PAUK HYDRO
POWER Pvt. Ltd.

PAUK HYDRO ELECTRIC PROJECT

1. Executive Summary
2. E.I.A.
3. E.M.P.
4. D.B.A.

Registered Office
G-77, Sujan Singh Park
New Delhi - 110003
CIN U40109DL2007PTC170439
Tel: +91 (11) 2461 8780, 2461 8781
Fax: +91 (11) 2464 3891

Administrative Office
130, Infantry Road,
"Prestige Infantry Court"
Unit No. M01, Mezzanine Floor,
Bangalore - 560 001
Tel: +91 (80) 4026 1600
Fax: +91 (80) 4026 1666

VELCAN Energy

www.velcan.fr

Nyse Euronext MLVel

DRAFT FINAL REPORT
JUNE 2012

CISMHE

Executive Summary of
ENVIRONMENTAL IMPACT ASSESSMENT & MANAGEMENT PLAN OF PAUK HYDROELECTRIC PROJECT, Arunachal Pradesh

Prepared for:

Pauk Hydro Power Pvt. Ltd., New Delhi

CENTRE FOR INTER-DISCIPLINARY STUDIES OF MOUNTAIN & HILL ENVIRONMENT

University of Delhi, Delhi

1. Developer Foreword

The strategy and philosophy followed by Velcan Energy, in all countries and for all projects, is to develop midsized run-of-the-river Hydroelectric Projects, which minimize the impact on the environment and local populations while allowing energy generation without greenhouse gases emissions.

Such kind of projects is highly environment friendly because contrary to large reservoir projects, they do involve only small ponds or very small ponds, and therefore small or very small submergence areas. In addition Velcan Energy takes up exclusively the development of Projects which do not require displacement of people.

Pauk H.E. Project is developed with the cooperation of local inhabitants right from the beginning of the field investigations and feasibility studies, and compensations and benefits are allocated through sponsoring, welfare activities and employment even before the start of Project construction.

This is the philosophy as per which the Pauk Hydro Electric Project is proposed:

- ✓ Submergence area: 34.1 ha including 8.8 ha of river bed (net submergence impact of 25.3 ha).
- ✓ Land requirement & impact on forest: net surface land impact 79.1 ha.
- ✓ Arch Dam design, hence requiring much less concrete / weight than a traditional barrage.
- ✓ No displacement of people.
- ✓ No wildlife sanctuary affected.
- ✓ Minimum environmental flow to guarantee sustenance of downstream aquatic life & afforestation measures.
- ✓ Local people getting benefits right from the investigation phase.
- ✓ Total budget for environmental and social mitigation measures: Rs 4158.19 Lakhs.
- ✓ Rehabilitation measures and Local Area Development budget: Rs 884.5 Lakhs (do not include the compensations per the Land Acquisition Act, which will be paid in addition whenever applicable)

A summary of baseline data, methodology technical impacts and corresponding mitigation measures is presented hereafter.

2. General Description

Pauk H.E project is the most upstream project of a cascade of three projects developed by Velcan Energy Group on the Yarjep (Shi) River, between Mechuka and Tato circles, in West Siang district of Arunachal Pradesh.

Pauk H.E. Project is located in Mechuka circle of West Siang district in Arunachal Pradesh (**Fig. 1**). The nearest road head at Chengrung is about 160 km from Aalo, the head quarters of West Siang district. Pauk Hydroelectric Project is a run of the river scheme proposed on the Yarjep (Shi) River (also known as Shi Chhu in the lower reaches), which is a right bank tributary of the Siyom River). The project Dam is located 1 km downstream of the confluence of Sae Chu with Yarjep (Shi) River, about 12 km downstream of Mechuka. The proposed dam site is located between 94°14’43’’E longitude and 28°32’46’’N latitude near Chengrung village. Proposed Power house site is located between 94°15’58’’E longitude and 28°32’22’’N latitude near Purying village. The nearest road heads are Hiri and Chengrung villages which are linked to Mechuka and Tato towns. From these villages foot tracks are used to access the proposed dam and power house sites. The nearest road is connected to National Highway-52 via state road and is about 295 km from Akajan in Assam. For Pauk project the nearest meter gauge rail head is at Silapathar (approx 300 km) and broad gauge at Naogaon (approx. 700 km) in Assam. From the project site, the nearest operational airport is around 350 km, located at Dibrugarh in Dibrugarh district of Assam and the nearest international airport is around 830 km located at Guwahati, the capital city of Assam.

Pauk H.E. Project involves a 110 m high arch dam, a horse shoe shaped head race tunnel (HRT) of 2.3 km and a surface powerhouse with an installed capacity of 145 MW. Total catchment area of the project is 982 sq km. The standard projected flood (SPF) and maximum probable flood were calculated to be 3000 and 3700 cumecs, respectively. The construction of the project will be completed in 4 years. The details of salient features of the project are given in the EIA report and in Table 1. The Project is designed with a relatively small reservoir, which involves a net submergence area of 25.3 Ha. The Land requirement is about 91.7 Ha, including underground structures and river bed area.

The design of project has been developed by the Engineering Department of VELCAN Energy. Reputed International consultants have also contributed significantly to the civil design, geology, geotechnics, and hydrology according to the latest international and Indian standards.

Table 1. Salient features of the proposed Pauk H.E. project

LOCATION	
State :	Arunachal Pradesh
District :	West Siang
River :	Yarjep (Shi)
Location of Dam	
Latitude :	28˚ 32’ 46”E
Longitude :	94˚ 14’ 43”N
Location of Power House	
Latitude :	28˚ 32’ 22”N
Longitude :	94˚ 15’ 58”E
Nearest Airport :	Dibrugarh
Nearest Rail head (Broad gauge) :	Nagaon
HYDROLOGY	
Catchment area at dam site :	982 sq km
Standard Project Flood :	3000 cumecs
Maximum Probable Flood :	3700 cumecs
DAM	
Type :	Concrete Arch Dam
Dam top :	EL 1550 m
Foundation Level :	EL 1445 m
Maximum Height above deepest foundation:	105 m
SPILLWAY	
Type of spillway #1 :	Free Ogee Spillway
Maximum discharge capacity at FRL/MWL:	0 / 3400 cumecs
Energy dissipation system:	Downstream dissipation basin
Type of spillway #2 :	Flushing Gate
Maximum discharge capacity at FRL/MWL:	785 / 860 cumecs
Energy dissipation system:	Downstream dissipation basin
Type of spillway #3 :	Flushing Gate
Maximum discharge capacity at FRL/MWL:	823 / 894 cumecs
Energy dissipation system:	Downstream dissipation basin
RESERVOIR	
Maximum Water Level (MWL) :	EL 1548.5 m
Full Reservoir Level (FRL) :	EL 1540 m
Area under submergence at FRL :	34.1 ha
Total storage :	11.5 M cum
Active storage :	5.7 M cum
INTAKE	

Number of Intakes :	1 no.
Design discharge :	119 cumecs

HEAD RACE TUNNEL

Head Race Tunnel :	One
Internal section :	28.3 sq m
Type:	Horse shoe
Design discharge :	119 cumecs
Internal Section :	28.3 sq.m
Thickness of lining (mm):	300
Length :	2.35 km (approx)

SURGE SHAFT

Type :	Vertical Orifice
Size :	12 m diameter
Vertical shaft height :	81 m

PENSTOCK

Numbers :	One
Diameter :	5.5 m
Length :	317 m

POWER HOUSE COMPLEX

Type :	Surface
Installed capacity :	145 MW
Number of units :	3nos of 48.3 MW
Type of turbine :	Vertical Francis
Tail water level at outlet :	EL 1400.0 m
Powerhouse size (W x H) :	35 m x 37 m
Length of Powerhouse :	72 m

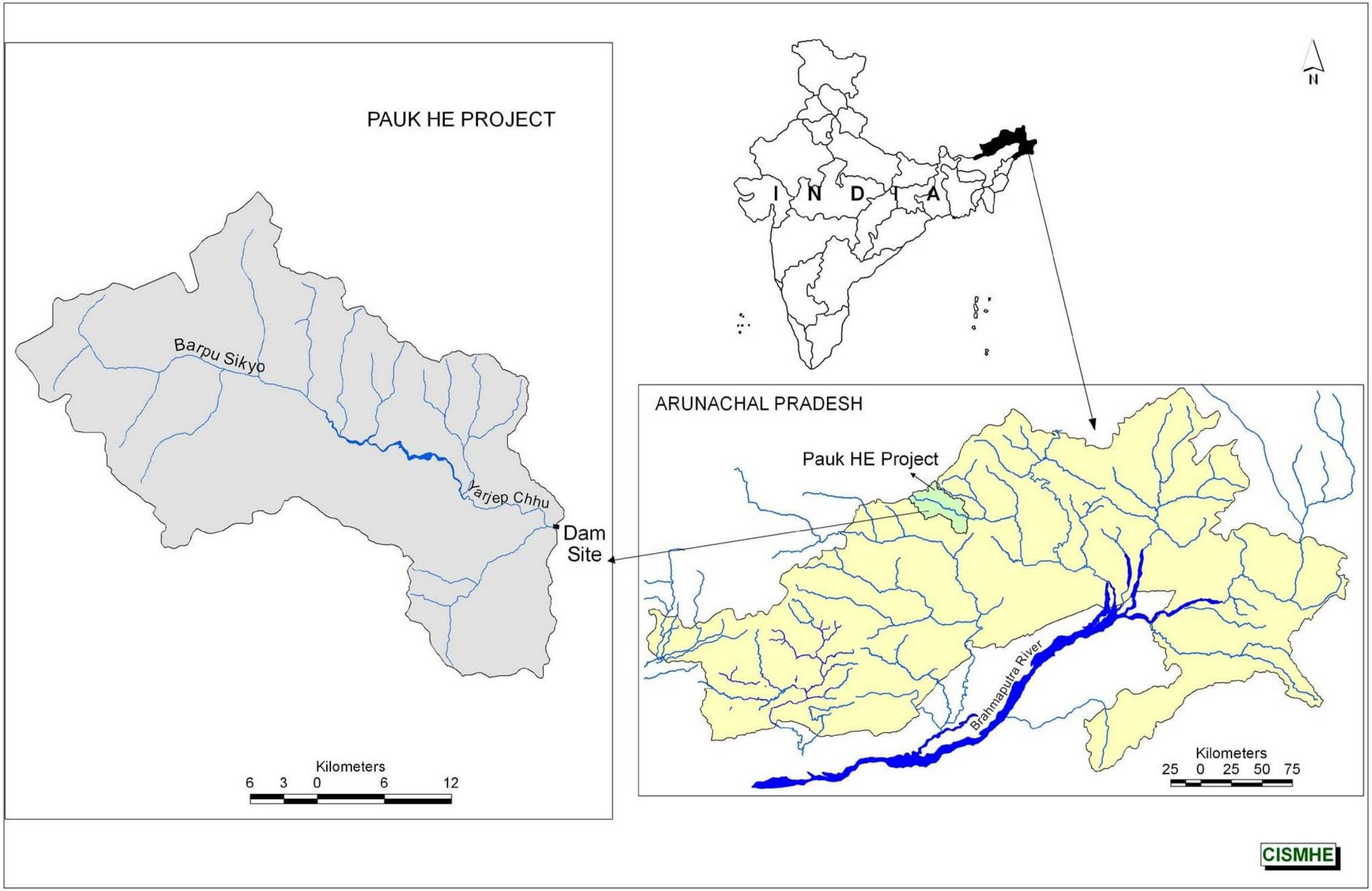


Figure 1.1: Location map of Pauk H.E. Project Stage-I

3. Project Background and Legal & Administrative Framework

VELCAN Energy Group has entered into a MoA with the State of Arunachal Pradesh for the development of the Pauk. H.E. Project on Build, Own, Operate and Transfer (BOOT) basis.

The final stretch of river available for Project development was finally determined by the Government of Arunachal Pradesh on 31^{st} July 2009, through the signature of an amendment to the Memorandum of Agreement. In addition, the first two years of Hydrological & Meteorological studies and data collection showed more available water than initially estimated and the installed capacity of the Project was increased to 120 MW accordingly, through the aforesaid Amendment dated 31^{st} July 2009. Following the signature of this Amendment, involving new features, the Pauk H. E. Project had to be thoroughly designed again in order to arrive at a new PFR which was submitted in October 2009.

Water Availability Studies have been approved by the C.E.A / C.W.C in July 2010. The Power Potential Studies have been submitted in July 2010 to the C.E.A, which finally requested the Project developer, in April 2011, to increase again the installed capacity from 120 MW to 145 MW. Hence the Power Potential Studies have been approved with a capacity of 145 MW.

The Ministry of Environment and Forests, Govt. of India, granted to PHPPL the revised TORs and clearance of preconstruction activities, updated with the new project capacity and features in April 2010 for the first increase and then in October 2011 for the second increase.

VELCAN Group has set up operations in order to conduct the field surveys and investigations. One Guest house is located in Mechuka and the local head office is located at Aalo. Locally, VELCAN Group is employing a team on permanent employment basis in the West Siang District, in addition to a variable team of daily labours or temporary employees depending on site works requirements. Local population has been integrated to the project development right from the beginning through welfare activities or employment.

Since June 2007, PHPPL has performed surveys & investigations for project reconnaissance and then for DPR preparation:

- Hydrological and climatic surveys of the area

- Topographical Surveys
- Geological mapping
- Sub-surface geological investigations
- Environmental surveys for EIA/EMP preparation.

Pauk HE Project is proposed to be developed by meeting statutory environmental requirements of Arunachal Pradesh as well as the Central Government. The Ministry of Environment & Forests (MoEF) is the nodal regulatory agency of the Central Government for planning, promotion, co-ordination and overseeing the formulation and implementation of environmental and forest policy, legislations and programs. Given the installed capacity of the Project, regulatory functions like grant of Environment Clearance (EC), Forest Clearance (FC) are part of the mandate of the Ministry of Environment & Forests (MoEF).

4. Environmental Impact Assessment / Environmental Management Plan

The aim of the Environmental Impact Assessment (EIA) is to enumerate the entire panel of environmental issues involved in the construction and exploitation of the Pauk structures, with the scope listed in the Terms of Reference (TOR) accorded by the MoEF during scoping and pre-construction clearance of the named project. Standard methodologies of Environment Impact Assessment were followed in the EIA study of Pauk HE Project. The present study has been based on the guidelines for EIA reported by several workers and institutions including CISMHE. All the methods were structured for the identification, collection and organization of environmental impacts data. The information, thus gathered, has been analyzed and presented in the form of a number of visual formats for easy interpretation and decision-making. The study was carried out in the catchment area, influence area (10 km radius of proposed dam and power house) and the project area (directly impacted area). Spatial database on physiographic features were taken from various sources including Survey of India (SOI) toposheet, satellite data and analyzed with the help of Geographic Information System (GIS) tools. Successive phases of the EIA study include reconnaissance visit, survey and data collection, determination of environmental baseline setup, identification, prediction and evaluation of impacts and possible mitigation measures and formulation of environment management plans.

The Environmental Management Plan (EMP) is conducted in order to minimize the effects of the project on the surrounding environment by establishing a sustainable work line.

5. Baseline Environmental Status

5.1. Land Environment

5.1.1. Physiography

The proposed dam site is located on the Yarjep (Shi) River . This river forms one of the major tributaries of Siyom River in Arunachal Pradesh. In the middle stretch, Yarjep (Shi) (Shi) runs from WNW to ESE and several tributary streams flowing from north hills to south and southern hills to north join this river in the Indian part of the catchment. The area of the Pauk project's influence zone is around 40100 ha. The drainage network of the catchment area up to the dam site is shown in **Fig. 2**.

5.1.2. Geology & Seismicity

The Himalayan ranges continuing from NW India to NE India occurs as a "gigantic crescent" in this part of the country with its convex side towards south and extends from the Western border of Bhutan to Lohit valley in the east and is divisible into four linear zones namely the Tibetan Himalaya, Higher Himalaya, Lesser Himalaya, and Sub Himalaya abutting against the Trans Himalayan range, and the Mishmi Hills famously known as the Eastern Syntaxial Bend.

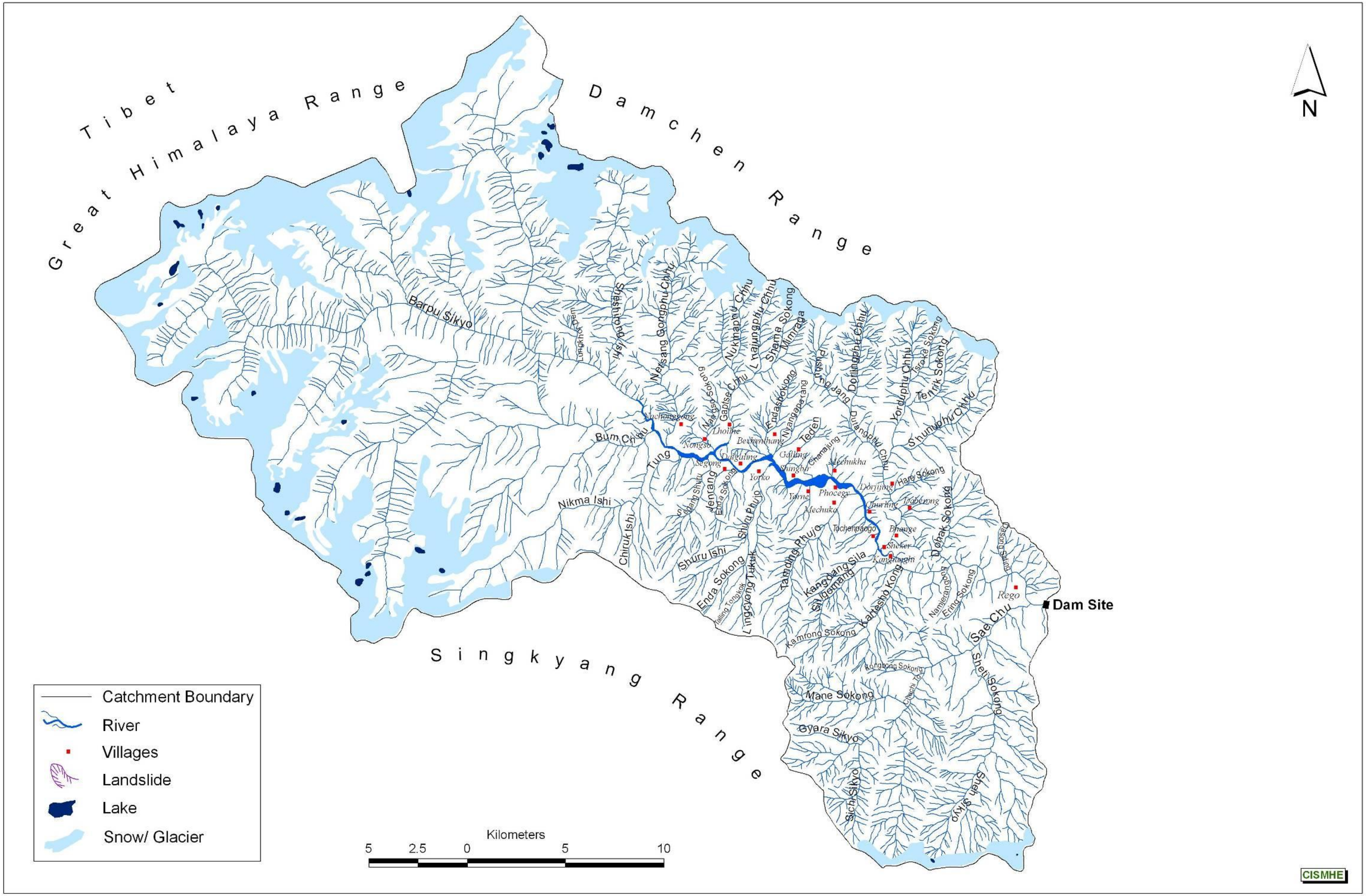


Figure 2: Drainage map of Yarjep (Shi) River in the catchment area of the proposed Pauk H.E. project up to the proposed dam site

The proposed dam site is located in a narrow and deep gorge. The geology of the dam site consists essentially of gneiss with thin bands of schist. The proposed Head Race Tunnel (HRT) alignment passes through a rough and rugged terrain with very difficult access on the left bank of Yarjep (Shi) River. The geological mapping carried out and correlation of other data indicates that the tunnel will encounter the following rock: Schistose Gneisses, Marble and banded gneisses (dominant) with schistose bands and basic rock layers. The site is located downstream of very steep cliffs. The predominant rock type at selected site is gneiss.

The area falls in Seismic Zone V, of the Seismic Zoning Map as adumbrated in the Indian Standard Criteria for Earthquake Resistant Design of structures. However, the project area manifests relatively fewer incidences of earthquakes and the focal mechanism of two fault plane solutions of two nearby events to the south indicates strike slip mechanism.

