyom Sub-basin-III

Siyom Sub-basin-II is comprised of upper most part of Siyom river in West Siang district. This Sub-basin comprises of the catchment of Siyom River from its origin to its confluence with Yargyap Chhu river near Tato village (Figure 2.27). The major streams joining at right bank are Shir River and Shi Nala, while Shier River, Ramosubar Nala, Shirum Nala and Shishit Nala joins at left bank. Most of the habitations on the left bank are in the lower reaches of sub-basin, villages on the left bank are Karle,

Toyong, Kate, Lungte, Pamne and Hirong. Villages on the right bank namely Pongle, Gayching, Yangrang, Pangri and Roing are near Shir river.

The elevation varies from 900 m to about 5000 m (Figure 2.28). Only 9% of the sub-basin area lies in the 900 to 2000m elevation band. Around 42% of the area lies in the 2000 and 3000 m elevation band. Majority of the sub-basin area i.e. 49% lies in the bands of higher elevation (3000 to 5000 m).

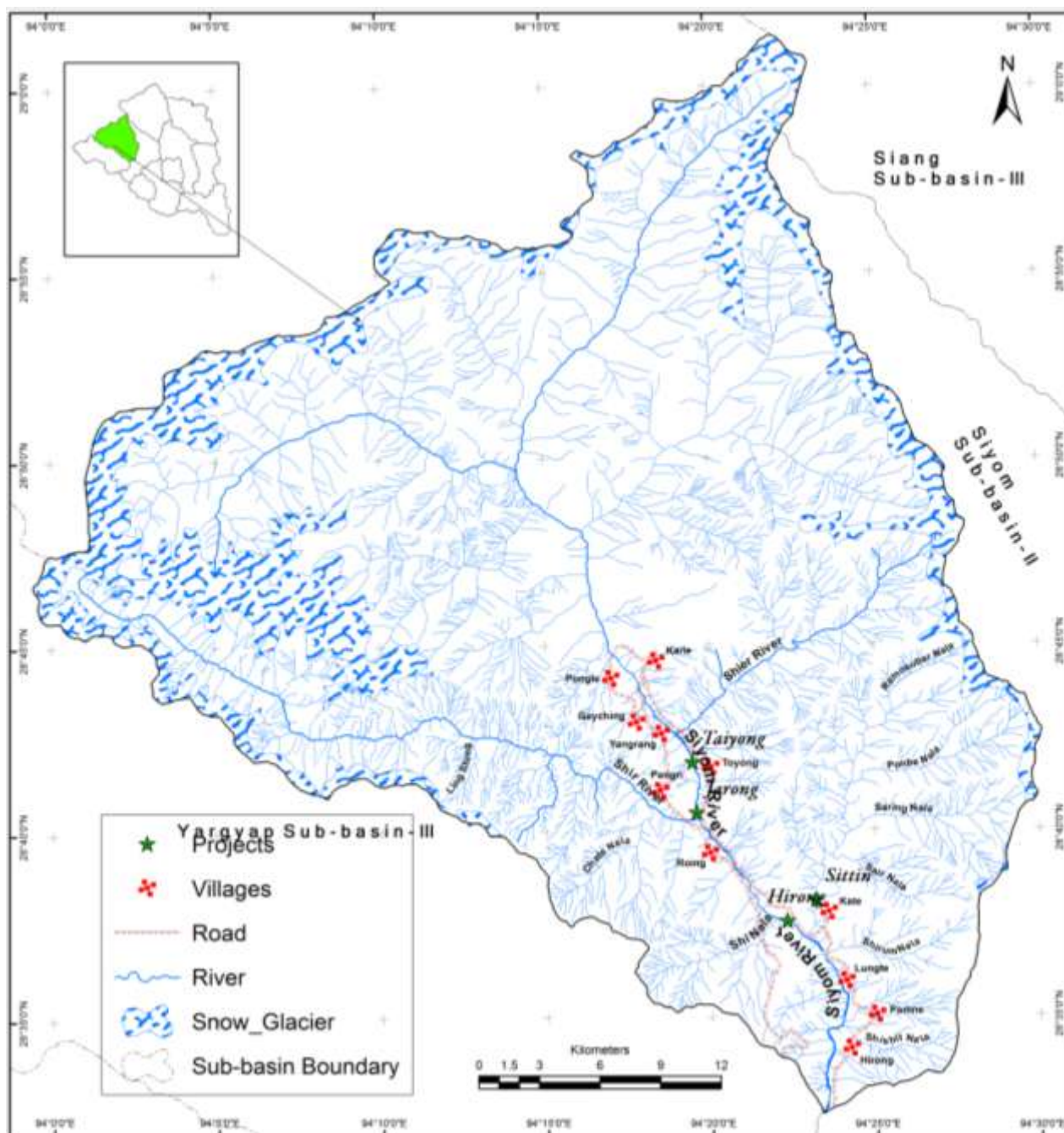


Figure 2.27: Drainage map of Siyom Sub-basin-III

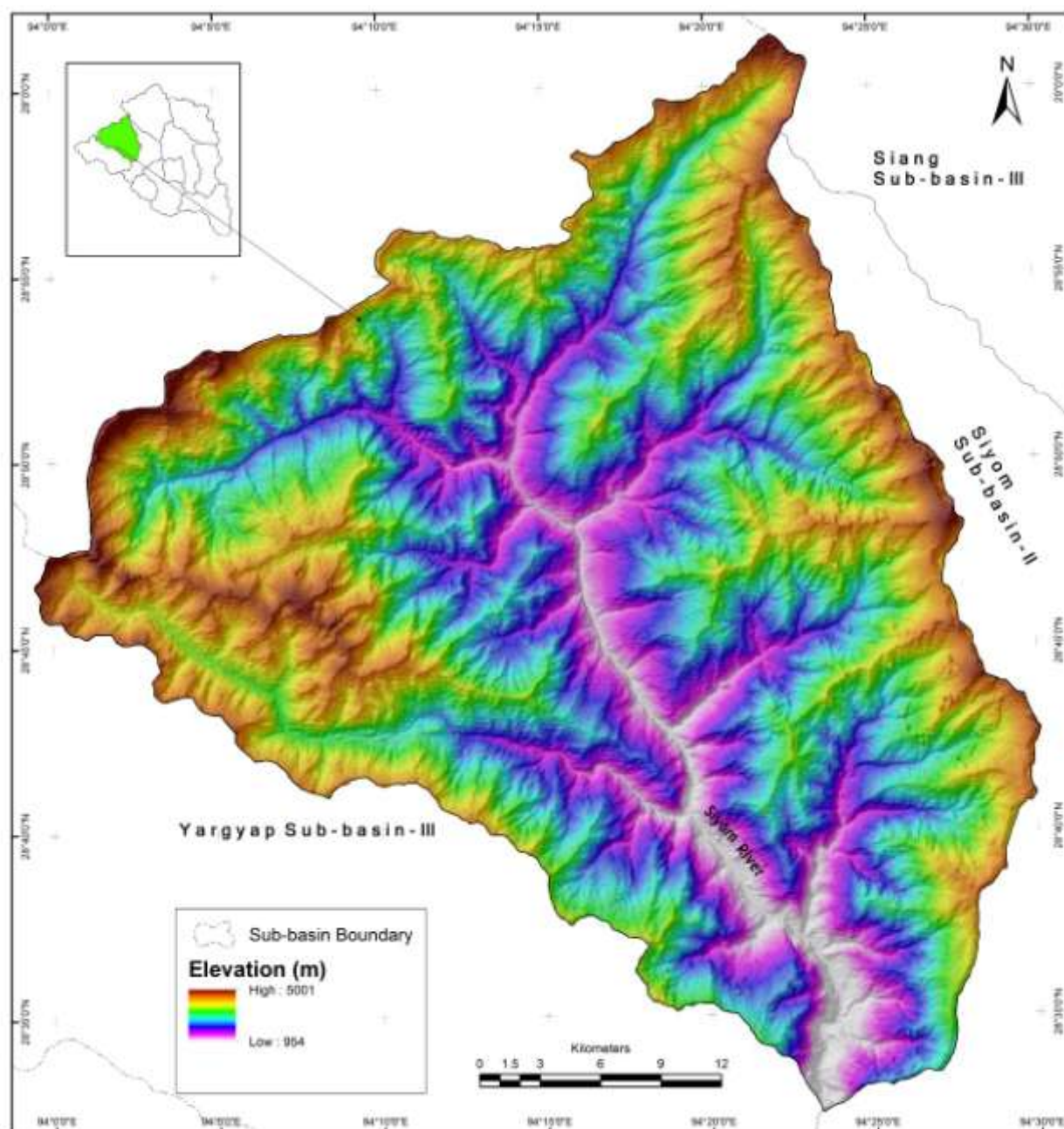


Figure 2.28: DEM of Siyom Sub-basin-III

2.8.11 Yargyap Chhu Sub-basin

Yargyap Sub-basin comprises of the catchment of Yargyap Chhu River from its origin to its confluence with Siyom River near Tato village (**Figure 2.29**). Yargyap Chhu is formed after the confluence of Barpu Sikyo river and Bum Chhu Nala. Yargyap Chhu, from its origin up to its confluence with Siyom river is known by other names in different stretches such as Barpu Sikyo, Site and Shi Chhu (local name). Streams joining the right bank of the Yargyap Chhu are Bum Chhu, Nikma Ishi, Shuru Phuja, Tamding Phuja, Sae Chhu, Sarak Korong and Sethi Nala. The left bank streams are Netsang Gongphu Chhu, Nukumaphu Chhu, Dutungphu Chhu and Songshi Bu.

The elevation varies from 900 m to about 5000 m (**Figure 2.30**). Only 8% of the sub-basin area lies in the 900 to 2000m elevation band. Around 42% of the area lies in the 2000 and 3000 m elevation band. Majority of the sub-basin area i.e. 50% lies in the bands of higher elevation (3000 to 5000 m).

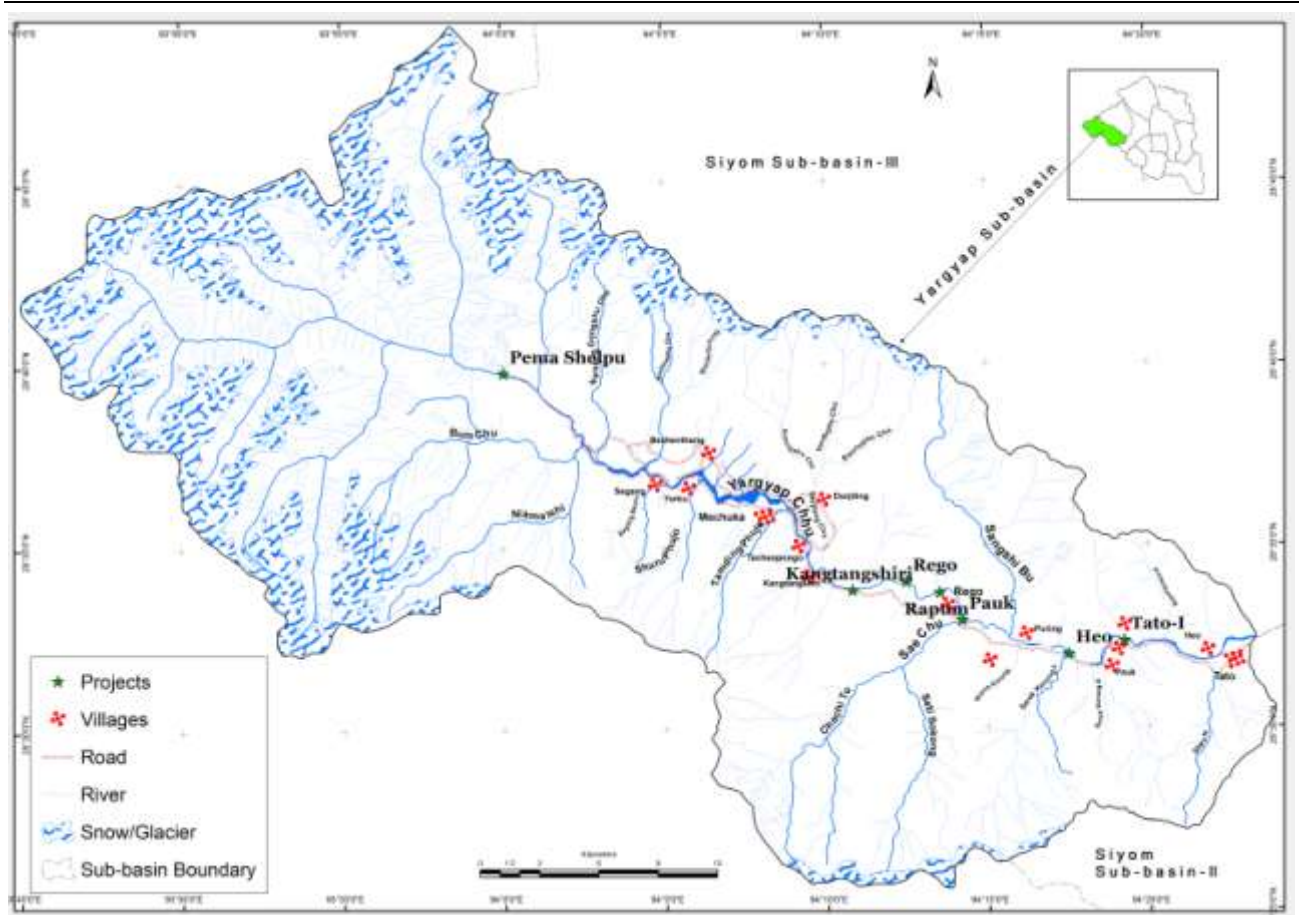


Figure 2.29: Drainage map of Yargyap Chhu Sub-basin

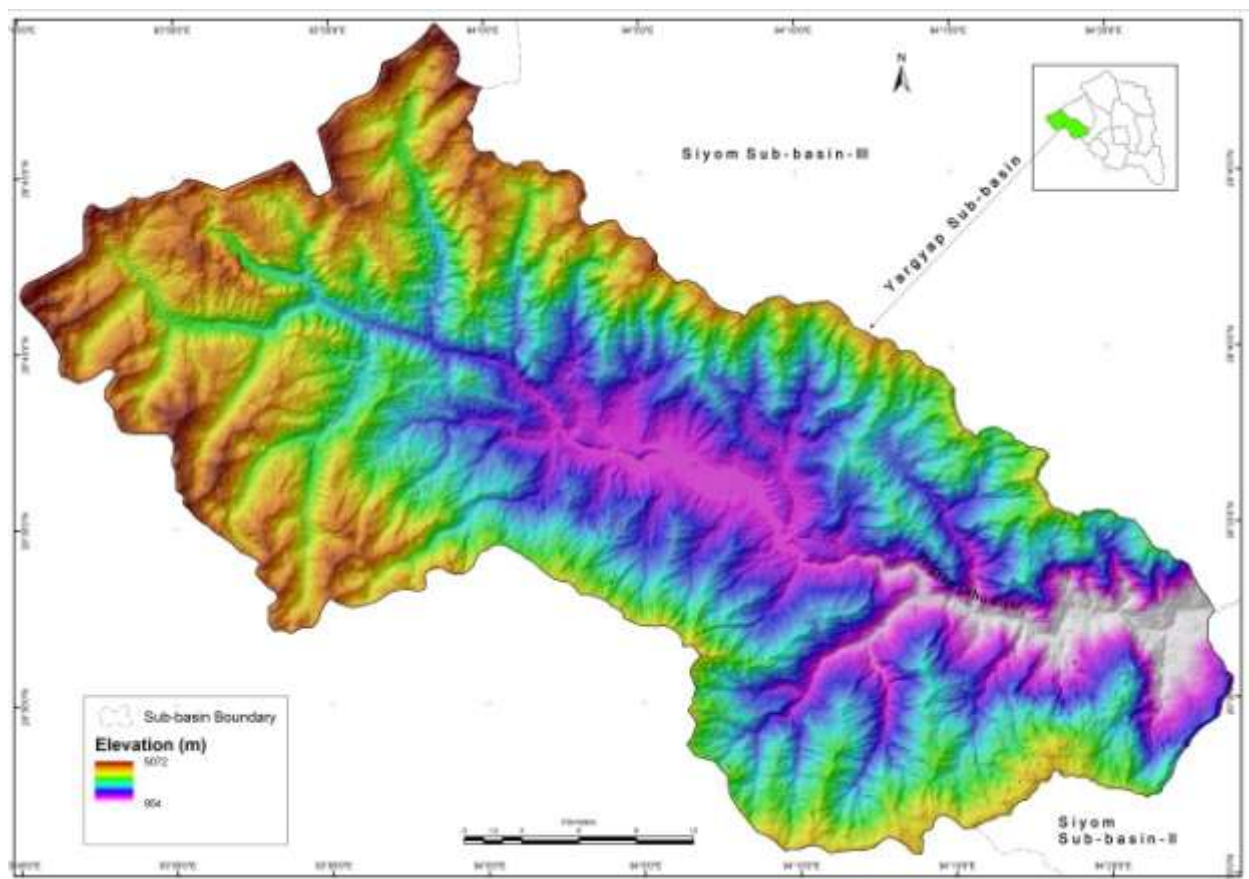


Figure 2.30: DEM of Yargyap Chhu Sub-basin

Chapter-3

HYDROPOWER DEVELOPMENT IN SIANG BASIN

3.1 HYDROPOWER PROJECTS IN SIANG BASIN

Topography of Arunachal Pradesh provides ideal conditions for development of hydropower projects. Five major river basins in state viz. Lohit, Dibang, Siang, Subansiri and Kameng and several smaller river systems offer conducive conditions for hydropower development. CEA ranking study has identified 89 major hydropower projects in state with total potential of 49,126 MW. Under PM's 50,000 MW initiative, Central Government has identified 42 schemes in the state with an installed capacity of 27,293 MW, for preparation of Pre-feasibility Reports (PFRs). Siang basin is considered the largest basin in terms of hydropower potential, which is presently estimated as 18293 MW. Apart from the projects on the main river, hydropower projects are planned on all major tributaries and sub-tributaries with installed capacity ranging from 4 MW to 6000 MW.

At the beginning of the study, detailed interaction was carried out with the Department of Hydro Power Development, Government of Arunachal Pradesh to get the updated information about the planned and allotted projects, along with the status of each, in Siang Basin. As per the information provided by the Power Department, there are 44 hydropower projects in Siang basin, out of which 40 HEPs have been allotted and remaining four are yet to be allotted. Compiling all the information, a comprehensive list of all the allotted/potential projects has been prepared along with their present status and the same is given at **Table 3.1**. For locations of these projects in Siang Basin see **Figure 2.3** of Chapter 2.

3.2 PROJECTS DESCRIPTION

Efforts have been made to collect the data of all the planned projects in the basin. Data have been procured from Department of Hydro Power Development, Government of Arunachal Pradesh as well as by contacting project promoters so that all the relevant information required to make basin level impact assessment can be compiled for data analysis.

All the promoters of hydropower projects in Siang Basin were contacted through email and letters based on the contact information provided by the power department. Information was sought on the salient features, installed capacities and status of survey and investigation, environment and forest clearance, etc. Many of the developers have not responded despite repeated reminders and it was assumed that no progress has been made on these projects.

Required information could be collected for the projects where progress has been made in Survey and Investigation, preparation of Pre-Feasibility Reports (PFRs)/Detailed Project Reports (DPRs), etc. Many of the projects have obtained scoping clearances from MoEF and are making progress in finalizing, EIA/EMP reports, DPRs, land acquisition and processing the case for diversion of forestland. Information collected is compiled in the form of Salient Features of each project and is given in **Tables 3.2 to 3.21**. For the remaining 24 projects, locations, levels and expected installed capacities are available as other information was not shared by developers; this data is used during basin wide impact assessment, however, their salient features and status was not provided.

Table 3.1: Comprehensive List of Hydropower Projects in Siang Basin

Sl.No.	Name of Project	Address of Agency	Capacity (MW)	Revised Capacity (MW)	Status of EC
1	Siang Upper Stage-I	Yet to be allotted	6000	6000	Yet to be allotted
2	Siang Upper Stage-II	NEEPCO Ltd., Shillong	3750	3750	Yet to Apply
3	Siang Lower	Jaiprakash Associates Ltd, New Delhi	1600	2700	Scoping
4	Siyom Middle	Reliance Power Ltd, Navi Mumbai	1000	1000	EC
5	Naying	DS Construction Power Ltd, New Delhi	1000	1000	Scoping and PH
6	Tato-II	Reliance Power Ltd, Navi Mumbai	700	700	EC
7	Hirong	Jaiprakash Associates Ltd, New Delhi	500	500	Scoping and PH
8	Jarong	CESC Ltd. CESC House, Kolkata*	90	90	Scoping/Dropped
9	Taiyong	Abhyudaya Power (P) Ltd	56	56	Yet to Apply
10	Tato-I	Velcan Energy Holdings Ltd, New Delhi	80	186	Scoping and PH
11	Heo	Velcan Energy Holdings Ltd, New Delhi	90	240	Scoping
12	Pauk	Velcan Energy Holdings Ltd, New Delhi	50	145	Scoping
13	Rapum	Raajratna Energy Holdings Pvt. Ltd, Hyderabad	40	66	Scoping
14	Rego	Greenko Energies Pvt Ltd	70	80	Yet to apply
15	Kangtangshiri	Raajratna Energy Holdings Pvt. Ltd, Hyderabad	35	80	Scoping and PH
16	Pemashelpu	Raajratna Energy Holdings Pvt. Ltd, Hyderabad	70	90	Scoping
17	Sangoshi	Chadalavada Constructions (P) Ltd, Hyderabad	12.5	12.5	NA
18	SaeChhu	Chadalavada Constructions (P) Ltd, Hyderabad	15	15	NA
19	Tagurshit	L & T Power Development Ltd, Mumbai	60	84	Scoping
20	Tagurshit Stage-II	Chadalavada Constructions (P) Ltd, Hyderabad	27.5	27.5	Yet to Apply
21	Kaying	Sarda Eco Power Ltd, Hyderabad	14	14	NA
22	Pitgong	Nano Excel Power Corp Ltd, Hyderabad	14	14	NA
23	Hirit	Velcan Energy Holdings Ltd, New Delhi	84	9	NA
24	Hirit Korong	Saisudhir Energy Ltd.	30	42	Yet to Apply
25	Soying Korong	Saisudhir Energy Ltd.	68	48	Yet to Apply
26	Siri Korong	Saisudhir Energy Ltd.	58	58	Yet to Apply
27	Sibu	Supereco India Pvt. Ltd. New Delhi	4	4	NA
28	Sittin	Abhyudaya Power(P) Ltd.	24	24	NA
29	Gameng	Yet to be allotted	37	37	Yet to be allotted
30	Yemsing	KVK Energy Pvt. Ltd, Hyderabad	15	38	Yet to Apply

Sl.No.	Name of Project	Address of Agency	Capacity (MW)	Revised Capacity (MW)	Status of EC
31	Simang-I	Adishankar Power Pvt. Ltd, New Delhi	67	67	Scoping and PH
32	Simang-II	Adishankar Power Pvt. Ltd, New Delhi	39	66	Scoping and PH
33	Nyikong	Aswani Power projects Pvt Ltd, Hyderabad	8	13	NA
34	Pango/ Minniying	Meenakshi Power Ltd, Hyderabad	96	96	Yet to Apply
35	Mirak	Yet to be allotted	141	141	Yet to be allotted
36	Palsi	Meenakshi Power Ltd, Hyderabad	24	24	NA
37	Sippi	Meenakshi Power Ltd, Hyderabad	96	96	Yet to Apply
38	Ringong	Yet to be allotted	150	150	Yet to be allotted
39	Jidu/ Yangsang	Meenakshi Power Ltd, Hyderabad	92	92	Yet to Apply
40	Sipit Upper	Srikar Energy, Hyderabad	7	45	Yet to Apply
41	Yamne Stage-I	SS Yamne Power Pvt. Ltd, New Delhi	60	135	Scoping
42	Yamne Stage-II	SS Yamne Energy Ventures Pvt. Ltd, New Delhi	60	96	Scoping
43	Lower Yamne Stage - I	Yamne Power Pvt. Ltd, Hyderabad	50	75	Scoping
44	Lower Yamne Stage - II	Yamne Power Pvt. Ltd, Hyderabad	40	87	Scoping
Total			16524	18293	

*Jarong HEP was not found viable during Survey and Investigation stage; hence project developer has requested state government for cancellation

** Rego HEP's allotment was cancelled by state government due to lack of progress by developer, however recently has been allotted to Greenko Energies.

Summary of the projects status with respect to environment clearance is given below:

Projects identified but yet to be allotted	4
Projects less than 25 MW	9
Projects accorded Scoping Clearance (Public Hearing yet to be conducted)	8
Public Hearing Conducted but EC not accorded (Hirong, Naying, Tato-I, Pauk, Heo, Simang-I, Simang-II and Kantangshiri HEPs)	8
Project accorded EC under EIA notification 2006 (Tato II HEP)	1
Project accorded EC under EIA notification 1994 (Siyom Middle HEP)	1
Projects yet to apply for Scoping	12
Projects cancelled/dropped	1
Total Number of Planned HEPs	44

Table 3.2: Salient Features of Siang Upper Stage I (6000 MW)

LOCATION	
District	Upper Siang
Name of River	Siang
Coordinates - Diversion Site	N28°47'14" E95°53'33"
Type	Dam Toe Project
HYDROLOGY	
Catchment area at diversion site (Sq km)	2,39,491
Design Discharge (m ³ /s)	4555
LAND REQUIREMENT (Ha)	
Total	7000
DIVERSION STRUCTURE	
Type	Concrete Gravity
Height from river bed (m)	175
Top of Structure (masl)	515
FRL (masl)	510
MDDL (masl)	470
Average Bed level (masl)	340
Live Storage (10 ⁶ m ³)	1032
HEADRACE TUNNEL	
Type	Horse Shoe
Diameter (m)	12
Length (m)	3300 (Max)
Number	8
SURGE SHAFT	
Type	Restricted orifice type
Diameter (m)	32/35
Height (m)	114
PRESSURE SHAFT	
Type	Steel Lined
Number	16
Diameter (m)	6.5
Length (m)	150
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	6000
Net Head (m)	149.17
Tail water level (masl)	340 (max)
TURBINE	
Type	Vertical shaft Francis
Number's	16
Rated Output	375 MW each
POWER BENEFITS	
90% Dependable Energy (MU)	29079

(Source: Pre Feasibility Report)

Table 3.3: Salient Features of Siang Upper Stage II (3750 MW)

LOCATION	
District	Upper Siang
Name of River	Siang
Coordinates - Diversion Site	N28°28'37" E95°06'11.9"
Type	Dam Toe Project
HYDROLOGY	
Catchment area at diversion site (Sq km)	2,40,477
Design Discharge (m ³ /s)	4500
LAND REQUIREMENT (Ha)	
Total	4750
DIVERSION STRUCTURE	
Type	Concrete Gravity
Height from river bed (m)	110
Top of Structure (masl)	345
FRL (masl)	340
MDDL (masl)	320
Average Bed level (masl)	235
Live Storage (10 ⁶ m ³)	750
HEADRACE TUNNEL	
Type	Horse Shoe
Diameter (m)	9
Length (m)	2050
Number	12
SURGE SHAFT	
Type	Vertical with Restricted Orifice
Diameter (m)	32
Height (m)	100
PRESSURE SHAFT	
Type	Steel Lined
Number	12
Diameter (m)	6.8
Length (m)	162
POWERHOUSE	
Type	One Surface, Two Underground
Installed Capacity (MW)	3750 MW
Net Head (m)	94.33
Tail water level (masl)	235 (max)
TURBINE	
Type	Vertical shaft Francis
Number's	15
Rated Output	250 MW each
POWER BENEFITS	
90% Dependable Energy (MU)	17977

(Source: Pre Feasibility Report)

Table 3.4: Salient Features of Siang Lower (2700 MW)

LOCATION	
District	East Siang
Name of River	Siang
Coordinates - Diversion Site	N28°09'59" E95°14'00"
Type	Dam Toe Project
HYDROLOGY	
Catchment area at diversion site (Sq km)	2,50,594
Design Discharge (m ³ /s)	5440
LAND REQUIREMENT (Ha)	
Total	6424
DIVERSION STRUCTURE	
Type	Concrete Gravity
Height from river bed (m)	86
Top of Structure (masl)	234.4
FRL (masl)	230
MDDL (masl)	225.5
Average Bed level (masl)	149
Live Storage (10 ⁶ m ³)	204.07
PENSTOCK	
Number	9
Diameter (m)	11.75
Length (m)	73
POWERHOUSE	
Type	Surface (Dam Toe)
Installed Capacity (MW)	2700 MW
Net Head (m)	
Tail water level (masl)	168.56 (max)/161.72 (min)
TURBINE	
Type	Francis
Number's	9
Rated Output	300 MW each
POWER BENEFITS	
50% Dependable Energy (MU)	13,930.16MU
90% Dependable Energy (MU)	13,236.47MU

(Source: Detailed Project Report)

Table 3.5: Salient Features of Siyom Middle (1000 MW)

LOCATION	
District	West Siang
Name of River	Siyom
Coordinates - Diversion Site	N28°29'10" E94°39'10"
Type	Run-off-the river with pondage
HYDROLOGY	
Catchment area at diversion site (Sq km)	3,879
Design Discharge (m ³ /s)	709.1
LAND REQUIREMENT (Ha)	
Total	1704.21
DIVERSION STRUCTURE	
Type	Roller Compacted Concrete
Height from river bed (m)	169
Top of Structure (masl)	525
FRL (masl)	520
MDDL (masl)	515.5
Average Bed level (masl)	356
Live Storage (10 ⁶ m ³)	153.42
SURFACE PENSTOCK	
Type	Circular (3 nos)
Diameter (m)	7.5
Length (m)	202
PRESSURE SHAFT & PRESSURE TUNNEL	
Type	Circular
Number	6
Diameter (m)	6
Length (m)	402
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	1000
Net Head (m)	154.86
Tail water level (masl)	360.06 (normal)/ 358.40 (min)
TURBINE	
Type	Vertical Francis
Number's	6
Rated Output	166.67 each
POWER BENEFITS	
90% Dependable Energy (MU)	4086

(Source: Project Developer)

Table 3.6: Salient Features of Naying (1000 MW)

LOCATION	
District	West Siang
Name of River	Siyom
Coordinates - Diversion Site	N28°31'10" E94°30'25"
Coordinates - Powerhouse	N28°31'56" E94°34'10"
HYDROLOGY	
Catchment area at diversion site (Sq km)	2760
Design Discharge (m ³ /s)	411
LAND REQUIREMENT (Ha)	
Total	644
DIVERSION STRUCTURE	
Type	Concrete Gravity Dam
Height from river bed (m)	108
Top of Structure (masl)	808
FRL (masl)	805
MDDL (masl)	800
Average Bed level (masl)	700
Live Storage (10 ⁶ m ³)	7.6
HEADRACE TUNNEL	
Type	Circular
Diameter (m)	10.6
Length (m)	7080
SURGE SHAFT	
Type	Circular Open
Diameter (m)	28
Height (m)	89.1
PRESSURE SHAFT	
Type	Underground
Number	4
Diameter (m)	4.5
Length (m)	383
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	1000 MW
Net Head (m)	275.5
Tail water level (masl)	528.4 (normal)/520.72 m (min)
TURBINE	
Type	Vertical Axis Francis
Number's	4
Rated Output	250 MW each
POWER BENEFITS	
50% Dependable Energy (MU)	4657.4
90% Dependable Energy (MU)	4603

(Source: Detailed Project Report)

Table 3.7: Salient Features of Tato II (700 MW)

LOCATION	
District	West Siang
Name of River	Siyom
Coordinates - Diversion Site	N28°32'4.5" E94°23'57.2"
Coordinates - Powerhouse	N28°31'25.18" E94°25'35.22"
HYDROLOGY	
Catchment area at diversion site (Sq km)	2560
Design Discharge (m ³ /s)	384
LAND REQUIREMENT (ha)	
Total	313.88
DIVERSION STRUCTURE	
Type	Concrete Gravity
Height from river bed (m)	123
Top of Structure (masl)	1025
FRL (masl)	1020
MDDL (masl)	1012
Average Bed level (masl)	902
Live Storage (10 ⁶ m ³)	6.55
HEADRACE TUNNEL	
Type	Circular, Concrete Lined
Diameter (m)	10.4
Length (m)	3876
SURGE SHAFT	
Type	one
Diameter (m)	31.5
Height (m)	61.7 (incl vault)
PRESSURE SHAFT	
Type	Underground and Steel Lined
Number	Four
Diameter (m)	4.5
Length (m)	311.4 * 2 for outer shafts; 294.4 * 2 for inner shafts
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	700
Net Head (m)	207
Tail water level (masl)	810
TURBINE	
Type	Vertical Francis
Number's	4
Rated Output	175 MW each
POWER BENEFITS	
50% Dependable Energy (MU)	3263.7
90% Dependable Energy (MU)	3306.2

(Source: Project Developer)

Table 3.8: Salient Features of Hiron (500 MW)

LOCATION	
District	West Siang
Name of River	Siyom
Coordinates - Diversion Site	N28°37'36.6" E94°22'53"
HYDROLOGY	
Catchment area at diversion site (Sq km)	1289
Design Discharge (m ³ /s)	181.8
LAND REQUIREMENT (Ha)	
Total	492.76
DIVERSION STRUCTURE	
Type	Concrete Gravity Dam
Height from river bed (m)	128.5
Top of Structure (masl)	1358.5
FRL (masl)	1355
MDDL (masl)	1349
Average Bed level (masl)	1230
Live Storage (10 ⁶ m ³)	3.2
DIVERSION WORK ON SITTIN NALLAH	
Type	Trench Weir
Length (m)	19
Width (m)	2.65 (top), 1.25 (bottom)
Linked Tunnel	Underground; 4 m dia; 1070m long
HEADRACE TUNNEL	
Type	Horse Shoe
Diameter (m)	7.5
Length (m)	9200
SURGE SHAFT	
Type	Restricted Orifice Type
Diameter (m)	15
Height (m)	140.25
PRESSURE SHAFT	
Type	Underground
Number	2
Diameter (m)	4.25
Length (m)	383
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	500 MW
Net Head (m)	313.874
Tail water level (masl)	1025 (max)/1013 (min)
TURBINE	
Type	Vertical Axis Francis
Number's	4
Rated Output	125 MW each
POWER BENEFITS	
50% Dependable Energy (MU)	2513.2
90% Dependable Energy (MU)	2228.28

(Source: Detailed Project Report)

Table 3.9: Salient Features of Tato I (186 MW)

LOCATION	
District	West Siang
Name of River	Yargyap Chhu
Coordinates - Diversion Site	N28°32'32" E94°18'43"
Coordinates - Powerhouse	N28°31'53" E94°21'31"
HYDROLOGY	
Catchment area at diversion site (Sq km)	1154
Design Discharge (m ³ /s)	133
LAND REQUIREMENT (Ha)	
Total	52.8 ha
DIVERSION STRUCTURE	
Type	Trench Weir Coupled with Heo
Height from river bed (m)	Tail race development
Top of Structure (masl)	
FRL (masl)	
MDDL (masl)	
Average Bed level (masl)	1176
Live Storage (10 ⁶ m ³)	
HEADRACE TUNNEL	
Type	Horse Shoe
Diameter (m)	6.4
Length (m)	3900
SURGE SHAFT	
Type	Vertical Orifice
Diameter (m)	14
Height (m)	85
PRESSURE SHAFT	
Type	
Number	1
Diameter (m)	5.75
Length (m)	633
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	186
Net Head (m)	153.2
Tail water level (masl)	1025
TURBINE	
Type	Francis vertical
Number's	3
Rated Output	62 MW each
POWER BENEFITS	
90% Dependable Energy (MU)	838.159

(Source: Detailed Project Report)

Table 3.10: Salient Features of Heo (240 MW)

LOCATION	
District	West Siang
Name of River	Yargyap Chhu
Coordinates - Diversion Site	N28°32'20" E94°16'31"
Coordinates - Powerhouse	N28°32'32" E94°18'43"
HYDROLOGY	
Catchment area at diversion site (km ²)	1065
Design Discharge (m ³ /s)	130
LAND REQUIREMENT (Ha)	
Total	55.7
DIVERSION STRUCTURE	
Type	Concrete Gravity Dam
Height from river bed (m)	22.5
Top of Structure (masl)	1406.5
FRL (masl)	1400
MDDL (masl)	1398
Average Bed level (masl)	1384
Live Storage (10 ⁶ m ³)	0.15
HEADRACE TUNNEL	
Type	Horse Shoe
Diameter (m)	6.4
Length (m)	3578
SURGE SHAFT	
Type	Vertical Orifice
Diameter (m)	10
Height (m)	81.8
PRESSURE SHAFT	
Type	Circular
Number	1
Diameter (m)	5.75
Length (m)	633
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	240
Net Head (m)	201.8
Tail water level (masl)	1189
TURBINE	
Type	Francis vertical
Number's	3
Rated Output	80 MW each
POWER BENEFITS	
90% Dependable Energy (MU)	1049.3

(Source: Detailed Project Report)

Table 3.11: Salient Features of Pauk (145 MW)

LOCATION	
District	West Siang
Name of River	Yargyap Chhu
Coordinates - Diversion Site	N28°32'46" E94°14'43"
Coordinates - Powerhouse	N28°32'22" E94°15'58"
HYDROLOGY	
Catchment area at diversion site (Sq km)	982
Design Discharge (m ³ /s)	119
LAND REQUIREMENT (Ha)	
Total	91.7
DIVERSION STRUCTURE	
Type	Concrete Arch Dam
Height from river bed (m)	73.5
Top of Structure (masl)	1550
FRL (masl)	1540
MDDL (masl)	1520
Average Bed level (masl)	1475
Live Storage (10 ⁶ m ³)	5.7
HEADRACE TUNNEL	
Type	Horse Shoe
Diameter (m)	6
Length (m)	2511
SURGE SHAFT	
Type	Vertical Orifice
Diameter (m)	13.8
Height (m)	63
PRESSURE SHAFT	
Number	1
Diameter (m)	5.5
Length (m)	391
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	145
Net Head (m)	135.1
Tail water level (masl)	1400
TURBINE	
Type	Francis vertical
Number's	3
Rated Output	48.3 MW each
POWER BENEFITS	
90% Dependable Energy (MU)	640

(Source: Detailed Project Report)

Table 3.12: Salient Features of Rapum (66 MW)

LOCATION	
District	West Siang
Name of River	Yargyap Chhu
Co-ordinates - Diversion Site	N28°33'35.08" E94°12'46.29"
Co-ordinates - Powerhouse	N28°33'45.15" E94°13'36.64"
HYDROLOGY	
Catchment area at diversion site (Sq km)	834
Design Discharge (m ³ /s)	78.33
LAND REQUIREMENT (Ha)	
Total	41 ha (approx.)
DIVERSION STRUCTURE	
Type	Barrage
Height from river bed (m)	22
Top of Structure (masl)	1652
FRL (masl)	1650
MDDL (masl)	1643
Average Bed level (masl)	1630
Live Storage (10 ⁶ m ³)	0.1(approx.)
HEADRACE TUNNEL	
Type	Horse Shoe Shape
Diameter (m)	6.0
Length (m)	1515
SURGE SHAFT	
Type	Restricted Orifice
Diameter (m)	14
Height (m)	40 (approx)
PRESSURE SHAFT	
Type	Steel lined
Number	One bifurcating into two
Diameter (m)	5.0
Length (m)	Main shaft 96m (approx.) up to bifurcation and 20m each after bifurcation
POWERHOUSE	
Type	Under ground
Installed Capacity (MW)	66 MW (2 x 33MW)
Net Head (m)	92.85
Tail water level (masl)	1555
TURBINE	
Type	Vertical Axis Francis
Number's	2
Rated Output	2 x 33 MW
POWER BENEFITS	
50% Dependable Energy (MU)	284.97
90% Dependable Energy (MU)	296.68

(Source: Project Developer)

Table 3.13: Salient Features of Rego (80 MW)

LOCATION	
District	West Siang
Name of River	Yargyap Chhu
Coordinates - Power Intake Chamber (At the	N28 ⁰ 34'9.76" E94 ⁰ 11'35.81"
Coordinates - Powerhouse	N28 ⁰ 34' 12.86" E94 ⁰ 12'18.25"
HYDROLOGY	
Catchment area at diversion site (km2)	810
Design Discharge (m3/s)	74.76
LAND REQUIREMENT (Ha)	
Total	Less than 5 Ha (approx.)
POWER INTAKE CHAMBER	Rego HEP is proposed as Tail Race Scheme of U/s project of Kangtangshiri HEP
Type	Underground (Provided at the end of TRT of U/s Kangtangshiri HEP)
FRL (masl)	NA, as it is a tailrace development of Kangtangshiri
MDDL (masl)	
HEADRACE TUNNEL	
Type	Horse Shoe Shaped
Diameter (m)	6.0
Length (m)	1135
SURGE SHAFT	
Type	Restricted Orifice
Diameter (m)	14m approx.
Height (m)	39m approx.
PRESSURE SHAFT	
Type	Underground, steel lined
Number	One no. starting from HRT and bifurcating in to two near power house
Diameter (m)	5.0
Length (m)	Horizontal 50m & Vertical 110m approx.
POWERHOUSE	
Type	Under ground
Installed Capacity (MW)	80 MW (2 x 40 MW)
Net Head (m)	118.57
Tail water level (masl)	1685
TURBINE	
Type	Vertical Axis Francis
Number's	2
Rated Output	40 MW each
POWER BENEFITS	
50% Dependable Energy (MU)	345.20
90% Dependable Energy (MU)	359.28

(Source: Department of Hydro Power Development, Government of Arunachal Pradesh and Project Developer)

Table 3.14: Salient Features of Kantangshiri (80 MW)

LOCATION	
District	West Siang
Name of River	Yargyap Chhu
Coordinates - Diversion Site	N28°33'50.75" E94°10'50.84"
Coordinates - Powerhouse	N28°34'6.46" E94°11'25.49"
HYDROLOGY	
Catchment area at diversion site (Sq km)	810
Design Discharge (m ³ /s)	94.86
LAND REQUIREMENT (Ha)	
Total	37.31 Ha
DIVERSION STRUCTURE	
Type	Gated Barrage
Height from river bed (m)	22
Top of Structure (masl)	1902
FRL (masl)	1900
MDDL (masl)	1891.5
Average Bed level (masl)	1880
Live Storage (10 ⁶ m ³)	0.46
HEADRACE TUNNEL	
Type	Horse shoe shaped
Diameter (m)	6.6
Length (m)	370.87
SURGE SHAFT	
Type	Surge gallery
Diameter (m)	6.6
Height (m)/length (m)	421 m long
PRESSURE SHAFT	
Type	Steel lined
Number	One bifurcating into two
Diameter (m)	5.6
Length (m)	Main shaft 118.90m up to bifurcation and 24.7m each after bifurcation
POWERHOUSE	
Type	Underground
Installed Capacity (MW)	80 (2 x 40MW)
Net Head (m)	92.94
Tail water level (masl)	1805
TURBINE	
Type	Vertical Francis Turbine
Number's	2
Rated Output	40 MW each
POWER BENEFITS	
50% Dependable Energy (MU)	345.89
90% Dependable Energy (MU)	353.81

(Source: Revised Pre-Feasibility Report)

Table 3.15: Salient Features of Pemashelpu (90 MW)

LOCATION	
District	West Siang
Name of River	Yargyap Chu
Coordinates - Diversion Site	N28°39'47.08" E94°00'9.25"
Coordinates - Powerhouse	N28°38'08" E94°01'56.7"
HYDROLOGY	
Catchment area at diversion site (Sq km)	366
Design Discharge (m ³ /s)	37.73
LAND REQUIREMENT (Ha)	
Total	55.25
DIVERSION STRUCTURE	
Type	Concrete
Height from river bed (m)	25
Top of Structure (masl)	2238
FRL (masl)	2236
MDDL (masl)	2226
Average Bed level (masl)	2213
Live Storage (10 ⁶ m ³)	0.202
HEADRACE TUNNEL	
Type	Horse Shoe Shaped
Diameter (m)	4.5
Length (m)	3708
SURGE SHAFT	
Type	Restrlicated Orifice
Diameter (m)	12.5
Height (m)	53.5
PRESSURE SHAFT	
Type	steel Lined; circular
Number	1
Diameter (m)	3.5
Length (m)	782
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	90 MW
Net Head (m)	264.3
Tail water level (masl)	1955
TURBINE	
Type	Francis
Number's	3
Rated Output	30 MW each
POWER BENEFITS	
90% Dependable Energy (MU)	422.78

(Source: Revised Pre-Feasibility Report)

Table 3.16: Salient Features of Simang I (67 MW)

LOCATION	
District	East Siang
Name of River	Simang
Coordinates - Diversion Site	N28°22'11.3" E94°56'34.2"
Coordinates - Powerhouse	N28°20'39.3" E94°57'48.3"
HYDROLOGY	
Catchment area at diversion site (Sq km)	494
Design Discharge (m ³ /s)	90.72
LAND REQUIREMENT (Ha)	
Total	54.58
DIVERSION STRUCTURE	
Type	Barrage
Height from river bed (m)	18
Top of Structure (masl)	341
FRL (masl)	339
MDDL (masl)	334
Average Bed level (masl)	323
Live Storage (10 ⁶ m ³)	0.53
HEADRACE TUNNEL	
Type	Horse Shoe
Diameter (m)	6.1
Length (m)	4093
SURGE SHAFT	
Type	Restricted Orifice
Diameter (m)	21
Height (m)	36.4
PRESSURE SHAFT	
Type	Steel lined
Number	1
Diameter (m)	4.4
Length (m)	200
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	67 MW
Net Head (m)	81.83
Tail water level (masl)	246.5 (min)/247 (max)
TURBINE	
Type	Vertical Axis Francis
Number's	3
Rated Output	22.33 MW each
POWER BENEFITS	
90% Dependable Energy (MU)	273.85

(Source: Detailed Project Report)

Table 3.17: Salient Features of Simang II (66 MW)

LOCATION	
District	East Siang
Name of River	Simang
Coordinates - Diversion Site	N28°26'00" E94°53'52"
Coordinates - Powerhouse	N28°23'04" E94°55'44"
HYDROLOGY	
Catchment area at diversion site (Sq km)	422
Design Discharge (m ³ /s)	78.4
LAND REQUIREMENT (Ha)	
Total	46.14
DIVERSION STRUCTURE	
Type	Barrage
Height from river bed (m)	18
Top of Structure (masl)	460
FRL (masl)	458
MDDL (masl)	453
Average Bed level (masl)	442
Live Storage (10 ⁶ m ³)	0.41
HEADRACE TUNNEL	
Type	Horse Shoe
Diameter (m)	5.6 m for 3700 m & 6.2 m for 3700 m
Length (m)	7400
SURGE SHAFT	
Type	Restricted Orifice
Diameter (m)	17
Height (m)	54
PRESSURE SHAFT	
Type	Steel lined
Number	1
Diameter (m)	4.5
Length (m)	225
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	66 MW
Net Head (m)	93.37
Tail water level (masl)	350.58
TURBINE	
Type	Vertical Axis Francis
Number's	3
Rated Output	22 MW each
POWER BENEFITS	
50% Dependable Energy (MU)	341.03
90% Dependable Energy (MU)	267.59

(Source: Detailed Project Report)

Table 3.18: Salient Features of Yamne Stage I (135 MW)

LOCATION	
District	Upper Siang
Name of River	Yamne
Coordinates - Diversion Site	N28°31'11" E95°10'31"
Coordinates - Powerhouse	N28°26'06" E95°14'05"
HYDROLOGY	
Catchment area at diversion site (Sq km)	625
Design Discharge (m ³ /s)	96.97
LAND REQUIREMENT (Ha)	
Total	493.5
DIVERSION STRUCTURE	
Type	Concrete Gravity Dam
Height from river bed (m)	47
Top of Structure (masl)	737
FRL (masl)	735
MDDL (masl)	730
Average Bed level (masl)	690
Live Storage (10 ⁶ m ³)	9.69
HEADRACE TUNNEL	
Type	Modified Horse Shoe
Diameter (m)	6.5
Length (m)	11200
SURGE SHAFT	
Type	Restricted Orifice
Diameter (m)	15
Height (m)	90.9
PRESSURE SHAFT	
Type	Steel lined
Number	1
Diameter (m)	5.0
Length (m)	709.1
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	135
Net Head (m)	154.26
Tail water level (masl)	565 (max)/563 (min)
TURBINE	
Type	Vertical Axis Francis
Number's	3
Rated Output	45 MW each
POWER BENEFITS	
90% Dependable Energy (MU)	602

(Source: Revised Pre-Feasibility Report)

Table 3.19: Salient Features of Yamne Stage II (96 MW)

LOCATION	
District	Upper Siang
Name of River	Yamne
Coordinates - Diversion Site	N28°23'28.2" E95°14'6.8"
Coordinates - Powerhouse	N28°20'4.2" E95°12'25.4"
HYDROLOGY	
Catchment area at diversion site (Sq km)	890
Design Discharge (m ³ /s)	131.64
LAND REQUIREMENT (Ha)	
Total	90.4
DIVERSION STRUCTURE	
Type	Barrage
Height from river bed (m)	20
Top of Structure (masl)	538
FRL (masl)	536
MDDL (masl)	530
Average Bed level (masl)	518
Live Storage (10 ⁶ m ³)	1.72
HEADRACE TUNNEL	
Type	Modified Horse Shoe
Diameter (m)	6.5
Length (m)	6400
SURGE SHAFT	
Type	Restricted orifice
Diameter (m)	25
Height (m)	60
PRESSURE SHAFT	
Type	Steel lined
Number	1
Diameter (m)	5.5
Length (m)	175
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	96
Net Head (m)	80.80
Tail water level (masl)	440
TURBINE	
Type	Vertical Axis Francis
Number's	3
Rated Output	32 MW each
POWER BENEFITS	
90% Dependable Energy (MU)	441.11

(Source: Revised Pre-Feasibility Report)

Table 3.20: Salient Features of Lower Yamne Stage I (75 MW)*

LOCATION	
District	Upper Siang
Village	Padu
Name of River	Yamne
Coordinates - Diversion Site	N28°18'50" E95°10'53"
Coordinates - Powerhouse	N28°16'00" E95°12'00"
HYDROLOGY	
Catchment area at diversion site (Sq km)	1015
Design Discharge (m ³ /s)	123.25
LAND REQUIREMENT (Ha)	
Total	128.25
DIVERSION STRUCTURE	
Type	Barrage
Height from river bed (m)	21
Top of Structure (masl)	427
FRL (masl)	425
MDDL (masl)	420
Average Bed level (masl)	406
Live Storage (10 ⁶ m ³)	1.6
HEADRACE TUNNEL	
Type	Modified Horse Shoe
Diameter (m)	6.4
Length (m)	5575
SURGE SHAFT	
Type	Restricted Orifice, Open to sky
Diameter (m)	25
Height (m)	50
PENSTOCK	
Type	Surface & Underground
Number	3
Diameter (m)	3.3
Length (m)	110 (surface) ; 90 (underground)
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	75 MW
Net Head (m)	67.7
Tail water level (masl)	343.9
TURBINE	
Type	Vertical Axis Francis
Number's	3
Rated Output	25 MW Each
POWER BENEFITS	
50% Dependable Energy (MU)	353.8
90% Dependable Energy (MU)	343.7

(Source: Project Developer)

*Project is of 75 MW capacity as per the CEA approved power potential provided by Project Developer. However, TOR for EIA/EMP studies accorded by Ministry of Environment & Forests (MOEF) is still for 88 MW.

Table 3.21: Salient Features of Lower Yamne Stage II (87 MW)*

LOCATION	
District	Upper Siang
Village	Jeru
Name of River	Yamne
Coordinates - Diversion Site	N28°15'08" E95°12'30"
Coordinates - Powerhouse	N28°13'07" E95°13'23"
HYDROLOGY	
Catchment area at diversion site (Sq km)	1203
Design Discharge (m ³ /s)	149.27
LAND REQUIREMENT (Ha)	
Total	105.89
DIVERSION STRUCTURE	
Type	Barrage
Height from river bed (m)	22
Top of Structure (masl)	320.5
FRL (masl)	318
MDDL (masl)	313
Average Bed level (masl)	298
Live Storage (10 ⁶ m ³)	0.87
HEADRACE TUNNEL	
Type	Modified Horse Shoe
Diameter (m)	7.1
Length (m)	4500
SURGE SHAFT	
Type	Restricted Orifice, Open to sky
Diameter (m)	30
Height (m)	53
PENSTOCK	
Type	Surface & Underground
Number	3
Diameter (m)	3.65
Length (m)	160 (surface); 50 (underground)
POWERHOUSE	
Type	Surface
Installed Capacity (MW)	87 MW
Net Head (m)	64.86
Tail water level (masl)	244.15
TURBINE	
Type	Vertical Axis Francis
Number's	3
Rated Output	29 MW each
POWER BENEFITS	
50% Dependable Energy (MU)	404.9
90% Dependable Energy (MU)	391.5

(Source: Project Developer)

*Project is of 87 MW capacity as per the CEA approved power potential provided by Project Developer. However, TOR for EIA/EMP studies accorded by Ministry of Environment & Forests (MOEF) is still for 90 MW.

CHAPTER-4

HYDROMETEOROLOGY

4.1 GENERAL CLIMATIC CONDITIONS IN ARUNACHAL PRADESH

Arunachal Pradesh exhibits varied climatic zones from place to place in the state due to its geographical position and varied topography. In general, the major parts of the State have humid subtropical climate with wet summer and winter, whereas it is cold humid in the remaining parts. On the basis of the monsoon, roughly the 12 months can be divided into three distinct seasons:

- a) Winter season (December, January and February)
- b) Pre-monsoon Season (March, April and May)
- c) Monsoon Season (June to September)
- d) Post-monsoon season (October and November)

Generally, December, January, and February are the coldest months, whereas June is the hottest month. Sometimes the temperature rises as high as 35°C during summer months in the plains and broad valleys.

4.2 RAINFALL

The mean monthly rainfall variation for 22 rain gauge stations in Siang basin is shown in Table 4.1. **Figure 4.1** give location of these rain gauge stations on a map and **Figure 4.2** shows the bar chart of monthly rainfall data. General rainfall in the catchment area is high during monsoon i.e. in the month of June and July, followed by August and September. Through out the basin low rainfall is observed during the winter months of December and January. Pre-monsoon season generally shows the increasing trend in rainfall from March to May.

In addition, the rainfall scenario of Siang basin has been studied and analyzed using TRMM data which is shown in **Figure 4.3**. The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between NASA and the Japan Aerospace Exploration Agency (JAXA) designed to measure rainfall for weather and climate research. TRMM is designed to measure tropical precipitation and its variation from a low-inclination orbit combining a suite of sensors to overcome many of the limitations of remote sensors previously used for such measurements from space. TRMM is a comprehensive and systematic program designed to increase the extent and accuracy of tropical rainfall measurement. The TRMM science program consists of a broad research effort which includes development of cloud models, rain retrieval algorithms for the space sensors, use of TRMM measurements with other satellite data to improve sampling, a surface-based verification system, and a TRMM science data and information system (TSDIS).

The average annual rainfall for the period 1998-2009 is available for the tropic region in Geotiff format which gives a fairly good assessment of hypsometric variation in rainfall in Himalayan region and same has been presented as **Figure 4.3**, which shows that in Siang basin area, rainfall variation is approximately of the order of 1000 - 2000 mm in Yargyap Chhu catchment and upper reaches of Siyom catchment while in Yamne and Simang catchments, rainfall variation is approximately of the order of 2000 - 3000 mm. Rainfall variation of 3000 to 4000 mm can also be observed in some regions like upstream portion of Siang River and lower portions of Siyom river. This rainfall data was assessed for comparative estimation of yields during environment flow assessment.

Table 4.1: Average Monthly Rainfall at Various Rain Gauge Stations in Siang Basin

MONTH	Pasihat	Rotung	Riga	Karko	Pagi	Daring	Aalo	Kaying	Raying	Mechuka	Monigong
Jan	68	38.8	69.2	75	27.1	71.7	41.4	155.8	111.3	64.3	44.3
Feb	112	67.5	151.7	163	98.8	121.6	57.7	152.7	193	96.3	102.3
Mar	149.4	122.1	255	305.6	73.5	144.4	103.6	325	331.6	158.7	165.5
Apr	256.7	177.6	262.6	336.4	109	239.1	158.2	355	363	200.3	345.1
May	393.2	252.5	262.5	240.1	164.3	456.9	195.6	395.9	469.9	335	581.4
Jun	806.9	441.8	555.3	468	376.1	792.6	401.1	649.8	688.4	477.5	525.7
Jul	1055	611.1	536.2	601.7	390	1170.2	401.8	768.3	908.5	369.5	748.1
Aug	695.2	303.5	364.7	357.1	287.3	634	222.5	625.1	641.3	341.1	319.2
Sep	512.4	259.4	355	549.9	383.6	688.8	288.5	535.3	631.7	314.2	267.7
Oct	209.7	113.5	177.3	271.4	86	243.2	104.3	244.4	288.4	185.4	154.6
Nov	33.1	40.6	53.1	18.3	18.6	41.6	30.8	69.4	62.6	61.2	71.8
Dec	19.8	17.1	43.5	58	18.6	102.6	17.1	50	50.5	24.9	61.4
ANNUAL	4311	2446	3086	3445	2033	4707	2022	4327	4740	2628	3387
MONTH	Tuting	Migging	Nyering	Bomdo	Pugging	Yingkiong	Moying	Gabuk	Nyorak	Boleng	Mayum
Jan	103.8	135	66.8	131.3	121.3	68.7	134	45.7	29	25.4	85.7
Feb	207.2	175.6	91.5	153.8	157.5	115.6	242.9	185.1	116.5	37.1	215
Mar	392.9	280.8	259.2	265	371.2	250.8	408.8	276.3	94.7	82	335.1
Apr	416.9	379.8	255.9	319.3	375.4	214.2	356.8	250.9	163.6	293.2	278.1
May	470.4	503.4	327.6	315.5	447.4	371.2	388.8	231.2	180	384.6	304.6
Jun	762	635.6	437.4	120.5	405	336.3	481.2	523.8	266	240.8	465.6
Jul	726.2	549.5	536.3	141.5	548.3	409.1	664.9	667.8	490.3	286.4	473.2
Aug	499	625.5	361.9	254.5	342	221.6	567.8	394.9	368.8	206.4	467.3
Sep	594.6	780.7	293.9	312.5	293.5	319.2	363.6	364	278.5	140.1	253.5
Oct	318.4	376.5	163.7	219.7	231.4	152.4	360.9	106.9	102.7	56.9	268.7
Nov	91.5	61	46.7	3.1	65.6	53.9	134.4	57.1	24.6	1.3	47
Dec	51	13.3	40.5	12.5	30.2	22.2	33.8	39	57.2	12.9	28.3
ANNUAL	4634	4517	2881	2249	3389	2535	4138	3116	2172	1767	3222

Source: Approved Hydrology DPR of Siang Lower HEP, 2009. Note: All the rainfall values are in mm.

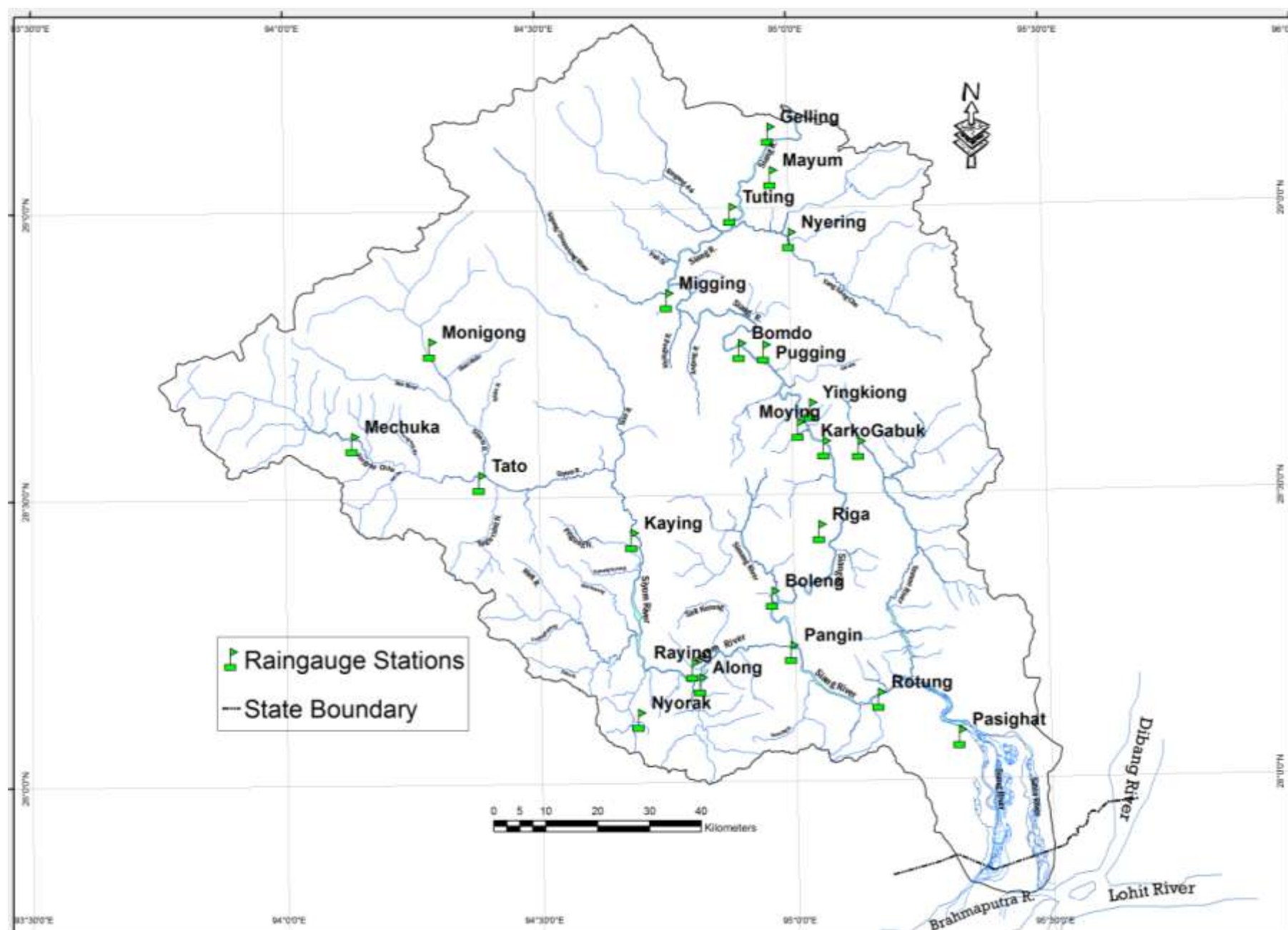


Figure 4.1: Map showing rain gauge stations in Siang basin

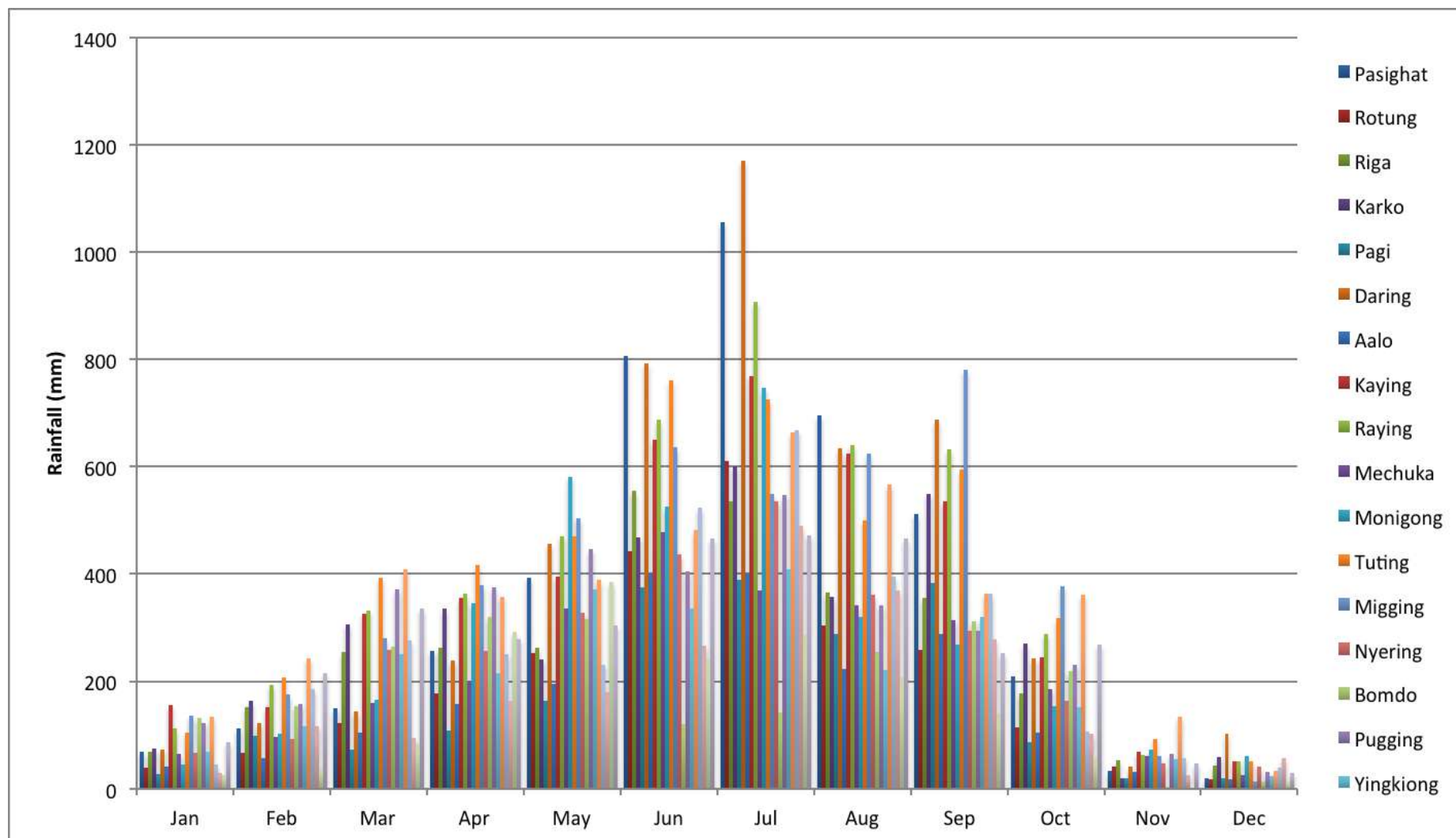


Figure 4.2: Monthly rainfall pattern at different rain gauge stations in Siang basin

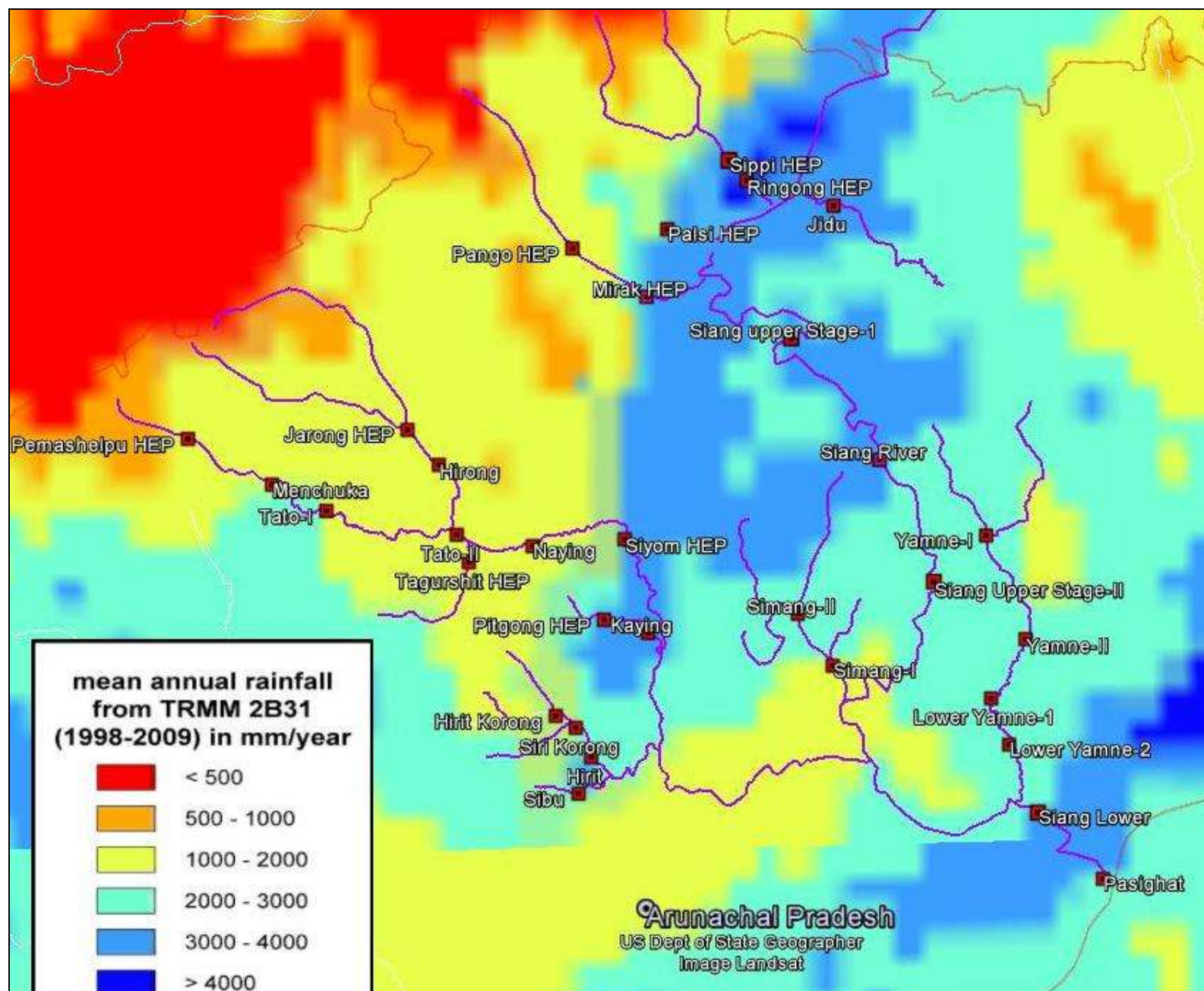


Figure 4.3: Rainfall Scenario of Siang Basin

4.3 TEMPERATURE AND HUMIDITY

Temperature varies with altitude in the basin and varies considerably from place to place, depending on elevation and exposure to the sun. At Pangin (397 m), the average annual temperature is between 33.6°C and 17.1°C; at Kaying (360 m), it is from 30.6°C to 14.1°C; at Tato (1390 m), it varies from 26.1°C to 11.4°C and at Pugging (339 m), it is from 31.2°C to 16.5°C. During summer (April to June), average maximum temperature reaches up to 33.3°C and reduces to 8.1°C during winter (December to February). Normally, January is the coldest month, while June is the hottest month. The temperature data recorded in four sites viz. Pangin, Kaying, Tato, and Pugging is given in **Table 4.2**. Relative humidity in the Siang catchment area varies from 98.8% to 38.2%. Humidity is generally low during April to May and high in the months of July and August.

4.4 WATER DISCHARGE AND AVAILABILITY

Gauge and discharge (G&D) station in the Siang river system was established at Pasighat in 1949. The measurement at this site continues since 1962 with a break from 1963 to 1974. Another G&D station is located at Ranaghat, about 2 km upstream of Pasighat. The daily measurement observation at Rotung area, which was the proposed dam axis of Brahmaputra board, was started from 1977 onwards. Another G&D site established by Brahmaputra board is located at Yingkiong area. The daily measurement data in this site is available from 1978 onwards. NHPC established its G&D sites on the main Siang river and its tributary (the Yamne river). The G&D station located at 29th mile (350 m downstream of an old dam axis at Rottung) operational since March 2001. Measurement at G&D site at Komlighat (located about 32 km d/s of Rotung) was started from 2004. At Raying (located at 600 m d/s of Siang Middle dam site), the observation measurement starts from May 2000. At Goging (near Upper Siang dam site) and Ditedime, daily measurement is recorded since 2001 and 2005, respectively.

As discussed above, there are 44 identified projects in Siang basin and they are at different stages of survey and investigation. Using the above data, projects proponents have developed long term discharge data for their projects as part of water availability studies. So far Central Water Commission (CWC) has approved water availability series for 16 projects and same data was procured for modeling exercise. For another 7 project locations, series have been generated on catchment area proportion and rainfall variability factor basis from the available CWC approved series. For Gameng, Hirit Korong and Siri Korong projects, flow series were computed from Siyom Middle HEP and for Ringong, Pango, Mirak and Palsi, series computed from Yamne Stage-I HEP.

From the long term flow series, 90% dependable year for different projects have been calculated as the year with over 90% dependability and used in the modeling exercise as input flow data. It has been noted that some developers have considered a different year as 90% dependable year in their PFRs/DPRs i.e. year with less than 90% dependability (say 88%) and hence there might be difference between 90% dependable year (DY) considered in present study with that considered by hydro developers.

Table 4.2: Monthly maximum and minimum temperature (in °C) at various sites in the Siang catchment

Month	Pangin		Kaying		Tato		Pugging	
	Max	Min	Max	Min	Max	Min	Max	Min
Jan	26.33	10.1	22	6	19.7	4.9	25.8	9.6
Feb	29.2	11	25.1	7.9	21.3	5.2	27.1	10.9
Mar	33.1	14	27.7	8.4	25.9	6.9	28.4	14.8
Apr	34.7	15.1	32.2	13	26.9	11.3	33.2	15.5
May	37.85	18.1	34.3	16.5	28.1	13	34	18.5
Jun	37.93	22.6	36	21.2	30	17.5	34.7	20.1
Jul	38.68	24.1	37.5	23	30.9	18.7	36.6	22.2
Aug	39.1	23.5	36.1	22.2	30.6	18.8	37.2	22.7
Sep	36.07	22.3	34.4	20.2	29.7	17.1	34.6	21.6
Oct	33.13	19.2	30.9	14	25.9	11.1	30.3	18.4
Nov	30.25	14.2	29	10.8	23.9	8	27.3	13.7
Dec	27.27	11.1	24	6.1	20.2	5.1	25.6	9.7

Source: Approved Hydrology DPR of Siang Lower HEP, 2009.

Discharge data for all these projects for 90% dependable year has been shown in Tables 4.3 to 4.8.

Table 4.3: 90% Dependable Year Discharge Data for Projects on Siyom River

		Hirong	Tato II	Naying
90% dependable year		2004-05	2004-05	2004-05
Catchment Area (Sq Km)		1289	2560	2760
		Discharge (cumec)		
June	I	123.58	292.18	310.49
	II	135.59	320.58	340.67
	III	195.27	461.66	490.61
July	I	187.12	442.41	470.14
	II	225.32	532.72	566.12
	III	140.64	332.50	353.35
August	I	117.81	278.54	296.01
	II	82.43	194.88	207.10
	III	137.25	324.49	344.84
Sept	I	162.52	384.25	408.34
	II	80.62	190.62	202.57
	III	137.49	325.06	345.44
Oct	I	126.03	297.97	316.65
	II	87.38	206.58	219.53
	III	46.34	109.57	116.43
Nov	I	34.45	81.46	86.56
	II	24.60	58.15	61.80
	III	25.42	60.09	63.86
Dec	I	21.68	51.25	54.46
	II	18.21	43.05	45.75
	III	18.95	44.79	47.60
Jan	I	17.64	41.69	44.31
	II	16.22	38.34	40.74
	III	14.74	34.86	37.04
Feb	I	16.49	38.98	41.43
	II	27.25	64.41	68.45
	III	34.43	81.39	86.49
March	I	40.51	95.79	101.79
	II	58.50	138.32	146.99
	III	78.62	185.89	197.54
April	I	88.40	209.00	222.10
	II	101.80	240.69	255.78
	III	99.40	235.00	249.74
May	I	90.79	214.64	228.10
	II	112.55	266.10	282.79
	III	97.39	230.26	244.70

Table 4.4: 90% Dependable Year Discharge Data for Projects on Yargyap Chhu

		Pemashelpu	Kang-tangshiri	Rapum	Pauk	Heo	Tato-I
90% DY		1992-93	1992-93	1992-93	1992-93	1992-93	1992-93
CA (Sq Km)		368	810	839	982	1065	1154
Discharge (cumec)							
June	I	31.05	72.76	76.39	89	97	105
	II	34.02	79.7	83.69	98	106	115
	III	56.64	132.7	139.33	163	177	192
July	I	50.59	118.52	124.44	146	158	171
	II	43.91	102.87	108.02	126	137	149
	III	40.75	95.47	100.24	117	127	138
August	I	38.09	89.24	93.7	110	119	129
	II	35.15	82.36	86.48	101	110	119
	III	49.51	115.99	121.79	143	155	168
Sept	I	45.24	106	111.3	130	141	153
	II	46.47	108.88	114.32	134	145	157
	III	38.48	90.15	94.65	111	120	130
Oct	I	35.4	82.94	87.08	102	111	120
	II	31.79	74.48	78.21	92	99	108
	III	28.75	67.36	70.73	83	90	97
Nov	I	6.23	14.8	15.51	18	20	21
	II	5.68	13.5	14.14	17	18	19
	III	5.38	12.78	13.39	16	17	18
Dec	I	5.07	12.05	12.62	15	16	17
	II	4.48	10.67	11.16	13	14	15
	III	3.97	9.45	9.89	12	13	14
Jan	I	4.74	11.26	11.79	14	15	16
	II	4.43	10.53	11.02	13	14	15
	III	3.84	9.15	9.57	11	12	13
Feb	I	3.71	8.82	9.23	11	12	13
	II	4.07	9.69	10.14	12	13	14
	III	4.03	9.6	10.04	12	13	14
March	I	3.79	9.02	9.44	11	12	13
	II	3.95	9.39	9.82	12	12	14
	III	4.93	11.72	12.27	14	16	17
April	I	5.22	12.4	12.99	15	17	18
	II	6.38	15.17	15.89	19	20	22
	III	7.38	17.53	18.38	22	23	25
May	I	30.32	71.03	74.58	87	95	103
	II	33.45	78.36	82.28	96	104	113
	III	28.21	66.09	69.39	81	88	95

Table 4.5: 90% Dependable Year Discharge Data for Projects on Other Tributaries of Siyom River

		Hirit Korong	Siri Korong	Gameng
90% dependable year		2004-05	2004-05	2004-05
Catchment Area (Sq Km)		198	265	422
		Discharge (cumec)		
June	I	23.11	30.93	49.25
	II	25.35	33.93	54.03
	III	36.51	48.86	77.81
July	I	34.99	46.83	74.57
	II	42.13	56.39	89.79
	III	26.30	35.19	56.04
August	I	22.03	29.48	46.95
	II	15.41	20.63	32.85
	III	25.66	34.35	54.69
Sept	I	30.39	40.67	64.77
	II	15.07	20.18	32.13
	III	25.71	34.41	54.79
Oct	I	23.56	31.54	50.22
	II	16.34	21.87	34.82
	III	8.66	11.60	18.47
Nov	I	6.44	8.62	13.73
	II	4.60	6.16	9.80
	III	4.75	6.36	10.13
Dec	I	4.05	5.42	8.64
	II	3.40	4.56	7.26
	III	3.54	4.74	7.55
Jan	I	3.30	4.41	7.03
	II	3.03	4.06	6.46
	III	2.76	3.69	5.87
Feb	I	3.08	4.13	6.57
	II	5.09	6.82	10.86
	III	6.44	8.61	13.72
March	I	7.57	10.14	16.14
	II	10.94	14.64	23.31
	III	14.70	19.68	31.33
April	I	16.53	22.12	35.23
	II	19.03	25.48	40.57
	III	18.59	24.87	39.61
May	I	16.97	22.72	36.18
	II	21.04	28.17	44.85
	III	18.21	24.37	38.81

Table 4.6: 90% Dependable Year Discharge Data for Projects on Tributaries of Siang River

		Ringong	Sippi	Pango	Mirak	Palsi
90% dependable year		2004-05	2004-05	2004-05	2004-05	2004-05
Catchment Area (Sq Km)		738	697	788	945	92
		Discharge (cumec)				
June	I	86.12	81.34	73.57	99.25	9.66
	II	94.49	89.24	80.72	108.90	10.60
	III	136.08	128.52	116.24	156.83	15.27
July	I	130.41	123.16	111.39	150.29	14.63
	II	157.03	148.30	134.13	180.96	17.62
	III	98.01	92.57	83.72	112.95	11.00
August	I	82.11	77.54	70.13	94.62	9.21
	II	57.44	54.25	49.07	66.20	6.44
	III	95.65	90.34	81.70	110.23	10.73
Sept	I	113.26	106.97	96.75	130.53	12.71
	II	56.19	53.07	48.00	64.75	6.30

		Ringong	Sippi	Pango	Mirak	Palsi
	III	95.82	90.49	81.85	110.42	10.75
Oct	I	87.83	82.95	75.03	101.22	9.85
	II	60.89	57.51	52.01	70.17	6.83
	III	32.30	30.50	27.59	37.22	3.62
Nov	I	24.01	22.68	20.51	27.67	2.69
	II	17.14	16.19	14.64	19.76	1.92
	III	17.71	16.73	15.13	20.41	1.99
Dec	I	15.11	14.27	12.90	17.41	1.69
	II	12.69	11.99	10.84	14.62	1.42
	III	13.20	12.47	11.28	15.22	1.48
Jan	I	12.29	11.61	10.50	14.16	1.38
	II	11.30	10.67	9.65	13.02	1.27
	III	10.27	9.70	8.78	11.84	1.15
Feb	I	11.49	10.85	9.82	13.24	1.29
	II	18.99	17.93	16.22	21.88	2.13
	III	23.99	22.66	20.49	27.65	2.69
March	I	28.23	26.67	24.12	32.54	3.17
	II	40.77	38.51	34.83	46.99	4.57
	III	54.79	51.75	46.80	63.15	6.15
April	I	61.60	58.18	52.62	71.00	6.91
	II	70.95	67.00	60.60	81.76	7.96
	III	69.27	65.42	59.17	79.83	7.77
May	I	63.27	59.75	54.05	72.91	7.10
	II	78.44	74.08	67.00	90.40	8.80
	III	67.87	64.10	57.98	78.22	7.62

Table 4.7: 90% Dependable Year Discharge Data for Projects on Yamne River

		Yamne-I	Yamne-II	Lower Yamne-I	Lower Yamne-II
90% dependable year		2004-05	2004-05	2004-05	2004-05
Catchment Area (Sq Km)		625	890	1015	1203
Discharge (cumec)					
June	I	72.94	103.87	113.48	134.50
	II	80.03	113.96	124.51	147.58
	III	115.25	164.12	179.31	212.52
July	I	110.44	157.26	171.82	203.64
	II	132.98	189.38	206.91	245.24
	III	83.00	118.21	129.15	153.07
August	I	69.53	99.03	108.19	128.23
	II	48.65	69.27	75.68	89.70
	III	81.00	115.34	126.02	149.36
Sept	I	95.92	136.59	149.23	176.87
	II	47.58	67.75	74.03	87.74
	III	81.15	115.55	126.24	149.63
Oct	I	74.38	105.91	115.71	137.15
	II	51.57	73.44	80.24	95.11
	III	27.35	38.96	42.57	50.45
Nov	I	20.33	28.96	31.64	37.50
	II	14.52	20.67	22.59	26.77
	III	15.00	21.36	23.34	27.66
Dec	I	12.79	18.22	19.90	23.59
	II	10.75	15.30	16.72	19.82
	III	11.18	15.92	17.40	20.62
Jan	I	10.41	14.82	16.19	19.19
	II	9.57	13.63	14.89	17.65
	III	8.70	12.39	13.54	16.04
Feb	I	9.73	13.86	15.14	17.95
	II	16.08	22.90	25.02	29.65
	III	20.32	28.93	31.61	37.47
March	I	23.91	34.05	37.20	44.09

		Yamne-I	Yamne-II	Lower Yamne-I	Lower Yamne-II
	II	34.53	49.17	53.72	63.67
	III	46.40	66.08	72.20	85.57
April	I	52.17	74.29	81.17	96.20
	II	60.08	85.56	93.48	110.79
	III	58.67	83.54	91.27	108.18
May	I	53.58	76.30	83.36	98.80
	II	66.43	94.59	103.35	122.49
	III	57.48	81.85	89.43	105.99

Table 4.8: 90% Dependable Year Discharge Data for Projects on Simang River

		Simang I	Simang II
90% dependable year		1978-79	1978-79
Catchment Area (sq Km)		494	422
		Discharge (cumec)	
June	I	76.09	65.01
	II	102.49	87.56
	III	143.63	122.70
July	I	86.17	73.62
	II	96.77	82.67
	III	90.93	77.68
August	I	88.84	75.89
	II	68.28	58.34
	III	44.64	38.13
Sept	I	81.91	69.98
	II	102.80	87.82
	III	84.42	72.13
Oct	I	78.16	66.78
	II	49.04	41.90
	III	39.34	33.61
Nov	I	34.87	29.79
	II	26.62	22.75
	III	34.12	29.15
Dec	I	17.21	14.71
	II	15.32	13.09
	III	12.80	11.79
Jan	I	12.43	10.62
	II	11.91	10.18
	III	12.39	10.59
Feb	I	10.31	8.81
	II	9.19	7.85
	III	12.42	10.61
March	I	17.35	14.82
	II	19.65	15.94
	III	21.99	18.78
April	I	24.61	21.03
	II	30.11	25.72
	III	36.75	31.40
May	I	49.77	42.52
	II	43.98	37.57
	III	31.24	26.69

CHAPTER-5

METHODOLOGY

To undertake environment impact assessment of Siang sub-basin, it is essential to establish the present environment setting in the basin on which impacts of development can be predicted and strategy for sustainable development can be formulated. Scoping for the study has set the requirement of extensive baseline data to be collected. Over a period of one year, extensive baseline surveys were carried out for data collection, sampling and analysis. Additionally, data was collected from secondary sources, collated and analyzed. Entire data collection and analysis work was undertaken scientifically based on the pre-defined methodology, which is discussed in ensuing text.

5.1 LAND USE/ LAND COVER MAPPING

One of the objectives of the study is to produce a detailed vegetation/ land use/ land cover map of the Siang basin using hybrid digital classification technique. The study also aims to produce land cover data set appropriate for applications like erosion mapping, etc. Land use and land cover map of the basin was prepared from the latest data procured from Forest Survey of India (FSI). It was further refined by ground checks carried out during the field surveys. For this purpose FCC of the entire study area was generated from digital satellite data of IRS-1D LISS-III, Path/Row - 94/47 of dt. 19.10.2001 with Bands 2, 3 and 4. In addition Landsat ETM+ data was also downloaded from Global Land Cover Facility web site (<http://glcf.umd.edu/data/landsat>).

False Color Composite (FCC) covering the entire Siang basin was prepared using enhanced data of Bands 2, 3 and 4 of LISS III, IRS-P6 as well from LANDSAT ETM+ data. The image was interpreted digitally using various digital image-processing techniques. The data procured from FSI was downloaded and further processed to generate mosaic of entire Siang basin (see **Figure 5.1**).

5.1.1 Classification Scheme

In order to understand the extent of forest cover in particular, the classification scheme suggested by Forest Survey of India was adopted for the preparation of land use/land cover maps. Three forest density classes were interpreted for the forest cover mapping. The forests with <70% canopy cover has been demarcated as Very Dense Forest, between 40% and 70% canopy cover was delineated as Moderately Dense Forest and between 10% and 40% crown density as Open Forest. Furthermore, degraded forests, grass covered slopes with canopy density <10% were delineated as Scrubs. The area not included in any of the above classes is delineated as Non-forest land cover.

Data Set Used

Survey of India (Sol)	:	82/P-14, 82/P-15, 83D/2 & 82/D-3 (Scale: 1:50000)
Forest Surveys of India	:	The Status of Forest Survey of India (2011)
Projection and Datum	:	UTM and WGS 84; 46 North
Satellite Data	:	IRS P6 LISS 3 and LANDSAT ETM+

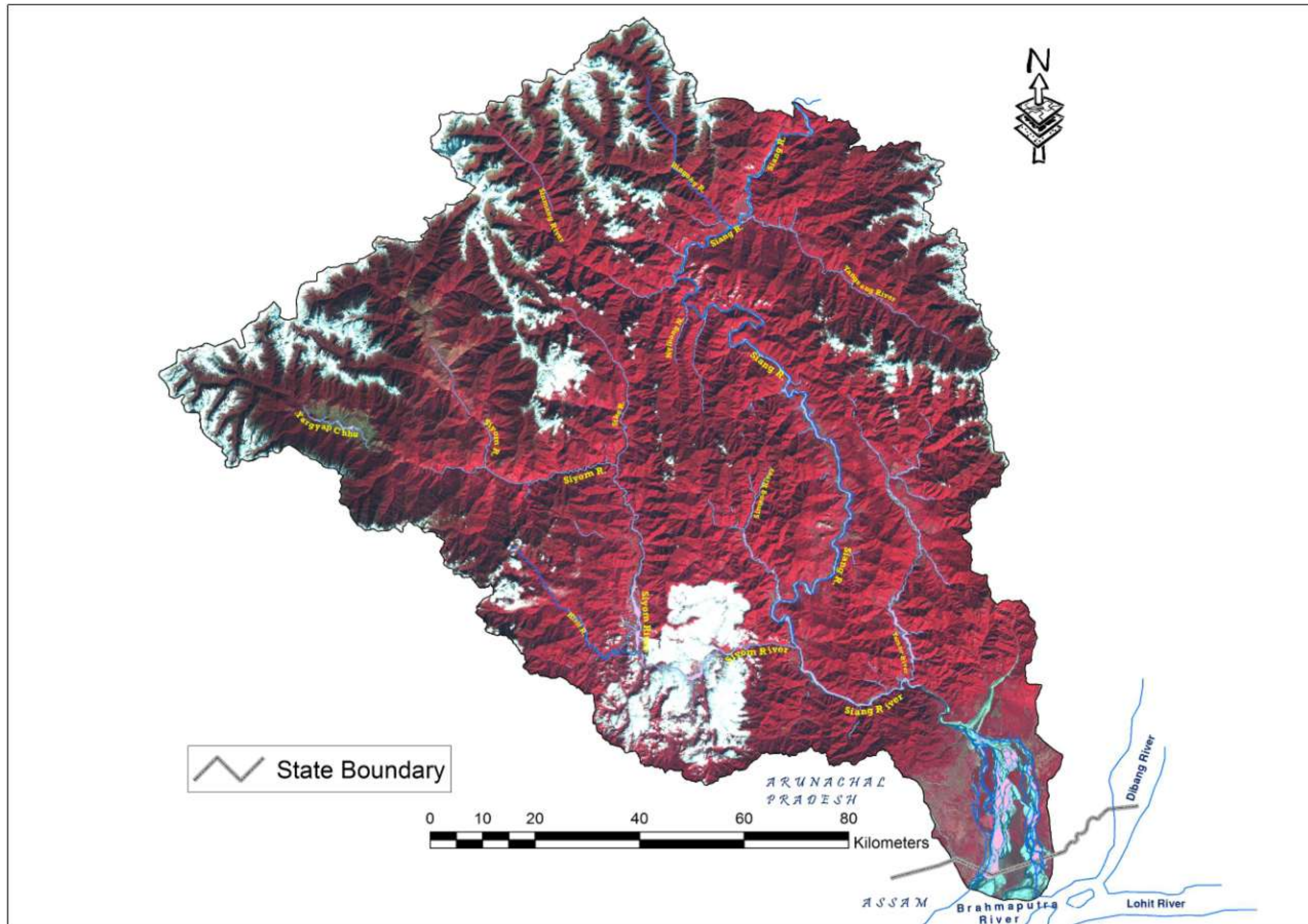


Figure 5.1: False Color Composite (FCC) of Siang basin prepared from LISS-III IRS- P6 Data

5.2 FOREST TYPES

The forests in Siang basin fall under Central Circle with headquarters at Pasighat whereas the Protected Areas in the basin are under the administrative control of Additional PCCF (Wildlife & Biodiversity), Itanagar. The basin area under Central Circle is further administered by three Forest Divisions viz. Yingkiong, Along and Pasighat Forest Divisions with headquarters at Yingkiong, Along and Pasighat, respectively. Yingkiong Forest division is comprised of Yingkiong, Karko and Boleng Ranges, Along FD is comprised of Along, Mechuka, Basar and Liromoba Ranges and Pasighat FD has Mebo, Pasighat, Ruksin and Nari Ranges. The three Protected Areas in the basin are D'Ering Memorial Wildlife Sanctuary, Yordi Rabe Supse Wildlife Sanctuary and Mouling National Park.

The details of forest types in the basin has been referenced from Working Plans of three Forest Divisions, Management Plans of Mouling National Park and D'Ering Memorial Wildlife Sanctuary, and information provided by the Department of Forest, Government of Arunachal Pradesh. Their distribution in the basin is also described as per Forest Working Plans as well as supplemented with information gathered during field surveys in the area. The major forest types encountered in the area have been described based on the classification of Champion and Seth (1968) and also supplemented by information collected from literature like Kaul and Haridasan (1987), Negi (1989, 1996), Chowdhery (1996) and Muddgal & Hajra (1999).

5.3 COMMUNITY STRUCTURE

The objectives of the present floristic study are as follows:

- To prepare an inventory of various groups plants (Angiosperms, Gymnosperms, Pteridophytes, Bryophytes, and Lichens) in the basin
- To assess the community structure in the study area
- To determine Importance Value Index and
- Shannon Wiener Diversity Index for trees, shrubs and herbs in the basin.

In order to understand the community structure, vegetation sampling was done at 49 locations in the Siang basin to cover three seasons i.e. Winter (January-February, 2012), Pre-monsoon (April, 2012) and Monsoon (July-August, 2012) covering forests in and around locations of structures like dam site and submergence area, power house site of the proposed hydropower projects. The list of sampling locations is given in Table 5.1.

5.3.1 Sampling Locations and Methodology

The size and number of quadrats needed were determined using the species- area curve (Misra, 1968). The data on vegetation were quantitatively analyzed for abundance, density, frequency as per the methodology given in Curtis & McIntosh (1950). The Importance Value Index (IVI) for trees was determined as the sum of relative density, relative frequency and relative dominance (Curtis, 1959).

Sampling Site Selection

The sampling locations were selected on the basis of the area located in the vicinity of proposed projects and its components. Entire Siang basin has been covered with adequate number of sampling locations as per TOR i.e. 47 locations within basin and 2 outside the basin. Sampling locations were identified to capture the baseline status and depending upon the anticipated changes in the topography, vegetation, forest types, water quality, aquatic ecology, etc. so as to capture the representative baseline of the area. Proposed project locations were also kept in mind while identifying the sampling locations, as these locations will be direct impact areas during

project construction and operation. Hydropower projects can spread over several km along river stretches and cannot be represented by a single point sampling locations. Reach of project is considered from tip of the FRL to the tail water outfall point. Therefore, for projects in cascade each sampling location can represent more than one project also. Moreover, sampling locations vegetation as well as aquatic ecology wherein sampling sites sometimes extend over a distance of 2-3 km for the collection of composite water sample while terrestrial ecology sampling sites were invariably spread over an area of 4-5 sq km over which 10-15 number of 10mx10m quadrats were laid to capture the vegetation structure.

A good representation of baseline has been done focusing more on the locations where tributaries are meeting the main river and where changes are expected in vegetation profile. Critical locations have also been covered where river is flowing free and no projects are proposed such as near Mechuka and Along. Sampling locations were therefore identified scientifically keeping in mind the project locations and their accessibility and also in line with the TOR requirement.

Sampling was undertaken to assess the composition of vegetation in a particular area. Forty seven sampling sites located within the basin and two sites located outside the basin were selected for carrying out phyto-sociological surveys of the vegetation and in addition an inventory of various floristic elements was also prepared by walking along different transects around these sampling sites. The location of sampling sites has already been described later in the document. In order to understand the composition of the vegetation, most of the plant species were identified in the field itself whereas the species that could not be identified the photographs were taken of different plant parts for identification later with the help of available published literature and floras of the region.

Detailed list of sampling locations along with their coordinates is given at **Table 5.1** and their location on the map of Siang basin has been marked and is shown in **Figure 5.2**.

Standard methodology of vegetation sampling i.e. nested quadrat sampling method was used for the study of community structure of the vegetation. Each sampling unit consisted of randomly placed quadrats of 10 x 10 m² for trees, 5 x 5m² for shrubs and 1 x 1m² for herbs (**Table 5.2**). For sampling of vegetation, number of quadrats to be laid varied from minimum of 9 quadrats to 15 quadrats at a particular sampling site/ area depending upon the heterogeneity/ homogeneity of the vegetation encountered at a particular site/ area (**see Table 5.2**). At each site the quadrats were laid along the altitudinal gradient beginning from the vegetation along the river bank/riverine vegetation and further up along the slope ensuring maximum possible representative coverage of the vegetation of a particular sampling location. Each sampling location/ area was divided into grids vertically as well as horizontally along the slopes thereby capturing the maximum diversity of vegetation. In case of trees total basal area/cover per unit area was calculated by measuring the 'cbh' (circumference at breast height) of each individual tree belonging to different species, which was then converted into basal area using the formula given in the following paragraph. However in case of herbs and shrubs the circumference of at least 10-20 was measured by bunching them together which was then converted into circumference of total number of individuals which was then further used to calculate basal area of herbs and shrubs per unit area. As already mentioned the number of individuals of herbs and shrubs to be bunched together depends upon the thickness of their stems.

Calculation of Dominance & Diversity Indices

Based on the quadrat data, frequency, density and cover (basal area) of each species were calculated. The data on density and basal cover are presented on per ha basis.

The **Importance Value Index (IVI)** for different tree species was determined by adding up the Relative Density, Relative Frequency and Relative Dominance/ Cover values. The Relative Density and Relative Frequency values were used to calculate the IVI of shrubs and herbs.

For the calculation of dominance, the basal area was determined by using following formula.

$$\text{Basal area} = \pi r^2$$

The index of diversity was computed by using Shannon Wiener Diversity Index (Shannon Wiener, 1963) as:

$$H = - \sum (n_i/n) \times \ln (n_i/n)$$

Where, n_i is individual density of a species and n is total density of all the species

The Evenness Index (E) is calculated by using Shannon's Evenness formula (Magurran, 2004).

$$\text{Evenness Index (E)} = H / \ln(S)$$

Where, H is Shannon Wiener Diversity index; S is number of species

Table 5.1: Sampling sites and their locations for vegetation sampling in Siang basin

Sl.No.	Code	Sub-basin/ Sites	Nearby Town/Village	Latitude	Longitude	Altitude (m)
Yamne River						
1	Y1	Lower Yamne Stage-II HEP	Jerring	28°15'20.7"N	95°12'24.5"E	310-400
2	Y2	Lower Yamne Stage-I HEP	U/s of Padu	28°19'09.5"N	95°11'37.7"E	400-500
3	Y3	Yamne - II (Barrage site) HEP	Siyat	28° 23'58.4" N	95°14'16.2"E	500-600
4	Y4	Yamne - I (dam site) HEP	Lagru / Damro	28°30'34.6" N	95°10'36.3"E	600-750
Simang River						
5	Sm1	Simang-I HEP - Barrage site	Boleng	28°22'11.3" N	94°56'34.2"E	230-310
6	Sm2	Simang-I (PH site) HEP	Lileng	28°20' 05.5"N	94° 57'32.5"E	350-460
7	Sm3	Simang-II (Diversion site) HEP	Suple	28°26' 03.4"N	94° 53'39.8"E	430-510
Siang River						
8	S1	Siang Lower HEP project area	Near dam site - Bodak	28° 9' 59"N	95° 10'00"E	139-150
9	S2	Siang Lower HEP project area	D/s of Ranaghat	28° 9' 39"N	95° 10'30"E	130-150
10	S3	Siang Lower HEP project area	Ranaghat	28° 8' 29"N	95° 11'20"E	140-160
11	S4	D/s of Siang & Siyom Confluence	Kebang	28°11' 27.9"N	95° 00'49.3"E	195-250
12	S5	Siang Upper Stage-II HEP (d/s of confluence Simang with Siang)	Boleng	28°18'44.4"N	94° 57'35.1"E	200-300
13	S6	Siang Upper Stage-II HEP (dam site)	11km u/s of Hawaii camp	28°44'20.8"N	94° 55'25.5"E	
14	S7	Mirak HEP	Near dam site	28° 15'53.3"N	94° 39'22.1"E	420-450
15	S8	Pango/Minnying	Near dam site	28° 53'28.2"N	94° 36'45.7"E	615-625
16	S9	Siang Upper Stage- I & II HEPs (D/s of Ringong river confluence)	U/s of Nunning	28° 57'21.2"N	94° 51'44.4"E	400-510
17	S10	Ringong HEP (d/s of dam site)	8 km d/s of Tuting	28° 57'40.6"N	94°51'41.9"E	440-550
18	S11	Siang Upper Stage-I HEP (d/s of Yangsang confluence)	12 km d/s of Tuting	28° 57'29.6"N	94°51'56.2"E	410-500
19	S12	U/s of Yangsang & Siang confluence	Tuting	28° 59'47.0"N	94° 54'13.3"E	450-500
20	S13	Jidu/Yang Sang HEP (dam site)	Jidu village	28° 58'36.8"N	94° 54'18.7"E	435-520

Hirit River						
21	SY1	D/s of Hirit & Siyom confluence		28°13'53.3"N	94°41'16.4"E	480-520
22	SY2	Confluence of Hirit with Siyom	d/s of Kamba			650-730
23	SY3	Hirit HEP (near dam site)	u/s of Poma Basti	28°14'04.4"N	94°35'34.8"E	
Siyom River						
24	SY4	Siyom Middle HEP (near dam site)	U/s of Reying Basti	28°27'39.6"N	94°41'04.8"E	500-540
25	SY5	Gameng HEP (near confluence)	Gameng river	28°32'48.2"N	94°38'33.3"E	620-750
26	SY6	Naying HEP (near powerhouse)	Pene	28°31'37.9"N	94°34'48.1"E	980-1020
27	SY7	Naying HEP (near dam site)	Yapik	28°30'32.4"N	94°27'9.9"E	1000-1050
28	SY8	Tato-II HEP PH	Near PH	28°30'30.4"N	94°25'19.9"E	1010-1050
29	SY9	Confluence of Yargyap with Siyom	Near Tato-II dam site	28°31'9.9"N	94°23'15.2"E	1050-1100
30	SY10	Tagurshit HEP (Diversion site)	Tadogitu	28°29'58.7"N	94°24'43.2"E	1470-1510
31	SY11	Hirong HEP (PH site)	Before confluence of Yagyap Chu with Siyom river	28°37'08.5"N	94°22'59.3"E	1200-150
32	SY12	Hirong HEP (dam site)	Lungte-D/s of Sitin Nala	28°37'04.5"N	94°22'50.3"E	1240-1300
33	SY13	Jarong HEP (near dam site)	U/s of Karo village	28°40'06.3"N	94°19'40.3"E	1410-1480
Yargyap Chhu						
34	YG1	Tato-I HEP	Near Trench weir site, Tato	28°31'36.3"N	94°20'21.8"E	1320-1410
35	YG2	Heo HEP	Near PH	28°31'37"N	94°20'17.8"E	1400-1450
36	YG3	Heo HEP	Near dam site	28°31'36.5"N	94°20'16"E	1420-1500
37	YG4	Pauk HEP	Near PH dam site	28°33'41.0"N	94°15'41"E	1510-1630
38	YG5	Pauk HEP	Near dam site	28°33'41.7"N	94°15'35.7"E	1500-1610
39	YG6	Rapum HEP	Near PH	28°33'41.5"N	94°12'49"E	1650-1620
40	YG7	Rapum HEP	Near barrage site	28°33'38"N	94°12'11.5"E	1810-11850
41	YG8	Rego HEP	Powerhouse	28°33'39.5"N	94°12'41.8"E	1800-1850
42	YG9	Rego HEP (near intake point)	Intake point	28°33'36.2"N	94°11'31.5"E	1800-1930
43	YG10	Kangtangshiri HEP	Near PH	28°37'44.8"N	94°2'53"E	1820-1950
44	YG11	Kangtangshiri HEP	Near barrage site	28°37'53.8"N	94°2'50.4"E	1870-1930

45	YG12	Pemashelpu HEP	Near PH	28° 37'54.8"N	94° 2'45.4"E	1940-2100
46	YG13	Pemashelpu HEP	Near barrage site	28° 37'54.8"N	94° 2'45.4"E	1910-2200
47	YG14	U/s of Hanuman Camp	Yarlong	28° 40'22.0"N	94° 58'04.1"E	2390-2450

DS= Dam site; PH = Power house

Sites Located Outside the Siang Basin

Sl.No.	Code	Sub-basin/ Sites	Nearby Town/Village	Latitude	Longitude	Altitude (m)
48	B2	Jiyadhol (d/s of dam site)	Jiyadhol	27° 25'34.5"E	94°27'42.5"E	50
49	B1	Brahmaputra river (Dibrugarh)	Ghat (u/s of constr. Bridge) near Dibrugarh	27° 25'58.1"N	94° 45'05.2"E	20

Table 5.2: No. of quadrats studied for each vegetation component

Sampling Site	Trees (10x10) m ²	Shrubs (5x5) m ²	Herbs (1x1) m ²
Y1	10	10	14
Y2	11	10	15
Y3	10	10	11
Y4	10	10	15
Sm1	10	10	15
Sm2	12	10	15
Sm3	15	10	12
S1	12	10	15
S2	15	10	12
S3	10	10	14
S4	11	10	15
S5	10	10	11
S6	10	10	15
S7	10	10	15
S8	12	10	15
S9	15	10	12
S10	10	10	14
S11	11	10	15
S12	10	10	11
S13	10	10	15
SY1	15	10	12
SY2	10	10	14
SY3	11	10	15
SY4	10	10	11
SY5	10	10	15
SY6	10	10	15
SY7	12	10	15
SY8	15	10	12
SY9	10	10	14
SY10	11	10	15
SY11	10	10	11
SY12	10	10	15
SY13	10	10	15
YG1	15	10	12
YG2	10	10	14
YG3	11	10	15
YG4	10	10	11
YG5	10	10	15
YG6	10	10	15
YG7	12	10	15
YG8	15	10	12
YG9	10	10	14
YG10	11	10	15
YG11	10	10	11
YG12	10	10	15
YG13	10	10	15
YG14	12	10	15
B1	10	10	-
B2	-	10	-

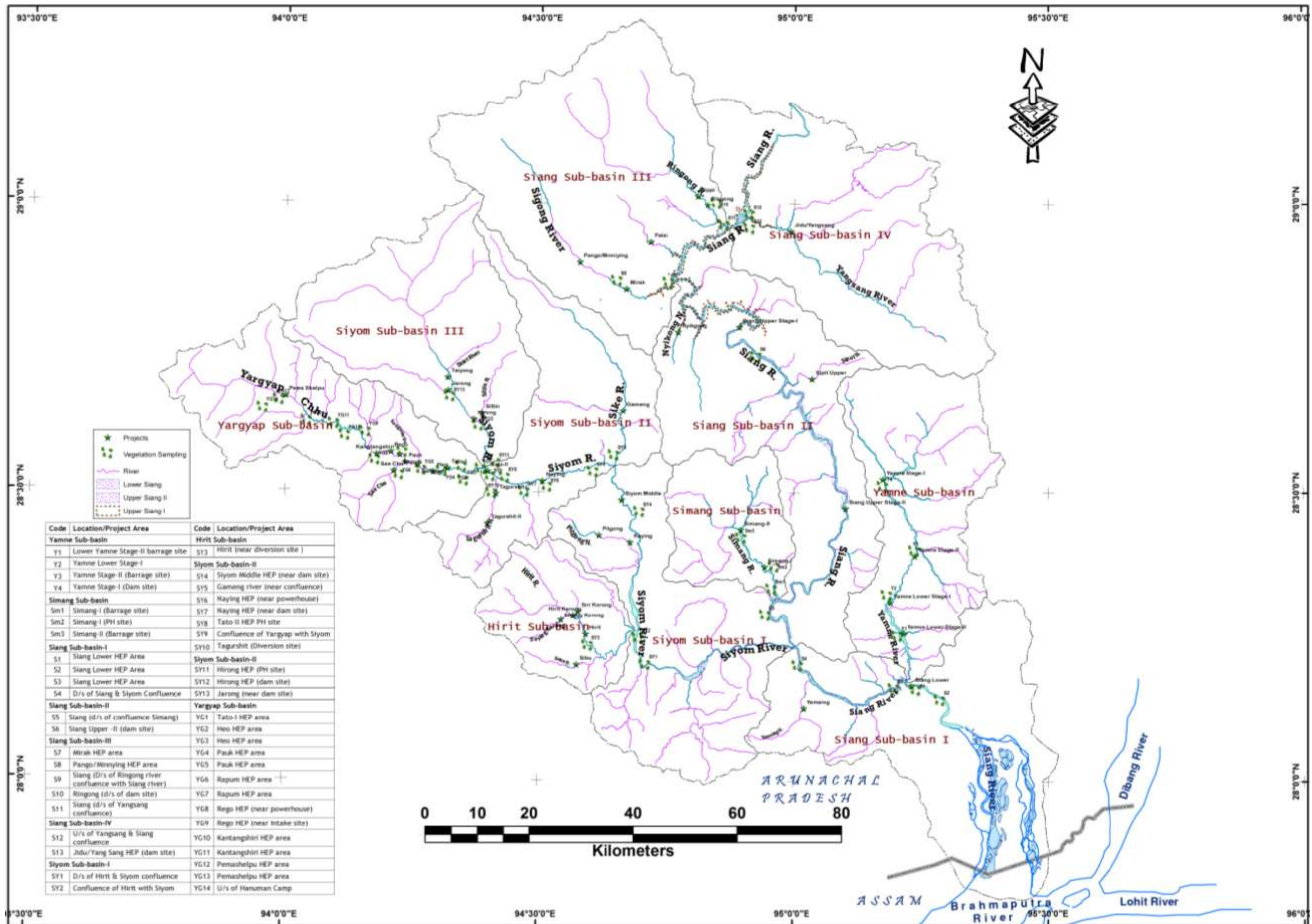


Figure 5.2: Sampling sites/locations for terrestrial ecology in Siang basin

5.4 FAUNAL ELEMENTS

The data on faunal elements of the basin has been compiled with the help of secondary sources supplemented with information provided by local people during field surveys conducted in different areas of the basin as discussed in previous section.

For the preparation of checklist of animals, Forest Working Plan of Pasighat Forest Division, Along Forest Division, and Yingkiong Forest Division, as well as Management Plans of D'Ering Memorial Wildlife Sanctuary, and Mouling National Park were consulted. The Management Plan of Yordi Rabe Supse Wildlife Sanctuary is yet to be prepared. In addition data was compiled from published literature like De *et al.* (2006), Sanyal & Gayen (2006), Sarkar & Ray (2006), Ali & Ripley (1983), Grewal *et al.* (2002), Grimmeth and Flaming *et al.* (1984).

The study area was divided into different strata based on vegetation and topography. Sampling for habitat and animals was done in each strata. As the normal systematic transects for mammals and birds were not possible in this study area due to difficult terrain, therefore trails were used for faunal sampling. In addition to the field sampling the data/ information was also collected as follows.

- Direct sighting and indirect evidences such as calls, signs and trophies of mammals were recorded along the survey routes taking aid from Prater (1980).
- Interviews of local villagers for the presence and relative abundance of various animal species within each locality.
- Data collection on habitat condition, animal presence by direct sighting and indirect evidences by forest personnel and villagers.

The checklist of mammalian fauna of the basin has been compiled with the help of secondary sources supplemented with information provided by local people during field surveys.

For the compilation of checklist of birds found in the Siang basin in the documents and published literature consulted are the Management Plans of Mouling National Park and D'Ering Memorial Wildlife Sanctuary and Forest Working Plans of Yingkiong, Along and Pasighat Forest Divisions. In addition published research papers by Sen and Mukhopadhyay (1999), Newton (2002), Pawar and Birand (2001), Birand and Pawar (2004), Ringu (2002), Katti *et al* (1992), and Choudhury (2008, 2010) were also consulted.

5.5 AQUATIC ECOLOGY

The physic-chemical parameters provide a broad picture to define the aquatic environment. Biological parameters detect water quality changes that other methods might miss or underestimate. Organisms in their environments are continual monitors of environmental quality, increasing the detection of impacts that chemical sampling is unlikely to detect due to any modification of river course or flow pattern. Plankton (phytoplankton and zooplankton), benthic macro-invertebrates, aquatic plants, and fish are the most commonly used in assessing biological integrity of any river ecosystem. The benthic macro-invertebrates are most often studied for wade able riffles in streams and rivers while Algae are often used in lakes to examine eutrophication. Therefore, to get a complete picture of the river water quality, physico-chemical as well as biological parameters are analyzed.

5.5.1 Sampling Locations & Schedule

The sampling was carried out at 49 locations to study various physico-chemical and biological characteristics of Siang river and its major tributaries like Siyom, Yamne, Simang, Yargyap Chhu, Ringong, Yangsang, etc. in the basin. Water samples were collected on monthly basis for 9 months and analyzed for physico-chemical and biological parameters.

The frequency of sampling for various aspects being covered under primary data collection as a part of the study is given as below:

For Physico-Chemical Water Quality	: Once per month
For Aquatic Ecology	: Once per month
Fisheries surveys	: Once per month

5.5.2 Methodology

The composite water samples from the river were taken in triplicates at each site and average values were computed for the results. The details of sampling sites and their location along with coordinates are given in **Table 5.3** and locations of sampling sites are marked on map is given in **Figure 5.3**.

Selection of Sampling Sites

Monthly sampling was carried out at 49 different locations as described in the table to study various physico-chemical and biological characteristics (**Table 5.3 & Figure 5.3**). Water samples were collected during each sampling season for physico-chemical as well as biological parameters. The sampling sites were located near the area where major project components are proposed like dam site, powerhouse, muck dumping sites, working area, near the confluence of major tributaries with the main channel and near settlements.

5.5.2.1 Physico-chemical Parameters

The analysis of several physico - chemical parameters of surface water are necessary for the ecological studies of any river. The parameters like pH, temperature, electrical conductivity, total dissolved solids and dissolved oxygen were measured in the field with the help of portable instruments. The water temperature was measured with the help of graduated mercury thermometer; pH, electrical conductivity and total dissolved solids were recorded with the help of a pH, EC and TDS probes (Hanna instruments HI 98130) in the field. Dissolved oxygen was measured with the help of Digital DO meter (Eutech ECDO 602K) in the field. For the analysis of turbidity, separate water samples were collected and brought to the laboratory for analysis. The turbidity was recorded with the help of Digital Turbidity meter.

Similarly separate water samples were collected and after the addition of preservative were brought to the laboratory for the analysis of the parameters such as total alkalinity, total hardness, chlorides, sulphates, phosphates, and nitrates at CISMHE, University of Delhi, Delhi. Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) was analysed by standard analytical methods. Calcium, Magnesium, Manganese, Potassium, Sodium, Iron, and heavy metals Cd, Hg, Pb, Zn, Cr, Cu were also analysed. Total coliform was assessed via media method. To assess the primary productivity, DO analysis with dark and light bottle, applying Alkali Azide analysis technique and measuring DO with digital DO meter (diurnal curve method) was used.

5.5.2.2 Sampling of Phytoplankton & Periphyton - Benthic (Epilithic) Diatoms and Zooplankton

For the quantification of phytoplankton and zooplankton 50 liters of water for each community was filtered at each site by using plankton net made up of fine silk cloth (mesh size 25 μm). The study was repeated three times at each site and samples were pooled. The filtrate collected for phytoplankton was preserved in 1% Lugol's Iodine solution.

For periphyton the sampling was performed across width of stream at a depth of 15 - 30 cm. The samples were taken from the accessible banks only. The cobbles (64 -128 mm size) usually 4 - 5 in number, were picked from the riffle and pools, in apparently different flows such as stones above and below gushing waters, swift flow and slow flow conditions so as to obtain a representative sample. Benthic diatom samples were collected by scratching the pebbles with a brush of hard bristles in order to dislodge benthos from crevices and minute cavities on the boulder surface from an area of 3 x 3 cm^2 , using a sharp edged razor. The scrapings from each cobble were collected in 25 μ mesh and transferred to storage vials. The samples were preserved in 1% Lugol's iodine solution.

Acid treatment according to Reimer (1962) method, adopted also by Nautiyal & Nautiyal (1999, 2002), was followed to process the samples for light microscopy. The treated samples were washed repeatedly to remove traces of acid. Samples with high organic content were treated with hydrogen peroxide (H_2O_2) to clean the diatom frustules. The permanent mounts were prepared in Naphrax for further analysis. They were examined using a BX-40 Trinocular Olympus microscope (x10 and x15 wide field eyepiece) fitted with Universal condenser and PLANAPO x100 oil immersion objective under bright field using appropriate filters to identify the species.

For preparing permanent mounts from the treated samples, the slide was first smeared with Mayer's albumen. The sample was then agitated to render it homogeneous. Quickly a drop of known volume (0.04 ml) of processed material was placed on the slide and heated gently till it dried. It was dehydrated using 95% and 100% alcohol, consecutively. The dehydrated material was transferred to Xylol twice before finally mounting in Euparal.

Table 5.3: Details of Sampling locations for the collection of data on aquatic ecology

SL.No.	Code	Sub-basin/ Sites	Nearby Village	River/Stream	Latitude	Longitude	Altitude (m)
Yamne River							
1	Y1	Lower Yamne Stage-II HEP	Jerring	Yamne	28°15'20.7"N	95°12'24.5"E	310
2	Y2	Lower Yamne Stage-I HEP	U/s of Padu	Yamne	28°19'09.5"N	95°11'37.7"E	430
3	Y3	Yamne - II (Barrage site) HEP	Siyat	Yamne	28°23'58.4" N	95°14'16.2"E	545
4	Y4	Yamne - I (dam site) HEP	Lagru / Damro	Yamne	28°30'34.6" N	95°10'36.3"E	680
Simang River							
5	Sm1	Simang-I HEP - Barrage site	Boleng	Simang	28°22'11.3" N	94°56'34.2"E	230
6	Sm2	Simang-I (PH site) HEP	Lileng	Simang	28°20'05.5"N	94°57'32.5"E	350
7	Sm3	Simang-II (Diversion site) HEP	Suple	Simang	28°26'03.4"N	94°53'39.8"E	430
Siang River							
8	S1	Siang Lower HEP project area	Near dam site - Bodak	Siang	28°9'59"N	95°10'00"E	120
9	S2	Siang Lower HEP project area	D/s of Ranaghat	Siang	28°9'39"N	95°10'30"E	140
10	S3	Siang Lower HEP project area	Ranaghat	Siang	28°8'29"N	95°11'20"E	150
11	S4	D/s of Siang & Siyom Confluence	Kebang	Siang	28°11'27.9"N	95°00'49.3"E	194
12	S5	Siang Upper Stage-II HEP (d/s of confluence Simang with Siang)	Boleng	Siang	28°18'44.4"N	94°57'35.1"E	210
13	S6	Siang Upper Stage-II HEP (dam site)	11km u/s of Hawa camp	Siang	28°44'20.8"N	94°55'25.5"E	310
14	S7	Mirak HEP	Near dam site	Sigong	28°15'53.3"N	94°39'22.1"E	421
15	S8	Pango/Minnying	Near dam site	Sigong	28°53'28.2"N	94°36'45.7"E	520
16	S9	Siang Upper Stage- I & II HEPs (D/s of Ringong river confluence)	U/s of Nunning	Siang	28°57'21.2"N	94°51'44.4"E	410
17	S10	Ringong HEP (d/s of dam site)	8 km d/s of Tuting	Ringong	28°57'40.6"N	94°51'41.9"E	440
18	S11	Siang Upper Stage-I HEP (d/s of Yangsang confluence)	12 km d/s of Tuting	Siang	28°57'29.6"N	94°51'56.2"E	410

19	S12	U/s of Yangsang & Siang confluence	Tuting	Siang	28° 59'47.0"N	94° 54'13.3"E	450
20	S13	Jidu/Yang Sang HEP (dam site)	Jidu village	Yangsang	28° 58'36.8"N	94° 54'18.7"E	435
Hirit River							
21	SY1	D/s of Hirit & Siyom confluence		Siyom	28°13'53.3"N	94° 41'16.4"E	254
22	SY2	Confluence of Hirit with Siyom	d/s of Kamba	Hirit			350
23	SY3	Hirit HEP (near diversion site)	u/s of Poma Basti	Hirit	28° 14'04.4"N	94°35'34.8"E	650
Siyom River							
24	SY4	Siyom Middle HEP (near dam site)	U/s of Reying Basti	Siyom	28° 27'39.6"N	94° 41'04.8"E	454
25	SY5	Gameng HEP (near confluence)	Gameng river	Gameng	28° 32'48.2"N	94° 38'33.3"E	620
26	SY6	Naying HEP (near powerhouse)	Pene	Siyom	28° 31'37.9"N	94° 34'48.1"E	970
27	SY7	Naying HEP (near dam site)	Yapik	Siyom	28° 30'32.4"N	94° 27'9.9"E	1000
28	SY8	Tato-II HEP PH	Near PH	Siyom	28° 30'30.4"N	94° 25'19.9"E	1010
29	SY9	Confluence of Yargyap with Siyom	Near Tato-II dam site	Siyom	28° 31'9.9"N	94° 23'15.2"E	1100
30	SY10	Tagurshit HEP (Diversion site)	Tadogitu	Tagurshit	28° 29'58.7"N	94° 24'43.2"E	1410
31	SY11	Hirong HEP (PH site)	Before confluence of Yagyap Chu with Siyom river	Siyom	28° 37'08.5"N	94° 22'59.3"E	1200
32	SY12	Hirong HEP (dam site)	Lungte-D/s of Sitin Nala	Siyom	28° 37'04.5"N	94° 22'50.3"E	1239
33	SY13	Jarong HEP (near dam site)	U/s of Karo village	Siyom	28°40'06.3"N	94°19'40.3"E	1416
Yargyap Chhu							
34	YG1	Tato-I HEP	Near Trench weir site, Tato	Yargyap Chhu	28° 31'36.3"N	94° 20'21.8"E	1150
35	YG2	Heo HEP	Near PH	Yargyap Chhu	28° 31'37"N	94° 20'17.8"E	1210
36	YG3	Heo HEP	Near dam site	Yargyap Chhu	28° 31'36.5"N	94° 20'16"E	1250
37	YG4	Pauk HEP	Near PH dam site	Yargyap Chhu	28° 33'41.0"N	94° 15'41"E	1300
38	YG5	Pauk HEP	Near dam site	Yargyap Chhu	28° 33'41.7"N	94° 15'35.7"E	1410
39	YG6	Rapum HEP	Near PH	Yargyap Chhu	28° 33'41.5"N	94° 12'49"E	1450

40	YG7	Rapum HEP	Near barrage site	Yargyap Chhu	28° 33'38"N	94° 12'11.5"E	1500
41	YG8	Rego HEP	Powerhouse	Yargyap Chhu	28° 33'39.5"N	94° 12'41.8"E	1650
42	YG9	Rego HEP (near intake point)	Intake point	Yargyap Chhu	28° 33'36.2"N	94° 11'31.5"E	1700
43	YG10	Kangtangshiri HEP	Near PH	Yargyap Chhu	28° 37'44.8"N	94° 2'53"E	1750
44	YG11	Kangtangshiri HEP	Near barrage site	Yargyap Chhu	28° 37'53.8"N	94° 2'50.4"E	1770
45	YG12	Pemashelpu HEP	Near PH	Yargyap Chhu	28° 37'54.8"N	94° 2'45.4"E	1800
46	YG13	Pemashelpu HEP	Near barrage site	Yargyap Chhu	28° 37'54.8"N	94° 2'45.4"E	1816
47	YG14	U/s of Hanuman Camp	Yarlong	Yargyap Chhu	28° 40'22.0"N	94° 58'04.1"E	2390

PH=Powerhouse

Sites Located Outside the Siang Basin

Sl.No.	Code	Sub-basin/ Sites	Nearby Town/Village	Latitude	Longitude	Altitude (m)
48	B2	Jiyadhol (d/s of dam site)	Jiyadhol	27° 25'34.5"E	94° 27'42.5"E	50
49	B1	Brahmaputra river (Dibugarh)	Ghat (u/s of constr. Bridge) near Dibugarh	27° 25'58.1"N	94° 45'05.2"E	20

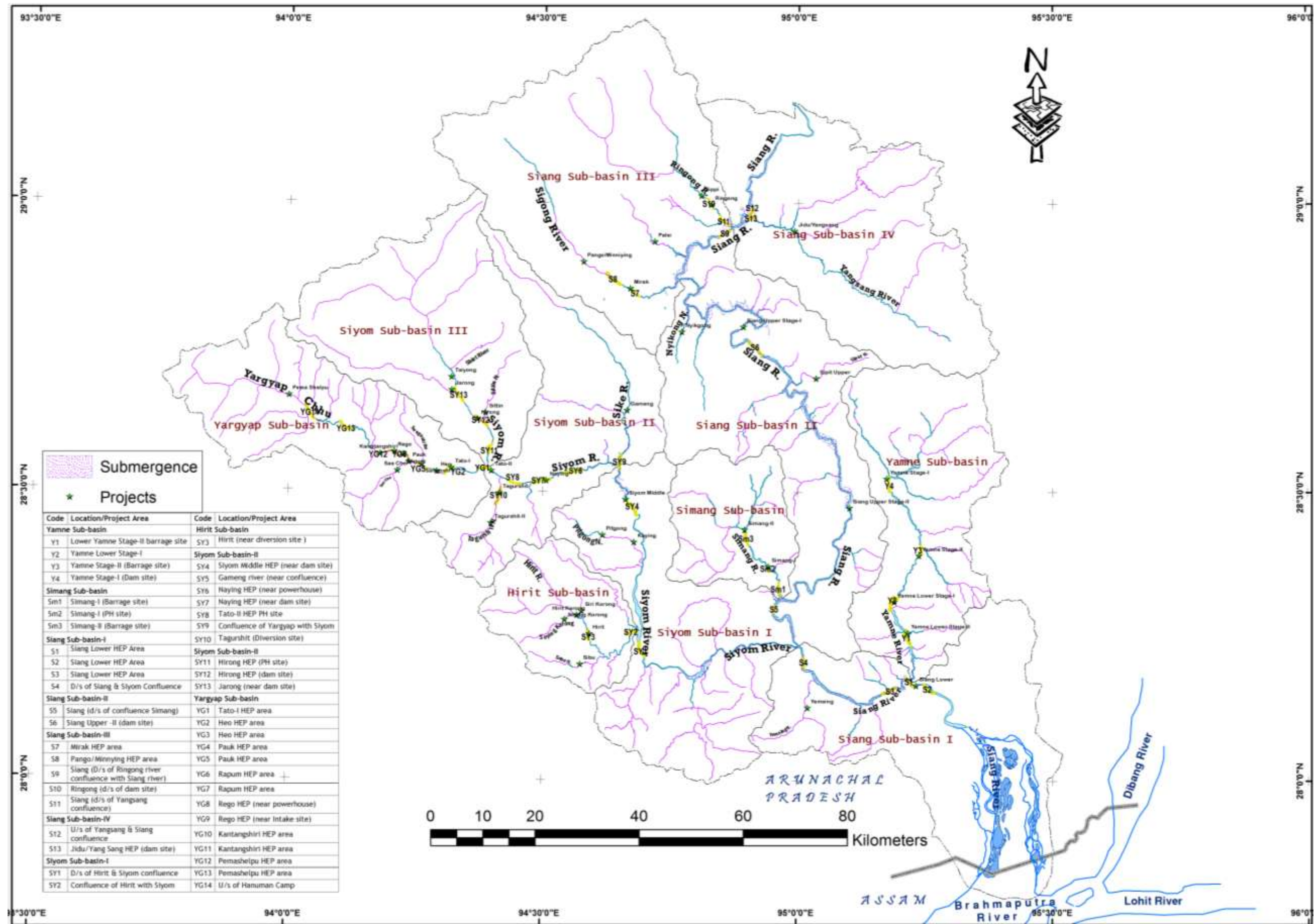


Figure 5.3: Location of Sampling sites for aquatic ecology in Siang basin

5.5.2.3 Identification of Benthic (epilithic) Diatoms & Zooplankton

The permanent mounts were then subjected to analysis under a phase contrast binocular microscope using an oil immersion lens of x100 magnification. For identifying the various diatom species, varieties and forms, the morphological characteristics used included length, width (μm), number of striae, raphe, axial area, central area, terminal and central nodules. Identifications were made according to standard literature viz. Schmidt 1914 -1954, Hustedt 1943, Hustedt 1985, Krammer & Lange - Bertalot 1986, 1991, 1999, 2000 a & b, Lange - Bertalot, H. Krammer, K. 2002, Metzeltin & Lange - Bertalot 2002, Krammer 2000, 2003, Lange Bertalot et al., 2003, Werum & Lange - Bertalot 2004, Metzeltin et al., 2005. Sarode & Kamat (1984), Prasad (1992) and Gandhi (1998) were also consulted for the oriental species.

The identification of zooplankton was made with the help of Ward and Whipple (1959) and Battish (1992).

Density and Diversity of different species was calculated as follows:

a) **Density of phytoplankton** (cells/lit) **and zooplankton** (indiv./lit)

b) **Density of phytobenthos** (Individuals mm^{-2}):

Total count of cells $\times$ cover glass size/length of visual field of microscope $\times$ counted rows $\times$ total sample volume (ml)/observed sample / sampled area

c) **Species Diversity Index** (Shannon & Wiener 1963): The Shannon diversity indices were determined on the basis of counts (500 - 600 valves).

Shannon-Wiener Diversity Index $H = - \sum (n_i/n) \times \ln (n_i/n)$

where, p_i is the proportion of total number of species made up of the i^{th} species

d) **Evenness Index** (Shannon & Wiener 1963)

Evenness Index (E) = $H / \ln(S)$

where, H is Shannon Index of general diversity and S is Number of species

5.5.2.4 Sampling & Identification of Macro-invertebrates

For Macro-invertebrate samples were collected from 1 sq ft area by lifting of stones and sieving of substratum from the wadeable portion of the river. The material was sieved through 125 μm sieve and preserved in 70% ethyl alcohol. Samples were collected in three replicates and pooled for further analysis. The organisms obtained were then counted after identifying them up to family level. Standard keys were used for the identification of macro invertebrate samples (Pennek 1953; Edmondson 1959; Macan 1979; Edington and Hildrew 1995).

Crude density (Indiv/m^2) = total numbers of individuals in each quadrat/ total quadrats $\times$ 11

5.5.2.5 Estimation of Primary Productivity in River Water

Phytoplanktons are autotrophic, prokaryotic or eukaryotic algae that live near the water surface where there is sufficient light to support photosynthesis. Among the more important groups are the diatoms, cyanobacteria, dinoflagellates and coccolithophores. Phytoplankton accounts for half of all photosynthetic activity on earth and contribute significantly to primary production process in aquatic ecosystems. Phytoplankton primary productivity is defined as the rate of organic matter production by the growth of planktonic plants.

The primary productivity was determined by light and dark bottle method (Wetzel and Likens, 1991). The water samples were collected in light and dark BOD bottles. Three replicates were maintained for each sample. The experimental bottles were kept for 6 hours in the river from where the water samples were collected. Winkler's method was used for determination of oxygen in the light and dark bottles.

Following formula was used for calculation of phytoplankton primary productivity.

Gross Primary productivity (GPP) (mgC/m³/hr) =

$$\frac{(\text{O}_2 \text{ content of light bottle} - \text{O}_2 \text{ content of dark bottle}) \times 0.375 \times 1000}{1.2 \times \text{Incubation hour}}$$

Net Primary productivity (NPP) (mgC/m³/hr) =

$$\frac{(\text{O}_2 \text{ content of light bottle} - \text{O}_2 \text{ content of control bottle}) \times 0.375 \times 1000}{4.2 \times \text{Incubation hour}}$$

5.5.3 Physico-Chemical Water Quality

The water quality objectives for freshwaters focus on a core indicator set that reflects their importance along a river stretch in a valley/basin. The core indicators pH, turbidity, electrical conductivity (salinity) and dissolved oxygen are addressed in this report.

In order to assess the water quality of Siang river and its tributary streams a Water Quality Index was used which has been developed at Washington State Department of Ecology, Environmental assessment Programme. The Water Quality Index (WQI) used in the report is a unitless number ranging from 1 to 100. A higher number is indicative of better water quality. For temperature, pH, faecal coliform bacteria and dissolved oxygen, the index expresses results relative to levels required to maintain beneficial uses (based on criteria in Washington's Water Quality Standards, WAC 173-201A).

Water quality index is a 100 point scale that summarizes results from a total of nine different measurements viz.

- pH,
- Dissolved Oxygen
- Turbidity
- Faecal Coliform
- Biochemical Oxygen Demand
- Total Phosphates
- Nitrates, and
- Total Suspended Solids

During the Water Quality analysis number of other parameters were also analysed from the water samples collected from different locations during the field surveys. These are as follows:

Electrical conductivity (EC)	Potassium
Total Dissolved Solids (TDS)	Iron
Chlorides	Manganese
Total Alkalinity	Zinc
Total Hardness	Cadmium
Chemical Oxygen Demand (COD)	Lead
Sulphates	Copper
Sodium	Mercury
Calcium	Total Chromium
Magnesium	

The analysis of above mentioned parameters revealed that most of the parameters are of least importance in hilly and mountainous streams with very scanty population and good forest landscape. In addition the concentration of most of the heavy metals is Not Detectable or Below Detectable limits. The values for all or most of the parameters have been averaged for each

sampling /field surveys and from different sampling locations to arrive at a meaningful conclusion and interpretation otherwise the data collected for each and every month for each parameter becomes too voluminous to arrive at any meaningful outcome.

The analysis of water quality therefore has been based upon 9 parameters as defined for WQI above.

Water Quality Index Legend	
Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

5.5.4 Biological Water Quality Index

As discussed in earlier sections waters of Siang river and its major tributaries like Siyom river, Yamne river, Simang river, Hirit river and also Yargyap Chhu which is tributary of Siyom in upper catchment harbour very good diversity of all the aquatic ecosystem components like Phytoplankton, Phytobenthos, Zooplanktons, Algal micro-flora and also macro-invertebrates which determine the biological water quality of any river/stream in a hilly stream.

For the assessment and analysis of Biological Water Quality an index named **Biological Monitoring Working Party (BMWP)** procedure was employed using species of macro-invertebrates as biological indicators (<http://www.nethan-valley.co.uk/insectgroups.doc>). The method is based on the principle that different aquatic invertebrates have different tolerances to pollutants. The presence of mayflies or stoneflies for instance indicates the cleanest water. The BMWP score equals the sum of the tolerance scores of all macroinvertebrate families in the sample. Therefore a higher BMWP score is considered to reflect a better water quality. The number of different macroinvertebrates is also an important factor, because a better water quality is assumed to result in a higher diversity. Alternatively, also the **Average Score Per Taxon (ASPT)** score is calculated. The ASPT equals the average of the tolerance scores of all macroinvertebrate families found, and ranges from 0 to 10. The main difference between both indices is that ASPT does not depend on the family richness.

For the presently analysis of biological water quality above indices have been calculated for each location in Siang basin.

5.6 FISH AND FISHERIES

Freshwater is an important source of food for humans, in which fish play a significant role. Running water of Himalaya comprise many torrential rivers and streams providing a wide variety of ecological niches for freshwater fish. The fish species of Himalaya are well adapted to fast flowing water, low to medium water temperature, boulders on river bed, etc.

Fishes are regarded as most impacted group of freshwater biotic communities due to the flow regulation by damming because dammed rivers destroy and degrade not only the habitat but

hamper the various phenomena viz. migration, spawning, etc. The baseline data on fish and understanding of various attributes of fish communities will be helpful in the fishery management and conservation.

5.6.1 Field Surveys

The sampling for fishes was done at 47 locations in Siang and Siyom rivers as well as their tributaries like Yamne, Simang, Tagurshit, Yargyap, Ringong and Sigong rivers covering all the sub-basins as well as impact zones of the proposed project area. Sampling was done on monthly basis for 9 months, January to September, 2012. List of sampling sites along with their location on map is given at (Table 5.4 and Figure 5.4). Common fishing methods were used to land fish from Siang and Siyom rivers and their tributaries. The fish were landed with the help of local fishermen, who used hooks and cast nets to land fish. At each site all fishing gears except cast net were used at least 10 times while the cast nets were laid at least 15 times. All the fish species landed during the experimental fishing were identified with the help of Talwar & Jhingran (1991) and were classified according to Nelson (2006) and their correct scientific names were checked and updated following <http://www.fishbase.org>.

Table 5.4: Sampling locations for fish fauna

Code	Location/Project Area	River/Stream	Altitude (m)
Yamne Sub-basin			
Y1	Yamne Lower Stage-II	Yamne	310
Y2	Yamne Lower Stage-I	Yamne	430
Y3	Yamne -II (Barrage site)	Yamne	545
Y4	Yamne -I (dam site)	Yamne	680
Simang Sub-basin			
Sm1	Simang- I Dam site	Simang	230
Sm2	Simang-I (PH site)	Simang	350
Sm3	Simang-II (Barrage site)	Simang	430
Siang Sub-basin-I			
S1	Siang Lower HEP Area	Siang	120
S2	Siang Lower HEP Area	Siang	140
S3	Siang Lower HEP Area	Siang	150
S4	D/s of Siang & Siyom Confluence	Siang	194
Siang Sub-basin-II			
S5	Siang (d/s of confluence of Simang)	Siang	210
S6	Siang Upper Stage-II (dam site)	Siang	310
Siang Sub-basin-III			
S7	Mirak	Sigong	421
S8	Pango/Minnying	Sigong	520
S9	Siang (D/s of Ringong river confl.)	Siang	410
S10	Ringong (d/s of dam site)	Ringong Asi	440

S11	Siang (d/s of Yangsang confl.)	Siang	410
Siang Sub-basin-IV			
S12	U/s of Yangsang & Siang confluence	Yang Sang	450
S13	Jidu/Yang Sang (dam site)	Yang Sang	435
Siyom Sub-basin-I			
SY1	D/s of Hirit & Siyom confluence	Siyom	254
SY2	Confluence of Hirit with Siyom	Siyom	350
Hirit Sub-basin			
SY3	Hirit (near diversion site)	Hirit	650
Siyom Sub-basin-II			
SY4	Siyom Middle HEP (near dam site)	Siyom	454
SY5	Gameng (near confluence)	Siyom	620
SY6	Naying HEP Area (near powerhouse)	Siyom	970
SY7	Naying HEP Area (near dam site)	Siyom	1000
SY8	Tato-II HEP Area near PH	Siyom	1010
SY9	Confluence of Yargyap with Siyom	Siyom	1100
SY10	Tagurshit HEP Area (Diversion site)	Tagurshit nadi	1410
Siyom Sub-basin-II			
SY11	Hirong HEP (PH site)	Siyom	1200
SY12	Hirong HEP (dam site)	Siyom	1240
SY13	Jarong HEP (near dam site)	Siyom	1420
Yargyap Sub-basin			
YG1	Tato-I HEP	Yargyap	1150
YG2	Heo HEP	Yargyap	1210
YG3	Heo HEP	Yargyap	1250
YG4	Pauk HEP	Yargyap	1300
YG5	Pauk HEP	Yargyap	1410
YG6	Rapum HEP	Yargyap	1450
YG7	Rapum HEP	Yargyap	1500
YG8	Rego HEP (near powerhouse)	Yargyap	1650
YG9	Rego HEP (near intake point)	Yargyap	1700
YG10	Kangtangshiri HEP	Yargyap	1750
YG11	Kangtangshiri HEP	Yargyap	1770
YG12	Pemashelpu HEP	Yargyap	1800
YG13	Pemashelpu HEP	Yargyap	1820
YG14	U/s of Hanuman Camp	Yargyap	2390

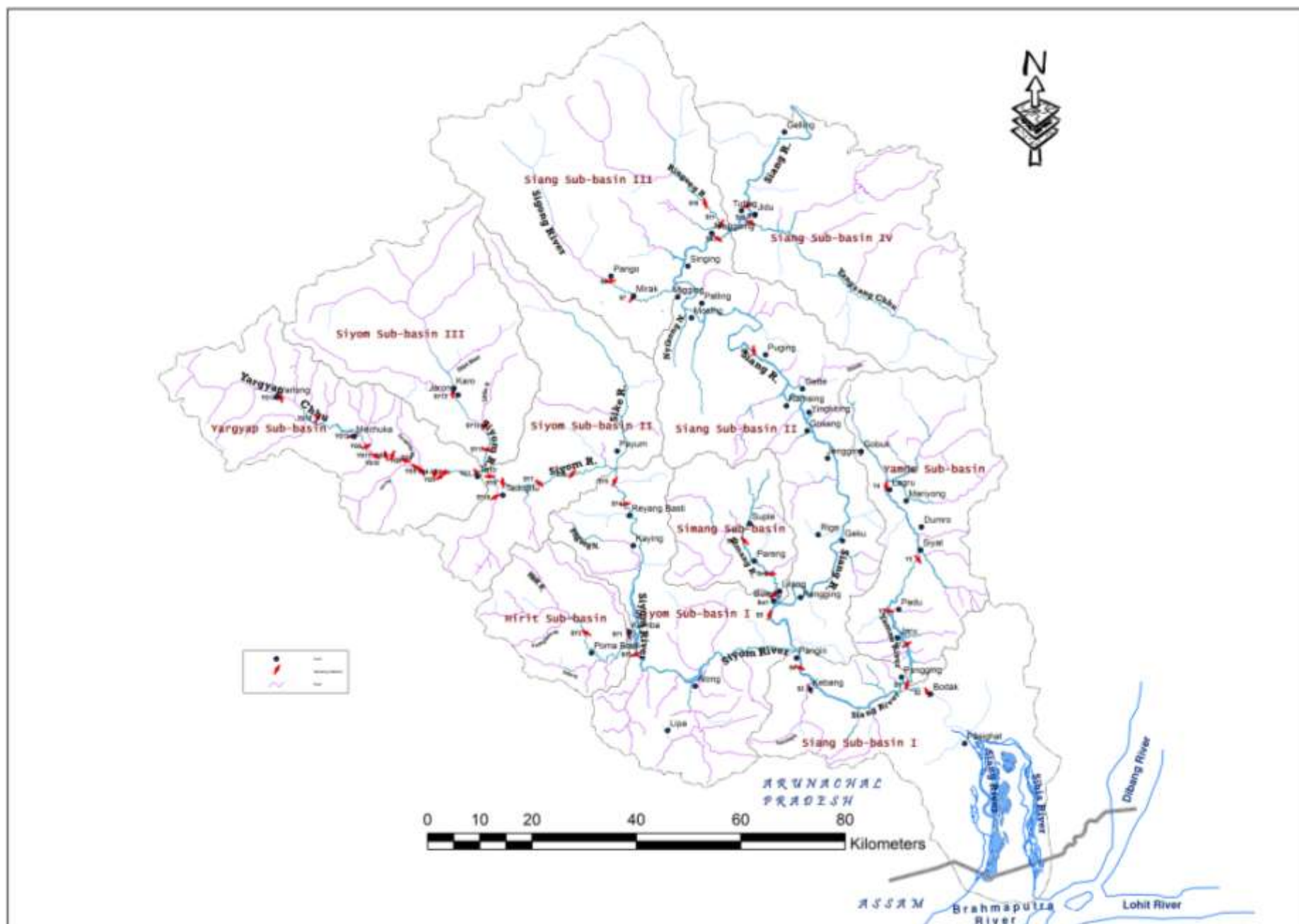


Figure 5.4: Sampling locations for fish

CHAPTER-6

TERRESTRIAL ECOLOGY

6.1 LAND USE/ LAND COVER

Arunachal Pradesh is one of the Himalayan biodiversity hot spots and is endowed with rich diversity of terrestrial and aquatic species. The diversity of topographical and climatic condition has favoured the growth of luxuriant forests, which are home to myriad plant and animal species.

The total forest cover in the state is 67,417 sq km which is 80.50% of its geographical area (Forest Survey of India, 2011). The area under Very Dense forest is 20,868 sq km (24.92%), under Moderately Dense forest is 31,519 sq km (37.64%) and under Open forest is 15,023 sq km (17.94%) (refer Table 6.1). About one fourth (25%) of Very Dense forests of the country exist in this state (FSI, 2011). Major portion of the area in the state is still covered with primary forests. Several forest types and subtypes with characteristic floristic composition occur in Arunachal Pradesh. The forests vegetation comprises a variety of medicinal and other commercially useful plants.

The Recorded Forest Area in the state is 51540 sq km which is 61.55% of its geographic area. Reserved Forests, Protected Forests and Unclassified State Forests (USF) constitute 20.46%, 18.49% and 61.05% of the total Recorded Forest area, respectively. The Protected Areas constitute 11.68% of the geographic area of the state.

The Siang river basin constitutes the main drainage system of East, West and Upper Siang districts of Arunachal Pradesh. The course of the river in these districts covers a length of about 250 km, and throughout this course it is fed by many tributaries viz., Yangsang, Ringong, Sigong, Simang, Siyom and Yamne flowing in a north-south direction. The downstream of the river, a little south of Pasighat, it descends into the plains of Assam and becomes Brahmaputra after it is joined by the Siang and Dibang.

Table 6.1: Area under different forest classes in Arunachal Pradesh

S. No.	Legal Classification	Area (Sq km)	% of Recorded Forest	% of Geographic Area
1	Reserved Forest	9722.69	18.86	11.61
2	Protected Forest	694.30	1.35	0.82
3	Anchal Reserve Forest	329.38	0.64	0.39
4	Village Reserve Forest	300.24	0.58	0.36
5	National Parks	2468.24	4.79	2.94
6	Wildlife Sanctuaries	7059.75	13.70	8.43
7	Unclassified State Forest (USF)	30965.39	60.08	36.90
	Total	51540.00	100.00	61.55

(Source: Department of Environment & Forests, Government of Arunachal Pradesh)

Total forest cover in the three districts (West Siang, East Siang and Upper Siang) comprising Siang basin is 15,232 sq km (82.26%) as compared to state's average forest cover of 80.50% (see Table 6.2). The three districts have 82.26% of area under forests of which Very Dense forest covers 26.99% of total area as compared state average of 24.92% of Very Dense Forest. The Siang basin

study area however has 80.61% area under forests of which Very Dense forests constitute 27.08% of the total area. West Siang district has highest area under forests among the three districts i.e. 86.83%.

Land use/ Land cover map prepared for the entire basin is given at **Figure 6.1** and area under different classes is given in **Table 6.3** and **Figures 6.1 - 6.3**.

As seen from the **Table 6.3** and **Figures 6.1 - 6.3** forests constitute main land use in the basin and account for more than 81% of the entire basin area.

6.2 FOREST COVER

6.2.1 Forest Cover in Sub-basins

The state of Arunachal Pradesh occupies the largest area (83,743 sq km) in the northeastern region of India. It is uniquely situated in the transition zone between the Himalayan and Indo-Burmese regions (Mani, 1974; Rodgers and Panwar, 1988).

Table 6.2: Area under different forest cover classes as per FSI data (2011) in three districts covering Siang basin in Arunachal Pradesh

District	Forest Cover (Sq km)					Total Geographic area (Sq km)	Scrub	Non-forest
	Very Dense	Moderately Dense	Open	Total (Sq km)	% of Geographic Area			
West Siang	2476	2726	1582	6784	86.83	7813	0	1029
East Siang	883	1269	669	2821	77.18	3655	0	834
Upper Siang	1638	2630	1359	5627	79.82	7050	2	1423
Total	4997	6625	3610	15232	82.26	18518	2	3286
STATE	20868	31519	15023	67410	80.50	83743	122	16333

(Source: Indian State of Forest Report, 2011, Forest Survey of India)

Table 6.3: Area under different land use/ land cover categories in Siang basin

S. No.	Land use/ land cover	Area (sq km)
1	Very Dense Forest	4052.95
2	Medium Dense Forest	5562.43
3	Open Forest	2449.32
4	Scrub	3.61
5	Non-Forest	2737.06
6	Water	159.94
	Total	14965.30

Bio-geographically it is situated in the Eastern Himalayan province, the richest Bio-geographical province of the Himalayan zone. The entire territory forms a complex hill system with varying elevations ranging from 50m in the foot-hills and gradually ascending to about 7750m, traversed throughout by a number of rivers and rivulets.

Among the 11 sub-basins in Siang maximum area under Very Dense (313.83 ha) as well as Dense forest (513.38 ha) cover classes is in Siang basin-II by being the largest sub-basin in Siang (total area 2018.83 ha) where two large hydropower projects Siang Upper Stage-I & II have been planned. However on the basis of percentage forest cover Hirit sub-basin has the maximum area under forests i.e. it has 97% of its area under forest cover followed by Yamne and Simang sub-basins with 96% and 95% area under forest cover as compared overall 81% of area under forests.

According to percent area under various forest cover classes Yargyap Chhu has maximum area under Very Dense forest cover class i.e. 55% followed by Siyom sub-basin-III with 50% as compared to average of 34% for entire Siang basin. However percent area under Dense forest cover is highest in Siang sub-basin-I (52%) followed by Yamne and Siyom sub-basin-II with 51% as compared average of 46% for entire Siang basin.

6.3 FOREST TYPES

The forests in Siang basin fall under Central Circle with headquarters at Pasighat whereas the Protected Areas in the basin are under the administrative control of Addl. Principal Chief Conservator Forests (Wildlife & Biodiversity), Itanagar. The basin area under Central Circle is further administered by three Forest Divisions viz. Yingkiong, Along and Pasighat Forest Divisions with headquarters at Yingkiong, Along and Pasighat, respectively (see **Figure 6.4**). In addition there are Mouling National Park and D'Ering Memorial Forest Divisions under the Central Circle. Yingkiong Forest division is comprised of Yingkiong, Karko and Boleng Ranges, Along Forest Division is comprised of Along, Mechuka, Basar and Liromoba Ranges and Pasighat Forest Division has Mebo, Pasighat, Ruksin and Nari Ranges. The three Protected Areas in the basin are D'Ering Memorial Wildlife Sanctuary, Yordi Rabe Supse Wildlife Sanctuary and Mouling National Park.

The details of forest types in the basin is primarily based upon Working Plans of three Forest Divisions, Management Plans of Mouling National Park and D'Ering Memorial Wildlife Sanctuary, and information provided by the Department of Forest, Government of Arunachal Pradesh. Their distribution in the basin is also described as per Forest Working Plans as well as supplemented with information gathered during field surveys in the area. The major forest types encountered in the area have been described based on the classification of Champion and Seth (1968) and also supplemented by information collected from literature like Kaul and Haridasan (1987), Negi (1989, 1996), Chowdhery (1996) and Muddgal & Hajra (1999).

The vegetation particularly in the lower valleys is comprised mainly of Tropical plains and Riverine semi-evergreen forests. In the mid hills Sub-tropical wet hill and Assam pine forest occurs, while towards higher elevations Wet temperate broad-leaved, Dry temperate coniferous and Mixed coniferous forests are prevalent. In the entire basin, there are number of Reserved Forests inhabited by local tribal and practice shifting cultivation for production of their food grains and agricultural crops. This practice has been detrimental to the forests in general and has lead to the formation of degraded secondary forest especially near the settlements. A view of Siang river and its tributaries is shown in **Figure 6.1**.

The basin in general can be demarcated into four major ecological zones like Tropical Zone (Plains up to 900m), Sub-Tropical Zone (900-1800 m), Temperate Zone (1800-2750 m), and Alpine Zone above 2800m. The major forest types found in the Siang Basin are given below.

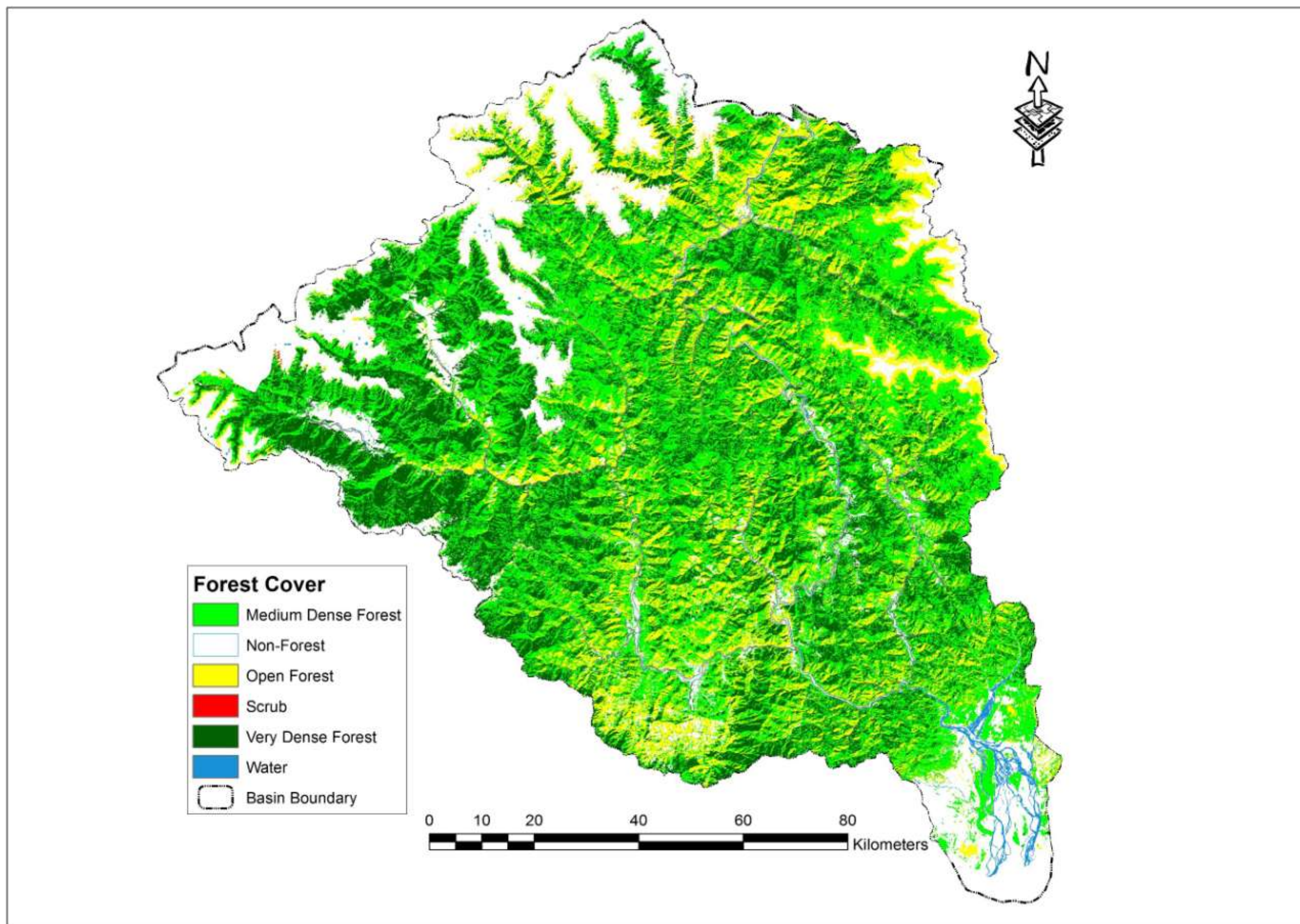


Figure 6.1: Forest cover map of Siang basin based upon FSI data (2011)

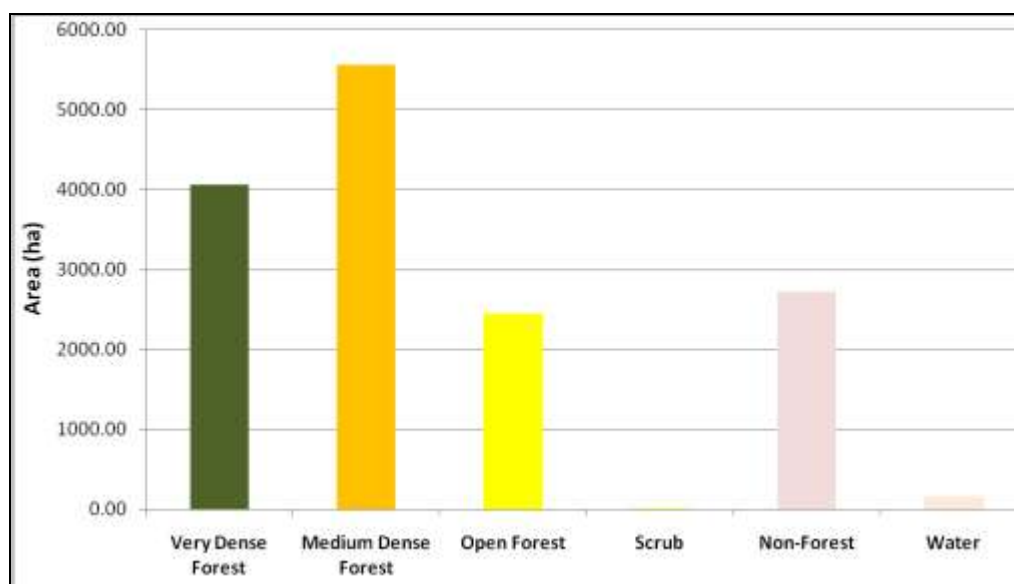


Figure 6.2: Area under different land use/ land cover classes in Siang basin

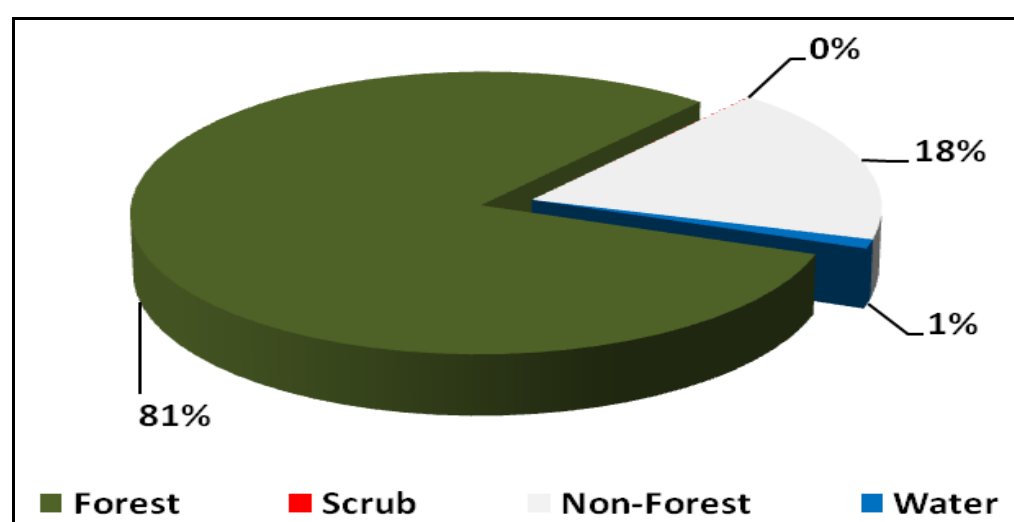


Figure 6.3: Percent area under forest and non-forest in Siang basin

6.3.1 2B/C1a Tropical Semi-Evergreen forest/ Assam Alluvial Plains semi-evergreen forest

This type of forest occurs all along the low hills and river banks with a large proportion of deciduous trees in the top storey. The top canopy is represented by *Altingia excelsa*, *Amoora wallichii*, *Artocarpus lakoocha*, *Beilschmiedia roxburghii*, *Canarium strictum*, *Castanopsis indica*, *Cinnamomum pauciflorum*, *Dysoxylum gobara*, *Kydia calycina*, *Michelia champaca*, *Phoebe hainesiana*, *Tetrameles nudiflora* and *Toona ciliata*. Second storey is represented by *Artocarpus integrifolia*, *Ficus semicordata*, *Gynocardia odorata*, *Litsea citrata*, *Magnolia hodgsonii* and *Saurauia punduana*. Understorey consists of small trees and shrubs up to 10 m tall. Shrubs are comprised of the prominent species of *Ardisia*, *Boehmeria*, *Capparis*, *Clerodendrum*, *Luculia*, *Pinanga*, *Psychotria*, *Rubus* and *Strobilanthes*. Epiphytes and twiners are many. Epiphytes are represented by many species of mosses, ferns and orchids. Climbers are *Cissus discolor*, *Entada phaseoloides*, *Aralia leschenaultii* (= *Pentapanax leschenaultii*) and *Rubia sikkimensis*, *Rubus lineata*, *Smilax aspericaulis*, *Thunbergia coccinea* and *Toddalia asiatica*. The ground floor is occupied by some herbs and grasses like *Begonia nepalensis*, *Bidens pilosa*, *Carex cruciata*, *Colocasia affinis*, *Commelina paludosa*, *Lecanthus peduncularis*, *Pilea scripta*, *Saccharum longisetosum*, *S. spontaneum* and *Viola betonicifolia*.



Figure 6.4: Forest Divisions in Siang basin

6.3.2 1B/2S Secondary Bamboo brakes

The thorny bamboo brakes occur throughout the lower valleys of Siang and its tributaries. *Bambusa tulda*, *B. nutans*, *Dendrocalamus hamiltonii* and *Melocanna baccifera* form thick and spreading clumps at several places. These thick clumps make it impossible for the regeneration of any tree species, but scattered shrubs and thin layer of grass occurs on the forest floor.

6.3.3 3/1S2 (b) Eastern *Terminalia*- *Duabanga* forest

This type of forest occurs in the sub-Himalayan tracts of Pasighat and adjoining Assam area. This is an irregular type of forest in which deciduous trees are predominant. The dominant trees in the top storey include *Acacia catechu*, *Ailanthus integrifolia*, *Bombax ceiba*, *Garuga pinnata*, *Pterospermum acerifolium* and *Terminalia myriocarpa*. Second storey represented by predominantly evergreen woody species. *Albizia lucida*, *Dillenia indica*, *Duabanga grandiflora*, *Elaeocarpus rugosus*, *Magnolia hodgsonii*, *Vatica lanceifolia* and *Vitex peduncularis* are present in the second storey. Tall grasses form the ground cover.

6.3.4 8B/ C I East Himalayan Sub-tropical wet hill forests

These forests occur on hilly terrain between 900 and 1750 m and are dominated mostly by evergreen species. A few tall deciduous trees also occur in the top canopy. The dominant trees of the top canopy are *Albizia odoratissima*, *Beilschmiedia roxburghiana*, *Calophyllum polyanthum*, *Castanopsis indica*, *Engelhardtia spicata*, *Kydia calycina*, *Phoebe attenuate* and *Terminalia myriocarpa*. The second storey is represented by tree species like *Alangium chinensis*, *Brassaiopsis aculeata*, *Ficus semicordata*, *F. oligodon*, *Gynocardia odorata*, *Lepisanthes senegalensis*,

Oroxylum indicum, *Rhus chinensis* and *Saurauia nepalensis*. The third storey consists of shrubs and climbers. Shrubs are *Boehmeria macrophylla*, *Clerodendrum griffithianum*, *Debregeasia longifolia*, *Eurya* spp., *Leea aequata*, *Maesa chisia* and *Oxyspora paniculata*. These forests were observed in Hirong, Tato and Rapum areas. Climbers and epiphytes are abundant. Climbers belong to the species of *Canavalia*, *Cissus*, *Caesalpinia*, *Clematis*, *Dioscorea*, *Raphidophora* and *Stephania*. Epiphytes are represented by orchids and pteridophytes like species of *Colysis*, *Cymbidium*, *Dendrobium*, *Lepisorus* and *Vittaria*. The ground cover is dominated by the herb species like *Ageratum conyzoides*, *Anaphalis busua*, *Bidens bipinnata*, *Cardamine hirsuta*, *Impatiens* spp., *Persicaria capitata*, *P. barbata*, *Setaria glauca*, *Saccharum longisetosum*, *Themeda arundinacea*, *Thysanolaena latifolia* and *Viola pilosa*.

6.3.5 9/C2 Assam sub-tropical pine forest

This forest type is similar to the Himalayan pine forest but with a slightly different species composition. These types of forests were observed near Lungte village (West Siang) and areas adjoining Boleng in East Siang. *Pinus kesiya* is the dominant species in the top canopy. Next storey is represented by *Alnus nepalensis*, *Castanopsis indica*, *Lyonia ovalifolia*, *Ostodes paniculata* and *Rhus chinensis*. Shrubs are represented by species of *Boehmeria*, *Desmodium*, *Indigofera*, *Luculia*, *Plectranthus* and *Rubus*. Climbers and epiphytes are least common in these forests.

6.3.6 11b/C1 East Himalayan wet temperate forest

These forests occur between 1750 and 2750 m elevations in the upper reaches of Lungte (Siyom catchment), Rego (Yargyap valley) and Migging (Upper Siang) areas. The top canopy of these forests is represented by *Acer acuminatum*, *Castanopsis tribuloides*, *Engelhardtia spicata*, *Litsea sericea*, *Michelia* spp., *Prunus cerasoides*, *Quercus lamellosa*, *Rhododendron arboreum* and *Tetradium fraxinifolium*. The middle storey is dominated by moderate sized trees and shrubs like *Cotoneaster baccularis*, *Eurya acuminata*, *Gaultheria trichophylla*, *Ilex dipyrena*, *Lyonia ovalifolia*, *Saurauia roxburghii*, *Symplocos theaeifolia*, *Thamnocalamus spathiflorus* and *Viburnum cylindricum*. Other associates of middle storey are *Berberis asiatica*, *Debregeasia longifolia*, *Myrsine semiserrata*, *Rubus ellipticus*, *Salix wallichiana* and *Spiraea canescens*. Climbers and twiners are rare except for the species of *Clematis*, *Dioscorea*, *Smilax* and *Vitis*. Epiphytes are abundant and are comprised of mosses, ferns, lichens and orchids. The ground flora is represented ferns, grasses and other herbs. Dominant genera are *Ageratina*, *Anaphalis*, *Anemone*, *Cardamine*, *Campanula*, *Cirsium*, *Fragaria*, *Plantago*, *Persicaria*, *Potentilla*, *Pilea*, *Rorippa*, *Sedum*, *Stellaria* and *Viola*.

6.3.7 12/1S1 Alder forest

These forests are more or less pure forests present along the banks of streams and water courses. *Alnus nepalensis* grows abundantly along water courses and is the chief colonizer of new landslips and degraded areas. The undergrowth is often absent, but its composition depends on site and conditions. These type of forests were observed near Mariyang (East siang), BB camp area, Hirong, Lungte, Rapum, Rego (West Siang) and Sinmang and Migging (Upper Siang) areas.

6.3.8 12/C3 East Himalayan mixed coniferous forest

A dense evergreen forest of oak and rhododendron predominate with large Hemlock trees on the higher and drier ridges. With the oak are mixed deciduous trees such as *Acer*, *Alnus*, *Magnolia* and *Pinus* to a varying extent. These forests were observed on the higher ridges of Yorko, Gurudwara and Yarlong in West Siang District. Undergrowth was also dense growth comprising evergreen

shrubs and small bamboos. Among shrubs the dominant species include *Berberis asiatica*, *Cotoneaster bacillaris*, *Dicranopteris linearis*, *Gaultheria trichophylla*, *Lonicera spinosa*, *Pteris vittata*, *Pyrifomis formosa*, *Salix wallichiana*, *Rhododendron* spp., and *Thamnocalamus spathiflorus*. Most of the tall trees and shrubs often loaded with many epiphytic mosses and lichens.

6.3.9 13/C6 East Himalayan dry temperate coniferous forest

This is a mixed coniferous forest found in the inner valleys of Mechuka Reserve forest. Predominant conifer such as blue pine (*Pinus wallichiana*) is the principal species with other conifers (*Tsuga dumosa*). The top and middle storey is composed of blue pine, whereas the lower storey and ground vegetation have the typical coniferous associates. These include *Acer acuminatum*, *Lyonia ovalifolia*, *Populus ciliata*, *Quercus lamellosa*, *Rhododendron arboreum* and *Salix wallichiana*. Shrub layer is represented by *Berberis asiatica*, *Cotoneaster bacillaris*, *Eurya acuminata*, *Indigofera dosua*, *Rosa macrophylla*, *Rubus ellipticus*, *R. niveus* and *Thamnocalamus spathiflorus*. The ground flora consists of herbs and grasses belonging to the genera such as *Anaphalis*, *Anemone*, *Artemisia*, *Arundinella*, *Cirsium*, *Digitaria*, *Fragaria*, *Potentilla*, *Pilea*, *Rumex*, *Senecio* and *Stellaria*.

6.3.10 15/C1 Birch-rhododendron alpine scrub forest

This is an evergreen forest dominated by *Rhododendron* and some deciduous broad leaf species. These forests are found in the high ridges of Labang area. The main associates are *Betula alnoides*, *Rhododendron campanulatum*, *Rosa sericea* and *Viburnum nervosum*.

6.3.11 15/C2 Deciduous alpine scrub

This is a deciduous scrub formation. The climate in these habitats is too cold and severe for tree growth. The vegetation comprises few stunted scrubs and herbs like *Betula alnoides*, *Cotoneaster sanguineus*, *Lonicera angustifolia* and *Rosa sericea*. Most common herbs are the species of *Anemone*, *Polygonatum*, *Ranunculus*, *Senecio* and *Viola*, which have a very short growing season.

6.3.12 15/C3 Alpine pastures

These are meadows of gentle mountain slopes constitute the habitats of many perennial mesophytic herbs and grasses. Important herbs in these habitats are the species of *Aconitum*, *Allium*, *Anemone*, *Fragaria*, *Gaultheria*, *Juncus*, *Kobresia*, *Potentilla*, *Primula* and *Ranunculus*.

6.3.13 Forest Types in different Sub-basins

Each sub-basin of entire Siang basin harbours various forest types depending upon the altitudinal range and the same is given at Table 6.4.

Table 6.4: Forest types found in different sub-basins of Siang basin

S.No.	Forest Type	Sub-Basins
1	2B/C1a Tropical Semi-Evergreen forest/ Assam Alluvial Plains semi-evergreen forest	SSb I to II, YSb, SmSb, HSb, SYSb I, BSb
2	1B/2S Secondary Bamboo brakes	SSb II to IV, YSb, SmSb, HSb, SYSb I to III, YGSb
3	3/1S2 (b) Eastern <i>Terminalia</i> - <i>Duabanga</i> forest	SSb I to IV, YSb, SmSb, HSb, SYSb I to II, YGSb
4	8B/ C I East Himalayan Sub-tropical wet hill forest	SSb III and IV, YSb, SmSb, HSb, SYSb I to II, YGSb

S.No.	Forest Type	Sub-Basins
5	9/C2 Assam sub-tropical pine forest	SSb1, YSb
6	11b/C1 East Himalayan wet temperate forest	SYSb III, YGSb
7	12/1S1 Alder forest	SYSbIII
8	12/C3 East Himalayan mixed coniferous forest	SySb III, YGSb
9	13/C6 East Himalayan dry temperate coniferous forest	YGSb
10	15/C1 Birch-rhododendron alpine scrub forest	YGSb
11	15/C2 Deciduous alpine scrub	SYSb III, SSbIV, YGSb
12	15/C3 Alpine pastures	SYSb III, YGSb

SSBI-IV= Siang Sub-Basins; YSB= Yamne Sub-Basin; SMSB=Simang Sub-Basin; HSB= Hirit Sub-Basin; SYSBI-III=Siyoum Sub-Basins; YGSB=Yargyap Sub-Basin

6.4 FLORISTICS

The varied climate and the altitude have greatly influenced the rich diversity of vegetation in this region. The state is known for its verdant rainforest and rich vegetation with unique ecosystem ranging from tropical belt to the snow clad alpine mountains. The vegetation of the state is rich and diverse abounding in spectacular flora including some of the tallest trees in India, ferns, orchids, primulas and a variety of colourful rhododendrons.

Various plant collectors have explored different regions of Arunachal Pradesh like Aka Hills, Abor Hills, Dafla Hills, Mishmi Hills, Sadiya, Daphabum Ranges and they were botanically explored by British botanists viz. H.Wilcox (Mishmee hills in 1836), W.Griffith (Sadiya- Mishmee hills in 1890 & 1894), J.D.Lister (Dafla hills in 1874), I.H.Burkill (Abor hills in 1911,1912), N.L. Bor (Aka hills in 1931-34) and F. Kingdon Ward (Mishmi hills in 1926,1928; Aka hills in 1938). Later, after the Independence, several parties from Botanical Survey of India; Research Institutes like State Forest Research Institute (SFRI), Itanagar; North Eastern Regional Institute for Science & Technology (NERIST), Nirjuli; universities like North Eastern Hill University (NEHU), Shillong; Rajiv Gandhi University, Itanagar; Gauhati University, Guwahati have made extensive botanical tours to understand the flora of the state.

The flora of Arunachal Pradesh has been explored by different workers viz. Griffith, 1837; Booth, 1840-1850; Robinson, 1841; Hooker, 1854 & 1906; Burkill, 1924-25; Ward, 1929-1931; Bor, 1938; Biswas, 1941; Kanjilal et al., 1934-1940. After the establishment of the Eastern Circle of Botanical Survey of India (BSD) at Shillong, in 1955 and Arunachal field station at Itanagar in 1978, Chauhan, 1996; Chowdhery et al., 1996 and Chowdhery, 1998 have extensively explored the plant diversity in different parts of Arunachal Pradesh.

Arunachal Pradesh falls in the richest Botanical Province with nearly 50% of the flora of the Indian Subcontinent. Chowdhery et al. (1996) have enumerated 4117 species of flowering plants belonging to 1295 genera and 192 families of flowering plants from the state. The Siang basin area has good vegetation with predominant subtropical evergreen, bamboo mixed, temperate mixed broad leaved and coniferous forests at higher elevations.

6.4.1 Taxonomic Diversity

During the field surveys an inventory of different plant groups was prepared. Detailed list of flowering plant species compiled from primary data collection and published literature (Awasthi, 1960; Rao & Joseph, 1965; Rao & Kumari, 1968; Rao & Verma, 1969; Rao & Deori, 1980; Paul & Nayar, 1985; Srivastava, 1985; Bennet & Sumer, 1986; Dash, 1986; Thomas & Haridasan, 1997;

Behera et. al., 2002; Singh et al., 2002; Tayung & Saikia, 2003; Paul et al., 2005; Roy & Behera, 2005; Gusman, 2006; Joshi et. al., 2006; Rao, 2006; Rawat & Khanduri, 2006; Singh et al, 2006; Barik & Sanjappa, 2007; Behera & Kushwaha, 2007; Sikarwar & Lokesh, 2007; Chandra et. al., 2008; Choudhary, 2008; Choudhey, 2008; Sharma & Borthakur, 2008; SFRI, 2008; Srivastava & Choudhary, 2008; Benjamin et. al., 2009; Singh et. al., 2009, 2010; WWF, 2009; Dash, 2010; Dey & Singh, 2010; Rao, 2010; Rout et. al., 2010; Upadhyay & Ansari, 2010; Bharali et. al., 2011, 2012; Bhaumik & Pathak, 2011; Dandotiya et. al., 2011; Dash & Mao, 2011; Gibbs et. al., 2011; Saikia et. al., 2011; Yumnam et. al., 2011; Bharali & Khan, 2011, 2012; Mao et. al., 2013). A list of plant species reported from the Siang basin thus prepared is given at **Annexure-I in Volume-II:DATA**.

Plant group-wise description of the same is given in the following paragraphs.

In all 1349 vascular plant species belonging to 138 families were recorded including Gymnosperms (see **Volume-II**). A summary of number of plant species reported from Siang basin is given in **Table 6.5**.

6.4.1.1 *Angiosperms*

Angiosperms is the largest group wherein the dominant family in the basin is Orchidaceae with 102 species followed by Poaceae with 91 species, Asteraceae with 64 species, and Ericaceae with 31 species. Among Gymnosperms Pinaceae is the largest family with 6 species and amongst Pteridophytes Polypodiaceae is the largest family with 17 species followed by Pteridaceae with 16 species while Mniaceae is the largest family among Bryophytes with 9 species. The plant names and families are based upon <http://www.theplantlist.org>.

6.4.1.2 *Gymnosperms*

The gymnosperms are represented by 11 species belonging to four families Pinaceae, Podocarpaceae, Cephalotaxaceae and Taxaceae.

Table 6.5: Summary of number plants species in Siang basin

VASCULAR PLANTS				
Group	Angiosperms	Gymnosperms	Pteridophytes	Total
Species	1250	11	88	1349
Families	138	2	22	162
LOWER PLANTS				
Group	Bryophytes	Lichens		
Species	51	41		
Families	22	17		

6.4.1.3 *Pteridophytes*

Pteridophytes being the second largest group of vascular plants, they form a significant and are represented by 88 species dominant component of plant communities. Many ferns and fern-allies that grow luxuriantly in Eastern Himalaya are threatened by deforestation and frequent landslides. A comprehensive compilation of Ferns and Fern-Allies of Arunachal Pradesh in 2 volumes have been published by Singh and Panigrahi (2005). They have reported 305 taxa of the ferns and fern-allies in the state.

Based upon the data compiled from secondary information as well as primary surveys 76 species of Pteridophytes in Siang basin have been enumerated belonging to 19 families. A detailed list of the same is given in **Table 6.6**.

Table 6.6: List of Pteridophytes reported from Siang basin

S.No	Family	Name of Species
1	Adiantaceae	<i>Adiantum capillus-veneris</i>
2	Adiantaceae	<i>Adiantum edgeworthii</i>
3	Adiantaceae	<i>Adiantum lunulatum</i>
4	Adiantaceae	<i>Onychinum japonicum</i> var. <i>lucidum</i>
5	Adiantaceae	<i>Onychinum siliculosum</i>
6	Adiantaceae	<i>Onychium lucidum</i>
7	Aspleniaceae	<i>Asplenium nidus</i>
8	Blechnaceae	<i>Stenochlaena palustris</i>
9	Cyatheaceae	<i>Alsophila spinulosa</i>
10	Cyatheaceae	<i>Gymnosphaera gigantea</i>
11	Cyatheaceae	<i>Cyathea spinulosa</i>
12	Dipteridaceae	<i>Dipteris wallichii</i>
13	Dryopteridaceae	<i>Tectaria polymorpha</i>
14	Dryopteridaceae	<i>Cyrtomium macrophyllum</i>
15	Dryopteridaceae	<i>Diplazium caudatum</i>
16	Dryopteridaceae	<i>Dryopteris juxtaopposita</i>
17	Dryopteridaceae	<i>Dryopteris serrato-dentata</i>
18	Dryopteridaceae	<i>Dryopteris stenolepis</i>
19	Dryopteridaceae	<i>Polystichum aleuticum</i>
20	Dryopteridaceae	<i>Polystichum lachenense</i>
21	Equisetaceae	<i>Equisetum diffusum</i>
22	Equisetaceae	<i>Equisetum ramossimum</i>
23	Gleicheniaceae	<i>Dicranopteris linearis</i>
24	Gleicheniaceae	<i>Diplopterygium volubile</i>
25	Hemionitidaceae	<i>Coniogramme caudata</i>
26	Lycopodiaceae	<i>Huperzia squarrosa</i>
27	Lycopodiaceae	<i>Lycopodium obscurum</i>
28	Lycopodiaceae	<i>Lycopodium pseudosclavatum</i>
29	Lycopodiaceae	<i>Lycopodium clavatum</i>
30	Lygodiaceae	<i>Lygodium japonicum</i>
31	Lygodiaceae	<i>Lygodium salicifolium</i>
32	Marattiaceae	<i>Angiopteris assamica</i>
33	Marattiaceae	<i>Angiopteris evecta</i>
34	Marsileaceae	<i>Marsilea minuta</i>
35	Nephrolepidaceae	<i>Nephrolepis cordifolia</i>
36	Ophioglossaceae	<i>Botrychium lanuginosum</i>
37	Ophioglossaceae	<i>Botrychium virginianum</i>
38	Osmundaceae	<i>Osmunda claytonianum</i>
39	Polypodiaceae	<i>Colysis latiloba</i>
40	Polypodiaceae	<i>Colysis pedunculata</i>
41	Polypodiaceae	<i>Lepisorus mehrae</i> (=L. <i>kashyapii</i>)
42	Polypodiaceae	<i>Lepisorus loriformis</i>
43	Polypodiaceae	<i>Lepisorus nudus</i>
44	Polypodiaceae	<i>Microsorium membranaceum</i>
45	Polypodiaceae	<i>Microsorium pteropus</i>
46	Polypodiaceae	<i>Microsorium punctatum</i>
47	Polypodiaceae	<i>Phymatopsis chrysotricha</i>

S.No	Family	Name of Species
48	Polypodiaceae	<i>Polypodioides microrhizoma</i>
49	Polypodiaceae	<i>Polypodioides wattii</i>
50	Polypodiaceae	<i>Pyrrosia lanceolata</i> (= <i>P. adnascens</i>)
51	Polypodiaceae	<i>Pyrrosia lingua</i>
52	Polypodiaceae	<i>Arthromeris wallichiana</i>
53	Polypodiaceae	<i>Lepisorus kashyapii</i>
54	Polypodiaceae	<i>Lepisorus ussuriensis</i>
55	Polypodiaceae	<i>Microsorium membranaceum</i>
56	Pteridaceae	<i>Cheilanthes albomarginata</i>
57	Pteridaceae	<i>Cheilanthes tenuifolia</i>
58	Pteridaceae	<i>Phegopteris aurita</i>
59	Pteridaceae	<i>Pteris aspericaulis</i> ssp. <i>subindivisa</i>
60	Pteridaceae	<i>Pteris stenophylla</i>
61	Pteridaceae	<i>Pteris vittata</i> ssp. <i>vermae</i>
62	Pteridaceae	<i>Pteris wallichiana</i>
63	Pteridaceae	<i>Pteris biaurita</i>
64	Pteridaceae	<i>Pteris cretica</i>
65	Pteridaceae	<i>Pteris nervosa</i>
66	Pteridaceae	<i>Pteris quadriaurita</i>
67	Pteridaceae	<i>Pteris scabristipes</i>
68	Pteridaceae	<i>Pteris semipinnata</i>
69	Pteridaceae	<i>Pteris stenophylla</i>
70	Pteridaceae	<i>Pteris wallichiana</i>
71	Pteridaceae	<i>Pteridium aquilinum</i>
72	Selaginellaceae	<i>Selaginella inaequalifolia</i>
73	Selaginellaceae	<i>Selaginella indica</i>
74	Selaginellaceae	<i>Selaginella wallichii</i>
75	Selaginellaceae	<i>Selaginella decipiens</i>
76	Thelypteridaceae	<i>Christella parasitica</i>
77	Thelypteridaceae	<i>Cyclosorus appendiculatus</i>
78	Thelypteridaceae	<i>Thelypteris opulenta</i> (= <i>Amphineuron opulentum</i>)
79	Vittariaceae	<i>Antrophyum plantagineum</i>
80	Vittariaceae	<i>Vittaria elongata</i>
81	Vittariaceae	<i>Vittaria flexuosa</i>
82	Vittariaceae	<i>Vittaria linearifolia</i>
83	Vittariaceae	<i>Vittaria merrillii</i>
84	Vittariaceae	<i>Vittaria sikkimensis</i>
85	Woodsiaceae	<i>Athyrium angustum</i>
86	Woodsiaceae	<i>Athyrium flabellulatum</i>
87	Woodsiaceae	<i>Athyrium himalaicum</i>
88	Woodsiaceae	<i>Deparia allantodioides</i>

6.4.1.4 Bryophytes

Bryophytes play an important role in nutrient cycling, soil formation, providing microhabitat for other plants and animals, promote seed germination and fill gaps in the habitat. In the recent years bryophytes have been widely used for pollution monitoring and bioremediation as well as in the molecular biology studies.

Due to rapid urbanization and pressures inflicted by growth of human population and their intense activities the natural resources especially biodiversity is greatly influenced and bryophytes have been observed to be most affected. The conservation of bryophytes is very important in view of the critical role they play in ecosystem dynamics. The plants are also used as natural antibiotics, fungicides and pesticides for their high concentration of flavonoids and terpenoids.

Not much literature has been published on bryophytes of northeastern Indian Himalayan region barring checklist of Bryophytes published recently by Dandotiya et al. in 2011 though there have been some occasional reports of new species from the region by some authors and Bryophytes of Namdhaba by Chauhan *et al.* (1996) and Dandotiya *et al.* (2011). A list of 51 species of bryophytes reported from Siang basin was prepared from the published data and field surveys and the same is given at Table 6.7. *Marchantia polymorpha* has been commonly found in Siyom valley (Figure 6.5)

Table 6.7: List of Bryophytes reported from Siang basin

S. No.	Family	Name of species
1	Anthocerotaceae	<i>Anthoceros bhardwajii</i>
2	Bartramiaceae	<i>Bartramia halleriana</i>
3	Bartramiaceae	<i>Bartramia leptodonta</i>
4	Bryaceae	<i>Anomobryum filiforme</i> var. <i>conccinatum</i>
5	Bryaceae	<i>Bryum argentum</i> var. <i>lanatum</i>
6	Bryaceae	<i>Bryum cellulare</i>
7	Bryaceae	<i>Rhodobryum giganteum</i>
8	Calymperaceae	<i>Calymperes burmense</i>
9	Calymperaceae	<i>Calymperes hampei</i>
10	Calymperaceae	<i>Mitthyridium piluliferum</i>
11	Calymperaceae	<i>Octoblepharum albidum</i>
12	Calymperaceae	<i>Thyridium piluliferum</i>
13	Dicranaceae	<i>Dicranodontium caespitosum</i>
14	Dicranaceae	<i>Dicranodontium capillifolium</i>
15	Dicranaceae	<i>Leptotrichella assamica</i>
16	Dicranaceae	<i>Microdus assamicus</i>
17	Entodontaceae	<i>Entodon luridus</i>
18	Entodontaceae	<i>Entodon ovicarpus</i>
19	Fissidentaceae	<i>Fissidens leptolema</i>
20	Fissidentaceae	<i>Fissidens subpulchellus</i>
21	Funariaceae	<i>Funaria hygromerica</i> var. <i>calvascens</i>
22	Funariaceae	<i>Physcomitrium pulchellum</i>
23	Funariaceae	<i>Physcomitrium rpendum</i>
24	Hookeriaceae	<i>Daltonia perlaxiretis</i>
25	Lejeuneaceae	<i>Leptolejeunea mirikana</i>
26	Marchantiaceae	<i>Marchantia palmata</i>
27	Marchantiaceae	<i>Marchantia polymorpha</i>
28	Meteoriaceae	<i>Barbela cubensis</i>
29	Meteoriaceae	<i>Meteorium buchananii</i>
30	Mniaceae	<i>Mnium heterophyllum</i>
31	Mniaceae	<i>Mnium laevinerve</i>
32	Mniaceae	<i>Mnium lycopodiodes</i>
33	Mniaceae	<i>Mnium rostratum</i>

S. No.	Family	Name of species
34	Mniaceae	<i>Orthomnium bryoides</i>
35	Mniaceae	<i>Orthoniopsis dilatata</i>
36	Mniaceae	<i>Pohlia cruda</i>
37	Mniaceae	<i>Pohlia elongata</i>
38	Mniaceae	<i>Pohlia flexuosa</i>
39	Monoseleniaceae	<i>Monosolenium tenerum</i>
40	Notothyladaceae	<i>Phaeoceros himalayensis</i>
41	Orthotrichaceae	<i>Macromitrium nepalense</i>
42	Orthotrichaceae	<i>Macromitrium sulcatum</i>
43	Polytrichaceae	<i>Lyellia crispa</i>
44	Porellaceae	<i>Porella campylophylla</i>
45	Pottiaceae	<i>Barbula gregaria</i>
46	Pottiaceae	<i>Hydrogonium arcuatum</i>
47	Pottiaceae	<i>Hyophila involuta</i>
48	Pottiaceae	<i>Semibarbula orientalis</i>
49	Rhabdoweisiaceae	<i>Symblepharis reinwardtii</i>
50	Sematophyllaceae	<i>Sematophyllum humile</i>
51	Thuidiaceae	<i>Thuidium cymbifolium</i>

6.4.1.5 Lichens

Lichens are one of the most common groups of epiphyllous organisms. The lichen flora of Arunachal Pradesh is represented by 477 species (Sinha & Tam, 2011).

Lichens in Siang basin are represented by 41 species (Table 6.8). The species of lichens found in basin are shown in Figure 6.5.

Table 6.8: List of lichens reported from Siang basin

S. No.	Family	Name of species
1	Coccocarpiaceae	<i>Coccocarpia palmicola</i>
2	Cladoniaceae	<i>Cladonia aggregata</i>
3	Cladoniaceae	<i>Cladonia corniculata</i>
4	Cladoniaceae	<i>Cladonia singhii</i>
5	Cladoniaceae	<i>Stereocaulon cf. piluliferum</i>
6	Cladoniaceae	<i>Stereocaulon nesteum</i>
7	Collemataceae	<i>Leptogium denticulatum</i>
8	Collemataceae	<i>Leptogium denticulatum</i>
9	Cryptotheciaceae	<i>Cyptothecia granulata</i>
10	Graphidaceae	<i>Acanthothecis aquilonia</i>
11	Graphidaceae	<i>Acanthothecis</i> spp.
12	Graphidaceae	<i>Phaeographina</i> sp.
13	Letrovitiaceae	<i>Letrovitia</i> sp.
14	Lobariaceae	<i>Menegazzia terebrata</i>
15	Parmeliaceae	<i>Cetraria stracheyi</i> f. <i>ectocarpisma</i>
16	Parmeliaceae	<i>Cetrariastracheyi</i> f. <i>ectocarpisma</i>
17	Parmeliaceae	<i>Parmelia cirrhata</i>

S. No.	Family	Name of species
18	Parmeliaceae	<i>Parmelina orientalis</i>
19	Parmeliaceae	<i>Parmotrema</i> sp.
20	Peltigeraceae	<i>Peltigera dolichorhiza</i>
21	Peltigeraceae	<i>Peltigera dolichorhiza</i>
22	Phyllobatheliaceae	<i>Phyllobathelium indicum</i>
23	Physciaceae	<i>Heterodermia lutescens</i>
24	Physciaceae	<i>Physcia</i> sp.
25	Pilocarpaceae	<i>Byssolma</i> sp.
26	Pyrenulaceae	<i>Anthracothecium</i> sp.
27	Pyrenulaceae	<i>Pyrenula introducta</i>
28	Pyrenulaceae	<i>Pyrenula introducta</i>
30	Rhizocarpaceae	<i>Rhizocarpon</i> sp.
32	Stereocaulaceae	<i>Stereocaulon</i> cf. <i>piluliferum</i>
34	Stictaceae	<i>Loberia retigera</i>
36	Stictaceae	<i>Pseudocyphellaaria aurata</i>
38	Stictaceae	<i>Pseudocyphellaria aurata</i>
39	Stictaceae	<i>Sticta</i> sp.
40	Usneaceae	<i>Bryonia</i> sp.
41	Usneaceae	<i>Usnea spinulosa</i>

6.4.2 Predominant Plant Groups in the Basin

Amongst all flowering plant families Orchidaceae is the most dominant family in the basin being represented by 102 species followed by Poaceae with 91 species, Asteraceae with 64 species, Rubiaceae 44 species, Urticaceae and Fabaceae with 37 species each, Rosaceae with 35 species, Ericaceae with 31 species, Cyperaceae with 30 species, Lamiaceae 28 species, and Fagaceae and Lauraceae with 27 species each and are the other dominant families. The key plant groups like orchids, rhododendrons, bamboos, canes and rattans have been discussed in the following paragraphs.

6.4.2.1 Orchids

According to various researchers Arunachal Pradesh can be termed as an 'orchid paradise' as it harbours more than 40% of orchid species occurring in India. Out of about 1300 species of orchids reported so far from India and 558 species are from Arunachal Pradesh (Rao, 2010). The high concentration of orchids in Arunachal Pradesh is generally attributed to the favourable eco-climatic conditions like high rainfall, high atmospheric relative humidity, and dense forest cover with diverse vegetation at different ecozones ranging from tropical to alpine regions. The orchid flora Arunachal Pradesh is unique in the sense that it harbours more than 40 endemic species.

Based upon available secondary data collected from different sources like published reports, research papers and handbooks, an inventory of orchid species has been prepared. It also includes the information collected during field surveys. A list of orchid species reported from Siang basin is given at **Table 6.9**. According to this 102 species are found in the basin. However according to a list prepared by Rao (2010) there are 234 orchid species are found in central zone of Arunachal Pradesh. This zone also includes Dibang valley in addition to Siang basin which is known as Abor Hills. More than 50% of the species are found in the subtropical region whereas 30% are in tropical

region, 16% in temperate and about 4% are reported from alpine region. Out of 102 species documented in this report, 79 are epiphytes and only 22 are terrestrial orchids while there is only one species which is mycotrophic (living in association with mycorrhiza).

Paphiopedilum fairrieianum is under Endangered Category as per IUCN Redlist while *Cymbidium eburneum* is under Vulnerable category. There are 7 endemic species which are found in Siang basin. These are *Calanthe densiflora*, *Cymbidium eburneum*, *Dendrobium cathcartii*, *D. hookerianum*, *Galeola falconeri*, *Stichorkis plantagenia* (= *Liparis plantaginea*) and *Paphiopedilum fairrieianum*.

In the Siang basin most of the orchid species are reported from main Siang valley, Simang valey, Yamne valley and in the Mouling National Park as well as Yorde Rabe Supse Wildlife sanctuary.

Table 6.9: List of orchid species reported from Siang basin

S. No.	Name of Species	Habit
1	<i>Acampe papillosa</i>	E
2	<i>Acampe rigida</i>	E
3	<i>Acanthophippium sylheinese</i>	T
4	<i>Aerides multiflorum</i>	E
5	<i>Aerides williamsii</i>	E
6	<i>Agrostophyllum brevipes</i>	E
7	<i>Anoectochilus sikkimensis</i>	T
8	<i>Anthogonium gracile</i>	T
9	<i>Arachnis clarkii</i>	E
10	<i>Arundina graminifolia</i>	T
11	<i>Beirmannia bimaculata</i>	E
12	<i>Bulbophyllum affine</i>	E
13	<i>Bulbophyllum apodum</i>	E
14	<i>Bulbophyllum capillipes</i>	E
15	<i>Bulbophyllum delitescens</i>	E
16	<i>Bulbophyllum hirtum</i>	E
17	<i>Bulbophyllum leopardinum</i>	E
18	<i>Bulbophyllum penicillium</i>	E
19	<i>Bulbophyllum sikkimensis</i>	E
20	<i>Calanthe biloba</i>	T
21	<i>Calanthe densiflora</i>	T
22	<i>Calanthe mannii</i>	T
23	<i>Calanthe ovalis</i>	T
24	<i>Calanthe ovata</i>	T
25	<i>Cattleya labiata</i>	E
26	<i>Ceratostylis teres</i>	E
27	<i>Chiloschista lunifera</i>	E
28	<i>Cleisocentrom trichromum</i>	E
29	<i>Cleisostoma filiforme</i>	E
30	<i>Cleisostoma racemiferum</i>	E
31	<i>Coelogyne arunachalensis</i>	E
32	<i>Coelogyne barbata</i>	E

S. No.	Name of Species	Habit
33	<i>Coelogyne flaccida</i>	E
34	<i>Coelogyne flavida</i>	E
35	<i>Coelogyne griffithii</i>	E
36	<i>Coelogyne nitida</i>	E
37	<i>Coelogyne prolifera</i>	E
38	<i>Coelogyne schultesii</i>	E
39	<i>Cryptochilus sanguineus</i>	E
40	<i>Cymbidium aloifolium</i>	E
41	<i>Cymbidium eburneum</i>	E
42	<i>Dendrobium acinaciforme</i>	E
43	<i>Dendrobium amoenum</i>	E
44	<i>Dendrobium aphyllum</i>	E
45	<i>Dendrobium cathcartii</i>	E
46	<i>Dendrobium cumulatum</i>	E
47	<i>Dendrobium densiflorum</i>	E
48	<i>Dendrobium falconeri</i>	E
49	<i>Dendrobium fimbriatum</i>	E
50	<i>Dendrobium hookerianum</i>	E
51	<i>Dendrobium jenkinsii</i>	E
52	<i>Dendrobium longicornu</i>	E
53	<i>Dendrobium nobile</i>	E
54	<i>Dendrobium pendulum</i>	E
55	<i>Dendrobium porphyrochilum</i>	E
56	<i>Dienia muscifera</i>	T
57	<i>Diplomeris hirsuta</i>	E
58	<i>Epigeneium amplum</i>	E
59	<i>Eria acervata</i>	E
60	<i>Eria discolor</i>	E
61	<i>Eria floribunda</i>	E
62	<i>Eria graminifolia</i>	E
63	<i>Eria jenggingensis</i>	E
64	<i>Eria spicata</i>	E
65	<i>Eria stricta</i>	E
66	<i>Galeola falconeri</i>	M
67	<i>Gastrochilus calceolaris</i>	E
68	<i>Gastrochilus dasypogon</i>	E
69	<i>Geodorum pulchellum</i>	E
70	<i>Goodyera procera</i>	T
71	<i>Goodyera recurva</i>	T
72	<i>Liparis cathcartii</i>	T
73	<i>Liparis dongchenii</i>	T
74	<i>Luisia filiformis</i>	E
75	<i>Luisia tenuifolia</i>	E
76	<i>Micropera mannii</i>	E
77	<i>Nervilia gammieana</i>	T
78	<i>Oberonia maxima</i>	E

S. No.	Name of Species	Habit
79	<i>Oreorchis micrantha</i>	T
80	<i>Ornithochilus difformis</i>	E
81	<i>Otochyllus fuscus</i>	E
82	<i>Paphiopedilum fairrieianum</i>	T
83	<i>Papilionanthe teres</i>	E
84	<i>Phaius flavus</i>	T
85	<i>Phaius tankervilleae</i>	T
86	<i>Phalaenopsis deliciosa</i> (= <i>Kingidium deliciosum</i>)	E
87	<i>Phalaenopsis parishii</i>	E
88	<i>Pholidota articulata</i>	E
89	<i>Phreatia elegans</i>	E
90	<i>Platanthera cumminsiana</i>	E
91	<i>Pleione praecox</i>	E
92	<i>Pomatocalpa armigerum</i>	E
93	<i>Pteroceras suaveolens</i>	E
94	<i>Renanthera indica</i>	E
95	<i>Rhynchostylis retusa</i>	E
96	<i>Spiranthes sinensis</i>	T
97	<i>Stichorkis plantagenia</i> (= <i>Liparis plantaginea</i>)	T
98	<i>Thelasis longifolia</i>	E
99	<i>Thelasis pygmaea</i>	E
100	<i>Vanda alpina</i>	E
101	<i>Vanda coerulea</i>	E
102	<i>Zeuxine strateumatica</i>	T

E= Epiphyte; T= Terrestrial; M= Mycotrophic

6.4.2.2 Rhododendrons

Rhododendron is one of the important dominant plant taxa found in the temperate, subalpine and alpine regions of Arunachal Pradesh. Of the total 111 species of *Rhododendron* known from Indian sub-continent, 90 occur in Arunachal Pradesh i.e. about 81% of the Indian *Rhododendron* species are found in Arunachal Himalaya (Mao et al. 2001). Rhododendrons exhibit great diversity in form and habitat and height of species ranges from 2.5 cm alpine plants to 30 m tall trees which are either evergreen, semi-deciduous or deciduous (Hora, 1981). They are known to occupy every possible habitat such as the forest floor, stream sides, marshes, ridges, glades, cliffs, rocks and boulders, open meadows and thickets, scree and mountain tops and even trees, where many species grow as epiphytes in the moss and debris at all levels from trunks to the topmost branches. Majority of *Rhododendron* species are reported from the districts of Kameng and Tawang where 47 species have been recorded (Paul et al. 2010).

In Siang basin total 16 species of *Rhododendron* have been reported (refer Table 6.10). They are found between 1500 and 4000m elevations and majority of the species have been found between 1500 and 3000m elevations in the basin. Two endemic species viz. *Rhododendron dalhousiae* var. *rhabdotum* and *Rhododendron falconeri* ssp. *eximium* are found in the basin. There are 6 species which fall under Red Data List of BSI viz. *Rhododendron arizelum* (Rare), *R. boothii* (Threatened), *R. dalhousiae* var. *rhabdotum* (Rare), *R. edgeworthii* (Rare), *R. falconeri* ssp. *eximium* (Endangered) and *R. kenderickii* (Rare). Recently a new species of rhododendron *Rhododendron*

mechukae has been discovered from Yargyap Chhu catchment in area between Mechuka and Yarlung by Mao et al. (2013) and has been kept under Critically Endangered category by IUCN Redlist. It found in association with *Rhododendron arboreum*, *R. arizelum* and *Taxus wallichiana*.

Table 6.10: List of *Rhododendron* species reported from Siang basin

S. No.	Name of Species	Elevation (m)	Habit
1	<i>Rhododendron arboreum</i>	1500-3200	Tree
2	<i>Rhododendron arizelum</i>	3000-4000	Large shrub or small tree
3	<i>Rhododendron barbatum</i>	2000-4000	Tree
4	<i>Rhododendron boothii</i>	1800-2500	Epiphytic shrub
5	<i>Rhododendron campanulatum</i>	3000-4500	Shrub
6	<i>Rhododendron dalhousieae</i> var. <i>rhabdotum</i>	2500-3500	Epiphytic or terrestrial on trees and ground
7	<i>Rhododendron edgeworthii</i>	2000-3000	Epiphytic shrub
8	<i>Rhododendron falconeri</i>	2000-3500	Large shrub or small tree
9	<i>Rhododendron grande</i>	2000-3000	Large shrub or small tree
10	<i>Rhododendron griffithianum</i>	2000-3000	Tree
11	<i>Rhododendron hodgsonii</i>	2000-3000	Shrub
12	<i>Rhododendron kenderickii</i>	2000-3500	Large shrub or small tree
13	<i>Rhododendron mechukae</i>	2300-3500	Tree
14	<i>Rhododendron ponticum</i>	1500-4500	Shrub
15	<i>Rhododendron vaccinooides</i>	2400-3000	Epiphytic shrub
16	<i>Rhododendron wightii</i>	3300-4100	Shrub or small tree

6.4.2.3 Bamboos and Canes

Bamboo forms a major constituent of the forest vegetation of Arunachal Pradesh. Tropical, subtropical and temperate species are found well distributed in the State. The state has about 46 bamboo species and the bamboo species are found up to an elevation of 2000 m or even more. In Siang basin 15 species of bamboos have been found based upon the available data of which 5 belong to genus *Bambusa*, 5 species belong to *Schizostachyum*, 2 each belong to *Dendrocalamus* and *Thamnochlamus* and one species each of *Phyllostachys* and *Sinarundinaria*.

Canes form important resource of Arunachal Pradesh. Canes (Rattans - climbing palms) belong to genus *Calamus* of family Arecaceae. Out of 20 species of canes found in the state, 14 species have been reported from Siang basin. *Calamus leptospadix* is an endemic species (refer Table 6.11).

Table 6.11: List of bamboo and cane species reported from Siang basin

S. No.	Name of species
BAMBOOS: Family - Poaceae	
1	<i>Bambusa balcooa</i>
2	<i>Bambusa longispiculata</i>
3	<i>Bambusa nutans</i>
4	<i>Bambusa pallida</i>
5	<i>Bambusa tulda</i>
6	<i>Dendrocalamus hamiltonii</i>
7	<i>Dendrocalamus strictus</i>
8	<i>Phyllostachys bambusoides</i>

S. No.	Name of species
9	<i>Schizostachyum arunachalensis</i>
10	<i>Schizostachyum fuchsianum</i>
11	<i>Schizostachyum helferi</i>
12	<i>Schizostachyum pergracile</i>
13	<i>Schizostachyum polymorphum</i>
14	<i>Thamnocalamus aristatus</i>
15	<i>Thamnocalamus spathiflorus</i>
CANES : Family - Arecaceae	
1	<i>Calamus acanthospathus</i>
2	<i>Calamus arunachalensis</i>
3	<i>Calamus erectus</i>
4	<i>Calamus flagellum</i>
5	<i>Calamus floribundus</i>
6	<i>Calamus guruba</i>
7	<i>Calamus inermis</i>
8	<i>Calamus latifolius</i>
9	<i>Calamus leptospadix</i>
10	<i>Calamus tenuis</i>
11	<i>Calamus viminalis</i>
12	<i>Plectocomia assamica</i>
13	<i>Plectocomia himalayana</i>
14	<i>Zalacca secunda</i>

6.4.3 Threatened & Endemic Plant Species

Nayar and Sastry (1987-1990) have reported 35 species of rare and endangered plant species from Arunachal Pradesh. In Siang basin all there are 27 plant species that are either under different threat categories as per IUCN or under Red Data Book categories. The Siang basin as discussed above is also very rich in floristic resources and there are still number of areas in the basin which are either under-explored or yet to be explored like Yomcha area in Yordi Rabe Supse Wildlife Sanctuary, Sike river catchment and upstream catchments of Sigong and Ringong rivers. There is a probability of discovery of new species in some of these areas.

Some of the plant species found in the basin under different conservation status categories are listed in **Table 6.12**. *Begonia burkilli* was found in Hirit valley and *Cephalotaxus griffithii* was recored from Yargyap Chhu valley.

Conservation Assessment and Management Plan (CAMP) workshop was held during March 2003 at Guwahati to assess the threat status of prioritized Medicinal plants of Arunachal Pradesh. During this process 44 medicinal plant species were assigned the Regional Level status of Near Threatened (NT) and above. Of these 44 species 17 are reported from Siang basin. A list of these medicinal plants of concern is given at **Table 6.13**.

Table 6.12: RET plant species reported from Siang basin

S. No.	Family	Plant Species	Distribution (m)	Habit	Conservation Status	
					BSI Red Data Book	IUCN Redlist
1	Aceraceae	<i>Acer oblongum</i> var. <i>microcarpum</i>	700-1000	Tree	EN	VU
2	Actinidiaceae	<i>Actinidia callosa</i>	1300-2500	Climber	R	-
3	Actinidiaceae	<i>Saurauia punduana</i>	1000-1800	Tree	-	CR
4	Arecaceae	<i>Calamus inermis</i>	200-1200	Shrub	EN	-
5	Arecaceae	<i>Livistona jenkinsiana</i>	110-600	Shrub	-	NA
6	Begoniaceae	<i>Begonia aborensis</i>	600-760	Herb	R	NA
7	Begoniaceae	<i>Begonia burkillii</i> *	600-760	Herb	R	NA
8	Begoniaceae	<i>Begonia scintillans</i>	250-1200	Herb	I	NA
9	Cephalotaxaceae	<i>Cephalotaxus griffithii</i> **	1800-2000	Tree	-	NT
10	Ericaceae	<i>Rhododendron arizelum</i>	3000-4000	Large shrub or small tree	R	NA
11	Ericaceae	<i>Rhododendron boothii</i>	1800-2500	Epiphytic shrub	T	NA
12	Ericaceae	<i>Rhododendron dalhousieae</i> var. <i>rhabdotum</i>	2500-3500	Epiphytic/terrestrial	R	NA
13	Ericaceae	<i>Rhododendron edgeworthii</i>	2000-3000	Epiphytic shrub	R	NA
14	Ericaceae	<i>Rhododendron falconeri</i> ssp. <i>eximium</i>	2000-3500	Large shrub or small tree	EN	NA
15	Ericaceae	<i>Rhododendron kenderickii</i>	2000-3500	Large shrub or small tree	R	NA
16	Ericaceae	<i>Rhododendron mechucae</i> **!	2300-3500	Tree	R	NA
17	Magnoliaceae	<i>Magnolia gustavii</i>	1800-2500	Tree	-	NA
18	Malvaceae	<i>Pterospermum reticulatum</i>	200-1000	Tree	-	NA
19	Orchidaceae	<i>Paphiopedilum fairrieanum</i>	1400-2000	Herb	EN	NA
20	Orchidaceae	<i>Cymbidium eburneum</i>	1000-1500	Herb	VU	NA
21	Orchidaceae	<i>Diplomeris hirsuta</i>	1000-1800	Herb	VU	NA
22	Orchidaceae	<i>Galeola falconeri</i>	400-1500	Herb	Indeterminate	-
23	Rubiaceae	<i>Psychotria aborensis</i>	300-1200	Shrub	EN	VU
24	Scrophulariaceae	<i>Picrorhiza kurroa</i>	2000-3000	Herb	VU	-
25	Solanaceae	<i>Paauia belladonna</i>	-	Herb	R	-
26	Theaceae	<i>Camellia siangensis</i>	1100-1800	Tree	R	NA
27	Xanthophyllaceae	<i>Xanthophyllum burkillii</i>	800-1400	Tree	R	-

*Found in Hirit valley; ** Found in Yargyap Chhu valley; !=New species

EN= Endangered; T=Threatened; R=Rare; VU=Vulnerable; I=Indeterminate; NA=Not Assessed

Table 6.13: Medicinal plant species of conservation reported from Siang basin

S. No.	Family	Name of species	Conservation Status
1	Apocynaceae	<i>Rauwolfia serpentina</i>	CR
2	Bignoniaceae	<i>Oroxylum indicum</i>	VU
3	Cephalotaxaceae	<i>Cephalotaxus griffithii</i>	EN
4	Clusiaceae	<i>Garcinia pedunculata</i>	NT
5	Lauraceae	<i>Cinnamomum tamala</i>	VU
6	Orchidaceae	<i>Dendrobium nobile</i>	VU
7	Pinaceae	<i>Abies densa</i>	NT
8	Piperaceae	<i>Piper pedicellatum</i>	VU
9	Piperaceae	<i>Piper peepuloides</i>	VU
10	Primulaceae	<i>Embelia ribes</i>	NT
11	Saxifragaceae	<i>Bergenia ciliata</i>	VU
12	Schisandraceae	<i>Illicium griffithii</i>	NT
13	Scrophulariaceae	<i>Picrorhiza kurroa</i>	EN
14	Smilacaceae	<i>Smilax glabra</i>	CR
15	Taxaceae	<i>Taxus wallichiana</i>	EN

Source: CAMP Workshop. (2013). FRLHT, Bangalore

CR=Critically Endangered; EN= Endangered; T=Threatened; VU=Vulnerable; NT= Near Threatened

6.4.3.1 Endemic Plant Species

Endemism is one of the important criteria for making an assessment of biodiversity uniqueness of biodiversity existing in a particular area. The endemic species are entirely dependent on a single area for their survival, and by virtue of their more restricted ranges, are often the most vulnerable (Myers, 1988). According to Heywood and Watson (1995) these species, confined to highly threatened ecosystems, will almost certainly be the first to be hit by extinction processes, and hence need rapid and effective conservation action. These two main criteria, the plant endemism and degree of threat, determine the demarcation of hotspots i.e. areas which need immediate attention and conservation. Earth's 25 biodiversity hotspot regions collectively cover about 2% of the planet's land surface, yet claim more than 50% of all terrestrial species diversity. They have within them a phenomenal 125635 plant species. The top 11 hotspots (out of 25) for plant endemism harbor 5000 or more species as endemics. It accounts for 93214 plant species, or 37.3% of the total global plant endemics (Myers, 1988).

Endemic taxa are essentially restricted to a specified geographical area. In terms of spatial distribution, endemics may occupy limited geographical ranges - i.e., have a limited 'extent of occurrence' - and also have a limited 'area of occupation' within their geographical range (Gaston, 1991). Endemism may be expressed as a percentage of all extant taxa present (excluding exotics), or as the absolute number of endemics in the area. Proportionate levels of endemism increase with increasing geographical area (Major, 1988). Levels of endemism may vary in a predictable way along gradients of primary environmental variables such as rainfall, temperature and productivity. Theoretically, models that accurately predict levels of endemism on the basis of easily measurable environmental variables should be useful for the rapid identification of endemics-rich areas (Hill and Keddy 1992). Mountains are often rich in endemics, in both tropical and temperate countries (Matthews et. al., 1993).

Phytogeographically, the eastern Himalaya forms a distinct floristic region. The area comprises Nepal, Bhutan, and neighboring states of northern India along a continuous sector of the Yunnan province in south-west China. In the neighbouring state of Sikkim (geographical area 7298 km²), of

the 4250 plant species, 2550 (60%) are endemic (Myers 1988). In Nepal, there are around 7000 plant species, many of which overlap those of India, Bhutan, and even Yunnan. Of these species, at least 500 (almost 8%) are believed to be endemic to Nepal. Bhutan possesses an estimated 5000 species, of which as many as 750 (15%) are considered to be endemic to the eastern Himalaya (Anon, 1992). This region is the meeting ground of the Indo-Malayan, Afro-tropic and Indo-Chinese biogeographical realms as well as the Himalayan and Peninsular Indian elements, formed when the peninsular plate struck against the Asian landmass, after it broke off from Gondwana land. The region is recognized as refugium of flowering plants and center of active speciation (Rao 1994). The numerous primitive angiosperm families found in this region include Magnoliaceae, Degeneriaceae, Himantandraceae, Eupomatiaceae, Winteraceae, Trochodendraceae, Tetracentraceae, and Lardizabalaceae. The primitive genera are *Alnus*, *Aspidocarya*, *Betula*, *Decaisnea*, *Euptelea*, *Exbucklandia*, *Haematocarpus*, *Holboellia*, *Houttuynia*, *Magnolia*, *Mangelietia*, *Pycnarrhena*, and *Tetracentron* (Malhotra and Hajra, 1977). Studies have shown that northeastern India along with the contiguous region of the Chinese provinces of Yunnan and Szechwan is an active center of organic evolution and is the cradle of flowering plants (Takhtajan, 1969).

Endemic plant species in India has been estimated at 33% with *ca.* 140 endemic genera but no endemic families (Anon. 1983). Hooker (1904) attributed the floristic diversity of the Indian subcontinent to the immigration of plants from different bordering countries, notably Chinese and Malayan on the east and south, of Oriental, European and African on the west and of Tibetan and Siberian on the north. Out of 150 important botanical sites identified for conservation action by the World Conservation Monitoring Center (WCMC), five locations are in India, of which the eastern Himalaya is one (IUCN, 1987). The humid conditions have resulted in speciation in several genera, thus adding to the high endemism of the flora (Chatterjee, 1939).

The Siang basin falls in the eastern Himalayan biogeographic zone and owes its high floral and faunal diversity to its strategic location - at the junction of three biogeographic realms viz. the palaearctic, the Indo-Malayan and the Indo-Chinese. According to the biogeographic classification, the area resides in the Himalaya-east-Himalaya biogeographic region (Rodgers and Panwar, 1988).

Forty six plant species that are endemic to Arunachal Pradesh have been recorded from various regions in the Siang basin (Table 6.14). These belong to 24 families and 38 genera. These species predominantly attributed to six plant families (i.e., Orchidaceae - 8 species; Rubiaceae - 5 species, Magnoliaceae 4 species; and Arecaceae, Balsaminaceae and Begoniaceae represented by 3 species each). Majority of endemic species are found in Tropical semi-evergreen forest followed by subtropical evergreen forest, temperate broad-leaved evergreen forest, abandoned *jhum* land, degraded forest, temperate/sub-alpine coniferous and sub-tropical pine forest. Only one endemic species recorded in alpine/sub-alpine region i.e. *Rhododendron dalhousiae* var. *rhabdotum*.

In addition there are 55 species which are endemic to Northeast India are reported from Siang basin (refer Table 6.15). Most of these species are reported from main Siang valley and Yamne catchment.

Table 6.14: Plant species endemic to Arunachal Pradesh reported from Siang basin

S. No.	Family	Name of Species	Distribution (m)
1	Aceraceae	<i>Acer oblongum</i> var. <i>microcarpum</i>	1000-1500
2	Arecaceae	<i>Calamus leptospadix</i>	1000-1500
3	Arecaceae	<i>Zalacca secunda</i>	600-1000
4	Arecaceae	<i>Livistona jenkinsiana</i>	500-1800
5	Asparagaceae	<i>Peliosanthes teta</i> ssp. <i>humilis</i>	400-1000
6	Asteraceae	<i>Prenanthes scandens</i>	600
7	Balsaminaceae	<i>Impatiens laevigata</i>	400-1000
8	Balsaminaceae	<i>Impatiens racemosa</i>	500-1000
9	Balsaminaceae	<i>Impatiens racemulosa</i>	500-1001
10	Begoniaceae	<i>Begonia aborensis</i>	400-1000
11	Begoniaceae	<i>Begonia burkilli</i>	300-1000
12	Begoniaceae	<i>Begonia scintillans</i>	1200-2000
13	Celastraceae	<i>Euonymus glaber</i>	100-400
14	Clusiaceae	<i>Garcinia acuminata</i>	400-800
15	Dipterocarpaceae	<i>Hopea shinkeng</i>	400-1000
16	Ericaceae	<i>Rhododendron dalhousiae</i> var. <i>rhabdotum</i>	2500-3500
17	Ericaceae	<i>Rhododendron falconeri</i> ssp. <i>eximium</i>	2000-3500
18	Gesneriaceae	<i>Aeschynanthus parasiticus</i>	1000-1400
19	Lauraceae	<i>Litsea mishmiensis</i>	600-1200
20	Magnoliaceae	<i>Magnolia gustavii</i>	300-800
21	Magnoliaceae	<i>Magnolia rabaniana</i>	600-2400
22	Magnoliaceae	<i>Michelia doltsopa</i>	300-1000
23	Magnoliaceae	<i>Michelia oblonga</i>	500-1400
24	Meliaceae	<i>Aglaia edulis</i>	200-1600
25	Musaceae	<i>Musa velutina</i>	500-1000
26	Myrtaceae	<i>Syzygium aborense</i>	400-800
27	Orchidaceae	<i>Calanthe densiflora</i>	1800-2500
28	Orchidaceae	<i>Cymbidium eburneum</i>	1000-1500
29	Orchidaceae	<i>Dendrobium cathcartii</i>	150-800
30	Orchidaceae	<i>Dendrobium hookerianum</i>	1800-2000
31	Orchidaceae	<i>Eria ferruginea</i>	600-800
32	Orchidaceae	<i>Galeola falconeri</i>	200-800
33	Orchidaceae	<i>Liparis plantaginea</i>	1800-2400
34	Orchidaceae	<i>Paphiopedilum fairrieianum</i>	1000-2300
35	Poaceae	<i>Schizostachyum arunachalensis</i>	300-1000
36	Primulaceae	<i>Ardisia pedunculosa</i>	800-1400
37	Rubiaceae	<i>Lasianthus biermanii</i>	1500-2400
38	Rubiaceae	<i>Luculia pinceana</i>	1000-1400
39	Rubiaceae	<i>Ophiorrhiza calcarata</i>	600-1200
40	Rubiaceae	<i>Psychotria aborensis</i>	300-1200
41	Rubiaceae	<i>Rubus burkillii</i>	800-1400
42	Solanaceae	<i>Pauia belladonna</i>	1000-2000
43	Theaceae	<i>Camellia siangensis</i>	1100-1800
44	Theaceae	<i>Pyrenaria barringtoniifolia</i>	100-600
45	Xanthophyllaceae	<i>Xanthophyllum burkillii</i>	300-1000
46	Zingiberaceae	<i>Globba multiflora</i>	300-900

Table 6.15: Plant species endemic to Northeast India reported from Siang basin

S. No.	Family	Name of species
1	Araceae	<i>Arisaema album</i>
2	Araceae	<i>Arisaema setosum</i>
3	Araliaceae	<i>Brassaiopsis hispida</i>
4	Araliaceae	<i>Brassaiopsis simplicifolia</i>
5	Asparagaceae	<i>Peliosanthes macrophylla</i>
6	Asteraceae	<i>Cirsium interpositum</i>
7	Begoniaceae	<i>Begonia sikkimensis</i>
8	Begoniaceae	<i>Begonia tessaricarpa</i>
9	Begoniaceae	<i>Begonia thomsonii</i>
10	Caprifoliaceae	<i>Viburnum corylifolium</i>
11	Celastraceae	<i>Euonymus lawsonii</i>
12	Crassulaceae	<i>Sedum triactina</i>
13	Cucurbitaceae	<i>Indofevillea khasiana</i>
14	Ericaceae	<i>Vaccinium venosum</i>
15	Fabaceae	<i>Indigofera sesquipedalis</i>
16	Gesneriaceae	<i>Chirita hookerii</i>
17	Gesneriaceae	<i>Chirita macrophylla</i>
18	Gesneriaceae	<i>Rhynchotechum alternifolium</i>
19	Lamiaceae	<i>Plectranthus griffithii</i>
20	Lamiaceae	<i>Pogostemon amarantoides</i>
21	Lauraceae	<i>Beilschmiedia brandisii</i>
22	Lauraceae	<i>Beilschmiedia pseudomicropora</i>
23	Lauraceae	<i>Persea minutiflora</i>
24	Lauraceae	<i>Phoebe goalparensis</i>
25	Loranthaceae	<i>Elytranthe psilantha</i>
26	Melastomataceae	<i>Sonerila khasiana</i>
27	Musaceae	<i>Musa sikkimensis</i>
28	Oleaceae	<i>Jasminum caudatum</i>
29	Orchidaceae	<i>Anoectochilus sikkimensis</i>
30	Orchidaceae	<i>Coelogyne arunachalensis</i>
31	Orchidaceae	<i>Eria jenggingensis</i>
32	Orchidaceae	<i>Goodyera recurva</i>
33	Orchidaceae	<i>Platanthera cumminsiana</i>
34	Poaceae	<i>Arthraxon quarlinianus</i> var. <i>glabrescens</i>
35	Poaceae	<i>Arundinella khaseana</i>
36	Poaceae	<i>Baliospermum calycinum</i>
37	Poaceae	<i>Bambusa barpatharica</i>
38	Poaceae	<i>Bambusa rangaensis</i>
39	Poaceae	<i>Schizostachyum helferi</i>
40	Poaceae	<i>Schizostachyum pergracile</i>
41	Poaceae	<i>Schizostachyum polymorphum</i>
42	Poaceae	<i>Schizostachyum seshagiriana</i>
43	Primulaceae	<i>Ardisia pedunculosa</i>
44	Rhamnaceae	<i>Ziziphus rugosa</i> var. <i>glabrescens</i>

S. No.	Family	Name of species
45	Rubiaceae	<i>Ixora subsessilis</i>
46	Rubiaceae	<i>Neonauclea gageana</i>
47	Rubiaceae	<i>Ophiorrhiza succirubra</i>
48	Rubiaceae	<i>Ophiorrhiza repens</i>
49	Rubiaceae	<i>Psychotria silhetensis</i> var. <i>tomentosa</i>
50	Rubiaceae	<i>Randia griffithii</i>
51	Rubiaceae	<i>Rubus lucens</i>
52	Smilacaceae	<i>Smilax minutiflora</i>
53	Urticaceae	<i>Elatostema sikkimense</i>
54	Vitaceae	<i>Tetrastigma planicaule</i>
55	Vitaceae	<i>Vitis planicaulis</i>

Source : Choudhary (2008)

6.4.4 Community Structure

In order to understand the community structure, vegetation sampling was done at 47 locations in the Siang basin and 2 locations outside the basin to cover different seasons from January-September 2012 covering forested areas around proposed locations of proposed hydropower project especially structures like dam/barrage site, submergence area, power house site in Siang basin (see **Plates 6.6-6.8**). Detailed list of plant species (sub-basin-wise) encountered during field surveys is given at **Annexure-II** in **Volume-II:DATA**.

6.4.4.1 Density & Dominance

Season-wise details regarding the density, frequency, basal cover and Importance Value Index (IVI) at each sampling site covered under terrestrial ecology are given in **Annexures-IIIa, IIIb & IIIc** in **Volume-II:DATA**.

The data on density and dominance of various plant species recorded at each sampling site was analysed and the results of the same are discussed below sub-basin-wise.

a) Density

i) Siang Sub-basins : I-IV

Siang Sub basin is comprised of 4 sub-basins i.e. I- IV and in these sampling was undertaken at 13 different locations and details of the same have already been given in Chapter 4 - Methodology. The highest density of trees i.e. 433 trees/ha in the Siang sub basin was recorded from the area between Mirak and Tuting. Highest density was observed for *Castanopsis indica*, *Grewia polygama*, *Ailanthus integrifolia*, *Saurauia punduana* and *Alnus nepalensis*. Lowest density of trees was observed in the stretch covering area between Bodak and Ranaghat where average tree density was 247 trees/ha.

In case of shrubs maximum density was observed during monsoon season. Highest density was recorded from area located in between Tuting and Jidu villages, where 5853 individuals/ha was recorded. During winter season area between Bodak and Ranaghat shows maximum shrub density of 4773 individual/ha. Shrub species with highest density in the area are *Pentapanax leschenaultiana*, *Pteracanthus rubescens*, *Alsophila spinulosa*, *Elatostema sesquifolium*, *Melocalamus compactiflorus*, *Boehmeria glomerulifera*, *Piper pedicellatum* and *Chromolaena odoratum*.

Regarding the herbaceous species maximum density was observed during summer season. The density was highest at sampling sites located between Bodak and Ranaghat (4,07,333 ind./ha). During monsoon season the density was comparatively low than summer season. The species which recorded highest density are *Athyrium angustum*, *Athyrium drepanopterum*, *Persicaria barbata*, *Bidens pilosa*, *Oplismenus compositus*, *Ageratum conyzoides*, *Nephrolepis bauriculata*, *Saccharum spontaneum*, *Pteris subindivisa*, *Miscanthus nepalensis*, *Pilea umbrosa* and *Urtica dioica*.

ii) Yamne Sub-basin

In Yamne sub-basin maximum tree density was observed between Jerring and Padu with 380 trees/ha. *Castanopsis indica*, *Lannea coromandelica*, *Ostodes paniculata*, *Albizia procera*, *Duabanga grandiflora*, *Macaranga denticulata* and *Pandanus nepalensis* are the dominant tree species in the area with the high density.

Density of shrub species was observed highest at sampling sites located between Siyat and Lagru with 3920 individuals/ha to 4062 individuals/ha. The shrubs with highest density are *Ardisia thyrsoflora*, *Chromolaena odoratum*, *Boehmeria macrophylla*, *Chromolaena odoratum*, *Bambusa tulda*, *Ascophyllum spinulosa* and *Oxyspora paniculata*.

Herbaceous flora density in the area was recorded highest in between Siyat and Padu area ranging from 3,65,000 individuals/ha to 3,67,000 individuals/ha. *Athyrium angustum*, *Urtica parviflora*, *Pogonatherum paniceum*, *Pteris subindivisa*, *Pilea umbrosa*, *Pilea scripta*, *Pteris vittata*, *Miscanthus nepalensis* and *Saccharum narenga* are most dominant species with high density.

iii) Simang Sub-basin

In Simang sub basin highest tree and shrub density was observed from the area adjacent to Supple village i.e. trees 510 individuals/ha and shrubs 3560 individuals/ha. However maximum shrub density (4320 individual/ha) was observed during winter near Simang-I HEP dam site area sampling Site.

Altingia excelsa, *Ficus semicordata*, *Terminalia myriocarpa*, *Duabanga grandiflora*, *Syzygium assamicum*, *Artocarpus heterophyllus*, *Macaranga denticulata*, *Ailanthus integrifolia* and *Cinnamomum glaucescens* are the most dominant trees in the area with high density in the area.

Amongst shrub species *Alsophila spinulosa*, *Boehmeria macrophylla*, *Pteracanthus rubescens*, *Solanum erianthum*, *Cinnamomum tamala*, *Cinnamomum pauciflorum*, *Oxyspora paniculata*, *Piper pedicellatum*, *Debregeasia longifolia*, *Leea asiatica* and *Eupatorium odoratum* are most dominant in the sub-basin.

Maximum density of herbs was recorded during summer season especially area between Lileng and Boleng with density of 3,98,000 individuals/ha. *Imperata cylindrica*, *Mikania micrantha*, *Fragaria nubicola*, *Athyrium angustum*, *Nephrolepis cordifolia*, *Pteridium acquilenium*, *Imperata cylindrica*, *Ageratum conyzoides*, *Persicaria capitata*, *Oxalis corniculata* are the most dominant herb in the sub-basin.

iv) Hirit Sub-basin

In Hirit sub basin tree density was highest in area between Kamba and Poma Basti, where it was 270 individuals/ha. *Engelhardtia spicata*, *Ostodes paniculata*, *Podocarpus neriifolia*, *Pongamia pinnata*, *Terminalia myriocarpa*, *Bauhinia variegata* are the dominant tree species in the sub-basin with the high density values.

Shrub density in the sub-basin was highest at sampling sites located adjacent to the confluence of Hirit and Siyom river i.e. near Poma basti with 3634 individuals/ha. The dominant species are *Melocalamus compactiflorus*, *Bambusa tulda*, *Calamus tenuis*, *Calamus floribundus*, *Oxyspora paniculata*, *Boehmeria glomerulifera*, *Pinanga gracilis*, and *Chromolaena odoratum*.

Amongst herb species maximum density was observed during summer season. It was highest at sampling sites located near confluence of Siyom with Hirit river (3,49,003 individuals/ha). The species with highest density are *Saccharum narenga*, *Bidens bipinnata*, *Bidens pilosa*, *Oplismenus compositus*, *Ageratum conyzoides*, *Digitaria ciliaris*, *Pteris subindivisa* and *Elatostema glabra*.

v) Siyom Sub-basins : I-III

In Siyom sub basin high density of trees was recorded from the area located between Hiron and Jarong as it was 410 individuals/ha. The density was hishest of species like *Ailanthus grandis*, *Alnus nepalensis*, *Albizia odoratissima* *Ficus semicordata*, *Terminalia myriocarpa* and *Macaranga denticulata*.

The highest density of shrub species was recorded from Hiron and Jarong area with 3880 individuals/ha and also in area between Tato and Tagurshit with 3847 individuals/ha. The shrub species with highest density are *Bambusa tulda*, *Psychotria aborensis*, *Aconogonum molle*, *Elatostema sessile*, *Boehmeria macrophylla*, *Oxyspora paniculata*, *Melocalamus compactiflorus*, *Piper peepuloides*, *Musa acuminata* and *Alsophila spinulosa*.

The highest herbaceous flora density was observed near Hiron in the upstream of Siyom -Yargyap Chhu confluence to Karo village (3,05,000 individuals/ha). The dominating herb species are: *Bidens bipinnata*, *Ageratum conyzoides*, *Capillipedium assimile*, *Cyrtococcum accrescens* and *Miscanthus nepalensis*.

vi) Yargyap Chhu

In Yargyap Chhu sub basin, area between Rapum and Pauk have highest tree density with 400 individuals/ha *Engelhardtia spicata*, *Macaranga denticulata*, *Alnus nepalensis*, *Saurauia punduana*, *Illicium griffithii*, *Castanopsis indica*, *Pinus wallichiana* and *Albizia odoratissima*.

Highest density of shrubs was observed from the Yalong and Rego regions of the sub-basin, with 6670 individuals/ha and 4020 individuals/ha, respectively. The species with highest density in the sub basin are *Aconogonum molle*, *Melocalamus compactiflorus*, *Strobilanthes extensa*, *Elatostema lineolatus*, *E. sessile*, *Rubus ellipticus*, *R. burkillii*, *Rhododendron borthii*, *R. ponticum*, *Boehmeria macrophylla*, *Berberis asiatica*, *Lonicera obovata*, *Leucosceptrum canum* and *Thamnocalamus aristatus*.

The density of herbs was highest in area between Rapum and Rego with 2,61,900 individuals/ha. *Molineria capitulata*, *Imperata cylindrica*, *Artemisia nilagirica*, *Rubia cordifolia* *Musa balbisiana*, *Oplismenus compositus*, *Saccharum longisetosum*, *Rubia cordifolia*, *Bambusa pallida*, *Amomum subulatum*, *Carex cruciata*, *C. longipes*, *C. filicina*, *Capillipedium assimile*, and *Anaphalis busua* are the most dominant herb species in the sub-basin.

An overall assessment of the three season data for the entire Siang basin has been tabulated in Table 6.16.

Table 6.16: Average density of plant species (no. of individuals/ha) in Siang basin

Sub Basin	Trees	Shrubs (maximum from all three season)	Herbs (maximum from three season)
Siang-I	247	4773	407333
Siang-II	275	4747	364667
Siang-III	433	4965	297000
Siang-IV	327	5853	288833
Yamne	360	3635	335500
Simang	338	3483	295000
Siyom-I	335	3390	238031
Siyom-II	307	3847	216022
Siyom-III	410	3880	305000
Hirit	267	3397	222071
Yargyap Chu	310	3599	216324

b) Dominance (Importance Value Index)

In order to understand the relative dominance of various species among trees and shrubs, Importance Value Index (IVI) for each species was calculated. The results of the same showing IVI values of most dominant species have been given in Figures 6.5-6.11. However the details of all the species are given in Data Volume. Analysis of the same is given in following paragraphs.

i) Siang sub-basins I-IV

Among the trees *Duabanga grandiflora*, *Canarium strictum*, *Ailanthus integrifolia*, *Ficus semicordata*, *Kydia calycina* and *Ficus semicordata* were the most dominant tree species (Figure 6.5).

Amongst shrubs *Boehmeria glomerulifera*, *Actinidia callosa*, *Chromolaena odoratum* and *Boehmeria rugulosa* are the most dominant species with highest IVI values in all sub-basins. *Aconogonum molle*, *Caryopteris odorata*, *Maesa chisia* and *Elatostema sesquifolium* are other dominant shrub species these sub-basins (Figure 6.6).

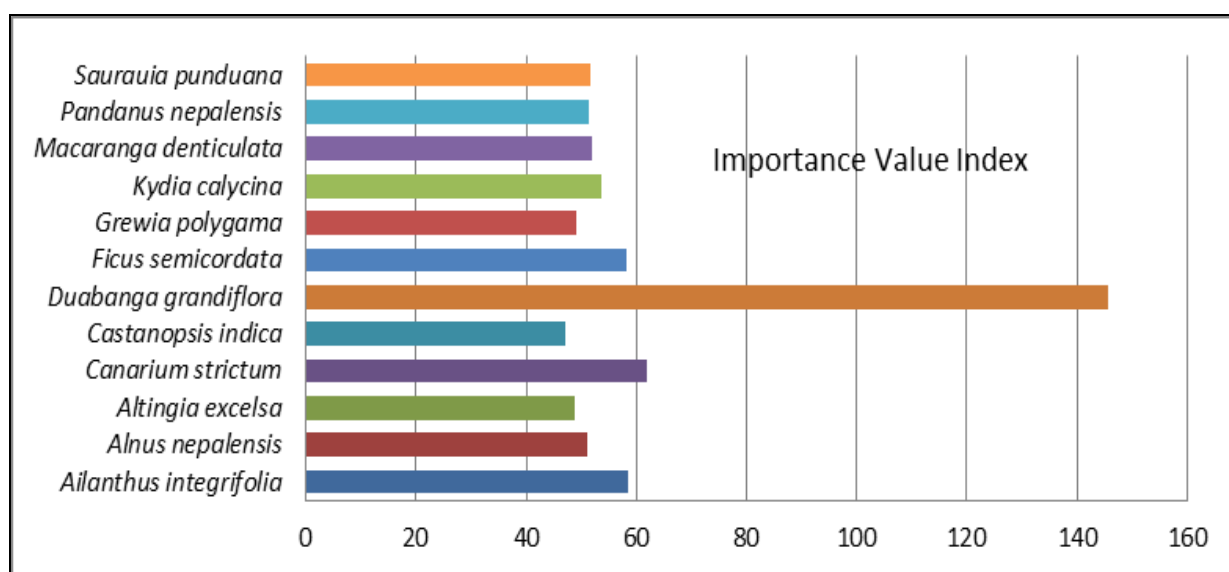


Figure 6.5: Importance Value Index of dominant tree species found in Siang sub-basins

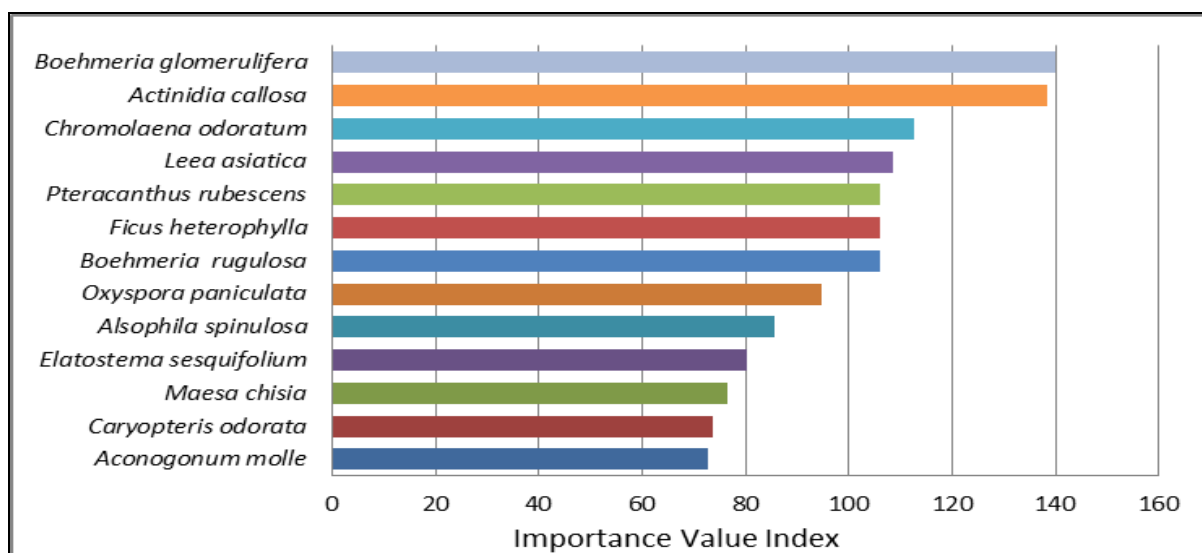


Figure 6.6: Importance Value Index of dominant shrub species found in Siang sub-basins

ii) Yamne Sub-basin

Ficus auriculata, *Duabanga grandiflora*, *Castanopsis indica* and *Ostodes paniculata* are the most dominant tree species in this sub-basin with highest IVI values followed by *Albizia procera* and *Lannea coromandelica* (Figure 6.7). The dominant shrub species are *Boehmeria macrophylla*, *Bambusa tulda*, *Alsophila spinulosa* and *Chromolaena odoratum* with highest IVI value in the sub basin (Figure 6.8).

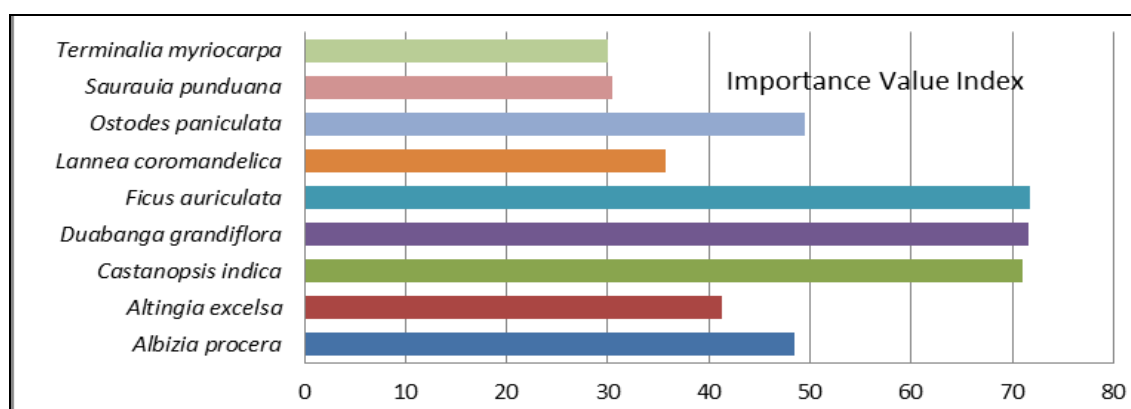


Figure 6.7: Importance Value Index of dominant tree species found in Yamne sub-basin

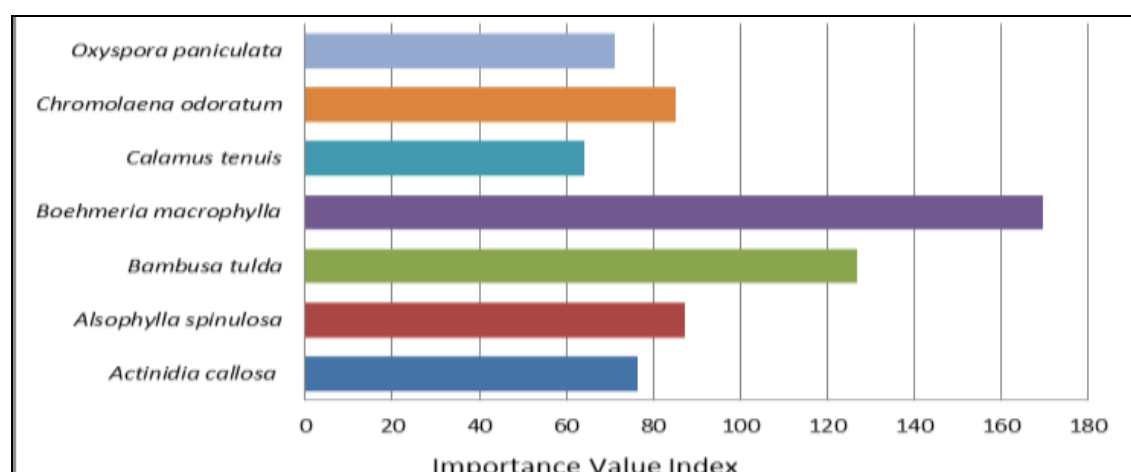


Figure 6.8: Importance Value Index of dominant shrub species found in Yamne sub-basin

iii) Simang Sub-basin

The tree species dominant in Simang sub-basin are *Duabanga grandiflora*, *Ficus semicordata* and *Terminalia myriocarpa* (Figure 6.9) while amongst the shrubs layer *Pteracanthus rubescens*, *Alsophila spinulosa*, *Cinnamomum obtusifolium* and *Gonostegia hirta* are dominant in the sub-basin (Figure 6.10). *Altingia excelsa*, *Eupatorium odoratum* and *Oxyspora paniculata* are the other dominant species.

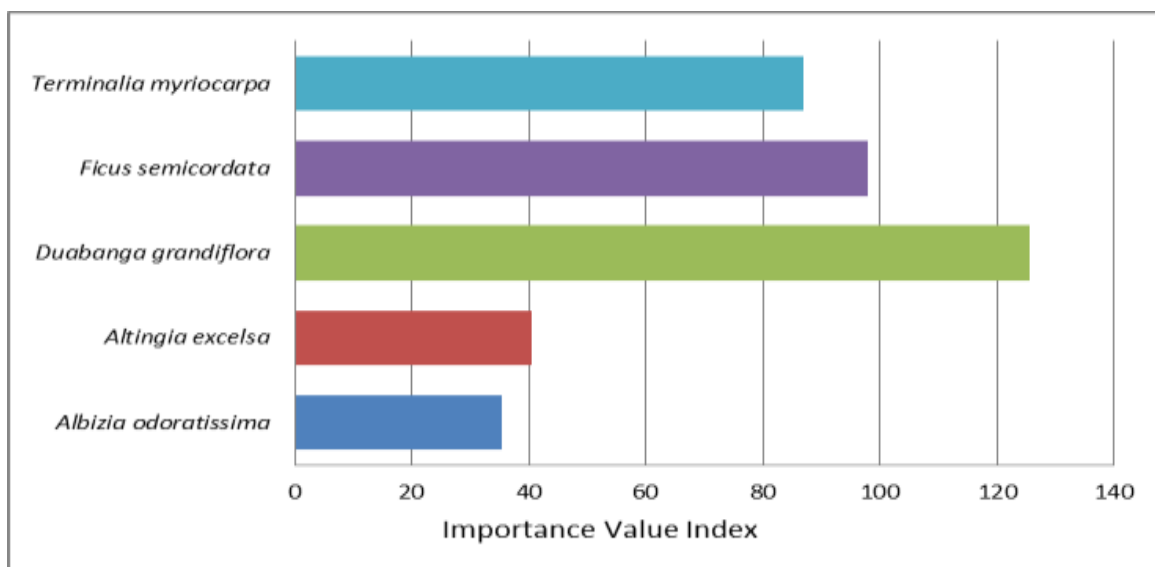


Figure 6.9: Importance Value Index of dominant tree species found in Simang sub-basin

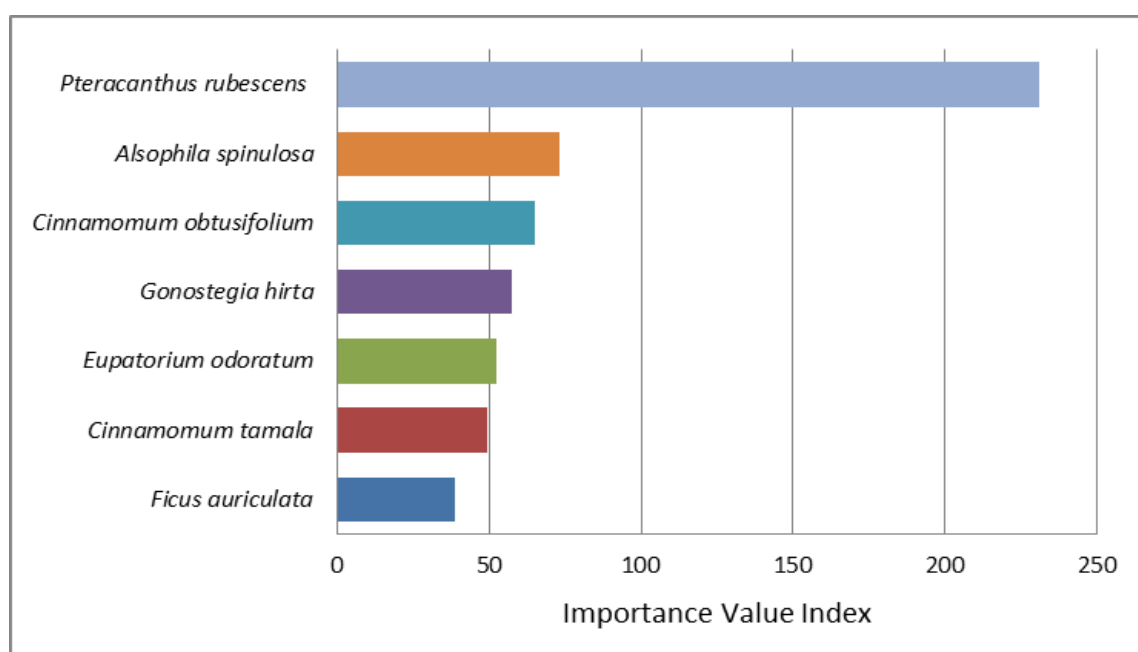


Figure 6.10: Importance Value Index of dominant shrub species found in Simang sub-basin

iv) Hirit Sub-basin

In Hirit sub basin, *Engelhardtia spicata*, *Duabanga grandiflora* and *Terminalia myriocarpa* are the dominant tree species (Figure 6.11). *Boehmeria glomerulifera* and *Calamus tenuis* are the dominant shrub species. *Bambusa tulda*, *Oxyspora paniculata* and *Boehmeria macrophylla* are the other dominant shrubs in the sub-basin (Figure 6.12).

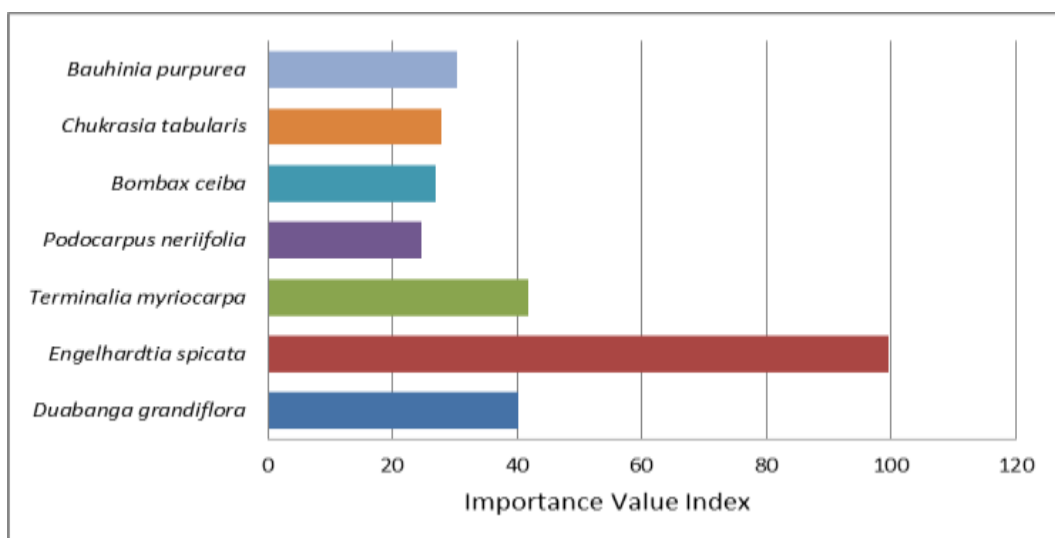


Figure 6.11: Importance Value Index of dominant tree species found in Hirit sub-basin

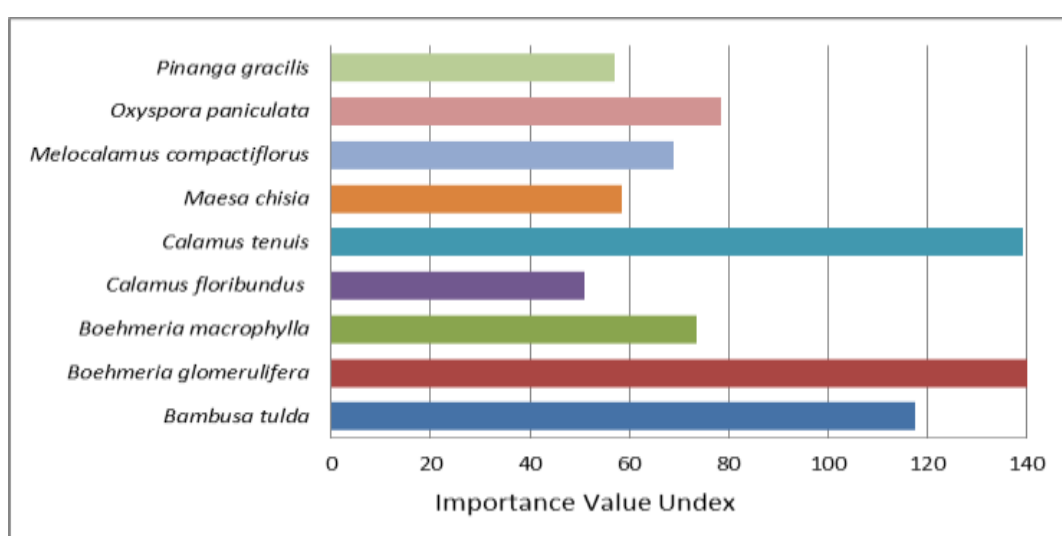


Figure 6.12: Importance Value Index of dominant shrub species found in Hirit sub-basin

v) Siyom Sub-basins I-III

Ficus semicordata is the most dominant tree species in the Siyom sub-basins while *Albizia odoratissima*, *Terminalia myriocarpa*, *Ailanthus grandis*, *Brassaiopsis griffithii*, *Saussurea nepalensis*, *Aralia armata* and *Macropanax dispermus* are the other dominant species (Figure 6.13).

The dominant shrub species are *Bambusa tulda*, *Musa acuminata* and *Rosa brunonii*, followed by *Melocalamus compactiflorus*, *Boehmeria glomerulifera*, *B. macrophylla* and *Elatostema sessile* (Figure 6.14). *Dendrocalamus strictus*, *Elatostema sesquifolium*, *Oxyspora paniculata*, *Debregeasia longifolia*, *Alsophila spinulosa* and *Piper peepuloides* are the other dominant species in these sub-basins.

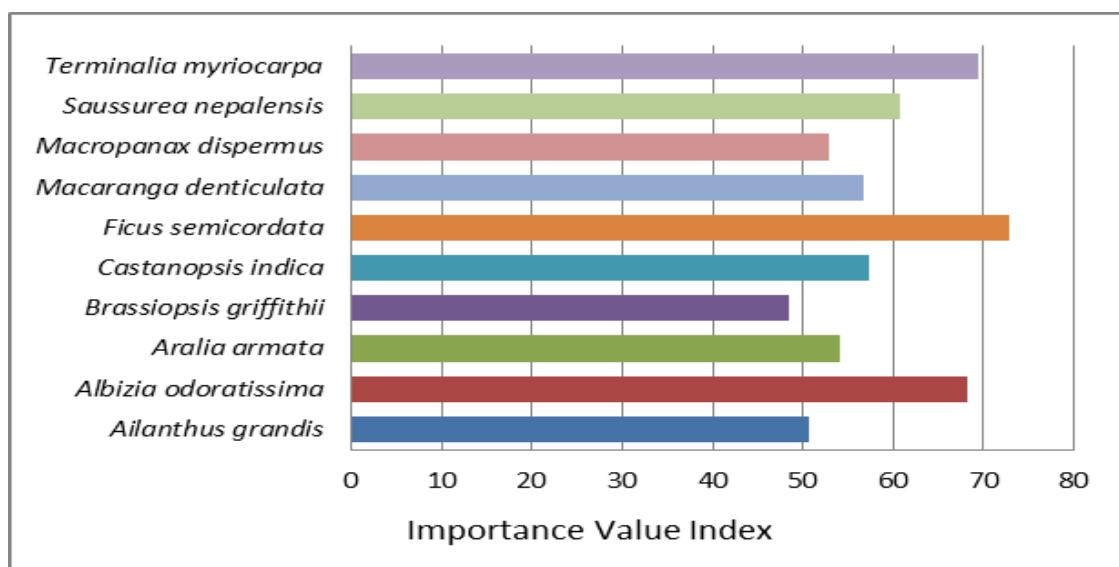


Figure 6.13: Importance Value Index of dominant tree species found in Siyom sub-basins

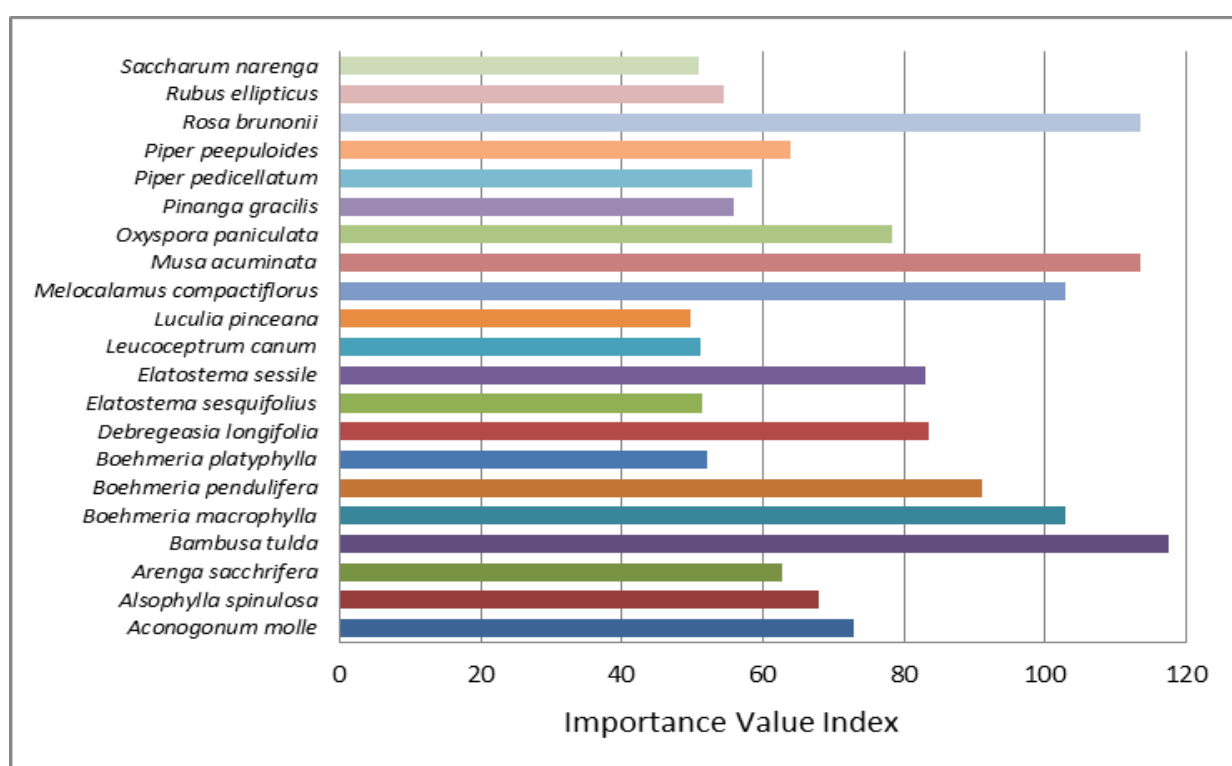


Figure 6.14: Importance Value Index of dominant shrub species found in Siyom sub-basins

vi) Yargyap Chhu

In Yargyap Chhu sub-basin, the dominant tree species are *Engelhardtia spicata* and *Macaranga denticulata*. *Saurauia punduana*, *Pinus wallichiana*, *Altingia excelsa*, *Quercus lamellosa* and *Alnus nepalensis* are the other dominant tree species.

Amongst shrubs *Strobilanthes extensa*, *Boehmeria macrophylla*, *Rubus burkillii* and *Melocalamus compactiflorus* are the most dominant species followed by *Melocalamus compactiflorus*, *Musa acuminata*, *Solanum surattense* and *Maesa chisia* in the sub-basin.

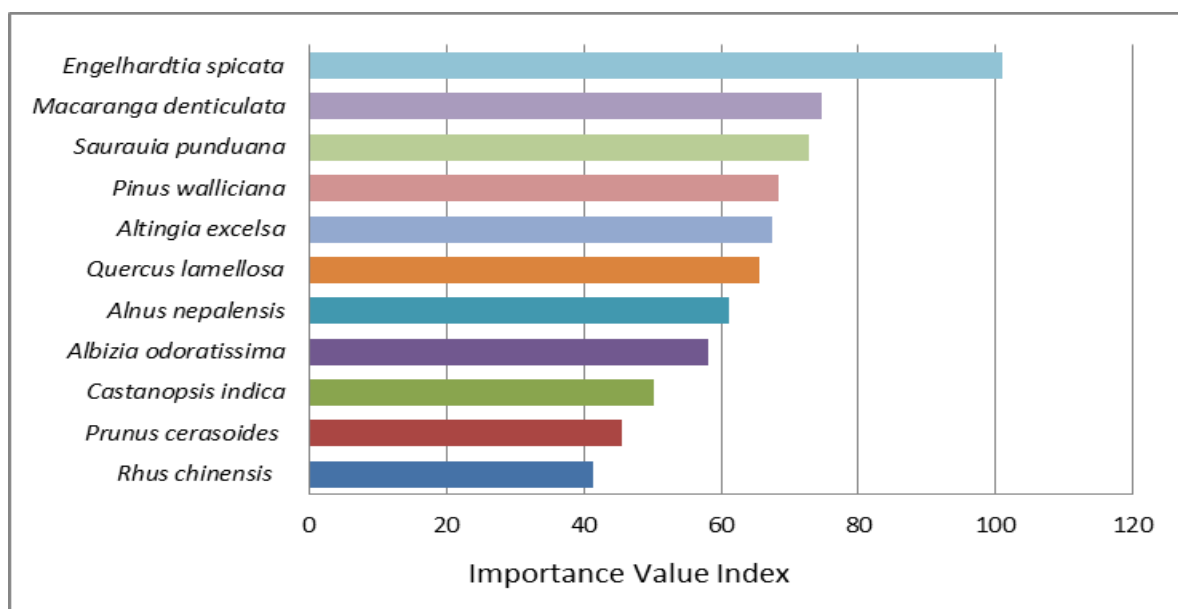


Figure 6.15: Importance Value Index of dominant tree species found in Yargyap sub-basins

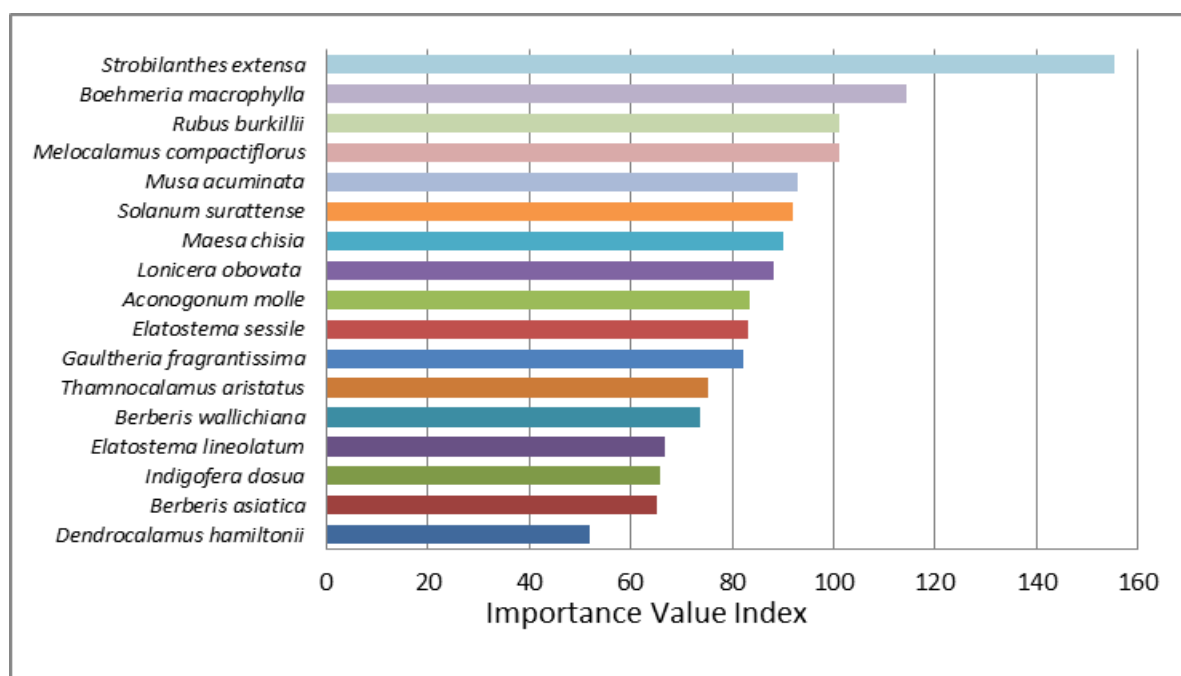


Figure 6.16: Importance Value Index of dominant shrub species found in Yargyap sub-basins

6.4.4.2 Density and Dominance at Sampling Sites Outside Basin

i) Density

At sampling sites located outside Siang basin i.e. Jiya Dhol and Dibrugarh average density of trees was 220 trees/ha at Jiya Dhol while trees were toatlly absent at sampling site near Kareng Ghat near Dibrugarh. *Trewia nudiflora* and *Bridelia retusa* recorded higher highest density (Table 6.17).

The shrub density was higher at sampling site located near Kareng Ghat (6960 individuals/ha) than at iya Dhol site (5120 individuals/ha). The density of species like *Cassia tora*, *Piper pedicellatum*, *Chromolaena odoratum*, *Ricinus communis*, *Tamarix dioica* and *Ipomoea carnea* was high at these sites (Table 6.17).

Table 6.17: Average density of plant species (no. of individuals/ha) at sampling sites located outside Siang basin

Sampling Sites	Trees	Shrubs		
		Winter	Summer	Monsoon
B1 (Jiya Dhol)	247	1520	3080	5120
B2 (Kareng Ghat)	-	3620	1980	6960

The herbaceous flora was almost non-existent in the sampling locations.

ii) Dominance

At Jiya Dhol site *Trewia nudiflora*, *Ficus religiosa* and *Bridelia retusa* were the most dominant tree species showed with high IVI values (Figure 6.3). Among the shrubs *Ziziphus mauritiana*, *Chromolaena odoratum*, *Cassia tora*, *Ricinus communis* and *Piper pedicellatum* were the dominant species (Figure 6.17).

At Kareng Ghat sampling site dominant shrubs were *Lantana camara*, *Ziziphus mauritiana*, *Caryopteris odorata*, *Urena lobata*, *Tamarix dioica*, *Ipomoea carnea* and *Cassia tora* (Figure 6.18).

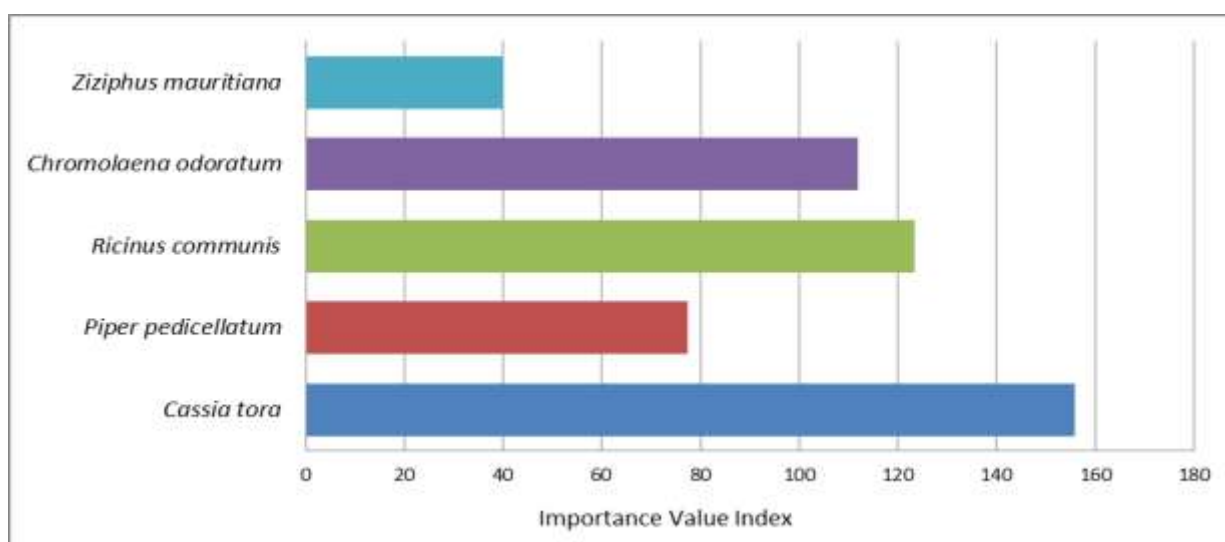


Figure 6.17: Importance Value Index of dominant shrub species found at Jiya Dhol sampling site outside Siang basin

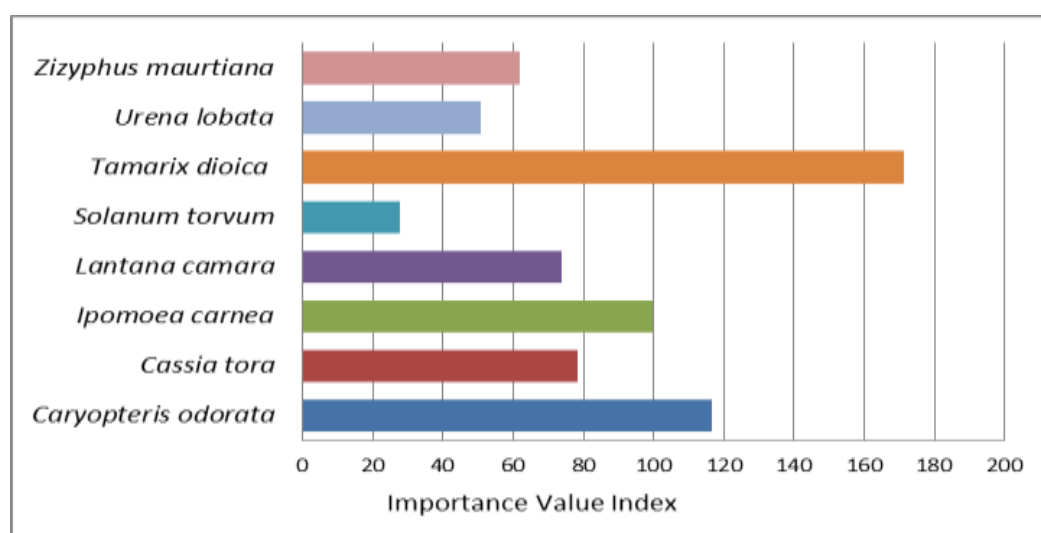


Figure 6.18: Importance Value Index of dominant shrub species found at Karen Ghat (Dibrugarh) sampling site outside Siang basin

6.4.4.3 Species Diversity & Distribution

Shannon-Weiner Diversity index (H') and Pielou's Evenness Index of trees, shrubs and herbs were calculated for each sampling site in all the sub-basins and results of the same are discussed here. While Shannon-Weiner Diversity index (H') gives diversity pattern and Evenness Index shows distribution pattern. The value of Shannon-Weiner Diversity index more than 2 is indicative higher species diversity while its value around 1 or less than 1 indicates low diversity. The value of Pielou's Evenness Index nearing 1 is indicative of regular distribution with undisturbed habitat while lower values indicate disjunct distribution or patchy vegetation distribution pattern in a disturbed habitat in a particular area.

c) Shannon-Weiner Diversity Index

i) Siang sub-basins I-IV

In all Siang sub-basins, the Shannon-Weiner Diversity index for trees ranges from 1.30 to 2.55, maximum value was recorded from the sampling sites located near villages like Bodak (2.55), Jidu village (2.49) and Mirak (2.33) while the lowest value was recorded at sites located near Hawai camp.

Maximum value of Shannon-Weiner Diversity index for shrubs was observed during monsoon season from Ranaghat area (3.32) during winter season sampling while during summer season maximum value was recorded from sampling sites located near Nunning village downstream of confluence of Ringong with Siang river (2.42) and Mirak village (2.37). Lowest values of Shannon-Weiner Diversity index for shrubs were recorded from Boleng area.

The highest values of Shannon-Weiner Diversity index for herbaceous species was recorded from the sampling sites located near Bodak village (3.11) followed by Ranaghat (3.09), Kebang area (3.05) near Siang-Siyom confluence and sites located near Yangsang river and Siang river confluence nearby Jidu village (2.98) (Table 6.18).

Table 6.18: Shannon-Weiner Diversity Index (H') of plant species in Siang sub-basins

Sampling Site	Trees	Shrubs			Herbs		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
S1	2.55	1.90	1.64	2.19	1.80	3.11	2.98
S2	2.33	1.64	1.67	2.02	2.15	2.59	2.94
S3	2.03	2.02	1.90	3.32	2.74	3.09	2.83
S4	2.25	1.85	1.82	1.85	2.18	3.05	2.94
S5	2.11	1.14	1.81	1.14	1.89	2.09	2.77
S6	1.30	2.02	1.73	2.02	2.74	2.65	2.95
S7	2.33	2.24	2.37	2.24	2.49	2.74	2.89
S8	2.31	2.28	2.12	2.28	2.49	2.62	2.83
S9	2.24	2.42	1.98	2.42	2.23	2.58	2.75
S10	1.81	1.93	2.01	1.94	2.09	2.75	2.79
S11	2.21	2.21	1.69	2.21	2.84	2.31	2.87
S12	1.92	1.60	2.01	1.60	2.31	2.91	2.92
S13	2.49	2.15	2.26	2.14	2.26	2.98	2.82

ii) Yamne Sub-basin

In Yamne sub-basin maximum value Shannon-Weiner Diversity index for trees of 2.57 recorded near Siyat village sampling site while minimum values were recorded from sites located near Lagaru (1.97).

Highest value of Shannon-Weiner Diversity index for shrubs was observed during monsoon from Siyat (2.59) during winter while during summer season sampling highest Shannon-Weiner Diversity index values were observed from sampling sites located near Jerring area (2.15) and Padu (2.47).

Shannon-Weiner Diversity index values for herbaceous species were highest during summer season from the sampling sites located near Jerring (3.08) and Siyat (2.97). During winters also the diversity values were highest at sampling sites located near Jerring have highest diversity value (2.20). During monsoon season sampling highest diversity was recorded at sites located near Siyat (2.94) (Table 6.19).

Table 6.19: Shannon-Weiner Diversity Index (H') of plant species in Yamne sub-basin

Sampling Site	Trees	Shrubs			Herbs		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
Y1	2.55	2.15	2.15	2.37	2.20	3.08	2.72
Y2	2.24	1.8	2.47	2.45	1.76	2.93	2.93
Y3	2.57	1.30	2.22	2.59	2.17	2.97	2.94
Y4	1.97	1.15	2.30	2.49	1.86	2.91	2.92

iii) Simang Sub-basin

The Shannon-Weiner Diversity index values in Simang sub-basin for trees range between 2.03 and 2.37 at sampling sites located near Lileng.

Shannon-Weiner Diversity index values for shrub species were highest during monsoon season at sampling sites located near Lilang (2.66) while during winter and summer season samplings highest values were recorded from Supple sampling sites i.e. 1.60 and 2.24, respectively (Table 6.20).

The herbaceous species Shannon-Weiner Diversity index values in Simang sub-basin were highest during summer season which was recorded from the sampling sites located near Boleng village (3.14) followed by sampling sites near Supple village (2.93). During winter diversity values ranged from 2.31 to 2.67 with highest diversity at Boleng sampling site. During monsoon season sampling highest diversity was recorded from Supple village (2.97) and lowest from Boleng village sampling site (2.81) (Table 6.20).

Table 6.20: Shannon-Weiner Diversity Index (H') of plant species in Simang sub-basin

Sampling Site	Tree	Shrub			Herb		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
Sm1	2.34	0.47	2.22	2.61	2.67	3.14	2.81
Sm2	2.37	1.44	2.01	2.66	2.51	2.56	2.94
Sm3	2.03	1.60	2.24	2.50	2.31	2.93	2.97

iv) Hirit Sub-basin

Shannon-Weiner Diversity index values for trees was highest (2.55) at sampling sites located near Kamba village and as a whole it ranged from 2.45 to 2.55.

The highest Shannon-Weiner Diversity index value for shrubs was observed from sampling sites located near Along (2.46) during monsoon while during winter season sampling highest diversity once again was recorded from sites located near Kamba and Along (1.67). During summer season sampling highest shrub diversity was recorded Poma Basti area (1.90).

The diversity of herbs was highest at sampling sites located near Kamba and Along (2.80) during monsoon season sampling. The diversity was highest near Poma Basti (2.55) during winter season sampling while it was highest near Kamba and Along sampling sites (2.80) during monsoon season (Table 6.21).

Table 6.21: Shannon-Weiner Diversity Index (H') of plant species in Hirit sub-basin

Sampling Site	Trees	Shrubs			Herbs		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
SY1	2.45	1.67	1.70	2.46	2.17	2.47	2.80
SY2	2.55	1.67	1.78	2.44	2.33	2.14	2.80
SY3	2.51	1.34	1.90	2.27	2.55	2.40	2.77

v) Siyom Sub-basins I-III

In all Siyom sub-basins maximum value for Shannon-Weiner Diversity index for trees was highest (2.78) at sampling sites located near Karo village (Jarong) and in general its values ranged from 2.07 to 2.78.

Maximum value of Shannon-Weiner Diversity index for shrubs was recorded from sampling sites located at Tato-II Powerhouse (2.67) during monsoon. During winter and summer season samplings highest diversity was recorded from Tato (2.61) and Pene (2.45) sampling sites, respectively.

The herbaceous species diversity was highest at sampling sites located at Pene (3.09) and then at Rego (2.94) during summer season sampling. During winter season sampling the diversity was highest at Reying Basti (2.72) while during monsoon season sampling it again highest at sampling sites near Rego (2.95) (Table 6.22).

Table 6.22: Shannon-Weiner Diversity Index (H') of plant species in Siyom sub-basins

Sampling Site	Trees	Shrubs			Herbs		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
SY4	2.28	2.21	1.34	2.23	2.72	2.82	2.91
SY5	2.07	2.21	2.26	2.23	2.19	2.03	2.78
SY6	2.24	2.20	2.45	2.22	2.72	3.09	2.85
SY7	2.04	2.56	2.26	2.32	2.44	2.46	2.80
SY8	2.25	2.61	1.75	2.46	2.57	2.94	2.95
SY9	2.07	2.15	1.73	2.20	2.00	2.83	2.81
SY10	2.42	1.62	2.23	2.67	2.07	2.72	2.76
SY11	2.59	1.52	2.30	1.63	2.19	2.61	2.79
SY12	2.42	2.25	1.62	2.67	2.09	2.96	2.84
SY13	2.78	1.71	2.62	2.36	2.17	2.92	2.81

vi) Yargyap Chhu

In this sub-basin Shannon-Weiner Diversity index for trees ranged from 1.93 to 2.67 with sampling sites located between Rego and Kantangshiri area recording species diversity.

Regarding the shrubs also highest species diversity was recorded from Rego area with 2.78 and 2.58, during winter and summer seasons, respectively. However during monsoon highest diversity (2.54) was observed near Pema Shelpu (Table 6.23).

For herbaceous flora species diversity was highest during summer season sampling at sampling sites located near Rego (3.04) followed by at Rapum (2.99). During winter herbaceous species diversity ranged from 1.52 to 3.03 with highest value at Rego. However during monsoon season sampling highest species diversity was recorded at Heo sampling site (2.93) and lowest value at Pema Shelpu (2.60) (Table 6.23).

Table 6.23: Shannon-Weiner Diversity Index (H') of plant species in Yargyap Chhu sub-basin

Sampling Site	Tree	Shrub			Herb		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
YG1	1.93	1.56	1.85	1.61	2.27	2.88	2.9
YG2	2.81	1.15	1.88	2.12	1.52	2.83	2.93
YG3	1.93	1.56	1.69	1.81	1.87	2.88	2.89
YG4	2.21	0.99	2.02	1.73	2.22	2.55	2.86
YG5	2.06	1.88	2.17	2.11	2.17	2.89	2.88
YG6	1.97	2.02	2.31	2.07	2.15	2.77	2.79
YG7	2.02	2.15	2.27	2.14	2.35	2.99	2.90
YG8	2.52	1.7	1.55	2.2	2.38	3.04	2.86
YG9	2.55	2.78	2.58	2.2	3.03	2.62	2.71
YG10	2.67	2.4	2.33	2.44	2.68	2.94	2.79
YG11	1.99	1.82	2.22	2.19	2.08	2.88	2.90
YG12	2.32	2.21	2.32	2.54	2.14	2.66	2.78
YG13	2.29	1.97	1.82	2.22	2.46	2.55	2.6
YG14	2.36	2.05	0.51	2.16	2.62	2.55	2.77

vii) Sites outside Siang basin

At Jiya Dhol sampling site which located outside the basin the Shannon Weiner species diversity index for trees was 1.55 while highest value of diversity for shrubs was recorded during winter season sampling (1.93). It was 1.39 during summer and 1.21 during monsoon season sampling (Table 6.24).

For sampling site at Kareng Ghat (Dibrugarh) highest value of Shannon Weiner species diversity index for shrub diversity was recorded during winter (1.46) and minimum diversity was observed during monsoon season (0.84) (Table 6.24).

Table 6.24: Shannon-Weiner Diversity Index (H') of plant species at sampling sites outside Siang Basin

Sampling Sites	Trees	Shrubs		
		Winter	Summer	Monsoon
B1 (Jiya Dhol)	1.55	1.93	1.39	1.21
B2 (Kareng Ghat)	-	1.46	1.25	0.84

b) Evenness Index

i) Siang Sub-basins (I-IV)

Amongst the tree community the evenness index ranged between 0.68 and 0.95 at different sampling sites (Table 6.25). The distribution at sampling sites located at Bodak, Tuting and Jidu village was regular.

The distribution of shrub layer was irregular at most of the sampling sites even during different seasons. Only at sampling site located near Ranaghat, Boleng and Tuting the distribution was regular during all seasons (Table 6.25).

The herbaceous layer was more or less evenly distributed at all the sampling sites during all seasons. However during monsoon season sampling value was found to be highly regular with Evenness index ranging between 0.92 and 0.99 at all locations (Table 6.25).

Table 6.25: Evenness Index of plant species in Siang sub-basins

Sampling Sites	Trees	Shrubs			Herbs		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
S1	0.94	0.76	0.79	0.88	0.78	0.92	0.99
S2	0.86	0.79	0.86	0.84	0.90	0.84	0.99
S3	0.79	0.77	0.76	1.27	0.91	0.91	0.99
S4	0.91	0.80	0.71	0.80	0.88	0.90	0.99
S5	0.91	0.50	0.93	0.50	0.76	0.77	0.99
S6	0.68	0.77	0.72	0.77	0.91	0.90	0.97
S7	0.84	0.87	0.90	0.87	0.90	0.90	0.98
S8	0.79	0.89	0.85	0.87	0.90	0.87	0.98
S9	0.82	0.89	0.86	0.89	0.87	0.91	0.97
S10	0.95	0.88	0.91	0.88	0.79	0.90	0.93
S11	0.82	0.96	0.73	0.96	0.77	0.76	0.98
S12	0.93	0.70	0.87	0.70	0.93	0.94	0.96
S13	0.94	0.81	0.88	0.81	0.86	0.91	0.92

ii) Yamne Sub Basin

In Yamne sub basin, all the vegetation layers i.e. trees, shrubs and herbs were more or less evenly distributed throughout the sub-basin (Table 6.26). Only at sampling sites located near Padu and Jerring the shrub layer was irregularly distributed during winter season.

Table 6.26: Evenness Index of plant species in Yamne sub-basin

Sampling Sites	Trees	Shrubs			Herbs		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
Y1	0.92	0.82	0.83	0.84	0.78	0.85	0.88
Y2	0.87	0.70	0.82	0.85	0.71	0.89	0.98
Y3	0.89	0.59	0.94	0.93	0.82	0.88	0.98
Y4	0.75	0.59	0.87	0.90	0.89	0.94	0.97

iii) Simang Sub Basin

In Simang sub basin the Evenness index values indicate that the distribution of tree layer were highly regular at all the sampling sites. The shrub layer was more or less evenly distributed during summer and monsoon season sampling while during winter season it was highly irregular ranging between 0.34 and 0.74. The herbaceous layer in the sub basin exhibited regular distribution pattern at all sampling sites during all seasons (Table 6.27).

Table 6.27: Evenness Index of plant species in Simang sub-basin

Sampling Sites	Trees	Shrubs			Herbs		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
Sm1	0.90	0.34	0.89	0.96	0.91	0.95	0.97
Sm2	0.93	0.74	0.97	0.98	0.91	0.89	0.98
Sm3	0.99	0.70	0.85	0.92	0.93	0.88	0.96

iv) Hirit Sub Basin

In Hirit sub basin, tree species were evenly distributed throughout the sub-basin (Table 6.28). The distribution of shrub layer was evenly distributed throughout the area in all seasons except in winter when it was slightly less evenly distributed.

The herbaceous layer in summer season sampling at site located near Kamba was less evenly distributed as compared to other sites while distribution pattern was highly regular at rest of all the sites during all seasons (Table 6.28).

Table 6.28: Evenness Index of plant species in Hirit sub-basin

Sampling Sites	Trees	Shrubs			Herbs		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
SY1	0.93	0.86	0.82	0.91	0.87	0.98	0.92
SY2	0.96	0.86	0.81	0.95	0.94	0.75	0.95
SY3	0.92	0.75	0.91	0.84	0.94	0.83	0.98

v) Siyom Sub-basins

For tree community, the evenness index ranged between 0.92 and 0.98 indicating highly regular distribution at all sampling sites (Table 6.29).

The distribution of shrub layer was more or less even (Table 6.29).

The herbaceous layer also was more or less evenly distributed at all the sites during winter and summer seasons. However, during monsoon season evenness value ranged between 0.92 and 0.99 indicating regular distribution pattern (Table 6.29).

Table 6.29: Evenness Index of plant species in Siyom sub-basins

Sampling Sites	Trees	Shrubs			Herbs		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
SY4	0.95	0.96	0.75	0.97	0.96	0.99	0.99
SY5	0.90	0.89	0.91	0.89	0.83	0.82	0.98
SY6	0.95	0.96	0.93	0.96	0.96	0.84	0.99
SY7	0.98	0.92	0.91	0.92	0.95	0.96	0.99
SY8	0.98	0.96	0.90	0.96	0.97	0.98	0.98
SY9	0.93	0.93	0.72	0.93	0.76	0.98	0.97
SY10	0.92	0.83	0.90	0.83	0.76	0.96	0.98
SY11	0.93	0.78	0.93	0.84	0.88	0.80	0.90
SY12	0.96	0.94	0.83	0.99	0.84	0.86	0.98
SY13	0.95	0.69	0.95	0.95	0.84	0.84	0.97

vi) Yargyap Chhu Sub Basin

In Yargyap Chhu sub-basin, all the layers i.e. trees, shrubs and herbs were more or less evenly distributed throughout the area (Table 6.30).

Table 6.30: Evenness Index of plant species in Yargyap Chhu sub-basin

Sampling Sites	Trees	Shrubs			Herbs		
		Winter	Summer	Monsoon	Winter	Summer	Monsoon
YG1	0.84	0.75	0.80	0.70	0.91	1.00	0.99
YG2	0.95	0.46	0.82	0.50	0.69	1.00	0.95
YG3	0.84	0.75	0.77	0.87	0.85	1.00	0.96
YG4	0.92	0.51	0.88	0.89	0.84	0.99	0.94
YG5	0.86	0.82	0.94	0.85	0.84	1.00	0.96
YG6	0.85	0.88	0.93	0.90	0.81	1.00	0.89
YG7	0.98	0.90	0.95	0.93	0.94	1.00	0.99
YG8	0.96	0.87	0.67	0.96	0.96	1.00	0.94
YG9	0.99	0.96	0.93	0.97	0.97	0.92	0.98
YG10	0.94	0.97	0.91	0.92	0.97	0.94	0.92
YG11	0.95	0.93	0.93	0.95	0.95	1.00	0.93
YG12	0.97	0.96	0.97	0.96	0.89	0.96	0.91
YG13	0.96	0.86	0.83	0.89	0.96	0.96	0.98
YG14	0.95	0.89	0.46	0.84	0.97	0.97	0.94

vii) Sites outside Siang Basin

For tree community, the species evenness index was 0.74, indicating poor regularity amongst the species of tree community (Table 6.31).

Distribution of shrub community was more or less even. During winter the evenness value was high at both the sites, and in summer and monsoon shrub community have uneven distribution of species at both the sites (Table 6.31).

Table 6.31: Evenness Index (H') of plant species at sampling sites outside Siang Basin

Sampling Sites	Trees	Shrubs		
		Winter	Summer	Monsoon
B1 (Jiya Dhol)	0.74	0.93	0.72	0.62
B2 (Kareng Ghat)	-	0.90	0.78	0.52

6.4.5 Natural Resource Use in the basin

Natural resources in Siang valley are comprised of different species of bamboo, cane and reed that provide raw materials for construction of their house as well as other essential articles of their daily use like baskets, bags, caps, etc. The material for these is collected from the surrounding forest (Figure 6.8). The following description on use plant species for different purposes is based upon Choudhry et al. (2011), SFRI (2001), Srivastava & Adi community (2009), Ali & Ghosh (2006), Yumnam et al. (2011), Gajurel et al. (2006), Kagyung et al. (2010), Singh et al. (2008, 2009, 2010), Rethy et al. (2010), Rawat et al. (1996, 2010, 2011), Nimachow et al. (2008), Saravanan (2010), Chakraborty et al. (2012), Yumnam & Tripathi (2013).

6.4.5.1 Housing Material

The neighbouring jungle and forests provide the materials for construction of house such as bamboo, cane, thatch / hay, palm leaves, wood, etc. The houses are made with the help of wooden beam and bamboo structures (Table 6.32). Wood is used in the form of posts for which tall, straight trees are cut and the branches and barks are removed. Different varieties of bamboo are used for different purposes. Cane is used to tie the pieces of bamboo and timber together. The roof is thatched with dry *tek anne* (*Livistona jenkinsiana*) and *ammung* (*Erianthus* sp.) The

whole house is a work of bamboo and wood, bamboo sheets form the floor and the wall and the wooden logs serve as the main pillars over which the structure of the house is raised. Almost all houses are made in rectangular form having two or three doors according to the individual will and fashion. The doors have wooden ladder leading to the ground. The most important feature is the fire place (*meram*). Over the fire hearth (*perap*) hangs a square-shaped bamboo shelf used to dry meat, fish, etc. *Meram* is prepared with the help of bamboo, wood, soil and cane. Some of the varieties of bamboos viz. *Dendrocalamus hamiltonii*, *Arundinaria* sp., *Bambusa tulda*, and *B. pallida* are used for wall, floor and ropes for binding the poles. House is decorated with skulls of mithuns, jaws of pigs and wild boars on the wall.

Table 6.32: List of bamboo and cane species used for house construction

Local Name	Common Name	Scientific Name	Family
BAMBOOS			
<i>Dibang</i>	Jeti Mistenga	<i>Bambusa tulda</i>	Poaceae
<i>Baluka</i>	Bhaluka Barua	<i>Bambusa balcoa</i>	Poaceae
<i>Epo</i>	Kako Pacha	<i>Dendrocalamus hamiltonii</i>	Poaceae
<i>Homing</i>	--	<i>Arundinaria</i> sp.	Poaceae
RATTAN/CANE			
<i>Yoyi</i>	Lejai	<i>Calamus floribundus</i>	Arecaceae
<i>Takat</i>	Raidang	<i>Calamus flagellum</i>	Arecaceae
<i>Esong</i>	Sundi	<i>Calamus guruba</i>	Arecaceae
<i>Jeying</i>	--	<i>Calamus tenuis</i>	Arecaceae
TREE (Wood)			
<i>Eyum</i>	Bola	<i>Morus laevigata</i>	Moraceae
<i>Silok</i>	Hollock	<i>Terminalia myriocarpa</i>	Combretaceae
<i>Nahar</i>	Nahar	<i>Mesua ferrea</i>	Clusiaceae
<i>Gomari</i>	--	<i>Gmelina arborea</i>	Verbenaceae
<i>Hileng</i>	Borpat	<i>Ailanthus grandis</i>	Simaroubaceae
<i>Hepop</i>	Hatipoila	<i>Pterospermum acerifolium</i>	Sterculiaceae
<i>Kebo</i>	Khokon	<i>Duabanga grandiflora</i>	Sonneratiaceae
<i>Heri</i>	Jutuli	<i>Altingia excelsa</i>	Hamamelidaceae
<i>Simul</i>	Seveal	<i>Bombax ceiba</i>	Bombacaceae

Various species of bamboos mentioned in the table above are used for floor and wall of the house. It is also sliced into small pieces to tie the roof of the house. Rattan species are used as rope to tie the roof and poles. Sometimes the leaves are used as thatching material. The trunks of the trees are used for pillars and poles of the house. Now-a-days wooden planks are used for both wall and floor. There are many household articles, which are made of wood, leaves, bamboo, cane, animal bones and skin, etc. These items are collected or gathered from the forest resources.

6.4.5.2 Household Materials

The household materials like handicraft, utensils etc. used by the people are given in Table 6.33.

Table 6.33: Bamboos, cane and other species used as household materials

Local Name	Common Name	Material used	Purpose
<i>Tirkak</i>	Bamboo cup	Bamboo	Bamboo tube of used as a cup for drinking Apong
<i>Alo-Lodung</i>	Bamboo tube	Bamboo	For storing salt
<i>Ambin dupung</i>	Container	Bamboo	Bamboo tube used as a paddy container where open mouth is provided with section of bamboo

			lid and a cane handle
<i>Kaksur</i>	Bamboo tube	Bamboo	Bamboo tube with a lid of Bamboo section and serves the purposes of storing Apong and other things
<i>Apo-petok</i>	Bamboo jug	Bamboo/ Cane	This basket is provided with a cane loop near the open end and with a hole at the closed end. The hole at the bottom is provided with a cane stopper to pug it when required during filtration of millet beer and is mainly use during the preparation of millet beer
<i>Egin</i>	Basket	Bamboo/ Cane	For carrying food grains and storing food grains and other things
<i>Epo</i>	Winnowing pan	Bamboo/ Cane	Made of flat Bamboo strips and the border is tied with cane. Used to separate from the grain and keeping vegetables etc.
<i>Suje</i>	Container	Bamboo/ Cane	Used as a basket for storing rice etc.
<i>Apong Perop/Ape</i>	Basket	Bamboo	Used for storing fermented rice from which Apong (rice beer) is prepared
<i>Epu</i>	Mat	Bamboo/ Cane	Used for drying cereals, rice grains either in the sun or over the hearth
<i>Ebong</i>	Rain shield	Bamboo/ Toko-palm	Used as a rain shield
<i>Megap</i>	Tong	Bamboo/ Cane	Used for picking up of fire and other materials
<i>Penyo</i>	Spoon	Bamboo wood/cane	Used for cooking purpose
<i>Ebar</i>	Basket	Cane	Used for carrying fire wood etc.
<i>Hobuk</i>	Scabbard	Wood/ cane	Used for keeping dao, knife & sword
<i>Tayi</i>	String	Cane	Used for weaving carrying materials and for carrying the child
<i>Dumlup</i>	Cap/hat	Bamboo/ Cane	Cane hat, finely woven which is decorated with bear skin and wild boars tooth
<i>Sotka</i>	String/rope	Bamboo/ Cane	Like a jute rope but made of cane/Bamboo for tying Mithun, Cow and Goat etc.
<i>Tali</i>	Haversacks	Bamboo/ Cane	Used by men folk for carrying food and basic needs
<i>Kurpyak (Mat)</i>	Mat	Bamboo/ (TakoTrees)	Used for sleeping and seating
<i>Doket</i>	Ginning Machine	Wood	Used for ginning locally produced cotton

Source: Nimachow et al. (2008)

6.4.5.3 Medicinal Plants

This region harbours a wide range of medicinal plants used in Ayurvedic, Homoeopathic and Unani medicines or used by the local people. Some of the medicinal plants of West Siang like *Acorus calamus*, *Ageratum conyzoides*, *Artemisia nilagirica*, *Bergenia ciliata*, *Cissampelos pareira*, *Cyperus rotundus*, *Elatostema platyphyllum*, *Oxalis corniculata*, *Gynocardia odorata*, *Houttuynia cordata*, *Oroxylum indicum* and *Viola betonicifolia* are quite common in the tropical and sub-tropical parts of Siang basin. *Castanopsis indica*, *Hedychium spicatum*, *Lyonia ovalifolia*, *Origanum vulgare*, *Rubia cordifolia*, *Tetradium fraxinifolium* and *Zanthoxylum armatum* are some other important medicinal plants of the region used by local populace in their daily life. These plants are used internally for treating stomachic diarrhea, dysentery, cough, cold, fever and asthma and externally for rheumatism, skin diseases, cuts, boils and injuries. The list of some medicinally important plants species used for medicinal purposes is given in Table 6.34.

The *Adis* of Siang region use their traditional knowledge in health care system where herbs, plants and roots of some trees and plants locally available are used for curing the ailment. They have indigenous method of treatment for different kinds of diseases with the help of local herbal medicines. They also use body parts of animals such as antelopes, bear, etc. for curing diseases of orthopedic, stomach, and liver pain. The common diseases occur in the village are dysentery, fever, malaria, jaundice, cough, fracture, etc. Villagers of the remote localities are still relaying on their traditional medicines for the alleviation of the local ailments. They mostly use herbals and sometime an admixture of plants, animal and mineral substances coupled with local rituals.

A list of medicinal plants that are frequently used by the villagers located in Siang basin is given at Table 6.35.

Table 6.34: Locally used plants, plant parts for medicinal purposes

Scientific Name	Local Name	Disease	Plant part used
<i>Terminalia bellerica</i>	Lokyo	Cold, cough, fever	Whole plant
<i>Centella asiatica</i>	Kiling-kiro	Gastric, stomach, dysentery	Leaves
<i>Aristolochia indica</i>	Hinger	Snake bite, skin disease	Whole parts of plant
<i>Zingiber zerambet</i>	Kekir	Stomach, Vomiting, Diarrhoea	Tuber
<i>Smilax perfoliata</i>	Dangal-Engin	Fracture	
<i>Tinospora cordifolia</i>	Kynie-rimang	Fracture	
<i>Zanthoxylum rhetsa</i>	Onger	Jaundice, wart, Hair cleaning	Consumed as a vegetables
<i>Gleditsia assamica</i>	Dikang	Skin disease	Fruits
<i>Dendrocalamus strictus</i>	E-a-Ashik	Bamboo injuries, wound or cut	Used in blood clotting
<i>Kalanchoe pinnata</i>	Nevi-nelum	Burn	Leaves
<i>Lucas aspera</i>	Eki-Sipyak	Nose bleeding, ear ache	Leaves
<i>Solanum spirale</i>	Bangko	Stomach pain	
<i>Zanthoxylum hamiltonianum</i>	Ombe	Malaria	
<i>Ficus</i> spp.	Takuk	Dysentery	
<i>Coffea bengalensis</i>	Wanco	Stomach disorder	
<i>Morus alba</i>	Hinsai	Inflammation of vocal cord	
<i>Spilanthes paniculata</i>	Marshang	Tooth-ache	
	Pazi pereng	Deworming cows and bullocks	
	Namsing Ing	Blood clotting	
	Rukja	Dysentery	
	Ongin	To check blood pressure	
<i>Oroxylum indicum</i>	Paksum Alang	Blood dysentery and Diarrhoea	
<i>Blumea fistulosa</i>	Rumbdum	Diarrhoea	
<i>Alocasia macrorrhiza</i>	Engge	Pain reliever of insect bite	
<i>Solanum xanthocarpum</i>	Sengelathang	Expectorant, tooth-ache	
<i>Amaranthus spinosus</i>	Gobrai	Antidote in snake bite; gonorrhea	
<i>Oxalis corniculata</i>	Phakep	Relieves intoxication from wine; Diarrhoea	

6.4.5.4 Food Plants

The people of Arunachal Pradesh collect a large number of wild edible plants in the form of tubers, rhizomes, shoots, flowers, fruits, berries, seeds, etc. as the natural supplement for their diet. These wild edible species are very rich in carbohydrates, starch, protein, sugar and oil. Among the wild edible plants consumed are the leaves and young twigs of *Aconogonum molle*, *Amaranthus spinosus*, *Cardamine hirsuta*, *Chenopodium album*, *Fagopyrum esculentum*, *Girardinia diversifolia* and *Rumex nepalensis*. The rhizomes and tubers of *Alpinia allughas*, *Alocasia indica*, *Colocasia esculenta* and *Dioscorea* spp. are commonly consumed as vegetables. Young shoots of *Bambusa tulda* and *Dendrocalamus hamiltonii* are used as food ingredients. Flower buds of *Bauhinia purpurea* and *Oroxylum indicum* are used as vegetables. Fruits of *Garcinia pedunculata*, *Elaeagnus* sp., *Rubus ellipticus*, *Ficus semicordata*, *Prunus cerasoides*, *Musa* sp., *Syzygium formosum* and *Tetradium fraxinifolium* are eaten raw or cooked as vegetables.

Agriculture is the main occupation of the people inhabiting near project area. Paddy (*Oryza sativa*), maize (*Zea mays*), millets (*Pennisetum typhoides*), wheat (*Triticum aestivum*), potato (*Solanum tuberosum*), ginger (*Zingiber officinale*), soybean (*Glycine max*) are main cash crops of this region.

6.4.5.5 Timber Trees and Fuel wood

Forest is the most important source of timber in the study area. Most important timber yielding species of the area are *Alnus nepalensis*, *Artocarpus heterophyllus*, *Bischofia javanica*, *Castanopsis indica*, *Canarium strictum*, *Gynocardia odorata*, *Terminalia myriocarpa*, *Tetrameles nudiflora*, *Populus ciliata* and *Pinus wallichiana*. In addition to these trees, some bamboos like *Bambusa tulda* and *Dendrocalamus hamiltonii* are commonly used for house construction.

Timber: *Hollock* or *Terminalia myriocarpa* (*Sanglo*) and *bola* or *Morus laevis* (*Sangyam*) are the two timber yielding species most preferred for use in construction and repairs of dwelling houses. In the typical long house of the *Adis*, bamboo and roofing leaves of wild banana are also made use of. *Bola* is now available rarely and the local communities have now taken to protecting it. As a general understanding among the community members, timber for domestic use can be taken from the community forest or the *Jhum* land, irrespective of the ownership of the *jhum* land. *Mekhahi* (*Phoebe cooperiana*), *taram* (*Alnus nepalensis*) and *jutuli* (*Altingia excelsa*) are the other timber yielding species which are also made use of.

Poles: The houses of the locals are raised normally on stilts and the requirement of poles for the same is met from the forests. *Yah-changne* (*Macaranga denticulata*) and *Yarphu-changne* (*Callicarpa arborea*) are the more commonly used species for the same. For construction of their long houses, bamboo also comes in very handy as stilts, struts, purlins and rafters in the same along with the woody species.

Ropes: Ropes made of locally available bamboo, canes and local species *tapetarig* are commonly used for construction works, livestock and other miscellaneous works.

Fuelwood: The most preferred species for fuel wood here is *yah-changne* (*Macaranga denticulata*). A local species *Yarphu-changne* (*Callicarpa arborea*) is also highly preferred for use as fire wood. These are very light woods, easily combustible, leave less smoke while burning and dry easily. In addition to these, many inferior wood species are also made use of for fuel wood purposes. The availability of the same is throughout the year and in addition to meeting their subsistence requirement; head loads from the *Jhum* land are also sold in the nearby market. The general rule of collecting only dry and fallen stems and branches is practised. Wood of other species is also made use of for burning, depending upon the demand and relative availability.

Table 6.35: List of medicinal plants found in Siang basin

Sl. No.	Scientific Name	Local Name	Part Used	Uses for Ailments/Diseases
1	<i>Acorus calamus</i>	Kilatolyo	Rhizome & leaves	Paste of fresh rhizome is applied on swollen and dislocation of bones, wound healing and in abscesses; Antidote in snake bite
2	<i>Ageratum conyzoides</i>	Pasho	Leaves	Cuts and wounds to check bleeding and early healing; red eye treatment
3	<i>Alocasia macrorrhiza</i>	Engee	Root stock	Pain reliever of insect bite
4	<i>Alpinia allughas</i>	Taraka	Fruit & Seed	In madness and as fish poison
5	<i>Amaranthus spinosus</i>	Gobrai	Leaves	Antidote in snake bite; gonorrhea
6	<i>Bauhinia purpurea</i>	Tanki	Flower bud	
7	<i>Blumea fistulosa</i>	Rumbdum		Diarrhoea
8	<i>Callicarpa arborea</i>	Talo	Flower	
9	<i>Centella asiatica</i>	Barong	Whole plant	Blood purifier, abdominal pain, gastric, and increase digestive power.
10	<i>Cissampelos pareira</i>	Akanadu	Leaf	
11	<i>Coptis teeta</i>	Rinko		Malarial fever, backache, stomach disorder, aphrodisiac
12	<i>Engelhardtia spicata</i>	Silapoma	Bark	
13	<i>Ficus</i> spp.	Takuk		Dysentery
14	<i>Girardinia diversifolia</i>	Awa	Leaf	
15	<i>Gynocardia odorata</i>	Tak	Fruit	Teeth extraction, fruit used as poison for killing insects, worms and fishes
16	<i>Houttuynia cordata</i>	Honya	Leaves	
17	<i>Juglans regia</i>	Okhar	Bark	
18	<i>Lyonia ovalifolia</i>	Sinka	Leaf	
19	<i>Molineria capitulata</i>	Kimu	Fruit	
20	<i>Morus alba</i>	Hinsai		Inflammation of vocal cord
21	<i>Oroxylum indicum</i>	Paksam	Seed	
22	<i>Ostodes paniculata</i>	Byapari	Leaves	
23	<i>Oxalis corniculata</i>	Phakep		Relieves intoxication from wine; Diarrhea
24	<i>Piper attenuatum</i>	Dolopan		Liver and urinary troubles
25	<i>Piper pedicellatum</i>		Seed	

26	<i>Piper peepuloides</i>		Seed	
27	<i>Solanum virginianum</i>	Sengelathang		Expectorant, tooth-ache
28	<i>Solanum spirale</i>	Bangko		Stomach pain
29	<i>Spilanthes paniculata</i>	Marshang		Tooth-ache
30	<i>Zanthoxylum rhetsa</i>	Onger		Hair cleaning
31	<i>Zanthoxylum armatum</i>	Honyum	Whole plant	Toothache, stomach disorder, Cold, cough and fever
32	<i>Zanthoxylum hamiltonianum</i>	Ombe		Malaria
33	<i>Dioscorea bulbifera</i>		Root	Cooling effect on burning and bulbils cases, for stopping dysentery

6.4.5.6 Fodder

Major fodder species used by the community are *Gynocardia odorata* (*takuk-changne*) and wild banana or *Musa* sp. (*kulung*), the former for being palatable, easy to digest and for its milk enhancing properties and the latter for its easy availability and palatability. Traditionally these people leave their animals and livestock for grazing and feeding in the open areas, *jhum* fallows and the community forests. *Gynocardia* leaves are available only during the monsoon months, whereas wild banana is available throughout the year. In addition bamboo foliage also acts as a supplementary fodder. Fodder collection is only for meeting the requirement of their domestic cattle and has been taken up in the recent past.

6.4.5.7 Other uses

Other than the traditional food items of modern man, like the rice, wheat, millets, etc. they have a treasure house of knowledge about potential food plants from the surrounding forests. These includes leaves, stems, bark, roots, fruits of wild plants and a number of animals and insects gathered as food items. The area is very rich in various types of edible and nonedible items found abundantly in the nearby jungles. Nature has provided plenty of edible plants from which leaves, roots, fruits, flowers, seeds, tuber, etc. are taken as food. They collect these edible plants for their own consumption and other uses. If there is any excess quantity of collected materials, they sell those in the market or exchange with some other essential items of daily needs. The various edible vegetables collected from the forests are bamboo shoot (*Dendrocalamus hamiltonii*), wild banana flowers (*Musa balbasiana*), *Onger* (*Zanthoxylum rhetsa*), *Oyik* (*Pouzolzia benettiana*), *Ongin* (*Clerodendrum colebrookianum*), *Rori* (*Piper pedicellatum*) and *Enge* (*Colocasia esculenta*). Mushrooms (*Termitomyces* sp., *Cantherallus* sp., *Schizophyllum* sp., *Pleurotus pulmonarius*, *Auricularia* sp.) locally known as *Tatar* are seasonally collected and many more edible plants but scientific names are not known. They also eat number of fruits that are collected from the forest such as *Tagung* (*Mangifera sylvatica*) *Tapir* (*Phoebe* sp.), *Anke* (Unidentified), *Hillum* (*Canarium strictum*), *Tadar* (*Myristica fragrans*) and *Tak-api* (palm fruits).

Some of the plant species from the forest is commonly used by the local inhabitants for various purposes (Table 6.36).

The tribal people also eat different kinds of insects seasonally. During winter season people use to collect *Tari* (Stink bug) (*Podisus maculiventris*) from the banks of rivers. The other insects like grasshoppers, red-ant, etc. are eaten occasionally.

Table 6.36: List of plants used for the various purposes in Siang basin

S. No.	Plant species	Miscellaneous uses
1	<i>Alpinia allughas</i>	Fruits of this plant are used as fish poison to catch fish
2	<i>Artemisia nilagirica</i>	The extracted juice from the leaves is diluted when taken bath in it relieves itching
3	<i>Cardamine hirsuta</i>	Leaves are eaten as vegetables
4	<i>Colocasia esculenta</i>	Tubers are eaten as vegetables
5	<i>Eleusine coracana</i>	Cultivated for seeds in <i>jhummed</i> areas
6	<i>Gynocardia odorata</i>	The fruit pounded and mixed with water and used as poison for killing insects
7	<i>Houttuynia cordata</i>	The whole plant is used as condiment
8	<i>Leea compactiflora</i>	The plant is used for cure of snake and insect bite
9	<i>Macaranga denticulata</i>	Berries are eaten fresh in case of fever
10	<i>Molineria capitulata</i>	Fruits are eaten
11	<i>Oxalis corniculata</i>	The juice of leaves used as ear drops for removal of dust
12	<i>Oxyspora paniculata</i>	The stem is used as tooth brush
13	<i>Pinanga gracilis</i>	Fiber is extracted from the leaves and used for making a dark black jacket

S. No.	Plant species	Miscellaneous uses
14	<i>Terminalia myriocarpa</i>	It is planted for timber and landscaping
15	<i>Calamus flagellum</i>	Basket and furniture
16	<i>Calamus floribundus</i>	Basket and furniture
17	<i>Thysanolaena latifolia</i>	Making of Broom

6.4.5.8 Hunting & Fishing

Forest is the only source for hunting animals and birds. But hunting is never considered as an occupation. On the other hand it gets more importance as an obligatory recreation especially during some rituals and festivals, when it is performed collectively. Forest of the area provides wide range of animals of different species. Some animals such as Tiger, Wolf and Fox are not killed and consumed. These animals are killed only when they cause danger to the human beings and domesticated animals. Sometimes, these animals kill mithun (*Bos frontalis*), cattle and pig. The other species of animals commonly eaten by the people includes Deer, Bear, Wild Boar, Monkey, Squirrel, Rat, Porcupine, Pangolin, Rabbit and Elephant. Besides, there are many domesticated animals which supplement the meat requirements of the people like Mithun, Pig, Buffalo, Cow and Goat.

Birds are elegant creatures for the tribal societies. They hunt birds for various purposes such as to supplement diet with flesh, to procure beaks for decoration in the headgear and to test and develop hunting skills. In fact, hunting birds is a fascination to them. They are predominantly meat eaters and for procuring their meat, they largely rely on hunting. Birds are one of the major attractions to the people for hunting. Various birds eaten by them are wild fowls, hornbills, parrots (small size) (*peke*), Bulbul, Pigeon, *Myna*, Dove, etc. Birds like vulture, Sparrow, Crow, Owl are restricted for consumption to the people.

For hunting and catching animals and birds, people usually use different kind of implements made by them from plants like bamboo, wood, cane, etc. The hunting implements of the people consist of gun, bow and arrow and other trappers.

a) Hunting Implements

Eyyi (Bow): Bow is made of Bamboo and the string is made of a cane.

Epuk (Arrow): Arrow is made of slender Bamboo split with a pointed end.

Yokmo: is another kind of Arrow used for killing wild big animals like Boars, Bear, Tiger, and Elephant etc. Its pointed end is fitted with a triangular piece of iron which is smeared with poison called *emo* (aconite) made from the roots of kinds of herbs.

Etku: *Etku* is the most common implements of hunting. This is generally used for catching rat, squirrels, birds and other small animals only. The *etku* is prepared from Bamboo; string is especially made from '*tabum*' (other type of Bamboo) species. Besides all these there are innumerable devices for trapping birds and animals such as *eda*, *songkit*, *egum*, *etpeng*, *komang*, etc.

b) Fishing

Fish are beautiful aquatic creatures that form an important part of human diet due to richness in protein, vitamins and essential oils. Fishes are found in a variety of water bodies ranging from stagnant ponds to flowing rivers or streams. The area has diversity in different species of fishes. Different species of fishes eaten by the people are locally known as *Talu*, *Ngopi*, *Tageng*, *kadang*, *Horche*, *Ribi*, *Tasum*, *Take*, etc. As per the fishery department the following species of fishes are found in the area Rohu (*Labeo rohita*), *Labeo pangusia*, *Labeo gonius*, *Glyptothorax cavia*, *Garra* spp., *Aorichthys aor*, *Pseudecheneis sulcata*, *Psilorhynchus balitora*, *nob*, eel (*Anguilla bengalensis*), prawn (*Penaeus* sp.) and crab (*Cancer* sp.). The surrounding forest provides various

species of insects for consumption. Fish resource is declining in the village and adjoining areas since it is felt that there are more fishes in the past than now. Decline in fishes are because of rise in human population and unscientific fishing by blasting and poisoning streams with chemicals such as bleaching powder and use of generator.

Biological resources also play vital role in fishing activities of the people. For fishing they are using varieties of traps made of bamboo, cane, wood, which are locally known as *edir*, *porang*, *churi*, *etkong*, *kodong*, *tari*.

Edir is a trapping implement which is made of bamboo splinted and tied with the help of cane.

Porang is also a trapping tool.

Porang is prepared from bamboo. The upside end of the one meter length Bamboo is splinted into many but the other end kept intact. Then the splinted portion is prepared with the help of splinted *tabum* (other kind of Bamboo species) in such a way that it expands and make an easy passage for the fish to enter in the *Porang*. The shape of *Ponang* is conical.

Huri is bigger types of *Porang* which is prepared from bamboo.

Tari is one form of *Porang*. It is prepared by inserting thorny plant leaves so that when fishes enter the *Porang* the thorny leaves / plants obstruct the fishes from coming out of it.

Kodong is a conical shape trappers made of Bamboo and cane use by women folk. *Bokong* is angling stick extracted from forest i.e. from a bamboo species known a *homing* (*Arundinaria* sp.).

During *sibok* (river diversion) lots of hardwood and leaves of plants and plantains (*kolung*) are collected for diverting the river. After diverting the river, if the river is not completely dried-up, then the leaves, barks and fruits of plants (mostly the roots of *Derris scandens* and bark of *Aesculus assamica* are used to poison the fish locally known as *Tamu*. Here barks of poisonous plants are used to poison the fishes for easy catch.

There are many poisonous plants, the bark of which are used in this method namely- *Tanir*, *Taki-sidik*, *Ripik*, *Reliom*, etc. There are also many toxic plants viz. *Marshang* (*Spilanthus oleracea*), *Diku-Tamu* (*Thelypteris opulenta* Syn. *Amphineuron opulentum*) - a fern, *Onger* (*Zanthoxylum rhetsa*) and *Muyum* that are used as fish poison.

The natural flora and fauna used by ethnic groups in the form of medicines in curing and preventing different ailments and diseases are known as ethno-medicine. The tribal people residing in different parts of the basin have rich knowledge about these forms of medicine and medication, which has been handed down for generations merely on verbal tradition. This art is highly endangered and can be seen only at remote Siang basin villages rather still governing the *Adi* way of medication for its people.

The most preferred species for fuel wood here is *yah-changne* (*Macaranga denticulata*). A local species *yarphu-changne* (*Callicarpa arborea*) is also highly preferred for use as fire wood. These are very light woods, easily combustible, leave less smoke while burning and dry easily. In addition to these, many inferior wood species are also made use of for fuel wood purposes. The availability of the same is throughout the year and in addition to meeting their subsistence requirement; head loads from the *jhum* land are also sold in the nearby market. The general rule of collecting only dry and fallen stems and branches is practised. Wood of other species is also made use of for burning, depending on the demand and relative availability.

6.5 FAUNAL RESOURCES

6.5.1 Introduction

Conservation of faunal diversity is of principal importance to the survival of human life. It leads to the essential ecological conservation to continue the food chains. For a few decades, factors such

as increasing human population, developmental activities, agricultural expansion and urbanization have led to the immense pressures on the wildlife world wide, which have resulted into increasing rate of extinction of species. In order to maintain the ecological balance and conservation of wildlife, some significant efforts like declaration of protected areas, hot spots, etc. have been taken in the recent past. In India two great mountain chains have been recognized as among the eighteen 'hot spots' of the world due to the presence of diverse fauna and flora; Arunachal Pradesh is a part of one of the hot spot - Eastern Himalaya. The huge water resources of Eastern Himalaya have made it target of a large number of river valley projects to accomplish the energy requirement of country. These developmental projects are anticipated to have detrimental impacts on the wildlife, which are already under threat due to the customary hunting by tribes and shifting cultivation especially in Arunachal Pradesh. In order to preserve the biodiversity a detailed assessment of wildlife was made based upon field surveys and published literature.

The Abor hills form a phytogeographic node for the mingling of Chinese, Malaysian and Himalayan flora (Sahni, 1969). Mani (1974) considers the state of Arunachal Pradesh as the "Indo-Chinese amphitheatre". Such type of floristic diversity greatly affects the faunal composition of the region, which shows close affinities with the fauna of Assam, Myanmar and China.

The biogeographic classification includes this region under the Eastern Himalaya- Province 2D (Rodgers et al. 2002). The fauna of Eastern Himalaya is mainly governed by the species of southern China, Indo-china and Indo-Malaya regions. The fauna of Eastern Himalaya also have affinities with the Mediterranean, Ethiopian and Turkmenian regions. The species, viz. *Elephas maxima*, *Bubalus bubalis*, *Bos frontalis*, hornbill species, pittas, cobras, etc. inhabit the monsoon forests below 1000 m, and have close affinity with that of the Indo-Malayan region. The north part of Eastern Himalaya is close to palaearctic region in the faunal composition. It includes animal species - *Uncia uncia*, *Ursus arctos*, *Canis lupus* and many species of alpine ungulates. A large number of mammals, birds, reptiles and fish species of Arunachal Pradesh, easternmost part of Himalaya are similar to the Northeastern states of India.

6.5.2 Mammals

The description of various components of wildlife in the basin has been given in the preceeding paragraphs.

A list of mammalian fauna reported from the basin prepared from published data and surveys is given at Table 6.37. The following literature was consulted for the same: Chatterjee (1989), Kumar, (2009), SFRI (2008), Maheswaran (2012), Molur et al (2005), Choudhury (2009, 2010), Chinlampiang et al (2013), and Borang (1996, 2002). It comprises of about 143 species belonging to 32 families and 11 Orders. Family Muridae is the largest family represented by 22 species while Vespertilionidae is represented by 13, species, Sciuridae 12 species, Mustelidae 10 species and Felidae is represented by 9 species. The conservation status of the mammals reported from the basin was assessed based upon their listing in different lists published by agencies like Zoological Survey of India (ZSI), Conservation Assessment & Management Plan (CAMP), International Union for Conservation of Nature (IUCN) Red List of Threatened Species 2012.2 and different Schedules notified under Wildlife (Protection) Act, 1972. Detailed accounts on the distribution and conservation status of the species are described in following paragraphs.

6.5.2.1 Primates

Order Primates is represented by 5 species belonging to 2 families (see Table 6.37). Slow loris inhabits tropical dense forest and is distributed up to 800m. Slow loris is shy in nature and rarely observed around the settlements. Capped langur, Assamese macaque and Rhesus macaque inhabits open forest and are frequently seen near settlement areas. They are distributed up to 2000m

elevation. Macaques are also found areas nearby the settlements. They are not considered as threatened species however, are ranked under the Schedule III (WPA, 1972). The Primates are hunted by the tribes mainly for food and their skins and fur is used as large knife case.

6.5.2.2 *Carnivora*

Carnivora is one of the three the largest order in the basin, which comprises of 35 species belonging to 7 families (Table 6.37). Most of the species of cat and dog families (Common leopard, Clouded leopard, Leopard cat, Jungle cat, Fishing cat, Jackal, Wild dog) are widely distributed up to elevation of 1500 m. Tiger is generally restricted to the lower reaches of the basin whereas bears inhabit the area above 1000 m elevation (ZSI, 2006). All civet species are found in the dense forest and are rarely sighted. Mongooses inhabit open forest areas; distributed up to 800 m elevation. They are very common around the proposed hydroproject areas. Common leopard, Fishing cat and Leopard cat are the most hunted animals. Tiger and Himalayan black bear are globally 'threatened' species, categorized as 'endangered' and 'vulnerable', respectively. Mammals like Tiger, Common leopard, Clouded leopard, Leopard cat, Fishing cat and Black bear have been included in 'threatened' category, in which Clouded leopard is 'endangered' and remaining are 'vulnerable' (ZSI, 1994). On the basis of conservation prioritization, 9 species are included under the Schedule I (Table 6.37).

6.5.2.3 *Proboscidae*

Proboscidae is represented by Asian elephant, which inhabits foothill stretch (up to 300m elevation) of Siang river areas downstream of Pasighat in D'Ering Memorial Wildlife Sanctuary. Asian elephant is classified as 'vulnerable' and is under Schedule I.

6.5.2.4 *Artiodactyla*

Artiodactyla is comprised of 7 species belonging to 4 families Bovidae, Cervidae, Moschidae and Suidae (Table 6.37). Mithun (*Bos frontalis*), Goral, Barking deer, Serow, Hog deer and Wild boar inhabit the areas near settlement and its surroundings. Mithun is very common, semi-domesticated cattle in the region. Wild buffalo is restricted in the lower reaches downstream of Ranaghat areas adjoining D'Ering Memorial Wildlife sanctuary while Goral, Barking deer, Serow, Hog deer and Wild boar are distributed up to 1000 m elevation. Mishmi Takin and Musk deer are found in the high altitudes of the catchment; Takin inhabits the elevation range between 2100 m and 3000 m whereas Musk deer is found above 3000 m elevation range. All species of Artiodactyla are considered as game animals. The criterion used by Zoological Survey of India (ZSI) publication of 1994 for assessing nconservation status includes Musk deer and Wild boar under the 'Endangered' category and Serow as 'vulnerable'. Except Mithun all species have been scheduled (Table 6.37). Only Takin is considered as endemic to Eastern Himalaya.

6.5.2.5 *Lagomorpha*

Lagomorpha is represented by five species belonging to 2 families. Indian hare and Hispid hare are under Leporidae family. These inhabit scrubs forest and distributed from foothills to 1200 m. Hispid hare is a Schedule-I mammal while Indian hare is a game animal hunted by tribals for its skin. It is categorized under the Schedule IV. Family Ochotonidae is represented by 3 species *Ochotona roylei*, *O. thibetana* and *O. forresti*. All these are Least Concern species.

6.5.2.6 *Pholidota*

This Order is represented by 2 species i.e. Chinese pangolin and Indian pangolin which are reported from the lower reaches of the basin. Both species belong to the family Manidae. They are

found up to 300 m. Indian pangolin is locally ‘vulnerable’ species (ZSI, 1994) whereas Chinese pangolin has been placed under the Schedule I (WPA, 1972).

6.5.2.7 Rodentia

Rodentia is comprised of rats, porcupine, squirrels and shrews and is represented by 38 species belonging to 5 families. Rats are widely distributed and are quite common around the settlement areas. Indian porcupine is found up to 1000 m elevation and inhabits open areas. Squirrels (*Tamiops macClelland*, *Petaurista magnificus*, *Petaurista petaurista* and *Hylopetes alboniger*) and shrew (*Tupaia belangeri* and *Soriculus leucops*) inhabit dense forests. They are very common around the habitations. None of the rodent species is globally and locally threatened. Most of them have been placed under the Schedule V and considered as ‘vermin’ (pest). It is to be noted that *Petaurista mechukaensis* (Mechuka Giant Flying squirrel) is new species that has been reported from Mechuka area by Choudhury (2007).

6.5.2.8 Chiroptera

Order Chiroptera is represented by 39 species belonging to 7 families. All bat species are restricted to the lower reaches. They are nocturnal and invade citrus orchards in the region. They have been placed under the Schedule V.

6.5.2.9 Conservation Status

As there are large numbers of hydropower projects are planned in the basin and they are anticipated to have detrimental impacts on the wildlife, which are already under threat due to the customary hunting by tribes and shifting cultivation especially in Arunachal Pradesh. In order to understand the importance of conservation of wildlife vis-a-vis proposed development projects an assessment of their conservation status was made.

As already discussed in Section 5.6.2 the conservation status of the mammals reported from the basin was assessed based upon their listing in different lists published by agencies like ZSI, C.A.M.P., IUCN Red List of Threatened Species 2012.2 and different Schedules notified under Wildlife (Protection) Act, 1972 and the same has been given in **Table 6.38**.

There are 25 species of mammals of total 143 reported (about 18%) that have been included in Schedule-I according to WPA, 1972, 26 species in Schedule-II and 3 species in Schedule-III while rest of the species are either under Schedule-IV or V. According to IUCN Red List there are 8 species under Endangered category viz. *Uncia uncia*, *Panthera tigris*, *Manis pentadactyla*, *Prionailurus viverrinus*, *Cuon alpinus*, *Moschus chrysogaster*, *Caprolagus hispidus* and *Elephas maximus*. While first three species are found at higher elevations, *Caprolagus hispidus* (Hispid hare) and *Elephas maximus* are found only in D’Ering Memorial Wildlife Sanctuary in Siang basin. In addition there are 13 more species which are under Vulnerable category viz. *Nycticebus coucang*, *Neofelis nebulosa*, *Ursus thibetanus*, *Capricornis sumatraensis* and *Budorcas taxicolor*. In the assessment done by C.A.M.P. four species are under Endangered category which are *Panthera tigris*, *Uncia uncia*, *Caprolagus hispidus* and *Bubalus bubalis* while 4 are under Vulnerable category like *Panthera pardus*, *Nemorhaedus sumatraensis*, *Hystrix indica* and *Moschus chrysogaster*.

From Mechuka area recently a new species of squirrel has been discovered i.e. Mechuka Giant Flying squirrel (*Petaurista mechukaensis*).

Table 6.37: List of mammals reported from Siang basin compiled from secondary data

S.No.	Family	Name of species	Common Name	Conservation status		Distribution range (m)
				IUCN 3.1	WPA 1972	
ORDER: PHOLIDOTA						
	MANIDAE					
1		<i>Manis pentadactyla</i>	Chinese pangolin	EN	I	Up to 1500
2		<i>Manis crassicaudata</i>	Thick-tailed pangolin	NT	I	1100-2300
ORDER: INSECTIVORA						
	TALPIDAE					
3		<i>Talpa micrura</i>	Indian Short-taile	#	-	1000-3000
ORDER: SORICOMORPHA						
	SORICIDAE					
4		<i>Soriculus nigrescens</i>	Sikkim Large-clawed Shrew	LC	-	1500-4300
5		<i>Episoriculus caudatus</i>	Hodgson's Brown-toothed Shrew	LC	-	Below 1000
6		<i>Soriculus leucops</i>	Long-tailed Brown-toothed Shrew	LC	-	2900-3500
7		<i>Suncus murinus</i>	Asian house shrew	LC	-	-
8		<i>Suncus etruscus</i>	Etruscan shrew	LC	-	Up to 3000
9		<i>Crocidura attenuata</i>	Indochinese Shrew	LC	-	Up to 3000
10		<i>Anourosorex squamipes</i>	Mole shrew	LC	-	-
11		<i>Chimarrogale himalayica</i>	Himalayan water shrew	LC	-	800-1500
ORDER: SCANDENTIA						
	TUPAIIDAE					
12		<i>Tupaia belangeri</i>	Northern Treeshrew	LC	-	Up to 3000
ORDER: CHIROPTERA						
	PTEROPODIDAE					
13		<i>Pteropus giganteus</i>	Indian flying fox	LC	IV	Up to 2000
14		<i>Rousettus leschenaulti</i>	Leschenault's Rousette	LC	IV	Up to 1140
15		<i>Cynopterus sphinx</i>	Greater Shortnosed Fruit bat	LC	IV	Up to 400
16		<i>Cynopterus brachyotis</i>	Lesser short-nosed fruit bat	LC	IV	-
17		<i>Megaerops niphanae</i>	Ratanaworabhan's Fruit Bat	LC	-	100-2100

S.No.	Family	Name of species	Common Name	Conservation status		Distribution range (m)
				IUCN 3.1	WPA 1972	
18		<i>Eonycteris spelaea</i>	Dawn Bat	LC	IV	-
19		<i>Macroglossus sobrinus</i>	Long-tongued fruit bat	LC	IV	Up to 2000
	RHINOPOMATIDAE					
20		<i>Rhinopoma hardwickii</i>	Lesser mouse-tailed bats	LC	-	Up to 1100
	EMBALLONURIDAE					
21		<i>Taphozous longimanus</i>	Long-winged Tomb Bat	LC	-	Up to 1200
	MEGADERMATIDAE					
22		<i>Megaderma spasma</i>	Lesser false vampire bat,	LC	-	Up to 1600
23		<i>Megaderma lyra</i>	Greater False Vampire Bat	LC	-	1000
	RHINOLOPHIDAE					
24		<i>Rhinolophus trifolius</i>	Trefoil Horseshoe Bat	LC	-	Up to 1800
25		<i>Rhinolophus luctus</i>	Woolly Horseshoe Bat	LC	-	1600
26		<i>Rhinolophus pearsoni</i>	Pearson horseshoe bat	LC	-	610 -3070
27		<i>Rhinolophus yunanensis</i>	Dobson horseshoe bat	LC	-	Up to 1231
28		<i>Rhinolophus lepidus</i>	Blyth's Horseshoe Bat	LC	-	Up to 2330
29		<i>Rhinolophus pusillus</i>	Least Horseshoe Bat	LC	-	-
30		<i>Rhinolophus rouxii</i>	Rufous Horseshoe Bat	LC	-	Up to 1370
31		<i>Rhinolophus affinis</i>	Intermediate Horseshoe Bat	LC	-	290-2000
32		<i>Rhinolophus ferrumequinum</i>	Greater horseshoe bat	LC	-	800-3000
	HIPPOSIDERIDAE					
33		<i>Hipposideros pomona</i>	Andersen's Leaf-nosed Bat	LC	-	-
34		<i>Hipposideros fulvus</i>	Fulvus Leaf-nosed Bat	LC	-	Up to 2600
35		<i>Hipposideros cineraceus</i>	Least Leaf-nosed Bat	LC	-	62-1280
36		<i>Hipposideros galeritus</i>	Cantor's Leaf-nosed Bat	LC	-	Up to 1100
37		<i>Hipposideros armiger</i>	Great Himalayan Leaf-nosed Bat	LC	-	1000-2000
38		<i>Hipposideros larvatus</i>	Horsfield's Leaf-nosed Bat	LC	-	-
	VESPERTILIONIDAE					
39		<i>Myotis formosus</i>	Hodgson's bat	LC	-	Up to 3000

S.No.	Family	Name of species	Common Name	Conservation status		Distribution range (m)
				IUCN 3.1	WPA 1972	
40		<i>Scotomanes ornatus</i>	Harlequin bat	LC	-	Up to 1400
41		<i>Scotophilus kuhlii</i>	Lesser Asiatic Yellow House Bat	LC	-	Up to 1110
42		<i>Scotophilus heathii</i>	Greater Asiatic Yellow House Bat	LC	-	Up to 1500
43		<i>Plecotus auritus</i>	Brown long-eared bat	LC	-	1900-2300
44		<i>Eptesicus serotinus</i>	serotine bat	LC	-	Up to 1440
45		<i>Pipistrellus paterculus</i>	Mount Popa pipistrelle	LC	-	Up to 1500
46		<i>Pipistrellus tenuis</i>	Least pipistrelle	LC	-	Up to 800
47		<i>Pipistrellus coromandra</i>	Coromandel Pipistrelle	LC	-	Up to 1000-2700
48		<i>Pipistrellus kuhlii</i>	Kuhl's pipistrelle	LC	-	Up to 2000
49		<i>Murina tubinaris</i>	Scully's Tube-Nosed Bat	LC	-	Up to 1200-2600
50		<i>Kerivoula picta</i>	Painted Bat	LC	-	Up to 1500
51		<i>Kerivoula hardwickii</i>	Hardwicke's Woolly Bat	LC	-	60-2100
ORDER: PRIMATES						
	CERCOPITHECIDAE					
52		<i>Macaca assamensis</i>	Assamese macaque	NT	II	2000-6000
53		<i>Macaca mulatta</i>	Rhesus macaque	LC	II	Up to 4000
54		<i>Trachypithecus pileatus</i>	Capped langur	VU	I	100-2000
55		<i>Nycticebus coucang</i>	Slow loris	VU	I	-
	PRIONODONTIDAE					
56		<i>Prionodon pardicolor</i>	Spotted linsang	LC	I	150-2700
ORDER: CARNIVORA						
	AILURIDAE					
57		<i>Ailurus fulgens</i>	Red panda	VU	I	2800-3600
	CANIDAE					
58		<i>Canis aureus</i>	Golden jackal	LC	II	Up to 3800
59		<i>Canis lupus</i>	Gray wolf	LC	I	-
60		<i>Vulpes vulpes</i>	Red fox	LC	II	Up to 4500

S.No.	Family	Name of species	Common Name	Conservation status		Distribution range (m)
				IUCN 3.1	WPA 1972	
61		<i>Vulpes bengalensis</i>	Bengal fox	LC	II	-
62		<i>Cuon alpinus</i>	Dhole	EN	II	-
	URSIDAE					
63		<i>Melursus ursinus</i>	Sloth bear	VU	I	1500-2000
64		<i>Ursus thibetanus</i>	Asian Black Bear	VU	I	-
	MUSTELIDAE					
65		<i>Mustela kathiah</i>	Yellow-bellied weasel	LC	II	1800-4000
66		<i>Mustela strigidorsa</i>	Back-striped weasel	LC	-	Up to 2500
67		<i>Mustela sibirica</i>	Siberian weasel	LC	II	1500-4800
68		<i>Martes flavigula</i>	Yellow-throated marten	LC	II	Up to 3000
69		<i>Mellivora capensis</i>	Honey badger	LC	I	2600-4000
70		<i>Arctonyx collaris</i>	Hog badger	NT	I	Up to 3500
71		<i>Melogale moschata</i>	Chinese ferret-badger	LC	II	50- 2000
72		<i>Lutra lutra</i>	European otter	NT	II	1000-3600
73		<i>Lutrogale perspicillata</i>	Smooth-coated otter	VU	II	-
74		<i>Aonyx cinerea</i>	Oriental small-clawed otter	VU	-	-
	VIVERRIDAE					
75		<i>Viverra zibetha</i>	Large Indian civet	NT	II	Up to 1600
76		<i>Viverricula indica</i>	Small Indian civet	LC	II	-
77		<i>Paradoxurus hermaphroditus</i>	Asian palm civet	LC	II	Up to 2400
78		<i>Paguma larvata</i>	Masked palm civet	LC	II	Up to 2500
79		<i>Arctictis binturong</i>	Binturong	VU	I	Up to 1100
80		<i>Arctogalidia trivirgata</i>	Small-toothed palm civet	LC	II	Up to 1500
	HERPESTIDAE					
81		<i>Herpestes edwardsii</i>	Indian grey mongoose	LC	II	Up to 1500
82		<i>Herpestes urva</i>	Crab-eating mongoose	LC	II	Up to 1200
	FELIDAE					
83		<i>Felis chaus</i>	Jungle cat	LC	II	1000-2400

S.No.	Family	Name of species	Common Name	Conservation status		Distribution range (m)
				IUCN 3.1	WPA 1972	
84		<i>Prionailurus bengalensis</i>	Leopard cat	LC	I	Up to 3000
85		<i>Prionailurus viverrinus</i>	Fishing cat	EN	I	Up to 1525
86		<i>Catopuma temminckii</i>	Asian golden cat	NT	I	Up to 3800
87		<i>Pardofelis marmorata</i>	Marbled cat	VU	I	-
88		<i>Neofelis nebulosa</i>	Clouded leopard	VU	I	2500-3000
89		<i>Panthera pardus</i>	Leopard	NT	I	Up to 4000
90		<i>Panthera tigris</i>	Tiger	EN	I	Up to 4000
91		<i>Uncia uncia</i>	Snow leopard	EN	I	3000-4500
ORDER: PROBOSCIDEA						
	ELEPHANTIDAE					
92		<i>Elephas maximus</i>	Asiatic elephant	EN	I	Up to 3000
ORDER: ARTIODACTYLA						
	SUIDAE					
93		<i>Sus scrofa</i>	Wild boar	LC	III	Up to 2400
	CERVIDAE					
94		<i>Cervus unicolor</i>	Sambar deer	VU	III	2000-3000
95		<i>Muntiacus muntjak</i>	Common muntjac	LC	III	Up to 800
	MOSCHIDAE					
96		<i>Moschus chrysogaster</i>	Alpine Musk Deer	EN	I	2000-5000
	BOVIDAE					
97		<i>Naemorhedus goral</i>	Himalayan goral	NT	III	900-2700
98		<i>Budorcas taxicolor</i>	Mishmi Takin	VU	I	1500-4000
99		<i>Capricornis sumatraensis</i>	Serow	VU	I	200-3000
100		<i>Bos frontalis</i>	Mithun	-	-	
ORDER: RODENTIA						
	SCIURIDAE					
101		<i>Ratufa bicolor</i>	Black giant squirrel	NT	II	500-2500
102		<i>Callosciurus erythraeus</i>	Pallas squirrel	LC	-	Above 3000

S.No.	Family	Name of species	Common Name	Conservation status		Distribution range (m)
				IUCN 3.1	WPA 1972	
103		<i>Callosciurus pygerythrus</i>	Hoary-bellied Squirrel	LC	-	500-1560
104		<i>Tamias maccllellandi</i>	Himalayan striped squirrel	LC	-	Up to 1500
105		<i>Dremomys rufigenis</i>	Asian Red-cheeked Squirrel	LC	-	Up to 1500
106		<i>Petaurista petaurista</i>	Red Giant Flying Squirrel	LC	-	500-3100
107		<i>Petaurista candidatus</i>	Flying squirrel	#	-	
108		<i>Petaurista elegans</i>	Spotted Giant Flying Squirrel	LC	-	3000-4000
109		<i>Pteromys magnificus</i>	Hodgson's Flying Squirrel	#	II	
110		<i>Petaurista mechukaensis</i>	Mechuka Giant Flying squirrel			
111		<i>Belomys pearsonii</i>	Hairy-footed flying squirrel	Data Deficient	II	
		<i>Hylopetes alboniger</i>	Particolored Flying Squirrel	LC	II	1500-3400
112	MURIDAE					
113		<i>Mus musculus</i>	House mouse	LC	IV	-
114		<i>Mus boodunga</i>	Little Indian field mouse	#	-	-
115		<i>Mus cookii</i>	Cook's mouse	LC	-	50-2500
116		<i>Mus cervicolor</i>	fawn-colored mouse	LC	-	Up to 2000
117		<i>Mus platythrix</i>	Flat-haired Mouse	LC	IV	Up to 2000
118		<i>Mus saxicola</i>	Rock-loving Mouse	LC	-	Up to 1000
119		<i>Mus pahari</i>	Gairdner's Shrewmouse	LC	-	200-2000
120		<i>Vandeleuria oleracea</i>	Asiatic long-tailed climbing mouse	LC	-	200-1500
121		<i>Rattus rattus</i>	Black rat	LC	IV	-
122		<i>Rattus nitidus</i>	Himalayan Field Rat	LC	IV	700-2700
123		<i>Rattus turkestanicus</i>	Turkestan Rat	LC	-	1200-4250
124		<i>Golunda ellioti</i>	Gulandi Bush Rats	LC	IV	-
125		<i>Bandicota indica</i>	Greater Bandicoot Rat	LC	V	Up to 1500
126		<i>Bandicota bengalensis</i>	Indian mole-rat	LC	IV	Up to 3500
127		<i>Micromys minutus</i>	Harvest mouse	LC	-	Up to 1700
128		<i>Apodemus sylvaticus</i>	Wood mouse	LC	-	-
129		<i>Dacnomys millardi</i>	Millard's Rat	Data	-	-

S.No.	Family	Name of species	Common Name	Conservation status		Distribution range (m)
				IUCN 3.1	WPA 1972	
				Deficient		
130		<i>Niviventer niviventer</i>	Anderson's white-bellied rat	LC	IV	Up to 3600
131		<i>Niviventer tenaster</i>	Tenasserim White-bellied Rat	LC	-	1300-2200
132		<i>Niviventer fulvescens</i>	Chestnut White-bellied Rat	LC	-	Up to 2200
133		<i>Niviventer brahma</i>	Brahma White-bellied Rat	LC	-	2000-2800
134		<i>Niviventer eha</i>	Smoke-bellied Rat	LC	-	2000-3700
	CRICETIDAE					
135		<i>Microtus sikimensis</i>	Sikkim Vole	LC	-	2100-2700
	SPALACIDAE					
136		<i>Cannomys badius</i>	Lesser bamboo rat	LC	-	Up to 4000
137	HYSTRICIDAE					
138		<i>Hystrix brachyura</i>	Himalayan porcupine	LC	II	Up to 1300
		<i>Atherurus macrourus</i>	Asiatic Brush-tailed Porcupine	LC	II	Up to 750
ORDER: LAGOMORPHA						
	LEPORIDAE					
139		<i>Lepus nigricollis</i>	Indian hare	LC	IV	500-4500
140		<i>Caprolagus hispidus</i>	Hispid hare	EN	I	100-250
	OCHOTONIDAE					
141		<i>Ochotona roylei</i>	Royle's Pika	LC	IV	2400-4300
142		<i>Ochotona thibetana</i>	Moupin Pika	LC	-	2400-4100
143		<i>Ochotona forresti</i>	Forrest's Pika	LC	-	2600-4400

ZSI : EN = Endangered; VU = Vulnerable; IK = Insufficiently Known

IUCN ver. 3.1 : CR = Critically Endangered; EN = Endangered; VU = Vulnerable; LC = Least Concern, NT = Near Threatened,

CAMP : EN = Endangered; VU = Vulnerable; LRnt = Low Risk near threatened; LRlc = Low Risk least concern

6.5.3 Avi-fauna

Arunachal Pradesh harbours a high richness of avian fauna. More than 700 species of birds are known to occur in Arunachal Pradesh (Choudhury, 2004; ZSI, 2006). Bird Life International (www.birdlife.org) has identified 28 Important Birding Areas (IBA) in the state. Siang basin too is a good representative of avian diversity harbouring more than 400 species of birds. Five Birding areas have been identified in Siang basin by IBA (see Table 6.38). International Birding Areas are achieved through the application of quantitative ornithological criteria, grounded in up-to-date knowledge of the sizes and trends of bird populations. The Global criteria are as follows:

A1. Globally threatened species

Criterion: The site is known or thought regularly to hold significant numbers of a globally threatened species, or other species of global conservation concern.

A2. Restricted-range species

Criterion: The site is known or thought to hold a significant component of a group of species whose breeding distributions define an Endemic Bird Area (EBA) or Secondary Area (SA).

A4. Congregations

Criteria: A site may qualify on any one or more of the four criteria listed below:

- i) Site known or thought to hold, on a regular basis, $\geq 1\%$ of a biogeographic population of a congregatory waterbird species.

Table 6.38: Important Birding areas in Siang basin

IBA Code	IBA Site name	IBA Criteria
IN-AR-03	D'Ering Memorial Wildlife Sanctuary	A1, A2, A4i
IN-AR-04	Dibang Reserve Forest and adjacent areas	A1, A2
IN-AR-13	Mechuka-Monigong-Jorgging	A1, A2
IN-AR-15	Mouling National Park	A1, A2
IN-AR-27	Yordi-Rabe Supse Wildlife Sanctuary	A1

The avifauna in Siang basin is comprised of eagles, pheasants, hoopoe, barbets, woodpeckers, hornbills, pigeons, doves, tits, flycatchers, bulbuls, thrushes, laughing thrushes, shrikes, redstarts, drongo, crow, wagtails, forktails, minivets, sunbirds, swallow, tree pies, etc.

For the compilation of checklist of birds found in the Siang basin the documents and published literature consulted are the Management Plans of Mouling National Park and D'Ering Memorial Wildlife Sanctuary and Forest Working Plans of Yingkiong, Along and Pasighat Forest Divisions. In addition published papers like Sen & Mukhopadhyay (1999), Newton (2002), Pawar and Birand (2001), Birdlife International (2001), Birand and Pawar (2004), Ringu (2002), Katti et al (1992), Naoroji & Sangha (2006), Sangha & Naoroji (2007), Singh (1994), Stattersfield et al (1998), and Choudhury (2008, 2010).

Based upon the information compiled from secondary sources as well field surveys 447 species of bird species belonging to 19 orders and 80 families inhabit Siang basin (Annexure-IV in Volume-II:DATA). Timaliidae with 48 species is the largest family in the basin followed by Muscicapidae with 37 species. More than 33% of the total number of bird species are widespread residents while as many as sparse residents (39%). The remaining species belong either to the sparse winter visitors or sparse summer visitors. For the correct scientific names of bird species and their classification is based upon avibase portal <http://avibase.bsc-eoc.org/avibase.jsp>.

However during the surveys only 102 species of birds could be sighted and the list of the same has been given at Table 6.39. An account the bird species sighted has been given below.

Family Phasianidae of Order Galliformes is represented by 13 species and families Upupiformes of Upupidae, Trogonidae of Trogoniformes, Tytonidae of Strigiformes, Pittidae of Passeriformes, Cinclidae of Gruiformes are represented by one species each i.e. Common hoopoe, Red headed Trogon, Grass Owl, Blue-naped Pitta and Brown Dipper. All these are under Least Concern category as per IUCN and under Schedule IV species (WPA, 1972). Families Picidae and Megalaimidae of Order Piciformes, and family Cerylidae of Coraciiformes, are represented by 2 species each i.e. Bay woodpecker, Lesser yellownape, Coppersmith barbet, Blue-throated barbet, Pied kingfisher and Common kingfisher. Both the species belong to Least Concern category.

Order Ciconiiformes is comprised of three families Accipitridae, Charadriidae and Phalacrocoracidae. Four birds sighted during the surveys are: *Pluvialis apricaria* - European golden plover, *Ictinaetus malayensis* - Black Eagle, *Accipiter nisus* - Eurasian (or Northern) Sparrowhawk and *Phalacrocorax niger* - Little Cormorant. Black eagle is a Schedule-I species as per WPA, 1972.

Order Passeriformes is represented by 25 families and Timaliidae is the largest family with 20 species. Other families are: Family Laniidae (2 species), Corvidae (two species), Dicruridae (one species), Campephagidae (3 species), Muscicapidae (9 species), Turdidae (4 species), Sturnidae (2 species), Sittidae (one species), Paridae (2 species), Hirundinidae (2 species), Pycnonotidae (8 species), Cisticolidae (2 species), Zosteropidae (one species), Phylloscopidae (5 species), Cettiidae (4 species), Nectariniidae (3 species), and families Passeridae, Chloropseidae, Eurylaimidae, Motacillidae, Fringillidae, Emberizidae and Stenostiridae with one species each. All these are Schedule IV species.

6.5.3.1 Conservation Status & Migration Pattern

Out of 447 bird species reported from Siang basin of which checklist was prepared as many as 31 species belong to Schedule-I as per Wildlife (Protection) Act, 1972 (see Volume-II :Data Volume). However no species is under Schedules -II & III whereas 373 species are under Schedule-IV. Prominent Schedule-I species are two species of hornbills i.e. Great Indian Hornbill, and Oriental Pied Hornbill. On the other hand 7 species of eagles are under Schedule-I and 7 other species of harriers, kites and buzzards belonging to the same family Accipitridae are under Schedule-I.

According to IUCN Red List ver 3.1 three species are under Critically Endangered category viz. Bengal Florican, Slender billed vulture and White-rumped vulture. Two species are under 'Endangered' category i.e. Baer's Pochard and Greater Adjutant. In addition 13 species have been listed under Vulnerable category.

Amongst the 102 species sighted during surveys 3 are Schedule I species as per WPA, 1972. These are Oriental pied hornbill, Black eagle and Eurasian sparrowhawk.

Out of 102 birds sighted 29 of them are widespread residents of Siang basin while 56 are sparse residents (Table 6.39).