5.1.3. Soil

The study covers soil properties for the catchment area, project influence area and project area. Soil association of Lithic Udorthents – Dystrict Eutrochretps is predominant in these areas. All the project components like dam, HRT, powerhouse colony area, etc. are located on the soil association of Lithic Udorthents – Typic Udorthents. Soil is loamy skeletal and shallow to moderately deep which is susceptible to severe to very severe soil erosions. Physical, chemical and biological properties of soil, which impact the life span of the reservoir and the viability of the project, are developed further in the EIA study.

5.1.4. Land Use and Land Cover

Land use and land cover mapping of the Pauk H.E. Project was carried out by standard methods like digital image processing (DIP) supported by ground truthing. The land use and land cover of the Pauk catchment area includes Dense forest, Open Forest, Scrub/Alpine scrub, Degraded forest, Alpine Meadow, Cultivation, Moraines, Barren, River, Lakes, Snow and glaciers. The catchment area is prevalently covered by Dense Forest, which occupies 36.46% of the total 98200 ha area, as shown in **Fig 3**.

Additionally, MoEF has been following a general practice of baseline data to be collected in a 10 km radius of a project while conducting EIA studies. A base map was developed to demarcate the submergence zone and influence zone of the Pauk H.E project. Therefore land cover and land use maps will be examined within the 10 km radius of power house and dam sites. It is called as the study area (Influence zone and the submergence area). The land cover and land use patches in the influence zone include dense forest, which accounts for 44.86% of the total influence zone and it is prevalent along the right bank of the Yarjep (Shi) River.

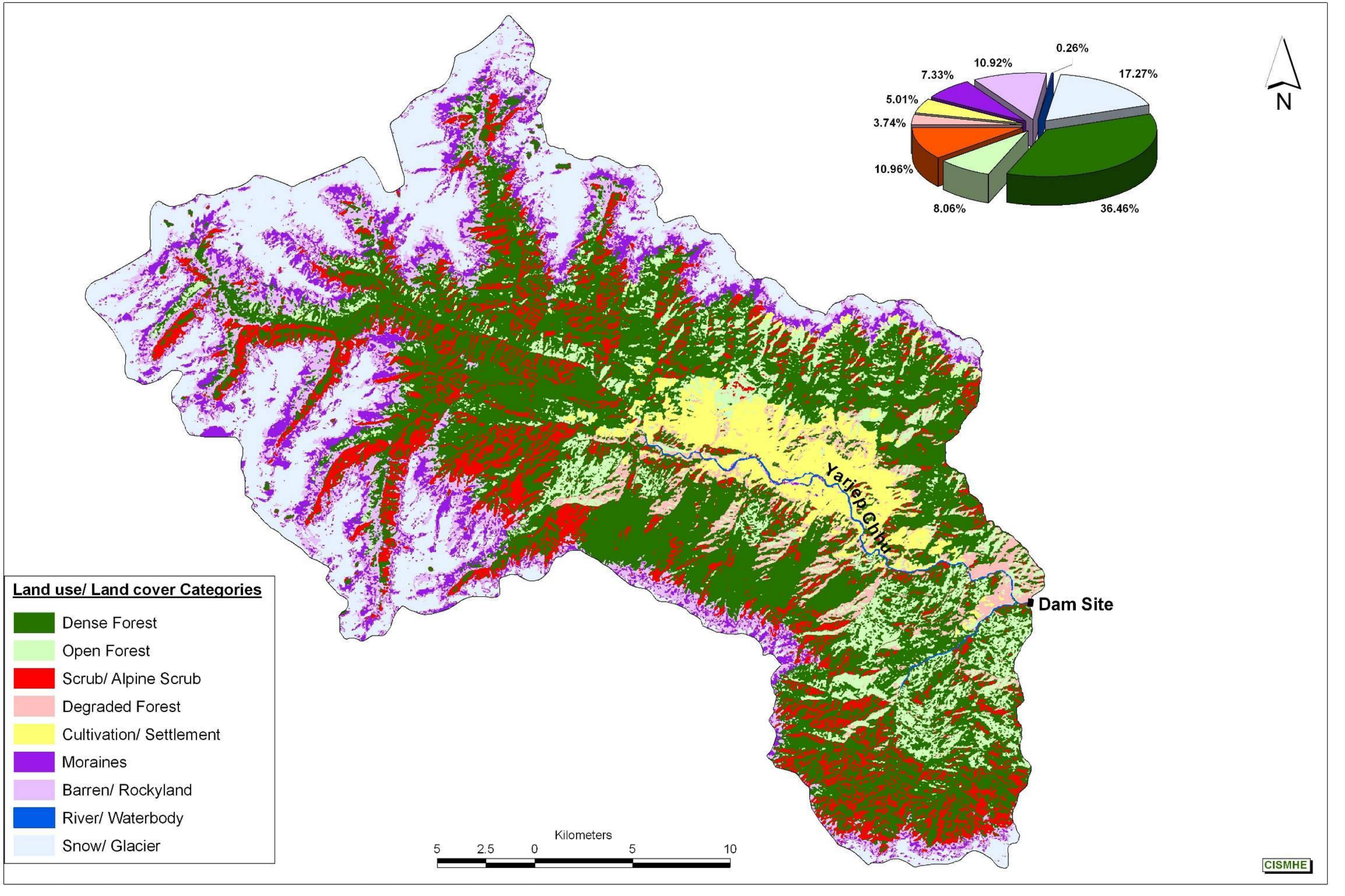


Figure 3: Land use / Land cover map of Pauk H.E. Project

5.2. Fluids Environment

5.2.1. Air Quality & Noise Pollution

The main sources of outdoor air pollution in the project area may be road construction activities (excavation, paving etc…), vehicular movement and Jhum fires while burning of fuel woods is the only source of indoor air pollution. SPM levels varied in the range 83.61 to 311.00 $\mu g/m^3$. RSPM varied in the range of 13.75 to 137.61 $\mu g/m^3$ and SO2 and NOx are significantly lower than the tolerable levels. These values are well within the National Ambient Air Quality Standards (NAASQ).

Except the gurgling sounds of river, there is no other unwarranted sound in the project sites. The baseline data of air environment, detailed in the study, would be useful in preparing the mitigation measures of air quality during the construction phase. All parameters are anticipated to increase significantly during the construction phase.

5.2.2. Water Quality

Stream flow, which is strongly correlated to many critical physicochemical characteristics of rivers, such as water temperature, channel geomorphology, and habitat diversity, can be considered a "master variable" that limits the distribution and abundance of river species and regulates the ecological integrity of flowing water systems. The study of the water quality in Yarjep (Shi) stretch from Mechuka to downstream Tato in West Siang district of Arunachal Pradesh was conducted in three seasons, Winter season (February, 2009), Pre-monsoon (May, 2009) and Monsoon (August, 2009). Sampling was done at following five sites W1 (upstream of proposed dam site), W2 (proposed dam site), W3 (proposed power house site), W4 (downstream of proposed power house site) and in a main tributary of Yarjep (Shi) River. The profile of the water quality is presented in the report.

5.2.3. Hydro-Meteorology

The average monthly rainfall data for rain Gauge stations in the catchment area are ranged between 186 to 908 mm/month during the monsoon and between 16 and 140 mm in December. Precise figures are given in the study for Mechuka, Monigong, Raying, Kaying, Aalo and Tato R&G stations.

The optimization studies for the Pauk H.E Project have been conducted on the basis of the 10 daily discharge data for 25 years. The average discharge in Yarjep (Shi) River during the monsoon months (June to September) vary from 128 to 194 cumec at dam site respectively, while the minimum and maximum are respectively 64 and 410 cumec during this period.

5.3. Biological Environment

The region of Arunachal Pradesh is located at the boundary of Indo-china and Indo-Malayan bio-geographic region and is one of the richest areas in habitat and species diversity. The state has wide variation in altitude, topography and climatic conditions, which result in a rich floral and faunal diversity.

5.3.1. Floristic and Forest Types

The forest of Arunachal Pradesh falls under five major categories of vegetation: tropical, sub-tropical, temperate broad-leaved and temperate coniferous, sub-alpine and alpine forests. All these types are represented in the study/catchment area of the Pauk H.E. Project, and the EIA gives an exhaustive list of the floral species within each category.

Complementary studies on site have been conducted in order to quantify the density of natural organisms living in the areas of Pauk project. The study focuses on communities, which are assemblages of organisms living in a particular area or aggregations of organisms which form a distinct ecological unit.

The present ecological study in the project area of Pauk HE Project was undertaken with the objectives of preparing a checklist of flora in the submergence area and locations where project components are proposed and its adjoining areas (listing of rare/ endangered, economically important and medicinal plant species; determination of frequency, abundance and density of different vegetation components). A total of 93 species of plants were recorded under the ecological investigation during different sampling seasons. Out of which 18 were trees, 17 shrubs and 58 herbs. The ground vegetation comprised of ephemeral, annual and perennial species of grasses, sedges, legumes and non legume forbs.

5.3.2. Faunal diversity

The study of Pauk H.E. Project's EIA highlights the zoogeographical distribution, conservation status, endemism of the faunal species in catchment area, influence zone and project area. It also outlines the likely impacts of the proposed project on the faunal elements.

A total of 26 mammals species are expected to inhabit in the catchment area of Pauk H.E. Project on Yarjep (Shi) River. Out of 26 species, 21 are common in the catchment and influence areas, and four *Carnivora* type's species, were considered as threatened species by the Zoological Survey of India, the International Union of Conservation for Nature and the Wildlife Protection Act.

An exhaustive list of the species in the Arunachal Pradesh territory (mammalian fauna, avifauna, herpetofauna, butterflies...) is given in the study, along with their conservation statuses. A local survey has also been carried out in order to determine more precisely the wildlife environment in a short range around Pauk H.E. structures.

5.3.3. Aqua Flora and Fauna

Biological quality of water flows can be assessed by different kinds of organisms: algae, riparian and aquatic vegetation, invertebrates and fishes (Kelly and Whitton, 1995). As they are part of the overall biodiversity, the study records density and abundance of these bio indicators in order to provide holistic information regarding the water biological quality of Yarjep (Shi) and its tributaries.

Yarjep (Shi) is one of the main tributaries of Siyom River in middle stretch, which regroups 12 different species of fish according to a survey by Sen in 2006. However, Yarjep (Shi) is not considered as rich as Siyom in fish resource. The inhabitants have little fishing activities as very low capture and disorganized fishing occur in the region. Specie *Schizothorax Richardsonii* is predominant in Yarjep (Shi) River, and most fishing depends on it. None of the species inhabiting Yarjep (Shi) River and tributaries is endemic to Siyom river system.

5.4. Socio Cultural & Economic Environment

Socio-cultural and economic statement in an EIA report essentially covers the demography, education, occupation, history, culture, ethnography, and lifestyle of the inhabitants which are directly and indirectly affected by the H.E. project activities.

The district headquarter of West Siang is located at Aalo. According to Census (2001) the total population of West Siang district is 103,575 with sex ratio of 912 (females to 1,000 males). The population density of the district is 12 individuals per sq. km, nearly same as that of the State (13 person/sq km). The scheduled tribe population accounts for 81.7% of the total population in the district. The district recorded a total literacy rate of 59.47%.

Influence area of Pauk H.E. Project is inhabited by a total of 20 villages in which 19 come under the jurisdiction of Mechuka circle and one are under Tato circle. Total population of villages of influence area is 1382 and comes from 232 households (Census, 2001). Average sex ratio in these villages is 1044, that is higher than state average. Scheduled tribe population accounts for 100% of the total population. All villages are inhabited by Scheduled tribe population. Average literacy rate in these villages is 47.5%, considerably higher in male population (57.4%). Nearly 45% inhabitants are employed in various works. The majority of the main workers are involved in cultivation. Most of the villages have facilities of tap non treated water, supplied from spring. Mechuka and Tato are the main centres of influence and gather the public facilities such as bank, post office, secondary school and primary health.

Four villages are affected by the various project components. It represents a total population of 250 individualities belonging to 43 households (Census 2001). Territory of Hiri and Purying villages would be used for the power house complex while the dam complex would be located near Chengrung and Rapum villages. A total of 202 persons coming from 24 households (55 families) are affected in the proposed project. The sex ratio in the project affected families is 957. All project affected persons belong to Scheduled Tribe, which are mainly ‘Adi’ tribes and its sub-tribes. Average literacy rate in the project affected families is 52.3%. The socio-economic and cultural profiles of these villages and families are given in the EIA report.

6. Environmental Impacts Assessment

The Environmental Impact Assessment relies on 4 steps: impact identification, impact prediction, impact evaluation and identification of mitigation. Impact identification brings together project characteristics and baseline environmental characteristics with the aim of ensuring that all potentially significant environmental impacts (adverse or favorable) are identified and taken into account. Quantitative predictions have been set as priority in order to take the most precise measures. The identification and prediction of likely impacts are the starting points which lead to identification of monitoring requirements and mitigating measures.

6.1. Impact Identification

Impacts study for the Pauk H.E. Project has been divided into 4 environments:

- Terrestrial, which group geophysical matters and land ecosystem preservation.
- Aquatic, including water quality and aquatic biodiversity.
- Atmospheric, for air quality and noise pollution issues.
- Human, focusing on sociologic and economic impacts.

For each domain, impact study is levelled on every step of the project development: pre-construction, construction and exploitation.

6.2. Prediction of Impacts

The major impacts anticipated on land environment during construction phase are acquisition of land, quarrying operations, excavation of construction material, operation of constructing equipment, soil erosion, muck disposal and construction of roads. A total of 79.1 ha of land would be required for the surface works. The forest area will be cleared for the purpose, which would result into land use and land cover changes. Around 34.1 ha of land would be required for the submergence. Some of the negative impacts are local and temporary, as they are expected to last mainly during the construction phase. Other long term major impacts on land would be the submergence area (34.1 ha) and the place dedicated to project components, mainly dam and power house.

Both sides of the Yarjep (Shi) River, downstream and upstream of the plant will be impacted. Water diversion from the main channel is anticipated to various impacts on the aquatic ecosystem. The reduction of the water in the downstream stretch would decrease the self purification capacity of water and most of the physical and chemical characteristics would be affected adversely. The water may be prone to deterioration due to project activities and workers. The physical and chemical characteristics would affect the biological composition and fisheries. The dearth of water would not be able to sustain the large column feeder fish and would affect the fish movement adversely. These impacts are anticipated in the operation phase, they are long term, permanent and irreversible.

Civil works during construction will inevitably downgrade air quality levels, such as average concentration of SPM, carbon dioxide and monoxide etc, and would have negative impacts on the health of neighbouring environments. Noise pollution would be substantially increased. The activities of the construction phase would disturb the human population as well as wildlife. Such negative impacts would remain for short time during construction phase only. The impacts are temporary and reversible in nature.

A dam of 110 m height is expected to hamper the fish movement and exert a negative impact on the fish fauna. In addition, reservoir would also be non conducive and act as area of fragmentation for bottom dwellers. The proposed reservoir would increase the possibilities of reservoir fisheries, therefore, it is considered as positive impact. These impacts are foreseen in the operation phase of the projects. The impacts are permanent in nature.

A total of about 1600 persons including the family members of peak labour force are expected to enter the area of the project works, It would double the total population in influence area during the labour force peak of the construction period. Change in the demography may trigger the cultural tensions between natives and outsiders. Also, there are fair possibilities of overexploitation of fuel wood, poaching, animal hunting and river pollution.

The area is dominated by ‘Adi’ and its sub tribes. These tribes are unique in their culture, customs and their traditions. The high number of migrant population of different culture may bring the anxiety among the tribe, which may result in the confliction during the construction phase.

Sometimes a temporary and numerous outsider population is associated with social unrest in a context of confliction. The natives may be affected adversely. In addition, the migrant population could carry new diseases.

7. Environmental Management Plan

The Environment Management Plan is a document of mitigation measures, which are taken to avoid, minimize, remedy or compensate for the predicted adverse impacts of the project and to take full advantages of the positive effects of the Pauk project. Each management plan budget is detailed in the report, as it will be integrated in the costs of the overall project.

7.1. Biodiversity Management & Wildlife Conservation Plan

Biodiversity Management Plan will be implemented during operational phase, however, some aspects will be implemented during the construction phase too. The State Forest Department will be implementing the plan, in close relationship with the tribal inhabitants. The main objective of this plan is to conserve the crucial habitats which hold potentially shelters for several keystone species. The major activities under this plan are Establishment of a Botanical Garden, implementation of an Awareness Programme. It would also involve a forest protection plan and strict safeguards measures. The total cost estimated for this plan would be would be **Rs. 227.00 Lakhs**.

7.2. Fuel Wood Energy Management & Conservation

In order to sustainably maintain wood resources and avoid over exploitation, the EMP suggests setting up Liquefied Petroleum Gas (LPG) connections, Kerosene depots and Community Kitchens in the project area. In addition locals would be encouraged to use solar cookers, pressure cookers and smokeless chullahs. Shared resources may be managed with the downstream projects of Heo and Tato-1 to ease the furniture of Kerosene and LPG, and to limit the number of storage tanks. The allocated budget for this plan would be **Rs 49.5 lakhs**.

7.3. Waste Management Plan

As it is essential to collect, treat and dispose of all types of wastes generated by native and immigrant populations on site, a proper waste management plan has been set up for Pauk H.E. Project. This plan includes management of solid and liquid waste except muck. Based on several assumptions, the peak migrant population in the project area would be around 1 600 persons, producing a total amount of solid waste of around 265 tons per annum. Therefore septic tanks, community toilets, bathrooms and washing places, sewage treatment plant, dumpers and wheel barrows, and water and toilet facilities will be installed in the project colonies and the estimated cost would be **Rs 225.4 lakhs.**

7.4. Management of Air & Water Quality and Noise Level

The main reason for the management of the quality of the aquatic, air and noise environments is to maintain the observed water and air quality properly within desirable limit. This section regroups additional measures for air and water quality which are not part of other environment managing plans. The report recommends the use of quality levels monitoring devices and first protection equipments such as dust masks. It also establishes a list of works habits that helps keeping pollution at acceptable levels. A special responsibility of sustainable work control would be given to a site officer. Overall budget should not exceed **Rs 40 lakhs**.

7.5. Catchment Area Treatment Plan

Catchment area treatment plan will be implemented during the construction phase and operational phase. The objective of this plan is to reduce and minimize soil erosion in the free draining area. Several engineering methods as well as biological measures will be adopted, especially the use of check dams that will rectify slopes while supporting vegetation growth. The total free draining area is about 15223 ha, and 8966 ha are concerned with severe to very severe erosion. The total surface to be treated would be around 5954 ha. The State Forest Department will be in charge of the activities and the total budget estimated for this plan would be **Rs 2156.36 lakhs.**

7.6. Public Health Delivery System

One single plan has been considered to cover the zone of the three projects and such plan is divided between in the Heo H.E. Project and the Tato-I H.E. Project. However, an additional budget has been planned under the EMP of Pauk HE Project, which includes setting up of immunization and vaccination programs, and distribution of first aid boxes in the surrounding villages. Total financial outlay estimated for the health management system of the proposed Pauk H.E. Project is **Rs. 100.00 lakhs.**

7.7. Fishery Development & Downstream Management plan

The plan of fishery development was also formulated for Tato I and Heo H.E. Projects. The measures suggested in Heo and Tato I H.E. projects were not included in the plan of Pauk H.E. Project to avoid any repetition because the three projects are owned by the same developers. The plan for Pauk HE Project includes training for fish farming and financial assistance for fish farms.

The downstream management plan is to regulate the environmental flow along the downstream stretch of the reservoir. Besides, other mitigation measures related to river ecosystem were also suggested in various sections like Fishery Development, Waste Management and Environmental monitoring. The three major component of this plan are maintenance of river flow level, channelization of river stretch and maintenance of pools and tributaries.

The total financial outlay for this plan is estimated to be **Rs. 55 Lakhs.**

7.8. Muck Disposal Plan

Muck would be excavated from the HRTs & TRTs during the tunneling, construction of power house complex, approach roads etc. The excavated material will need to be relocated and dumped in such a manner that it does not impose any negative impact on terrestrial and aquatic environment.