Table 6.39: Avi-fauna recorded from Siang basin

S. No.	Order/ Family	Scientific Name	Common Name	IUCN 3.1	Schedule as per WPA 1972	Habit
	Order: Galliformes					
1	Phasianidae	<i>Gallus gallus</i>	Red Jungle fowl	LC	Schedule IV	R
	Order: Piciformes					
2	Picidae	<i>Blythipicus pyrrhotis</i>	Bay woodpecker			
3	Picidae	<i>Picus chlorolophus</i>	Lesser yellownape			
4	Megalaimidae	<i>Megalaima haemacephala</i>	Coppersmith Barbet	LC	Schedule IV	R
5	Megalaimidae	<i>Megalaima asiatica</i>	Blue-throated Barbet			
6	Bucerotidae	<i>Anthracoceros albirostris</i>	Oriental Pied Hornbill	LC	Schedule I	R
	Order: Upupiformes					
7	Upupidae	<i>Upupa epops</i>	Common Hoopoe	LC	#	RW
	Order: Coraciiformes					
8	Cerylidae	<i>Ceryle rudis</i>	Pied Kingfisher	LC	Schedule IV	R
9	Cerylidae	<i>Alcedo atthis</i>	Common Kingfisher			
	Order: Cuculiformes					
10	Cuculidae	<i>Eudynamys scolopacea</i>	Asian Koel	LC	Schedule IV	R
11	Cuculidae	<i>Centropus sinensis</i>	Greater coucal / Crow Pheasant	LC	Schedule IV	R
12	Cuculidae	<i>Cuculus micropterus</i>	Indian Cuckoo			
	Order: Strigiformes					
13	Strigidae	<i>Strix aluco</i>	Tawny Owl	LC	Schedule IV	r
14	Strigidae	<i>Otus spilocephalus</i>	Mountain Scops Owl	LC	Schedule IV	r
15	Strigidae	<i>Glaucidium brodiei</i>	Collared Owlet			
	Order: Columbiformes					
16	Columbidae	<i>Columba livia</i>	Blue Rock Pigeon	LC	Schedule IV	R
17	Columbidae	<i>Chalcophaps indica</i>	Emerald Dove	LC	Schedule IV	R
18	Columbidae	<i>Ducula aenea</i>	Green imperial pigeon	LC	Schedule IV	R
19	Columbidae	<i>Treron apicauda</i>	Pin tail green pigeon	LC	Schedule IV	r
	Order: Ciconiiformes					
20	Charadriidae	<i>Pluvialis apricaria</i>	European golden plover	LC	Schedule IV	V
21	Accipitridae	<i>Ictinaetus malayensis</i>	Black Eagle	LC	Schedule I	R

S. No.	Order/ Family	Scientific Name	Common Name	IUCN 3.1	Schedule as per WPA 1972	Habit
22	Accipitridae	<i>Accipiter nisus</i>	Eurasian (or Northern) Sparrowhawk	LC	Schedule I	RW
23	Phalacrocoracidae	<i>Phalacrocorax niger</i>	Little Cormorant	LC	Schedule IV	R
	Order: Passeriformes					
24	Laniidae	<i>Lanius tephronotus</i>	Grey backed shrike	LC	#	rW
25	Laniidae	<i>Lanius schach</i>	Long tailed shrike / Rufous-backed Shrike	LC	#	R
26	Corvidae	<i>Garrulus glandarius</i>	Eurasian jay	LC	Schedule IV	r
27	Corvidae	<i>Corvus macrorhynchos</i>	Jungle Crow	LC	Schedule IV	R
28	Dicruridae	<i>Dicrurus leucophaeus</i>	Ashy Drongo	LC	Schedule IV	R
29	Campephagidae	<i>Hemipus picatus</i>	Bar-winged Flycatcher-shrike	LC	Schedule IV	R
30	Campephagidae	<i>Pericrocotus solaris</i>	Grey-chinned Minivet	LC	Schedule IV	r
31	Campephagidae	<i>Pericrocotus brevirostris</i>	Short-billed Minivet	LC	Schedule IV	r
32	Muscicapidae	<i>Copsychus saularis</i>	Oriental Magpie Robin	LC	Schedule IV	R
33	Muscicapidae	<i>Cyornis rubeculoides</i>	Bluethroated Flycatcher	LC	Schedule IV	r
34	Muscicapidae	<i>Monticola rufiventris</i>	Chestnut-bellied rock Thrush	LC	Schedule IV	r
35	Muscicapidae	<i>Niltava grandis</i>	Large Niltava	LC	Schedule IV	r
36	Muscicapidae	<i>Cyornis unicolor</i>	Pale blue flycatcher	LC	Schedule IV	r
37	Muscicapidae	<i>Ficedula tricolor</i>	Slaty blue flycatcher	LC	Schedule IV	r
38	Muscicapidae	<i>Niltava macgrigoriae</i>	Small Niltava	LC	Schedule IV	r
39	Muscicapidae	<i>Rhyacornis fuliginosus</i>	Plumbeous Water Redstart	LC	Schedule IV	r
40	Muscicapidae	<i>Eumyias thalassina</i>	Verditer Flycatcher	LC	Schedule IV	r
41	Turdidae	<i>Turdus dissimilis</i>	Black breasted thrush	LC	Schedule IV	w
42	Turdidae	<i>Myophonus caeruleus</i>	Blue Whistling Thrush	LC	Schedule IV	NA
43	Turdidae	<i>Turdus boulboul</i>	Grey winged black bird	LC	Schedule IV	r
44	Turdidae	<i>Turdus albocinctus</i>	Whitecollared Blackbird	LC	Schedule IV	r
45	Sturnidae	<i>Acridotheres tristis</i>	Common myna / Indian myna	LC	Schedule IV	R
46	Sturnidae	<i>Gracula religiosa</i>	Hill Myna	LC	Schedule IV	R
47	Sittidae	<i>Sitta castanea</i>	Chestnut-bellied Nuthatch	LC	#	R
48	Paridae	<i>Parus monticolus</i>	Green backed tit	LC	Schedule IV	r
49	Paridae	<i>Melanochlora sultanea</i>	Sultan Tit	LC	Schedule IV	r
50	Hirundinidae	<i>Hirundo rustica</i>	Barn Swallow	LC	#	RW

S. No.	Order/ Family	Scientific Name	Common Name	IUCN 3.1	Schedule as per WPA 1972	Habit
51	Hirundinidae	<i>Delichon nipalensis</i>	Nepal House Martin	LC	#	r
52	Pycnonotidae	<i>Hemixos flavala</i>	Ashy Bulbul	LC	Schedule IV	r
53	Pycnonotidae	<i>Hypsipetes leucocephalus</i>	Black Bulbul	LC	Schedule IV	R
54	Pycnonotidae	<i>Pycnonotus cafer</i>	Red vented bulbul	LC	Schedule IV	R
55	Pycnonotidae	<i>Pycnonotus melanicterus</i>	Black-crested Bulbul	LC	Schedule IV	R
56	Pycnonotidae	<i>Pycnonotus leucogenys</i>	Himalayan Bulbul	LC	Schedule IV	r
57	Pycnonotidae	<i>Hypsipetes maclellandii</i>	Mountain Bulbul	LC	Schedule IV	NA
58	Pycnonotidae	<i>Pycnonotus striatus</i>	Striated Bulbul	LC	Schedule IV	r
59	Pycnonotidae	<i>Rhipidura albicollis</i>	White-throated Fantail Flycatcher	LC	Schedule IV	R
60	Cisticolidae	<i>Orthotomus sutorius</i>	Common Tailorbird	LC	Schedule IV	R
61	Cisticolidae	<i>Prinia hodgsonii</i>	Grey-breasted Prinia	LC	Schedule IV	R
62	Zosteropidae	<i>Zosterops palpebrosus</i>	Oriental White-eye Dove	LC	Schedule IV	R
63	Timaliidae	<i>Heterophasia picaoides</i>	Long-tailed Sibia	LC	Schedule IV	r
64	Timaliidae	<i>Heterophasia pulchella</i>	Beautiful Sibia	LC	Schedule IV	r
65	Timaliidae	<i>Yuhina nigrimenta</i>	Black-chinned Yuhina	LC	Schedule IV	r
66	Timaliidae	<i>Yuhina gularis</i>	Striped-throated Yuhina	LC	Schedule IV	r
67	Timaliidae	<i>Yuhina flavicollis</i>	Whiskered Yuhina	LC	Schedule IV	r
68	Timaliidae	<i>Pteruthius melanotis</i>	Black-eared Shrike Babbler	LC	Schedule IV	r
69	Timaliidae	<i>Alcippe nipalensis</i>	Nepal Fulvetta	LC	Schedule IV	r
70	Timaliidae	<i>Pellorneum ruficeps</i>	Puff-throated Babbler	LC	Schedule IV	R
71	Timaliidae	<i>Leiothrix argentauris</i>	Silver-eared Mesia	LC	Schedule IV	r
72	Timaliidae	<i>Leiothrix lutea</i>	Red billed leiothrix	LC	Schedule IV	r
73	Timaliidae	<i>Minla ignotincta</i>	Red-tailed Minla	LC	Schedule IV	r
74	Timaliidae	<i>Heterophasia annectens</i>	Rufous-backed Sibia	LC	Schedule IV	r
75	Timaliidae	<i>Pomatorhinus ferruginosus</i>	Coral-billed Scimitar Babbler	LC	Schedule IV	r
76	Timaliidae	<i>Stachyris chrysaea</i>	Golden Babbler	LC	Schedule IV	r
77	Timaliidae	<i>Garrulax pectoralis</i>	Greater Necklaced Laughing Thrush	LC	Schedule IV	r
78	Timaliidae	<i>Garrulax caeruleus</i>	Grey-sided laughingthrush	LC	Schedule IV	r
79	Timaliidae	<i>Stachyris nigriceps</i>	Grey-throated Babbler	LC	Schedule IV	r
80	Timaliidae	<i>Turdoides striatus</i>	Jungle Babbler	LC	Schedule IV	R

S. No.	Order/ Family	Scientific Name	Common Name	IUCN 3.1	Schedule as per WPA 1972	Habit
81	Timaliidae	<i>Alcippe castaneiceps</i>	Rufous-winged Fulvetta	LC	Schedule IV	r
82	Timaliidae	<i>Actinodura egertoni</i>	Rusty-fronted Barwing	LC	Schedule IV	r
83	Phylloscopidae	<i>Phylloscopus trochiloides</i>	Greenish Warbler	LC	Schedule IV	rW
84	Phylloscopidae	<i>Phylloscopus reguloides</i>	Blyth's Leaf Warbler	LC	Schedule IV	r
85	Phylloscopidae	<i>Seicercus xanthoschistos</i>	Grey-hooded Warbler	LC	Schedule IV	r
86	Phylloscopidae	<i>Seicercus poliogenys</i>	Grey cheeked warbler	LC	Schedule IV	r
87	Phylloscopidae	<i>Seicercus affinis</i>	White spectaclad warbler	LC	Schedule IV	r
88	Cettiidae	<i>Cettia fortipes</i>	Brownish Flanked Bush Warbler	LC	Schedule IV	r
89	Cettiidae	<i>Tesia cyaniventer</i>	Grey-bellied Tesia	LC	Schedule IV	r
90	Cettiidae	<i>Tesia olivea</i>	Slaty-bellied Tesia	LC	Schedule IV	r
91	Cettiidae	<i>Orthotomus cuculatus</i>	Mountain Tailorbird	LC	Schedule IV	r
92	Dicaeidae	<i>Dicaeum cruentatum</i>	Scarlet-backed Flowerpecker	LC	Schedule IV	r
93	Nectariniidae	<i>Aethopyga saturata</i>	Black-throated Sunbird	LC	Schedule IV	r
94	Nectariniidae	<i>Aethopyga nipalensis</i>	Green-tailed Sunbird	LC	Schedule IV	r
95	Nectariniidae	<i>Arachnothera magna</i>	Streaked Spider Hunter	LC	Schedule IV	r
96	Passeridae	<i>Passer montanus</i>	Eurasian Tree-Sparrow	LC	Schedule IV	R
97	Chloropseidae	<i>Chloropsis hardwickii</i>	Orange bellied leaf bird	LC	Schedule IV	R
98	Eurylaimidae	<i>Psarisomus dalhousiae</i>	Long-tailed Broadbill	LC	#	r
99	Motacillidae	<i>Motacilla alba</i>	White wagtail	LC	Schedule IV	rW
100	Stenostiridae	<i>Culicicapa ceylonensis</i>	Grey-headed Canary flycatcher	LC	Schedule IV	r
101	Fringillidae	<i>Haematospiza sipahi</i>	Scarlet Finch	LC	Schedule IV	r
102	Emberizidae	<i>Emberiza pusilla</i>	Little-Bunting	LC	Schedule IV	w

LC = Least concern, NT = Near Threatened, VU = Vulnerable, EN = Endangered, IK = Insufficiently Known; # Not listed

R = Widespread Resident, r = Sparse resident, W = Widespread winter visitor, w = Sparse winter visitors, s = sparse summer visitors; NA = No Information Available

6.5.4 Butterflies

The mountainous landscape and moist dense forest cover of Arunachal Pradesh provides conducive climatic conditions for the butterflies. The studies on the butterflies are limited in Arunachal Pradesh; viz. Evans (1912), Betts (1950) and Bhattacharya (1885) from Namdapha region. However, the entire state of Arunachal Pradesh harbours more than 600 species of butterflies. The richness of butterfly gradually decreases with increasing elevation. The surrounding area of different proposed projects falls in Sub-tropical zone. The density and diversity of butterflies is comparatively low at higher altitudes especially in Yargyap Chhu and upper Siyom catchment as compared to lower valleys of Siyom and Siang rivers. Based upon the data compiled from field surveys and secondary sources like published papers (Borang, 2008; Fleming, 2006; Fleming, 2006), Forest Working Plans, Management Plans of Protected areas, etc. a list of butterflies was prepared. According to it total of 111 species of butterflies are found in the basin. These species belong to six families - Papilionidae, Pieridae, Lycaenidae, Hesperidae, Nymphalidae and Riodinidae. Nymphalidae was most dominant family represented by 74 species. Of all the species 8 species, viz. Common rose (*Pachliopta aristolochia*), Common sailer (*Neptis hylas varmona*), Common grass yellow (*Eurema hecabe*) and Indian cabbage white (*Pieris canidia*) are abundantly found. They were recorded in large numbers from various sampling sites. Common earl (*Tanaecia julii appiades*), Blue duchess (*Euthalia duda*), Grey count (*Tanaecia lepidea lepidea*), Common maplet (*Chersonesia risa*), Redbase jezebel (*Delias aglaia*) are recorded quite regularly from different areas. Variegated sailor and Crimson rose are categorised as Schedule I species (WPA 1972). A check-list of species of butterflies found in the basin compiled through field surveys as well as published literature is given at Table 6.40.

Table 6.40: List of butterflies reported from Siang basin

S.No.	Scientific Name	Common Name
Family : Hesperidae		
1	<i>Polytremis discreta</i>	Himalayan Swift
2	<i>Coladenia indrani</i>	Tri color Pied Flat
3	<i>Matara aria</i>	Common Red Eye
4	<i>Spialia galba</i>	Indian Skipper
Family : Lycaenidae		
5	<i>Curetis dentate fortunatus</i>	Angle Sunbeam
6	<i>Heliophorus bramah</i>	Golden Sapphire
7	<i>Heliophorus epicles</i>	Purple Sailor
8	<i>Narathura fulla</i>	Spotless oak Blue
9	<i>Ticherra acte</i>	Blue Imperial
10	<i>Una usta</i>	Una
11	<i>Acytolepis puspa</i>	Common Hedge Blue
12	<i>Arhopala amantes</i>	Large oak Blue
13	<i>Heliophorus epicles</i>	Purple Sapphire
14	<i>Jamides alecto</i>	Metallic Cerulean
15	<i>Jamides bochus</i>	Dark Cerulean
16	<i>Nacaduba helicon</i>	Pointed line Blue
Family : Nymphalidae		
17	<i>Ahtyma zeroa</i>	Small Staff Sergeant
18	<i>Athyma perius perius</i>	Common Sergeant
19	<i>Charaxes marmax</i>	Yellow Rajah
20	<i>Cirrochroa aoris</i>	Large Yeoman

S.No.	Scientific Name	Common Name
21	<i>Cynthia cardui</i>	Painted Lady
22	<i>Danaus chrysippus</i>	Plain Tiger
23	<i>Danaus genutia</i>	Common Tiger
24	<i>Doleschallia bisaltide</i>	Autumn Leaf
25	<i>Euploea mulciber</i>	Striped Blue Crow
26	<i>Junonia iphita</i>	Chocolate Soldier
27	<i>Junonia almana</i>	Peacock Pansy
28	<i>Junonia hierta</i>	Yellow Pansy
29	<i>Junonia iphita</i>	Chocolate Pansy
30	<i>Kallima inachus</i>	Orange Oak leaf
31	<i>Lethe scanda</i>	Blue Forester
32	<i>Lethe sidonis</i>	Common Wood Brown
33	<i>Melanitis phedima</i>	Dark Evening Brown
34	<i>Mycalesis malsarida</i>	Plain Bush Brown
35	<i>Mycalesis mestra vetus</i>	White-Edged Bush Brown
36	<i>Mycalesis visala</i>	Long-Brand Bush Brown
37	<i>Neptis cartica</i>	Plain Sailor
38	<i>Neptis magadha Khasiana</i>	Spotted Sailor
39	<i>Neptis soma</i>	Sullied Sailor
40	<i>Parantica aglea</i>	Glassy Tiger
41	<i>Parantica sita</i>	Chestnut Tiger
42	<i>Parthenos sylvia</i>	Clipper
43	<i>Pseudergolis wedah</i>	Tabby
44	<i>Ragdia crisilda crito</i>	Striped Ringlet
45	<i>Symbrenthia hypselis</i>	Himalayan Jester
46	<i>Tirumala septentrionis</i>	Dark Blue Tiger
47	<i>Ypthima asterope mahratta</i>	Common Three Ring
48	<i>Ypthima philomela</i>	Baby Five Ring
49	<i>Argynnis hyperbius</i>	Indian Fritillary
50	<i>Athyma cama</i>	Orange staff Sergeant
51	<i>Cethosia biblis</i>	Red Lacewing
52	<i>Cethosia cyane</i>	Leopard Lacewing
53	<i>Chersonesia risa</i>	Common Maplet
54	<i>Cirrochroa tyche</i>	Common yeoman
55	<i>Cyrestis thyodamas</i>	Common Mapwing
56	<i>Junonia lemonias</i>	Lemon Pansy
57	<i>Kallima inachus</i>	Orange Oak Leaf
58	<i>Lethe mekara</i>	Common Red Forester
59	<i>Lethe rohria</i>	Himalayan Common tree Brown
60	<i>Limenitis danava</i>	Commodore
61	<i>Melanitis leda</i>	Common Evening Brown
62	<i>Neptis hylas</i>	Common Sailor
63	<i>Pantoporia hordonia</i>	Common Lascar
64	<i>Parantica aglea</i>	Grassy Tiger
65	<i>Phalanta phalantha</i>	Common Leopard
66	<i>Polyura athamas</i>	Common Nawab
67	<i>Precis atlites</i>	Grey Pansy

S.No.	Scientific Name	Common Name
68	<i>Symbrenthia lilaea</i>	Common Jester
69	<i>Tanaecia lepeidea</i>	Grey Count
70	<i>Vanessa indica</i>	Indian red Admiral
71	<i>Ypthima asterope</i>	Common three Ring
72	<i>Ypthima huebneri</i>	Common four Ring
73	<i>Ypthima sacra</i>	Himalayan five Ring
Family : Papilionidae		
74	<i>Atrophaneura dasarada</i>	Great Windmill
75	<i>Atrophaneura polyeuctes</i>	Common Windmill
76	<i>Atrophaneura varuna</i>	Common bird Wing
77	<i>Chilasa clytia</i>	Common Mime
78	<i>Euploea core</i>	Common Crow
79	<i>Graphium sarpedon</i>	Common Blue Bottle
80	<i>Junonia almanac</i>	Peacock Pansy
81	<i>Lamproptera curius</i>	White Dragon Tail
82	<i>Pachliopta aristolochiae</i>	Common Rose
83	<i>Pachliopta hector</i>	Crimson Rose
84	<i>Papilio arcturus</i>	Blue Peacock
85	<i>Papilio castor</i>	Common Raven
86	<i>Papilio memnon</i>	Great Mormon
87	<i>Papilio nephelus chaon</i>	Yellow Helen
88	<i>Papilio polytes</i>	Common Mormon
89	<i>Paranticopsis xenocles</i>	Great Zebra
90	<i>Princeps demoleus</i>	Lime Butterfly
Family : Pieridae		
91	<i>Aporia agathon</i>	Great black Vein
92	<i>Appias lalage</i>	Spot Puffin
93	<i>Appias lyncida</i>	Chocolate Albatross
94	<i>Artogeia napi Montana</i>	Green-Vein White
95	<i>Catopsilla Pomona</i>	Common Emigrant
96	<i>Cepora nadina</i>	Lesser Gull
97	<i>Delias acalis</i>	Red Breast Jezebel
98	<i>Delias belladonna</i>	Hill Jezebel
99	<i>Eurema blanda</i>	Three Spot Grass Yellow
100	<i>Eurema hecabe</i>	Common grass Yellow
101	<i>Gandaca harina</i>	Tree Yellow
102	<i>Hebomoia glaucippe</i>	Great Orange Tip
103	<i>Ixias pyrene</i>	Yellow orange Tip
104	<i>Leptocia nina</i>	Psyche
105	<i>Peiris brassicae</i>	Large Cabbage White
106	<i>Pieris canidia</i>	Indian cabbage White
107	<i>Pieris melaina</i>	Green Vein
108	<i>Prioneris thestylis</i>	Spotted saw Tooth
Family : Riodinidae		
109	<i>Dodona adonira</i>	Striped Punch
110	<i>Dodona eugenes venox</i>	Tailed Punch
111	<i>Zemeros flegyas</i>	Punchinello

6.5.5 Herpetofauna

Herpetofauna comprise of amphibians that include frogs, toads, newts, salamanders, etc. and reptiles which include snakes, lizards, turtles, terrapins, tortoises, etc. An inventory of herpetofauna comprising reptiles and amphibians was prepared from the Forest Working Plans, management plans of Protected Area and published literature (Kato & Gopi, 2009; ENVIS, 2011; Tamang & Choudhry, 2012; Chakravorty *et al.* 2011; Purkayastha *et al.* 2010) and the same is given at **Table 6.41**. Total 116 species are reported from the Siang basin of which 31 species are of amphibians and 85 species are of reptiles.

6.5.5.1 Reptiles

Reptilian fauna is comprised of 85 species belonging to 14 families. Colubridae is the largest family represented by 41 species followed by Viperidae with 13 species. Sun skink, Forest skink, Khasi lizard, house lizard, common krait, Indian monitor, pit viper, rat snake are most common in the basin. Python and Indian monitor lizard have been categorized as 'endangered' species (ZSI, 1994) (**Table 6.41**). Indian egg-eating snake (*Elachistodon westermanni*) and Yellow monitor lizard (*Varanus flavescens*) are the Schedule I species while Common Asian monitor (*Varanus bengalensis*), Water monitor (*Varanus salvator*), Rat snake (*Ptyas mucosus*), Russels' viper (*Vipera russelli*), Monocellate cobra (*Naja kaouthia*), Cobra (*Naja naja*) and King cobra (*Ophiophagus hannah*) are categorized as Schedule II species. IUCN Red List has kept Assam roofed terrapin (*Pangshura sylhetensis*) under Endangered category while King cobra (*Ophiophagus hannah*), Southeast Asian box turtle (*Cuora amboinensis*) and Spotted pond turtle (*Geoclemys hamiltonii*) have been kept under Vulnerable category.

6.5.5.2 Amphibia

Amphibians play a pivotal role in ecosystem as secondary consumers in many food chains. Tadpoles have significant impact in nutritional cycling. They are herbivorous to omnivorous and are the prey items for both invertebrates and vertebrates. Adult amphibians are the best biological pest controllers. Invertebrates and vertebrates also predate upon them. Owing to their importance in ecosystem, decline or extinction of their population has significant impact on other organisms along with them.

From the ecological perspective, amphibians are regarded as good ecological indicators. Due to high degree of sensitivity, either during tadpole stage or as adults, they respond to very slight change in the environment. Such responses have been used to indicate habitat fragmentation, ecosystem stress, impact of pesticides, and various anthropogenic activities.

In many parts of the world, frog population has been declining due to habitat destruction during development and the damming of rivers and streams.

From the Siang basin 31 species of Amphibians are reported which belong to 4 families, which comprises of toads and frogs. Ranidae is the largest family with 14 species followed by Rhacophoridae with 8 species. *Rana* spp. and *Bufo melanostictus* are very common in the basin (see **Table 6.41**). There is only one species of frog i.e. Pied tree frog (*Theloderma moloch*) which falls in IUCN Red List Vulnerable category and is known from very few locations found between 300 and 1500m while two species viz. Tuberculate tree frog (*Rhacophorus tuberculatus*) and Large toad (*Xenophrys robusta*) has been kept in Data Deficient category while rest all of the species are under Least Concern category. Tuberculate tree frog is known from bamboo forests, where it hides in the stems of the bamboo during the day.

Table 6.41: List of herepetofauna reported from Siang basin

S. No.	Family/ Common name	Scientific name	Conservation Status	
			IUCN Red List	WPA, 1972
Reptiles				
	Agamidae			
1	Montane green calotes	<i>Calotes jerdoni</i>	#	#
2	Roux's Forest calotes	<i>Calotes rouxi</i>	#	#
3	Southern flying lizard draco	<i>Draco dussumieri</i>	#	#
4	Spotted flying draco	<i>Draco maculatus</i>	#	#
5	Anderson's mountain lizard	<i>Japalura andersoniana</i>	#	#
6	Small forest lizard	<i>Oriocalotes paulus</i>	#	#
	Gekkonidae			
7	Spiny-tailed House gecko	<i>Cyrtodactylus khasiensis</i>	#	#
8	Indo-Myanmarese bent-toed gecko	<i>Ptyctolaemus gularis</i>	#	#
9	Brook's house gecko	<i>Hemidactylus brookii</i>	#	#
10	Asian flat-footed gecko	<i>Hemidactylus frenatus</i>	#	#
11	Flat tailed house gecko	<i>Cosymbotus platyurus</i>	#	#
	Lacertidae		#	#
12	Asian grass lizard	<i>Takydromus sexlineatus</i>	#	#
	Scinidae		#	#
13	Sikkim sun skink	<i>Scinella sikimmensis</i>	#	#
14	Indo-Myanmarese pigmy forest skink	<i>Sphenomorphus courcyanum</i>	#	#
15	Large forest skink	<i>Sphenomorphus indicum</i>	#	#
16	Streamside forest skink	<i>Sphenomorphus maculatus</i>	#	#
17	Speckled little skink	<i>Mabuya macularia macularia</i>	#	#
	Varanidae			
18	Common Asian monitor	<i>Varanus bengalensis</i>	#	II
19	Yellow monitor lizard	<i>Varanus flavescens</i>	#	I
20	Water monitor	<i>Varanus salvator</i>	#	II
	Colubridae			
21	Asian vine snake	<i>Ahaetulla prasina</i>	#	#
22	Khasi hills keelback	<i>Amphiesma khasiensis</i>	#	#
23	Himalayan keelback	<i>Amphiesma platyceps</i>	#	#
24	Buff stripped Keelback	<i>Amphiesma stolatum</i>	#	#
25	Banded racer	<i>Argyrogena fasciolata</i>	#	#
26	Blyth's reticulated snake	<i>Blythia reticulata</i>	#	#
27	Large spotted Cat Snake	<i>Boiga multomaculata</i>	#	#
28	Common cat snake	<i>Boiga trigonata</i>	#	#
29	Golden tree snake	<i>Chrysopelea ornata</i>	#	#
30	Painted bronze back	<i>Dendrelaphis pictus</i>	#	#
31	Indo-chinese bronze back	<i>Dendrelaphis gorei</i>	#	#
32	Bronze backed tree snake	<i>Dendrelaphis tristis</i>	#	#
33	Indian egg-eating snake	<i>Elachistodon westermanni</i>	#	I

S. No.	Family/ Common name	Scientific name	Conservation Status	
			IUCN Red List	WPA, 1972
34	Common water snake	<i>Enhydryis enhydryis</i>	#	#
35	Common Wolf snake	<i>Lycodon aulicus</i>	#	#
36	Yellow banded Wolf snake	<i>Lycodon fasciatus</i>	#	#
37	Green keelback	<i>Macropisthodon plumbicolor</i>	#	#
38	Almeida whip-snake	<i>Masticophis lateralis</i>	#	#
39	Common Kukri snake	<i>Oligodon arnensis</i>	#	#
40	Burmese Glass snake	<i>Ophisaurus gracilis</i>	#	#
41	Common mock viper	<i>Psammodynastes pulverulentus</i>	#	#
42	Large eyed bamboo snake	<i>Pseudoxenodon macrops</i>	#	#
43	Indo-chinese rat snake	<i>Ptyas korros</i>	#	#
44	Common rat snake	<i>Ptyas mucosus</i>	#	II
45	Blind snake	<i>Ramphotyphlops braminus</i>	#	#
46	Yellow bellied forest snake	<i>Rhabdophis bicolor</i>	#	#
47	Collard keelback	<i>Rhabdophis himalayanus</i>	#	#
48	Collard black-headed snake	<i>Sibynophis collaris</i>	#	#
49	Checkered keelback	<i>Xenochrophis piscator</i>	#	#
50	Green rat snake	<i>Zcocys nigromavginaka</i>	#	#
	Elapidae			
51	Banded krait	<i>Bungarus fasciatus</i>	#	#
52	Common krait	<i>Bungarus niger</i>	#	#
53	Trinket snake	<i>Elaphe helena</i>	#	#
54	Mandarin racer	<i>Elaphe mandarina</i>	#	#
55	Red mountain racer	<i>Elaphe porphyracea</i>	#	#
56	Copper head	<i>Elaphe radiata</i>	#	#
57	Stripe-tailed racer	<i>Elaphe taeniura</i>	#	#
58	Monocellate cobra	<i>Naja kaouthia</i>	#	II
59	Cobra	<i>Naja naja</i>	VU	II
60	King cobra	<i>Ophiophagus hannah</i>	#	II
61	McClelland's coral snake	<i>Calliophis macClellandi</i>	#	#
	Viperidae			
62	Saw scaled Viper	<i>Echis carinatus</i>	#	#
63	Himalayan Pit Viper	<i>Gloydius himalayanus</i>	#	#
64	Jerdon's pit viper	<i>Protobothrops jerdoni</i>	#	#
65	Brown-spotted pit viper	<i>Protobothrops mucrosquamatus</i>	#	#
66	Common Bamboo Viper	<i>Trimeresurus gramineus</i>	#	#
67	Russels' viper	<i>Vipera ruselli</i>	#	II
68	Oriental Stripneck	<i>Liopeltis frenatus</i>	#	#
69	Speckled wolfsnake	<i>Liopeltis jara</i>	#	#
70	Mountain worm-eating snake	<i>Trachischium monticola</i>	#	#
71	Banded kukri	<i>Oligodon albocinctus</i>	#	#
72	Abor hills kukri snake	<i>Oligodon melanozonatus</i>	#	#

S. No.	Family/ Common name	Scientific name	Conservation Status	
			IUCN Red List	WPA, 1972
73	Montane snail eater	<i>Pareas monticola</i>	#	#
74	Montane pit viper	<i>Ovophis monticola</i>	#	#
	Emydidae			
75	Black turtle	<i>Melanochelys trijuga</i>	#	#
	Boidae			
76	Earth boa	<i>Eryx johnii</i>	#	#
77	Python	<i>Python molurus</i>	NT	#
78	Reticulated python	<i>Python reticulatus</i>	#	#
	Geoemydidae			
79	Assam roofed terrapin	<i>Pangshura sylhetensis</i>	EN	#
80	Indian roofed turtle	<i>Pangshura tecta</i>	LR	#
81	Southeast Asian box turtle	<i>Cuora amboinensis</i>	VU	#
82	Spotted pond turtle	<i>Geoclemys hamiltonii</i>	VU	#
	Chamaeleonidae			
83	Indian chameleon	<i>Chamaeleo zeylanicus</i>	#	#
	Ichthyophiidae		#	#
84	Beddome's Ichthyophis	<i>Ichthyophis beddomei</i>	#	#
	Salamandridae		#	#
85	Himalayan newt	<i>Tylototriton verrucosus</i>	#	#
Amphibians				
	Bufonidae		#	#
1	Common toad	<i>Bufo bufo</i>	#	#
2	Himalayan toad	<i>Bufo himalayanas</i>	#	#
3	Common oriental toad	<i>Bufo melanostictus</i>	#	#
	Ranidae		#	#
4	Meghalaya stream frog	<i>Amolops afghanus</i>	#	#
5	Long-fingered tree frog	<i>Amolops formosus</i>	LC	#
6	Tree frog	<i>Amolops gerbillus</i>	LC	#
7	Common amolops	<i>Amolops marmoratus</i>	LC	#
8	Green spotted amolops	<i>Amolops cf. viridimaculatus</i>	#	#
9	Daniel's oriental stream frog	<i>Rana danielli</i>	#	#
10	Silver-lined paddy frog	<i>Rana erythraea</i>	#	#
11	Skittering frog	<i>Rana cyanophlyctis</i>	#	#
12	Cricket frog	<i>Rana limnocharis</i>	#	#
13	Nepal Cricket frog	<i>Fejervarya nepalensis</i>	LC	#
14	Asian Skitterer	<i>Euphlyctis cyanophlyctis</i>	LC	#
15	Bull frog	<i>Limnonectes limnocharis</i>	#	#
16	North-western trickle frog	<i>Occidozyga borealis</i>	#	#
17	Sikkim spiny frog	<i>Paa liebigii</i>	#	#
	Rhacophoridae			
18	Spotted tree frog	<i>Litoria spenceri</i>	LC	#

S. No.	Family/ Common name	Scientific name	Conservation Status	
			IUCN Red List	WPA, 1972
19	Lineated tree frog	<i>Polypedatus leucomystax himalayanus</i>	#	#
20	Spot-legged tree frog	<i>Polypedates megacephalus</i>	LC	#
21	Large green tree frog	<i>Rhacophorus maximus</i>	LC	#
22	Twin spotted tree frog	<i>Rhacophorus bipunctatus</i>	LC	#
23	Long nosed tree frog	<i>Rhacophorus naso</i>	#	#
24	Jerdon's Tree Frog	<i>Rhacophorus jerdonii</i>	#	#
25	Tuberculate tree frog	<i>Rhacophorus tuberculatus</i>	DD	#
26	Pied warty frog	<i>Theloderma asperum</i>	LC	#
27	Pied tree frog	<i>Theloderma moloch</i>	VU	#
28	Annandale's bush frog	<i>Raochestes annandalii</i> (= <i>Philautus annandalii</i>)	#	#
29	Bush frog	<i>Theloderma andersoni</i> (= <i>Philautus andersoni</i>)	#	#
	Megophryidae			
30	Boettgers toad	<i>Xenophrys boettgeri</i>	LC	#
31	Large toad	<i>Xenophrys robusta</i>	DD	#

LC = Least Concern, DD = Data Deficient, NT = Near Threatened, VU = Vulnerable, EN = Endangered, # Not listed

Species names and their classification followed as per <http://reptile-database.reptarium.cz/> for reptiles and <http://amphibiaweb.org/> for amphibians

6.5.5.3 Insects

All the entomofauna except butterflies sighted in this area during monsoon season were absent during the winter survey. This might be by the influence of chilly winter season weather which forces them to migrate and hibernate. Insects have a variety of methods for surviving the coldness of winter. Hibernation is a well known natural phenomenon among insects. In general, insects are able to survive cold temperatures easiest when the temperatures are stable, not fluctuating through alternate thaws and freezes. Many insects can gain shelter and nourishment through the winter in a variety of microhabitats. Among these niches are under the soil, inside the wood of logs and trees, and even in plant galls.

Overwintering into different stages larvae, nymphs, eggs, pupae, or as adults of insect life is very common. Many large wasps seek shelter in the eaves and attics of houses or barns. Tree holes, leaf litter, and under logs and rocks are common shelters for overwintering adult insects. Honeybees have been studied during the winter and are found to remain semi-active in hollow trees through the generation of body heat provided by the oxidation of honey. Only a few species especially Orthopterans migrate to lower elevation to survive the winter cold. List of insects reported from Siang basin prepared from secondary data is given at Table 6.42.

Table 6.42: List of insects reported from Siang basin

S.No.	Family	Common name	Scientific name
	Coccinellidae		
1.		Convergent lady beetle	<i>Hippodamia convergens</i>
2.		Nine Spotted Ladybird beetle	<i>Coccinella novemnotata</i>
3.		Green Head Ladybird beetle	<i>Coccinella septempunctata</i>

S.No.	Family	Common name	Scientific name
4.		Yellow Ladybird beetle	<i>Apolinus lividigaster</i>
	Derambycidae		
5.		Sleade Tree Long horn	
6.		Yellow Spotted Long horn	<i>Psacotheta hilaris</i>
7.		Red Spotted Long horn	<i>Batocera rufomaculata</i>
8.		Wasp like Long horn	<i>Clytus arietis</i>
9.		Hardwood Stump Borer	<i>Mallodon dasystemus</i>
10.		Tiger Spotted Flower Lepturine	<i>Leptalia macilenta</i>
	Meloidae		
11.		Fire blister beetle	<i>Epicauta stuarti</i>
12.		Striped Blister Beetle	<i>Epicauta vittata</i>
	Scarabaeidae		
13.		Large Clouded Scarab	
14.		Dung Roller beetle	<i>Copris fricator</i>
15.		Rain beetle	<i>Pleocoma minor</i>
16.		Beyer's Scarab	<i>Chrysina beyeri</i>
17.		Rhinoceros beetle	<i>Xylotrupes ulysses</i>
18.		Green June beetle	<i>Cotinis nitida</i>
	Buprestidae		
19.		Pied Click beetle	<i>Athous haemorroidalis</i>
20.		Black Click beetle	<i>Melanoactes puncticollis</i>
21.		Small eyed Click beetle	<i>Selatostomus cruciatus</i>
22.		Lantern Click beetle	
	Acrididae		
		Giant Grass hopper	<i>Valanga irregularis</i>
23.		Short winged toothpick Grass hopper	<i>Pseudopomala brachyptera</i>
	Tettigoniidae		
24.		Fork tailed brush Katydid	<i>Scudderia furcata</i>
25.		Board winged Katydid	<i>Microcentrum rhombifolium</i>
26.		Leaf insect	
	Phasmitidae		
27.		Giant walking stick	<i>Diapheromera femorata</i>
	Pentatomidae		
28.		Forest Bug	<i>Pentatoma rufipes</i> ,
	Vespidae		
29.		Asian giant hornet	<i>Vespa mendrinia</i>
30.		Greater banded hornet	<i>Vespa tropica</i>
31.		Common paper Wasp	<i>Polistes annularis</i>
32.		Eastern Paper nest Wasp	<i>Polistes humilis</i>
	Apidae		
33.		Black shield wasp	<i>Vespa bicolor</i>
	Curculionidae		
34.		Giant Bamboo Weevil	<i>Cyrtotrachelus buqueti</i>
	Belostomatidae		
35.		Giant water bug	<i>Belostoma indicus</i>
	Apidae		
36.		Indian honeybee	<i>Apis indica</i>
37.		Giant honey bee	<i>Apis dorsata</i>

Species names as per <http://www.insectclopedia.com/>

Insecta is the largest group, comprises of about more than 1000 species in Arunachal Pradesh. The important groups are Diptera, Coleoptera, Hymenoptera, Lepidoptera, Hemiptera, Odonata, Ephemeroptera, Plecoptera and Trichoptera. Lepidoptera is largest group followed by Diptera. The basin has a good share of insect diversity represented by 31 species (Table 6.42). *Chironomus* sp., *Simulium* spp., *Limonia* spp., *Gonomyia* spp., *Conosia irrorata* are important Dipteran species in the basin. Hymenoptera in the basin comprises of bees, wasps, ants and spiders. *Apis* spp., *Pachycondyla* spp., *Tiphia* spp., *Camponotus* spp., *Solenopsis geminata*, *Ampules* spp. are the common Hymenopterans of the basin. Coleoptera are mainly represented by *Epilachna bipunctata* and *Acanthosese decipiens*. *Heptagenia* spp., *Ephemerella* spp. and *Baetis* spp. account for major share in Ephemeroptera. *Perla* sp. and *Hydropsyche* sp. are main species of Plecoptera and Trichoptera in Siang basin.

6.5.6 Other Invertebrates

Among the parasitic protozoans *Trypanosoma rotatorium* and *Opalina lata* are very restricted in distribution, however, they are not found in Siang. *Giardia lamblia*, *Plasmodium vivax* and *P. falciparum* are most common species, occur throughout Arunachal Pradesh. Crustacean fauna in the region comprises of Potamonids (crabs) only. Crabs are widely distributed, found in larger part of surroundings. They are represented by *Carcinus* sp. and *Portunus* sp. Annelids in the region comprise of leeches and earthworms. The common leech species in the basin are *Haemadipsa montana*, *H. sylvestris* and *H. montivindicus* (Mandal, 2006). In addition, there are many species of earthworms having ethno - zoological importance.

6.6 PROTECTED AREAS

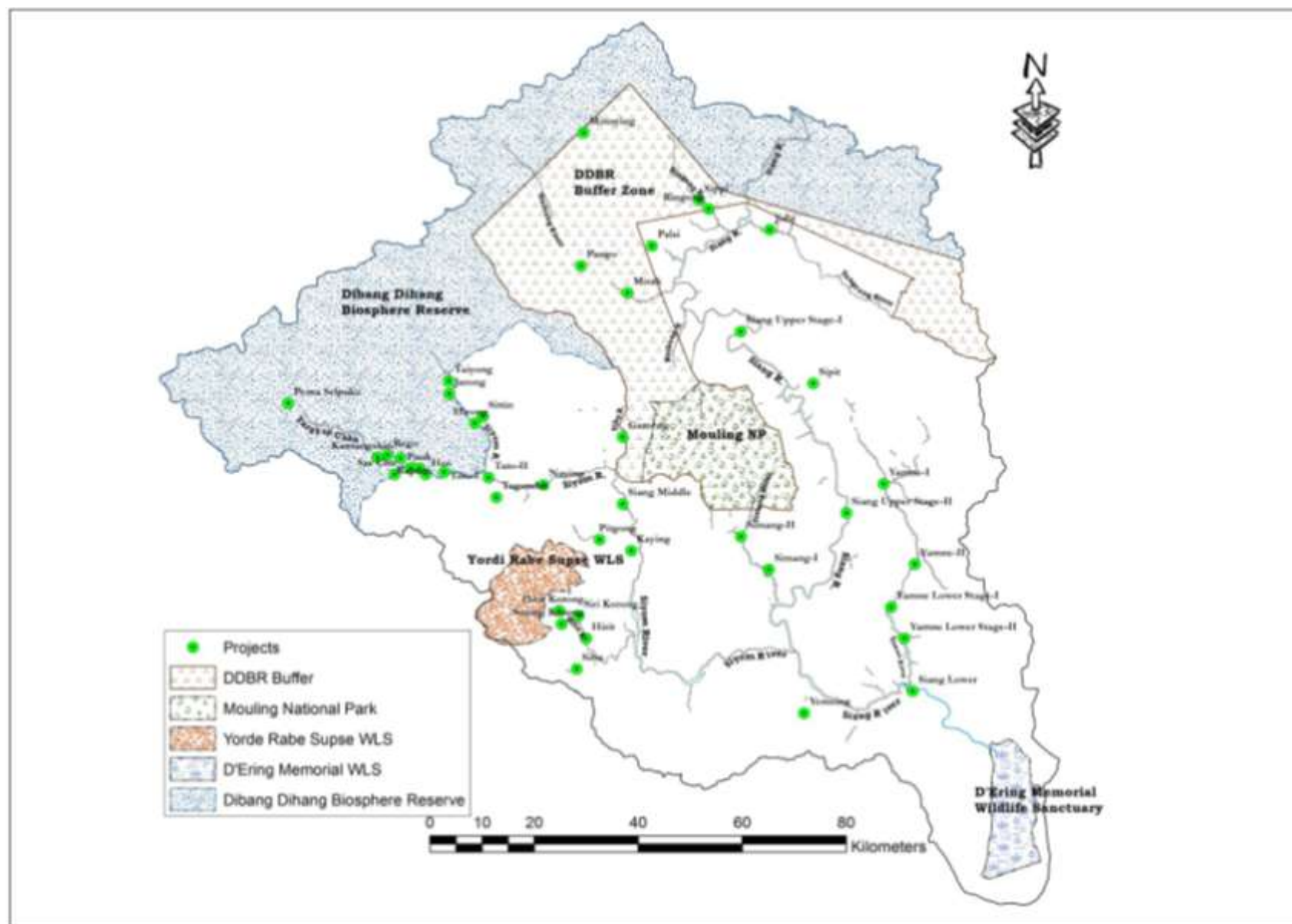
Arunachal Pradesh is recognized as one of the 25 Biodiversity “Hot Spots” in the world. The state possesses myriad types of life forms co-existing in diverse ecological systems. There are eight Wildlife Sanctuaries, one Orchid Sanctuary and two National Parks in the state covering an area of 9,488.48 sq km. There are two Sanctuaries i.e. D’Ering Memorial Wildlife Sanctuary and Yordi Rabe Supse WLS and one Mouling National Park. In addition Dibang Dihang Biosphere Reserve covers parts of three districts i.e. East Siang, West Siang and Upper Siang (see Figure 6.19).

Protected Area	Area (Sq km)
D’Ering Memorial Wildlife Sanctuary	190.00
Mouling National Park	483.00
Yordi-Rabe Supse Wildlife Sanctuary	397.00
Dibang Dihang Biosphere Reserve	5112.50 Core Area = 4094.80; Buffer Area = 1016.70

Brief description of these protected areas is given in the following paragraphs.

6.6.1 Mouling National Park

The Mouling national park was notified in the year 1986 vide gazette notification no. FOR/55/Gen/81 dated 30th December 1986. The national park covers an area of 483 sq km and is located between Longitude 94° 42” to 95° 51” E and Latitude 28° 28” N to 28° 43” N. The national park derives its name from the highest peak “Mouling” amongst the high peaks of Upper Siang district of Arunachal Pradesh. Various mythological beliefs abound. The protected area comprises parts of East Siang, Upper Siang and West Siang districts of Arunachal Pradesh. The park is presently under the administrative control of Divisional Forest Officer, Mouling National Park cum



Wildlife Division with its divisional headquarters located at Jengging. The National park area comprises of Jengging Wildlife range, Ramsing Wildlife range and Boleng Wildlife protection beat.

A brief description about the MNP has been given which is entirely based upon the Management Plan of Mouling National Park for the period 2007-08 to 2011-12 prepared by Bitem Darang, Divisional Forest Officer, Mouling Wildlife Division, Department of Environment & Forests, Jengging.

There is no motorable approach road even to the boundary of the Mouling National Park from any side. The national park area is accessed only by seasonal trekking paths at Jengging, Ramsing and Bomdo area. Jengging, the divisional headquarter is located at a distance of about 15 km from the boundary of the Mouling national park. Jengging is a mini-town and is connected by the lone BRTF defence road. Along and Pasighat which are the district headquarters of West Siang and East Siang districts are located at a distance of about 130 km and 195 km respectively from Jengging. Yingkiong, the headquarters of Upper Siang district located at a distance of 28 km is connected though a makeshift cane suspension bridge over Siang river.

The Mouling National Park is a bio-diversity hotspot and part of the Siang -Dibang Biosphere Reserve. Because of non existence of road even to the boundary of the park and as the park area is not easily accessible, the overall status of the existing wildlife and forest is in pristine state. Predator-prey base is healthy. The national park harbours many rare and threatened species of wildlife and flora. Although the park area has diverse flora and fauna, research studies and documentation have been very little. The same is for the orchids which are abundantly found in the Park. The altitudinal range of the national park varies from 550 m to 3064 m. The unique feature of the park is the presence of five high altitude lakes with varieties of trout fishes and lakes are of mythological and religious significance. The park is an ideal place for bird/animal watching, water sports, nature treks and wilderness experience.

The Mouling National Park consists of numerous rivers/streams/ rivulets which criss-cross the entire tract of the park area. Apart from the five numbers of high altitude lakes, there are number of large and small waterfalls distributed all through the park area. The water flowing in these rivers/streams/rivulets/waterfalls are perennial. Much of these originate from the catchment area of the mountain peaks /hills inside the protected area. Natural waterholes have also been reported. The Mouling National Park is as a whole a perfect natural watershed system. The Siang river receives much of its discharge from various streams flowing through the national park. The rivers/ streams flowing down from the catchment area of Ganging Mouling are Yarku, Niyikong, Sikir Umding, from the catchment area of Marang Mouling are Simang, Karbung, Siring, Sitik, Angong and from the catchment area of Mouling Sibum are Karbung, Subbung and Sipo.

The entire area of Mouling national park falls under the Indo-Malayan bio-geographic zone along with rest of North Eastern region of India.

According to Champion and Seth's revised classification of forests types of India (1968) the following forest types occur in the Mouling National park.

i) 1B/C1	: Assam valley tropical wet evergreen forest
ii) 2B/C1	: Assam valley Semi evergreen forest
iii) 3B/IS2 (B)	: Eastern Hollock moist deciduous forest
iv) 8B/C	: Eastern Himalayan Sub-tropical hill forest
v) 9/C1	: Himalayan Sub-tropical Pine forest

vi) 11B/C1	: East Himalayan wet temperate forest
vii) 12/C3a	: East Himalayan moist temperate forest
viii) 12/DS1	: East Himalayan montane Bamboo brakes
ix) 14/C2S1	: East Himalayan Sub-alpine Birch/Fir forest

These forests harbour 197 flowering plant species and 64 species of mammals. It is also rich in bird life which is represented by 329 species (Management Plan for the period 2007-08 to 2011-12 Mouling Wildlife Division, Department of Environment & Forests, Jengging. Mouling NP is also home to 47 species of reptiles.

It is to be noted that the proposed hydropower projects Simang-II, Gameng and Siang Middle are located within 10 km radius of Mouling National Park (see Figure 6.20).

6.6.2 D'Ering Memorial Wildlife Sanctuary

The erstwhile Lali Reserve Forest was notified as Lali Wildlife Sanctuary vide notification no, FOR.284/78/2 dated 23/08/78 and then subsequently renamed as Daying Ering Memorial Wildlife Sanctuary after an eminent pioneer leader of the area vide notification no. CW/37/83/D/T/4524-54 Dt. 27/10/86.

The Sanctuary is spread over an area of 190 sq km as a large alluvial grassland located between long 95° 22'E to 95° 29'E & Lat. 27°51'N to 28° 5'N. It comprises of northern half of a river island formed between river Siang & Sibia (see Figure 6.21). Both the rivers criss cross the sanctuary forming several islands. This Sanctuary is under the administrative control of the D.F.O., Daying Ering Memorial Wildlife Sanctuary Division, Pasighat. The area is divided into three ranges viz. Anchalthat, Namsing and Borguli wildlife ranges. D'Ering Memorial Wildlife Sanctuary is about 16 km south-east of Pasighat town, headquarters of East Siang district.

The description of the sanctuary is based upon the Management Plan prepared by T. S. Eko, Department of Environment & Forests, Pasighat for the year 2007-09 to 2012. The D'Ering Memorial Wildlife Sanctuary is approachable from Anchalthat range headquarter which is 35 km from Pasighat. During dry season it becomes approachable from Borguli also which is approximately 25 km from Mebo Sub-Division headquarter. Entry with vehicle is possible from Borguli during winter season. In case of Anchalthat there is no direct approach up to range headquarter. The vehicles have to be loaded on motorboat at Oyiramghat and taken across the river Siang up to Jeepghat.

The Sanctuary is surrounded by river water from all sides except southern side, which is contiguous with Kobo Chapory of Assam. On the eastern and western side the Sibia and Siang rivers form a network of river course. Therefore the outer parts of the Sanctuary on east, west and north are very well connected with water body. But the core area is devoid of water source except for few ponds. There are no streams/nallas flowing through the core area of the Sanctuary. However the farthest distance between river Siang and Sibia is along inner line which is only 7 km. this means that in the whole sanctuary the farthest points is only 3.5 km away from water source. Apart from that, the water table in the area is quite high resulting in easy accessibility of ground water.

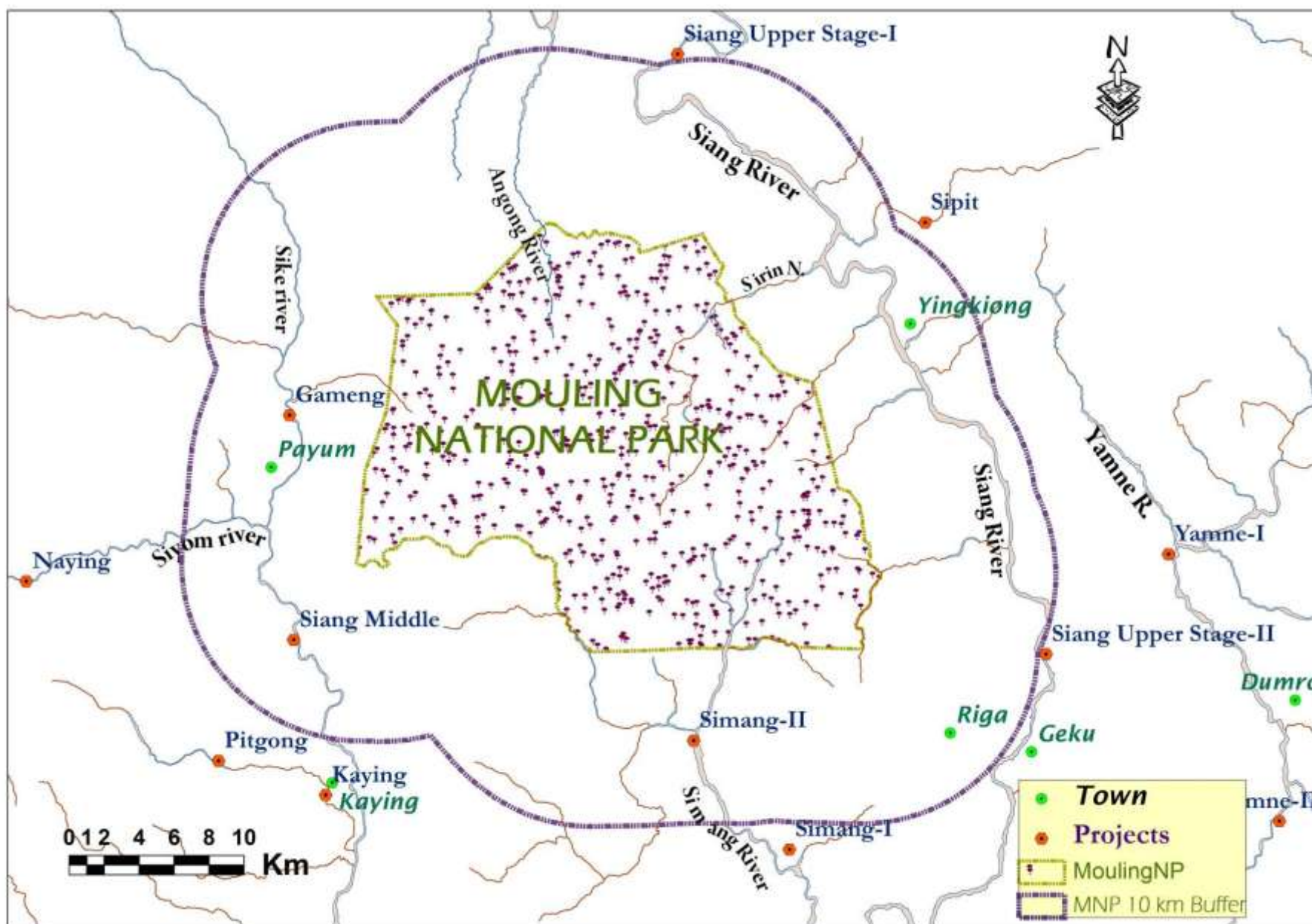


Figure 6.20: Map of Mouling National Park and proposed hydropower projects in its vicinity

The sanctuary constitutes the migratory corridors of elephants and two corridors have been identified in the sanctuary i.e. Sigur at the northern boundary of the sanctuary and another Kongul near Kongul village located on the eastern part of the sanctuary (refer Figure 6.21).

The sanctuary is characterised by extensive floodplain grasslands (about 75%). *Saccharum spontaneum*, *S. arundinaceum*, *Vetiveria sp.* and *Neyraudia reynaudina* are the main grass species, and sedges such as *Cyperus* spp. also very common. Other habitat types include riverine forests, with tree species such as *Terminalia myriocarpa*, *Bombax ceiba* and *Dillenia indica*.

The vegetative covers of the sanctuary are in early stages of succession. 75% of the area is under the cover of alluvial grassland & approximately 15% of the area is underwood. The woodland falls under Assam alluvial plain semi evergreen forest [2/C-1/ (a)] of Champion & Seth's classification. The entire grassland offers an ideal grazing ground for the herbivores with palatable grasses of various species. Apart from leafy food the area also bears fruit plants of various species, e.g., *Ziziphus*, *Ficus*, *Emblia* and Gamari.

There are 91 species of plants found in the sanctuary area (SFRI, Itanagar); however the Management Plan lists 104 species. The sanctuary also harbours diversity of vertebrates i.e. mammal, reptiles, fishes and birds many of which are under rare/threatened/endangered category. None of the animals are restricted to any particular pocket but are distributed throughout the sanctuary. However, habitat specificity of some of the wildlife makes the probability of occurrence in particular type of habitat. For example waterfowl are most likely to be found along the rivers and ponds, macaques and langurs in woodland.

Habitat in the sanctuary area can be divided into 3 main types and these are spread all over the area.

- i. Grassland,
- ii. Woodland, &
- iii. Water consisting of ponds & rivers.

As mentioned earlier overall quality of the habitat are ideal for wildlife management with 75% grassland, 15% woodland & 10% water. It is home to 26 species of mammals, 157 bird species and 13 species of reptiles.

The Sanctuary falls under Indo-Malayam Biogeographic zone along with rest of North Eastern Region. Mammal species reported from D'Ering are elephant (*Elephas maximus*), tiger (*Panthera tigris*), wild pig (*Cuon alpinus*) and hog deer (*Axis porcinus*). More than 150 species of birds have been reported, including endangered bird species like the Bengal Florican (*Houbaropsis bengalensis*) and White-winged Duck (*Cairina scutulata*). Elephants are known to cross over to sanctuary through Jonai and Kobo Chapory in Assam (Choudhury, 1999 & Sundaram et. al. (2003). According them Dibru-Deomali elephant corridor includes D'Ering WLS, Jonai and Kobo Chapori area (Assam), Dibru-Saikhowa National Park, Joypur RF and Deomali Forest Division.

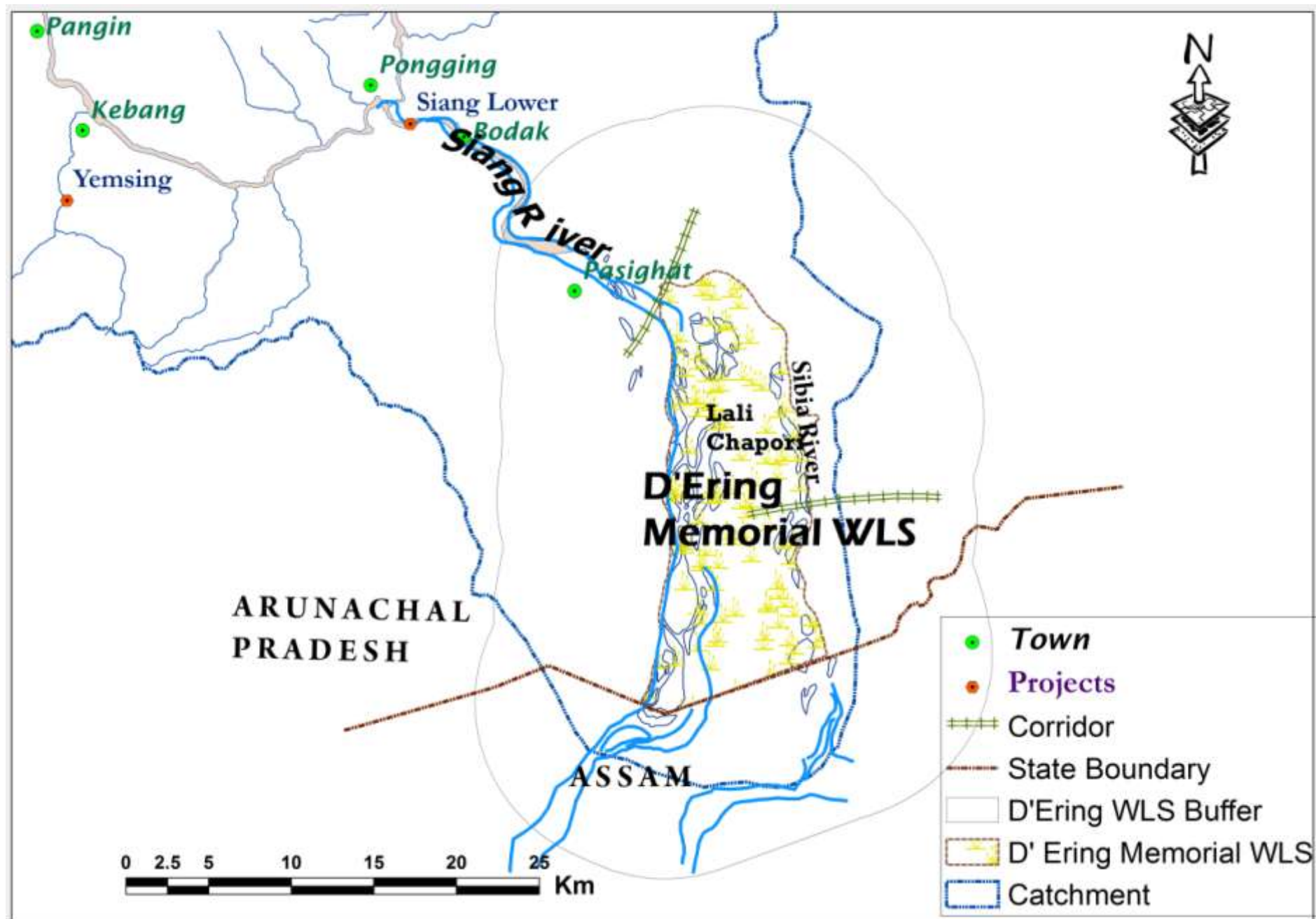


Figure 6.21: Map of D'Ering Memorial Wildlife Sanctuary

Large number of grassland-dependent bird species such as Swamp Francolin (*Francolinus gularis*), Jerdon's Babbler (*Chrysosoma altirostre*) and Black-breasted Parrotbill (*Paradoxornis flavirostris*) are also found. Other waterbirds found are large numbers of migratory ducks during the winter, and Indian Skimmer (*Rhynchops albicollis*).

Owing to avian diversity in the sanctuary BirdLife International has demarcated it as one of the IBAs. It can be seen from the table below that it encompasses three important criteria.

IBA Code	IBA Site name	IBA Criteria
IN-AR-03	D'Ering Memorial Wildlife Sanctuary	A1, A2, A4i

A1. Globally threatened species

Criterion: The site is known or thought regularly to hold significant numbers of a globally threatened species, or other species of global conservation concern.

Such species are listed above.

A2. Restricted-range species

Criterion: The site is known or thought to hold a significant component of a group of species whose breeding distributions define an Endemic Bird Area (EBA) or Secondary Area (SA).

A4. Congregations

Criteria: A site may qualify on any one or more of the four criteria listed below:

i) Site known or thought to hold, on a regular basis, $\geq 1\%$ of a biogeographic population of a congregatory waterbird species.

6.6.3 Yordi Rabe Supse Wildlife Sanctuary

It is located near Yomcha in the West Siang District and is well connected by road to Along and covers an area of 397 sq km. Though Yordi Rabe Supse Wildlife Sanctuary was declared in 1996, however the sanctuary boundary was notified in June 4, 2007 vide letter no. CWL/D/33/96/1451-91 under section 26-A (1) of Wildlife (Protection) Act 1972 by the Government of Arunachal Pradesh Gazette. The sanctuary is administered by the Divisional Forest Officer, Along Forest Division.

The sanctuary lies entirely in the mid-altitudes in the Siang basin, with an altitude ranging from 1,500 to 2,500 m (see Figure 6.22). The sanctuary is comprised of upper catchment of Hirit river. The forests in Yordi Rabe Supse WLS vary from Sub-tropical to temperate broadleaved forests, with some areas under Subtropical pine forests. Its biodiversity is under-explored and detailed biological exploration of the sanctuary is yet to be carried out and is considered to be home of number of RET species.

Mammals reported from the area include tiger (*Panthera tigris*), clouded leopard (*Neofelis nebulosa*), Asiatic black bear (*Ursus thibetanus*), serow (*Capricornis sumatraensis*) and goral (*Nemorhaedus goral*). However, more detailed surveys are required to adequately catalogue the mammalian diversity of the area. Project Snow Leopard lists Yordi Rabe Supse as a potential snow leopard (*Uncia uncia*) conservation area requiring surveys to assess its appropriateness for inclusion under the program.

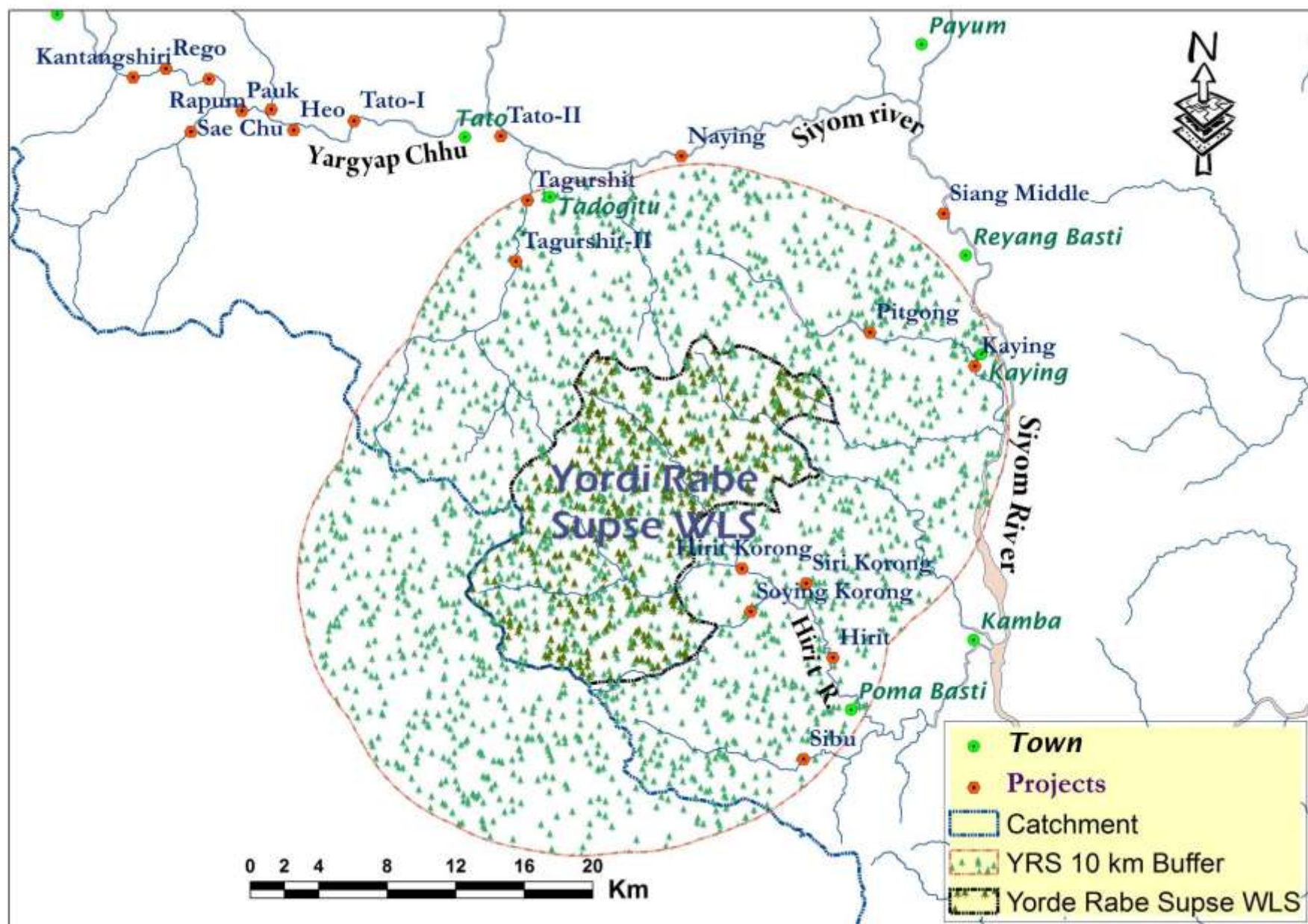


Figure 6.22: Map of Yordi Rabe Supse Wildlife Sanctuary

Information regarding birdlife and other faunal groups is also scanty and no Management plan has been prepared by the Department of Environment & Forests, Itanagar. A large population of Rufous-necked Hornbill (*Aceros nipalensis*) is believed to occur in Yordi Rabe Supse, and there have been unconfirmed reports of Chestnut-breasted hill Partridge (*Arborophila mandellii*) which have been put under Vulnerable category by IUCN (IBA, <http://www.birdlife.org>). While Hill partridge has been put under A1 (Globally threatened species) and A2 (Restricted-range species) categories and Hornbill has been included under A1 (Globally threatened species) category. The sanctuary has been put under IN-AR-27 IBA category with A1 criterion.

It is to be noted that the proposed Tagurshit HEP and Tagurshit-II HEP on Tagurshit Nala and all the proposed hydropower projects in Hirit Sub-basin and Pitgong and Kaying HEPs on Pitgong N. are located within 10 km radius of the sanctuary.

6.6.4 Dibang Dihang Biosphere Reserve

The Dibang Dihang Biosphere Reserve (DDBR) is one of the important sites of wilderness in the Eastern Himalaya. It is located in the upper catchments of rivers Siang and Dibang (between the coordinates 28°27'-29°03'N latitude and 94°29'-95°49'E longitude inside the upper region of Abor Hills and Mishmi Hills tracts of Arunachal Pradesh (see **Figure 6.19**). In the west, it encompasses the north-eastern peripheral part of West Siang district extending to Mouling National Park then north-eastward and turning eastward through northern montane areas of the Upper Siang district, then through entire northern part of Dibang Valley district up to the eastern most part of the district on the east. It extends over an area of 5111.50 sq km; the Reserve is comprised of 1,016.7 sq km of Buffer area and 4,094.80 sq km of Core area. The DDBR area is characterized by rugged mountainous terrain with altitudinal range varying from 500m to about 6000 m. The forests of the area vary greatly from Sub-tropical to Alpine forests. It is comprised of three administrative subdivisions viz. Yingkyong subdivision with two circles (Yingkyong and Jengging); Mariyang subdivision (with three circles viz., Geku, Katan and Mariyang) and Tuting subdivision (consisting of five circles viz., Tuting, Gelling, Singa, Palling and Migging).

Part of buffer area of DDBR includes Mouling NP also in West Siang district.



Siang river



Yamne river

Plate 6.1: View of Siang river and its tributary Yamne river



Yargyap Chhu



Yargyap Chhu - near Mechuka

Plate 6.2 View of tributaries of Siyom river



Riverine forest in Siyom valley



Typical *Musa* sp. forest



Forested slopes along Siyom river bank

Plate 6.3: Forest cover in Siyom sub-basin



Thick forest cover along the banks of Siyom river



Plate 6.4 Very Dense and Dense Forest cover in Siyom sub-basin



View inside dense forest



Jhummed landscape



Coniferous forest in Yargyap valley

Plate 6.5 Forest types and jhumming in Siang basin



Marchantia polymorpha



A lichen species

Plate 6.6: Lower plants found in Siang basin



Plate 6.7 Vegetation mapping in Siang basin



***Begonia burkii* - a rare plant found in Hirit valley**



Plate 6.8 Flowering plants of Siang basin

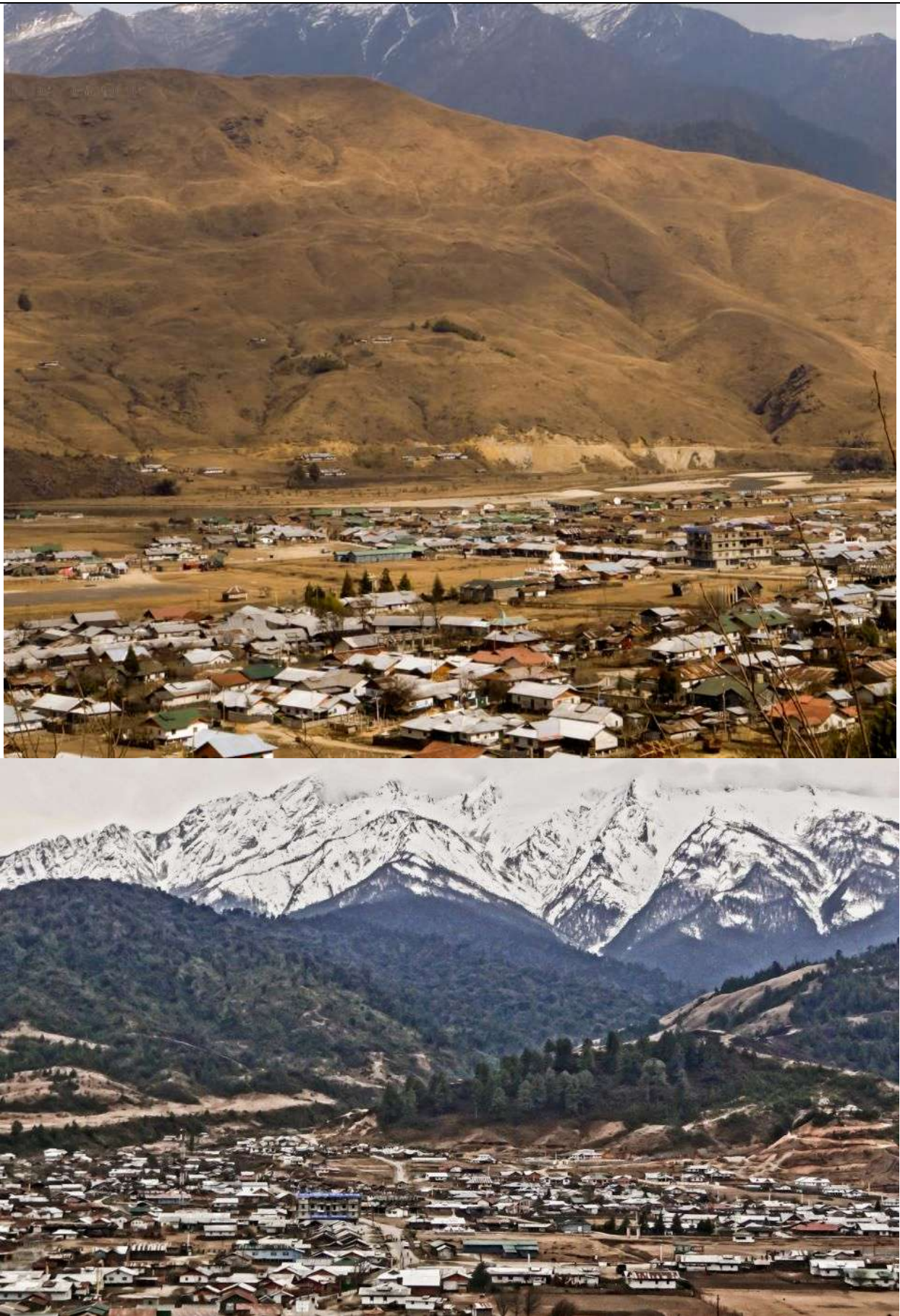


Calamus floribundus - A common cash crop in Siang basin



Typical settlement in Siang basin with bamboo scrub

Plate 6.9: Traditional housing pattern



Mechuka town in two different seasons

Plate 6.10: Settlements/towns in Siyom sub-basin



Plate 6.11: Butterflies found in Siang basin

CHAPTER-7

AQUATIC ECOLOGY

7.1. WATER QUALITY

The chemical and physical sampling and analyses provide a broad picture of the parameters that define the aquatic environment. Biological parameters detect water quality changes that other methods might miss or underestimate. Resident biotic components in their environments are indicators of environmental quality for assessing the impacts that chemical sampling is unlikely to detect due to any modification of river course or flow pattern. Plankton (phytoplankton and zooplankton), benthic macro-invertebrates, aquatic plants, and fish are the most commonly used in assessing biological integrity of any river ecosystem. The benthic macroinvertebrates are most often studied for wadeable riffles in streams and rivers while algae are often used in lakes to examine eutrophication. Therefore the river water quality assessments are best analysed when these are based upon the biological together with physical and chemical assessments that provide a complete picture of the river water quality. In the description of physico-chemical and biological parameters the results have been discussed based upon averages of seasonal variations though sampling and data was collected on monthly basis.

7.1.1 Physico-Chemical Water Quality

Sampling for water quality as already discussed in Chapter 5 was done on monthly basis (**Plate 7.1**). The detailed results of all the water quality parameters analysed for water samples collected monthly from January to September from Siang and Siyom rivers and as well as their tributaries at different sampling locations are given at **Annexure-V of Volume-II:DATA**.

It can be seen from the results of all the parameters analysed that water quality of Siang and Siyom rivers as well as its tributaries is very good to excellent and is well within tolerance limits of inland surface water as per IS:2296 and falls under Class-A (**Table 7.1**) and within limits of prescribed Central Pollution Control Board (CPCB) standards for drinking water (**Table 7.2**). In addition the concentration of parameters like Iron is Below Detectable Limits (BDL) whereas all the heavy metals i.e. Cd, Hg, Cu, Cr, Zn, and Cr and Manganese are Not Detectable (ND) from any of the samples.

Table 7.1: Tolerance Limits for Inland Surface Waters (as per IS:2296:1982)

S. No.	Parameter and Unit	Class-A	Class-B	Class-C	Class-D	Class-E
1	Colour (Hazen Units)	10	300	300	-	-
2	Odour	Unobjectionable	-	-	-	-
3	Taste	Tasteless	-	-	-	-
4	pH (max) (min:6.5)	8.5	8.5	8.5	8.5	8.5
5	Conductivity ($\mu\text{S}/\text{cm}$)	-	-	-	1000	2250
6	DO (mg/L) (min)	6	5	4	4	-
7	BOD (3 days at 27°C) (mg/L)	2	3	3	-	-
8	Total Coliforms (MPN/100 mL)	50	500	5000	-	-
9	TDS (mg/L)	500	-	1500	-	2100
10	Oil and Grease (mg/L)	-	-	0.1	0.1	-
11	Mineral Oil (mg/L)	0.01	-	-	-	-
12	Free Carbon Dioxide (mg/L CO_2)	-	-	-	6	-
13	Free Ammonia (mg/L as N)	-	-	-	1.2	-
14	Cyanide (mg/L as CN)	0.05	0.05	0.05	-	-
15	Phenol (mg/L $\text{C}_6\text{H}_5\text{OH}$)	0.002	0.005	0.005	-	-
16	Total Hardness (mg/L as CaCO_3)	300	-	-	-	-
17	Chloride (mg/L as Cl)	250	-	600	-	600
18	Sulphate (mg/L as SO_4)	400	-	400	-	1000
19	Nitrate (mg/L as NO_3)	20	-	50	-	-
20	Fluoride (mg/L as F)	1.5	1.5	1.5	-	-
21	Calcium (mg/L as Ca)	80	-	-	-	-
22	Magnesium (mg/L Mg)	24.4	-	-	-	-
23	Copper (mg/L as Cu)	1.5	-	1.5	-	-
24	Iron (mg/L as Fe)	0.3	-	50	-	-
25	Manganese (mg/L as Mn)	0.5	-	-	-	-
26	Zinc (mg/L as Zn)	15	-	15	-	-
27	Boron (mg/L as B)	-	-	-	-	2

S. No.	Parameter and Unit	Class-A	Class-B	Class-C	Class-D	Class-E
28	Barium (mg/L as Ba)	1	-	-	-	-
29	Silver (mg/L as Ag)	0.05	-	-	-	-
30	Arsenic (mg/L as As)	0.05	0.2	0.2	-	-
31	Mercury (mg/L as Hg)	0.001	-	-	-	-
32	Lead (mg/L as Pb)	0.1	-	0.1	-	-
33	Cadmium (mg/L as Cd)	0.01	-	0.01	-	-
34	Chromium (VI) (mg/L as Cr)	0.05	0.05	0.05	-	-
35	Selenium (mg/L as Se)	0.01	-	0.05	-	-
36	Anionic Detergents (mg/L MBAS)	0.2	1	1	-	-

Class-A: Drinking water source without conventional treatment but after disinfection

Class-B: Outdoor bathing

Class-C: Drinking water source with conventional treatment followed by disinfection

Class-D: Fish culture and wild life propagation

Class-E: Irrigation, industrial cooling and controlled waste disposal

Table 7.2: Drinking Water Quality Standards (as per IS:10500:2012)

Parameters	Desirable Limit*	Permissible Limit**
Color (Hz)	5.0	25
Odour	Unobjectionable	-
Taste	Agreeable	-
Turbidity (ntu)	5	10
pH	5-8.5	No relaxation
Total coliforms (MPN/100 ml)	0	-
TDS (mg/l)	500	2000
Total hardness (mg/l) as CaCO ₃	300	600
Total alkalinity (mg/l)	200	600
Chlorides (mg/l)	250	1000
Sulphates (mg/l)	200	400
Flourides (mg/l)	1.0	1.5
Nitrate (mg/l)	45	100
Calcium (mg/l)	75	200
Magnesium (mg/l)	30	100
Manganese (mg/l)	0.05	0.5
Copper (mg/l)	0.05	1.5
Zn (mg/l)	5.0	15.0
Iron (mg/l)	0.30	1.0
Lead (mg/l)	0.05	No relaxation
Cadmium (mg/l)	0.01	No relaxation
Chromium (mg/l)	0.05	0.05
Phenolic compounds as phenol (mg/l)	0.001	0.001
Anionic detergents as MBAS (mg/l)	0.001	0.002
Arsenic as As (mg/l)	0.05	0.05
Selenium as Se (mg/l)	0.01	0.01
Mercury total as Hg (mg/l)	0.001	0.001
Cyanides (mg/l)	0.05	0.05
Mineral oil (mg/l)	0.01	0.3
Polynuclear aromatic hydrocarbons (PAH)	0.02µg/l	0.02µg/l

*1. The figures indicated under the column 'Acceptable' are the limits up to which water is generally acceptable to the consumers

**2 Figures in excess of those mentioned under 'Acceptable' render the water not acceptable, but still may be tolerated in the absence of alternative and better source but up to the limits indicated under column "Cause for Rejection" above which are supply will have to be rejected.

Therefore keeping above results in mind water quality objectives for Siang basin focuses on a core indicator set that reflects their importance along a river stretch in a valley/basin. The key indicators like pH, electrical conductivity, total dissolved solids, total suspended solids, dissolved oxygen, nitrates, sulphates and phosphates have been discussed in the present report. In addition other parameters like Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total coliforms have also been discussed.

7.1.1.1 Siang River & its Tributaries : Sub-basins I-IV

During winters the water temperature of Siang river and its tributary streams varied from 9.3°C-11.4°C at all the sampling sites (Figure 7.1). The highest temperature was observed at downstream of Ranaghat (Sampling site - S2) while the lowest temperature was recorded at Tuting (Sampling site - S12). During pre-monsoon season sampling the temperature ranged from 12.7-13.7°C with highest at upstream of Hawai camp (S6) and lowest at sampling site (S13) located near

Jidu village. During monsoon season temperature range varied from 16.5-17.7°C, highest at Bodak (Sampling site - S1) and lowest at sampling site (S8) near Minnying.

The pH of at most of the sampling sites was from almost neutral to slightly alkaline. It varied from 8.14-8.50 during the winter season. Highest pH was recorded at sampling site (S3) near Ranaghat and lowest at sampling site (S11) 12 km d/s of Tuting (Figure 7.1). During the pre-monsoon season, it varied from 8.15-8.54 and highest pH was at (S9) u/s of Nunning and lowest at (S7) near Mirak. During monsoon season pH varied from 8.07-8.44, highest pH was at (S1) near Bodak and lowest at (S4) near Kebang.

During winter season dissolved oxygen values varied from 9.93-10.62 mg/l as highest value of DO was found at sampling site (S9) u/s of Nuning and lowest at sampling site (S2) d/s of Ranaghat (Figure 7.1). In pre-monsoon season DO value varied from 9.13-9.72mg/l, highest value of DO observed at (S5) Boleng whereas lowest at (S6)11 km upstream of Hawaii camp. Monsoon season DO was recorded range from 7.88-8.28 mg/l. highest value of DO observed at (S13) Jidu village whereas lowest at (S12) Tuting.

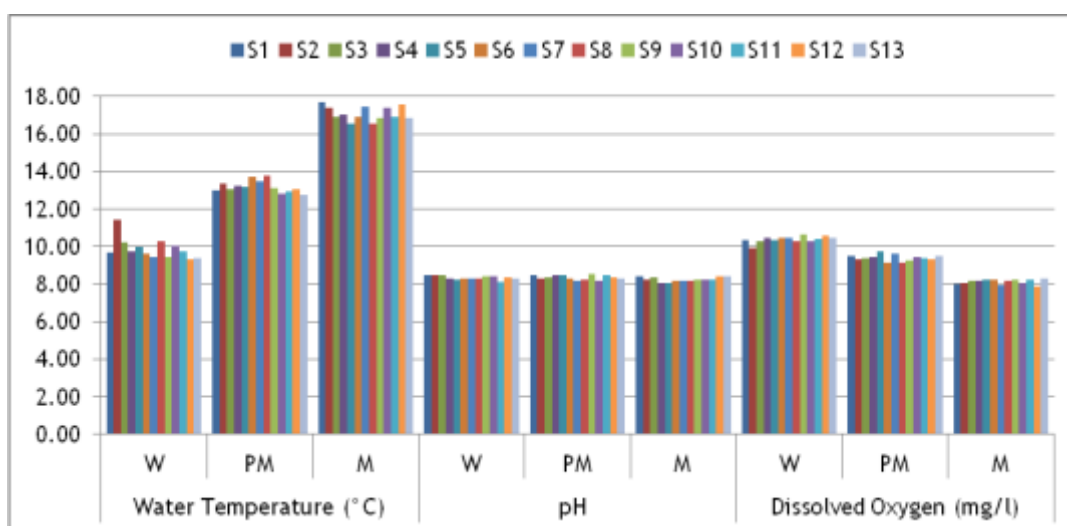


Figure 7.1: Water temperature, pH and DO data of Siang river and its tributaries

Total Dissolved Solids, Total Suspended Solids and Electrical Conductivity varied from 42.02-179.14, 6.67-30.67 and 68.89-293.67 $\mu\text{S}/\text{cm}$, respectively at different sampling locations in Siang and its tributaries during winter season (Figure 7.2). In pre-monsoon season it ranged from 33.95-140.10 mg/l, 22.30-42.33 mg/l and 55.13-227.67 $\mu\text{S}/\text{cm}$. During the monsoon seasons it was Frecorded 36.59-79.04 mg/l, 196.97-326.95 mg/l and 59.87-129.23 $\mu\text{S}/\text{cm}$.

TDS and electrical conductivity was observed highest during the winter season as compare to the pre-monsoon and monsoon season (Figure 7.2). Total suspended solids were observed highest during the monsoon season followed by pre-monsoon and winter season.

BOD and COD values at all sampling sites were very low. During winter season sampling insignificant values of Total Coliforms were recorded but in other seasons coliforms could not be detected at any of the sampling sites (Figure 7.3).

The Chlorides, Total alkalinity, Total hardness were recorded 8.4-12.9 mg/l, 46.6-63.3 mg/l and 37.4-60.6 mg/l during winter, pre-monsoon it ranged from 5.7-8.3 mg/l, 30.3-36.0 mg/l and 22.8-31.8 mg/l and monsoon season it ranged from 6.0-7.9 mg/l, 31.1-35.1 mg/l and 23.8-33.5 mg/l, respectively (see Table 7.3).

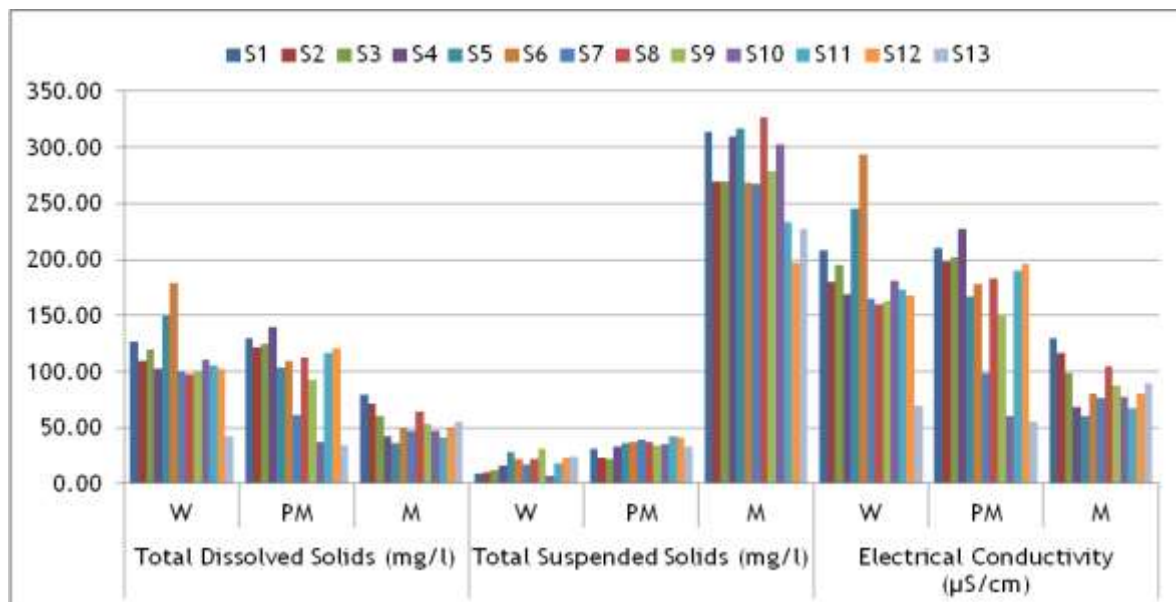


Figure 7.2: Total dissolved solids, TSS and EC data of Siang river and its tributaries

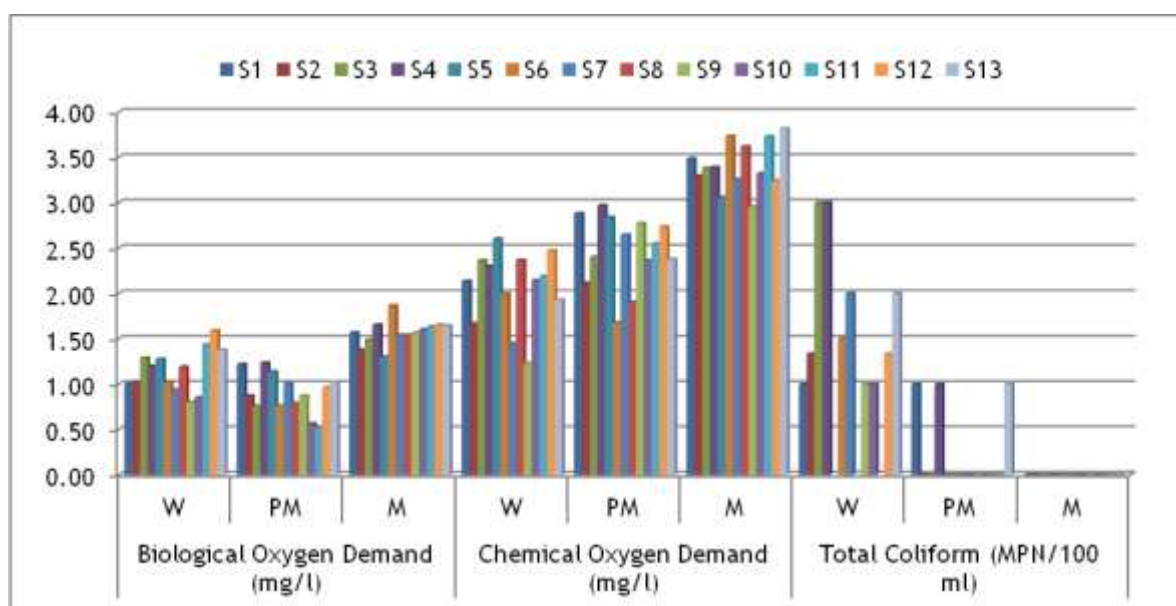


Figure 7.3: BOD, COD and total coliforms in Siang river and its tributaries

The values of chloride, alkalinity and hardness in river water were found highest in the winter season.

Nitrate and phosphate concentration in water were very low. Sulphate values were observed highest during winter season (see Table 7.3).

7.1.1.2 Yamne & Simang Rivers

Water temperature in Yamne river and its tributaries varied from 9.5-10.10°C during the winter season and was observed highest at sampling site (Y3) near Siyat and lowest at (Y1) near Jerring. BOD and COD values at all sampling sites were very low as well as Total Coliforms were completely absent (Figure 7.4). During pre-monsoon season temperature ranged from 13.30-13.77°C. Thus highest temperature was recorded at sampling site (Y4) near Lagru and lowest at (Y3) at Siyat

Table 7.3: Physico-chemical characteristics of Siang river and its tributaries

Parameters		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
Chloride (mg/l)	W	9.4	9.4	11.0	9.4	11.9	11.0	9.4	12.9	10.3	8.4	8.4	10.7	9.1
	PM	6.3	7.3	8.3	6.0	5.7	6.3	6.0	7.3	6.3	6.3	6.0	6.3	6.0
	M	6.0	6.6	7.9	6.4	6.3	6.6	6.4	6.5	6.2	7.5	6.1	6.7	6.4
Total alkalinity (mg/l of CaCO ₃)	W	59.49	58.25	63.26	46.57	54.62	61.74	56.28	59.83	63.04	58.22	53.40	52.79	58.55
	PM	32.83	33.80	36.03	31.23	30.27	34.47	33.50	33.17	32.20	33.50	31.57	32.53	31.57
	M	31.67	31.95	35.11	31.45	31.17	33.61	33.67	32.34	31.39	34.00	31.45	32.39	31.12
Total Hardness (mg/l)	W	49.68	47.67	60.58	37.38	47.60	52.52	50.70	54.50	56.13	49.33	43.60	45.73	52.04
	PM	25.70	22.80	23.11	23.75	27.30	23.46	26.35	24.42	31.18	26.37	26.99	26.01	31.80
	M	26.59	23.76	25.62	26.25	29.72	25.29	29.07	25.94	31.96	28.74	28.78	28.45	33.53
Calcium ions (mg/l)	W	16.02	15.74	20.03	12.78	16.21	17.17	17.31	18.44	18.87	16.79	14.72	15.47	17.73
	PM	8.99	7.42	7.73	7.47	9.07	7.73	8.99	7.87	9.73	8.80	8.80	8.40	9.33
	M	9.25	7.72	7.97	7.82	9.46	8.12	9.37	8.35	10.31	9.38	9.35	8.97	10.01
Magnesium ions (mg/l)	W	3.85	3.78	4.81	3.07	3.89	4.12	4.16	4.42	4.53	4.03	3.53	3.71	4.26
	PM	2.16	1.78	1.86	1.79	2.18	1.86	2.16	1.89	2.34	2.11	2.11	2.02	2.24
	M	2.22	1.85	1.91	1.88	2.27	1.95	2.25	2.00	2.47	2.25	2.24	2.15	2.40
Potassium (mg/l)	W	1.68	1.20	1.19	1.73	1.47	1.44	1.22	1.25	1.14	1.32	1.53	1.31	1.15
	PM	0.47	0.37	0.67	1.20	0.40	0.50	0.67	0.70	1.20	0.32	0.37	1.74	1.21
	M	0.61	0.89	0.76	0.45	0.85	0.98	0.62	0.82	0.35	0.49	0.36	0.32	0.63
Sodium (mg/l)	W	3.35	1.98	2.42	2.97	2.48	2.86	2.07	2.03	2.67	2.33	2.68	2.64	2.18
	PM	1.33	1.47	1.20	1.87	1.67	1.57	1.53	1.33	1.70	1.13	1.35	2.62	2.11
	M	1.33	1.69	1.41	1.85	1.86	1.84	1.80	1.35	6.37	1.23	1.48	1.39	1.78
Nitrates (NO ₃) (mg/l)	W	0.066	0.043	0.033	0.020	0.027	0.035	0.036	0.015	0.034	0.024	0.027	0.021	0.015
	PM	0.051	0.047	0.039	0.032	0.032	0.040	0.031	0.026	0.029	0.020	0.020	0.020	0.018
	M	0.050	0.046	0.039	0.031	0.031	0.040	0.031	0.026	0.029	0.020	0.019	0.020	0.018
Sulphate (mg/l)	W	4.73	3.78	8.55	5.70	6.65	4.73	4.76	3.78	6.62	5.67	3.78	5.67	8.51
	PM	5.33	5.00	6.00	7.33	5.33	7.00	7.67	5.67	5.67	4.67	4.67	6.67	7.67
	M	5.22	4.92	5.25	6.59	5.60	6.38	6.92	5.20	4.90	4.61	4.57	6.55	7.54
Phosphate (PO ₄) (mg/l)	W	0.009	0.009	0.007	0.003	0.001	0.006	0.003	0.005	0.005	0.001	0.003	0.006	0.007
	PM	0.002	0.005	0.002	0.002	0.001	0.004	0.004	0.005	0.004	0.001	0.002	0.002	0.005
	M	0.002	0.005	0.002	0.002	0.001	0.004	0.004	0.005	0.004	0.001	0.002	0.002	0.006

S1 - S13 - Sampling Sites; W= Winter; PM= Pre-monsoon; M=Monsoon

The pH of Yamne river water varied from 8.12-8.36 during the winter season. Highest pH was recorded at (Y2) u/s of Padu and lowest at (Y3) Siyat. BOD and COD values at all sampling sites were very low. Total Coliforms were either completely absent (**Figure 7.4**). During the pre-monsoon pH varied from 8.18-8.45, highest pH was observed at near Siyat (Y3) and lowest at site (Y2) upstream of Padu whereas in monsoon season pH varied from 8.14-8.31 and highest pH was recorded at site (Y4) Lagru and lowest was at site (Y1) near Jerring.

During winter season Dissolved Oxygen (DO) values varied from 10.26-10.63 mg/l. The highest value was found at site (Y1) near Jerring and lowest at site (Y4) near Lagru. BOD and COD values at all sampling sites were very low. Total Coliforms were completely absent in the river water (**Figure 7.4**). In pre-monsoon season DO value varied from 8.85-9.30 mg/l, highest value of DO was observed at site (Y3) near Siyat whereas lowest at site (Y4) Lagru. During monsoon DO varied from 7.83-8.43 mg/l. The highest value was recorded at site (Y2) U/s of Padu and lowest at site (Y4) near Lagru.

Water temperature in Simang river ranged from 9.14°C -10.32°C in winter, from 13.2-14.2°C in pre-monsoon and from 16.9-18.0°C during monsoon (**Figure 7.4**).

The pH value in Simang river water varied from 8.16-8.43 during the winter season, from 8.28-8.46 during pre-monsoon and from 7.21-7.55 during monsoon (**Figure 7.4**).

Dissolved Oxygen (DO) values varied from 10.21-10.59 mg/l, 8.89-9.35 mg/l and 8.25-8.40 mg/l, during winter, pre-monsoon and monsoon season sampling, respectively (**Figure 7.4**).

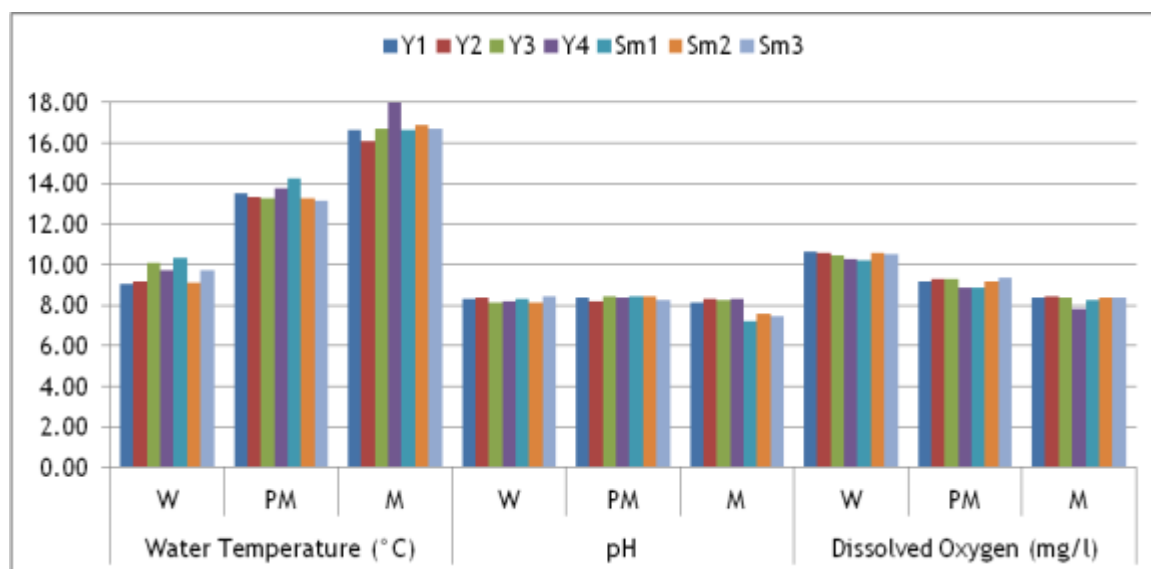


Figure 7.4: Water temperature, pH and DO data of Yamne and Simang rivers

Total Dissolved Solids, Total Suspended Solids and Electrical Conductivity varied from 91.17-150.84 mg/l, 7.00-25.00 mg/l and 149.46-247.28 $\mu\text{S}/\text{cm}$ respectively at different sampling locations in Yamne river in winter season (**Figure 7.5**). In pre-monsoon season Total Dissolved Solids, Total Suspended Solids and Electrical Conductivity values ranged from 80.06-93.41 mg/l, 18.00-27.67 mg/l and 138.06-152.87 $\mu\text{S}/\text{cm}$ and in monsoon values varied from 44.23-53.57 mg/l, 285.0-319.83 mg/l and 71.33-86.40 $\mu\text{S}/\text{cm}$, respectively.

Total Dissolved Solids, Total Suspended Solids and Electrical Conductivity values varied from 128.73-173.21 mg/l, 15.33-17.67 mg/l and 211.04-283.95 $\mu\text{S}/\text{cm}$, respectively at different sampling locations in Simang during winter season (**Figure 7.6**). In pre-monsoon their values

ranged from 82.82-142.39 mg/l, 38.00-40.00 mg/l and 131.93-239.00 $\mu\text{S}/\text{cm}$ and in monsoon seasons varied from 44.23-53.51 mg/l, 271.70-285. mg/l and 71.33-86.30 $\mu\text{S}/\text{cm}$, respectively.

BOD and COD values at all sampling sites in the two rivers were very low. Total Coliforms were either completely absent or could not be detected in the river water (Figure 7.6).

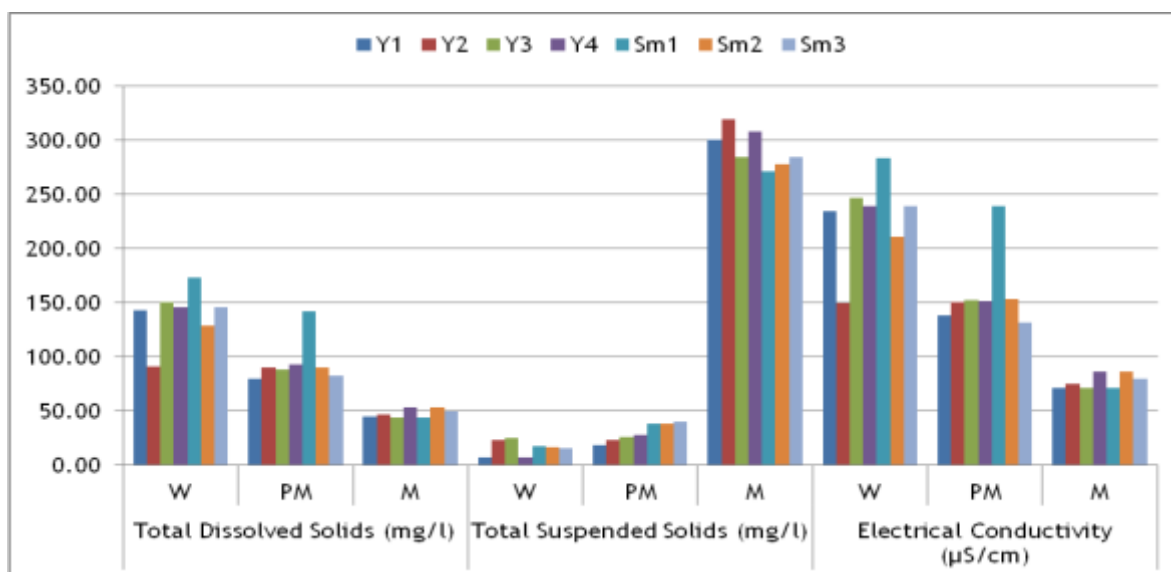


Figure 7.5: Total dissolved solids, TSS and EC data of Yamne and Simang rivers

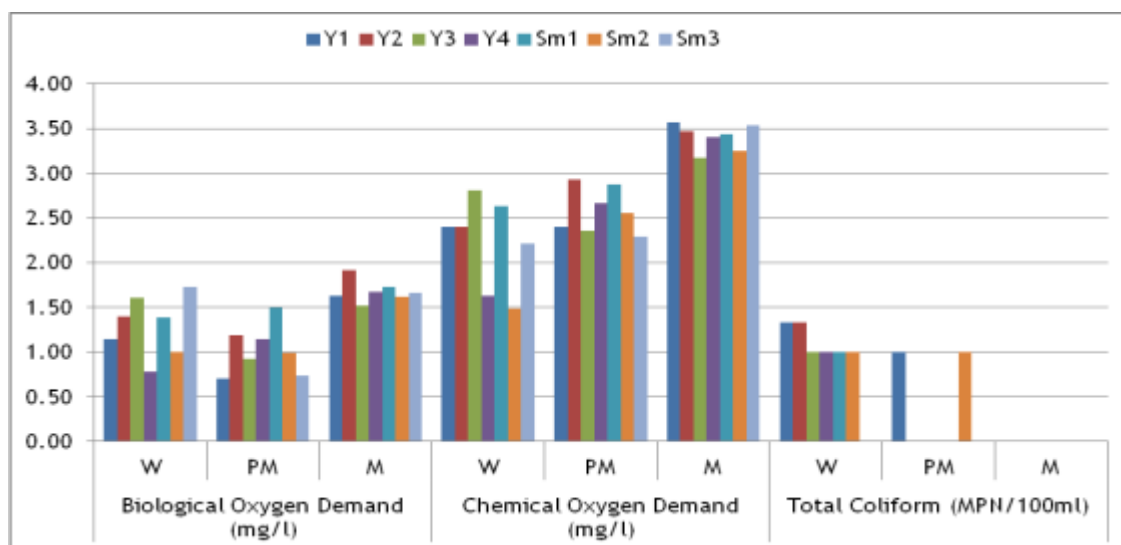


Figure 7.6: BOD, COD and total coliforms in Yamne and Simang rivers

The concentration of Chlorides, Total alkalinity, Total hardness in Yamne river ranged from 8.5-12.3 mg/l, 52.4-66.4 mg/l and 44.4-60.8 mg/l during winter, from 5.6-8.2 mg/l, 31.5-48.4 mg/l and 27.0-41.6 mg/l in pre-monsoon and from 5.8-7.4mg/l, 30.8-42.6mg/l and 27.2-37.5 mg/l in monsoon, respectively (see Table 7.4).

The concentration of nitrates, sulphate and phosphates in Yamne river varied from 0.014-0.076 mg/l, 2.85-8.53 mg/l and 0.010-0.076 mg/l during winter, from 0.001-0.084 mg/l, 2.46-5.37 mg/l and 0.001-0.006 mg/l in pre-monsoon and from 0.001-0.080 mg/l, 2.37-5.18 mg/l and 0.001-0.0062 mg/l, respectively in monsoon (Table 7.4).

Sulphate concentration was highest during winter season as compared to the pre monsoon and monsoon season.

Table 7.4: Physico-chemical characteristics of Yamne and Simang rivers

Parameters		Y1	Y2	Y3	Y4	SM1	SM2	SM3
Chloride (mg/l)	W	9.4	12.3	8.8	9.5	9.1	9.4	8.5
	PM	6.6	8.2	6.9	6.6	5.9	6.2	5.6
	M	6.6	7.4	5.8	6.8	6.2	6.5	5.9
Total alkalinity (mg/l of CaCO ₃)	W	58.40	60.99	60.60	55.69	66.44	60.51	52.44
	PM	35.82	32.28	42.12	31.49	48.41	48.41	38.57
	M	34.05	30.84	35.99	31.68	42.26	42.59	35.44
Total Hardness (mg/l)	W	53.15	55.06	52.36	48.67	60.80	55.24	44.40
	PM	30.74	27.70	36.15	27.03	41.55	41.55	33.11
	M	30.08	27.24	31.63	28.05	37.18	37.49	31.26
Calcium ions (mg/l)	W	18.01	19.24	17.91	16.87	20.92	18.92	15.85
	PM	11.20	10.09	13.17	9.84	15.13	15.13	12.06
	M	11.03	9.94	12.97	9.69	14.90	14.90	11.88
Magnesium ions (mg/l)	W	4.32	4.62	4.30	4.05	5.02	4.54	3.80
	PM	2.69	2.42	3.16	2.36	3.63	3.63	2.89
	M	2.65	2.38	3.11	2.33	3.58	3.58	2.85
Potassium (mg/l)	W	1.28	1.84	1.25	1.58	1.48	1.12	1.35
	PM	0.49	0.76	0.39	0.73	0.79	0.39	0.99
	M	0.17	0.48	0.44	0.29	0.41	0.45	0.43
Sodium (mg/l)	W	1.67	2.03	1.72	1.74	2.07	1.85	1.97
	PM	1.37	1.27	1.18	1.28	1.57	1.45	2.06
	M	1.45	1.41	1.52	1.27	1.48	1.22	1.39
Nitrates (NO ₃) (mg/l)	W	0.015	0.076	0.016	0.017	0.025	0.028	0.014
	PM	0.084	0.001	0.003	0.005	0.007	0.007	0.005
	M	0.080	0.001	0.002	0.005	0.007	0.007	0.005
Sulphate (mg/l)	W	4.75	2.85	3.80	4.75	8.53	6.64	2.85
	PM	4.70	5.37	4.03	3.13	4.25	3.58	2.46
	M	4.53	5.18	3.88	3.02	4.10	3.45	2.37
Phosphate (PO ₄) (mg/l)	W	0.076	0.010	0.029	0.067	0.048	0.057	0.047
	PM	0.006	0.006	0.001	0.005	0.004	0.005	0.003
	M	0.006	0.006	0.001	0.005	0.005	0.005	0.003

Y1 - Y4, Sm1-Sm3 : Sampling Sites; W= Winter; PM= Pre-monsoon; M=Monsoon

7.1.1.3 Siyom River & its Tributaries

Water temperature of Siyom river varied from 7.27-9.80°C in winter season, from 11.43-14.17°C in pre-monsoon and from 13.23-15.47°C during monsoon season sampling (Figure 7.7).

The pH of Siyom river water varied from 7.55-8.11 during the winter season, from 7.34-8.31 in pre-monsoon and from 7.48-8.31 in monsoon season (Figure 7.7).

Dissolved Oxygen (DO) concentrations varied from 10.34-11.59 mg/l in winter, varied from 8.93-9.72 mg/l and from 8.62-9.28 mg/l in monsoon (Figure 7.7).

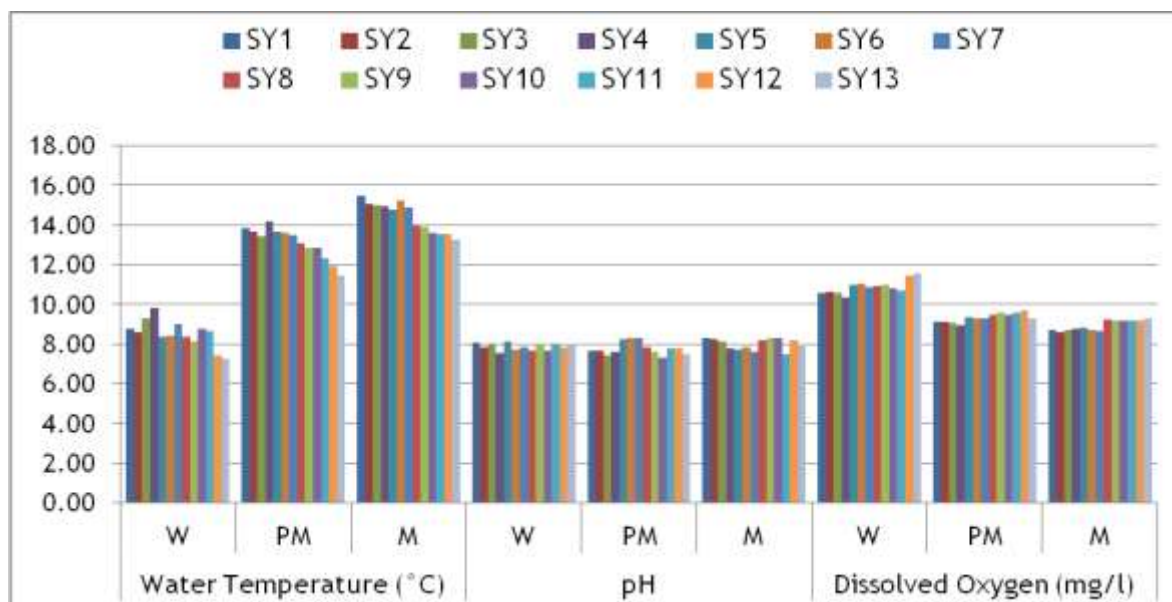


Figure 7.7: Water temperature, pH and DO data of Siyom river and its tributaries

Total Dissolved Solids, Total Suspended Solids and Electrical Conductivity varied from 20.29-79.49 mg/l, 3.00-33.67 mg/l and 33.27-130.31 $\mu\text{S}/\text{cm}$, respectively at different sampling locations in Siyom river and its tributaries during winter season (**Figure 7.8**). In pre-monsoon season it ranged from 26.38-72.43 mg/l, 18.00-42.47 mg/l and 48.67-140.37 $\mu\text{S}/\text{cm}$, respectively. During the monsoon their values ranged from 15.42-35.28 mg/l, 83.20-213.76 mg/l and 24.87-56.90 $\mu\text{S}/\text{cm}$, respectively (**Figure 7.8**).

BOD and COD values at all sampling sites were very low (**Figure 7.9**). Total Coliforms were recorded at some sampling sites during winter but with very low values otherwise these were totally absent at all the sampling sites during pre-monsoon and monsoon sampling (**Figure 7.9**).

The Chlorides, Total alkalinity, Total hardness were recorded 8.8-14.3 mg/l, 26.80-73.89 mg/l and 50.4-68.33 mg/l during winter, pre-monsoon it ranged from 4.5-10.0 mg/l, 15.7-37.39 mg/l and 13.5-37.03 mg/l and monsoon season it ranged from 4.3-9.2 mg/l, 20.2-35.40 mg/l and 18.0-33.10 mg/l. respectively (**Table 7.5**).

Chlorides and alkalinity values were observed highest during winter season followed by pre monsoon and monsoon season whereas total hardness values were observed highest during winter season.

The value of nitrates, sulphate and phosphates varied from 0.005-0.018 mg/l, 2.87-5.70 mg/l and 0.001-0.009 mg/l during winter, pre-monsoon it ranged from 0.001-0.014 mg/l, 1.56-4.92 mg/l and 0.001-0.008 mg/l and monsoon season values ranged from 0.001-0.014 mg/l, 2.08-4.74 mg/l and 0.001-0.008 mg/l. respectively (**Table 7.5**).

Nitrate and phosphate in river water were observed in very low concentration. Sulphate concentration in water was observed highest during winter season followed by pre-monsoon and monsoon season.

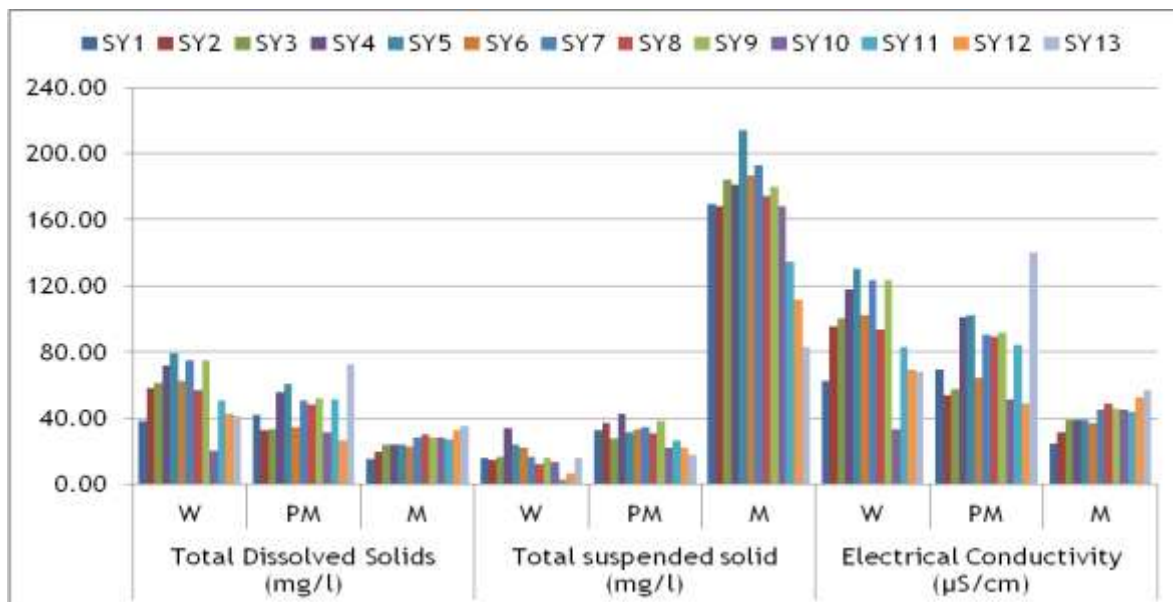


Figure 7.8: Total dissolved solids, TSS and EC data of Siyom river and its tributaries

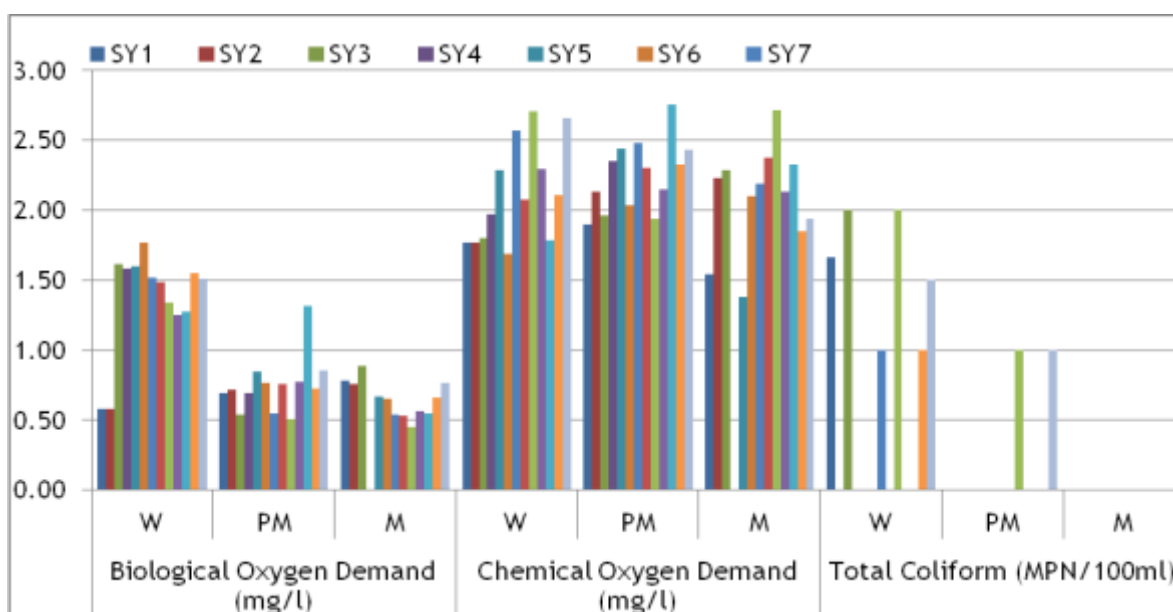


Figure 7.9: BOD, COD and total coliforms in Siyom river and its tributaries

7.1.1.4 Yargyap Chhu

Water temperature of Yargyap Chhu river varied from 5.91-8.95°C in winter season, from 8.50-12.88°C in pre-monsoon and from 8.30-12.17°C during monsoon season sampling and the lowest temperature was recorded at sampling site YG14 upstream of Hanuman camp near Yarlong during winter (Figure 7.10).

The pH of Yargyap Chhu river water varied from 7.63-7.88 during the winter season, from 7.10-7.92 in pre-monsoon and from 7.13-7.92 in monsoon season (Figure 7.10).

Dissolved Oxygen (DO) concentrations varied from 10.82-11.92 mg/l in winter, varied from 9.32-10.93 mg/l and from 9.75-11.03 mg/l in monsoon (Figure 7.10).

Table 7.5: Physico-chemical characteristics of Siyom river and its tributaries

Parameters		SY1	SY2	SY3	SY4	SY5	SY6	SY7	SY8	SY9	SY10	SY11	SY12	SY13
Chloride (mg/l)	W	10.4	9.0	10.1	12.3	14.3	9.1	10.8	12.5	10.4	9.5	12.4	8.8	13.0
	PM	7.9	6.2	4.9	4.9	4.6	5.2	6.2	10.0	6.8	7.8	6.8	4.5	8.4
	M	6.6	5.9	4.9	4.7	4.4	5.0	5.8	9.2	6.4	7.3	6.4	4.3	7.9
Total alkalinity (mg/l of CaCO ₃)	W	55.29	60.84	65.03	63.02	71.07	57.53	63.39	61.78	61.91	26.80	73.89	58.90	68.05
	PM	27.16	24.40	22.04	23.22	22.04	30.70	15.74	28.73	29.91	29.91	19.68	30.70	37.39
	M	27.31	25.59	20.44	24.18	23.44	29.52	20.17	30.96	30.03	30.36	22.97	28.19	35.40
Total Hardness (mg/l)	W	50.38	54.03	60.68	57.31	66.42	50.87	56.02	57.54	55.45	57.62	68.33	51.16	61.59
	PM	23.31	20.95	18.92	19.93	18.92	26.35	13.51	26.15	27.22	27.22	17.91	27.94	34.03
	M	24.17	22.69	18.04	21.44	20.80	26.09	18.01	28.89	28.05	28.36	21.41	26.36	33.10
Calcium ions (mg/l)	W	16.80	18.22	20.59	19.46	22.02	17.75	18.83	19.60	18.81	18.89	22.46	16.90	20.41
	PM	8.49	7.63	6.89	7.26	6.89	9.60	4.92	9.53	9.92	9.92	6.52	10.18	12.40
	M	8.36	7.51	6.79	7.15	6.79	9.45	4.85	9.38	9.76	9.76	6.42	10.02	12.20
Magnesium ions (mg/l)	W	4.03	4.37	4.94	4.67	5.29	4.26	4.52	4.70	4.51	4.53	5.39	4.06	4.90
	PM	2.04	1.83	1.65	1.74	1.65	2.30	1.18	2.29	2.38	2.38	1.57	2.44	2.98
	M	2.01	1.80	1.63	1.72	1.63	2.27	1.16	2.25	2.34	2.34	1.54	2.40	2.93
Potassium (mg/l)	W	1.08	1.20	1.40	1.30	1.08	1.43	1.35	1.23	1.15	1.01	1.15	0.97	0.99
	PM	0.94	0.76	0.30	0.40	0.51	0.86	0.10	0.28	0.85	0.65	0.44	0.71	0.85
	M	0.70	0.76	0.39	0.58	0.59	0.89	1.26	0.89	0.87	0.82	0.75	0.75	0.78
Sodium (mg/l)	W	1.79	2.72	1.35	1.53	1.88	2.35	1.92	1.88	1.85	1.69	1.46	1.54	1.65
	PM	1.98	1.68	1.38	1.27	1.15	1.89	1.33	1.22	1.45	1.14	1.61	1.67	1.64
	M	1.45	1.74	1.37	1.35	1.63	2.03	2.11	1.63	1.87	1.52	1.96	1.83	1.72
Nitrates (NO ₃) (mg/l)	W	0.013	0.016	0.017	0.009	0.014	0.009	0.013	0.016	0.007	0.014	0.018	0.005	0.009
	PM	0.008	0.001	0.005	0.014	0.001	0.014	0.001	0.001	0.001	0.001	0.006	0.005	0.002
	M	0.008	0.001	0.005	0.014	0.001	0.013	0.001	0.001	0.001	0.001	0.006	0.005	0.002
Sulphate (mg/l)	W	3.80	4.08	4.75	4.46	5.70	4.75	2.88	4.80	2.87	2.89	3.85	2.89	3.85
	PM	4.25	3.80	3.13	3.58	4.03	1.57	4.03	2.91	2.91	4.25	1.57	4.70	4.92
	M	4.10	4.02	3.23	3.88	3.95	2.08	3.67	2.52	3.02	4.10	2.51	4.24	4.74
Phosphate (PO ₄) (mg/l)	W	0.005	0.004	0.001	0.001	0.004	0.005	0.005	0.006	0.005	0.008	0.009	0.009	0.004
	PM	0.004	0.002	0.004	0.008	0.001	0.004	0.001	0.001	0.002	0.003	0.005	0.003	0.002
	M	0.004	0.002	0.005	0.008	0.001	0.004	0.001	0.001	0.002	0.003	0.006	0.004	0.002

SY1 - SY13 - Sampling Sites; W= Winter; PM= Pre-monsoon; M=Monsoon

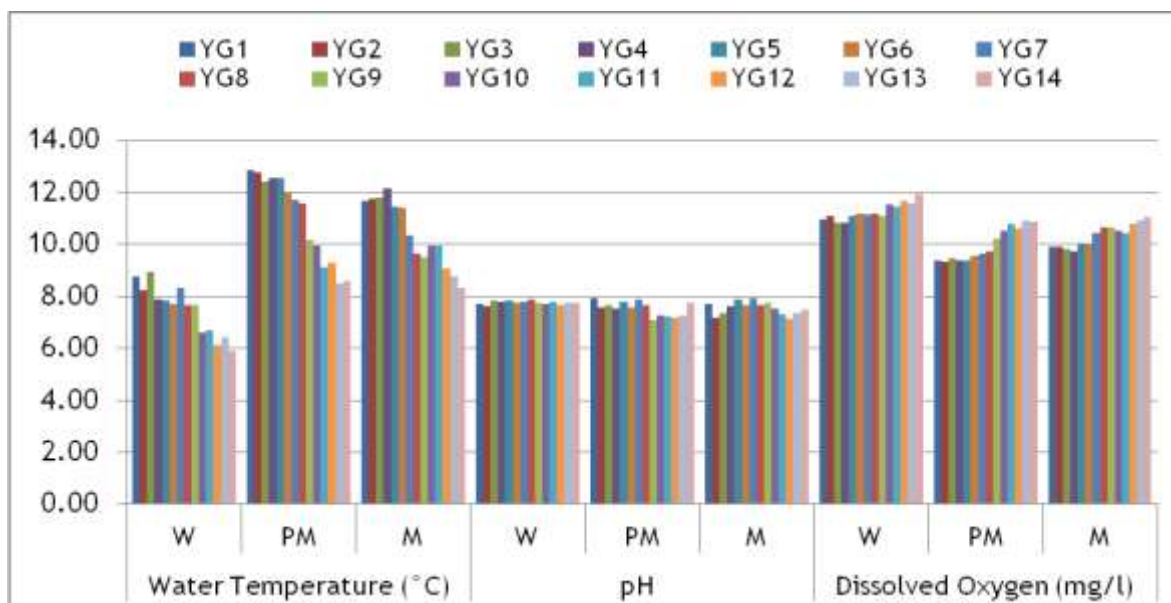


Figure 7.10: Water temperature, pH and DO data of Yargyap Chhu

Total Dissolved Solids, Total Suspended Solids and Electrical Conductivity varied from 44.41-92.56 mg/l, 4.33-17.00 mg/l and 72.80-151.74 $\mu\text{S}/\text{cm}$, respectively at different sampling locations in Yargyap Chhu river and its tributaries during winter season (Figure 7.11). In pre-monsoon season it ranged from 25.35-84.06 mg/l, 11.00-41.67 mg/l and 44.77-148.93 $\mu\text{S}/\text{cm}$, respectively. During the monsoon their values ranged from 9.13-15.42 mg/l, 22.05-156.87 mg/l and 14.73-24.87 $\mu\text{S}/\text{cm}$, respectively.

BOD and COD values at all sampling sites were very low (Figure 7.12). Total Coliforms were totally absent at all the sites during all seasons.

The Chlorides, Total alkalinity, Total hardness varied from 9.0-14.0 mg/l, 48.1-73.3 mg/l and 45.5-65.7 mg/l during winter, from 5.2-8.1 mg/l, 9.0-26.4 mg/l and 8.2-24.0 mg/l during pre-monsoon and from 5.0-7.6 mg/l, 16.9-28.4 mg/l and 15.7-26.5 mg/l during monsoon (Table 7.6).

The values of chlorides were recorded highest during the winter season whereas alkalinity and hardness was found highest during winter season as followed by pre-monsoon and monsoon season.

The concentrations of nitrates, sulphate and phosphates varied from 0.01-0.18 mg/l, 2.88-5.76 mg/l and 0.00-0.01 mg/l during winter, from 0.00-0.01 mg/l, 2.01-4.92 mg/l and 0.00-0.01 mg/l during pre-monsoon and during monsoon these ranged from 0.00-0.01 mg/l, 1.94-4.74 mg/l and 0.00-0.01 mg/l, respectively (Table 7.6).

The water quality parameters were also assessed at two sites outside the basin i.e. at Jiya Dhol in Jiya Dhol river and near Kareng Ghat in Brahmaputra though not excellent but was good in general as seen from the values of all the parameters (see Table 7.7).

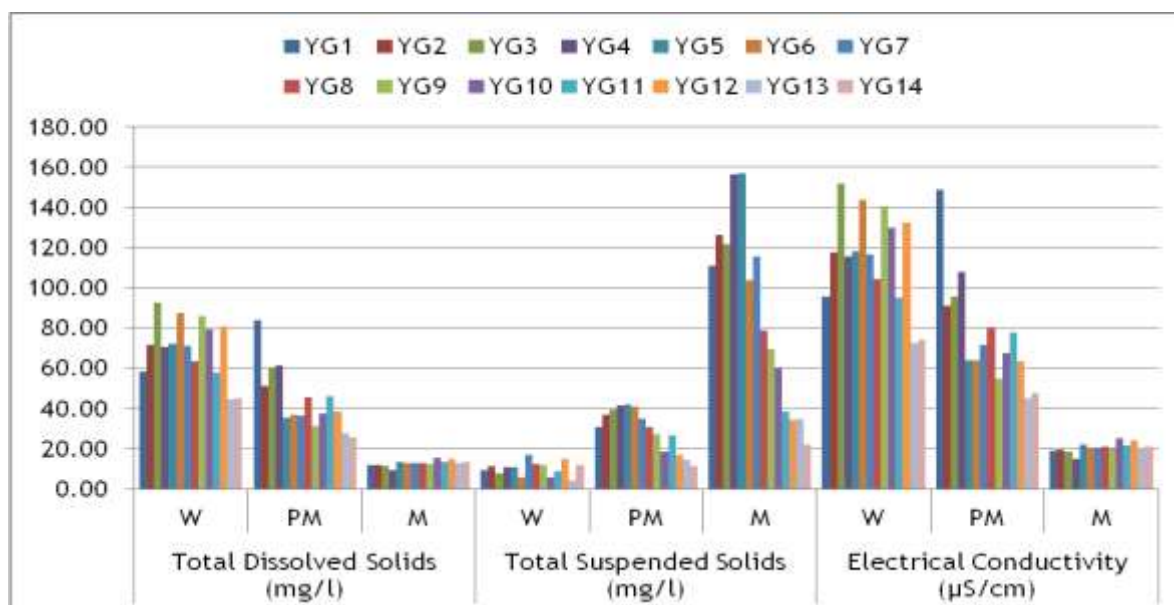


Figure 7.11: Total dissolved solids, TSS and EC data of Yargyap Chhu

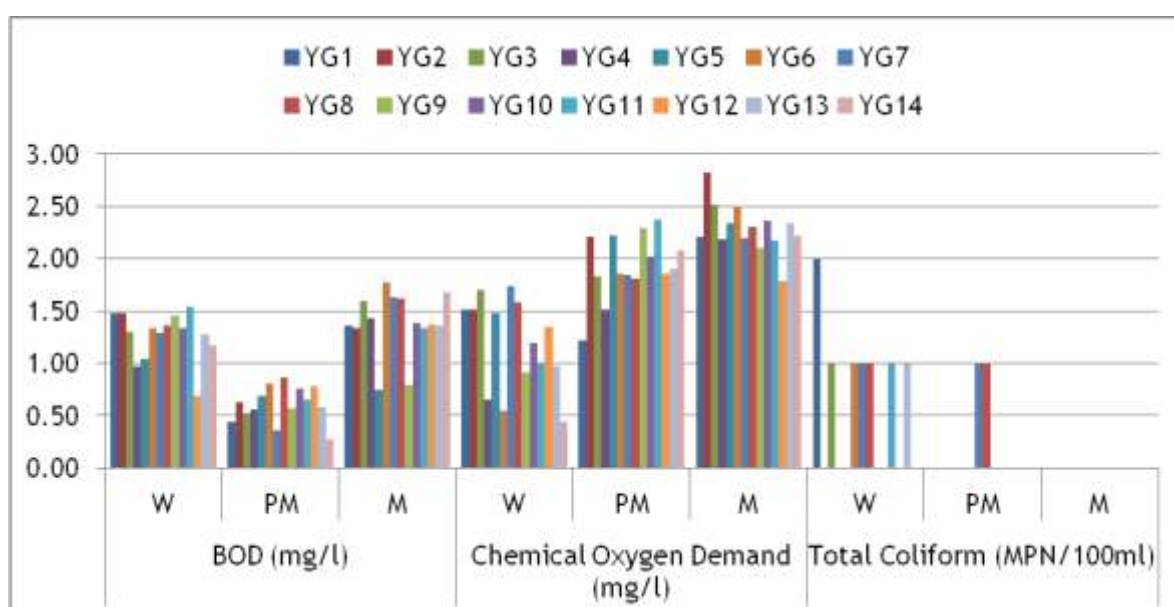


Figure 7.12: BOD, COD and total coliforms in Yargyap Chhu

7.1.2 Conclusions

The pH levels in the Siang river and its tributaries ranged from 7.10 to 8.50 in all seasons at various sites covered as a part of the study. Though at number of sites pH was more than 8 indicating marginally higher alkaline nature of water, the pH levels in general are well within the permissible limit specified for drinking water requirements (**Refer Table 7.2**). The dissolved oxygen values in general were quite high owing cold waters and turbulent waters of most of the streams.

The BOD values are well within the permissible limit which is due to the absence of organic pollution loading sources in the basin as the population density is very low and there is complete absence of industries in the basin. The low COD values also indicate the absence of chemical pollution loading in the area. Total Coliform level was nil at all the sampling sites except for few sites located near Pasighat town.

The TDS levels ranged from as low as 9.13 to 293.67 mg/l which are well below the permissible limit of 500 mg/l specified for drinking water. The TDS levels were found to be much lower in monsoon months as compared to winter and summer months. Similar trend was also observed for various cations and anions monitored as a part of the study. These lower levels are generally attributed to higher discharges in monsoon months in all streams.

The hardness level ranged from 8.20 to 68.33 mg/l indicating soft nature of water. The hardness level was well below the permissible limit of 300 mg/l specified for drinking water Class A standards. It is caused by cations like calcium, magnesium, and iron. The low levels of calcium and magnesium are mainly responsible for the soft nature of water. Alkalinity of water is a measure of its capacity to neutralize acids. The alkalinity of natural water is due primarily because of the salts of weak acids. The alkalinity as usual was found to be higher than the total hardness in all the water sampling sites indicating that entire hardness in the water is on account of carbonate hardness and there are no bicarbonates hardness in the water.

Chlorides occur in all natural waters in widely varying concentrations and its levels ranged from 4.26 to 14.29 mg/l, which are well below the permissible limit of 200 mg/l, specified for meeting drinking water requirements. The sulphates levels at various sampling sites were quite low and ranged from 1.57 to 8.55 mg/l.

Nitrates are an important source of nitrogen necessary for plants and animals to synthesize amino acids and proteins whereas phosphorus in surface water is present in the form of phosphates. The concentration of nitrates and phosphates at various sampling sites was observed to be below detectable limit of 0.01 mg/l.

The concentration of various cations, e.g. sodium, potassium, calcium and magnesium was observed to be quite low which is also reflected by the low TDS levels. Iron was found to be well below the permissible limit of 1 mg/l specified for drinking water purposes.

Heavy metals were not detected at any of the sampling sites in the basin during different sampling periods (see Annexure-V of Volume-II: DATA). This is because there is no industry in the located in the basin and people do not use any fertilisers or pesticides/insecticides as they practice only *jhum* cultivation in the area.

Overall as seen from the analysis of all the physico-chemical parameters in the entire basin the water quality of Siang river and all its tributaries is well within prescribed limits of CPCB.

In order to assess the overall water quality of Siang river its tributaries like Siyom, Simang, Yamne and Yargyap Chhu an index was employed which is discussed in the following paragraphs.

7.1.3 Water Quality Index

In order to assess the overall water quality of Siang and Siyom rivers along with their tributary streams a Water Quality Index was used which has been developed at Washington State Department of Ecology, Environmental Assessment Programme. The Water Quality Index (WQI) used in the report is a unitless number ranging from 1 to 100. A higher number is indicative of better water quality. For temperature, pH, faecal coliform bacteria and dissolved oxygen, the index expresses results relative to levels required to maintain beneficial uses (based on criteria in Washington's Water Quality Standards, WAC 173-201A).

Water quality index is a 100 point scale that summarizes results from a total of nine different parameters listed below.

pH	Total/Faecal Coliform	Nitrates
Dissolved Oxygen	Biochemical Oxygen Demand	Total Suspended Solids
Turbidity	Total Phosphates	

Table 7.6: Physico-chemical characteristics of Yargap Chhu

Parameters		YG1	YG2	YG3	YG4	YG5	YG6	YG7	YG8	YG9	YG10	YG11	YG12	YG13	YG14
Chloride (mg/l)	W	14.0	10.5	13.7	9.0	11.4	10.4	13.0	11.3	13.4	12.1	11.4	12.1	13.5	11.9
	PM	7.8	8.1	7.5	5.2	6.2	5.5	6.8	5.5	5.5	7.5	6.8	7.5	7.5	7.8
	M	6.4	6.4	6.3	5.2	6.8	5.6	6.7	5.6	5.0	6.1	5.9	6.6	7.6	6.8
Total alkalinity (mg/l of CaCO ₃)	W	69.05	55.60	71.33	48.08	59.72	58.07	61.03	56.49	67.55	67.89	64.79	67.62	63.06	68.29
	PM	26.37	25.98	22.04	24.72	9.01	24.76	25.70	22.04	21.26	17.71	22.04	20.94	22.04	9.45
	M	25.81	24.60	22.78	26.12	17.97	26.81	28.40	24.78	22.95	20.40	23.44	23.42	26.44	16.90
Total Hardness (mg/l)	W	63.71	51.30	65.71	45.50	56.26	55.05	57.39	51.50	62.13	63.31	59.57	60.74	61.13	64.84
	PM	24.00	23.64	20.06	22.49	8.20	22.53	23.39	20.06	19.34	16.12	20.06	19.06	20.06	8.60
	M	24.08	22.95	21.23	24.34	16.65	24.98	26.45	23.07	21.38	19.00	21.85	21.81	24.61	15.68
Calcium ions (mg/l)	W	21.37	17.14	22.00	15.51	20.10	18.96	19.54	17.91	20.72	21.48	19.57	20.88	20.30	21.64
	PM	8.74	8.61	7.31	8.19	2.99	8.21	8.52	7.31	7.05	5.87	7.31	6.94	7.31	3.13
	M	8.58	8.45	7.17	8.04	2.93	8.05	8.36	7.17	6.91	5.76	7.17	6.81	7.17	3.07
Magnesium ions (mg/l)	W	5.13	4.11	5.28	3.72	4.82	4.55	4.69	4.30	4.97	5.16	4.70	5.01	4.87	5.19
	PM	2.10	2.07	1.75	1.97	0.72	1.97	2.05	1.75	1.69	1.41	1.75	1.67	1.75	0.75
	M	2.06	2.03	1.72	1.93	0.70	1.93	2.01	1.72	1.66	1.38	1.72	1.63	1.72	0.74
Potassium (mg/l)	W	1.33	1.11	1.22	1.22	1.18	0.94	1.16	1.14	0.89	1.37	1.22	1.48	1.03	1.11
	PM	0.78	0.60	0.15	0.47	0.52	0.59	0.97	0.67	0.39	1.17	0.83	0.66	0.74	0.53
	M	0.45	0.58	0.27	0.65	0.49	0.57	0.53	0.27	0.30	0.66	0.42	0.32	0.60	0.43
Sodium (mg/l)	W	1.37	1.74	1.69	1.74	1.94	1.64	2.00	1.89	1.56	1.85	2.08	2.49	1.64	1.27
	PM	1.18	1.09	1.14	1.38	1.32	0.85	1.27	1.37	1.16	1.48	1.43	1.12	1.43	1.13
	M	1.59	1.17	1.11	1.68	1.54	1.15	1.37	1.47	1.59	1.52	1.57	1.44	1.38	1.14
Nitrates (NO ₃) (mg/l)	W	0.18	0.04	0.07	0.17	0.16	0.16	0.09	0.07	0.05	0.06	0.05	0.07	0.03	0.01
	PM	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01
	M	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01
Sulphate (mg/l)	W	4.81	4.81	5.76	2.88	3.84	2.88	4.80	2.88	3.84	4.80	5.75	5.76	4.80	5.75
	PM	3.80	4.92	4.25	3.36	3.36	2.01	3.58	4.25	4.70	3.80	3.80	3.80	4.92	4.25
	M	3.67	4.74	4.10	3.24	3.24	1.94	3.45	4.10	4.53	3.67	3.52	3.52	3.82	3.88
Phosphate (PO ₄) (mg/l)	W	0.008	0.009	0.001	0.005	0.007	0.003	0.003	0.005	0.002	0.008	0.004	0.005	0.009	0.009
	PM	0.008	0.006	0.005	0.008	0.006	0.001	0.010	0.002	0.001	0.005	0.003	0.005	0.006	0.002
	M	0.008	0.006	0.006	0.008	0.006	0.001	0.010	0.002	0.001	0.005	0.003	0.005	0.006	0.003

YG1 - YG14 - Sampling Sites; W= Winter; PM= Pre-monsoon; M=Monsoon

The analysis of above mentioned parameters revealed that most of the parameters are of least importance in hilly and mountainous streams with very scanty population and with very good forested landscape around as seen from the results discussed in previous sections earlier that most of them are within prescribed standards. In addition the concentration of most of the heavy metals is Not Detectable or Below Detectable limits.

Therefore values for all or most of the parameters for each sampling site were used to arrive at a meaningful conclusion and interpretation otherwise the data collected for each and every month for each parameter becomes too voluminous to arrive at any meaningful outcome.

The analysis of water quality therefore has been based upon 9 parameters as defined for WQI above.

Water Quality Index Legend	
Range	Quality
90-100	Excellent
70-90	Good
50-70	Medium
25-50	Bad
0-25	Very bad

Analysis of river water quality in the basin based upon WQI is given in the following paragraphs.

As discussed earlier in order to assess the physico-chemical water quality of Siang river and its tributary streams WQI was calculated and results of the same are shown in **Figure 7.13**. As seen from the chart WQI in general varies from 70 to 92 which indicates that water quality is Good to Excellent.

The water quality of Siang river, Siyom river, Yamne river, Simang river, Hirit river, and Yargyap Chhu during winter season sampling is excellent in general as it remained above 90 (**Figure 7.13**). During monsoon only the water quality degraded a little bit but still remained under Good category.

Water quality at sampling sites located outside Siang basin i.e. at Jiya Dhol which directly drains into Brahmaputra river as well as that of water samples collected from Brahmaputra at Kareng Ghat near Dibrugarh are of Good category as per WQI (**Table 7.7**) though the water quality index is lower than that recorded at other locations in Siang basin.

Table 7.7: Water Quality Index of Jiya Dhol and Brahmaputra near Kareng Ghat

Site	Winter	Pre-monsoon	Monsoon
B1	89	76	67
B2	81	72	70

Overall Water Quality Index as shown in **Figure 7.13** reveals that water quality in Siang river and its tributaries is either under Good or Excellent category (WQI > 90) or under Good category (WQI=60-90). Yargyap Chhu and upper reaches of Siyom river have excellent water quality.

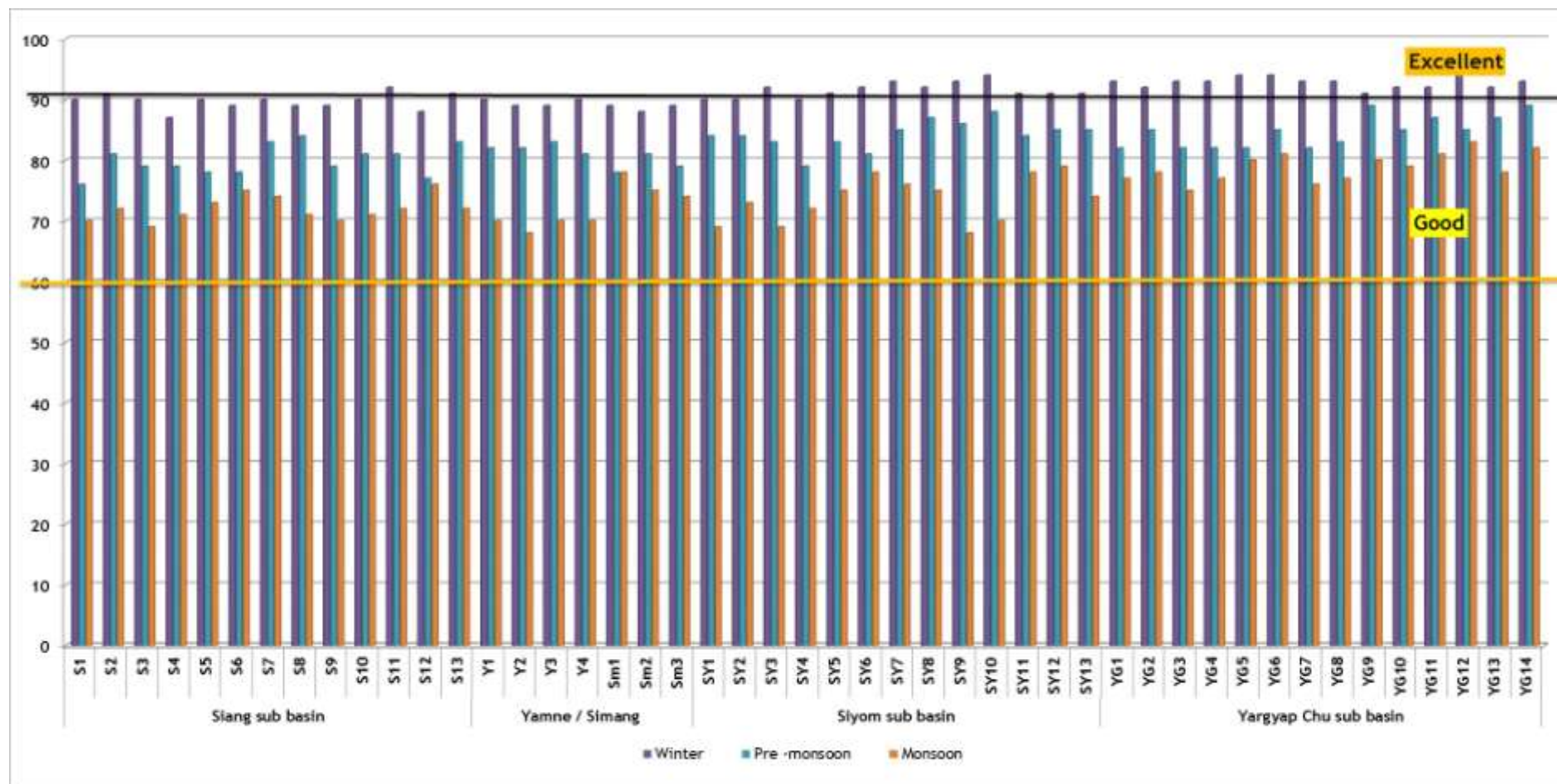


Figure 7.13: Overview of Physico-chemical Water Quality Index in Siang basin

7.1.4 Biological Water Quality

Rock surfaces, plant surfaces, leaf debris, logs, silt and sandy sediments and all other spaces in the stream provide habitat for different organisms. According to these habitats, organisms are divided into plankton, benthos, nektons and neuston. In order to evaluate the biological water quality various aquatic organisms viz. phytoplankton, phytobenthos, zooplankton and macro-invertebrates were sampled during the study in different seasons.

7.1.4.1 Phytoplankton

The word “plankton” is an umbrella term for organisms that live their lives adrift in the water and are unable to move independently. The term comes from an Ancient Greek word which means “floating,” and these organisms do indeed float through bodies of water both fresh and salty around the world. They nourish larger animals, which are in turn eaten by even bigger animals, and so on up to organisms like humans at the top of the food chain. Plankton are also responsible for the Earth's atmosphere, thanks to the efforts of billions of photosynthesizing phytoplankton. The phytoplankton comprise of diatoms, dinoflagellates, cyanobacteria, and other groups of unicellular algae.

The damming of rivers for of hydropower invariably has profound impact on the planktonic communities as the planktonic organisms are forced to inhabit regulated stream/s with cascades of reservoirs. The species composition of two conditions as a result of damming of river i.e. lake conditions and free flowing river conditions are different. Hence, prior to dam construction it is necessary to know the species composition, density and diversity of phytoplankton.

Siang River and its tributaries are rich in all biotic components. In all total 116 species of Phytoplankton were recorded from all the locations during surveys conducted in different months of three seasons. Site-wise detailed list of all the species has been given at **Annexure-V of Volume-II:DATA**. *Achnantheidium* was the most dominant genus represented by 33 species followed by *Gomphonema* with 23 species. *Achnantheidium affinis* and *Achnantheidium austriaca* are most common and abundant species as they were recorded with highest Proportionately Realive Abundance from Siang basin. *Achnantheidium lapidosa* and *Navicula cryptocephala* are the other two most abundantly found species in the basin.

a) Siang River & its Tributaries : Sub-basins I-IV

In these sub-basin total 88 species of diatoms were recorded varying from 79 in sub-basin-I to highest (87) in sub-basin-IV. Lowest number of species (9) at S10 in sub-basin-III during monsoon and highest (76) were recorded from S2 site in sub-basin-I in winter months and maximum number of species was recorded during winter months (**Table 7.8**).

Phytoplankton density too was highest during winter as compared to the other seasons and highest was recorded at site S13 near Jidu village and lowest at site S5 near Boleng (**Table 7.8**). Density of Phytoplankton during pre monsoon season was ranged from (271-835 indiv/lit), highest density was recorded at (S13) near Jidu village and lowest at (S11) 12 km downstream of Tuting. Density was lowest recorded form monsoon season where it ranged from (128-568 indiv/lit) whereas highest density observed at (S12) near Tuting and lowest at (S6) 11km upstream of Hawai camp.

Shannon Weiner species diversity during winters was highest at site S13 Jidu village (3.27) lowest at (S2) downstream of Ranaghat (2.85) (**Table 7.8**). During pre-monsoon it ranged from 1.82-2.25 and in monsoon it ranged from 1.13-1.57 with highest at site S13 near Jidu village and lowest at at S4 located near Kebang.

Regarding the distribution pattern most of the species were more or less evenly distributed during winter and pre-monsoon seasons while the the distribution was irregular during monsoon (**Table 7.8**).

b) Yamne & Simang Rivers

The number of phytoplankton species recorded were highest during winter months sampling and overall number of species ranged between 13 (monsoon at site Sm1 in Simang sub-basin) and 61 (winter at site Y1 in Yamne sub-basin) (**Table 7.9**). Total number of species in Yamne sub-basin recorded is 72 while there are 88 species in Simang sub-basin.

Phytoplankton density in this sub-basin varied from 869- 1015 during winter (**Table 7.9**). During pre-monsoon season density varied from 293-580 with highest density at site Y2 upstream of Padu and lowest at site Y4 near Lagru. In monsoon it varied from 188-292 with highest at site Y1 Jerring and lowest at site Y4 near Lagru.

The density of phytoplankton in these sub-basins was highest during winter as compared to other seasons and it ranged from 320-1264 indiv/l with highest recorded at site Sm1 and lowest at site Sm2 located near Lilang (**Table 7.9**). Density of Phytoplankton during pre-monsoon season ranged from 285-405 indiv/l with highest at Lilang (Sm2) and lowest at Simang (Sm1). Overall density was lowest during monsoon season when it ranged between 154 and 342 indiv/l (**Table 7.9**).

The Shannon-Weiner species diversity index of phytoplanktons in Yamne sub-basin was highest during winter season (2.82-3.08) (**Table 7.9**). It was lowest during pre monsoon (1.88-2.37).

The Shannon-Weiner species diversity index of phytoplanktons in Simang sub-basin was highest during winter season (2.88-3.04) and lowest during monsoon (1.19-1.35) (**Table 7.9**).

According to Evenness values recorded during different periods, most of the species were more or less evenly distributed during winter and pre-monsoon seasons while the the distribution was irregular during monsoon (**Table 7.9**).

c) Hirit River

In Hirit sub-basin total 83 species of phytoplankton were recorded during the surveys conducted in different seasons. Maximum number of species was recorded from site SY1 during winters (**Table 7.10**). The density of phytoplankton and Shannon Weiner Diversity idex were highest during winters and lowest during monsoon.

d) Siyom River & its Tributaries

In these sub-basins total 94 species of diatoms were recorded varying from lowest of 87 in Siyom sub-basin-II to highest (94) in sub-basin-I. Lowest number of species (8) was recorded at SY4 in during monsoon and highest (64) were recorded from SY1 during winter season and overall maximum number of species was recorded during winter month samplings (**Table 7.10**).

In Siyom sub-basins and Hirit sub-basin phytoplankton density varied from 467-1711 during winter, highest at site before confluence of Yargyap Chu with Siyom river (SY11) and lowest at Kamba (SY2) (**Table 7.10**). During pre-monsoon months density ranged from 262 indiv/l - 699 indiv/l with highest at site located downstream of Sittin nala (SY12) and lowest at Kamba site (SY2) near Hirit river confluence with Siyom river. During monsoon density ranged from 140 indiv/l -378 699 indiv/l with highest recorded at site upstream of Raying Basti (SY4) and lowest at Karo site (SY13).

Table 7.8: Density and Diversity of Phytoplankton in Siang river and its tributaries in Siang sub-basins I-IV

	Season	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
No. of species	Winter	61	76	69	72	59	62	68	51	46	62	69	55	58
	Pre-monsoon	23	26	21	24	22	25	23	21	24	25	16	19	21
	Monsoon	11	13	8	9	13	17	13	13	11	7	9	13	15
Density (cells/lit.)	Winter	448	976	646	762	354	489	657	921	645	531	402	1409	6860
	Pre-monsoon	661	708	496	574	330	390	621	589	396	305	271	766	835
	Monsoon	196	309	262	345	135	128	258	229	156	265	189	568	354
Shannon Weiner Diversity	Winter	3.13	2.85	3.05	3.24	2.93	3.07	3.16	3.10	2.88	2.90	3.00	3.07	3.27
	Pre-monsoon	2.22	1.85	2.17	1.89	1.82	2.04	2.16	2.09	2.23	2.03	2.15	2.25	2.24
	Monsoon	1.34	1.41	1.39	1.13	1.36	1.40	1.38	1.37	1.33	1.22	1.34	1.43	1.57
Evenness Index	Winter	0.76	0.79	0.77	0.79	0.75	0.76	0.77	0.77	0.76	0.76	0.75	0.79	0.78
	Pre-monsoon	0.65	0.61	0.65	0.56	0.61	0.65	0.65	0.65	0.67	0.67	0.65	0.67	0.66
	Monsoon	0.55	0.54	0.55	0.53	0.55	0.52	0.55	0.55	0.56	0.55	0.56	0.54	0.53

Table 7.9: Density and Diversity of Phytoplankton in Yamne & Simang sub-basins

	Season	Y1	Y2	Y3	Y4	Sm1	Sm2	Sm3
No. of species	Winter	61	59	59	53	58	55	48
	Pre-monsoon	24	28	26	22	18	22	25
	Monsoon	17	15	18	16	13	14	13
Density (cells/lit.)	Winter	1015	947	869	1006	1264	320	575
	Pre-monsoon	577	580	488	293	405	285	340
	Monsoon	292	245	189	188	342	167	154
Shannon Weiner Diversity Index	Winter	2.82	3.08	3.02	2.85	3.03	3.04	2.88
	Pre- monsoon	2.37	2.10	2.13	1.88	1.97	2.07	2.09
	Monsoon	1.64	1.28	1.39	1.30	1.19	1.35	1.30
Evenness Index	Winter	0.71	0.80	0.77	0.76	0.77	0.75	0.77
	Pre-monsoon	0.67	0.63	0.66	0.60	0.58	0.66	0.66
	Monsoon	0.54	0.56	0.52	0.56	0.54	0.55	0.56

The diversity during winter season varied from 2.88-3.18 indiv/l with highest at site SY13 upstream of Karo village and lowest at site SY6 near Pene (**Table 7.10**). Overall diversity was ranged between 1.26 and 3.18 in these sub-basins and was lowest during monsoon season sampling.

According to Evenness values recorded during different periods, most of the species were more or less evenly distributed during winter and pre-monsoon seasons while the the distribution was irregular during monsoon (**Table 7.10**).

e) Yargyap Chhu

In Yargyap Chhu sub-basin total 90 species of diatoms were recorded varying from lowest of 11 at site YG8 during monsoon to highest (61) from site YG12 during winters (**Table 7.11**). Overall maximum number of species was recorded during winter month samplings (**Table 7.11**).

Phytoplankton density as expected was highest during winter as compared to the other seasons and it ranged between 478 and 3841 indiv/l in this period (**Table 7.11**). It was highest at Kangtangshiri dam site (YG11) and lowest at near Tato-I dam site (YG1). Density during pre-monsoon months was highest at Heo near powerhouse (YG2) and again lowest at Kangtangshiri near dam site (YG11). Density was lowest during monsoon season.

The Shannon Weiner diversity during winters ranged from 2.80-3.09 and was highest at Pauk dam site (YG5) and lowest at Pema Shelpu dam site (YG13) (**Table 7.11**). In pre-monsoon varied from 2.00-2.93 and in monsoon it varied from 1.33-1.52.

Regarding the distribution pattern (Evenness Index) most of the species were more or less evenly distributed during winter and pre-monsoon seasons while the the distribution was irregular during monsoon (**Table 7.11**).

f) Sites located outside Siang basin

At two sampling sites located outside basin total 57 species of diatoms were recorded varying from lowest of 19 at site B1 during monsoon to highest (55) from site B2 during winters (**Table 7.12**). Overall maximum number of species as usual was recorded during winter month samplings (**Table 7.12**).

The density of phytoplankton and phytobenthos at Jiya Dhol site was very low (**Table 7.12**). The density at B1 site was highest during winters (445 indiv/l) and similarly it was highset (765 indiv/l) at B2 during winters.

Shannon Weiner species diversity index also was maximum during winters and lowest during mosoon samplings (**Table 7.12**).

The distributaion pattern of species at these two sites was irregular in general during most of the samplings.

Table 7.10: Density and Diversity of Phytoplankton in Hirit sub-basin and Siyom sub-basins I-III

	Season	SY1	SY2	SY3	SY4	SY5	SY6	SY7	SY8	SY9	SY10	SY11	SY12	SY13
No. of species	Winter	66	52	54	58	61	55	57	56	58	62	57	59	55
	Pre-monsoon	23	24	21	25	26	23	28	27	25	22	24	26	21
	Monsoon	13	11	18	8	17	15	18	13	9	11	14	17	16
Density (cells/lit.)	Winter	1209	467	502	467	659	1075	1523	1120	1324	1369	1711	1323	681
	Pre-monsoon	607	262	270	499	489	660	411	338	325	517	433	699	519
	Monsoon	234	154	180	378	176	156	192	214	289	166	156	171	140
Shannon Weiner Diversity Index	Winter	3.02	3.00	2.96	3.13	2.98	2.88	2.90	3.12	2.94	3.09	3.02	2.91	3.18
	Pre-monsoon	2.18	2.07	2.12	2.02	2.28	2.07	2.16	2.19	2.06	2.17	2.29	2.19	2.18
	Monsoon	1.52	1.32	1.45	1.50	1.52	1.31	1.41	1.40	1.26	1.59	1.39	1.39	1.44
Evenness Index	Winter	0.74	0.78	0.79	0.78	0.79	0.74	0.75	0.78	0.77	0.76	0.76	0.75	0.75
	Pre-monsoon	0.66	0.64	0.66	0.56	0.66	0.67	0.69	0.68	0.57	0.67	0.67	0.67	0.69
	Monsoon	0.54	0.56	0.53	0.55	0.54	0.52	0.54	0.53	0.54	0.56	0.55	0.53	0.54

Table 7.11: Density and Diversity of Phytoplankton in Yargyap Chhu sub-basin

	Season	YG1	YG2	YG3	YG4	YG5	YG6	YG7	YG8	YG9	YG10	YG11	YG12	YG13	YG14
No. of species	Winter	59	52	50	55	59	60	54	57	60	52	57	61	56	53
	Pre-monsoon	18	24	23	24	23	26	28	23	23	23	21	24	26	24
	Monsoon	15	13	12	18	16	14	13	11	13	17	15	16	16	15
Density (cells/lit.)	Winter	478	1285	1611	1627	1351	1658	2581	2226	2341	2489	3841	839	3110	2651
	Pre-monsoon	512	778	492	560	507	559	613	480	591	571	407	427	522	581
	Monsoon	244	271	298	214	213	176	456	164	189	167	159	187	253	173
Shannon Weiner Diversity Index	Winter	2.98	2.97	2.94	2.88	3.09	2.92	3.07	3.04	3.07	2.98	2.94	3.08	2.80	2.97
	Pre-monsoon	2.19	2.34	2.12	2.17	2.23	2.29	2.29	2.00	2.17	2.21	2.93	2.13	2.25	2.23
	Monsoon	1.48	1.44	1.46	1.34	1.39	1.37	1.33	1.36	1.49	1.35	1.52	1.42	1.37	1.46
Evenness Index	Winter	0.77	0.79	0.75	0.74	0.78	0.76	0.77	0.74	0.80	0.77	0.78	0.79	0.72	0.77
	Pre-monsoon	0.67	0.67	0.68	0.68	0.62	0.66	0.69	0.60	0.67	0.68	0.68	0.68	0.67	0.66
	Monsoon	0.56	0.55	0.54	0.52	0.52	0.53	0.54	0.55	0.54	0.56	0.55	0.53	0.56	0.54

Table 7.12: Density and Diversity of Phytoplankton at Jiya Dhol & Kareng Ghat

	Season	B1	B2
No. of species	Winter	43	55
	Pre-monsoon	29	49
	Monsoon	19	22
Density (cells/lit.)	Winter	445	765
	Pre-monsoon	234	356
	Monsoon	87	109
Shannon Weiner Diversity Index	Winter	2.55	2.76
	Pre-monsoon	1.66	1.78
	Monsoon	0.98	1.03
Evenness Index	Winter	0.79	0.75
	Pre-monsoon	0.56	0.61
	Monsoon	0.43	0.52

7.1.4.2 *Phytobenthos*

Benthos is the community of organisms that live on or in the river bed also known as benthic zone. The main food sources for the benthos are algae and organic runoff from land. The depth of water, temperature and salinity, and type of local substrate all affect what benthos is present. Phytobenthos comprises the plants belonging to the benthos, mainly benthic diatoms.

In all total 79 species of Phytobenthos were recorded from all the locations during surveys conducted in different months of three seasons. Site-wise detailed list of all the phytobenthos species has been given at **Annexure-V of Volume-II:DATA**. The genus *Achnantheidium* was the most dominant genus represented by 21 species followed by *Gomphonema* with 13 species. *Achnantheidium austriaca* are most common and abundant species as they were recorded with highest Proportionately Relative Abundance from Siang basin and was recorded from all the sites during all samplings.

a) *Siang River & its Tributaries : Sub-basins I-IV*

Total number of species in Siang sub-basins ranged between 51 and 61. Maximum number of species (44) was recorded from three sites i.e. S1, S6 and S11 during winters (**Table 7.13**). *Achnantheidium austriaca* and *A. boyei* are the most abundant species found in these sub-basins. The density of phytobenthos (indiv/lit) was highest during winters ranging from 1104-7726 with maximum at site S12 located upstream of Yangsang and Siang confluence near Tuting and lowest at site S7 near Mirak HEP dam site (**Table 7.13**). It was lowest in monsoon season when it ranged from 50-1563 with maximum at site S9 upstream of Nunning and lowest at site S1 near Bodak the dam site of Siang Lower HEP.

The Shannon-Weiner Species Diversity index in Siang river and its tributaries was highest during winters and varied between 3.08 and 3.34) as highest diversity values of phytobenthos was observed at site S12 upstream of Yangsang and Siang confluence near Tuting and lowest at sampling site S1 near Bodak (**Table 7.13**). The diversity in monsoon season was lowest and ranged from 1.23-1.60 with highest diversity at site S11 located 12 km downstream of Tuting and lowest at site S2 located downstream of Ranaghat.

b) *Yamne & Simang Rivers*

Total 46 species of phytobenthos were recorded from Yamne sub-basin while 52 species were recorded from Simang sub-basin (**Table 7.14**). The number of phytobenthos species recorded were highest during winter months sampling and overall number of species ranged between 5 (during

Table 7.13: Density and Diversity of phytobenthos in Siang river and its tributaries in Siang sub-basins I-IV

	Season	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
No. of species	Winter	44	43	43	37	43	44	41	40	39	37	44	43	41
	Pre-monsoon	19	19	20	22	22	18	22	20	23	17	24	19	17
	Monsoon	9	11	8	10	11	9	10	10	8	7	9	10	10
Density (cells/cm ²)	Winter	1474	1813	2269	1804	3329	3189	1104	3394	3291	1593	1689	7726	3204
	Pre-monsoon	337	137	134	2483	1139	1636	225	1690	14886	510	38470	1446	1369
	Monsoon	50	98	56	700	667	137	112	211	1563	321	1389	432	323
Shannon Weiner Diversity Index	Winter	3.08	3.14	3.23	3.13	3.26	3.13	3.25	3.24	3.11	3.16	3.33	3.34	3.31
	Pre- monsoon	2.16	2.00	2.09	2.40	2.33	2.04	2.17	2.27	2.37	2.05	2.41	2.35	2.33
	Monsoon	1.26	1.23	1.24	1.56	1.46	1.28	1.29	1.27	1.55	1.34	1.60	1.28	1.30
Evenness Index	Winter	0.88	0.89	0.89	0.85	0.84	0.88	0.85	0.88	0.85	0.84	0.88	0.89	0.88
	Pre-monsoon	0.77	0.79	0.73	0.74	0.73	0.74	0.71	0.79	0.76	0.78	0.74	0.79	0.73
	Monsoon	0.56	0.55	0.56	0.62	0.57	0.60	0.55	0.57	0.58	0.58	0.54	0.55	0.56

Table 7.14: Density and Diversity of phytobenthos in Yamne and Simang river sub-basins

	Season	Y1	Y2	Y3	Y4	Sm1	Sm2	Sm3
No. of species	Winter	45	42	41	43	43	40	38
	Pre-monsoon	19	19	20	22	29	20	14
	Monsoon	9	9	8	5	8	10	11
Density (cells/cm ²)	Winter	3047	2120	2154	4465	23718	25883	29511
	Pre-monsoon	897	855	1408	700	29640	6442	6658
	Monsoon	136	132	809	453	1543	148	274
Shannon Weiner Diversity Index	Winter	3.30	3.26	3.22	3.28	3.31	3.26	3.19
	Pre- monsoon	2.09	2.15	2.20	2.16	2.61	2.09	1.90
	Monsoon	1.24	1.23	1.34	1.33	1.67	1.24	1.28
Evenness Index	Winter	0.88	0.87	0.87	0.88	0.86	0.88	0.88
	Pre-monsoon	0.74	0.76	0.78	0.70	0.71	0.73	0.76
	Monsoon	0.56	0.56	0.54	0.55	0.57	0.55	0.53

monsoon at site Y4 in Yamne sub-basin) and 45 (during winter at site Y1 in Yamne sub-basin) (Table 7.14). *Achnantheidium austriaca*, *A. conspicua* and *A. nodosa* are the most abundant species found in these two sub-basins.

Density of Phytobenthos was observed highest during winter season as compare to other seasons. In winter phytobenthos density varied from (2120-4465) in Yamne sub-basin and 23718-29511 indiv/l in Simang sub-basin (Table 7.14). In Yamne sub-basin it was highest at site Y4 near Lagru and lowest at site Y2 located upstream of Padu. In Simang sub-basin density was highest at Supple at site Sm3.

Phytobenthos diversity (no. of individuals/l) was highest during the winter season and ranged between 3.22 and 3.30 in Yamne sub-basin and between 3.19 and 3.31 in Siamng sub-basin. In Yamne sub-basin it was maximum at site Y1 near Jerring and lowest at site Y3 near Siyat (Table 7.14). The density was lowest during monsoon season and ranged from 1.23-1.34 in Yamne sub-basin and 1.24-1.67 in Simag sub-basin.

c) *Hirit River*

Total 58 species of phytobenthos were recorded from Hirit sub-basin (Table 7.15). The number of phytobenthos species recorded was highest during winter months sampling. *Achnantheidium austriaca* and *A. nodosa* are the most abundant species found in this sub-basin.

As expected the density of phytoplankton and Shannon Weiner Diversity idex were highest during winters and lowest during monsoon.

d) *Siyom River & its Tributaries*

Total 95 species of phytobenthos were recorded from different Siyom sub-basins wth 94, 87 and 88 species recorded from Siyom sub-basins I, II and III, respectively (Table 7.15). The number of phytobenthos species recorded was highest during winter months sampling. Highest number of species (41 in winters) was recorded from site SY5 and lowest (6 in monsoon) from site S8. *Achnantheidium austriaca*, *A. boyei*, *A. exigua* and *Cocconeis placentula* var. *euglypta* are the most abundant species found in these sub-basins.

The density of Phytobenthos (no. of individuals/l) was highest during winter season as compared to the pre-monsoon and monsoon. The density varied from 1427-47246 in winters, 554-25204 in pre-monsoon and 92-3209 in monsoon (Table 7.15). The highest density was recorded during winters at site SY11 before confluence of Yargyap Chu with Siyom river and lowest at SY5 during monsoon.

Table 7.15: Density and Diversity of phytobenthos in Siyom river and its tributaries in Hirit sub-basin and Siyom sub-basins I-III

	Season	SY1	SY2	SY3	SY4	SY5	SY6	SY7	SY8	SY9	SY10	SY11	SY12	SY13
No. of species	Winter	42	34	38	35	41	37	40	38	38	37	38	41	35
	Pre-monsoon	20	20	22	22	19	20	26	19	24	31	21	24	18
	Monsoon	8	11	9	13	9	11	8	6	9	11	8	9	9
Density (cells/cm ²)	Winter	1707	2773	1427	1775	2807	2466	2992	19946	3864	3149	47246	41078	35517
	Pre-monsoon	1188	954	668	701	608	687	676	9638	554	917	1157	19401	25204
	Monsoon	304	256	288	432	92	388	233	2351	296	566	604	2221	3209
Shannon Weiner Diversity Index	Winter	3.28	3.12	3.16	3.09	3.25	3.16	3.28	3.17	3.19	3.17	3.20	3.26	3.14
	Pre-monsoon	2.10	1.95	2.18	2.09	2.01	2.01	2.21	1.99	2.12	2.77	2.08	2.19	2.06
	Monsoon	1.23	1.06	1.24	1.19	1.21	1.27	1.33	1.09	1.33	1.67	1.23	1.24	1.29
Evenness Index	Winter	0.88	0.87	0.87	0.86	0.88	0.87	0.87	0.87	0.85	0.87	0.86	0.87	0.89
	Pre-monsoon	0.74	0.79	0.74	0.71	0.72	0.73	0.69	0.72	0.67	0.70	0.71	0.74	0.71
	Monsoon	0.59	0.57	0.58	0.61	0.62	0.55	0.57	0.59	0.56	0.58	0.59	0.57	0.55

Table 7.16: Density and Diversity of phytobenthos in Yargyap Chhu

	Season	YG1	YG2	YG3	YG4	YG5	YG6	YG7	YG8	YG9	YG10	YG11	YG12	YG13	YG14
No. of species	Winter	34	40	36	37	41	38	34	35	42	38	35	39	37	35
	Pre-monsoon	20	21	17	22	21	25	24	18	17	23	26	21	27	26
	Monsoon	9	10	13	11	8	9	8	11	10	9	11	10	9	11
Density (cells/cm ²)	Winter	1736	3872	3177	5601	6022	4611	7309	9091	14158	11319	8069	7649	10853	16186
	Pre-monsoon	715	973	1527	1165	1420	2086	2324	2700	2937	2945	3505	2590	3488	3439
	Monsoon	123	678	1078	974	694	1432	1678	1212	1193	1115	2456	2091	1118	2134
Shannon Weiner Diversity Index	Winter	3.05	3.23	3.16	3.00	3.26	3.16	3.09	3.15	3.27	3.19	3.17	3.28	3.15	3.08
	Pre-monsoon	1.99	2.08	1.93	2.08	2.06	2.19	2.18	2.02	2.00	2.08	2.26	2.10	2.33	2.26
	Monsoon	1.24	1.56	1.19	1.32	1.21	1.45	1.40	1.32	1.23	1.25	1.56	1.44	1.62	1.58
Evenness Index	Winter	0.87	0.87	0.88	0.87	0.89	0.86	0.87	0.87	0.85	0.87	0.88	0.90	0.86	0.87
	Pre-monsoon	0.71	0.73	0.70	0.71	0.73	0.72	0.72	0.72	0.75	0.72	0.73	0.73	0.72	0.72
	Monsoon	0.59	0.60	0.58	0.58	0.62	0.53	0.59	0.56	0.53	0.56	0.57	0.51	0.59	0.54

The Shannon-Weiner diversity index during winter season was highest and varied from 3.09-3.28 (Table 7.15). The highest diversity was recorded at site SY7 near Yapik during winters and lowest at site SY2 downstream of Kamba.

e) Yargyap Chhu

Total 90 species of phytobenthos were recorded from this sub-basin (Table 7.16). The number of phytobenthos species recorded was highest during winter months sampling.

Highest number of species (41 in winters) was recorded from site YG5 and lowest (8 in monsoon) from site YG7. *Achnanthydium austriaca*, *Achnanthydium austriaca* var. *helvetica*, *A. exigua* and *Gomphonema gracile* are the most abundant species found in the sub-basin.

During winter season density of phytobenthos (no. of individuals/l) ranged from 1736-16186 in winters (highest at site YG14 - Yarlom and lowest site YG1- Tato-I HEP weir site. It ranged from 715-3505 indiv/l in pre-monsoon and from 123-2456 indiv/l in monsoon (Table 7.16).

The Shannon-Weiner Diversity index of phytobenthos species in Yargyap Chhu river and its tributaries varied from 3.00 -3.28 in winters (Table 7.16). Lowest diversity was during monsoon when it was recorded with 1.19-1.62 range.

According to Evenness values recorded during different periods at all the sampling locations in different sub-basins, most of the phytobenthos species were more or less evenly distributed during winter and pre-monsoon seasons while the distribution was irregular during monsoon (Tables 7.13-7.17).

f) Outside Siang basin

The density of phytobenthos at Jiya Dhol site was very low (Table 7.17).