Total quantity of the muck to be generated from the different components of the project would be 8,18,020 cum. Considering the swelling factors (10 to 20%), the volume of muck would increase to 9,76,449 cum

One single dumping site has been identified for the disposal of muck which is located near the Hiri village. Both engineering and biological methods will be adopted for rehabilitation of muck. Engineering method includes the construction of retaining wall and compaction while biological method includes plantation with geo textiles technology. Total financial outlay for the relocation of muck and rehabilitation dumping sites including engineering and biological measures would be **Rs 121 lakhs.**

7.9. Green Belt Development Plan

The green canopy has the inherent capacity to absorb pollution, increase water retention by soil and decrease sediment transport. In order to reduce different kind of pollutions and avoid land slips from the portion of catchment area draining directly into the reservoir, the green belt in and around the project areas is an obvious choice. Thus a green belt would provide the stability to immediate vicinity of reservoir and will contribute to the aesthetic and beautification of the project area. For the Pauk H.E. Project, the areas to be treated are around the dam site, power house sites and around the periphery of the reservoir. Budget is expected to be **Rs. 24.63 lakhs.**

7.10. Restoration of Construction Areas and Landscaping

Around 79.1 ha of land will be directly disturbed due to various construction activities of the proposed project, like access roads, muck dumping sites, quarry sites, colonies, offices, etc. Therefore, all areas disturbed by construction activity including access roads will be landscaped to reflect natural contours, suitable drainage paths will be restored and the reestablishment of vegetation will be encouraged. For this purpose, many biological methods would be employed, such as the removal of top nutritive soil before excavation for re implantation, and construction of retaining wall. Overall restoration project would cost approximately **Rs. 72.20 lakhs.**

7.11. Disaster Management Plan

The present study for the Pauk H.E. Project comprises of the following hydrodynamic simulations due to occurrence of:

- PMF with Dam break with initial reservoir level at top of the dam
- PMF without dam in place (virgin condition)

The study comprises of prediction of outflow hydrograph due to dam breach and routing of dam breach flood hydrograph through the downstream valley, routing the design flood hydrograph through the reservoir and downstream valley without dam breach and channel routing the design flood hydrograph through the downstream valley in the virgin condition of Yarjep (Shi) i.e. without Pauk Dam to get the maximum discharge and water level at different locations of the river downstream of the dam. In the instant case, MIKE 11 model developed by Danish Hydraulic Institute has been selected for the present study because of its wide acceptability in India and abroad. Disaster management plan of Pauk H. E. project includes surveillance, emergency action plan, administrative and procedural aspects, preventive action, communication System, etc. The estimated total cost of execution of disaster management plan including the equipment would be **Rs 117.60 lakh.**

7.12. Rehabilitation & Ressettlement Plan

The R & R plan for the affected persons or families of Pauk H.E. Project follows the guidelines of Rehabilitation & Resettlement Policy of Government of Arunachal Pradesh (2008). The plan addresses all regional and national issues. It includes relief package to project affected families, compensation against rights and privileges, and a comprehensive social development plan.

Rehabilitation plan is based on the study of the socio economic profile of the neighboring population, and one of its purposes is to develop different skills and education. Relief and rehabilitation package for the affected families includes eligible person family grant, livelihood grant, schedule tribe grant, BPL family grant, pension for vulnerable persons and free electricity grant. A compensation for the loss on customary rights on Unclassified State Forest is also planned. Peripheral Development Plan is proposed to improve the quality life of the local inhabitants and infrastructure in the area. The provisions of the plan are education facilities, merit scholarship programme, training on various courses for income generation, adoption of a village, community welfare centers, construction of rain shelters and footpath, provision of sanitation facilities and skill upgradation for handicrafts. Total budget for the Rehabilitation and Resettlement Plan and Peripheral Development Plan would be **Rs. 884.50 Lakhs.**

7.13. Good Practice

The good practice is a set of safeguard and precautionary measures, which do not require detailed management plan and high financial outlay but are decisive to keep sustainable ecological and social environments. As well, the good practice is a way to maintain respectful relationship between project authorities and local inhabitants. The project authorities would establish their Environment Cell and Corporate Social Responsibility cell which will execute and monitor all the good practices. A **Rs 25 Lakhs** budget is allocated to Good practice implementation

7.14. Implementation & Monitoring program

Various plans and measures are proposed/ suggested in the Environment Management Plan (EMP) to reduce the adverse impacts of proposed project on the environment and biodiversity of the area as well socio-economic development of the region. The given plans will be executed by various agencies and departments of government of Arunachal Pradesh as well as project authorities. However, it would require a proper coordination among these agencies for smooth functioning. For this reason, two committees are suggested for the monitoring and evaluation i.e. the independent committee and project level committee. Various environmental variables would require a regular monitoring like air, water, noise, etc. In addition, various other agencies are involved in the monitoring and evaluation of some mitigation measures. Total budget allocated for the Implementation and Environment Monitoring programmes would be **Rs.60 lakhs** only.

7.15. Summary of Costs

S.No.	Plans	Amount (Rs in Lakhs)
1	Catchment Area Treatment Plan	2156,36
2	Biodiversity Management and Wildlife Conservation Plan	227
3	Muck Disposal Plan	121
4	Restoration of Construction Areas and Landscaping	72,2
5	Green Belt Development Plan	24,63
6	Fishery Development and Downstream Management Plan	55
7	Public Health Delivery System	100
8	Solid Waste Management Plan	225,4
9	Fuel Wood Energy & Bio-Resource Conservation	49.5
10	Management of Air & Water Quality and Noise Level	40
11	Rehabilitation and Resettlement Plan	884,5
12	Disaster Management Plan	117.60
13	Good Practice	25
14	Implementation & Monitoring Programme	60
	TOTAL	**4158.19**

CISMHE

DRAFT FINAL REPORT
JUNE 2012

ENVIRONMENTAL IMPACT ASSESSMENT OF PAUK HYDROELECTRIC PROJECT, Arunachal Pradesh

Volume-I
Baseline Data

Prepared for:
Pauk Hydro Power Pvt. Ltd., New Delhi

CENTRE FOR INTER-DISCIPLINARY STUDIES OF MOUNTAIN & HILL ENVIRONMENT
University of Delhi, Delhi

Project Team

Principal Investigator

Professor Maharaj K. Pandit

Core Team

Dr. J.P. Bhatt, Senior Scientist

Dr. D.C. Nautiyal, Senior Scientist

Dr. Dawa Dorje, Research Scientist

Mr. Rajender Mehta, GIS-Remote Sensing

Research Laboratory Staff

Mr. Basudev Singh Bisht, Lab Analyst

Ms. Sudha Tiwari, JRF

Mr. Rohit Singh, LA/FA

Support Staff

Mr. Ajay Gaur, Accounts

Ms. Laxmi Negi, JACT

Mr. Dharam Singh, LA

Mr. Kalam Singh, LA

Mr. Yashpal Singh, LA

Mr. Digamber Singh, LA

<u>**CONTENTS**</u>

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

1 INTRODUCTION

1.1 GENERAL

Pauk H.E. Project is the most upstream one of the cascade of three projects developed by Velcan Energy Group in the Mechuka subdivision of West Siang district of Arunachal Pradesh. The nearest township from the project is Mechuka, located 15 km upstream of the dam site. The project area can be approached through a motorable road followed by foot tracks from the Tato - Mechuka road. The project falls in a steep mountainous area between elevations 1550 m and 1400 m.

Pauk H.E. Project involves a 110 m high concrete arch dam with installed capacity of 145 MW (3x48.3 MW) for an annual energy of 637.5 GWh. In order to generate energy it would utilize 140 m gross head on the Yarjep (Shi) River. Geographically dam site is located between 94°14’43’’E longitude and 28°32’46’’N latitude near Chengrung village. The Powerhouse is situated between 94°15’58’’E longitude and 28°32’22’’N latitude. The project has been developed by the Engineering Department of VELCAN Energy. Reputed International consultants have also contributed significantly to the civil design, geology, geotechnics, and hydrology according to the latest international and Indian standards.

1.2 YARJEP (SHI) RIVER BASIN

The Pauk HE project is proposed to harness the potential in Yarjep (Shi) River which is a major tributary of river Siyom, forming a part of Brahmaputra river system. Yarjep (Shi) River is a snow and lake fed river. In the upper stretch before confluence of Sae Chu nallah it is popularly known as known as Yargyap River. Downstream of this confluence it flows as Siet River and further downstream it is called as Yarjep (Shi) . After the confluence of Phipir Korong it flows as Shi Chu and finally joins Siyom River on its right bank at 960 m. With many streams joining it on both of its banks this is a well developed subsystem within the Siyom river system. In the Tibetan part of its catchment, two northeast to southwest and southwest to northeast flowing streams feed the southeastward flowing Yarjep (Shi). These streams are snow and lake fed and flow in the altitudinal zone between 4000 to 4430 m. About 2 km downstream of this confluence another stream, flowing from a lake lying above 3400 m drains into the Yarjep (Shi) River on its right bank. Another lake fed stream flowing on the northern slope of 4418 m peak confluences with Yarjep (Shi) at 2440 m on its right bank. Further downstream, a stream flowing southward from 5003 m peak (the highest elevation in the catchment) and draining thick forest region confluences with Yarjep (Shi) on its left bank at 2320 m. This small stream is also fed by four lakes on its left bank, which lie above 4000 m.

The catchment area of the proposed schemes lies between 28° 25′ N to 28° 49′ N latitudes and 93° 45′ E to 94° 20′ E longitudes. The catchment area up to the proposed dam site is 982 Sq. km. The river bed level at the dam site is 1440 m. The catchment area presents a shape of basin oriented NW-SE surrounded with mountain chain reaching 3500 m on the northern and southern sides and 4000m on the western side. The bottom part of the basin is constituted with an alluvial plain ended by Mechuka village. Leaving the Mechuka valley, the Yarjep (Shi) River enters into quite steep and narrow gorges borders (50% up to 100% slopes) for 35 km down to Tato village where it joins Siyom River. In these 35 km stretch, the river is losing 900 m. The project is located in these narrow gorges between Mechuka and Tato village. From mountain top down to Mechuka valley (from 4500m down to 2000m), the area is steep and covered with forest. The surrounding crown (3000 m - 2000 m) of the Mechuka valley is deforested due to the past activity of the valley development. Coming out from the valley down to Tato village, the river enters into steep gorges stretch. The banks are covered with thick and dense or open semi-tropical forests.

1.3 PROJECT CONTEXT

Comparing the projected growth of peak power demand, energy requirement anticipated and increase in the generating capacity on the basis of new projects proposed and/or under construction/consideration during 11th and 12th Five Year Plans, it is evident that there is a dire need to provide additional power to the National Grid to meet the objective of power on demand. New schemes have to be taken up immediately and implemented to derive timely benefits. The most important source of power development in the Northern Eastern region is hydroelectric power located in Arunachal Pradesh and other sister states.

The power from hydro projects in the North Eastern region would be in excess of the demand in the region and would have to be exported for utilization in other regions of the country through the Siliguri corridor. Presently there is no problem in the availability of transmission systems beyond the Northeastern power region for dispersal of power as the five power regions of the country are in the process of greater integration within a national grid.

1.3.1 Policy Initiatives

Several policy initiatives has been taken in the power sector, viz., 100% FDI in generation, transmission and distribution, long-term power purchase and fuel supply agreements, mandatory International Competitive Bidding (ICB), R&M schemes costing up to Rs.500 crores are not required to be submitted for the concurrence of the Central Electricity Authority (CEA) etc.

The new Hydel Policy announced with an objective of making investment in hydro projects more attractive. Tariff dispensation and innovative financing mechanisms is expected to minimize the risks associated with hydro projects. The key GoI policy statements that guide hydropower development are National Policy for Hydropower Development and the 50,000 MW Hydroelectric Initiative (2003). The latter sets a long term target for hydroelectric power to meet 40% national generation mix, and medium term target as 28.63% of generation mix by end 10th Five Year Plan (the starting point being 25% in 2003). The policy statements describe the policy objectives of hydropower development as: (i) environmental benefits, in particular avoidance of pollution and emissions from thermal plant (ii) benefits for power system operation, especially for meeting peak demand (iii) energy security - reducing exposure to fuel price and supply risks. The policy statements also propose several policy actions to promote hydropower. A key feature of these policy statements is the concept of planning for the development of a 'shelf' (portfolio) of hydroelectric projects. India had adopted a portfolio approach to project development given (i) the scale of projected demand increases relative to individual project size (ii) the benefits of having a portfolio of projects in terms of diversifying project development and timing risks.

1.3.2 Initial Ranking

The CEA study on "Preliminary Ranking Study of Hydro Electric Schemes" identified potential hydroelectric sites at various river basins, which are prioritized in the order of their attractiveness for implementation. With the objective of expediting hydro power development in a systematic manner, Central Electricity Authority (CEA) completed the ranking study of the hydro potential sites for all the basins in the country during 2001-02 .The ranking of hydro sites has been carried out based on a weightage criteria for various aspects involved in the development of hydro schemes. Considering these aspects, the schemes have been graded in A, B and C categories in order of their priority development. Based on the Preliminary Ranking Study, 399 schemes with an aggregate installed capacity of about 106910 MW have been prioritized in the six major river systems of the country. Out of this, 98 schemes with probable installed capacity of 15641 MW fall under A category, 247 schemes with probable installed capacity of 69853 MW under B category and 54 schemes with probable installed capacity of 21416 MW under C category.

1.4 POWER POTENTIAL

1.4.1 Power Potential in India

India is endowed with a vast hydropower potential. As per the latest assessment carried out by the CEA, feasible hydro potential in India has been estimated as about 148700 MW which corresponds to a potential of about 84000 MW at 60% load factor, which can yield an annual power generation of over 440 TWh of electricity with additional seasonal energy, the total energy potential is about 600 TWh a year. Only 22.34% of this potential is under operation and 8.64% of the potential is under execution. Thus the bulk of the potential amounting to 69.01% is yet to be developed.

About 75% of the potential of the country comes from the Himalayan river systems (the Indus, the Ganga and the Brahmaputra) of that 39.6% is located in the North-Eastern region and 35.9% in the Northern region. The hydro potential of the NE region is approx. 32,000MW at 60% load factor, which is almost 95% of the Brahmaputra basin potential (Table 1.1).

Table 1.1 Status of Development of Hydro Power Potential (As on 28/02/2009)

Sl. No.	Region	Feasible Potential / Projects identified	Potential already developed		Potential under development		Total Potential development		Potential yet to be developed	
		MW	MW	%	MW	%	MW	%	MW	%
1	Northern	53395	13772	25.79	6734	12.61	20506	38.40	32889	61.60
2	Western	8928	5804	65.01	400	4.48	6204	69.49	2724	30.51
3	Southern	16458	9395	57.08	786	4.78	10181	61.86	6277	38.14

Sl. No.	Region	Feasible Potential / Projects identified	Potential already developed		Potential under development		Total Potential development		Potential yet to be developed	
		MW	MW	%	MW	%	MW	%	MW	%
4	Eastern	10949	3049	27.85	2211	20.19	5260	48.04	5688	51.96
5	North-East	58971	1203	2.04	2724	4.62	3927	6.66	55044	93.34
Total (India)		148,701	33223	22.34	12855	8.64	46078	30.98	102622	69.01

1.4.2 Need of Hydro-power

About 75% of India's total installed capacity is thermal-based (Table 1.2). However expansion of this energy source is encountering difficulties because of the burden it places on the infrastructure for supply (mines) and transportation (railways) of coal. Considering that the capacity of Indian Railways to carry coal effectively is limited and the coal is of low quality which needs costly transportation over long distances, it appears logical to develop thermal projects in specific areas, e.g. coal- rich areas in Bihar, Orissa, Eastern Uttar Pradesh and surrounding areas, and gas-based power near the port belts of Gujarat and Maharashtra, and thus place total emphasis on hydropower in States such as Himachal Pradesh, Punjab, Haryana, Western Uttaranchal and far-East India - the Himalayan belt.

Table 1.2 Share of Hydropower in India's Installed Capacity

Year	Total Installed Capacity (MW)	Hydropower Capacity (MW)	Share of Hydropower (%)
1962-63	5801	2936	50.6
1969-70	14102	6135	43.5
1979-80	28448	11384	40.0
1989-90	63636	18308	28.8
1991-92	69070	19189	27.8
1993-94	76718	20366	26.6
2001-02	105045	26268	25.0
2006-07	135299	33776	25.0

Year	Total Installed Capacity (MW)	Hydropower Capacity (MW)	Share of Hydropower (%)
2008-09	147965	36878	24.92
2009-10	159398	36878	23.14
2010-11	169798	37367	22.00

The declining share of hydropower also strongly advocates development of hydropower projects.

1.4.3 Power Potential in Arunachal Pradesh

Arunachal Pradesh along with the States of Assam, Meghalaya, Tripura, Manipur, Nagaland and Mizoram form part of the Brahmaputra Basin. This basin comprises five major rivers, viz., Kameng, Siang, Subansiri, Lohit and Dibang. During 2001 to give fillip to the efforts for the development of hydropower potential, CEA under took 'Preliminary ranking studies of 'yet to be developed sites'. The study analyzed about 399 sites out of 845 identified sites to determine the priority for development of schemes identified in the re-assessment studies. This was followed by "50,000 MW hydro electric initiative" launched by Hon'ble Prime Minister of India. Under this initiative, preliminary feasibility reports (PFR) of 162 hydro sites were prepared. Out of 162, seventy two (72) projects were identified in North eastern region itself with total installed capacity of 31925 MW. The State wise distribution of the main schemes in NE region is as under:

- Arunachal Pradesh : 42 schemes (27293 MW)
- Meghalaya : 11 schemes (931 MW)
- Nagaland : 3 schemes (370 MW)
- Mizoram : 2 schemes (1500 MW)
- Sikkim : 10 Schemes (1469 MW)

1.4.4 Hydro Electric Potential of Siang Basin

As per the study on "Re-assessment of Hydro Electric Potential" carried out by CEA during 1978-87, Siang river system has a probable hydropower potential of about 10730 MW from 16 identified schemes at 60% load factor. These schemes are run of river and storage types. Survey and investigation works were taken up at Siang Upper/Intermediate (11000 MW), Siyom (1000 MW) and Siang Lower (2000 MW) by NHPC.

In addition to the above, following nine schemes totaling to 3152 MW in Siang basin have also been identified.

- Ringong HE Project 150 MW
- Tato-II HE Project 700 MW
- Naying HE Project 1000 MW
- Mirang HE Project 141 MW
- Hirong HE Project 500 MW
- Simang HE Project 90 MW
- Pauk H.E. Project 145 MW
- Heo H.E. Project 240 MW
- Tato-I H.E. Project 186 MW

1.5 POLICY, LEGAL & ADMINISTRATIVE FRAMEWORK

It is important, for the proposed project, to identify applicable environmental regulations and legislations of the country which necessitate compliance in respect to its nature, type, scale, area and region of the proposed development.

1.5.1 Policy Framework

The National Environment Policy (NEP) of 2006 is intended to mainstream environmental concerns in all development activities. It is built on earlier policies for environmental management, viz., the National Forest Policy (1988), National Conservation Strategy and Policy Statement on Environment and Development (1992), Policy Statement on Abatement of Pollution (1992) and on some sector policies like National Water Policy (2002), National Agriculture Policy (2000), and National Population Policy (2000). The NEP is intended to be a guide to act in regulatory reforms, programmes and projects for environmental conservation and to review and enactment of legislation, by agencies of the central, state, and local Governments. The dominant theme of this policy is that while conservation of environmental resources is necessary to secure livelihoods and well-being of all, the most secure basis for conservation is to ensure that people dependent on particular resources obtain better livelihoods from the fact of conservation, than from degradation of the resource.

In the course of its development, the Pauk HEP needs to adhere to all relevant policies and guidelines in general and the following, in particular.

i.) National Forest Policy (NFP), 1988

ii.) National Water Policy (NWP), 2002

iii.) National Rehabilitation and Resettlement Policy (NRRP), 2007

iv.) Rehabilitation and Resettlement Policy (RRP), 2008 of GoAP

1.5.2 Legal Framework

The legal environmental framework stems from the national commitment to a clean environment, mandated in the Constitution in Articles 48 A and 51 A (g) and strengthened by judicial interpretation of Article 21. The Ministry of Environment & Forests (MoEF) is the nodal regulatory agency of the Central Government for planning, promotion, co-ordination and overseeing the formulation and implementation of environmental and forest policy, legislations and programmes. Regulatory functions like grant of Environment Clearance (EC), Forest Clearance (FC) are part of the mandate of this agency.

The Environment (Protection) Act, 1986 is the national umbrella legislation that provides a holistic framework for the protection and conservation of environment. The Act, its associated Rules and their subsequent amendments require for obtaining environmental clearances for new or expansion of river valley and hydro-electric projects as addressed under the Environmental Impact Assessment Notification, 2006 and require for submission of an Environmental Impact Assessment (EIA) report as one of the pre-requisites for EC.

Pauk H.E. Project is proposed to be developed by meeting statutory environmental requirements of Arunachal Pradesh as well as the Central Government. The project is to be complied with applicable environmental regulations and guidelines. Some of the Acts, Rules, notifications and standards relevant for this project development are given as under.

i.) Water (Prevention & Control of Pollution) Act, 1974 ii.) Forest (Conservation) Act, 1980 and its amendments

iii.) Air (Prevention and Control of Pollution) Act, 1981

iv.) Environment (Protection) Rules, 1986 and its amendments

v.) Wildlife (Protection) Amendment Act, 2002

vi.) The Biological Diversity Act, 2002

vii.) Forest (Conservation) Rules, 2003 and its amendments

viii.) Noise Pollution (Regulation & Control) Rules, 2003 and its amendments

ix.) EIA Notification, 2006 and its amendments

x.) National Ambient Air Quality Standard, 2009

xi.) Supreme Court's Orders on Diversion Forest Land for Non-Forest Purpose

xii.) IS Codes & CPCB Guidelines for monitoring & analysis of air, water, soil etc.

1.5.3 Administrative Framework

For ensuring environmental and related compliance by project proponents, the administrative framework consists of following entities:

i.) MoEF, GoI and its Regional Establishments

ii.) Central Pollution Control Board (CPCB)

iii.) State Pollution Control Boards or Union Territory Pollution Control Committees

iv.) State Forest Departments

v.) Ministry/Department of Environment in respective States

vi.) Ministry of Tribal Affairs (MoTA)

vii.) Central/State Ground Water Boards (CGWB/SGWB)

viii.) Ministry of Social Justice and Empowerment (MoSJE)

ix.) Ministry of Power (MoP)

x.) Ministry of Water Resources (MoWR)

xi.) Ministry/Department of Water Resources in respective States

1.6 PURPOSE AND SCOPE OF EIA STUDY

Hydro-power is considered as 'green energy' as compared to other projects like thermal power, nuclear power, etc. However, it has some adverse impacts on the environment and social structure. An EIA study is always focused to identify the negative impacts and to ensure that development is sustained with minimal environmental degradation. The purpose of the identification of the negative impacts is to formulate the suitable mitigation measure in order to require the prior environmental clearance (EC) as per EIA Notification, 2006. The EIA is expected to serve one or more of the purposes, viz., (i) decision making during project development, (ii) choosing among various project design alternatives and (iii) integrating environmental cost into the project cost. The scope of EIA study has been determined through scoping, the second stage of EC process. Hence, the scope of the present study is listed in the Terms of Reference (TOR) accorded by the MoEF during scoping and pre-construction clearance.

Chapter 2

PROJECT DESCRIPTION

2
DESCRIPTION OF PROJECT

2.1 GENERAL

The Pauk H.E. project is the most upstream project of a cascade development on Yarjep (Shi) River in West Siang district of Arunachal Pradesh. The nearest village from the project is Chengrung, located on the right bank of the Dam site. District headquarters are located at Aalo (about 160 km from the Dam site), and Mechuka is the nearest township for commodities and logistical support for the project development (about 12 km upstream of the Dam site). The project area is a steep mountainous area at an average elevation of 1000-1500m. The project aims at valorising a natural head of 140 m on the Yarjep (Shi) River between the areas downstream of Rego and Purying villages. The flow will be diverted from the river through 2.2 km long head race tunnel. The installed capacity of the project is 145 MW (3x48.3 MW) for an annual energy of 637.5 GWh (90% dependable). A location map is shown in **Figure 2.1**.

The nearest road is Tato-Mechuka state road, which is connected to the National Highway-52 (and is about 295 km from Akajan in Assam). For Pauk HE Project, the nearest meter gauge rail head is at Silapathar (approx 300 km) and broad gauge at Naogaon (approx. 700 km) in Assam. From the project site, the nearest operational airport is around 450 km, located at Likhabali in North Lakhimpur district of Assam and the nearest international airport is around 830 km located at Guwahati, the capital city of Assam.

2.2 BACKGROUND OF THE PROJECT

The Pauk HE Project is one of the 3 schemes located on the Yarjep (Shi) River and entrusted to VELCAN Energy Holdings (Dubai) Ltd by the Government of Arunachal Pradesh for the implementation of project vide MoA signed on 30.06.2007 on Build, Own, Operate and Transfer (BOOT) basis. The two other projects on the Yarjep (Shi) River are Heo HEP and Tato-I HEP. Pauk Hydro Power Pvt. Ltd, a member of Velcan Energy Group, is now the Special Purpose Vehicle dedicated to the development of the Tato-I HEP on B.O.O.T. basis.

A pre-feasibility report has been prepared and submitted to the State of Arunachal Pradesh in March 2008. Due to interference of upstream project (Rapum HEP) the initial project had to be modified, which was worked out for 50 MW and a new PFR was submitted accordingly in November 2008. The interference of upstream project has however continued after this second PFR, and was finally cleared by the Government of Arunachal Pradesh on 31st July 2009 through the signature of an amendment to the Memorandum of Agreement. Hence, the final stretch of river available for Project development was finally determined by the Government of Arunachal Pradesh on 31st July 2009, through the signature of such Amendment. In addition, the first two years of Hydrological and Meteorological studies and data collection showed more available water than initially estimated and the installed capacity of the Project was increased to 120 MW accordingly, through the aforesaid Amendment dated 31st July 2009. Following the signature of this Amendment, involving new features, the Pauk H. E. Project had to be thoroughly designed again in order to arrive at a new PFR which was submitted in November 2009.

Water Availability Studies have been approved by the Central Electricity Authority (CEA)/ Central Water Commission (CWC) in July 2010. The Power Potential Studies have been submitted in July 2010 to the CEA, which finally requested the Project developer in April 2011 to increase again the installed capacity from 120 MW to 145 MW. Hence, the Power Potential Studies have been approved with a capacity of 145 MW.

The Ministry of Environment and Forests, Govt. of India, granted to Pauk Hydro-electric Power Private Limited (PHPPL) the revised TORs and clearance of preconstruction activities, updated with the new project capacity and features in April 2010 for the first increase and then in October 2011 for the second increase. VELCAN Group has set-up guest houses in order to conduct the surveys. One guest house is located in Mechuka and the local head office is at Aalo. Locally, VELCAN Group is employing a team on site depending on site works requirements from time to time. Local population has been integrated to the project development right from the beginning through employment and/or welfare activities. In addition, all the daily / temporary labour contracts, whenever required, have been awarded to local tribal people in order to provide support to field investigations and various works. Since June 2007, VELCAN Energy has performed preliminary surveys for project reconnaissance (on various sites depending on interference issue):

- Hydrological and climatic surveys of the area
- Topographical Surveys
- Geological mapping
- Sub-surface geological investigations
- Environmental surveys for EIA/EMP preparation
- Preliminary Material availability for construction

Pauk HE Project is proposed to be developed by meeting statutory environmental requirements of Arunachal Pradesh as well as the Central Government. The Ministry of Environment & Forests (MoEF) is the nodal regulatory agency of the Central Government for planning, promotion, co-ordination and overseeing the formulation and implementation of environmental and forest policy, legislations and programs. Given the installed capacity of the Project, regulatory functions like grant of Environment Clearance (EC), Forest Clearance (FC) are part of the mandate of the Ministry of Environment & Forests (MoEF).

2.3 SCHEME ARRANGEMENT & SALIENT FEATURES

The technical conception of the project has been performed in order to reach the most cost-effective solution to take benefit of the natural head available between the Dam site and the Power House site. During study stages, different alternatives have been identified. Alternatives have been worked out in regards of geological constraints, cost-effectiveness and risks approach. Out of this study, the alternative described here has been selected.

The dam is located in the inlet of a left bend of the Yarjep (Shi) River. Orientation of axis is chosen so that flood discharge will not damage the downstream banks. At this location, the river bed level is at around 1443m. In order to ensure a sufficient reservoir for peak generation, the crest of the overtopping dam (FRL of the reservoir) is fixed at 1540 m. The dam is a Concrete Arch dam.

The 2.2 km tunnel excavated within a hilly area is driving the flow up to the entrance of the pressure shaft at the vertical of the power house platform. This platform is the only suitable location for surface power house. A surge shaft protects the tunnel from water hammer.

Pauk H.E. Project envisages a 110 m high arch dam above deepest foundation level, a head race tunnel of 2.2 km (approx) length with 118 cumec design discharge and a surface power house with an installed capacity of 145 MW. The proposed dam site is located between 28˚ 32’ 46” N latitude and 94˚ 14’ 43” E longitude while power house is proposed between 28˚ 32’ 22” N latitude and 94˚ 15’ 58” E longitude. Total catchment area of Pauk dam site is 982 sq. km. The construction period of the project is 43 months. Details of the salient features are given in Table 2.1. The project viability has been reaffirmed through the present preliminary report. Detailed layout plan of the project is given in **Figure 2.2**.

Table 2.1 Salient features of Pauk H.E. Project in West Siang district of Arunachal Pradesh

LOCATION		
State	:	Arunachal Pradesh
District	:	West Siang
River	:	Yarjep (Shi)
Location of Dam		
Latitude	:	28˚ 32’ 46”N
Longitude	:	94˚ 14’ 43”E
Location of Power House		
Latitude	:	28˚ 32’ 22”N
Longitude	:	94˚ 15’ 58”E
Nearest Airport	:	Dibrugarh
Nearest Rail head (Broad gauge)	:	Nagaon
HYDROLOGY		
Catchment area at dam site	:	982 sq km
Standard Project Flood	:	3000 cumecs
Maximum Probable Flood	:	3700 cumecs
DAM		
Type	:	Concrete Arch Dam
Dam top	:	EL 1550 m
Foundation Level	:	EL 1445 m
Maximum Height above deepest foundation	:	105 m
SPILLWAY		
Type of spillway -1	:	Free Ogee Spillway
Maximum discharge capacity at FRL/MWL	:	0 / 3400 cumecs
Energy dissipation system	:	Downstream dissipation basin

Type of spillway - 2	:	Flushing Gate
Maximum discharge capacity at FRL/MWL	:	785 / 860 cumecs
Energy dissipation system	:	Downstream dissipation basin
Type of spillway -3	:	Flushing Gate
Maximum discharge capacity at FRL/MWL	:	823 / 894 cumecs
Energy dissipation system	:	Downstream dissipation basin
RESERVOIR		
Maximum Water Level (MWL)	:	EL 1548.5 m
Full Reservoir Level (FRL)	:	EL 1540 m
Area under submergence at FRL	:	34.1 ha
Total storage	:	11.5 M cum
Active storage	:	5.7 M cum
INTAKE		
Number of Intakes	:	1 no.
Invert level of intake	:	EL 1505 m
Design discharge	:	118 cumecs
HEAD RACE TUNNEL		
Head Race Tunnel	:	One
Internal section and type	:	28.3 sq m, horse shoe, concrete lined
Design discharge	:	118 cumecs
Length	:	2.2 km (approx)
SURGE SHAFT		
Type	:	Vertical Orifice
Size	:	14 m diameter
Vertical shaft height	:	110 m
PENSTOCK		
Numbers	:	One
Diameter	:	5.5 m
Length	:	398 m
POWER HOUSE COMPLEX		
Type	:	Surface
Installed capacity	:	145 MW
Number of units	:	3nos of 48.3 MW each
Type of turbine	:	Vertical Francis
Tail water level at outlet	:	EL 1400.0 m

Powerhouse size	:	35 m (W) x 37 m (H)
Length of Powerhouse	:	72 m

2.4 ALTERNATIVE SITES

Different alternatives have been studied. The selected one is the only one that satisfies the different administrative, financial and technical constraints.

2.4.1 Cascade Optimization: three projects instead of one single project

The developer has chosen to develop the separate projects. The option of merging the three projects in one single mega-project has been envisaged. The following aspects have been evaluated:

- Use of intermediate inflow: in the 3 projects solution, it is possible to valorise the intermediate catchment area between projects. The loss of intermediate inflows leads to a loss of around 15% of power generation for the entire the cascade: 510 MW for the merged projects solution against 571MW for the 3 projects solution.
- Construction timing: the merged projects solution implies the construction of an 11.5 km long tunnel with a section of 5 km without any possible intermediate adit. The 3 projects scheme has got a similar total length of tunnel but the sections with no intermediate adit are shorter (max 1.3 km). The construction of the 3 tunnels is expected to last 3 years against 5 years for the single tunnel of the merged projects solution. Thus, a loss of production of 2 years can be associated to the merged projects solution compared to the split solution.
- Risk mitigation/financing: the solution with one unique project is considered riskier regarding time and cost control during the construction. As described above, the merged projects solution presents a section of 5 km of tunnel with no intermediate adit. In case of geological exploration during execution, the loss of time will be greater than in the case of a shorter section (pumping time, transportation and logistics, etc.). The delay would lead to increased construction costs. The single project solution bears a larger risk at execution than the 3 projects solution. This may complicate the financing process of the project.

Consequently to the above analysis, it has been decided to choose the best technical and economically efficient solution, that is to say the 3 projects solution, which is also the less risky one. Moreover, the Government of Arunachal Pradesh has allotted three concessions to Velcan Energy.

The 3 projects solution fits with the administrative issues. The process is facilitated if three concessions are developed in parallel, and a lot of time is saved. The layout of the cascade follows the here under principles in order to maximize the synergies between the projects:

- **One storage capacity in the most upstream project**, Pauk, is sufficient to regulate the natural flow during the lean season, and to ensure the peaking hours of the entire cascade. Hence, Heo and Tato-I HEPs do not need to have a reservoir, and the height of the dam and submergence areas can be lowered to the required minimum, which limits the socio-environmental and cost impacts
- Taking into account of both the high gross head of the projects and the steep slope of the river, the **same basic layout is proposed for the three projects**: a dam, a head race tunnel and a power house a few kilometres downstream of the dam.

2.4.2 Pauk Dam

Four main constraints have been guiding the dam axis selection:

- Suitable Geological conditions
- The possibility to create a sufficient storage to regulate the flows during the lean season for the entire cascade allotted to the developer
- A dam axis downstream of Sae Chu Nalah to tap the inflows coming from this major tributary of the Yarjep (Shi) River, and also increase the storage availability
- To avoid any impact on the local population and limit the environmental impacts.

Only one site was available under these constraints. The detail is given in the following sections.

a) *The geological Constraint*

The geological survey has been carried out as the first action. Three site visits have been made by geologists (see reports as appendices of the Geology Volume). The survey has been realized from the road located on the right bank to determine the potential suitable dam and intake sites. One potential site has been identified upstream of the confluence of the Sae Chu Nalah with the Yarjep (Shi) River, this site is described by the reports of COB 2008 and BRGM 2008. Later, another site has been identified downstream of the confluence of the Sae Chu Nalah with the Yarjep (Shi) River. This site is described by the report of COB 2011. It is preferable to set the axis downstream of the confluence of the Sae Chu Nalah with the Yarjep (Shi) River, for the reasons described in the sections below. Downstream of the confluence of the Sae Chu Nalah with the Yarjep (Shi) River, at only one site **rock** is visible on both banks. Elsewhere in the valley downstream of the Sae Chu Nalah confluence, either the right bank or the left bank shows mild slopes indicating unstable zones (see the geological map in the Geology Volume). At the unique site where outcrops are visible on both banks, cliffs are starting from the river bed and present outcrops. The slopes of the banks indicate good rock at small depth. This assessment has been confirmed by the investigation adit and the first drill. The width at the bottom of the valley is about 20 to 30m, and the valley is very narrow with exposed good rock. No fault has been identified. Such a site is ideal to host an arch dam.

b) ***Storage availability***

With a sufficient storage, it is possible to regulate the flows during the lean season. During the leanest month, the water is stored the most part of the day and turbined during the peaking hours. All day long, a minimum flow is released in the river to regulate the aquatic life. The developer has been allotted at the same time the concession of Pauk, and the concession of the two downstream projects namely Heo and Tato-I HEPs. When one looks at the natural flows of the river, it appears that the dispersion of the flows along a hydrological year is very high. Inflows are close to 10 times higher during the three months of the monsoon season than during the three months of the lean season. The developer wishes to be able to mobilize a storage at the most upstream allotted project, namely Pauk HEP, in order to regulate the flows during lean season for the entire cascade. The developer would then be able to ensure minimum generation whole year long, without endangering the river life. The allotted FRL is 1540 m. In the present case of Pauk H. E. Project, because of the narrow valley of the Yarjep (Shi) River, having an available storage implies a high dam.

If the dam is built downstream of the Sae Chu Nalah confluence with the Yarjep (Shi) River, the available storage would be increased significantly. A site is adequate from a geological point of view to host the dam and intake structures downstream of the confluence of Sae Chu Nalah with the Yarjep (Shi) River (see above section). This gross storage available at this site is 11.5 Mm^3. Such storage allows running around 3h at full load during the 90% dependable year, which is the requirement of the CERC guidelines. It is the maximum reservoir possible under the other constraints, particularly because of the geological and the socio-environmental constraints.

c) *Take benefit of the Sae Chu nalah inflows*

The allotted FRL is 1540 m. The confluence of the main tributary of the Yarjep (Shi) River named Sae Chu Nalah occurs at the elevation 1488. If the dam axis is set downstream of the confluence of the Sae Chu Nalah with the Yarjep (Shi) River, the catchment area of the project would be increased significantly. For the same natural gross head, the inflows available are increased. The energy generation and finally the profitability of the project is increased. With a dam axis downstream of the Sae Chu Nalah confluence with the Yarjep (Shi) River, the Sae Chu stretch will contribute to the storage of the Pauk reservoir.

d) *Socio-environmental impacts*

The reservoir at the proposed site, despite the great storage of water of 11.5 Mm^3, has got no impact on the local population. No village is overflowed and the submergence is small i.e. 25.3 ha of surface area. No population is displaced. That could have been the case if the dam would have been shifted some hundred meters downstream.

e) *Dam type: Arch dam*

Arch dam is the best option in the case of a narrow valley with exposed rock on both banks. Arch dam needs less volume of concrete than gravity dam to be built up. In the case of Pauk, a gravity dam would have implied a volume of 2 Lakh m^3 of concrete, whereas an arch dam needs approximately only 1 Lakh m^3. Moreover, an arch needs less time than a gravity dam for the execution of the works. Less risk are taken with an arch dam while considering the floods during the construction.

2.4.3 HRT Route

a) *Right bank*

A detailed geological survey has been carried out on the right bank, along the Tato-Mechuka road. To assess the rock quality, boreholes and an investigation adit have been carried out where access was possible. During last expert site visit, a major tectonic deformation has been identified on the right bank. The presence of marble and schist layers of very poor quality at the end of the right bank option route of HRT has been observed. There, the presence of sound rock at reasonable depth is not expected. The right band alignment of HRT does not seem feasible.

b) ***Left bank***

No such bad geological conditions have been identified on the left bank. The left bank option HRT is expected to be dug into gneissic rock exclusively (see Geology volume of DPR). The left bank is geologically the most suitable bank to excavate the HRT. This is also the case for the Power House (see next section). Hence, the left bank has been chosen for the excavation of the HRT. The route has been optimized in order to reduce to its minimum the length of the HRT, and to reduce to its minimum the head losses. The Don Deere and Indian Standards rules have been followed to ensure the minimum required rock cover.

2.4.4 Power House

a) ***Location of the Power House***

Left bank is the most geologically suitable for Power house. The TWL has been set while optimizing the whole allotted cascade (see above sections). The TWL has been proposed for Pauk at 1400 m., which is also the FRL of downstream project Heo HEP. A site on the right bank at the toe of Hiri village has been investigated by both experts and a geological survey has been conducted (drilling and seismic refraction survey). The depth of overburden could not have been established by the undertaken drilling, and is higher than 20 m. The expert site visit pointed out that this site was subject to sliding. The survey showed also that the right bank was also not appropriate for the HRT route. The left bank has been investigated in the vicinity of Purying village, where a cliff is visible along the river just upstream of the proposed site. Seismic profile has been carried out and showed that the foundation of the Power House would be founded on the sound rock. This site appears hence more suitable for the Power house settlement and has been selected.

b) Surface Power House

The possibility to build an underground power house has been envisaged. Potential faults on upper side of the selected site have been highlighted by the geologist during the site visit (see Geology Volume of DPR, Coyne-et-Bellier report, dated March 2011). A stress relief may also be expected close to the cliff. If these hypotheses are revealed accurate, the construction of an underground power house cavern and a tail race tunnel would lead to the dramatic rising of costs and delays. On the other hand, a surface power house is expected to be founded on the sound rock. The stability of a surface power house can easily be ensured at this location. A surface power house has been selected to avoid any risk in terms of costs and delays during construction.

The presence of potential faults underlined here above has been taken into account for the design of the pressure shaft. Its location has been chosen to limit the risk to meet a fault during its excavation. It is steel lined to avoid any stress relief.

2.5 CONSTRUCTION METHODOLOGY

There are three main construction components, namely, power house near Purying village, as well as 2 smaller elevated structures for tunnel and surge shaft works, diversion dam and intake platform near Chengrung village. Network of consolidated paths has been implemented for investigation purposes. Before the commencement of the work, access roads will be built from the existing Tato to Mechuka road. The access roads preparation will be awarded in an advanced stage once all clearances are obtained, so that this preliminary activity will not jeopardize the tunneling work starting date.