Table 7.17: Density and Diversity of phytobenthos in Jiya Dhol & Kareng Ghat

Indices	Season	B1	B2
No. of species	Winter	36	40
	Pre-monsoon	22	26
	Monsoon	13	9
Density (cells/cm ²)	Winter	876	1256
	Pre-monsoon	322	489
	Monsoon	98	134
Shannon Weiner Diversity Index	Winter	2.43	2.51
	Pre- monsoon	1.54	1.66
	Monsoon	1.02	1.06
Evenness Index	Winter	0.85	0.88
	Pre-monsoon	0.71	0.79
	Monsoon	0.55	0.57

7.1.4.3 Zooplankton

Zooplanktons are represented by protozoa, rotifer and crustacean (copepods and cladoceran). Among protozoans *Arcella*, *Peridinium*, *Actinophrys*, *Paramecium* and *Ceratium* genera were observed at most of the sites in Siang basin, however their occurrence is low at sampling sites located in the lower reaches. The Rotifers are represented by species of *Keratella*, *Brachionus*, *Epiphanes*, *Philodina*, and *Asplanchna*. Among Crustaceans *Moina*, *Bosmina*, and *Daphnia* species of order Cladocera were found, whereas Copepods were represented by *Cyclopes* sp. (water fleas) and *Diaptomus* sp. only. The abundance of zooplankton ranged from 15 - 160 individuals/m² (Tables 7.18).

Table 7.18: Density and Diversity of zooplankton in Siang river and its tributaries in Siang sub-basins I-IV

	Season	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
No. of species	Winter	7	7	6	7	8	6	7	7	6	6	6	7	7
	Pre-monsoon	3	3	3	3	4	3	5	4	4	3	5	3	3
	Monsoon	2	1	3	3	1	1	1	2	3	2	1	1	1
Density (indiv/lit.)	Winter	109	111	93	92	160	129	140	141	116	101	119	119	141
	Pre-monsoon	46	57	46	43	75	39	98	72	79	55	78	55	37
	Monsoon	34	29	15	22	33	18	36	30	33	16	29	27	19
Shannon Weiner Diversity Index	Winter	1.34	1.46	1.52	1.54	1.68	1.48	1.55	1.49	1.42	1.38	1.37	1.47	1.46
	Pre- monsoon	0.48	0.67	0.44	0.43	0.58	0.56	0.65	0.64	0.80	0.57	0.73	0.50	0.74
	Monsoon	0.17	0.24	0.19	0.21	0.18	0.16	0.20	0.19	0.21	0.13	0.21	0.18	0.16
Evenness Index	Winter	0.77	0.80	0.78	0.76	0.79	0.81	0.78	0.80	0.77	0.81	0.77	0.78	0.81
	Pre-monsoon	0.70	0.67	0.65	0.61	0.62	0.67	0.58	0.64	0.61	0.55	0.62	0.60	0.67
	Monsoon	0.48	0.49	0.45	0.33	0.45	0.53	0.41	0.47	0.41	0.37	0.34	0.48	0.50

Table 7.19: Density and Diversity of zooplankton in Yamne and Simang sub-basin

	Season	Y1	Y2	Y3	Y4	Sm1	Sm2	Sm3
No. of species	Winter	7	7	6	7	6	6	6
	Pre-monsoon	4	4	3	3	3	4	4
	Monsoon	1	2	1	2	2	2	2
Density (indiv/lit.)	Winter	82	138	103	124	103	111	107
	Pre-monsoon	78	82	49	48	47	73	66
	Monsoon	45	41	32	23	18	33	25
Shannon Weiner Diversity Index	Winter	1.48	1.53	1.38	1.50	1.34	1.37	1.37
	Pre- monsoon	0.60	0.55	0.71	0.61	0.44	0.69	0.92
	Monsoon	0.37	0.33	0.29	0.25	0.14	0.21	0.15
Evenness Index	Winter	0.80	0.81	0.81	0.78	0.79	0.78	0.76
	Pre-monsoon	0.58	0.57	0.65	0.55	0.56	0.63	0.66
	Monsoon	0.39	0.45	0.45	0.43	0.39	0.38	0.43

Table7.20: Density and Diversity of zooplankton in Siyom river and its tributaries in Siyom Sub-basins I-III

	Season	SY1	SY2	SY3	SY4	SY5	SY6	SY7	SY8	SY9	SY10	SY11	SY12	SY13
No. of species	Winter	8	7	8	7	6	7	7	6	7	6	7	7	7
	Pre-monsoon	3	5	5	4	3	3	3	3	3	3	3	4	3
	Monsoon	1	2	2	3	2	1	2	2	2	2	2	1	1
Density (indiv/lit.)	Winter	146	137	123	123	114	109	136	113	139	158	143	140	119
	Pre-monsoon	63	88	97	80	53	30	34	39	53	52	38	58	41
	Monsoon	21	24	29	28	35	13	26	17	18	23	15	28	21
Shannon Weiner Diversity Index	Winter	1.53	1.48	1.50	1.49	1.44	1.52	1.53	1.40	1.45	1.35	1.63	1.51	1.53
	Pre- monsoon	0.43	0.76	0.75	0.61	0.47	0.65	0.39	0.45	0.49	0.54	0.46	0.51	0.47
	Monsoon	0.12	0.24	0.28	0.27	0.34	0.11	0.25	0.13	0.15	0.24	0.10	0.19	0.17
Evenness Index	Winter	0.76	0.77	0.80	0.79	0.80	0.81	0.78	0.81	0.79	0.77	0.79	0.80	0.83
	Pre-monsoon	0.57	0.63	0.61	0.57	0.63	0.59	0.56	0.58	0.52	0.57	0.67	0.55	0.60
	Monsoon	0.39	0.35	0.37	0.45	0.35	0.37	0.36	0.28	0.36	0.42	0.35	0.32	0.40

Table7.21: Density and Diversity of zooplankton in Yargyap Chhu

	Season	YG1	YG2	YG3	YG4	YG5	YG6	YG7	YG8	YG9	YG10	YG11	YG12	YG13	YG14
No. of species	Winter	7	6	6	6	6	6	6	5	6	6	6	4	6	6
	Pre-monsoon	4	2	4	2	4	2	3	3	2	3	2	2	3	4
	Monsoon	1	1	2	2	2	2	2	1	2	2	3	2	3	2
Density (indiv/lit.)	Winter	92	82	108	108	71	117	115	92	82	148	114	120	109	118
	Pre-monsoon	49	24	56	33	47	24	45	41	31	51	18	26	51	54
	Monsoon	33	15	24	22	32	11	21	22	25	17	10	13	23	26
Shannon Weiner Diversity Index	Winter	1.23	1.31	1.35	1.32	1.40	1.34	1.37	1.24	1.29	1.56	1.35	1.33	1.34	1.33
	Pre- monsoon	0.45	0.44	0.54	0.38	0.54	0.30	0.43	0.43	0.34	0.49	0.33	0.25	0.48	0.48
	Monsoon	0.26	0.13	0.22	0.20	0.27	0.10	0.13	0.19	0.14	0.11	0.19	0.31	0.24	0.29
Evenness Index	Winter	0.77	0.79	0.81	0.78	0.78	0.76	0.75	0.74	0.78	0.75	0.74	0.80	0.75	0.79
	Pre-monsoon	0.51	0.63	0.54	0.55	0.51	0.54	0.56	0.58	0.57	0.53	0.48	0.55	0.55	0.47
	Monsoon	0.27	0.30	0.30	0.33	0.36	0.30	0.34	0.28	0.39	0.33	0.37	0.32	0.34	0.30

The density of zooplankton (no. of individuals/l) varied from 1 to 8 in Siang and Siyom sub-basins, 1 to 7 in Yargyap Chhu, Yamne and Simang sub-basins (Tables 7.18-7.21). Density in general was higher during winters.

The result shows that highest diversity of zooplankton was found during the winter season followed by pre-monsoon and monsoon season. Zooplankton diversity during winter and pre-monsoon and monsoon seasons ranged from 1.38-1.53, 0.55-0.71 and 0.25-0.37, respectively in all the sub-basins.

The density of zooplankton (no. of individuals/l) at sites outside the basin also followed the pattern of other sampling sites in basin (Table 7.22). The Shannon Weiversity index was much lower that at sampling sites located in the basin.

Table 7.22: Density and Diversity of zooplankton in Jiya Dhol & Kareng Ghat

	Season	B1	B2
No. of species	Winter	8	7
	Pre-monsoon	6	3
	Monsoon	3	1
Density (indiv./lit.)	Winter	192	119
	Pre-monsoon	68	73
	Monsoon	35	25
Shannon Weiner Diversity Index	Winter	1.55	1.37
	Pre-monsoon	0.69	0.44
	Monsoon	0.22	0.17
Evenness Index	Winter	0.78	0.76
	Pre-monsoon	0.63	0.66
	Monsoon	0.38	0.43

7.1.4.4 Macro-invertebrates

Macro-invertebrates are widely used to determine biological conditions and acts as an in-line monitoring system for pollution. They are important part of food chain especially for fish. During the study, macro-invertebrate fauna comprised of 41 species falling under 7 Orders belonging to 29 families like Heptageniidae, Baetidae, Ephemerillidae, Leptophlebiidae, Hydropsychidae, Psychomidae, Perlidae, Perlodidae and Chironomidae (Table 7.23). *Cinygmula* was the most abundant genus and was recorded from all the sampling sites in all the seasons Tables 7.24 - 7.27. *Hydropsyche* was next most dominant macro-invertebrate genus recorded from Siang river and its tributaries in different seasons. The Heptageniidae was most dominant family and found to be present during all the seasons. The number of species recorded from different sampling sites during different seasons varied from lowest in Siyom sub-basin at sites SY1, SY2, SY7 and SY9 where only one species was recorded during monsoon season and highest 21 at site YG7 in Yargyap Chhu sub-basin during winters (Tables 7.28 - 7.33).

In four Siang sub-basins lowest number 2 species was recored at sites S1, S5 and S11 and highest number 19 was recorded from site S1 in winters. In Yamne and Simang sub-basins lowest number of species (2 nos.) was recorded from Sm1 and Sm2 during monsoon and highest (17 nos.) from site Sm2 during winters (Table 7.28).

Table 7.23: Macro-invertebrates found in Siang river and its tributaries

S. No.	Order	Family	Genus/species
1	Ephemeroptera	Heptageniidae	<i>Cinygmula</i>
2		Heptageniidae	<i>Stenonema</i>
3		Heptageniidae	<i>Heptagenia</i>
4		Heptageniidae	<i>Epeorus</i>
5		Baetidae	<i>Baetis</i>
6		Ephemerellidae	<i>Ephemerella</i> sp.
7		Ephemerellidae	<i>Ephemerella excrucians</i>
8		Caenidae	<i>Caenis</i>
9		Leptophlebiidae	<i>Paraleptophlebia</i>
10		Leptophlebiidae	<i>Chroterpes</i>
11		Leptophlebiidae	<i>Leptophlebia</i>
12		Neoephemeridae	<i>Neoephemera</i> sp.1
13		Neoephemeridae	<i>Neoephemera</i> sp.2
14	Plecoptera	Perlidae	<i>Acroneuria</i>
15		Perlodidae	<i>Isoperla</i>
16	Coleoptera	Elmidae	<i>Heterolimnius</i>
17		Psephenidae	<i>Psephenus</i>
18		Dytiscidae	<i>Agabinus glabrellus</i>
19	Megaloptera	Corydalidae	<i>Corydalus</i>
20	Trichoptera	Hydroptilidae	<i>Ochrotrichia</i>
21		Hydroptilidae	<i>Hydroptila</i>
22		Hydroptilidae	<i>Leucotrichia</i>
23		Hydropsychidae	<i>Hydropsyche</i>
24		Helicopsychidae	<i>Helichopsyche</i>
25		Glossosomatidae	<i>Glossosoma</i>
26		Leptoceridae	<i>Leptocerus</i>
27		Molannidae	<i>Molanna</i>
28	Diptera	Chironomidae	<i>Chironomus</i>
29		Chironomidae	<i>Ablabesmyia</i>
30		Ephydriidae	Unidentified genus/species
31		Tipulidae	<i>Antocha saxicola</i>
32		Simuliidae	<i>Simulium pictipes</i>
33		Psychodidae	<i>Psychoda</i>
34		Psychodidae	<i>Maruina</i>
35		Ceratopogonidae	<i>Culicoides variipennis</i>
36		Blepharoceridae	<i>Blepharocera</i>
37		Blepharoceridae	<i>Horaia</i>
38		Tabanidae	<i>Tabanus</i>
39		Rhagionidae	<i>Atherix variegata</i>
40		Culicidae	<i>Culex</i>
41	Acari	Limnocharidae	<i>Limnocharis</i>

Table 7.24: Macro-invertebrates found in Siang river and its tributaries in sub-basins:I-IV

Genus/Species	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
<i>Cinygmula</i>	W,PM,M	W,PM,M	W,PM,M	W,PM	W,PM,M	W,PM	W,PM,M	W,PM,M	W	W,PM,M	W,PM,M	W,PM,M	W,PM,M
<i>Stenonema</i>		W,PM,M	W,PM		W	PM,M	W	W	PM,M	W,PM	W,PM,M	PM	W,PM,M
<i>Heptagenia</i>	W,PM,M	PM, M	W,PM,M	W,PM	W		W,PM	W	PM	W,PM	W,PM	W	
<i>Epeorus</i>	W	W	W	PM	W,PM,M	W,PM	W	PM,M	W		W	W,PM,M	W,PM,M
<i>Baetis</i>	W,PM	W,PM	W,PM	W	PM			W	PM,M	W	PM		W,PM
<i>Ephemerella</i>	W,PM	PM	W		W	W,PM,M	W,PM	PM	W	W,PM,M	W,PM		W,PM
<i>Ephemerella excrucians</i>	W	W	PM,M	W,PM,M	PM			W	W,PM,M			W	W
<i>Caenis</i>	PM	PM,M		PM	W	W	W	PM		W	W		PM,M
<i>Paraleptophlebia</i>	W,PM	PM	W	W				W		M		W	W
<i>Chroterpes</i>		W,PM	W	PM	W,PM	PM,M	W,PM	W		PM	W,PM	PM,M	
<i>Leptophlebia</i>	W,PM		W,PM	W,PM		PM		W,PM		W		W	W,PM
<i>Neoephemera</i> sp.1		W			W	W,PM	M	W		W	PM		
<i>Neoephemera</i> sp.2		W											
<i>Acroneuria</i>	PM		PM	PM,M		PM	W				W	PM,M	
<i>Isoperla</i>	W	W,PM,M	W	W	W	W	PM,M		W	W,PM	PM	W	W
<i>Heterlimnius</i>	PM							PM,M					PM,M
<i>Psephenus</i>	W	W,PM	W,PM		W	PM		W					+
<i>Agabinus glabrellus</i>				W			W	PM		W	W,PM	W	
<i>Corydalus</i>		PM			W,PM								PM
<i>Ochrotrichia</i>		W	PM	W		PM	W			W	W	W	
<i>Hydroptila</i>	W,PM			PM					W				W
<i>Leucotrichia</i>		PM			W	W		W,PM	PM,M	W	W,PM		
<i>Hydropsyche</i>	W	W	W	W	PM							W	W
<i>Helichopsyche</i>	W												W
<i>Glossosoma</i>		W	W	W	W			W			PM	W	
<i>Leptocerus</i>	W		W				W		W,PM,M	W	W		W
<i>Molanna</i>		PM	PM	W	W	W						W	PM
<i>Chironomus</i>	W	W	W				W,PM		W	W,PM	W		W
<i>Ablabesmyia</i>				W,PM	PM		W	PM			W	W	

Genus/Species	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
Unidentified genus/species				W							W		
<i>Antocha saxicola</i>		W,PM								W	W		
<i>Simulium pictipes</i>					W								
<i>Psychoda</i>	W												W
<i>Maruina</i>			PM					W				W	
<i>Culicoides variipennis</i>	W	W	W							W			
<i>Blepharocera</i>				W					W				
<i>Culex</i>					W								

W=Winter; PM=Pre-monsoon; M=Monsoon

Table 7.25: Macro-invertebrates found in Yamne and Simang sub-basins

Genus/Species	Y1	Y2	Y3	Y4	Sm1	Sm2	Sm3
<i>Cinygmula</i>	W,PM	W,PM,M	W,PM,M	W,PM,M	W,PM,M	W,PM,M	W,PM,M
<i>Stenonema</i>	PM,M	W,PM		W,PM	W	W	PM
<i>Heptagenia</i>	PM,M	PM	PM,M	W	W,PM,M	PM	PM
<i>Epeorus</i>		W		PM,M		W	W,PM,M
<i>Baetis</i>	W,PM	W,PM,M	W,PM,M		W,PM	PM,M	
<i>Ephemerella</i>	PM,M		W	W,PM,M	PM	W	W
<i>Ephemerella excrucians</i>	W	W	W,PM		W	W	
<i>Caenis</i>		PM		W	W	W	W
<i>Paraleptophlebia</i>	W,PM	W	W,PM				
<i>Chroterpes</i>		PM		PM		W,PM	W,PM,M
<i>Leptophlebia</i>		W	W	W	W		
<i>Neoephemera</i> sp.1	W,PM	PM	PM,M		PM	W	
<i>Neoephemera</i> sp.2		W		W	W		
<i>Acroneuria</i>	PM,M		W		W		
<i>Isoperla</i>	W	W		W		W	W
<i>Heterlimnius</i>		PM,M	W		W,PM	PM	
<i>Psephenus</i>	W,PM	W	PM	W,PM		W	W,PM
<i>Agabinus glabrellus</i>			W				
<i>Corydalus</i>					W		W
<i>Ochrotrichia</i>	W	W	W	W		W	
<i>Hydroptila</i>		PM	PM				
<i>Leucotrichia</i>				W	W	W	W
<i>Hydropsyche</i>	W,PM,M	W	W	PM,W	PM		W
<i>Helichopsyche</i>		PM					
<i>Glossosoma</i>	PM	W		W	W	W	W
<i>Leptocerus</i>	W		W,PM,M			W	
<i>Molanna</i>				W			W
<i>Chironomus</i>		W		W		W	
<i>Ablabesmyia</i>	W			W	W		
-					W		W,PM
<i>Antocha saxicola</i>	W		W	W	W	W	
<i>Simulium pictipes</i>		W					W
<i>Psychoda</i>			PM		W,PM		
<i>Maruina</i>	W						PM
<i>Culicoides variipennis</i>				W	W		
<i>Blepharocera</i>		W				W	
<i>Horiaia</i>	W						
<i>Culex</i>							W

W=Winter; PM=Pre-monsoon; M=Monsoon

Table 7.26: Macro-invertebrates found in Siyom sub-basins

Genus/Species	SY1	SY2	SY3	SY4	SY5	SY6	SY7	SY8	SY9	SY10	SY11	SY12	SY13
<i>Cinygmula</i>	W,PM,M	W	W,PM,M	W,PM,M	W,PM,M	W,PM,M	PM,M	W,PM,M	W,PM	W,PM,M	W,PM,M	W,PM,M	W,PM,M
<i>Stenonema</i>	W,PM	W,PM,M		W,PM,M	W,PM	W,PM,M	W,PM	W	W	W	PM	W	W
<i>Heptagenia</i>	W,PM		W,PM,M	PM	W	W,PM,M	PM		W	PM	W	W	W,PM,M
<i>Epeorus</i>	W	W	PM	W,PM,M	W	W	W	W,PM,M		W	PM,M	W	
<i>Baetis</i>	PM	W,PM	W		PM,M		PM	PM	W,PM,M	W,PM,M	W	W	PM,M
<i>Ephemerella</i>	W,PM	W		W	W	PM	W	W				W,PM,M	W
<i>Ephemerella excrucians</i>			W,PM	PM,M					W	W	W	W	
<i>Caenis</i>	W			W	W	PM	W				W		
<i>Paraleptophlebia</i>		W,PM	W			W	PM	W,PM		PM,M	W	W	
<i>Chroterpes</i>	W		PM	PM	W	PM	W		W	W	W,PM		W
<i>Leptophlebia</i>		W	W						W			W	
<i>Neoephemera</i> sp.1				W	W,PM,M	PM		W		W,PM			W
<i>Neoephemera</i> sp.2	PM	W	PM						W	W		W	
<i>Acroneuria</i>	W			PM		W	W,PM	W					WM
<i>Isoperla</i>		W	W	W	W					W,PM	W	W	
<i>Heterolimnius</i>			PM,M		PM	PM	W					PM,M	
<i>Psephenus</i>		W		W,PM,M	W			W	W	W		W	
<i>Agabinus glabrellus</i>													W
<i>Corydalus</i>					W				W				
<i>Ochrotrichia</i>	W		W					W		W	W		W
<i>Hydroptila</i>	PM	W	PM			PM						W	
<i>Leucotrichia</i>				W	W								
<i>Hydropsyche</i>			W							W	W	W	W
<i>Helichopsyche</i>		W		PM	PM			W				W	
<i>Glossosoma</i>													W
<i>Leptocerus</i>	W	W										PM	
<i>Molanna</i>				W	PM,M								
<i>Chironomus</i>	W	W		PM							W		

Genus/Species	SY1	SY2	SY3	SY4	SY5	SY6	SY7	SY8	SY9	SY10	SY11	SY12	SY13
<i>Ablabesmyia</i>			W					W					
<i>Antocha saxicola</i>	W												
<i>Simulium pictipes</i>				W							W		
<i>Psychoda</i>		W											
<i>Blepharocera</i>			W										
<i>Culex</i>					W								

W=Winter; PM=Pre-monsoon; M=Monsoon

Table 7.27: Macro-invertebrates found in Yargyap Chhu

Genus/Species	YG1	YG2	YG3	YG4	YG5	YG6	YG7	YG8	YG9	YG10	YG11	YG12	YG13	YG14
<i>Cinygmula</i>	W,PM,M	W,PM,M	W,PM,M	W,PM,M	W,PM,M	W,PM,M	W,PM,M	W,PM,M	W,PM,M	W,PM,M	W,PM,M	W,PM,M	PM,M	W,PM,M
<i>Stenonema</i>	W,PM,M	W,PM,M	W,PM	W,PM,M		W	W,PM,M	W,PM	W,PM,M		W,PM,M	W	W,PM	W,PM,M
<i>Heptagenia</i>	W,PM	W	W,PM,M	W	W	W,PM,M	W	W,PM,M	PM	W	W	W,PM	W,PM	W
<i>Epeorus</i>	W	PM,M	W		W,PM	W,PM	W,PM,M	W	W,PM	PM,M	W	W	W	W
<i>Baetis</i>	W,PM,M	W	W,PM	W,PM	W	W,PM	W	W	W,PM,M	W	W	PM	W	W,PM
<i>Ephemerella</i>		PM		W	W,PM		PM	W,PM			PM	W	PM,M	
<i>Ephemerella excrucians</i>	W,PM	W	W,PM,M	W,PM	W	W	W		W			W,PM,M	W	W,PM,M
<i>Caenis</i>	W,PM	W,PM				W,PM	W	W,PM		W	W	W	W,PM	
<i>Paraleptophlebia</i>			W,PM	W,PM	W,PM,M	W	W,PM		W	W,PM,M	PM	W		W
<i>Chroterpes</i>	W,PM	W		W	W	W		W,PM,M	PM,M			PM,M	W,PM	
<i>Leptophlebia</i>	W	W,PM	W			PM	W	W			PM		W	W
<i>Neoephemera</i> sp.1	W,PM	W	PM	W,PM	W,PM,M	W			W	W	W	W	PM,M	W,PM,M
<i>Neoephemera</i> sp.2	W	PM	W	W		W,PM	W,PM	W	PM			W	W	
<i>Acroneuria</i>		W	W	W		W	W	PM		W	W,PM			
<i>Isoperla</i>	PM	W			W,PM			W	W	PM,M			W	W,PM
<i>Heterlimnius</i>	W		W	W,PM	W	W		W				W	W,PM	
<i>Psephenus</i>	PM	W	PM	W,PM		PM	W			W	W,PM			
<i>Agabinus glabrellus</i>	W				W,PM	W	W,PM	W,PM				W	W	PM
<i>Corydalus</i>	W	W,PM	W	W		W,PM			W					W
<i>Ochrotrichia</i>				PM			W,PM	W			W	W		

Genus/Species	YG1	YG2	YG3	YG4	YG5	YG6	YG7	YG8	YG9	YG10	YG11	YG12	YG13	YG14
<i>Hydroptila</i>		W			W,PM		W	PM	PM				W,PM	W,PM
<i>Leucotrichia</i>	W	PM	W	W		W,PM	W	W				W		W
<i>Hydropsyche</i>	W,PM			W			PM	PM						
<i>Helichopsyche</i>		W	PM		PM	W	W	W	W		W	W		W
<i>Glossosoma</i>	W		W	PM	W					PM		W		
<i>Leptocerus</i>		W,PM				W	W	W				W		
<i>Molanna</i>					W	W					W		W,PM	
<i>Chironomus</i>					PM				W					W
<i>Ablabesmyia</i>		W	W			PM	W	W				W	W	
Unidentified genus/species	W									W				
<i>Antocha saxicola</i>				W	W			W					W	
<i>Simulium pictipes</i>	PM					W	W				W	W	W	W
<i>Psychoda</i>		W		PM										
<i>Maruina</i>							W					W	W	
<i>Culicoides variipennis</i>				W		PM			W	W				W
<i>Blepharocera</i>			W		W								W	
<i>Horaia</i>	W								PM					
<i>Tabanus</i>							W							

W=Winter; PM=Pre-monsoon; M=Monsoon

Table 7.28: Density and Diversity of Macro-invertebrates at different locations in Siang river

	Season	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
No. of Genera/Species	Winter	19	16	16	14	17	8	13	14	9	16	14	14	17
	Pre-monsoon	11	13	10	11	9	10	6	9	7	7	12	5	10
	Monsoon	2	4	3	3	2	3	3	3	5	4	2	5	5
Density (Indiv./m ²)	Winter	798	752	835	958	1261	508	730	605	1968	1177	577	401	1234
	Pre-monsoon	122	368	181	401	251	567	284	268	159	406	357	406	892
	Monsoon	98	76	67	156	102	236	82	98	87	166	108	177	307
Shannon Weiner Diversity Index	Winter	2.14	1.85	1.92	1.95	2.23	2.01	2.12	2.22	1.92	2.20	2.25	2.29	2.23
	Pre-monsoon	1.59	1.18	1.33	1.95	1.25	1.75	1.30	1.42	1.53	1.18	1.99	1.71	1.77
	Monsoon	0.67	0.46	0.41	0.80	0.66	1.05	0.70	0.57	0.51	0.67	0.57	0.70	1.15

Table 7.29: Density and Diversity of Macro-invertebrates at different locations in Yamne and Simang sub-basins

	Season	Y1	Y2	Y3	Y4	Sm1	Sm2	Sm3
No. of Genera/ Species	Winter	15	16	14	17	18	17	16
	Pre-monsoon	11	10	9	7	7	5	7
	Monsoon	6	3	4	4	2	2	3
Density (Indiv/m ²)	Winter	1531	2091	2312	2531	1251	1700	2739
	Pre-monsoon	498	1211	646	720	205	103	154
	Monsoon	156	100	178	304	89	52	66
Shannon Weiner Diversity Index	Winter	2.18	2.19	2.19	2.38	1.89	2.17	2.26
	Pre- monsoon	1.17	1.22	1.37	1.45	1.39	1.71	1.26
	Monsoon	0.87	0.49	1.09	1.19	0.32	0.51	0.34

Table 7.30: Density and Diversity of Macro-invertebrates at different locations in Siyom & Hirit rivers

	Season	SY1	SY2	SY3	SY4	SY5	SY6	SY7	SY8	SY9	SY10	SY11	SY12	SY13
No. of Genera/ Species	Winter	12	15	11	12	14	6	7	11	10	12	12	15	11
	Pre-monsoon	7	3	8	9	7	9	6	4	2	7	4	6	3
	Monsoon	1	1	3	4	3	3	1	2	1	3	2	3	4
Density (Indiv/m ²)	Winter	1678	1235	710	1021	832	378	412	729	570	731	824	1408	1234
	Pre-monsoon	250	721	871	475	735	416	588	412	345	319	191	215	387
	Monsoon	155	342	387	176	265	136	178	263	166	132	110	194	123
Shannon Weiner Diversity Index	Winter	2.17	2.17	2.13	2.19	2.21	1.85	1.93	2.15	2.17	2.24	2.34	2.20	2.02
	Pre-monsoon	1.35	1.86	1.28	1.56	1.39	1.52	1.38	1.34	1.65	1.50	1.00	1.21	0.95
	Monsoon	0.78	1.21	1.09	0.67	1.01	0.56	0.77	1.02	0.99	0.56	0.53	0.76	0.66

Table 7.31: Density and Diversity of Macro-invertebrates at different locations in Yargyap Chhu

	Season	YG1	YG2	YG3	YG4	YG5	YG6	YG7	YG8	YG9	YG10	YG11	YG12	YG13	YG14
No. of Genera/Species	Winter	19	18	16	18	17	20	21	19	12	10	13	18	19	16
	Pre-monsoon	11	10	9	10	7	9	9	10	8	5	7	5	10	8
	Monsoon	3	3	13	2	3	2	3	4	3	4	2	3	4	4
Density (Indiv/m ²)	Winter	876	538	550	614	478	801	640	243	306	199	417	472	622	2263
	Pre-monsoon	140	217	307	445	244	776	477	1003	797	946	901	972	411	309
	Monsoon	99	103	127	157	107	276	166	536	345	489	404	562	263	178
Shannon Weiner Diversity Index	Winter	2.16	2.04	2.15	2.00	2.00	2.27	2.18	2.07	1.93	1.83	1.99	2.17	2.05	2.11
	Pre- monsoon	1.23	1.34	1.26	1.56	1.15	1.67	1.32	1.65	1.55	1.89	1.92	1.98	1.34	1.30
	Monsoon	0.25	0.34	0.37	0.45	0.44	0.89	0.66	1.02	0.89	1.19	1.11	1.23	1.07	0.89

In three Siyom sub-basins and Hirit sub-basin only one species was recorded during monsoon at sites S1, S2, S7 and S9 (Table 7.30). Highest number of macro-invertebrate species (15 nos.) was recorded from sites SY2 and SY15 during winters.

In Yargyap Chhu sub-basin lowest number of species i.e. only 2 species were recorded during monsoon at sites YG3, YG6 and YG10 (Table 7.31).

The density of macro-invertebrates varied from season to season. In the four Siang sub-basins the density of macro-invertebrates ranged from 166 individuals/m² at S6 near Siang Upper Stage-I dam site to 6422 individuals/m² at SY1 downstream of confluence of Hirit with Siyom river (Tables 7.28 - 7.33). The density in general was highest during winter months.

Following the pattern of density Shannon Weiner diversity index too was highest during winter months and lowest in monsoon months (Tables 7.28-7.33).

At the two sampling sites located outside the basin i.e. B1 and B2 *Cinygmula* was the most dominant genus (Table 7.32) found at both sites and in all 22 species were recorded during surveys. The density and diversity at these sites also followed the overall pattern of Siang basin sites (Table 7.33).

Table 7.32: Macro-invertebrates found at Jiya Dhol & Kareng Ghat

Family	Genus/Species	B1	B2
Heptageniidae	<i>Cinygmula</i>	W,PM,M	W,PM
	<i>Stenonema</i>		W,PM
	<i>Heptagenia</i>	W,PM	W,PM,M
	<i>Epeorus</i>	W	
Baetidae	<i>Baetis</i>		W,PM
Ephemerellidae	<i>Ephemerella</i>	PM	
	<i>Ephemerella excrucians</i>		PM,M
Leptophlebiidae	<i>Paraleptophlebia</i>	PM	W
	<i>Chroterpes</i>	W,PM	
	<i>Leptophlebia</i>		PM
Neophemeridae	<i>Neophemera</i> sp.1	W	
Perlidae	<i>Acroneuria</i>		PM
Perlodidae	<i>Isoperla</i>	W,PM	W
Corydalidae	<i>Corydalus</i>	PM	
Hydroptilidae	<i>Ochrotrichia</i>	W	PM
	<i>Leucotrichia</i>	PM	
Hydropsychidae	<i>Hydropsyche</i>	W	W
Leptoceridae	<i>Leptocerus</i>		W
Chironomidae	<i>Chironomus</i>	W	
	<i>Ablabesmyia</i>		W
Tipulidae	<i>Antocha saxicola</i>	W,PM	
Rhagionidae	<i>Atherix variegata</i>	W	

W=Winter; PM=Pre-monsoon; M=Monsoon

Table 7.33: Diversity of Macro-invertebrates at Jiya Dhol and Kareng Ghat

	Season	B1	B2
No. of species	Winter	12	10
	Pre-monsoon	8	5
	Monsoon	3	2
Density (indi./m ²)	Winter	316	299
	Pre-monsoon	197	246
	Monsoon	45	89
Shannon Weiner Diversity Index	Winter	1.93	1.83
	Pre- monsoon	1.55	1.89
	Monsoon	0.89	1.19

7.1.4.5 Aquatic Microflora

Algal microflora of different rivers and streams of Siang river system is comprised of species each belonging to Cyanophyceae (Blue green algae), Chlorophyceae (Green algae), and a large number of species of Bacillariophyceae (Brown algae, the Diatoms).

Chlorophyceae is comprised of *Rhizoclonium* sp., *Spirotaenia* sp. and *Ulothrix* sp., *Spirogyra* sp., and *Zygnema* sp. The filamentous algae are represented by *Cladophora* sp. Other predominant Green algae found were *Chlorella* sp., *Scenedesmus* sp. and *Closterium* sp. with flagellates like *Chlamydomonas* sp. and *Euglena* sp. Blue green algae are comprised of *Anabaena* sp., *Oscillatoria* sp., *Phormidium* sp. and *Aphanothece* sp.

Among macrophytes *Potamogeton* sp. was also found in abundance followed by other species of algae like *Nitella* and *Chara*.

7.1.4.6 Biological Water Quality Index

As discussed in earlier sections on Phytoplankton, Phytobenthos, Zooplanktons, Algal micro-flora and also macro-invertebrates, their presence in waters of Siang river and its major tributaries like Siyom river, Yamne river, Simang river, Hirit river and also Yargyap Chhu which is tributary of Siyom in upper catchment harbor very good diversity of all these aquatic ecosystem components which determine the biological water quality of any river/stream in a hilly streams.

For the assessment and analysis of Biological Water Quality an index named **Biological Monitoring Working Party (BMWP)** procedure would be employed using species of macro-invertebrates as biological indicators (<http://www.nethan-valley.co.uk/insectgroups.doc>). The method is based on the principle that different aquatic invertebrates have different tolerances to pollutants. The presence of mayflies or stoneflies for instance indicates the cleanest water. The BMWP score equals the sum of the tolerance scores of all macroinvertebrate families in the sample. Therefore a higher BMWP score is considered to reflect a better water quality. The number of different macroinvertebrates is also an important factor, because a better water quality is assumed to result in a higher diversity. Alternatively, also the Average Score Per Taxon (ASPT) score is calculated. The ASPT equals the average of the tolerance scores of all macroinvertebrate families found, and ranges from 0 to 10. The main difference between both indices is that ASPT does not depend on the family richness. The BMWP scope calculated sub-basin-wise reveals that biological water quality in Yargyap sub-basin was the best amongst all 11 sub-basins in all the seasons (Tables 7.34-7.37).

Table 7.34: BMWP/ASPT score in Siang Sub-basins: I-IV

	Season	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13
BMWP	Winter	61	64	70	75	68	69	62	65	68	71	60	68	63
	Pre-monsoon	55	60	55	62	54	58	50	65	60	67	60	65	62
	Monsoon	23	21	33	36	26	21	32	24	33	34	36	36	40
ASPT	Winter	7.63	7.40	7.77	7.50	8.50	6.50	6.89	8.13	7.56	8.20	6.25	8.29	7.88
	Pre-monsoon	6.83	6.50	6.86	5.65	6.89	6.55	6.13	6.23	7.89	7.75	6.89	7.78	7.00
	Monsoon	5.67	5.00	5.00	7.00	6.33	7.00	5.00	7.00	6.54	6.50	6.50	6.00	7.75

Table 7.35: BMWP/ASPT score in Yamne and Simang sub-basins

	Season	Y1	Y2	Y3	Y4	Sm1	Sm2	Sm3
BMWP	Winter	72	70	69	62	75	74	80
	Pre-monsoon	65	62	69	66	75	64	70
	Monsoon	38	37	45	43	40	33	34
ASPT	Winter	7.20	7.78	7.56	7.89	7.82	7.43	7.27
	Pre-monsoon	7.23	7.00	7.20	7.50	7.20	7.75	7.00
	Monsoon	7.35	6.00	7.75	6.75	6.85	7.00	6.33

The BMWP score in all 4 Siang sub-basins remained between 61 and 75 during winter season which is indicative good health of Siang river and its tributaries (Table 7.34). The average BMWP score in winters was 66 and it was 59 in pre-monsoon and 30 in monsoon.

The biological water quality of Yamne and Simang rivers is also under very good category as the average BMWP score is above 71 during winters, while it was 67 in pre-monsoon. During monsoons due high floods it goes down and was recorded as 39 (Table 7.35).

The water quality of Siyom river and its tributary Hirit river also is very good as the average BMWP score during monsoon, pre-monsoon and winters was 44, 68 and 80, respectively (Table 7.36).

The BMWP score in Yargyap Chhu sub-basin was highest amongst all sub-basins where on average it was 88 during winters and remained between 78 and 98 at all sampling sites. It is indicative of excellent pristine water Yargyap Chhu (Table 7.37). The average BMWP score in winters was 66 and it was 59 in pre-monsoon and 30 in monsoon. Even during monsoon the water quality was good in general where BMWP values varied between 55 and 70 with average of 63.

ASPT values in all sub-basins at all sampling sites during different seasons indicate that the biological water quality is good to excellent (Tables 7.34-6.37).

Table 7.36: BMWP/ASPT score in Hirit sub-basin and Siyom Sub-basins: I-III

	Season	SY1	SY2	SY3	SY4	SY5	SY6	SY7	SY8	SY9	SY10	SY11	SY12	SY13
BMWP	Winter	72	77	83	85	82	76	80	85	80	72	76	89	86
	Pre-monsoon	71	67	63	69	72	70	72	58	65	66	70	67	77
	Monsoon	47	56	45	47	33	45	43	36	38	42	40	45	50
ASPT	Winter	7.40	7.67	7.67	8.33	7.13	8.50	8.40	7.67	8.75	8.50	8.13	8.22	8.43
	Pre-monsoon	6.80	7.14	7.20	7.71	7.63	7.50	7.13	5.57	6.86	7.80	6.80	7.40	7.25
	Monsoon	7.76	6.85	8.50	7.65	7.75	7.00	6.33	7.00	6.25	7.75	8.33	6.33	6.15

Table 7.37: BMWP/ASPT score in Yargyap Chhu sub-basin

	Season	YG1	YG2	YG3	YG4	YG5	YG6	YG7	YG8	YG9	YG10	YG11	YG12	YG13	YG14
BMWP	Winter	85	79	90	92	88	85	87	89	78	87	90	90	97	98
	Pre-monsoon	77	79	75	69	76	80	76	71	78	82	87	86	90	92
	Monsoon	57	66	55	58	69	61	64	59	67	62	60	65	70	70
ASPT	Winter	8.50	87.80	8.40	8.00	8.33	8.00	9.00	8.00	9.13	8.71	9.38	9.33	9.50	9.87
	Pre-monsoon	8.38	8.00	8.86	8.71	8.75	8.80	8.60	7.38	8.14	8.00	8.00	8.29	8.88	9.80
	Monsoon	7.25	7.75	6.75	7.25	7.75	7.00	6.75	6.50	7.75	7.00	7.75	8.00	7.00	8.33

7.1.5 Primary Productivity

Primary productivity (gross primary productivity) is the rate at which solar energy is stored as organic molecules by plants in an ecosystem. However, the net primary productivity reflects the energy that is used by plants as they carry out respiration, and is calculated by subtracting the amount of respiration from the gross primary productivity.

The capacity of the algal composition of the stream and other aquatic vegetation to convert carbon dioxide, water and light energy into glucose and oxygen through the process of photosynthesis is expressed as primary productivity. Primary productivity or primary production indicates the stream health, whether it is oligotrophic, mesotrophic or eutrophic. Mostly the primary productivity in headwater streams in a mountainous area is insignificant.

To assess the primary productivity, DO method with both dark and light bottle method applying Alkali Azide analysis technique and on spot by measuring DO with digital DO meter (diurnal curve method) were used and expressed as $\text{mgC}/\text{m}^3/\text{day}$. The analysis of Primary Productivity in major rivers and streams of Siang river system at different samples during different seasons is given in Tables 7.38-7.46.

Table 7.38: Primary productivity in Siang river during winter season

Sites	Gross Primary Productivity ($\text{mgC}/\text{m}^3/\text{day}$)	Net Primary Productivity ($\text{mgC}/\text{m}^3/\text{day}$)
S1	56.0-60.6	12.5-24.9
S2	73.2-79.1	26.0-32.6
S3	54.8-59.3	18.0-24.4
S4	56.0-60.5	18.0-24.9
S5	45.5-49.2	19.1-25.5
S6	35.2-38.1	14.8-18.0
S7	36.3-39.2	14.9-16.0
S8	30.1-32.5	12.6-14.0
S9	26.0-28.1	10.9-15.0
S10	21.5-23.3	9.1-16.0
S11	18.0-19.5	7.6-12.5
S12	18.0-19.5	7.7-12.5
S13	19.1-20.6	8.0-11.5

Table 7.39: Primary productivity in Yamne and Simang rivers during winter season

Sites	Yamne river		Sites	Simang river	
	Gross Primary Productivity ($\text{mgC}/\text{m}^3/\text{day}$)	Net Primary Productivity ($\text{mgC}/\text{m}^3/\text{day}$)		Gross Primary Productivity ($\text{mgC}/\text{m}^3/\text{day}$)	Net Primary Productivity ($\text{mgC}/\text{m}^3/\text{day}$)
Y1	57.4-62.1	24.1-25.6	Sm1	59.4-63.1	23.0-26.0
Y2	44.7-48.3	18.8-25.0	Sm2	42.9-45.6	18.0-22.0
Y3	32.6-35.3	13.8-24.0	Sm3	67.0-71.2	11.0-29.3
Y4	55.8-59.3	12.5-24.4			

Table 7.40: Primary productivity in Siyom river and its tributaries during winter season

Sites	Siyom river		Sites	Yargyap Chhu	
	Gross Primary Productivity (mgC/m ³ /day)	Net Primary Productivity (mgC/m ³ /day)		Gross Primary Productivity (mgC/m ³ /day)	Net Primary Productivity (mgC/m ³ /day)
SY1	63.2-67.3	24.0-27.7	YG1	18.0-19.5	2.9-8.0
SY2	56.6-61.2	12.5-25.2	YG2	16.7-18.1	2.5-7.4
SY3	41.7-45.1	12.5-20.0	YG3	11.6-12.5	2.1-5.1
SY4	36.5-39.5	12.5-16.3	YG4	6.9-7.5	3.1-1.8
SY5	36.5-39.5	12.5-16.3	YG5	6.2-6.7	1.6-2.9
SY6	25.1-27.1	10.5-14.0	YG6	3.7-4.0	1.4-1.7
SY7	22.7-24.6	9.6-12.5	YG7	3.5-3.8	1.1-1.6
SY8	27.3-29.5	8.0-12.2	YG8	3.3-3.6	1.1-1.5
SY9	25.4-27.4	6.0-12.8	YG9	2.9-3.1	0.5-1.4
SY10	25.0-27.0	10.5-11.1	YG10	1.8-1.9	0.5-0.8
SY11	22.6-24.4	9.5-10.0	YG11	1.6-1.7	0.5-0.7
SY12	19.6-21.2	8.2-9.0	YG12	1.2-1.3	0.4-0.5
SY13	15.1-16.3	3.2-6.8	YG13	1.2-1.3	0.3-0.6
			YG14	0.6-0.6	0.3-0.3

Table 7.41: Primary productivity in Siang river during Pre-monsoon season

Sites	Gross Primary Productivity (mgC/m ³ /day)	Net Primary Productivity (mgC/m ³ /day)
S1	47.1-52.8	19.8-22.2
S2	61.5-69.1	25.8-29.0
S3	46.1-51.7	19.4-21.7
S4	47.0-52.8	19.7-22.2
S5	39.3-43.2	16.5-18.1
S6	29.6-33.2	12.4-14.0
S7	30.5-34.2	12.6-14.1
S8	25.3-28.4	10.6-11.9
S9	21.8-24.5	9.2-10.3
S10	18.1-20.3	7.6-8.5
S11	15.5-17.1	6.5-7.2
S12	15.2-17.0	6.5-7.3
S13	16.0-18.0	6.7-7.6

Table 7.42: Primary productivity in Yamne and Simang rivers during Pre-monsoon season

Sites	Yamne river		Sites	Simang river	
	Gross Primary Productivity (mgC/m ³ /day)	Net Primary Productivity (mgC/m ³ /day)		Gross Primary Productivity (mgC/m ³ /day)	Net Primary Productivity (mgC/m ³ /day)
Y1	48.3-54.2	20.3-22.8	Sm1	49.9-56.0	21.0-23.5
Y2	37.5-42.2	15.8-17.7	Sm2	36.1-40.5	15.1-17.0
Y3	27.4-30.8	11.6-13.0	Sm3	55.0-63.2	23.1-26.5
Y4	49.4-53.5	20.7-22.5			

Table 7.43: Primary productivity in Siyom river and its tributaries during pre monsoon season

Sites	Siyom river		Sites	Yargyap Chhu	
	Gross Primary Productivity (mgC/m ³ /day)	Net Primary Productivity (mgC/m ³ /day)		Gross Primary Productivity (mgC/m ³ /day)	Net Primary Productivity (mgC/m ³ /day)
SY1	53.2-59.7	22.3-29.9	YG1	15.2-17.0	6.4-7.1
SY2	47.6-53.4	20.4-22.4	YG2	14.1-15.8	5.9-6.6
SY3	35.0-39.4	15.8-17.8	YG3	9.7-10.9	4.1-4.6
SY4	30.7-34.5	12.9-14.5	YG4	5.8-6.5	2.4-2.7
SY5	30.7-34.5	12.9-14.5	YG5	5.2-5.8	2.3-2.5
SY6	21.1-23.7	8.8-9.9	YG6	3.1-3.5	1.3-1.5
SY7	19.1-21.5	8.0-9.0	YG7	3.0-3.3	1.2-1.4
SY8	23.0-25.8	9.6-10.8	YG8	2.8-3.1	1.2-1.3
SY9	21.3-23.9	10.1-11.4	YG9	2.4-2.7	1.1-1.2
SY10	21.0-23.6	8.8-9.9	YG10	1.5-1.7	0.6-0.8
SY11	18.8-21.3	7.9-8.9	YG11	1.3-1.5	0.6-0.7
SY12	16.5-18.5	6.9-7.8	YG12	1.0-1.1	0.4-0.5
SY13	12.7-14.2	5.4-6.1	YG13	1.0-1.1	0.5-0.5
			YG14	0.5-0.5	0.2-0.2

Table 7.44: Primary productivity in Siang river during monsoon season

Sites	Gross Primary Productivity (mgC/m ³ /day)	Net Primary Productivity (mgC/m ³ /day)
S1	39.5-44.4	17.6-18.7
S2	51.7-58.0	23.0-24.4
S3	38.7-43.5	17.2-18.3
S4	39.5-44.4	17.6-18.6
S5	33.6-37.3	14.9-15.7
S6	24.9-27.9	11.1-11.7
S7	25.5-28.7	11.6-13.3
S8	20.5-23.0	9.1-9.7
S9	18.4-20.6	8.2-8.7
S10	15.2-17.1	6.8-8.2
S11	13.3-14.3	5.9-6.2
S12	12.7-14.3	5.8-6.1
S13	12.8-15.1	5.8-6.3

Table 7.45: Primary productivity in Yamne and Simang rivers during monsoon season

Sites	Yamne river		Sites	Simang river	
	Gross Primary Productivity (mgC/m ³ /day)	Net Primary Productivity (mgC/m ³ /day)		Gross Primary Productivity (mgC/m ³ /day)	Net Primary Productivity (mgC/m ³ /day)
Y1	40.6-45.5	18.1-19.1	Sm1	41.9-47.1	18.7-19.8
Y2	30.8-35.4	13.7-14.9	Sm2	30.7-34.0	13.5-14.3
Y3	23.1-25.9	10.3-12.7	Sm3	46.2-51.9	20.6-21.8
Y4	43.7-47.4	19.8-20.6			

Table 7.46: Primary productivity in Siyom river and its tributaries during monsoon season

Sites	Siyom river		Sites	Yargyap Chhu	
	Gross Primary Productivity (mgC/m ³ /day)	Net Primary Productivity (mgC/m ³ /day)		Gross Primary Productivity (mgC/m ³ /day)	Net Primary Productivity (mgC/m ³ /day)
SY1	45.0-50.2	20.0-21.1	YG1	12.7-14.3	5.3-6.0
SY2	40.0-44.9	17.8-18.9	YG2	11.8-13.3	5.0-5.6
SY3	27.8-33.1	12.6-15.0	YG3	8.6-9.2	3.6-3.9
SY4	25.8-29.0	11.5-12.2	YG4	4.9-5.5	2.1-2.3
SY5	25.8-29.0	11.5-12.2	YG5	4.4-4.9	1.9-2.1
SY6	17.7-19.9	7.9-8.3	YG6	2.7-3.0	1.1-1.5
SY7	16.1-18.0	6.7-7.6	YG7	2.6-2.9	1.1-1.2
SY8	19.3-21.7	7.8-9.1	YG8	2.5-2.6	1.0-1.1
SY9	17.5-20.1	8.3-9.6	YG9	2.0-2.3	0.9-1.0
SY10	17.6-19.8	7.4-8.3	YG10	1.2-1.4	0.5-0.6
SY11	15.8-17.8	6.6-7.5	YG11	1.1-1.2	0.5-0.6
SY12	13.8-15.5	5.8-6.5	YG12	0.9-1.0	0.4-0.4
SY13	10.6-12.0	4.5-5.1	YG13	0.8-0.9	0.4-0.4
			YG14	0.4-0.4	0.2-0.2

The details of Gross Primary Productivity (GPP) and Net Primary Productivity (NPP) from January to September months are given in **Annexure-VI of Volume-II:DATA**. The variation in NPP and GPP is attributed to change in river geomorphology, valley type, habitat structure, water current, percent slope and light availability despite all favourable dissolve oxygen concentration. The river is found to be oligotrophic in nature, as the primary productivity values recorded were found to be quite low and insignificant (see **Tables 7.38 - 7.46**), except for the upstream reaches of Yargyap Chhu near Mechuka where it flows in open valley with gentler flow and shallow depth forming riffle and pools habitats, as such habitats are not very common in rest of the areas in the basin. Gross primary production (GPP) and net primary production (NPP) show slight decrease in premonsoon and monsoon seasons at all the sites and was highest during winters.

The concentrations of nitrate and total phosphorous at most of the sites during different seasons were quite low (NO₃ ranging from 0.001 to 0.043 mg/l and PO₄ ranging between 0.001 and 0.074 mg/l). Overall, the populations of phytoplankton and phytobenthos also were on lower side and the planktonic community is mainly dominated by Bacillariophyceae (diatoms), although Chlorophyceae and Cyanophyceae are also found. Overall, zooplanktons are represented by protozoa and rotifers which mostly feed on fish waste, dead bacteria, algae and small particles of food suspended in water generated from decomposing falling leaves from the riparian vegetation. The benthic invertebrate communities (Macroinvertebrates) are dominated by Ephemeroptera and Plecoptera which are abundant in undisturbed habitats which mainly feed on detritus. The GPP values for all the sampling sites lie within the range of 0.02 - 0.3 mgC/m³/day. Based upon the trophic structure at the sampling sites according to Vollenweider (1974) the river can be classified as oligotrophic in nature.

7.2. FISH AND FISHERIES

Freshwaters are an important source of food for humans, in which fish play a significant role. Running waters of Himalaya comprise many torrential rivers and streams providing a wide variety

of ecological niches for freshwater fish. The fish species of Himalaya are well adapted in fast flowing water, low to medium water temperature, boulderous river bed etc.

Fishes are regarded as most impacted group of freshwater biotic communities due to the river regulation by damming because dammed rivers destroy and degrade not only the habitat but hamper the various phenomena (migration, spawning etc) of life cycle of the species. This section focuses the diversity and distribution of fish and cumulative impact of cascade development. The baseline data on fish and understanding of various attributes of fish communities will be helpful in the fishery management and conservation.

7.2.1 Fish Composition & Distribution

The vast mountainous landscape of Arunachal Pradesh, poor road network and infrastructure facilities can be attributed to the less known fishery resources of Arunachal Pradesh. However, Zoological Survey of India has made several faunal surveys in Arunachal Pradesh. On the basis of comprehensive surveys Sen (2006) provided a list of 143 fish species in Arumachal Pradesh. The distribution of fish species based upon data collected from secondary sources along the altitudinal gradient was plotted to understand the distribution pattern of fishes in Arunachal Pradesh reveals that species richness monotonously decreases along the altitudinal gradient (**Figure 7.14**). According to this the river stretch up to 1000 m can be considered as critical stretch, which harbours higher number of species.

The number of fish species decreases monotonously along the elevational gradient in Siang basin (**Figure 7.14**). River stretch up to 500 m seems critical from the conservation point of view. Each elevational band within 500 m is inhabited by more than 20 fish species in Siang basin.

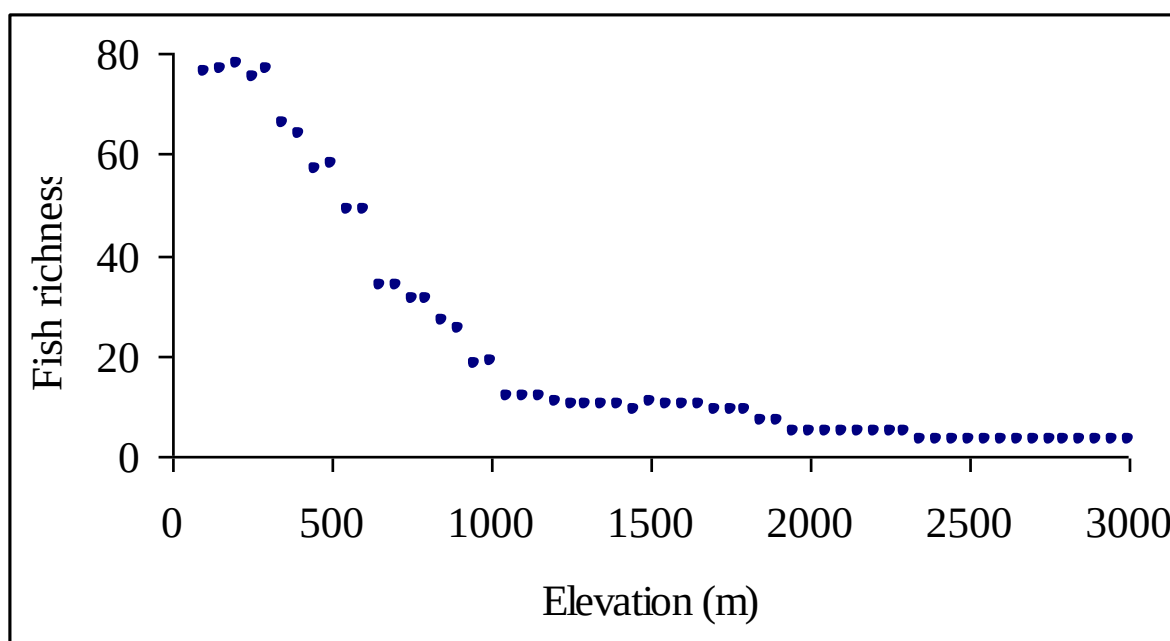


Figure 7.14: Fish species richness pattern along the elevational gradient in Arunachal Pradesh

7.2.2 Important Fish Habitats

The following discussion of habitats of fishes in Himalayan rivers is based upon an article published by Sehgal (1999). The generally clear, cool, fast-flowing waters and bedrock and coarse sediment beds of rivers like Siang encourage fish species with limited temperature tolerances, high oxygen needs, and strong swimming ability and specialised reproductive strategies to prevent eggs or

larvae being swept away. These characteristics also encourage invertebrate species with limited temperature tolerances, high oxygen needs and ecologies revolving around coarse sediments and interstices or "gaps" between those coarse sediments.

The eastern Himalaya drained by the Brahmaputra has a greater diversity of coldwater fish than the Western Himalayan drainage. For the whole Himalaya, 218 species are listed (Menon, 1962). The subsistence and commercial fisheries exploit carps (*Labeo* spp. and *Tor* spp.), lesser barils (*Barilius* spp.), schizothoracines (*Schizothorax* spp.), garrids (*Garra* spp.) and sisorids (*Glyptothorax* spp. and *Glyptosternum* spp.).

Generally more turbid, warm, slow-flowing waters and fine sediment beds of lowland rivers encourage fish species with broad temperature tolerances and greater tolerances to low oxygen levels, and life history and breeding strategies adapted to these and other traits of lowland rivers. These characteristics also encourage invertebrate species with broad temperature tolerances and greater tolerances to low oxygen levels and ecologies revolving around fine sediments or alternative habitats such as submerged woody debris ("snags") or submergent macrophytes ("water weed").

The main factors which influence fish life in the Himalayan streams are:

- i) current velocity;
- ii) fluctuation in water discharge;
- iii) water temperature and dissolved oxygen level;
- iv) substratum;
- v) shelter from the current; and
- vi) food availability represented mostly by organisms clinging to and growing on rock and stone surfaces in fast current.

The Himalayan fishes spend the major part of their life facing the current. This helps them in two ways: firstly, to maintain their upright position, and secondly, to make respiration easier. They have to open their mouths to take in water and boost the respiratory current. Shoals of lesser barils (*Barilius* spp.) are found in shallow pools (20-25 cm in depth). Loaches, which have coloration of their backs matching the background of sandy pools, swim rapidly in short bursts.

The need for shelter from the current has led to territoriality i.e. having a fixed territory/tributary. Mahseers and schizothoracines chase intruders to defend the limited food resource and available shelter. Such behaviour develops after the young fish emerges from the eggs that are laid in gravel. During winter months groups of all sizes of mahseers and schizothoracines inhabit the pools when the water level is at its lowest and water is highly transparent. Such pools are present in the rivers Jhelum, Beas, Sutlej and Yamuna (Sehgal, 1988). Shoaling behaviour has been observed in lesser barils and juvenile mahseers in shallow pools of the principal tributaries of the rivers Beas, Sutlej and Yamuna. This is one of the devices employed by these species to confuse predators. When a few fish are caught in a cast net, the rest disperse.

Water temperature is always an important limiting factor affecting geographical distribution and local occurrence within one water system. Cold stenothermic species such as the endemic schizothoracines (*Schizothorax esocinus* and *Diptychus maculatus*) and exotic brown trout have an upper tolerance around 20°C. Carps, mahseers and lesser barils have a wider tolerance and even survive water temperatures over 25°C. Schizothoracines and brown trout remain active in the

near-zero temperature which prevail in streams of the Lesser and Greater Himalaya during December and January.

According to Sehgal (1999) to cope up with the steep fall in temperature in winter months schizothoracines migrate from headwaters to lower altitudes where they represent a sizeable part in fish catches in large rivers and their tributaries. The rise in temperature in Jammu & Kashmir streams varies from near-freezing level to 10-17°C during May-June and induces *Schizothorax richardsonii*, *S. longipinnis* and *S. curvifrons* to spawn. In the Sulej River, *S. richardsonii* starts upstream migration with the rise in water temperature during March. During the upstream migration the fish still finds itself in waters of low temperature of 8.0-9.5°C, owing to the steady influx of snow-melt water. This induces the species to migrate to and spawn in side streams, which receive warm ground water of 17.5-21.5°C. In the Ravi River system the fish spawn in May. In the upper Beas, however, the fish spawn only in July-August when the stream water temperature warms up to 16.5-18.5°C. In the same drainage *Schizothorax richardsonii* migrates downstream to the lowermost reaches where it spawns from October to December at 19.0 to 22.5°C. These observations indicate that in some schizothoracines multiple spawning is determined by temperatures and flow rates optimal for egg laying. The eggs are large-sized (3.0-4.0 mm diameter) and sticky in nature. They are laid in shallow pools (50-70 cm depth) and remain adhered to the substratum until the hatching of fry.

In the Himalaya, two zones can be distinguished i.e. **rhithron zone** and **potamon zone**. The **rhithron zone** is characterized by a monthly mean temperature of 17.3°C, high concentrations of dissolved oxygen (10.0 mg l⁻¹), fast current (0.9-1.8 m/sec), and turbulent waters. The substratum is rocks and boulders with sand and silt patches and with some pools. The fish of this zone are stenothermic, such as brown trout and snow trouts (*Schizothorax richardsonii*, *S. esocinus* and *S. progastus*). This zone borders on the **potamon zone** which has a higher mean water temperature of 22.1°C, dissolved oxygen of 8.0 mg l⁻¹, and current velocity of 0.5-0.7 m/sec. The substratum consists of boulders, stones, gravel and patches of aquatic vegetation in the pools. The fish fauna is eurythermic or warm-stenothermic (*Labeo dero*, *Tor putitora* and *Garra gotyla*).

Menon (1954) related the distribution pattern of Himalayan fish to morphological characteristics which enable them to inhabit the torrential streams. He recognised six major groups: (a) fish dwelling in shallow, clear cold waters in the foothills without any striking modifications to current: *Labeo*, *Tor*, *Barilius* and *Puntius*; (b) fish inhabiting the bottom water layers in deep fast current, with powerful muscular cylindrical bodies: schizothoracines and the introduced trouts; (c) fish sheltering among pebbles and stones to ward off the strong current: *Crossocheilus diplocheilus*; (d) fish sheltering among pebbles and shingles in shallows, with special attachment devices: the loaches *Noemacheilus*, *Botia* and *Amblyceps*; (e) fish which cling to exposed surfaces of bare rocks in slower current, with adhesive organs on their ventral surface for attachment to rocks: *Garra*, *Glyptothorax* and *Glyptosternum*; and (f) fish which cling to the exposed surfaces of bare rocks in fast current, with limpet-shaped bodies and mouth, gills and fins highly modified to suit the habitat: *Balitora*.

7.2.3 Fishes of Siang Basin

The fish resources in the lotic systems of Arunachal Pradesh rivers have not been completely explored because most of the rivers are located in unapproachable mountainous steep terrain with dense forest cover. In order to understand the fishery resources of Siang basin information was collected from State Fishery Department, Itanagar which was supplemented with published

literature like reports and research articles (Jhingran, 1961; Jayram, 1963, Jayram, and Mazumdar; 1964; Srivastava, 1966; Talwar & Jhingran, 1991; Nath & Dey, 2000; Sen, 1999, 2006; Nebeshwar *et al.* 2007; Bagra *et al.* 2009a,b; Nath *et al.* 2010; Bagra & Das, 2010; Lakra *et al.* 2010; Vishwanath *et al.* 2010; Geetakumari & Kadu, 2011; Tamang & Chaudhry, 2012; Yumnam & Tripathi, 2013). Nath & Dey, 2000 had reported 74 species of fishes from Siang river system. However more information and data was collected from different secondary sources to prepare a checklist of fishes found in Siang. According to it Siang basin harbours 114 species of fishes belonging to 27 families. The list does not include two exotic species like *Salmo trutta* (Brown trout) and *Oncorhynchus mykiss* (Rainbow trout) introduced in Yargyap Chhu and Siyom river. Cyprinidae is largest family with 42 species accounting for 37% of total fish fauna. A list of fish species thus prepared from secondary sources as well as field surveys along with their conservation status according to CAMP report (Molur & Walker, 1998) and IUCN Red list is given at Table 7.47. Golden mahseer has been declared as Arunachal Pradesh State fish (Anon, 2011).

Following C.A.M.P. guidelines all the 116 fish species were assessed for their conservation status, of which 31 are under 'Least Concern' category (see Table 7.47). *Schistura kangjupkhulensis* and *Tor putitora* are categorized as 'endangered species' and *Schizothorax richardsonii* has been placed under 'vulnerable' category. The category of 'Near Threatened' includes *Tor tor*, *Bagarius bagarius*, *Acrossocheilus hexagonolepis*, *Wallago attu*, *Ompok bimaculatus*, *Ompok pabda* and *Schistura manipurensis*.

According to IUCN 2011.2 criterion *Tor putitora*, *Lepidocephalichthys arunachalensis* (= *Nemacheilus arunachalensis*) and *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*) are under Endangered category whereas 7 species are under Vulnerable category (see Table 7.47). These are *Cyprinus carpio*, *Schizothorax richardsonii*, *Bagarius bagarius*, *Pseudecheneis sirenica*, *Botia rostrata* and *Aborichthys garoensis* (= *Nemacheilus garoensis*). Twelve species are under Near Threatened category viz. *Balitora brucei*, *Labeo pangusia*, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Tor tor*, *Syncrossus berdmorei* (= *Botia berdmorei*), *Aborichthys kempfi* (= *Nemacheilus kempfi*), *Nemacheilus devdevi*, *Schistura manipurensis* (= *Nemacheilus manipurensis*), *Ompok pabda*, *Ompok pabo*, *Ompok bimaculatus* and *Wallago attu*.

Table 7.47: Fish species reported from Siang basin and their conservation status

S. No.	Order	Name of species	Distribution (m)	Conservation Status	
				CAMP Report	IUCN Red List Ver 3.1
1	Clupeidae	<i>Gudusia chapra</i>	Up to 300	LRLc	LC
2	Notopteridae	<i>Notopterus notopterus</i>	Up to 200	LRnt	LC
3	Engranulidae	<i>Setipinna phasa</i>	Up to 500	LRLc	LC
4	Balitoridae	<i>Balitora brucei</i>	500-1500	LRnt/N	NT
5	Cyprinidae	<i>Amblypharyngodon mola</i>	Up to 500	LRLc/N	LC
6		<i>Aspidoparia jaya</i>	250	VU/N	LC
7		<i>Bangaba dero</i> (=Labeo dero)	1500	VU/N	NA
8		<i>Barilius barila</i>	Up to 1500	VU/N	LC
9		<i>Barilius barna</i>	Up to 2000	LRnt/N	LC
10		<i>Barilius bendelisis</i>	Up to 2001	LRLc	LC
11		<i>Barilius shacra</i>	1200	LRnt/N	LC
12		<i>Barilius tileo</i>	2000	LRnt/N	LC
13		<i>Barilius vagra</i>	1500	VU/N	LC
14		<i>Cabdio morar</i> (=Aspidoparia morar)	Up to 500	LRnt/N	LC
15		<i>Chagunius chagunio</i>	Up to 1500	LRLc	LC
16		<i>Cirrhinus reba</i>	up to 500	VU/N	LC
17		<i>Crossocheilus latius</i>	1500	DD	DD
18		<i>Cyprinion semiplotum</i> (=Semiplotus semiplotus)	up to 500	VU/N	VU
19		<i>Cyprinus carpio</i>	100-500	VU	VU
20		<i>Danio dangila</i>	100-300	LRLc	LC
21		<i>Danio rerio</i> (=Brachydanio rerio)	Up to 300	LRnt/N	LC
22		<i>Devario aequipinnatus</i>	1000	LRnt/N	LC
23		<i>Devario devario</i>	Up to 1000	LRnt/N	LC
24		<i>Esomus danricus</i>	100-300	LRLc/N	LC
25		<i>Garra annandalei</i>	500	LRLc	LC
26		<i>Garra gotyla gotyla</i>	Up to 2000	VU/N	LC
27		<i>Garra kemp</i>	1000-2000	VU	LC
28		<i>Garra lissorhynchus</i>	200-1500	VU	LC
29		<i>Garra mcClellandi</i>	500-600	LRLc	LC
30		<i>Garra naganensis</i> (=Garra tirapensis)	200-1000	VU	LC

S. No.	Order	Name of species	Distribution (m)	Conservation Status	
				CAMP Report	IUCN Red List Ver 3.1
31		<i>Labeo calbasu</i>	up to 500	LRnt/N	LC
32		<i>Labeo gonius</i>	up to 500	LRnt/N	LC
33		<i>Labeo pangusia</i>	up to 500	LRnt/N	NT
34		<i>Megarasbora elanga</i>	300-700	LRlc	LC
35		<i>Neolissochilus hexagonolepis</i> (=Acrossocheilus hexagonolepis)	300-1000	LRnt/N	NT
36		<i>Oreochthys cosuatis</i>	100-300	LRlc	LC
37		<i>Puntius chola</i>	100-700	VU	LC
38		<i>Puntius sarana</i>	100	VU/N	LC
39		<i>Puntius sophore</i>	Up to 700	LRnt/N	LC
40		<i>Puntius ticto</i>	up to 500	LRnt/N	LC
41		<i>Rasbora rasbora</i>	100-300	LRlc	LC
42		<i>Salmostoma bacaila</i>	up to 500	LRlc/N	LC
43		<i>Schizothorax esocinus</i>	2000	LRnt/N	NA
44		<i>Schizothorax progastus</i>	3000	LRnt/N	LC
45		<i>Schizothorax richardsonii</i>	Up to 3000	VU	VU
46		<i>Tor putitora</i>	Up to 1000	EN/N	EN
47		<i>Tor tor</i>	150-1000	EN/N	NT
48	Sisoridae	<i>Bagarius bagarius</i>	Up to 500	VU	VU
49		<i>Exostoma labiatum</i>	300-700	LRlc	LC
50		<i>Glyptosternon reticulatum</i>	2000	EN/N	
51		<i>Glyptothorax annandeli</i>	1000-1500	LRlc	LC
52		<i>Glyptothorax brevipinnis</i>	700-1000	VU	DD
53		<i>Glyptothorax cavia</i>	800	EN/N	LC
54		<i>Glyptothorax indicus</i> (=Glyptothorax horai)	Up to 1000	VU/N	LC
55		<i>Glyptothorax trilineatus</i>	1000-1500	LRlc	LC
56		<i>Parachiloganis hodgarti</i> (=Euchiloglanis hodgarti)	1200	VU/N	LC
57		<i>Pseudecheneis sirenica</i>		VU/N	VU
58		<i>Pseudecheneis sulcata</i>	1500	LRlc	LC
59	Heteropneustidae	<i>Heteropneustes fossilis</i>	100-650	VU/N	LC
60	Bagridae	<i>Batasio fasciolatus</i>	200-300	LRlc	LC

S. No.	Order	Name of species	Distribution (m)	Conservation Status	
				CAMP Report	IUCN Red List Ver 3.1
61		<i>Sperata aor</i> (=Aorichthys aor)	300-500	LRLc	LC
62		<i>Sperata seenghala</i> (=Aorichthys seenghala)	300-500	LRLc	LC
63		<i>Mystus bleekeri</i>	50-700	VU	LC
64		<i>Mystus cavasius</i>	up to 500	LRnt/N	LC
65		<i>Mystus vittatus</i>	100-300	VU/N	LC
66	Amblycipitidae	<i>Amblyceps apangi</i>	200-1000	VU	LC
67		<i>Amblyceps arunachalensis</i>	200-1001	EN	NA
68		<i>Amblyceps mangois</i>	1000	LRnt/N	LC
69	Cobitidae	<i>Botia dario</i>	Up to 1500	LRLc	LC
70		<i>Botia rostrata</i>	Up to 1500	VU	VU
71		<i>Lepidocephalichthys annandalei</i> (=Lepidocephalus annandalei)	200-500	LRnt	LC
72		<i>Lepidocephalichthys arunachalensis</i> (=Nemacheilus arunachalensis)	500-1000	EN/N	EN
73		<i>Lepidocephalichthys guntea</i> (=Lepidocephalus guntea)	300	LRLc	LC
74		<i>Syncrossus berdmorei</i> (=Botia berdmorei)	500-1000	EN/N	NT
75	Nemacheilidae	<i>Aborichthys elongatus</i>	500	LRLc	LC
76		<i>Aborichthys garoensis</i> (=Nemacheilus garonesis)	500	VU	VU
77		<i>Aborichthys kempfi</i> (=Nemacheilus kempfi)	500	NT	NT
78		<i>Acanthocobitis botia</i>	400-600	LRLc	LC
79		<i>Nemacheilus devdevi</i>	1000-2000	EN	NT
80		<i>Schistura kangjupkhulensis</i> (=Nemacheilus kangjupkhulensis)	800-1200	VU	EN
81		<i>Schistura manipurensis</i> (=Nemacheilus manipurensis)	800-1500	VU	NT
82		<i>Schistura multifasciata</i> (=Nemacheilus multifasciatus)	1500	EN/N	LC
83		<i>Schistura rupecula</i>	1000-1500	LRnt	LC
84		<i>Schistura savona</i>		LRLc	LC
85	Siluridae	<i>Ompok pabda</i>	100-250	EN/N	NT
86		<i>Ompok pabo</i>		NT	NT
87		<i>Ompok bimaculatus</i>	100-2500	EN/N	NT

S. No.	Order	Name of species	Distribution (m)	Conservation Status	
				CAMP Report	IUCN Red List Ver 3.1
88		<i>Pterocryptis gangelica</i> (= <i>Silurus afgana</i>)	200-2000	EN/N	DD
89		<i>Wallago attu</i>	100-250	LRnt/N	NT
90	Olyridae	<i>Olyra longicaudata</i>	Up to 1000	LRLc	LC
91	Mastacembelidae	<i>Macrognathus aculeatus</i>	300-500	NA	NA
92		<i>Macrognathus pancalus</i> (= <i>Mastacembelus pancalus</i>)	Up to 300	LRnt	LC
93		<i>Mastacembelus armatus</i>	500	LRLc	LC
94	Anguillidae	<i>Anguilla bengalensis</i>	Up to 100	EN	LC
95	Synbranchidae	<i>Monopterusuchia</i>	Up to 500	LRnt/N	LC
96	Belonidae	<i>Xenentodon cancila</i>	Up to 200	LRnt/N	LC
97	Psilorhynchidae	<i>Psilorhynchus arunachalensis</i>	500	DD	DD
98		<i>Psilorhynchus balitora</i>	500	LRLc	LC
99		<i>Psilorhynchus homaloptera</i>	200-1000	VU	LC
100	Clariidae	<i>Clarias batrachus</i>	100-150	VU	LC
101	Ambassidae	<i>Chanda nama</i>	100-300	LRLc	LC
102		<i>Parambassis ranga</i> (= <i>Chanda ranga</i>)	100-300	LRLc	LC
103		<i>Pseudambassis baculis</i> (= <i>Chanda baculis</i>)	200-600	LRLc	LC
104	Nandidae	<i>Nandus nandus</i>	50-500	LRnt	LC
105	Anabantidae	<i>Anabas testudineus</i>	Up to 300	VU/N	DD
106	Osphronemidae	<i>Trichogaster fasciata</i> (= <i>Colisa fasciatus</i>)	Up to 800	LRnt/N	LC
107		<i>Trichogaster labiosa</i> (= <i>Colisa labiosa</i>)	100-300	LRLc	LC
108	Badidae	<i>Badis badis</i>	100-300	LRLc	LC
109	Gobiidae	<i>Glossogobius giuris</i>	200-800	LRnt	LC
110	Channidae	<i>Channa marulius</i>	200-600	LRnt/N	LC
111		<i>Channa orientalis</i>	Up to 500	VU/N	NA
112		<i>Channa punctata</i>	Up to 600	LRnt/N	LC
113		<i>Channa striata</i>	up to 600	LRLc/N	LC
114	Erethistidae	<i>Conta pectinata</i>	100-300	DD	DD
115		<i>Pseudolaguvia shawi</i>	500-1500	EN	LC
116		<i>Pseudolaguvia viriosa</i>	100-300	NA	NA

LRLc = Low Risk Least Concern; LRnt = Low Risk Near Threatened; VU= Vulnerable;
 EN = Endangered; DD = Data Deficient; - No data; N = Nationally; NA = Not Assessed

7.2.4 Fishery Activities and Fishing Techniques/Devices used in basin

Adi & Galo tribes of Arunachal Pradesh constitute the major section of the locals in the lower stretch, who are generally non-vegetarian in their diet habit. Fish is also one of their important diet constituent among other hunted animals. Normally, the fishing activity takes place during the months of September to April, when river flow is moderate.

The maximum fishing activities are concentrated downstream of Siang Lower HEP dam site near Pasighat area in 6-10 km river stretch. Fishing is well organized in this area; however, there is no interference of governmental agencies like Forest department or Fishery department. The tribal villages along the both banks of river form fishermen's societies separately. The society is locally called 'Ayung'. 'Ayung' meets biannually and selects a contractor among the villagers. The contractor pays an certain amount (the present contractor of right bank paid Rs. 1,50,000/-) of money to 'Ayung' which is used for developmental works of the region. To facilitate the small stretches of the river contractor generally divides it into many sub-contracts. More than 40 fishermen are engaged in the fishing activities on the one of the bank of river. In Pasighat stretch average daily catch per fisherman was around 20 -25 kg. According to locals 1000 kg fish are landed per day in 10 km of river stretch near Pasighat river stretch during November to April. The fishing activities cease permanently during June to September months due to high flow of Siang river.

Fishermen use gill net and hooks to land fish in Siang river. They used boat to stretch the gill net across the river. *Chagunius chagunio*, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Labeo pangusia*, *L. gonius*, and *Schizothorax richardsonii* accounted for major catch in the river Siang.

Fishing activities decrease gradually towards upstream section of the river. Hook is main gear of fishing in the region. In Siyom river tribals land fish with the help of hook while in Yargyap river and lower part of Siyom river migrant labourers were found to use cast net.

In the area in the upstream catchments of Siang and Siyom rivers cultural fishery is negligible and there are no fish farms and hatcheries for the fishery development in this region. Capture fishery is solely restricted to the snow trout species. Kamba is the main village and Along is the main market in Siyom river catchment for fishes. During the field surveys only five fishermen who were engaged in the fishing activities in the Siyom catchment area. The average fish catch during field surveys in middle catchment of Siyom river was recorded to be 1.2 kg/fishermen/day. The inhabitants of the area are mostly non-vegetarian, but that has not necessitated the involvement of local population in fisheries activity as an economic pursuit. This may be due to prevalent customary hunting of terrestrial animals, which fulfills people's food and protein requirements.

Intensity of capture fishery in the upper catchments of Siyom and Yargyap Chhu is very low as tribal people are reluctant to land fish in general. During the field surveys few fishermen could be located in the area, though; they are not regularly engaged in fishing activities. During the surveys fishermen were hired and fishing was made in Siyom river as well as Yargyap Chhu. During field surveys experimental fishing in 4 km river stretch of Siyom for about 2 hours resulted into capture of 3.5 kg fish. No fish could be landed in higher reaches of Yargyap Chhu in January while it was around 1.2 kg in months of March-April. *Schizothorax richardsonii* was pre-dominant species of capture fishery. It accounted for nearly 90% of the total catch. Other species which come rarely in the catch are *Garra naganensis* and *Schistura multifasciata* and *Schistura rupecola*. These species are not of fishery interest.

Fishermen with various types of fishing gears used during the surveys and the fish catch is shown in **Plates 7.2 - 7.4**.

Schizothorax and *Garra* species constituted the major contributors to the total fish catch in Yargyap Chhu. Fish catch in this area is generally done by locally made hooks, and special trap locally called 'Porang' which is often set in the opposite directions of the river. This is very effective fishing method in the main streams. Yargyap Chhu being wider for longer stretches, fishing nets are not laid across the river. During breeding seasons, fishing is strictly banned as per the local authority. Fishing rights in these areas are governed by the Village head called "Gram Burrah" and SDO.

The commonly used indigenous fishing gears as reported by Bagra et al., 2009, are based upon their construction and the methods of application are as follows:

- i) **Takom gaanam:** technique of placing a *Takom* in the river or stream. *Takom* is a conical shaped fish trap made of bamboo with a mouth diameter ranging from 0.1 to 0.3 m. It is fixed against the water current. Once the fish entered inside, they remained entangled in the base with the pressure of water current.
- ii) **Tasum kunam:** fishing method in which a conical shaped basket made of cane is used to collect fishes from streams or rivers. With this fishing gear small sized fishes, especially bottom dwellers, are easily collected.
- ii) **Lipum paanam:** fishing method in which the flat stones are piled one on other in the pool or slow flowing river of approximately 1 m depth. The stone are piled in such a way that forms a round shape of aggregated stone block called *lipum*. The diameter of *lipum* ranges from 1.2 to 2.0 m and height ranges from 0.4 to 0.5 m. *Lipum paanam* is practiced during winter season and is allowed to remain undisturbed for 2 to 3 months where fish used to take shelter. The aggregated fishes are then collected by unpiling stones just after cordoning the *lipum* with a circular screen made of bamboo. These indigenous devices are used where common fishing gears were not available.

7.2.5 Fishes Found During Study

The sampling for fishes was done at 47 different locations in Siang and Siyom rivers as well as their tributaries like Yamne, Simang, Tagutshit, Yargyap Chhu, Ringong and Sigong rivers covering all the Sub-basins as well as proposed project area. List of sampling sites along with their location is given in Chapter 4 on Methodology. Common fishing methods were used to land fish from Siang and Siyom rivers and their tributaries. The fish were landed with the help of local fishermen, who used hooks and cast nets to land fish. At each site all fishing gears except cast net were used at least 10 times at each sampling location while the cast nets were laid at least 15 times at each location. All the fish species landed during the experimental fishing were identified with the help of Talwar & Jhingran (1991) and were classified according to Nelson (2006) and their correct scientific names were checked and updated following <http://www.fishbase.org>.

During the course of field surveys experimental fishing was done during different seasons and 39 species were recorded from the Siang river system (**Table 7.48**). The details of different fish species recorded during surveys at all sampling sites are given at **Annexure-VII of Volume-II : DATA**. *Chagunius chagunio*, *Labeo pangusia*, *L. gonius*, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Puntius ticto*, *P. sarana*, *Xenotodon cancila*, *Psilorhynchus balitora* were most common in lower stretches. *Chagunius chagunio* is most dominant followed by

Labeo pangusia, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*) and *Labeo gonius*. In the upper reaches of Siang basin *Schizothorax richardsonii*, *Labeo gonius*, *Garra naganensis*, *Barilius shacra*, *B. tileo*, *Glyptothorax annandeli* were found. *Schizothorax richardsonii* and *Labeo gonius* were predominant species in this zone. The species like *Barilius shacra* and *B. tileo* were found in the tributaries like Hirit and Simang rivers. *Labeo pangusia* was collected from Hirit river.

Of the 39 fish species recorded during the field surveys, 24 species were recorded from the main Siang river at different sampling locations in Siang Sub-basin-I & II at lower elevations with maximum 24 species at Site S1 (**Figure 7.15**). In tributaries like Sigong, Ringong and Yang Sang at slightly higher elevations 10-11 species were landed. Overall catch was much less during the month of January when water temperature was quite low. As discussed earlier *Chagunius chagunio*, *Labeo pangusia*, *L. gonius*, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Puntius ticto*, *P. sarana*, *Xenotodon cancila* formed the major portion of catch.

From major tributaries of Siang river like Yamne and Simang rivers 15 different species were landed (**Figure 7.16**). Here also the catch was very low during the month of February. *Ompok bimaculatus*, *Glossogobius guiris*, *Labeo pangusia*, *L. gonius*, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*) were the main species caught.

In Siyom river and its tributaries like Hirit, Sike and Tagurshit Nadi 22 species were landed (**Figure 7.17**). Highest number of species i.e. 22 species were landed at Sites SY1 and SY2 during the month of March. Among the fish species caught were *Barilius tileo*, *Garra naganensis* (= *Garra tirapensis*), *Labeo pangusia*, *Schistura rupecola*, *Schizothorax progastus*, *Schizothorax richardsonii*, *Syncrossus berdmorei* (= *Botia berdmorei*) and *Ompok bimaculatus*. Snow trout was most common fish in Siyom river. *Labeo pangusia*, *Schistura rupecola*, *Schistura multifasciata* and *Ompok bimaculatus* were mainly found in tributaries. *Garra naganensis*, *Puntius ticto*, *Glossogobius guiris* and *Mystus bleekeri* preferred main Siyom river.

In Yargyap Chhu only 14 species of fish were landed (**Figure 7.18**). Number of fish species landed decreased beyond sampling Site YG10. The fish catch was very small. Highest number of species i.e. 14 species were landed at Sites YG2 and YG3, during the month of March. The fish comprised of *Garra annandalei*, *Garra naganensis*, *Glyptothorax annandeli*, *Pseuecheneis sulcata*, *Schistura rupecola*, *Schizothorax esocinus*, *Schizothorax progastus* and *Schizothorax richardsonii*.

Table 7.48: List of fish species caught during field surveys

Family	Scientific name	Commom/Local name	Sub-basin/ Sampling site
Cyprinidae	<i>Neolissochilus hexagonolepis</i> (= <i>Acrossocheilus hexagonolepis</i>)	Taga	SSb I-IV; YmSb
	<i>Barilius tileo</i>	Garyong	SSb I-IV; SYSb-I,II; SmSb
	<i>Barilius barila</i>	Garyong	SSb I-IV; YmSb
	<i>Barilius shacra</i>	Garyong	SSb I-IV; YmSb
	<i>Chagunius chagunio</i>	Ngopee	SSb I-IV; YmSb
	<i>Cyprinus carpio</i>		SYSb I; YGSb
	<i>Danio rerio</i> (= <i>Brachydanio rerio</i>)		SSb I, SY I, HSb
	<i>Garra annadalei</i>		SSb I-IV; YmSb; SmSb; SYSb I-III; YGSb
	<i>Garra naganensis</i> (= <i>Garra tirapensis</i>)	Ngopi	SSb I-IV; SYSb I; HSb; YmSb
	<i>Labeo gonius</i>	Kuri	SSb I-IV;
	<i>Labeo pangusia</i>	Tengir	SSb I-IV; SYSb I-II
	<i>Puntius ticto</i>	Chiniputhi	SSb I-IV; SYSb I-II
	<i>Puntius sarana</i>	Chiniputhi	SSb II, III; YmSb
	<i>Schizothorax progastus</i>	Kandeng	SSb IV, SYSb I-III; HSb; YmSb; SmSb; YGSb
	<i>Schizothorax esocinus</i>		SSb I-IV; SYSb I; YmSb; SmSb; YGSb
	<i>Schizothorax richardsonii</i>	Kandeng	SSb I-IV; SYSb I-III; YmSb; SmSb; YGSb
	<i>Tor putitora</i>	Golden mahseer; Rulbung	SSb I-II, YmSb; HSb
	<i>Tor tor</i>	Silver mahseer; Rulbung	
	<i>Cyprinion semiplotum</i> (= <i>Semiplotus semiplotus</i>)	Orpeng	SSb II, III
Sisoridae	<i>Bagarius bagarius</i>	Ngone	SSb I; SYSb I, II

Family	Scientific name	Commom/Local name	Sub-basin/ Sampling site
	<i>Glyptothorax trilineatus</i>	Gebo	SSb III, IV; SYSb III
	<i>Glyptothorax annandeli</i>	Gebo	SSb III, IV; YmSb; YGSb
	<i>Parachiloganis hodgarti</i> (= <i>Euchiloglanis hodgarti</i>)		SY III, YGSb
	<i>Pseuecheneis sulcata</i>	-	SSb III; SYSb II; YmSb
Bagaridae	<i>Sperata aor</i> (= <i>Aorichthys aor</i>)	Ari	SSb I, II, YmSb
	<i>Sperata seenghala</i> (= <i>Aorichthys seenghala</i>)	Ari	SSb I, II, YmSb
	<i>Mystus bleekeri</i>	-	SSb II, III; SYSb II; YmSb
	<i>Mystus cavasius</i>		SSb I
Cobitidae	<i>Syncrossus berdmorei</i> (= <i>Botia berdmorei</i>)	Ribi	SSb II; SYSb I-II; HSb; SmSb
	<i>Lepidocephalichthys arunachalensis</i> (= <i>Nemacheilus arunachalensis</i>)		
Balitoridae	<i>Schistura multifasciata</i> (= <i>Nemacheilus multifasciatus</i>)	-	SSb I; SYSb I-II; HSb; SmSb
	<i>Schistura rupecola</i>		SSb IV; SYSb I-III; HSb; SmSb; YmSb
Siluridae	<i>Ompok bimaculatus</i>		SSb IV; SYSb I-II; HSb; YmSb; SmSb
Belonidae	<i>Xenetodon cancila</i>	Pesi	SSb III, IV; YmSb
Psilorhynchidae	<i>Psilorhynchus balitora</i>	Chepua	SSb III, IV
Gobiidae	<i>Glossogobius giuris</i>	-	SSb III, IV; SY I; HSb; YMSb
	<i>Pseudolaguvia viriosa</i>		SSb I (Sille river)
	<i>Barilius arunachalensis</i>		SSb I (D'Ering WLS)

SSb = Siang Sub-basin; HSb=Hirit Sub-basin; YmSb=Yamne Sub-basin; SmSb=Simang Sub-basin; SYSb=Siyom Sub-basin; YGSb=Yargyap Sub-basin

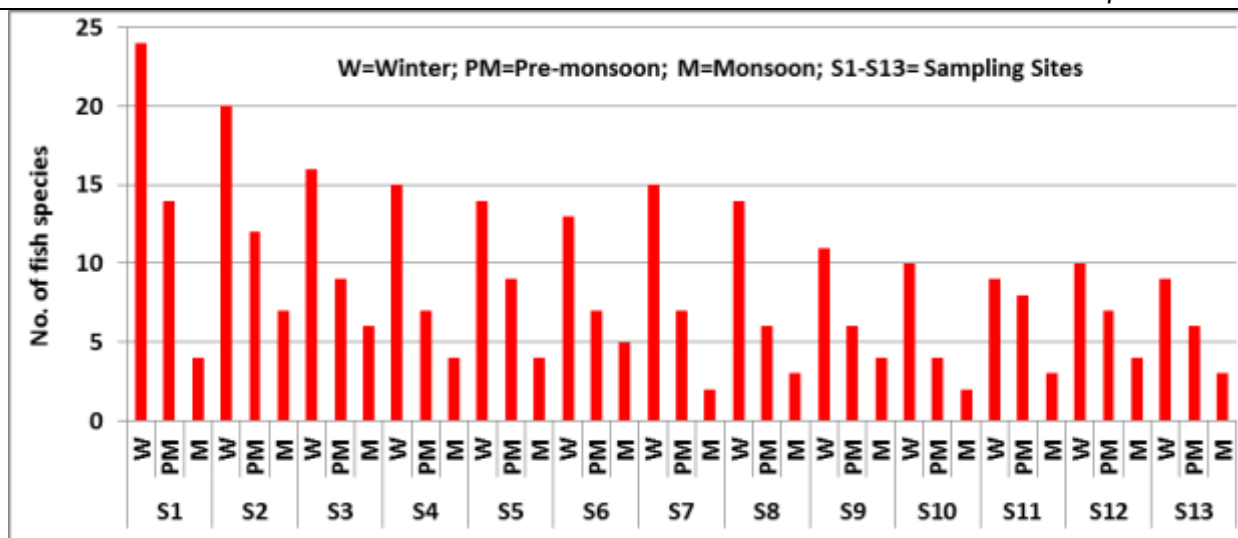


Figure 7.15: Number of fish species landed in Siang river and its tributaries

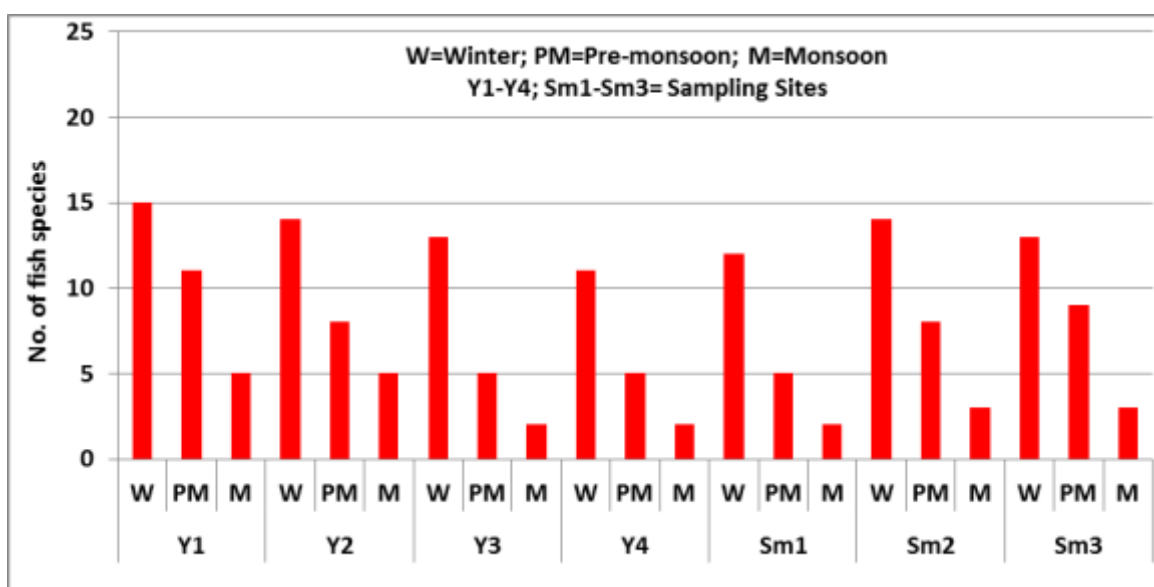


Figure 7.16: Number of fish species landed in Yamne and Simang rivers

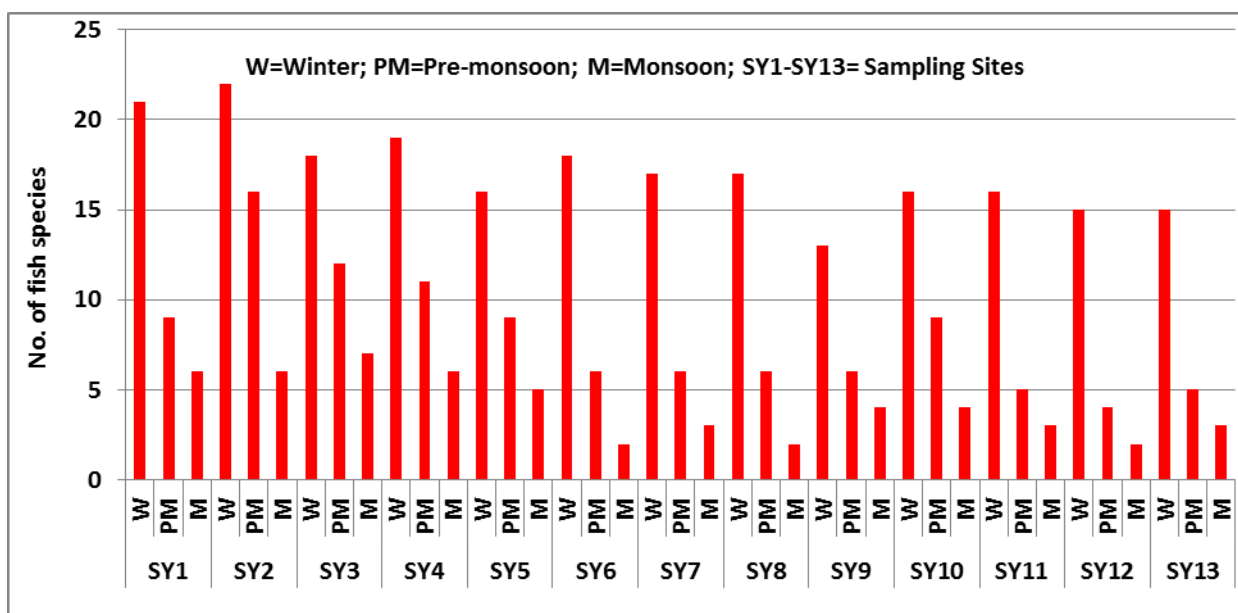


Figure 7.17: Number of fish species landed in Siyom river and its tributaries

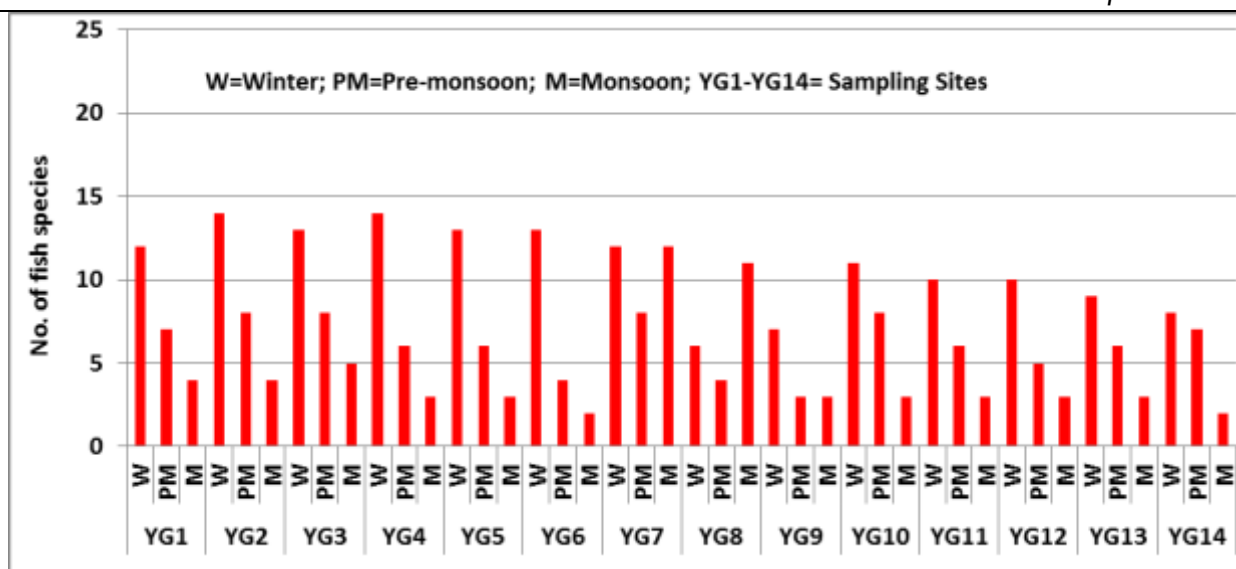


Figure 7.18: Number of fish species landed in Yargyap Chhu

7.2.6 Habitat Characteristics of Threatened fish species reported from Siang river

As already discussed under Section 7.2.3 there are 19 species of fishes reported from Siang basin which are under different threat categories (Endangered, Vulnerable & Near Threatened) according to IUCN Red List Ver. 3.1. The list is given at Table 7.49. Some of these species are migratory species like mahseer, snow trout, labeo and bagarius.

Table 7.49: List of RET fish species

S. No.	Name of Species	Conservation Status
1	<i>Tor putitora</i>	EN
2	<i>Lepidocephalichthys arunachalensis</i> (= <i>Nemacheilus arunachalensis</i>)	EN
3	<i>Schistura kangjupkhulensis</i> (= <i>Nemacheilus kangjupkhulensis</i>)	EN
4	<i>Tor tor</i>	NT
5	<i>Glyptothorax brevipinnis</i>	NT
6	<i>Syncrossus berdmorei</i> (= <i>Botia berdmorei</i>)	NT
7	<i>Aborichthys kempfi</i> (= <i>Nemacheilus kempfi</i>)	NT
8	<i>Nemacheilus devdevi</i>	NT
9	<i>Schistura manipurensis</i> (= <i>Nemacheilus manipurensis</i>)	NT
10	<i>Ompok pabda</i>	NT
11	<i>Ompok pabo</i>	NT
12	<i>Ompok bimaculatus</i>	NT
13	<i>Cyprinion semiplotum</i> (= <i>Semiplotus semiplotus</i>)	VU
14	<i>Cyprinus carpio</i>	VU
15	<i>Schizothorax richardsonii</i>	VU
16	<i>Bagarius bagarius</i>	VU
17	<i>Pseudecheneis sirenica</i>	VU
18	<i>Botia rostrata</i>	VU
19	<i>Aborichthys garoensis</i> (= <i>Nemacheilus garonesis</i>)	VU

Threatened; VU= Vulnerable; EN = Endangered; NT= Near Threatened

The fish communities of a particular river system largely depend on the kind of available aquatic habitat conditions and other river characteristics in which they dwell, grow, move around, complete their life cycle and survive. Likewise other Himalayan rivers in Siang basin too, two distinct fish communities/ zones can be demarcated such as Golden mahseer (*Tor putitora*) and its associated species, and Snow trout (*Schizothorax richardsonii*) and its associated species. While Mahseer (*Tor putitora*) is the most common and dominant fish species found in Siang river at lower elevations, it is *Schizothorax richardsonii* which is the most dominant species in the upper reaches of the basin and it can exist in certain elevations with and without mahseer species i.e. the overlapping elevations. Accordingly in the present the entire Siang basin was classified into three zones/categories such as Mahseer zone, Snow trout zone and 'No-fish zone'. No fish zone has been demarcated in the higher altitudes i.e. 1800 m and above. Very few fish could be caught in this zone despite persistent efforts and moreover, there has no published report/ literature or documentation of fish species reported from this zone. Even the locals deny the existence of fishes in this zone. Immediately below the 'no fish zone', is the snow trout zone where water temperature is always low whereas in the mahseer zone, which falls in the lower altitude rivers and streams, water is relatively warm. A map depicting the same has been given at **Figure 7.19**.

Since fish occur in most of the major streams and channels in Siang basin and are considered important constituent of food aquatic ecosystem trophic structure, therefore the fish community of the Siang river system as critical faunal element of the riverine system for making any reasonable workable estimation of the minimum environmental flow that is required in the different stretches of Siang and Siyom rivers and their tributaries. This is one of the most overriding requirement for the maintenance of not only the fish diversity but their population sizes in particular and overall aquatic ecosystem in general. The collection of primary habitat requirement of all fish species is a huge task and time consuming and moreover very little information and data is available in literature on most of the fishes, therefore the available data on key threatened species reported from the basin has been compiled and is presented in **Table 7.50**. This data on habitat requirement has been used to arrive at minimum environmental flow required for different stretches of Siang and Siyom rivers and its tributary streams in the basin vis-a-vis availability of water in a particular stretch. There are 19 threatened fish species as mentioned above in **Table 7.50** and out of these data on 7 species could be collected from literature and majority of the information on these species was sourced from WII CIA Report on Bhagirathi and Alaknanda Basins (2012). Feeding habits, habitat preference, breeding/spawning characteristics of 7 fish species under RET category is given at **Table 7.50**.

Mahseers

The mahseer fishes grow large, and are considered largest among the Indian indigenous cyprinids. Few large growing mahseer may attain 25-30 kg but are frequently found in size ranging from between 3 to 5 kg. They inhabit and reproduce in coldwater (temperature range of 10-25°C) zones in rivers, mostly remain within 10° to 2° slopes (steep to gentle). In the steep slopes region, the substratum is comprised predominantly of boulders, rocks, and cobbles; while in gentle slopes region, the substratum composition becomes cobbles, pebbles, gravels, and sands.

Therefore the habitat of mahseer comprises cold water temperature, high level of dissolved oxygen, habitat heterogeneity with occurrence of in-stream pools/ deep storage of water, substratum conducive for spawning, etc. among others. Hence, due to various constraints, the availability of habitats for mahseer fishes are less in certain rivers in India resulting in their restricted occurrence in certain river segments in India.

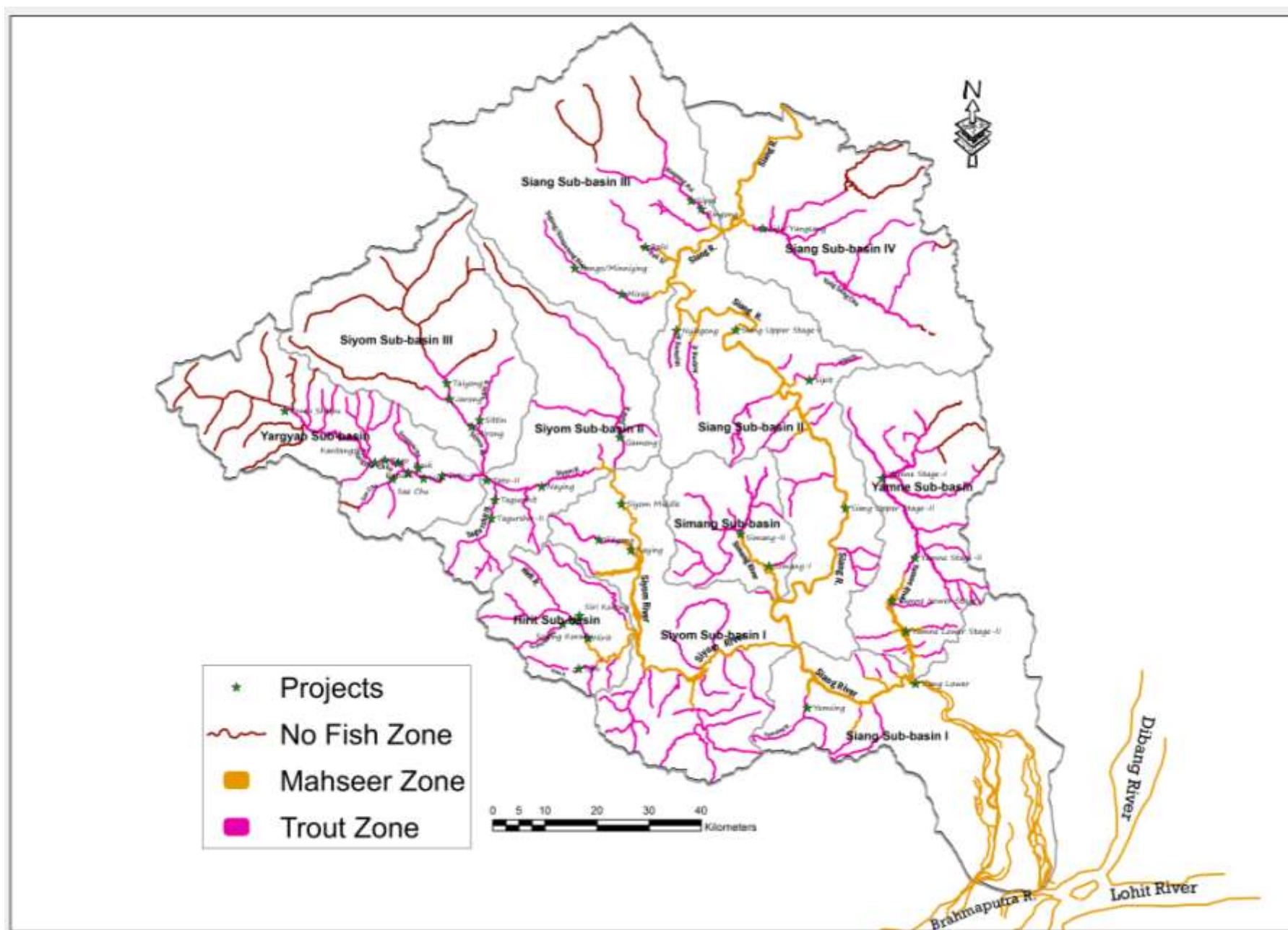


Figure 7.19: Different fish zones demarcated in Siang basin

In Arunachal Pradesh, all the major rivers like Kameng, Subansiri, Siyom, Siang, Dibang, Lohit, and Tirap have mahseer. There are 3 species of mahseer, viz., *Tor putitora*, *T. tor*, and *Neolissochilus hexagonolepis*. Many authors have confirmed the presence of Golden Mahseer (*Tor putitora*) in Siang river around Boleng and Pasighat areas and its tributaries like Siyom, Yamne and Simang and Hirit rivers and in the present study too it was recorded from these areas. There are various local names of the Golden Mahseer in different tribes in the state, viz., Gesik in Adi, Gassey in Galo, Ngochi/ Ngoi Talo in Nishi, Aaro in Idu Mishmi, etc.

In their habitat, the level of dissolved oxygen remains always high due to continuous agitation and bubbling of coldwater, therefore the mahseer fishes are used to live in water having high level of dissolved oxygen (minimum 6 mg/L). In a river, there may be multiple species of mahseer and of diverse size classes because of inter-specific and inter-age niche differences. But, the existence of big size of mahseer depends primarily on the availability of depth of water in the form of many in-stream pools; so that during recession period, the adult mahseer is able to take shelter in deeper waters.

The mahseers are also known as seasonal migratory fish, as they migrate upward for reproduction (Badola and Singh, 1984; Sharma, 1984; Nautiyal and Lal, 1984; Singh, 1988). During March-April the brooder Mahseer migrate much up in the river, sometimes in the tributaries in search of shallow waters having pebbles and gravels as substratum and habitat conducive for breeding and spawning. These species use mainstream as migratory route and access a particular stream for spawning. After spawning, they descend in the months of September and October.

1. Golden Mahseer (*Tor putitora*) - IUCN Status: Endangered

It is known by the local names like *Gesik* in *Adi*, *Gassey* in *Galo*, Ngochi/ Ngoi Talo in the basin and also is a **State fish**. The Golden mahseer, *Tor putitora* is the most popular mahseer and the most popular game fish in India and recently has been declared as State Fish. It inhabits the montane and submontane regions like rapid streams with rocky bottom and riverine pools in the basin. It prefers moderately cold waters of Siang river (13°C-30°C) and its tributary streams. It is an omnivorous in nature during their adult stage and feed on periphytic algae and diatoms in juvenile stage. The food choice changes with age and size. Hatchlings have higher inclination towards planktonic food and fingerlings and juveniles prefer animal origin food. It migrates upstream from the main river into the rivulets mainly during the southwest monsoon (July-September with peaking in July-August) for the purpose of spawning; this is when they ascend to elevations up to 700-800m. Most of the female mahseer mature above 390 mm in length and spawn from May to September. Most of the mahseer species are known to have very similar spawning behavior and breeding habits. Natural spawning habitats usually comprise the marginal pool areas. In addition to well-oxygenated water, water temperature from 21°C to 26°C proves to be effective for final maturation of eggs.

As soon as spawning is over, they move downstream to feeding areas of larger rivers where they grow older and larger every year and continue the cycle. During winter months the fish moves into warmer waters due to its migratory habits.

The adult fishes are long-lived, slow growing and feed on insects and fish fry of other species and feed mainly on drifting aquatic and terrestrial insects. As they grow, they become increasingly piscivorous. Male fish matures when two years old and of about 200 mm total length. The female matures at 300 mm total length after about three years (Shrestha, 1994).

Adults and juveniles of species such as *Tor* spp. move upstream and downstream respectively in river Siang including its streams namely Yamney and Siyom. Majority of the tributaries serve as the routes through which the fish can have easy access to the spring-fed placid streams that provide congenial environment for fish to breed. The presence of gravel, pebbles, sand and bankside vegetation is prerequisite for Mahseer to build their spawning nests. Mahseer needs clean, stable, well oxygenated, gravel habitats to spawn. The eggs laid in the gravels require well-oxygenated water (Sharma, 1984).

Table 7.50: Important characteristics of key fish species found in Siang basin
Golden Mahseer (*Tor putitora*) - IUCN Status: Endangered

	Adults	Juveniles	Sapwning	Incubation & Larval development
Depth	Deep (>1 m) 0.5 - 1.5 m	Shallow (<0.75 - 1.5m)	Shallow to high (0.5-2.0m)	Shallow to high (0.3 - 2.00 m)
Velocity	Medium to high (0.5 - 1.5 m/s)	Low to medium (0.1-1.5 m/s)	Low to medium (0.1 -1.0 m/s)	Low to medium (0.1-0.5 m/s)
Habitat	Riffles, pools, glides	Pools, backwater pools closer to the banks and run habitats	Low gradient riffles, backwater pools, secondary channel	Backwater Pools and secondary channels
Substratum	Bed rock, Boulders, Cobbles, gravel to sandy bottom	Cobbles, gravel to sandy bottom Bed rock undercut	Boulder undercut Gravel bed	Cobbles, gravel to sandy bottom, leaf litter
Temperaure	12-30 °C	12-20 °C	<12 °C	10-15°C
Dissolved Oxygen (mg/l)	8-12 mg/l	8-12 mg/l	8-12 mg/l	8-12 mg/l
Food	Omnivorous: small fishes, benthic invertebrates larvae, mollusc, crab, fronds and seeds, etc.	Benthic invertebrates larvae, worms etc.	Not applicable	Periphytic algae and diatoms
Breeding Period	March - April; October to December			
Passage requirement	Moves long distance to streams associated with main river, nearby side channels, shallow water and pools to breed			
Migration timing	March - April; October -December			
Migration Cues	Change in flow pattern and water temperature may be a factor which trigger the breeding migration			

Silver Mahseer (*Tor tor*) - IUCN Status: Near Threatened

	Adults	Juveniles	Sapwning	Incubation & Larval development
Depth	Deep (>1 m)	Shallow (<0.75 - 1.5 m)	Shallow to high (0.5 - 2.00 m)	Shallow to high (0.3 - 2.00 m)
Velocity	Medium to high (0.5 - 1.5 m/s)	Low to medium (0.1- 1.5 m/s)	Low to medium (0.1 -1.0 m/s)	Low to medium (0.1-0.5 m/s)
Habitat	Riffles, pools, glides	Pools, backwater pools closer to the banks and run habitats	Low gradient riffles, backwater pools, secondary channels	Backwater Pools and secondary channels
Substratum	Bed rock, boulders, cobbles, gravel to sandy bottom	Cobbles, gravel to sandy bottom	Bed rock undercut boulder undercut gravel bed	Cobbles, gravel to sandy bottom leaf litter
Temperaure	16-30 °C	16-30 °C	<20 °C	16 - 20°C
Dissolved Oxygen (mg/l)		8-12 mg/l	8-12 mg/l	8-12 mg/l
Food	Omnivorous: small fishes, benthic invertebrates larvae, mollusc, crab, fronts and seeds etc.	Benthic invertebrates larvae, worms, etc.	Not applicable	Periphytic algae and diatoms
Breeding Period	March to September			
Passage requirement	Moves long distance to streams associated with main river, nearby side channels, shallow water and pools to breed			
Migration timing	March to April			
Migration Cues	Change in flow pattern and water temperature may be a factor which triggers the breeding migration			

Snow trout (*Schizothorax richardsonii*) IUCN Status: Vulnerable

	Adults	Juveniles	Sapwning	Incubation & Larval development
Depth	>0.5 m	0.1 - 1 m	0.5 - 1.00 m	0.1 - 1.00 m
Velocity	Low to high (0.5-1.5 m/s)	Low to medium (0.5-1.0 m/s)	Low to medium (0.5 -1.0 m/s)	Low (0.1-0.5 m/s)
Habitat	Riffles, pools, glides,	Riffles, glides, closer to the banks	Low gradient riffle Glides	Backwater pools and bank undercuts
Substratum	Boulders, Cobbles, Pebbles, Gravel	Cobbles, boulders, pebbles, gravel	Cobbles, pebbles, gravel	Cobbles, gravel
Temperaure	4-20 °C	4-20 °C	<15 °C	4-15°C
Dissolved Oxygen (mg/l)	8-12 mg/l	8-12 mg/l	8-12 mg/l	8-12 mg/l
Food	Large portion of periphytic algae and diatoms. Also feed on benthic invertebrates	Periphytic algae and diatoms.	Not applicable	Diatoms
Breeding Period	April to September			
Passage requirement	This species is a migrant species, moves from river to upstreams and adjoin streams for spawning.			
Migration timing	April to September			
Migration Cues	Movement is believed to be triggered by the variation in water temperature and flow			
Other flow related needs	Flow may be a crucial factor for the migration of this species.			

Devil catfish or Goonch (*Bagarius bagarius*) IUCN Status : Vulnerable

	Adults	Juveniles	Sapwning	Incubation & Larval development
Depth	> 1.0 m	1.0 - 1.5 m	0.25 - 0.5 m	0.25 - 0.5 m
Velocity	Low to high (0.1-1.5 m/s)	Low to medium (0.1-1 m/s)	Low to medium (0.1 -1 m/s)	Low to medium (0.1-1 m/s)
Habitat	Riffles, pools	Riffles, pools, glides	pools, riffle	Pools and bank undercuts
Substratum	Cobbles, boulders, pebbles, also stony to gravelly beds	Cobbles, boulders, pebbles, also stony to gravelly beds	Fine gravel	Cobbles, boulders, pebbles, also stony to gravelly beds fine gravel
Temperaure	18°C - 25°C	18°C -25°C	18 -20 °C	18 - 20 °C
Dissolved Oxygen (mg/l)	6-10 mg/l	6-10 mg/l	8-12 mg/l	8-12 mg/l
Food	Benthic insects, fishes, frog, crustaceans	Benthic invertebrate larvae, worms, fish fry	Not applicable	Not known
Breeding Period	July to August			
Passage requirement	Migratory fish, requires very strong current and turbid water			
Migration timing	Upstream migration begins close to the peak of flood			
Migration Cues	Monsoon flow			
Other flow related needs	They are specialized in torrential flow; it may be a crucial factor for spawning of this species			

Sisorid catfish (*Glyptothorax brevipinnis*) IUCN Status: Near Threatened

	Adults	Juveniles	Sapwning	Incubation & Larval development
Depth	0.2 - 0.5 m	0.2 - 0.5 m	0.2 - 0.5 m	0.1 - 0.20 m
Velocity	Low to high (0.1-1.5 m/s)	Low to medium (0.1-1.0 m/s)	Low to medium (0.1 -1 m/s)	Low to medium (>0.1 m/s)
Habitat	Riffles, cascades, glides	Riffles, cascades, glides	Riffles, Run	Run
Substratum	Cobbles, pebbles, gravelly beds	Cobbles, pebbles, gravelly beds	Pebbles and gravels Pebbles and gravels	
Temperaure	4-18 °C	4-18 °C	<15 °C	10-16 °C
Dissolved Oxygen (mg/l)	8-12 mg/l	8-12 mg/l	8-12 mg/l	8-12 mg/l
Food	Benthic Invertebrates	Benthic Invertebrates	Not applicable	Worms
Breeding Period	Probably May to July. Gravid females were found during July			
Passage requirement	This species is locally migrates for breeding			
Migration timing	After the monsoon			
Migration Cues	Fresh oxygenated water			
Other flow related needs	Survival of this species needs continuous flow of water			

7.2.7 Fish Migration & Breeding/Spawning Grounds in Siang basin

Similar to the behaviour of Himalayan fish species, in Siang river too Mahseer (*Tor putitora* and *T. tor*) ascend long distances for breeding purpose, and then move from main stream to the tributaries. Other species like *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Labeo dero*, *Anguilla bengalensis* and snow trout species traverse relatively short distances. Mahseer and *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*) start their migration during the onset of monsoon and perform triphased migration. All ‘schizothoracines’ show variable migration. They descend in monsoon towards warmer places and spawn in the main streams or tributaries. *Labeo* spp. also migrates into the nearby tributaries for breeding.

The fish species mentioned above like fast flowing, rocky bottom waters and are seen frequently around the foothills. During surveys mahseer was landed mostly in the lower stretches of river Siang downstream of Siang Lower HEP site near Bodak. It was also found upstream of Bodak but in much lesser numbers. According to fishermen the main breeding zone for mahseer in river Siang and its tributary streams upstream of Bodak village like Yamne, Hirit and main Siang channel and also streams that join Siang downstream of Bodak village, where water flow (0.6-1.2 m/s), water depth (0.5-1.5 m), Dissolved Oxygen (>8 mg/l) and temperature (16-19°C) and substratum is gravelly.

Other Migratory Fish Species

Schizothorax richardsonii and *Garra naganensis* are column feeders, thus, considered to move relatively longer distance as compared to other species dwelling the river bed (see Table 7.50). *Schizothorax richardsonii* is considered to perform migration within same river. To cope with the low temperature in peak winter season it moves downwards. It finds a tributary to spawn from May to September. In the region migratory pattern of *Schizothorax richardsonii* is not well studied but other studies in Himalayan river show that they do not have specific breeding grounds. The ova of fish species (probably of *Schizothorax richardsonii*) from Siyom river and tributaries.

A few other species like *Labeo pangusia*, *L. gonius* and *Anguilla bengalensis* ascend comparatively for short distance. Among catfishes *Aorichthys seenghala* does migrate for breeding and spawning purposes. The fry of *Labeo pangusia* were found in Hirit river.

According to Welcomme (1985) the river fish species are broadly classified by life cycle strategy into ‘black fishes’ and ‘white fishes’. Black fish species like the Snakeheads (*Channa* spp.), Gouramis (*Trichogaster* spp.) and the catfishes (Clariidae) undertake relatively short migrations between the flooded areas in the rainy season and permanent water bodies in or close to the floodplain in the dry season. They are adapted to withstand adverse environmental conditions (e.g. low dissolved oxygen) often prevailing on the floodplains. During wet season, fish go back to the floodplains for feeding and spawning.

The large group of “white fish species” carries out considerably longer migrations. At the beginning of the dry season, most species move from the floodplains to main stream. In the main stream, they use the deeper parts of the river as refuges for rest of the dry season. At the onset of the rains, spawning takes place near these areas, before the adult fish move back again for feeding to the floodplains.

Well known ‘white’ fish species in river Siang are the Indian Mahseer *Tor putitora*, *Neolissochilus hexagonolepis*, catfish as Giant seenghala (*Ompok bimaculatus*) and *Chagunio chagunio* and *Angulina bengalensis*. The dominant species are the cyprinid, which constitute an important food

fish, as this forms the basis for a large production of traditional fishes. The second most dominant group is cat fishes. Typically, most migrations in river Siang is potamodromous type and take place during the rising flood and the drawdown period. The migrations are basically movements out of the floodplains where a number of species spawn around their dry season refuges usually at the onset of the monsoons. The return migration is made to the floodplains with the receding of flood. The fish larvae generally drift downstream during the rising flood. However, most of the species except a few which are reported from the basin show local migration. Therefore, the impact of proposed hydropower projects on these fish species have been assessed in the Chapter on impacts and also to sustain the riverine ecosystem minimum environmental flows that are required to be released have been discussed.

Mahseer

Mahseer is a column feeder and mid-water dweller where optimum depth cannot be defined. Mahseer ascends upstream in the month of April and May for the purpose of spawning. After spawning, they descend in the months of September and October.

Snow trout

Snow trout includes two species - *Schizothorax richardsonii* and *Schizothorax progastus* in Siang basin. *Schizothorax richardsonii* is categorized as 'vulnerable' species (Plate 7.5). They are widely distributed in the basin (400 to 2300 m) and constitute an important part of capture fishery in the middle part of the basin. In the peak winter they move towards the lower elevation to cop the low temperature. Snow trout finds relatively warmer waters for the spawning in monsoon season, thus, prefer tributaries to spawn.

Snow trout is most vulnerable due to cascade development because they are widely distributed in the basin. The cascade development would lead to the habitat fragmentation, therefore, it would difficult for snow trout to undertake migration and find suitable tributaries to spawn.

Chocolate/Copper Mahseer [*Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*)]

Neolissochilus hexagonolepis (= *Acrossocheilus hexagonolepis*) has been categorized as 'near threatened' species (Plate 7.5) and is distributed up 1000 m. in Siang basin. The species is restricted to the Eastern Himalaya. It constitutes important capture fishery in lower stretch of Siyom river, Hirit river, and lower and middle stretch of Siang river and lower stretch of Simang river. *Neolissochilus hexagonolepis* also is considered as migratory species, which finds tributaries for spawning. Due to its migratory habit, it would be affected adversely due to cascade development.

Common Carps

Common carp comprises *Labeo pangusia* and *L. gonius* in Siang basin (Plate 7.5). These species are distributed up to 1000 m in Siang basin and constitute important fishery in lower stretches of the basin. All species are considered as 'Least Concern'. Being under the Least Concern conservation status and migratory phenomenon of these major carps, they might also be affected by cascade development. However, they are widely used in cultural fishery.

Minor Carps

Minor carp comprises *Puntius* spp. and *Barilius* spp. (Plate 7.6). They are predominant in tributaries like Hirit, Yamne rivers, and Yargyap Chhu, etc. Minor carp are not of any fishery interest. All minor carp in Siang basin belong to 'least concern' category.

Garra Spp.

Garra spp. comprises of *Garra naganensis* (Plate 7.7). *Garra naganensis* occurs over a wide elevational range and is common in tributaries like Hirit, Yargyap Chhu, Ringong, Simang, etc. and also in main Siyom river. It is endemic to north-eastern region and belongs to 'least concern' category. This species neither are nor of fisheries importance but come in the catch executed by cast net.

Loaches and Catfish

Fish species belonging to Bagaridae, Sisoridae, Cobitidae and Balitoridae represent the loaches and catfish in Siang basin. Generally these species are bottom dwellers and prefer rivulets in the basin.

Loaches are dorso-laterally compressed fishes with cylindrical bodies and well known as water cleaner, sweeper and scavengers. Most of these are found in shallow water of small streams or in the shallow and slow flowing water riffles of main rivers like Siang and Siyom

The famous sport cat fish in the river water is Gounch, *Bagarius bagarius* found in the rapids, riffle and deep perennial pools of the Siang river. It performs the long distance migration. The fish may move downstream area of dam site due to submergence of upstream area and further deterioration of water quality. Other cat fish like *Glyptothorax* sp. also prefer fast water current with rocky sub-stratum with comparatively lesser depth. Other species from Bagaridae and Siluridae, which are common in occurrence in the Ranaghat area where river is having mix habitat of hill streams and floodplains are present. River is having an average bank width of 1000 m where flowing water is 600 m wide with 0.45-1.2 m/s water flow and gradient less than 0.5%. The depth varies from 1m to 5m with gravels at meander and sandy beds. Bagaridae group makes nests during breeding season and prefers slow moving waters of 0.2-0.4 m/s with depth 1.0m and grow better with water depth more than 3m.

The famous giant river cat fish *Aeorichthys seenghala*, *A. aor*, *Mystus* spp., *Wallago attu* and *Ompok* spp. are present in this stretch. However, these fishes are widely distributed in India i.e. floodplains, rivers, lakes, ponds, beels and wetlands. Among Claridae, Magur is common in occurrence that is due to favourable habitat of sandy beds and downstream area of swamps, marshes, and wetlands of Dihang and Dibang rivers.

Miscellaneous species

Fish species like *Xenotodon cancila* and *Chanda ranga* are exclusively restricted to the lower reaches (up to 250 m) of the basin. None of the species is 'vulnerable' or 'endangered'. Since they are restricted to the lower part, therefore, cascade development in the basin may not have major impact on these species.

7.2.8 Factors that need Attention for Maintenance of Aquatic Ecosystem

As already discussed above the Himalayan rivers comprise mainly of two zones i.e. Rhithron zone and Potamon zone.

The main morphological characteristic of rhithron zone is the alternation of pools and riffles which arise from changes in gradient classify the rhithron into morphological types other than pools and riffles.

According to Bisson and Sedell (1982) the rhithron zone is comprised of the following:

- **Riffle:** Low gradient riffles - shallow stream reaches with moderate current velocity and turbulence. Substrate usually gravel, pebble and cobblesized particles.

- **Rapids** - gradient greater than 4% with swiftly flowing water and considerable turbulence.
- Substrate generally coarser with larger boulders.
- **Cascades** - steep reaches with variations in gradient consist of alternating small waterfalls and shallow pools. Substrate consists of boulders.
- **Pools**: Secondary channel pools - often temporary pools remaining in areas flooded by freshets, often associated with gravel bars; sand or silt substrate.
- **Backwater pools** - found along channel margins caused by eddies from large obstructions. Often shallow and dominated by fine-grained substrates.
- **Trench pools** - long, often deep, slots arising downstream of major obstructions. Usually with coarse-grained but stable bottoms.
- **Plunge pools** - arise where a stream passes over a major obstacle and scours out the bottom. Variable in depth and substrate.
- **Lateral scour pools** - occur where flow is diverted by a large obstacle or obstruction.
- **Dammed pools** - consist of water impounded upstream of a complete or nearly complete channel blockage. Tends toward low current and finer substrates.
- **Glides**: a third general habitat category consisting of moderately shallow reaches with even flow that lack obstructions or pronounced turbulence. Bottoms usually gravel and small cobbles. Glides are particularly common in large rivers passing through mountainous terrain where channels may run relatively straight for many kilometers.

The **Potamon** zone is characterized by higher temperatures comparatively lower gradient and the substratum consists of boulders, stones, gravel and patches of aquatic vegetation in the pools.

7.2.8.1 *Floodplains*

It is the interface stretch in the lower reaches where the river leaves the hills and enters plains and has a network of channels and creeks which penetrate the levees to connect the main river with the back-swamps and meander scroll lakes. Such channels may or may not retain water at all times of the year, but they represent the main path of water and fish movement during the earlier periods of rising water and later phases of falling water.

The floodplain is itself divided into two components:

- i) the plain itself which is seasonally inundated, but remains dry for at least part of the year, and
- ii) the standing waters which remain in the plain during the dry season.

In the temperate rivers examined by the river continuum group, the following shifts in community structure can be identified. Riverine communities can be separated into three main groups, headwaters (orders 1-3), medium-sized streams (orders 4-6) and large rivers (orders >6). Headwater streams are heavily influenced by riparian vegetation, which is responsible for large-scale inputs of allochthonous nutrients while at the same time hindering autotrophic production by shading. As stream size increases allochthonous inputs become less important and the aquatic communities tend to concentrate more on autochthonous processing of nutrient transported from upstream. This transport, with the exception of new allochthonous material arising from floodplains and feeder tributaries, is the basis for all subsequent living processes.

7.2.8.2 *Role of Phytoplankton & Phytobenthos*

a) *Phytoplankton*

Phytoplankton abundance is also associated with seasonal differences in flow. Densities generally reach a peak in the dry season and diminish in the floods in both types of water unless otherwise influenced by temperature (Hynes, 1970).

Phytoplanktonic organisms are sensitive to velocity and turbulence of flow in rivers as the rapid currents and mechanical stresses of rapids and waterfalls inhibit the development of new plankton and rapidly suppress any existing organisms discharged from associated lentic waters. Thus the agitated waters of the rhithron generally support little plankton, although some does develop in the occasional quiet backwater and pool. In addition a drift is present in the main channel made up of primarily bottom living algal forms which are dislodged by the rapidity of the flow.

b) Phytobenthos

Production by algae, especially diatoms growing on rocks, submerged wood and floating or submersed vegetation may well be more important than the phytoplankton. This is certainly true in the rhithronic headwaters where phytoplankton is virtually absent but where the rocks of the riffles support. Mats of epilithic algae which in turn, provide the substrate for the complex of organisms constitute the “aufwuchs” or the surface growth. In the pools too, the floating leafy vegetation of the slacks (wet sand) are colonized by dense aggregations of epiphytic algae.

c) Higher Plants

Higher plants provide the major biotic structural elements in fluvial ecosystems. Not only does their distribution depend on the geology and morphology of the environment, but the presence of vegetation can itself modify the form of the system. Although only rarely used directly for food by fish, vegetation has a range of ecological values for fish communities. It provides refuge, shade, a substrate for spawning and a support for many organisms which are of dietary importance for fish. Longitudinal zonation of vegetation within rivers is based mainly upon the related factors of depth, flow, and mechanical stress. In torrential headwaters liverworts and mosses are the earliest forms to appear on rocks, both submersed and in the splash zone. This type of vegetation persists into the rocky riffles of the rhithron, but in these reaches the pools increasingly support rooted, floating leafed species in the slacks and emergent vegetation along the banks as slope decreases. As the river enters the more mature potamon, the ideal channel is fringed with emergent plants and floating grasses which give way to floating leafed plants and submersed species as the depth increases toward the centre of the river. Such a stable state is rarely attained in natural rivers, where one or other of these elements may be lacking. Similar successions can be seen in islands within the river channel where sand banks laid down by the current became colonised by plants which fix the bank and lead to further siltation.

In forested rivers and streams, riparian or floodplain vegetation contributes considerable amounts of nutrients to the system. This has been best studied in low order temperate rivers where the autumn-shed leaves form an important source of allochthonous organic matter as well as food for invertebrates. Kaushik and Hynes (1971) have documented the decomposition of such leaves to show the build up of protein, nitrogen and phosphorus in water where the decomposing leaves serve not only to nourish invertebrates but to provide food for detritivore fish. Indeed in nutrient poor rivers the leaf fall may be the biggest single source of nutrients to the aquatic system.

7.2.8.3 River Morphology

The river geomorphology consists of hill stream morphology at dam site, buffer zone area of wide valley (Ranaghat area) and floodplain morphology (d/s of Pasighat) as it emerges in the plains. River flows in low gradient and consists of sandy flood plains in the main river and its tributaries where flow pattern shows meander to straight channel and depth varies from shallow to deep zones. Right bank of river has steep slope with rocky river and stable river banks where as left bank has moderate slope at dam site to low slope downstream area.

River Siang is a low gradient river in the lower reaches of basin, where water runs all along the river except for some pools and riffles that are observed frequently along the course of the river.

Many small pocket pools were noticed during the monsoon season alongside the river bank. These pools were predominantly found with fingerlings of variety of fishes, particularly, the Golden mahseer (*Tor putitora*) and Copper mahseer (*Neolissochilus hexagonolepis*).

In the upper reaches, Siyom river and Yargyap Chhu flow through stable and confined valley at project site. River banks are stable and rocky. These comprise the zone of Snow trout (*Schizothorax richardsonii*). However Rainbow Trout and Brown Trout have also been introduced in its upper reaches and cold waters of Siyom river and Yargyap Chhu.

7.2.8.4 D'Ering Memorial Wildlife Sanctuary

The morphology is changed as the river emerges into the plains from Pasighat. The bankful river bed is 2 -2.5km wide at the point where it enters into the plains. Bifurcation of river takes place on eastern side, where one of the branch flows on right banks (about 400-430m wide) and makes northern boundary. Pasighat town is situated in the north of wildlife sanctuary and always face threats from heavy floods. The second branch again fragmented into many small rivulets/multiple channels feeding the wildlife sanctuary area and its farthest branch makes southern boundary which is about 800-900m wide. However river is having multiple channel morphology of floodplains with sandy beds and sand bars (about 4.5 - 4.7km). D'Ering Memorial Wildlife Sanctuary from where one of the branches flow at north bank and other branch flow towards south bank of the sanctuary, which later again join at the far end point of Wildlife sanctuary area. The total area of this Dihang-Dibang wetlands is spread over 190 sq km, however Dibang is joining downstream of sanctuary area. Thus, wildlife sanctuary area is having island morphology.

7.2.8.5 Aquatic Birds

Aquatic birds are a very conspicuous feature of the floodplain ecosystem. As with most wetlands various kinds of waterfowl are extremely common, but it is doubtful whether most of these react directly with fish populations. In general, the life cycle of water birds is closely linked to the floods. Avian breeding seasons coincide with those of the fish and the fledgelings are being reared at just that time when small fish suitable for their feeding are most abundant. There is a particular heavy predation during the period of receding water when many fish are stranded in temporary pools (Lowe-McConnell, 1964; Bonetto, 1975).

The lower stretch of river Siang near Assam boundary is comprised of islands, small streams, rivulets and springs form an important habitat for a variety of birds. While few species habitually enter the water, there are few birds that are adapted to living near the rivers and streams, but do not enter there. There are many beels (ox-bow lakes and depressions with swamps and marshes at the edge) in the flood plains including the D'Ering Memorial Sanctuary in the Siang River. The beel margins are covered with reeds (*Arundo donax*) and herbs (*Alpinia allughas*). In the Kobo Chapory, there are seasonal lagoons called *ghuli*, which are also the domain of various species of water birds. The lower stretch of river Siang, from the dam site to confluence of Siang with Lohit and Dibang provides stretches of open water for a distance of more than 60 km. All these freshwater habitats provide conducive environment for aquatic birds (resident and migratory). The important aquatic birds which dwell these habitats as resident or winter visitor in the area of Siang Lower Project including the D'Ering Memorial Wildlife Sanctuary and Kobo Chapory are -Great Cormorant (*Phalacrocorax carbo*), Black Stork (*Ciconia nigra*), Goldeneye Duck (*Bucephala clangula*), Little Ringed Plover (*Charadrius dubius*) and Pied Kingfisher (*Ceryle rudis*) which are common aquatic birds. Various species of waders throng the edges often resting in the shallow water in the typical one legged stance. Black storks are very common near Kobo Chapory. The river banks are also important nesting sites for the kingfishers.



Plate 7.1: Aquatic Ecology Sampling in Siang basin



Plate 7.2: Fisherman with fishing gears



Plate 7.3: Fisherman with fish basket



Plate 7.4: Different species of fish in the catch



Schizothorax richardsonii



Neolissochilus hexagonolepis (=Acrossocheilus hexagonolepis)



Labeo sp.

Plate 7.5: Different species of fish in the catch



Barilius barila



Pseuecheneis sulcata



Schizothorax sp.

Plate 7.6: Different species of fish in the catch



Glyptothorax annandeli



Garra naganensis



Garra sp.

Plate 7.7: Different species of fish in the catch

CHAPTER-8

SUB-BASIN-WISE ASSESSMENT OF BIODIVERSITY VALUES

8.1 INTRODUCTION

As has already been discussed in baseline chapters and methodology part the biodiversity baseline for Siang basin was developed based on expert knowledge of professionals working on different taxa and ecosystems, national and global database, published species records, researched information. Information collected from all of the above sources was assessed for its adequacy and relevance and information gaps wherever observed were overcome by supplementing specific information through primary data collection efforts during the field visits undertaken during the study. Though lot of data was generated during field surveys however it was found insufficient to prepare an overall profile of the basin. Therefore in order to overcome this limitation of field surveys as discussed above, for the preparation of baseline status of the very large area like Siang basin extending over an area of 14,965 sq km, a comprehensive exercise was undertaken considering the importance of biodiversity richness of the basin. Furthermore as the area of Siang basin too large and diverse where altitudes vary from as low as 80m to more than 6000m and ecosystems as diverse as floodplain grasslands to alpine pastures and scrubs comprised of very difficult and inaccessible terrain to understand different aspects related to biodiversity, the study area i.e. entire Siang basin was sub-divided into 11 sub-basins in order to evaluate the impact of development on biodiversity values and accordingly baseline assessment was made sub-basin-wise.

8.2 SUB-BASIN LEVEL BIODIVERSITY ASSESSMENT

8.2.1 Siang Sub-basin-I

Siang Sub-basin-I is the southern-most sub-basin and falls under Pasighat Forest Division and is comprised of lower catchment of Siang river up to the confluence of Siyom (**Figure 8.1**). The sub-basin extends over Pasighat forest range, Bodak village and adjoining project area up to Pangin, the confluence of Siyom with Siang. It is comprised of tropical alluvial plains to low hills around Pasighat, Bodak village and adjoining Siang Lower project area up to confluence of Siyom river near Pangin. Two hydropower projects are planned in the sub-basin i.e. Siang Lower and Yemsing. While Yemsing is a small project, Siang Lower is large project which will lead to submergence of 6414 ha of forest.

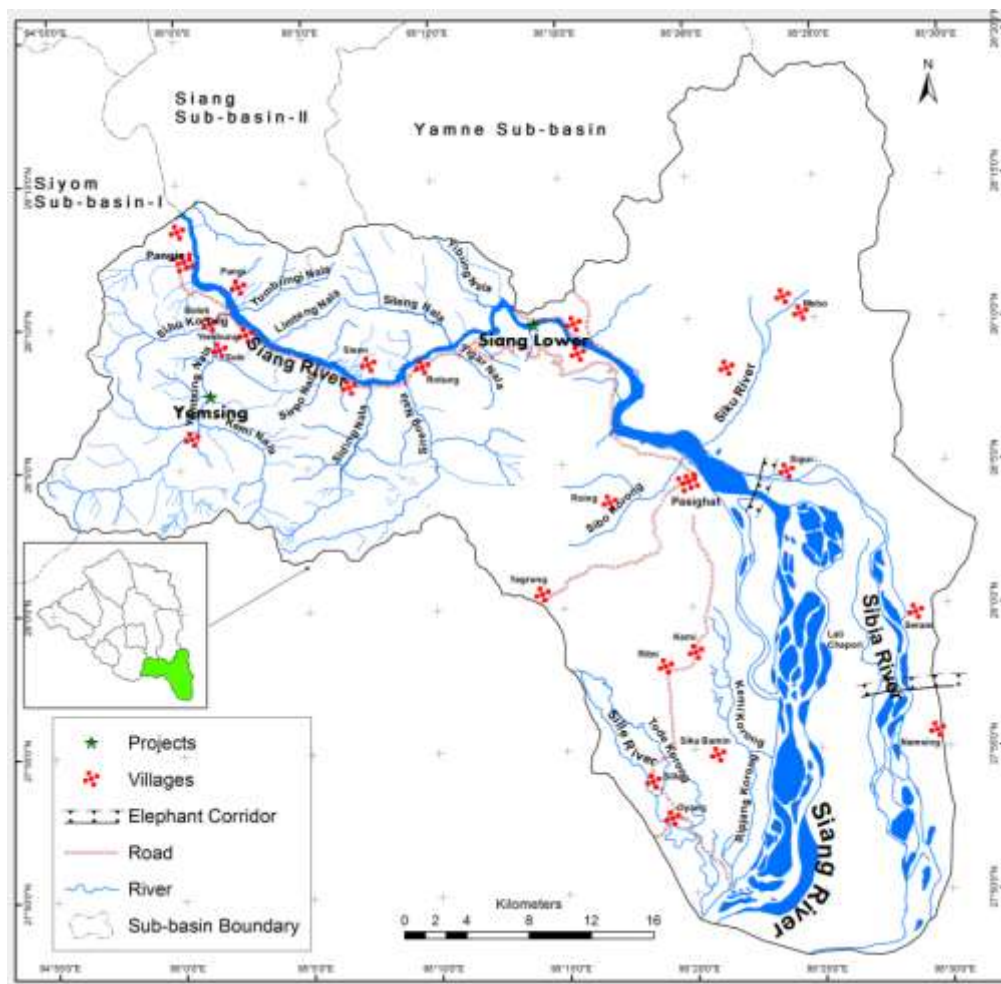


Figure 8.1: Drainage map of Siang Sub-basin-I

8.2.1.1. Forest Cover

Total forest cover in the sub-basin is 65% and is lowest amongst all sub-basin. This is because large part of the sub-basin is comprised of river beds of Siang and Sibia rivers (Figures 8.2 & 8.3). Accordingly the vegetation is also comprised of grasslands, and forests in the higher parts of low hills that characterize this sub-basin.

The forests of this area cover the major parts of Pasighat and Mebo Reserved Forests in the outer Himalaya and in foot hills of Siwalik. The southern aspects of the area gradually tilt towards the Assam plains in the south. The southern part characterised by floodplains and consisting of network of branches of Siang and Sibia rivers is comprised of D'Ering Memorial Wildlife Sanctuary.

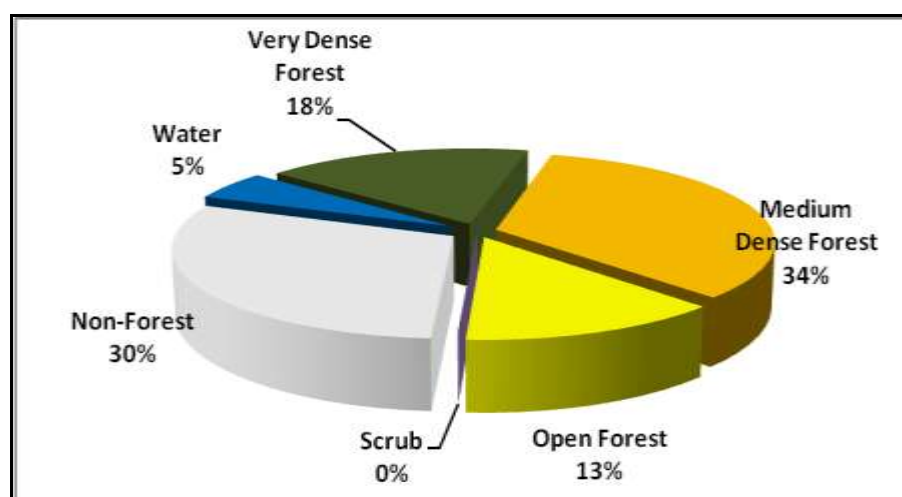


Figure 8.2: Area under different land use/ land cover categories in Siang Sub-basin-I

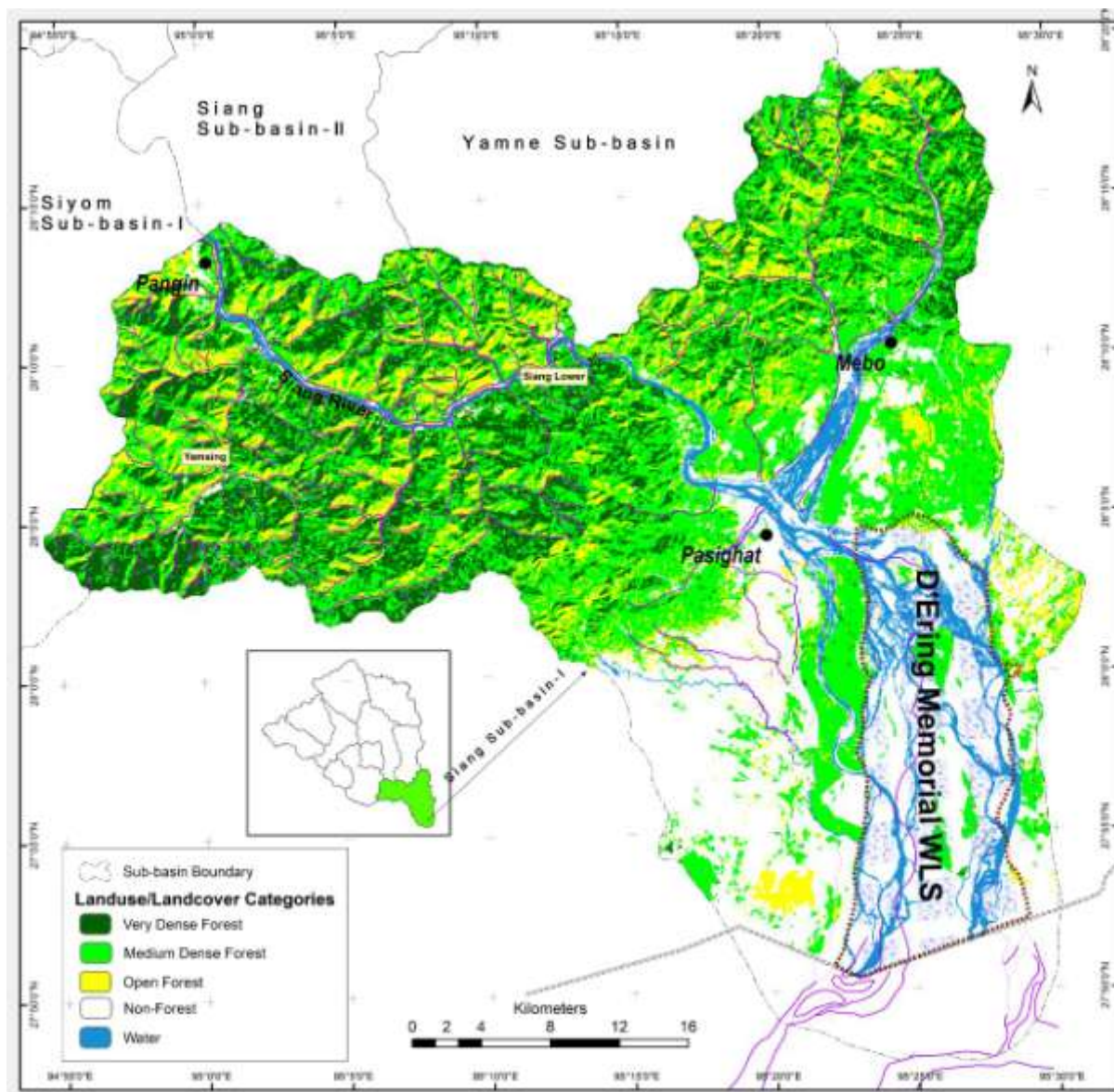


Figure 8.3: Land use/ land cover map of Siang Sub-basin-I

8.2.1.2. Floristic Diversity

The forest found in the Pasighat Reserved Forest are diverse and consists of mixture of evergreen and deciduous species like Dorpat (*Ailanthus integrifolia*), Siris (*Albizia procera*), Jutli (*Altingia excelsa*), Amari (*Amoora wallichii*), Devsali (*Artocarpus lakoocha*), Semul (*Bombax ceiba*), Urium (*Bischofia javanica*), Dhuna (*Canarium strictum*), Bogipoma (*Chukrasia tabularis*), Khokan (*Duabanga grandiflora*), Pichola (*Kydia calycina*), Hatipyle (*Pterospermum acerifolium*), Udal (*Sterculia villosa*), Hillika (*Terminalia chebula*) and Hollock (*Terminalia myriocarpa*). Second storey in these forests is composed mainly of evergreen species like Urium (*Bischofia javanica*), Hinguri (*Castanopsis indica*), Outenda (*Dillenia indica*), Banderdima (*Dysoxylum binectiferum*), Bopromthuri (*Magnolia hodgsonii*) and Nahar (*Mesua ferrea*). The ground cover is also thick and diverse.

The forest on the right bank of Siang river around Ranaghat area is degraded semi-evergreen type having uniform species composition. The trees are tall and mixture of evergreen and deciduous species. Middle and lower storeys consist of mainly evergreen species. *Anthocephalus cadamba*, *Bombax ceiba*, *Castanopsis indica*, *Duabanga grandiflora*, *Kydia calycina*, *Pterospermum acerifolium*, *Spondias pinnata* and *Terminalia myriocarpa* form the top canopy. *Albizia lucida*, *Cinnamomum pauciflorum*, *Endospermum chinense*, *Mallotus philippensis* and *Magnolia hodgsonii* form the middle storey. The river terraces and nala fans are colonized by *Aesculus assamica*,

Bischofia javanica, *Oroxylum indicum*, *Macaranga denticulata* and *Rhus chinensis*. The riverine elements are tall grasses such as *Saccharum longisetosum*, *S. spontaneum* and *Thysanolaena latifolia*. The trunks of trees are covered with a number of epiphytic ferns and orchids such as the species of *Bulbophyllum*, *Cymbidium*, *Dendrobium* and *Rhynchostylis*. Some notable parasitic plants like *Cuscuta reflexa* and *Scurrulla elata* can be seen growing on *Ficus semicordata*. The climbers are abundant represented by species like *Acacia pennata*, *Bauhinia vahlii*, *Cryptolepis buchanani*, *Mikania micrantha*, *Piper pedicellatum*, *Rhaphidophora decursiva* and *Stephania glabra*.

The vegetation on upper ridges especially towards Rengging is fairly dense mixed with abundant growth of tree ferns, kewra palm, other palms and bamboos. *Hopea shinkeng* an endemic plant of Abor hills is found along the Rotung- Yembung route. Many citrus and ginger orchards/crop fields can be seen along the way. Around Pangin, the vegetation is sparse and characterized by few tall trees like *Artocarpus lakoocha*, *Castanopsis indica*, *Michelia doltstopa*, *Chukrasia tabularis*, *Choerospondias axillaris*, *Harpulia cupanoides* and *Sloanea sterculacea*.

The vegetation at left bank of Siang from Ayeng to Bodak is characterized by dense mixed semi-evergreen forest, with dense growth of canes, palms, bamboos and *Dracaena angustifolia* in the understorey. The dominant tree species are *Aglaia spectabilis*, *Ailanthus integrifolia*, *Artocarpus lakoocha*, *Bischofia javanica*, *Canarium strictum*, *Castanopsis indica*, *Chukrasia tabularis*, *Duabanga grandiflora*, *Harpulia arborea*, *Phoebe hainesiana*, *Terminalia myriocarpa* and *Toona microcarpa*. Second storey comprised mainly of evergreen species such as *Albizia lucida*, *Artocarpus chaplasha*, *A. integrifolia*, *Aesandra butyracea*, *Gynocardia odorata*, *Magnolia hodgsonii* and *Mallotus philippensis*, *Saurauia punduana*. Lower storey comprises of small trees and shrubs like *Boehmeria macrophylla*, *B. rugulosa*, *Clerodendrum bracteatum*, *Chromolaena odoratum*, *Debregeasia longifolia*, *Dracaena angustifolia* and *Rubus niveus*. Gregarious growth of some tall bamboos like *Bambusa pallida*, *B. tulda* and *Dendrocalamus hamiltonii* are often seen near habitation areas of upper reaches. Climbers and straggling shrubs within these forests are *Actinida callosa*, *Clematis gouriana*, *Combretum pilosum*, *Dioscorea bellophylla*, *Mikania micrantha*, *Toddalia asiatica* and *Thunbergia coccinea*. Among herbs are *Alpinia hispida*, *Amomum subulatum*, *Begonia* spp., *Cappilipedium assimile*, *Isachne albens*, *Saccharum longisetosum*, *S. spontaneum* and *Thysanolaena latifolia*.

Further upstream on the mid hills in this sub-basin lie an open, degraded semi-evergreen forest. Radang/Yemsing and adjoining Babuk area on the right bank of Siang comprise gentle slopes under orchard terraces. Thin patches of a few semi-evergreen trees are found all along the road side. *Aglaia spectabilis*, *Artocarpus chaplasha*, *Duabanga grandiflora*, *Erythrina stricta* and *Terminalia myriocarpa* are found with scattered distribution in the area. Other trees observed in the area are *Celtis tetrandra*, *Elaeocarpus floribundus*, *Leea indica*, *Macaranga denticulata*, *Oroxylum indicum* and *Saurauia roxburghii*. The shrub elements are composed of *Bambusa tulda*, *Chromolaena odoratum* and *Nyssa javanica*. Fruit trees of Citrus, Mango, Kathal and Guava are also found as plantations in the area. Vegetation of left bank i.e. from Sissen to Pangin consists of dense mixed semi-evergreen forest. The upper slopes are covered with dense thickets of *Musa*, *Pandanus* and bamboos. From Ribbing towards Pangin some citrus orchards can be seen along the gentle slopes. The natural vegetation is dominated by some tall semi-evergreen and deciduous trees along the river banks. *Alpinia allughas*, *Boehmeria macrophylla*, *Hedychium spicatum*, *Pteris* spp. and *Trevisia palmata* are tall shrubs and undershrubs in the understorey.

In this sub-basin about 254 species of plants are reported and they represent riverine elements consisting of tall grasses such as *Saccharum longisetosum*, *S. spontaneum* and *Thysanolaena latifolia*. The trunks of trees are covered with a number of epiphytic ferns and orchids such as the species of *Bulbophyllum*, *Cymbidium*, *Dendrobium* and *Rhynchostylis*. Thirty three of them are trees, 29 are shrubs while rest of them are herbs.

The area harbours some of the medicinal plants like *Abroma angusta*, *Achyranthes aspera*, *Andrographis paniculata*, *Artemisia nilagirica*, *Boerhavia diffusa*, *Buddleja asiatica*, *Clerodendrum colebrookianum*, *Eleusine indica*, *Gynocardia odorata*, *Oroxylum indicum*, *Phyllanthus emblica*, *Spondias pinnata*, *Terminalia chebula*, *Centella asiatica*, *Castanopsis hystrix*, *Fagopyrum esculentum*, *Hedychium spicatum*, *Plantago major*, *Rubia cordifolia*, *Saurauia roxburghii*, *Zanthoxylum armatum*.

In the sub-basin 6 species falling under RET category are found viz. *Begonia aborensis*, *B. scitillans*, *Cymbidium eburneum*, *Psychotria aborensis*, *Livistona jenkinsiana* and *Paphiopedilum fairrieianum*. The species which are endemic to Arunachal Pradesh are represented by *Begonia aborensis*, *B. scintillans*, *Hopea shinkeng*, *Syzygium aborense* and *Xanthophyllum burkillii* have been reported from low hills in the altitudinal range of 250-1400 m. *Hopea shinkeng* is found along the Rotung- Yembung route. There are 16 species reported from this sub-basin which are endemic to north-east. These are *Brassaiopsis hispida*, *Brassaiopsis simplicifolia*, *Peliosanthes macrophylla*, *Cirsium interpositum*, *Begonia sikkimensis*, *Begonia tessaricarpa*, *Begonia thomsonii*, *Plectranthus griffithii*, *Pogostemon amarantoides*, *Beilschmiedia brandisii*, *Beilschmiedia pseudomicropora*, *Persea minutiflora*, *Bambusa rangaensis*, *Schizostachyum helferi*, *Schizostachyum pergracile* and *Ophiorrhiza repens*.

D'Ering Memorial Wildlife Sanctuary is the main component of this sub-basin formed by a network of river courses Sibia and Siang rivers. It is contiguous with Kobo Chapory of Assam. The core area is devoid of water source except for few ponds. There are no streams/nallas flowing through the along inner line which is only 7 km. Apart from that, the water table in the area is quite high resulting in easy accessibility of ground water. The sanctuary is characterised by extensive floodplain grasslands (about 75%). The vegetative is in early stages of succession as majority of the area is under alluvial grassland while only a small portion of the area is open forest (Assam alluvial plain semi evergreen forest [2/C-1/ (a)] of Champion and Seth's classification). The entire grassland offers an ideal grazing ground for the herbivores with palatable grasses of various species. Apart from leafy food the area also bears fruit plants of various species, e.g., *Ziziphus*, *Ficus*, *Embllica* and *Gmelina*.

8.2.1.3. Faunal Resources

The sub-basin harbours 64 species of mammals. Most of these species are mainly restricted to D'Ering Memorial Wildlife sanctuary and nearby forested areas and of which Asiatic elephant (*Elephas maximus*), tiger (*Panthera tigris*), wild pig (*Cuon alpinus*) and hog deer (*Axis porcinus*) are prominent. Tiger (*Panthera tigris*), Wild buffalo (*Bubalus bubalis*), Dhole (*Cuon alpinus*), Chinese pangolin (*Manis pentadactyla*), Fishing cat (*Prionailurus viverrinus*), Elephant (*Elephas maximus*) and Hispid hare (*Caprolagus hispidus*) have been kept under IUCN Red List "Endangered category" while Hog deer (*Cervus unicolor*) is under Vulnerable category. Eurasian otter (*Lutra lutra*) has been kept in Near Threatened category. Accordingly to Wildlife (Protection) Act, 1972 Schedules, Tiger (*Panthera tigris*) and Wild buffalo (*Bubalus bubalis*), Chinese pangolin (*Manis pentadactyla*), Fishing cat (*Prionailurus viverrinus*), Elephant (*Elephas maximus*) and Hispid hare (*Caprolagus hispidus*) are the Schedule-I mammals. *Cuon alpinus*, *Lutra lutra*, *Viverricula indica*,

Paradoxurus hermaphrodites, *Paguma larvata*, *Herpestes edwardsii*, *Hystrix brachyura* and *Felis chaus* are the Schedule-II mammals.

The grasslands of D'Ering Memorial Wildlife Sanctuary offer suitable habitat for large diversity of avi-fauna. More than 156 species of birds are reported from this area. These include Critically Endangered (CR) bird species like the Bengal Florican (*Houbaropsis bengalensis*), White-rumped vulture (*Gyps bengalensis*), Indian vulture (*Gyps indicus*) and Slender billed vulture (*Gyps tenuirostris*). Baer's duck (*Aythya baeri*), Great adjutant (*Leptoptilos dubius*), and White-winged Duck (*Cairina scutulata*) are in Endangered list. There are 12 species that are in Vulnerable list viz. *Arborophila mandellii*, *Lophophorus sclateri*, *Francolinus gularis*, *Tragopan blythii*, *Anser erythropus*, *Geotrygon caniceps*, *Haliaeetus leucoryphus*, *Leptoptilos javanicus*, *Sitta formosa*, *Parus nuchalis*, *Chrysomma altirostre* and *Rynchops albigollis*. Most of these species are typical of grassland ecosystem which is highly suitable habitat for breeding and nesting. According to WPA, 1972, the area is home to 21 Schedule-I species. Some of species like Cinereous vulture, Lammergeier or bearded vulture, Himalayan Griffon, Eurasian griffon, Long-billed vulture, Slender-billed vulture and White-rumped vulture have been rarely sighted from the sanctuary. Prominent grassland-dependent bird species found in the area are Swamp Francolin (*Francolinus gularis*), Jerdon's Babbler (*Chrysomma altirostre*) and Black-breasted Parrotbill (*Paradoxornis flavirostris*). It is also home to large number of migratory ducks during the winter, and Indian Skimmer (*Rynchops albigollis*).

Elephant Migration Corridors

As already discussed in Chapter 7 on Terrestrial Ecology, Elephants are known to cross over to D'Ering Memorial sanctuary through Jonai and Kobo Chapory in Assam (Choudhury, 1999 & Sundaram et. al. (2003). According them Dibru-Deomali elephant corridor includes D'Ering WLS, Jonai and Kobo Chapori area (Assam), Dibru-Saikhowa National Park, Joypur RF and Deomali Forest Division. According to report by Tiwari et. al. (2005) on elephants corridors of India, there are two corridors of elephant migration in this region. These are D'Ering - Mebo at Sagar Nalla and D'Ering Mebo at Kongkul (refer Figures 8.1, 8.4 & 8.5). These corridors are regularly used by elephants only during paddy season (October-December).

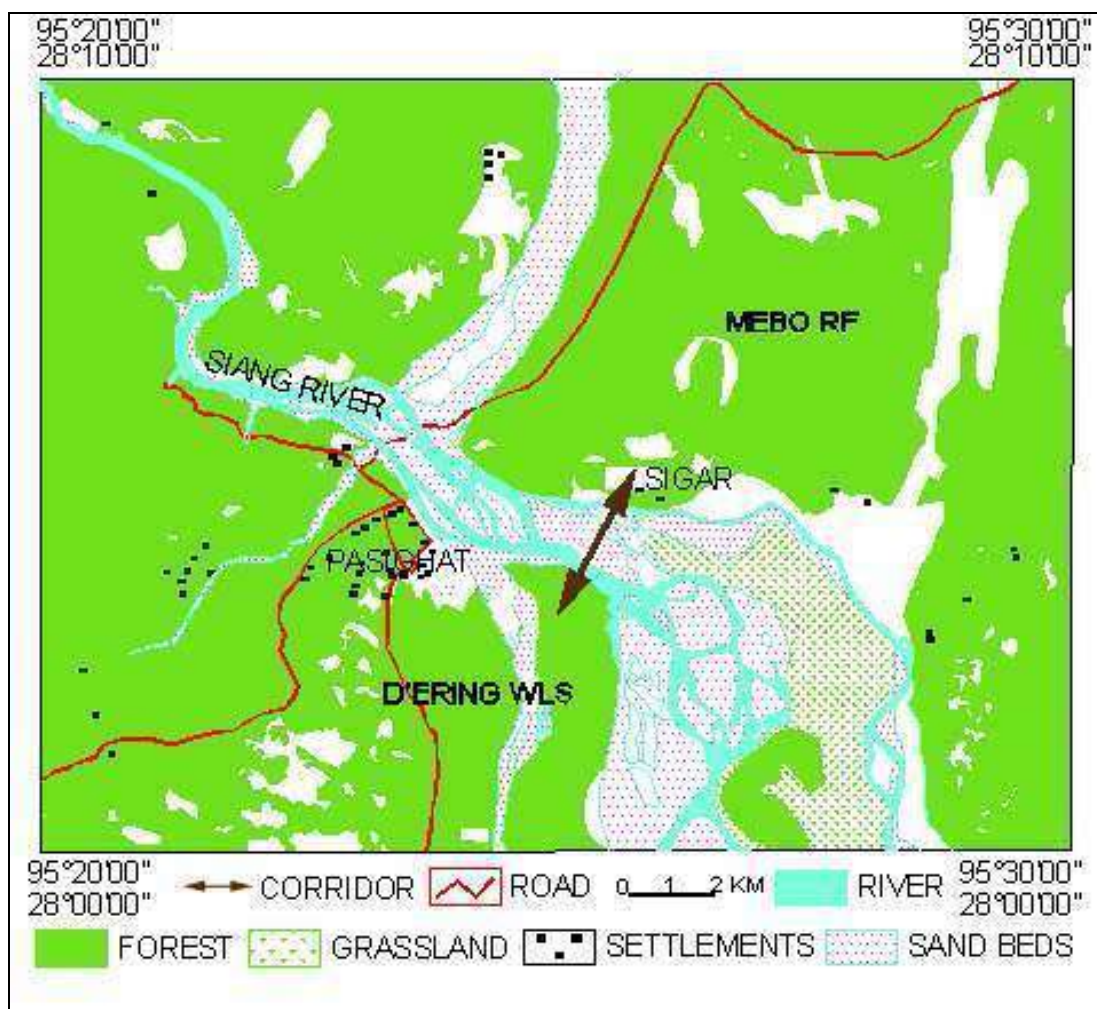


Figure 8.4: D'Ering - Mebo at Sigar Nalla Elephant migration corridor
(Source: Tiwari et. al. 2005. *Right of Passage: Elephant Corridors of India*)

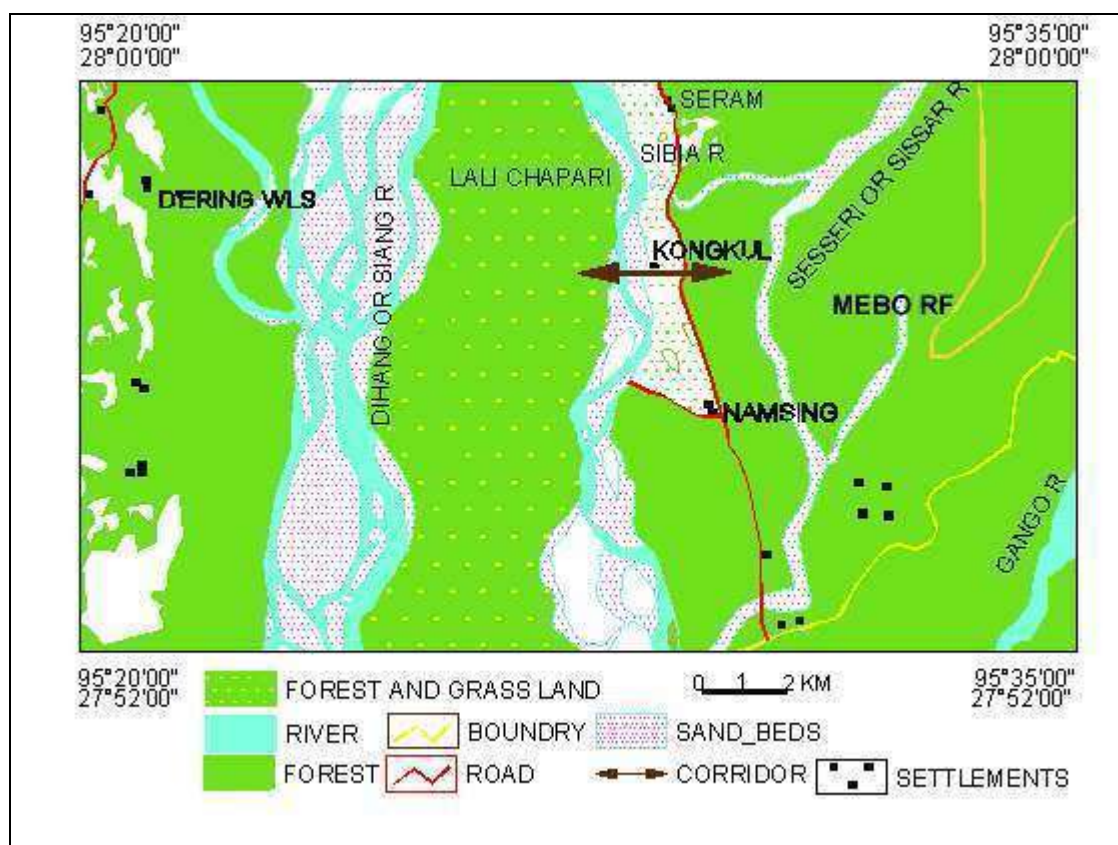


Figure 8.5: D'Ering - Mebo at Kongkul elephant migration corridor
(Source: Tiwari et. al. 2005. *Right of Passage: Elephant Corridors of India*)

D'Ering - Mebo corridor at Singur Nalla connects the D'Ering Memorial Wildlife Sanctuary and Mebo Reserve Forest on either side of the Siang River and forms an important passage for elephant movement to Dibang Forest Division through Aohali village. Pasighat Forest Division and D'Ering Memorial Wildlife Sanctuary. Its length is about 3 km and about 1 km wide. The forests in this corridor are under Reserve Forest and private land. Sigar village is the main habitation in this corridor and has 49 houses with a human population of 330, however there are other dependent villages like Raling (27 houses) and Motum, Siluk and Angkali in this corridor.

D'Ering - Mebo corridor at Kongkul corridor is used by elephants from D'Ering Wildlife Sanctuary to move to Mebo Reserve forest through the Sissiri River bed. This corridor then leads to Dibang Forest Division criss-crossing several private forests. The corridor is near Kongkul village, a new settlement of Padam community and is at about six to seven kms from Namsing village. Its length is about 2 km and about 0.5 km wide. Kongkul village is the main habitation in this corridor. It is regularly used by bulls and herds of 20-30 during paddy season (October-December).

8.2.1.4. Fish Diversity

It is one of the richest zone of fish diversity with 74 species of fish reported from this area. This is primarily the mahseer zone where *Tor tor* and *Tor putitora* fish species predominantly found in the area. The rivering stretch is characterised by wide river and very gentle gradient and after coming out of the hills, Siang river spreads and forms a network of number of branches of Siang river as well as Sibia river. This part constitutes the area of D'Ering Memorial WLS which harbours large number of fish species. Number of new records of fish species have been reported from the area.

According to CAMP 8 species belong to Endangered category i.e. *Anguilla bengalensis*, *Ompok pabda*, *Ompok bimaculatus*, *Pseudolaguvia shawi*, *Pterocryptis gangelica* (= *Silurus afgana*), *Schistura multifasciata*, (= *Nemacheilus multifasciatus*), *Tor putitora* and *Tor tor*.

Nineteen species are under Vulnerable category. These are *Aspidoparia jaya*, *Amblyceps apangi*, *Bagarius bagarius*, *Barilius barila*, *Channa orientalis*, *Cirrhinus reba*, *Clarias batrachus*, *Cyprinion semiplotum* (= *Semiplotus semiplotus*), *Cyprinus carpio*, *Garra lissorhynchus*, *Garra naganensis* (= *Garra tirapensis*), *Mystus bleekeri*, *Mystus vittatus*, *Psilorhynchus homaloptera*, *Puntius chola*, *Puntius sarana*, *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*), *Schistura manipurensis* (= *Nemacheilus manipurensis*) and *Schizothorax richardsonii*.

According to IUCN only one species is under Endangered category i.e. *Tor putitora* while 3 species are under Vulnerable category i.e. *Aborichthys garoensis* (= *Nemacheilus garoensis*), *Bagarius bagarius* and *Pseudecheneis sirenica* and 9 are under Near Threatened category viz. *Balitara brucei*, *Labeo pangusia*, *Nemacheilus devdevi*, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Ompok bimaculatus*, *Ompok pabda*, *Schistura manipurensis* (= *Nemacheilus manipurensis*) and *Wallago attu*.

The endemic species are *Batasio fasciolatus*, *Conta pectinata*, *Garra lissorhynchus*, *Garra McClellandi*, *Garra naganensis* (= *Garra tirapensis*), *Psilorhynchus arunachalensis*, *Schistura manipurensis* (= *Nemacheilus manipurensis*) and *Setipinna phasa*.

Mahseer migrates upstream during monsoon for breeding in the tributaries of Siang river.

8.2.2 Siang Sub-basin-II

Siang Sub-basin-II comprises the middle catchment of Siang river in Arunachal Pradesh. The river elevation varies from 195 m (confluence of Siyom river) near Pangin to 420m (confluence of Yangsang Chhu) near Tuting (Figure 8.6). The south-western part of the sub-basin is comprised of Mouling National Park.

This sub-basin falls under Yingkiong Forest Division and is comprised of lower catchment of Siang river up to the confluence of Siyom. Two hydropower projects are planned on the main Siang river i.e. Siang Upper Stage-II and Siang Upper Stage-I. In addition 2 more projects are planned on its tributaries i.e. Sipit HEP on Sipit Nala and a small project Nyikgong HEP on Nyikgong river.

The stretch is comprised of the area upstream of confluence of Siyom with Siang up to confluence of Sigong and Yangsang rivers. On the left bank of Siang river, the vegetation around Sissen is characterised by fairly dense mixed semi-evergreen forest in lower reaches. On the middle of the hill slopes open degraded forest can be seen due to impact of *jhum* cultivation.

8.2.2.1 Forest Cover

Total forest cover in the sub-basin is 95% and is highest amongst all sub-basin. This is because significant part of the sub-basin is comprised of Mouling National Park with very little human interference. Accordingly the vegetation is comprised of Very Dense to Dense forest on the high slopes that characterize this sub-basin (Figures 8.7 & 8.8). The settlements are concentrated along the valley which is narrow in general.

8.2.2.2 Floristic Diversity

In this sub-basin total 277 species of plants have been recorded. The forests in the sub-basin are Very Dense to Dense canony forests belonging to Assam valley tropical wet evergreen forest, Assam valley Semi evergreen forest, Eastern Hollock moist deciduous forest, East Himalayan Sub-tropical wet hill forest, Himalayan Sub-tropical Pine forest, East Himalayan wet temperate forest, East Himalayan montane Bamboo brakes, and East Himalayan Sub-alpine Birch/Fir forest at higher elevations. Main components of trees in this area are *Anthocephalus cadamba*, *Artocarpus chaplasha*, *Bauhinia purpurea*, *Betula alnoides*, *Bischofia javanica*, *Duabanga grandiflora*, *Endospermum chinense*, *Ficus semicordata*, *Gynocardia odorata* and *Pterospermum acerifolium*. The shrubs are comprised of *Alsophila spinulosa*, *Abroma angusta*, *Boehmeria macrophylla*, *Schefflera bengalensis*, *Murraya koenigii* and *Oroxylum indicum*.

The area harbours some of the medicinal plants like *Abroma angusta*, *Achyranthes aspera*, *Andrographis paniculata*, *Artemisia nilagirica*, *Boerhavia diffusa*, *Buddleja asiatica*, *Clerodendrum colebrookianum*, *Eleusine indica*, *Gynocardia odorata*, *Oroxylum indicum*, *Phyllanthus emblica*, *Spondias pinnata*, *Terminalia chebula*, *Centella asiatica*, *Castanopsis hystrix*, *Fagopyrum esculentum*, *Hedychium spicatum*, *Plantago major*, *Rubia cordifolia*, *Saurauia roxburghii*, *Zanthoxylum armatum*.