The construction methodology and equipment planning for various works is based on the site conditions prevailing in the project area. Construction activities are planned in such a way that the project will be completed in the shortest possible time period. The following assumptions have been made for construction methodology and equipment planning of the project.

- All the pre-construction activities like land acquisition, infrastructure works and government approvals are completed before the start of construction works on main components of the project.
- All civil, hydro-mechanical and electro-mechanical works are executed in the main packages of contract, described in 2.5.2

2.5.1 Material sources

2.5.1.1 *Concrete*

15 km upstream of the site, the Mechuka valley is filled with a deep layer of alluvium and sandy material. A quarry site for sand will be developed in the vicinity and the required quantity of sand will be transported from Mechuka to the construction sites. During investigation stages, various

quarry sites for coarse aggregates have been identified in the vicinity of the construction sites. Based on direct availability of rock *in situ* and construction sites proximity, 2 locations have been selected.

- Sae Chu nalah, lower part, right bank (upstream of Chengrung village)
- Downstream of Hiri village, right bank

Crushing plant will be located at the construction sites. According to test results, aggregates extracted from these quarry sites are suitable for concrete production. Cement has to be brought by road from the closest cement factory (most probably from Assam).

2.5.1.2 *Steel and Equipment*

Due to site specific conditions, almost all equipments and steel parts will have to be brought from remote factories, either in other districts of Arunachal Pradesh or even from other States of India in the case of E&M equipment. For heavy equipment delivery, alternative solutions over Brahmaputra River as well as rail transport up to Dibrughar were investigated.

2.5.2 Contract Packages

The entire project is envisaged to comprise the following eighteen main contract packages:

CIVIL WORKS

- **Package I** : Dam, Power Intake Structure
- **Package II** : Head Race Channel, Head Race Tunnel and Valve House
- **Package III** : Surge Shaft, Pressure Shaft, Powerhouse complex and Tail Race Basin

HYDRO-MECHANICAL WORKS

- **Package IV** :Hydro Mechanical works comprising of gates, hoists and Pressure Shaft steel liner

ELECTRO-MECHANICAL WORKS

Package V : Generating Units (Turbine & Generator), Cooling Water System, Drainage/ Dewatering System, Unit Control & Automation, Bus duct.

- **Package VI** : Valves-MIV& BFV
- **Package VII**: EOT Crane,
- **Package VIII**: Air Conditioning, Ventilation etc.
- **Package IX** : Fire Fighting,

- **Package X**: Transformers (Generator Transformer),
- **Package XI**: 415 V Switchgear & 11 kV Switchgear
- **Package XII**: Illumination
- **Package XIII**: DG sets (construction power)
- **Package XIV**: Cable &Cable Trays
- **Package XV** : Switchyard & Protection metering
- **Package XVI**: Transformer (Dry Type UAT SST),
- **Package XVII**: DC System (Battery & Battery Charger), UPS
- **Package XVIII**: Miscellaneous and finishing works

Contractors eligibility for each Package mentioned above shall be fixed suitably based on the working experience under similar conditions. The auxiliary works of the river diversion including cofferdams shall be part of the civil works. However, depending on the basic site facilities available such as storage facilities for contractor, site offices, testing laboratory, staff colony, plant and access roads at power house and diversion dam sites, some or all of the related works have to be taken up by the Contractor departmentally to enhance the pace of work and cost recovered from the contractors. Package-IV to XVIII listed above being equipment packages, they shall be contracted earlier so that by the time civil contractors mobilize site facilities and manpower, minimum equipment are made available for furthering the work on site.

2.5.3 Schedule of Work

As per plan, underground works such as headrace tunnel, adits and the related works should not be hampered by the restricted working season The peak of workforce is expected to reach up to around 550 people during the construction period.

2.5.4 Construction Activities

Following construction activities for various components of the H.E.P are described herein.

2.5.4.1 Diversion of river – Dam and Diversion channel

Construction activities for structures located on the left and right banks are highly impacted by the water level seasonal variation. Therefore, the work sequence shows 4 phases, each of which corresponding to either lean or monsoon time.

Phase 1: Diversion works

The diversion tunnel will be located on the left bank of Dam site. Its construction shall be started as soon as the access tunnel 1 is excavated and the access to the mouth of the diversion tunnel is possible. The excavation is made from downstream end to avoid problems during the monsoon season.

At the beginning of the lean season the cofferdam shall be erected, so the final part of the dam excavation program will start.

Phase 2: Excavation works

The excavation works will first start on the right bank, as soon as the tunnel 4 is finished and it will reach the 1470 m. at the end of the first year of dam construction.

The excavations on the left bank shall start as soon as the access through the tunnel 2 is possible. It will reach the 1470 m.at the end of the monsoon season of the second year of dam construction.

At that time the cofferdam upstream will be already erected, so the flow of the river will entirely pass through the diversion tunnel during the second lean season of the dam construction activities. The river diversion will enable the excavation on both banks to reach 1445 m, the level of dam foundations.

Phase 3: Dam concreting

Dam concreting will start as soon as the excavation is finished. The concrete in the dam body is proposed to be poured in blocks of 13 m large and 1.5 m high. The spaces between the columns of blocks are the joints of the dam, which will be filled later. The time rate of concreting has been estimated in two pours per week, which a total of 0.5 metres of height per day.

The 1460 m. must be reached before the end of the lean season. From that point the water flow going beyond the cofferdam during the monsoon season will pass through the opening located in the inferior part of the arch dam, so it will not disturb dam concreting above.

Dam concreting will reach the top (1550 m) after 16 months. Since then, just the spillway and the bridge over it will remain to finish the project, at the end of the fourth year of construction.

Phase 4: Electro-Mechanical equipment

The Electro-Mechanical equipments to be erected in Pauk dam consist in the flush gate structure completion and the gates and servomotor erection. The installation will carried out after concreting reaching the top of the dam, simultaneously with the spillway and bridge construction, so the testing and commissioning will be performed at the end of the fourth year of construction.

2.5.4.2 Intake Structure

The excavation of the Intake structure on the left bank will start on the 22nd month of construction activities. Concreting will start once the excavation is completed, on the 26th month of construction activities. The excavation of the HRT through the intake will start once the concreting has reached the 1520 m. so intake will be used as mouthpiece for the tunnel excavation.

2.5.4.3 Tunneling

The HRT is horizontal with a horse shoe shape section with a 5.9 m finished inner diameter and an overall length of about 2.375 km, it has been proposed for carrying water from the head race channel to the pressure shaft. A 300 mm thick concrete lining layer has been proposed all along the length of the tunnel. The excavation will be carried out from two faces, as shown in the **Figure 2.3** gaining access through the access tunnel 5 from the powerhouse site, and from the Intake structure, from the dam site.

Tunnelling works will be started with the construction of the Access tunnel 5 with the same section that will provide access & start point for further excavation activities. The excavation of the Access tunnel 5 will start in the 11th month of construction works and will be completed in the 13th month of construction works. The critical path for Pauk H.E. project is the HRT excavation and concrete lining, as well as dam construction, so special attention in terms of resources is required at this front for completion of work in time schedule.

The tunnel will be excavated by conventional drill and blast method using mechanised equipment, 3-Boom Drill Jumbo will be used for drilling holes and robotic shotcrete machine will be used for temporary rock support. After blasting, fresh air will be supplied by a duct at excavated face to extract gas and dust produced during blasting. The excavated muck will be loaded through one 1.5 cum bucket capacity hydraulic excavator and transported by dump trucks of 20/25 T capacity to muck dumping area. After excavation scaling will be done followed by the rock bolting and shotcreting. Pre-splitting or smooth blasting technique shall also be adopted to avoid over break. The proposed cycle time for the excavation and rock support of HRT is proposed in the next table.

The excavation works on the HRT will start on the 14th month of construction works and will be completed 20 months later, in the 34th month of construction. In the underground works three shifts per day are proposed. The working time is estimated as 24 hours per day, 26 days per month. A typical excavation cycle for class II (a pull of 6.00 m) is given in Table 2.2.

Table 2.2 Estimated Cycle Time in class II Rock (For a pull of 6 m)

Components	**Time**
i) Preparation for the job	0.5 hr
ii) Drilling of charge holes	6.0 hr
iii) Charging	1.0 hr
iv) Removal of jumbo to safe position	0.5 hr
v) Blasting and defuming	2.0 hr
vi) Mucking	7.0 hr
vii) Scaling	1.0 hr
viii) Tunnel supports	6.0 hr
Total	**24.0 hrs**

Tunnel supports

As per international and Indian Standards, vault reinforcement solution shall depend on geological conditions and progress rate will be affected consequently:

A. Rock Class I

About 5% length of tunnel is expected to pass through slightly jointed rock mass evaluated as Class II and characterized by RMR in the range 81-100. Generally no support required except for occasional spot bolting.

B. Rock Class II

About 35% length of tunnel is expected to pass through moderately jointed rock mass evaluated as Class II and characterized by RMR in the range 61-80. The excavated section will be supported by wire mesh 50 mm shotcrete where required followed by local use of rock bolts / rock anchors of 25 mm diameter 3 m long at a square spacing of 2,5 m in the crown portion only, where required.

C. Rock Class III

About 40% length of the tunnel is expected to pass through moderately jointed rock mass evaluated as class III and caracterized by RMR in the range 41-60. The excavated section will be supported by 50-100 mm thick shotcrete followed by systematic use of rock bolts / rock anchors of 25 mm diameter 3 m long at a square spacing of 1,5-2.5 m in crown and walls.

D. Rock Class IV

About 15% length of the tunnel is expected to pass through weak rock formation evaluated as class IV and characterized by RMR in the range 21-40, requiring additional stiff support in the form of ribs. The excavated heading will be provided with immediate support by 100-150 mm thick shotcrete with wire mesh followed by 25 mm diameter 4.5 m long rock bolts at a square spacing of 1-1.5 m.

E. Rock Class V

About 5% length of the tunnel is expected to pass through weak rock formation evaluated as class IV and characterized by RMR in the range 4-20, requiring additional stiff support in the form of ribs. The excavated heading will be provided with immediate support by 100-200 mm in crown and 50 mm on face or medium to heavy ribs spaced 0.75m with steel lagging and forepoling if required close invert. Spot bolting (Swellex, expansion bolt, etc) and self drilling bolt are proposed as rock bolts in poor rock quality.

2.5.4.4 Surge Shaft and Pressure Shaft

The surge shaft (81 m deep and 12 m dia) construction will begin from the 13th month. A first shaft will be excavated by a raise borer. Thereafter, the final surge shaft diameter will be obtained by blasting. The construction of the access to Surge Shaft top and to Surge Shaft bottom (i.e. HRT DS access tunnel 5) is independent of the other construction sites. It would be taken up in the 11th month of construction. Adit to the bottom of the shaft is planned to be completed in 3 months. Once the pilot shaft is made through, a first shaft (81 m deep and 3m dia.) is excavated from the bottom to the top using a Raise Borer. Then the shaft is enlarged from the top to bottom by drilling and blasting up to the final external diameter (81 m deep and 12 m dia.) of the surge shaft. The muck will be dumped into the diameter shaft and loaded at the HRT access tunnel 5 by one Dozer of 100 HP, one Hydraulic Excavator of 1.0 cum capacity and sufficient nos. of 20/25 T Dumpers. Bolting, meshing and shotcreting will be proceeded after dumping the muck. This activity is planned to be completed in 10 months time.

One 5.75 m dia circular steel lined pressure shaft has been provided for taking the water from the HRT to the bifurcations. At the end of the underground pressure shaft, three smaller surface penstocks of 2.75 m of diameter feed the vertical axis Francis machines in the surface power house. The pressure shaft consists of horizontal and vertical portions. Access tunnel 5 to Pressure Shafts at top shall be completed before the start of excavation work in Vertical Pressure Shafts. The construction of horizontal pressure shafts at top shall be taken up by full face drilling and blasting method. It is basically the beginning of the Head Race Tunnel excavation. The length of this part is 95 m and the time necessary for the excavation is 16 days. The excavation shall be taken up with 3-Boom Drill Jumbo will be used for drilling holes and robotic shotcrete machine will be used for temporary rock support, one hydraulic excavator, one dozer (100HP) and sufficient Nos. of 10T/20T dumpers.

Similarly the horizontal pressure shafts at bottom shall be taken up from the Power House platform located at El 1405 masl. The length of this part is 134 m and the time necessary for its excavation 45 days. After the excavation in these horizontal Pressure Shafts, the excavation of the vertical pressure shaft of a depth of about 80 m will be taken up. A pilot shaft is first drilled from the top to bottom. Once the pilot shaft is made through, a first shaft (80 m deep and 3m dia.) is excavated from the bottom to the top using a Raise Borer. Then the shaft is enlarged from the top to bottom by drilling and blasting up to the final external diameter (80 m deep and 7.4 m dia.) of the pressure shaft. The estimated time necessary for this operation is 40 days. The muck will be dumped into the diameter shaft and loaded at the HRT adit 2 by one Dozer of 100 HP, one Hydraulic Excavator of 1.0 cum capacity and sufficient nos. of 20/25 T Dumpers. Bolting, meshing and shotcreting will be proceeded after dumping the muck. The same raise boring machine can be used for both the surge shaft and the pressure shaft excavation.

Steel lining of pressure shaft will be undertaken after completion of the excavations. Ferrules of 3 m length shall be rolled and welded in the workshop outside and shall be transported on trailers to the pressure shaft for lowering. Inside the tunnel, ferrules shall be transported on trolleys travelling on rails and pulled by winch. For vertical portion, steel lining shall proceed from bottom to top first and there after horizontal portion shall be taken. The concrete backfilling of these ferrules will immediately follow after the erection and welding of ferrules inside the shaft. The concrete shall be poured after welding 2 pieces of 3 m ferrules. A mean progress of 2 m/day (erection and backfilling) per shaft is planned for the Pressure Shaft.

2.5.4.5 Power House Site

The powerhouse is designed to accommodate 3 x 48.3 MW turbine units and all equipment required for their operation. Excavation of the power house and tailrace basin shall use standard method deploying Drill & Blast machinery and jack hammers. Rock faces will be stabilized with steel mesh, shotcrete and/or rock bolts wherever needed. Mucking of the excavated soil and rock will be carried out through site roads to dumping site. Approach to the powerhouse on the left bank of the river is planned from the existing road on the right bank and by crossing the Yarjep (Shi) River through a bridge built for this purpose. The left bank will be treated by grouting so that the site will have limited water infiltration from the river. Concreting of the powerhouse will be carried out in 2 major phases.

- A substructure that accommodates machinery and several specific embedded parts such as draft tube and spiral case
- A superstructure that is similar to conventional industrial building works

Tailrace channel walls will be concreted in 3 m lifts with appropriate number of shutters. A common batching and mixing plant at this location shall be employed for Heo HEP Dam. Erection, Testing and Commissioning of the three TG units shall be a parallel activity to the entire scope of works described here above. However, commissioning may only be completed after impounding of the whole installation, which requires work completion of the other project components (dam, intake, HRT).

2.5.5 Land Requirement

Total land requirement for the Pauk H.E. Project is 91.7 ha including 3.3 ha of underground land (Table 2.3). Out of 88.4 ha surface area, river bed accounts for 9.3 ha. Total submergence area is 34.1 ha, in which river bed area is 8.8 ha.

Table 2.3 Details of land requirement for the various components of Pauk H.E. Project

S. No.	Project Component	Surface Area (ha)		Underground Area (ha)	Total Area (ha)
		Surface	River Bed		
1	Submergence area	25.3	8.8		34.1
A	**Surface Structures**				
2	Dam area	3.5	0.5		4.0
3	Dam storage area, Office and Colony area	3.5			3.5
4	Dam Quarry site	1.0			1.0
5	Dam Access Road	2.4			2.4
6	Power house area (including penstocks and Tail Race)	16.8			16.8
7	Muck disposal area	5.1			5.1
8	PH Storage area, Office and colony	1.3			1.3
9	PH Quarry site	0.2			0.2
10	PH Access Road	3.1			3.1
11	Surge Shaft Access Road	3.3			3.3
12	Muck Access Road	12.6			12.6
13	Explosive storage area	1.0			1.0
	Total of surface areas	**79.1**	**9.3**		88.4
B	**Under Ground Structures**				
5	Dam Access Road (underground part)			1.1	

12	Muck Access Road (underground part)		0.3	
14	Head Race Tunnel		1.7	
15	Diversion Tunnel		0.2	
C	**GRAND TOTAL**			
	Total	**88.4**	**3.3**	**91.7**

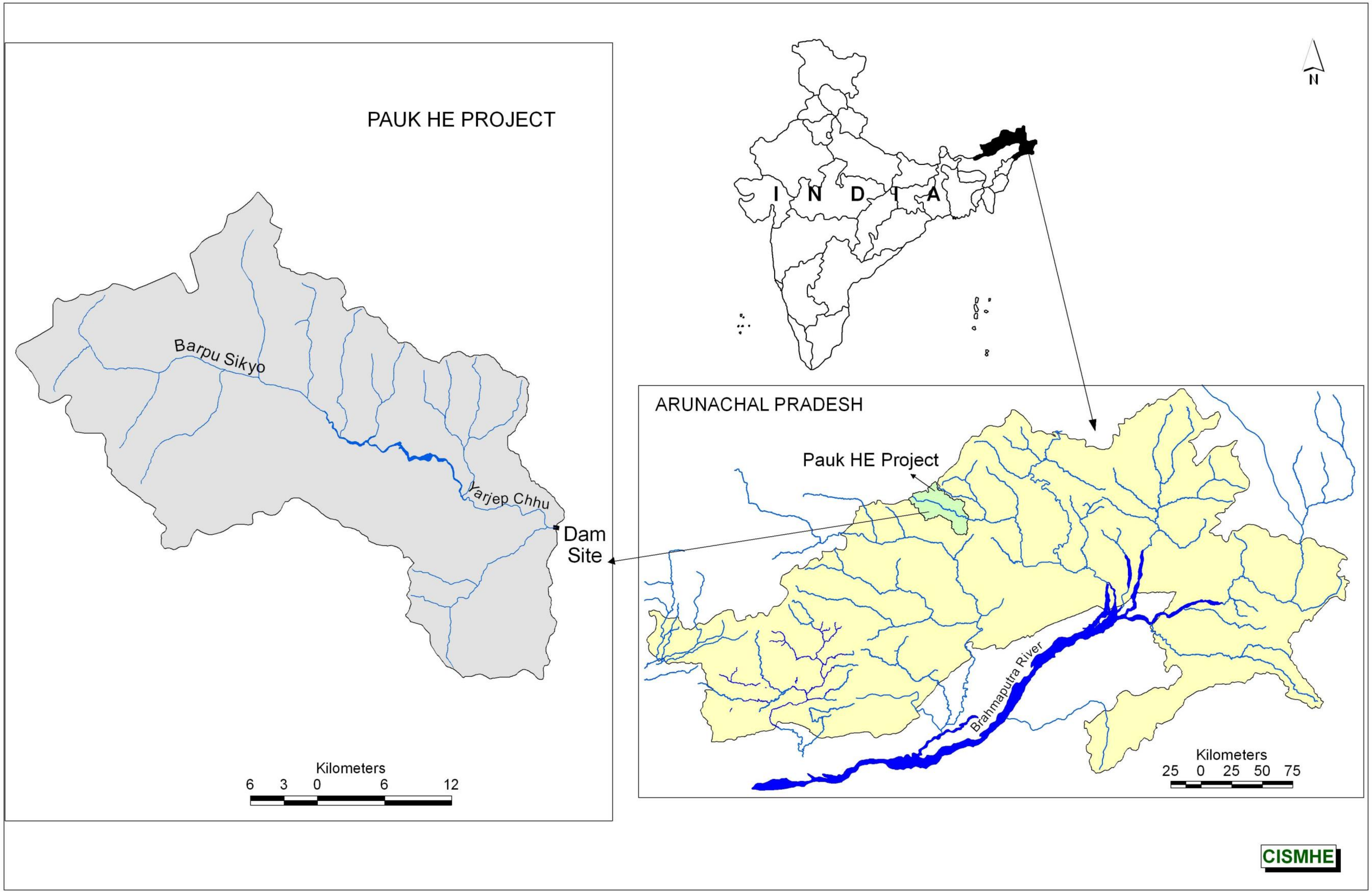


Fig.2.1 Location map of Pauk H.E. Project Stage-I

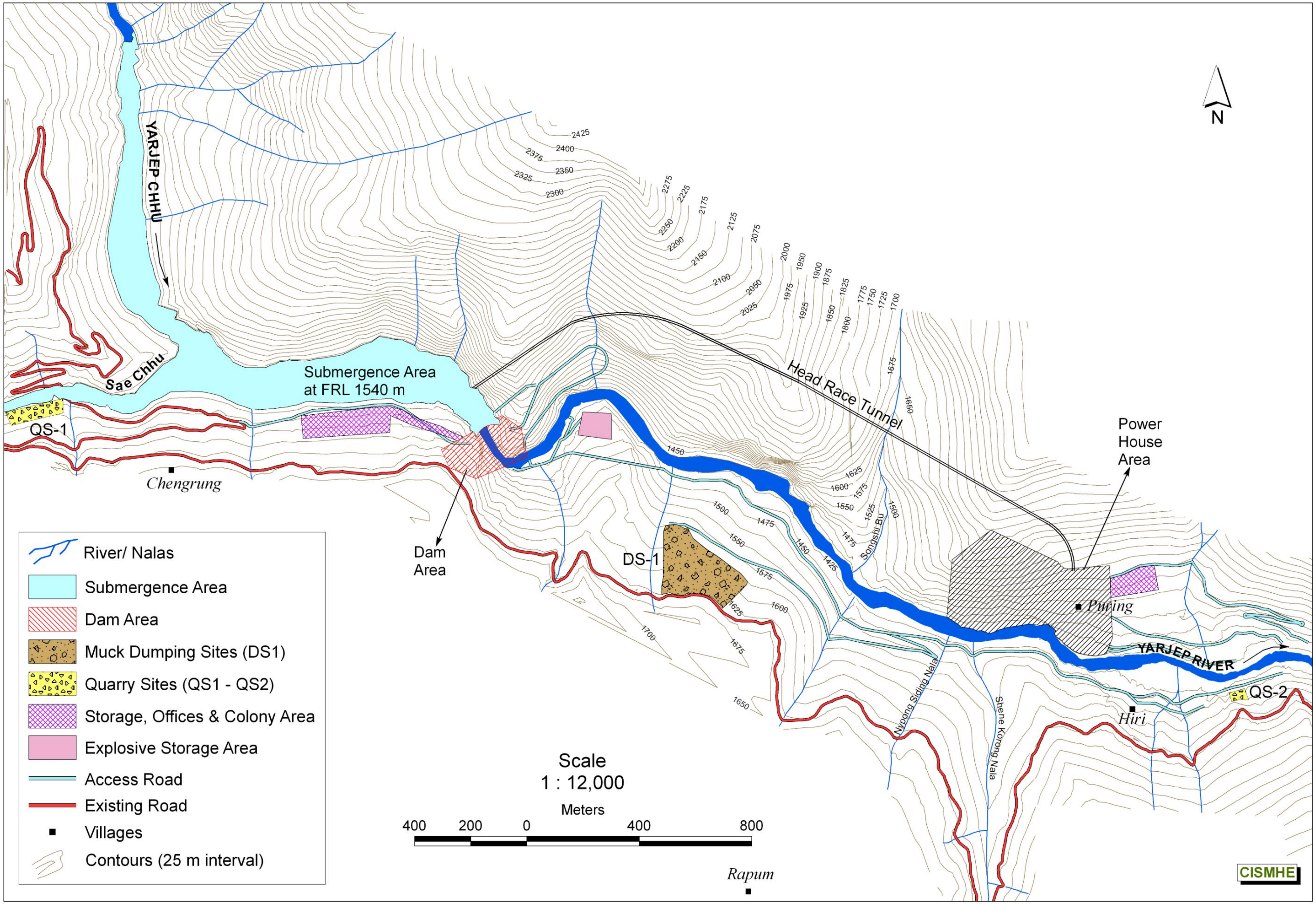


Fig.2.2 Layout map showing the different components in the stretch of Pauk H.E. project area (Source : Velcan Energy)

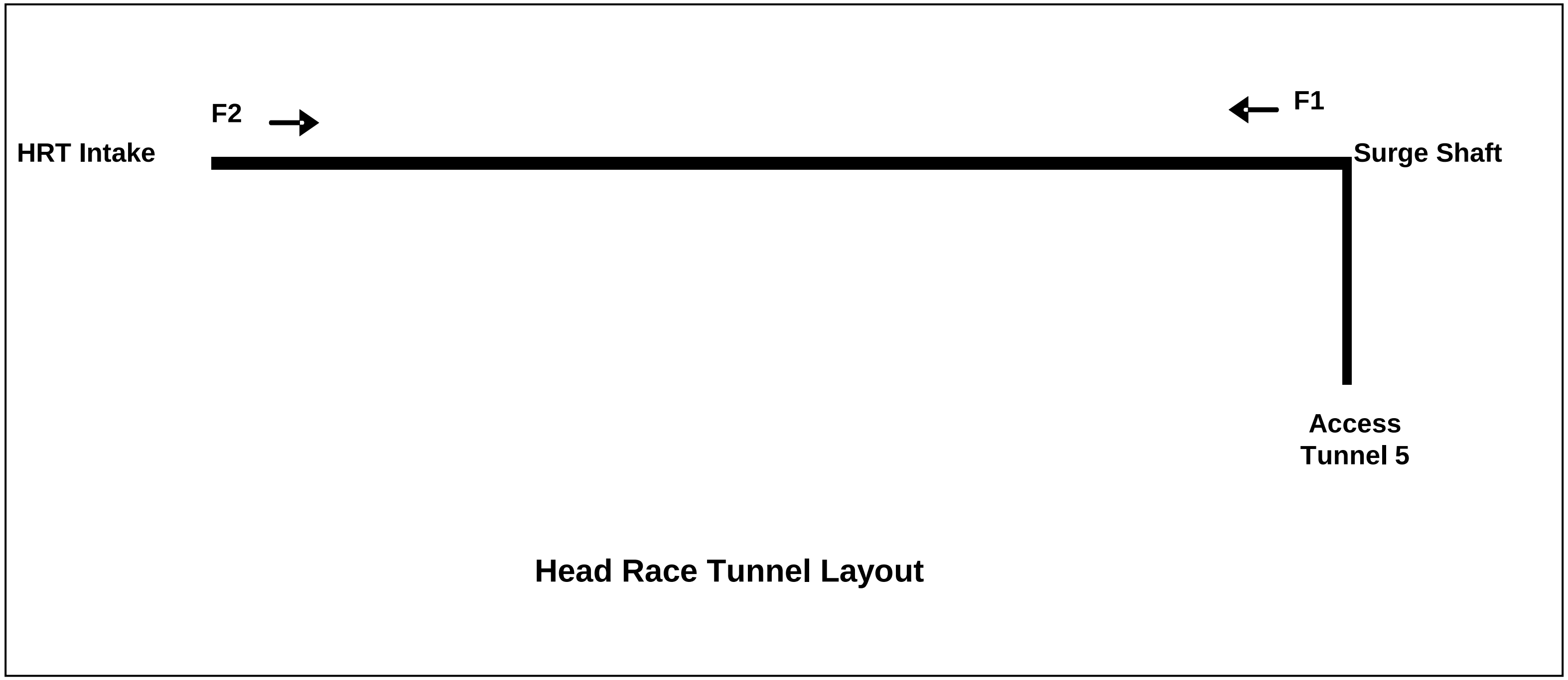


Fig. 2.3 Schematic diagram of H.R.T.

Chapter 3
BASELINE DATA

3
BASELINE DATA

3.1 CONCEPTS & METHODOLOGY

3.1.1 CONCEPT

Environment Impact assessment is a systematic process that examines the environmental consequences of development actions in advance (Singh et al., 2008). The emphasis, compared with many other mechanisms for environmental protection, is on prevention. It requires systematic, holistic and multidisciplinary approach. The EIA is not only intended to identify impacts which will result from implementation of a project, but is also an effective planning tool in environment management. The EIA identifies potential negatives which may on a long term basis require substantial economic expenditure for solutions.

After the Stockholm Conference in 1972, an increasing concern has been expressed over the adverse environmental impacts of water projects in general and creation of man made reservoirs by building dams in particular. In spite of the positive gains offered by hydropower projects, one can not deny the fact the creation of dams and reservoirs have significant environmental repercussion on physical, chemical and biological aspects of the environment. Any change in natural topography and water regime of a river will affect its ecological and biological diversity. However, a major conflict arises between developmental progress and biodiversity conservation when many projects are sited in the remote tracts. With implementation of such projects, the wild habitats come under greater biotic pressures. These are causing irreparable damage to the flora of the state.

In India, Ministry of Environment and Forests has taken several policy initiatives and enacted environmental and pollution control legislation to promote integration of environmental concerns in developmental projects. The Ministry of Environment and Forests initiated the EIA with the river valley projects during 1978-79. Subsequently, its scope has been enhanced to cover other developmental sectors such as thermal power projects, mining schemes, industries, etc. The government of India enacted the Environment (Protection) Act on 23rd May 1986. Under the provisions of Environment (Protection) act, 1986, the notification of Environmental Impact

Assessment (EIA) of developmental projects was issued on 27th January 1994 and subsequently amended on 4th May, 1994, 10th April 1997 and 27th January 2000. The EIA has been made mandatory for 30 categories of developmental projects.

The Environmental Impact Assessment study involves the assessment of various base line parameters of environment like land, water, air, noise, flora, fauna, drainage, erosion problems, socioeconomics, etc. and to suggest mitigation measures for the same by integration of these parameters which gives an overall perception of positive or negative short or long term effects on environment due to construction of a hydroelectric project, if any. Besides these components the impact on quality of life on the people living in the vicinity of the proposed project is important to arrive at the informed decision as to the environment feasibility of the project. Recently new dimensions have been added to the EIA studies encompassing ethnic diversity, cultural sensitivity of human communities and issues such as displacement, resettlement and rehabilitation.

The developmental actions may have impacts on physical, biological, social and economic environments. It requires a suitable and feasible management plan which emphasize to avoid the action which has negative impacts on the resources or to minimize or compensate the potential adverse impacts.

3.1.2 METHODOLOGY

In the present study standard methods, either developed at the Centre or published elsewhere, such as CISMHE (1993, 1998, 2000, 2002, 2005, 2008), Clark, *et al.* (1981), Leopold, *et al*. (1971), Sassaman, (1981), Lohani & Halim (1987), Biswas & Geping, (1987) etc., were followed for Environment Impact Assessment of Pauk H.E. project. Studies on water resource development projects by various authors viz. Bisset (1987); Dee, *et al.* (1973), Duke, *et al*. (1979) and LEUP, (1979) were particularly consulted for the present study. A brief account of the methodologies and matrices followed in the present study is given below under different headings. All the methods were structured for the identification, collection and organization of environmental impacts data. The information, thus gathered, has been analyzed and presented in the form of a number of visual formats for easy interpretation and decision-making.

3.1.3 SCOPE OF THE STUDY

The present study on Environmental Impact Assessment (EIA) of Pauk H.E project in West Siang district of Arunachal Pradesh includes all the aspects outlined in the Terms of Reference (TOR) by Environment Appraisal Committee of Ministry of Environment & Forest, India. The study areas comprise free draining catchment area, areas within 10 km radius (influence zone) and areas of project activities. With the help of baseline information, likely impacts were identified and a comprehensive Environment Management Plan (EMP) was formulated to avoid and /or minimize the negative impacts.

3.1.4 STUDY AREA

Pauk Hydroelectric Project is a run of the river scheme proposed on Yarjap River near village Rapum in West Siang district of Arunachal Pradesh.. The dam site is situated near Rapum village and power house site is located near Purying village (opp. to Hiri village) having total installed capacity of 145 MW. The study area was bifurcated into areas of direct and indirect impacts. The area of indirect impact includes the free-draining catchment area of proposed Pauk HE Project, which comprises nearly 840 sq km. The indirect impacts on the various aspects included in the EIA were also assessed in the 10 km radius of proposed project. It includes 10 km periphery of proposed dam and power house sites, tail of reservoir and river bed. The areas of direct impacts constituted the area of major activities like dam site, submergence area and other proposed activity sites. The various aspects depending on the magnitude of impacts were studies in the areas of direct impacts.

3.1.5 SURVEYS

Primary surveys were conducted in different seasons of the year to collect data related to geology, flora, fauna, forest types and ecological parameters including soil and water. During these surveys data and information were collected on geophysical and biological attributes of the catchment and free-draining areas in brief, influence area (10 km radius) and project areas in details. In addition, detailed surveys and studies were also conducted for understanding aquatic ecology and fish life of Yarjep River and its tributaries. Primary surveys in the entire catchment area were also conducted for the purpose of ground truthing and augmenting the remotely sensed data. For this purpose various attributes such as land features, rivers, forest and vegetation types were recorded on the ground in the catchment area, in project and in study area (**Fig. 3.1.1**). A detailed schedule of the survey and samplings is given below.

S.No.	Duration of Survey	Parameters studied
1	February, 2009	Water, Fauna, Flora, Geology, soil, Fish, Air, Noise, Climatic attributes, Fish and fisheries
2	May, June, 2009	Water, Fauna, Flora, Geology, Soil, Fish, Air, Ground truthing
3	Aug., September, 2009	Water, Fauna, Flora, Geology, soil, Fish, Air, Noise, Ground truthing, socio-economic survey
4	May, June 2010	Fauna, Flora, Geology, Soil, Fish, Noise
5	December 2010	Socio-economic Surveys

Detailed methodology followed to collect the primary data on various environments, viz. land environment, water environment, air environment, biological environment and social environment has been described under the following headings.

3.1.5.1 Physiography

Spatial database on physiographic features were taken from various sources including Survey of India (SOI) toposheets, satellite data and analyzed with the help of Geographic Information System (GIS) tools. These data were collected, arranged and thematic maps according to the EIA methods were used in the study. The thematic maps are presented in the form of general drainage map of catchment and its sub-watersheds, relief map, aspect map, slope etc. In addition, river gradient profile of the Yarjep River was calculated from its upper reaches to the proposed intake site.

3.1.5.2 Geology & Seismicity

The regional geology around project area highlighting geomorphology, stratigraphy and structural features were based on the existing information, viz., i) Detail Project Report (DPR, 2011), ii) Geology of Arunachal Pradesh (Kumar, 1997), iii) Geodynamics of Northeastern India and adjoining region (Nandy, 2001), iv) Seismotectonics of South Asia (Kayal 2008), v) Indian Meterological Department (IMD) earthquake data in the vicinity of the project area and vi) published literatures (Verma and Kumar, 1987; Kayal, 1996, etc.). The discussion on project geology has been based on the available data in DPR of Pauk (2011) and field observation in the selected sites.

3.1.5.3 Soil

The soils are classified by using the standard method of NBSS (1998). It was prepared for the catchment area, influence area (1200 – 3600 m) and the project components area. Soil samples were retrieved from various locations of downstream area, proposed power house area, dam site area and the catchment area for three seasons and grouped into four sites. Description of the sampling sites are given below.

i. Site S1 - Mechuka (upstream of dam site, site inhabited by sparse coniferous forest)
ii. Site S2 - Near Pauk dam site (right bank, dense forest)
iii. Site S3 – uphills of Puyring village
iv. Rapum village

Three replicates samples at each site was collected after analyses of samples, an average value for each parameter was calculated. The soil samples were collected with the help of auger. Soils were removed from upper temporary layer (5cm or more according to the soil profile) with help of digger; soil samples were retrieved from a depth of about 10 - 30 cm and about 10 x 10 sq cm in width. The physical properties included moisture content, water holding capacity, bulk density and pore size measurement (soil texture) while chemical characteristics included pH, organic carbon, organic matter, phosphate, nitrate, and chloride. Soil moisture was calculated by evaporating moisture from pre-weighed soil, at 105^{o}C for 24 hours in an oven and reweighed the soil. Standard methods for the soil analysis were followed as given in Jackson (1958) for bulk density, soil texture and water holding capacity. The soil was divided into 6 textural classes – very coarse, coarse sand, medium sand, fine and very fine sand, coarse silt and fine, medium silt and clay by using the sieve of mesh sizes 500-2000 µm for very coarse and coarse sand, 200-500 µm for medium fine sand, 50 - 200 µm for very fine sand and 20-50 µm for coarse and medium silt and < 20 µm for fine silt and clay.

Soil pH and conductivity were measured by the instruments pH Scan and TD Scan 3 (Oakton, Eutech Instruments), respectively. Nitrate and phosphate were determined by the icon specific meter (Hanna Instruments). Chloride estimation was done by colorimetric analysis given by Adoni (1985) while organic matter was calculated by Walkley's method (Walkley, 1947).

For the present study, we carried out the analysis of soil microbes for samples collected from four different sites of Pauk H.E. Project. Microbial population analysis was carried out by Serial

Dilution Technique. Microbes were isolated at 10^{-6} dilution on Potato Dextrose Agar (PDA, Himedia) and Nutreint Agar (NA, Himedia) for fungal and bacterial populations, respectively. Media were prepared by dissolving the ingredients in distilled water and heated until the agar was completely dissolved. The pH of the media was adjusted to 5.4 (± 0.2) and 7.2 (± 0.2) for fungal and bacterial cultures, respectively. Finally, media were autoclaved at 15 lb/ $inch^2$ for 15 minutes and allowed to cool to about 40 - 45^{o}C and poured into sterilized Petri plates. Inoculated Petri plates were incubated at 27^{o}C (± 2.0) for fungal and at 34^{o}C (± 2.0) for bacterial colonies. Five to seven days old Petri plates were scanned for population counting and these were expressed as CFU (Colony Forming Units) for fungi and MPN (Most Probable Number) for bacteria.

3.1.5.4 Land Use and Land Cover

Land use and land cover was prepared for the Pauk H.E project area. Remote sensing technology and GIS spatial functionalities were used in the preparation of Land use and Land cover maps for the whole catchment, with area coverage of 982 sq km. Satellite imageries of IRS-P6 LISS-III was used and it was radiometrically corrected using dark pixel subtraction technique before the land use/ land cover map was generated. Nine land use/ land cover classes were generated for the catchment. The land use and land cover maps were prepared for the catchment area, influence area and project area.

3.1.5.5 Hydrology

The data on rainfall are available from 7 rain gauge stations namely, Mechuka, Monigong, Raying, Kaying, Aalo and Tato sourced from various third parties (IMD, Brahmaputra Board and other private project developers) and have been used, along with the developer own Gauge station, to assess the water availability. Two data sources were acquired for Mechuka (i.e. external data source and rain gauge stations installed by Velcan Energy Group). Average annual precipitation was recorded at all the mentioned rain gauge stations. Based on the data described above, the detailed water availability studies have been conducted to arrive at the 10 daily discharge data of Yarjep River available from June 1978-79 to May 2008 - 2009 (DPR, 2011). This data set was utilized for calculating monthly, annual water discharge and 90% and 50% dependable years for Pauk H.E. Project. The Central Water Commission has approved the Hydrology chapter of the DPR in July 2010.

3.1.5.6 Aquatic Ecology and Water Quality

Sampling sites: The water sampling was conducted at different locations in the 10 km river stretch of Yarjep River. To assess the water quality in Yarjep river stretch from Mechuka to downstream Heyo village sampling was conducted in three seasons namely winter (February, 2009), pre-monsoon (May, 2009) and monsoon (August, 2009). For Pauk HEP, sampling was conducted at five sites namely W1 (upstream of proposed dam site), W2 (proposed dam site), W3 (proposed power house site) and W4 (downstream of proposed power- house site) (Fig. 3.1.1). In W1 site sampling could not be carried out in monsoon season only. During the environmental flow assessment two tributaries namely Shongsh Bu (SB), Shene Korong (SK) were sampled for three seasons (winter, monsoon and post monsoon). This data was also included in this contribution to strengthen the baseline data.

Method: A total of 16 physical and chemical parameters and 5 biological parameters were studied to assess the river water quality. Three replicates for each parameter were taken at each site and an average value for each parameter was calculated. The discharge data provided in the DPR VELCAN (2011) was used for analyzing the seasonal variation in the flow of Yarjep River. The water current velocity at all sites was measured with the help of float method. A 20 m stretch of the river was measured and marked at both ends. A float was thrown at upper end and the time taken by the float to travel the marked distance, was recorded by a stop watch. The water temperature was recorded with the help of graduated mercury thermometer. Care was taken in measuring the temperature as it was recorded from surface, column and near the bottom of the river. Average value of these readings was computed. The pH was recorded with the help of pH Scan (Eutech) and pH meter (EI – 132 E) in the field. For the turbidity of water, samples were collected in sampling bottles from different sites in the field and brought to the laboratory for analysis. The turbidity was recorded with the help of Nephelometer or turbido meter (EI – 331 E). The total dissolved solids were measured with the help of TDScan 1 (Eutech) at each site. Similarly conductivity was recorded with the help of TDScan 3 (Eutech) at the site. Dissolved oxygen was measured by using digital DO meters (Eutech ECDO 602K). Total alkalinity, alkalinity as carbonates and bicarbonates, total hardness, Ca and Mg contents, chloride and heavy metals were measured with the help of APHA (1992) and Adoni (1985). Nitrate (NO_3 – N) and phosphate (PO_4 – P) were measured using HAANA instruments namely HI 93728 and HI 93713, respectively.