In the sub-basin 4 species falling under RET category are found viz. *Acer oblongum* var. *microcarpum*, *Begonia aborensis*, *Begonia scintillans* and *Livistona jenkinsiana*. The species which are endemic to Arunachal Pradesh are represented by *Acer oblongum* var. *microcarpum*, *Aglaia edulis*, *Calanthe densiflora*, *Globba multiflora*, *Livistona jenkinsiana*, *Michelia doltsopa*, *Musa velutina* and *Pyrenaria barringtoniifolia* have been reported from area falling within Mouling NP. There are 29 species reported from this sub-basin which are endemic to north-east. These are *Brassaiopsis hispida*, *Brassaiopsis simplicifolia*, *Peliosanthes macrophylla*, *Cirsium interpositum*, *Begonia sikkimensis*, *Begonia tessaricarpa*, *Begonia thomsonii*, *Plectranthus griffithii*, *Pogostemon amarantoides*, *Beilschmiedia brandisii*, *Beilschmiedia pseudomicropora*, *Persea minutiflora*, *Bambusa rangaensis*, *Schizostachyum helferi*, *Schizostachyum pergracile*, *Ophiorrhiza repens*, *Euonymus lawsonii*, *Sedum triactina*, *Indigofera sesquipedalis*, *Chirita hookerii*, *Phoebe*

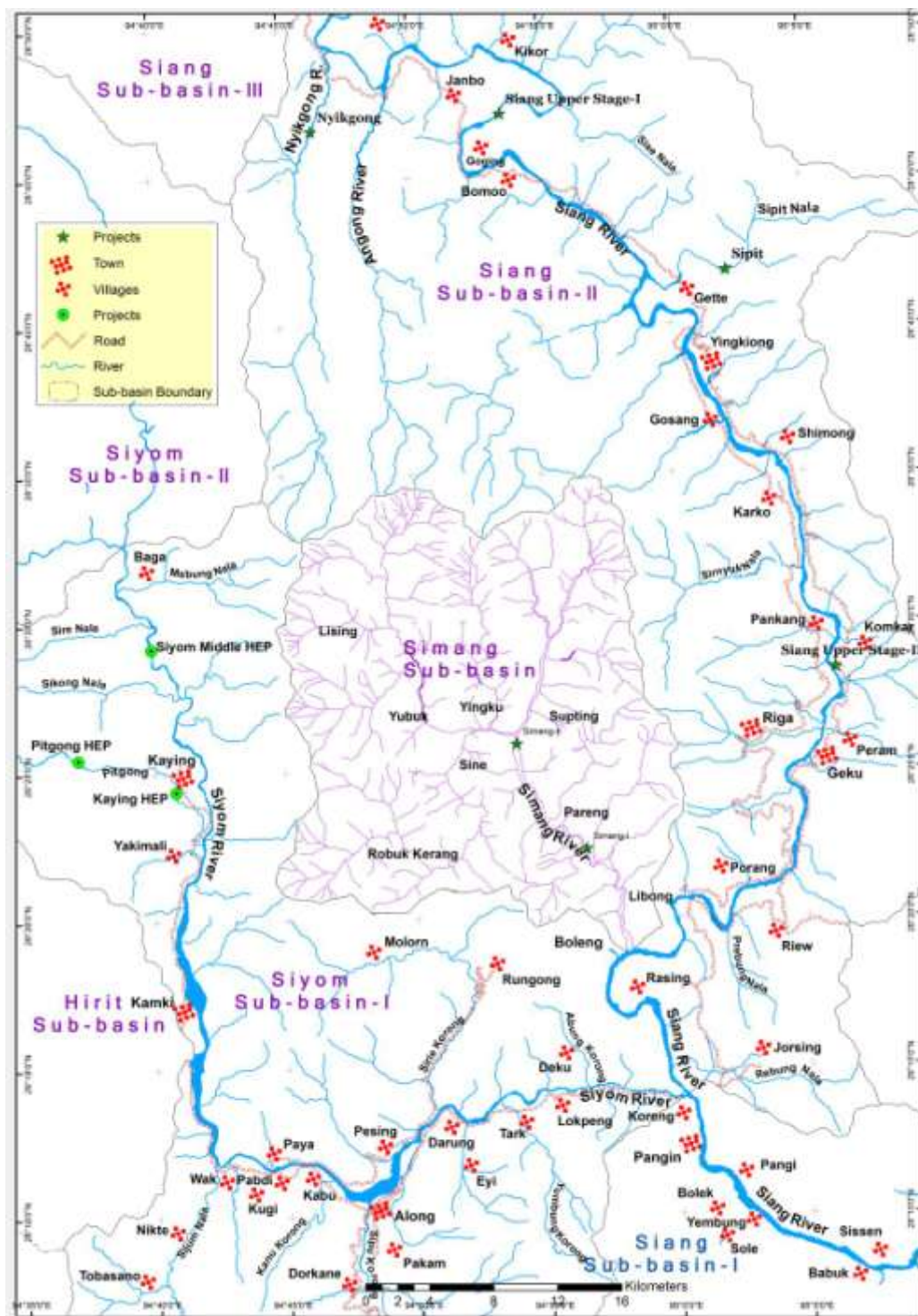


Figure 8.6: Drainage map of Siyom Sub-basin-I, Siang Sub-basin-II & Simang sub-basin

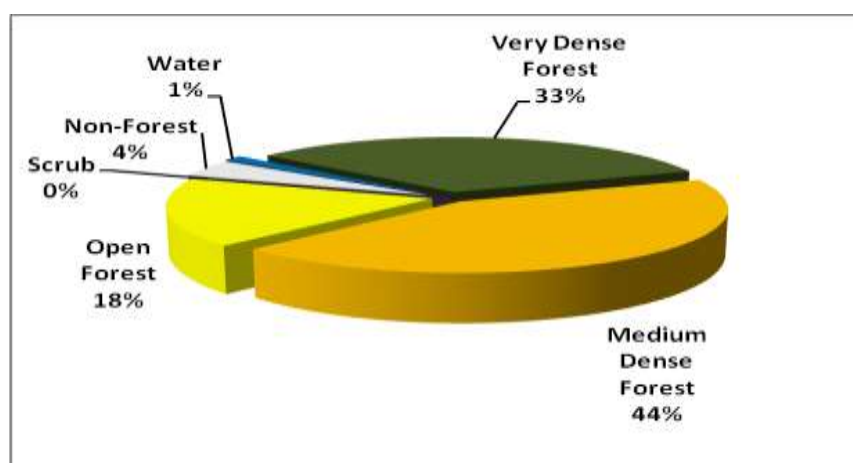


Figure 8.7: Area under different land use/ land cover categories in Siang Sub-basin-II

goalparensis, *Elytranthe psilantha*, *Sonerila khasiana*, *Musa sikkimensis*, *Eria jenggingensis*, *Goodyera recurva*, *Platanthera cumminsiana*, *Arthraxon quarlinianus* var. *glabrescens*, *Arundinella khaseana*, *Ophiorrhiza repens*, *Psychotria silhetensis* var. *tomentosa*, *Randia griffithii* and *Rubus lucens*.

8.2.2.3 Faunal Resources

This sub-basin harbours 58 species of mammals. Most of these species are mainly restricted to Mouling National Park area and nearby forested areas. Tiger (*Panthera tigris*), Musk deer (*Moschus chrysogaster*), Fishing cat (*Prionailurus viverrinus*), and Hispid hare (*Caprolagus hispidus*) have been kept under IUCN Red List “Endangered category” while Mishmi takin (*Budorcas taxicolor*) is under Vulnerable category. Eurasian otter (*Lutra lutra*) has been kept in Near Threatened category.



Figure 8.8: Land use/ land cover map of Siang Sub-basin-II

Accordingly to Wildlife (Protection) Act, 1972 Schedules, Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Red Panda (*Ailurus fulgens*), Mishmi takin (*Budorcas taxicolor*), Capped Langur (*Trachypithecus pileatus*), Leopard Cat (*Prionailurus bengalensis*), Serow (*Capricornis*

sumatraensis), Indian pangolin (*Manis crassicaudata*), Clouded leopard (*Neofelis nebulosa*), Spotted Linsang (*Prionodon pardicolor*), Asiatic Black Bear (*Ursus thibetanus*), Slow loris (*Nycticebus coucang*) and Hispid hare (*Caprolagus hispidus*) are the Schedule-I mammals. *Lutra lutra*, *Herpestes edwardsii*, *Hystrix brachyuran*, *Viverricula indica*, *Paguma larvata*, *Cuon alpinus* and *Felis chaus* are the Schedule-II mammals.

Dense forests in the sub-basin offer suitable habitat for large diversity of avi-fauna. More than 300 species of birds are reported from this area. More importantly the sub-basin's constituent Mouling National Park is an Important Birding Area identified by Bird Life International (2000) and is named as IBA-AR15. It harbours number of Vulnerable and Near Threatened species. The species that are in Vulnerable list are Blyth's tragopan (*Tragopan blythii*), Red-breasted Hill-Partridge (*Arborophila mandellii*), Rufous-necked Hornbill (*Aceros nipalensis*), Rusty-bellied Shortwing (*Brachypteryx hyperythra*), Beautiful Nuthatch (*Sitta Formosa*) and Chestnut-breasted Partridge (*Arborophila mandellii*). The species under Near Threatened category are Rufous-throated Wren-Babbler (*Spelaornis caudatus*) and Wedge-billed Wren-Babbler (*Sphenocichla humei*).

According to WPA, 1972, the area is home to 5 Schedule-I species. These are Black Eagle (*Ictinaetus malayensis*), Black redstart (*Phoenicurus ochruros*), Common buzzard (*Buteo buteo*), Oriental Honey Buzzard (*Pernis ptilorhynchus*), and Pied harrier (*Circus melanoleucos*).

It also constitutes a part of Endemic Birding Area (EBA) 130: Eastern Himalaya. This site comes under the Eastern Himalayas Endemic Bird Areas (Stattersfield *et al.* 1998). Of the 21 species of this EBA, nine have been found at Mouling National Park in the sub-basin. These are Red-breasted Hill-Partridge (*Arborophila mandellii*), Blyth's Tragopan (*Tragopan blythii*), Rusty-bellied Shortwing (*Brachypteryx hyperythra*), Rufous-throated Wren-Babbler (*Spelaornis caudatus*), Wedge-billed Wren-Babbler (*Sphenocichla humei*), Beautiful Sibia (*Heterophasia pulchella*), White-naped Yuhina (*Yuhina bakeri*), Black-browed Leaf- Warbler (*Phylloscopus cantator*) and Broad-billed Flycatcher-Warbler (*Tickellia hodgsoni*).

8.2.2.4 Fish Diversity

It is one of the richest zone of fish diversity with 59 species of fish reported from this area. This is primarily the mahseer zone where *Tor tor* and *Tor putitora* are the main fish species found in the area. The rivering stretch is characterised by narrow river valley with gentle gradient.

According CAMP criteria 6 species belong to Endangered category i.e. *Anguilla bengalensis*, *Lepidocephalichthys arunachalensis*, *Syncrossus berdmorei* (= *Botia berdmorei*), *Schistura multifasciata*, (= *Nemacheilus multifasciatus*), *Tor putitora* and *Tor tor*.

Twenty three species are under Vulnerable category. These are *Bangaba dero* (= *Labeo dero*), *Barilius barila*, *Barilius vagra*, *Botia rostrata*, *Cyprinion semiplotum* (= *Semiplotus semiplotus*), *Garra gotyla gotyla*, *Garra kempfi*, *Garra lissorhynchus*, *Garra naganensis* (= *Garra tirapensis*), *Glyptothorax brevipinnis*, *Glyptothorax indicus* (= *Glyptothorax horai*), *Heteropneustes fossilis*, *Mystus bleekeri*, *Mystus vittatus*, *Parachilognan hodgarti* (= *Euchilognan hodgarti*), *Pseudecheneis sirenica*, *Psilorhynchus homaloptera*, *Puntius chola*, *Puntius sarana*, *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*), *Schistura manipurensis* (= *Nemacheilus manipurensis*), and *Schizothorax richardsonii*.

According criteria of IUCN only one species is under Endangered category i.e. *Tor putitora*. There are 7 species under Vulnerable category viz. *Aborichthys garoensis* (= *Nemacheilus garonesis*), *Bagarius bagarius*, *Botia rostrata*, *Cyprinion semiplotum* (= *Semiplotus semiplotus*), *Cyprinus*

carpio, *Pseudecheneis sirenica*, *Schizothorax richardsonii* and 7 under Near Threatened category viz. *Aborichthys kempfi* (= *Nemacheilus kempfi*), *Labeo pangusia*, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Ompok pabo*, *Schistura manipurensis* (= *Nemacheilus manipurensis*), *Syncrossus berdmorei* (= *Botia berdmorei*) and *Tor tor*.

The endemic species are *Aborichthys elongatus*, *Aborichthys garoensis* (= *Nemacheilus garonesis*), *Garra lissorhynchus*, *Garra naganensis* (= *Garra tirapensis*), *Glyptothorax brevipinnis*, *Pseudecheneis sirenica*, *Psilorhynchus arunachalensis*, and *Schistura manipurensis* (= *Nemacheilus manipurensis*).

8.2.3 Siang Sub-basin-III

This sub-basin is comprised of right bank drainage catchment of Siang river after it enters India. Sigong/Singong river and Ringong Asi are the two major tributaries in this sub-basin while Pali Si is another tributary (refer Figure 8.9). All these tributaries drain snow covered areas in the catchment. Two projects Pango/Minniying and Mirak HEPs are proposed on Sigong river while Palsi HEP is proposed on Pali Si streams. Another two projects Sippi and Ringong HEPs are proposed on Ringong Asi. Entire upper catchment falls under Dibang Dihang Biosphere Reserve.

8.2.3.1 Forest Cover

This sub-basin is covered with forests (61%) while as much 39% is snow covered. There is very little human settlement in the sub-basin (Figures 8.10 & 8.11).

8.2.3.2 Floristic Diversity

In this sub-basin nearly 245 plant species have been enumerated. It is one of the least disturbed areas of the basin and Semi-evergreen forest along the valley and alpine vegetation is found at higher reaches.

The forests in the sub-basin are Very Dense to Dense forests belong to Assam valley tropical wet evergreen forest, Assam valley Semi evergreen forest, Eastern Hollock moist deciduous forest, East Himalayan Sub-tropical wet hill forest, East Himalayan wet temperate forest, East Himalayan montane Bamboo brakes, and East Himalayan Sub-alpine Birch/Fir forest at higher elevations. Main components of trees in this sub-basin are *Anthocephalus cadamba*, *Artocarpus chaplasha*, *Bauhinia purpurea*, *Betula alnoides*, *Bischofia javanica*, *Duabanga grandiflora*, *Endospermum chinense*, *Ficus semicordata*, *Gynocardia odorata* and *Pterospermum acerifolium*. The shrubs are comprised of *Alsophila spinulosa*, *Abroma angusta*, *Boehmeria macrophylla*, *Schefflera bengalensis*, *Murraya koenigii* and *Oroxylum indicum*.

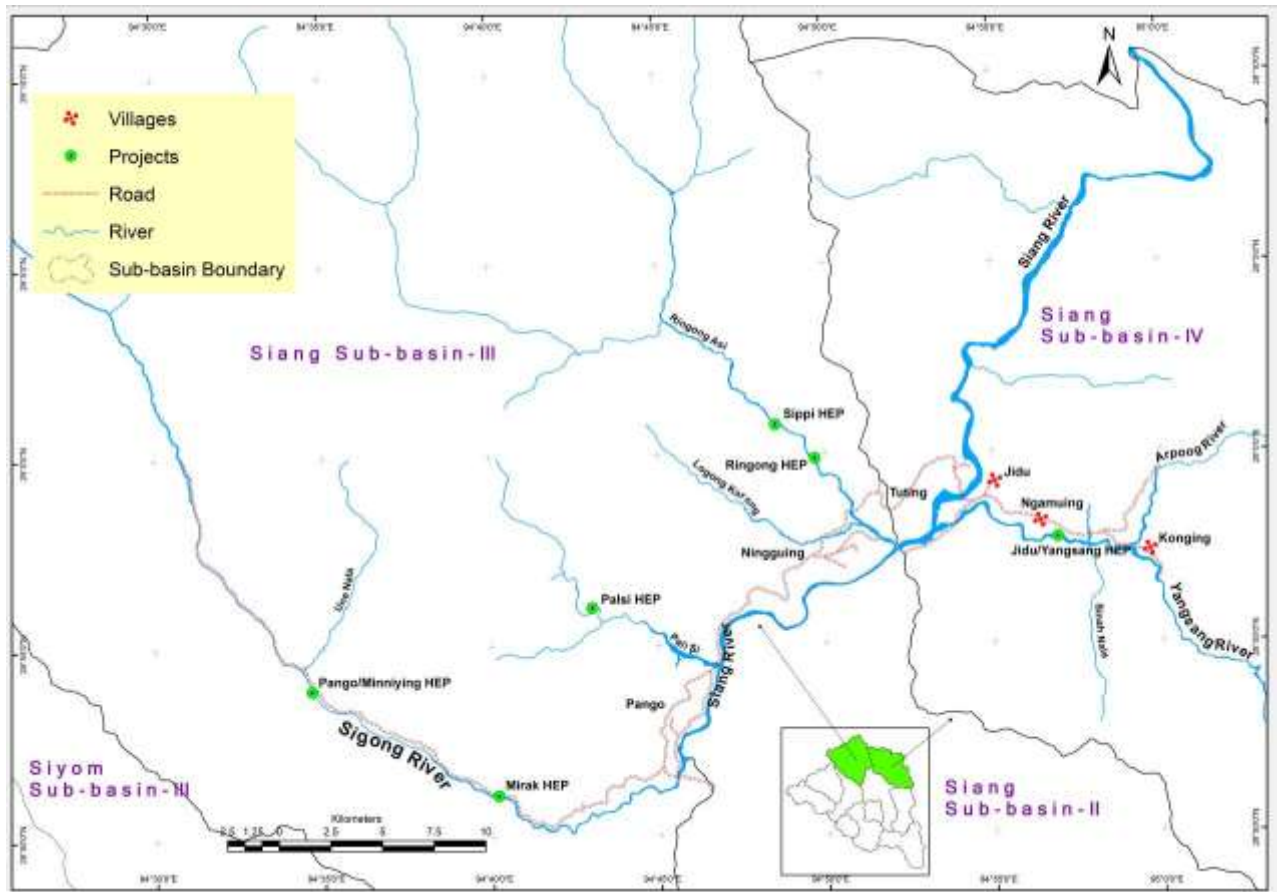


Figure 8.9: Drainage map of Siang Sub-basin-III & IV

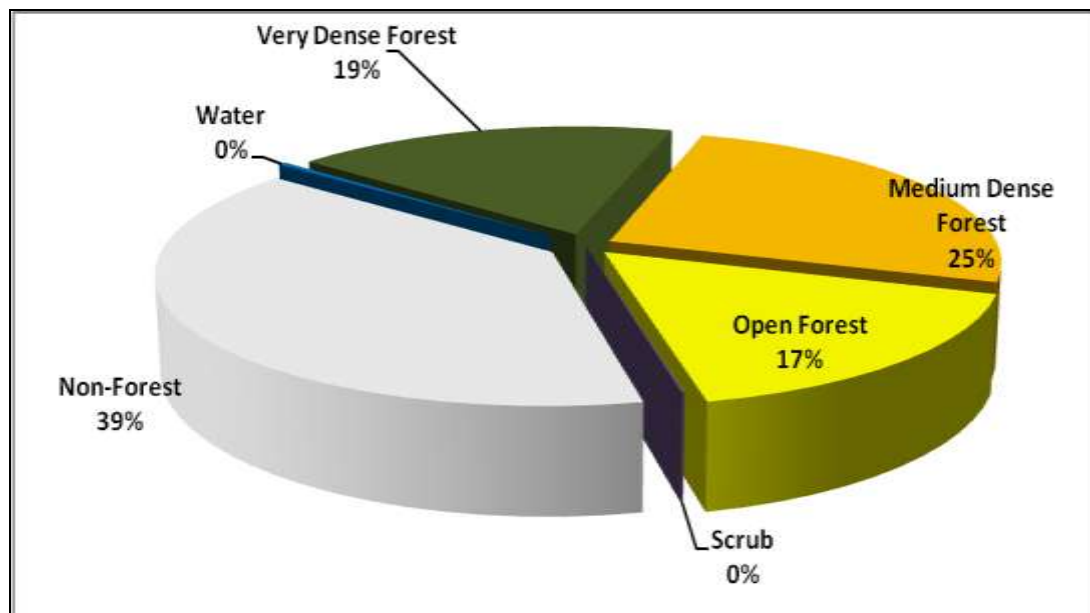


Figure 8.10: Area under different land use/ land cover categories in Siang Sub-basin-III

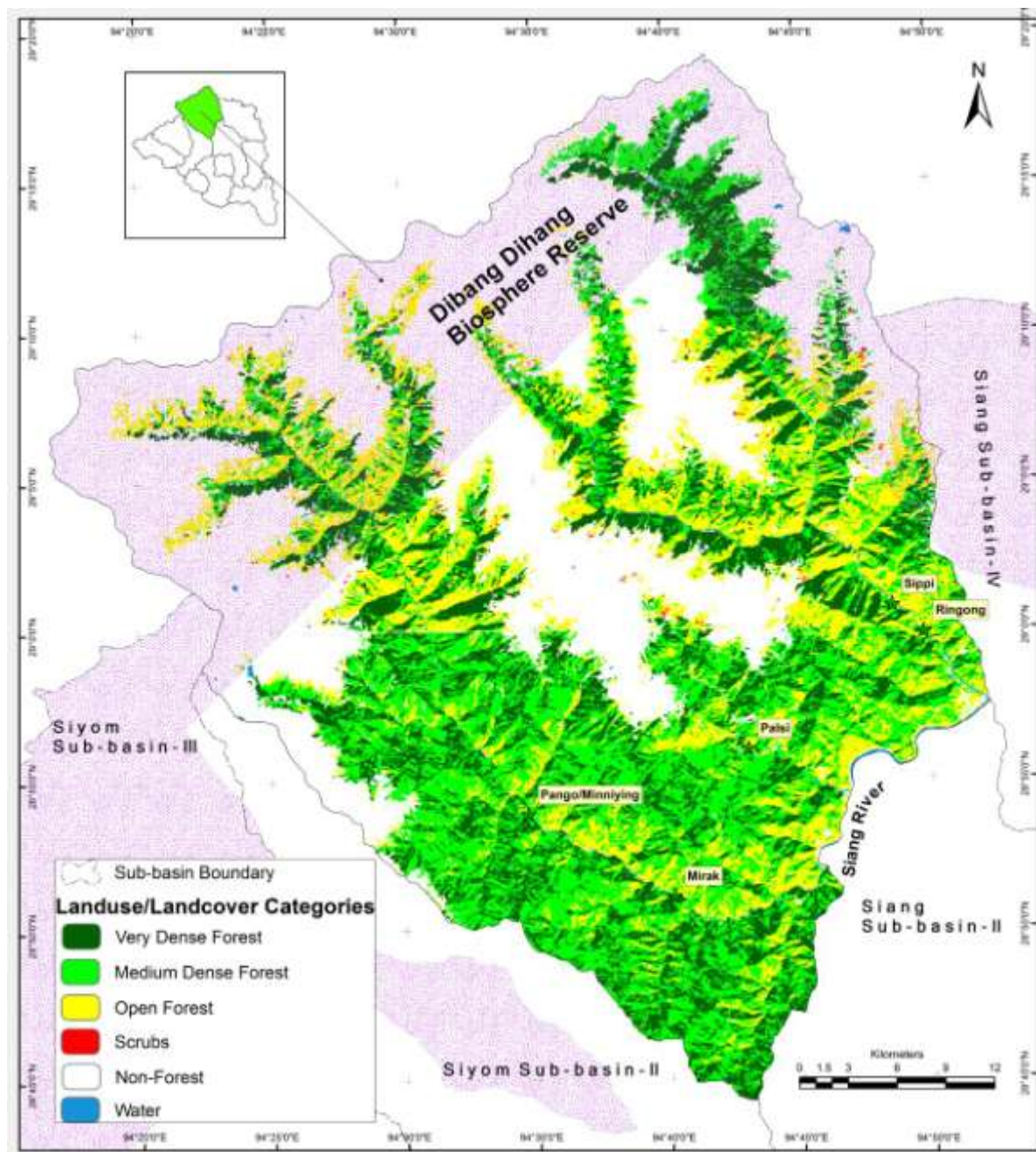


Figure 8.11: Land use/ land cover map of Siang Sub-basin-III

In the sub-basin 5 species falling under RET category are found viz. *Acer oblongum* var. *microcarpum*, *Actinidia callosa*, *Begonia aborensis*, *Begonia scintillans* and *Livistona jenkinsiana*. The species which are endemic to north-east and Arunachal Pradesh are represented by *Acer oblongum* var. *microcarpum*, *Aglaia edulis*, *Impatiens laevigata*, *Impatiens racemosa*, *Livistona jenkinsiana*, *Michelia doltsopa*, *Musa velutina* and *Pyrenaria barringtoniifolia* have been reported from the sub-basin.

There are 36 species reported from this sub-basin which are endemic to north-east India are listed below.

<i>Anoectochilus sikkimensis</i>	<i>Neonauclea gageana</i>
<i>Arisaema album</i>	<i>Ophiorrhiza repens</i>
<i>Arisaema setosum</i>	<i>Persea minutiflora</i>
<i>Arthraxon quarlinianus</i> var. <i>glabrescens</i>	<i>Phoebe goalparensis</i>
<i>Arundinella khaseana</i>	<i>Platanthera cumminsiana</i>
<i>Bambusa rangaensis</i>	<i>Pogostemon amarantoides</i>
<i>Beilschmiedia brandisii</i>	<i>Psychotria silhetensis</i> var. <i>tomentosa</i>

<i>Chirita hookerii</i>	<i>Randia griffithii</i>
<i>Chirita macrophylla</i>	<i>Rhynchochelydium alternifolium</i>
<i>Coelogyne arunachalensis</i>	<i>Rubus lucens</i>
<i>Elytranthe psilantha</i>	<i>Schizostachyum helferi</i>
<i>Eria jenggingensis</i>	<i>Schizostachyum pergracile</i>
<i>Euonymus lawsonii</i>	<i>Sedum triactina</i>
<i>Goodyera recurva</i>	<i>Sonerila khasiana</i>
<i>Indigofera sesquipedalis</i>	<i>Tetrastigma planicaule</i>
<i>Indofevillea khasiana</i>	<i>Vaccinium venosum</i>
<i>Ixora subsessilis</i>	<i>Viburnum corylifolium</i>
<i>Musa sikkimensis</i>	<i>Vitis planicaulis</i>

8.2.3.3 Faunal Resources

Though very scanty information is available for this sub-basin, however based primarily upon secondary information it is home to more than 54 species of mammals. Tiger (*Panthera tigris*), Musk deer (*Moschus chrysogaster*), Fishing cat (*Prionailurus viverrinus*), and Hispid hare (*Caprolagus hispidus*) are IUCN Red List “Endangered category” while Mishmi takin (*Budorcas taxicolor*) is under Vulnerable category animals found in the sub-basin. Accordingly to Wildlife (Protection) Act, 1972 Schedules, Tiger (*Panthera tigris*), Mishmi takin (*Budorcas taxicolor*), Serow (*Capricornis sumatraensis*), Indian pangolin (*Manis crassicaudata*), Clouded leopard (*Neofelis nebulosa*), Slow loris (*Nycticebus coucang*) and Hispid hare (*Caprolagus hispidus*) are the Schedule-I mammals. *Herpestes edwardsii*, *Hystrix brachyura* and *Felis chaus* are the Schedule-II mammals.

Dense forests in the sub-basin offer suitable habitat for large diversity of avi-fauna. More than 280 species of birds are reported from this area. There are 2 species that are in Vulnerable list viz. Blyth’s tragopan (*Tragopan blythii*), and Chestnut-breasted Partridge (*Arborophila mandellii*). According to WPA, 1972, the area is home to 5 Schedule-I species. These are Black Eagle (*Ictinaetus malayensis*), Black redstart (*Phoenicurus ochruros*), Common buzzard (*Buteo buteo*), Oriental Honey Buzzard (*Pernis ptilorhynchus*), and Pied harrier (*Circus melanoleucos*).

Upper reaches of the sub-basin being a part of Dibang Dihang Biosphere Reserve has been identified as a part of International Birding Area by Bird Life International (2000) and has been termed as IN-AR-04 as follows:

IN-AR-04	Dibang Reserve Forest and adjacent areas	A1, A2

8.2.3.4 Fish Diversity

Though not much is known about the fish diversity of the sub-basin, however nearly 55 species of fishes have been listed based upon available data from this area. This sub-basin is primarily a snow trout zone where mahseer migrates from the main channel for spawning. The riverine stretch is characterised by narrow river valley with steep gradient.

There are 8 endemic species reported from the sub-basin i.e. *Garra lissorhynchus*, *Garra mcClellandi*, *Garra naganensis* (= *Garra tirapensis*), *Glyptothorax brevipinnis*, *Lepidocephalichthys arunachalensis* (= *Nemacheilus arunachalensis*), *Nemacheilus devdevi*, *Pseudecheneis sirenica*, and *Schistura manipurensis* (= *Nemacheilus manipurensis*).

According to criteria of CAMP 11 species belong to Endangered category i.e. *Glyptosternon reticulatum*, *Glyptothorax cavia*, *Lepidocephalichthys arunachalensis* (= *Nemacheilus*

arunachalensis), *Nemacheilus devdevi*, *Ompok bimaculatus*, *Pseudolaguvia shawi*, *Pterocryptis gangetica* (= *Silurus afgana*), *Schistura multifasciata* (= *Nemacheilus multifasciatus*), *Syncrossus berdmorei* (= *Botia berdmorei*), *Tor putitora* and *Tor tor*.

Twenty one species are under Vulnerable category. These are *Amblyceps apangi*, *Bangaba dero* (= *Labeo dero*), *Barilius barila*, *Barilius vagra*, *Botia rostrata*, *Garra gotyla gotyla*, *Garra kemp*, *Garra lissorhynchus*, *Garra naganensis* (= *Garra tirapensis*), *Glyptothorax brevipinnis*, *Glyptothorax indicus* (= *Glyptothorax horai*), *Heteropneustes fossilis*, *Mystus bleekeri*, *Parachiloganis hodgarti* (= *Euchiloglanis hodgarti*), *Pseudecheneis sirenica*, *Psilorhynchus homaloptera*, *Puntius chola*, *Puntius sarana*, *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*), *Schistura manipurensis* (= *Nemacheilus manipurensis*) and *Schizothorax richardsonii*.

According to criteria defined by IUCN there are 3 species which are under Endangered category viz. *Lepidocephalichthys arunachalensis* (= *Nemacheilus arunachalensis*), *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*) and *Tor putitora*. In addition 4 species are under Vulnerable category (*Bagarius bagarius*, *Botia rostrata*, *Pseudecheneis sirenica* and *Schizothorax richardsonii*) and 8 species are under Near Threatened category (*Labeo pangusia*, *Nemacheilus devdevi*, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Ompok pabo*, *Ompok bimaculatus*, *Schistura manipurensis* (= *Nemacheilus manipurensis*), *Syncrossus berdmorei* (= *Botia berdmorei*) and *Tor tor*).

8.2.4 Siang Sub-basin-IV

This sub-basin is comprised of left bank drainage of Siang river after it enters India. Yangsang Chhu is main drainage in the sub-basin (refer Figure 8.9). There is only one project Jidu/Yangsang HEP proposed on Yangsang Chhu. Tuting is the major town in the area.

8.2.4.1 Forest Cover

More than 88% of the sub-basin is under forest cover while upper reaches are covered with snow (Figures 8.12 & 8.13). The forests in the sub-basin are Very Dense to Dense forests belong to Assam valley tropical wet evergreen forest, Assam valley Semi evergreen forest, Eastern Hollock moist deciduous forest, East Himalayan Sub-tropical wet hill forest, East Himalayan wet temperate forest, East Himalayan montane Bamboo brakes, and East Himalayan Sub-alpine Birch/Fir forest at higher elevations.

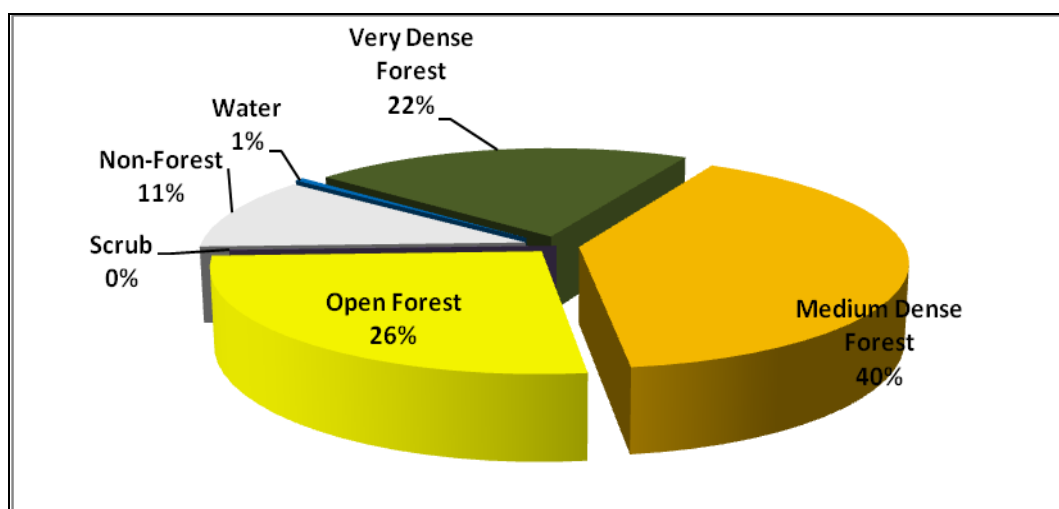


Figure 8.12: Area under different land use/ land cover categories in Siang Sub-basin-IV

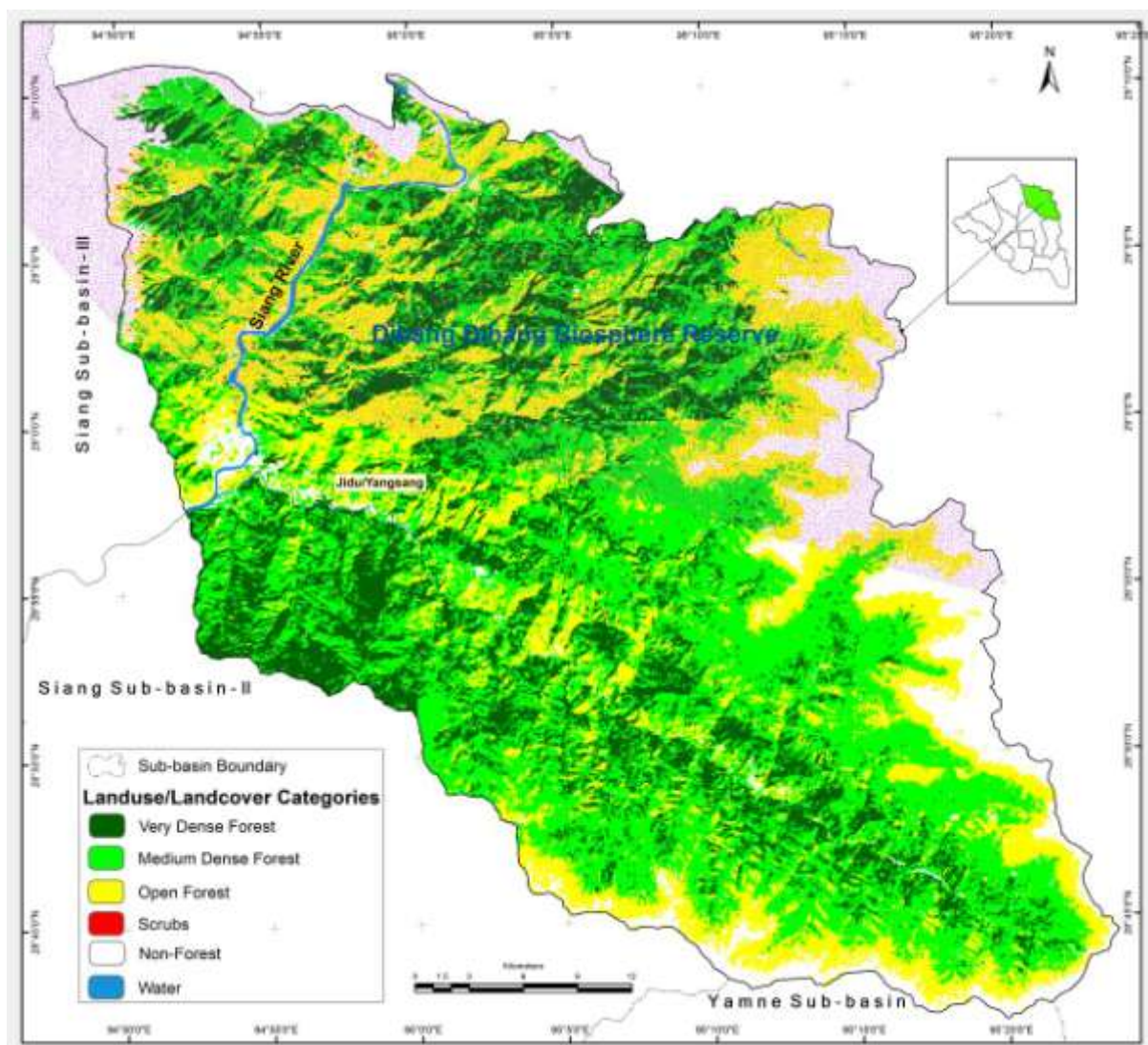


Figure 8.13: Land use/ land cover map of Siang Sub-basin-IV

8.2.4.2 Floristic Diversity

In this sub-basin nearly 194 plant species have been recorded. It is one of the least disturbed areas of the basin and Semi-evergreen forest along the valley and alpine vegetation is found at higher reaches.

Main components of trees in this area are *Anthocephalus cadamba*, *Artocarpus chaplasha*, *Bauhinia purpurea*, *Betula alnoides*, *Bischofia javanica*, *Duabanga grandiflora*, *Endospermum chinense*, *Ficus semicordata*, *Gynocardia odorata* and *Pterospermum acerifolium*. The shrubs are comprised of *Alsophila spinulosa*, *Abroma angusta*, *Boehmeria macrophylla*, *Schefflera bengalensis*, *Murraya koenigii* and *Oroxylum indicum*.

The species endemic to Arunachal found in the area are represented by *Acer oblongum* var. *microcarpum*, *Aglaia edulis*, *Impatiens laevigata*, *Impatiens racemosa*, *Livistona jenkinsiana*, *Michelia doltsopa*, *Musa velutina*, *Ophiorrhiza calcarata* and *Pyrenaria barringtoniifolia* have been reported from the sub-basin. In addition there are 34 species found in the sub-basin which are endemic to northeast India. The list is given below.

<i>Anoectochilus sikkimensis</i>	<i>Musa sikkimensis</i>
<i>Arisaema album</i>	<i>Neonauclea gageana</i>
<i>Arisaema setosum</i>	<i>Ophiorrhiza repens</i>
<i>Arthraxon quarlinianus</i> var. <i>glabrescens</i>	<i>Persea minutiflora</i>
<i>Arundinella khaseana</i>	<i>Phoebe goalparensis</i>

<i>Baliospermum calycinum</i>	<i>Platanthera cumminsiana</i>
<i>Bambusa barpatharica</i>	<i>Psychotria silhetensis</i> var. <i>tomentosa</i>
<i>Bambusa rangensis</i>	<i>Randia griffithii</i>
<i>Coelogyne arunachalensis</i>	<i>Rubus lucens</i>
<i>Elatostema sikkimense</i>	<i>Schizostachyum helferi</i>
<i>Elytranthe psilantha</i>	<i>Schizostachyum pergracile</i>
<i>Eria jenggingensis</i>	<i>Sedum triactina</i>
<i>Euonymus lawsonii</i>	<i>Smilax minutiflora</i>
<i>Goodyera recurva</i>	<i>Sonerila khasiana</i>
<i>Indigofera sesquipedalis</i>	<i>Tetrastigma planicaule</i>
<i>Indofevillea khasiana</i>	<i>Vaccinium venosum</i>
<i>Jasminum caudatum</i>	<i>Viburnum corylifolium</i>

8.2.4.3 Faunal Resources

Though very scanty information is available for this sub-basin, however based primarily upon secondary information it is home to more than 50 species of mammals. Tiger (*Panthera tigris*), Musk deer (*Moschus chrysogaster*), Fishing cat (*Prionailurus viverrinus*), and Hispid hare (*Caprolagus hispidus*) are IUCN Red List “Endangered category” while Mishmi takin (*Budorcas taxicolor*) is under Vulnerable category animals found in the sub-basin. Accordingly to Wildlife (Protection) Act, 1972 Schedules, Tiger (*Panthera tigris*), Mishmi takin (*Budorcas taxicolor*), Serow (*Capricornis sumatraensis*), Indian pangolin (*Manis crassicaudata*), Clouded leopard (*Neofelis nebulosa*), Slow loris (*Nycticebus coucang*) and Hispid hare (*Caprolagus hispidus*) are the Schedule-I mammals. *Herpestes edwardsii*, *Hystrix brachyura* and *Felis chaus* are the Schedule-II mammals.

Dense forests in the sub-basin offer suitable habitat for large diversity of avi-fauna. More than 300 species of birds are reported from this area. There are 2 species that are in Vulnerable list viz. Blyth’s tragopan (*Tragopan blythii*), and Chestnut-breasted Partridge (*Arborophila mandellii*). According to WPA, 1972, the area is home to 5 Schedule-I species. These are Black Eagle (*Ictinaetus malayensis*), Black redstart (*Phoenicurus ochruros*), Common buzzard (*Buteo buteo*), Oriental Honey Buzzard (*Pernis ptilorhynchus*), and Pied harrier (*Circus melanoleucos*).

Found between Tuting and Gelling Eastern Imperial Eagle *Aquila heliaca*.

8.2.4.4 Fish Diversity

For this sub-basin also not much is known about the fish diversity. However a list of 36 species of fishes has been prepared based upon information collected from the people and published literature. This sub-basin also is primarily a snow trout zone where mahseer migrates from the main channel for spawning. The riverine stretch is characterised by narrow river valley with steep gradient.

There are 5 endemic species reported from the sub-basin i.e. *Garra lissorhynchus*, *Garra naganensis* (= *Garra tirapensis*), *Glyptothorax brevipinnis*, *Pseudecheneis sirenica*, and *Schistura manipurensis* (= *Nemacheilus manipurensis*).

According to CAMP criteria 7 species belong to Endangered category i.e. *Glyptosternon reticulatum*, *Glyptothorax cavia*, *Nemacheilus devdevi*, *Schistura multifasciata* (= *Nemacheilus multifasciatus*), *Syncrossus berdmorei* (= *Botia berdmorei*), *Tor putitora* and *Tor tor*.

Fourteen species are under Vulnerable category. These are *Bangaba dero* (= *Labeo dero*), *Barilius barila*, *Garra gotyla gotyla*, *Garra kempfi*, *Garra lissorhynchus*, *Garra naganensis* (= *Garra tirapensis*), *Glyptothorax brevipinnis*, *Heteropneustes fossilis*, *Parachilognan hodgarti*

(=*Euchiloglanis hodgarti*), *Pseudecheneis sirenica*, *Puntius sarana*, *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*), *Schistura manipurensis* (= *Nemacheilus manipurensis*) and *Schizothorax richardsonii*.

According to IUCN criteria 2 species are under Endangered category i.e. *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*) and *Tor putitora*. There are 4 species under Vulnerable category i.e. *Bagarius bagarius*, *Botia rostrata*, *Cyprinion semiplotum* (= *Semiplotus semiplotus*) and *Schizothorax richardsonii* and 5 species are under Near Threatened category i.e. *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Ompok bimaculatus*, *Schistura manipurensis* (= *Nemacheilus manipurensis*), *Syncrossus berdmorei* (= *Botia berdmorei*) and *Tor tor*.

8.2.5 Yamne Sub-basin

This sub-basin is comprised of the catchment of Yamne river which is the main left bank tributary in the lower reaches of Siang basin (Figure 8.12).

8.2.5.1 Floristic Diversity

In this sub-basin more than 210 species of plants have been reported. The tree trunks are covered with a number of epiphytic ferns and orchids such as the species of *Bulbophyllum*, *Cymbidium*, *Dendrobium* and *Rhynchostylis*.

The area harbours some of the medicinal plants like *Abroma angusta*, *Achyranthes aspera*, *Andrographis paniculata*, *Artemisia nilagirica*, *Boerhavia diffusa*, *Buddleja asiatica*, *Clerodendrum colebrookianum*, *Eleusine indica*, *Gynocardia odorata*, *Oroxylum indicum*, *Phyllanthus emblica*, *Spondias pinnata*, *Terminalia chebula*, *Centella asiatica*, *Castanopsis hystrix*, *Fagopyrum esculentum*, *Hedychium spicatum*, *Plantago major*, *Rubia cordifolia*, *Saurauia roxburghii*, *Zanthoxylum armatum*.

This sub-basin comprises the entire catchment of Yamne river up to the confluence of Yamne with Siang river. The Yamne river, a tributary of Siang river joins on its left bank. This stream confluences with Siang river near Silli Basti. The vegetation from Bodak to Silli Basti consists mostly of mixed evergreen and deciduous trees. *Albizia lucida*, *A. procera*, *A. odoratissima*, *Altingia excelsa*, *Callicarpa arborea*, *Castanopsis indica*, *Dysoxylum binectiferum*, *Erythrina stricta*, *Kydia calycina*, *Terminalia myriocarpa* and *Toona microcarpa* form the first storey. *Aglaia heirni*, *Alangium procera*, *Ficus semicordata*, *Ostodes paniculata* and *Pandanus nepalensis* are found in the second storey. Understorey represented by shrubs, climbers and herbs. Climbers are represented by species of *Cissus*, *Derris*, *Mikania*, *Pentapanax*, *Rhapidophora*, *Rubia*, *Smilax* and *Stephania*. Tree ferns occur commonly on shaded and damp areas of the forest. Pteridophytes are many represented by both terrestrial and epiphytic fern species. Among terrestrial ferns are the species of *Athyrium*, *Dicranopteris*, *Lygodium*, *Pteris* and *Pteridium*. Bamboos, palms, shrubs and herbs form undergrowth. A fairly dense mixed semi-evergreen forest was observed between Silli and Jeging Basti. Shifting cultivation is a common practice in the area. Dense thickets of tall bamboo trees (*Bambusa tulda* and *B. nutans*) are often seen near settlement areas. From Jegging to Jeru (Lower Yamne Projects), the vegetation is sparse and patchy. *Albizia*, *Altingia*, *Bischofia*, *Castanopsis*, *Duabanga*, *Ficus*, *Kydia* and *Terminalia myriocarpa* are often seen in the patchy tree layer. A parasitic plant like *Scurrula elata* is observed growing on Pear trees (*Pyrus communis*). The vegetation around Padu is patchy and consists of some mixed deciduous tall trees in the first storey and evergreen species in the middle storey. *Ardisia formosa*, *Cassia tora*, *Chromolaena odoratum*, *Datura stramonium* and *Rubus ellipticus* in the understorey. There are many Citrus orchards in the area on gentle and moderate slopes.

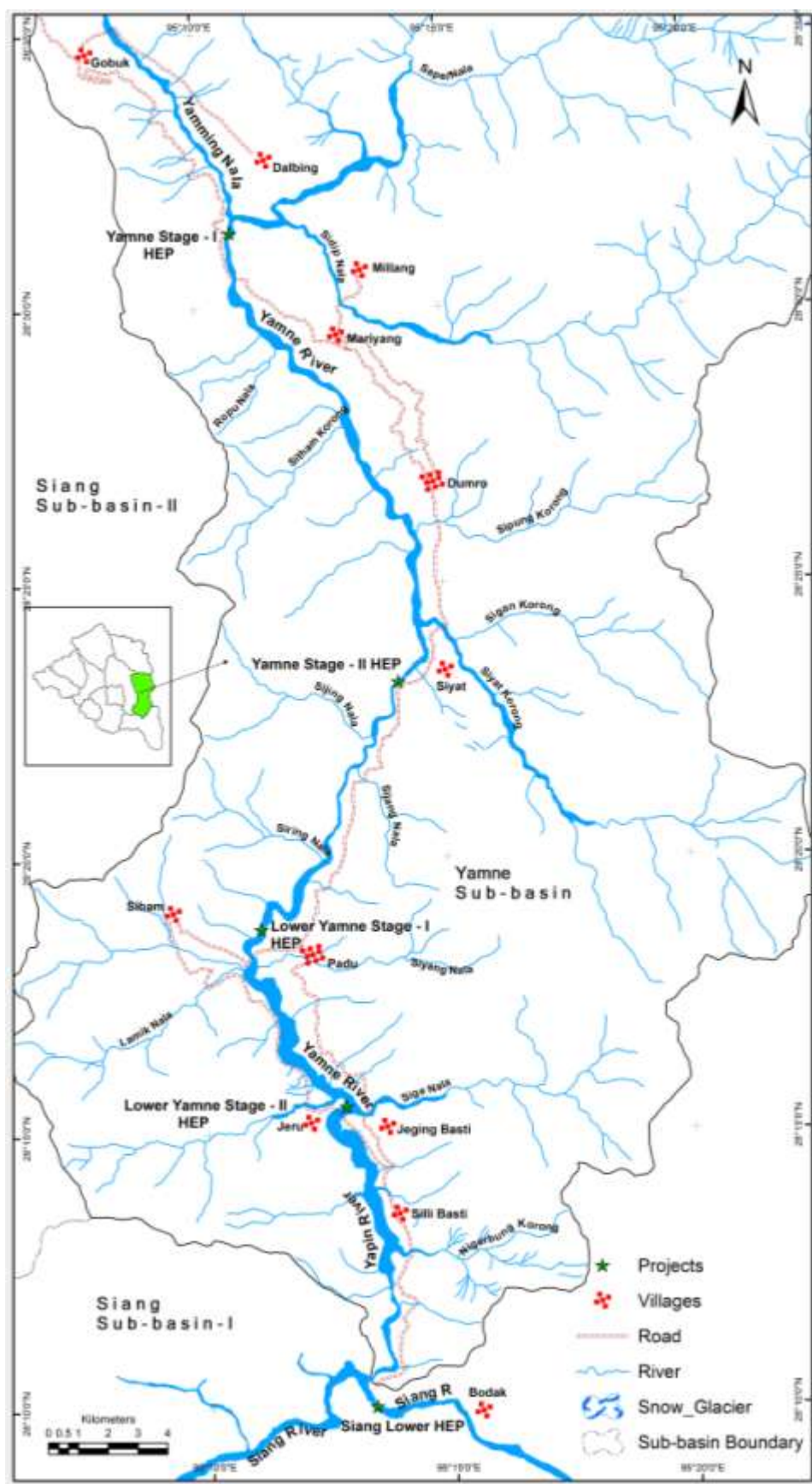


Figure 8.14: Drainage map of Yamne Sub-basin

8.2.5.2 Forest Cover

More than 95% of the sub-basin is under forest cover especially in the upper reaches (Figures 8.15 & 8.16). The vegetation from Padu to Siyat consists of degraded forest in the middle reaches and dense mixed semi-evergreen forest in lower reaches. At lower reaches (left bank of Yamne), the predominant trees include *Albizia odoratissima*, *Altingia excelsa*, *Bischofia javanica*, *Castanopsis*

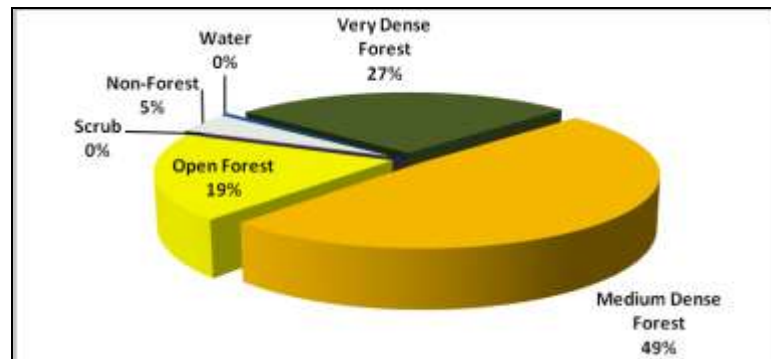


Figure 8.15: Area under different land use/ land cover categories in Yamne Sub-basin

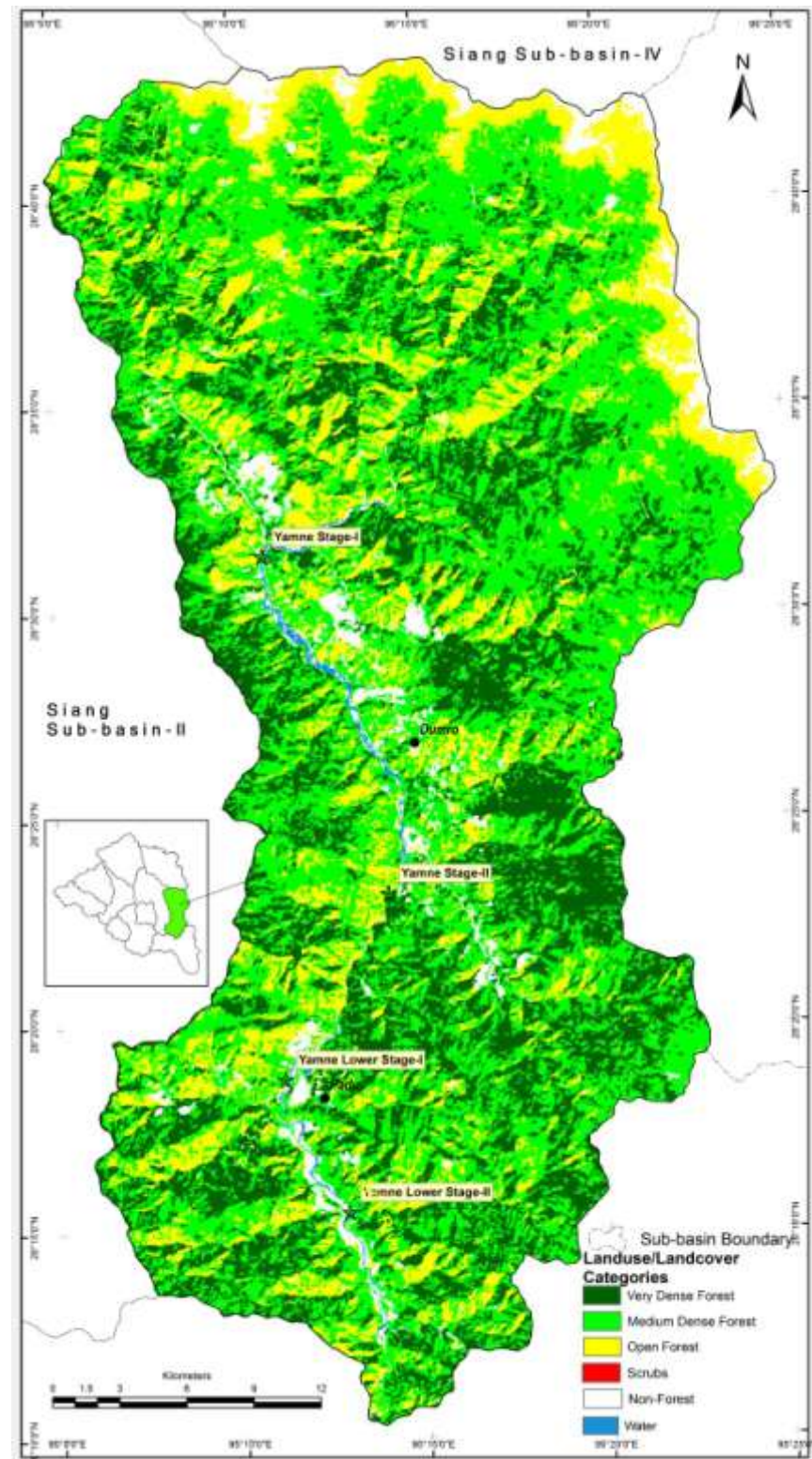


Figure 8.16: Land use/ land cover map of Yamne Sub-basin

indica, *Engelhardtia spicata*, *Ostodes paniculata*, *Pterospermum acerifolium*, *Schima wallichii* and *Terminalia myriocarpa*. Tall bamboos can be seen in the jhummed areas. Among shrubs are *Actinidia*, *Chromolaena*, *Leea*, *Randia* and *Rhamnus*. Dense *Musa* thickets can be often seen in damp and shaded areas. The herbaceous flora includes species of *Alpinia*, *Begonia*, *Hedychium*, *Commelina*, *Impatiens*, *Lygodium*, *Mikania*, *Oplismenus*, *Persicaria*, *Pilea* and *Pteris*.

The vegetation from Siyat to Mariyang consists of dense forest in lower reaches and degraded patchy forest in the middle reaches. At right bank of Yamne river, downstream of Mariyang village (near Yamne Stage-I HEP site), the vegetation is characterized by fairly dense mixed semi-evergreen forest in lower reaches. *Aglaia heirni*, *Albizia lucida*, *Altingia excelsa*, *Artocarpus lakoocha*, *Castanopsis indica*, *Dysoxylum strictum*, *Garuga pinnata*, *Phoebe hainsiana*, *Saurauia punduana*, *Terminalia myriocarpa* and *Tetradium fraxinifolium* are important trees in the first storey. Second storey represented by *Brassiopsis aculeata*, *Carpinus viminea*, *Cinnamomum glaucescens*, *Ficus racemosa*, *Lannea coromandelica*, *Macaranga denticulata* and *Ostodes paniculata*. Predominant shrubs here are *Actinidia callosa*, *Ardisia formosa*, *Boehmeria pendulifera*, *Buddleja asiatica*, *Debregeasia longifolia*, *Melastomia normale*, *Maesa chisia*, *Oxysopra paniculata*, *Pteris subindivisa* and *Vernonia volkemerifolia*. Epiphytes and climbers are few. Climbers are species of *Cissus*, *Piper*, *Rhapidophora*, *Rubia* and *Smilax*. Herbs include species of weeds, ferns, sedges and grasses.

In the sub-basin 6 species falling under RET category are found viz. *Begonia aborensis*, *B. scitillans*, *Cymbidium eburneum*, *Psychotria aborensis*, *Livistona jenkinsiana* and *Paphiopedilum fairrieanum*. The endemic species found in the area are *Ardisia pedunculosa*, *Begonia aborensis*, *Begonia scitillans*, *Begonia silhetensis*, *Calanthe densiflora*, *Dendrobium hookerianum*, *Eria ferruginea*, *Syzygium aborens* and *Xanthophyllum burkillii* have been reported from this sub-basin.

The species endemic to Arunachal found in the area are represented by *Aglaia edulis*, *Calanthe densiflora*, *Globba multiflora*, *Impatiens laevigata*, *Impatiens racemosa*, *Livistona jenkinsiana*, *Michelia doltsopa*, *Musa velutina*, *Ophiorrhiza calcarata*, *Prenanthes scandens* and *Pyrenaria barringtoniifolia* have been reported from the sub-basin. In addition there are 38 species found in the sub-basin which are endemic to northeast India. The list is given below.

<i>Anoectochilus sikkimensis</i>	<i>Ixora subsessilis</i>
<i>Arisaema album</i>	<i>Musa sikkimensis</i>
<i>Arisaema setosum</i>	<i>Ophiorrhiza succirubra</i>
<i>Arthraxon quarlinianus</i> var. <i>glabrescens</i>	<i>Ophiorrhiza repens</i>
<i>Arundinella khaseana</i>	<i>Peliosanthes macrophylla</i>
<i>Baliospermum calycinum</i>	<i>Persea minutiflora</i>
<i>Bambusa barpatharica</i>	<i>Phoebe goalparensis</i>
<i>Bambusa rangaensis</i>	<i>Plectranthus griffithii</i>
<i>Begonia tessaricarpa</i>	<i>Pogostemon amarantoides</i>
<i>Begonia thomsonii</i>	<i>Randia griffithii</i>
<i>Beilschmiedia brandisii</i>	<i>Rhynchoetechum alternifolium</i>
<i>Beilschmiedia pseudomicropora</i>	<i>Rubus lucens</i>
<i>Brassiopsis simplicifolia</i>	<i>Schizostachyum polymorphum</i>
<i>Chirita macrophylla</i>	<i>Schizostachyum seshagiriana</i>

<i>Cirsium interpositum</i>	<i>Smilax minutiflora</i>
<i>Elatostema sikkimense</i>	<i>Sonerila khasiana</i>
<i>Elytranthe psilantha</i>	<i>Tetrastigma planicaule</i>
<i>Goodyera recurva</i>	<i>Vitis planicaulis</i>
<i>Indigofera sesquipedalis</i>	<i>Ziziphus rugosa</i> var. <i>glabrescens</i>

8.2.5.3 Faunal Resources

This sub-basin harbours about 54 species of mammals. Tiger (*Panthera tigris*), wild pig (*Coun alpinus*) and hog deer (*Axis porcinus*) are prominent. Tiger (*Panthera tigris*), Wild buffalo (*Bubalus bubalis*), Dhole (*Coun alpinus*), Chinese pangolin (*Manis pentadactyla*), Fishing cat (*Prionailurus viverrinus*) and Hispid hare (*Caprolagus hispidus*) have been kept under IUCN Red List “Endangered category” while Hog deer (*Cervus unicolor*) is under Vulnerable category. Eurasian otter (*Lutra lutra*) has been kept in Near Threatened category. Accordingly to Wildlife (Protection) Act, 1972 Schedules, Tiger (*Panthera tigris*) and Wild buffalo (*Bubalus bubalis*), Chinese pangolin (*Manis pentadactyla*), Fishing cat (*Prionailurus viverrinus*) and Hispid hare (*Caprolagus hispidus*) are the Schedule-I mammals. *Cuon alpinus*, *Lutra lutra*, *Viverricula indica*, *Paradoxurus hermaphrodites*, *Paguma larvata*, *Herpestes edwardsii*, *Hystrix brachyura* and *Felis chaus* are the Schedule-II mammals.

Dense forests in the sub-basin offer suitable habitat for large diversity of avi-fauna. More than 224 species of birds are reported from this area. It harbours number of Vulnerable and Near Threatened species. The species that are in Vulnerable list are Blyth’s tragopan (*Tragopan blythii*), Red-breasted Hill-Partridge (*Arborophila mandellii*), Rufous-necked Hornbill (*Aceros nipalensis*), Rusty-bellied Shortwing (*Brachypteryx hyperythra*), Beautiful Nuthatch (*Sitta Formosa*) and Chestnut-breasted Partridge (*Arborophila mandellii*). The species under Near Threatened category are Rufous-throated Wren-Babbler (*Spelaornis caudatus*) and Wedge-billed Wren-Babbler (*Sphenocichla humei*).

According to WPA, 1972, the area is home to 5 Schedule-I species. These are Black Eagle (*Ictinaetus malayensis*), Black redstart (*Phoenicurus ochruros*), Common buzzard (*Buteo buteo*), Oriental Honey Buzzard (*Pernis ptilorhynchus*), and Pied harrier (*Circus melanoleucos*).

8.2.5.4 Fish Diversity

Yamne sub-basin is quite rich in fish diversity with 62 species of fish reported from this area. This is primarily the mahseer zone where *Tor tor* and *Tor putitora* fish species predominantly found in the area. The lower part of Yamne river is characterised by wide river and very gentle gradient whereas higher reaches have moderate to steeper gradient.

Ten endemic fish species are found in the sub-basin. These are: *Garra lissorhynchus*, *Garra mcClellandi*, *Garra naganensis* (= *Garra tirapensis*), *Glyptothorax brevipinnis*, *Pseudecheneis sirenica*, *Lepidocephalichthys arunachalensis* (= *Nemacheilus arunachalensis*), *Aborichthys elongates*, *Aborichthys garoensis* (= *Nemacheilus garonesis*), *Schistura manipurensis* (= *Nemacheilus manipurensis*) and *Psilorhynchus arunachalensis*.

According to CAMP criteria 7 species belong to Endangered category. These are: *Glyptothorax cavia*, *Lepidocephalichthys arunachalensis* (= *Nemacheilus arunachalensis*), *Ompok bimaculatus*, *Pseudolaguvia shawi*, *Schistura multifasciata* (= *Nemacheilus multifasciatus*), *Syncrossus berdmorei* (= *Botia berdmorei*) and *Tor tor*.

Twenty species are under Vulnerable category. These are: *Aborichthys garoensis* (= *Nemacheilus garonesis*), *Amblyceps apangi*, *Anabas testudineus*, *Bangaba dero* (= *Labeo dero*), *Barilius barila*, *Barilius vagra*, *Botia rostrata*, *Garra lissorhynchus*, *Garra naganensis* (= *Garra tirapensis*), *Glyptothorax brevipinnis*, *Glyptothorax indicus* (= *Glyptothorax horai*), *Heteropneustes fossilis*, *Mystus bleekeri*, *Parachiloganis hodgarti* (= *Euchiloglanis hodgarti*), *Pseudecheneis sirenica*, *Psilorhynchus homaloptera*, *Puntius chola*, *Puntius sarana*, *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*), *Schistura manipurensis* (= *Nemacheilus manipurensis*) and *Schizothorax richardsonii*.

According to criteria defined by IUCN there are 3 species which are under Endangered category viz. *Lepidocephalichthys arunachalensis* (= *Nemacheilus arunachalensis*), *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*) and *Tor putitora*. There are 6 species under Vulnerable category i.e. *Aborichthys garoensis* (= *Nemacheilus garonesis*), *Bagarius bagarius*, *Botia rostrata*, *Cyprinion semiplotum* (= *Semiplotus semiplotus*), *Pseudecheneis sirenica* and *Schizothorax richardsonii* and 8 species are under Near Threatened category i.e. *Aborichthys kempfi* (= *Nemacheilus kempfi*), *Labeo pangusia*, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Ompok pabo*, *Ompok bimaculatus*, *Schistura manipurensis* (= *Nemacheilus manipurensis*), *Syncrossus berdmorei* (= *Botia berdmorei*) and *Tor tor*.

8.2.6 Simang Sub-basin

Simang sub-basin is comprised of the entire catchment of Simang river up to its confluence with Siang river on its right bank near Boleng town (refer Figure 8.9). Upper catchment of sub-basin constitutes a part of Mouling National Park.

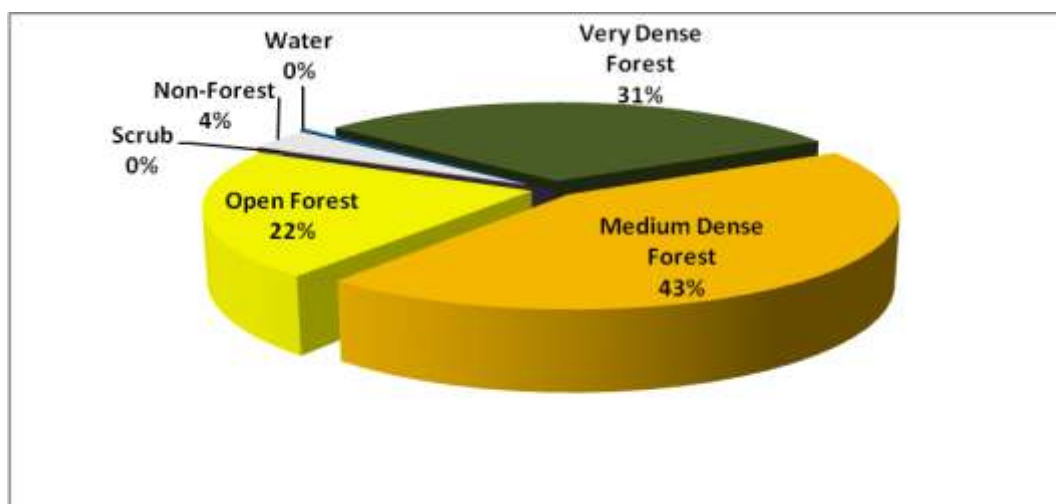


Figure 8.17: Area under different land use/ land cover categories in Simang Sub-basin

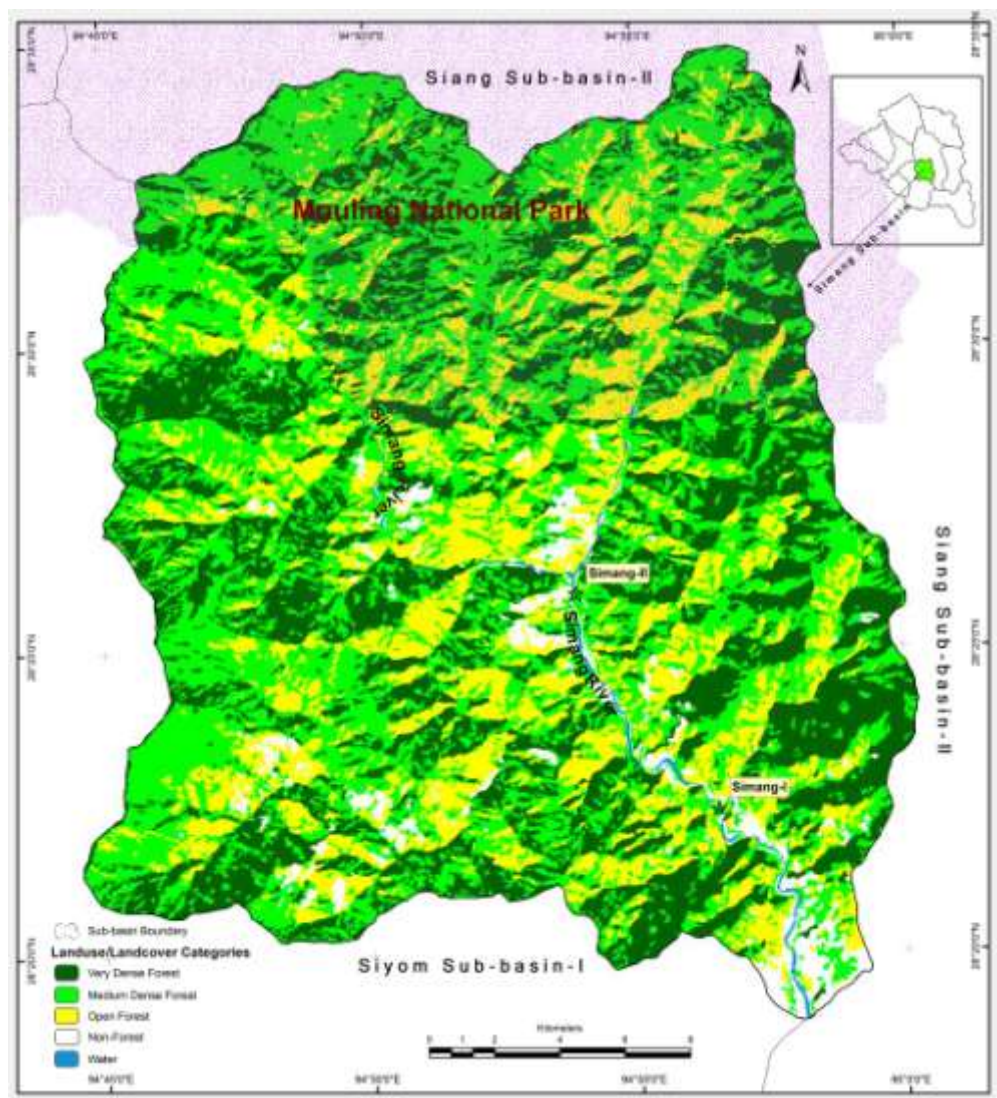


Figure 8.18: Land use/ land cover map of Simang Sub-basin

8.2.6.1 Forest Cover

As much as 96% of Simang sub-basin area is under forest cover (Figures 8.17 & 8.18). These belong to Assam Alluvial Plains Semi-Evergreen Forest, Eastern Sub-montane Semi-Evergreen Forest, Sub- Himalayan light Alluvial Semi- Evergreen Forest, Secondary Moist Bamboo Brakes (Pioneer Euphorbiaceous scrub) and Eastern Himalayan Dry Temperate Coniferous Forests.

8.2.6.2 Floristic Diversity

It constitutes the entire catchment of Simang river up to its confluence with Siang river. Around Boleng village Mixed semi-evergreen forests are seen at the right bank. Important constituents of the first storey are *Aglaia spectabilis*, *Castanopsis indica*, *Duabanga grandiflora*, *Dysoxylum gobara*, *Kydia calycina* and *Spondias pinnata*. Second storey is composed of *Callicarpa arborea*, *Erythrina stricta*, *Gynocardia odorata*, *Magnolia hodgsonii* and *Ostodes paniculata*. Along the riverine areas there are few trees of *Alangium chinense*, *Altsonia scholaris*, *Bischofia javanica*, *Oroxylum indicum* and *Saurauia punduana*. Shrubs are represented by species of *Boehmeria*, *Caesalpinia*, *Chromolaena*, *Debregeasia*, *Leea* and *Rubus*. The tree trunks are laden with several epiphytic mosses, ferns and climbers. The ground flora is represented by herbs and tall grasses viz., *Imperata cylindrica*, *Saccharum spontaneum*, *Setaria verticillata*, *Themeda arundinacea* and *Thysanolaena latifolia*.

Beyond Boleng only scattered patches of semi-evergreen vegetation is met with some seral communities of secondary forests all over the area. These are represented by palms (*Livistona*

jenkinsiana) and *Macaranga-Schima-Mallotus* association which ultimately leads to *Bischofia-Duabanga* association. The area in the catchment of Simang river from Boleng to the bank of Siang river is characterized by gentle slopes covered with dense mixed semi-evergreen vegetation. The prominent trees are *Albizia lebbbeck*, *Bischofia javanica*, *Castanopsis indica*, *Duabanga grandiflora*, *Ficus semicordata*, *Terminalia myriocarpa* and *Toona microcarpa*. The shrubby layer is represented by species of *Bambusa*, *Boehmeria*, *Brassiopsis*, *Clerodendrum*, *Lantana*, *Oxyspora* and *Rubus*. The ground flora is comprised of herbaceous species like *Artemisia nilagirica*, *Bidens bipinnata*, *Hedychium spicatum*, *Mikania micrantha*, *Saccharum spontaneum*, *Solanum nigrum* and *Xanthium strumarium*.

More than 220 species belonging to different plant groups have been recorded from the sub-basin. Major medicinally important plants found in the sub-basin are *Alpinia allughas*, *Alocasia macrorrhiza*, *Calotropis procera*, *Crassocephalum crepidioides*, *Drymaria cordata*, *Equisetum diffusum*, *Eupatorium odoratum*, *Ocimum gratissimum*, *Oxalis corniculata*, *Piper pedicellatum*, *Rauwolfia serpentina*, *Rhus javanica* and *Solanum torvum*.

Saurauia punduana is a Critically Endangered plant species as per IUCN Red List recorded from this area. *Begonia scitillans* is under rare category.

Among the species endemic to Arunachal Pradesh found in the sub basin are: *Ardisia pedunculosa*, *Begonia aborensis*, *Livistona jenkinsiana*, *Calanthe densiflora*, *Dendrobium hookerianum*, *Impatiens laevigata*, *Impatiens racemosa* and *Xanthophyllum burkillii*.

There are 28 species found in the sub-basin which are endemic to northeast India. The list is given below.

<i>Arisaema album</i>	<i>Indigofera sesquipedalis</i>
<i>Arisaema setosum</i>	<i>Musa sikkimensis</i>
<i>Arthraxon quarlinianus</i> var. <i>glabrescens</i>	<i>Ophiorrhiza succirubra</i>
<i>Baliospermum calycinum</i>	<i>Ophiorrhiza repens</i>
<i>Bambusa barpatharica</i>	<i>Peliosanthes macrophylla</i>
<i>Bambusa rangaensis</i>	<i>Persea minutiflora</i>
<i>Begonia sikkimensis</i>	<i>Platanthera cumminsiana</i>
<i>Beilschmiedia brandisii</i>	<i>Plectranthus griffithii</i>
<i>Brassaiopsis hispida</i>	<i>Randia griffithii</i>
<i>Brassiopsis simplicifolia</i>	<i>Rubus lucens</i>
<i>Cirsium interpositum</i>	<i>Schizostachyum helferi</i>
<i>Coelogyne arunachalensis</i>	<i>Schizostachyum pergracile</i>
<i>Eria jenggingensis</i>	<i>Smilax minutiflora</i>
<i>Goodyera recurva</i>	<i>Ziziphus rugosa</i> var. <i>glabrescens</i>

8.2.6.3 Faunal Resources

This sub-basin harbours about 52 species of mammals. Tiger (*Panthera tigris*), wild pig (*Coun alpinus*) and hog deer (*Axis porcinus*) are prominent. Tiger (*Panthera tigris*), Wild buffalo (*Bubalus bubalis*), Dhole (*Coun alpinus*), Chinese pangolin (*Manis pentadactyla*), Fishing cat (*Prionailurus viverrinus*, and Hispid hare (*Caprolagus hispidus*) have been kept under IUCN Red List “Endangered category” while Hog deer (*Cervus unicolor*) is under Vulnerable category. Eurasian otter (*Lutra lutra*) has been kept in Near Threatened category. Accordingly to Wildlife (Protection) Act, 1972 Schedules, Tiger (*Panthera tigris*), Wild buffalo (*Bubalus bubalis*), Chinese pangolin (*Manis*

pentadactyla), Fishing cat (*Prionailurus viverrinus*) and Hispid hare (*Caprolagus hispidus*) are the Schedule-I mammals. *Cuon alpinus*, *Lutra lutra*, *Viverricula indica*, *Paradoxurus hermaphrodites*, *Paguma larvata*, *Herpestes edwardsii*, *Hystrix brachyura* and *Felis chaus* are the Schedule-II mammals.

As upper catchment area of Simang River is comprised of a part of Mouling National Park it is rich in avi-fauna. Amongst the 211 bird species reported from this sub-basin 4 species are Schedule-I species. These are Black kite (*Milvus migrans*), Eurasean sparrowhawk (*Accipiter nisus*), Black redstart (*Phoenicurus ochruros*), Black eagle (*Ictinaetus malayensis*) and Shikra (*Accipiter badius*). Three species are under IUCN Redlist i.e. *Rynchops albicollis*, *Sitta formosa* and *Spelaornis caudatus* under Vulnerable category

8.2.6.4 Fish Diversity

Fish diversity is comprised of 41 species. Mahseer (*Tor putitora* and *T. tor*), *Labeo pangusia*, *Garra gotyla*, and *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*) are the dominant fish species recorded from this sub-basin.

According to CAMP criteria Mahseer (*Tor putitora* and *T. tor*) is under Endangered category while two species *Garra gotyla gotyla* and *Cyprinion semiplotum* (= *Semiplotus semiplotus*) of Cyprinidae family fall under the Vulnerable category. Four species: *Puntius sarana* and *Neolissochilus hexagonolepis* of Cyprinidae family fall under Near Threatened category and all others fish species falls under the least concern category.

According to IUCN criteria only Golder mahseer (*Tor putitora*) is under Endangered category. There are 4 species under Vulnerable category i.e. *Botia rostrata*, *Cyprinion semiplotum* (= *Semiplotus semiplotus*), *Pseudecheneis sirenica* and *Schizothorax richardsonii* and 6 species are under Near Threatened category i.e. *Labeo pangusia*, *Neolissochilus hexagonolepis* (= *Acrossocheilus hexagonolepis*), *Ompok bimaculatus*, *Schistura manipurensis* (= *Nemacheilus manipurensis*), *Syncrossus berdmorei* (= *Botia berdmorei*) and *Tor tor*.

Three endemic species are found in this sub-basin viz. *Glyptothorax brevipinnis*, *Pseudecheneis sirenica* and *Schistura manipurensis* (= *Nemacheilus manipurensis*).

8.2.7 Hirit Sub-basin

Hirit sub-basin is comprised of entire catchment of Hirit river which is one of the largest tributaries of Siyom river at lower reaches and it meets Siyom river near Kamba village (Figure 8.19). Four hydropower projects are planned in Hirit Sub-basin i.e. Hirit Korong HEP on Hirit R., Siri Korong HEP on Siri Korong N., Soying Korong HEP on Soying Korong N., and a small project Sebu HEP on Sebu nala. Another project Hirit HEP earlier planned on Hirit R. has now been abandoned.

8.2.7.1 Forest Cover

Almost 97% of Hirit sub-basin is under forest cover of which 79% is Dense to Very Dense forest (Figures 8.20 & 8.21). Entire Yordi Rabe Supse Wildlife Sanctuary constitutes the upper catchment of Hirit sub-basin. Only at lower elevations there are settlements whereas most of the area is under pristine forests.

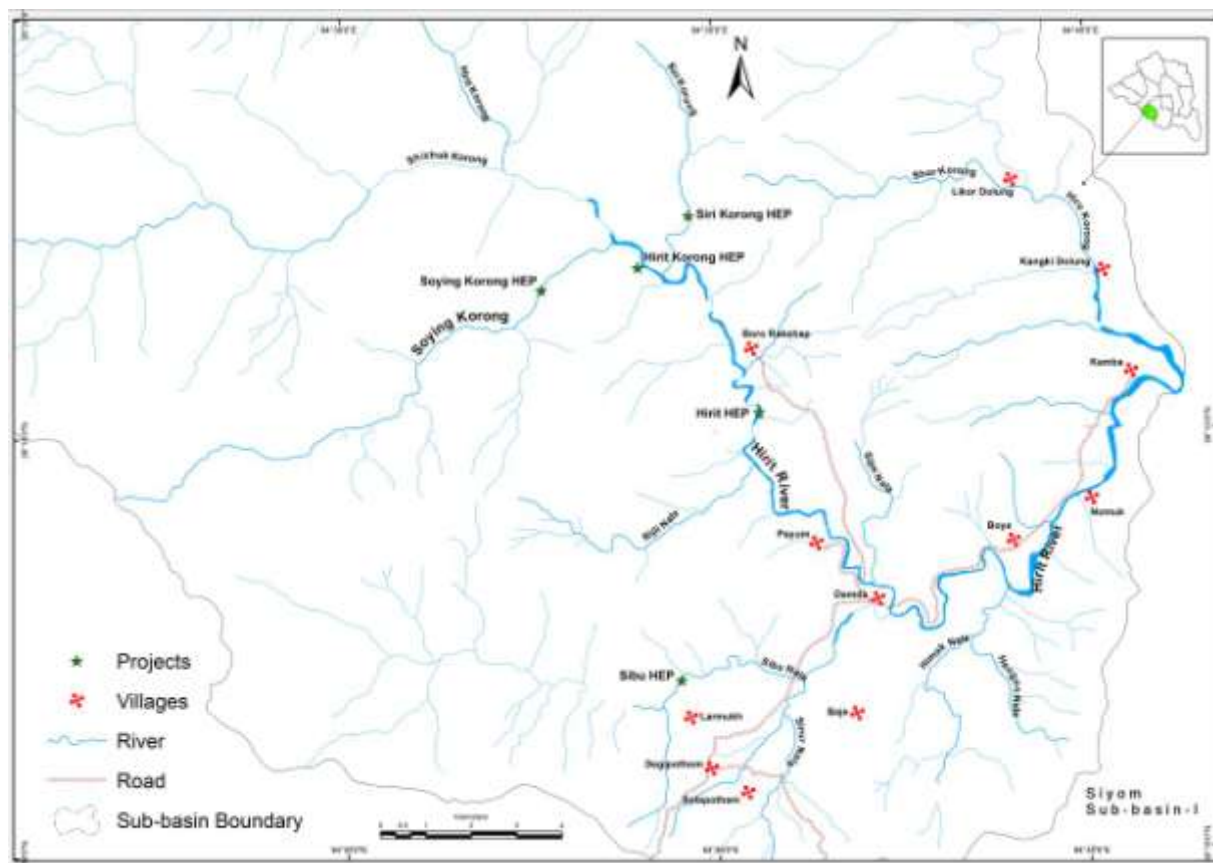


Figure 8.19: Drainage map of Hirit Sub-basin

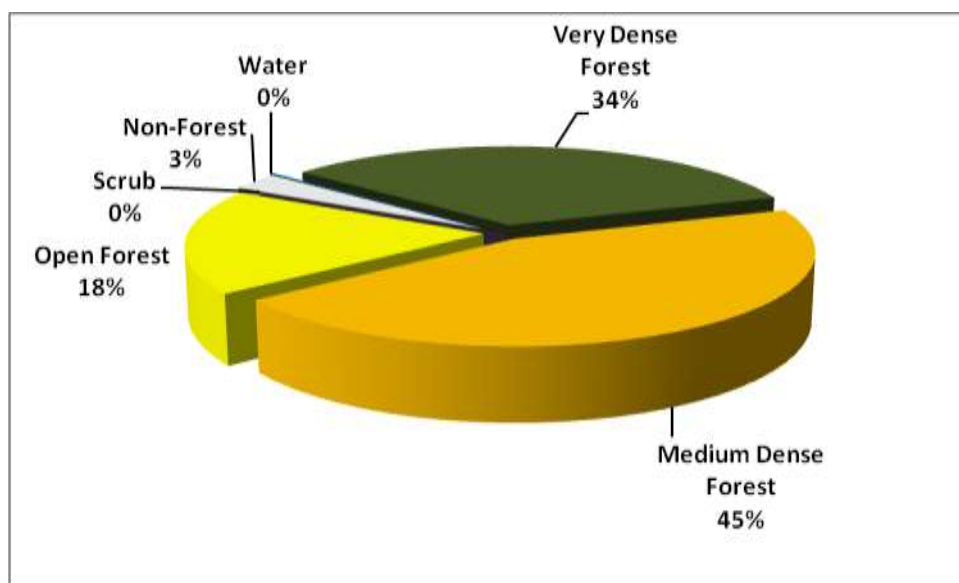


Figure 8.20: Area under different land use/ land cover categories in Hirit Sub-basin

8.2.7.2 Floristic Diversity

The forests in Hirit sub-basin including Yordi Rabe Supse WLS vary from Sub-tropical to temperate broadleaved forests, with some areas under Subtropical pine forests. Its biodiversity is under-explored and detailed biological exploration of the sanctuary is yet to be carried out and is considered to be home of number of RET species. It comprises the catchment area of Hirit river. Hirit is one of the majot hydropower projects proposed in the catchment.

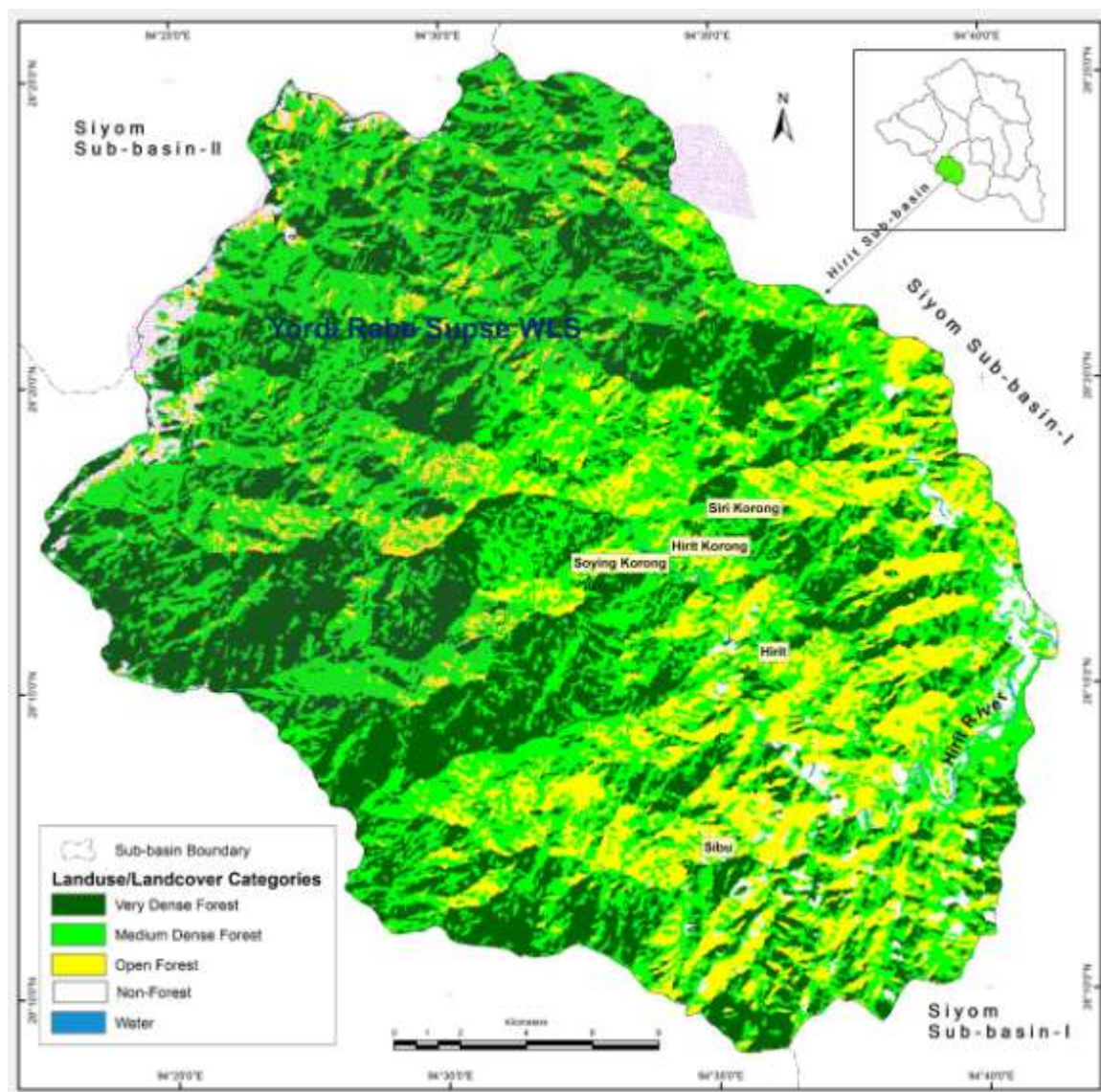


Figure 8.21: Land use/ land cover map of Hirit Sub-basin

The vegetation especially around the proposed Hirit Korong HE project area i.e. near Payum village and Boro Rakshap is comprised of dense sub-Himalayan light alluvial semi evergreen forest in the lower reaches. In the mid hills, sub-tropical wet hill forests are found. Towards higher hills wet temperate forests are prevalent. On the right bank slopes of Hirit Korong, the top canopy of the forest is occupied by some tall trees like *Aglaia spectabilis*, *Ailanthus integrifolia*, *Alnus nepalensis*, *Bischofia javanica*, *Dysoxylum gobara*, *Engelhardtia spicata*, *Kydia calycina*, *Michelia champaca*, *Magnolia hodgsonii*, *M. rabaniana* and *Terminalia myriocarpa*. Second storey is represented by some small trees like *Euonymus*, *Eurya*, *Ficus*, *Oroxylum*, *Ostodes* and *Trema*. Understorey is occupied by shrubs like *Aconogonum molle*, *Alphonsea spinulosa*, *Bambusa tulda*, *Boehmeria macrophylla*, *Maesa chisia*, *Melocalamus compactiflorus*, *Oxyspora paniculata*, *Pandanus nepalensis* and *Trachycarpus takil*. Climbers and epiphytes are abundant. Climbers are represented by species of *Clematis*, *Dioscorea*, *Cissus*, *Derris*, *Pothos*, *Raphidophora*, *Rubia* and *Stephania*. Herbaceous flora is comprised of ferns, orchids, grasses and many forbs like *Amomum aromaticum*, *Begonia burkii*, *B. megaptera*, *B. nepalensis*, *Colocasia affinis*, *Hedychium spicatum*, *Paliosanthes teta* and *Setaria palmifolia*.

On the left bank slopes, species composition at lower reaches is more or less similar but undergrowth is very dense with dense population of tree fern (*Alsophila spinulosa*) and kewra palm (*Pandanus nepalensis*) trees.

Around areas near Poyum Basti fairly dense mixed light alluvial semi-evergreen forest occurs at lower reaches. The top canopy of the forest is represented *Aglaia hierne*, *Garcinia lanceolata*, *Dysoxylum grande*, *Endospermum chinense*, *Lannea coromandelica* and *Sterculia guttata*. Second storey is represented by *Eurya acuminata*, *Cinnamomum glauscens*, *Clausena heptaphylla*, *Litsea doshia* and *Sapium sebiferum*. Undergrowth is open and represented by shrubs like *Boehmeria macrophylla*, *Calamus floribundus*, *Oxyspora paniculata*, *Pinanga gracilis* and *Pteris* sp. Herbs are represented by weeds and some other forbs viz., *Amomum subulatum*, *Colocasia affinis*, *Molineria capitulata*, *Musa balbisiana* and *Polia hasskarlii*.

Total 214 plant species have been enumerated from this sub-basin. The sub-basin harbours some of the rare and endangered plant species like *Begonia burkili*, *Begonia scintillans*, and orchid species like *Cymbidium eberneum*, *Diplomeris hirsuta*, *Galeola falconeri*, *Livistona jenkinsiana* and *Paphiopedilum fairrieianum*.

Amongst the Arunachal endemic species following are found in the sub-basin: *Calamus leptospadix*, *Calanthe densiflora*, *Dendrobium cathcartii*, *Dendrobium hookerianum*, *Eria ferruginea*, *Garcinia acuminata*, *Liparis plantaginea*, *Livistona jenkinsiana*, *Michelia oblonga*, *Prenanthes scandens* and *Zalacca secunda*.

There are 37 species found in the sub-basin which are endemic to northeast India. The list is given below.

<i>Ardisia pedunculosa</i>	<i>Goodyera recurva</i>
<i>Arisaema album</i>	<i>Ophiorrhiza succirubra</i>
<i>Arisaema setosum</i>	<i>Ophiorrhiza repens</i>
<i>Arundinella khaseana</i>	<i>Persea minutiflora</i>
<i>Baliospermum calycinum</i>	<i>Phoebe goalparensis</i>
<i>Bambusa barpatharica</i>	<i>Platanthera cumminsiana</i>
<i>Bambusa rangaensis</i>	<i>Plectranthus griffithii</i>
<i>Begonia sikkimensis</i>	<i>Pogostemon amarantoides</i>
<i>Begonia tessaricarpa</i>	<i>Psychotria silhetensis</i> var. <i>tomentosa</i>
<i>Begonia thomsonii</i>	<i>Randia griffithii</i>
<i>Beilschmiedia brandisii</i>	<i>Schizostachyum helferi</i>
<i>Beilschmiedia pseudomicropora</i>	<i>Schizostachyum polymorphum</i>
<i>Brassaiopsis hispida</i>	<i>Schizostachyum seshagiriana</i>
<i>Brassaiopsis simplicifolia</i>	<i>Sedum triactina</i>
<i>Chirita macrophylla</i>	<i>Smilax minutiflora</i>
<i>Coelogyne arunachalensis</i>	<i>Sonerila khasiana</i>
<i>Elatostema sikkimense</i>	<i>Tetrastigma planicaule</i>
<i>Elytranthe psilantha</i>	<i>Vaccinium venosum</i>
<i>Euonymus lawsonii</i>	

8.2.7.3 Faunal Resources

Important mammals reported from the area include Tiger (*Panthera tigris*), Clouded leopard (*Neofelis nebulosa*), Asiatic black bear (*Ursus thibetanus*), Serow (*Capricornis sumatraensis*) and Goral (*Nemorhaedus goral*). However, more detailed surveys are required to adequately catalogue

the mammalian diversity of the area. Project Snow Leopard lists Yordi Rabe Supse as a potential snow leopard (*Uncia uncia*) conservation area requiring surveys to assess its appropriateness for inclusion under the program (SFRI). However according an assessment by SFRI, there are 118 mammalian species that are reported from the area. Tiger (*Panthera tigris*) and Fishing cat (*Prionailurus viverrinus*) are under Endangered category according to IUCN Red List) while Clouded leopard (*Neofelis nebulosa*), Capped langur (*Trachypithecus pileatus*), Marbled cat (*Pardofelis marmorata*) and Mishmi takin (*Budorcas taxicolor*) are in Vulnerable category. As per WPA, 1972 12 mammals are Schedule-I species. High percentage of rarity ascribes high sensitivity to this sub-basin.

As more than 97% of the sub-basin area is under forests it harbours rich diversity of avi-fauna. More than 205 species of birds are reported from the sub-basin. According IUCN Red list criteria the species that are in Vulnerable category are Blyth's tragopan (*Tragopan blythii*), Red-breasted Hill-Partridge (*Arborophila mandellii*), Rufous-necked Hornbill (*Aceros nipalensis*), Rusty-bellied Shortwing (*Brachypteryx hypertyra*), Beautiful Nuthatch (*Sitta Formosa*) and Chestnut-breasted Partridge (*Arborophila mandellii*). The species under Near Threatened category are Rufous-throated Wren-Babbler (*Spelaornis caudatus*) and Wedge-billed Wren-Babbler (*Sphenocichla humei*).

According to WPA, 1972, the area is home to 5 Schedule-I species. These are Black Eagle (*Ictinaetus malayensis*), Black redstart (*Phoenicurus ochruros*), Common buzzard (*Buteo buteo*), Oriental Honey Buzzard (*Pernis ptilorhynchus*), and Pied harrier (*Circus melanoleucos*).

Information regarding birdlife and other faunal groups is also scanty and no Management plan has yet been prepared by the Department of Environment & Forests, Itanagar. A large population of Rufous-necked Hornbill (*Aceros nipalensis*) is believed to occur in Yordi Rabe Supse, and there have been unconfirmed reports of Chestnut-breasted hill Partridge (*Arborophila mandellii*) which have been put under Vulnerable category by IUCN (IBA, <http://www.birdlife.org>). While Hill partridge has been put under A1 (Globally threatened species) and A2 (Restricted-range species) categories and Hornbill has been included under A1 (Globally threatened species) category. The sanctuary has been put under IN-AR-27 IBA category with A1 criterion.

8.2.7.4 Fish Diversity

The sub-basin harbours more than 42 species of fishes which includes species like mahseer (*Tor putitora*), snow trout (*Schizothorax* spp.), *Garra gotyla*, *Labeo calbasu*, *Labeo pangusia*, *Garra annandeli*, *Acrossocheilus hexagonolepis*, *Schistura multifasciata* (= *Nemacheilus multifasciatus*), *Puntius ticto*, *Psilorhynchus balitora* and *Glossogobius giuris* are found.

According to CAMP criteria Mahseer (*Tor tor*) is under Endangered category while two species *Garra gotyla gotyla* and *Cyprinion semplotum* (= *Semplotus semplotus*) of Cyprinidae family fall under the Vulnerable category. Four species: *Puntius sarana* and *Neolissochilus hexagonolepis* of Cyprinidae family fall under Near Threatened category.

According to IUCN criteria only Golder mahseer (*Tor putitora*) is under Endangered category. There are 4 species under Vulnerable category i.e. *Aborichthys garoensis* (= *Nemacheilus garoensis*), *Botia rostrata*, *Cyprinion semplotum* (= *Semplotus semplotus*) and *Schizothorax richardsonii* and 9 species are under Near Threatened category i.e. *Balitora brucei*, *Labeo pangusia*, *Nemacheilus devdevi*, *Ompok bimaculatus*, *Ompok pabda*, *Neolissochilus hexagonolepis*

(=*Acrossocheilus hexagonolepis*), *Ompok bimaculatus*, *Schistura manipurensis* (= *Nemacheilus manipurensis*), *Syncrossus berdmorei* (= *Botia berdmorei*) and *Tor tor*.

Five endemic species are found in this sub-basin viz. *Garra lissorhynchus*, *Garra mcClellandi*, *Glyptothorax brevipinnis*, *Pseudecheneis sirenica* and *Schistura manipurensis* (= *Nemacheilus manipurensis*).

Tor tor and *Labeo pangusia* migrate into Hirit river for spawning. *Schizothorax richardsonii* is an important migratory fish species in this sub-basin.

8.2.8 Siyom Sub-basin-I

This sub-basin constitutes the lower catchment of Siyom river up to its confluence with Siang river excluding the catchment of Hirit river and Along is the major town located here which is the headquarter of West Siang district (Figure 8.22). Siyom Middle is the main project located on Siyom river while there are other two small projects planned on its tributary i.e. Pitgong and Kaying HEPs.

8.2.8.1 Forest Cover

Like other sub-basins Siyom Sub-basin-I also is under forest cover (91%) of which Very Dense and Dense Forest cover accounts for 73% (Figures 8.23 & 8.24).

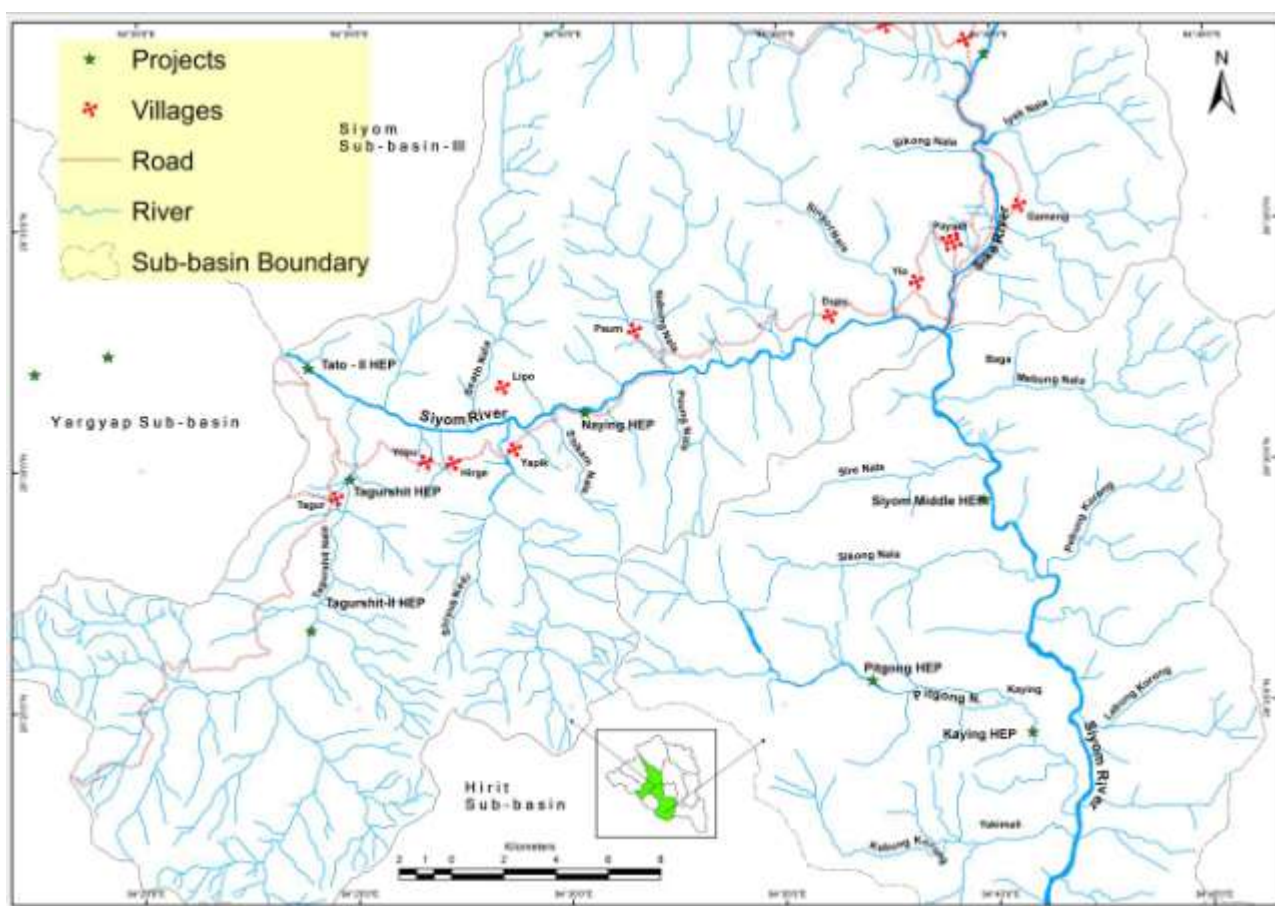


Figure 8.22: Drainage map of Siyom Sub-basin-I & II

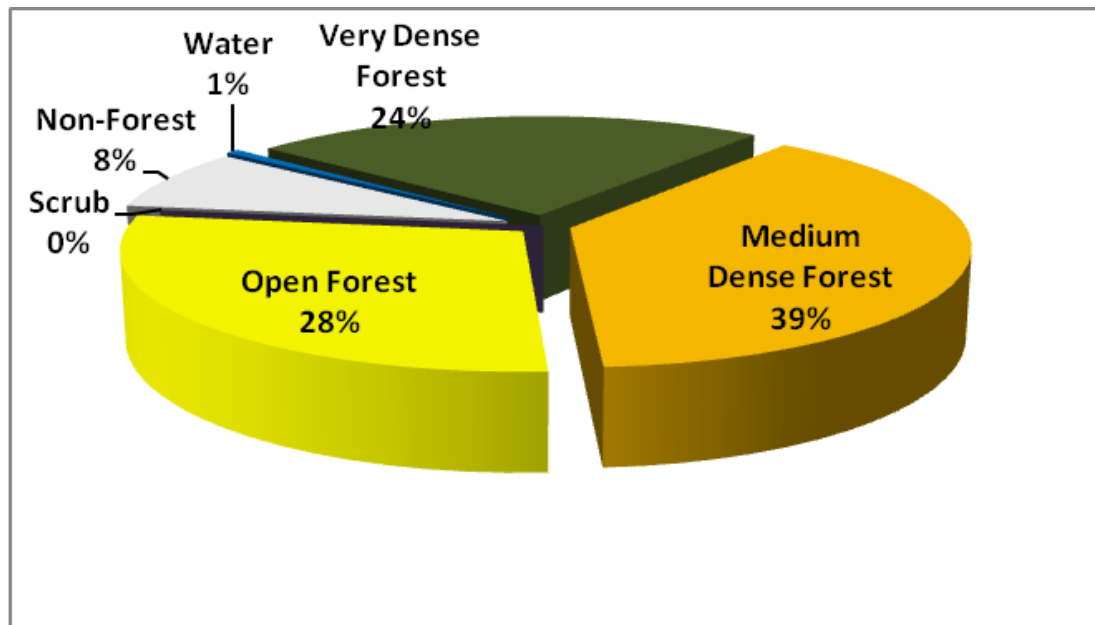


Figure 8.23: Area under different land use/ land cover categories in Siyom Sub-basin-I

8.2.8.2 Floristic Diversity

Siyom is the largest tributary of Siang river and this area covers the forests upstream of Koreng, Lokpeng, Tark and Along areas. On both the banks of Siyom river, patches of semi-evergreen forest interspersed with agricultural fields and settlements in the lower reaches can be seen. Main components of trees in this area are *Anthocephalus cadamba*, *Artocarpus chaplasha*, *Bauhinia purpurea*, *Bischofia javanica*, *Duabanga grandiflora*, *Endospermum chinense*, *Ficus semicordata*, *Gynocardia odorata* and *Pterospermum acerifolium*. Understory is comprised of *Alsophila spinulosa*, *Abroma angusta*, *Boehmeria macrophylla*, *Schefflera bengalensis*, *Murraya koenigii* and *Oroxylum indicum*. At many places dense patches of tall bamboos are found all along the roadside. Many twiners like *Cissus repens*, *Entada phaseoloides*, *Cryptolepis buchanani*, *Canavalia gladiata* and *Stephania elegans* are found on the trees and forest floor. A parasitic plant like *Scurrula elata* can be seen growing on *Ficus semicordata* and Citrus trees. Some scattered populations of *Pandanus nepalensis* is also seen in the area. Road construction, collection of fuel and fire wood and *jhumming* has led to the formation of secondary forests in the area. At many places prominent paddy fields, Citrus orchards and *Musa* thickets can be seen.

From this sub-basin 248 plant species were recorded. The main trees are *Ailanthus grandis*, *Terminalia myriocarpa*, *Cinnamomum pauciflorum*, *Ficus semicordata* and the shrubs are *Lithocarpus listeri*, *Macaranga denticulata*, *Saurauia nepalensis*, *Trevesia palmata*, *Calamus floribundus*, *Ficus oligodon* and *Musa acuminata*. The ground layer is comprised of plant species like *Piper sylvaticum*, *Solanum torvum*, *Embelia ribes*, *Alpinia allughas*, *Begonia nepalensis*, *Elatostema sessile*, *Hedychium spicatum* and *Rubia cordifolia*. *Alnus nepalensis* and grasses like *Saccharum spontaneum* and *Thysanolaena latifolia* are also commonly found.

The sub-basin harbours some of the rare and endangered plant species like *Begonia burkili*, *Begonia scintillans*, *Calamus inermis*, *Camellia siangensis*, *Cymbidium eberneum*, *Diplomeris hirsuta*, *Galeola falconeri*, *Livistona jenkinsiana*, *Magnolia gustavii*, *Paphiopedilum fairrieum*, *Pauia belladonna* and *Xanthophyllum burkillii*.

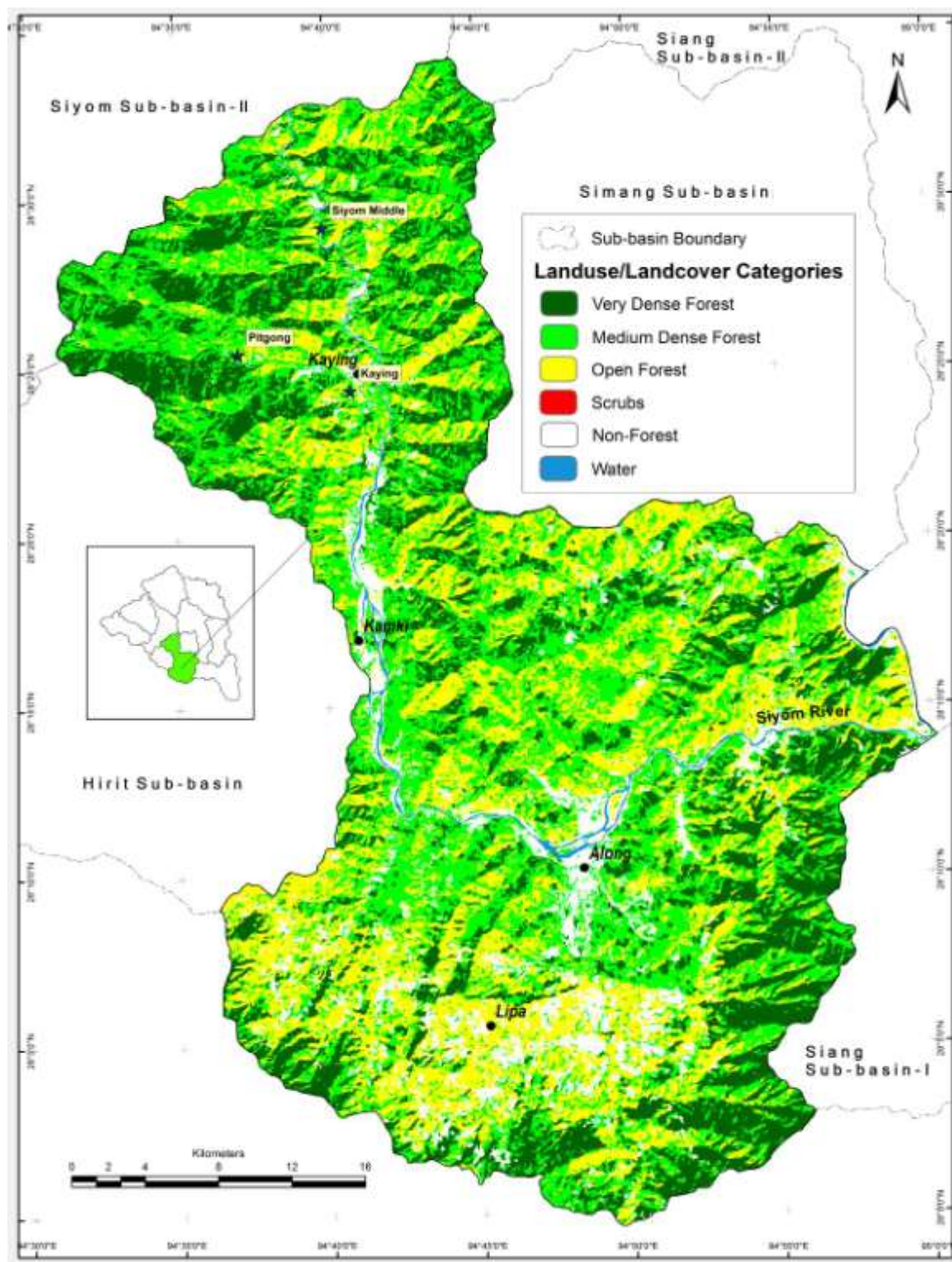


Figure 8.24: Land use/ land cover map of Siyom Sub-basin-I

Amongst the endemic species following are found in the sub-basin: *Aglaia edulis*, *Calamus leptospadix*, *Calanthe densiflora*, *Dendrobium cathcartii*, *Dendrobium hookerianum*, *Eria ferruginea*, *Garcinia acuminata*, *Liparis plantaginea*, *Livistona jenkinsiana*, *Luculia pinceana*, *Magnolia rabaniana*, *Michelia oblonga*, *Prenanthes scandens*, *Psychotria aborensis*, *Schizostachyum arunachalensis* and *Zalacca secunda*.

There are 28 species reported from this sub-basin which are endemic to north-east. These are *Arisaema setosum*, *Brassaiopsis hispida*, *Brassaiopsis simplicifolia*, *Peliosanthes macrophylla*, *Cirsium interpositum*, *Begonia sikkimensis*, *Begonia tessaricarpa*, *Begonia thomsonii*, *Plectranthus griffithii*, *Pogostemon amarantoides*, *Beilschmiedia brandisii*, *Beilschmiedia pseudomicropora*,

Persea minutiflora, *Schizostachyum polymorphum*, *Schizostachyum pergracile*, *Ophiorrhiza repens*, *Euonymus lawsonii*, *Sedum triactina*, *Indigofera sesquipedalis*, *Chirita hookerii*, *Phoebe goalparensis*, *Elytranthe psilantha*, *Musa sikkimensis*, *Eria jenggingensis*, *Goodyera recurva*, *Platanthera cumminsiana*, *Arthraxon quarlinianus* var. *glabrescens*, *Arundinella khaseana*, *Ophiorrhiza repens*, *Psychotria silhetensis* var. *tomentosa*, *Randia griffithii* and *Rubus lucens*.

8.2.8.3 Faunal Resources

Important mammals reported from the area include Clouded leopard (*Neofelis nebulosa*), Asiatic black bear (*Ursus thibetanus*), and Serow (*Capricornis sumatraensis*). However, more detailed surveys are required to adequately catalogue the mammalian diversity of the area. According an assessment based upon secondary data compilation, there are 88 mammalian species that are reported from the area. Tiger (*Panthera tigris*) and Fishing cat (*Prionailurus viverrinus*) are under Endangered category according to IUCN Red List) while Clouded leopard (*Neofelis nebulosa*), Capped langur (*Trachypithecus pileatus*), Marbled cat (*Pardofelis marmorata*) and Mishmi takin (*Budorcas taxicolor*) are in Vulnerable category. As per WPA, 1972 12 mammals are Schedule-I species.

As this sub-basin lies adjacent to two protected areas i.e. Mouling National park and Yordi Rabe Supse WLS, it also harbours rich diversity of avi-fauna. More than 194 species of birds are reported from the sub-basin. According IUCN Red list criteria the species that are in Vulnerable category are Red-breasted Hill-Partridge (*Arborophila mandellii*), Rufous-necked Hornbill (*Aceros nipalensis*), Rusty-bellied Shortwing (*Brachypteryx hyperythra*), Beautiful Nuthatch (*Sitta Formosa*) and Chestnut-breasted Partridge (*Arborophila mandellii*). The species under Near Threatened category are Rufous-throated Wren-Babbler (*Spelaeornis caudatus*) and Wedge-billed Wren-Babbler (*Sphenocichla humei*).

According to WPA, 1972, the area is home to 5 Schedule-I species. These are Black Eagle (*Ictinaetus malayensis*), Black redstart (*Phoenicurus ochruros*), Common buzzard (*Buteo buteo*), Oriental Honey Buzzard (*Pernis ptilorhynchus*), and Pied harrier (*Circus melanoleucos*).

8.2.8.4 Fish Diversity

According to a recent study undertaken by Bagra and Das (2010) regarding the fish diversity of Siyom river in this sub-basin there are 43 species. These include species like mahseer (*Tor tor*, and *Tor putitora*), snow trout (*Schizothorax* spp.), *Garra gotyla*, *Labeo calbasu*, *Labeo pangusia*, *Garra annandeli*, *Acrossocheilus hexagonolepis*, *Schistura multifasciata* (= *Nemacheilus multifasciatus*), *Puntius ticto*, *Psilorhynchus balitora* and *Glossogobius giuris* are found.

Eight endemic species are found in thus sub-basin. These are: *Aborichthys elongates*, *Batasio fasciolatus*, *Garra lissorhynchus*, *Garra naganensis* (= *Garra tirapensis*), *Lepidocephalichthys arunachalensis* (= *Nemacheilus arunachalensis*), *Nemacheilus devdevi*, *Psilorhynchus arunachalensis* and *Schistura manipurensis* (= *Nemacheilus manipurensis*).

According to CAMP criteria the species falling under Endangered category are : *Amblyceps arunachalensis*, *Anguilla bengalensis*, *Lepidocephalichthys arunachalensis* (= *Nemacheilus arunachalensis*), *Nemacheilus devdevi*, *Pterocryptis gangelica* (= *Silurus afgana*), *Schistura multifasciata* (= *Nemacheilus multifasciatus*), *Tor putitora* and *Tor tor*.

Fourteen species fall under Vulnerable category and these are: *Amblyceps apangi*, *Bagarius bagarius*, *Bangaba dero* (= *Labeo dero*), *Barilius vagra*, *Botia rostrata*, *Cyprinion semiplotum*

(=*Semiplotus semiplotus*), *Cyprinus carpio*, *Garra gotyla gotyla*, *Garra kemp*i, *Garra lissorhynchus*, *Garra naganensis* (= *Garra tirapensis*), *Puntius sarana*, *Schistura manipurensis* (= *Nemacheilus manipurensis*) and *Schizothorax richardsonii*.

According to criteria defined by IUCN there are 2 species which are under Endangered category viz. *Lepidocephalichthys arunachalensis* (= *Nemacheilus arunachalensis*), and *Tor putitora*. There are 7 species under Vulnerable category i.e. *Aborichthys garoensis* (= *Nemacheilus garonesis*), *Bagarius bagarius*, *Botia rostrata*, *Cyprinion semiplotum* (= *Semiplotus semiplotus*), *Cyprinus carpio*, *Pseudecheneis sirenica* and *Schizothorax richardsonii* and 4 species are under Near Threatened category i.e. *Schistura manipurensis* (= *Nemacheilus manipurensis*), *Syncrossus berdmorei* (= *Botia berdmorei*), *Tor tor* and *Wallago attu*.

8.2.9 Siyom Sub-basin-II

Siyom Sub-basin-II comprises the middle catchment of Siyom river located between the confluence of Sike river near Gameng and confluence of Yargyap Chhu near Tato village (refer Figure 8.22). Two major projects are planned on Siyom river in this stretch i.e. Naying and Tato-II HEPs. One project is planned on its tributary viz. Gameng HEP on Sike river while two projects are planned on Tagurshit nadi a right bank tributary.

8.2.9.1 Forest Cover

More than 75% of the sub-basin is under dense to very dense forest cover (Figures 8.25 & 8.26). The area is represented by evergreen tropical forest. The tree canopy is dominated by *Albizia lucida*, *Aralia armata*, *Kydia calycina* and *Ficus semicordata*. Middle canopy is composed of some small trees and shrubs like *Saurauria nepalensis*, *Trevesia palmata*, *Ficus oligodon*, *Bambusa pallida*, *Dendrocalamus hamiltonii*, *Calamus floribundus* and *Embelia ribes*. The herbaceous layer is represented by *Begonia nepalensis*, *Costus speciosus*, *Dicranopteris linearis*, *Elatostema sessile*, *Nephrolepis cordifolia*, *Pteris quadriaurita* and *Pteridium aquilinum*.

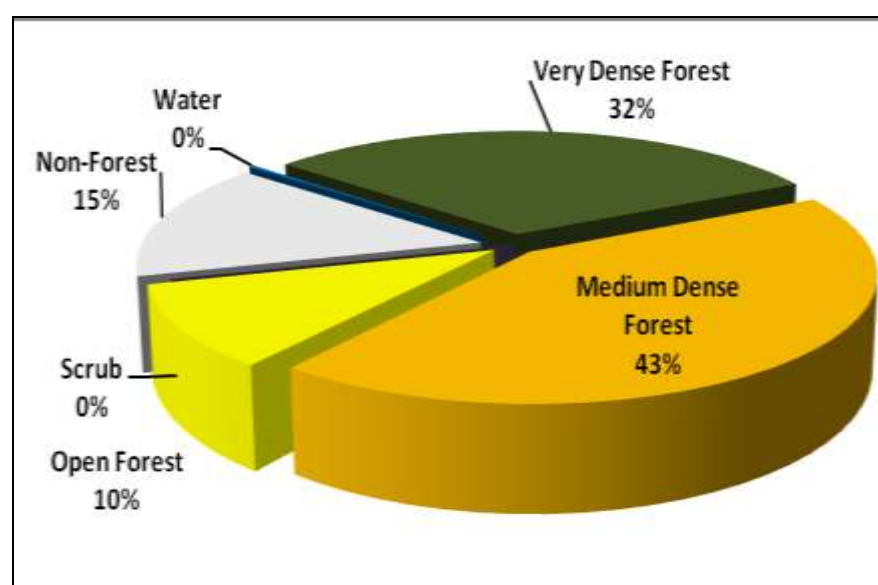


Figure 8.25: Area under different land use/ land cover categories in Siyom Sub-basin-II

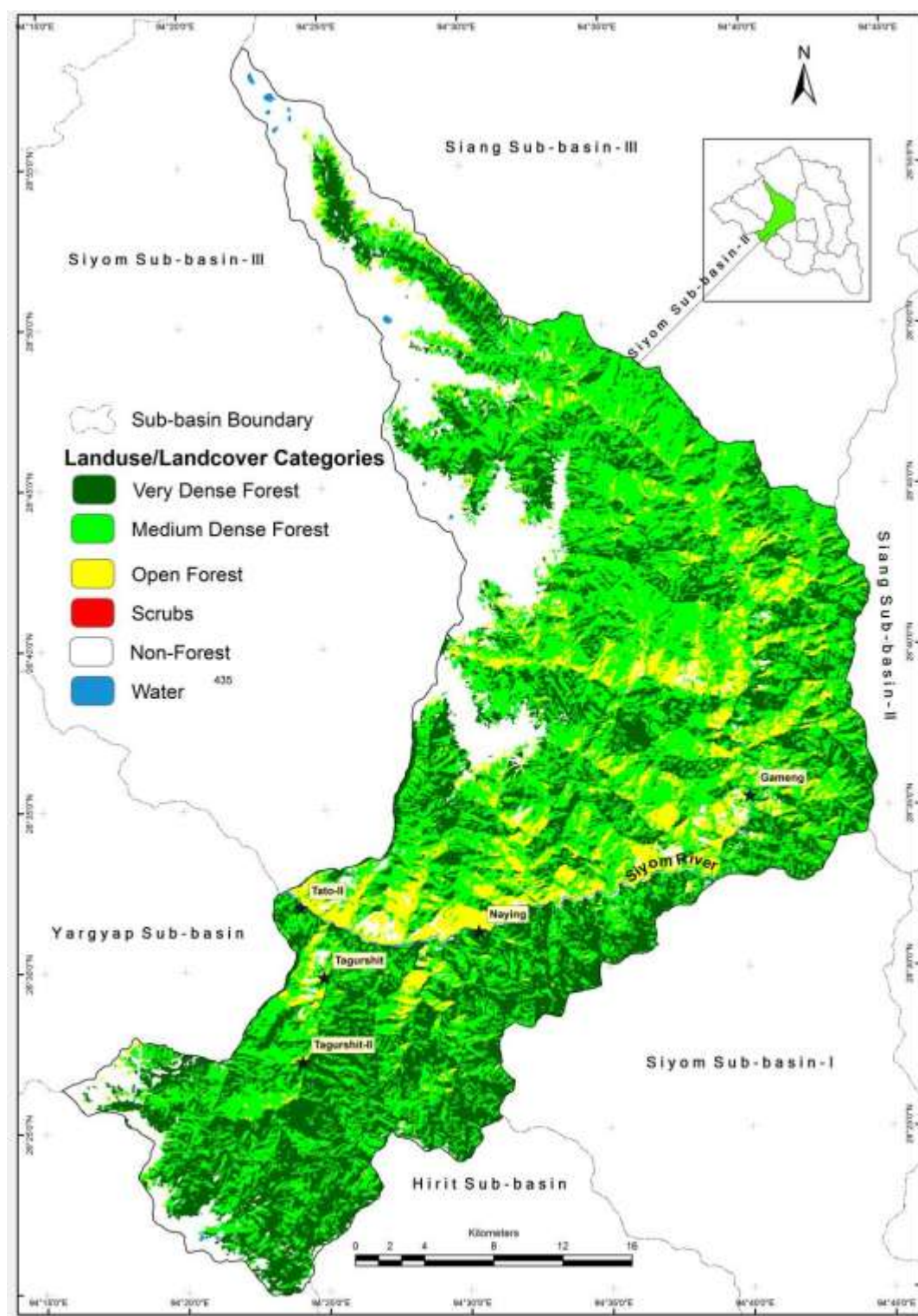


Figure 8.26: Land use/ land cover map of Siyom Sub-basin-II

8.2.9.2 Floristic Diversity

Both the banks of Siyom river are with moderate to steep slope are covered with dense tree canopy. The tree canopy is represented by *Ailanthus grandis*, *Terminalia myriocarpa*, *Cinnamomum pauciflorum*, *Ficus semicordata*. Middle canopy is with small trees and shrubs like *Lithocarpus listeri*, *Macaranga denticulata*, *Saurauia nepalensis*, *Trevesia palmata*, *Calamus floribundus*, *Ficus oligodon* and *Musa acuminata*. The ground layer is comprised of some shrubs and herbs, such as *Piper sylvaticum*, *Solanum torvum*, *Embelia ribes*, *Alpinia allughas*, *Begonia nepalensis*, *Elatostema sessile*, *Hedychium spicatum* and *Rubia cordifolia*. *Alnus nepalensis* and grasses like *Saccharum spontaneum* and *Thysanolaena latifolia* are commonly observed near river bank only.

The area is represented by evergreen tropical forest. The tree canopy is dominated by *Albizia lucida*, *Aralia armata*, *Kydia calycina* and *Ficus semicordata*. Middle canopy is composed of some small trees and shrubs like *Saurauria nepalensis*, *Trevesia palmata*, *Ficus oligodon*, *Bambusa pallida*, *Dendrocalamus hamiltonii*, *Calamus floribundus* and *Embelia ribes*. The herbaceous layer is represented by *Begonia nepalensis*, *Costus speciosus*, *Dicranopteris linearis*, *Elatostema sessile*, *Nephrolepis cordifolia*, *Pteris quadriaurita* and *Pteridium aquilinum*.

The slopes on right bank of the Siyom river near the dam site of Naying HEP are covered with *Musa acuminata* thickets. The slopes on the left bank of river are steep and are covered by shrubs and grasses. Trees are dominant only nearby the river banks. The upper canopy is dominated by *Aralia armata*, *Artocarpus heterophyllus*, *Alnus nepalensis*, *Duabanga grandiflora* and *Kydia calycina*. The middle canopy is represented by small trees and shrubs like *Saurauria nepalensis*, *Bambusa pallida*, *Dendrocalamus hamiltonii*, *Calamus floribundus* and *Oxyspora paniculata*. The ground layer is dominated mainly by *Begonia nepalensis*, *Colocasia affinis* and *Elatostema sessile* near by the river bank. In the *Musa* forest herbaceous layer is sparse and represented only by *Hedychium spicatum* and *Crassocephalum crepidioides*.

The submergence area of Naying HE project is characterized by steep to moderate slopes covered with Evergreen tropical forest with some area having degraded forest because of *jhumming* practice. Tree layer is comprised of *Albizia lucida*, *Artocarpus heterophyllus*, *Macaranga denticulata*, *Ficus semicordata* and *Macropanax oreophilus*. *Buddleja asiatica*, *Calamus floribundus*, *Boehmeria longifolia*, *Musa acuminata*, *Piper peepuloides* and *Oxyspora paniculata* represent the shrub layer. *Arisaema erubescens*, *Begonia nepalensis*, *Cyperus rotundus*, *Galium asperuloides*, *Impatiens arguta* and *Rubia cordifolia* are commonly found herbs in this area.

The upstream catchment are of the Siyom River between 1300 and 5500 m elevations is covered with Evergreen tropical, Tropical broad leaved, Coniferous, Pine and Alpine forest types. The tree canopy is represented by *Ficus semicordata*, *Lithocarpus wrayi*, *Saurauria nepalensis* and *Alnus nepalensis*. *Piper peepuloides* is commonly found with *Embelia ribes*, *Boehmeria longifolia*, *Calamus flagellum*, *Clerodendrum colebrookianum*. *Begonia nepalensis*, *Costus speciosus*, *Elatostema sessile*, *Hedychium spicatum*, *Persicaria pubescens* and *Plantago erosa* are the commonly found herbs in this area.

From this sub-basin in all 298 plant species were recorded, which includes 55 trees, 66 shrubs, 121 herbs. Twelve species under RET category are found in the sub-basin i.e. *Begonia scintillans*, *Calamus inermis*, *Camellia siangensis*, *Cymbidium eberneum*, *Diplomeris hirsuta*, *Galeola falconeri*, *Livistona jenkinsiana*, *Magnolia gustavii*, *Paphiopedilum fairrieianum*, *Paui belladonna*, *Psychotria aborensis* and *Xanthophyllum burkillii*.

The endemic plant species are represented by *Aglaia edulis*, *Ardisia pedunculosa*, *Calamus leptospadix*, *Calanthe densiflora*, *Dendrobium cathcartii*, *Dendrobium hookerianum*, *Eria ferruginea*, *Garcinia acuminata*, *Lasianthus biermanii*, *Liparis plantaginea*, *Livistona jenkinsiana*, *Luculia pinceana*, *Magnolia rabaniana*, *Michelia oblonga*, *Musa velutina*, *Ophiorrhiza calcarata*, *Prenanthes scandens*, *Psychotria aborensis*, *Rubus burkillii*, *Schizostachyum arunachalensis* and *Zalacca secunda*.

In addition there are 28 species found in the sub-basin which are endemic to northeast India. The list is given below.

<i>Anoectochilus sikkimensis</i>	<i>Ixora subsessilis</i>
<i>Ardisia pedunculosa</i>	<i>Jasminum caudatum</i>
<i>Arisaema setosum</i>	<i>Musa sikkimensis</i>
<i>Arthraxon quarlinianus</i> var. <i>glabrescens</i>	<i>Neonauclea gageana</i>
<i>Arundinella khaseana</i>	<i>Ophiorrhiza succirubra</i>
<i>Baliospermum calycinum</i>	<i>Ophiorrhiza repens</i>
<i>Begonia tessaricarpa</i>	<i>Peliosanthes macrophylla</i>
<i>Beilschmiedia pseudomicropora</i>	<i>Randia griffithii</i>
<i>Brassiopsis simplicifolia</i>	<i>Rhynchoetechum alternifolium</i>
<i>Chirita hookerii</i>	<i>Schizostachyum seshagiriana</i>
<i>Chirita macrophylla</i>	<i>Sedum triactina</i>
<i>Cirsium interpositum</i>	<i>Smilax minutiflora</i>
<i>Euonymus lawsonii</i>	<i>Vaccinium venosum</i>
<i>Goodyera recurva</i>	<i>Viburnum corylifolium</i>

8.2.9.3 Faunal Resources

Mammalian fauna of the sub-basin is comprised of 54 species.

Some mammalian species are listed in the Red Data Book (Version 3.1: IUCN 2001). According to this Fishing Cat and Jungle Cat are under Endangered category. Clouded Leopard and Himalayan Black Bear are under Vulnerable, Eurasian Otter and Large Indian Civet are under Near Threatened category.

Based upon WPA (1972) criterion, Capped Langur, Slow loris, Common leopard, Clouded leopard, and Leopard cat inhabiting the sub-basin are categorized as Schedule I species, while Rhesus macaque, Wild dog and Indian fox are classified as Schedule II species. Based on the criterion of ZSI (1994) total 5 species are classified as 'Threatened' out of which 3 are 'Vulnerable' and a single species is 'endangered'. According to the criterion of CAMP-BCPP (1998), species like Common leopard and Musk deer are categorized as 'vulnerable' species. Total 9 species are under category like Low risk - Near threatened (LRnt) while 12 species are at Low risk-least concerned (LRlc). Only Common leopard and Black bear have been identified as 'Vulnerable' species according to the criterion of IUCN.

The habitat of Clouded Leopard is in the upper reaches of hills in the sub-basin. Fishing Cat is rarely spotted by local people in forest near by the Yapik village.

Amongst the avifauna 165 species of birds have been documented from this sub-basin. Nuthatch (*Sitta formosa*) and *Parus nuchalis* (White-napped Tit) have been placed under the 'vulnerable' category by Birdlife International (2000).

There are 2 species that are in Vulnerable list viz. Blyth's tragopan (*Tragopan blythii*), and Chestnut-breasted Partridge (*Arborophila mandellii*). According to WPA, 1972, the area is home to 5 Schedule-I species. These are Black Eagle (*Ictinaetus malayensis*), Black redstart (*Phoenicurus ochruros*), Common buzzard (*Buteo buteo*), Oriental Honey Buzzard (*Pernis ptilorhynchus*), and Pied harrier (*Circus melanoleucos*).

8.2.9.4 Fish Diversity

On the basis of secondary data available, experimental fishing and consultation with local inhabitants and casual fishermen, a total of 32 fish species are reported to inhabit the Siyom river. In addition to these a few species, viz. *Schizothorax* spp., *Barilius* spp. and *Puntius* spp. are also

found in different tributaries of the Siyom river. These fishes are known to perform local migration from these tributaries to main channel, but do not undertake long migration. No commercial fishing is available in the area. However, the fish capture was limited around Yapik by the local people of near villages by using cast net, gill net and drag net for their daily needs. Though, according to fishermen of the region mahseer occasionally comes in the fish catch of Siyom river. During field visit *Schizothorax* spp., *Glyptothorax* spp. and *Garra* spp. were commonly found in the Siyom river near Yapik village.

According to CAMP criteria the species falling under Endangered category are : *Amblyceps arunachalensis*, *Nemacheilus devdevi*, *Pterocryptis gangelica* (= *Silurus afgana*), *Schistura multifasciata* (= *Nemacheilus multifasciatus*) *Tor putitora* and *Tor tor*.

Fourteen species fall under Vulnerable category and these are: *Amblyceps apangi*, *Bagarius bagarius*, *Bangaba dero* (= *Labeo dero*), *Barilius vagra*, *Botia rostrata*, *Cyprinion semiplotum* (= *Semiplotus semiplotus*), *Cyprinus carpio*, *Garra gotyla gotyla*, *Garra kempfi*, *Garra lissorhynchus*, *Garra naganensis* (= *Garra tirapensis*), *Puntius sarana*, *Schistura manipurensis* (= *Nemacheilus manipurensis*) and *Schizothorax richardsonii*.

According to criteria defined by IUCN Golden mahseer (*Tor putitora*) is under Endangered category and there are 6 species are under Vulnerable category i.e. *Aborichthys garoensis* (= *Nemacheilus garonesis*), *Bagarius bagarius*, *Botia rostrata*, *Cyprinion semiplotum* (= *Semiplotus semiplotus*), *Cyprinus carpio* and *Schizothorax richardsonii* and 3 species are under Near Threatened category i.e. *Schistura manipurensis* (= *Nemacheilus manipurensis*), *Syncrossus berdmorei* (= *Botia berdmorei*) and *Tor tor*.

Two endemic species are reported from this sub-basin i.e. *Garra naganensis* (= *Garra tirapensis*) and *Schistura manipurensis* (= *Nemacheilus manipurensis*).

8.2.10 Siyom Sub-basin-III

Siyom sub-basin-III is comprised of upper catchment of Siyom upstream of confluence of Yagyap Chhu (Figure 8.27). Most part of the sub-basin is comprised of Dibang Dihang Biosphere Reserve. Three projects are planned on Siyom river i.e. Hirong, Jarong and Taiyong HEPs.

8.2.10.1 Forest Cover

This sub-basin encompasses middle to higher altitudes and 69% of its area is under dense to very dense forest cover (Figures 8.28 & 8.29). The area upstream of Taiyong falls under Dibang Dihang Biosphere Reserve. The forests in this region are dense to very dense while higher elevations are under snow cover.

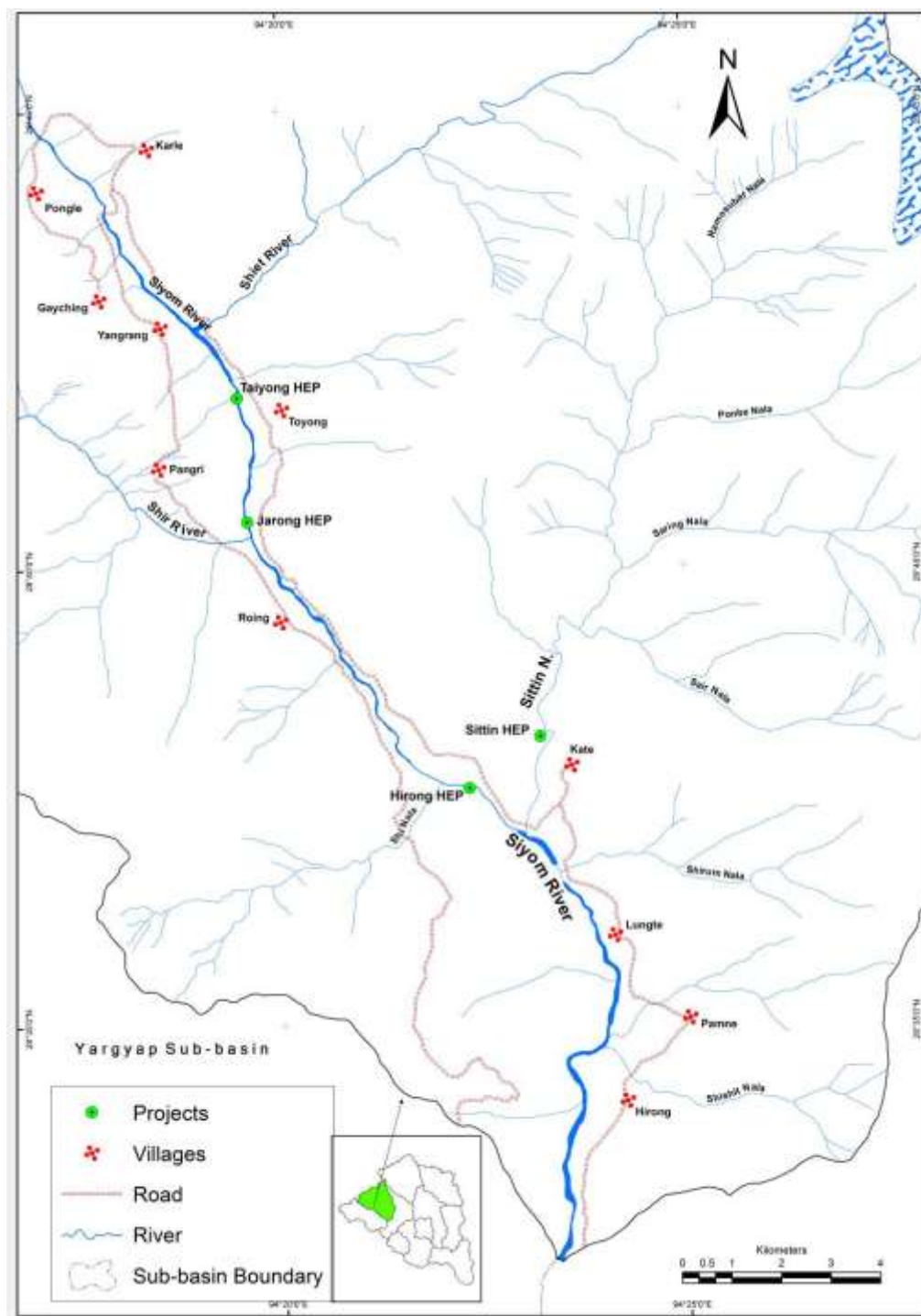


Figure 8.27: Drainage map of Siyom Sub-basin-III

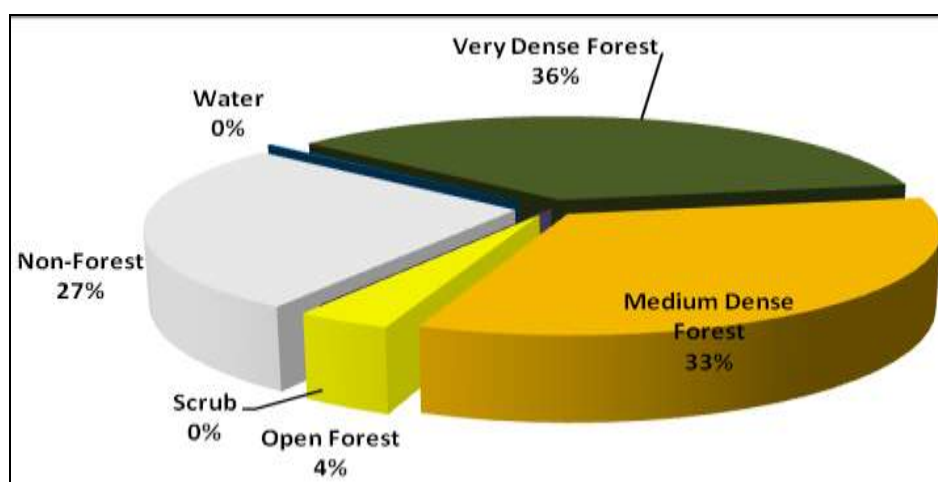


Figure 8.28: Area under different land use/ land cover categories in Siyom Sub-basin-III

8.2.10.2 Floristic Diversity

In this sub-basin 388 plant species belonging to various plant groups have been recorded.

The forest types in the sub-basin vary from Subtropical Broadleaf and Subtropical Pine forest on the lower slopes and river gorges, to Sub-alpine forest on the slopes of the higher reaches. The tops and ridges of the Great Himalayan mountain slopes are covered with subalpine and alpine scrub forest. The forests of Monnigong area have been identified as International Birding Area by Bird Life International.

It comprises area upstream of BB Camp and Hirong Basti and constitutes the catchment of Siyom upstream of confluence of Yargyap Chhu with Siyom river.

a) Area upstream of confluence of Yagyap Chhu and Siyom river

The lower reaches in this zone from BB Camp upstream are characterized by mixed patchy riverine semi-evergreen forest, whereas degraded open scrub forest in the mid hills. The tree canopy consists of *Actinodaphne angustifolia*, *Alangium chinense*, *Albizia odoratissima*, *Brassiopsis griffithii*, *Ficus semicordata*, *Lannea coromandelica*, *Kydia calycina*, *Macaranga denticulata* and *Oroxylum indicum*. Understorey is comprised of *Bambusa tulda*, *Buddleja asiatica*, *Boehmeria macrophylla*, *B. pendulifera*, *Brassiopsis mitis*, *Debregeasia longifolia*, *Rubus ellipticus*, *R. niveus* and *Saurauia roxburghii*. A notable parasitic plant like *Scurrulla elata* can be seen growing on *Ficus semicordata*. The trunks of trees are covered with a number of epiphytic ferns and orchids like species of *Bulbophyllum*, *Coelogyne*, *Cymbidium* and *Dendrobium*. Climbers are represented by species of *Aristolochia*, *Canavalia*, *Cissus*, *Rhaphidophora* and *Stephania*. Herbs are *Adiantum edgeworthii*, *Ageratum conyzoides*, *Artemisia nilagirica*, *Bidens bipinnata*, *Capillipedium assimile*, *Crassocephalum crepidioides*, *Dichrocephala crepidioides*, *Lygodium salicifolium*, *Pteris stenophylla*, *Saccharum longisetosum* and *Themeda arundinacea*. Dense Banana (*Musa balbisiana*) thickets with other shrubs such as *Bambusa pallida*, *Boehmeria macrophylla*, *Chromolaena odoratum*, *Debregeasia longifolia* and *Oxyspora paniculata* can be seen growing in the degraded slopes of mid hills. Towards Hirong Basti, the vegetation is sparse and patchy with few shrubs and trees along roadside.

b) Area between Hirong Basti and Lungte

This area covers warm broad-leaved forest in the lower reaches, while evergreen mixed oak forests are found in the upper reaches. The middle reaches in this zone are degraded and dominated by shrubs and small trees. *Alnus nepalensis* grows along streams or water courses and is the chief colonizer of landslip areas. Other prominent trees are *Albizia odoratissima*, *Baccaurea sapida*, *Callicarpa arborea*, *Castanopsis indica*, *Engelhardtia spicata*, *Ficus semicordata*, *Litsea polyantha*, *Macaranga denticulata*, *Ostodes paniculata*, and *Saurauia roxburghii*. The lower reaches are dominated by *Albizia odoratissima*, *Bischofia javanica*, *Glochidion assamicum*, *Mallotus philippensis*, *Oroxylum indicum*, *Rhus chinensis* and *Spondias pinnata*. The shrub layer is represented by *Buddleja asiatica*, *Chromolaena odoratum*, *Debregeasia longifolia*, *Desmodium triflorum*, *Ficus subulata*, *Maesa chisisa* and *Rubus ellipticus*. The notable parasitic plant species like *Cuscuta reflexa* and *Scurrulla elata* were found growing on branches of trees like *Maesa chisia* and *Ficus semicordata*. The trunks of trees are often loaded with mosses, ferns, vines and orchids. The herbaceous flora is represented by weeds, grasses and some ferns. *Ageratum conyzoides*, *Artemisia nilagirica*, *Bidens bipinnata*, *Conyza japonica*, *Gamochoeta purpurea* (= *Gnaphalium pensylvanicum*), *Pteridium aquilinum* and *Saccharum longisetosum* are the common herbs.

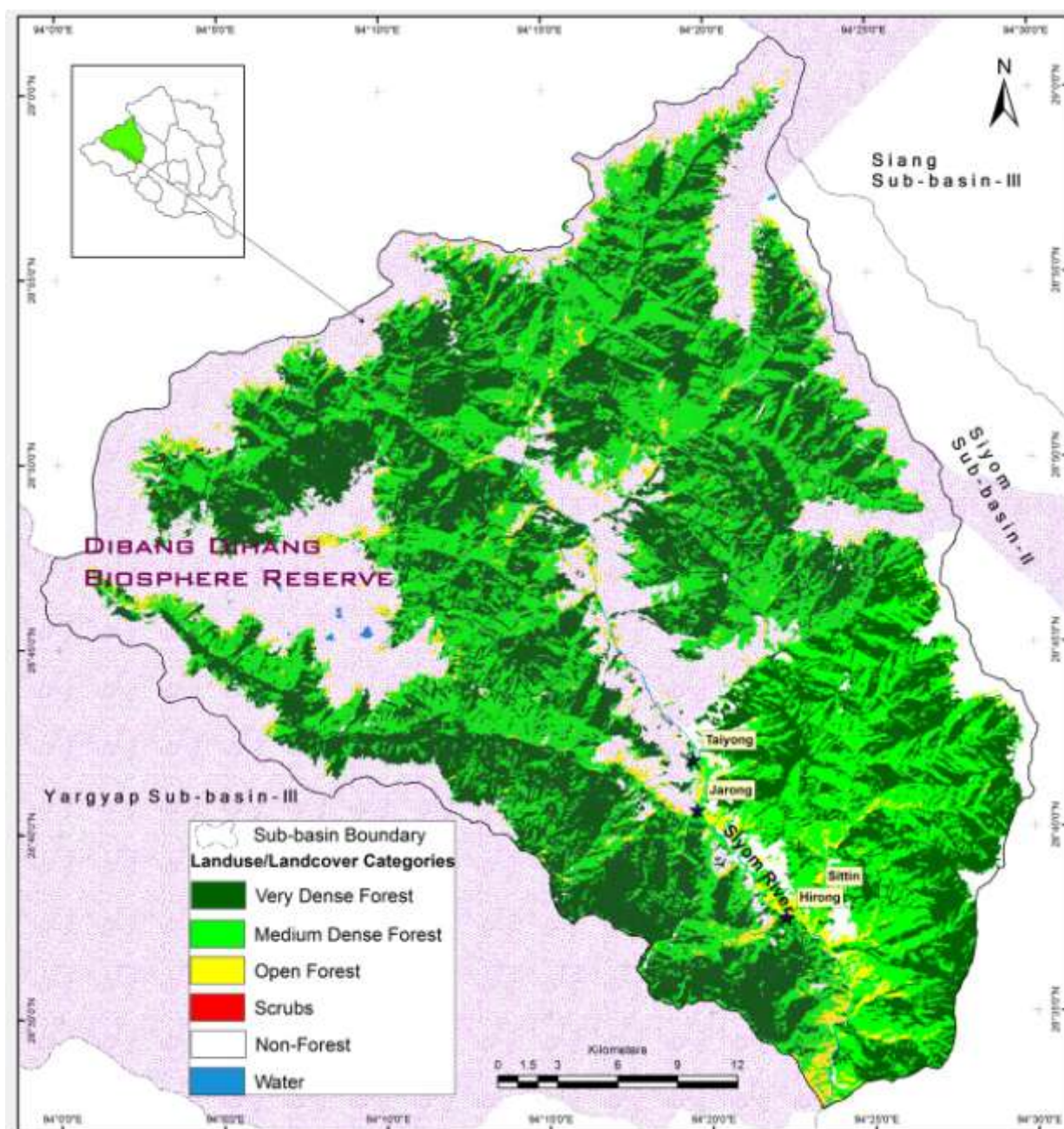


Figure 8.29: Land use/ land cover map of Siyom Sub-basin-III

c) Area between Lungte village and Hirong Dam site

There are sub-tropical wet hill and Assam pine forest in the lower and middle reaches of this area. Common tree associates in the middle of forest are *Quercus leucotricophra*, *Q. semiserrata*, *Pinus kesiya*, *Engelhardtia spicata*, *Cinnamomum tamala*, *Lyonia ovalifolia*, *Prunus zeylanica* and *Schima wallichii*. Understorey is scanty and represented by *Aconogonum molle*, *Boehmeria macrophylla*, *Hydrangea robusta*, *Luculia pinceana*, *Rubus ellipticus*, *R. niveus* and *Schefflera venulosa*. Assam pine (*Pinus kesiya*) is found in patchy dense population between 1000 and 1800m in this area. These forests are a very characteristic feature of this area. Understorey is very thin and represented by few tall shrubs and grasses. At some places, vegetation is cleared for *jhum* cultivation. The abandoned areas have very low species richness and dominated by shrubs and small trees viz., *Aconogonum molle*, *Buddleja asiatica*, *Callicarpa arborea*, *Chromolaena odoratum*, *Melastoma hispida*, *Osbeckia stellata*, *Oxyspora paniculata* and *Pteridium aquilinum*.

At lower reaches especially near river bank, warm broad-leaved forest occurs with rich growth of bamboos, canes, palms and many other shrubs. The dominant species of this forest are *Albizia odoratissima*, *Alnus nepalensis*, *Altingia excelsa*, *Castanopsis indica*, *Cinnamomum glaucescens*,

Kydia calycina, *Lannea coromandelica*, *Macaranga denticulta*, *Rhus chinensis* and *Sloanea tomentosa*. Second storey represented by *Brassiopsis griffithii*, *Celtis tetrandra*, *Desmodium triflorum*, *Ficus semicordata*, *Luculia pinceana*, *Maesa chisia*, *Pentapanax leschenaultia* and *Saurauia roxburghii*.

d) Area beyond Lungte and its environs

Beyond Lungte village, the vegetation in upper reaches up to Manegaon is met with wet temperate broad-leaved forest with a few scattered pine (*Pinus kesiya*) trees in lower and middle reaches. Common tree associates include *Alnus nepalensis*, *Castanopsis hystrix*, *Litsea sericea*, *Lyonia ovalifolia*, *Prunus cerasoides*, *Quercus lamellosa*, *Q. semiserrata* and *Schima wallichii*. Shrub elements are comprised of *Chromolaena odoratum*, *Myrsine semiserrata*, *Osbeckia stellata*, *Oxyspora paniculata*, *Rubus ellipticus*, *R. niveus* and *Rhododendron arboreum*. The trunks of trees are often loaded with epiphytic flora of lichens, mosses, ferns and orchid species. Herbaceous vegetation is represented by *Anaphalis busua*, *Anemone vitifolia*, *Arundinella nepalensis*, *Capillipedium assimile*, *Cirsium wallichii*, *Conyza japonica*, *Fagopyrum esculentum*, *Fragaria nubicola*, *Hydrocotyle nepalensis*, *Persicaria capitata*, *Potentilla fulgens* and *Saccharum rufipilum*. Fir (*Abies densa*) makes appearance above 2700m elevation. The areas higher above these zones are characterized by alpine scrubs and pastures. The main associates of the high elevation area are *Betula alnoides*, *Cotoneaster microphylla*, *Juniperus recurva*, *Rhododendron campanulatum*, *R. dalhousieae* var. *rhabdotum* and *Rosa sericea*. The herbaceous vegetation comprised of species of *Aconitum*, *Agrostis*, *Anaphalis*, *Calamagrostis*, *Fragaria*, *Potentilla*, *Primula*, *Ranunculus* and *Senecio*.

Nine RET species have been reported from the area. Six species are under Endangered category i.e. *Acer oblongum* var. *microcarpum*, *Livistona jenkinsiana*, *Paphiopedilum fairrieanum*, *Rhododendron edgeworthii*, *Rhododendron falconeri* ssp. *eximium* and *Psychotria aborensis* while *Cymbidium eburneum* is under Vulnerable category. *Cammelia siangensis* and *Xanthophyllum burkillii* are under Rare category.

Acer oblongum var. *microcarpum*, *Cammelia siangensis*, *Lasianthus biermanii*, *Liparis plantaginea*, *Livistona jenkinsiana*, *Magnolia rabaniana*, *Psychotria aborensis* and *Xanthophyllum burkillii* are the endemic species.

In addition there are 18 species found in the sub-basin which are endemic to northeast India. The list is given below.

<i>Ardisia pedunculosa</i>	<i>Euonymus lawsonii</i>
<i>Arisaema setosum</i>	<i>Ophiorrhiza succirubra</i>
<i>Arthraxon quarlinianus</i> var. <i>glabrescens</i>	<i>Ophiorrhiza repens</i>
<i>Arundinella khaseana</i>	<i>Peliosanthes macrophylla</i>
<i>Baliospermum calycinum</i>	<i>Rhynchoetichum alternifolium</i>
<i>Beilschmiedia pseudomicropora</i>	<i>Sedum triactina</i>
<i>Chirita hookerii</i>	<i>Smilax minutiflora</i>
<i>Chirita macrophylla</i>	<i>Vaccinium venosum</i>
<i>Cirsium interpositum</i>	<i>Viburnum corylifolium</i>

8.2.10.3 Faunal Resources

Mammalian fauna is comprised of 35 species. Among the major mammals are the Snow Leopard (*Uncia uncia*), Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Clouded leopard (*Neofelis*

nebulosa), Asiatic Black Bear (*Ursus thibetanus*), Red Panda (*Ailurus fulgens*), Musk Deer (*Moschus chrysogaster*) and Takin (*Budorcas taxicolor*) (Choudhury 2003).

Capped langur and Slow loris are categorized as 'Vulnerable' species under the Red Data Book of India (ZSI, 1994) and IUCN red list of 2010. As per the criterion of WPA (1972) both species are Schedule I species while Rhesus macaque is Schedule-II species.

As per WPA (1972) 6 species of mammals in the catchment area are Schedule I while 5 are Schedule II. ZSI (1994) listed 3 species under the 'Vulnerable' category and one under 'endangered, category. IUCN Red list Ver. 3.1 has categorized 2 species under 'Vulnerable' category and 2 under 'Endangered' category. Other species are under 'Near Threatened' or 'least concern' category. Four species, viz. *Panthera pardus*, *Panthera uncia*, *Neofelis nebulosa* and *Prionailurus bengalensis* are considered as Threatened species. Only *Capricornis sumatraensis* has been placed under the 'Vulnerable' category while 2 are under category 'Insufficiently Known' as per ZSI criterion. In IUCN categorization *Capricornis sumatraensis* and *Budorcas taxicolor* are 'vulnerable' species.

The birds are represented by 98 species. According to the conservation status defined by WPA (1972) 5 species namely *Lophophorus sclateri* (Scalater's monal), *Tragopan temminckii* (Temminck's tragopan), *Lerwa lerwa* (Snow partridge), *Accipiter nisus* (Northern Sparrow Hawk) and *Anthraceroceros albirostris* (Great Indian Pied Hornbill) are the Schedule I species while majority of the species are Schedule IV species.

According to IUCN Red List Ver.3.1 six species are under Vulnerable category. These species are Rufous-necked Hornbill (*Aceros nipalensis*), Peacock Pheasant (*Polyplectron bicalcaratum*), Blyth's Tragopan (*Tragopan blythii*), Sclater's monal (*Lophophorus sclateri*), Streak-throated barwing (*Actinodura waldeni*), and Beautiful Nuthatch (*Sitta Formosa*). The Great Indian hornbill (*Buceros bicornis*) is under Near Threatened category.

Owing to rich avi-faunal diversity the forests of Monnigong area have been identified as International Birding Area by Bird Life International. It extends in Yargyap Chhu catchment up to Mechuka.

Beautiful Nuthatch (*Sitta formosa*) and *Parus nuchalis* (White-napped Tit) have been placed under the 'vulnerable' category by Birdlife International (2000).

8.2.10.4 Fish Diversity

On the basis of secondary data available, experimental fishing and consultation with local inhabitants and casual fishermen, a total of 24 fish species are reported to inhabit the Siyom river. Commonly found species are *Schizothorax* spp., *Barilius* spp. and *Puntius* spp. are also found in different brooks of the Siyom river. These fishes are known to perform local migration from these brooks to main channel, but do not undertake long migration. No commercial fishing is practised in the area.

Two endemic species are reported from this sub-basin i.e. *Nemacheilus devdevi* and *Schistura manipurensis* (= *Nemacheilus manipurensis*).

According to CAMP criteria there are four endangered species reported from the basin i.e. *Glyptosternon reticulatum*, *Nemacheilus devdevi*, and *Schistura multifasciata* (= *Nemacheilus*

multifasciatus). Fish species under Vulnerable category are *Barilius barila*, *Barilius vagra*, *Garra gotyla gotyla*, *Garra kemp*, *Parachiloganis hodgarti* (= *Euchiloglanis hodgarti*), *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*), *Schistura manipurensis* (= *Nemacheilus manipurensis*) and *Schizothorax richardsonii*.

According to criteria defined by IUCN only *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*) is under Endangered category and there are 2 species are under Vulnerable category i.e. *Cyprinion semiplotum* (= *Semiplotus semiplotus*) and *Schizothorax richardsonii* and 4 species are under Near Threatened category i.e. *Balitona brucei*, *Nemacheilus devdevi*, *Ompok bimaculatus* and *Schistura manipurensis* (= *Nemacheilus manipurensis*).

8.2.11 Yargyap Sub-basin

This sub-basin is comprised of catchment of Yargyap Chhu (Figure 8.30). Most of its area fall under Dibang Dihang Biosphere Reserve. As many as 7 seven projects have been planned on Yargyap Chhu as a cascade development and another 2 are planned on its tributaries.

8.2.11.1 Forest Cover

The forest of the sub-basin comprise of sub-tropical to temperate forests. More than 64% of its area is under dense to very dense forest cover (Figures 8.31 & 8.32). These forests belong to mainly to Eastern Himalayan Dry Temperate Coniferous Forests and Sub-Himalayan light alluvial Semi-Evergreen Forests. Open forests are found near the settlements at lower reaches of the sub-basin where *jhumming* is practiced. Higher elevations are covered with snow.

The forest cover in the sub-basin especially on the right bank of Yargyap Chhu starting from Kangtangshiri-Rego area up to Yarlung and Hanuman camp and surrounding the Mechuka area on both the banks of Yargyap Chhu are very dense and are in pristine condition. These forests harbor number of rare and endangered plant species.

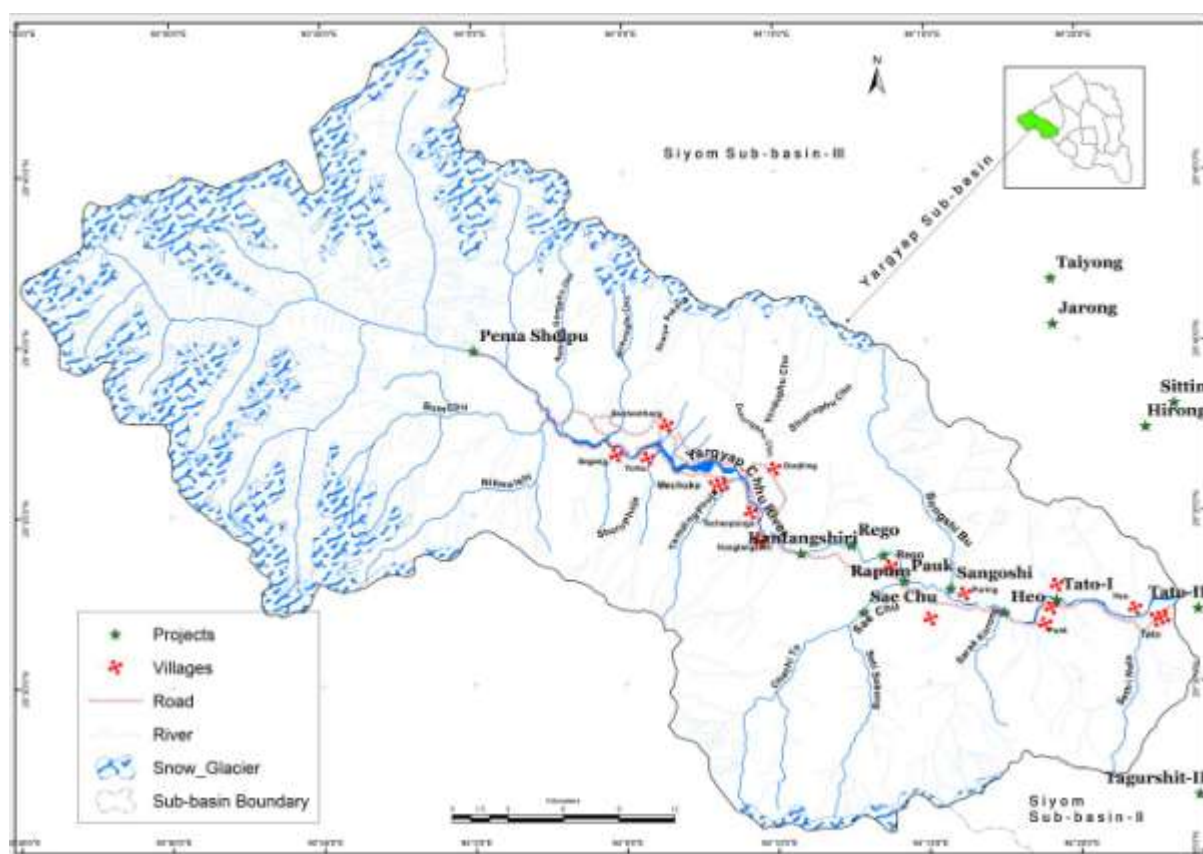


Figure 8.30: Drainage map of Yargyap Sub-basin

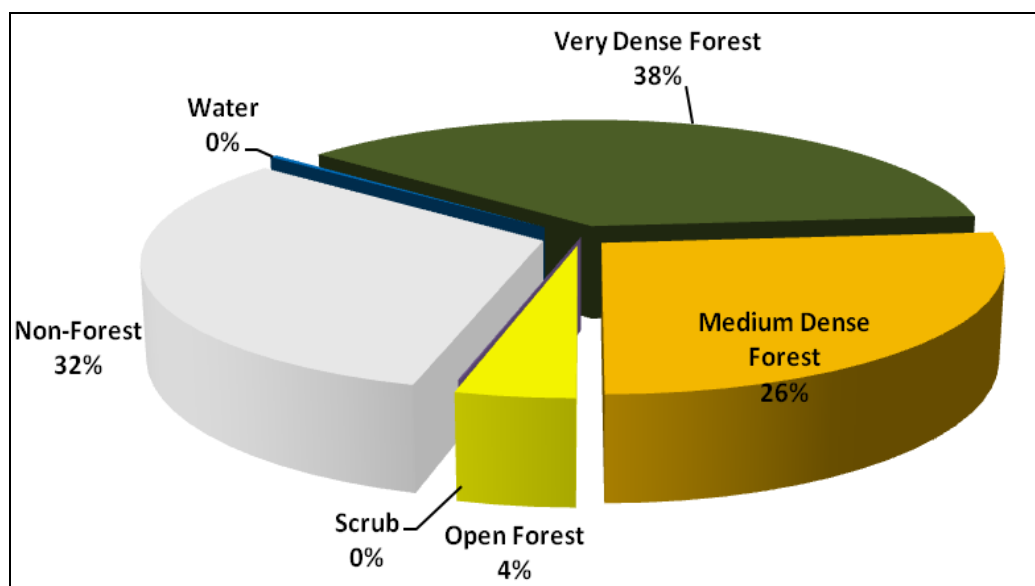


Figure 8.31: Area under different land use/ land cover categories in Yargyap Sub-basin

8.2.11.2 Floristic Diversity

From this sub-basin 357 plant species have been recorded. The forest types in the sub-basin vary from Subtropical Broadleaf and Subtropical Pine forest on the lower slopes and river gorges, to Sub-alpine forest on the slopes of the higher reaches. The tops and ridges of the Great Himalayan mountain slopes are covered with subalpine and alpine scrub forest. Most of the area of the sub-basin upstream of Rapum village falls in Dibang Dihang Biosphere Reserve.

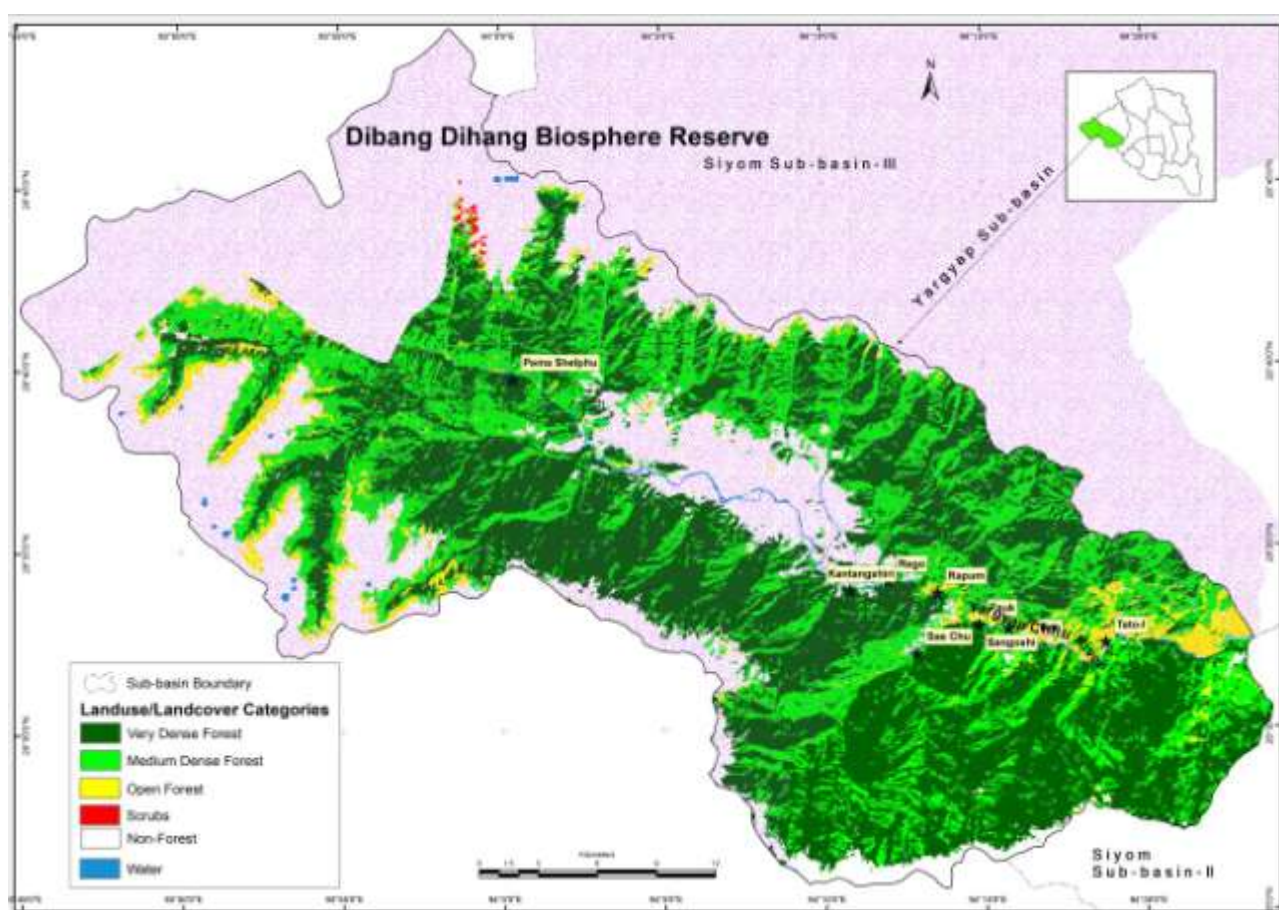


Figure 8.32: Land use/ land cover map of Yargyap Sub-basin

a) Area between BB Camp and Tato village

This description covers area between Bailey Bridge Camp and Tato village is characterized by tropical semi-evergreen forest in the lower reaches, while evergreen oak forest is found in the upper reaches. The lower reaches in this area are characterized by degraded riverine semi-evergreen forest especially near confluence of Yargyap Chhu with Siyom river. The prominent trees in this area are *Alnus nepalensis*, *Brassiopsis griffithii*, *Ficus semicordata*, *Macaranga denticulata*, *Saurauia roxburghii* and *Terminalia myriocarpa*. The river terraces are being stabilized by *Albizia odoratissima*, *Oroxylum indicum* and *Rhus chinensis*. The shrub layer is degraded and is represented by *Buddleja asiatica*, *Debregeasia longifolia*, *Desmodium triflorum*, *Phragmites karka* and *Rubus ellipticus*. There are parasitic plant species like *Cuscuta reflexa* and *Scurrula elata* which are found growing on trunks/branches of *Maesa chisia* and *Ficus semicordata*. The trunks of some of the trees are often loaded with epiphytic ferns, vines and orchids. The ground floor is occupied by weeds and grasses like *Ageratum conyzoides*, *Artemisia nilagirica*, *Bidens bipinnata*, *Conyza japonica*, *Crassopcephalum crepidioides*, *Gnaphalium affine*, *Pteridium aquilinum*, *Saccharum spontaneum* and *Thysanolaena latifolia*.

The slopes along the banks of river Yargyap near Tato village are gentle interspersed with terrace cultivation. The natural vegetation is sparse and comprises few trees like *Alnus nepalensis*, *Altingia excelsa*, *Beilschmiedia dalzellii*, *Brassiopsis aculeata*, *Erythrina arborescens*, *Ostodes paniculata* and *Saurauia roxburghii*. The vegetation on the slopes from Tato village to Gapo village consists of dense subtropical broad-leaved forest in lower reaches and patchy mixed sub-tropical forest along roadside with many semi-ergreen plant species.

b) Area between Tato village and Gapo Basti

The slopes of area upstream Tato and Gapo villages along Yargyap and many adjoining tributaries are covered with dense forests in this stretch. Fairly dense sub-tropical broad-leaved hill forest can be observed in the lower reaches on both banks of Yargyap river. The forest is dominated by tall evergreen species, but some deciduous tree species also occur in the top canopy. The trees are 20-30m in height with distinct second storey. *Altingia excelsa*, *Castanopsis indica*, *Dysoxylum procerum*, *Engelhardtia spicata*, *Kydia calycina*, *Phoebe hainesiana* and *Schima wallichii* form the top storey. Other prominent trees are *Ficus semicordata*, *Gynocardia odorata*, *Magnolia hodgsonii*, *Michelia glabra* and *Saurauia roxburghii*. Understorey consists of dense thickets of bamboos, *Musa* and many shrubs. The common shrubs are *Bambusa tulda*, *Boehmeria macrophylla*, *Buddleja asiatica*, *Debregeasia longifolia*, *Leea asiatica* and *Rubus ellipticus*. The tree trunks are loaded with a number of epiphytic mosses, ferns and orchids. On *Engelhardtia* and *Castanopsis* there is abundance of orchids like *Bulbophyllum*, *Dendrobium*, *Eria* and *Liparis*. Climbers are abundant. Tree fern (*Alsophila spinulosa*) is often seen in shaded and damp areas.

The vegetation around Gapo village is characterized by open degraded forest interspersed with settlement in middle reaches and dense riverine forest in lower reaches. A few tree species like *Alnus nepalensis*, *Altingia excelsa*, *Exbucklandia populnea* and *Macaranga denticulata* are found sporadically in the area. The shrubs are *Bambusa tulda*, *Boehmeria macrophylla*, *Leea asiatica*, *Leucosceptrum canum*, *Maesa chisia*, *Oxyspora paniculata*, *Rubus ellipticus* and *Sida acuta*. Herbaceous flora includes species of *Anaphalis*, *Anemone*, *Arenaria*, *Arisaema*, *Artemisia*, *Hydrocotyle*, *Malva*, *Rumex*, *Saccharum* and *Themeda*.

c) Area between Gapo Basti and Menying Basti

Gapo village area right from the bank of Yargyap is characterized by moderately steep slopes subjected to *jhum* cultivation. At lower reaches, the natural vegetation comprises open degraded forest. *Albizia odoratissima*, *Alnus nepalensis*, *Altingia excelsa*, *Castanopsis indica*, *Lithocarpus elegans* and *Macaranga denticulata* are found with patchy distributed. Other trees found in this area are *Brassiopsis aculeata*, *Carpinus viminea*, *Casearia glomerata*, *Eurya acuminata*, *Garcinia cowa*, *Lyonia ovalifolia* and *Rhus chinensis*. Shrub elements are comprised of *Boehmeria macrophylla*, *Debregeasia longifolia*, *Elaeagnus parviflora*, *Maesa chisia*, *Rubus ellipticus* and *Schefflera bengalensis*. Tree trunks are clothed with a number of epiphytic mosses, ferns and orchids. Herbaceous flora includes *Ageratum conyzoides*, *Artemisia nilagirica*, *Brachystemma calycinum*, *Dicranopteris linearis*, *Dipteris wallichii*, *Pteridium aquilinum*, *Houttuynia cordata*, *Persicaria capitata*, *P. chinensis* and *Spiranthes sinensis*.

Around Menying village patches of sub-tropical broad-leaved forest are seen at lower reaches. Some large trees such as *Actinodaphne obovata*, *Altingia excelsa*, *Albizia odoratissima*, *Engelhardtia spicata* and *Macaranga denticulata* are seen all along the river bank. This area has also fruit tree plantations of Citrus, Plums and Guava. Large area of forest has been cleared for *jhum* cultivation in the area. *Aconogonum molle*, *Bambusa tulda*, *Boehmeria rugulosa*, *B. macrophylla*, *Debregeasia longifolia*, *Hydrangea robusta*, *Leea asiatica*, *Leucosceptrum canum*, *Maesa chisia* and *Oreocnide frutescens* are found in the understorey. The herbaceous flora includes ferns, tall grasses and many herbs like *Begonia megaptera*, *Commelina benghalensis*, *Impatiens angustiflora*, *Imperata cylindrica*, *Lecanthus pedicularis*, *Phragmites karka* and *Saccharum longisetosum*.

d) Area beyond Menying village up to Purying

Beyond Menying village, the vegetation in upper reaches up to Mechuka is met with wet temperate broad-leaved and dry temperate mixed coniferous forests. Still higher mixed coniferous forest of *Tsuga dumosa*, *Cephalotaxus griffithii* and *Pinus wallichiana* occur. In the area between Menying and Purying dense broad-leaved sub-tropical forest is encountered. Beyond Purying and Rapum wet temperate broad-leaved forests occur. Important associates of the temperate forest are *Alnus nepalensis*, *Castanopsis indica*, *Litsea sericea*, *Lyonia ovalifolia*, *Magnolia campbellii*, *Michelia doltsopa*, *M. punduana*, *Prunus cerasoides*, *Quercus lamellosa*, *Q. semiserrata*, *Rhododendron arboreum* and *Tetradium fraxinifolium*. Shrub elements are composed of *Ardisia macrocarpa*, *Berberis hookeri*, *Cotoneaster acuminatus*, *Gaultheria fragrantissima*, *Pieris formosa*, *Rubus ellipticus*, *R. niveus*, *Salix wallichiana* and *Thamnocalamus spathiflorus*. Climbers are rare. The trunks of the trees are often loaded with rich epiphytic flora viz. lichens, mosses, ferns and orchid species. Herbaceous flora includes species of *Agrostis*, *Anaphalis*, *Anemone*, *Calamagrostis*, *Cirsium*, *Conyza*, *Fagopyrum*, *Fragaria*, *Persicaria*, *Potentilla* and *Saccharum rufipilum*.

e) Area between Purying village and Rapum village

The lower reaches in this zone are characterized by degraded sub-tropical forests whereas areas lying above Rapum and Purying are characterized by temperate broad-leaved forest passing into dry mixed coniferous forest on the higher elevations. Rapum area from the bank of Yargyap river is a moderately steep slope interspersed with *jhum* cultivation. The natural vegetation is dominated by few shrubs and trees. The prominent tree species seen include *Alnus nepalensis*, *Brassiopsis aculeata*, *Lithocarpus elegans*, *Saurauia roxburghii* and *Tetradium fraxinifolium*. Lower storey is represented by small trees and shrubs viz. *Aconogonum molle*, *Hydrangea robusta*, *Luculia pinceana* and *Maesa chisia* along with weed species like *Ageratum conyzoides*, *Artemisia*

nilagirica, *Bidens bipinnata* and *Galinsoga parviflora*. The river terraces and nala fans are being stabilized by *Albizia odoratissima*, *Alnus nepalensis*, *Macaranga denticulata* and *Rhus chinensis*. Dense bamboo (*Bambusa pallida*) thickets and tall grasses like *Themeda arundinacea* and *Setaria palmifolia* are seen in *jhummed* area on the right bank. The vegetation from river bank to Purying consists of degraded secondary forest with few scattered pine trees (*Pinus wallichiana*). The prominent tree species in the area include *Engelhardtia spicata*, *Ficus oligodon*, *F. semicordata*, *Rhus chinensis*, *Saurauia roxburghii* and *Xylosma longifolium*. Shrub elements are composed of *Ardisia thyrsoiflora*, *Debregeasia longifolia*, *Elaeagnus parviflora*, *Leea asiatica*, *Oxyspora paniculata* and *Vernonia volkemerifolia*. The tree trunks are often loaded with a number of epiphytic mosses, ferns and orchids. Notable epiphytic plant like *Aeschynanthus parasiticus* can be seen on the trunks of *Engelhardtia spicata*. Herbs include *Ageratum*, *Arisaema*, *Artemisia*, *Crawfordia*, *Hydrocotyle*, *Impatiens*, *Malva*, *Oxalis*, *Rumex*, *Saccharum*, *Sida* and *Themeda*.

f) Area between Rapum village and Rego village

There are dense alder, wet temperate broad-leaf and dry mixed coniferous forest above Rapum village. In the vicinity of Rapum area, the natural vegetation is comprised of *Albizia odoratissima*, *Alnus nepalensis*, *Altingia excelsa*, *Castanopsis hystrix*, *Cinnamomum tamala*, *Schefflera impressa* and *Tetradium fraxinifolium*. Shrubs are *Ardisia thyrsoiflora*, *Brassiopsis aculeata*, *Dichroa febrifuga*, *Elaeagnus parviflora*, *Leucosceptrum canum*, *Maesa chisia*, *Oxyspora paniculata* and *Rubus ellipticus*. Tree trunks of most of the trees are clothed with a number of epiphytic mosses, lichens and ferns. Herbaceous flora represented by species of *Anemone*, *Artemisia*, *Brachystemma*, *Carduus*, *Dicranopteris*, *Fragaria*, *Impatiens*, *Lycopodium*, *Pteridium*, *Persicaria*, *Potentilla* and *Spiranthes sinensis*.

The vegetation around Rego village is characterized by mixed coniferous forest. Top canopy is represented by tall trees like *Cephalotaxus griffithii*, *Eurya acuminata*, *Magnolia hodgsonii*, *Michelia doltsopa*, *Pinus wallichiana*, *Quercus lamellosa*, *Rhododendron arboreum*, *Schefflera impressa* and *Tetradium fraxinifolium*. Climbers are few and represented by species of *Clematis*, *Parthenocissus*, *Smilax* and *Vitis*. Understorey consists of dense thickets of *Thamnocalamus spathiflorus* along with other shrub species like *Berberis hookeri*, *Cotoneaster acuminatus*, *Gaultheria fragrantissima*, *Hypericum oblongum*, *Rabdosia rugosa*, *Rosa brunonii* and *Rubus niveus*. The herbs include various species of ferns, orchids and grasses. Some herb species belong to the genera like *Anaphalis*, *Anemone*, *Conyza*, *Carduus*, *Desmodium*, *Digitaria*, *Galeola*, *Potentilla*, *Rhynchospora*, *Rumex* and *Scirpus*.

g) Area between Rego village and Mechuka

This area has a predominantly mixed broad-leaved temperate forest and patchy dry temperate coniferous forest interspersed with terrace cultivation in the lower reaches. Trees of *Acer acuminatum*, *Magnolia hodgsonii*, *Michelia* spp., *Pinus wallichiana*, *Rhododendron kenderickii*, *Tetradium fraxinifolium*, are quite conspicuous on gentle slopes. The other plants observed in this area are *Cephalotaxus griffithii*, *Eurya acuminata*, *Litsea sericea*, *Lyonia ovalifolia*, *Quercus lamellosa* and *Symplocos paniculata*. Shrub elements are composed of *Berberis wallichiana*, *Cotoneaster bacillaris*, *Rubus niveus*, *Thamnocalamus spathiflorus* and *Viburnum cylindricum*.

The vegetation around Mechuka is characterized by *Pinus wallichiana* which occurs on flattened and gentle slopes. Along the river bank some stunted broad-leaved trees and scrubs are seen. *Alnus nepalensis*, *Berberis wallichiana*, *Cotoneaster bacillaris*, *Magnolia hodgsonii* and *Eurya acuminata* are important associates along the river bank. Herbaceous flora includes species of

Anaphalis, *Artemisia*, *Carduus*, *Digitaria*, *Fragaria*, *Fagopyrum*, *Galeola*, *Lycopodium*, *Persicaria*, *Potentilla*, *Pteris*, *Pteridium*, *Rumex*, *Selaginella* and *Viola*.

h) Area beyond Mechuka and its environs

Vegetation beyond Mechuka up to Hanuman Camp is represented by mixed coniferous forest with a few evergreen oaks and rhododendrons in the middle and lower storeys. Common tree associates include *Acer caesium*, *Castanopsis tribuloides*, *Litsea sericea*, *Magnolia hodgsonii*, *Michelia velutina*, *Pinus wallichiana*, *Quercus lamellosa*, *Rhododendron kenderickii* and *Rhododendron grande*. Shrub elements are composed of *Cotoneaster bacillaris*, *Gaultheria fragrantissima*, *Pieris formosa*, *Rhododendron boothii*, *R. vaccinoides*, *Rosa sericea*, *Rubus niveus*, *Salix wallichiana* and *Thamnocalamus spathiflorus*. The trunks of trees are often loaded with rich epiphytic flora of lichens, mosses, ferns and orchid species. Herbaceous flora includes species of genera like *Anaphalis*, *Anemone*, *Bistorta*, *Cardamine*, *Carex*, *Cirsium*, *Fragaria*, *Potentilla*, *Scirpus* and *Senecio*. Above Yorko Hemlock (*Tsuga dumosa*) makes appearance as a dominant tree species and is associated with other tree species like *Acer*, *Quercus* and *Pinus*. In the Gurudwara area dense mixed coniferous forest are seen. The main tree associates in the area include *Acer*, *Alnus*, *Actinodaphne*, *Eurya*, *Quercus* and *Rhododendron*. Beyond Hanuman Camp dense Hemlock (*Tsuga dumosa*) forests are seen on upper reaches. Lower reaches consists of temperate mixed evergreen species with dense thickets of small bamboo (*Thamnocalamus spathiflorus*).

Eleven RET species have been reported from the area. Three species are under Endangered category i.e. *Acer oblongum* var. *microcarpum*, *Rhododendron falconeri* ssp. *eximium* and *Paphiopedilum fairrieanum*. An important medicinal plant *Picrorhiza kurroa* and an orchid *Cymbidium eburneum* are under Vulnerable category while *Rhododendron boothii* is under Threatened category. *Rhododendron arizelum*, *Rhododendron dalhousieae* var. *rhabdotum*, *Rhododendron edgeworthii*, *Rhododendron kenderickii* and *Psychotria aborensis*, *Cammelia siangensis* and *Xanthophyllum burkillii* are under Rare category. *Cephalotaxus griffithii* a gymnosperm reported from this area is under Indeterminate category.

Recently a new species of *Rhododendron* has been discovered *Rhododendron mechukae* which has a very limited distribution in the area.

The following 10 species endemic to Arunachal Pradesh are found in the area : *Acer oblongum* var. *microcarpum*, *Calanthe densiflora*, *Cammelia siangensis*, *Lasianthus biermanii*, *Liparis plantaginea*, *Liparis plantaginea*, *Livistona jenkinsiana*, *Magnolia rabaniana*, *Psychotria aborensis* and *Xanthophyllum burkillii* are the endemic species.

In addition there are 15 species found in the sub-basin which are endemic to northeast India. The list is given below.

<i>Ardisia pedunculosa</i>	<i>Euonymus lawsonii</i>
<i>Arisaema setosum</i>	<i>Peliosanthes macrophylla</i>
<i>Arthraxon quarlinianus</i> var. <i>glabrescens</i>	<i>Rhynchosyche alternifolium</i>
<i>Baliospermum calycinum</i>	<i>Sedum triactina</i>
<i>Beilschmiedia pseudomicropora</i>	<i>Smilax minutiflora</i>
<i>Chirita hookerii</i>	<i>Vaccinium venosum</i>
<i>Chirita macrophylla</i>	<i>Viburnum corylifolium</i>
<i>Cirsium interpositum</i>	

8.2.11.3 Faunal Resources

Mammalian fauna of the sub-basin is comprised of more than 36 species, belonging to 15 families. Based on the WPA (1972) criterion 10 species are Schedule-I species. These are Capped Langur (*Semnopithecus plataeus*), Slow loris (*Nycticebus coucang*), Snow leopard (*Uncia uncia*), Common leopard (*Panthera pardus*), Clouded leopard (*Neofelis nebulosa*), Leopard cat (*Prionailurus bengalensis*), Asian black bear (*Ursus thibetanus*), Musk deer (*Moschus chrysogaster*), Serow (*Capricornis sumatraensis*) and Mishmi takin (*Budorcas taxicolor*). Schedule II species are Rhesus macaque (*Macaca mulatta*), Jungle cat (*Felis chaus*), Wild dog (*Cuon alpinus*), Jackal (*Canis aureus*), Indian fox (*Vulpes bengalensis*), and Small Indian civet (*Viverricula indica*).

As per criterion of BCPP - CAMP, two species namely Common leopard and Musk deer are categorized as 'vulnerable' species while Snow leopard is considered as 'endangered' species. The remaining species are either 'low risk - least concerned' or 'low risk-near threatened'. In the IUCN red list 5 species are placed under 'vulnerable' category while 3 are 'endangered'. Other species are considered as 'least concern' or 'near threatened'. Recently a new species of squirrel Mechuka giant flying squirrel (*Petaurista mechukaensis*) has been discovered from the area.

Avifauna of the sub-basin is comprised of pheasants, partridge, hawk, eagle, hornbill, barbets, Cuckoo, woodpeckers, Hoopoe, owl, crow, magpie, tree pie, drongo, swallows, Myna, pitta, shrike, sparrow, tits, bulbuls, flycatcher, thrushes, laughing thrushes, warblers, babblers, redstarts, sun birds, flower peckers, rose finches, pipits, scarlet etc. The avifauna is represented by 98 species belonging to 25 families. Five species viz. *Lophophorus sclateri* (Scalater's monal), *Tragopan temminckii* (Temminck's tragopan), *Lerwa lerwa* (Snow partridge), *Accipiter nisus* (Northern Sparrow Hawk) and *Anthraceroceros albirostris* (Great Indian Pied Hornbill) are the Schedule I species while majority of the species reported from the sub-basin are Schedule IV species.

According to IUCN Red List Ver.3.1 7 species are under Vulnerable category. These species are Rufous-necked Hornbill (*Aceros nipalensis*), Black Partridge (*Melanoperdix niger*), Peacock Pheasant (*Polyplectron bicalcaratum*), Blyth's Tragopan (*Tragopan blythii*), Sclater's monal (*Lophophorus sclateri*), Streak-throated barwing (*Actinodura waldeni*), and Beautiful Nuthatch (*Sitta formosa*). The Great Indian hornbill (*Buceros bicornis*) is under Near Threatened category. Beautiful Nuthatch (*Sitta formosa*) and *Parus nuchalis* (White-napped Tit) have been placed under the 'Vulnerable' category by Birdlife International (2000). A wide range bird species Blue-and-White Flycatcher *Cynoptila cyanomelana* has also been reported from the area.

Owing to rich avian diversity the forests around Mechuka have been identified as International Birding Area by Bird Life International. According to it the forests starting from right bank of Yargyap Chhu excluding Mechuka town, extending up to Monnigong area in Siyom valley has been demarcated as IBA. The site lies in the Eastern Himalayas Endemic Bird Area (EBA 130) (Stattersfield *et al.* 1998). The following Restricted range bird species are found in the area.

Blyth's Tragopan (<i>Tragopan blythii</i>)	A1, A2	Vulnerable
Sclater's Monal (<i>Lophophorus sclateri</i>)	A1, A2	Vulnerable
Eastern Imperial Eagle (<i>Aquila heliaca</i>)	A1	Vulnerable
Rufous-necked Hornbill (<i>Aceros nipalensis</i>)	A1	Vulnerable
Streak-throated Barwing (<i>Actinodura waldeni</i>)	A2	Least Concern
Beautiful Sibia (<i>Heterophasia pulchella</i>)	A2	Least Concern
Beautiful Nuthatch (<i>Sitta Formosa</i>)	A1	Vulnerable

8.2.11.4 Fish Diversity

Fish fauna of the sub-basin comprises 19 species belonging to families Cyprinidae, Balitoridae, Cobitidae, Siluridae and Sisoridae. Most common species in the area are *Schizothorax richardsonii*, *Nemacheilus multifasciatus*, *Schistura rupecola* and *Garra naganensis*. The species like *Labeo calbasu* and *Puntius ticto* are confined to the lower reaches. The loaches prefer to inhabit tributaries. *Schizothorax richardsonii*, *Labeo calbasu*, and *Garra naganensis* are column feeders, thus, considered to move relatively longer distance as compared to other species dwelling in the river bed. *Schizothorax richardsonii* and *Labeo calbasu* are considered to perform migration in river system. To cope with the low temperature in peak winter season Snow trout moves downwards. It usually finds a tributary to spawn from May to September. It sometimes moves to Sae Chu or Sangoshi Bu also. Brown trout (*Salmo trutta fario*) has been introduced in the river.

According to CAMP criteria there are four endangered species reported from the basin i.e. *Glyptosternon reticulatum*, *Nemacheilus devdevi*, and *Schistura multifasciata* (= *Nemacheilus multifasciatus*). Fish species under Vulnerable category are *Barilius barila*, *Barilius vagra*, *Garra gotyla gotyla*, *Garra kempfi*, *Parachilognathus hodgarti* (= *Euchiloglanis hodgarti*), *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*), *Schistura manipurensis* (= *Nemacheilus manipurensis*) and *Schizothorax richardsonii*.

According to criteria defined by IUCN only *Schistura kangjupkhulensis* (= *Nemacheilus kangjupkhulensis*) is under Endangered category and there are 2 species are under Vulnerable category i.e. *Cyprinion semiplotum* (= *Semiplotus semiplotus*) and *Schizothorax richardsonii* and 4 species are under Near Threatened category i.e. *Balitora brucei*, *Nemacheilus devdevi*, *Ompok bimaculatus* and *Schistura manipurensis* (= *Nemacheilus manipurensis*).

CHAPTER-9

ENVIRONMENTAL FLOWS

9.1 INTRODUCTION

The environmental flow is an important aspect in the development of hydropower projects. Release of environmental flow is to be ensured immediately downstream of the diversion structure at all times to sustain the ecology and environment of project area. Protecting and maintaining river flow regimes and hence the ecosystems they support by providing adequate environmental flows have become a critical aspect of hydropower development. Ecological systems supported by the rivers are too complicated to be summarized by a single minimum flow requirement but require comprehensive environmental flow regimes to be defined. "Environmental flow regime" means a schedule of flow quantities that reflects seasonal fluctuations and should be adequate to support a sound ecological environment to maintain productivity, extent, and persistence of key aquatic habitats in and along the affected water bodies.

The aquatic biota in Himalayan glacier-fed rivers has adapted to annual flow pulses, which vary from a gradual increase in discharge in summer, through floods in the monsoon period, and reduce to low flows in winter. During the dry season, the waters become clear, allowing algae (primarily diatoms) to obtain necessary light and carbon dioxide for photosynthesis. Effective quantification of flow includes the ecologically important range of flow magnitudes (low flows, high flow pulses, and floods), as well as the timing, duration, frequency, and rate of change of these flow conditions. Globally, these flows are most commonly referred to as "environmental flows".

The most critical reach for assessing release of environmental flow is immediately downstream of diversion structure till first significant tributary meets river.

9.2 CURRENT NORMS BEING FOLLOWED FOR ENVIRONMENTAL FLOW

There are no set norms for minimum releases to be maintained at all times on account of ecology and environment and to address issues concerning riparian rights, drinking water, health, aquatic life, wildlife, fisheries, silt and even to honour the sensitive religious issues like cremation and other religious rites, etc. on the river banks.

Expert Appraisal Committee (EAC) for River Valley and Hydroelectric Projects of Ministry of Environment & Forests (MOEF) recommends minimum environmental flow during lean season as 20% of the average discharge in four leanest months in 90% dependable year of the water availability series used to design the project. Lately, they have also started discussing the requirement of varied environment flow during monsoon and other months as discharge available in the river and flow requirement cannot be the same as that of lean season. EAC is recommending ecological releases for monsoon months should be maintained as 30% of flows in monsoon months of 90% dependable year and for non-lean and non-monsoon months, environment flow provision should be kept between 20-30%.

Scope of present study requires suggesting approach to be adopted for determining environmental flows and to determine environmental releases for various planned projects and river reaches in the Siang basin.

9.3 DESCRIPTION OF VARIOUS METHODOLOGIES FOR E-FLOW

There are four relatively discrete types of environmental flow methodology: (1) hydrological, (2) hydraulic rating, (3) habitat simulation and (4) holistic methodologies; among other techniques occasionally applied during Environment Flow Assessment. The four types are briefly described below.

9.3.1 Hydrological Methodologies

These represent the simplest set of techniques where, at a desktop level, hydrological data, as naturalized, historical monthly or average daily flow records are analysed to derive standard flow indices, which then become the recommended environmental flows.

Hydrological Index Methods provide a relatively rapid, non-resource intensive, but low-resolution estimate of environmental flows. The methods are most appropriate at the planning level of water resources development, or in low controversy situations where they may be used as preliminary estimates. Hydrological Index methods may be used as tools within habitat simulation, holistic or combination environmental flow methodologies. They have been applied in developed and developing countries. Commonly, the EFR is represented as a proportion of flow (often termed the 'minimum flow',) intended to maintain river health, fisheries or other highlighted ecological features at some acceptable level, usually on an annual, seasonal or monthly basis. As a result of the rapid and non-resource intensive provision of low resolution flow estimates, hydrological methodologies are generally used mainly at the planning stage of water resource developments, or in situations where preliminary flow targets and exploratory water allocation trade-offs are required.

Environmental flow is usually given as a percentage of average annual flow or as a percentile from the flow duration curve, on an annual, seasonal or monthly basis.

The most frequently used methods under this category are:

(i) Tennant Method

Donald Tennant developed this method in Montana, USA through several field observations and measurements. The Tennant study used 58 cross sections from 11 streams in Montana, Nebraska and Wyoming (Mann, 2006). The technique utilizes only the Mean Annual Flow (MAF) for the stream. It then states that certain flows relate to the qualitative fish habitat rating, which is used to define the flow needed to protect fish habitat, expressed in tabular form. Tennant concluded that 10% of MAF is the minimum for short-term fish survival, 30% of MAF is considered to be able to sustain fair survival conditions and 60% of MAF is excellent to outstanding habitat (Tennant, 1975).

Description of Flow	Flow to be released during	
	April to September	October to March
Flushing flow (from 48 - 96 hours)	200% MAF (Mean Annual Flow)	Not Applicable
Optimum range of flow	60-100% MAF	60-100% MAF
Outstanding habitat	60% MAF	40% MAF
Excellent habitat	50% MAF	30% MAF
Good habitat	40% MAF	20% MAF
Fair or degrading habitat	30% MAF	10% MAF
Poor or minimum habitat	10% MAF	10% MAF
Severe degradation	<10% MAF	<10% MAF

This means that if the quantity of water that the basin managers can provide for EFR is $\leq 20\%$ of MAF (10% during April to September and 10% during October to March) then the environmental quality of the habitat in that reach will face “Severe Degradation”. If a “Good” habitat is desired, then at least 60% of the MAF must be allocated for EFR, 40% during April-September and 20% during October to March.

Tessman modified the Tennant method and it resulted in an approach called as Modified Tennant Method or Tessman Method. Tessman adopted Tennant seasonal flow recommendation to calibrate the percentage of Mean Annual flow (MAF) to local hydrologic and biological conditions including monthly variability in terms of Minimum Monthly Flow (MMF).

Under these changes, the following rules were formulated.

- If $MMF < 40\%$ of MAF, then monthly minimum equals the MMF
- If $MMF > 40\%$ MAF, then monthly minimum equals 40% MAF
- If 40% MMF $> 40\%$ MAF, then monthly minimum equals 40% MAF
- The flushing flow criterion is still a requirement to be met on an annual basis.

(ii) Index Method

This method defined the value of the Minimum In-stream Flow (MIF) that must be maintained downstream of water diversion in order to maintain vital conditions of ecosystem functionality and quality (Maran, 2007). Based on Q355 (the flow not exceeded more than 355 days per year) this means that, on average, the natural flow is less than Q355 value only for 10 days in a year (Maran, 2007).

$MIF = K_a * K_b * K_c * Q_{355}$ where:

- K_a is corrective coefficient for different environmental sensitive of the interested river stretch [0.7 to 1.0]
- K_b = implementation factor [0.25 to 1.0]
- K_c is corrective coefficient to account for different level of protection due to the naturalistic value of the interested area [1.0 to 1.5].

The concept of “environmental sensitive” is linked with Flow Duration Curve (FDC). When the slope of the FDC is flat, for example when $Q_{90} \geq 30\%$ AAF, the flow in the river is very stable thought the year, and the ecosystem is getting used to have a constant rate of flow in the river most of the time. This type of ecosystem is more sensitive to any change in river flow regime and the value of K_a will be taken as 1 (one). On other hand, when the FDC slope is steep, say $Q_{90} < 10\%$ AAF, the river flow is very unstable and present high extreme values (floods and droughts). Under this condition, ecosystem is getting used to water scarcity during some periods of the year, therefore this ecosystem is less sensitive to changes in flow regime, because the river naturally present a wide variability in flow regime. In this case, the value of K_a can be taken as 0.7.

The implementation factor refers to upgrade a degraded river condition, in which the quantity of water in the river is very low, due to abstractions made for different purposes (domestic, industrial, agriculture, etc.). The recovery of natural conditions of the river flow must be done gradually, because another uses of water will be affected. In this case, the value of K_b could be 0.25. In the case of no significant abstractions, the value of K_b will be 1.

The Kc factor increases the value of MIF, for protection of special conditions in the river ecosystem like naturalistic and tourism values, fisheries development and medicinal or religious issues.

(iii) Desktop Analysis

Desktop analysis can be sub-divided into (i) those based purely on hydrological data, and (ii) those that employ both hydrological and ecological data.

Desktop methods based on hydrological data

(a) Flow Duration Curve Based Method

A flow duration curve (FDC) is a plot of flow vs. percentage time equalled or exceeded. FDC can be prepared using the entire time series data of flow or the flow data pertaining to a specific period (such as a month) in different years. Further, it can be developed for a particular site or combining data for different sites on per unit catchment area basis in a hydro meteorologically homogeneous region.

(b) Environmental Management Class (EMC) based FDC Approach

Smakhtin and Anputhas (2006) reviewed various hydrology based environmental flow assessment methodologies and their applicability in Indian context. Based on the study, they suggested a flow duration curve based approach which links environmental flow requirement with environmental management classes.

This EFA method is built around a period-of-record FDC and includes several subsequent steps. The first step is the calculation of a representative FDC for each site where the environmental water requirement (EWR) is to be calculated. In this study, the sites where EF is calculated coincide with the major flow diversion. The sites with observed flow data are further referred to as 'source' sites. The sites where reference FDC and time series are needed for the EF estimation are referred to as 'destination' sites. All FDCs are represented by a table of flows corresponding to the 17 fixed percentage points. For each destination site, a FDC table was calculated using a source FDC table from either the nearest or the only available observation flow station upstream. To account for land-use impacts, flow withdrawal, etc., and for the differences between the size of a source and a destination basin, the source FDC is scaled up by the ratio of 'natural' long term mean annual runoff (MAR) at the outlet and the actual MAR calculated from the source record.

(c) Defining Environmental Management Classes

EF aim to maintain an ecosystem in, or upgrade it to, some prescribed or negotiated condition/ status also referred to as "desired future state", "environmental management class"/ "ecological management category", "level of environmental protection", etc. (e.g., Acreman and Dunbar 2004; DWAF 1997). This report uses the term 'environmental management class' (EMC). The higher the EMC, the more water will need to be allocated for ecosystem maintenance or conservation and more flow variability will need to be preserved. Ideally, these classes should be based on empirical relationships between flow and ecological status/conditions associated with clearly identifiable thresholds. However, so far there is insufficient evidence for such thresholds (e.g., Beecher 1990; Puckridge et al. 1998). These categories are therefore a management concept, which has been developed and used in the world because of a need to make decisions in the conditions of limited lucid knowledge. Placing a river into a certain EMC is normally accomplished by expert judgment using a scoring system. Alternatively, the EMCs may be used as default

‘scenarios’ of environmental protection and corresponding EWR and EF - as ‘scenarios’ of environmental water demand. Six EMCs are used generally and six corresponding default levels of EWR may be defined. The set of EMCs starts with the *unmodified and largely natural conditions* (rivers in classes A and B), where no or limited modification is present or should be allowed from the management perspective. In *moderately modified* river ecosystems (class C rivers), the modifications are such that they generally have not (or will not - from the management perspective) affected the ecosystem integrity. *Largely modified* ecosystems (class D rivers) correspond to considerable modification from the natural state where the sensitive biota is reduced in numbers and extent. *Seriously and critically modified* ecosystems (classes E and F) are normally in poor conditions where most of the ecosystem’s functions and services are lost. Rivers which fall into classes C to F would normally be present in densely populated areas with multiple man-induced impacts. Poor ecosystem conditions (classes E or F) are sometimes not considered acceptable from the management perspective and the management intention is always to “move” such rivers up to the least acceptable class D through river rehabilitation measures (DWAF 1997). This restriction is not however applied here, primarily because the meaning of every EMC is somewhat arbitrary and needs to be filled with more ecological substance in the future. Some studies use transitional EMCs (e.g., A/B, B/C, etc.) to allow for more flexibility in EWR determinations. It can be noted, however, that ecosystems in class F are likely to be those which have been modified beyond rehabilitation to anything approaching a natural condition. It is possible to estimate EWR corresponding to all or any of the above EMCs and then consider which one is best suited/feasible for the river in question, given existing and future basin developments. On the other hand, it is possible to use expert judgment and available ecological information in order to place a river into the most probable/achievable EMC. The EMCs are described in **Table 9.1** as scenarios of aquatic ecosystem condition.

Table 9.1: Environment Management Classes

EMC	Ecological description	Management perspective
A: Natural	Pristine condition or minor modification of in-stream and riparian habitat	Protected rivers and basins. Reserves and national parks. No new water projects (dams, diversions, etc.) allowed
B: Slightly modified	Largely intact biodiversity and habitats despite water resources development and/or basin modifications	Water supply schemes or irrigation development present and/or allowed
C: Moderately	The habitats and dynamics of the modified biota have been disturbed, but basic ecosystem functions are still intact. Some sensitive species are lost and/or reduced in extent. Alien species present	Multiple disturbances associated with the need for socio-economic development, e.g., dams, diversions, habitat modification and reduced water quality
D: Largely modified	Large changes in natural habitat, biota and basic ecosystem functions have occurred. A clearly lower than expected species richness. Much lowered presence of intolerant species. Alien species prevail	Significant and clearly visible disturbances associated with basin and water resources development, including dams, diversions, transfers, habitat modification and water quality degradation
E: Seriously modified	Habitat diversity and availability have declined. A strikingly lower than expected species richness. Only tolerant species remain. Indigenous species can no longer breed. Alien species have invaded the ecosystem	High human population density and extensive water resources exploitation

EMC	Ecological description	Management perspective
F: Critically modified	Modifications have reached a critical level and ecosystem has been completely modified with almost total loss of natural habitat and biota. In the worst case, the basic ecosystem functions have been destroyed and the changes are irreversible	This status is not acceptable from the management perspective. Management interventions are necessary to restore flow pattern, river habitats, etc. (if still possible/feasible) - to 'move' a river to a higher management category

9.3.2 Hydraulic Rating Methodologies

Hydraulic rating methodologies use changes in simple hydraulic variables, such as wetted perimeter or maximum depth, usually measured across single, flow-limited river cross-sections (commonly riffles), as a surrogate for habitat factors known or assumed to be limiting to target biota. Environmental flows are determined from a plot of the hydraulic variable(s) against discharge, commonly by identifying curve breakpoints where significant percentage reductions in habitat quality occur with decreases in discharge. It is assumed that ensuring some threshold value of the selected hydraulic parameter at a particular level of altered flow will maintain aquatic biota and thus, ecosystem integrity. These relatively low-resolution hydraulic techniques have been superseded by more advanced habitat modelling tools, or assimilated into holistic methodologies (Tharme 1996; Jowett 1997; Arthington and Zalucki 1998; Tharme 2003). However, select approaches continue to be applied and evaluated, notably the Wetted Perimeter Method (e.g. Gippel and Stewardson 1998).

9.3.3 Habitat Simulation or Micro-Habitat Modelling Methodologies

Habitat simulation methodologies also make use of hydraulic habitat-discharge relationships, but provide more detailed, modelled analyses of both the quantity and suitability of the physical river habitat for the target biota. Thus, environmental flow recommendations are based on the integration of hydrological, hydraulic and biological response data. Flow-related changes in physical microhabitat are modelled in various hydraulic programs, typically using data on depth, velocity, substratum composition and cover; and more recently, complex hydraulic indices (e.g. benthic shear stress), collected at multiple cross-sections within each representative river reach. Simulated information on available habitat is linked with seasonal information on the range of habitat conditions used by target fish or invertebrate species (or life-history stages, assemblages and/or activities), commonly using habitat suitability index curves (e.g. Groshens and Orth 1994). The resultant outputs, in the form of habitat-discharge relationships for specific biota, or extended as habitat time and exceedence series, are used to derive optimum environmental flows. The habitat simulation-modelling package PHABSIM (Bovee 1982, 1998; Milhous 1998, 1982; Milhous et al. 1989; Stalnaker et al. 1994), housed within the In-stream Flow Incremental Methodology (IFIM), is the pre-eminent modelling platform of this type.

9.3.4 Holistic Methodologies

Over the past decade, river ecologists have increasingly made the case for a broader approach to the definition of environmental flows to sustain and conserve river ecosystems, rather than focusing on just a few target fish species (Arthington and Pusey 1993; King and Tharme 1994; Sparks 1992, 1995; Richter et al. 1996; Poff et al. 1997). From the conceptual foundations of a holistic ecosystem approach, a wide range of holistic methodologies has been developed and applied, initially in Australia and South Africa and later in the United Kingdom. This type of approach reasons that if certain features of the natural hydrological regime can be identified and

adequately incorporated into a modified flow regime, then, all other things being equal, the extant biota and functional integrity of the ecosystem should be maintained (Arthington et al. 1992; King and Tharme 1994). Importantly, holistic methodologies aim to address the water requirements of the entire “riverine ecosystem” rather than the needs of only a few taxa (usually fish or invertebrates). These methodologies share a common objective - to maintain or restore the flow related biophysical components and ecological processes of in-stream and groundwater systems, floodplains and downstream receiving waters (e.g. terminal lakes and wetlands, estuaries and near-shore marine ecosystems). Ecosystem components that are commonly considered in holistic assessments include geomorphology, hydraulic habitat, water quality, riparian and aquatic vegetation, macro-invertebrates, fish and other vertebrates with some dependency upon the river/riparian ecosystem (i.e. amphibians, reptiles, birds, mammals). Each of these components can be evaluated using a range of field and desktop techniques and their flow requirements are then incorporated into EFA recommendations, using various systematic approaches.

Holistic approaches have been described as either ‘bottom-up’ methods, which are designed to ‘construct’ a modified flow regime by adding flow components to a baseline of zero flows; or ‘top-down’ methods i.e. by assessing how much a river’s flow regime can be modified before the aquatic ecosystem begins to noticeably change or degrade.

9.3.4.1 *The Building Block Methodology (BBM)*

The BBM is introduced in King & Tharme (1994) and King (1996), and is comprehensively described in Tharme & King (1998), and King & Louw (1998). The methodology is under on going development, and has been applied routinely in South Africa, with some application in Australia and UK. The methodology is based on the concept that some flows within the complete hydrological regime of a river are more important than others for maintenance of the riverine ecosystem, and that these flows can be identified, and described in terms of their magnitude, duration, timing, and frequency. In combination, these flows constitute the EFR as a river-specific modified flow regime, linked to a predetermined future state. A number of specialists in a workshop situation use hydrological base flow and flood data, including various hydrological indices, cross-section based hydraulic data, and information on the flow-related needs of ecosystem components, to identify specific flow elements for the EFR.

9.3.4.2 *The Downstream Response to Imposed Flow Transformations Methodology*

The DRIFT Methodology was developed in southern Africa for use in the Palmiet IFR study (Brown et al., 2000) and Lesotho Highlands Water Project (Brown & King 1999, 2000). It is an interactive, top-down holistic approach based on the same conceptual tenets and multidisciplinary, workshop-based interaction as the BBM and Holistic Approach. However, it focuses on the identification of a series of river water levels associated with a particular set of biophysical functions and of specific hydrological and hydraulic character. Specialists in each discipline describe the consequences of reducing discharges through these identified flow bands and their thresholds, in terms of deterioration in biotic and abiotic condition. The identification of the ‘minimum degradation’ reduction level and its consequences typically provides the starting point for the process. Once a wide range of flow reductions has been assessed, there is considerable scope for the comparative evaluation of a vast number of EFR scenarios, each reflecting the presence or absence of different flow bands with attendant consequences.

Holistic methodologies exhibit several advantages over other types of environmental flow methodology, most importantly in that they can potentially be used to address all components of

the riverine ecosystem and have strong links with the natural hydrological regime. Also, they incorporate biological, geomorphological and hydrological data, and consider all aspects of the flow regime, such as the magnitude and timing of both base flow and flood events. However, holistic methodologies rely to a considerable extent on professional judgment, so care must be taken to apply them in a rigorous, well structured manner, in order to ensure sufficiently reproducible results. The methodologies are firmly based on South African and Australian experiences of variable climate and hydrology, heterogeneous geomorphology, and of limited available information on biological flow dependencies of riverine biota (Grouns & Kotlash 1994; Tharme 1996). As with most other current environmental flow methodologies, there are few applications of holistic methodologies other than in their place of origin.

For the purpose of environmental flow assessment in Siang basin, hydraulic modelling and habitat simulation methodologies is considered to be best suited as discussed in the following section.

9.4 ADOPTED METHODOLOGY TO ESTABLISH ENVIRONMENTAL FLOW

9.4.1 Basics of Environmental Flow Assessment Methods

Environmental flows (EF) are an ecologically acceptable flow regime designed to maintain a river in an agreed or predetermined state. Therefore, EF are a compromise between hydro development, on one hand, and river maintenance in a healthy or at least reasonable condition, on the other. Difficulties in the actual estimation of EF values arise primarily due to the inherent lack of both the understanding of and quantitative data on relationships between river flows and multiple components of river ecology. The major criteria for determining EF should include the maintenance of both spatial and temporal patterns of river flow, i.e., the flow variability, which affect the structural and functional diversity of rivers, and which in turn influence the species diversity of the river. All components of the hydrological regime have certain ecological significance. High flows of different frequency are important for channel maintenance, bird breeding, wetland flooding and maintenance of riparian vegetation. Moderate flows are critical for cycling of organic matter from river banks and for fish migration, while low flows of different magnitudes are important for algae control, water quality maintenance and the use of the river by local people. Therefore, many elements of flow variability have to be maintained in a modified-EF-regime.

The focus on maintenance of flow variability has several important implications. First, it moves away from a 'minimum flow attitude' to aquatic environment. Second, it effectively considers that aquatic environment is also 'held accountable' and valued similarly to other sectors - to allow informed trade-offs to be made in water deprived conditions. Because wetland and river ecosystems are naturally subjected to droughts or low flow periods and can recover from those, then building this variability into the picture of EFA may be seen as environmental water demand management. This brings us back to the issue of 'compromise' and implies that EF is a very pragmatic concept: it does not accept a bare minimum, but it is for a trade. Bunn and Arthington (2002) have formulated four basic principles that emphasize the role of flow regime in structuring aquatic life and show the link between flow and ecosystem changes:

- Flow is a major determinant of physical habitat in rivers, which in turn is the major determinant of biotic composition. Therefore, river flow modifications eventually lead to changes in the composition and diversity of aquatic communities.

- Aquatic species have evolved life history strategies primarily in response to the natural flow regimes. Therefore, flow regime alterations can lead to loss of biodiversity of native species.
- Maintenance of natural patterns of longitudinal and lateral connectivity in river systems determines the ability of many aquatic species to move between the main river and its tributaries. Loss of longitudinal and lateral connectivity can lead to local extinction of species.

In this report, hydraulic rating methodologies and habitat simulations or micro-habitat modelling methodologies have been used. The primary reason for using this method is objectivity of the methodology, availability of data including surveyed river cross-sections and limited timeframe available for the study.

Main reasons for not using Hydrological Index Methods is that though these provide a relatively rapid, non-resource intensive, but give low resolution estimate of environmental flows. The methods are only appropriate at the planning level where they may be used as preliminary estimates. These methods may be used as tools within habitat simulation, holistic or combination environmental flow methodologies. Commonly, the EFR is represented as a proportion of flow (often termed the 'minimum flow',) intended to maintain river health, fisheries or other highlighted ecological features at some acceptable level, usually on an annual, seasonal or monthly basis.

Building Block Method (BBM) could not be used because of following reasons:

- The BBM is essentially a prescriptive approach, designed to construct a flow regime for maintaining a river in a predetermined condition. Building Block Method can use detailed data from different sectors and have the provision of consultation among the experts and stakeholders. However, application of BBM for large number of sites requires a lot of time and resources.
- The BBM has advanced the field of environmental flow assessment and being a holistic methodology it addresses the health (structure and functioning) of all components of the riverine ecosystem, rather than focusing on selected group or species. But in context of Siang basin study, the major stakeholder is only riverine ecology and fish. Hence adopting such rigorous exercise is neither needed nor practical within a limited time frame and resources.

Environmental flow regime has been worked out keeping annual occurrence of following main seasons in this region. These are:

- (a) Season I: This season is considered as low or lean or dry flow season which covers the months from December to March
- (b) Season II: It is considered as high flow season influenced by monsoon. It covers the months from June to September.
- (c) Season III: This season is considered as average flow period, covers the months of April, May and October, November

9.5 HYDRO-DYNAMIC MODELLING

To assess environmental flow requirements, a flow simulation study has been carried out using one dimensional mathematical model **HEC-RAS version 4.1.0** developed by Hydrologic Engineering Center of U.S. Army Corps of Engineers.

9.5.1 HEC-RAS Model

HEC-RAS is an integrated system of software, designed for interactive use in a multi-tasking environment. The system is comprised of a graphical user interface, separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities. The present version of HEC-RAS system contains three one-dimensional hydraulic components for: i) Steady flow surface profile computations; ii) quasi-unsteady flow simulation and iii) unsteady flow simulation. The steady/unsteady flow components are capable of modelling subcritical, supercritical, and mixed flow regime water surface profiles. The system can handle a full network of channels, a dendric system, or a single river reach. The basic computational procedure is based on the solution of one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the velocity head). The momentum equation is utilized in situations where the water surface profile is rapidly varied.

The graphics include X-Y plots of the river system schematic, cross-sections, profiles, rating curves, hydrographs, and many other hydraulic variables. Users can select from pre-defined tables or develop their own customized tables. All graphical and tabular output can be displayed on the screen, sent directly to a printer, or passed through the Windows clipboard to other software, such as word processor or spread sheet. Reports can be customized as to the amount and type of information desired.

The following approach has been used for various data inputs:

9.5.2 Hydropower Projects considered for Modelling

There are 44 hydro projects being planned in the Siang river basin on different tributaries and their details and status is discussed in Chapter 3. None of the projects have started construction; many of the projects are at various stages of survey and investigation and quite a few of projects have yet to start the survey and investigation work as well and therefore data availability of such projects is very limited. 23 projects have been selected for simulation modelling based on data availability and to ensure that major tributaries of Siang river are covered in this modelling exercise. These are listed in **Table 9.2**.

Table 9.2: HEPs covered for Hydrodynamic Modelling

Sl. No.	Name of Project	Capacity (MW)	River/ Tributary	Main River	Intermediate River Length* (km)
1	Naying	1000	Siyom	Siang	7.60
2	Tato-II	700	Siyom	Siang	3.90
3	Hirong	500	Siyom	Siang	10.30
4	Tato-I	186	Yargyap	Siyom	5.10
5	Heo	240	Yargyap	Siyom	5.90
6	Pauk	145	Yargyap	Siyom	2.80
7	Rapum	66	Yargyap	Siyom	2.00
8	Rego**	80	Yargyap	Siyom	0.00
9	Kangtangshiri**	80	Yargyap	Siyom	3.70

Sl. No.	Name of Project	Capacity (MW)	River/ Tributary	Main River	Intermediate River Length* (km)
10	Pemashelpu	90	Yargyap	Siyom	5.50
11	Hirit Korong	42	Hirit	Siyom	2.40
12	Siri Korong	58	Siri Korong	Hirit	3.00
13	Gameng	37	Sike	Siyom	3.50
14	Simang-I	67	Simang	Siang	5.40
15	Simang-II	66	Simang	Siang	7.70
16	Pango/ Minnying	96	Sigong	Siang	7.00
17	Mirak	141	Sigong	Siang	4.00
18	Palsi	24	Palsi	Siang	5.40
19	Ringong	150	Ringong	Siang	3.00
20	Yamne Stage-I	135	Yamne	Siang	13.30
21	Yamne Stage-II	96	Yamne	Siang	7.00
22	Lower Yamne Stage - I	75	Yamne	Siang	9.30
23	Lower Yamne Stage - II	87	Yamne	Siang	2.60

* Intermediate River length is the distance along the river between diversion site and tail water discharge point i.e. the river reach, which will be deprived of flow due to diversion of water to HRT. Adequate environment flow will ensure that river in this reach should have sufficient water through out the year.

** Intermediate River length mentioned against Kangtangshiri HEP is from Kangtangshiri HEP diversion site till tail water discharge point of Rego HEP (Rego HEP is tailrace development scheme of upstream Kangtangshiri HEP). Intermediate river length is mentioned as zero against Rego HEP as it is already covered under Kangtangshiri HEP.

Projects on Main Siang River

Three planned projects on main Siang River are in cascade without any free flowing stretch between adjacent projects. These are planned as dam toe projects with large storage reservoirs. In the absence of intermediate river reach and free flowing river reach between adjacent projects, environment flow recommendations are not relevant. Operations of these projects will involve generating power in peaking hours resulting in release of water immediate downstream of the dam into the reservoir of downstream project. Lower most project in cascade i.e. Siang Lower HEP would release water after peaking in Siang river downstream of dam. Flow modelling for these projects to study the impact of huge diurnal variation especially in lean season have been separately carried out to understand down stream impacts and dealt in next chapter.

Input data used for present modelling study has been described below:

9.5.3 Discharge Data

Efforts have been made to procure discharge data for various projects from Central Water Commission (CWC). Out of 24 projects listed above, CWC has already approved water availability series for 16 projects; this data was provided to us and same is used for simulation modelling. Rego is tailrace development scheme of Kangtangshiri HEP, therefore no separate modelling is carried out for Rego HEP. Simang I and Simang II series have been taken from the respective approved DPRs for these projects. For the remaining projects, series have been generated on catchment area proportion and rainfall variability factor basis from the available CWC approved series. For Gameng, Hirit Korong and Siri Korong projects, flow series were computed from Middle Siyom HEP and for Ringong, Pango, Mirak and Palsi, series computed from Yamne Stage I HEP. These flow series are given in Chapter 4, "Hydro-meteorology".

From the long term flow series, 90% dependable year for different projects have been calculated as the year with over 90% dependability and used in the modelling exercise as input flow data. *It has been noted that some developers have considered a different year as 90% dependable year in*

their PFRs/DPRs i.e. year with less than 90% dependability (say 88%) and hence there might be difference between 90% dependable year considered in present study with that of considered by hydro developers.

Out of the full year flow series (90% Dependability), three average values have been calculated viz.

- Average of four leanest months
- Average of four monsoon months
- Average of remaining four months

Flow simulations have been carried out for 10%, 15%, 20%, 25%, 30%, 40%, 50% and 100% releases of the average discharge for each of above three scenarios for the identified 22 projects. Various key parameters for establishing habitat requirement have been calculated which include water depth, flow velocity and top width of waterway.

Average discharge for four leanest months, monsoon months and other months have been calculated for 90% dependable year and is shown in Tables 9.3 to 9.8.

Table 9.3: 90% DY Average Discharge Data for Projects on Siyom River

	Hirong	Tato II	Naying
90% dependable year	2004-05	2004-05	2004-05
Catchment Area (sq.Km)	1289	2560	2760
	Discharge (cumec)		
Monsoon (June-September)			
Average	143.80	339.99	361.30
10 % of average	14.38	34.00	36.13
15 % of average	21.57	51.00	54.20
20 % of average	28.76	68.00	72.26
25 % of average	35.95	85.00	90.33
30 % of average	43.14	102.00	108.39
40 % of average	57.52	136.00	144.52
50 % of average	71.90	170.00	180.65
Lean (November-February)			
Average	22.50	53.21	56.54
10 % of average	2.25	5.32	5.65
15 % of average	3.38	7.98	8.48
20 % of average	4.50	10.64	11.31
25 % of average	5.63	13.30	14.14
30 % of average	6.75	15.96	16.96
40 % of average	9.00	21.28	22.62
50 % of average	11.25	26.60	28.27
Non-monsoon, non-lean (October, March, April, May)			
Average	85.64	202.48	215.18
10 % of average	8.56	20.25	21.52
15 % of average	12.85	30.37	32.28
20 % of average	17.13	40.50	43.04
25 % of average	21.41	50.62	53.80
30 % of average	25.69	60.75	64.55
40 % of average	34.26	80.99	86.07
50 % of average	42.82	101.24	107.59

Table 9.4: 90% DY Average Discharge Data for Projects on Yargyap Chhu

	Pema-shelpu	Kang-tangshri	Rapum	Pauk	Heo	Tato I
90% DY	1992-93	1992-93	1992-93	1992-93	1992-93	1992-93
CA (sq Km)	368	810	839	982	1065	1154
Discharge (cumec)						
Monsoon (June-September)						
Average	42.49	99.55	104.53	122.33	132.67	143.83
10 % of average	4.25	9.96	10.45	12.23	13.27	14.38
15 % of average	6.37	14.93	15.68	18.35	19.90	21.58
20 % of average	8.50	19.91	20.91	24.47	26.53	28.77
25 % of average	10.62	24.89	26.13	30.58	33.17	35.96
30 % of average	12.75	29.87	31.36	36.70	39.80	43.15
40 % of average	17.00	39.82	41.81	48.93	53.07	57.53
50 % of average	21.25	49.78	52.26	61.17	66.33	71.92
Lean (December-March)						
Average	4.25	10.11	10.58	12.50	13.50	14.58
10 % of average	0.43	1.01	1.06	1.25	1.35	1.46
15 % of average	0.64	1.52	1.59	1.88	2.03	2.19
20 % of average	0.85	2.02	2.12	2.50	2.70	2.92
25 % of average	1.06	2.53	2.65	3.13	3.38	3.65
30 % of average	1.28	3.03	3.17	3.75	4.05	4.38
40 % of average	1.70	4.05	4.23	5.00	5.40	5.83
50 % of average	2.13	5.06	5.29	6.25	6.75	7.29
Non-monsoon, non-lean (October, November, April, May)						
Average	18.68	43.87	46.05	54.00	58.50	63.25
10 % of average	1.87	4.39	4.60	5.40	5.85	6.33
15 % of average	2.80	6.58	6.91	8.10	8.78	9.49
20 % of average	3.74	8.77	9.21	10.80	11.70	12.65
25 % of average	4.67	10.97	11.51	13.50	14.63	15.81
30 % of average	5.60	13.16	13.81	16.20	17.55	18.98
40 % of average	7.47	17.55	18.42	21.60	23.40	25.30
50 % of average	9.34	21.94	23.02	27.00	29.25	31.63

Table 9.5: 90% DY Average Discharge Data for Projects on Tributaries of Siyom River

	Hirit Korong	Siri Korong	Gameng
90% dependable year	2004-05	2004-05	2004-05
Catchment Area (sq.Km)	198	265	422
Discharge (cumec)			
Monsoon (June-September)			
Average	26.89	35.99	57.31
10 % of average	2.69	3.60	5.73
15 % of average	4.03	5.40	8.60
20 % of average	5.38	7.20	11.46
25 % of average	6.72	9.00	14.33
30 % of average	8.07	10.80	17.19
40 % of average	10.76	14.39	22.92
50 % of average	13.44	17.99	28.65
Lean (November-February)			
Average	4.21	5.63	8.97
10 % of average	0.42	0.56	0.90
15 % of average	0.63	0.84	1.35
20 % of average	0.84	1.13	1.79
25 % of average	1.05	1.41	2.24
30 % of average	1.26	1.69	2.69
40 % of average	1.68	2.25	3.59
50 % of average	2.10	2.82	4.48

	Hirit Korong	Siri Korong	Gameng
Non-monsoon, non-lean (October, March, April, May)			
Average	16.01	21.43	34.13
10 % of average	1.60	2.14	3.41
15 % of average	2.40	3.21	5.12
20 % of average	3.20	4.29	6.83
25 % of average	4.00	5.36	8.53
30 % of average	4.80	6.43	10.24
40 % of average	6.41	8.57	13.65
50 % of average	8.01	10.72	17.06

Table 9.6: 90% DY Average Discharge Data for Projects on Tributaries of Siang River

	Ringong	Pango	Mirak	Palsi
90% dependable year	2004-05	2004-05	2004-05	2004-05
Catchment Area (sq Km)	738	788	945	92
Discharge (cumec)				
Monsoon (June-September)				
Average	100.22	85.61	115.49	11.24
10 % of average	10.02	8.56	11.55	1.12
15 % of average	15.03	12.84	17.32	1.69
20 % of average	20.04	17.12	23.10	2.25
25 % of average	25.06	21.40	28.87	2.81
30 % of average	30.07	25.68	34.65	3.37
40 % of average	40.09	34.24	46.20	4.50
50 % of average	50.11	42.80	57.75	5.62
Lean (November-February)				
Average	15.68	13.40	18.07	1.76
10 % of average	1.57	1.34	1.81	0.18
15 % of average	2.35	2.01	2.71	0.26
20 % of average	3.14	2.68	3.61	0.35
25 % of average	3.92	3.35	4.52	0.44
30 % of average	4.71	4.02	5.42	0.53
40 % of average	6.27	5.36	7.23	0.70
50 % of average	7.84	6.70	9.04	0.88
Non-monsoon, non-lean (October, March, April, May)				
Average	59.69	50.98	68.78	6.70
10 % of average	5.97	5.10	6.88	0.67
15 % of average	8.95	7.65	10.32	1.00
20 % of average	11.94	10.20	13.76	1.34
25 % of average	14.92	12.75	17.20	1.68
30 % of average	17.91	15.29	20.64	2.01
40 % of average	23.87	20.39	27.51	2.68
50 % of average	29.84	25.49	34.39	3.35

Table 9.7: 90% DY Average Discharge Data for Projects on Yamne River

	Yamne Stage I	Yamne Stage II	Lower Yamne Stage I	Lower Yamne Stage II
90% dependable year	2004-05	2004-05	2004-05	2004-05
Catchment Area (sq Km)	625	890	1015	1203
Discharge (cumec)				
Monsoon (June-September)				
Average	84.87	120.86	132.05	156.51
10 % of average	8.49	12.09	13.20	15.65
15 % of average	12.73	18.13	19.81	23.48
20 % of average	16.97	24.17	26.41	31.30
25 % of average	21.22	30.22	33.01	39.13
30 % of average	25.46	36.26	39.61	46.95

	Yamne Stage I	Yamne Stage II	Lower Yamne Stage I	Lower Yamne Stage II
40 % of average	33.95	48.34	52.82	62.60
50 % of average	42.44	60.43	66.02	78.25
Lean (November-February)				
Average	13.28	18.91	20.66	24.49
10 % of average	1.33	1.89	2.07	2.45
15 % of average	1.99	2.84	3.10	3.67
20 % of average	2.66	3.78	4.13	4.90
25 % of average	3.32	4.73	5.17	6.12
30 % of average	3.98	5.67	6.20	7.35
40 % of average	5.31	7.57	8.27	9.80
50 % of average	6.64	9.46	10.33	12.25
Non-monsoon, non-lean (October, March, April, May)				
Average	50.55	71.98	78.64	93.21
10 % of average	5.05	7.20	7.86	9.32
15 % of average	7.58	10.80	11.80	13.98
20 % of average	10.11	14.40	15.73	18.64
25 % of average	12.64	18.00	19.66	23.30
30 % of average	15.16	21.59	23.59	27.96
40 % of average	20.22	28.79	31.46	37.28
50 % of average	25.27	35.99	39.32	46.60

Table 9.8: 90% DY Average Discharge Data for Projects on Simang River

	Simang I	Simang II
90% dependable year	1978-79	1978-79
Catchment Area (sq Km)	494	422
Discharge (cumec)		
Monsoon (June-September)		
Average	88.91	75.96
10 % of average	8.89	7.60
15 % of average	13.34	11.39
20 % of average	17.78	15.19
25 % of average	22.23	18.99
30 % of average	26.67	22.79
40 % of average	35.57	30.38
50 % of average	44.46	37.98
Lean (December-March)		
Average	14.41	12.32
10 % of average	1.44	1.23
15 % of average	2.16	1.85
20 % of average	2.88	2.46
25 % of average	3.60	3.08
30 % of average	4.32	3.69
40 % of average	5.77	4.93
50 % of average	7.21	6.16
Non-monsoon, non-lean (Oct, Nov, April, May)		
Average	39.88	34.08
10 % of average	3.99	3.41
15 % of average	5.98	5.11
20 % of average	7.98	6.82
25 % of average	9.97	8.52
30 % of average	11.97	10.22
40 % of average	15.95	13.63
50 % of average	19.94	17.04

9.5.4 River cross sections

Environmental flow assessment is carried out for the stretch of river, which starts downstream of diversion structure and up to the tailrace channel outfall point; generally termed as intermediate stretch between dam and powerhouse. For each project this stretch is calculated and given in **Table 9.2**. Out of this stretch initial 1-2 Km or the length up to which first major tributary meets the river is considered critical as for the rest of the stretch tributary will add to the environment flow released from the diversion structure. Therefore, modelling exercise to work out the environment flow to meet the habitat requirement for the initial critical stretch hold good for the rest of the river. Keeping this in view, 8-10 cross sections were taken immediate downstream of the diversion structure for each project and used in the modelling exercise. These sections have been represented in HEC-RAS model set up. Typical model set up showing locations of river cross-sections and actual surveyed river cross sections have been shown in **Figure 9.1 and 9.2**.

9.5.5 Manning's roughness coefficient

Manning's roughness coefficient for different type of channels as suggested in HEC-RAS manual is given in **Table 9.9**. For the present study the river reaches correspond to mountain stream with steep bank and bed consisting of cobbles and large boulders. For such type of river the value of Manning's n varies from 0.040 to 0.070. For a lower value of Manning's n the depth of water will be less in comparison to a higher value of Manning's n for the same discharge. Hence to have a conservative estimate of water depth the Manning's n has been adopted as 0.040 for the study reach.

Table 9.9: Manning's roughness coefficient

	Type of Channel and Description	Minimum	Normal	Maximum
	Natural Streams			
1	Main Channels			
	a. Clean, straight, full, no rifts or deep pools	0.025	0.030	0.033
	b. Same as above, but more stones and weeds	0.030	0.035	0.040
	c. Clean, winding, some pools and shoals	0.033	0.040	0.045
	d. Same as above, but some weeds and stones	0.035	0.045	0.050
	e. Same as above, lowwe stages, more ineffective slopes and sections	0.040	0.048	0.055
	f. Same as "d" but more stones	0.045	0.050	0.060
	g. Sluggish reaches, weedy. deep pools	0.050	0.070	0.080
	h. Very weedy reaches. deep pools, or floodways with heavy stands of timber and brush	0.070	0.100	0.150
2	Flood Plains			
	a. Pasture no brush			
	1. Short grass	0.025	0.030	0.035
	2. High grass	0.030	0.035	0.050
	b. Cultivated areas			
	1. No crop	0.020	0.030	0.040
	2. Mature row crops	0.025	0.035	0.045
	3. Mature field crops	0.030	0.040	0.050
	c. Brush			
	1. Scattered brush, heavy weeds	0.035	0.050	0.070
	2. Light brush and trees, in winter	0.035	0.050	0.060
	3. Light brush and trees, in summer	0.040	0.060	0.080
	4. Medium to dense brush, in winter	0.045	0.070	0.110
	5. Medium to dense brush, in summer	0.070	0.100	0.160
	d. Trees			
	1. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
	2. Same as above, but heavy sprouts	0.050	0.060	0.080
	3. Heavy stand of timber, few down trees, little	0.080	0.100	0.120

	Type of Channel and Description	Minimum	Normal	Maximum
	undergrowth, flow below branches			
	4. Same as above, but with flow into branches	0.100	0.120	0.160
	5. Dense willows, summer, straight	0.110	0.150	0.200
3	Mountain Streams, no vegetation in channel, banks usually steep, with trees and brush on banks submerged			
	a. Bottom: gravels, cobbles and few boulders	0.030	0.040	0.050
	b. Bottom: cobbles with large boulders	0.040	0.050	0.070

9.5.6 HEC-RAS Model set up

The HEC-RAS model set up for flow simulation study consist of a river reach, upstream boundary and a downstream boundary. The reach of rivers from diversion site of a hydro electric project up to its confluence with first stream has been represented in model by number of surveyed cross sections. The releases from the respective diversion sites are the upstream boundary of the model set up applied at upper most cross section. The Normal depth has been used as the downstream boundary for the model set up. In order to have independent results of water depth the downstream boundary has been applied at the cross section of respective rivers at few hundred meters downstream of the study reach. A typical HEC-RAS model set up for Tato-I HE project is given in **Figure 9.3**. The model set up for all other projects have been carried out in the same manner.

9.5.7 Model outputs

Model output for each HEP is for three different scenario viz. monsoon average, lean season average and other four months average discharge values. For each scenario, output is in the form of water depth, flow velocity and flow top width for each river cross-section considered in the critical reach i.e. from diversion structure to where first tributary meets the river. As the model output for all the projects for all the scenarios runs into over 250 pages, the same has been given in Volume II (Data). To discuss the results of the simulation modelling and assess the environmental flow requirement for each project separately, average values calculated for depth, velocity and flow top width for each scenario have been worked out and are given from **Tables 9.10 through 9.31**.

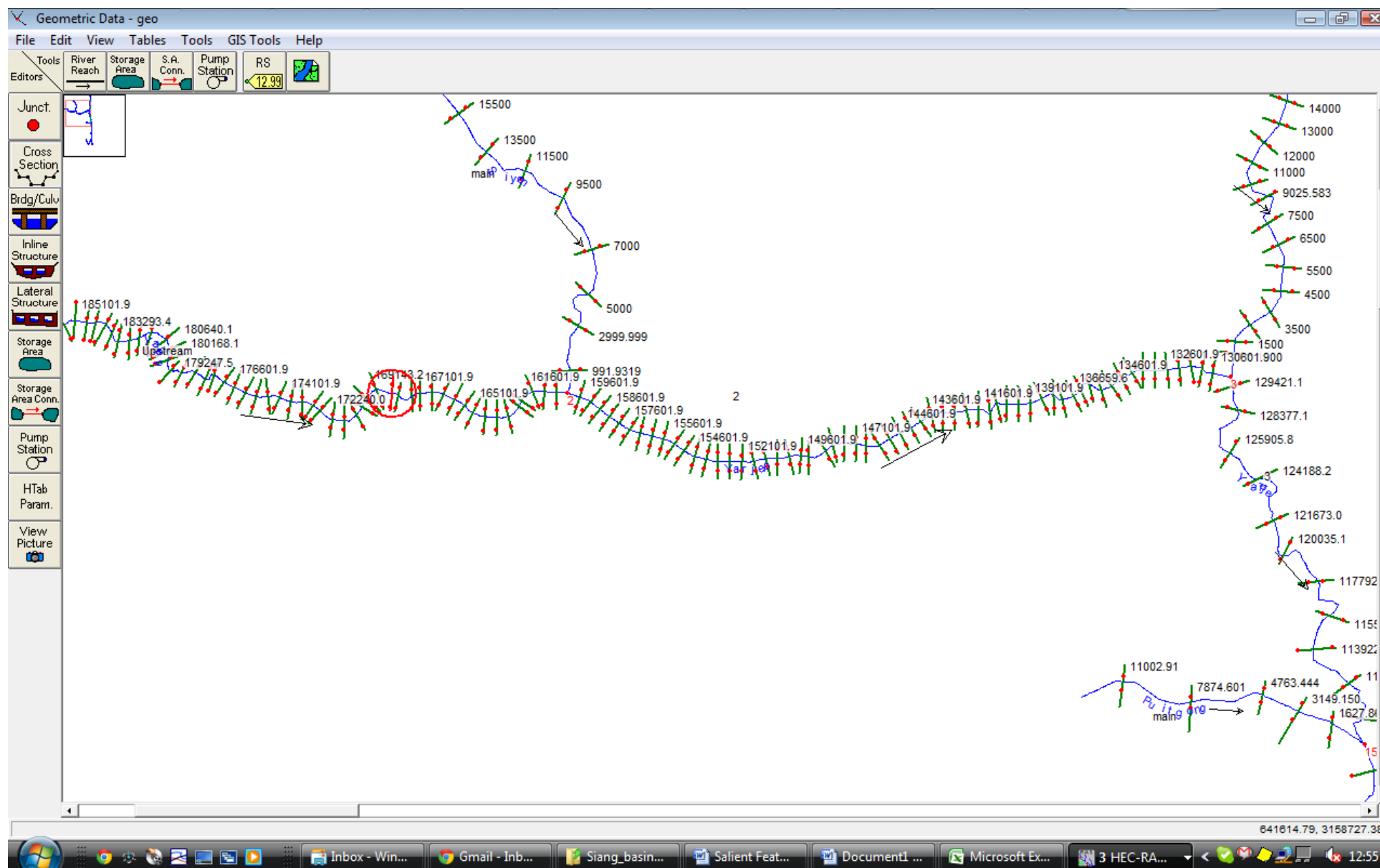


Figure 9.1: Location of various surveyed river cross sections in Siang river basin (HEC-RAS model set-up)

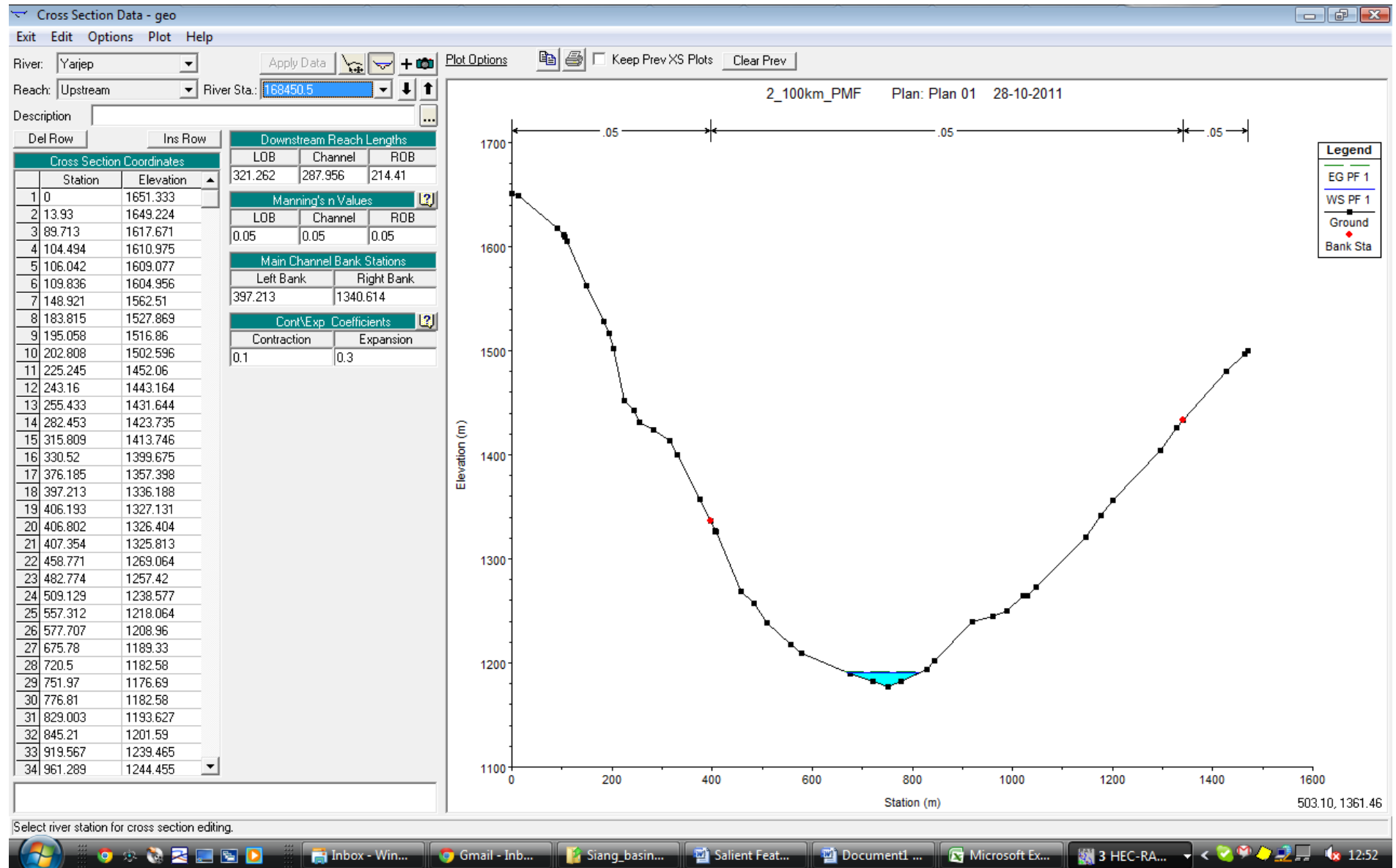


Figure 9.2: A typical view of surveyed river cross section considered for hydro-dynamic modelling (HEC-RAS model set-up)

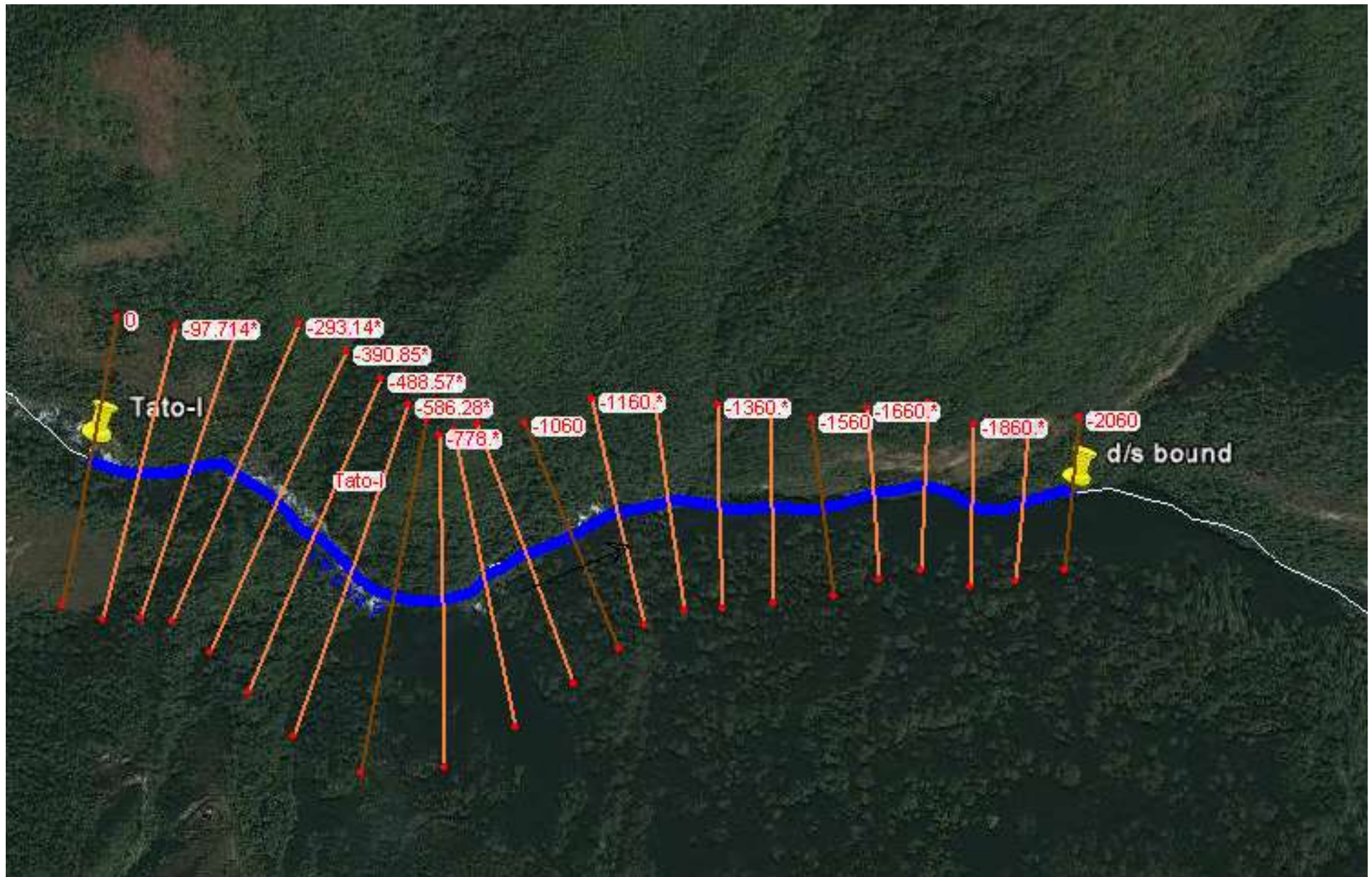


Figure 9.3: HEC-RAS Model set up for flow simulation study

Table 9.10: Model Output for Different Release Scenarios for Hirong HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	1218.18	1218.78	60.43	0.96	10.28
	15% release	1218.18	1218.89	70.71	1.06	11.70
	20% release	1218.18	1218.97	79.07	1.13	12.85
	25% release	1218.18	1219.04	85.93	1.19	13.78
	30% release	1218.18	1219.10	92.43	1.25	14.49
	40% release	1218.18	1219.21	103.21	1.34	15.72
	50% release	1218.18	1219.30	112.43	1.41	16.78
	100% release	1218.18	1219.65	146.93	1.68	20.69
Monsoon (June-Sept)	10% release	1218.18	1219.42	123.57	1.50	18.05
	15% release	1218.18	1219.62	144.29	1.66	20.42
	20% release	1218.18	1219.79	161.43	1.78	22.35
	25% release	1218.18	1219.94	175.86	1.89	23.99
	30% release	1218.18	1220.07	188.64	1.98	25.37
	40% release	1218.18	1220.29	210.71	2.13	27.60
	50% release	1218.18	1220.47	229.36	2.26	29.43
	100% release	1218.18	1221.17	299.07	2.73	35.80
Other Months (Oct, Mar, April, May)	10% release	1218.18	1219.19	101.29	1.32	15.50
	15% release	1218.18	1219.36	118.43	1.46	17.45
	20% release	1218.18	1219.50	132.07	1.57	19.03
	25% release	1218.18	1219.62	144.07	1.66	20.38
	30% release	1218.18	1219.72	154.43	1.73	21.56
	40% release	1218.18	1219.91	172.64	1.87	23.62
	50% release	1218.18	1220.06	188.00	1.97	25.32
	100% release	1218.18	1220.63	245.21	2.37	30.97

Table 9.11: Model Output for Different Release Scenarios for Tato II HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	884.39	885.17	77.80	1.56	9.28
	15% release	884.39	885.30	90.80	1.71	10.85
	20% release	884.39	885.40	101.20	1.82	12.11
	25% release	884.39	885.49	110.20	1.91	13.17
	30% release	884.39	885.58	118.50	1.99	14.12
	40% release	884.39	885.71	132.10	2.13	15.71
	50% release	884.39	885.83	144.00	2.24	17.12
	100% release	884.39	886.27	187.40	2.62	22.41
Monsoon (June-Sept)	10% release	884.39	885.97	158.20	2.36	18.83
	15% release	884.39	886.24	184.40	2.60	22.04
	20% release	884.39	886.45	205.90	2.76	24.69
	25% release	884.39	886.64	224.30	2.91	26.93
	30% release	884.39	886.79	240.10	3.03	28.89
	40% release	884.39	887.07	267.90	3.24	32.27
	50% release	884.39	887.30	291.00	3.42	35.16
	100% release	884.39	888.17	377.90	4.01	46.21
Other Months (Oct, Mar, April, May)	10% release	884.39	885.69	129.70	2.10	15.43
	15% release	884.39	885.91	151.40	2.30	18.02
	20% release	884.39	886.08	169.00	2.47	20.12
	25% release	884.39	886.23	183.90	2.59	21.98
	30% release	884.39	886.37	197.40	2.69	23.63
	40% release	884.39	886.59	220.10	2.88	26.41
	50% release	884.39	886.79	239.50	3.03	28.80
	100% release	884.39	887.50	310.80	3.56	37.63

Table 9.12: Model Output for Different Release Scenarios for Naying HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	678.29	678.90	60.56	1.61	14.75
	15% release	678.29	679.00	71.17	1.76	16.95
	20% release	678.29	679.09	79.72	1.88	18.68
	25% release	678.29	679.16	87.17	1.97	20.06
	30% release	678.29	679.23	93.78	2.05	21.27
	40% release	678.29	679.35	105.61	2.18	23.38
	50% release	678.29	679.45	115.78	2.28	25.19
	100% release	678.29	679.83	154.11	2.64	31.15
Monsoon (June-Sept)	10% release	678.29	679.57	128.00	2.40	27.21
	15% release	678.29	679.81	151.28	2.62	30.76
	20% release	678.29	680.00	170.72	2.79	33.46
	25% release	678.29	680.17	187.50	2.93	35.73
	30% release	678.29	680.31	202.22	3.05	37.62
	40% release	678.29	680.58	228.61	3.25	40.78
	50% release	678.29	680.81	251.50	3.42	43.42
	100% release	678.29	681.68	339.06	4.00	52.48
Other Months (Oct, Mar, April, May)	10% release	678.29	679.33	103.39	2.15	23.01
	15% release	678.29	679.52	122.28	2.34	26.27
	20% release	678.29	679.67	137.61	2.49	28.73
	25% release	678.29	679.80	151.00	2.62	30.70
	30% release	678.29	679.92	162.67	2.72	32.37
	40% release	678.29	680.13	183.67	2.90	35.24
	50% release	678.29	680.31	201.67	3.05	37.54
	100% release	678.29	681.00	270.89	3.56	45.45

Table 9.13: Model Output for Different Release Scenarios for Pemashelpu HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (December-March)	10% release	2178.07	2178.35	27.82	0.98	3.37
	15% release	2178.07	2178.39	32.45	1.07	3.94
	20% release	2178.07	2178.43	36.36	1.14	4.39
	25% release	2178.07	2178.46	39.45	1.19	4.80
	30% release	2178.07	2178.49	42.55	1.24	5.16
	40% release	2178.07	2178.54	47.36	1.33	5.76
	50% release	2178.07	2178.59	51.91	1.39	6.29
	100% release	2178.07	2178.75	67.82	1.62	8.24
Monsoon (June-Sept)	10% release	2178.07	2178.75	67.82	1.62	8.24
	15% release	2178.07	2178.86	79.45	1.76	9.67
	20% release	2178.07	2178.96	89.09	1.87	10.84
	25% release	2178.07	2179.04	97.09	1.97	11.84
	30% release	2178.07	2179.11	104.36	2.04	12.72
	40% release	2178.07	2179.23	116.64	2.18	14.25
	50% release	2178.07	2179.34	127.45	2.28	15.59
	100% release	2178.07	2179.74	167.55	2.65	20.43
Other Months (Oct, Nov, April, May)	10% release	2178.07	2178.56	49.09	1.36	5.97
	15% release	2178.07	2178.64	57.64	1.48	6.99
	20% release	2178.07	2178.71	64.55	1.57	7.83
	25% release	2178.07	2178.77	70.27	1.65	8.55
	30% release	2178.07	2178.82	75.64	1.71	9.20
	40% release	2178.07	2178.91	84.64	1.82	10.30
	50% release	2178.07	2178.99	92.27	1.91	11.25
	100% release	2178.07	2179.28	121.18	2.22	14.79

Table 9.14: Model Output for Different Release Scenarios for Kangtangshiri HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (December-March)	10% release	1843.08	1843.42	33.82	1.30	4.84
	15% release	1843.08	1843.48	39.73	1.41	5.69
	20% release	1843.08	1843.53	44.55	1.50	6.38
	25% release	1843.08	1843.57	48.64	1.56	6.98
	30% release	1843.08	1843.61	52.36	1.62	7.50
	40% release	1843.08	1843.67	58.82	1.71	8.43
	50% release	1843.08	1843.73	64.36	1.79	9.22
	100% release	1843.08	1843.93	84.55	2.05	12.11
Monsoon (June-Sept)	10% release	1843.08	1843.93	84.73	2.05	12.11
	15% release	1843.08	1844.08	99.55	2.22	14.24
	20% release	1843.08	1844.20	111.64	2.35	15.96
	25% release	1843.08	1843.76	67.41	1.80	9.65
	30% release	1843.08	1844.40	131.27	2.55	18.77
	40% release	1843.08	1844.56	147.27	2.71	20.81
	50% release	1843.08	1844.70	161.18	2.83	22.55
	100% release	1843.08	1845.21	212.73	3.29	28.23
Other Months (Oct, Nov, April, May)	10% release	1843.08	1843.69	60.73	1.74	8.71
	15% release	1843.08	1843.80	71.55	1.88	10.26
	20% release	1843.08	1843.89	80.27	2.00	11.49
	25% release	1843.08	1844.20	111.67	2.31	15.71
	30% release	1843.08	1844.03	94.73	2.16	13.54
	40% release	1843.08	1844.14	106.09	2.29	15.19
	50% release	1843.08	1844.25	116.18	2.40	16.61
	100% release	1843.08	1844.62	153.18	2.75	21.57

Table 9.15: Model Output for Different Release Scenarios for Rapum HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (December-March)	10% release	1602.81	1603.10	29.19	0.96	9.26
	15% release	1602.81	1603.15	34.34	1.06	10.42
	20% release	1602.81	1603.20	38.61	1.14	11.36
	25% release	1602.81	1603.21	39.67	1.16	11.56
	30% release	1602.81	1603.27	45.54	1.27	12.68
	40% release	1602.81	1603.32	51.21	1.36	13.72
	50% release	1602.81	1603.37	56.20	1.44	14.62
	100% release	1602.81	1603.56	75.08	1.72	17.68
Monsoon (June-Sept)	10% release	1602.81	1603.51	69.89	1.64	16.84
	15% release	1602.81	1603.64	83.00	1.82	18.75
	20% release	1602.81	1603.75	94.00	1.97	20.09
	25% release	1602.81	1603.84	103.11	2.10	20.99
	30% release	1602.81	1603.93	111.78	2.21	21.68
	40% release	1602.81	1604.08	126.67	2.41	22.85
	50% release	1602.81	1604.21	140.11	2.56	23.78
	100% release	1602.81	1604.73	192.44	3.13	27.33
Other Months (Oct, Nov, April, May)	10% release	1602.81	1603.31	50.00	1.33	13.45
	15% release	1602.81	1603.40	58.78	1.48	15.06
	20% release	1602.81	1603.47	66.22	1.59	16.26
	25% release	1602.81	1603.54	72.67	1.68	17.31
	30% release	1602.81	1603.60	78.67	1.76	18.21
	40% release	1602.81	1603.70	89.00	1.90	19.51
	50% release	1602.81	1603.79	97.56	2.02	20.49
	100% release	1602.81	1604.13	132.33	2.47	23.24

Table 9.16: Model Output for Different Release Scenarios for Pauk HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (December-March)	10% release	1474.79	1475.24	45.00	0.63	9.04
	15% release	1474.79	1475.31	52.33	0.70	10.55
	20% release	1474.79	1475.37	58.33	0.75	11.74
	25% release	1474.79	1475.42	63.50	0.80	12.77
	30% release	1474.79	1475.47	68.17	0.83	13.67
	40% release	1474.79	1475.54	75.67	0.89	15.24
	50% release	1474.79	1475.61	82.33	0.94	16.59
	100% release	1474.79	1475.86	107.17	1.12	21.39
Monsoon (June-Sept)	10% release	1474.79	1475.85	106.17	1.11	21.23
	15% release	1474.79	1476.02	123.50	1.24	24.19
	20% release	1474.79	1476.16	137.17	1.34	26.09
	25% release	1474.79	1476.27	148.83	1.44	27.31
	30% release	1474.79	1476.38	159.50	1.52	28.42
	40% release	1474.79	1476.57	178.17	1.66	30.37
	50% release	1474.79	1476.73	194.33	1.77	31.93
	100% release	1474.79	1477.36	257.00	2.20	37.53
Other Months (Oct, Nov, April, May)	10% release	1474.79	1475.57	78.00	0.91	15.69
	15% release	1474.79	1475.70	91.00	1.00	18.29
	20% release	1474.79	1475.80	101.50	1.08	20.35
	25% release	1474.79	1475.89	110.00	1.14	21.97
	30% release	1474.79	1475.96	117.83	1.20	23.26
	40% release	1474.79	1476.10	131.00	1.30	25.31
	50% release	1474.79	1476.21	142.17	1.39	26.61
	100% release	1474.79	1476.64	185.00	1.71	31.08

Table 9.17: Model Output for Different Release Scenarios for Heo HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (December-March)	10% release	1374.07	1374.59	52.12	1.11	5.14
	15% release	1374.07	1374.68	60.87	1.22	6.01
	20% release	1374.07	1374.75	67.94	1.30	6.71
	25% release	1374.07	1374.81	74.00	1.36	7.31
	30% release	1374.07	1374.86	79.56	1.41	7.83
	40% release	1374.07	1374.96	88.75	1.51	8.74
	50% release	1374.07	1375.04	96.75	1.58	9.53
	100% release	1374.07	1375.33	126.25	1.84	12.51
Monsoon (June-Sept)	10% release	1374.07	1375.32	125.31	1.84	12.42
	15% release	1374.07	1375.53	146.44	2.01	14.60
	20% release	1374.07	1375.70	163.37	2.14	16.35
	25% release	1374.07	1375.85	178.19	2.25	17.86
	30% release	1374.07	1375.98	191.06	2.34	19.17
	40% release	1374.07	1376.20	213.25	2.49	21.38
	50% release	1374.07	1376.39	232.19	2.62	23.22
	100% release	1374.07	1377.10	303.31	3.06	30.71
Other Months (Oct, Nov, April, May)	10% release	1374.07	1374.98	91.37	1.54	9.02
	15% release	1374.07	1375.14	107.00	1.68	10.55
	20% release	1374.07	1375.26	119.31	1.79	11.81
	25% release	1374.07	1375.37	130.13	1.88	12.92
	30% release	1374.07	1375.46	139.56	1.95	13.88
	40% release	1374.07	1375.63	155.75	2.08	15.55
	50% release	1374.07	1375.77	169.81	2.19	16.98
	100% release	1374.07	1376.28	221.19	2.55	22.17

Table 9.18: Model Output for Different Release Scenarios for Tato I HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (December-March)	10% release	1162.05	1162.58	53.55	1.36	4.90
	15% release	1162.05	1162.67	62.30	1.50	5.70
	20% release	1162.05	1162.74	69.65	1.60	6.35
	25% release	1162.05	1162.81	75.95	1.69	6.90
	30% release	1162.05	1162.86	81.20	1.76	7.38
	40% release	1162.05	1162.95	90.70	1.88	8.19
	50% release	1162.05	1163.04	99.10	1.97	8.85
	100% release	1162.05	1163.35	130.00	2.30	11.19
Monsoon (June-Sept)	10% release	1162.05	1163.34	129.30	2.29	11.13
	15% release	1162.05	1163.57	151.95	2.51	12.78
	20% release	1162.05	1163.75	170.10	2.68	14.10
	25% release	1162.05	1163.91	185.80	2.81	15.23
	30% release	1162.05	1164.05	199.85	2.93	16.22
	40% release	1162.05	1164.29	224.10	3.12	17.93
	50% release	1162.05	1164.50	245.05	3.28	19.40
	100% release	1162.05	1165.28	323.40	3.84	24.88
Other Months (Oct, Nov, April, May)	10% release	1162.05	1162.99	93.85	1.91	8.43
	15% release	1162.05	1163.14	109.75	2.09	9.69
	20% release	1162.05	1163.28	123.00	2.23	10.66
	25% release	1162.05	1163.39	134.25	2.34	11.50
	30% release	1162.05	1163.49	144.40	2.44	12.23
	40% release	1162.05	1163.67	161.80	2.60	13.50
	50% release	1162.05	1163.81	176.65	2.73	14.57
	100% release	1162.05	1164.38	232.85	3.19	18.54

Table 9.19: Model Output for Different Release Scenarios for Hirit Korong HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov- Feb)	10% release	719.83	720.22	38.31	1.22	1.83
	15% release	719.83	720.28	44.69	1.34	2.14
	20% release	719.83	720.33	50.15	1.43	2.39
	25% release	719.83	720.38	54.54	1.50	2.61
	30% release	719.83	720.42	58.62	1.56	2.80
	40% release	719.83	720.49	65.46	1.66	3.14
	50% release	719.83	720.55	71.62	1.74	3.43
	100% release	719.83	720.78	94.23	2.01	4.51
Monsoon (June-Sept)	10% release	719.83	720.62	78.92	1.83	3.78
	15% release	719.83	720.76	92.69	1.99	4.43
	20% release	719.83	720.87	103.85	2.11	4.96
	25% release	719.83	720.96	113.15	2.21	5.42
	30% release	719.83	721.05	121.69	2.30	5.83
	40% release	719.83	721.19	135.77	2.45	6.51
	50% release	719.83	721.32	148.23	2.57	7.11
	100% release	719.83	721.78	194.46	2.98	9.33
Other Months (Oct, Mar, April, May)	10% release	719.83	720.48	64.38	1.64	3.08
	15% release	719.83	720.59	75.46	1.79	3.61
	20% release	719.83	720.68	84.38	1.90	4.05
	25% release	719.83	720.76	92.31	1.98	4.42
	30% release	719.83	720.83	99.23	2.06	4.75
	40% release	719.83	720.94	111.15	2.19	5.32
	50% release	719.83	721.05	121.23	2.30	5.81
	100% release	719.83	721.42	158.92	2.66	7.62

Table 9.20: Model Output for Different Release Scenarios for Siri Korong HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	610.97	611.29	32.00	1.16	3.16
	15% release	610.97	611.35	37.56	1.26	3.70
	20% release	610.97	611.39	42.00	1.34	4.16
	25% release	610.97	611.43	45.78	1.40	4.54
	30% release	610.97	611.46	49.11	1.45	4.88
	40% release	610.97	611.52	55.11	1.54	5.46
	50% release	610.97	611.57	59.89	1.62	5.97
	100% release	610.97	611.76	79.00	1.86	7.85
Monsoon (June-Sept)	10% release	610.97	611.63	66.00	1.70	6.57
	15% release	610.97	611.75	77.67	1.85	7.72
	20% release	610.97	611.84	87.11	1.96	8.66
	25% release	610.97	611.92	95.22	2.05	9.47
	30% release	610.97	611.99	102.11	2.13	10.18
	40% release	610.97	612.12	114.67	2.26	11.40
	50% release	610.97	612.22	125.22	2.36	12.47
	100% release	610.97	612.62	164.89	2.73	16.43
Other Months (Oct, Mar, April, May)	10% release	610.97	611.51	54.00	1.53	5.35
	15% release	610.97	611.60	63.22	1.66	6.28
	20% release	610.97	611.68	70.89	1.76	7.05
	25% release	610.97	611.74	77.33	1.84	7.70
	30% release	610.97	611.80	83.33	1.92	8.28
	40% release	610.97	611.90	93.44	2.03	9.29
	50% release	610.97	611.99	102.11	2.13	10.15
	100% release	610.97	612.31	134.22	2.45	13.36

Table 9.21: Model Output for Different Release Scenarios for Gameng HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	610.05	610.30	24.77	0.94	8.77
	15% release	610.05	610.34	28.69	1.03	10.31
	20% release	610.05	610.37	32.31	1.09	11.45
	25% release	610.05	610.40	35.00	1.15	12.50
	30% release	610.05	610.43	37.77	1.19	13.43
	40% release	610.05	610.47	42.23	1.28	14.86
	50% release	610.05	610.51	45.85	1.34	15.99
	100% release	610.05	610.65	60.00	1.59	19.91
Monsoon (June-Sept)	10% release	610.05	610.56	50.69	1.42	17.38
	15% release	610.05	610.64	58.85	1.57	19.66
	20% release	610.05	610.71	65.92	1.68	21.45
	25% release	610.05	610.77	71.77	1.78	22.99
	30% release	610.05	610.82	77.23	1.85	24.38
	40% release	610.05	610.92	86.92	1.97	27.36
	50% release	610.05	611.00	95.15	2.06	30.15
	100% release	610.05	611.30	124.69	2.45	36.93
Other Months (Oct, Mar, April, May)	10% release	610.05	610.46	41.23	1.26	14.61
	15% release	610.05	610.53	48.38	1.39	16.73
	20% release	610.05	610.59	54.00	1.49	18.37
	25% release	610.05	610.64	58.69	1.56	19.62
	30% release	610.05	610.68	63.08	1.64	20.72
	40% release	610.05	610.75	70.46	1.75	22.66
	50% release	610.05	610.82	77.08	1.85	24.31
	100% release	610.05	611.07	101.77	2.15	32.23

Table 9.22: Model Output for Different Release Scenarios for Ringong HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	598.78	599.15	37.00	1.09	11.87
	15% release	598.78	599.21	43.55	1.20	13.10
	20% release	598.78	599.26	48.55	1.27	14.13
	25% release	598.78	599.31	53.18	1.33	15.00
	30% release	598.78	599.35	57.09	1.39	15.78
	40% release	598.78	599.42	63.82	1.47	17.11
	50% release	598.78	599.47	69.64	1.55	18.25
	100% release	598.78	599.70	91.73	1.81	22.50
Monsoon (June-Sept)	10% release	598.78	599.55	76.82	1.64	19.64
	15% release	598.78	599.68	90.18	1.79	22.25
	20% release	598.78	599.79	101.27	1.91	24.08
	25% release	598.78	599.88	110.36	2.01	25.65
	30% release	598.78	599.97	118.73	2.10	26.94
	40% release	598.78	600.11	132.91	2.26	28.78
	50% release	598.78	600.23	145.27	2.39	30.37
	100% release	598.78	600.70	191.91	2.85	36.26
Other Months (Oct, Mar, April, May)	10% release	598.78	599.40	62.64	1.46	16.86
	15% release	598.78	599.51	73.45	1.59	19.00
	20% release	598.78	599.60	82.45	1.70	20.73
	25% release	598.78	599.68	89.91	1.79	22.20
	30% release	598.78	599.74	96.64	1.86	23.36
	40% release	598.78	599.86	108.45	1.99	25.30
	50% release	598.78	599.96	118.36	2.09	26.90
	100% release	598.78	600.34	155.73	2.49	31.74

Table 9.23: Model Output for Different Release Scenarios for Pango HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	938.73	939.09	35.50	1.13	7.45
	15% release	938.73	939.15	41.56	1.23	8.72
	20% release	938.73	939.19	46.39	1.32	9.75
	25% release	938.73	939.24	50.56	1.38	10.63
	30% release	938.73	939.27	54.28	1.44	11.40
	40% release	938.73	939.34	60.56	1.54	12.73
	50% release	938.73	939.39	65.94	1.61	13.89
	100% release	938.73	939.59	86.11	1.89	17.73
Monsoon (June-Sept)	10% release	938.73	939.46	72.50	1.70	15.17
	15% release	938.73	939.58	84.61	1.87	17.45
	20% release	938.73	939.68	94.67	2.00	19.30
	25% release	938.73	939.76	103.11	2.11	20.79
	30% release	938.73	939.84	110.50	2.21	21.98
	40% release	938.73	939.97	123.44	2.36	24.07
	50% release	938.73	940.08	134.61	2.50	25.86
	100% release	938.73	940.50	176.61	2.95	32.29
Other Months (Oct, Mar, April, May)	10% release	938.73	939.32	59.33	1.52	12.49
	15% release	938.73	939.43	69.44	1.66	14.57
	20% release	938.73	939.50	77.39	1.78	16.11
	25% release	938.73	939.57	84.39	1.87	17.41
	30% release	938.73	939.64	90.67	1.95	18.56
	40% release	938.73	939.74	101.11	2.08	20.45
	50% release	938.73	939.83	110.22	2.20	21.93
	100% release	938.73	940.17	144.00	2.60	27.39

Table 9.24: Model Output for Different Release Scenarios for Mirak HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	570.53	570.93	39.36	1.25	8.13
	15% release	570.53	570.99	45.91	1.37	9.49
	20% release	570.53	571.04	51.18	1.46	10.59
	25% release	570.53	571.09	55.91	1.54	11.54
	30% release	570.53	571.13	59.73	1.60	12.37
	40% release	570.53	571.20	67.09	1.70	13.84
	50% release	570.53	571.26	73.27	1.78	15.13
	100% release	570.53	571.50	96.36	2.06	19.47
Monsoon (June-Sept)	10% release	570.53	571.34	80.91	1.87	16.68
	15% release	570.53	571.48	94.91	2.04	19.20
	20% release	570.53	571.59	106.18	2.17	21.20
	25% release	570.53	571.69	115.91	2.28	22.93
	30% release	570.53	571.78	124.91	2.35	24.99
	40% release	570.53	571.93	140.27	2.49	29.07
	50% release	570.53	572.06	153.00	2.61	31.46
	100% release	570.53	572.54	201.18	3.05	38.28
Other Months (Oct, Mar, April, May)	10% release	570.53	571.19	65.91	1.68	13.58
	15% release	570.53	571.30	77.18	1.83	15.93
	20% release	570.53	571.40	86.45	1.95	17.73
	25% release	570.53	571.48	94.45	2.04	19.15
	30% release	570.53	571.55	101.64	2.12	20.40
	40% release	570.53	571.67	113.73	2.26	22.54
	50% release	570.53	571.78	124.82	2.35	24.87
	100% release	570.53	572.17	164.00	2.71	33.16

Table 9.25: Model Output for Different Release Scenarios for Palsi HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	854.49	854.68	18.42	0.95	2.39
	15% release	854.49	854.71	21.25	1.02	2.76
	20% release	854.49	854.73	24.08	1.09	3.11
	25% release	854.49	854.76	26.50	1.14	3.40
	30% release	854.49	854.78	28.33	1.18	3.67
	40% release	854.49	854.81	31.67	1.25	4.09
	50% release	854.49	854.84	34.92	1.31	4.49
	100% release	854.49	854.95	45.83	1.51	5.92
Monsoon (June-Sept)	10% release	854.49	854.87	38.08	1.38	4.94
	15% release	854.49	854.94	45.17	1.49	5.82
	20% release	854.49	855.00	50.75	1.58	6.53
	25% release	854.49	855.05	55.58	1.65	7.14
	30% release	854.49	855.09	59.75	1.71	7.69
	40% release	854.49	855.16	66.92	1.81	8.62
	50% release	854.49	855.22	73.17	1.89	9.42
	100% release	854.49	855.46	96.75	2.17	12.45
Other Months (Oct, Mar, April, May)	10% release	854.49	854.81	31.25	1.24	4.03
	15% release	854.49	854.86	36.50	1.35	4.72
	20% release	854.49	854.91	41.25	1.43	5.31
	25% release	854.49	854.94	45.00	1.49	5.80
	30% release	854.49	854.98	48.33	1.55	6.25
	40% release	854.49	855.04	54.33	1.64	7.01
	50% release	854.49	855.09	59.75	1.71	7.67
	100% release	854.49	855.28	78.58	1.96	10.11

Table 9.26: Model Output for Different Release Scenarios for Yamne Stage I HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	679.53	679.93	40.08	1.08	6.86
	15% release	679.53	680.00	46.58	1.18	7.99
	20% release	679.53	680.05	51.92	1.27	8.91
	25% release	679.53	680.10	56.58	1.34	9.69
	30% release	679.53	680.14	60.58	1.40	10.38
	40% release	679.53	680.21	67.58	1.50	11.58
	50% release	679.53	680.27	73.58	1.58	12.61
	100% release	679.53	680.49	96.00	1.84	16.34
Monsoon (June-Sept)	10% release	679.53	680.34	81.00	1.67	13.87
	15% release	679.53	680.48	94.75	1.83	16.11
	20% release	679.53	680.59	105.50	1.95	17.71
	25% release	679.53	680.68	115.08	2.05	19.09
	30% release	679.53	680.77	123.42	2.15	20.30
	40% release	679.53	680.91	137.92	2.29	22.40
	50% release	679.53	681.04	150.50	2.41	24.21
	100% release	679.53	681.51	197.42	2.83	30.98
Other Months (Oct, Mar, April, May)	10% release	679.53	680.20	66.25	1.48	11.36
	15% release	679.53	680.31	77.33	1.63	13.27
	20% release	679.53	680.40	86.33	1.74	14.83
	25% release	679.53	680.47	94.00	1.83	16.07
	30% release	679.53	680.55	101.17	1.90	17.06
	40% release	679.53	680.66	113.00	2.03	18.78
	50% release	679.53	680.76	123.08	2.14	20.25
	100% release	679.53	681.14	161.00	2.52	25.73

Table 9.27: Model Output for Different Release Scenarios for Yamne Stage II HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	503.09	503.59	50.24	0.89	9.44
	15% release	503.09	503.67	58.48	0.98	11.02
	20% release	503.09	503.74	65.24	1.04	12.28
	25% release	503.09	503.80	70.86	1.10	13.37
	30% release	503.09	503.85	75.90	1.15	14.32
	40% release	503.09	503.93	84.67	1.23	15.98
	50% release	503.09	504.01	92.05	1.30	17.39
	100% release	503.09	504.28	119.48	1.54	22.61
Monsoon (June-Sept)	10% release	503.09	504.10	100.90	1.38	19.08
	15% release	503.09	504.26	117.67	1.52	22.26
	20% release	503.09	504.40	131.00	1.63	24.80
	25% release	503.09	504.51	142.62	1.72	26.82
	30% release	503.09	504.61	152.57	1.81	28.57
	40% release	503.09	504.79	169.95	1.94	31.46
	50% release	503.09	504.94	185.48	2.05	34.86
	100% release	503.09	505.49	240.10	2.47	42.30
Other Months (Oct, Mar, April, May)	10% release	503.09	503.92	83.10	1.22	15.68
	15% release	503.09	504.05	96.76	1.34	18.28
	20% release	503.09	504.16	107.76	1.44	20.39
	25% release	503.09	504.26	117.33	1.52	22.19
	30% release	503.09	504.34	125.62	1.59	23.78
	40% release	503.09	504.49	139.95	1.70	26.37
	50% release	503.09	504.61	152.29	1.80	28.50
	100% release	503.09	505.06	197.76	2.14	36.83

Table 9.28: Model Output for Different Release Scenarios for Lower Yamne Stage I HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	400.64	401.09	45.32	0.79	13.77
	15% release	400.64	401.17	52.89	0.87	15.81
	20% release	400.64	401.23	59.05	0.93	17.47
	25% release	400.64	401.28	64.26	0.98	18.89
	30% release	400.64	401.33	68.84	1.02	20.14
	40% release	400.64	401.41	77.16	1.09	22.29
	50% release	400.64	401.48	83.84	1.15	24.07
	100% release	400.64	401.73	109.58	1.33	30.69
Monsoon (June-Sept)	10% release	400.64	401.56	92.21	1.21	26.27
	15% release	400.64	401.72	107.79	1.32	30.27
	20% release	400.64	401.84	120.32	1.41	33.30
	25% release	400.64	401.95	131.11	1.49	35.84
	30% release	400.64	402.04	140.58	1.56	38.01
	40% release	400.64	402.21	156.89	1.68	41.72
	50% release	400.64	402.35	171.05	1.77	45.26
	100% release	400.64	402.88	224.16	2.10	61.69
Other Months (Oct, Mar, April, May)	10% release	400.64	401.39	75.42	1.08	21.90
	15% release	400.64	401.52	88.11	1.18	25.24
	20% release	400.64	401.62	98.63	1.25	27.96
	25% release	400.64	401.71	107.32	1.32	30.19
	30% release	400.64	401.79	115.26	1.38	32.07
	40% release	400.64	401.92	128.63	1.47	35.28
	50% release	400.64	402.04	140.00	1.56	37.92
	100% release	400.64	402.47	182.79	1.86	47.73

Table 9.29: Model Output for Different Release Scenarios for Lower Yamne Stage II HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	269.41	269.83	41.96	1.00	12.78
	15% release	269.41	269.90	49.00	1.10	14.90
	20% release	269.41	269.96	54.60	1.17	16.64
	25% release	269.41	270.01	59.44	1.24	18.12
	30% release	269.41	270.05	63.80	1.29	19.40
	40% release	269.41	270.12	71.04	1.39	21.52
	50% release	269.41	270.19	77.32	1.46	23.27
	100% release	269.41	270.42	100.68	1.74	29.27
Monsoon (June-Sept)	10% release	269.41	270.26	84.84	1.56	25.30
	15% release	269.41	270.40	98.92	1.72	28.86
	20% release	269.41	270.52	110.52	1.85	31.61
	25% release	269.41	270.62	120.32	1.96	33.83
	30% release	269.41	270.71	129.28	2.05	35.79
	40% release	269.41	270.86	144.68	2.21	38.74
	50% release	269.41	270.99	158.00	2.35	41.03
	100% release	269.41	271.51	209.36	2.83	49.49
Other Months (Oct, Mar, April, May)	10% release	269.41	270.11	69.72	1.37	21.13
	15% release	269.41	270.23	81.32	1.51	24.34
	20% release	269.41	270.32	90.68	1.62	26.77
	25% release	269.41	270.40	98.68	1.72	28.79
	30% release	269.41	270.47	105.92	1.80	30.55
	40% release	269.41	270.59	118.12	1.94	33.33
	50% release	269.41	270.70	129.04	2.05	35.71
	100% release	269.41	271.11	169.44	2.46	42.94

Table 9.30: Model Output for Different Release Scenarios for Simang I HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	310.23	310.63	39.82	0.97	8.40
	15% release	310.23	310.69	45.68	1.06	9.33
	20% release	310.23	310.74	50.92	1.13	10.14
	25% release	310.23	310.79	55.67	1.19	10.88
	30% release	310.23	310.83	59.55	1.25	11.45
	40% release	310.23	310.89	65.87	1.34	12.26
	50% release	310.23	310.95	71.87	1.42	13.02
	100% release	310.23	311.18	94.28	1.71	16.08
Monsoon (June-Sept)	10% release	310.23	311.14	90.52	1.61	14.73
	15% release	310.23	311.18	94.42	1.76	16.57
	20% release	310.23	311.29	106.13	1.88	17.73
	25% release	310.23	311.39	115.47	1.98	18.80
	30% release	310.23	311.47	124.03	2.08	19.80
	40% release	310.23	311.62	139.10	2.24	21.67
	50% release	310.23	311.75	151.95	2.37	23.29
	100% release	310.23	312.25	201.23	2.87	27.85
Other Months (Oct, Mar, April, May)	10% release	310.23	310.84	60.47	1.30	11.57
	15% release	310.41	311.12	70.82	1.41	12.69
	20% release	310.23	311.12	88.51	1.51	13.61
	25% release	310.23	311.15	91.90	1.59	14.57
	30% release	310.23	311.16	92.87	1.66	15.46
	40% release	310.23	311.23	99.75	1.78	16.89
	50% release	310.23	311.32	108.73	1.89	17.84
	100% release	310.23	311.68	144.23	2.28	22.17

Table 9.31: Model Output for Different Release Scenarios for Simang II HEP

	Release Scenario	River Bed	Water Level	Water depth	Flow Velocity	Flow Width
		(m)	(m)	(cm)	(m/s)	(m)
Lean Season (Nov-Feb)	10% release	423.27	423.61	34.00	0.86	7.92
	15% release	423.27	423.66	39.00	0.98	8.64
	20% release	423.27	423.71	44.00	1.06	9.21
	25% release	423.27	423.75	48.00	1.13	9.71
	30% release	423.27	423.79	52.00	1.19	10.17
	40% release	423.27	423.86	59.00	1.29	11.03
	50% release	423.27	423.92	65.00	1.36	12.27
	100% release	423.27	424.13	86.10	1.57	20.54
Monsoon (June-Sept)	10% release	423.27	424.06	79.43	1.36	15.03
	15% release	423.27	424.19	92.43	1.50	17.62
	20% release	423.27	424.29	102.74	1.61	19.63
	25% release	423.27	424.38	111.52	1.71	21.13
	30% release	423.27	424.46	119.39	1.79	22.48
	40% release	423.27	424.59	132.83	1.94	24.63
	50% release	423.27	424.71	144.57	2.05	26.77
	100% release	423.27	425.14	187.52	2.44	34.66
Other Months (Oct, Mar, April, May)	10% release	423.27	423.84	57.17	1.16	9.72
	15% release	423.27	423.94	67.26	1.28	11.36
	20% release	423.27	424.03	76.30	1.33	14.32
	25% release	423.27	424.10	83.00	1.40	15.77
	30% release	423.27	424.15	88.91	1.46	16.93
	40% release	423.27	424.25	98.70	1.57	18.98
	50% release	423.27	424.34	107.22	1.66	20.39
	100% release	423.27	424.65	138.78	1.99	25.70

9.6 ENVIRONMENTAL FLOW ASSESSMENT

Environmental flows are flows that are to be released into a river system with the specific purpose of managing the modified river regime as close as possible to the natural state.

In Himalayan Rivers, annual discharges vary by orders of magnitude from year to year. Species that persist in such rivers generally survive, though not necessarily breed, during years when there is much less water than average. The presence of sequences of wet and dry years supports the suggestion that the biota can survive repeated years when the total annual discharge is less than the average, however, it may not remain unchanged in permanent drought conditions.

Studies in South African rivers (Weeks et al., 1996) showed that major community shifts occur among the fish fauna during droughts, and also during normal low flow seasons. However, provided conditions do not drastically differ from those that have occurred in the past, recovery reflects in the short to medium term. Some studies have shown evidence that a lower than normal flow regime, which still incorporates all the major features of the natural regime, would not permanently change the biota of the river. It is therefore suggested that, other things such as catchment condition being equal, a carefully designed modified flow regime which maintains the ecologically important components of the natural flow regime should be able to maintain a river's natural biota.

Therefore, for assessment of environmental flow focus should be on the characteristic features of the natural flow regime of the river. The most important of these are degree of perenniality; magnitude of base flows in the dry and wet season; magnitude, timing and duration of floods in the wet season; and small pulses of higher flow, that occur between dry and wet months. Attention is then given to which flow features are considered most important for maintaining or achieving the desired future condition of the river, and thus should not be eradicated during development of the river's water resources.

Fish assemblages often include a range of species and reflect the integrated effects of environmental changes. Their presence is used to infer the presence of other aquatic organisms, since the adult fish occupy the top of the food chain in most aquatic systems. They also pass through most trophic levels above the primary producer stage during their development from larvae to adults. Fish can thus be regarded as reflecting the integrated environmental health of a river (Karr et al., 1986). Fish species in river can guide to prepare specification of the flows necessary to meet their needs, and be useful in the monitoring and management of those flows. It is often surmised that if management of flows for fish maintenance is successful, then flow requirements for aquatic invertebrates will also be satisfied. This is because of the larger scale of fish habitat.

Therefore, the approach adopted for environmental flow assessment is based on the meeting the needs of dominant fish species with larger habitat requirement. Baseline data on fish fauna in Siang basin is discussed in Chapter - 7, Section 7.2.6, where entire Siang basin has been divided in two predominant fish zones viz. Mahseer Zone and Trout Zone. Mahseer being a large fish requires more flow in all the seasons and this aspect has been kept in mind while recommending environment flow for projects in Mahseer zone.

Mahseer zone covers the entire main Siang river, Siyom river up to the powerhouse of Naying HEP, Yamne river up to the power house of Yamne Stage II, Simang river up to the power house of

Simang II and Hirit river. Projects fall in Mahseer zone are Siang Lower, Siang Upper Stage I and II, Siyom Middle, Naying, Lower Yamne Stage I and II, Simang I and Hirit HEP. Rest of the basin where remaining HEPs are located falls in trout zone.

9.6.1 Environment Flow Assessment in Lean Season

Habitat requirement for mahseer and trout is discussed in Chapter 7. To assess the minimum environment flow requirement in lean season a criteria has been defined that projects in the Mahseer zone needs to provide a minimum 0.5 m average depth in the initial reach studied, and for projects in the trout zone this depth is considered as 0.4m. Keeping in view that there are streams of various sizes in Siang basin, a further check is made that reduction in water depth and flow width should not be more than 50% of pre-project levels. Pre-project water depth, flow width and flow velocity is assessed by reviewing the results of 100% release scenario.

As discussed in the previous sections, modelling study has given the output in terms of depth, width and flow velocity. Analysis of the modelling output is done with a view to evaluate the depth, and width at 15%, 20% and 25% release scenarios during lean season and the output is listed in Table 9.32 below for average depth output. Table gives reduced depth under three different scenarios along with pre-project values and 50% of pre-project values for comparison.

Table 9.32: Average Flow Depth under different release Scenarios during Lean Season

Project	Average Flow Depth (cm)				
	15% release	20% release	25% release	Pre-project	50% of Pre-project
Hirong	70.71	79.07	85.93	146.93	73.47
Tato II	90.80	101.20	110.20	187.40	93.70
Naying	71.17	79.72	87.17	154.11	77.06
Pemashelpu	32.45	36.36	39.45	67.82	33.91
Kangtangshiri	39.73	44.55	48.64	84.55	42.28
Rapum	34.34	38.61	39.67	75.08	37.54
Pauk	52.33	58.33	63.50	107.17	53.58
Heo	60.87	67.94	74.00	126.25	63.12
Tato I	62.30	69.65	99.10	130.00	65.00
Hirit Korong	44.69	50.15	54.54	94.23	47.12
Siri Korong	37.56	42.00	45.78	79.00	39.50
Gameng	28.69	32.31	35.00	60.00	30.00
Ringong	43.55	48.55	53.18	91.73	45.87
Pango	41.56	46.39	50.56	86.11	43.06
Mirak	45.91	51.18	55.91	96.36	48.18
Palsi	21.25	24.08	26.50	45.83	22.92
Yamne Stage I	46.58	51.92	56.58	96.00	48.00
Yamne Stage II	58.48	65.24	70.86	119.48	59.74
Lower Yamne Stage I	52.89	59.05	64.26	109.58	54.79
Lower Yamne Stage II	49.00	54.60	59.44	100.68	50.34
Simang I	45.68	50.92	55.67	94.28	47.14
Simang II	39.00	44.00	48.00	86.10	43.05

Following can be concluded from the above analysis:

- More than 50% of the pre-project flow depth is achieved under the 20% release scenario for all the projects.
- Projects in Mahseer zone viz. Naying, Lower Yamne Stage I and II and Simang I will have more than 50 cm of average flow depth under 20% release scenarios
- In the trout zone, four projects viz. Rapum, Pemashelpu, Gameng and Palsi are showing less than 40 cm of depth under 20% release scenarios

- Rapum and Pemashelpu can achieve close to 40 cm depth under 25% release scenario
- Gameng HEP can meet 40 cm depth criteria, only if it releases 35% of the average discharge in lean season, as pre-project depth is only 60 cm
- Palsi HEP can meet 40 cm depth criteria at over 70% of release in lean season as the pre-project flow depth is only 45.83 cm; this would certainly make the project unviable
- Reduction in flow velocity is observed of the order 30-35% for 15% and 20% release scenarios, which meets the habitat requirement criteria for trout as well as Mahseer.

9.6.2 Environment Flow Assessment in Monsoon Season

Environment flow requirement in monsoon season is different from that of lean season. Lean season flow is mainly base flow and therefore, an average value and constant release can meet the lean season flow requirement. Whereas in monsoon, apart from base flow, flood peaks are critical for various functions of the river. These flood peaks provide connectivity and wetting of side channels, opening up new habitat, gravel movement, and flushing sediment into side channels. These flows also add organic matter and nutrients through riparian vegetation into the main stream thus providing food to aquatic species. Newly connected side channels provide spawning and rearing habitat for aquatic life. Resident trout, macro-invertebrates, and other species also benefit by increased habitat diversity and clean substrates. These high flows should be planned in conjunction with possible gravel augmentation efforts to maximize benefits. Environmental flow requirement in monsoon months should meet the following requirement:

- It should provide adequate habitat in terms of water depth, velocity and water width of channel for needs of aquatic life, which includes migration, breeding and spawning.
- It should provide flood peaks distributed over the monsoon period for riparian vegetation abundance, to wet side channels and maintain habitat for aquatic species.
- The flows should mimic natural flow pattern that naturally occurred in the rainy season.
- It should meet flow requirements for breeding and spawning of prevalent fish species.

Requirement for base flow in monsoon can be established from the modelling output in terms of flow required to meet the habitat requirement i.e. water width, depth and velocity. No specific criteria can be established to exactly fix the minimum habitat requirement due to adaptability of the species to varied conditions in the rivers. Habitat requirements have been summarised in Chapter 7; from where it can be concluded that projects in trout zone should not reduce water depth below 1 m in monsoon and to meet the higher requirement in Mahseer Zone such project should provide about 1.2-1.4 m depth. Further, reduced flow depth and width of the river due to diversion of water should be of the order of 50% or more as compared to that of pre-project status.

Another important characteristic of the monsoon flow is flood peaks; this should also be mimicked in post project scenario. Sufficient flood peaks should be released through out the monsoon period. Limitation is in evaluation of the available flood pulses in monsoon because the discharge data available is ten daily series, which average out the flood peaks in most of the cases. For flood peak analysis twice daily/daily discharge data is considered most suitable. Wherever, daily data is available, data analysis is carried out for flood peak assessment and recommendations are made accordingly. In the absence of such data, higher release recommendations are made than what is assessed to meet base flow requirement to ensure flood peaks are released.

Assessing the Base Flow Availability

Table 9.33 below gives flow depth in monsoon season for 15%, 20%, 25% and 30% release scenarios

along with pre-project depth or 100% release scenario. Cells have been highlighted against each project where the adequate habitat is available in terms of flow depth to meet the base flow requirement only. Highlighted release requirement for base flow needs is compared with the pre-project depth and last column gives the % of depth available with respect to pre-project depth. Naying HEP was meeting the depth requirement even under 15% release scenario, however, the depth was reduced to 44% of the pre-project level and therefore next higher level (20%) is considered where depth is 50.35% of the pre-project depth. Gameng and Palsi don't meet the criteria even under 30% release scenario as pre-project depth is only 124.7 cm and 96.7 cm for Gameng and Palsi respectively. Reduction in flow width was also checked and reduced width was found to vary from 47.5% to 76.8% under the selected scenarios (not shown in Table), which is found to be adequate for all the projects. Current velocity is found to be high and is comparable with the pre-project current velocity.

Table 9.33: Model Output for different Release Scenario during Monsoon

Project	Average Flow Depth (cm)					% of Pre-project Depth (corresponding to highlighted release scenario)
	15% release	20% release	25% release	30% release	Pre-project	
Hirong	144.29	161.43	175.86	188.64	299.07	48.25
Tato II	184.40	205.90	224.30	240.10	377.90	48.80
Naying	151.28	170.72	187.50	202.22	339.06	50.35
Pemashelpu	79.45	89.09	97.09	104.36	167.55	62.29
Kangtangshiri	99.55	111.64	121.00	131.27	212.73	46.80
Rapum	83.00	94.00	103.11	111.78	192.44	53.58
Pauk	123.50	137.17	148.83	159.50	257.00	48.05
Heo	146.44	163.37	178.19	191.06	303.31	48.28
Tato I	151.95	170.10	185.80	199.85	323.40	46.99
Hirit Korong	92.69	103.85	113.15	121.69	194.46	53.40
Siri Korong	77.67	87.11	95.22	102.11	164.89	61.93
Gameng	58.85	65.92	71.77	77.23	124.69	
Ringong	90.18	101.27	110.36	118.73	191.91	52.77
Pango	84.61	94.67	103.11	110.50	176.61	58.38
Mirak	94.91	106.18	115.91	124.91	201.18	52.78
Palsi	45.17	50.75	55.58	59.75	96.75	
Yamne Stage I	94.75	105.50	115.08	123.42	197.42	53.44
Yamne Stage II	117.67	131.00	142.62	152.57	240.10	49.01
Lower Yamne Stage I	107.79	120.32	131.11	140.58	224.16	53.68
Lower Yamne Stage II	98.92	110.52	120.32	129.28	209.36	57.47
Simang I	94.42	106.13	115.47	124.03	201.23	61.63
Simang II	92.43	102.74	111.52	119.39	187.52	54.78

Assessing the Flood Peak Availability

Availability of flood pulses can be captured from daily/twice daily discharge data. Considering that daily flow time series carry much more information about flow variability and that monthly flow data can naturally be calculated from daily values, the daily flow time series are always the preferred data type for such type of analysis.

Hydro-developers who are in the process of survey and investigation have set up their own G&D sites at/near diversion sites. If 4-5 years period reliable data is available from such sites, potential releases in the monsoon can be assessed more realistically. Developers were contacted and self recorded G&D data was sought for review and analysis. Following projects developers have promptly responded and shared the data for the study, while others have not responded.

- Naying HEP on Siyom river
- Pemashelphu, Pauk, Heo and Tato I HEPs on Yargyap Chhu
- Simang I and Simang II HEPs on Simang river (June 2010-May 2012)
- Lower Yamne Stage I, Lower Yamne Stage II, Yamne Stage I and Yamne Stage II on Yamne River

It was considered important to establish data reliability before using the self-recorded data. Self-recorded data was analyzed for correctness and correlated with available rainfall data in respective area and/or with CWC approved series. Following was the outcome:

- Observed data at Pemashelphu HEP site was found to be incorrect as observed flows correspond to about 6000 mm of rainfall while average annual rainfall for that period should be of the order of 2800 mm. Hence the data was rejected.
- Observed data for all the sites falling on Yamne river was for a very short duration and none of the data sets covered one full calendar year. Therefore, these data sets were also rejected.
- Promoter of Simang I and Simang II HEPs has established G&D site at Boleng on Simang river (CA: 554 sq. Km) and started taking daily observation from June 2010 onwards. These observations were transferred to Simang I site (CA: 494 sq. Km) and Simang II (CA: 422 sq. Km) to have daily discharge data for individual projects. Data available is till May 2012 and with some gaps. The data sets are from June 14, 2010 till May 31, 2012 that too with some gaps. Monsoon data is only for one full year i.e. 2011, therefore, data analysis exercise was stopped here as no conclusive inference can be drawn from single year daily observed monsoon data.

Data supplied for Naying, Pauk, Heo and Tato I HEPs was for a period of more than five years. These data sets were also found to be generally corresponding to average rainfall in the catchment, however, it was felt that further consistency checks are needed to establish reliability of data.

9.6.2.1 Observed Data for Projects on Yargyap Chhu

In 2007, Velcan Energy one of the developers has undertaken daily-discharge measurements (three measurements per day). Two gauges have been installed on the Yargyap Chhu - one in Purying village (1065 sq. Km of catchment area), and the other one in Mechuka village (686 sq. Km of catchment area). Purying station is operated since October 2007 and Mechuka station is operated since July 2008. Reconciliation and consistency check is made systematically between the measurements. The 2 stations share 65% of common catchment area. Hence, it is expected that the correlation between the two stations shall be quite high. The reliability test of the discharge measurements made by the developer shows that the 2 stations installed on the Yargyap Chhu give consistent results. Hence, the discharge of Purying G&D station, which is closest G&D station to the projects and having longer period of record is used for hydrological computations. Mechuka G&D station is only used to check the measurements of Puring and to compute the Puring discharge in case of absence of record.

Developer is also monitoring and recording rainfall data at Mechuka and some scattered rainfall data at Mechuka is also available from IMD. IMD records show average annual rainfall at Mechuka is of the order of 2500 mm, which is consistent with the developers' records. However, 90-95% of the projects (Pauk, Heo and Tato I HEPs) catchment is above Mechuka and there are no rain gauge stations. Rainfall data at Mechuka is neither found corresponding with the discharge data recorded

nor it could be considered as representative average rainfall for the catchment. Therefore, before using the daily observed data (3 readings per day) for Tato I, Heo and Pauk HE projects on Yargyap Chhu, the observed flow was compared with the CWC approved series for these projects.

Annual runoff for three projects viz. Tato I, Heo and Pauk as per CWC approved series along with probability are given at 9.34.

Table 9.34: Annual Runoff (MCM) as per CWC approved series

Year	Annual Runoff (MCM)			Probability
	Tato I	Heo	Pauk	
2007-08	3959.88	3653.51	3368	3.85
2006-07	3896.29	3594.59	3316	7.69
2000-01	3886.96	3586.81	3310	11.54
2001-02	3717.19	3429.13	3161	15.38
1987-88	3602.79	3322.17	3062	19.23
1979-80	3509.05	3235.94	2983	23.08
1985-86	3473.80	3205.79	2954	26.92
1988-89	3345.84	3090.44	2849	30.77
2008-09	3186.78	2943.48	2712	34.62
1990-91	3154.20	2907.45	2683	38.46
1986-87	3135.28	2896.73	2669	42.31
1981-82	3114.55	2876.95	2650	46.15
2003-04	3081.72	2843.86	2622	50.00
1982-83	3078.00	2838.76	2619	53.85
1984-85	3032.64	2799.36	2584	57.69
1980-81	2991.86	2761.78	2545	61.54
1991-92	2970.69	2741.39	2526	65.38
1989-90	2958.51	2733.09	2517	69.23
1993-94	2783.64	2572.73	2372	73.08
2002-03	2776.46	2562.71	2366	76.92
2005-06	2725.75	2513.81	2318	80.77
1983-84	2721.43	2513.64	2314	84.62
1978-79	2671.57	2464.56	2272	88.46
2004-05	2345.76	2165.96	1997	92.31
1992-93	2342.65	2163.02	1996	96.15

To compare the observed data's consistency with that of CWC discharge data series on annual runoff basis, we have two years common data sets i.e. 2007-08 and 2008-09. Table 9.35 gives annual runoff from observed data.

Table 9.35: Annual Runoff (MCM) as per Observed Data

Year	Tato I	Heo	Pauk
2007-08	4648.11	4289.63	3955.32
2008-09	3803.16	3509.85	3236.31
2009-10	4718.28	4354.39	4015.04
2010-11	3609.73	3331.34	3071.71
2011-12	4280.82	3950.67	3642.78

A comparison of annual runoff from CWC approved series and observed data for common period i.e. for the year 2007-08 and 2008-09 show that observed runoff exceed CWC approved values by 15% and 16% for year 2007-08 and 2008-09 respectively. Therefore, to make a conservative estimate all observed values (thrice daily readings) for the period 2008-2012 are reduced by 20% before further analysis. Plots of the observed values (after 20% reduction) are given at Figures 9.4 to 9.6 for Tato I, Heo and Pauk HEPs.

The corrected observed thrice daily data of five years period (2008-12) was analyzed for availability of flood peaks downstream of diversion sites of each project. Refer Figures 9.7 through 9.21 for project wise discharge data charts during monsoon season of each year from 2008

to 2012. Red line indicates design discharge or abstraction and flow above design discharge will always be available in the river. As can be seen from the charts, inflow is substantially higher than the design abstraction and sufficient base flow as well as flood peaks will be available in the river during monsoon period.

Calculation was also carried out to understand the volumetric inflow during each monsoon and spills available in river after design abstraction as percentage of inflow and same is shown in Table 9.36.

Table 9.36: Flow Available in River after Design Abstraction

Year	Tato I	Heo	Pauk
2008	46.85	44.11	44.46
2009	38.84	36.49	36.79
2010	45.39	42.76	43.10
2011	36.77	34.01	34.37
2012	44.76	42.39	42.69
90% DY*	21.76	18.12	18.55
50% DY*	34.06	30.43	30.87

*90% DY and 50% DY are from CWC approved series and are based on 10-daily values

As can be seen from the above Table and charts in the following pages, analysis of corrected daily data show the peaks and flow available in the river during monsoon is adequate for these three projects on Yargyap Chhu i.e. Tato I, Heo and Pauk HEPs; even without any specific release restriction during monsoon. Base flow requirement is adequate at 15% release scenario in monsoon, where flow depth is 123.50 cm, 146.44 cm and 151.95 cm for Pauk, Heo and Tato I HEPs, respectively (Refer Table 9.33). Therefore, for these projects, monsoon release of 15% is considered adequate.

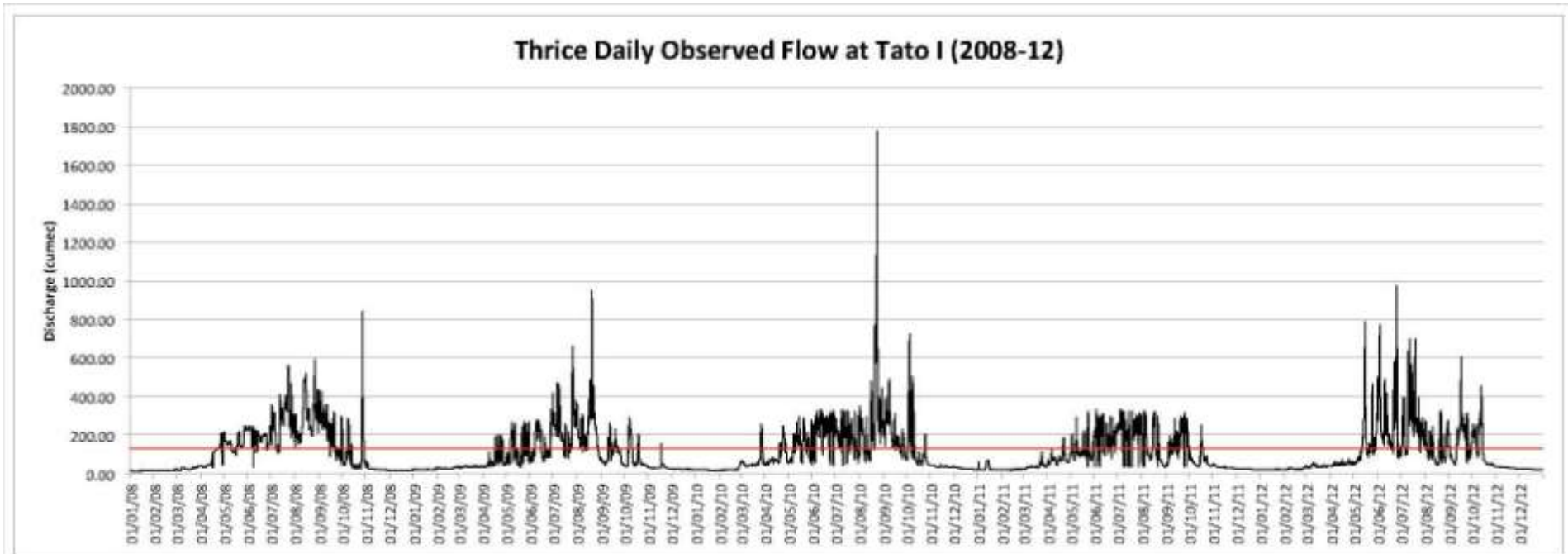


Figure 9.4: Thrice Daily Observed Flow at Tato I (2008-12)

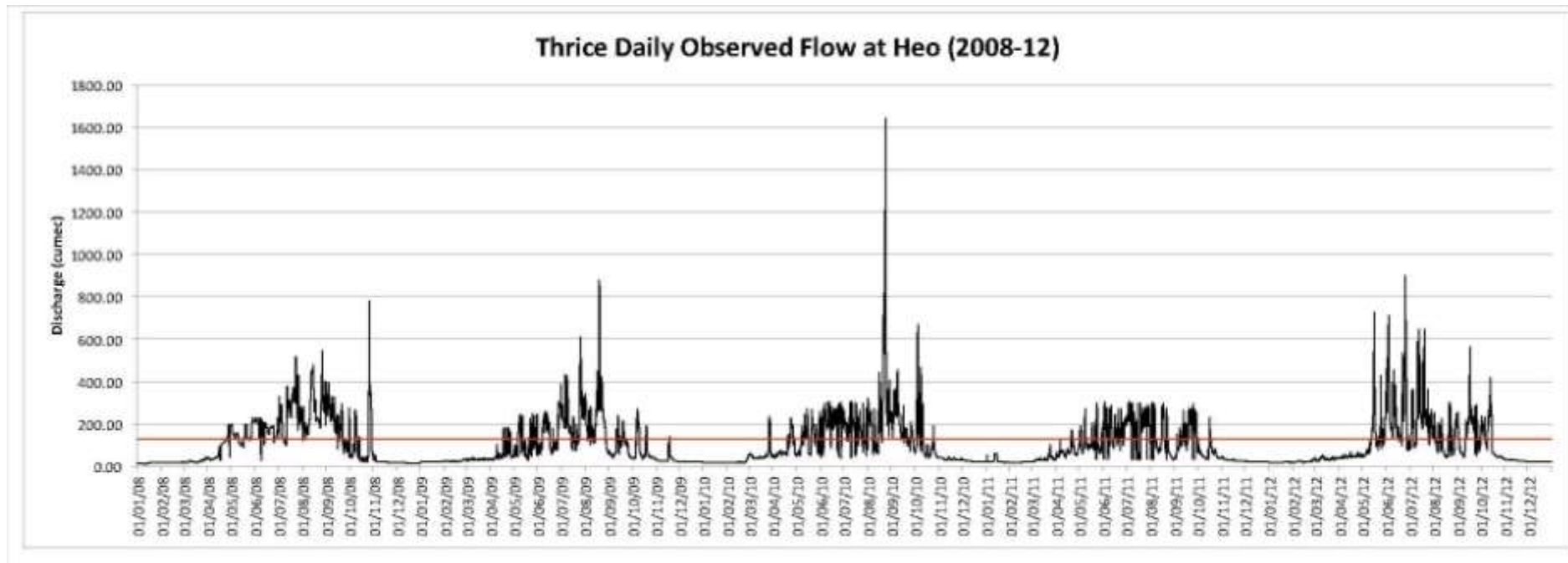


Figure 9.5: Thrice Daily Observed Flow at Heo (2008-12)

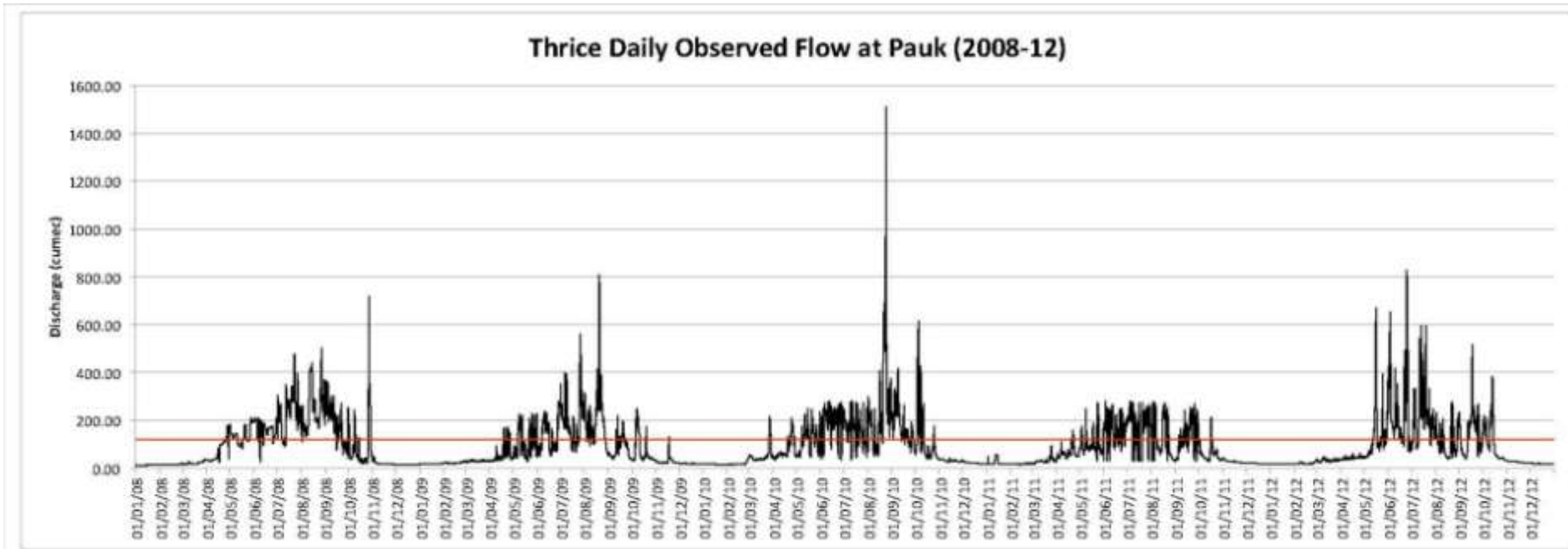


Figure 9.6: Thrice Daily Observed Flow at Pauk (2008-12)

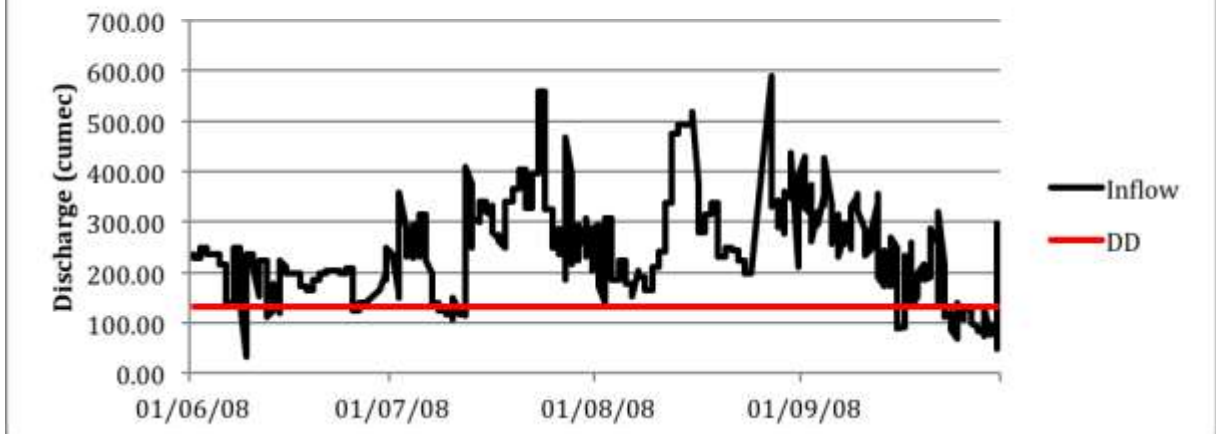
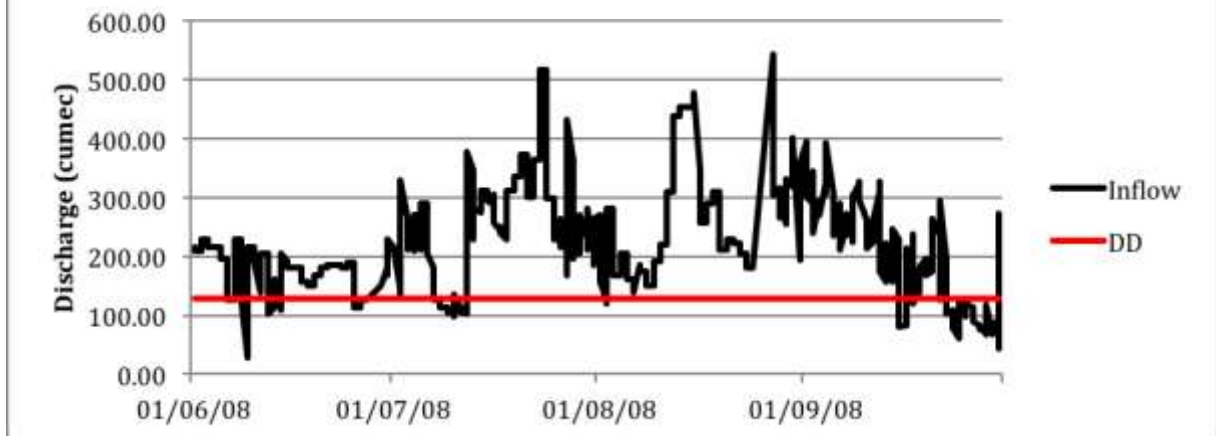
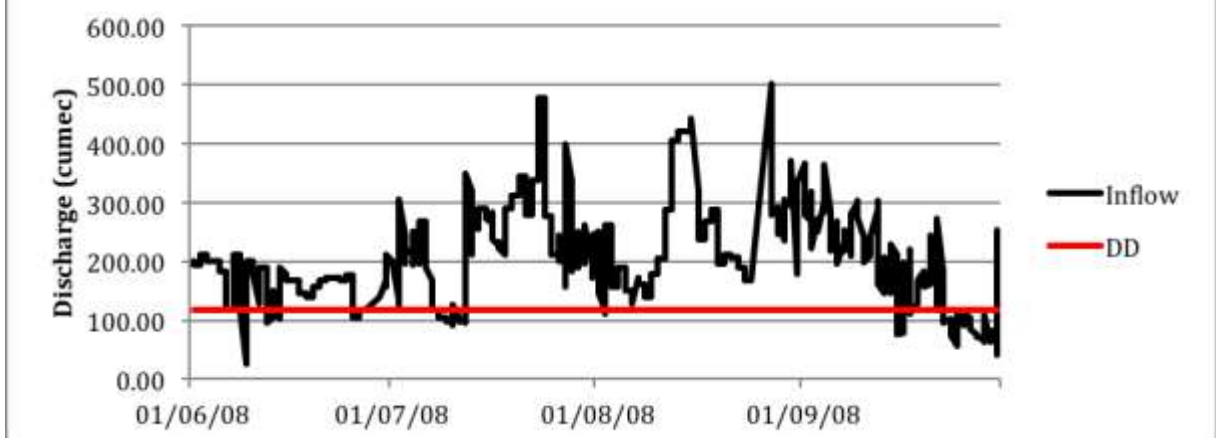
Figure 9.7: Monsoon Discharge at Tato I (2008)**Figure 9.8: Monsoon Discharge at Heo (2008)****Figure 9.9: Monsoon Discharge at Pauk (2008)**

Figure 9.10: Monsoon Discharge at Tato I (2009)

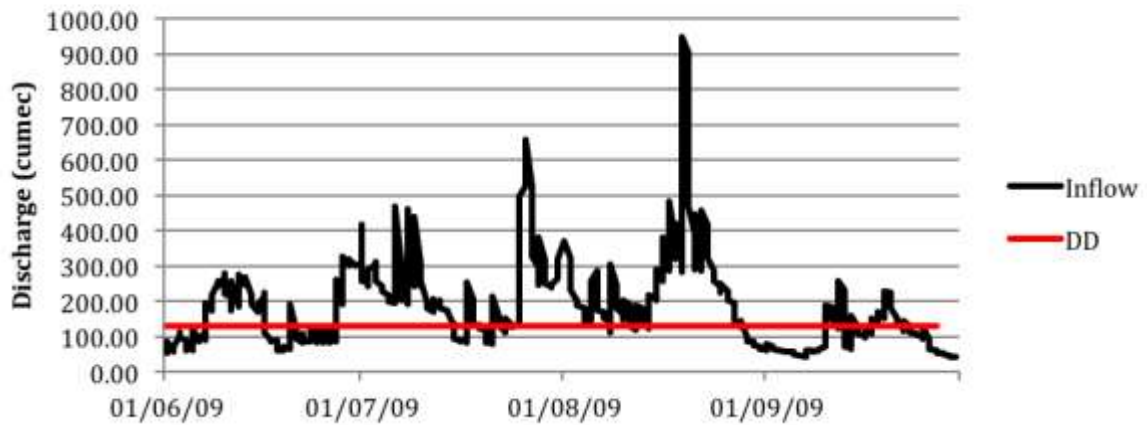


Figure 9.11: Monsoon Discharge at Heo (2009)

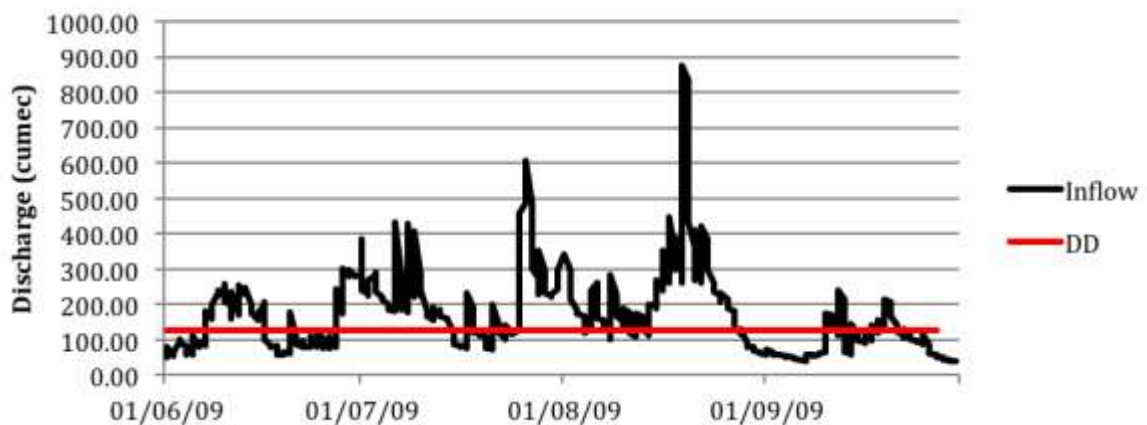


Figure 9.12: Monsoon Discharge at Pauk (2009)

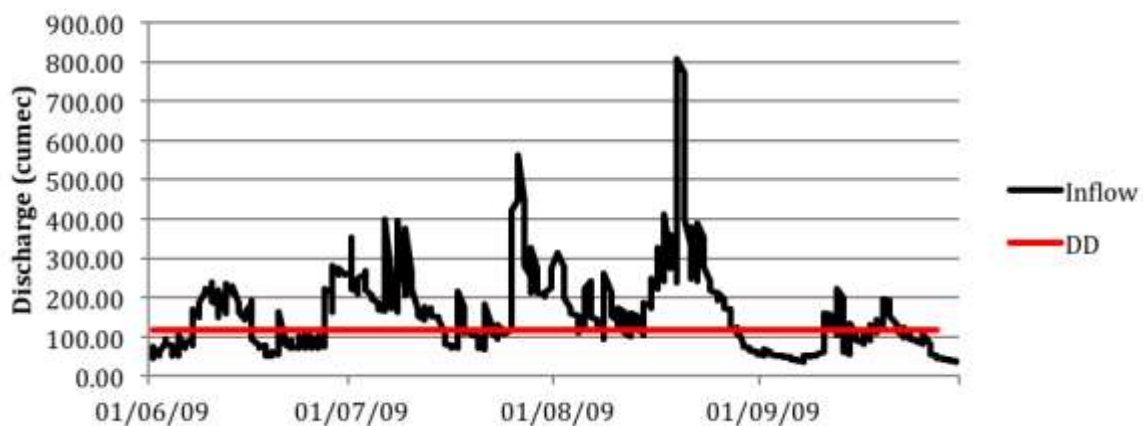


Figure 9.13: Monsoon Discharge at Tato I (2010)

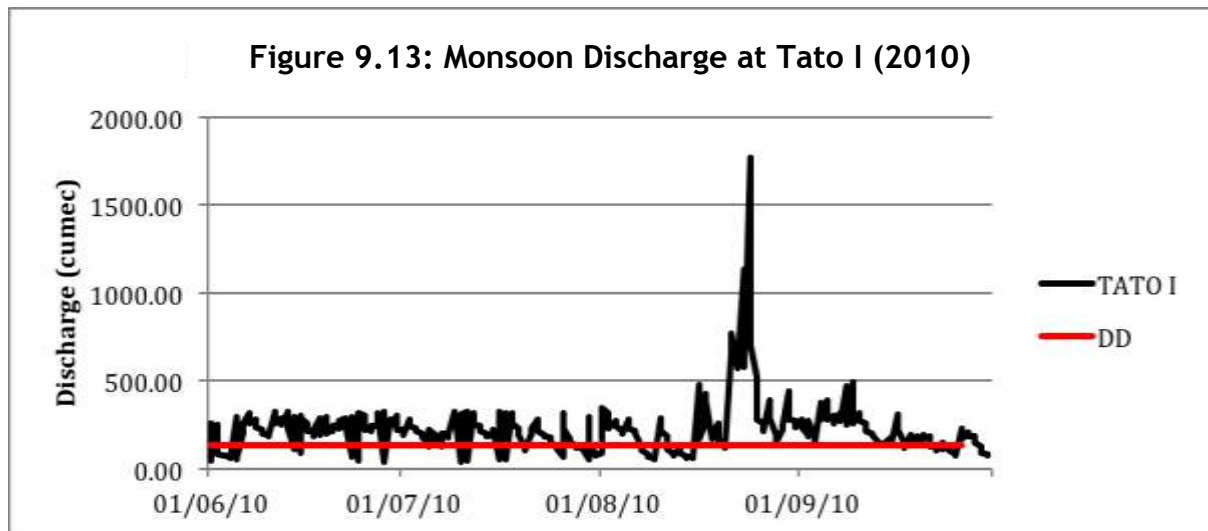


Figure 9.14: Monsoon Discharge at Heo (2010)

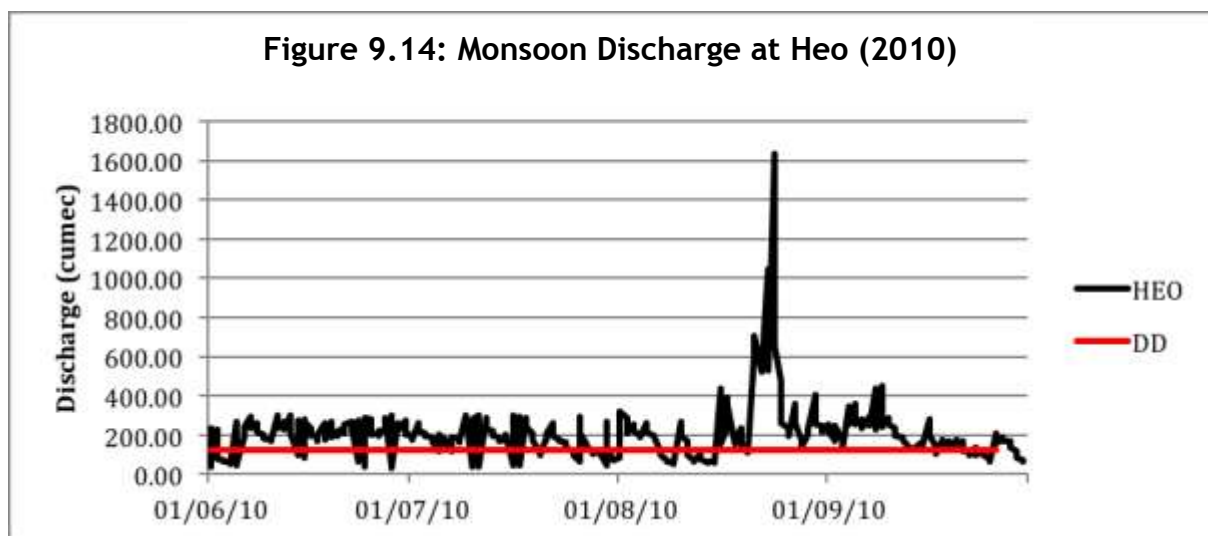


Figure 9.15: Monsoon Discharge at Pauk (2010)

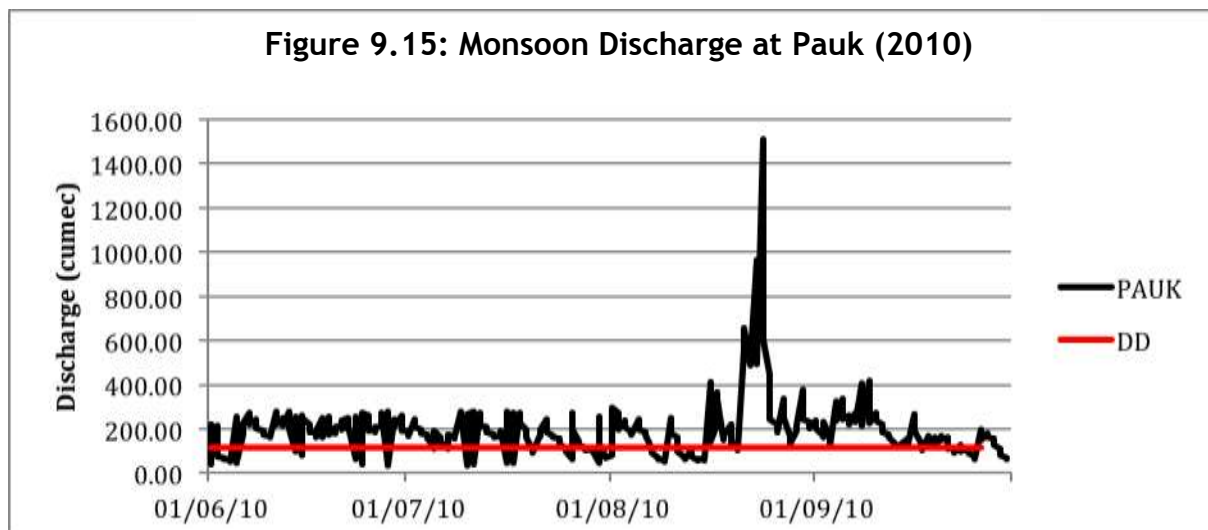


Figure 9.16: Monsoon Discharge at Tato I (2011)

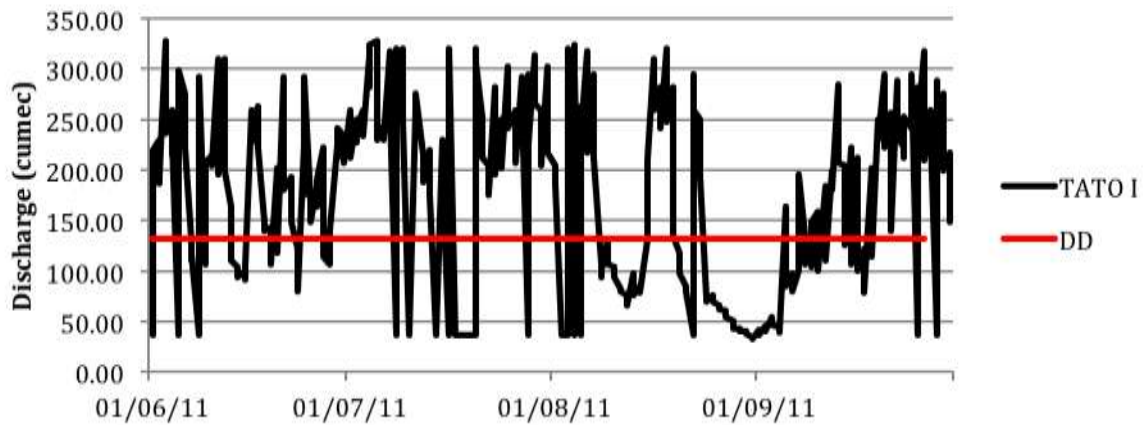


Figure 9.17: Monsoon Discharge at Heo (2011)

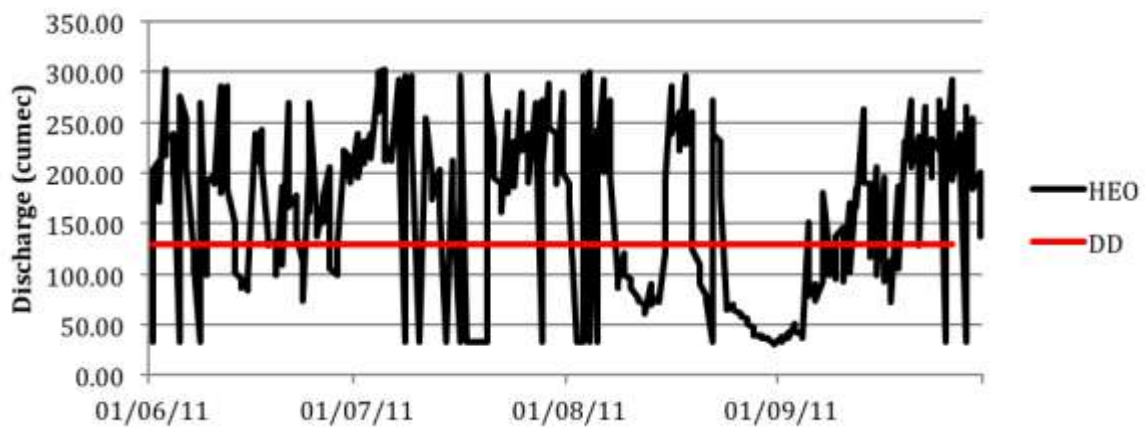


Figure 9.18: Monsoon Discharge at Pauk (2011)

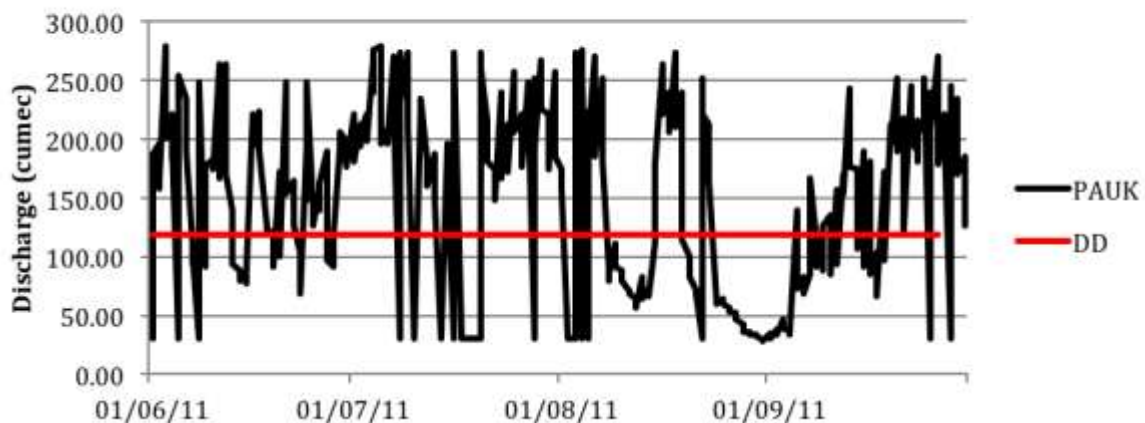


Figure 9.19: Monsoon Discharge at Tato I (2012)

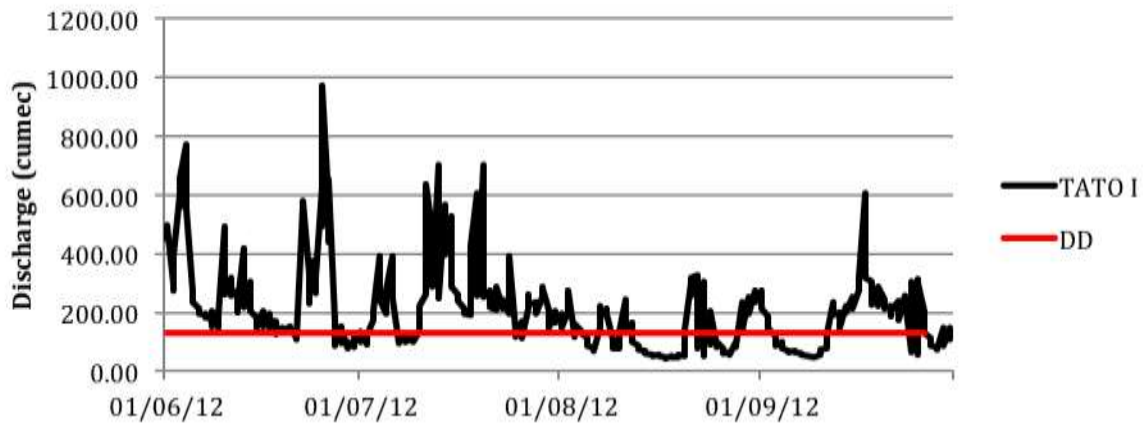


Figure 9.20: Monsoon Discharge at Heo (2012)

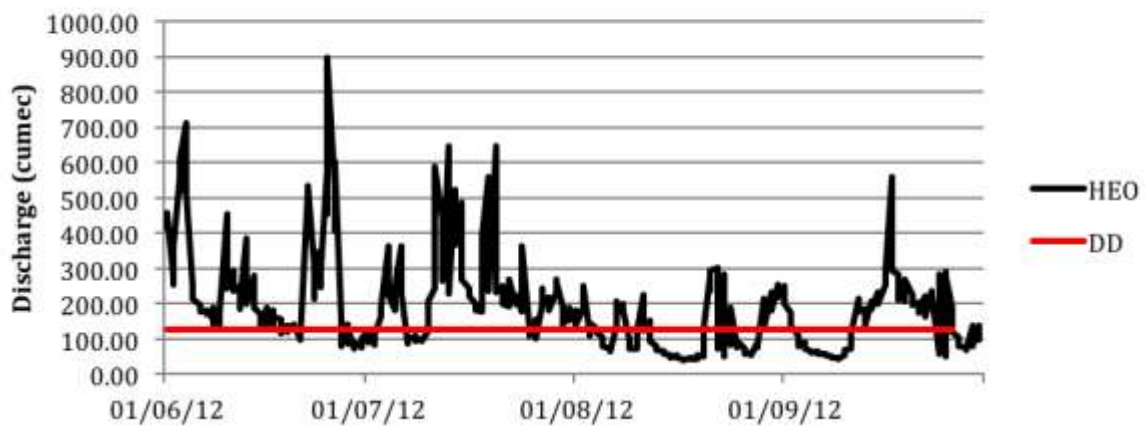
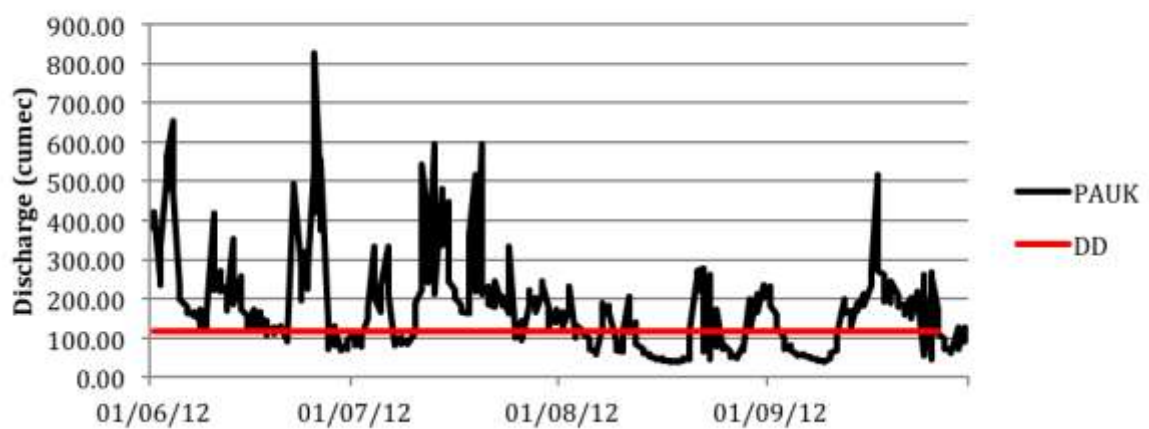


Figure 9.21: Monsoon Discharge at Pauk (2012)



9.6.2.2 Observed Flow for Naying HEP

Promoter of Naying HEP has established their own G&D site at the diversion site during 2007 and five years daily data records are available from 2007-08 till 2011-2012. As discussed earlier, before using the daily-observed data it is important to check data reliability and consistency. In the absence of concurrent period and representative rainfall data for the catchment, the observed flow was compared with the CWC approved series for Naying HEP. Annual runoff as per CWC approved series along with probability are given at Table 9.37.

Table 9.37: Annual Runoff (MCM) as per CWC approved series

Year	Annual (MCM)	Probability
2006-07	11355.00	3.85
2007-08	11259.00	7.69
2000-01	10995.00	11.54
2001-02	10431.00	15.38
1987-88	10135.00	19.23
1979-80	9896.00	23.08
1985-86	9879.00	26.92
1988-89	9334.00	30.77
2008-09	9071.00	34.62
1981-82	8691.00	38.46
1990-91	8689.00	42.31
1982-83	8669.00	46.15
1986-87	8634.00	50.00
1984-85	8547.00	53.85
2003-04	8516.00	57.69
1989-90	8239.00	61.54
1980-81	8187.00	65.38
1991-92	8055.00	69.23
2002-03	7812.00	73.08
2005-06	7738.00	76.92
1983-84	7708.00	80.77
1993-94	7544.00	84.62
1978-79	7482.00	88.46
2004-05	6664.00	92.31
1992-93	6349.00	96.15

Annual runoff figures from observed data are:

2007-08 10780.97 MCM

2008-09 8321.64 MCM

2009-10 6252.42 MCM

2010-11 9042.15 MCM

2011-12 8715.18 MCM

To compare the observed data's consistency with that of CWC discharge data series on annual runoff basis, we have two years common data sets i.e. 2007-08 (10780.97 MCM comparable to 11259 MCM of CWC approved series) and 2008-09 (8321.64 MCM comparable to 9071 MCM of CWC approved series). Therefore, data is considered reliable.

Runoff in 2009-10 is the lowest and is comparable with 1992-93 of CWC approved series, which has 96% probability.

Figure 9.22 give the observed flow chart for Naying HEP for entire period of record i.e. 2007-2012.

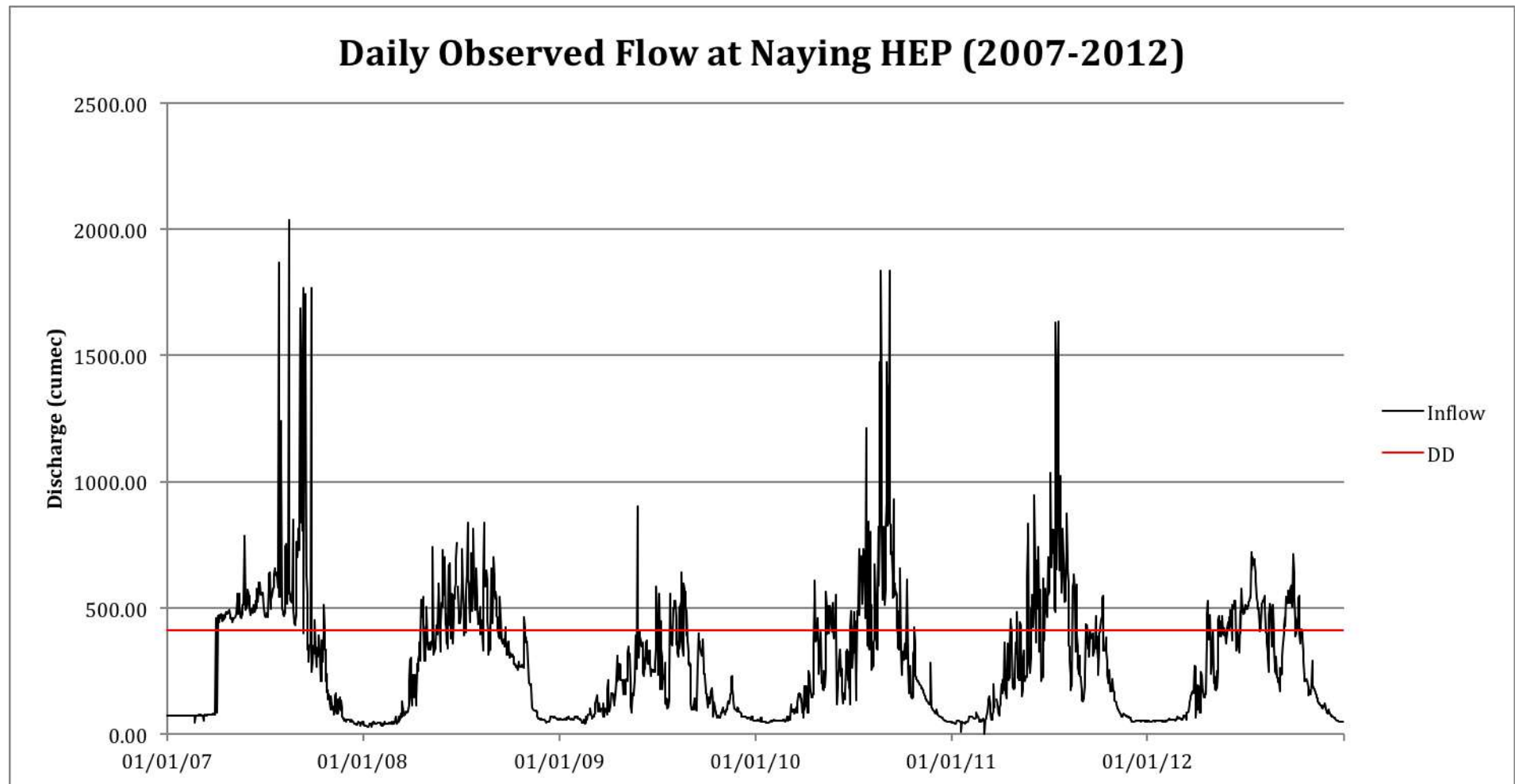


Figure 9.22: Daily Observed Flow at Naying (2007-12)

The observed daily data of five years period (2007-08 to 2011-12) was analyzed for availability of flood peaks downstream of diversion site. Refer **Figure 9.23** through **9.27** for discharge data charts during monsoon season of each year from 2007-08 to 2011-2012. Red line indicates design discharge or abstraction and flow above design discharge will always be available in the river. As can be seen from the charts of five years observed data, only in a good wet year sufficient flow will be available in river in monsoon, which will come in the form of spills after abstraction of 411 cumec (design discharge for Naying HEP). Flood peaks are available in 2007-08, 2008-09, 2010-11 and first half of monsoon period of 2011-12.

Volumetric calculations are given in **Table 9.38**, which also reveals a mixed output varying from 9.68% to 40.57%. 2009-10, an exceptionally dry year with total annual runoff comparable to 96% probable runoff of CWC approved series, spills only 9.68% of inflow even when the calculations are based on daily observed data. In comparison, 90% DY of CWC series 10-daily data show spill of 12.09% inflow. Therefore, in such cases mandatory monsoon releases are important, otherwise river will run almost dry during critical monsoon period.

Table 9.38: Flow Available in River after Design Abstraction by Naying HEP

Year	Flow in River after Design Abstraction (% of inflow)
2007-08	40.57
2008-09	20.91
2009-10	9.68
2010-11	35.18
2011-12	30.73
90% DY*	12.09
50% DY*	27.56

*90% DY and 50% DY are from CWC approved series and are based on 10-daily values

Base flow requirement can be met with 15% release in monsoon, however, 20% is considered in Table 9.33 to ensure depth reduction is not less than 50% of pre-project depth. Based on above analysis, it can be safely concluded that 20% release in monsoon will provide required flood peaks except for a very dry year like 2009-10; therefore, 20% of monsoon release is recommended for Naying HEP.

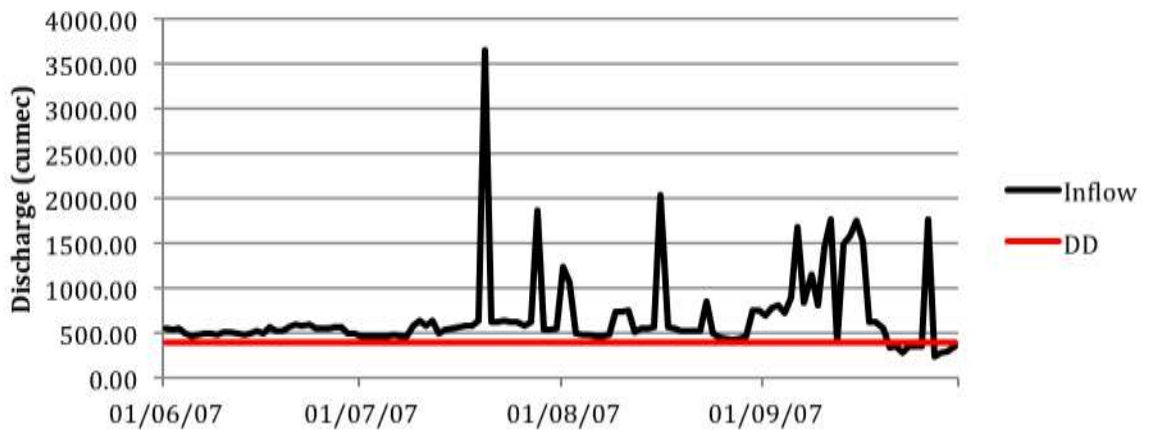
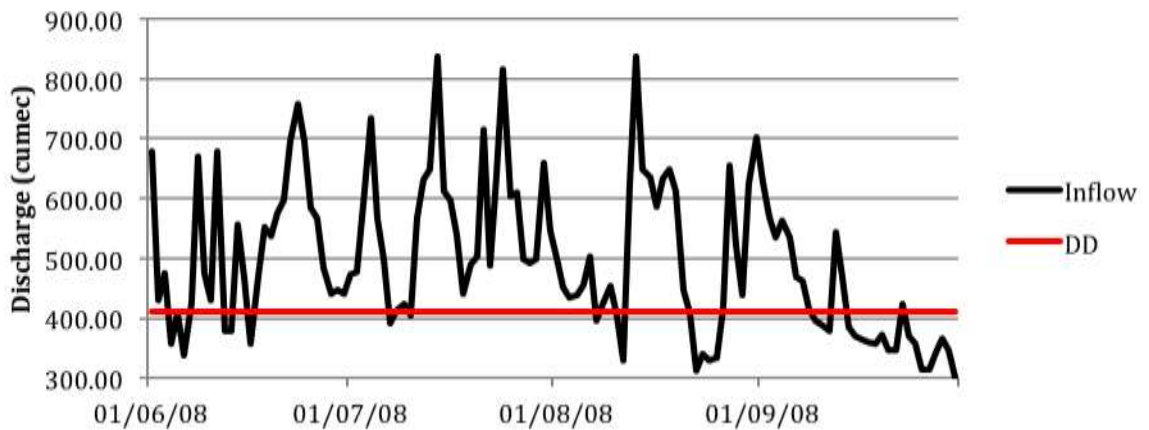
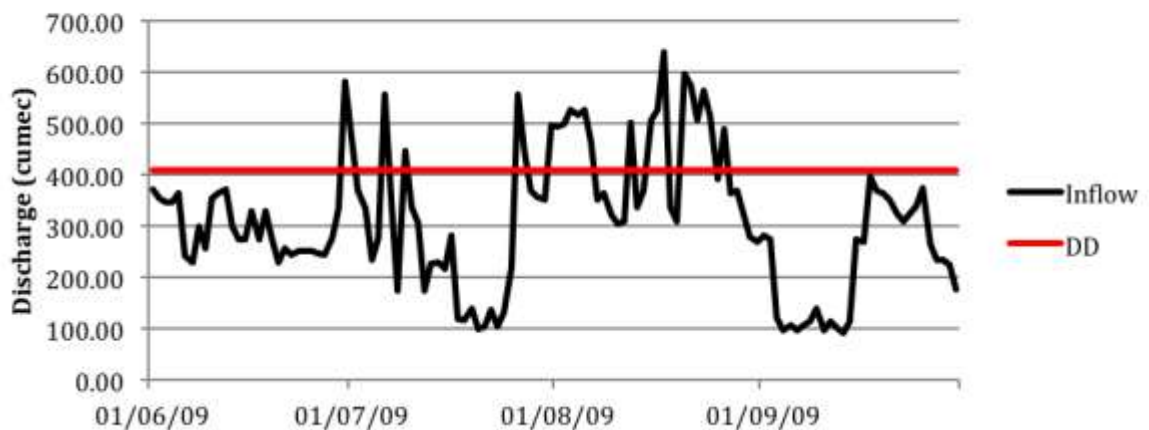
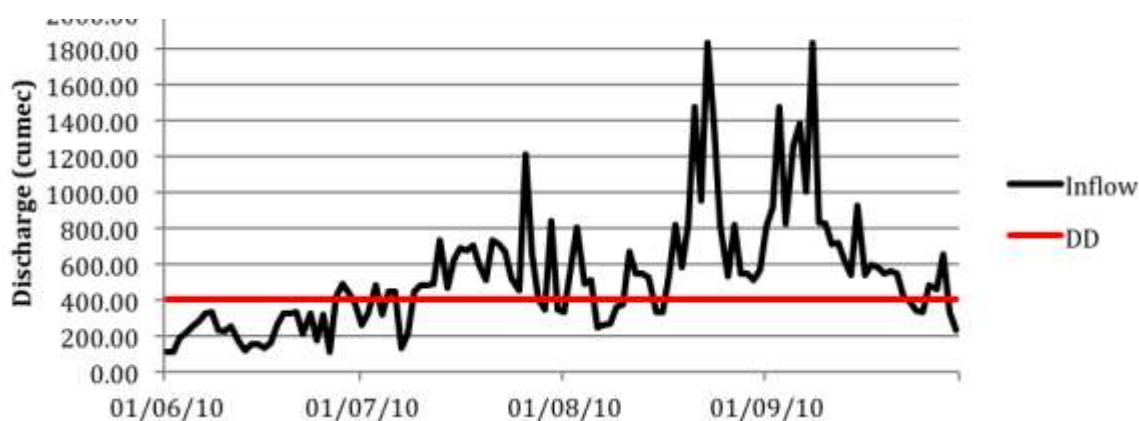
Figure 9.23: Observed Monsoon Discharge at Naying (2007-08)**Figure 9.24: Observed Monsoon Discharge at Naying (2008-09)****Figure 9.25: Observed Monsoon Discharge at Naying (2009-10)**

Figure 9.26: Observed Monsoon Discharge at Naying (2010-11)**Figure 9.27: Observed Monsoon Discharge at Naying (2011-12)**

9.6.3 Environment Flow in Non Monsoon Non Lean Season

Intervening months between monsoon and lean season or pre-monsoon and post monsoon period have their own characteristic flows which are equally important in a river's annual flow cycle. These flows also need to be retained in post project scenario as they define the fundamental difference between wet season and dry season base flows; and small pulses of higher flow, that occur in these months. Depending upon water temperature, migratory species such as Mahseer and Trout start upward migration during pre-monsoon period and migrate back to lower reaches during post monsoon period.