Biological characteristics involved the status of total coliforms, zooplankton, suspended algae, phytobenthos and macro-invertebrates. A presumptive test (presence/absence test) was performed for the estimation of total coliforms. The method described by Central Pollution Control Board (CPCB), New Delhi was adopted for this purpose. For the quantification of zooplankton and suspended algae, 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 the samples were pooled. The filtrate collected for suspended algae was preserved in the Lugol's solution while unpreserved samples of zooplankton were brought to the laboratory. Epilithic phytobenthos were obtained by scrapping the surface of rocks and boulders (4 x 4 cm^2) with the help of a hard brush. Three replicates, obtained from each site were pooled and preserved in Lugol's solution for further analyses. Before going further for other analysis of the plankton and benthic samples the density was estimated by using drop count method. The density of suspended algae and phytobenthos were estimated with the help of APHA (1992). The suspended algae and phytobenthos were identified with the help of Sarod and Kamat (1984), Hustedt and Jensen (1985) and Edmondson (1959). The zooplankton was identified by using literatures of Edmondson (1959) and Battish (1992).

The macro-invertebrates were obtained with the help of a square foot Surber's sampler or a square foot quadrate. The substrate, mainly stones were disturbed and immediately transferred to a bucket underwater and later rinsed thoroughly to dislodge all the attached macro-invertebrates. The organisms trapped in the Surber's sampler were also transferred to the bucket. The material was sieved through 100μm sieve. Samples were collected in three replicates and pooled for further analysis. The samples were preserved in 3% formalin or 70% ethyl alcohol. The organisms obtained were then counted after identifying them up to family level by the procedure described by Pennak (1953) and Edmondson (1959). In order to assess the quality of water, Macro-invertebrate Water Quality Index (Bhatt & Pandit, 2008) was calculated for various sites at Yarjep river.

3.1.5.7 Fish & Fisheries

The study of fish fauna was carried out in the river Yarjep and its tributaries. Common fishing methods were used to land fish from Yarjep River and its tributaries. The fish were landed with the help of local fisherman using cast nets and hooks. The fish were identified with the help of Talwar and Jhingran (1991). In addition, literature of Sen (2006) was consulted to make an inventory of fish fauna of Yarjep River.

Conservation Assessment Management Plan of Biodiversity Conservation Prioritization Project Worshop (CAMP-BCPP, 1997) and IUCN redlist (2011) were followed to know the conservation status of fish species inhabiting river Yarjep and its tributaries.

3.1.5.8 Air Environment & Noise Level

The sampling for weather condition, ambient air quality and recording of traffic density and noise pollution data were carried out based on the availability of facilities.

Climatic Attributes: Using pocket weather tracker (KESTREL 4000), primary data on climatic attributes like air temperature, wind speed, wind chill temperature, humidity, heat index, dew point, etc were recorded for three seasons, The sampling was carried out at Mechuka, Chengrung and Rapum (**Fig. 3.1.1**).

Traffic density: Number and types of vehicles plying on the Tato - Mechuka road were recorded for three seasons. In addition traffic density was recorded at Mechuka for three seasons.

Air pollution: To assess the level of pollutants in the air sampler (high volume, respirable dust sampler APM 460 BL and its attachment APM 411 TE) was run to record the concentrations of SPM, NO_2 and SO_2. Due to lack of electricity in the surroundings it was run at Aalo. Aalo is major town in the area and was considered as control. We assume that in any case the level of air pollutants in the surroundings of project area would be lower as compared to Aalo.

Noise Level: Sound levels were recorded at various sites in and around the project area by using Sound Level Meter D 2023 (Cygnet), a TYPE 2 instrument (IS 9779, 1981). The data for the noise level were taken at different places in the project area, in the villages and inside the forest.

3.1.5.9 Forest Types and Floristics

i) ***Study area***

The details on forest types and forest cover in the catchment area were based on our primary surveys in the area supplemented with the working plans and records of Mechuka circle and Aalo Forest Division, Arunachal Pradesh . The forest present in the catchment area have been grouped into different forest types following the classification Champion & Seth (1968), Negi, (1989, 1996), Chowdhery (1996) and Muddgal & Hajra (1999).

Influence area (i.e. 10 km radius from dam site, powerhouse site, and HRT) was selected for the description of vegetation in the area. In the influence area, the surveys were carried out along the altitudinal gradient (1200 - 2400 m). The important sites for the primary surveys were:

i) Area between Purying village and Rapum village
ii) Area between Rapum village and Rego village
iii) Area between Rego village and Mechuka town
iv) Area beyond Mechuka and its environ

The primary surveys for floristic study in the project area was undertaken with the objectives of preparing a checklist of flora in the submergence area and locations where project components (i.e. dam site, power house site, dumping sites and quarry sites) are proposed. Listing of rare/endangered, economically important and medicinal plant species was prepared by conducting primary surveys along all project components.

ii) *Samplings*

The detailed account of ecological study and plant communities has been described based on the primary surveys in the project area. During our surveys (Februrary, 2009 to May 2009 and Sept. 2009), two sites viz., dam site (Rapum, left bank of Yarjep) and powerhouse site (Purying, left bank of Yarjep) were selected for vegetation structure study on the basis of the presence of forest patches in the area. These surveys were undertaken during different seasons (Winter, premonsoon and monsoon) of the year to account for most of the floral elements found in the area. For sampling of various strata of vegetation, Nested Quadrat Sampling method was followed. Tree layer was analysed by sampling ten randomly placed quadrats of 10 x 10 m^2 size on each site. The shrub and saplings strata were analyzed by sampling ten quadrats of 5 x 5 m^2 randomly at each site. The size and number of quadrats needed were determined using the species area curve (Misra, 1968). Circumference at breast height (i.e. cbh at 1.37 m from the ground) of all trees with > 31.5 cm was recorded individually per species. The herbs were analysed by placing ten quadrats of 1m x 1 m on each site. Based on the quadrat data, frequency, density and cover (basal area) of each species were calculated. The importance value index (IVI) for different tree species were determined by summing up the Relative Density, Relative Frequency and Relative Cover values. The diversity index for all the layers at each site was computed by using Shanon-Wiener information index (Shanon Wiener, 1963) as :

$$H = -\Sigma\ (ni/n) \times LN\ (ni/n)$$

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

3.1.5.10 Fauna

Information on the fauna (mammals, birds, herpetofauna, butterfly and other invertebrates) was collected with the help of secondary information as well as primary surveys.. Secondary sources included Forest Working Plans of the Forest Divisions falling in the project area, ZSI (2006) publication, Ali & Ripley (1983), Dutta and Basu (2006), etc. The invertebrates were inventoried with the help of Das and Chattopaddhyay, 2006; Mondal, 2006).

Primary surveys were carried out for three seasons (namely winter, pre-monsoon and monsoon) following the standard methods. Avifaunal surveys were carried out in morning hours (6:00 to 10:00) while butterfly were surveyed in noon hours (12:00 to 14:00). Samplings were conducted in the following areas;

Rapum to Chengrung village
Dam site: Left bank, an altitudinal track was followed
Rego area
Upstream of Mechuka town
Riparian fauna at power house, dam site, Mechuka (**Fig. 3.1.1**)

During the inventorization, following criteria were followed :

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

iv. Detailed household surveys were carried out to collect the information on trophies and hunting patterns.

The criteria of IUCN (2010), Wildlife Protection Act (1970) and Zoological Survey of India (1994) were followed to describe the conservation status of the species.

3.1.5.11 Socio-Economic Aspects

Socio-economic profile includes brief description of Arunachal Pradesh, West Siang district and the circles in which project components are located. History, cultural aspects, ethic values and tribal life of Arunachal Pradesh and West Siang district are also mentioned briefly. A detailed account on demography, education, occupation and other amenities of the villages located in 10 km radius and project affected villages is discussed in EIA report. In order to collect the baseline data for preparation of R & R Plan, a door to door survey for project affected families was carried out for the proposed project. A detailed questionnaire was prepared for this purpose and the same is placed at Annexure-I&II. The surveys and preparation of the plan included following procedure:

i) Due to non availability of revenue records, the land for acquisition was identified by the project authority and submitted to district administration for discussion with Panchayat members and Gram Budha of the concerned village.

ii) Door to door socio-economic survey of the project affected families / owner was conducted to collect the base line data. Data was collected on various parameters e.g. Demography, Occupation, Education, Quality of life, Income patterns, Land holdings, Amount of land loss due to this project, etc. The detailed information has been used in preparation of the R & R plan.

iii) Discussion was held with all project affected families/persons, who have expressed their willingness to accept project.

iv) The existing socio-economic profile of the project-affected area has been given in the EIA report.

3.1.5.12 Impact Prediction

The assessment of impacts was based on the identification, prediction and evaluation of the impacts. The ecosystem like terrestrial, aquatic, air, social etc based approach has been followed for the identification and prediction of impacts. Evaluation of the impacts was assessed on the basis of nature (positive/negative, reversible/irreversible, direct/indirect, long term/short term), magnitude and other dimension (local/strategic, small/large) of impacts. Evaluation included an assessment of the relative significance of the impacts. The outputs and inputs related to evaluation of impacts are given in **Figure 3.1.2**. Generally, evaluation method ranges from simple to the complex, qualitative to quantitative, checklist to matrices etc.

In order to predict the impacts of Pauk H.E. Project, a modified Leopold index has been used. The index comprises of rows and columns, represented by actions and environmental variables. Each cell of the index was assigned with a relative score indicating an impact. After weighing the nature, magnitude or other dimension of impact, a suitable score has been assigned. The totaling of rows and columns were evaluated and a suitable mitigation plan was prepared.

Considering the all three projects, an cumulative approach of the impact assessment was followed in the Pauk H.E. Project.

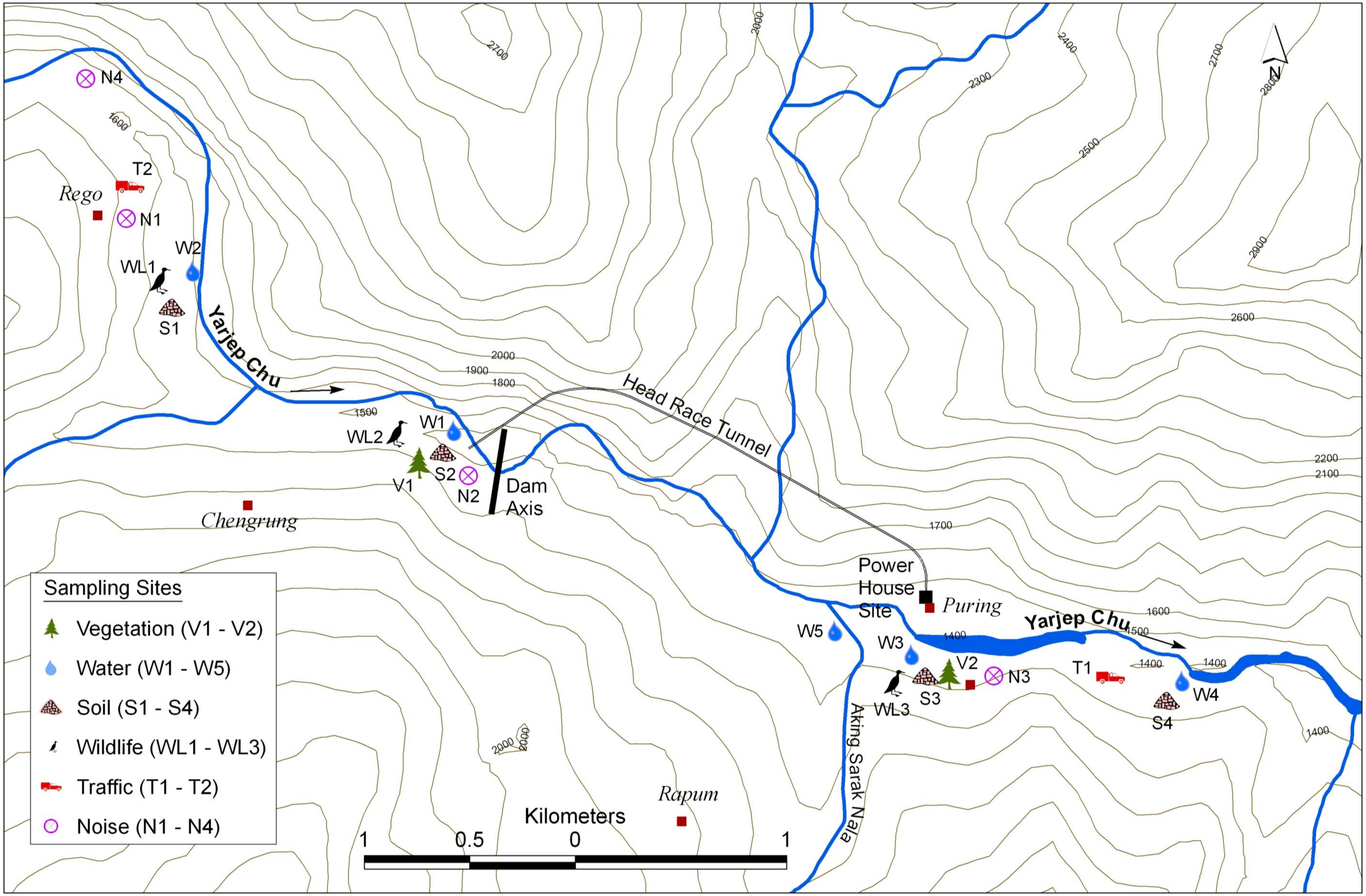


Fig.3.1.1 Map showing sampling sites of the proposed Pauk H.E. Project

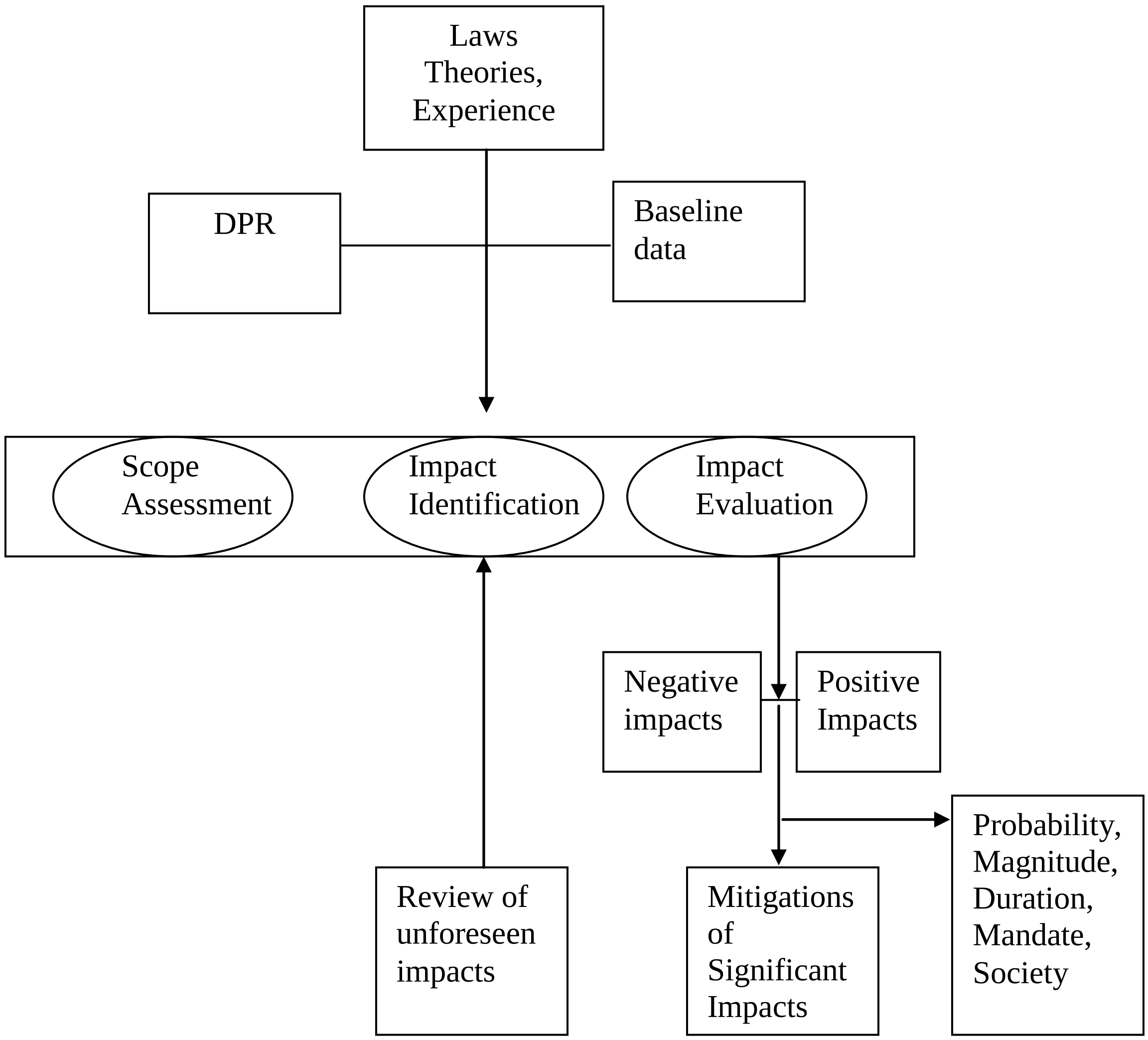


Fig. 3.1.2. Inputs and outputs related to evaluation of impacts

3.2 LAND ENVIRONMENT

3.2.1 PHYSIOGRAPHY

The physiographic condition of a region refers to the natural landscape and ongoing changes by several natural processes of geomorphic agents like water, glacier, wind etc. Many of these agents are controlled by the prevalent climatic conditions of the region and the internal dynamic functional mechanism of the earth system. Therefore for any hydroelectric project, the study of physiographic condition of the river catchment such as drainage, relief, slope etc is very crucial as it has a strong control on water availability and sediment load supplied to the river. The present chapter deals with physiography of Yarjep Chhu catchment area upstream of the proposed Pauk H.E Project dam site.

The geographical region of the proposed dam site is spread in the West Siang district of western Arunachal Pradesh. The proposed Dam site is located on the Yarjep Chhu near Chengrung village. A comprehensive physiographic database of Yarjep Chhu catchment was developed. Physiographic parameters were analyzed through the spatial analysis of Geographical Information System (GIS). Databases of different aspects were developed for all constituent sub-watersheds of the catchment. The Survey of India (SOI) toposheets were used to generate the contours and consequently contours were spatially interpolated in GIS to generate raster topographical data. Satellite data were utilized in preparation of different thematic maps. Analysis and interpretation of this spatial database were achieved by using GIS spatial analysis. The results were confirmed after ground truthing at specific locations in the catchment. The outcome of this study is discussed in the following sections. In this section drainage system, Digital Elevation Model (DEM), Relief, Aspect and Slope are presented. For each of the parameters two maps were prepared, catchment area and the influence area. Ministry of Environment and Forest (MoEF) has been following a general practice of baseline data to be collected in a 10 km radius (Influence area) of the project components while conducting EIA studies. A base map was developed to demarcate the influence zone was projected for Pauk H.E Project.

3.2.1.1 Drainage System

The Yarjep Chu catchment area up to Pauk dam site is 98200 ha and the drainage network of the catchment area of Yarjep Chu is shown in **Figure 3.2.1.1**. The river is called as Barpu Sikyo in the head water region. Barpu Sikyo is joined by large numbers of the snow fed, spring fed, glacial fed and seasonal rivers in the head water region. These streams flow in the elevational range of 4430 m to 4000 m. Further downstream another stream flowing from a lake lying above 3400 m drains into the Yarjep chu on its right bank. Another small lake fed stream flowing through northern part confluences with Yarjep Chhu at 2440 m on its right bank. Further downstream, a stream flowing from southern catchment drains into Yarjeb Chu on its left bank. This small stream is also fed by four lakes on its left bank, which lie above 4000 m. In the middle stretch, Yarjep Chu runs from WNW to ESE and a number of tributary streams flowing from north hills to south and southern hills to north join this river. Besides, there are number of glacial lakes in the northern part of the catchment and southern part of the catchment. The drainage characteristics of these subsystems are discussed in detail with the left and right bank of the Yarjep Chhu in the following sections. In Table 3.2.1.1 catchment characteristics, place of confluence with the main channel is given and the sub-tributaries associated are given along the left and right bank.

a) ***Left Bank Streams***

The streams joining the Yarjap (Yarjep, Shi) Chhu on its left bank are as follows and detail is given in the map.