Requirement for base flow in pre-monsoon and post monsoon period can be established from the modelling output in terms of flow required to meet the habitat requirement i.e. water width, depth and velocity. With a view to follow the natural flow regime, this should be higher than that of lean season and moderately less than that of monsoon therefore, needs to be separately assessed. Keeping it slightly lower than monsoon requirement, modelling output is assessed against the water depth of 65-70 cm for Trout Zone projects and 90-100 cm for Mahseer Zone projects. Further, reduced flow depth and width of the river due to diversion of water should be of the order of 50% or more as compared to that of pre-project status.

Additionally, flow variability during this period or small floods needs to be captured in environment flow during this period as these are the indicators of migration for breeding/spawning. Such flood pulses should also be mimicked in post project scenario and this evaluation can best be done with daily flow data. Such data analysis is carried out on limited basis due to non-availability of reliable daily discharge data for most of the projects. In the absence of such data, higher release recommendations are made than what is assessed to meet base flow requirement to ensure flood pulses are spilled in the post project scenario.

Assessing the Base Flow Availability

Table 9.39 below gives flow depth in pre and post monsoon season for 15%, 20%, 25% and 30% release scenarios along with pre-project depth or 100% release scenario. Cells have been highlighted against each project, under different release scenarios, where the habitat is considered adequate to meet base flow requirement only in terms of flow depth. Highlighted cells are compared with the pre-project depth and last column gives the % of depth available with respect to pre-project depth. Naying HEP was meeting the depth requirement even under 15% release scenario, however, the depth was reduced to 45.1% of the pre-project level and therefore next higher level (20%) is considered where depth is 50.8% of the pre-project depth. Simang I is showing about 88.5 cm depth under 20% release scenario and 91.90 cm under 25% release scenario; later is 63.7% of the pre-project depth. Therefore, 25% release is considered to include the flood pulse requirement. Gameng and Palsi don't meet the criteria even under 30% release scenario as pre-project depth is only 101.77 cm and 78.58 cm for Gameng and Palsi HEPs, respectively. Reduction in flow width was also checked and reduced width was found to vary from 47.4% to 70.0% under the selected scenarios (not shown in Table), which is found to be adequate for all the projects. Current velocity is found to be high and is comparable with the pre-project current velocity.

Table 9.39: Model Output for Different Release Scenario during Pre/Post Monsoon

Project	Average Flow Depth (cm)					% of Pre-project Depth (corresponding to highlighted release)
	15% release	20% release	25% release	30% release	Pre-project	
Hirong	118.43	132.07	144.07	154.43	245.21	48.30
Tato II	151.40	169.00	183.90	197.40	310.80	48.71
Naying	122.28	137.61	151.00	162.67	270.89	50.80
Pemashelpu	57.64	64.55	70.27	75.64	121.18	53.27
Kangtangshiri	71.55	80.27	88.00	94.73	153.18	52.40
Rapum	58.78	66.22	72.67	78.67	132.33	50.04
Pauk	91.00	101.50	110.00	117.83	185.00	49.19
Heo	107.00	119.31	130.13	139.56	221.19	48.37
Tato I	109.75	123.00	134.25	144.40	232.85	47.13
Hirit Korong	75.46	84.38	92.31	99.23	158.92	47.48
Siri Korong	63.22	70.89	77.33	83.33	134.22	52.82
Gameng	48.38	54.00	58.69	63.08	101.77	
Ringong	73.45	82.45	89.91	96.64	155.73	47.20
Pango	69.44	77.39	84.39	90.67	144.00	53.74
Mirak	77.18	86.45	94.45	101.64	164.00	47.06
Palsi	36.50	41.25	45.00	48.33	78.58	
Yamne Stage I	77.33	86.33	94.00	101.17	161.00	48.03
Yamne Stage II	96.76	107.76	117.33	125.62	197.76	48.93
Lower Yamne Stage I	88.11	98.63	107.32	115.26	182.79	53.96
Lower Yamne Stage II	81.32	90.68	98.68	105.92	169.44	58.24
Simang I	70.82	88.51	91.90	92.87	144.23	63.70
Simang II	67.26	76.30	83.00	88.91	138.78	48.46

Assessing the Flood Pulse Availability

For Pauk, Heo and Tato I, thrice-daily observed data series is available for a period of five years and 2010 is the leanest year. Therefore, corrected data for the months of April, May, October and November was plotted for three projects separately. Each chart shows two graphs simultaneously - pre-project river discharge and post-project river discharge worked out based on proportional 15% releases. These charts are given at **Figure 9.28 to 9.30** for Tato I, Heo and Pauk respectively. As can be observed from these charts, adequate flood peaks higher than that of design discharge is available during pre and post monsoon period, even after the proportionate 15% releases are maintained. Therefore, for projects like Tato I, Heo and Pauk 15% of release will be adequate during non-monsoon and non-lean period.

9.6.4 Overall Recommendation for Environment Flow

As can be seen from above discussion, flow requirement has been assessed project wise, separately for three seasons i.e. lean, monsoon and other months (pre-monsoon and post-monsoon based on habitat simulation and hydraulic modelling. Limitation faced was paucity of daily discharge data, which is important to assess the availability of flood pulses, which would still be available in river after diversion of water for power generation. Therefore, wherever such assessments could not be made, slightly higher recommendations are made for environmental flow release during monsoon and pre/post monsoon period. Projects where simulation modelling is not carried out due to non-availability of data, recommendations are made based on the other projects assessed on the same river/basin.

Project Specific flow requirement in different seasons is given in Chapter 12, “Conclusions and Recommendations”.

Figure 9.28: Tato I Discharges Before and After Project with 20% Release Scenario

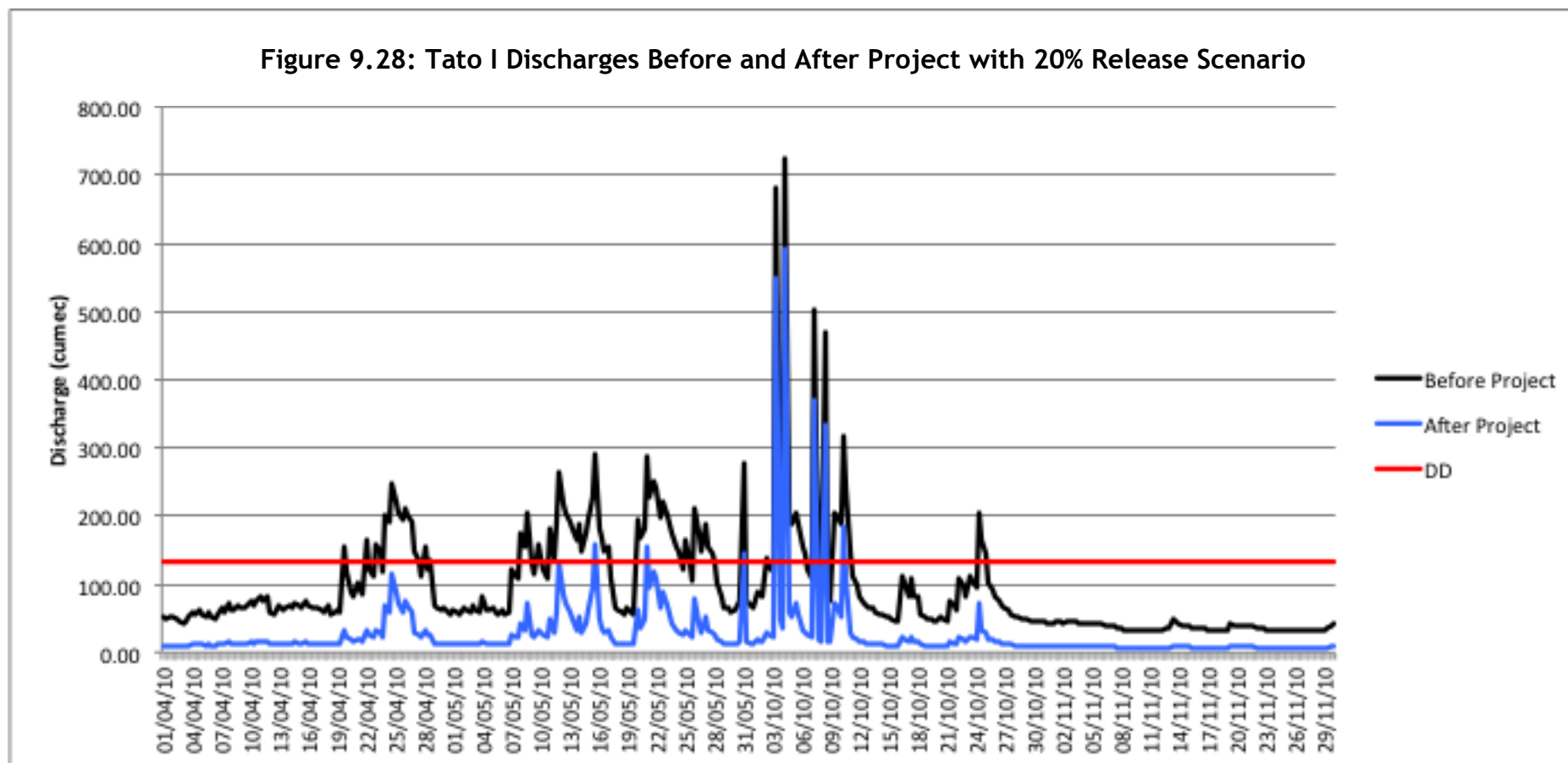


Figure 9.29: Heo Discharges Before and After Project with 20% Release Scenario

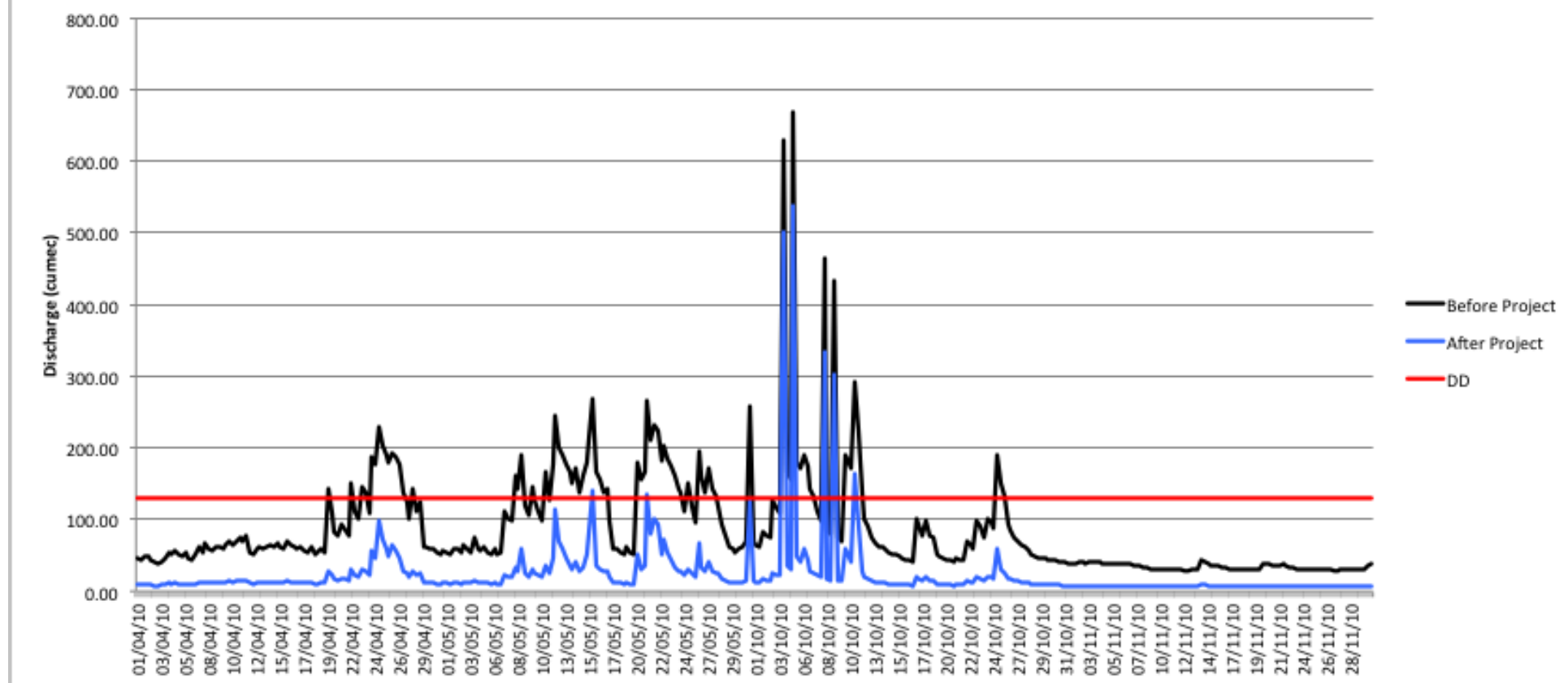
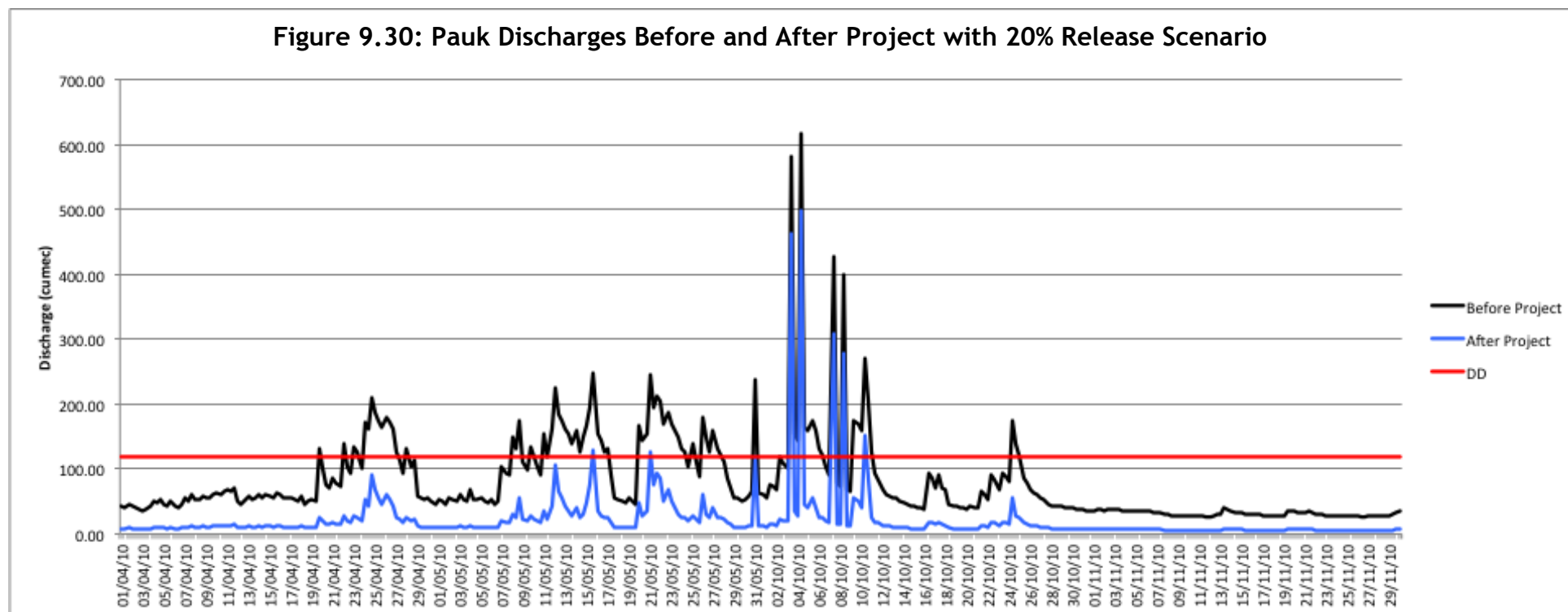


Figure 9.30: Pauk Discharges Before and After Project with 20% Release Scenario



CHAPTER-10

DOWNSTREAM IMPACTS DUE TO HYDRO DEVELOPMENT

10.1 INTRODUCTION

There are 44 HE projects proposed in Siang basin. Most of the projects are in different stages of planning and development. During the monsoon period there will be significant discharge in Brahmaputra river. The peaking discharge of these hydroelectric projects which are quite less in comparison to Brahmaputra discharge will hardly have any impact on Brahmaputra. Some impact in form of flow regulation can be expected during the Lean season peaking from these projects. Most of the projects are likely to be operated at MDDL during monsoon period and at FRL during the lean season. Further during the lean season the peaking discharge release of the projects in upper reaches of Siang basin will be utilized by the project at lower reaches of the basin and net peaking discharge from the lower most project of the basin in general will be the governing one for any impact study.

In Siang basin Siang Lower is the lowermost project on Siang river. The peaking discharge of Siang Lower HEP is about 4970 cumec. The other major projects are Siang Upper Stage-I and Siang Upper Stage-II with Siang Upper Stage-II proposed downstream Siang Upper Stage-I. For Lean season peaking of 7 hours, the peaking discharge of Siang Upper Stage-II is about 4500 cumec. One of the major tributary of Siang river is Siyom River. The peaking discharge of about 709 cumec corresponding to Siyom Middle HE Project will be available from this river. Considering the reservoir of Siang lower is maintained at FRL during the lean season the net inflow should be equal to net outflow. Further, Siang Upper projects are proposed as storage projects and their peaking volume of water is more than the Siang Lower project due to more peaking hours. Hence, after Siang Upper HE projects in place the peaking discharge of 4970 cumec at Siang lower will be available for a longer duration. Accordingly, the impact study has been carried out for following three conditions:

- Peaking and environmental flow releases from Siang Lower and Siyom Middle HE Projects without Siang Upper HE Projects in place
- Peaking and environmental flow releases from Siang Lower and Siyom Middle HE Projects with Siang Upper HE Projects in place
- Peaking and environmental flow releases from Siang Upper and Siyom Middle HE Projects without Siang Lower HE Project in place

10.2 APPROACH ADOPTED

The peaking release from the Siang Upper Stage-I will be re regulated from Siang Upper Stage-II. Hence, for the Siang upper projects, the peaking release from Siang Upper Stage-II only need to be considered for impact study. Further, the peaking release from all the projects in Siang basin will ultimately will be regulated by Siang Lower HE project. Hence For the downstream impact study the typical hourly Lean season releases during 24 hour from Siang Upper, Siang Lower and Siyom Middle HE Projects have been estimated and the same are given in **Table 10.1**.

Table 10.1: Lean season release and peaking discharge

Time	Lean season release from Siang Upper HE projects	Lean season release from Siang Lower HE Project	Lean season release from Siyom Middle HE Project
[hr]	[cumec]	[cumec]	[cumec]
1	171.13	178.33	20.78
2	171.13	178.33	20.78
3	171.13	178.33	20.78
4	171.13	178.33	20.78
5	171.13	178.33	20.78
6	171.13	178.33	20.78
7	171.13	178.33	20.78
8	171.13	178.33	20.78
9	4500.00	178.33	20.78
10	4500.00	178.33	20.78
11	4500.00	4970.30	709.10
12	4500.00	4970.30	709.10
13	4500.00	4970.30	709.10
14	4500.00	4970.30	709.10
15	4500.00	178.33	20.78
16	171.13	178.33	20.78
17	171.13	178.33	20.78
18	171.13	178.33	20.78
19	171.13	178.33	20.78
20	171.13	178.33	20.78
21	171.13	178.33	20.78
22	171.13	178.33	20.78
23	171.13	178.33	20.78
24	171.13	178.33	20.78

For the above estimated release the studies have been carried out for the following three conditions:

Case-1: Impact study for peaking release from Siang Lower HE Project and Siyom Middle HE Project without Siang Upper HE Projects in place

For the most of lean season months from December to March the available discharge at Siang Lower after deducting the discharge at Siyom Middle HE project is sufficient to meet the 4 hours peaking and environmental flow releases requirements of Siang Lower HE project. Hence, for this case it has been assumed that in the absence of Siang Upper HE projects the lean season peaking release from Siang Lower HE Project will be about 4970.30 cumec for 4 hours apart from the environmental release of 178.33 cumec for rest of 20 hours for each lean season day. The lean season peaking release from Siyom Middle HE Project will be about 709.10 cumec for 4 hours apart from the environmental flow release of 20.78 cumec for rest of 20 hours. Accordingly the discharge series as given in Table 10.2 has been used for hydrodynamic routing using MIKE11 model in order to get the resulting discharge series at different locations downstream of Siang Lower H.E. Project up to Guwahati.

Table 10.2: Hourly Lean season release of a typical 24 hour used for impact study without Siang Upper HE Projects in place

Time	Lean season release from Siang Lower HE Project	Lean season release from Siyom Middle HE Project
[hr]	[cumec]	[cumec]
1	178.33	20.78

2	178.33	20.78
3	178.33	20.78
4	178.33	20.78
5	178.33	20.78
6	178.33	20.78
7	178.33	20.78
8	178.33	20.78
9	178.33	20.78
10	178.33	20.78
11	4970.30	709.10
12	4970.30	709.10
13	4970.30	709.10
14	4970.30	709.10
15	178.33	20.78
16	178.33	20.78
17	178.33	20.78
18	178.33	20.78
19	178.33	20.78
20	178.33	20.78
21	178.33	20.78
22	178.33	20.78
23	178.33	20.78
24	178.33	20.78

Case-2: Impact study for peaking release from Siang Lower HE Project and Siyom Middle HE Project with Siang Upper HE projects in place

Two Siang Upper projects are proposed as a storage projects. Assuming a lean season peaking discharge of 4500 cumec, the volume of water released from Siang Upper projects during 7 hours of peaking will be about 113.40 MCM. Similarly the volume of water released from Siyom Middle HE Project during 4 hours of peaking discharge of 709.10 cumec will be about 10.21MCM. Hence total 123.61 MCM water will be available at Siang lower HE Project which can be utilized at Siang Lower HE Project for about 7 hours peaking for its peaking discharge of 4970.30 cumec. Hence for this case the hydrodynamic routing of the following releases have been carried out:

- Lean season peaking release of about 4970.30 cumec for 7 hours apart from the environmental release of 178.33 cumec for rest of 17 hours from Siang Lower HE Project
- Environmental release of 20.78 cumec from Siyom Middle HE Project

For this case the discharge series as given in Table 10.3 has been used for hydrodynamic routing in MIKE11 model to get the resulting discharge series at different locations downstream of Siang Lower H.E. Project up to Guwahati.

Table 10.3: Hourly Lean season release of a typical 24 hour used for impact study with Siang Upper HE Projects in place

Time	Lean season release from Siang Lower HE Projects	Lean season release from Siyom Middle HE Project
[hr]	[cumec]	[cumec]
1	178.33	20.78
2	178.33	20.78
3	178.33	20.78

4	178.33	20.78
5	178.33	20.78
6	178.33	20.78
7	178.33	20.78
8	178.33	20.78
9	4970.30	20.78
10	4970.30	20.78
11	4970.30	20.78
12	4970.30	20.78
13	4970.30	20.78
14	4970.30	20.78
15	4970.30	20.78
16	178.33	20.78
17	178.33	20.78
18	178.33	20.78
19	178.33	20.78
20	178.33	20.78
21	178.33	20.78
22	178.33	20.78
23	178.33	20.78
24	178.33	20.78

Case-3: Impact study for peaking release from Siang Upper HE Projects and Siyom Middle HE Project without Siang Lower HE Project in place

In this scenario the discharge and water level patterns at different downstream locations have been analyzed considering the peaking releases from Siang Upper HE Projects and Siyom Middle HE Project without Siang Lower HE Project in place. Accordingly, for this case the hydrodynamic routing of the following releases have been carried out:

- Lean season peaking release of 4500 cumec for 7 hours apart from the environmental release of 171.13 cumec for rest of 17 hours from Siang Upper HE Project
- Lean season peaking release of 709.10 cumec for 4 hours apart from the environmental flow release of 20.78 cumec for rest of 20 hours from Siyom Middle HE Project

For this case the discharge series as given in Table 10.4 has been used for hydrodynamic routing in MIKE11 model to get the resulting discharge series at different locations downstream of Siang Lower H.E. Project up to Guwahati.

Table 10.4: Hourly Lean season release of a typical 24 hour from Siang Upper HE Projects and Siyom Middle HE Project for impact study without Siang Lower HE Project in place

Time	Lean season release from Siang Upper HE Project	Lean season release from Siyom Middle HE Project
[hr]	[cumec]	[cumec]
1	171.13	20.78
2	171.13	20.78
3	171.13	20.78
4	171.13	20.78
5	171.13	20.78

6	171.13	20.78
7	171.13	20.78
8	171.13	20.78
9	4500.00	20.78
10	4500.00	20.78
11	4500.00	709.10
12	4500.00	709.10
13	4500.00	709.10
14	4500.00	709.10
15	4500.00	20.78
16	171.13	20.78
17	171.13	20.78
18	171.13	20.78
19	171.13	20.78
20	171.13	20.78
21	171.13	20.78
22	171.13	20.78
23	171.13	20.78
24	171.13	20.78

10.3 MIKE11 MODEL

MIKE11 is an integrated system of software, designed for interactive use in a multi-tasking environment. The core of the MIKE 11 system consists of the HD (hydrodynamic) module, which is capable of simulating steady, quasi-unsteady and unsteady flows in a network of open channels. The results of a HD simulation consist of time series of water level and discharge. MIKE 11 hydrodynamic module is an implicit, finite difference model for unsteady flow computations. The model can describe sub-critical as well as supercritical flow conditions through a numerical description, which is altered according to the local flow conditions in time and space. Advanced computational modules are included for description of flow over hydraulic structures, including possibilities to describe structure operation. The formulations can be applied for looped networks and quasi two-dimensional flow simulation on flood plains. The computational scheme is applicable for vertically homogeneous flow conditions extending from steep river flows to tidal influenced tributaries.

The following three approaches simulate the flow in branches as well as looped systems.

- i) **Kinematic wave approach:** The flow is calculated from the assumption of balance between the friction and gravity forces. The simplification implies that the Kinematic wave approach can not simulate backwater effects.
- ii) **Diffusive wave approach:** In addition to the friction and gravity forces, the hydrostatic gradient is included in this description. This allows the user to take downstream boundaries into account, and thus, simulate backwater effects.
- iii) **Dynamic wave approach:** Using the full momentum equation, including acceleration forces, the user is able to simulate fast transients, tidal flows, etc., in the system.

Depending on the type of problem, the appropriate description can be chosen. The dynamic and diffusive wave descriptions differ from kinematic wave description by being capable of calculating backwater effects. For the present case, dynamic wave approach has been adopted to have a better simulation of attenuation and translation pattern of flood wave.

The basic theory for dynamic routing in one dimensional analysis consists of two partial differential equations of open channel flow originally derived by Barre De Saint Venant in 1871. The equations are:

- i. **Conservation of mass (continuity) equation**

$$(\partial Q / \partial X) + \partial(A + A_0) / \partial t - q = 0$$
- ii. **Conservation of momentum equation**

$$(\partial Q / \partial t) + \{ \partial(Q^2 / A) / \partial X \} + g A ((\partial h / \partial X) + S_f + S_c) = 0$$

where Q = discharge;
 A = active flow area;
 A₀ = inactive storage area;
 h = water surface elevation;
 q = lateral outflow;
 x = distance along waterway;
 t = time;
 S_f = friction slope;
 S_c = expansion contraction slope and
 g = gravitational acceleration.

The boundary conditions in MIKE 11 are distinguished between external and internal boundary conditions. Internal boundary conditions are (i) links at nodal points, (ii) structures and (iii) internal inflows etc. External boundary conditions may consist of (i) constant values for h or Q, (ii) time varying values for h or Q, and (iii) relation between h and Q.

Generally, model boundaries should be chosen at points, where either water level or discharge measurements are available so that the model is used for predictive purposes. It is important that the selected boundary locations lie outside the range of influences of any anticipated changes in the hydraulic system.

10.4 MIKE11 MODEL SET UP FOR IMPACT STUDY

For present study, Siyom river from Siyom Middle HE project up to Siyom-Siang Confluence for a reach length of about 74 km has been represented in MIKE11 model through surveyed cross sections which are at an interval of about 10 km. The 42 km reach of Siang river from Siang Upper Stage-II up to Siang-Siyom confluence has been represented by 6 cross sections. Siang Lower HE Project is located about 32 km downstream of Siang-Siyom confluence. This reach of river has been represented by 5 cross sections. The Siang river from Siang Lower HE Project and up to Guwahati for a reach length of about 484 km has been represented through the surveyed cross sections. The Manning's roughness coefficient for the study river reach from Siyom Middle HE Project and up to the Siang-Lohit confluence has been adopted as 0.035. From this point onward and up to Guwahati the Manning's roughness coefficient has been adopted as 0.030 considering the alluvial bed of river. For the case impact study without Siang Upper HE Projects in place, the upstream boundary of model set up which is the discharge series as per Table 10.2 repeated for 40 continuous days, has been applied at Siyom Middle and Siang Lower HEP locations. For the case impact study with Siang Upper HE projects in place, the upstream boundary of model set up which is the discharge series as per Table 10.3 repeated for 40 continuous days, has been applied at Siyom and Siang Lower HEP locations. The normal depth has been assumed as downstream boundary and the same applied at the lower most cross section of the MIKE11 model set up located about 484 km downstream of Siang Lower HE Project i.e. at river cross section near Guwahati. Further the average Lean season flow of Siang river for the months November to April is about 1428 cumec at Siang Lower HE Project site where the catchment area of river is about 250594 sq km. The same at Pandu G&D site (Guwahati) with catchment area of about 417100 sq km is about 5377 cumec. The flow of Siang/Brahmaputra river between Siang Lower

HE Project and Pandu G&D site (Guwahati) has been distributed for natural condition of river and for the post Siang Lower HE Project scenario using the catchment area proportioning. The distributed flow impinged as lateral inflow at different locations of MIKE11 model set up is given below in **Table 10.5**.

Table 10.5: Distributed average Lean season flow of river Siang/Brahmaputra

Location	Catchment area (sq km)	Distributed flow for natural condition of river (cumec)	Distributed flow for post Siang Lower HE project scenario (cumec)
1	2	3	4
Bodak (Siang Lower HEP site)	250594	1428	Peaking release and Environmental flow
Dibrugarh	301730	2641	1213
Jorhat	314825	2951	1524
Tezpur	379088	4475	3048
Pandu (Guwahati)	417100	5377	3949

In the above distribution for post Siang lower HE Project scenario only flow of 3949 cumec which is (5377-1428) cumec has been assumed to be available in the river reach between Siang lower HE Project and Pandu (Guwahati) apart from the peaking release and environmental flow release from Siang lower HE Project. Accordingly the flow of 3949 cumec only has been distributed for impingement at different locations of Brahmaputra river between Siang Lower HE Project and Pandu (Guwahati) during the hydrodynamic simulations in post Siang Lower HE Project scenario.

With the above model set up and lateral inflow as per flow distribution of **Table 10.3**, the necessary hydro dynamic simulation has been carried out to get the net discharge and water level series at different locations of Study reach. The MIKE11 model set up for impact study is given in **Figure 10.1**. In the figure Siyom 0-74000 denotes the Siyom river reach of length 74000 m with the first cross section of river at chainage 0 m and last cross section at chainage 74000 m. Siang Upper 0-42000 denotes the Siang river reach of length 42000 m between Siang Upper Stage-II and Siang - Siyom confluence with the first cross section of river at chainage 0 m and last cross section at chainage 42000 m.

Siang 0-32000 denotes the Siang river reach of length 32000 m from Siang-Siyom confluence up to Siang Lower HE Project. The first cross section of this river reach is at chainage 0 m and last cross section is at chainage 32000 m.

Siang-Brahmaputra 0-484000 denotes the Siang/Brahmaputra river reach from Siang Lower HE Project up to Guwahati. The first cross section of this river reach is at chainage 0 m and last cross section is at chainage 484000 m.

The chainage of some of the important locations from Siang Lower HE Project as per MIKE11 model set up where discharge pattern and water level has been estimated are as follows:

D'Ering Memorial WLS - 20140 m to 33260 m

Dibrugarh - 102020 m

Bokaghat (near Kaziranga National Park) -269280 m

Tezpur - 355460 m

Guwahati - 462580 m

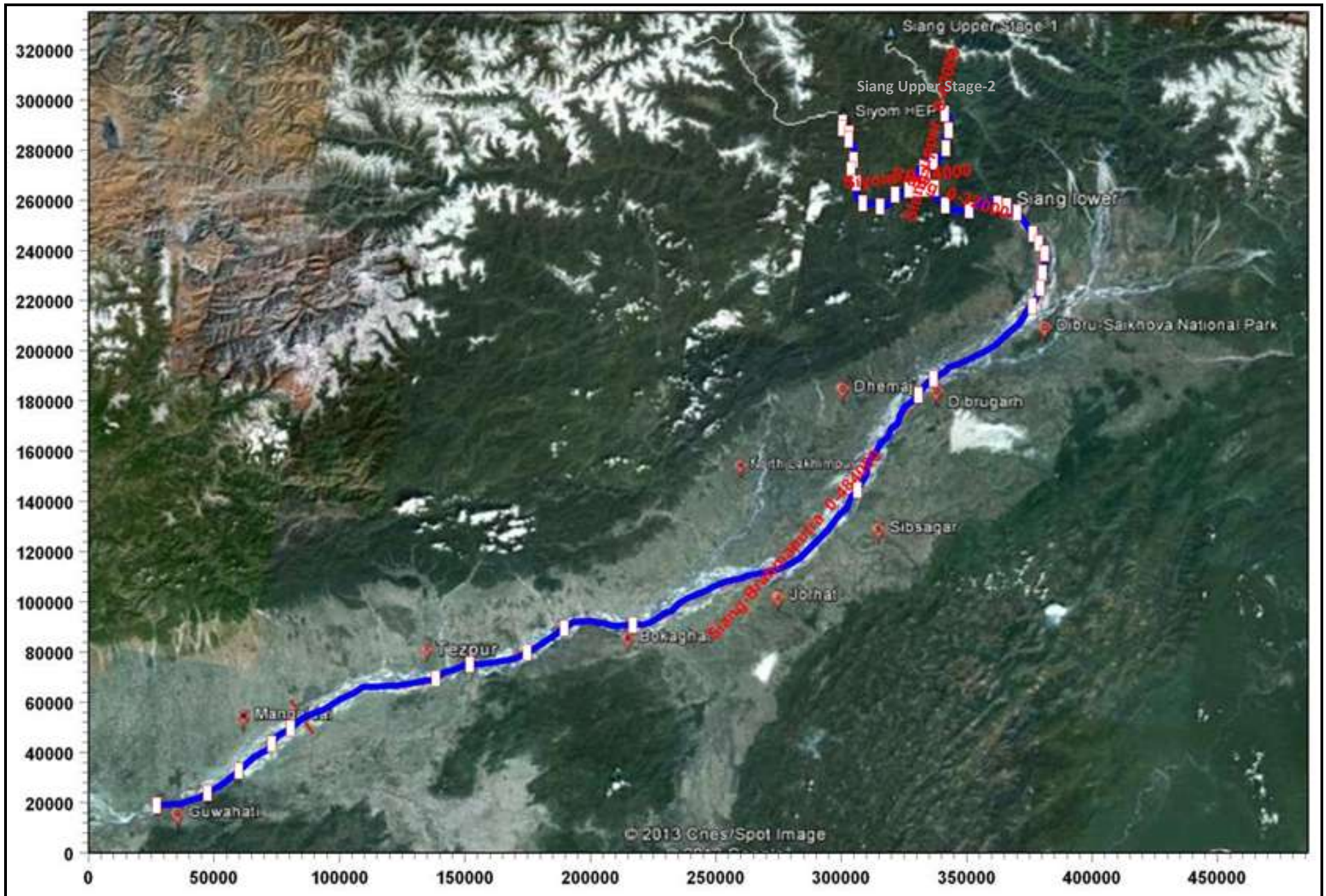


Figure 10.1: MIKE11 model set up for the Study

10.5 FLOW SIMULATION RESULTS IN NATURAL CONDITION OF RIVER

In order to assess the change in water level at different locations of river reach due to peaking release from hydroelectric projects in Siang basin it is essential to estimate the water level at these locations for the average lean season discharge corresponding to natural condition of river. In the natural condition of river, the water levels at different locations of the study reach for the discharge as per column3 of Table 10.5, as obtained from MIKE11 simulation are given in Table 10.6.

Table 10.6: Water level at salient locations in natural condition of river for average Lean season discharge

Place	Chainage from Siang Lower HEP (m)	Average non-monsoon discharge (cumec)	Bed level of river (m)	Simulated water level (m)
D'Ering Memorial WLS	20140	1428	145.67	150.09
D'Ering Memorial WLS	25090	1428	138.19	144.29
D'Ering Memorial WLS	33260	1428	137.66	140.51
Dibrugarh	102020	2641	92.38	96.68
Bokaghat-Kaziranga	269280	2951	86.77	94.46
Tezpur	355460	4475	67.22	74.21
Guwahati	462580	5377	30.96	39.89

10.6 FLOW SIMULATION RESULTS FOR PEAKING RELEASE FROM SIANG LOWER HE PROJECT AND SIYOM MIDDLE HE PROJECT WITHOUT SIANG UPPER HE PROJECTS IN PLACE

Without Siang Upper HE projects in place, the peaking release of 4970.30 cumec from Siang Lower HE Project and 709.10 cumec from Siyom Middle HE Project have been considered for 4 hours as per Table 10.2. Apart from that the distributed flow has also been impinged at different locations of study reach as per column4 of Table 10.5. The stabilized flow pattern and water level at salient locations as obtained are described in subsequent paragraphs.

10.6.1 Flow simulation results at D'Ering Memorial WLS for peaking release from Siang Lower HE Project and Siyom Middle HE Project without Siang Upper HE Projects in place

The plot of release from Siyom, Siang Lower and resulting stabilized discharge/water level series in Siang river near D'Ering Memorial WLS as obtained from MIKE11 simulation is shown in Figure 10.2. The dates given on X-axis of the plots are the arbitrary dates used for hydro dynamic simulation. The discharge series shown at Siang-Brahmaputra ch 29175 (representing the discharge pattern between ch 20140m to 33260m) is the resulting discharge series in Siang river D'Ering Memorial WLS.

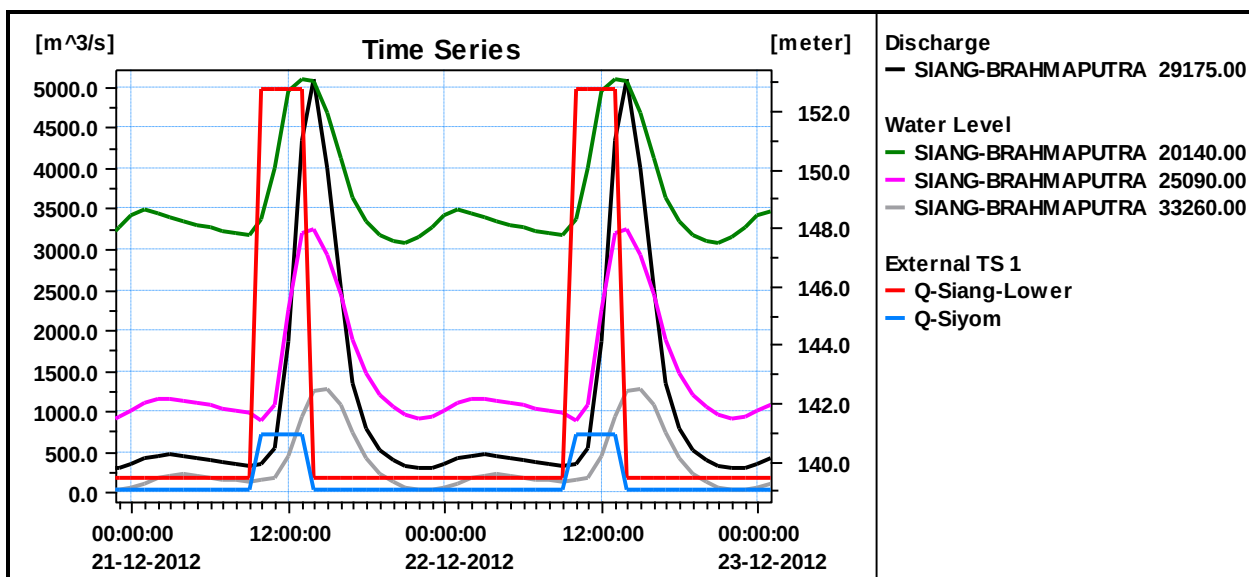


Figure 10.2: Plot of release from Siyom, Siang Lower and resulting discharge/water level series at D'Ering Memorial WLS without Siang Upper HE projects is in place

For 24 hour duration, release from Siang Lower and Siyom Middle HEP along with the stabilized discharge series at D'Ering Memorial WLS is given in Table 10.7. The corresponding stabilized water level pattern is given in Table 10.8. From Figure 10.2 it can be seen that variation in discharge in Siang river during 24 hour at D'Ering Wildlife sanctuary is from 250 cumec to about 5000 cumec. The consequent fluctuation in water level at ch 20140 m of Siang river near D'Ering Memorial WLS is from EL 147.51 m to 153.09 m. The same at ch 25090 m and ch 33260 m is from EL 141.37 m to 147.93 m and EL 139.01 m to 142.47 m, respectively.

Table 10.7: Release from Siang Lower and Siyom Middle HE Projects along with stablised flow pattern at D'Ering Memorial WLS without Siang Upper HE projects in place

Time	Lean season release from Siang Lower HE Project	Lean season release from Siyom Middle HE Project	Stabilized discharge series of Siang river at D'Ering Memorial WLS (starting segment)	Stabilized discharge series of Siang river at D'Ering Memorial WLS (Middle segment)	Stabilized discharge series of Siang river at D'Ering Memorial WLS (End segment)
[hr]	[cumec]	[cumec]	[cumec]	[cumec]	[cumec]
1	178.33	20.78	495.59	443.94	348.48
2	178.33	20.78	495.01	493.76	414.23
3	178.33	20.78	461.41	482.37	452.29
4	178.33	20.78	422.98	447.83	458.50
5	178.33	20.78	392.12	410.16	441.36
6	178.33	20.78	369.28	383.83	416.76
7	178.33	20.78	345.90	359.28	392.03
8	178.33	20.78	328.62	338.54	368.39
9	178.33	20.78	313.97	322.26	348.69
10	178.33	20.78	299.45	307.51	331.20
11	4970.30	709.10	361.81	281.58	355.71
12	4970.30	709.10	1940.00	1196.39	537.47
13	4970.30	709.10	4954.18	4069.84	1849.68
14	4970.30	709.10	5028.89	5016.85	4332.47
15	178.33	20.78	4482.63	4774.49	5082.99

16	178.33	20.78	2415.34	3189.13	4007.11
17	178.33	20.78	1144.86	1709.24	2508.66
18	178.33	20.78	477.18	657.35	1342.47
19	178.33	20.78	344.11	425.72	771.21
20	178.33	20.78	282.68	320.40	525.20
21	178.33	20.78	254.55	268.22	392.65
22	178.33	20.78	262.94	256.00	321.36
23	178.33	20.78	310.15	280.35	293.11
24	178.33	20.78	394.63	345.96	301.68

Table 10.8: Water level pattern of Siang river at different locations along D'Ering Wildlife sanctuary (with Siang Lower and Siyom Middle HE Projects and without Siang Upper HE projects in place)

Time	Stabilized water level pattern at ch 20140 m of Siang river near D'Ering Memorial WLS with river bed level at EL 145.67 m	Stabilized water level pattern at ch 25090 m of Siang river near D'Ering Memorial WLS with river bed level at EL 138.19 m	Stabilized water level pattern at ch 33260 m of Siang river near D'Ering Memorial WLS with river bed level at EL 137.66 m
[hr]	[cumec]	[cumec]	[cumec]
1	148.44	141.71	139.10
2	148.59	141.98	139.25
3	148.52	142.13	139.42
4	148.37	142.15	139.53
5	148.21	142.09	139.56
6	148.10	142.00	139.53
7	147.99	141.91	139.46
8	147.90	141.82	139.40
9	147.83	141.74	139.34
10	147.77	141.67	139.29
11	148.26	141.37	139.36
12	150.05	141.93	139.44
13	152.70	145.18	140.16
14	153.09	147.79	141.56
15	153.03	147.93	142.38
16	151.95	147.04	142.47
17	150.37	145.71	141.95
18	149.01	144.15	140.98
19	148.20	142.99	140.10
20	147.77	142.29	139.58
21	147.54	141.84	139.30
22	147.51	141.57	139.13
23	147.67	141.46	139.03
24	148.01	141.51	139.01

10.6.2 Flow simulation results at Brahmaputra river near Dibrugarh for peaking release from Siang Lower and Siyom Middle HE Projects without Siang Upper HE Projects in place

The plot of release from Siyom, Siang Lower HE Projects and resulting discharge/ water level series in Brahmaputra near Dibrugarh as obtained from MIKE11 simulation is shown in **Figure 10.3**. The dates

given on X-axis of the plot are the dates used for hydro dynamic simulation set up and the same are indicative only. In the plot Q-Siang-Lower represents the release from Siang Lower HEP while Q-Siyom represents release from Siyom Middle HEP. Discharge SIANG-BRAHMAPUTRA 977794.16 represents the resulting discharge series in Brahmaputra river near Dibrugarh, while water level SIANG-BRAHMAPUTRA 102020.00 represents consequent water level series in Brahmaputra near Dibrugarh.

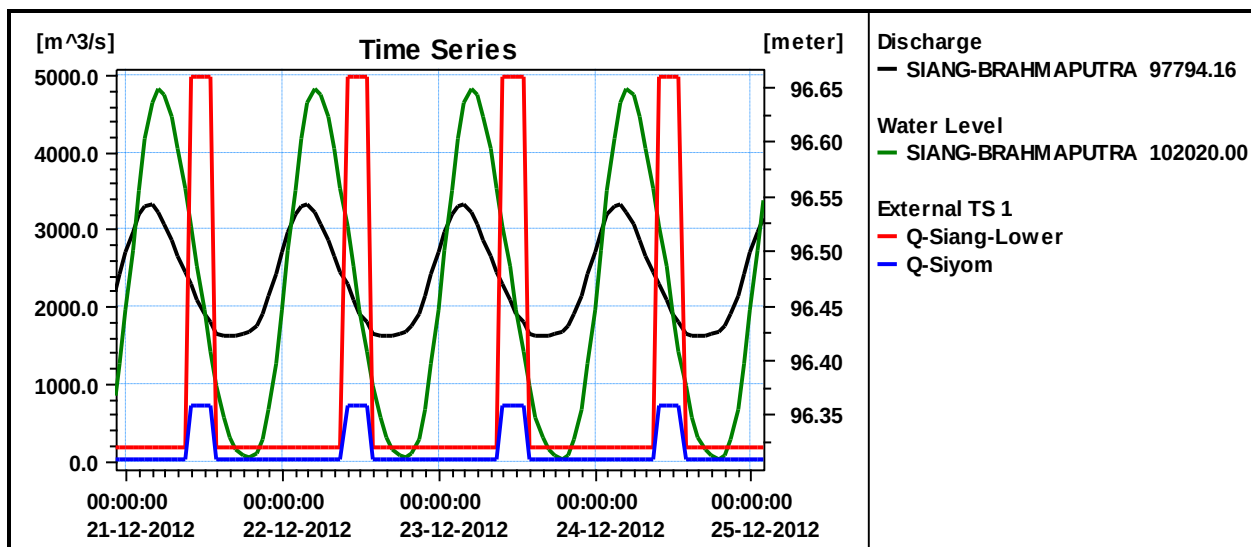


Figure 10.3: Plot of release from Siyom, Siang Lower and resulting discharge/water level series in Brahmaputra near Dibrugarh

It may be noted that in MIKE11 the water level series are computed at h-point which is the location of river cross section while the discharge series are computed between two river cross sections. Hence, the discharge and water level computations obtained for Brahmaputra River near Dibrugarh and also at other salient locations will be at two different chainages. For 24 hour duration, release from Siang Lower and Siyom Middle HE Projects and resulting discharge/water level series in Brahmaputra near Dibrugarh is given in Table 10.9. From Table 10.9, it can be seen that the simulated discharge series near Dibrugarh varies from 1615 cumec to 3318 cumec, while fluctuation in daily water level series is from EL 96.31 m to 96.65 m, about 34 cm. The average Lean season discharge and corresponding water level at Dibrugarh is natural condition of river as obtained by MIKE11 simulation is about 2641 cumec and 96.68 m, respectively. Due to peaking release from projects in Siang basin the change in discharge and water level pattern in Brahmaputra near Dibrugarh is about 700-1000 cumec and 37 cm respectively on lower side in comparison to natural condition of river.

Table 10.9: Release from Siang lower and Siyom Middle HE Projects without Siang Upper HE projects in place and resulting discharge/water level series in Brahmaputra near Dibrugarh

Time	Lean season release from Siang Lower HE Project	Lean season release from Siyom Middle HE Project	Stabilized discharge series in Brahmaputra river near Dibrugarh	Stabilized water level series in Brahmaputra river near Dibrugarh with river bed level at EL 92.38 m
[hr]	[cumec]	[cumec]	[cumec]	[m]
1	178.33	20.78	2689.78	96.50
2	178.33	20.78	2951.14	96.56
3	178.33	20.78	3184.36	96.60
4	178.33	20.78	3309.46	96.64
5	178.33	20.78	3317.94	96.65

6	178.33	20.78	3226.95	96.64
7	178.33	20.78	3055.43	96.62
8	178.33	20.78	2858.27	96.59
9	178.33	20.78	2650.75	96.56
10	178.33	20.78	2436.70	96.52
11	4970.30	709.10	2290.01	96.48
12	4970.30	709.10	2083.48	96.44
13	4970.30	709.10	1912.37	96.41
14	4970.30	709.10	1790.06	96.38
15	178.33	20.78	1650.15	96.35
16	178.33	20.78	1624.12	96.33
17	178.33	20.78	1614.74	96.32
18	178.33	20.78	1616.36	96.31
19	178.33	20.78	1632.61	96.31
20	178.33	20.78	1672.21	96.31
21	178.33	20.78	1748.51	96.33
22	178.33	20.78	1908.32	96.35
23	178.33	20.78	2138.35	96.40
24	178.33	20.78	2410.16	96.45

10.6.3 Flow simulation results at Brahmaputra river near Bokaghat (Kaziranga National Park) for peaking release from Siang Lower and Siyom Middle HE Projects without Siang Upper HE Projects in place

The plot of release from Siyom and Siang Lower HE Projects and resulting discharge /water level series in Brahmaputra river near Bokaghat (Kaziranga National Park) as obtained from MIKE11 simulation is shown in Figure 10.4. In the plot, Q-Siang-Lower represents the release from Siang Lower HEP while Q-Siyom represents release from Siyom Middle HEP. Discharge SIANG-BRAHMAPUTRA 264668.34 represents the resulting discharge series in Brahmaputra near Bokaghat, while water level SIANG-BRAHMAPUTRA 269280.00 represents consequent water level series in Brahmaputra near Bokaghat.

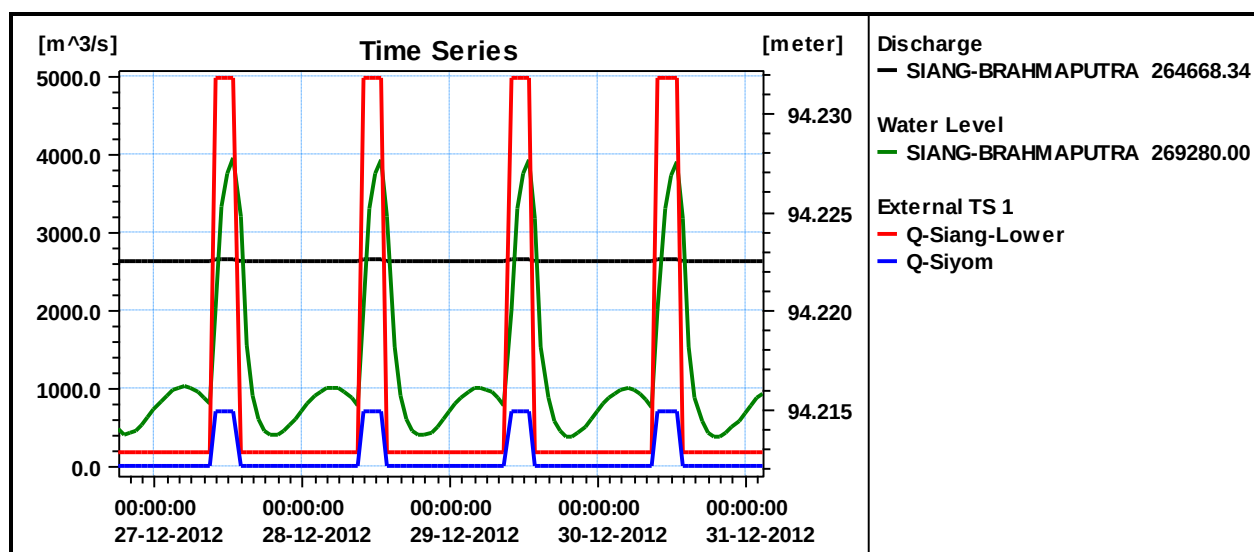


Figure 10.4: Plot of release from Siyom Middle, Siang Lower and resulting discharge/water level series in Brahmaputra near Bokaghat (Kaziranga National Park)

For 24 hour duration, release from Siang Lower and Siyom Middle HEP and resulting discharge/water level series in Brahmaputra near Bokaghat (Kaziranga National Park) is given in **Table 10.10**. From **Table 10.10**, it can be seen that the simulated discharge series near Bokaghat varies from 2622 cumec to 2661 cumec, while fluctuation in daily water level series is from EL 94.21 m to 96.23 m, about 2 cm only. This may be noted that the average Lean season discharge and corresponding water level at Bokaghat in natural condition of river is about 2951 cumec and 94.46 m respectively. Due to peaking release from projects in Siang basin the change in discharge and water level pattern at Bokaghat is about 300 cumec and 24 cm respectively on lower side in comparison to natural condition of river.

Table 10.10: Release from Siang lower and Siyom Middle HE Projects without Siang Upper HE projects in place and resulting discharge/water level series in Brahmaputra near Bokaghat

Time	Lean season release from Siang Lower HE Project	Lean season release from Siyom Middle HE Project	Stabilized discharge series in Brahmaputra river near Bokaghat	Stabilized water level series in Brahmaputra river near Bokaghat with river bed level at EL 86.77 m
[hr]	[cumec]	[cumec]	[cumec]	[m]
1	178.33	20.78	2636.33	94.22
2	178.33	20.78	2636.79	94.22
3	178.33	20.78	2637.05	94.22
4	178.33	20.78	2637.11	94.22
5	178.33	20.78	2636.96	94.22
6	178.33	20.78	2636.61	94.22
7	178.33	20.78	2636.08	94.22
8	178.33	20.78	2635.41	94.22
9	178.33	20.78	2634.63	94.22
10	178.33	20.78	2633.81	94.22
11	4970.30	709.10	2661.28	94.23
12	4970.30	709.10	2653.50	94.23
13	4970.30	709.10	2650.42	94.23
14	4970.30	709.10	2649.10	94.23
15	178.33	20.78	2622.31	94.21
16	178.33	20.78	2625.65	94.21
17	178.33	20.78	2629.04	94.21
18	178.33	20.78	2630.39	94.21
19	178.33	20.78	2631.35	94.22
20	178.33	20.78	2632.25	94.22
21	178.33	20.78	2633.16	94.22
22	178.33	20.78	2634.05	94.22
23	178.33	20.78	2634.89	94.22
24	178.33	20.78	2635.65	94.22

10.6.4 Flow simulation results at Brahmaputra river near Tezpur for peaking release from Siang Lower and Siyom Middle HE Projects without Siang Upper HE projects in place

The plot of release from Siyom and Siang Lower HE Projects and resulting discharge /water level series in Brahmaputra river near Tezpur as obtained from MIKE11 simulation is shown in **Figure 10.5**. In the plot, Q-Siang-Lower represents the release from Siang Lower HEP while Q-Siyom represents release from Siyom Middle HEP. Discharge SIANG-BRAHMAPUTRA 351635.00 represents the resulting discharge series in Brahmaputra near Tezpur, while water level SIANG-BRAHMAPUTRA 355460.00 represents consequent water level series in Brahmaputra near Tezpur.

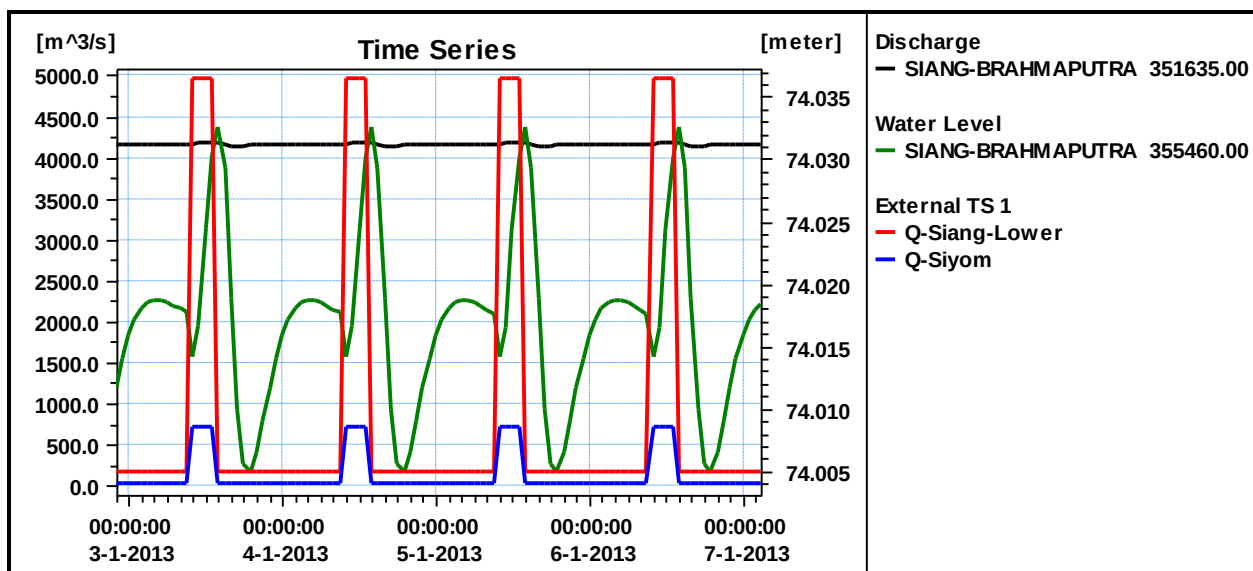


Figure 10.5: Plot of release from Siyom, Siang Lower and resulting discharge/water level series in Brahmaputra near Tezpur

For 24 hour duration, release from Siang Lower and Siyom Middle HEP and resulting discharge/water level series in Brahmaputra near Tezpur is given in Table 10.11. From Table 10.11, it can be seen that the simulated discharge series near Tezpur varies from 4138 cumec to 4189 cumec, while fluctuation in daily water level series is from EL 74 m to 74.03 m, about 3 cm only. The average Lean season discharge and corresponding water level at Tezpur in natural condition of river as obtained by MIKE11 simulation is about 4475 cumec and 74.21 m respectively. Due to peaking release from projects in Siang basin the change in discharge and water level pattern at Tezpur is about 300 cumec and 21 cm on lower side respectively in comparison to natural condition of river.

Table 10.11: Release from Siang lower and Siyom Middle HE Projects without Siang Upper HE projects in place and resulting discharge/water level series in Brahmaputra near Tezpur

Time	Lean season release from Siang Lower HE Project	Lean season release from Siyom Middle HE Project	Stabilized discharge series in Brahmaputra river near Tezpur	Stabilized water level series in Brahmaputra river near Tezpur with river bed level at EL 67.22 m
[hr]	[cumec]	[cumec]	[cumec]	[m]
1	178.33	20.78	4161.04	74.02
2	178.33	20.78	4161.98	74.02
3	178.33	20.78	4162.44	74.02
4	178.33	20.78	4162.53	74.02
5	178.33	20.78	4162.36	74.02
6	178.33	20.78	4162.03	74.02
7	178.33	20.78	4161.61	74.02
8	178.33	20.78	4161.16	74.02
9	178.33	20.78	4160.73	74.01
10	178.33	20.78	4160.36	74.02
11	4970.30	709.10	4155.64	74.02
12	4970.30	709.10	4176.53	74.03
13	4970.30	709.10	4188.75	74.03
14	4970.30	709.10	4188.87	74.03
15	178.33	20.78	4187.87	74.02
16	178.33	20.78	4160.11	74.01
17	178.33	20.78	4142.49	74.01
18	178.33	20.78	4138.16	74.00

19	178.33	20.78	4140.49	74.01
20	178.33	20.78	4145.08	74.01
21	178.33	20.78	4149.83	74.01
22	178.33	20.78	4153.92	74.01
23	178.33	20.78	4157.11	74.02
24	178.33	20.78	4159.44	74.02

10.6.5 Flow simulation results at Brahmaputra river near Guwahati for peaking release from Siang Lower and Siyom Middle HE Projects without Siang Upper HE Projects in place

The plot of release from Siyom and Siang Lower HE Projects and resulting discharge /water level series in Brahmaputra river near Guwahati as obtained from MIKE11 simulation is shown in **Figure 10.6**. In the plot, Q-Siang-Lower represents the release from Siang Lower HEP while Q-Siyom represents release from Siyom Middle HEP. Discharge SIANG-BRAHMAPUTRA 458625.50 represents the resulting discharge series in Brahmaputra near Guwahati while water level SIANG-BRAHMAPUTRA 462580.00 represents consequent water level series in Brahmaputra near Guwahati.

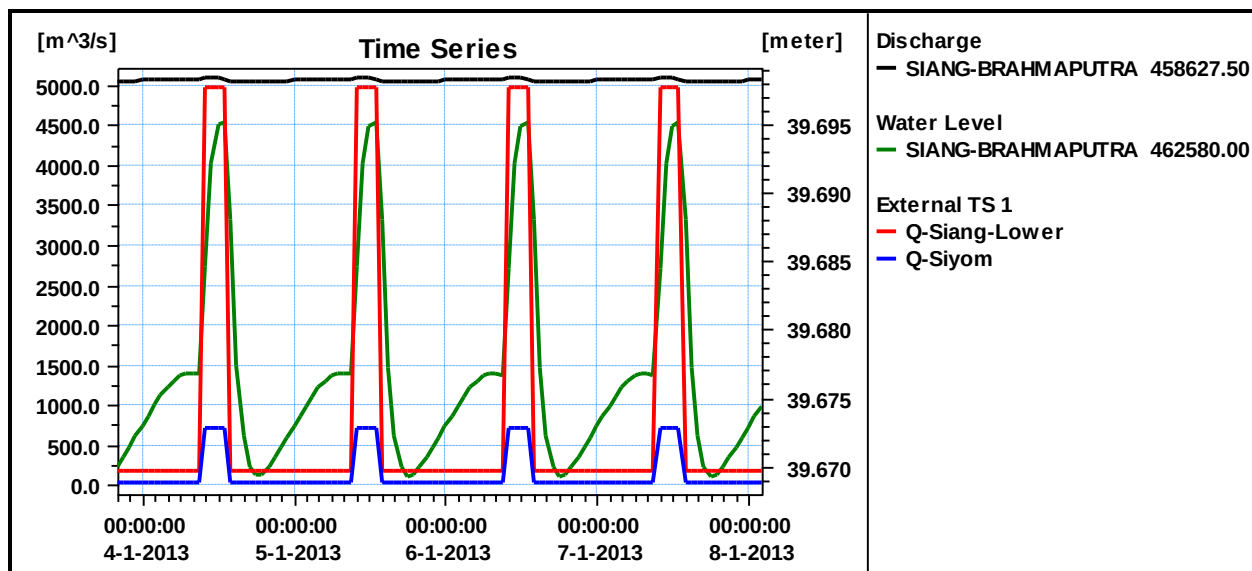


Figure 10.6: Plot of release from Siyom, Siang Lower and resulting discharge/water level series in Brahmaputra near Guwahati

For 24 hour duration, release from Siang Lower and Siyom Middle HEP and resulting discharge/water level series in Brahmaputra near Guwahati is given in **Table 10.12**. From **Table 10.12**, it can be seen that the simulated discharge series near Guwahati varies from 5042 cumec to 5097 cumec, while fluctuation in daily water level series is from EL 39.69 m to 39.71m, about 2 cm only. The average Lean season discharge and corresponding water level in Brahmaputra near Guwahati in natural condition of river as obtained by MIKE11 simulation is about 5377 cumec and 39.89 m, respectively. Due to peaking release from projects in Siang basin the change in discharge and water level pattern at Guwahati is about 300 cumec and 20 cm on lower side, respectively in comparison to natural condition of river.

Table 10.12: Release from Siang lower and Siyom Middle HE Projects without Siang Upper HE projects in place and resulting discharge/water level series in Brahmaputra near Guwahati

Time	Lean season release from Siang Lower HE Project	Lean season release from Siyom Middle HE Project	Stabilized discharge series in Brahmaputra river near Guwahati	Stabilized water level series in Brahmaputra river near Guwahati with river bed level at EL 30.96 m
[hr]	[cumec]	[cumec]	[cumec]	[m]
1	178.33	20.78	5060.11	39.7
2	178.33	20.78	5061.39	39.7
3	178.33	20.78	5062.58	39.7
4	178.33	20.78	5063.61	39.7
5	178.33	20.78	5064.43	39.7
6	178.33	20.78	5064.97	39.7
7	178.33	20.78	5065.20	39.7
8	178.33	20.78	5065.14	39.7
9	178.33	20.78	5064.81	39.7
10	178.33	20.78	5064.29	39.7
11	4970.30	709.10	5097.37	39.71
12	4970.30	709.10	5092.29	39.71
13	4970.30	709.10	5086.26	39.71
14	4970.30	709.10	5080.93	39.71
15	178.33	20.78	5041.87	39.69
16	178.33	20.78	5042.53	39.69
17	178.33	20.78	5045.52	39.69
18	178.33	20.78	5048.16	39.69
19	178.33	20.78	5050.59	39.69
20	178.33	20.78	5052.70	39.69
21	178.33	20.78	5054.49	39.69
22	178.33	20.78	5056.04	39.7
23	178.33	20.78	5057.44	39.7
24	178.33	20.78	5058.78	39.7

10.7 FLOW SIMULATION RESULTS FOR PEAKING RELEASE FROM SIANG LOWER HE PROJECT AND SIYOM MIDDLE HE PROJECT WITH SIANG UPPER HE PROJECTS IN PLACE

With Siang Upper HE Projects in place, the peaking release of 4970.30 cumec from Siang lower HE Project has been considered for 7 hours which has been computed on the basis of net released volume from Siang Upper and Siyom Middle HE Projects as shown in Table 10.3. Hence, taking the release pattern as per Table 10.3 and distributed flow as per column 4 of Table 10.5, the flow pattern has been simulated in MIKE11. The stabilized flow pattern and water level at salient locations as obtained are described in subsequent paragraphs.

10.7.1 Flow simulation results at D'Ering Memorial WLS for peaking release from Siang Lower HE Project and Siyom Middle HE Project with Siang Upper HE Projects in place

The plot of release from Siyom, Siang Lower and resulting stabilized discharge/water level series in Siang river near D'Ering Memorial WLS as obtained from MIKE11 simulation is shown in Figure 10.7. The dates given on X-axis of the plots are the arbitrary dates used for hydrodynamic simulation. The discharge series shown at Siang-Brahmaputra ch 29175 is the resulting discharge series in Siang river at D'Ering Memorial WLS.

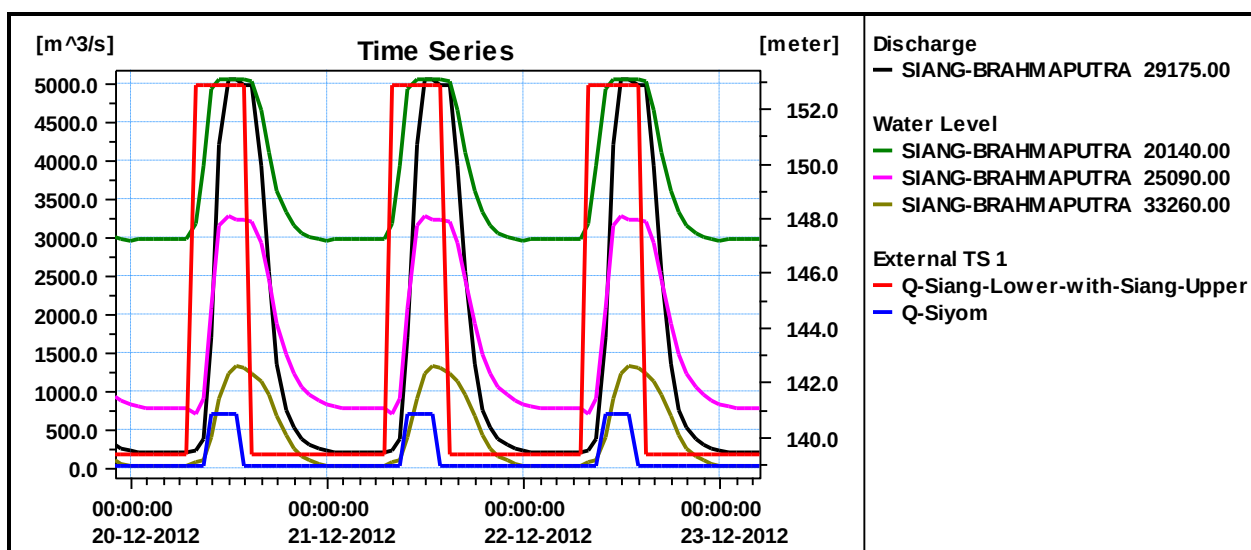


Figure 10.7: Plot of release from Siyom, Siang Lower and resulting discharge/water level series at D Ering Memorial Wildlife sanctuary with Siang Upper HE project in place

For 24 hour duration, release from Siang Lower and Siyom Middle HEP along with the stabilized discharge series at D'Ering Memorial WLS is given in Table 10.13. The corresponding stabilized water level pattern is given in Table 10.14. From Table 10.13 it can be seen that variation in discharge in Siang river during 24 hour at D'Ering Memorial WLS is from 200 cumec to about 5000 cumec with discharge of about 4000 cumec and above sustaining for about 6 hours. The consequent fluctuation in water level at ch 20140 m of Siang river near D'Ering Memorial WLS is from EL 147.19 m to 153.09 m. The same at ch 25090 m and ch 33260 m is from EL 140.85 m to 148.05 m and EL 138.90 m to 142.61 m, respectively.

Table 10.13: Release from Siang lower and Siyom Middle HE Projects along with stablised flow pattern at D'Ering Memorial WLS with Siang Upper HE project in place

Time	Lean season release from Siang Lower HE Project	Lean season release from Siyom Middle HE Project	Stabilized discharge series of Siang river at D'Ering Memorial WLS (starting segment)	Stabilized discharge series of Siang river at D'Ering Memorial WLS (Middle segment)	Stabilized discharge series of Siang river at D'Ering Memorial WLS (End segment)
[hr]	[cumec]	[cumec]	[cumec]	[cumec]	[cumec]
1	178.33	20.78	194.49	194.75	227.34
2	178.33	20.78	195.30	194.22	210.80
3	178.33	20.78	196.98	195.74	203.00
4	178.33	20.78	198.35	197.47	199.75
5	178.33	20.78	199.14	198.67	198.80
6	178.33	20.78	199.44	199.28	198.80
7	178.33	20.78	199.47	199.46	199.06
8	178.33	20.78	199.39	199.44	199.28
9	4970.30	20.78	259.78	200.28	230.32
10	4970.30	20.78	1768.26	1016.54	375.91
11	4970.30	20.78	4897.34	3946.83	1701.84
12	4970.30	20.78	4997.25	4991.71	4187.92
13	4970.30	20.78	4991.92	4986.35	5057.63
14	4970.30	20.78	4990.90	4992.55	5059.03

15	4970.30	20.78	4990.93	4991.62	4968.77
16	178.33	20.78	4467.93	4757.75	4975.16
17	178.33	20.78	2410.79	3180.83	3928.25
18	178.33	20.78	1137.76	1703.42	2555.62
19	178.33	20.78	468.51	651.39	1359.49
20	178.33	20.78	339.35	420.97	767.20
21	178.33	20.78	273.06	313.45	518.95
22	178.33	20.78	230.80	252.58	384.00
23	178.33	20.78	207.36	217.96	305.25
24	178.33	20.78	197.09	200.91	257.06

Table 10.14: Water level pattern of Siang river at different locations along D'Ering Memorial WLS

Time	Stabilized water level pattern at ch 20140 m of Siang river near D'Ering Memorial WLS with river bed level at EL 145.67 m	Stabilized water level pattern at ch 25090 m of Siang river near D'Ering Memorial WLS with river bed level at EL 138.19 m	Stabilized water level pattern at ch 33260 m of Siang river near D'Ering Memorial WLS with river bed level at EL 137.66 m
[hr]	[cumec]	[cumec]	[cumec]
1	147.19	141.17	138.93
2	147.20	141.09	138.90
3	147.21	141.06	138.90
4	147.22	141.04	138.91
5	147.23	141.04	138.93
6	147.23	141.04	138.95
7	147.24	141.04	138.96
8	147.24	141.04	138.97
9	147.78	140.85	139.05
10	149.92	141.40	139.13
11	152.69	144.72	139.96
12	153.08	147.72	141.42
13	153.09	148.05	142.34
14	153.09	147.93	142.61
15	153.09	147.90	142.51
16	153.02	147.85	142.29
17	151.95	147.09	142.05
18	150.36	145.77	141.55
19	148.99	144.16	140.77
20	148.18	142.98	140.06
21	147.73	142.28	139.59
22	147.45	141.82	139.32
23	147.29	141.51	139.14
24	147.21	141.30	139.01

10.7.2 Flow simulation results at Brahmaputra river near Dibrugarh for peaking release from Siang Lower and Siyom Middle HE Projects with Siang Upper HE Projects in place

The plot of release from Siyom, Siang Lower HE Projects and resulting discharge/ water level series in Brahmaputra near Dibrugarh as obtained from MIKE11 simulation is shown in **Figure 10.8**. The dates given on X-axis of the plot are the arbitrary dates used for hydro dynamic simulation. In the plot Q-Siang Lower represents the release from Siang Lower HEP while Q-Siyom represents release from Siyom Middle HEP. Discharge SIANG-BRAHMAPUTRA 977794.16 represents the resulting discharge series

in Brahmaputra river near Dibrugarh, while water level SIANG-BRAHMAPUTRA 102020.00 represents consequent water level series in Brahmaputra near Dibrugarh.

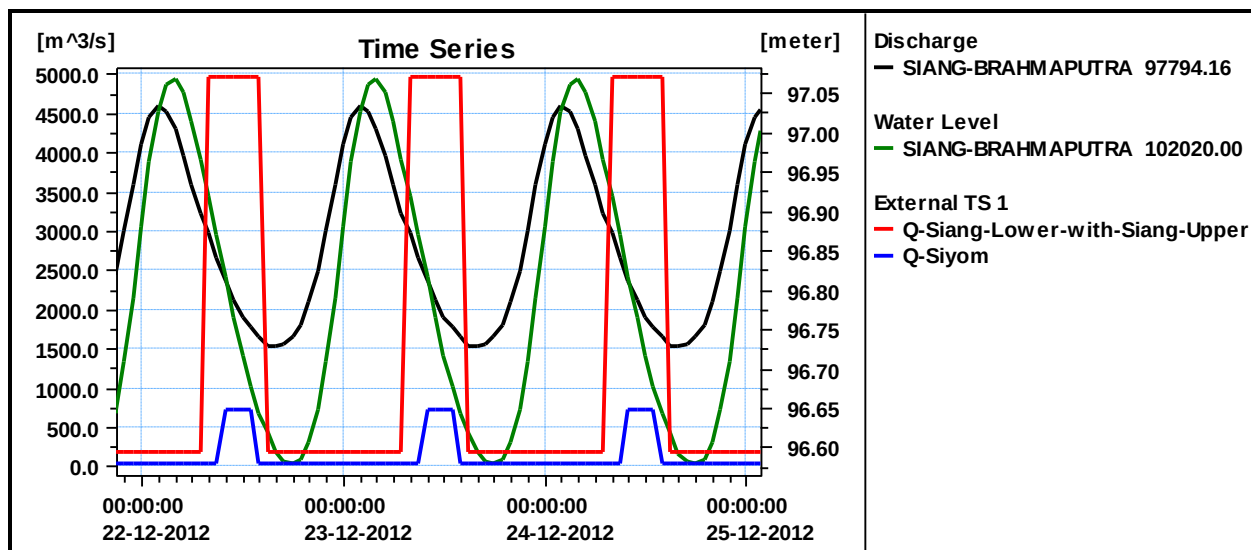


Figure 10.8: Plot of release from Siyom Middle, Siang Lower and resulting discharge/water level series in Brahmaputra near Dibrugarh with Siang Upper HE project in place

For 24 hour duration, release from Siang Lower and Siyom Middle HE Projects and resulting discharge/water level series in Brahmaputra near Dibrugarh is given in Table 10.15. From Table 10.15, it can be seen that the simulated discharge series near Dibrugarh varies from 1529 cumec to 4581 cumec, while fluctuation in daily water level series is from EL 96.58m to 97.07m, about 50cm. The average Lean season discharge and corresponding water level at Dibrugarh is natural condition of river as obtained by MIKE11 simulation is about 2641 cumec and 96.68 m, respectively. Due to peaking release from projects in Siang basin the change in discharge and water level pattern in Brahmaputra near Dibrugarh is about 1100-1900 cumec and 12cm to 38cm, respectively in comparison to natural condition of river. This may be noted that the water level at a particular location will depend upon the discharge at that location as well as water level at the downstream locations also. For the present case the computed water level at Dibrugarh is 96.58 m for 1529 cumec discharge, when the stabilized water level at Bokaghat is about 94.58 m. For the flow simulation of para 6.2 the computed water level at Dibrugarh is about 96.31 m for a discharge of 1615 cumec when the stabilized water level at Bokaghat is about 94.22 m. This clarifies the effect of downstream water level in the computation of water level at an upstream location.

Table 10.15: Release from Siang Lower and Siyom Middle HE Projects with Siang Upper HE projects in place and resulting discharge/water level series in Brahmaputra near Dibrugarh

Time	Lean season release from Siang Lower HE Project	Lean season release from Siyom Middle HE Project	Stabilized discharge series in Brahmaputra river near Dibrugarh	Stabilized water level series in Brahmaputra river near Dibrugarh with river bed level at EL 92.38 m
[hr]	[cumec]	[cumec]	[cumec]	[m]
1	178.33	20.78	1529.00	96.58
2	178.33	20.78	1529.60	96.58
3	178.33	20.78	1563.57	96.58
4	178.33	20.78	1639.30	96.61

5	178.33	20.78	1789.12	96.65
6	178.33	20.78	2084.97	96.71
7	178.33	20.78	2486.21	96.79
8	178.33	20.78	2986.88	96.88
9	4970.30	20.78	3597.77	96.96
10	4970.30	20.78	4112.09	97.03
11	4970.30	20.78	4451.74	97.06
12	4970.30	20.78	4581.00	97.07
13	4970.30	20.78	4510.04	97.05
14	4970.30	20.78	4285.45	97.01
15	4970.30	20.78	3960.78	96.97
16	178.33	20.78	3597.75	96.92
17	178.33	20.78	3229.71	96.87
18	178.33	20.78	2979.31	96.82
19	178.33	20.78	2661.35	96.76
20	178.33	20.78	2368.53	96.72
21	178.33	20.78	2115.90	96.68
22	178.33	20.78	1906.38	96.64
23	178.33	20.78	1761.35	96.62
24	178.33	20.78	1653.24	96.59

10.7.3 Flow simulation results at Brahmaputra river near Bokaghat (Kaziranga National Park) for peaking release from Siang Lower and Siyom Middle HE Projects with Siang Upper HE Projects in place

The plot of release from Siyom and Siang Lower HE Projects and resulting discharge /water level series in Brahmaputra river near Bokaghat (Kaziranga National Park) as obtained from MIKE11 simulation is shown in **Figure 10.9**. In the plot, Q-Siang-Lower represents the release from Siang Lower HEP while Q-Siyom represents release from Siyom Middle HEP. Discharge SIANG-BRAHMAPUTRA 264668.34 represents the resulting discharge series in Brahmaputra near Bokaghat, while water level SIANG-BRAHMAPUTRA 269280.00 represents consequent water level series in Brahmaputra near Bokaghat.

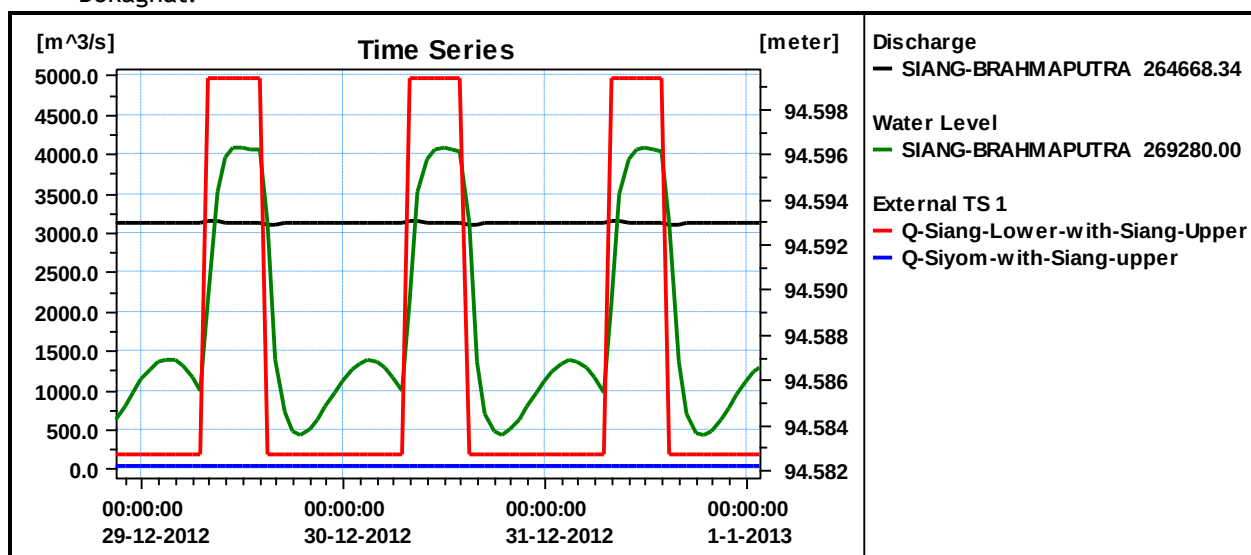


Figure 10.9: Plot of release from Siyom Middle , Siang Lower and resulting discharge/water level series in Brahmaputra near Bokaghat (Kaziranga) with Siang Upper HE projects in place

For 24 hour duration, release from Siang Lower and Siyom Middle HEP and resulting discharge/water level series in Brahmaputra near Bokaghat (Kaziranga National Park) is given in **Table 10.16**. From

Table 10.16, it can be seen that the simulated discharge series near Bokaghat varies from 3115 cumec to 3147 cumec, while fluctuation in daily water level series is from EL 94.58 m to 94.60 m, about 2 cm only. This may be noted that the average Lean season discharge and corresponding water level at Bokaghat in natural condition of river is about 2951 cumec and 94.46 m respectively. Due to peaking release from projects in Siang basin the change in discharge and water level pattern at Bokaghat is about 200 cumec and 14 cm on higher side respectively in comparison to natural condition of river.

Table 10.16: Release from Siang lower and Siyom Middle HE Projects with Siang Upper HE projects in place and resulting discharge/water level series in Brahmaputra near Bokaghat

Time	Lean season release from Siang Lower HE Project	Lean season release from Siyom Middle HE Project	Stabilized discharge series in Brahmaputra river near Bokaghat	Stabilized water level series in Brahmaputra river near Bokaghat with river bed level at EL 86.77 m
[hr]	[cumec]	[cumec]	[cumec]	[m]
1	178.33	20.78	3115.38	94.59
2	178.33	20.78	3146.91	94.60
3	178.33	20.78	3137.19	94.60
4	178.33	20.78	3132.16	94.60
5	178.33	20.78	3129.78	94.60
6	178.33	20.78	3128.52	94.60
7	178.33	20.78	3127.97	94.59
8	178.33	20.78	3127.98	94.59
9	4970.30	20.78	3097.26	94.58
10	4970.30	20.78	3103.46	94.58
11	4970.30	20.78	3109.37	94.58
12	4970.30	20.78	3112.53	94.58
13	4970.30	20.78	3114.88	94.58
14	4970.30	20.78	3116.86	94.58
15	4970.30	20.78	3118.55	94.59
16	178.33	20.78	3119.92	94.59
17	178.33	20.78	3120.94	94.59
18	178.33	20.78	3121.57	94.59
19	178.33	20.78	3121.77	94.59
20	178.33	20.78	3121.53	94.59
21	178.33	20.78	3120.88	94.59
22	178.33	20.78	3119.85	94.59
23	178.33	20.78	3118.52	94.59
24	178.33	20.78	3116.99	94.59

10.7.4 Flow simulation results at Brahmaputra river near Tezpur for peaking release from Siang Lower and Siyom Middle HE Projects with Siang Upper HE Project in place

The plot of release from Siyom and Siang Lower HE Projects and resulting discharge /water level series in Brahmaputra river near Tezpur as obtained from MIKE11 simulation is shown in **Figure 10.10**. In the plot, Q-Siang-Lower represents the release from Siang Lower HEP while Q-Siyom represents release from Siyom Middle HEP. Discharge SIANG-BRAHMAPUTRA 351635.00 represents the resulting discharge series in Brahmaputra near Tezpur, while water level SIANG-BRAHMAPUTRA 355460.00 represents consequent water level series in Brahmaputra near Tezpur.

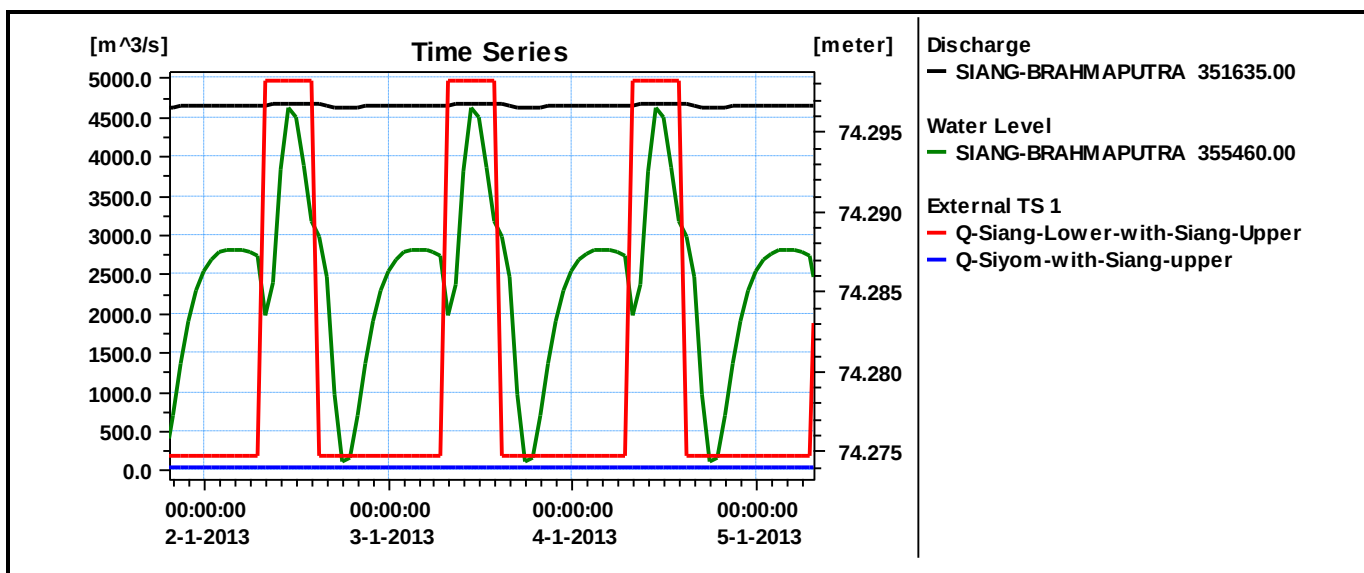


Figure 10.10: Plot of release from Siyom Middle, Siang Lower and resulting discharge/water level series in Brahmaputra near Tezpur with Siang Upper HE projects in place

For 24 hour duration, release from Siang Lower and Siyom Middle HEP and resulting discharge/water level series in Brahmaputra near Tezpur is given in Table 10.17. From Table 10.17, it can be seen that the simulated discharge series near Tezpur varies from 4616 cumec to 4646 cumec, while fluctuation in daily water level series is from EL 74.27m to 74.30m, about 3 cm only. The average Lean season discharge and corresponding water level at Tezpur in natural condition of river as obtained by MIKE11 simulation is about 4475 cumec and 74.21 m, respectively. Due to peaking release from projects in Siang basin the change in discharge and water level pattern at Tezpur is about 170 cumec and 6-9 cm on higher side respectively in comparison to natural condition of river.

Table 10.17: Release from Siang Lower and Siyom Middle HE Projects with Siang Upper HE projects in place and resulting discharge/water level series in Brahmaputra near Tezpur

Time	Lean season release from Siang Lower HE Project	Lean season release from Siyom Middle HE Project	Stabilized discharge series in Brahmaputra river near Tezpur	Stabilized water level series in Brahmaputra river near Tezpur with river bed level at EL 67.22 m
[hr]	[cumec]	[cumec]	[cumec]	[m]
1	178.33	20.78	4615.86	74.27
2	178.33	20.78	4621.42	74.27
3	178.33	20.78	4628.06	74.28
4	178.33	20.78	4633.79	74.28
5	178.33	20.78	4638.17	74.28
6	178.33	20.78	4641.34	74.29
7	178.33	20.78	4643.53	74.29
8	178.33	20.78	4644.95	74.29
9	4970.30	20.78	4645.78	74.29
10	4970.30	20.78	4646.16	74.29
11	4970.30	20.78	4646.21	74.29
12	4970.30	20.78	4646.05	74.29
13	4970.30	20.78	4645.76	74.29
14	4970.30	20.78	4645.40	74.29
15	4970.30	20.78	4637.63	74.28
16	178.33	20.78	4661.78	74.29
17	178.33	20.78	4675.49	74.30

18	178.33	20.78	4674.87	74.30
19	178.33	20.78	4668.22	74.30
20	178.33	20.78	4660.92	74.29
21	178.33	20.78	4654.99	74.29
22	178.33	20.78	4657.95	74.29
23	178.33	20.78	4631.56	74.29
24	178.33	20.78	4616.47	74.28

10.7.5 Flow simulation results at Brahmaputra river near Guwahati for peaking release from Siang Lower and Siyom Middle HE Projects with Siang Upper HE projects in place

The plot of release from Siyom and Siang Lower HE Projects and resulting discharge /water level series in Brahmaputra river near Guwahati as obtained from MIKE11 simulation is shown in **Figure 10.11**. In the plot, Q-Siang-Lower represents the release from Siang Lower HEP while Q-Siyom represents release from Siyom Middle HEP. Discharge SIANG-BRAHMAPUTRA 458625.50 represents the resulting discharge series in Brahmaputra near Guwahati while water level SIANG-BRAHMAPUTRA 462580.00 represents consequent water level series in Brahmaputra near Guwahati.

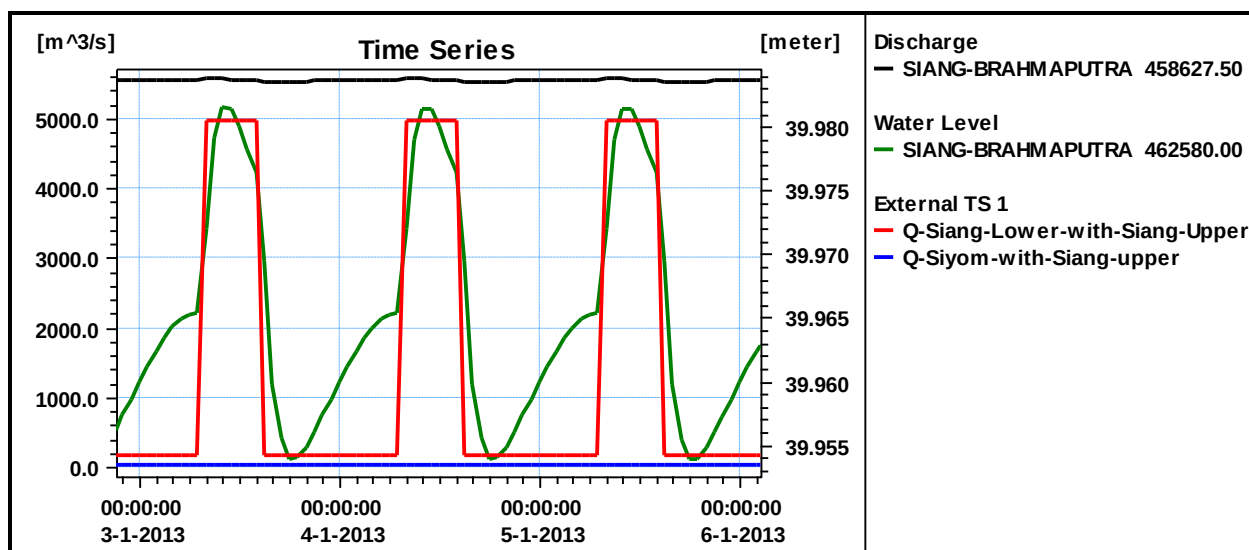


Figure 10.11: Plot of release from Siyom, Siang Lower and resulting discharge/water level series in Brahmaputra near Guwahati with Siang upper project in place

For 24 hour duration, release from Siang Lower and Siyom Middle HEP and resulting discharge/water level series in Brahmaputra near Guwahati is given in **Table 10.18**. From **Table 10.18**, it can be seen that the simulated discharge series near Guwahati varies from 5511 cumec to 5586 cumec, while fluctuation in daily water level series is from EL 39.95 m to 39.98m, about 3 cm only. The average Lean season discharge and corresponding water level in Brahmaputra near Guwahati in natural condition of river as obtained by MIKE11 simulation is about 5377 cumec and 39.89 m respectively. Due to peaking release from projects in Siang basin the change in discharge and water level pattern at Guwahati is about 200 cumec and 6-9 cm on higher side respectively in comparison to natural condition of river.

Table 10.18: Release from Siang lower and Siyom Middle HE Projects with Siang Upper HE projects in place and resulting discharge/water level series in Brahmaputra near Guwahati

Time	Lean season release from Siang Lower HE Project	Lean season release from Siyom Middle HE Project	Stabilized discharge series in Brahmaputra river near Guwahati	Stabilized water level series in Brahmaputra river near Guwahati with river bed level at EL 30.96 m
[hr]	[cumec]	[cumec]	[cumec]	[m]
1	178.33	20.78	5511.23	39.95
2	178.33	20.78	5515.88	39.95
3	178.33	20.78	5522.33	39.95
4	178.33	20.78	5527.47	39.96
5	178.33	20.78	5531.76	39.96
6	178.33	20.78	5535.33	39.96
7	178.33	20.78	5538.32	39.96
8	178.33	20.78	5540.93	39.96
9	4970.30	20.78	5543.29	39.96
10	4970.30	20.78	5545.46	39.96
11	4970.30	20.78	5547.44	39.96
12	4970.30	20.78	5549.15	39.96
13	4970.30	20.78	5550.51	39.97
14	4970.30	20.78	5551.44	39.97
15	4970.30	20.78	5551.89	39.97
16	4970.30	20.78	5551.85	39.98
17	178.33	20.78	5551.37	39.98
18	178.33	20.78	5586.21	39.98
19	178.33	20.78	5578.54	39.98
20	178.33	20.78	5570.12	39.98
21	178.33	20.78	5563.13	39.98
22	178.33	20.78	5557.45	39.97
23	178.33	20.78	5553.04	39.96
24	178.33	20.78	5549.73	39.96

10.8 FLOW SIMULATION RESULTS FOR PEAKING RELEASE FROM SIANG UPPER HE PROJECTS AND SIYOM MIDDLE HE PROJECT WITHOUT SIANG LOWER HE PROJECT IN PLACE

For the present case the peaking release of 4500 cumec from Siang Upper HE Project-II has been considered for 7 hours, and environmental flow release of 171.13 cumec has been considered for rest 17 hours. From the Siyom Middle HE Project the peaking release of 709.10 cumec for 4 hours and environmental flow release of 20.78 cumec for 20 hours have been considered. Hence, taking the release pattern as per Table 10.4 and distributed flow as per column 4 of Table 10.5, the flow pattern has been simulated in MIKE11. The stabilized flow pattern and water level at salient locations as obtained are described below.

10.8.1 Flow simulation results at D'Ering Memorial WLS for peaking release from Siang Upper HE projects and Siyom Middle HE Project without Siang Lower HE Project in place

The plot of release from Siyom, Siang upper and resulting stabilized discharge/water level series in Siang river near D'Ering Memorial WLS as obtained from MIKE11 simulation is shown in Figure 10.12. The dates given on X-axis of the plots are the arbitrary dates used for hydro dynamic simulation. The discharge series shown at Siang-Brahmaputra ch 29175 is the resulting discharge series in Siang river at D'Ering Wildlife sanctuary.

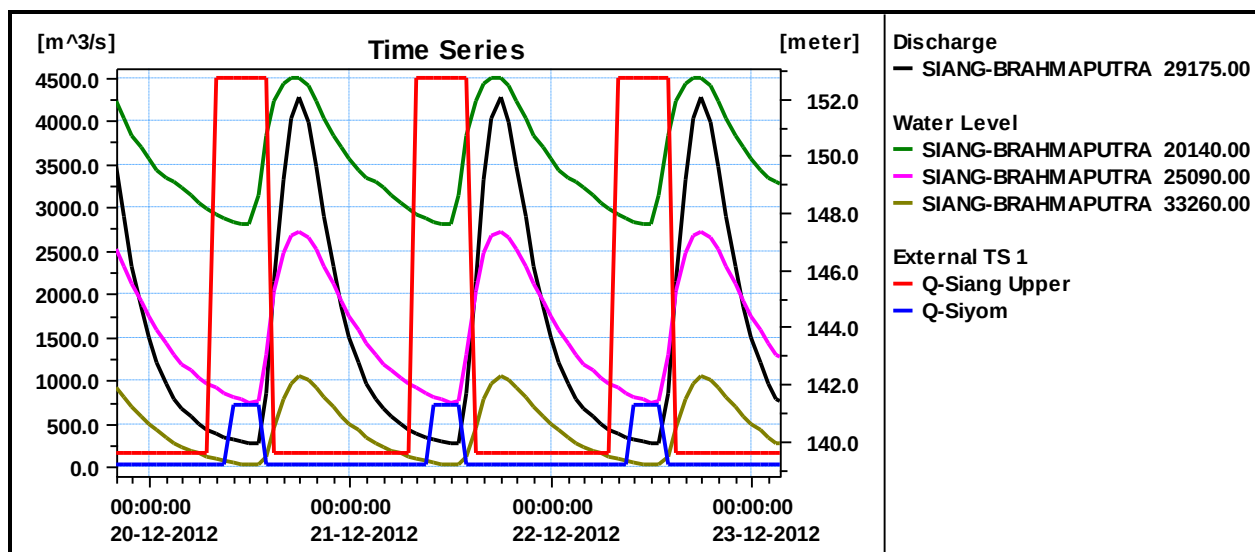


Figure 10.12: Plot of release from Siyom, Siang Upper and resulting discharge/water level series at D'Ering Memorial WLS without Siang Lower HE project in place

For 24 hour duration, release from Siang Lower and Siyom Middle HEP along with the stabilized discharge series at D'Ering Memorial WLS is given in Table 10.19. The corresponding stabilized water level pattern is given in Table 10.20. From Table 10.19 it can be seen that variation in discharge in Siang river during 24 hour at D'Ering Memorial WLS is from 244 cumec to about 4344 cumec with discharge of about 4000 cumec and above sustaining for about 3 hours. The consequent fluctuation in water level at ch 20140 m of Siang river near D'Ering Memorial WLS is from EL 147.60 m to 152.75 m. The same at ch 25090 m and ch 33260 m is from EL 141.35 m to 147.36 m and EL 139.15 m to 142.25 m respectively.

Table 10.19: Release from Siang Upper and Siyom Middle HE Projects along with stablised flow pattern at D'Ering Wildlife sanctuary without Siang Lower HE project in place

Time	Lean season release from Siang Upper HE projects	Lean season release from Siyom Middle HE Project	Stabilized discharge series of Siang river at D'Ering Memorial WLS (starting segment)	Stabilized discharge series of Siang river at D'Ering Memorial WLS (Middle segment)	Stabilized discharge series of Siang river at D'Ering Memorial WLS (End segment)
[hr]	[cumec]	[cumec]	[cumec]	[cumec]	[cumec]
1	171.13	20.78	243.70	248.39	268.36
2	171.13	20.78	266.78	421.06	285.36
3	171.13	20.78	851.46	1786.74	846.98
4	171.13	20.78	2427.30	3099.24	2144.37
5	171.13	20.78	3593.56	3914.63	3317.56
6	171.13	20.78	4123.70	4275.82	4027.93
7	171.13	20.78	4343.70	4229.67	4272.77
8	171.13	20.78	4125.87	3723.47	3989.68
9	4500.00	20.78	3484.26	3149.50	3464.67
10	4500.00	20.78	2840.34	2529.24	2895.98
11	4500.00	709.10	2238.66	1985.95	2312.80
12	4500.00	709.10	1781.05	1583.14	1851.67
13	4500.00	709.10	1440.24	1262.26	1498.61
14	4500.00	709.10	1152.57	989.43	1202.47
15	4500.00	20.78	910.57	783.46	962.49

16	171.13	20.78	735.56	644.02	784.28
17	171.13	20.78	613.91	567.52	663.25
18	171.13	20.78	520.66	488.75	579.92
19	171.13	20.78	436.43	417.02	501.86
20	171.13	20.78	385.95	370.12	439.02
21	171.13	20.78	346.25	332.68	389.68
22	171.13	20.78	313.65	301.16	350.18
23	171.13	20.78	284.99	273.79	316.82
24	171.13	20.78	260.38	251.91	288.49

Table 10.20: Water level pattern of Siang river at different locations along D'Ering Memorial Wildlife sanctuary

Time	Stabilized water level pattern at ch 20140 m of Siang river near D'Ering Memorial WLS with river bed level at EL 145.67 m	Stabilized water level pattern at ch 25090 m of Siang river near D'Ering Memorial WLS with river bed level at EL 138.19 m	Stabilized water level pattern at ch 33260 m of Siang river near D'Ering Memorial WLS with river bed level at EL 137.66 m
[hr]	[cumec]	[cumec]	[cumec]
1	147.60	141.35	139.15
2	147.61	141.43	139.43
3	148.64	143.01	140.46
4	150.67	145.27	141.47
5	151.91	146.61	142.04
6	152.53	147.23	142.25
7	152.75	147.36	142.17
8	152.73	147.13	141.90
9	152.42	146.70	141.55
10	151.92	146.14	141.19
11	151.31	145.51	140.85
12	150.73	144.92	140.59
13	150.27	144.38	140.36
14	149.87	143.87	140.15
15	149.52	143.41	139.95
16	149.25	143.02	139.79
17	149.07	142.71	139.67
18	148.88	142.47	139.56
19	148.58	142.23	139.46
20	148.31	142.02	139.38
21	148.12	141.84	139.31
22	147.96	141.69	139.25
23	147.82	141.56	139.21
24	147.70	141.44	139.17

10.8.2 Flow simulation results at Brahmaputra river near Dibrugarh for peaking release from Siang Upper and Siyom Middle HE Projects without Siang Lower HE Project in place

The plot of release from Siyom, Siang Lower HE Projects and resulting discharge/ water level series in Brahmaputra near Dibrugarh as obtained from MIKE11 simulation is shown in **Figure 10.13**. The dates given on X-axis of the plot are the arbitrary dates used for hydro dynamic simulation. In the plot Q-

Siang Lower represents the release from Siang Lower HEP while Q-Siyom represents release from Siyom Middle HEP. Discharge SIANG-BRAHMAPUTRA 977794.16 represents the resulting discharge series in Brahmaputra river near Dibrugarh, while water level SIANG-BRAHMAPUTRA 102020.00 represents consequent water level series in Brahmaputra near Dibrugarh.

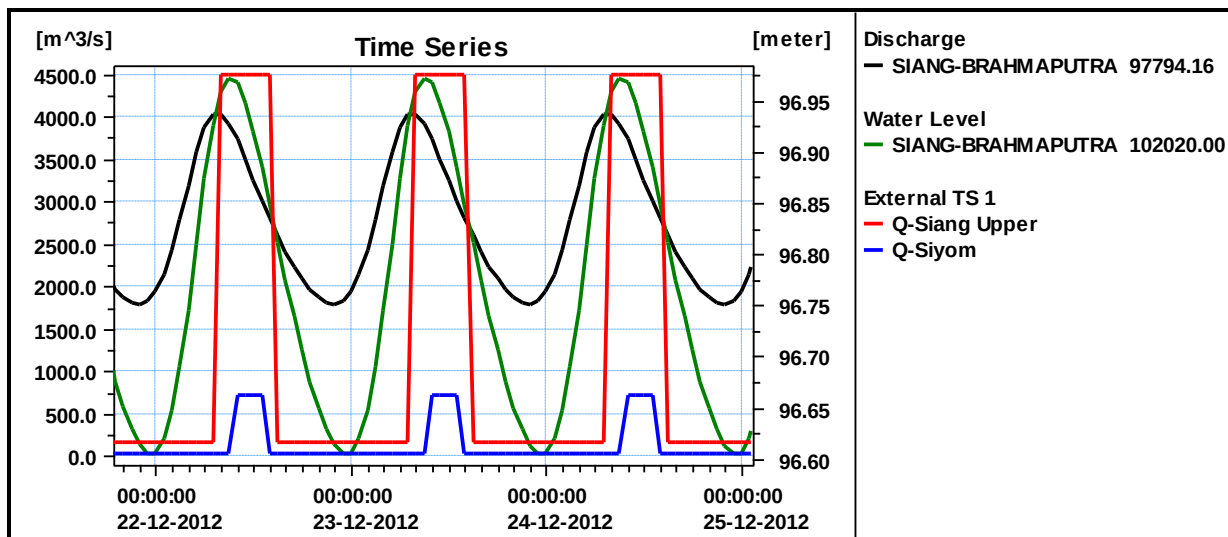


Figure 10.13: Plot of release from Siyom Middle, Siang Upper and resulting discharge/water level series in Brahmaputra near Dibrugarh without Siang Lower HE project in place

For 24 hour duration, release from Siang Lower and Siyom Middle HE Projects and resulting discharge/water level series in Brahmaputra near Dibrugarh is given in Table 10.21. From Table 10.21, it can be seen that the simulated discharge series near Dibrugarh varies from 1791 cumec to 4025 cumec, while fluctuation in daily water level series is from EL 96.6m to 96.97m, about 37cm. The average Lean season discharge and corresponding water level at Dibrugarh is natural condition of river as obtained by MIKE11 simulation is about 2641 cumec and 96.68 m respectively. Due to peaking release from projects in Siang basin the change in discharge and water level pattern in Brahmaputra near Dibrugarh is about 900-1400 cumec and 8cm to 30cm respectively in comparison to natural condition of river.

Table 10.21: Release from Siang Upper and Siyom Middle HE Projects without Siang Lower HE project in place and resulting discharge/water level series in Brahmaputra near Dibrugarh

Time	Lean season release from Siang Upper HE projects	Lean season release from Siyom Middle HE Project	Stabilized discharge series in Brahmaputra river near Dibrugarh	Stabilized water level series in Brahmaputra river near Dibrugarh with river bed level at EL 92.38 m
[hr]	[cumec]	[cumec]	[cumec]	[m]
1	171.13	20.78	1790.91	96.60
2	171.13	20.78	1819.29	96.61
3	171.13	20.78	1931.61	96.62
4	171.13	20.78	2137.84	96.65
5	171.13	20.78	2425.05	96.69
6	171.13	20.78	2773.59	96.74
7	171.13	20.78	3185.48	96.81
8	171.13	20.78	3587.26	96.87
9	4500.00	20.78	3876.61	96.93
10	4500.00	20.78	4021.67	96.96
11	4500.00	709.10	4025.40	96.97
12	4500.00	709.10	3916.39	96.97
13	4500.00	709.10	3728.04	96.95

14	4500.00	709.10	3500.61	96.92
15	4500.00	20.78	3255.60	96.88
16	171.13	20.78	3012.50	96.85
17	171.13	20.78	2803.64	96.81
18	171.13	20.78	2600.04	96.77
19	171.13	20.78	2408.73	96.74
20	171.13	20.78	2235.34	96.71
21	171.13	20.78	2088.32	96.68
22	171.13	20.78	1967.48	96.65
23	171.13	20.78	1873.12	96.63
24	171.13	20.78	1810.77	96.61

10.8.3 Flow simulation results at Brahmaputra river near Bokaghat (Kaziranga National Park) for peaking release from Siang Upper and Siyom Middle HE Projects without Siang Lower HE Project in place

The plot of release from Siyom and Siang Lower HE Projects and resulting discharge /water level series in Brahmaputra river near Bokaghat (Kaziranga National Park) as obtained from MIKE11 simulation is shown in **Figure 10.14**. In the plot, Q-Siang-Lower represents the release from Siang Lower HEP while Q-Siyom represents release from Siyom Middle HEP. Discharge SIANG-BRAHMAPUTRA 264668.34 represents the resulting discharge series in Brahmaputra near Bokaghat, while water level SIANG-BRAHMAPUTRA 269280.00 represents consequent water level series in Brahmaputra near Bokaghat.

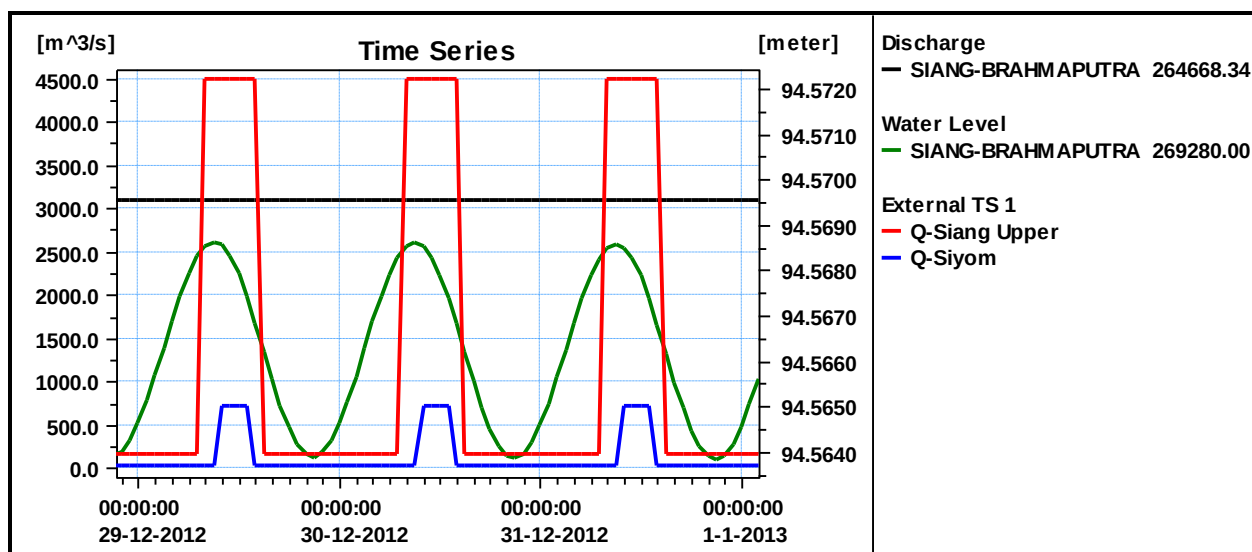


Figure 10.14: Plot of release from Siyom Middle, Siang Upper and resulting discharge/water level series in Brahmaputra near Bokaghat (Kaziranga) without Siang Lower HE project in place

For 24 hour duration, release from Siang Lower and Siyom Middle HEP and resulting discharge/water level series in Brahmaputra near Bokaghat (Kaziranga National Park) is given in **Table 10.22**. From **Table 10.22**, it can be seen that the simulated discharge series near Bokaghat varies from 3089 cumec to 3098 cumec, while fluctuation in daily water level series is from EL 94.56 m to 94.57 m, about 1 cm only. This may be noted that the average Lean season discharge and corresponding water level at Bokaghat in natural condition of river is about 2951 cumec and 94.46 m respectively. Due to peaking release from projects in Siang basin the change in discharge and water level pattern at Bokaghat is about 150 cumec and 10 cm on higher side respectively, in comparison to natural condition of river.

Table 10.22: Release from Siang Upper and Siyom Middle HE Projects without Siang Lower HE project in place and resulting discharge/water level series in Brahmaputra near Bokaghat

Time	Lean season release from Siang Upper HE projects	Lean season release from Siyom Middle HE Project	Stabilized discharge series in Brahmaputra river near Bokaghat	Stabilized water level series in Brahmaputra river near Bokaghat with river bed level at EL 86.77 m
[hr]	[cumec]	[cumec]	[cumec]	[m]
1	171.13	20.78	3088.90	94.56
2	171.13	20.78	3089.01	94.56
3	171.13	20.78	3089.42	94.56
4	171.13	20.78	3090.10	94.56
5	171.13	20.78	3091.00	94.56
6	171.13	20.78	3092.06	94.56
7	171.13	20.78	3093.21	94.56
8	171.13	20.78	3094.37	94.56
9	4500.00	20.78	3095.48	94.57
10	4500.00	20.78	3096.46	94.57
11	4500.00	709.10	3097.25	94.57
12	4500.00	709.10	3097.80	94.57
13	4500.00	709.10	3098.07	94.57
14	4500.00	709.10	3098.04	94.57
15	4500.00	20.78	3097.69	94.57
16	171.13	20.78	3097.05	94.57
17	171.13	20.78	3096.15	94.57
18	171.13	20.78	3095.06	94.57
19	171.13	20.78	3093.84	94.57
20	171.13	20.78	3092.60	94.57
21	171.13	20.78	3091.42	94.57
22	171.13	20.78	3090.39	94.57
23	171.13	20.78	3089.59	94.57
24	171.13	20.78	3089.07	94.57

10.8.4 Flow simulation results at Brahmaputra river near Tezpur for peaking release from Siang Lower and Siyom Middle HE Projects without Siang Upper HE projects in place

The plot of release from Siyom and Siang Lower HE Projects and resulting discharge /water level series in Brahmaputra river near Tezpur as obtained from MIKE11 simulation is shown in **Figure 10.15**. In the plot, Q-Siang-Lower represents the release from Siang Lower HEP while Q-Siyom represents release from Siyom Middle HEP. Discharge SIANG-BRAHMAPUTRA 351635.00 represents the resulting discharge series in Brahmaputra near Tezpur, while water level SIANG-BRAHMAPUTRA 355460.00 represents consequent water level series in Brahmaputra near Tezpur.

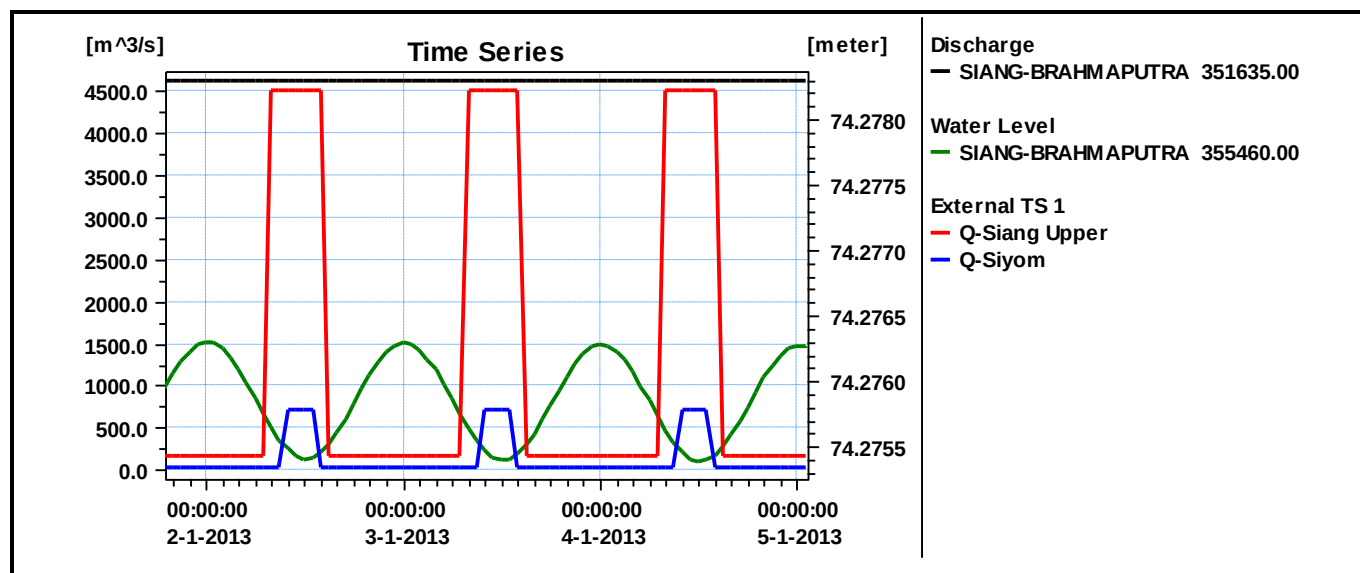


Figure 10.15: Plot of release from Siyom Middle, Siang Upper and resulting discharge/water level series in Brahmaputra near Tezpur without Siang Lower HE project in place

For 24 hour duration, release from Siang Lower and Siyom Middle HEP and resulting discharge/water level series in Brahmaputra near Tezpur is given in Table 10.23. From Table 10.23, it can be seen that the simulated discharge series near Tezpur varies from 4616 cumec to 4618 cumec, while daily water level remains almost constant at EL 74.28m. The average Lean season discharge and corresponding water level at Tezpur in natural condition of river as obtained by MIKE11 simulation is about 4475 cumec and 74.21 m respectively. Due to peaking release from projects in Siang basin the change in discharge and water level pattern at Tezpur is about 60 cumec and 7 cm on higher side respectively in comparison to natural condition of river.

Table 10.23: Release from Siang Upper and Siyom Middle HE Projects without Siang Lower HE project in place and resulting discharge/water level series in Brahmaputra near Tezpur

Time	Lean season release from Siang Upper HE projects	Lean season release from Siyom Middle HE Project	Stabilized discharge series in Brahmaputra river near Tezpur	Stabilized water level series in Brahmaputra river near Tezpur with river bed level at EL 67.22 m
[hr]	[cumec]	[cumec]	[cumec]	[m]
1	171.13	20.78	4616.43	74.28
2	171.13	20.78	4616.49	74.28
3	171.13	20.78	4616.61	74.28
4	171.13	20.78	4616.79	74.28
5	171.13	20.78	4617.02	74.28
6	171.13	20.78	4617.28	74.28
7	171.13	20.78	4617.55	74.28
8	171.13	20.78	4617.81	74.28
9	4500.00	20.78	4618.05	74.28
10	4500.00	20.78	4618.25	74.28
11	4500.00	709.10	4618.40	74.28
12	4500.00	709.10	4618.48	74.28
13	4500.00	709.10	4618.49	74.28
14	4500.00	709.10	4618.42	74.28
15	4500.00	20.78	4618.30	74.28
16	171.13	20.78	4618.11	74.28
17	171.13	20.78	4617.88	74.28

18	171.13	20.78	4617.62	74.28
19	171.13	20.78	4617.35	74.28
20	171.13	20.78	4617.09	74.28
21	171.13	20.78	4616.85	74.28
22	171.13	20.78	4616.65	74.28
23	171.13	20.78	4616.50	74.28
24	171.13	20.78	4616.42	74.28

10.8.5 Flow simulation results at Brahmaputra river near Guwahati for peaking release from Siang Upper and Siyom Middle HE Projects without Siang Lower HE Project in place

The plot of release from Siyom and Siang Lower HE Projects and resulting discharge /water level series in Brahmaputra river near Guwahati as obtained from MIKE11 simulation is shown in **Figure 10.16**. In the plot, Q-Siang-Lower represents the release from Siang Lower HEP while Q-Siyom represents release from Siyom Middle HEP. Discharge SIANG-BRAHMAPUTRA 458625.50 represents the resulting discharge series in Brahmaputra near Guwahati while water level SIANG-BRAHMAPUTRA 462580.00 represents consequent water level series in Brahmaputra near Guwahati.

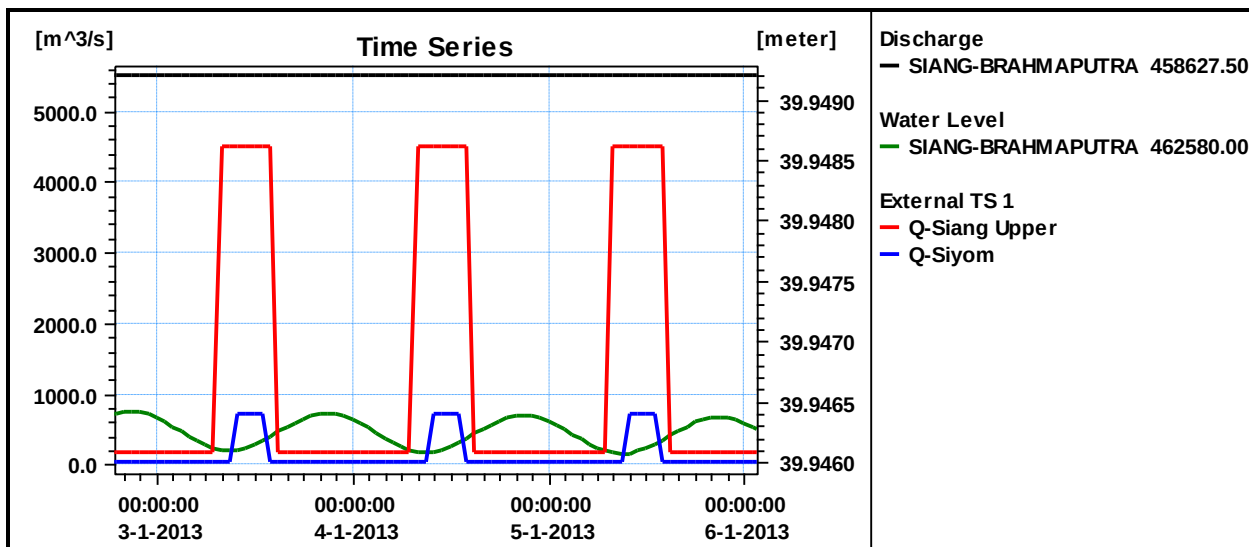


Figure 10.16: Plot of release from Siyom Middle, Siang Upper and resulting discharge/water level series in Brahmaputra near Guwahati without Siang Lower project in place

For 24 hour duration, release from Siang Lower and Siyom Middle HEP and resulting discharge/water level series in Brahmaputra near Guwahati is given in **Table 10.24**. From **Table 10.24**, it can be seen that the simulated discharge series near Guwahati is constant at about 5519 cumec. The daily water level series is also constant at EL 39.95m. The average Lean season discharge and corresponding water level in Brahmaputra near Guwahati in natural condition of river as obtained by MIKE11 simulation is about 5377 cumec and 39.89 m, respectively. Due to peaking release from projects in Siang basin the change in discharge and water level pattern at Guwahati is about 140 cumec and 6 cm on higher side respectively in comparison to natural condition of river.

Table 10.24: Release from Siang Upper and Siyom Middle HE Projects without Siang Lower HE project in place and resulting discharge/water level series in Brahmaputra near Guwahati

Time	Lean season release from Siang Upper HE projects	Lean season release from Siyom Middle HE Project	Stabilized discharge series in Brahmaputra river near Guwahati	Stabilized water level series in Brahmaputra river near Guwahati with river bed level at EL 30.96 m
[hr]	[cumec]	[cumec]	[cumec]	[m]
1	171.13	20.78	5519.18	39.95
2	171.13	20.78	5519.18	39.95
3	171.13	20.78	5519.20	39.95
4	171.13	20.78	5519.23	39.95
5	171.13	20.78	5519.29	39.95
6	171.13	20.78	5519.35	39.95
7	171.13	20.78	5519.42	39.95
8	171.13	20.78	5519.50	39.95
9	4500.00	20.78	5519.57	39.95
10	4500.00	20.78	5519.64	39.95
11	4500.00	709.10	5519.69	39.95
12	4500.00	709.10	5519.72	39.95
13	4500.00	709.10	5519.74	39.95
14	4500.00	709.10	5519.74	39.95
15	4500.00	20.78	5519.72	39.95
16	171.13	20.78	5519.68	39.95
17	171.13	20.78	5519.63	39.95
18	171.13	20.78	5519.56	39.95
19	171.13	20.78	5519.48	39.95
20	171.13	20.78	5519.41	39.95
21	171.13	20.78	5519.33	39.95
22	171.13	20.78	5519.27	39.95
23	171.13	20.78	5519.21	39.95
24	171.13	20.78	5519.17	39.95

10.9 COMPARISON OF DISCHARGE AND WATER LEVEL PATTERN OF DIFFERENT SIMULATIONS

A comparison of discharge and water level pattern at salient locations for different simulations is given in Table 10.25.

Table 10.25: Comparison of discharge and water level pattern at salient location for different simulations

D'Ering Wildlife Sanctuary located about 25 km d/s of Siang Lower HE Project (River bed EL 138.19 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	1428
Water level in natural condition of river (m)	144.29
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (cumec)	250-5000
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (m)	141.37-147.93
Discharge pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (cumec)	200-5000
Water level pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (m)	140.85-148.05
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (cumec)	248-4276
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (m)	141.35-147.36
Dibrugarh located about 102 km d/s of Siang Lower HE Project (River bed EL 92.68 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	2641

Water level in natural condition of river (m)	96.68
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (cumec)	1615-3338
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (m)	96.31-96.65
Discharge pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (cumec)	1529-4581
Water level pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (m)	96.58-97.07
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (cumec)	1791-4025
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (m)	96.60-96.97
Bokaghat (Kaziranga) located about 269 km d/s of Siang Lower HE Project (River bed EL 86.77 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	2951
Water level in natural condition of river (m)	94.46
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (cumec)	2622-2661
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (m)	94.21-94.23
Discharge pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (cumec)	3097-3147
Water level pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (m)	94.58-94.60
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (cumec)	3088-3098
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (m)	94.56-94.57
Tezpur located about 355 km d/s of Siang Lower HE Project (River bed EL 67.22 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	4475
Water level in natural condition of river (m)	74.21
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (cumec)	4138-4189
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (m)	74.00-74.03
Discharge pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (cumec)	4616-4675
Water level pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (cumec)	74.27-74.30
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (cumec)	4616-4618
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (m)	74.28
Guwahati located about 462 km d/s of Siang Lower HE Project (River bed EL 30.96 m)	
Average Lean season (Nov-Apr) discharge in natural condition of river (cumec)	5377
Water level in natural condition of river (m)	39.89
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (cumec)	5042-5097
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Upper HE projects in place (cumec)	39.69-39.71
Discharge pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (cumec)	5511-5586
Water level pattern due to peaking release from HE Projects in Siang basin with Siang Upper HE projects in place (m)	39.95-39.98
Discharge pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (cumec)	5519
Water level pattern due to peaking release from HE Projects in Siang basin without Siang Lower HE Project in place (m)	39.95

A plot of river cross sections at identified locations along with water level corresponding to different simulations is given at the end of this Chapter.

10.10 CONCLUSIONS

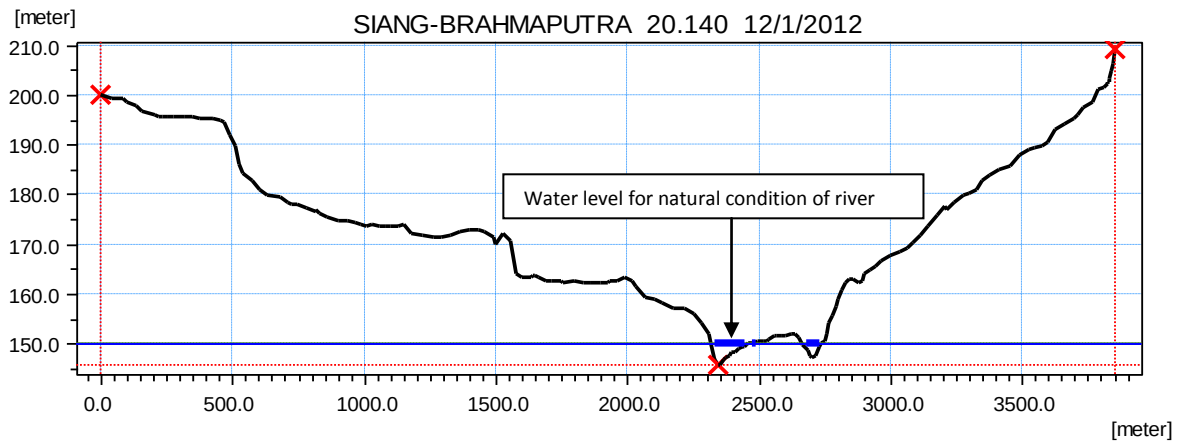
Due to non-availability of data for model calibration the water level estimated at different locations may vary by few centimeters in absolute term. Hence, the results obtained should be considered in terms of fluctuations in water level pattern and relative rise or fall with respect to natural condition only. Error if any in absolute water level estimate at different locations will get nullified when relative rise or fall in water level is considered.

With the above limitations, from the impact study of different simulated conditions, It has been concluded that in general the impact of peaking of hydroelectric projects of Siang basin on Brahmaputra river is almost NIL in terms of discharge and water level fluctuations from Bokaghat up to Guwahati. This is due to very wide reach and large discharge carrying capacity of Brahmaputra river. In this reach of the Brahmaputra river the discharge and water level pattern will be approximately close to the natural condition discharge and water level pattern. In absence of Siang Upper HE projects the Lean season peaking discharge releases of projects in Siang basin ultimately being re-regulated by Siang lower HE Project will result a stabilized discharge/water level series from Bokaghat onward resulting a discharge of about 2600 cumec at Bokaghat with water level about at EL 94.20 m, and a discharge of about 5000 cumec at Guwahati with water level about at EL 39.70 m. The stabilized discharge at Bokaghat with Siang Upper HE projects in place will be of the order of 3300 cumec with water level about at EL 94.5 m, while at Guwahati the same will be about 5700 cumec with water level at EL 40.10 m. For the peaking releases from Siang Upper and Siyom Middle HE Project without Siang Lower HE project in place, the stabilized discharge at Bokaghat will be of the order of 3090 cumec with water level about at EL 94.5 m, while at Guwahati the same will be about 5500 cumec with water level at EL 39.95 m. All the above patterns are approximately same to the natural condition discharge and water level pattern.

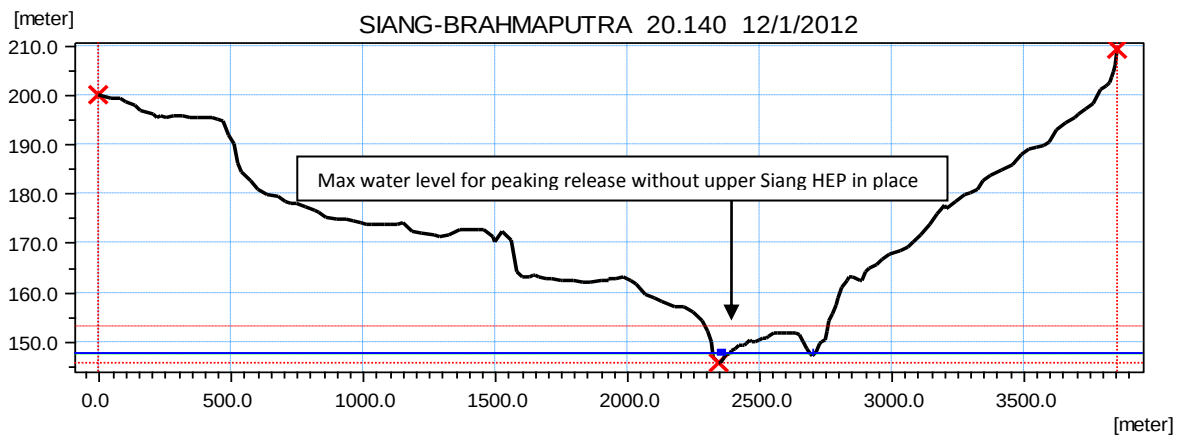
Further, from Siang lower HE Project location at Bodak and up to Dibrugarh there will be daily fluctuations in discharge and water level due to peaking. These fluctuations will be of the order of 250 to 5000 cumec with water level variation from EL 141.46-147.93 m near D'Ering Wildlife sanctuary and 1600-3300 cumec with water level variation from EL 96.31-96.65 m near Dibrugarh, without the upper Siang HE Project in place. The same with Siang Upper HE projects in place will be of the order of 200 to 5000 cumec with water level variation from EL 140.05-148.05 m near D'Ering Memorial WLS and 1530-4580 cumec with water level variation from EL 96.58-97.07 m near Dibrugarh. For the peaking releases from Siang upper and Siyom Middle HE Projects without Siang lower HE Project in place the discharge and water level fluctuations will be of the order of 250 to 4300 cumec with water level variation from EL 141.4-147.4 m near D'Ering Wildlife sanctuary and 1800-4000 cumec with water level variation from EL 96.60-96.97 m near Dibrugarh.

Plot of Cross Sections of Siang/Brahmaputra river at Identified Locations

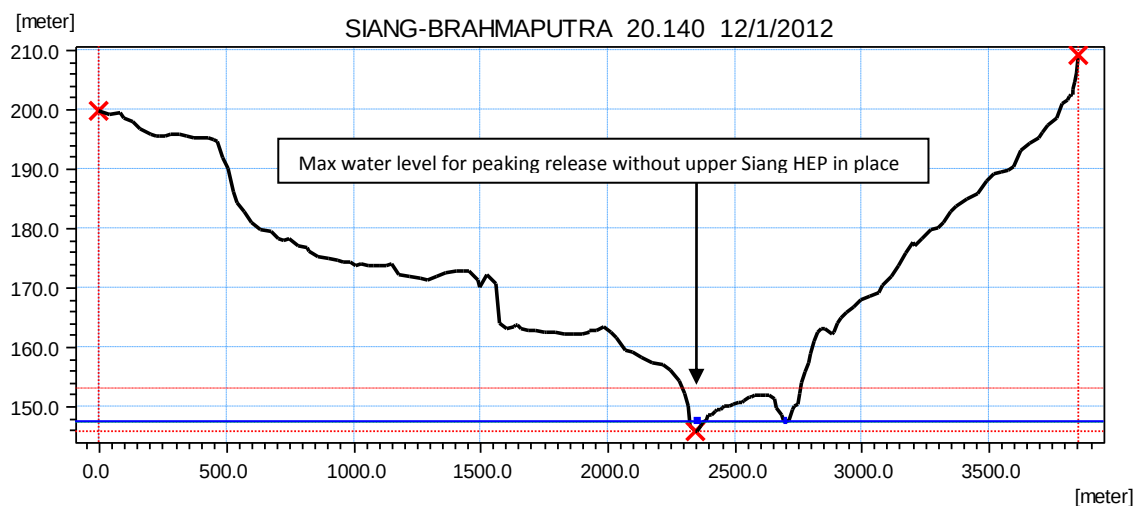
(Note: The dates shown on the plots are not the absolute dates but the arbitrary dates used in model simulation)



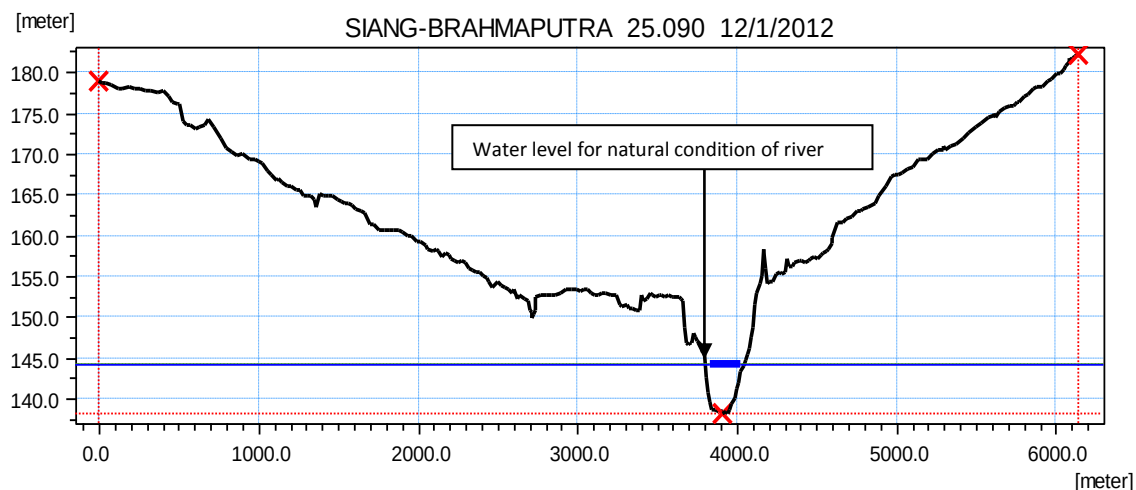
Cross section of Siang river near starting segment of D'Ering WLS showing simulated non-monsoon water level corresponding to natural condition of river



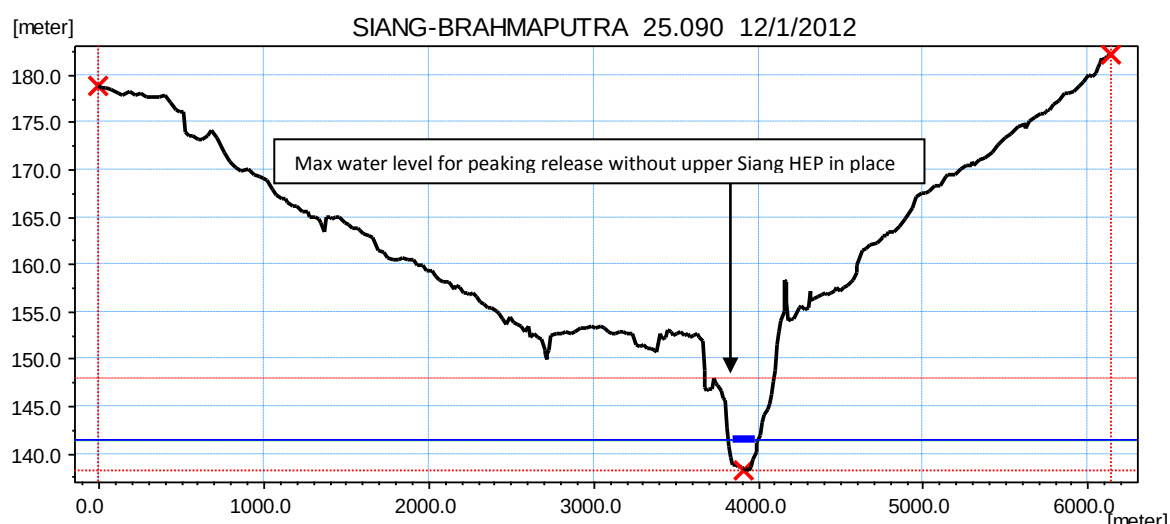
Cross section of Siang river near starting segment of D'Ering WLS showing simulated water level corresponding to peaking release without Siang UpperHE Projects in place



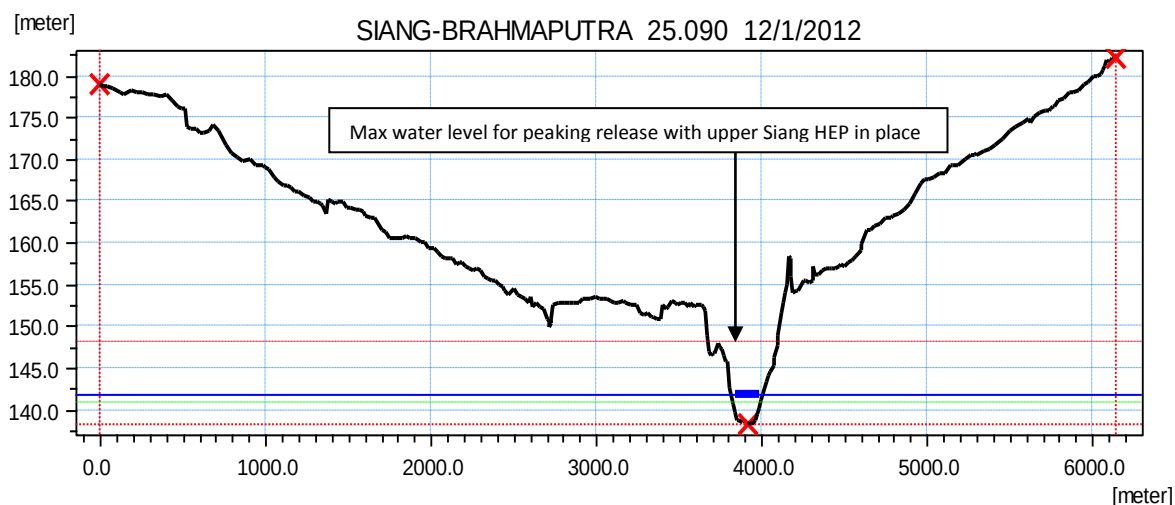
Cross section of Siang river near starting segment of D'Ering WLS showing simulated water level corresponding to peaking release with Siang UpperHE Projects in place



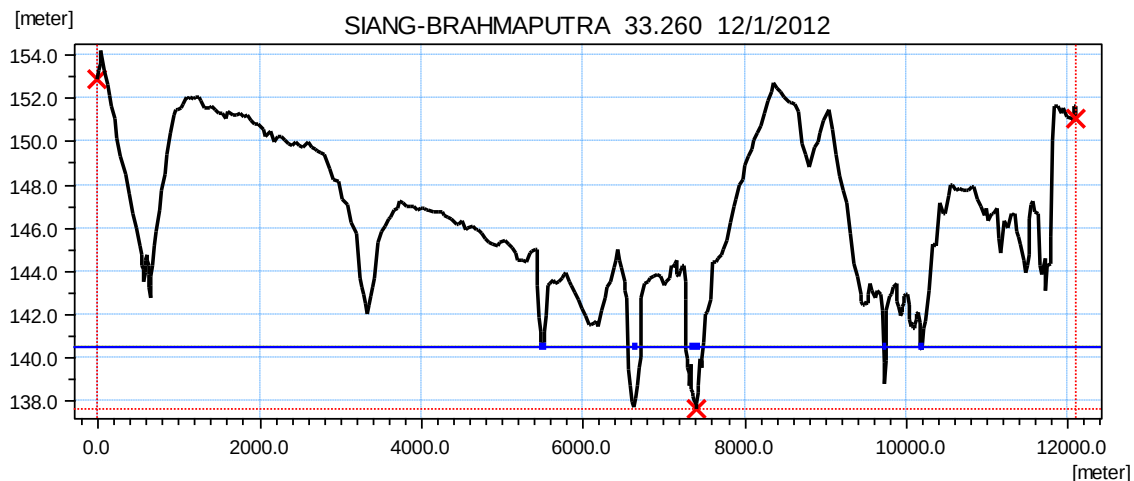
Cross section of Siang river near middle segment of D'Ering WLS showing simulated non-monsoon water level corresponding to natural condition of river



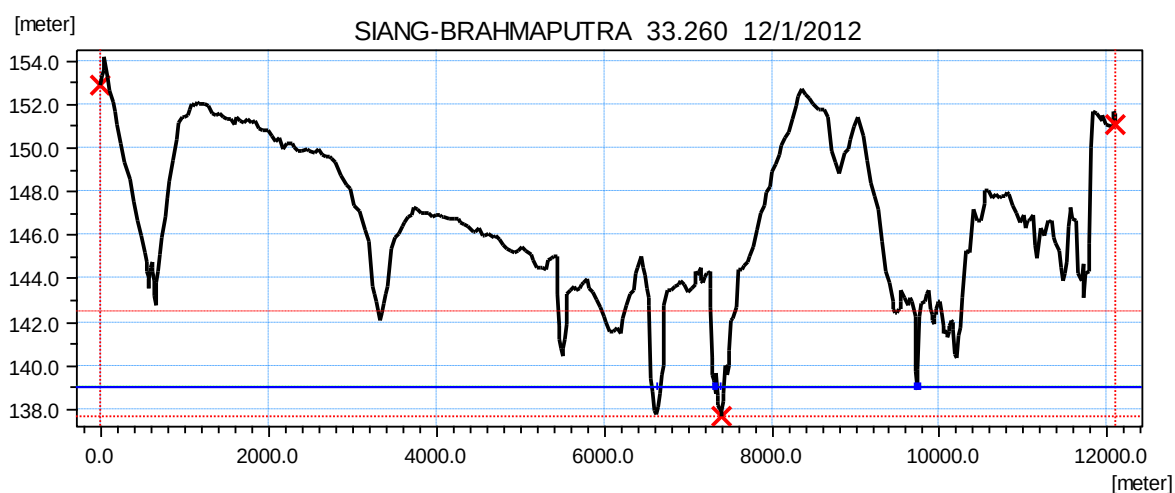
Cross section of Siang river near middle segment of D'Ering WLS showing simulated water level corresponding to peaking release without Siang UpperHEs Project in place



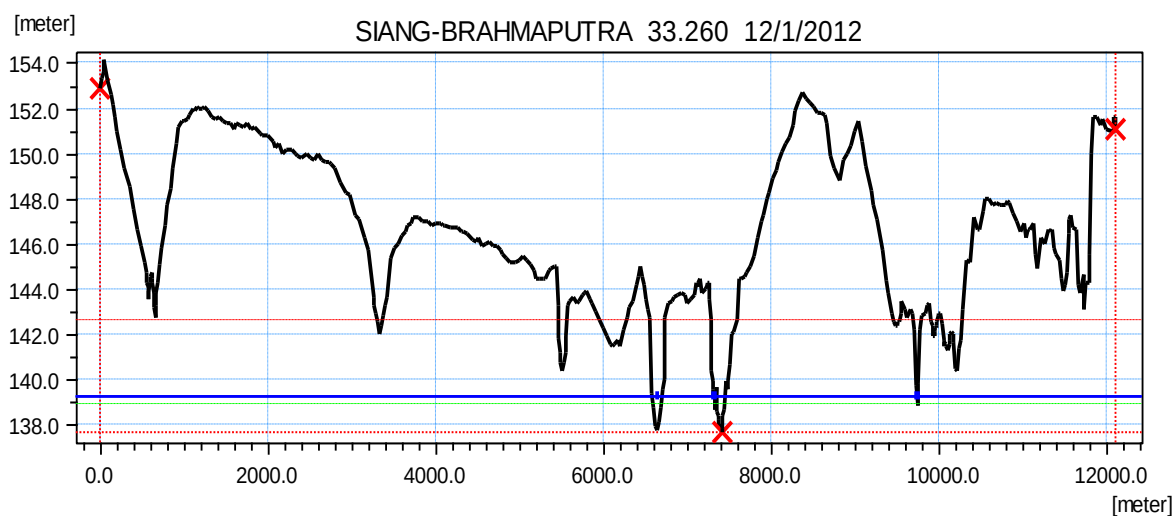
Cross section of Siang river near middle segment of D'Ering WLS showing simulated water level corresponding to peaking release with Siang UpperHEs Project in place



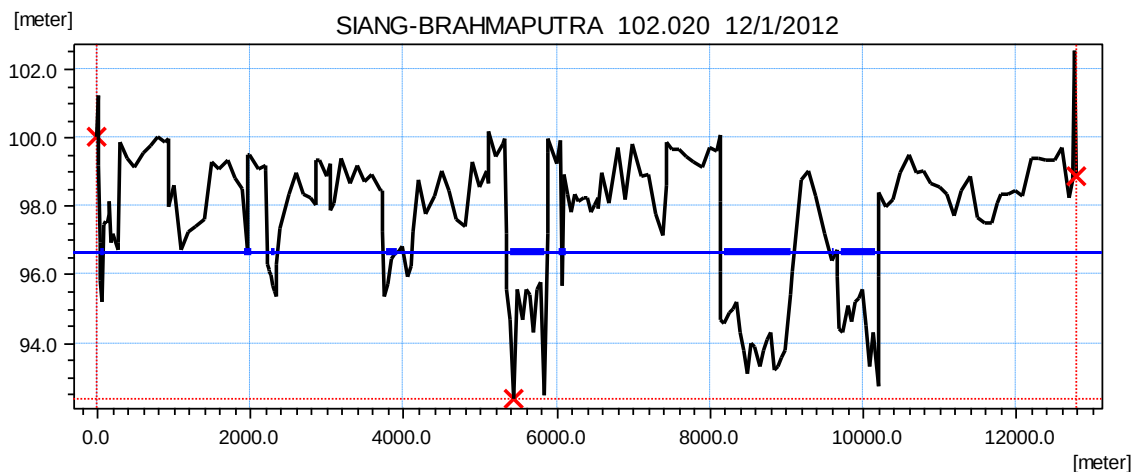
Cross section of Siang river near end segment of D'Ering WLS showing simulated non-monsoon water level corresponding to natural condition of river



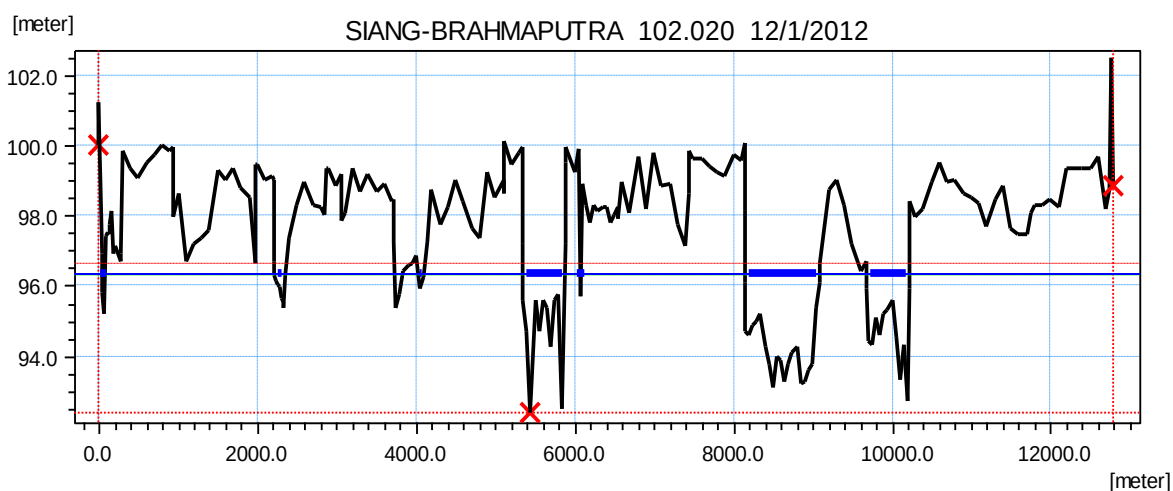
Cross section of Siang river near end segment of D'Ering WLS showing simulated water level corresponding to peaking release without Siang UpperHE Projects in place



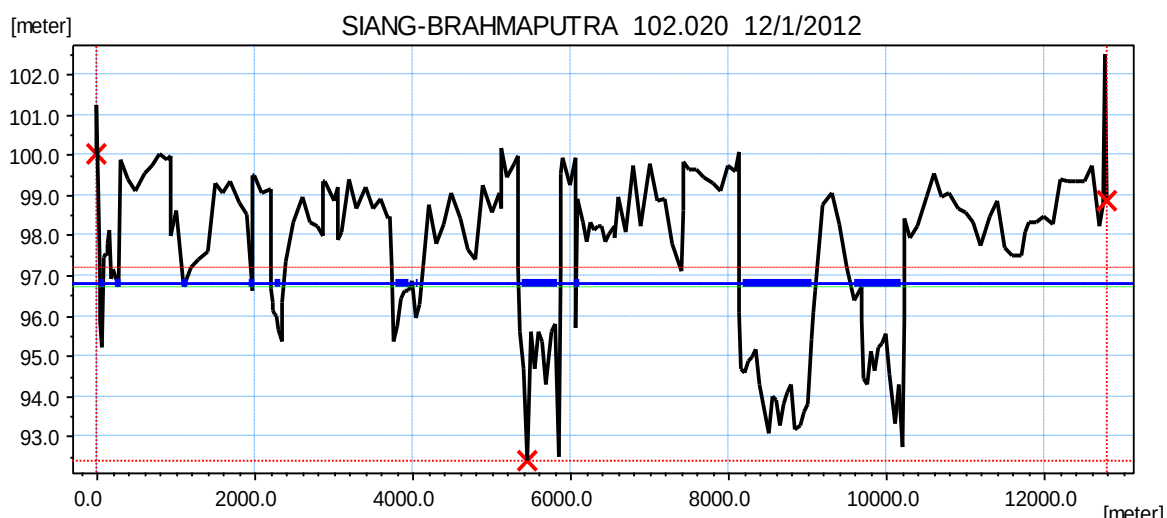
Cross section of Siang river near end segment of D'Ering WLS showing simulated water level corresponding to peaking release with Siang UpperHE Projects in place



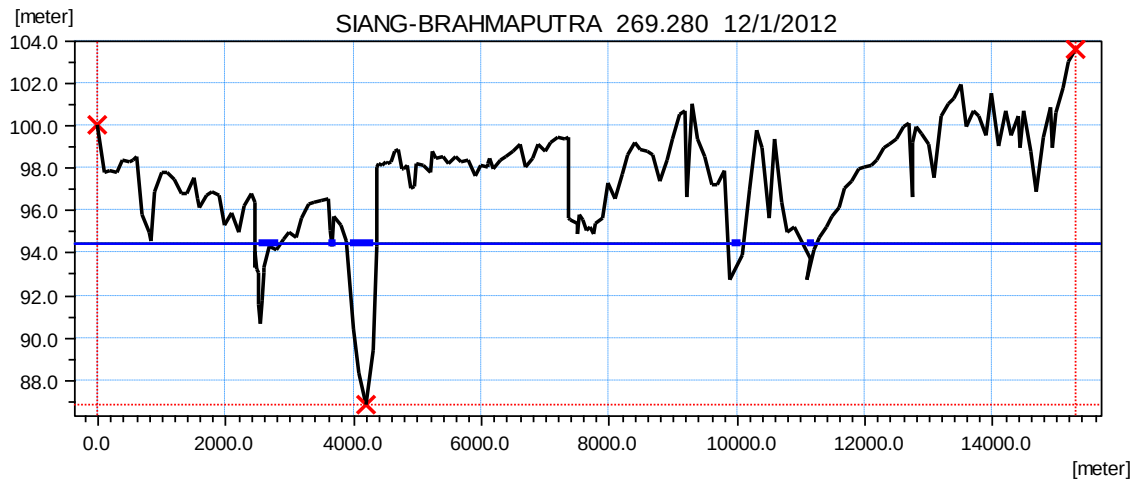
Cross section of Brahmaputra river near Dibrugarh showing simulated non-monsoon water level corresponding to natural condition of river



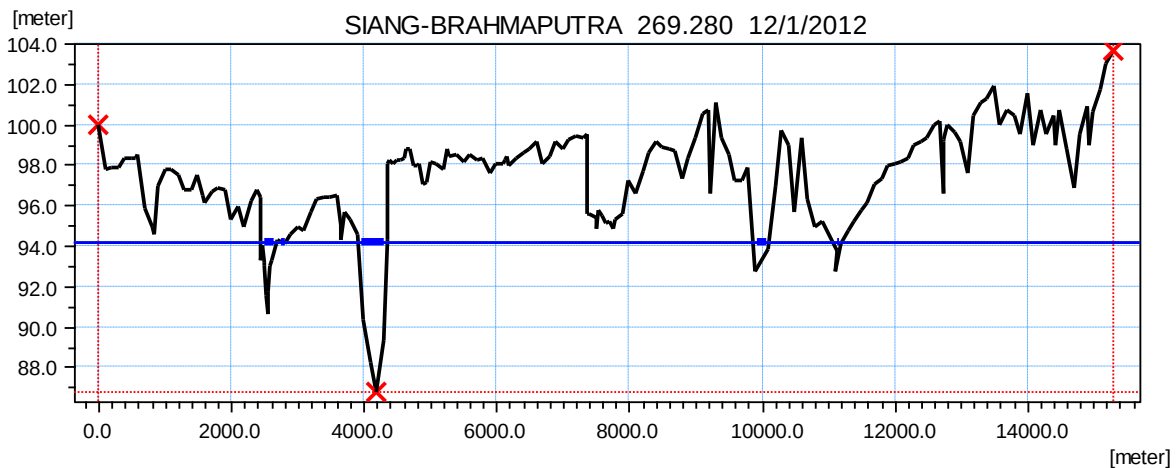
Cross section of Brahmaputra river near Dibrugarh showing simulated water level corresponding to peaking release without Siang Upper HE Projects in place



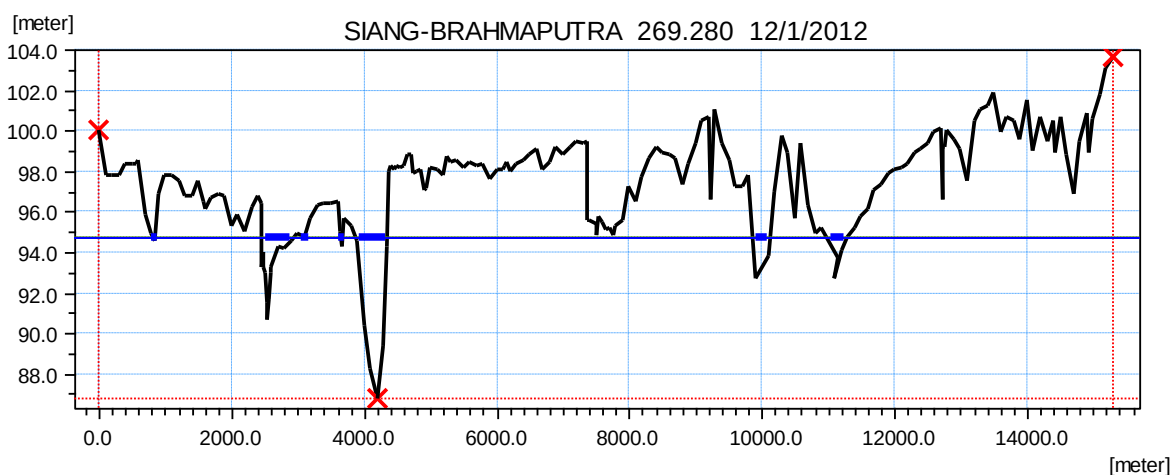
Cross section of Brahmaputra river near Dibrugarh showing simulated water level corresponding to peaking release with Siang Upper HE Projects in place



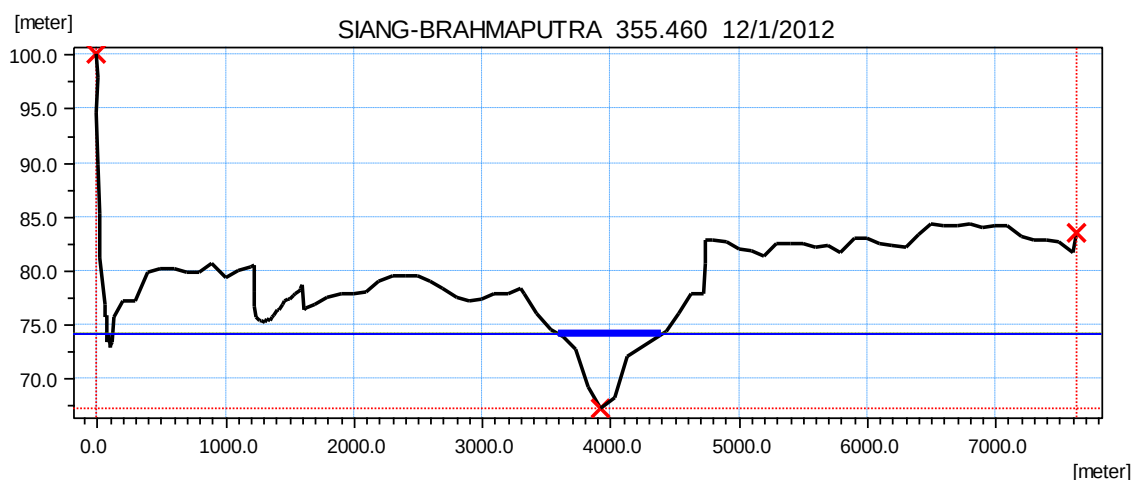
Cross section of Brahmaputra river near Bokaghat (Kaziranga) showing simulated non-monsoon water level corresponding to natural condition of river



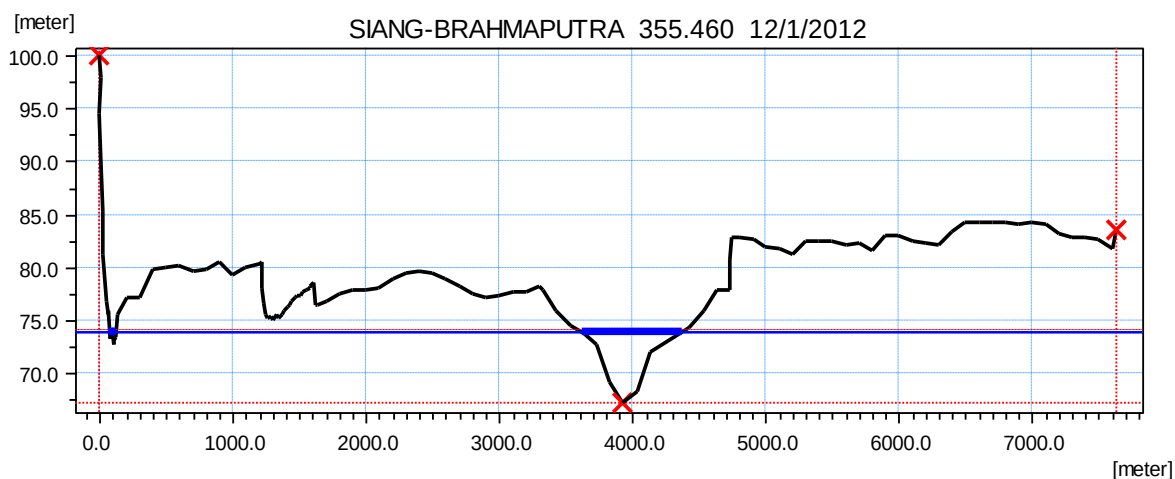
Cross section of Brahmaputra river near Bokaghat (Kaziranga) showing simulated water level corresponding to peaking release without Siang Upper HE Projects in place



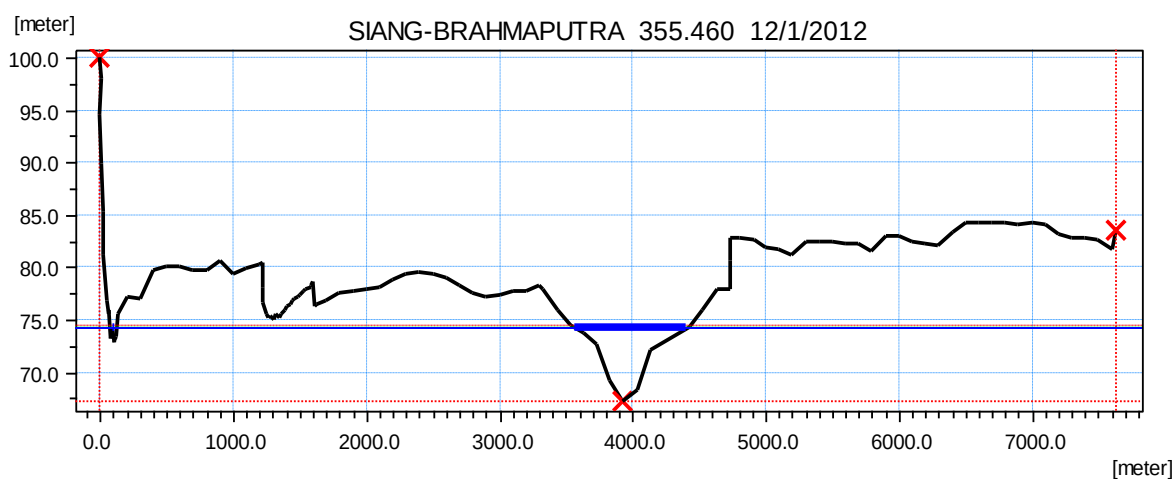
Cross section of Brahmaputra river near Bokaghat (Kaziranga) showing simulated water level corresponding to peaking release with Siang Upper HE Projects in place



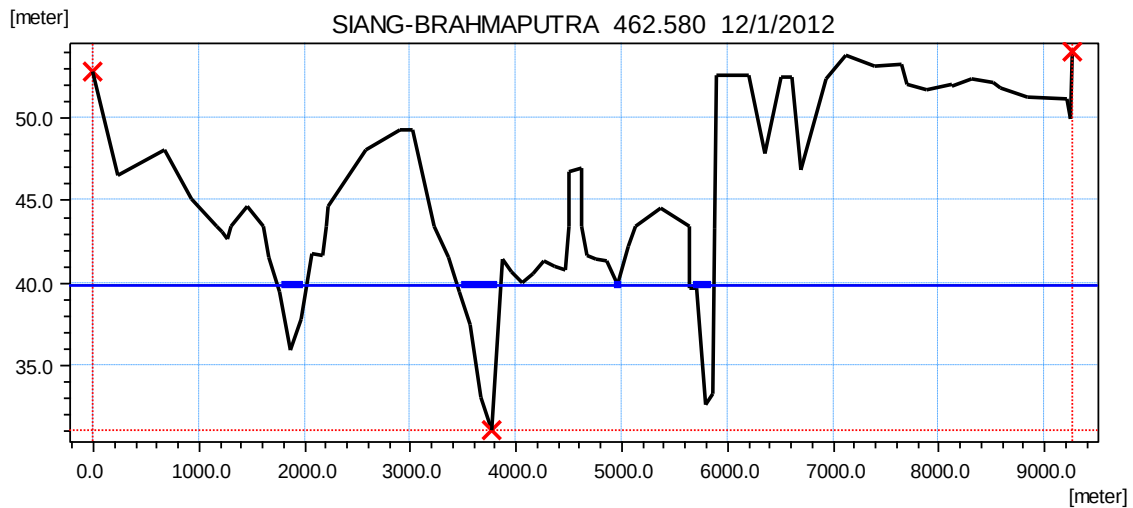
Cross section of Brahmaputra river near Tezpur showing simulated non-monsoon water level corresponding to natural condition of river



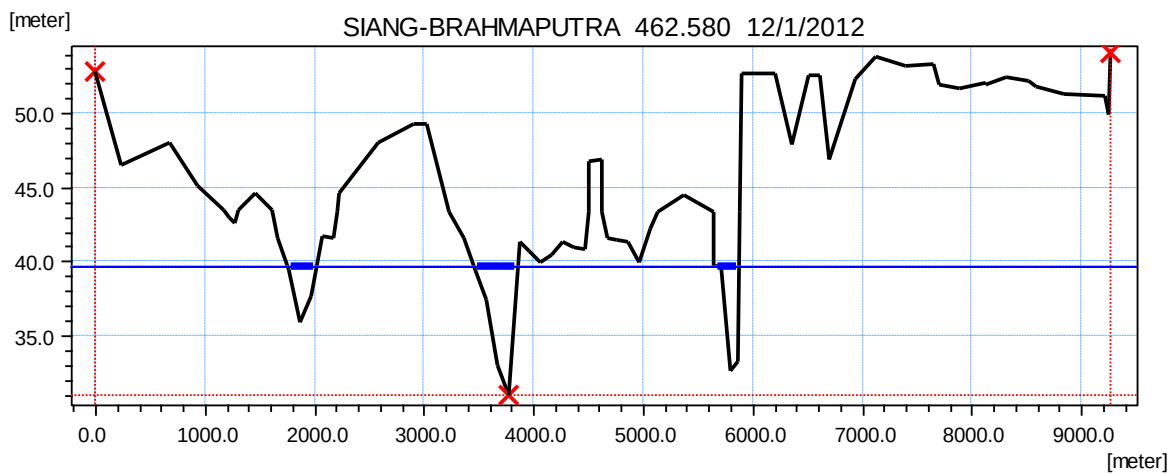
Cross section of Brahmaputra river near Tezpur showing simulated water level corresponding to peaking release without Siang Upper HE Projects in place



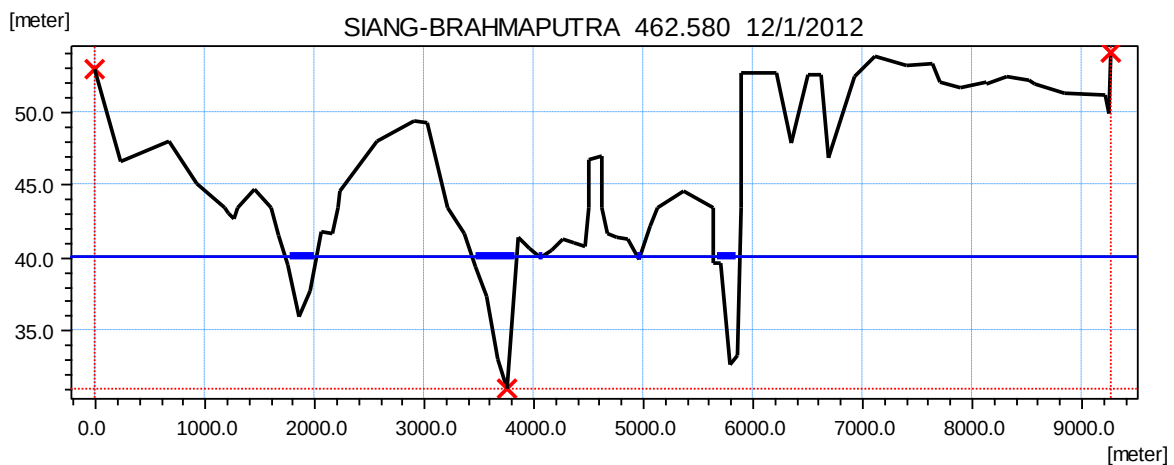
Cross section of Brahmaputra river near Tezpur showing simulated water level corresponding to peaking release with Siang Upper HE Projects in place



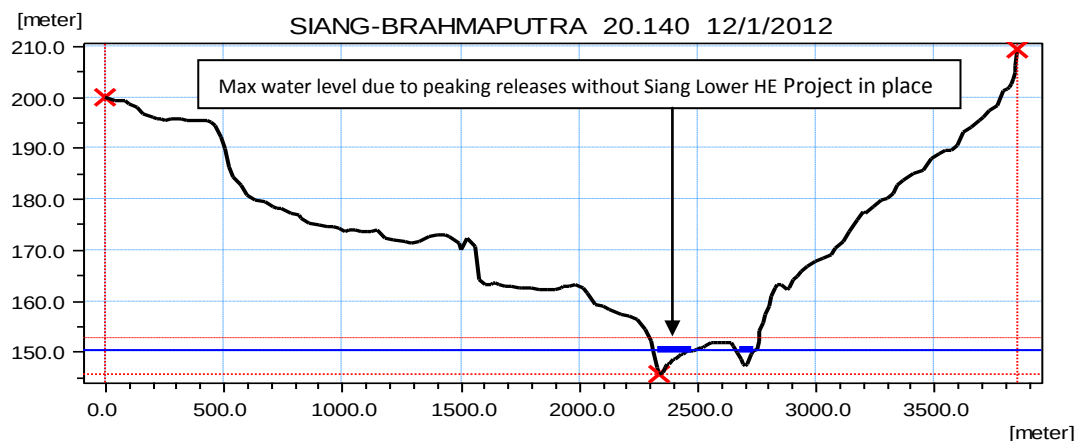
Cross section of Brahmaputra river near Guwahati showing simulated non-monsoon water level corresponding to natural condition of river



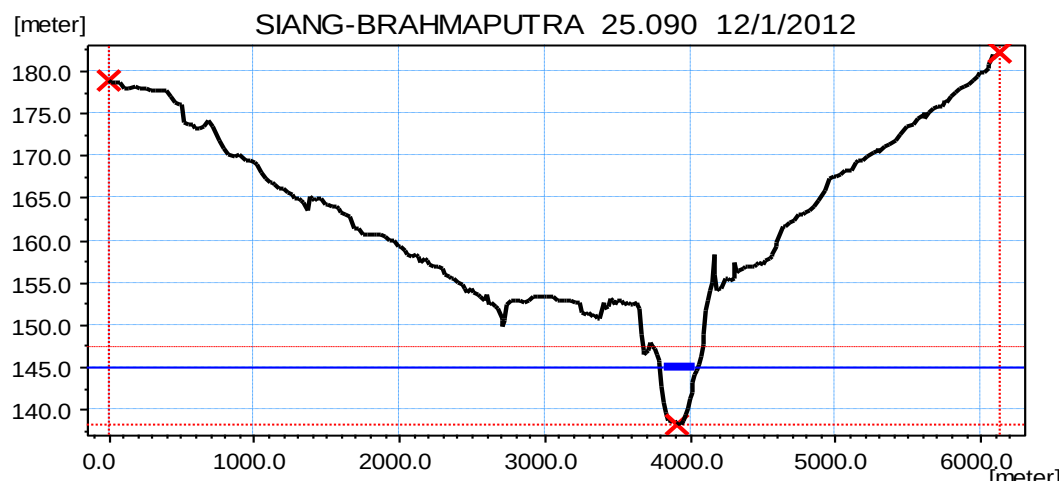
Cross section of Brahmaputra river near Guwahati showing simulated water level corresponding to peaking release without Siang Upper HE Projects in place



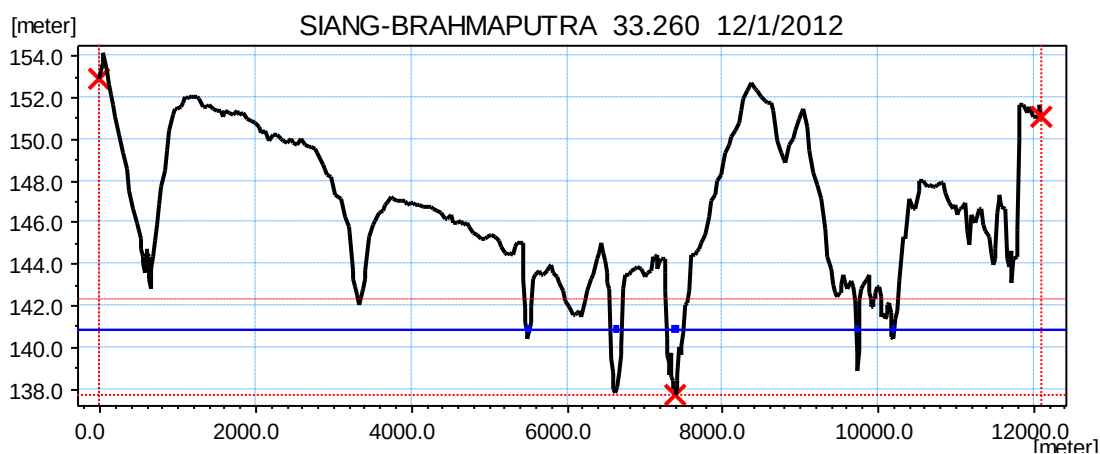
Cross section of Brahmaputra river near Guwahati showing simulated water level corresponding to peaking release with Siang Upper HE Projects in place



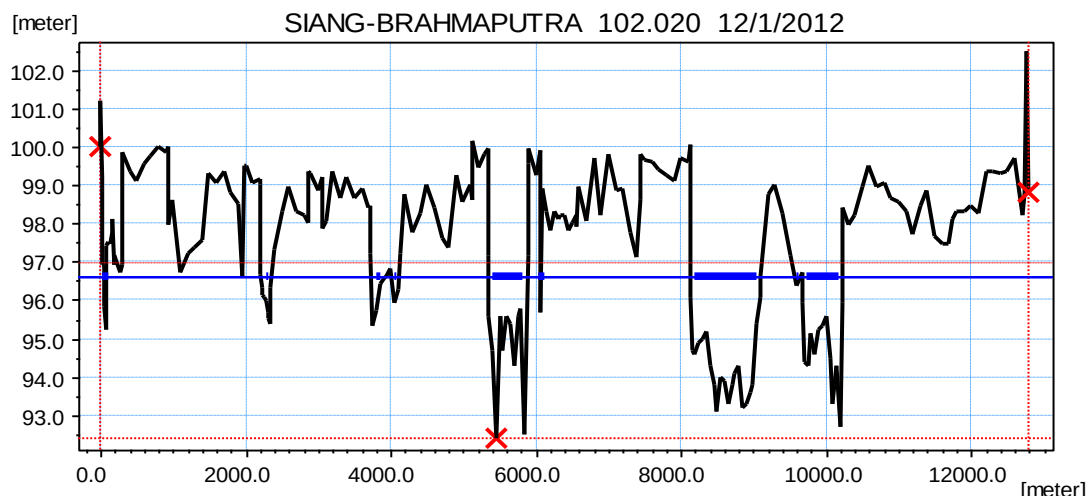
Cross section of Siang river near starting segment of D'Ering WLS showing simulated water level corresponding to peaking release without Siang Lower HE Project in place



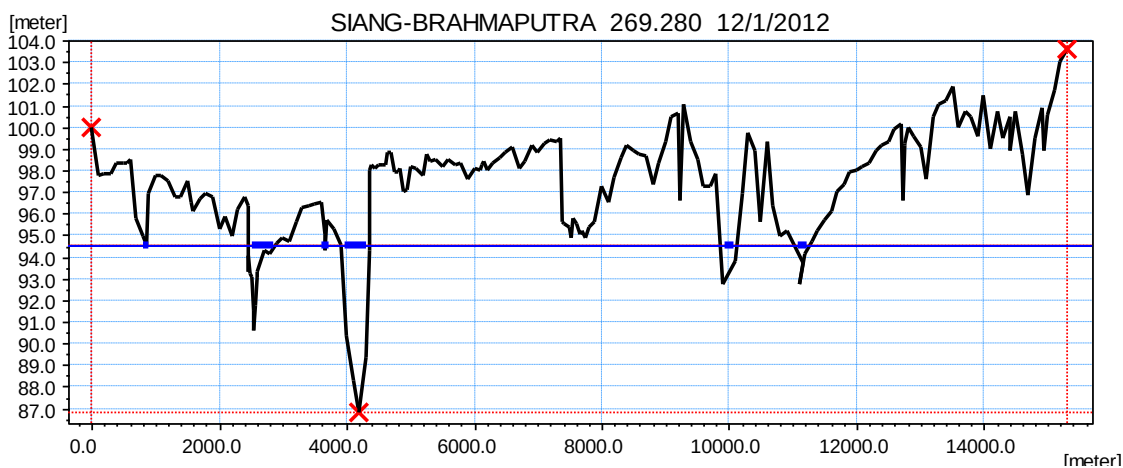
Cross section of Siang river near middle segment of D'Ering WLS showing simulated water level corresponding to peaking release without Siang lower HE Project in place



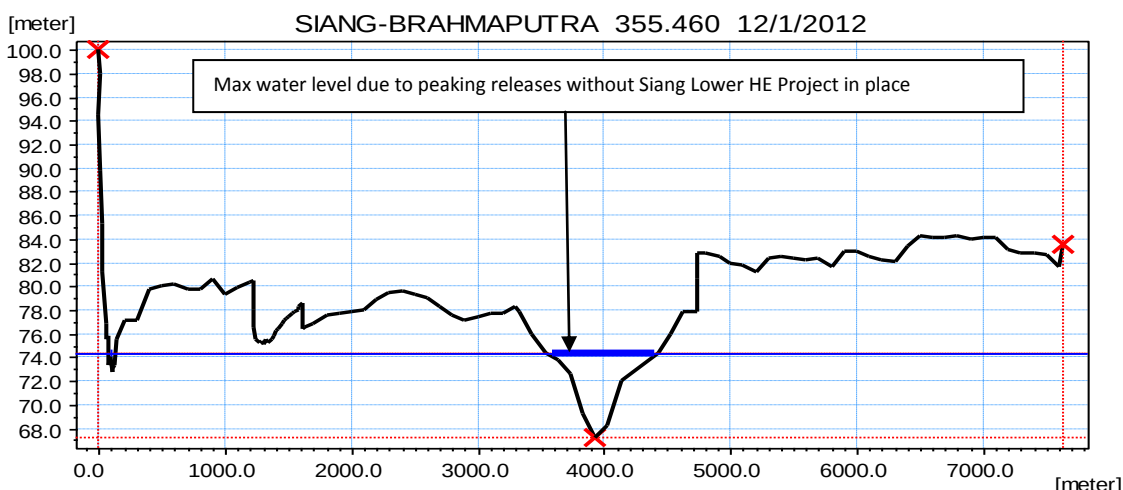
Cross section of Siang river near end segment of D'Ering WLS showing simulated water level corresponding to peaking release without Siang Lower HE Project in place



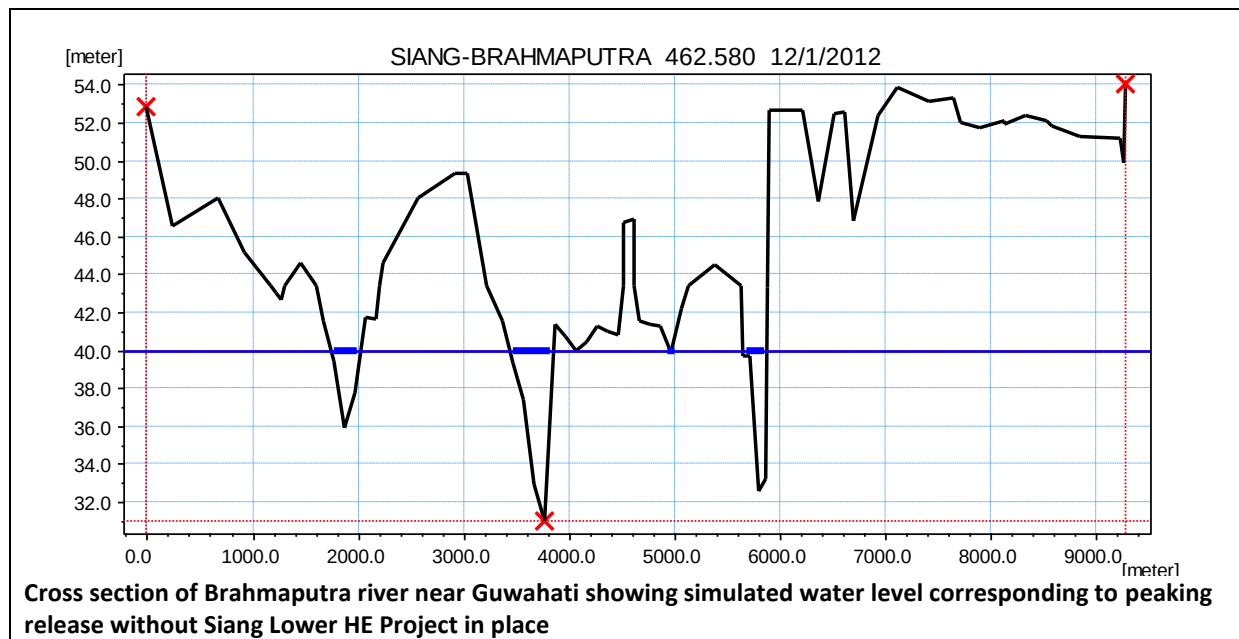
Cross section of Brahmaputra river near Dibrugarh showing simulated water level corresponding to peaking release without Siang Lower HE Project in place



Cross section of Brahmaputra river near Bokaghat (Kaziranga) showing simulated water level corresponding to peaking release without Siang Lower HE Project in place



Cross section of Brahmaputra river near Tezpur showing simulated water level corresponding to peaking release without Siang Lower HE Project in place



CHAPTER-11

CUMULATIVE IMPACT ASSESSMENT

11.1 INTRODUCTION

Cumulative Impact Assessment (CIA) is the analysis of all affects /impacts on an area from one or more activities as they tend to accumulate over time and space. CIA and Carrying Capacity Studies are focused on assessing long term changes in the environmental quality, not only as result of a single action or development, but as the combined effect of many actions over a period of time. Project/site specific Environmental Impact Assessment has its own limitations when it comes to evaluating and assessing the potential cumulative impacts on environmental resources. Each individual development, when assessed for its potential impacts, may produce impacts that are ecologically and socially acceptable, however, when the effects of the numerous individual developments are combined, impacts may become larger, additive, or even new and are therefore significant. The CIA study assesses additive impacts of a group of planned activities and provides optimum support for various natural processes while allowing sustainable development; therefore it is important to go for CIA, as a holistic development approach to be followed by project specific EIAs.

The objective of cumulative environment impact assessment study of Siang basin is to assess stress/ load due to hydropower development in the basin and envisage a broad framework of environmental action plan to mitigate the adverse impacts. Assessment of projects specific environmental impacts is part of the individual projects' EIA studies, where impacts are assessed by establishing site-specific environmental settings through baseline data collection and project development plan. In CIA study of Siang basin, where 44 hydropower projects are planned, focus of impact assessment is towards the broader issues or cumulative impacts of overall development.

Based on the projects data compilation, a summary list has been prepared for all the 44 projects planned in Siang Basin. This list contains information on project capacity, location with respect to river/tributary, total river reach affected by the project either in submergence or in the intermediate stretch where river is bypassed in tunnel and forest area likely to be acquired for the project. Information on forest area required for each project is not available for all the projects, as investigation work has not started for about 20 projects. For such projects, estimation is made based on the size and type of project to get a comprehensive picture and make basin level assessment. Table 11.1 gives river reach and forest area likely to be affected by each project.

11.2 CUMULATIVE IMPACTS ON TERRESTRIAL ECOLOGY

The formation of reservoir by construction of diversion structure results in permanent flooding of riverine and terrestrial habitats, and depending upon the topography and habitats of the river valley upstream from the site of the diversion structure, the impacts can vary greatly in extent and severity. Due to impoundment, all terrestrial animals disappear from the submerged areas and vicinity and animal populations decrease in directly affected area and vicinity within a few years in proportion to the habitat area that is lost (Dynesius and Nilsson, 1994). Flooding can result in not only local but also global extinctions of animal and plant species. Particularly hard hit are the species dependent upon riverine forests, and other riparian ecosystems, and those adapted to the fast-flowing conditions of the main river course. From a biodiversity conservation standpoint, the terrestrial natural habitats lost to flooding are usually much more valuable than the aquatic habitats created by the reservoir (McAllister *et al.*, 1999).

Table 11.1: Forest Area and River Reach to be affected

Sl. No.	Name of Project	Capacity (MW)	Tributary/ Main river	River Length Likely to be Affected (km)			Forest Area Likely to be Affected (ha)	Forest Area to be lost in ha/MW
				Reservoir Length (km)	Intermediate Stretch (km)	Total (km)		
1	Siang Upper Stage-I	6000	Siang	106.90*	0.00	106.90	7000.00	1.17
2	Siang Upper Stage-II	3750	Siang	57.00	0.00	57.00	4750.00	1.27
3	Siang Lower	2700	Siang	108.60**	0.00	108.60	6424.00	2.38
4	Siyom Middle	1000	Siyom	15.80	0.50	16.30	1704.21	1.70
5	Naying	1000	Siyom	7.90	7.60	15.50	644.00	0.64
6	Tato-II	700	Siyom	4.30	3.90	8.20	314.00	0.45
7	Hirong	500	Siyom	3.50	10.30	13.80	493.00	0.99
8	Jarong	90	Siyom	1.60	3.50	5.10	65.00	0.72
9	Taiyong	56	Siyom	1.60	0.90	2.50	40.00	0.71
10	Tato-I	186	Yargyap/Siyom	0.30	5.10	5.40	52.80	0.28
11	Heo	240	Yargyap/Siyom	0.50	5.90	6.40	55.70	0.23
12	Pauk	145	Yargyap/Siyom	0.70	2.80	3.50	91.70	0.63
13	Rapum	66	Yargyap/Siyom	1.10	2.00	3.10	41.00	0.62
14	Rego	80	Yargyap/Siyom	0.00	2.20	2.20	5.00	0.06
15	Kangtangshiri	80	Yargyap/Siyom	5.50	1.50	7.00	37.31	0.47
16	Pemashelpu	90	Yargyap/Siyom	0.50	5.50	6.00	55.25	0.61
17	Sangoshi	12.5	Sangoshi/Yargyap	0.20	0.50	0.70	10.00	0.80
18	Sae Chhu	15	Sae Chhu/Yargyap	1.00	2.60	3.60	10.00	0.67
19	Tagurshit	84	Tagurshit/Siyom	0.20	3.20	3.40	62.00	0.74
20	Tagurshit Stage-II	27.5	Tagurshit/Siyom	1.20	2.50	3.70	20.00	0.73
21	Kaying	14	Pitgong/Siyom	1.30	4.40	5.70	10.00	0.71
22	Pitgong	14	Pitgong/Siyom	0.60	1.30	1.90	10.00	0.71
23	Hirit	9	Hirit/Siyom	2.20	1.80	4.00	5.00	0.56
24	Hirit Korong	42	Hirit/Siyom	0.30	2.40	2.70	20.00	0.48
25	Soying Korong	48	Soying Korong/Hirit	0.50	2.00	2.50	45.00	0.94
26	Siri Korong	58	Siri Korong/Hirit	0.10	3.00	3.10	42.00	0.72
27	Sibu	4	Sibu/Hirit	0.50	1.60	2.10	5.00	1.25
28	Sittin	24	Sittin/Siyom	0.40	0.80	1.20	15.00	0.63
29	Gameng	37	Sike/Siyom	0.50	3.50	4.00	25.00	0.68
30	Yemsing	38	Yembung/Siang	2.00	6.80	8.80	25.00	0.66

Sl. No.	Name of Project	Capacity (MW)	Tributary/ Main river	River Length Likely to be Affected (km)			Forest Area Likely to be Affected (ha)	Forest Area to be lost in ha/MW
				Reservoir Length (km)	Intermediate [!] Stretch (km)	Total (km)		
31	Simang-I	67	Simang/Siang	1.60	5.40	7.00	54.58	0.81
32	Simang-II	66	Simang/Siang	1.00	7.70	8.70	46.14	0.70
33	Nyikong	13	Nyikong/Siang	7.00	1.70	8.70	5.00	0.38
34	Pango/ Minnying	96	Sigong/Siang	1.50	7.00	8.50	70.00	0.73
35	Mirak	141	Sigong/Siang	3.90	4.00	7.90	500.00	3.55
36	Palsi	24	Palsi/Siang	0.40	5.40	5.80	20.00	0.83
37	Sippi	96	Ringong/Siang	0.20	2.00	2.20	70.00	0.73
38	Ringong	150	Ringong/Siang	0.20	3.00	3.20	110.00	0.73
39	Jidu	92	Yangsang/Siang	1.40	3.30	4.70	65.00	0.71
40	Sipit Upper	45	Sipit/Siang	0.50	1.00	1.50	32.00	0.71
41	Yamne Stage-I	135	Yamne/Siang	4.20	13.30	17.50	493.50	3.66
42	Yamne Stage-II	96	Yamne/Siang	2.70	7.00	9.70	90.40	0.94
43	Lower Yamne Stage - I	75	Yamne/Siang	1.10	9.30	10.40	128.25	1.71
44	Lower Yamne Stage - II	87	Yamne/Siang	0.50	2.60	3.10	106.00	1.22
Total		18293		353.00	160.80	513.80	23867.84	1.30

! Intermediate River length is the distance along the river between diversion site and tail water discharge point i.e. the river reach, which will be deprived of flow due to diversion of water to HRT

**Includes reservoir spread of Siang Upper Stage-I HEP in tributaries like Angong, Nyikong, Sigong, Palsi, Ringong and Yangsang*

*** Includes reservoir spread of Siang Lower HEP in tributaries like Siyom (24 Km), Simang (2.8 Km) and Yamne (4.3 Km) rivers*

Dams can also have significant and complex impacts on downstream riparian plant communities. An important downstream manifestation of river impoundment is the loss of pulse-stimulated responses at the water-land interface of the riverine system. High discharges can retard the establishment of true terrestrial species, but many riparian plants have evolved with, and have become adapted to the natural flood regimes. Species adapted to pulse-stimulated habitats are often adversely affected by flow regulation and invasion of these habitats by terrestrial weeds is frequently observed (Malanson, 1993).

Typically riparian forest tree species are dependent on river flows and shallow aquifers. When diversion structures are constructed the variability in water discharge over the year is reduced; high flows are decreased and low flows may be increased. Reduction of flood peaks reduces the frequency, extent and duration of floodplain inundation. Reduction of channel-forming flows reduces channel migration. Truncated sediment transport (i.e. sedimentation within the reservoir) results in complex changes in degradation and aggregation below the diversion structure. These changes and others directly and indirectly influence a myriad of dynamic factors that affect the diversity and abundance of invertebrates, fish, birds and mammals downstream of diversion structures (Berkamp *et al.* 2000). Moreover, human disturbances during construction and operational phases of hydro projects would keep away several shy wild animals from the vicinity.

One of the major impacts of hydropower development on terrestrial biodiversity is the landscape degradation and fragmentation as a result of diversion of forestland for project and conversion of natural resource into commodity, which is an irreversible process.

In order to assess the cumulative impacts it essential to set up criteria for sensitivity analysis of a particular resource or ecosystem vis-à-vis construction of proposed hydropower projects and related activities or resource use. The Impact Assessment is made in form of degradation, exploitation of natural resources in changed and altered scenario that can be visualized in habitat destruction or disruption of essential ecological functions in due course of time. For the assessment of impacts on terrestrial biodiversity, a conceptual methodology used earlier in study by WII has been followed broadly in the present study also. The pattern of the same is described below:

RET (Rare, Endangered and Threatened) Species, as per IUCN and other Global Criteria	Number of RET species present in the sub-basin
Endemic Species	Number of endemic species present in the sub-basin reflecting the irreplaceability, and national importance that the species command
Habitat Diversity	Number of habitat types available. This is a surrogate for habitat heterogeneity and biodiversity richness
Species Richness	Number of different species present in a given area
Breeding/Congregation	Presence/ absence of breeding sites and congregation opportunities for the target taxonomic group in a sub-basin.
Migratory Pathways/Corridor	Presence/ absence of migratory pathways/corridor for aquatic biodiversity in the sub-basins

It is well known that the spatial configuration of ecosystems at a landscape scale plays a major part in determining how they function and the composition of their plant and animal populations. Fragmentation is the subdivision of a habitat or ecosystem by human activities like clearing forest

for roads, colonies, and other structures required during project construction. The main impacts of changes in the size and connectivity of land (particularly forest) ecosystems include:

- changes in patch size (impacts through species/area relationships)
- edge effects (biophysical impacts, sometimes increasing access for other uses)
- isolation effects (distance from core area increases vulnerability of predation and disease impacts and decreases ability of species to recolonize)

Less fragmented ecosystems are better for biodiversity, although many ecosystems are probably mosaics in an undisturbed state and eco-tones often increase species diversity. To avoid unnecessary fragmentation of ecosystems and habitats is a key aspect of national and regional land use plans and other relevant instruments such as environmental impact assessment at the project and the strategic levels and cumulative impact assessment.

11.2.1 Direct Forest Cover Loss

There are 44 planned hydropower projects in Siang basin and together they are likely to divert about 24000 ha of forest area, which amounts to 1.31 ha/MW of installed capacity (Refer Table 11.1). More than 81% of the Siang basin is under forest cover (82% for entire state). Of this 27% is under Very Dense Forest cover, 37% under Dense Forest cover while 17% is under Open Forest cover category (refer Figure 11.1). Non-forest constitutes only 18% which mainly comprised of *jhummed* area and wide river bed in the lower reaches, snow covered area and floodplain of Siang river.

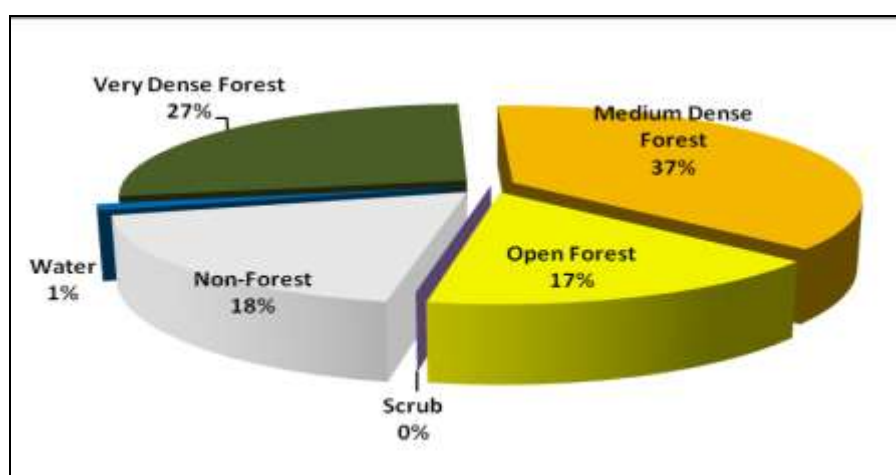


Figure 11.1: Area under different land use/ land cover classes in Siang basin

Among the 11 sub-basins in Siang basin, maximum area under Very Dense (313.83 ha) as well as Dense forest (513.38 ha) cover classes is in Siang sub-basin-II as this is the largest sub-basin in Siang (total area 2018.83 ha). Two large hydropower projects viz., Siang Upper Stage-I & II have been planned and together they will be directly impacting 11750 ha of forestland. (see Table 11.2, Figure 11.2). However on the basis of percentage forest cover, Hirit sub-basin has the maximum area under forests i.e. it has 97% of its area is under forest cover; five planned projects in this sub-basin would be acquiring 117 ha only. This is followed by Yamne and Simang sub-basins with 96% and 95% area under forest cover as compared to overall 81% of area under forests in whole Siang basin (see Table 11.2). In Simang sub-basin, there are two planned projects affecting 100 ha and in Yamne sub-basin there are four planned projects affecting 818 ha.

Table 11.2: Summary of biodiversity profile of sub-basins in Siang basin

	Siang Sub-basin-I	Siang Sub-basin-II	Siang Sub-basin-III	Siang Sub-basin-IV	Yamne	Simang	Hirit	Siyom Sub-basin-I	Siyom Sub-basin-II	Siyom Sub-basin-III	Yargyap	TOTAL SIANG BASIN
TOTAL GEOGRAPHIC AREA (SQ KM)	1716.89	1806.49	2018.83	1754.47	1257.10	557.51	581.33	1472.19	1203.17	1356.12	1241.58	14965.68
FOREST COVER (%)	65	95	61	88	95	96	97	91	75	69	64	81
FLORISTIC DIVERSITY												
No. of species	254	277	245	194	210	220	214	248	298	388	357	1349
No. of RET species	6	4	5	5	6	2	7	12	12	9	11	27
Endemic to Arunachal Pradesh	5	8	9	9	11	8	11	16	21	8	10	46
Endemic to North-east India	16	29	36	34	38	28	37	28	28	18	15	55
FAUNAL DIVERSITY												
Mammals												
No. of species	64	58	54	50	54	52	98	88	54	35	36	142
RET -IUCN	9	6	5	5	8	8	6	6	6	4	8	20
RET-WPA	14	20	10	10	13	13	12	12	8	11	16	50
Avi-fauna												
No. of species	156	300	280	300	224	211	205	194	165	98	95	447
RET-IUCN	19	8	2	2	8	3	8	7	2	7	7	33
RET-WPA	21	5	5	5	5	4	5	5	5	5	5	30
Fishes												
No. of species	74	59	55	36	62	41	42	43	32	24	19	116
RET-IUCN	13	15	15	11	17	11	14	13	10	7	7	22
RET-CAMP	27	29	32	21	27	10	7	22	20	9	9	47
No. of Endemic species	8	8	8	5	10	3	5	8	2	2	2	14

Cells highlighted in Red and Bold letter indicates maximum value of that particular biodiversity component in a sub-basin

According to percentage of area under various forest density classes Yargyap Chhu has maximum area under Very Dense forest cover class i.e. 55% followed by Siyom sub-basin-III with 50% as compared to average of 34% for entire Siang basin (refer **Figure 11.3**). However area under dense forest cover has highest percentage in Siang sub-basin-I (52%) followed by Yamne and Siyom sub-basin-II with 51% as compared to average of 46% for entire Siang basin (refer **Figure 11.4**).

Most importantly Siang Upper Stage-I, Siang Upper Stage-II and Siang Lower HEPs together would lead to direct loss of 18174 ha of forest cover spread over Siang sub-basins I, II, III & IV in Siang river catchment.

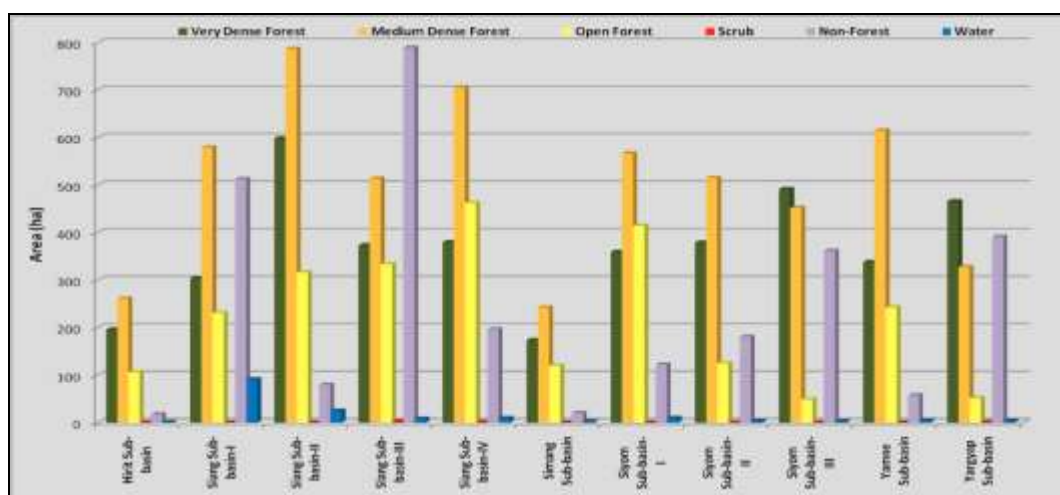


Figure 11.2: Area under various land use/ land cover classes in different sub-basins

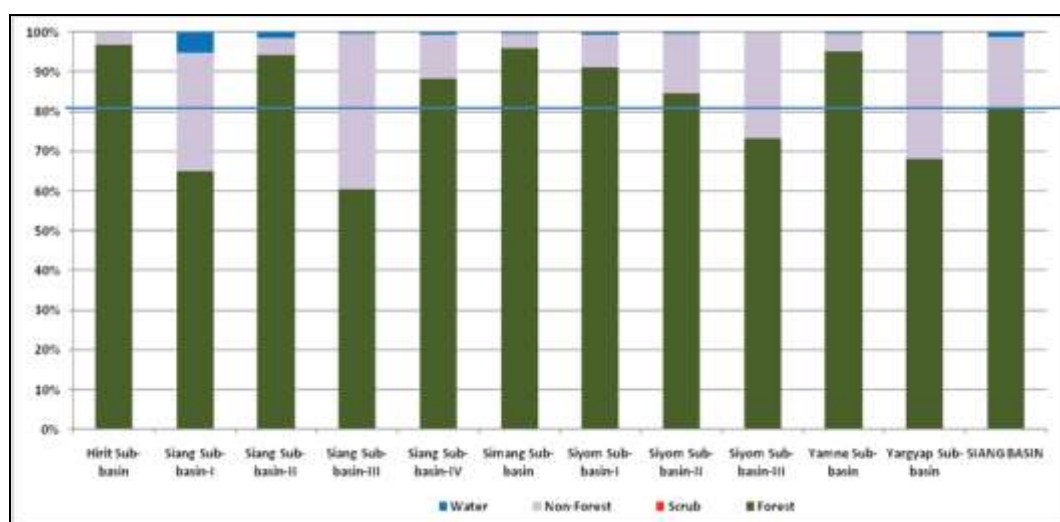


Figure 11.3: Percent area under forest and non-forest in different sub-basins in Siang river basin (Line indicates Total forest cover in entire state)

11.2.2 Forest Cover Loss due to Nibbling effect/ loss

A new land use would be created due to clearing of forest areas for reservoirs, muck dumping, construction works, quarrying, etc. and building of roads into otherwise remote forest areas and would lead to direct loss of forest land and habitat. This landscape change and its fragmentation would become apparent only over a long period of time. During the construction period, the projects would lead to gradual disturbance and loss of forestland and habitat due to increased access to otherwise remote forest areas. The impact can not be quantified at this stage,

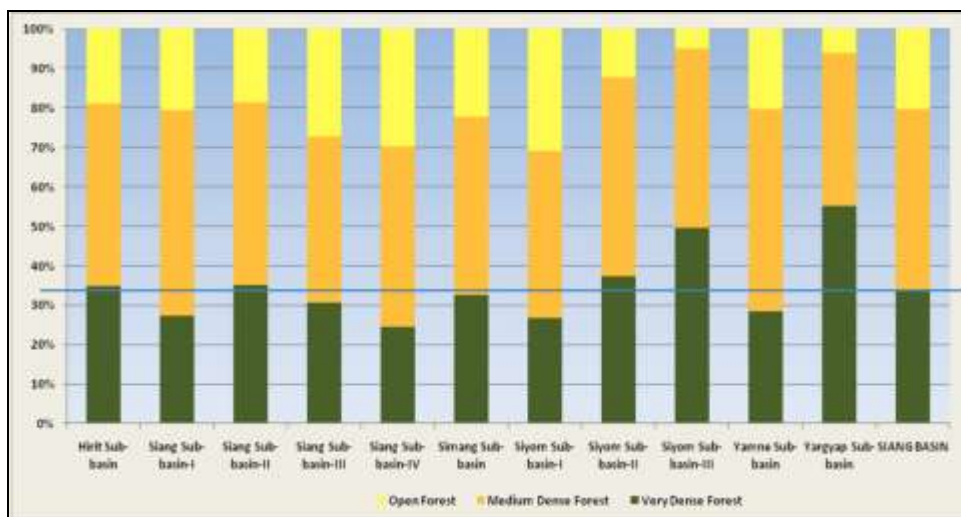


Figure 11.4: Percent area under various forest cover classes in different sub-basins in Siang river basin (Line indicates area under Very Dense forest cover in entire state)

however, these activities would lead to landscape change and its fragmentation which would become apparent only over a long period of time. This is a nibbling impact, which goes unnoticed during construction whereas its impacts are felt in long term especially due to cumulative impact from several projects. The loss of forest does not occur directly only due to diversion of forest land for non-forest use but also due to fragmentation of contiguous forest landscapes into patches of forests interrupted by forest land converted into other land uses like roads, colonies, muck dumping, quarrying, and other project construction activities. Therefore in a scenario when several projects are taken up for construction together, the project related activities too would also lead to forest cover degradation due to bunching of projects.

11.2.3 Impact of Spatial and Temporal crowding

It is a likely scenario that several projects will undergo construction simultaneously leading to substantial activities happening within a small area, which is otherwise pristine and has never faced any major disturbance. This type of spatial crowding would result in overlapping of different impacts e.g. land use change, change from lotic to lentic environment of river, fragmentation of wildlife habitat, reduction in flow in river, change in riverine habitat, etc. Temporal crowding might also occur if impacts generated by different projects taken up for construction over different periods of time but overlapping of construction period would add to the impact already generated before the resource (river, forest area, etc.) has had time to recover. The cumulative impact of several projects bunched together for construction would also result in forest losses due to nibbling effect.

11.2.4 Impact on Biodiversity Values

The direct loss of nearly 24000 ha of Very Dense and dense forests in entire Siang basin will adversely affect the biodiversity contained in these forests. In addition to direct loss of forest cover due to development of 44 projects, large tracts of forests would be indirectly affected by construction activities which will lead to degradation of forests in the vicinity of project sites and more forest areas will become accessible due to construction of roads resulting in disturbance of habitats of many RET plant species reported from these areas. It assumes importance in case of Siang basin which is rich in floral diversity as Siang basin falls in the Eastern Himalayan biogeographic zone and owes its high floral and faunal diversity to its strategic location being at the junction of three biogeographic realms viz. the Palaearctic, the Indo-Malayan and the Indo-

Chinese. According to the biogeographic classification, the area resides in the Himalaya-East-Himalaya biogeographic region (Rodgers and Panwar 1988).

In all 1349 higher plant species have been documented which include 1250 Angiosperms, 11 Gymnosperms and 88 Pteridophytes. Among the lower plants bryophytes are represented by 51 species and lichens are represented by 32 species. Amongst angiosperms orchids, bamboos, canes and rhododendrons are the important plant groups that are predominantly found in the basin. Orchidaceae is represented by 102 species, rhododendrons by 16 species and bamboos and canes together are represented by 29 species.

Forty six (46) plant species endemic to Arunachal Pradesh have been recorded from various parts of the Siang basin. These belong to 21 families and 33 genera. These species predominantly attributed to six plant families (i.e. Orchidaceae - 7 species; Magnoliaceae and Rubiaceae - 4 species each; and Arecaceae, Balsaminaceae and Begoniaceae represented by 3 species each). Majority of endemic species are found in Tropical semi-evergreen forest i.e. 29, followed by subtropical evergreen forest 26, temperate broad-leaved evergreen forest 18, abandoned *jhum* land 7, degraded forest 3, temperate/sub-alpine coniferous 1 and sub-tropical pine forest 1. There were no endemic species recorded in alpine/sub-alpine scrubland.

In order to make an overall assessment of biodiversity values in different sub-basins a summary of different biodiversity components was made and is given at **Table 11.2**.

Among all sub-basins Siyom sub-basins is the richest in terms of number of flowering plant species (**refer Table 11.2**). In terms of species richness for every 3 sq km of area in sub-basins of Hirit, Simang and Yargyap Chhu at least one new species is encountered whereas in entire Siang basin, for every 11 sq km of area traversed a new species is encountered. This kind of richness makes Siang basin important vis-à-vis its biodiversity values as discussed in earlier paragraphs too.

The southern-most part of Siang basin i.e. Siang sub-basin-I where Siang river flows in hilly terrain initially and later downstream of Pasighat it leaves the hilly terrain to enter the plains. Two hydropower projects fall in this sub-basin viz. Yemsing HEP, a small project planned on Yemsing river and Siang Lower HEP (2700 MW), a large project proposed on Siang river near Bodak. Total length of the reservoir along Siang river is 77.5 km while it is 28.5 km along Siyom river. About 5151 ha of forest land would be submerged (total forest land likely to be affected by project is 6224 ha) by Siang Lower HEP, out of which 1854 ha would be in this sub-basin. The loss of large area of forestland due to submergence would be major direct impact of this project. The secondary impact would become apparent only after a period of time. The construction activities would greatly affect the rich mammalian population wherein maximum percentage of RET species are reported. It is also home to rich diversity of birds. Sudden increase in human activities and loss of forestland would have adverse impact on the biodiversity.

In the main Siang river catchment upstream of confluence of Siyom, two large hydropower projects are planned i.e. Siang Upper Stage-II and Siang Upper Stage-I. These two projects would use up almost entire length of the river in the sub-basin as it would involve submergence of 3793 ha (total forest land likely to be affected is 4750 ha) and 6424 ha (total forest land likely to be affected is 7000 ha) forest land, respectively. Dense Tropical forests in the main Siang and Siyom river catchments in particular harbour rich diversity of flora especially orchids as evident from 102

orchid species reported from this area. The clearing of vegetation in these tropical forests for hydro projects would impact populations of large number of epiphytic orchids in Siang sub-basins II & III and adjacent Siyom sub-basins II and III as well. Increased activity and construction of approach roads for proposed hydropower projects would provide access to inaccessible forest areas, which could result in destruction of habitats of important endemic and RET species found in the area. The right bank slopes of Siang river catchment near Jegging are a part of Mouling National Park. Jegging too has been identified part of Birding Area by BirdLife International owing to this area's rich biodiversity. It is therefore envisaged that congregation of large population of migrant workers would affect this biodiversity rich area resulting in landscape degradation and fragmentation. The adjacent catchment of Simang river too is biodiversity rich area where two run of the river projects have been planned. Upper catchment of Simang basin is a part of Mouling National Park. Therefore the project development in these biodiversity rich areas have to be planned carefully taking into consideration its sensitivity.

Further upstream 6 projects are planned on Siang tributaries - Pango/Minniying and Mirak HEPs are proposed on Sigong river while Palsi HEP is proposed on Pali Si stream. Another two projects Sippi and Ringong HEPs are proposed on Ringong Asi. There is hardly any habitation in the area except for the town of Tuting. From this area also large number of plant species have been reported which are endemic to Arunachal and north-east. The forests in this area are largely in pristine condition due to very little human interference and if large numbers of projects are taken up together in addition to large Siang Upper Stage-I & II, sudden spurt in activities would adversely affect the biodiversity of the region.

Hirit sub-basin is another biodiversity rich area in Siang basin. Most of the upper catchment of Hirit sub-basin is still in pristine condition as it constitutes of Yorde Rabe Supse Wildlife Sanctuary and due to its remoteness and difficult terrain, its biodiversity is still intact and much of which is yet to be documented scientifically. In order to define their conservation, thorough exploration is required before they are lost to scientific world even before being discovered.

Yargyap Chhu and Siyom sub-basin-III are the two areas, which are characterized by warm temperate to temperate elements. Yargyap Chhu sub-basin has the highest percentage of its area under Dense forest cover. Within the sub-basin at least two distinct zones can be demarcated based upon forest cover and biodiversity richness. Upper catchment i.e. Zone-1 of Very Dense forest cover along with rich biodiversity which extends from Rego and Kangtangshiri villages and further up in the catchment covering areas like Yarlom, Yorko, Hanuman camp excluding Mechuka town area. The forests in this zone are marked by Mixed coniferous forests which harbour unique diversity of rhododendrons whose 16 species have been recorded. It is one of the few regions of Arunachal where such a large number of rhododendron species are found; other areas are Tawang and Dibang catchment. Out of 16 rhododendron species 7 species are RET species. One of the species *Rhododendron mechukae* has recently been discovered from the sub-basin. *Cephalotaxus griffithii* a species of scientific interest is reported from this area. It is only around Mechuka town these forests are degraded but higher up the slopes on right and left bank are covered with dense forests, which harbor such elements. The slopes in areas around villages like Yarlom, Rego, and Yorko are covered with dense forest. In this zone, 11 RET plant species are found. In addition 10 plant species, which are endemic to Arunachal, are found here. Mechuka giant flying squirrel (*Petaurista mechukaensis*) has also been reported from this zone and endemic to this area. The forests on left bank slopes from Mechuka higher up extending into catchment have been identified

as Birding Area by BirdLife International for its rich diversity of birds wherein numbers of restricted range bird species are found. Three hydropower projects viz. Rego, Kangtangshiri and Pemashelpu are proposed in this area, which can lead to serious impacts and loss of rich biodiversity of the zone. Development of such projects needs to be evaluated vis-à-vis preservation of biodiversity of this zone.

The Zone-2 is comprised of lower catchment of Yargyap Chhu where there are number of settlements like Tato, Gapo Basti, Menying Basti, Purying, Heo and Pauk villages. In this area slopes on the higher up are covered with dense forests but degraded open forests are seen near the settlements. The warm temperate and Sub-tropical forests in this zone, in the vicinity of these villages have been converted into open forests as *jhumming* is practiced. This zone-2 therefore is of lesser value in terms of biodiversity as compared to Zone-1. Projects planned in this zone are Rapum, Pauk, Heo and Tato I.

11.2.5 Impacts on Wildlife

The Siang basin is a part of the Eastern Himalaya- Province 2D according to biogeographic classification of Rodgers *et al.* (2002). Faunal elements of Arunachal Pradesh, easternmost part of Himalaya and as well as Siang basin i.e. mammals, birds, reptiles and fish species are similar to the North-eastern states of India.

Mammalian fauna of the basin comprises of about 143 species belonging to 32 families and 11 Orders. There are 25 species of mammals (18%), which are Schedule-I species according to WPA (1972) whereas 26 are Schedule-II species. According to IUCN Red List Ver. 3.1 there are 8 mammals under 'Endangered' category viz. *Uncia uncia*, *Cuon alpinus*, *Moschus chrysogaster*, *Manis pentadactyla*, *Prionailurus viverrinus*, *Panthera tigris*, *Elephas maximus* and *Caprolagus hispidus*. While first three species are found at higher elevations, *Elephas maximus* and *Caprolagus hispidus* (Hispid hare) are found only in D'Ering Memorial Wildlife Sanctuary in Siang basin. In addition there are 12 species, which are under vulnerable category viz. *Trachypithecus pileatus*, *Melursus ursinus*, *Nycticebus coucang*, *Lutrogale perspicillata*, *Aonyx cinerea*, *Arctictis binturong*, *Pardofelis marmorata*, *Neofelis nebulosa*, *Ursus thibetanus*, *Capricornis sumatraensis*, *Cervus unicolor* and *Budorcas taxicolor*. In the assessment done by C.A.M.P. four species are under Endangered category which are *Panthera tigris*, *Uncia uncia*, *Caprolagus hispidus* and *Bubalus bubalis* while four are under Vulnerable category like *Panthera pardus*, *Nemorhaedus sumatraensis*, *Hystrix indica* and *Moschus chrysogaster*.

Out of 447 bird species, 31 species belong to Schedule-I as per Wildlife (Protection) Act, 1972. Prominent Schedule-I species are two species of hornbills i.e. Great Indian Hornbill, and Oriental Pied Hornbill. On the other hand 7 species of eagles are under Schedule-I and 7 other species of harriers, kites and buzzards belonging to the same family Accipitridae are under Schedule-I. According to IUCN Redlist there are 33 species, which fall in various threat categories.

Owing to rich avi-faunal diversity 5 International Birding Areas (IBA) have been identified in Siang basin by Birdlife International (see Table 6.38 Chapter 6).

The Siang basin is home to 3 Protected Areas i.e. two Sanctuaries (D'Ering Memorial Wildlife Sanctuary and Yordi Rabe Supse WLS) and Mouling National Park. In addition Dibang Dihang Biosphere Reserve covers parts of three districts i.e. East Siang, West Siang and Upper Siang.

Some of the proposed projects are in close proximity to the Protected Areas. Simang -II, Gameng, Siyom Middle HEPs are located within 10 km radius of Mouling National Park. Siang Upper Stage - I & II HEPs and Nyikgong HEP also are located at a distance little more than 10 km radius of Mouling National Park. Tagurshit and Tagurshit-II HEPs on Tagurshit Nala, Hirit, Hirit Korong, Siri Korong, Soying Korong and Sibu HEPs in Hirit sub-basin, and Pitgong and Kaying HEPs on Pitgong Nala all are located within 10km radius of Yordi Rabe Supse Wildlife sanctuary. Being located in close proximity to Yordi Rabe Supse Wildlife sanctuary the activities of these projects would affect the biodiversity the sanctuary.

11.2.6 Impact on RET & Endemic Species

The highest number of RET plant species (12 species) is found in Siyom sub-basin-I and Siyom sub-basin-II, out of 27 found in the entire Siang basin. Similarly, number of endemic plant species is highest in Siyom sub-basin-II (21) followed by 16 in Siyom sub-basin-I (refer Table 11.2).

The number of mammalian species under RET (IUCN) is maximum in Siang sub-basin-I i.e. 9 species out of 20 found in entire basin. Similarly number of bird species under RET (IUCN) is maximum in this sub-basin i.e. 19 species. This sub-basin also harbours largest number of fish species i.e. 74 species out of total 116 reported from the basin (Table 11.2). Hirit sub-basin is home to highest number mammalian species along with highest area under forest cover.

The direct forest loss due to diversion of forest land and degradation of forest cover in the sub-basins mentioned above will adversely affect the RET species populations. The impacts of RET species occur due to loss of their habitat and their populations sizes decrease due to gradual degradation and shrinkage of their habitats which ultimately results in disappearance of their populations and which become known only over a longer period of time. Such species rich areas need to be preserved in addition to the existing protected areas in the basin.

The number of RET bird species is highest in Siang sub-basin-I along with highest number of fish species reported from this sub-basin.

It has been noted that large number of endemic plant species have been reported from Siyom sub-basin-I and Siyom sub-basin-II wherein projects viz. Siyom Middle, Gameng, Naying, Tato-II, Tagurshit and Tagurshit-II have been planned.

11.2.7 Loss of Riparian Habitats

The areas of special vegetation that grow along the sides of rivers are called the river's **riparian zone**. Riparian zones are critical to the health of rivers. Often the greatest contributor of plant food to streams is the **riparian zone** - the margins along the stream that are filled with vegetation. These plants, like all plants, drop their leaves, which fall into or are washed into the stream. This is **allochthonous** matter (from outside the stream), as opposed to **autochthonous** matter (from inside the stream, like algae and diatoms). These leaves can't make oxygen, since they are dead, but they provide food to the creatures in the stream. Not only the leaves themselves can be eaten, but also whatever bacteria or fungus is covering the leaves, rotting them. It is this bacteria and fungus that is what crayfish are really after when they eat decaying plant matter. Riparian plants also have bugs on them, which drop into the stream and provide food to stream-dwellers.

The riparian habitats are adversely affected by the altered flow regime i.e. the reduced flows in the river below the dam disturbs the natural ecological function of flood pulses vis-à-vis riparian vegetation. Periodic flood pulses inundating the riparian vegetation facilitate the exchanges of biota, sediments, organic matter and inorganic nutrients between the riparian vegetation and riverine ecology. It often leads to near disappearance or alteration of riparian vegetation due to non-wetting of vegetation, which acts as lateral connectivity of the river with the terrestrial landscape.

The riparian habitats of Yargyap Chhu, Siyom and Yamne rivers will be severely affected due to proposed projects resulting in long stretches of changed river flow regime i.e. the long stretches of these rivers will have reduced flows wherein the water would be diverted into head race tunnels and natural riparian vegetation will be deprived of wetting and resultant reduced nutrient flow into the river.

11.2.8 Overall Assessment of Biodiversity

In order to make a comparative assessment of biodiversity richness of each sub-basin, percentage richness of each of the 15 biodiversity components (listed in Table 2) is calculated w.r.t. to the biodiversity value of that component in the entire Siang basin. These values were added up to rank the sub-basins according to biodiversity richness and the same is given in table below.

Sub-basin	Rank
Yamne	1
Siang Sub-basin-II	2
Siang Sub-basin-I	2
Siyom Sub-basin-I	3
Hirit	4
Siang Sub-basin-III	5
Siang Sub-basin-IV	6
Siyom Sub-basin-II	7
Simang	8
Yargyap	9
Siyom Sub-basin-III	10

As can be seen from the above ranking, Yamne ranks at number one in terms of total biodiversity values i.e. the richest basin in terms of biodiversity values, followed closely by Siang sub-basin-I and Siang sub-basin-II (both have similar values). Thereafter these are followed by Siyom sub-basin-I, Hirit, and Siang sub-basin-III.

Yamne sub-basin harbours 38 plant species endemic to north-east, out of 55 reported from entire Arunachal Pradesh. More than 95% of sub-basin area is under forests. Most of its biodiversity is found in its upper reaches in and around village Mariyang whereas lower catchment is comparatively degraded due to *jhumming*, therefore activities in its upper catchment (Yamne Stage I HEP) need to be taken up with a caution taking into consideration its biodiversity richness.

Next in ranking are Sang sub basin I and II, where three major projects i.e. Siang Lower, Siang Upper Stage-II and Siang Upper Stage-I are planned. These three projects alone would involve direct loss of 18174 ha of forest, which is about 76% of total forestland required for all 44 projects in the basin. In addition 208.5 km of Siang river will be affected due to formation of reservoir of these projects. Reservoir spread in Siyom, Simang and other tributaries is in addition to this. Other

projects falling in these biodiversity rich sub-basins are Yemsing, Sipit and Nyikong. These projects together have the potential of seriously impacting the biodiversity in these rich areas.

Siyom sub basin I and Hirit sub basin are also very rich in terms of overall biodiversity values. Impacts are more pronounced in Hirit sub basin, which happens to be a suitable habitat for migratory fishes like mahseer, and *Labeo pangusia*. The upper catchment of Hirit sub-basin comprises of Yorde Rabe Supse WLS where forests are in pristine condition due to its remoteness. Once the projects are taken up in this sub-basin it will provide access to otherwise inaccessible areas leading to degradation of its flora and fauna.

11.3 CUMULATIVE IMPACTS ON AQUATIC ECOLOGY

Freshwater ecosystems including rivers, lakes and wetlands are extremely rich in species, but unfortunately, are also amongst the most altered and threatened ecosystems in the world. The natural flow regime and the longitudinal and lateral connectivity of rivers, which are essential to sustain the biophysical and ecological processes necessary for life in freshwaters, are disrupted when dams and their reservoirs fragment the rivers. This fragmentation and the consequent loss of ecosystem processes do not only affect ecosystems and species, but humans as well. For example, the loss of floodplain inundation patterns affects both native ecosystems and human communities dependent on floodplain fisheries and flood recession agriculture. In freshwater habitats the main impacts of fragmentation from dam-building are:

- changes in water flow/oxygenation rates/temperature regimes, and
- effects of physical barriers obstructing migratory movements of species.

The impacts on aquatic ecology happen in following ways:

- Reduced flows in downstream stretches
- Altered flow regime in different seasons viz. lean, monsoon, pre and post monsoon
- Discontinuity of river flow i.e. conversion of free flowing river into alternating small stretches of free flowing lotic ecosystem to lentic ecosystems of reservoirs and deprived stretches of river (run-of-the-river with long head race tunnels).
- Submergence
 - Alteration of river system from lotic to lentic environment
 - Loss of forest land
 - Alteration of landscape/aesthetics of area
- Alteration of river flow pattern downstream resulting due to variation in energy generation requirements in different periods.
 - Alteration of local ecosystem/ increased moisture conditions
 - Disruption of migration behaviour of fishes and other migratory animals
 - Health risks/Increased incidence/ proneness to unknown diseases
 - Downstream flooding due to sudden peaking

As discussed above, planned 44 projects in Siang basin will affect 513.8 km of the river length - 353 km will be converted to reservoirs and 160.8 km will be travelling through tunnels leading to significant alteration of free flowing fresh water ecosystem of Siang basin. To understand the contribution of individual project to cumulative impacts of diminishing river reach, river length affected by per MW of generation capacity is calculated project wise and is arranged in decreasing order in **Table 11.3**.

As can be seen from the Table 11.3, projects with lower generation capacity or smaller projects are affecting more river length per MW. Top four projects in above Table, affecting more than 400 m of river stretch per MW are all less than 14 MW. Therefore, there is a need to plan the development in the basin in such a manner so that direct impact on the aquatic ecology due to altering/diminishing the river stretches can be reduced/ minimized.

Table 11.3: River Length Affected per MW of Generation Capacity

Sl. No.	Name of Project	Capacity (MW)	River/ Tributary	Main River	Total River Length Likely to be Affected (Km)	River Length (m)/MW
1	Nyikong	13	Nyikong	Siang	8.70	669.23
2	Sibu	4	Sibu	Hirit	2.10	525.00
3	Hirit	9	Hirit	Siyom	4.00	444.44
4	Kaying	14	Pitgong	Siyom	5.70	407.14
5	Palsi	24	Palsi	Siang	5.80	241.67
6	Sae Chhu	15	Sae Chhu	Yargyap	3.60	240.00
7	Yemsing	38	Yembung	Siang	8.80	231.58
8	Lower Yamne Stage - I	75	Yamne	Siang	10.40	138.67
9	Pitgong	14	Pitgong	Siyom	1.90	135.71
10	Tagurshit Stage-II	27.5	Tagurshit	Siyom	3.70	134.55
11	Simang-II	66	Simang	Siang	8.70	131.82
12	Yamne Stage-I	135	Yamne	Siang	17.50	129.63
13	Gameng	37	Sike	Siyom	4.00	108.11
14	Simang-I	67	Simang	Siang	7.00	104.48
15	Yamne Stage-II	96	Yamne	Siang	9.70	101.04
16	Pango/ Minnying	96	Sigong	Siang	8.50	88.54
17	Kangtangshiri	80	Yargyap	Siyom	7.00	87.50
18	Pemashelpu	90	Yargyap	Siyom	6.00	66.67
19	Hirit Korong	42	Hirit	Siyom	2.70	64.29
20	Jarong	90	Siyom	Siang	5.10	56.67
21	Mirak	141	Sigong	Siang	7.90	56.03
22	Sangoshi	12.5	Sangoshi	Yargyap	0.70	56.00
23	Siri Korong	58	Siri Korong	Hirit	3.10	53.45
24	Soying Korong	48	Soying Korong	Hirit	2.50	52.08
25	Jidu	92	Yangsang	Siang	4.70	51.09
26	Sittin	24	Sittin	Siyom	1.20	50.00
27	Taiyong	56	Siyom	Siang	2.50	44.64
28	Tagurshit	84	Tagurshit	Siyom	3.40	40.48
29	Siang Lower	2700	Siang	Siang	108.60	40.22
30	Rapum	66	Yargyap	Siyom	3.10	38.75
31	Lower Yamne Stage - II	87	Yamne	Siang	3.10	35.63
32	Sipit Upper	45	Sipit	Siang	1.50	33.33
33	Tato-I	186	Yargyap	Siyom	5.40	29.03
34	Hirong	500	Siyom	Siang	13.80	27.60
35	Rego	80	Yargyap	Siyom	2.20	27.50
36	Heo	240	Yargyap	Siyom	6.40	26.67
37	Pauk	145	Yargyap	Siyom	3.50	24.14
38	Sippi	96	Ringong	Siang	2.20	22.92
39	Ringong	150	Ringong	Siang	3.20	21.33
40	Siang Upper Stage-I	6000	Siang	Siang	106.90	17.82
41	Siyom Middle	1000	Siyom	Siang	16.30	16.30
42	Siang Upper Stage-II	3750	Siang	Siang	57.00	15.20
43	Naying	1000	Siyom	Siang	15.10	15.10
44	Tato-II	700	Siyom	Siang	8.20	11.71

Cumulative impacts on aquatic ecology due to development of these projects, have been discussed in the following paragraphs.

11.3.1 Impacts of Damming of River

A large reservoir area implies the substantial loss of natural habitat and wildlife and/or the displacement of many people. Very large reservoirs are typically in the lowlands (often with tropical disease and aquatic weed problems) and usually impound larger rivers (with more fish and other aquatic species at risk).

Typical Impacts of large reservoirs are:

- a) flooding large areas of natural habitats and consequent loss of biodiversity;
- b) a large river with high aquatic biodiversity damaged;
- c) few or no downstream river/tributaries;
- d) water quality problems due to the decay of submerged forests;
- e) their location in the sub-tropics is conducive to the spread of vector-borne diseases; and
- f) serious problems with floating aquatic weeds.

Direct Impacts of Reservoir based projects:

- Barriers (high) severely restricts aquatic life migration
- Bottom layers are devoid of oxygen
- Changes river bottom profile

Direct impact of large reservoirs is the conversion of fast flowing river into stagnant reservoirs. Its direct impact is on oxygen concentration in the water. In the large reservoirs oxygen depletion results from eutrophication in which plant nutrients enter a river and phytoplankton blooms are encouraged. While phytoplankton, through photosynthesis raise DO saturation during daylight hours, the dense population of a bloom reduces DO saturation during the night by respiration. When phytoplankton cells die, they sink towards the bottom and are decomposed by bacteria, a process that further reduces DO in the water column. If oxygen depletion progresses to hypoxia, fish kills can occur and invertebrates like worms and clams on the bottom may be killed as well. Below 5 mg/L, most fish, especially the more desirable species such as trout, do not survive. Actually, trouts need at least 8 mg/L during their embryonic and larval stages and the first 30 days after hatching.

The consequence of river impoundment is the transformation of lotic environment to lentic habitats. Independently of free passage problems, species which spawn in relatively fast flowing reaches can be eliminated. From a study of the threatened fish of Oklahoma, Hubbs and Pigg (1976) suggested that 55% of the man-induced species depletions had been caused by the loss of free-flowing river habitat resulting from flooding by reservoirs, and a further 19% of the depletion was caused by the construction of dams, acting as barriers to fish migration.

Projects such as Siang Lower, Siang Upper Stage-I and Siang Upper Stage-II HEPs on Siang river and Siyom Middle on Siyom river are dam toe projects with large reservoirs. In addition other run of the river large projects such as Naying, Tato II and Hironig will also submerge substantial forest area. The creation of large reservoirs behind the proposed dams of Siang Upper Stage-II, Siang Upper Stage-I, Siang Lower and Siyom Middle HEPs would change free flowing character of Siang and Siyom rivers i.e. from lotic to lentic - running water becomes still. This results in silt deposition and the formation stratified bodies like reservoirs would change the temperature and

oxygen conditions making it unsuitable for existing riverine species. The projects would obstruct the migration of mahseer and there is no other stream in which fish like mahseer can effectively migrate into for breeding and spawning, which is part of natural life cycle of mahseer. The modified flow of the river adversely affects the fish populations by obstructing the migration as well as changed riverine profile.

11.3.2 Impact on Fish Populations

The fish species found in the Siang river and its tributaries prefer fast flowing, rocky bottom waters. Mahseer is the main fish species of Siang river and the main breeding zone for mahseer is river Siang and its tributaries like Yamne, Hirit, Sigong, Simang, Ringong and Yangsang which offer suitable habitats for its spawning and growth. Golden mahseer (*Tor putitora*) is an important endangered migratory fish, which migrates longitudinally upstream during April-May in Siang river and then undertakes lateral migration in the tributaries of Siang river for breeding, feeding and as refuge location. Thereafter it migrates downstream via main channel during post-monsoon period (September-October) to feed, thrive and grow in the main Siang where the temperature and oxygenation conditions in winters is conducive for its growth along with availability of substratum in Siang river.

Construction of several hydropower projects in Mahseer zone will seriously alter its habitat and challenge its existence. The projects like Siang Lower, Siang Upper Stage-I HEP and Siang Upper Stage-II HEPs on Siang river, and Siyom Middle HEP on Siyom river would block the movement of migratory species like mahseer up and down rivers, causing extirpation (loss of populations from a part of the species range) as these projects are planned in that part of river which has been marked as mahseer zone. These projects would also result in change in turbidity/sediment levels to which species/ecosystems are adapted. The trapping of silt in reservoirs would deprive the downstream Siang river ecosystem of maintenance materials and nutrients that help in maintaining productivity of Siang and Siyom river ecosystems.

Hirit river is one of the rivers where fish species like mahseer (*Tor putitora*) migrates for spawning and breeding. *Labeo pangusia* is another fish, which prefers waters of Hirit river for spawning. In addition snow trout (*Schizothorax* spp.) is important fish in the colder waters upstream. The species like *Labeo pangusia*, *L. gonius* and *Anguilla bengalensis* ascend comparatively for short distance. Among catfishes *Aorichthys seenghala* also migrate for breeding and spawning purposes. The fry of *Labeo pangusia* were found in Hirit river. The lower stretches of Hirit river and stretch of Siyom river 2-4 km downstream and upstream of confluence of Hirit river with Siyom, is known for fishing activities and harbours good diversity of fish (more than 50 species are reported from this small area only). The discontinuity of habitats of these important fishes due to construction of several hydropower projects would have adverse impact on their populations and their reproductive behaviour.

Hirit HEP and Hirit Korong HEP are planned on Hirit and 2 projects Siri Korong and Soying Korong HEPs are planned on its tributaries. It is therefore envisaged that the proposed projects on Hirit river would affect the populations of these fishes further by changing the riverine profile from lotic to lentic and reduction of available flow in the river during different periods of the year after the implementation of these projects.

In Yamne sub-basin four projects are planned in cascade viz. Yamne-Stage-I, Yamne Stage-II, Lower Yamne Stage-I and Lower Yamne Stage-II HEPs. *Bagarius bagarius* and *Labeo pangusia* are migratory fishes, which migrate into Yamne and Siyom rivers for feeding and spawning.

Schizothorax richardsonii and *Garra naganensis* are the two other important fishes of Trout zone in the basin and prefer colder waters. These are column feeders and perform local migration/movement for shorter distance. *Schizothorax richardsonii* performs migration within same river system but do not have any specific spawning grounds. To cope with the low temperature in peak winter season it moves downwards. Other species like *Labeo pangusia*, *L. gonius* and *Anguilla bengalensis* ascend comparatively for short distance. Among catfishes *Aorichthys seenghala* does migrate for breeding and spawning purposes. The populations of *Glyptothorax cavia* an important catfish of cooler fast-flowing streams of rheophilic zone, where they are adapted to live by using the adhesive apparatus on the underside to attach themselves to rocks and prevent being washed away, would also be affected due implementation of proposed projects on Siyom river by changed flow regime.

Run of the river projects like Naying, Tato-II, Hiron on Siyom river; four projects on Yamne river; two projects on Simang river and seven projects on Yargyap Chhu would affect the habitat of these fishes. Owing to diversion of water for power generation there will be reduced flow of water downstream of these projects up to the tailrace discharge of water from powerhouse. The reduced flows in these stretches would affect the movement of trout leading to reduction in their population. In the absence of any free flowing stretches as is the case on Siyom river, there would be disappearance of resident fish species populations over a period of time.

a) Loss of Habitat

The suppression of flood regime downstream from an impoundment by means of flow regulation can deprive many fish species of spawning grounds and valuable food supply (Petts, 1988). This can lead to changes in species composition with loss of obligate floodplain spawners. Dam construction for industrial uses within the Rio Mogi Guassu Brazil has resulted in the progressive loss of flood plain wetlands (Godoy, 1975). The cumulative effect of diminished peak discharges, stabilized water levels, reduced current velocities and water temperature eliminated spawning grounds below the dams on the Qiantang and Han rivers: six migratory fish and five species favoring torrential habitats declined severely (Zhong and Power, 1996). The reaction of the fish communities of the Chari, Niger and Senegal rivers to flood failures provoked by natural climatic variations illustrates the highly detrimental effect of suppressing the flood (Welcomme, 1985). The construction of proposed dams on Siang river would result in loss of habitat of native fish species inhabiting the Siang river and its tributaries.

b) Impact on Fish Migrations

One of the major effects of the construction of a dam on fish populations is the decline of anadromous and potamodromous fish species. The dams prevent migration between feeding and breeding zones. The effect can become severe, leading to the extinction of species, where no spawning grounds are present in the river or its tributary downstream of the dam.

The concept of obstruction to migration is often associated with the height of the dam. However, even low weirs can constitute a major obstruction to upstream migration. Whether an obstacle can be passed or not depends on the hydraulic conditions over and at the foot of the obstacle

(velocity, depth of the water, aeration, turbulence, etc.) in relation to the swimming and leaping capacities of the species concerned. The swimming and leaping capacities depend on the species, the size of the individuals, their physiological condition and water quality factors such as water temperature and dissolved oxygen. Certain catadromous species (species of *Anguilla*) have a special ability to clear obstacles during their upstream migration: in addition to speed of swimming, the young eels are able to climb through brush, or over grassy slopes, provided they are kept thoroughly wet; some species (i.e. gobies) possess a sucker and enlarged fins with which they can cling to the substrate and climb around the edge of waterfalls and rapids (Mitchell, 1995).

For a migratory species, an obstruction may be total, i.e. permanently insurmountable for all individuals. It may be partial, i.e. passable for certain individuals wherever the diversion structures are not very high. It may be temporary, i.e. passable at certain times of the year (under certain hydrological or temperature conditions). During low flow conditions diversion dams may be insurmountable because the depth of water on the face is too shallow to permit fish to swim. They may however become passable at a higher discharge rate, as water depth increases and the fall at the structure generally decreases. The negative impact on fish caused by temporary obstacles, which delay them during migration and which may cause them to stay in unsuitable zones in the lower part of the river, or cause injury as a result of repeated, fruitless attempts to pass, should not be underestimated.

In Siang basin mahseer and trouts are the two key fish species and accordingly the river can be delineated into mahseer and trout zones and the same has been given in a map at **Figure 7.19** in **Chapter 7**.

i) Mahseer Zone fishes

The migratory phenomenon of the fish species is directly related to its life cycle as fish moves from one habitat (stationary ground) to other (breeding ground) to spawn. The breeding migration in fish may be of a few meters to many hundreds of kilometers. In the Himalayan rivers Mahseer (*Tor putitora* and *T. tor*), important potamodromous fish species, ascend longest distance for breeding purpose, which move from main stream to the tributaries. Other species like *Neolissochilus hexagonolepis*, *Labeo dero* and *L. pangusia* (all potamodromous fish) and *Anguilla bengalensis* (catadromous) and snow trout species traverse relatively short distances. Mahseer and *Neolissochilus hexagonolepis* start their migration during the onset of monsoon and perform tri-phased migration. All 'schizothoracines' show migration variably. They descend in monsoon towards warmer places and spawn in the main streams or tributaries. *Labeo* spp. also migrates into the nearby tributaries for breeding.

The golden mahseer, *Tor putitora* is the most popular mahseer and the most popular game fish in India. These fish like fast flowing, rocky waters, and are seen frequently around the Himalayan foothills. The projects on Siang and Siyom river with large reservoirs will stall the migration of mahseer and in addition the projects on tributaries also would affect the breeding grounds and shelters of mahseer during monsoon.

ii) Trout Zone fishes

Trout thrive in cooler water than most other fish in temperatures that range from about 2-20°C. However, their optimum feeding range is about 10-18°C. Cold mountain streams with good snow melt provide those temperatures and are an ideal environment for trout. As the warmer weather

of summer progresses, the flow of the stream slows and the water temperature rises along with the hot weather, especially if there is little or no rain. Under these adverse conditions, the oxygen content of the water may be depleted and the trout will become sluggish and, if they can't move to water with more oxygen content, they will eventually die.

Trouts are cold-blooded by nature so their food needs vary with the temperature of the water as well as their body temperature. When the water is very cold, trout are almost dormant and require very little food to survive. As the water warms, they need more food and will become more aggressive in their feeding habits. In shallow mountain streams, the temperature can change rather abruptly as the temperature in the air changes along with snow melt, rainfall and direct sunlight on the water. Larger rivers provide a more stable water temperature due to the sheer volume of water.

The water where trout lives can be either a few centimeters or 1-2 m deep depending on if there is water close by that is deep enough (about 40-50cm) or if there is an overhanging bank or downed log to protect them from overhead threats such as hawks and eagles. When the snow melts there are usually good cold-water flow and just enough food to sustain the trout. As the air temperature warms and the water warms a few degrees with a good flow, trout then become very aggressive eaters. This is the time when the insects start hatching and provide the trout with one of their favorite diets. Spring rains increase the water flow and enabling more number of insects to hatch, which ensures that more food is available to them.

As the water flow slows down after November-December and the level drops causing some areas to dry up completely. As the current slows, the water temperature gets warmer, and the water begins forming pools. The riffles become less prevalent and there is less oxygen content in the water. As this process continues, the fish may start to become sluggish, but they are still in their feeding cycle. If there is one available, the fish may move to an area with better oxygen content (closer to a riffle or waterfall) and /or move to a cooler water source such as a small colder stream in a shady location. As the weather cools and the trout become aggressive again. They begin loading up on the abundant insects gaining weight for the winter. When winter arrives, the water cools and the trout's metabolism slows so they don't require as much food to keep them nourished. They will then move to the deeper holes even though they can still be enticed into taking an occasional offering.

Trout spends most of their lives in a small area of the stream and do little moving unless there is a shortage of food, the water temperature changes and /or the oxygen content gets too low. Since they live in such a small area of the stream, they are acutely aware of their surroundings. They know where the current is ideal for feeding or resting and will move to those positions as needed. They see very well above the water in front and to both sides and can detect even a slight movement in their line of vision. With their lateral lines they can detect the vibrations of a noisy, splashing fisherman wading in their section of the stream.

Living in small areas makes them keenly aware of their surroundings. Everything out there is trying to eat them. Bears, otters, owls, birds and other fish will all make a meal on them if they have an opportunity. So any strange movement or noise in their pool of water will push them into hiding or flight. However, they have short memory spans so in time they tend to return to normal.

Trout almost always lie facing upstream. Their bodies are designed to let the water flow around them so they can maintain their spot in the water with very little effort. They will choose a position in the slower moving water just outside the main current or behind a rock or log as they wait for their food to come floating by. They will dart from their resting place and often they will stop in front of the bait, follow and look carefully at their food choice before they softly swallow it down.

Dominant fishes of Trout zone viz. *Schizothorax richardsonii* (Snow trout) and *Garra naganensis* are column feeders, and are known to move relatively shorter distance as compared to mahseers. *Schizothorax richardsonii* generally performs migration within same river. To cope with the low temperature in peak winter season it moves downwards. It finds a tributary to spawn from May to September.

The species *Schizothorax richardsonii* and *Neolissochilus hexagonolepis* migrate from lower elevations to higher elevations in summer months and return to lower elevation in winter months. These species were observed at various sampling locations. Construction of proposed dams would hamper the upward and downward migratory movement of these fish species in summer and winter seasons. Likewise, migration of fish species from tributaries to Siang and Siyom rivers, would be affected on account of creation of reservoirs due to construction of proposed hydroelectric projects. Thus, the projects will lead to adverse impact on migration of these fish species. The fish migration would be restricted in the following stretches:

- Upstream of dam site of Siyom Middle HEP
- Upstream and Downstream of dam sites of Naying, Tato-II and Hirong hydroelectric projects
- Tributaries confluencing with Siang and Siyom rivers

c) Modification of Discharge

The modification of downstream river flow characteristics (regime) by an impoundment can have a variety of negative effects upon fish species: loss of cues/ stimuli for migration, loss of migration routes and spawning grounds, decreased survival of eggs and juveniles, diminished food production.

Regulation of stream flow during the migratory period can alter the seasonal and daily dynamics of migration. Regulation of a river can lead to a sharp decrease in a migratory population, or even to its complete elimination. Any reduction in river discharge during the period of migratory activity can diminish the attractive potential of the river, hence the numbers of spawners entering the river is reduced. Because of this, regulation of a river can greatly influence the degree of migration to the non-regulated part of the river below the dam site. This aspect will affect the migration behaviour of migratory fishes in Siang river.

Modification of discharge will take place in all the projects and cumulatively this impact will become serious as projects are planned in cascade in all the rivers and tributaries leading to discharge modification in almost the entire basin. This impact cannot be eliminated, however can be mitigated to certain extent by ensuring adequate environment flow in the intermediate stretch so that continuity with tributaries can be maintained; ensuring free flowing river stretches for the river to recover and maintain continuity with the tributaries in the free flowing river stretches, wherever tributaries are ensuring continuity of habitat with the free flowing stretch and intermediate stretch, development should be restricted on such tributaries.

d) Water Temperature and Water Quality Changes

Dams can modify thermal and chemical characteristics of river water: the quality of dam-releases is determined by the limnology of the impoundment, with surface-release reservoirs acting as nutrient traps and heat exporters and deep-release reservoirs exporting nutrient and cold-waters (Petts, 1988). This can affect fish species and populations downstream.

Water temperature changes have often been identified as a cause of reduction in native species, particularly as a result of spawning success (Petts, 1988). Cold-water release from high dams of the Colorado river has resulted in a decline in native fish abundance (Holden and Stalnaker, 1975). The fact that *Salmo* spp. had replaced some twenty native species has been attributed to the change from warm-water to cold-water.

Water-chemistry changes can also be significant for fish. Release of anoxic water from the hypolimnion can cause fish mortality below dams (Bradka and Rehackova, 1964).

During high water periods, water which spills over the crest of the dam can become over-saturated with atmospheric gases (oxygen and nitrogen) to a level which can be lethal for fish. Mortality can result from prolonged exposure to such lethal concentrations downstream of the spillways. Substantial mortalities of both adult and juvenile salmonids caused by high spillway flows which produced high supersaturation (120-145%) have been observed below the John Day dam on the Columbia river (Raymond, 1979). The Yacyreta dam on the Parana river generates supersaturated levels of total dissolved gases that can affect the health condition of fish: in 1994, massive fish mortality was observed in a 100 km reach below the dam (Bechara *et al.*, 1996).

Therefore not only the migration behaviour is likely to change due the proposed projects but changes in water temperature and quality also will have impact on fish populations and high fish mortality.

e) Increased Exposure to Predation

Normal predation behaviour may become modified with the installation of a dam, and although few data exist to date, it appears that migrating species suffer increased predation in the vicinity of an installation, whether by other fish or birds. This may be due to the unnatural concentration of fish above the dam in the forebay, or to fish becoming trapped in turbulence or recirculating eddies below spillways, or to shocked, stressed and disoriented fish being more vulnerable to predators after turbine passage. In some rivers or hydroelectric schemes, predation may affect a substantial proportion of the fish population. On the Columbia river, predator exposure associated to turbine passage was the major causes of salmon mortality. Tests at the Kaplan turbines indicated a mean loss of 7% and studies showed that the indirect mortality on juvenile coho salmon could reach 30% when indirect mortality from predation was included (Ebel *et al.* 1979).

The proposed projects in Siang basin will lead to increased exposure of fishes to predation which will affect their mortality and populations.

f) Impacts on Tributaries

Ecosystems of small streams or tributaries of Siang and Siyom rivers if exploited for hydropower generation would severely affect their role as natural resource replenishment character as these

streams are the main contributors of biological production of the main rivers. These small streams act as hatcheries for biological production at the first and second trophic levels.

The tributaries are a source of nutrients and energy by way of contributing dissolved organic matter from falling litter, overland flow and subsurface movement into the main channel. Their importance has been very well documented by Wipfli *et al.* (2007). Therefore any modification of tributary streams of large rivers like Siang, Siyom, Yargyap Chhu and Hirit would impair their capability to rejuvenate the main river channel by reduced resource flow. Their contribution assumes more significance especially in the stretch downstream of projects which have been affected by reduced flows by diversion of water for power generation. Therefore role of tributaries to reduce the impact of projects on main river should be taken into account before planning any project on tributaries.

Projects on tributaries like Hirit, Tagurshit, Gameng, Pitgong Nala, Yangsang, Ringong, Sigong, Palsi would impair the capabilities of these tributaries to resource flow into the main channels like Siang and Siyom.

11.3.3 Impact due to Modification of Flow Regime

Whereas storage projects with large reservoir result into obstruction of migration paths of fishes, and conversion of large sections of river from lotic to lentic ecosystems, the run-of-river (ROR) affects the riverine ecosystem in a different way. In general impacts of ROR projects are:

- Dry stretches
- Barrier (even low) may affect migration of aquatic life

River-wise impacts of projects are being discussed below.

i) Siang River

Main Siang River has three planned hydropower projects, viz.; Siang Upper Stage I (6000 MW) Siang Upper Stage II (3750 MW) and Siang Lower (2700 MW). Siang Upper Stage I and II are still in drawing board stage whereas survey and investigations work is almost complete for Siang Lower HEP. These three projects are planned in cascade without any free flowing river stretch between adjacent projects. Longitudinal profile of Siang River is given at **Figure 11.5**.

Total length of Siang river from where it enters India up to its confluence with Dibang and Lohit in Assam is about 294 km while in Arunachal Pradesh it is about 283 km. The proposed three projects on Siang river viz. Siang Lower, Siang Upper Stage-II and Siang Upper Stage-I HEPs would convert 208.5 km of Siang river into reservoir (77.5 km - Siang Lower, 57 km - Siang Upper Stage-II and 74 km - Siang Upper Stage-I). Only 85.5 km (29%) of free flowing water regime of Siang river will be left out of its total course in India i.e. 294 km of lotic ecosystem will be converted into 208.5 km of lentic ecosystem altering the entire Siang river aquatic system which will adversely impact the aquatic biodiversity and seriously affecting fish populations and their migration behaviour.

In addition, the proposed dams on Siang river will submerge large areas of forest land and would store water to enable peaking power generation. As a result the Siang river will have relatively less water flow for few hours daily for generation of peaking power during lean season. This storage period will result in drying up of the river, downstream of the Siang Lower dam site during winters. During this time the dry period will be followed by a wet or flow period with uniform flow corresponding to the number of units/turbines generating hydropower. Thus, the riverine ecology will be severely affected on account of modification in flow regime. This change will have

significant impact on the riverine fisheries affecting physiological behaviour like migration and also affecting their growth cycle like maturation and spawning periods.

ii) Siyom River and its Tributaries

Siyom river is a major tributary of Siang River and has six planned hydropower projects viz.

1. Taiyong (56 MW)
2. Jarong (90 MW)
3. Hirong (500 MW)
4. Tato II (700 MW)
5. Naying (1000 MW)
6. Siyom Middle (1000 MW)

Taiyong is in initial stage of investigation; Jarong was investigated and found unviable, Hirong and Naying has prepared DPR, EIA study report and has also completed Public Consultation process; Tato II has been accorded Environment Clearance; Siyom Middle was accorded Environmental Clearance under EIA notification 1994 while the project was with NHPC and later on the project has been acquired by Reliance Power. Total length of Siyom river up to its confluence with Siang at Pangin is about 184 km, out of which 86 km (46.7%) will be affected due to development of these projects, as per the following break up. About 59.70 km of river will be converted into reservoir and 26.30 km of river stretch will be deprived of water after the diversion of water into headrace tunnels for power generation.

Name of Project	Reservoir Length (km)	Intermediate Stretch (km)	Total (km)
Siyom Middle	15.80	0.50	16.30
Naying	7.90	7.20	15.10
Tato-II	4.30	3.90	8.20
Hirong	3.50	10.30	13.80
Jarong	1.60	3.50	5.10
Taiyong	1.60	0.90	2.50
Submergence of Siang Lower	25.00	0.00	25.00
Total	59.70	26.30	86.00

Jarong HEP, which is immediate downstream of Taiyong is not found to be viable and therefore developer has already requested for cancellation of allotment. It is assumed this project will not come and this stretch of 5 km will remain free.

Four projects viz. Hirong, Tato II, Naying and Siyom together will affect about 53.4 Km of the river stretch with hardly any free flowing stretch between adjacent projects. Out of this 31.5 Km will be in reservoirs, 22 km in tunnels and 400 m free flowing stretch as detailed below and can be seen from L-section at **Figure 11.6**. Downstream of Siyom Middle about 50 Km of river is free flowing along the Along town.

Hirong-Tato II	200 m
Tato II-Naying	200 m
Naying-Siang Middle	0 m

Project on Tributaries:

Downstream of Hiron HEP, Sittin river meets Siyom on right bank. Hiron HEP would be tapping the water of Sittin by having a weir and transferring water upstream of Hiron diversion site. Also there is Sittin HEP (24 MW) on Sittin river.

Downstream of Tato II HEP, Tagurshit river meets Siyom on right bank; having two planned projects viz. Tagurshit HEP (84 MW) and Tagurshit II HEP (27.5 MW).

Downstream of Naying HEP, Sike river meets Siyom on left bank; Gameng HEP (37 MW) is planned on Sike river.

Downstream of Middle Siyom HEP, Pitgong river meets Siyom on right bank. Two cascade projects planned on Pitgong are Kaying and Pitgong HEPs each of 14 MW.

Further, downstream Hirit river meets Siyom on right bank. There are two planned projects viz. Hirit (9 MW) and Hirit Korong (30 MW) on Hirit river. Also there are three planned projects on three tributaries of Hirit river viz. Siri Korong on left bank has Siri Korong HEP (58 MW), Soying korong on right bank has Soying Korong HEP (68 MW) and Sibu on right bank has 4 MW HEP by same name.

This large-scale development of Siyom river and its tributaries will alter the flow regime completely. Major areas of concern are:

- 53.4 Km long river stretch being affected by four projects without any free flowing stretch for the river to recover.
- Tributaries draining into intermediate stretch/free flowing stretch are also being exploited for hydropower development, whereas they should be left undisturbed so that they can rejuvenate the main river channel as they are the main contributors of biological production of the main rivers.

iii) Yargyap Chhu

Yargyap Chhu is a tributary of Siyom River and has seven planned hydropower projects on main river, viz.

1. Pemashelpu (90 MW)
2. Kangtangshiri (80 MW)
3. Rego (80 MW)
4. Rapum (66 MW)
5. Pauk (145 MW)
6. Heo (240 MW)
7. Tato-I (186 MW)

Out of above 7 projects, 6 projects (except Rego HEP) have obtained Scoping clearance from MoEF; Kangtangshiri, Tato I, Pauk and Heo HEPs have completed Public Consultation process, but yet to be appraised by EAC for environment clearance. Rego HEP, a tailrace development scheme of Kangtangshiri, is yet to apply for scoping clearance. Out of about 78.80 km long river stretch of Yargyap Chhu from origin to its confluence with Siyom river, these projects will use about 33.6 km (42%) of river stretch.

Name of Project	Reservoir Length (km)	Intermediate Stretch (Km)	Total (Km)
Tato-I	0.30	5.10	5.40
Heo	0.50	5.90	6.40
Pauk	0.70	2.80	3.50
Rapum	1.10	2.00	3.10
Rego	0.00	2.20	2.20
Kangtangshiri	5.50	1.50	7.00
Pemashelpu	0.50	5.50	6.00
Total	8.60	25.00	33.60

Major free stretch of 13.40 Km is between Pemashelpu and Kangtangshiri HEPs, where river is flat and Mechuka town falls in this stretch. Free flowing river stretch in adjacent projects can be seen from L-section given at **Figure 11.7**. Tato I is a tailrace development project linked to Heo tail water and Rego is a tailrace development project linked to Kangtangshiri tail water, therefore, free flowing stretches between Heo and Tato I as well as Kangtangshiri and Rego are not relevant. Overall reservoir length is small on Yargyap Chhu, however 25 Km of the river will be diverted to tunnels. Adequate environment flow release, as worked out for these projects in Chapter 9, would help in mitigating this impact.

In addition, there are two main tributaries of Yargyap Chhu viz. Sangoshi on left bank meets between Pauk and Heo and Sae Chhu on right bank meets between Rapum and Pauk; both have a planned project each. Sangoshi HEP is 12.5 MW and Sae Chhu HEP is 15 MW. Again as mentioned above in case of Siyom river, when there are planned projects on main channel, flow regime modification of tributaries would add to the impact and if left free of development, this would help in reducing the impact of alteration of flow regime of main channel.

iv) Yamne River

Yamne River is a tributary of Siang River and has four planned hydropower projects viz. Yamne Stage I (135 MW), Yamne Stage II (96 MW), Lower Yamne Stage I (75 MW) and Lower Yamne Stage II (87 MW). All the above 4 projects have been allotted and have obtained scoping clearances. Total length of Yamne river from its source up to its confluence with Siang river is about 82 km, these projects will use about 40.70 km (49.6%) of river stretch.

Name of Project	Reservoir Length (km)	Intermediate Stretch (km)	Total (Km)
Yamne Stage-I	4.20	13.30	17.50
Yamne Stage-II	2.70	7.00	9.70
Lower Yamne Stage - I	1.10	9.30	10.40
Lower Yamne Stage - II	0.50	2.60	3.10
Total	8.50	32.20	40.70

More than one kilometre of free flowing river stretch is available between all the projects in cascade and the total free stretch of about 8 km is spread as:

Project	River length (km)
Yamne Stage I-Yamne Stage II	2.90
Yamne Stage II-Lower Yamne Stage I	1.03
Lower Yamne Stage I-Lower Yamne Stage II	2.85
Lower Yamne Stage II-Lower Siang FRL	1.50
Total	8.28

L-section of Yamne River is given at **Figure 11.8**. As can be seen from the above data, three projects viz. Yamne Stage I & II and Lower Yamne Stage I, have long intermediate stretches and in the absence of adequate environment flow large part of Yamne river will remain dry. Therefore, it important to ensure that recommended environment flow is maintained in these stretches throughout the years. Additionally, assessment of contribution of intermediate catchment needs to be assessed during individual project EIA studies. Any major nallah/stream falling in intermediate catchment should be kept free of hydropower development.

v) Simang River

Simang River is a tributary of Siang River and has only two small planned hydropower projects viz. Simang I (67 MW) and Simang II (66 MW). L section of Simang River is given at **Figure 11.9**. Free flowing river stretch between two projects is 950m. River stretch affected by each projects is as follows:

These two projects viz. Simang I & II have significant intermediate stretches and in the absence of adequate environment flow large part of river will remain dry. Therefore, it important to ensure that recommended environment flow is maintained in these stretches throughout the years. Additionally, assessment of contribution of intermediate catchment needs to be assessed during individual project EIA studies. Any major nallah/stream falling in intermediate catchment should be kept free of hydropower development.

Name of Project	Reservoir Length (km)	Intermediate Stretch (km)	Total (km)
Simang-I	1.60	5.40	7.00
Simang-II	1.00	7.70	8.70
Total	2.60	13.10	15.70

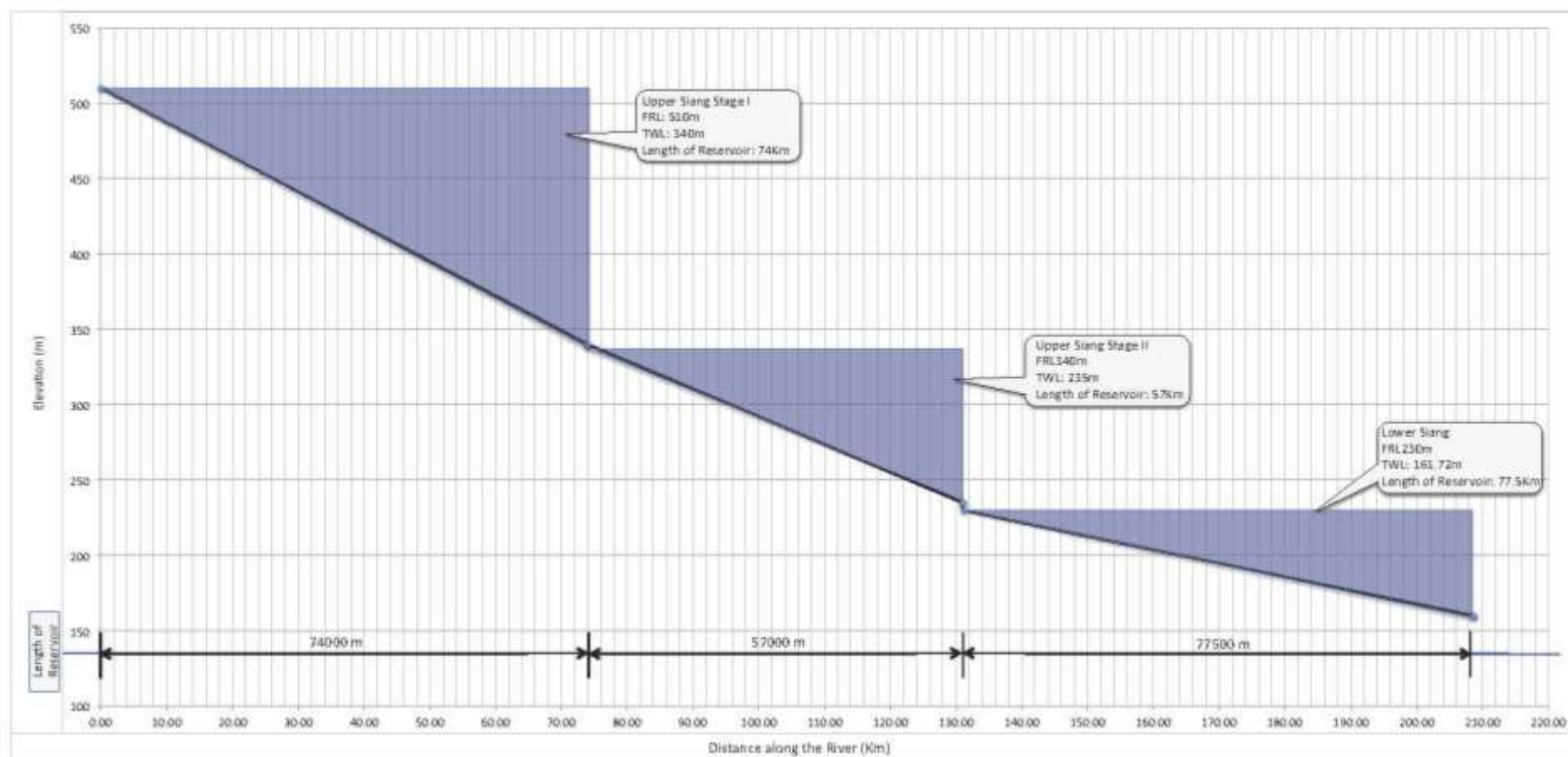


Figure 11.5: L-section of Siang River

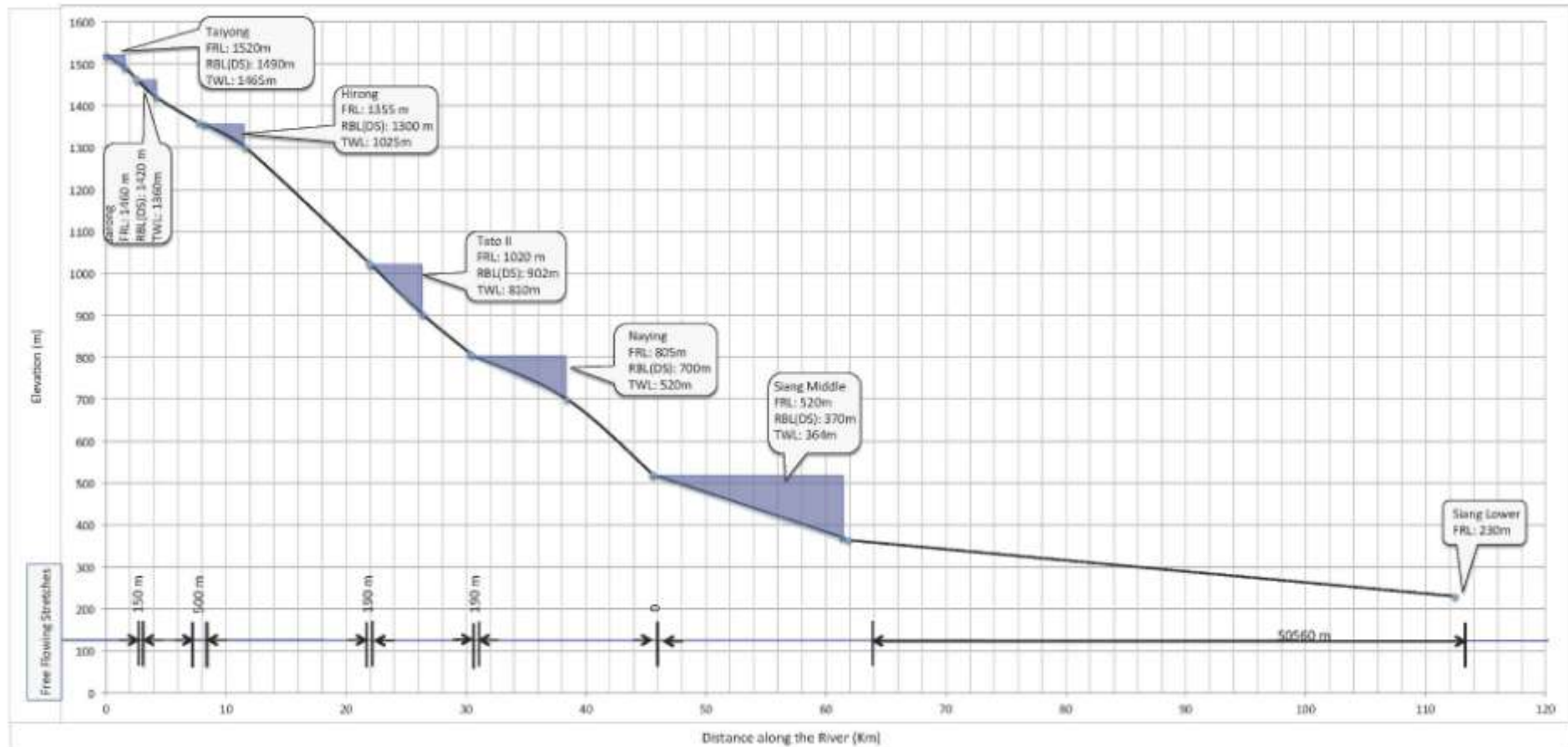


Figure 11.6: L-section of Siyom River

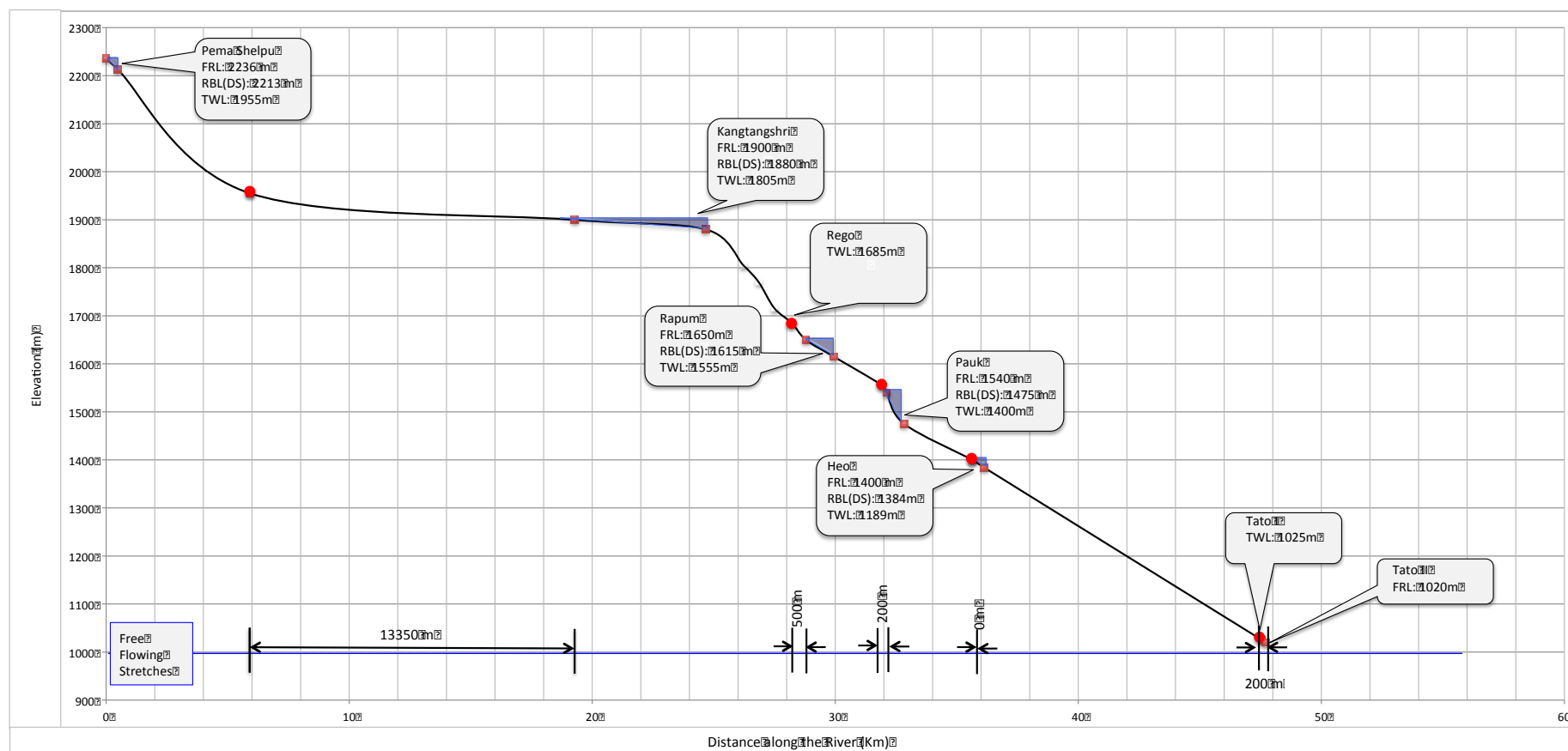


Figure 11.7: L-section of Yargyap Chhu

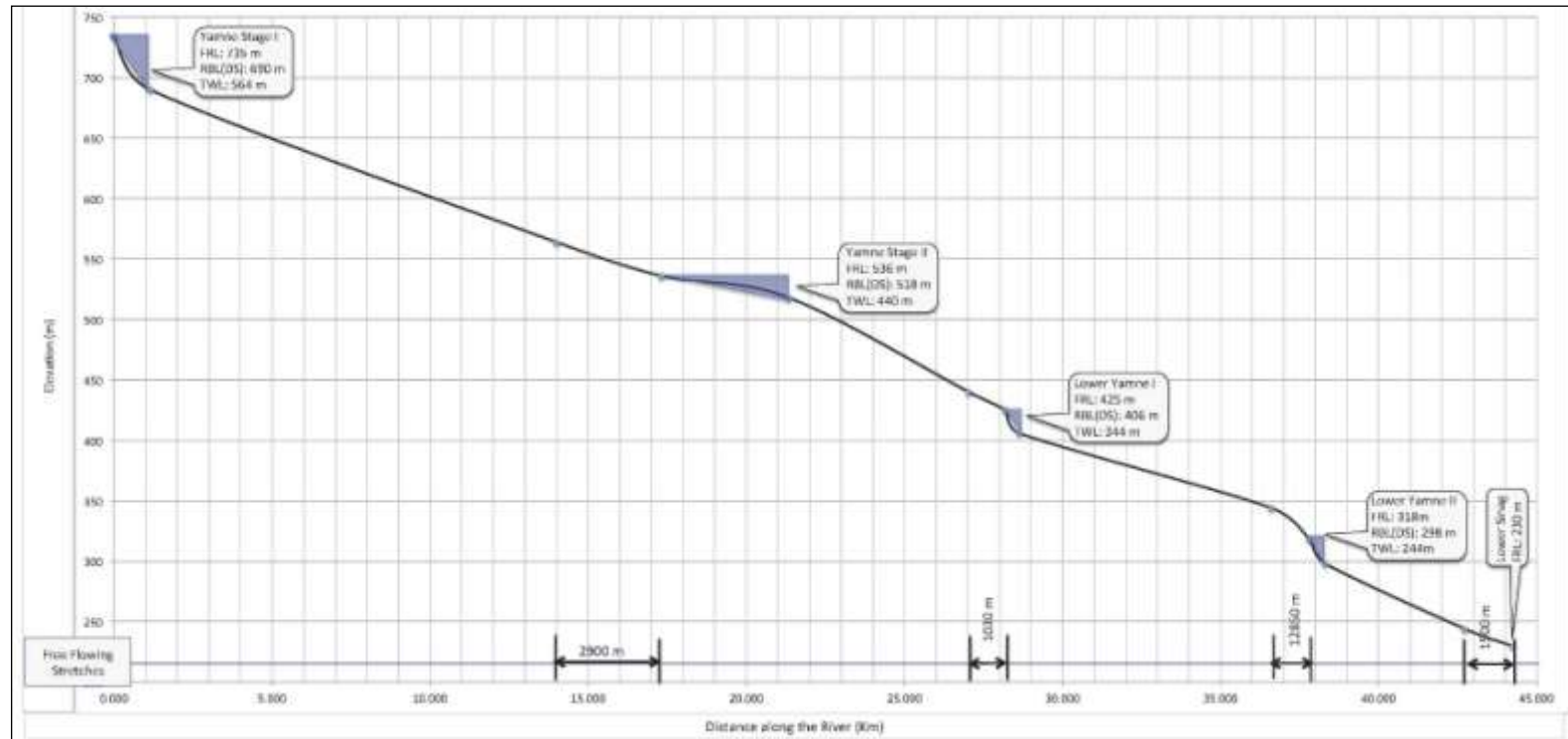


Figure 11.8: L-section of Yamne River

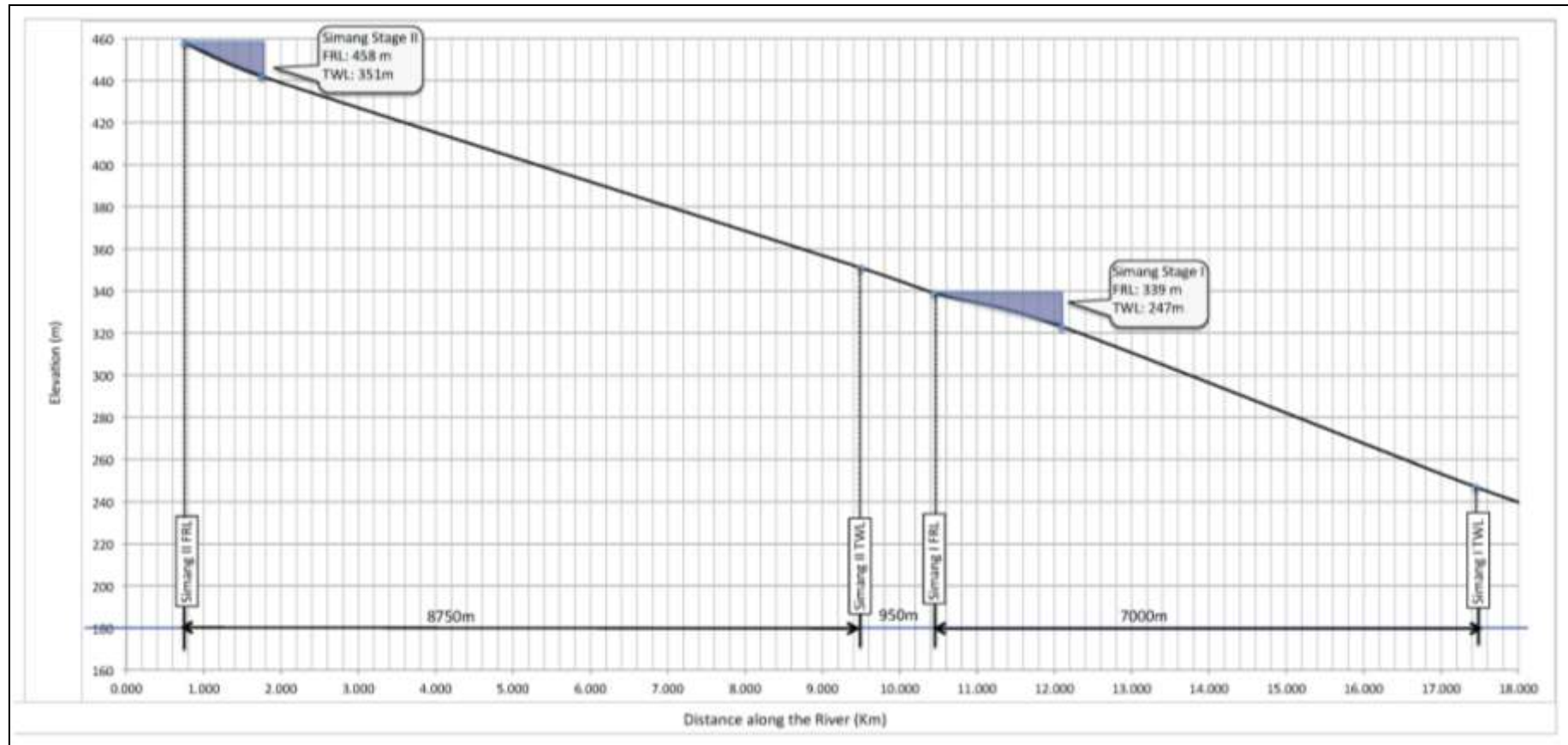


Figure 11.9: L-section of Simang River

11.4 DOWNSTREAM IMPACTS

A cumulative impact study has been carried out to quantify the downstream impacts due to peaking power generation by the projects on main Siang River viz. Siang Lower HEP and Siang Upper Stage I and Stage II HEPs and also by Siyom Middle HEP, which is a large project planned on Siyom river upstream of confluence of Siyom with Siang river. Hydrodynamic routing was carried out using MIKE 11 model, where different combinations of operations were simulated and flow variation was studied in the extended downstream reach upto Guwahati. Impacts of modification of flow regime in downstream reach due to peaking operations are discussed in ensuing paragraphs.

Downstream impacts include loss of fisheries; changes in *beel* (wetland) ecology in the floodplains; impacts on agriculture on the chapories (riverine islands and tracts); impacts on various other livelihoods due to the blockage of rivers by dams (e.g. driftwood collection, sand and gravel mining); increased flood vulnerability due to massive boulder extraction from river beds for dam construction.

Projects on main Siang river have been planned as dam toe projects with sufficient storage capacity to generate peaking power. Peaking power generation in most part of monsoon is generally of the order of 24 hours where plant run at installed capacity round the clock releasing water downstream which is equivalent to its design discharge. As the projects operate as run of the river projects, downstream releases are expected to be in tune with that of normal monsoon discharge in the river. Water available in addition to that of design discharge is released from the spillway and thereby variation in river flow is also reflected in the downstream discharge. In non-monsoon season i.e. during 4 months of lean period and other 4 months of pre-monsoon and post monsoon season, discharge in river is not enough to do 24 hours peaking or run the plant at installed capacity, therefore, reservoir storage capacity is used to store water to run the plant during the time of peak demand. During the storage period only, minimum prescribed environment flow is released. This alternating dry and flooding is likely to affect the downstream areas the flood plains especially the D'Ering Memorial WLS that is home to rich avian diversity, which is evident from the demarcation of the sanctuary as one of the IBAs.

There will be drastic daily fluctuation in river flows downstream of Siang Lower HE project during lean season. For example, the average winter (lean season) flow in the Siang river in its natural state is approximately 900 cumec. Both the ecology of the downstream areas and people's use of the riverine tracts in winter is adapted to this 'lean' but relatively uniform flow of water on any particular day. Chapories like Lali Chapori in the D'Ering Memorial WLS and Kobo Chapori in Assam for example, which are exposed and drier in winter, are used by wildlife, as well as for agriculture and cattle grazing purposes by local communities. After the implementation of the Siang Lower project, flows in the Siang river in winter will fluctuate drastically on a daily basis from 178 cumec for around 20 hours (when water is being stored behind the dam) to 4970 cumec for around four hours when the water is released for power generation in the evening hours.

Diurnal variation in winter in the downstream reach of Siang will have adverse impact on Siang river floodplain ecology, particularly for ground flora and fauna. Mammals, birds, reptiles and amphibians that live on the ground of the chapories (small islands that form in the winter season) will be severely affected and some of them will either be drowned or obliterated. The

eggs or young ones of the breeding animals will suffer badly. These chapories do experience seasonal flooding due to change of river flow in monsoon during which most of the animals move away to drier areas. In the dry lean winter season there is hardly any flooding of river for several months and this is the time when most of these birds and animals come to inhabit these chapories and often breed there. Sudden releases of water flow even for a few hours in the lean season will cause daily floods in large parts of these low-lying chapories. The breeding behaviour of birds, reptiles and mammals is not adapted to such levels of daily flooding in the breeding season. The populations of highly threatened species like the Bengal Florican and Swamp Francolin found in small pockets of suitable habitat for the survival of these species in these areas will be lost. The low fluctuations would also affect the fish populations thriving in the transition zones in the foothills. For example, in the winter, some species breed in the shallow waters (*Barilius* species), while other species such as *Channa* spp. hibernate along the shorelines. Such massive flow fluctuations will destroy these natural processes for many such species.

11.5 D'ERING MEMORIAL WILDLIFE SANCTUARY & OTHER DOWNSTREAM AREAS

The morphology of Siang river changes as the river emerges from the hills into the plains from Pasighat. The bank full river bed is 2-2.5 km wide at the point where it enters into the plains. Bifurcation of river takes place on eastern side, where one of the branch flows on right banks (about 400m wide) and makes northern boundary. Pasighat town is situated in the north of D'Ering Memorial Wildlife Sanctuary (DEMWS) and always faces threats from heavy floods. The second branch again gets fragmented into many small rivulets/multiple channels feeding the wildlife sanctuary area and its farthest branch makes southern boundary which is about 900m wide. However river is having multiple channel morphology of floodplains with sandy beds and sand bars (about 4.70km). D'Ering Memorial WLS, from where one of the branches flow at the north bank and other branch flow towards south bank of the sanctuary, which later again join at the far end point of sanctuary area. The total area of D'Ering Memorial WLS, which is comprised of Siang-Dibang wetlands is spread over 190 sq km. Dibang river, however joins Siang river downstream of the sanctuary area. The entire area of wildlife sanctuary is characterized by an island morphology interspersed with channels, large pools, flats, etc. There are many *beels* (ox-bow lakes and depressions with swamps and marshes at the edge) in the flood plains including the D'Ering Memorial WLS in the Siang River.

This stretch of river Siang in Arunachal (including D'Ering Memorial WLS) and after it leaves the state to enter Assam is comprised of islands, small streams, rivulets and springs which form an important habitat for a large variety of birds which is typical of such wetlands. Various kinds of aquatic birds are extremely common, closely interacting with the other faunal elements including mammals, reptiles, amphibians and fish populations. Tall grasses like Elephant grass provide suitable habitats for their growth and breeding requirements. The *beel* (ox-bow lakes) margins are covered with reeds (*Arundo donax*) and herbs (*Alpinia allughas*). The life cycle of aquatic birds is closely linked to the floods. Avian breeding seasons coincide with those of the fish and the fledglings are being reared at just that time when small fish suitable for their feeding are most abundant. There is a particular heavy predation during the period of receding water when many fish are stranded in temporary pools (Lowe-McConnell, 1964; Bonetto, 1975).

Immediately after Siang enters Assam it is joined by Dibang and Lohit rivers constituting Brahmaputra and in it lies number of islands like Kobo Chapory (river islands), which is the

nearest such island (about 4.5 km from state boundary) and seasonal lagoons called *ghulis*, which are home to large diversity of aquatic birds (refer Figure 11.10). It harbours 176 species of birds including 19 RET species (IUCN) and 74 species of fishes including 13 RET (IUCN) species along with 2 new fish species reported recently from this area. The entire stretch of river Siang, right from the Siang Lower HEP dam site up to confluence of Siang with Dibang and Lohit is marked by stretch of open water for a distance of more than 60 km.

These freshwater habitats provide a conducive environment for aquatic birds (resident and migratory). The important aquatic birds which dwell on these habitats as resident or winter visitor in the area of Siang Lower HE Project including the D'Ering Memorial Wildlife Sanctuary and Kobo Chapory are -Great Cormorant (*Phalacrocorax carbo*), Black Stork (*Ciconia nigra*), Goldeneye Duck (*Bucephala clangula*), Little Ringed Plover (*Charadrius dubius*) and Pied Kingfisher (*Ceryle rudis*) which are common aquatic birds. Various species of waders throng the edges often resting in the shallow water in the typical one-legged stance. Black storks are very common near Kobo Chapory. The river banks are also important nesting sites for the kingfishers. Kobo Chapory has been proposed as Reserved Forest and is an important part of Dibru Saikhowa National Park complex, which is located on southern bank of Brahmaputra river and is at distance of about 12 km from interstate boundary (refer Figure 11.10). Rahmani (2011) has recently studied and concluded that Demwe Lower HEP on Lohit river will have adverse impact on the biodiversity of chapories of Brahmaputra downstream including Dibru Saikhowa National Park.

11.5.1 Impacts of Peaking in Lean Season

Based on the modeling exercise (refer Chapter 10), peaking releases from projects on main Siang river have been studied to understand the change in water level at D'Ering Memorial WLS on daily basis in lean season and also up to Guwahati in Assam. Following cases have been studied:

Case I: Only Siang Lower HEP Operational

Case II: Siang Upper as well as Siang Lower HEPs Operational

Case III: Only Siang Upper HEPs Operational

In addition, another case is considered where natural condition lean season discharge (present situation i.e. no project in place) is simulated. This provided the baseline information, whereas impacts of rising water level on D'Ering Memorial WLS on diurnal basis was studied with respect to baseline under cases I, II and III. In all the three cases, operation of Siyom Middle has also been accounted for. On D'Ering Memorial WLS, three locations have been studied where actual surveyed river cross sections are available. These locations are at a distance of 20 km (the northernmost boundary of D'Ering Memorial WLS and Sigur corridor of elephant migration), 25 km (about 4 km upstream of Mebo-Kongul elephant migration corridor) and 33 km (about 5 km downstream of Mebo-Kongul elephant corridor) from the diversion site of Siang Lower HEP (refer Figures 8.4 & 8.5 in Chapter 8). Model output for each location is given in previous chapter. Increase in water level on three different locations in D'Ering Memorial WLS is given below.

Location	Variation in Levels (m)		
	Case 1	Case 2	Case 3
D'Ering Memorial WLS (20 Km d/s)	5.58	5.90	5.15
D'Ering Memorial WLS (20 Km d/s)	6.56	7.20	6.01
D'Ering Memorial WLS (20 Km d/s)	3.46	3.71	3.10
Dibrugrah	0.34	0.49	0.37
Bokaghat	0.02	0.02	0.01
Tezpur	0.03	0.03	0.00
Guwahati	0.02	0.03	0.00

Case 1: Operation of Siang Lower and Siyom Middle without Siang Upper

Case 2: Operation of Siang Lower and Siyom Middle with Siang Upper

Case 3: Operation of Siang Upper and Siyom Middle without Siang Lower

It can be seen from the above table, peaking power generation by projects on main Siang River in lean season will result in substantial diurnal variation of water level in D'Ering Memorial WLS. Life cycle of avian and aquatic flora and fauna of D'Ering Memorial WLS is closely linked to floods and dry periods and with alteration of their habitat due to peaking discharge, there will be serious impact on entire D'Ering Memorial Wildlife sanctuary. Further, downstream in Brahmaputra river, there will be small diurnal variation in levels up to Dibrugarh (102 Km downstream from Siang Lower HEP), however, beyond that variation is very small and almost nil at Guwahati. Therefore, downstream impacts due to peaking power generation by various projects on Siang river are not observed at Guwahati.

11.6 CONSTRUCTION PHASE IMPACTS

Construction phase impacts are generally dealt in detail during individual project EIA study with respect to local environment setting. For cumulative environment impact assessment, it is important to visualize the cumulative impacts of several projects under construction, simultaneously. 44 hydropower projects are considered as part of this cumulative EIA study of Siang basin and none of the projects have started construction. Around 50% projects are at various stages of survey and investigation and remaining are still in preliminary stages without any investigation work on ground. It is expected that it may take another few years before a medium to large size project will start construction in the basin, followed by another and so on. Thereafter there will be a peak period when several projects will be under construction at the same time. This construction phase might last for 10-15 years before large part of construction work will be over in the basin and many of the projects will be under operation.

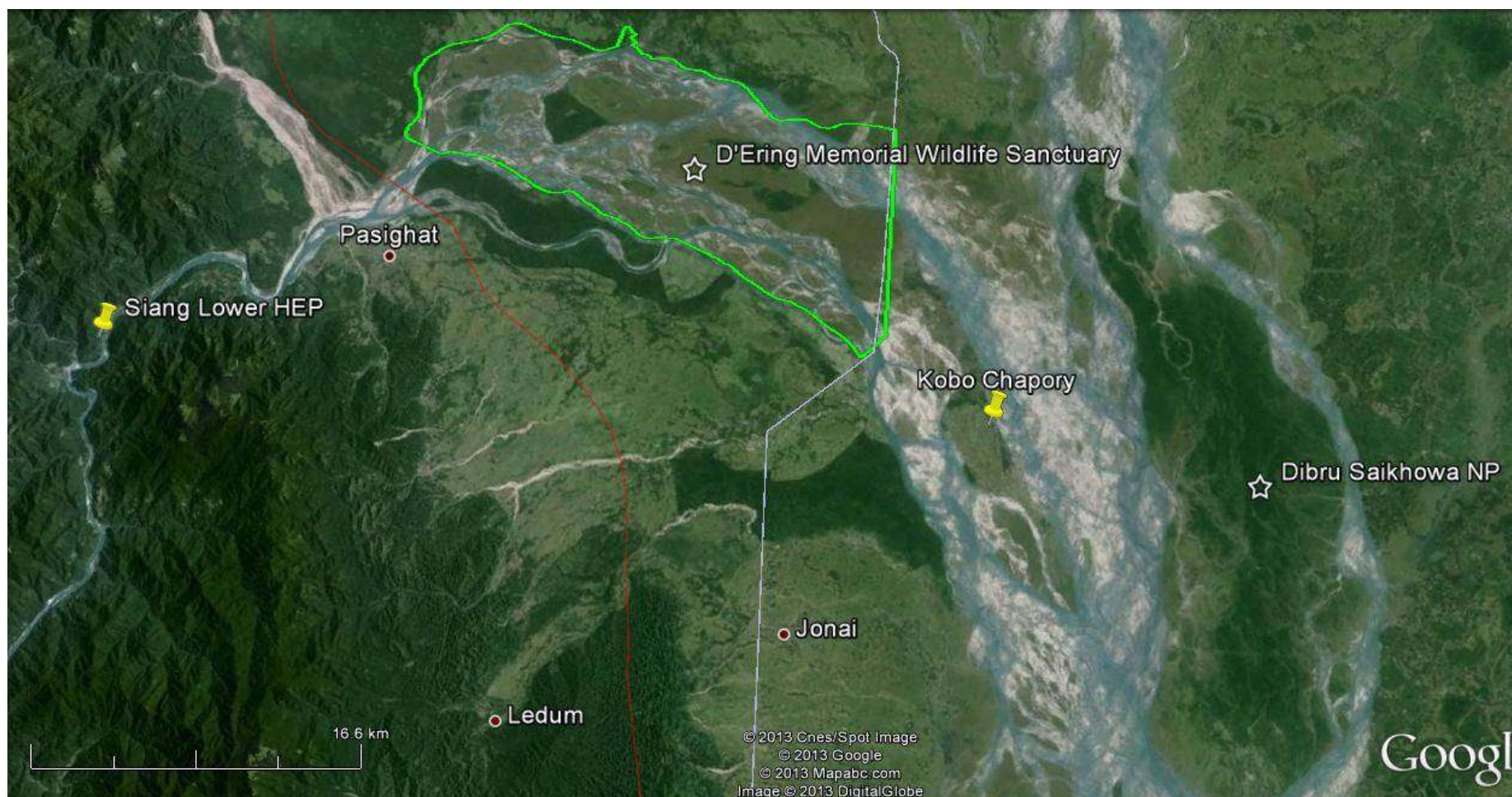


Figure 11.10: Siang Lower HEP vis-à-vis D'Ering Memorial Wildlife sanctuary & Dibru Saikhowa NP in Assam

Though environmental impacts attributed to construction phase of hydropower projects are considered temporary in nature, lasting mainly during the construction phase and often do not extend much beyond the construction period, their impacts however need to be minimised during this phase. The construction phase of Hydroelectric Projects is fairly large; therefore these impacts are required to be managed by strict implementation of pollution control and environment management measures. As the limited project data is available at this stage, quantification of construction phase impacts in detail is not possible. This is also not part of the scope of the present study. Broad framework of major impacts is discussed with recommendations/guidelines wherever possible.

11.6.1 Human Interference

Entire Arunachal Pradesh is scarcely populated. Average population density of three districts of Siang region (East Siang, West Siang and Upper Siang) is 13.3 persons per sq km. Construction of hydropower projects is labour intensive work and would lead to influx of manpower. Type of manpower needed in terms of skill sets and number, locals can only meet a small part of the total requirement and rest will come from outside the state. Project construction being long-term activity and generally located in remote areas, establishment of labour camps near construction sites is only practical solution. Labour requirement for a project will depend upon size and type of project and construction management and planning schedule. For a typical 1000 MW project, migrant population will be of the order of 2500-3000 persons including labours and their families, during peak construction period. With a few projects under construction simultaneously on the same river in cascade, this number will be multiplied and far exceeds the local population in that area. Such a large influx of people in otherwise pristine tribal area, can lead to several impacts requiring careful management to minimize their impacts. Major impacts include:

- Labour camps, in the absence of waste management system, can have serious impact on water and land environment as disposal of sewage and solid waste, in otherwise pristine and hilly terrain will seriously pollute land and water environment. Therefore, it is important to ensure that Sewage Treatment and Solid Waste Management measures are designed and implemented for the entire duration of the project. Pollution Control Board needs to be strengthened to monitor implementation of such measures.
- Labour generally resort to tree cutting to source wood for cooking and space heating and also hunting and poaching of wildlife in remote areas can become a common practice, if not controlled strictly. Developers need to ensure that the provision of adequate fuel to labour for cooking and space heating is made binding in contract for all the contractors. Forest Department need to monitor and control such damages with penalties to offenders.
- Influx of large labour force will increase the load on local infrastructure such as schools, hospitals, etc. Therefore, developers should plan as part of project budget to improve local infrastructure with a view to provide adequate medical and other amenities to migrant labour force as well as to local population.
- Influx of large labour force can also lead to introduction of new diseases in the area. Developers have to ensure through contractors, that before introduction of labour, they should undergo health check-up and persons with communicable disease should not be given entry unless he/she is disease free. After initial screening regular health check-ups should be organized and

record maintained till the completion of the project. Local medical officers need to be involved for certification.

11.6.2 Sourcing, Storing and Transportation of Construction Material

Out of main construction material viz. cement, steel, coarse aggregate and fine aggregate; aggregate requirement is met locally. In addition, to use the muck generated from excavation, some specific quarry sites are identified near the project site to quarry material for construction. Opening of the quarries cause visual impacts because they remove a significant part of the hills and with several projects coming under construction on the same river, large quarry sites or several quarry sites can spoil the local land scape altogether, unless the impact is adequately managed. Other impacts will be the noise generated during aggregate acquisition through explosive and crushing, which could affect wildlife in the area, dust produced during the crushing operation to get the aggregates to the appropriate size and transport of the aggregates, and transport of materials.

Storage of large quantities of construction material near construction sites and temporary storage of muck before disposal can spoil the local air quality with high levels of SPM and RPM. Strict implementation of Pollution Control and Environment Management measures can only mitigate such impacts. Regular monitoring, auditing and reporting to authorities should be made part of the EMP and Pollution Control Board should be strengthened to supervise all the construction activities to ensure that planned measures are implemented.

Transportation of construction material from outside the project area to the site will be a regular activity, once a project becomes operational. This should be considered as one of the major impact of hydropower project during construction phase. With several projects under construction at the same time, such impact will multiply with the number of projects. Road network is not designed to handle heavy traffic carrying raw material for construction; with substantial increase of heavy traffic impact will be severe and long term. A detailed separate study is needed at this stage where based on predicted traffic volume, infrastructure improvement plan can be prepared and implemented.

11.6.3 Operation of Construction Plant and Machinery

Operation of construction plants, machines and equipment will lead to pollution generation in various manifestations viz. air pollution, noise generation, wastewater generation, solid and hazardous waste generation, etc. These construction plants set up locally near the project sites are as good as industrial units generating pollution. Pollution generation should be controlled by use of pollution control equipment such as silencers/mufflers for DG sets, waste water treatment plants, etc. Pollution Control Board will play an important role in ensuring that pollution control measures are taken and all the required emission limits are adhered to at all the time.

11.6.4 Muck Disposal

The construction of hydropower involves generation large quantities of as a result of activities like tunnelling, road construction, etc. In a hilly terrain like Himalaya the disposal of muck generated from excavation has been a matter of grave concern over the years. The biggest obstacle in the way of dumping of muck and its rehabilitation is the non-availability of sites for safe disposal as the hydropower project sites in Himalaya characterised by steep slopes and fragile geology. It has invariably been seen that from designated areas for muck disposal, the muck tends to fall into the

river and contaminate its waters. These coupled with faulty disposal practices and improper management further deteriorates the landscape and augment the sediment load in the stream causing severe impact to the aquatic ecosystem as well as increased sediment deposition, siltation etc.

As part of the engineering study an estimation of the muck quantities likely to be generated is made. A part of it is considered for reuse in construction and balance for disposal after adding swell factor. Several samples of muck should be tested for correct estimation of reusable material and swell factor. Data, on quantum of muck generation, re-use and muck requiring disposal including area required for muck disposal, is available only for some of the projects in the basin. Based on this data, a broad estimation is made about the quantity of muck that would be required to be disposed of due to implementation of 44 projects in Siang basin and this amounts to **1630 lakh cum**. Disposal area requirement would depend upon topography and terrain, however, a general estimation showed that about 800 ha of land would be needed for muck disposal.

As muck disposal is a major cause of concern in hydropower projects, it is therefore of utmost importance to follow certain guidelines which if implemented can help in mitigation of impacts generated by this process. An attempt therefore has been made to prepare a general guideline for safe disposal of muck causing minimum environmental damage and the same has been appended as **Annexure-II** in this volume.

CHAPTER-12

CONCLUSIONS & RECOMMENDATIONS

Previous chapter has discussed the cumulative impacts of development of 44 hydropower projects in Siang basin keeping in view the baseline setting in the region. This chapter deals with specific recommendations for sustainable and optimal ways for hydropower development in the basin.

Recommendations are based upon the impacts evaluated and probable scenarios on biodiversity values, riverine ecosystem, riparian habitats, and environmental flow requirements in certain river stretches vis-à-vis proposed hydropower projects planned. Presently none of the project is under construction; these are planned projects under different stages of survey and investigation, environmental clearance processes, preparation of detailed project reports, obtaining various statutory approvals, etc., therefore, proposed recommendations, even if they lead to modification of project locations/parameters can be implemented during early stages of project lifecycle.

Recommendations are made under three major heads, keeping in view the outcome of the study as per scope of work, and are discussed in the ensuing text.

12.1 SUSTAINABLE AND OPTIMAL WAYS OF HYDROPOWER DEVELOPMENT

12.1.1 *Preclusion of projects*

Extensive exploitation of the basins resources have been planned by way of developing hydropower projects at almost all possible locations in the basin. For sustainable and optimal ways of hydropower development in the basin, projects which are not found to be ecological viable, are located in highly fragile areas, located on tributaries but are restricting the natural of the main channels, etc. have been recommended to be dropped.

Yemsing (38 MW), Nyikong (13 MW) and Sipit Upper (45 MW)

Biodiversity values of the entire Siang basin are assessed in Chapter 8. It is under dense to very dense forest cover, which harbor rich diversity of flora and fauna. All the sub-basins harbor varying diversity of flora and fauna wherein some of the sub-basins are comparatively rich in terms of floristic diversity and others are rich in mammalian and bird diversity as well as fish. Overall assessment of biodiversity values show that Siang Sub basin I and II are comparatively richer sub-basins. Large scale development is planned in these two sub-basins in terms of Lower Siang HEP, Siang Upper Stage I and II HEPs. These projects would be affecting almost entire stretch of main Siang river and additionally, their submergence area would extend to most of the tributaries. Keeping in view, the ecological sensitive of the basin and large scale planned development of main river, it is recommended that smaller projects on tributaries viz. Yemsing, Nyikong and Sipit Upper, be dropped in Siang sub basin I and II.

Additionally, an analysis of the river length affected per MW of installed capacity (Table 12.1) show that Nyikong is ranked number one as it would be affecting 8.7 Km of the river for 13 MW capacity and Yemsing would be affecting 8.8 Km of the river length for 38 MW. Dropping these projects will have little impact on power generation, whereas long river stretches will be saved in this biodiversity rich area.

Jarong (90 MW)

Jarong is a proposed project in upper reaches of Siyom river. Project has been allotted by State Government, however, after initial assessment it was found to be technically and economically unviable and therefore, the developer has requested the state government to cancel the allotment. As the project has already been considered unviable, it is recommended not to allot the project again as this will ensure that 5.1 Km of Siyom river stretch between upstream Taiyong HEP and downstream Hirong HEP will remain a free flowing river stretch.

Sittin HEP (24 MW) and Diversion of Sittin River for Hirong HEP

Sittin HEP is a planned project on Sittin river which is a left bank tributary of Siyom river and drains downstream of proposed diversion site of Hirong HEP.

The degree to which the impacts take place and disrupt the services provided by free-flowing rivers depends to some extent on the location of the diversion structure. River diversion just above the confluence with a large tributary which contributes a substantial percentage of the rivers flow will have a smaller impact than diversion just below the confluence, which effectively diverts both the tributary and the main river. It is therefore recommended that the tributary habitats, which are important for the migration of species and also act as natural resource provider to main channel should be protected. This is particularly important in those tributaries, which drain into the intermediate stretch of main channel downstream of diversion dam/barrage or in the free flowing river stretch between adjacent projects in cascade. In these locations, their contribution assumes importance that they not only augment the discharge but also provide resource inputs into the main channel.

Keeping this in view, it is recommended that Sittin HEP should be dropped to protect the tributary habitat.

It is also important not to divert the Sittin river for augmenting the capacity of Hirong HEP because this will deprive the 10.3 Km long intermediate stretch of Siyom river the entire contribution of Sittin river in terms of discharge as well as resource.

Hirit (9MW), Hirit Korong (42 MW), Soying Korong (48 MW), Siri Korong (58 MW) Sibü (4 MW)

Hirit river is one of the rivers where fish species like mahseer (*Tor putitora*) migrates for spawning and breeding. *Labeo pangusia* is another fish, which prefers waters of Hirit river for spawning. The lower stretches of Hirit river and stretch of Siyom river 2-4 km downstream and upstream of confluence of Hirit river with Siyom, is known for fishing activities and harbours good diversity of fish (more than 50 species are reported from this small area only). The discontinuity of habitats of these important fishes due to construction of several hydropower projects would have adverse impact on their populations and their reproductive behaviour.

All the projects in Hirit basin are in eco-sensitive zone i.e. within 10 km radius of Yordi Rabe Supse Wildlife sanctuary. Additionally, on the basis of percentage forest cover Hirit sub-basin has the maximum area under forests i.e. it has 97% of its area is under forest cover. Therefore, keeping this in view it is recommended that entire Hirit basin is kept free of development.

Hirit HEP and Hirit Korong HEP are planned on Hirit river; Siri Korong, Soying Korong and Sibü HEPs are planned on its three different tributaries by same name. It is therefore recommended that these five projects planned in a small and ecologically sensitive sub-basin be dropped.

Kaying (14 MW)

Kaying is a small project on right bank tributary of Siyom river which drains downstream of Siyom Middle HEP. For 14 MW installed capacity, 5.7 Km of river length is getting affected. Further, Kaying HEPs falls in eco-sensitive zone i.e. within 10 km radius of Yordi Rabe Supse Wildlife sanctuary. Keeping this in view and also to protect the tributary habitat, Kaying is recommended to be dropped.

Sae Chhu (15 MW) and Sangoshi (12.5 MW)

These are two small planned projects on separate tributaries of Yargyap Chhu, where seven projects are proposed. Therefore, to conserve the tributary habitat, it recommended to drop these two small projects on tributaries.

Palsi HEP (24 MW) and Gameng HEP (37 MW)

Palsi HEP s planned on Palsi River, which is a right bank tributary of Siang River.

During the environmental flow assessment it was observed that natural river flow is very small in Palsi river; average monsoon flow in 90% DY worked out to be 6.7 cumec which reduces to 1.7 cumec in lean season. Catchment area is only 92 sq. Km. For a long Intermediate stretch of 5.2 Km, hardly any flow will be left if the water is diverted.

Gameng HEP is also a similar case where substantial higher environmental flow provisions are required to meet the habitat requirement. Lean season flow requirement has been worked out as 35%. After meeting environmental flow requirement as discussed in Chapter 9, there will not be sufficient water left for power generation in these two projects. Projects on such small tributaries are not desirable especially in the case when main channels are being developed for hydropower generation.

Keeping the above in view, it is recommended that Gameng and Palsi HEP should be dropped.

Comprehensive list of projects recommended to be precluded

Comprehensive list of projects recommended to be precluded in Siang basin is given in Table 12.1. It can be seen from the table that by dropping 15 projects, only 473.5 MW of installed capacity will be sacrificed as against the total installed capacity of 18293 MW; which is about 2.6% reduction but would save about 59.5 Km of the river length in ecologically sensitive area. This would mitigate not only direct impact on forest and river reach but also substantial indirect impact on ecologically sensitive surroundings and would also help in preserving the habitat of main channels.

Table 12.1: List of Projects Recommended to be precluded

Sl. No.	Name of Project	Capacity (MW)	River/ Tributary	Main River	River Length Saved (Km)	Forest Area Saved (Ha)
1	Jarong	90	Siyom	Siang	5.1	65
2	Sangoshi	12.5	Sangoshi	Yargyap	0.7	10
3	Sae Chhu	15	Sae Chhu	Yargyap	3.6	10
4	Sittin	24	Sittin	Siyom	1.2	15
5	Kaying	14	Pitgong	Siyom	5.7	10
6	Hirit	9	Hirit	Siyom	4	5
7	Hirit Korong	42	Hirit	Siyom	2.7	20
8	Soying Korong	48	Soying Korong	Hirit	2.5	45
9	Siri Korong	58	Siri Korong	Hirit	3.1	42

Sl. No.	Name of Project	Capacity (MW)	River/ Tributary	Main River	River Length Saved (Km)	Forest Area Saved (Ha)
10	Sibu	4	Sibu	Hirit	2.1	5
11	Nyikong	13	Nyikong	Siang	8.7	5
12	Palsi	24	Palsi	Siang	5.8	20
13	Sipit Upper	45	Sipit	Siang	1.5	32
14	Gameng	37	Sike	Siyom	4	25
15	Yemsing	38	Yembung	Siang	8.8	25
Total		473.5			59.5	334

It is strongly recommended that after dropping these projects, these river reaches should be kept free. These projects should not be re-allotted by altering their features, locations, names, etc. Also on other free stretches/tributaries no further hydropower projects should be planned/allotted in the entire Siang basin even if they are small (less than 25 MW) and do not fall under the purview of EIA notification.

Environmental impacts are not directly proportion to installed capacity of the project; they are to be assessed with respect to project location, surrounding and project features. Therefore, it is recommended that Government of India should review the matter and consider bringing smaller i.e. less than 25 MW hydropower projects also under the purview of the EIA notification so that their impacts are adequately addressed and mitigated/managed.

12.1.2 Modification of Projects' Configurations

On main Siyom River, four projects in cascade taking about 55 Km of the river stretch will impact the river ecosystem. There should be at least 1 Km of free flowing river stretch between adjacent projects when river can flow in natural conditions with full flow in all the seasons to ensure habitat connectivity and preventing landscape fragmentation. All these four projects viz. Hirong, Tato II, Naying and Siyom Middle are in advance stages of Survey and Investigation.

Instead of dropping a project and increase the inter-project riverine reach, it is recommended that FRL of three projects viz. Tato II, Naying and Siyom Middle should be slightly reduced so that free flowing river stretches of 1 Km can be maintained between FRL and TWL of these four projects in cascade.

12.1.3 Development of Projects in Proximity to Protected Areas

Though biodiversity rich areas with critically sensitive habitats have already been delineated into Protected Areas like D'Ering Memorial Wildlife sanctuary, Mouling National Park, Yordi Rabe Supse Wildlife sanctuary and part of Dibang-Dihang Biosphere Reserve, there are large areas outside these Protected Areas which harbor rich biodiversity. The implementation of hydropower projects in such areas need to be taken up with caution. The cumulative impacts of these projects on biodiversity would be significant, which otherwise may not get captured in project specific studies, where they were to be assessed individually.

Simang -II, Gameng, Siyom Middle HEPs are located within 10 km radius of Mouling National Park. Siang Upper Stage - I is a large project and is located at a distance, little more than 10 km radius of Mouling National Park. Tagurshit-II HEPs on Tagurshit Nala and Pitgong on Pitgong Nala are located within 10 km radius of Yordi Rabe Supse Wildlife sanctuary. During individual project

assessment, references has to be taken from biodiversity assessment of these project areas as is done in Chapter 6-8 of this report so that comprehensive management plans can be prepared for impact mitigation.

12.1.4 Integrated Biodiversity Conservation Plan

To conserve the rich biodiversity of the basin, it is recommended that the State Wildlife Division under Department of Forests prepares an Integrated Biodiversity Conservation plan for the Siang basin rather than having individual project based conservation plans in consultation with State Forest Research Institute, Itanagar and Wildlife Institute of India, Dehradun. The database on biodiversity generated under this basin study should be maintained at SFRI, Itanagar which need to be further updated continuously for use by the stakeholders and policy makers for taking informed decisions.

12.1.5 Management of Construction Phase Impacts

Cumulative construction phase impacts become very significant due to large-scale development in the basin, which is otherwise pristine and has never faced any pollution load. As the impacts are largely related to:

- Increased pollution load - air emissions, water pollution, solid and hazardous waste generation
- Impact on forest and wildlife due to influx of workforce
- Socio-economic and socio-cultural impact due to influx of workforce

The construction related impacts can be minimised to great extent if mitigation measures are taken during construction period diligently, some of these are:

- Control of Dust by water sprinklers
- Covering and watering of stockpiles
- On-site stockpiles of debris, dirt or rusty material shall be covered or watered at least twice daily to prevent fugitive dust.
- Limiting Hours of Construction
- Control of Traffic
- Covering of Haul trucks
- All haul trucks hauling soil, sand, and other loose materials should either be covered or maintain two feet of freeboard.
- Temporary erosion control measures (such as silt fences, staked straw bales/wattles, silt/sediment basins and traps, check dams, geo-fabric/ geo-textiles, sandbag dikes, and temporary revegetation or other ground cover) need to be employed for disturbed areas.
- Earth dikes, drainage swales, and ditches should be provided to intercept, divert, and convey surface runoff and sheet flow, prevent erosion, and reduce pollutant loading. Specific areas that may need such measures should be identified on the construction drawings.
- Roads used during construction should be swept and cleaned of accumulated earth and debris in the construction zone during project construction, particularly before predicted rainfall events.
- Excavated materials deposited or stored onsite temporarily shall not be placed in or adjacent to open water channels and shall be wetted and covered as necessary to prevent runoff and erosion.
- Oils, fuels, and other toxicants spilled or deposited near the project site shall be removed and disposed of according to applicable laws and regulations.
- Fueling areas will be designated to afford separation from surface waters during fueling activity to prevent accidental spills from reaching the lagoon.

- Establish native grass or other vegetative cover over areas that have been disturbed by construction as soon as possible after disturbance to establish vegetative cover. This will reduce erosion by slowing runoff velocities, enhancing infiltration and transpiration, trapping sediment and other particulates, and protecting soil from raindrop impact.

Constant watch and vigilance need to be observed as fuels, oils, lubricants, and other hazardous materials with the potential to degrade water quality may be released from equipment during construction. Excavation equipment, generators, and other construction equipment would use these hazardous materials on a regular basis during construction. If a fuel tank or an oil line were ruptured, the surrounding environment would be at risk.

12.2 ENVIRONMENTAL FLOWS

There are 44 planned hydropower projects in Siang basin. Three planned projects on Siang River viz. Siang Upper Stage I and II and Siang Lower HEPs, are in cascade without any free flowing stretch between adjacent projects. These three projects and Siyom Middle HEP on Siyom River are planned as dam toe projects with large storage reservoirs; without any significant intermediate stretch. In the absence of detailed project layout at this stage, intermediate river reach if any between dam and tail water outfall point is not known.

Releases from Siang Upper Stage I tailrace will drain into reservoir of Siang Upper Stage II and similarly releases from Siang Upper Stage II tailrace will immediately drain into Lower Siang HEP's reservoir i.e. there is no free flowing river stretch downstream of these two projects. Whereas, Siang Lower HEP on Siang River and Siyom Middle HEP on Siyom river will change the flow regime of downstream river reach due to peaking discharge, especially in non-monsoon period. These projects are designed to run for 24 hours at full capacity for large part of monsoon. During non-monsoon months, water will not be sufficient to do peaking round the clock; therefore during this period to ensure that intermediate stretch, if any, and downstream river reach is not dry for large part of the day, it is recommended that one turbine should be running round the clock during non-monsoon period.

Dam toe projects, depending upon the project layout, can have significant river reach before the tail water outfall locations, which can run dry if no provisions are made for release of environment flow. Therefore, depending upon the project layout environment flow release arrangements are to be made so that water is released immediate downstream of the dam/plunge pool either through the turbine or separately as environment flow.

Out of remaining 40 projects, 15 have been recommended to be dropped. Rego HEP is a tailrace development scheme linked to Kangtangshiri HEP, therefore, does not require specific flow release recommendation. Environmental flow release recommendations for remaining 24 projects have been made in the Table 12.2 below based on the detailed assessment carried out and discussed in Chapter 9, "Environmental Flow".

Table 12.2: Environmental Flow release Recommendation

Sl. No.	Name of Project	Capacity (MW)	Lean Season	Pre and Post Monsoon	Monsoon
1	Naying	1000	20%	20%	20%
2	Tato-II	700	20%	20%	20%
3	Hirong	500	20%	20%	20%
4	Taiyong	56	20%	20%	20%
5	Tato-I	186	20%	15%	15%

Sl. No.	Name of Project	Capacity (MW)	Lean Season	Pre and Post Monsoon	Monsoon
6	Heo	240	20%	15%	15%
7	Pauk	145	20%	15%	15%
8	Rapum	66	25%	25%	30%
9	Kangtangshiri	80	20%	20%	20%
10	Pemashelpu	90	25%	25%	30%
11	Tagurshit	84	20%	25%	30%
12	Tagurshit Stage-II	27.5	20%	25%	30%
13	Pitgong	14	20%	25%	30%
14	Simang-I	67	20%	25%	30%
15	Simang-II	66	20%	20%	25%
16	Pango/ Minnying	96	20%	20%	30%
17	Mirak	141	20%	20%	25%
18	Sippi	96	20%	20%	25%
19	Ringong	150	20%	20%	25%
20	Jidu	92	20%	25%	30%
21	Yamne Stage-I	135	20%	20%	25%
22	Yamne Stage-II	96	20%	20%	20%
23	Lower Yamne Stage - I	75	20%	25%	25%
24	Lower Yamne Stage - II	87	20%	25%	30%
25	Rego HEP	80	No specific recommendation - Tailrace development scheme with Kangtangshiri		
26	Siang Upper Stage-I	6000	Directly draining into lower projects reservoir, without any free flowing stretch Dam toe projects needs to run one unit continuously through out the year*		
27	Siang Upper Stage-II	3750			
28	Siang Lower	2700			
29	Siyom Middle	1000			

*Downstream impacts in lean season are studied, keeping in view the lean season environment flow and peaking discharge available (Chapter 10); running of one unit continuously by Siang Lower HEP and Siyom Middle HEP will slightly alter the scenario resulting in minor variation in levels in the downstream reaches. Such scenarios were also simulated and results are shown in Annexure IX.

Lean Season

Lean Season flow release is found to be adequate for all but two projects with 20% release scenario i.e. 20% of the average discharge of four leanest months in 90% dependable year. Two projects viz. Pemashelpu and Rapum are found to meet habitat requirement in lean season with 25% release, which is 1.1 cumec and 2.65 cumec for Pemashelpu and Rapum, respectively. Therefore, it is recommended that these projects should ensure a minimum environmental flow release of 1.1 cumec (Pemashelpu HEP) and 2.65 cumec (Rapum HEP).

Calculations for environment flow release in lean season should be based on average of four leanest months discharge in 90% dependable year i.e. average of 12 - ten daily values in four leanest months in 90% dependable year. Recommended release in lean season should be worked out as percentage (as per Table 12.2) of the average value and should be subtracted from the every 10 daily value of discharge available in the river in four leanest months, balance should be shown and used as discharge available for power generation.

Monsoon Season

15% of releases have been recommended for Pauk, Heo and Tato I as habitat requirement for base flow is found to be adequate with 15% release where flow depth in trout zone is 121 cm, 146.44 cm and 151.95 cm for Pauk, Heo and Tato I HEPs. Flood peak requirement has been assessed in

detail based on daily long-term data and found to be adequate even without any specific release requirement for monsoon.

20% of release is recommended for Tato II, Hiron, Kangtangshiri and Yamne Stage II. Modeling results show that these projects meet habitat requirement for base flow at 15% release; however, in the absence of flood peak analysis, higher recommendation i.e. 20% release is made. Taiyong is an project upstream of Hiron HEP; therefore in the absence of hydraulic Modeling 20% of release recommendations is made for Taiyong as well.

Naying HEP falls in Mahseer zone and provide adequate depth under 15% release scenario, however, flow depth gets decreased to 44% of pre-project level, 20% is recommended to ensure depth is not reduced less than 50% of pre-project level and flood peak requirement can also be taken care of.

25% of release is recommended for Simang II, Mirak, Ringong, Yamne Stage I and Lower Yamne Stage I keeping in view the flood peak requirement in monsoon. Modeling results show that these projects meet habitat requirement for base flow at 20% release. Sippi is an upstream project of Ringong, therefore recommendations are made on similar lines.

For other projects, 30% of release is recommended. No specific analysis was carried out for Tagurshit, Tagurshit II, Jidu and Pitgong or for any other projects on these rivers; therefore, 30% release is recommended for these two projects.

Calculations for environment flow release in monsoon should be based on average monsoon discharge in 90% dependable year i.e. average of 12 - ten daily values in four monsoon months in 90% dependable year. Recommended release in monsoon should be worked out as percentage (as per Table 12.2) of the average value and should be subtracted from the every 10 daily value of discharge available in the river in monsoon, balance should be shown and used as discharge available for power generation.

Pre and Post Monsoon Season

15% of releases have been recommended for Pauk, Heo and Tato I as habitat requirement for base flow is found to be adequate with 15% release where flow depth in trout zone is 91cm, 107cm and 109.75 cm for Pauk, Heo and Tato I HEPs. Flood pulse requirement has also been met with for 15% release as due to availability of long-term reliable thrice daily data; such assessment could be done.

20% of release is recommended for Tato II, Hiron, Kangtangshiri, Simang II, Pango, Mirak, Ringong, Yamne Stage I and II. Modeling results show that these projects meet habitat requirement for base flow at 15% release; however, in the absence of flood pulse analysis higher recommendation i.e. 20% release is made. Taiyong and Sippi are upstream projects of Hiron and Ringong, respectively; therefore in the absence of hydraulic modeling 20% of release recommendations are made for these projects based on the assessment of downstream projects.

Naying HEP falls in Mahseer zone and provide adequate depth under 15% release scenario, however, depth gets decreased to 45% of pre-project level, 20% is recommended to ensure depth is not reduced less than 50% of pre-project level and flood pulse requirement can also be taken care of.

25% of release is recommended for Rapum and Pemashelpu. Modeling results show that these projects meet habitat requirement for base flow at 20% release; however, in the absence of flood pulse analysis higher recommendation i.e. 25% release is made.

No specific analysis is carried out for Tagurshit, Tagurshit II, Jidu and Pitgong or for any other projects on these rivers; therefore, 25% release is recommended for these two projects.

Lower Yamne Stage I and II and Simang I HEP fall in Mahseer zone. Lower Yamne Stage I and II meet the habitat requirement with 20% release and therefore, 25% is recommended. Simang I is showing about 88.5 cm depth under 20% release scenario and 91.90 cm under 25% release scenario; later is 63.7% of the pre-project depth. Therefore, 25% of release is recommended for Simang I to meet the habitat requirement for base flow and flood pulses.

Calculations for environment flow release in pre and post monsoon months (non monsoon and non lean period) should be based on average discharge in 90% dependable year in two pre-monsoon and two post-monsoon months i.e. average of 12 - ten daily values in four pre and post monsoon months in 90% dependable year. Recommended release in pre and post monsoon period should be worked out as percentage (as per Table 12.2) of the average value and should be subtracted from the every 10 daily value of discharge available in the river in pre and post monsoon period, balance should be shown and used as discharge available for power generation.

12.3 DOWNSTREAM IMPACTS

Downstream impacts of three major projects on Siang river viz. Siang Upper Stage I, Siang Upper Stage II and Siang Lower; and also Siyom Middle on Siyom river have been assessed and discussed in Chapter 10 and 11. Hydrodynamic routing was carried out using Mike 11 model for different combinations of operations of these projects, to assess the cumulative impacts in the downstream reach extended up to Guwahati. As the downstream impacts are more pronounced in lean season, change in water levels were studied under different simulated scenarios and compared with levels during average lean season discharge. 484 Km of Siang river reach from Lower Siang HEP up to Guwahati has been represented through surveyed cross sections. Variations in levels were studied at D'Ering Memorial WLS (three locations), Dibrugarh, Bokaghat (Kaziranga National Park), Tezpur and Guwahati and same are summarised in table below.

Location	Variation in Levels (m)		
	Case 1	Case 2	Case 3
D'Ering Memorial WLS (20 Km d/s)	5.58	5.90	5.15
D'Ering Memorial WLS (20 Km d/s)	6.56	7.20	6.01
D'Ering Memorial WLS (20 Km d/s)	3.46	3.71	3.10
Dibrugarh	0.34	0.49	0.37
Bokaghat	0.02	0.02	0.01
Tezpur	0.03	0.03	0.00
Guwahati	0.02	0.03	0.00

Case 1: Operation of Siang Lower and Siyom Middle without Siang Upper

Case 2: Operation of Siang Lower and Siyom Middle with Siang Upper

Case 3: Operation of Siang Upper and Siyom Middle without Siang Lower

As can be seen the above table, downstream impacts are more pronounced in the initial reach and are cause of concern for D'Ering Memorial Wildlife Sanctuary. Beyond that points variation in levels in Brahmaputra are of the order of 34 cm to 49 cm at Dibrugarh, which is about 102 Km downstream of Siang Lower HEP under different operation scenarios. Downstream of Dibrugarh variation is level in Brahmaputra due to peaking operations of projects on Siang river are insignificant and almost nil at Guwahati.

To mitigate the peaking impacts with respect to diurnal flooding at D'Ering Memorial WLS in lean season, mitigation measures need to be studied in detail separately including their technical and financial viability. Among other alternatives, a compensation basin can be considered, which is a way of reducing the impact of peaking. It is generally implemented directly downstream of the turbine outlet(s). The water is temporarily stored in the basin and then released to the river by a guided system, respecting ecologically defined operation rules. It is recommended that a comprehensive study be conducted to explore various alternatives and work out techno-economic feasibility for regulation of the peaking discharge downstream of Lower Siang HEP.

As discussed earlier, Siang sub-basins I and II have rich biodiversity and three large projects viz. Siang Lower HEP (2700 MW), Siang Upper Stage II (3750 MW) and Siang Upper Stage I (6000 MW) are planned to cover almost entire length of Siang river in India. 208.5 Km of the Siang river will be converted into one continuous reservoir as all the three projects (Siang Upper Stage I and II and Lower Siang HEPs) are planned back to back without any free flowing intermediate river stretch.

On the other hand, the large storage dams on Siang river are considered essential for flood moderation in Assam during monsoon and contributing to the flow in Brahmaputra in lean season. During the monsoon season (June-October), floods are a common occurrence in Brahmaputra and its tributaries almost every year and hit more than one lakh people inundating human habitations and farmland in several districts of Assam and Arunachal Pradesh. A substantial storage in Siang, is being considered for overall flood management of Brahmaputra and other downstream non-monsoon requirements.

As per the CWC data, 100 year and 25 year return flood at Pandu, Guwahati is about 62000 cumec and 55000 cumec, respectively. To mitigate such flood peaks, upstream storage requirements in Siang, Subansiri, Lohit and Dibang sub basins are considered essential. CWC has further analyzed that to bring down the flood peak to 40000 cumec at Guwahati, which would reduce the level in Brahmaputra by 1.2-15m, flood storage of 1.91 BCM in Subansiri, 0.56 BCM in Dibang, 1.61 BCM in Lohit and 9.2 BCM in Siang will be required. Keeping the substantial storage requirement in Siang, storage projects in Siang needs to be re-configured, which may lead to merging of Siang Upper Stage I and II into single project to create storage.

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ANNEXURE

“SCOPE OF WORK”

1. OBJECTIVE OF THE STUDY:-

The basin study envisages providing optimum support for various natural processes and allowing sustainable activities undertaken by its inhabitants. The same is determined in terms of the following:

- Inventorisation and analysis of the existing resource base and its production, consumption and conservation levels.
- Determination of regional ecological fragility/sensitivity based on geo-physical, biological, socio economic and cultural attributes.
- Review of existing and planned developments as per various developmental plans.
- Evaluation of impacts on various facets of environment due to existing and planned development.

The study should involve assessment of stress/load due to varied activities covering, e.g. exploitation of natural resources, industrial development, population growth which lead to varying degree of impacts on various facets of environment. The basin study should also envisage a broad framework of environmental action plan to mitigate the adverse impacts on environment which should be in the form of :

- Preclusion of an activity
- Infrastructure development
- Modification in the planned activity
- Implementation of set of measures for amelioration of adverse impacts.

The basin study is a step beyond the EIA, as it incorporates an integrated approach to assess the impacts due to various developmental projects.

2. STUDY AREA

The study area to be covered as a part of the Basin Study is for entire Siang Basin. The study should be based on secondary as well as primary data collection.

3. DATA COLLECTION

In the present study emphasis should be laid on terrestrial and aquatic ecology. The estimation of supportive capacity of the basin should involve the preparation of the existing scenario i.e., the preparation of detailed data base of the basins. This should be accomplished through the steps outlined in following sections.

3.1 Meteorology

The information on various meteorological aspects is to be collected from India Meteorological Department (IMD) for meteorological stations located within the basin area or in vicinity to the basin boundary. The information on various aspects such as rainfall, temperature wind, humidity etc. will be collected.

3.2 Water Resources

The information on following aspects should be collected:

- Review of drainage characteristics of the basin, including various surface water bodies like rivers and lakes.
- Data collection and review of past studies/reports/data etc.
- Review of existing water sharing agreements for meeting various need-based existing and future demands viz. municipal, irrigation, power generation and industrial.
- Analysis of all, past assessment of the water availability and assessing the water availability, as per updated data for the system as a whole and at existing ongoing/proposed project locations on annual/monsoon/non-monsoon and monthly basis.
- Estimation of sediment load at various points in the basin based on available secondary data.
- Identification of perennial sources of water and their designated usages.

3.3 Water Quality

As a part of the studies, secondary data is to be collected for water quality in the study area. In addition to above, information on human settlement, sewage generated and mode of collection, conveyance treatment and disposal of sewage should also be collected.

The water quality monitoring should be conducted at 45 locations in the study area. The frequency of sampling should be once per month for 9 months including one rainy season. The various parameters include pH, Dissolved Oxygen (DO), Electrical conductivity (EC), Total Suspended Solids (TSS), Total Dissolved Solids (TDS), Total Alkalinity, Total Hardness, Biochemical Oxygen Demand(BOD), Chemical Oxygen Demand(COD), Nitrates, Chlorides, Sulphates, Phosphates, Sodium, Calcium, Magnesium, Potassium, Iron, Manganese, Zinc, Cadmium, Lead, Copper, Mercury, Total Chromium, Total Coliform.

(i) The study may be linked as Cumulative Impact Assessment for Siang Basin and should cover the following aspects :

- Flow regime
- Flood plain including wetlands
- Aquatic ecology
- River morphology
- Sediment transport/erosion and deposition
- Impact on human activities and livelihood

ii) Management of impact and mitigation measures may be included in the study.

iii) Considering the total length of the main river in the basin and the HEPs already existing and planned for future development, how many more HEPs may be allowed to come up. In other words, how much of the total length of the river that may be tunneled inclusive of the tunneling requirement of all the projects that have been planned for development so that the integrity of the river is not grossly undermined.

iv) What may be criteria for downstream impact study in terms of length of the river downstream to the tail water discharge point and what may be the parameters of such a study. Currently the norm is 10 km radius area, which is inadequate for major projects.

v) If the states do not change their policy of allotting elevation-wise river reaches for hydropower development, what criteria the EAC may adopt in restricting the river reach for hydropower development. Alternatively, what should be the clear river length of uninterrupted flow between the reservoir tip at FRL of a downstream project and the tail water discharge point of the immediate upstream project.

vi) What will be the scientific procedure to decide on the minimum lean season flow that must be maintained in the downstream of a dam/barrage and based on such a procedure, what minimum lean season flow must be ensured by the hydropower developer in various reaches of a long river in relation to the aquatic lives and downstream water use.

vii) For peaking stations, what extent of diurnal flow variation may be considered safe for the aquatic life. There are examples where the release is drastically reduced during the long time for reservoir filling and the huge discharge flows through the river during the few hours of peak power generation. This is detrimental to the aquatic environment of the downstream stretch of the river.

viii) For muck disposal, what may be minimum distance that must be maintained between the outer boundary of the muck disposal sites and the river bank. If such a site is not available at the indicated distance and long haulage of muck may be involved for safe muck disposal at sites further away, what may be the pros and cons of including the enhanced cost of muck disposal in the project budget. Thus, the study may highlight on the existing norms, cost of haulage per tonne-kilometer, the percentage of the haulage cost of the total project cost and the extent to which the power may be more expensive to generate.

3.4 Flora

The following data should be collected from various secondary sources for river Siang and its tributaries in the basin area :

- Characterization of forest types in the study area and extent of each forest type.
- Information on general vegetation pattern and floral diversity.
- Presence of economically important species in the basin area.
- Presence of Rare, Endangered and Threatened floral species as per the categorization Botanical Survey of India's Red Data list in the basin area.
- Presence of endemic floral species found in the basin area, if any should be assessed as a part of the basin study.
- Location of wild life sanctuaries, national parks, biosphere reserves if any, in the study area

The field studies should be conducted for sampling at 45 locations to collect primary data on terrestrial ecology in the study area. The monitoring should be conducted for 3 seasons (one should be rainy season). The following should be covered as a part of the EIA study.

- Identification of forest type and density, bio-diversity in the study area.
- Preparation of comprehensive checklist of flora (Angiosperms, Gymnosperms, Lichens, Pteridophytes, Bryophytes, Fungi, Algae etc.) with Botanical and local name.
- Importance Value Index of the dominant vegetation at various sampling locations.
- Frequency, Abundance and density of each species of Trees, Shrubs and Herbs at representative sampling sites should be estimated.

- Identification and listing of plants of genetically, biologically, economical and medicinal importance.
- Major forest produce, if any, and dependence of locals on the same in the forests observed in the study area.

In addition, based on the published literature including various research papers, the information on forest types, presence of various species, biological diversity etc. should be collected for the study area.

3.5 Fauna

The following data be collected from various secondary sources for the study area :

- Inventory of Birds (resident, migratory), land animals including mammals, reptiles, amphibians, fishes etc reported & surveyed in the basin area should be prepared.
- Presence of RET faunal species as per the categorization of IUCN Red Data list and as per different schedules of Indian Wildlife Protection Act, 1972 in the basin area.
- Presence of endemic faunal species found in the basin area, if any should be assessed as a part of the Basin Study.
- Existence of barriers and corridors for wild animals, if any in the basin area should be covered as a part of the study.
- Identification of threats to wildlife in the region.
- Presence of National Park, Sanctuary, Biosphere, Reserve Forest etc. in the basin area should be assessed.

During ecological survey, identification of faunal species should be carried out simultaneously. Indirect observations of mammals should be carried out by identification of tracks, droppings (scal), claw marks and calls, etc. The listing of faunal species by direct observation techniques should be carried out. The detailed list of faunal species should be formulated based on forest records and published literature.

3.6 Aquatic flora and fauna

The following data should be collected from various secondary sources for river Siang and its tributaries in the basin area :

- Presence of major fish species
- Inventory of migratory fish species & migratory routes of various fish species
- Presence of major breeding and spawning sites.

The field studies should be conducted for sampling at 45 locations to collect primary data on aquatic ecology & fisheries in the study area. The density and diversity of phytoplankton, zooplankton should be estimated. In addition, primary productivity should be monitored at various locations to be covered as a part of the study.

The diversion of water for hydropower generation leads to reduction in flow downstream to the dam site upto disposal of tail race outfall. This leads to diverse impacts on riverine ecology. The dam could also act as a barrier for migration of fishes. The data on prevailing fish species should be collected from the Fisheries Department. To augment the existing data, a fisheries survey should be conducted

at 48 locations in the study area. The survey should be conducted once per month for six months. The details of the monitoring work should be carried out as per the following:

- Assessment of biotic resources with special reference to primary productivity, zooplanktons, phytoplanktons, benthos, macrophytes, macro-invertebrates and fishes in the study area.
- Population densities and diversities of phytoplanktons, zooplanktons, benthos, macrophytes, macro-invertebrates and fish shall be estimated. Diversity indices of these ecological groups should also be calculated separately.
- Fish composition
- Migratory route of migratory fishes
- Spawning & breeding grounds of fish species, if any, should be identified.

4. IMPACTS DUE TO HYDROPOWER DEVELOPMENT

The impacts on terrestrial and aquatic ecology should be studied. The scenario to be considered for assessment in the present study should be based on the hydropower projects presented in Table. The key aspects to be covered are listed as below :

- Modification in hydrologic regime due to diversion of water for hydropower generation.
- Depth of water available in river stretches during lean season and its assessment of its adequacy vis-a-vis various fish species.
- Length of river stretches with normal flow due to commissioning of various hydroelectric projects due to diversion of flow for hydropower generation.
- Impacts on discharge in river stretches during monsoon and lean seasons due to diversion of flow for hydropower generation.
- Impacts on water users in terms of water availability and quality
- Impacts on aquatic ecology including riverine fisheries as a result of diversion of flow for hydropower generation.
- Assessment of maintaining minimum releases of water during lean season to sustain riverine ecology, maintain water quality and meet water requirement of downstream users.
- Impact due to loss of forests
- Impact on RET species & impacts on economically important plant species.
- Impacts due to increased human interferences
- Impacts due to agricultural practices.

5. OUTCOME OF THE STUDY

The key outcomes of the study should be to:

- Provide sustainable and optimal ways of hydropower development of Siang river, keeping in view of the environmental setting of the basin
- Assess requirement of environmental flow during lean season with actual flow,
- depth and velocity at different level.
- Downstream impacts on Assam due to hydropower development in Siang basin in Arunachal Pradesh.

Guidelines for Muck dumping

An attempt therefore has been made to prepare a general guideline for safe disposal of muck causing minimum environmental damage. Different steps to be followed for safe disposal of muck disposal are discussed below:

- a) Qualification of muck
- b) Identification of muck disposal sites
- c) Identify landscaping measures for disposal of muck
- d) Identify modes of transportation for muck disposal
- e) Feasibility and species selection for use of bio-technological/bio-fertilizer method for vegetative growth on muck spreads
- f) Finalizing muck disposal options for each site, manpower requirements
- g) Feasibility in implementation and development of landscape
- h) Develop administrative guidance for identifying and feasibility of muck disposal activities within
- i) Muck Disposal Plan - Cost aspects and Implementation
- j) Determination of unit costs for each measures, engineering/biotechnology
- k) Determination of total costs for muck disposal for each identified site
- l) Phasing of activities for muck disposal represented through spatial and temporal bar charts
- m) Post-implementation scenario of muck disposal phase-wise maps
- n) Cash flow analysis as per activity chart and milestones
- o) Aggregation of costs and activity schedule for entire Muck Disposal Sites
- p) Delineation of monitoring mechanisms for implementation of Muck Disposal Plan, institutional analysis for reorienting activity within existing administrative setup and mode of payment schedule and appraisal of Muck Disposal Plan

1. Qualification of muck

The first and foremost step in the disposal of muck and rehabilitation and restoration of muck dumping sites is the identification of locations of muck generation.

- Identification of locations and activities wherein muck is generated (excavation and blasting operation)
- Qualification of the muck generated from each site
- Composition and characterization of muck generated from various sources with relevance to disposal option

The quantity of muck to be generated from excavation works should be estimated through detailed drawings. Efforts should be made to utilize as much as volume of muck in miscellaneous construction works. The generated muck to some extent should be used for strengthening of bunds, construction of roads, filling up of low-lying areas, aggregate for concrete work etc; so that cutting and filling will be equalized and also in some small roads locally required to be constructed as approach roads to work areas with labor colonies, workshops, stores etc. So some part of muck should be consumed in these roads for sealing as well as protection work. If

possible, some of the muck should be used in construction work of schools, dispensary, monuments, gardens, play grounds etc. being taken up in the adjoining areas. The respective state government and its agencies should facilitate in making available land, electricity and water for manufacturing activities and provide access to the muck lifting area for promoting and setting up of muck-based production units in the proximity of the area where muck is generated by the various activities.

2. Identification of muck dumping sites

After the characterization of muck generated, next step is the identification of muck dumping sites which should be done in consultation with department of forest. The identified muck disposal sites should satisfy the following conditions:

- proximity to source of generation to minimize dust pollution during transportation,
- located on downwind from villages,
- located at least 30 m away from the high flood level in case located near the river bank,
- good road connectivity,
- area under minimum/degraded forest cover, should not be habitat of any RET species,
- geologically stable area i.e. should be free from landslides or creeps,
- it should not block any small stream which may be seasonal
- preferably angle of repose should be 25° ,
- located on wind shadow region to prevent wind erosion,
- area suitable for landscape planning,
- area and depth should be at least 20% more than the volume of muck earmarked for disposal, and at least 40% swell factor to be assumed before assessment of volume of muck to be disposed
- cost effectiveness,
- ground water/blockage to surface water/relief, and
- should have ample scope and space for afforestation after disposal and erosion/sediment control.

3. Landscaping and Restoration Plan

The main objectives of process of muck dumping and restoration of muck disposal sites are:

- to protect and control soil erosion;
- to create greenery in the muck disposal areas;
- to improve and develop the sites into recreational sites;
- to ensure maximum utilization of muck for the construction purpose;
- to develop the muck disposal sites/ dumping yards to blend with the surrounding landscape; and
- to minimise damages due to the spoilage of muck in the project area.

The dumping, landscaping and rehabilitation of muck comprises of engineering as well as biological measures.

3.1 Engineering Measures

Engineering measures involve base protection work in the form of Rubble Masonry/Masonry wall/Retaining walls of required strength along the entire length of the base to hold the destabilized earth mass dumped for holding the soil and boulder mass. The first step in muck

dumping process is site preparation and construction of retaining walls beforehand stacking of dumping material on to the sites. The site preparation should be done by cut-fill operation.

General process of dumping is filling, stacking, compaction and fencing. The dimensions of each dumping site should be delineated beforehand.

Leveling should be done after dumping the material on every cycle and simultaneously improving the drainage of the disposal site.

Terraces should be developed at each dumping site so as to support the muck on vertical slope and for optimum space utilization. The muck disposal area should be developed in a series of terraces of retention. In between the terraces, catch water drains can also be provided. The terraces of the muck disposal area should be ultimately covered with fertile soil and suitable locally growing plants (herbs, shrubs & trees) will be planted adopting suitable bio-technological measures.

Adequate drainage arrangement in form of weep holes with inverted filter behind at a regular spacing and pipes should be kept in the retaining walls. Pipes should be provided with boulder filling around them for passage of rainwater.

The approach roads to the muck disposal sites should be constructed by employing the methodology recommended by Border Roads with minimal environmental damage. The methodology consists in developing the formation width is half cutting and half filling, so that the materials obtained from cutting are utilised in filling. The excavation on hill side should be done to get a stable slope for the materials encountered. Depending upon the terrain breast wall, gabion walls should be built in natural slope to retain filled material, particularly where there is problem of retaining the hill slope.

In order to minimise the environmental damage, construction material like stones, sand, etc., required for the construction of road should be obtained mostly from the excavated material. In addition, stone/concrete work on the downstream area should be provided at vulnerable places to minimize erosion.

Dumping sites which are completed should be levelled or dressed. Depending upon the slope at the dumping site, slope stabilisation work should be taken up accordingly.

- For gentle to moderate slopes: Random Rubble Masonry Grids, Dry Masonry Grids are used
- For moderate to steep slopes: Biomac-C (jute coir woven with polypropylene net - a biodegradable soil blanket, stops soil from washing out) can be adopted
- For steep slopes: Formation of the terrace and installation of Biomac-C + Steel mesh after laying mixture of top soil and farm yard manure and vermi-compost.

3.2 Biological Measures

Mostly the muck generated is inert without fertile soil having no organic matter where it is very difficult to raise vegetation. Vegetation cover plays a very important role in holding the dumped material over a period of time and controls the hydrological and mechanical effects on the soils and slopes. Vegetation cover controls the hydrological and mechanical effects on soils and slopes. Special efforts will be required to raise vegetation cover of grasses, shrubs and tree saplings.

Therefore, biological measures to stabilize the loose slope are essential. In order to implement the biological measures in dumping areas the following activities would be taken into account. The biological measures include the following:

i) Soil treatment

In order to make nutrient poor muck suitable for the plantation it will be provided bio-treatment. The re-vegetation of the dumping sites should be done through Integrated Biotechnological Approach.

ii) Plantation

The selected species will be planted after their nurseries have been developed. Separate nurseries should be developed for the rehabilitation of dumping areas. At least 1-2 years old tree saplings should be used for the plantation. The plantation should be carried out in lines across the slopes. Grass and herb species would be used in the inter space of tree species. They will help in providing the continuous chain of support in retaining debris, reinforcing soil and increasing the infiltration capacity of the area.

In order to stabilise the stacked dumped material, vegetation cover would be provided to hold dumped material over a period of time. Following steps are envisaged:

- Plantation of suitable tree species and soil binding using bio-fertilizer technology.
- Turfing of the exposed area and improvement of environment with ornamental species.
- Protection with mechanical support.
- Social fencing through mass public awareness.
- Water sprinkling arrangement should be made

Following work plan for re-vegetation of the dumping sites through 'Integrated Biotechnological Approach' based should be considered:

- i) Evaluation of dumped material for their physical and chemical properties to assess the nutrient status to support vegetation.
- ii) Formulation of appropriate blends of organic waste and soil to enhance the nutrient status of rhizosphere.
- iii) Isolation and screening of specialized strains of mycorrhizal fungi, rhizobium, azotobacter and phosphate solubilizers (biofertilizers inoculum) suitable for the dumped material.
- iv) Mass culture of plant specific biofertilizer and mycorrhizal fungi.

iii) Identification of Species for Plantation

Identification of plant species i.e. shrubs, ornamental plants and trees should be done depending upon elevation, water availability and type of soil, climate factor, local need of each

iv) Post implementation Monitoring

In order to assess the efficacy of measures undertaken Muck Dumping Plan phase-wise/year-wise monitoring should be undertaken. It should be assessed as follows:

- Phase-wise maps
- Cash flow analysis as per activity chart and milestones
- Aggregation of costs and activity schedule
- Formulation of mid-term correction, if required