Lungkhor Dem

It is a small springfed stream which flows from 3200 m to 2240 m. Most part of its catchment is barren. It flows for approximately 5.3 km before it drains into the Yarjep Chu.

Sheshirong Ishi

It flows approximately for 12.3 km before it is joined with the main channel of Yarjep Chhu. Sheshirong is originated from the Damchen range and it is fed by several large and small rivulets along both the right and left banks. The largest sub-tributary of the Sheshirong flows from the N-E for 4.2 km approximately before it drains into Sheshirong Ishi.

Netsrang Gongphu Chhu

It is a snowfed and springfed stream which originates from 4053 m peak in Damchan range and flows southward for 13.3 km approximately and confluences with Yarjap Chhu at 1990 m near Nachonggong Village. In its middle stretch it drains the region covered with fairly dense mixed forest. The tributary shows dendrite pattern with large number of tributaries along both banks (see **Fig. 3.2.1.1**).

Nangso Sokang

It is a small springfed stream which flows from Changkaria peak (2400 m) and confluences with Yarjap Chhu at 1940 m near Nangso village. The tributary flows approximately for 3.5 km before it drains into Yarjep Chu near the Nangso village. The catchment of this stream is also characterized with large amount of barren land.

Gaptse Chhu

Gaptse Chhu is a snowfed and springfed stream. This stream is separated from the stream in its east by the Puiling Pik ridge. It originates at the south of 3900 m on Damchan range. In the elevational range of 2200-3900 m. There are five streams which join and together form Lhalungphu Cho. Lhalungphu Cho in its downstream stretch is known as Gaptse Chhu. Lhollne village is situated on the right bank of Gaptse Chhu. The upper catchment of Gaptse Chhu is covered with thick vegetation. Gaptse Chu flows for 9.2 km and drains into Yarjep Chu near Lhollne village (see **Fig. 3.2.1.1**).

Endashokong

The tributary is a short traversed tributary system flowing for 2.8 km before joining Yarjep Chuu. It flows from 2800 m to 1930 m. In its upper reaches it drains through fairly mixed jungle and in the lower reaches there are cultivable terraces around Beehenthang. It also drains the swampy land in the downstream before joining Yarjep Chhu.

Nyangapa rang

It is a small springfed stream with a length of 2.7 km before draining into Yarjep Chhu. The catchment of this tributary is prevalent with barren land. .

Teden

It is also a small stream with approximately 3 km of length. The catchment area is characterized with barren land. Draining the Galling Gompa region. Eventually it meets with the Yarjep Chhu near Shinghir village.

Chanajung

The river traverses for 2.4 km southwards before draining into Yarjep Chhu. It flows from 2320 m and meets Yarjep Chhu at 1920 m in Chanajung village after taking a sharp bend.

Dutangphu Chhu

Dutanphu Chhu is one of the largest tributary of the Yarjep Chhu. It is drained by six snowfed and springfed streams namely: Phushung Jang, Dorlingphu Chhu, Yarduphu Chhu, Tsarok Sakong Tenrik Sokong and Shunuphu Chhu. All these sub tributaries flows through the slopes where land cover is fairly dense mixed forest. These six streams drain trough a bowl shaped region bounded by Dam Chan range in the north, Sengang range in the southwest and Sharcho Rego-Ranchenling range in southeast. The river flows for a distance of 14 km of length and joins the Yarjep Chhu at 1880 m upstream of Sheker village (see **Fig. 3.2.1.1**).

Dohak Sokang

The river flows south-eastwards along the Ranchenling range for 5.7 km and confluence with Yarjep Chhu. It is a springfed stream, drains through slopes covered with fairly dense mixed forest and joins the Yarjep Chhu at 1700 m. In its upper reaches it is also known as Darigyap Chhu.

Dasong Siding

It is a small springfed stream which flows from the steep southern slope of Shing Duk range. There is thick forest cover on these slopes. The stream course is marked by a 61 m high waterfall. The river flows for 1.6 km before it drains into Yarjep Channel before the dam site.

b) ***Right Bank Streams***

Most of the streams joining the Yarjep Chhu flow northwards. Most of them are small and short traversed river channels with narrow gorges. The tributary on its right bank are as follows.

Bum Chhu

It is one of the largest drainage systems originating from the western part of Great Himalayan range. Evidently the river system is a snowfed and springfed stream which drains northeastern slopes of Singyang range. The river flows for a distance of approximately 14 km eastwards before it drains into Yarjep Chhu near Nachonggong village. Nikma Ishi is a major tributary stream of Bum Chhu which flows northwards for 14.3 km. Further Nikma Ishi is joined by a small tributary system from the south called as Chirukishi stream. The catchment area of both these streams is covered with dense mixed forest (see **Fig. 3.2.1.1**).

Segang Shuru

Segarang Chu flows through a narrow channel for 5.2 km and drains into the main channel of Yarjep Chhu. This is a snowfed and springfed stream which flows northwards from 3400 m and drains the dense forest on the northern slopes of Singkyang ridge and confluences at 1940 m with Yarjep Chhu near Segang village.

Jenrang

This is a small snowfed stream which flows for 4 km. It is a springfed stream which flows northward and turns towards east to confluence with Yarjep Chhu downstream of Segang. The upper parts of its catchment are covered with dense mixed forest.

Enda Sokang

This is a small snowfed and springfed stream which drains the slopes with dense mixed forest in its upper part and cultivable terraces in the lower part before it confluences with Yarjep Chhu at 1920 m. The river has a length of 5.2 km from the origin to the confluence with Yarjep Chhu.

Shuru Phuja

Shuru Phuja is large river system and it is a snowfed and springfed stream which flows in the west of Dungzugong ridge in the north of Singkyang range. The headwater region is composite of several streams namely; Shuru Ishi, Enda Sokang, Talling Tongkok and Lingchonyg Tukuk. All these streams drain the slopes covered with thick forests in north of Singkyang ridge. The main channel of the Shuru Phuja flows for 10 km before it drains into the main channel of Yarjep Chhu (see **Fig. 3.2.1.1**).

Tamding Phujo

This is a small snowfed and springfed stream which drains the dense forest region between Barung Gong and Dungzu Gong ridge, flows through Mechukha and joins Yarjep Chhu on its right bank at 1880 m . The river flows for 9.6 km towards north and drains into the Yarjep Chhu downstream of Phocegy.

Tachenpaogo Sokang

It is a small springfed stream which flows for 2.6 km towards northeast on the northern slope of Barang Gong ridge draining along the dense forest and cultivable terraces. It confluences with Yarjep Chhu at 1920 m downstream of Churling.

Kangdang Sila

It also is a smaller springfed stream which flows for 3.6 km before it drains into the main channel of Yarjep Chhu. The tributary traverses through the thick forest region on the western slopes of Barang Gong ridge.

Siligomang

It is relatively a larger drainage system and flows north-eastwards for 6.6 km and drains into Yarjep Chu. It is a springfed stream which drains the western slopes of Barang Gang ridge and confluences with Yarjap Chhu downstream of Kangdangshiri. The slopes are covered with thick forest.

Kartesho Kong

This is a snowfed and springfed stream which flows towards northeast on the eastern slope of 4008 m peak on Singkyang range and confluences with Yarjep Chhu at 1720 m. The tributary shows dendrite pattern and it flows for 7.7 km before it drains into the main channel of Yarjep Chhu.

Namrangong

It is one of the smallest tributaries of the Yarjep Chhu on the right which is more a seasonal stream. The tributary has a length of 2.4 km before it drains into the main river channel.

Ering Sokang

This is a springfed stream which flows on the northeastern slope for 3.2 km from a peak of 2845m . Upper reaches of its catchment are covered with dense mixed jungle.

Sae Chhu

As shown in the map given in **Figure 3.2.1.1** Sae Chu is one of the largest tributary systems of the Yarjep Chhu and moreover the largest tributary along the right bank of the Yarjep Chhu. It is a snowfed and springfed stream which flows towards northeast and confluences with Yarjep Chhu at 1428 m. In its upper stretch it is also known as Chechi To. The tributary flows for 16 km stretch before it drains into the main river channel of Yarjep Chhu near Rego village before the Dam site at Pauk. Mane Sokong, Gyara Sikyo, Shichi Sikyo, Sheh Sikyo and Sheti Sokang are important tributaries of Sae Chhu. All these tributary systems form a large sub-watershed of Sae Chu in the south-eastern part of the Yarjeb catchment. The Northern slopes of Sae Chhu are almost vertical cliffs whereas the southern slopes are gentle.

Table 3.2.1.1 Tributaries of Yarjep Chhu and its catchment characteristics

Netsang Gongphu Chhu	Left bank	Upstream of Nachonggonh	Left Bank; Unnamed small nalas joined at both the banks	Netsang Gongphu Chhu is a left bank tributary of the Yarjep Chhu. The catchment area is covered with farily dense mixed forest Drainage pattern is characterized by dendritic.
Gaptse Chu	Left bank	Upstream of Dalgaling,	Composite of Nukmaphu Chhu,, Lhajungphu Chhu, Shama Sokong and Mimraga	This tributary flows southwards traversing a length of 9.2 km. Drainage network shows dendritic pattern. Catchment area is occupied by mixed forest, agricultural land etc.
Dutangphu Chhu	Left bank	Shekar	Phushung Jang, Dorlingphu Chhu, Yarduphu Chhu, Tsarok Sakong, Tenrik Sokong, Shunuphu Chhu	The tributary flows towards south traversing a distance of 14 km. The catchment area is covered with alpine meadows in the head water regions and mixed forest along the lower elevation area.
Dohak Sokong	Left bank	Downstream of Shekar	Several seasonal streams	It flows from north to south. The river flows for 5.7 km of length. It is covered with mixed forest.
Bum Chhu	Right bank	Upstream of Nongso	Several large streams from the both the banks.	This tributary flow north-eastwards and the catchment is partly covered with glaciers in the upper elevation of the catchment where as the lower part of the catchment is covered with mixed forest. The main channel flows for 14.7 km upto the point of confluence.
Shuruphujo Chhu	Right Bank	Shingbir	Shuru Ishi, Enda Sokang, Talling Tongkok and Lingchonyg Tukuk	The catchment is covered with slopes of thick forests in north of Singkyang ridge. The drainage shows dendritic pattern.

Tamding Phujo	Right Bank	Downstream of Phocegy	Seasonal streams	The tributary flows for 9.6 km and it drains into the main channel. There are several streams which are some of the
Kartesho Kong	Right Bank	Downstream of Sheker	Komrong Sokong	The catchment is small and it is represented by mixed forest. The stream flows for a length of 7.7 km.
Sae Chhu	Right bank	Downstream of Kangiaghi	Mane Sokong, Gyara Sikyo, Shichi Sikyo, Sheh Sikyo and Sheti Sokang	It is one of the largest catchment in Yarjep Chhu. The Northern slopes of Sae Chhu are almost vertical cliffs whereas the southern slopes are gentle. Land cover is characterized with mixed forest type.

3.2.1.2 Drainage System in the Influence Zone

Drainage thematic layer was generated within a 10 km radius of power house and dam site. The 10 km radius was demarcated from the power house and the dam site. The influence zone map was generated using the distance map calculation in GIS from the point coordinates of Dam site and Power house site. The same influence map is generated for all other physiographic thematic layers. The area of the influence zone is around 40155.74 ha. In the influence zone map as shown in the **Figure 3.2.1.2** main streams are Sae Chu, Songshi Bu, Sarak Korong and Pirpu Korong.

Songshi Bu is also a large tributary system near the power house site. It is called as Showong Sokong in its head water region. It drains into the main river channel near the Purying village. Another prominent tributary is the Sarak Korong, it flows from the south-eastern part of the catchment for 7.9 km towards north and joins with Yarjep Chhu near Lipusi village. It is a springfed stream which flows on the northern slopes of 2625 m peak, drains through a narrow gorge and joins Yarjepp Chhu at 1320 m downstream of Lipusi village. *Sittin Korong and Pirpu Korong are* small springfed streams which flow southwards and confluence with main channel near Meying village.

3.2.1.3 Stream Gradient

The longitudinal profile of Yarjep Chhu from the head water region to the proposed dam site is given in **Figure 3.2.1.3**. The river covers a distance of nearly 60 km. It flows from 4300 m in the Great Himalaya range to 1440 m to the Dam site. The gradient profiles of major tributary streams like Sae Chu, Dutangphu Chu, Gaptse Chu and Bum Chu are discussed in the next paragraph.

The Yarjep Chhu spans an elevation of 2860 m in 60.6 km of its flow. Thus, the gradient of main river channel of Yarjep Chhu is 1: 21.19. A knick point was observed at 0.77 km from the head water region where the elevation drops from 4300 m to 4000 m in a span of less than 1 km. One of the prominent tributaries is Bum Chu which flows for 15 km within the elevation range of 4000 to 2000 m. This channel has a gradient of 1: 7.35. One of the prominent knick points was observed along Bum Chhu lies at 31.35 km from the headwater region. Here, the river elevation drops down from 4000 to 3700 m in a span of about one kilometer distance. The presence of knick points indicates major structural discontinuity across the stream. High knick points were observed along the head water region of Sae Chhu where river elevation drops to 300 meters within a span of 1 km. The stream gradient for this river is 1:8.35. Other streams Songshi Bu, Dutangphu Chu and Gaptse Chu have stream gradient of 1:7.41, 1:7.36 and 1:5.57 respectively. Therefore lower gradient indicates that the river is in its advanced evolutionary stage and hence has low erodibility potential. The higher channel gradient indicates lower equilibrium stage and therefore, high erodibility potential. As evident from gradient values, the main Channel of Yarjep Chhu has the highest gradient (1:21.19), while others have less than 1:10 gradient (Table 3.2.1.2). Therefore, the Yarjep Chhu has little higher erodibility potential as compared to its tributaries.

Table 3.2.1.2 Gradient profiles of the Yarjep Chu and its major tributaries in the upstream of Dam Site

S.No.	Stream	Length	Gradient
1	Yarjep Chu	60.6	1:21.19
3	Songshi Bu	16.67	1:7.41
4	Sae chu	18.37	1:8.35
5	Dutangphu Chu	14.71	1:7.36
6	Gaptse Chu	10.31	1:5.57
7	Bum Chu	15.06	1:7.53

3.2.1.4 Digital Elevation Model

Topographical data and its aspects are the main input in much of environmental models. Most of the environmental models such as the soil erosion susceptibility model, geomorphologic and land cover mappings rely on topographical data as one of the major input (Zomer and Ives, 2002). Topography in GIS is usually termed as Digital elevation model (DEM). DEM as the term indicates a digital description of the terrain relief. A DEM can be stored in different forms: contours lines, TIN (triangulated interface network), raster based array of cells. DEM stores the surface height by means of array of elements which are called as pixels. Generally DEM (**Fig.3.2.1.4**) formed the basis for generation of elevation-relief, slope and aspect maps, which are shown in **Figures 3.2.1.6, 3.2.1.8 and 3.2.1.10**, respectively.

Raster based DEM was prepared from the toposheet of Survey of India. The toposheet was scanned and digitized in GIS platform. Similarly, thematic maps for elevation-relief and aspect were also generated using the base map of the DEM. The mountain ranges of Tibet Himalaya range in the NW, Damchen range in the north and Singkyang range in the south of catchments are elevated at a height above 4900 m (see **Fig. 3.2.1.4**). The low lying valley from Bum Chu confluence to the dam site is elevated at a gradient height of 1800 m to 1200 m.

In the influence zone of 10 km radius area, it is spread over an area of 40155.74 ha of land. The area of the Singkyang range in the south and Damchan in the north extends up to 3911 m. However the lower lying valleys of Siyom i.e., d/s of the power house goes to 972 m. **Figure 3.2.1.5** shows the influence zone within the 10 km radius.

3.2.1.5 Relief

The DEM was classified into 10 elevation bands in the catchment area up to the dam site. The lowest elevation band is classified up to 1600 m whereas the highest elevation band was classified above 4800 m. The four elevation bands from 2400-2800 m, 2800-3200 m, 3200-3600 and 3600-4000 covers 67.8% of the total catchment area. The largest area falls under the band of 3600-4000 m with area coverage of 18.41% of total catchment area (see **Fig. 3.2.1.6**). Lower elevation bands 1600-2000 m covers 4.43% of the catchment area, this elevation band is prevalently spread in the downstream of confluence of Yarjep Chhu and Lhajungphu Chu to the barrage site. Higher elevation bands are prevalent in the Singkyang range, Damchen range and Great Himalayan range. Please refer to Table 3.2.1.3 for further details.

Table 3.2.1.3 Elevation range and corresponding area of Pauk H.E. Project catchment

Elevation	Area (ha)	Percent
Up to 1600	98.2	0.1
1600-2000	4350.26	4.43
2000-2400	13905.12	14.16
2400-2800	17725.1	18.05
2800-3200	15515.6	15.80
3200-3600	15260.28	15.54
3600-4000	18078.62	18.41
4000-4400	11705.44	11.92
4400-4800	1522.1	1.55
> 4800	39.28	0.04
Total	**98200**	

As shown in **Figure 3.2.1.7**, three elevation band classes 1600-2000 m, 2000-2400 m and 2400-2800 covers 62.3% of the total area of 40155.74 ha in the influence zone. These classes are spread in the head water region of Kartsesho kong, Dohak Sokong, Ering Sokong, Songshi Bu, Sittin Korong, Pirpu Korong, Shene Sokong, Sarak Korong and Sheu Nadi. The consequent elevation bands 2800-3200 m, 3200-3600 m and above 3600 m form the head water region of Sarak Korong and Shou Chu along the right bank and Sittin Korong and Pirpu Korong along the right bank of power house and dam site. These three bands accounts for 31.8% of the total influence area. Apparently the lower elevation bands forms the valleys and they accounts for 6% of the influence zone. These bands are more prevalent along the downstream of the confluence of Sae Chu and Yarjep Chu.

3.2.1.6 Slope

In the catchment area moderately steep is most prevalent slope class in the catchment area and moreover it is spread along the right bank of Yarjep Chu. Moderately steep is spread on an area of 54010 ha of the land which accounts for 55% of the total catchment area (see **Fig. 3.2.1.8**). The second predominant slope class in the catchment area up to barrage site is steep class. It is spread in an area of 25532 ha of land i.e., 26% of the total catchment area. It is more prevalent on the left bank of Yarjep Chu and it is spread in the head water region of the Sheshirong Chu, Netsang Gongphu Chu, Nukmaphu chu and Lhajungphu Chu. Slope around project component are characterized with steep slope class and such high percentage of slope classes are more susceptible to soil erosion. Strongly sloping is prevalent in the middle stretch of the catchment with area coverage of 13031.14 ha of land i.e., 13.27% of the catchment. Lower slope classes such as gently sloping and moderately sloping are prevalent in the lower part of the valleys (see Table 3.2.1.4).

Table 3.2.1.4 Slope range and corresponding area of Pauk H.E. Project catchment

Slope Class	Area (ha)	Percent
Gently Sloping	883.8	0.90
Moderately Sloping	4202.96	4.28
Strongly Sloping	13031.14	13.27
Moderately Steep	54010	55.00
Steep	25532	26.00
Very Steep	549.92	0.56
Total	**98200**	

As shown in the **Figure 3.2.1.9** the 10 km radius of barrage site and power house site, moderately steep and steep are prevalently spread in the influence area. These slope classes account for 59.38% and 24.53% of the total influence area respectively. The head water region of most of the tributaries of Yarjep Chu are characterized with moderately steep class and followed by steep class.

3.2.1.7 Aspect

As shown in the aspect map of **Figure 3.2.1.10** all the facets Flat, NW-N-NE, NE-E-SE, SE-S-SW and SW-W-NW are more or less equally distributed. Moreover NW-N-NE facet is spread over an area of 25571.28 ha i.e., 26.04 % of the catchment area forms the predominant aspect class in the catchment. For further details of area coverage please refer to Table 3.2.1.5. Flat is also prevalent with area coverage of 20.17% of catchment. The remaining slope classes such as NE-E-SE, SE-S-SW and SW-W-NW are spread in an area of 17.13%, 18.88% and 17.78% respectively.

The facet SW-W-NW is prevalently spread in the influence zone. It is more prominent on the right bank of the power house and dam site. This facet is spread in an area of 10253.66 ha which forms 25.5 % of the influence zone. Flat lands are also widely spread within the 10 km radius. For details see **Figure 3.2.1.11**. Other classes such as NW-N-NE, NE-E-SE and SE-S-SW are spread in an area of 19.31%, 15.76% and 17.50% of the influence zone.

Table 3.2.1.5 Aspect and corresponding area of Pauk H.E. Project catchment

Aspect	Area (ha)	Percent
Flat	19806.94	20.17
NW-N-NE	25571.28	26.04
NE-E-SE	16821.66	17.13
SE-S-SW	18540.16	18.88
SW-W-NW	17459.96	17.78
Total	**98200**	

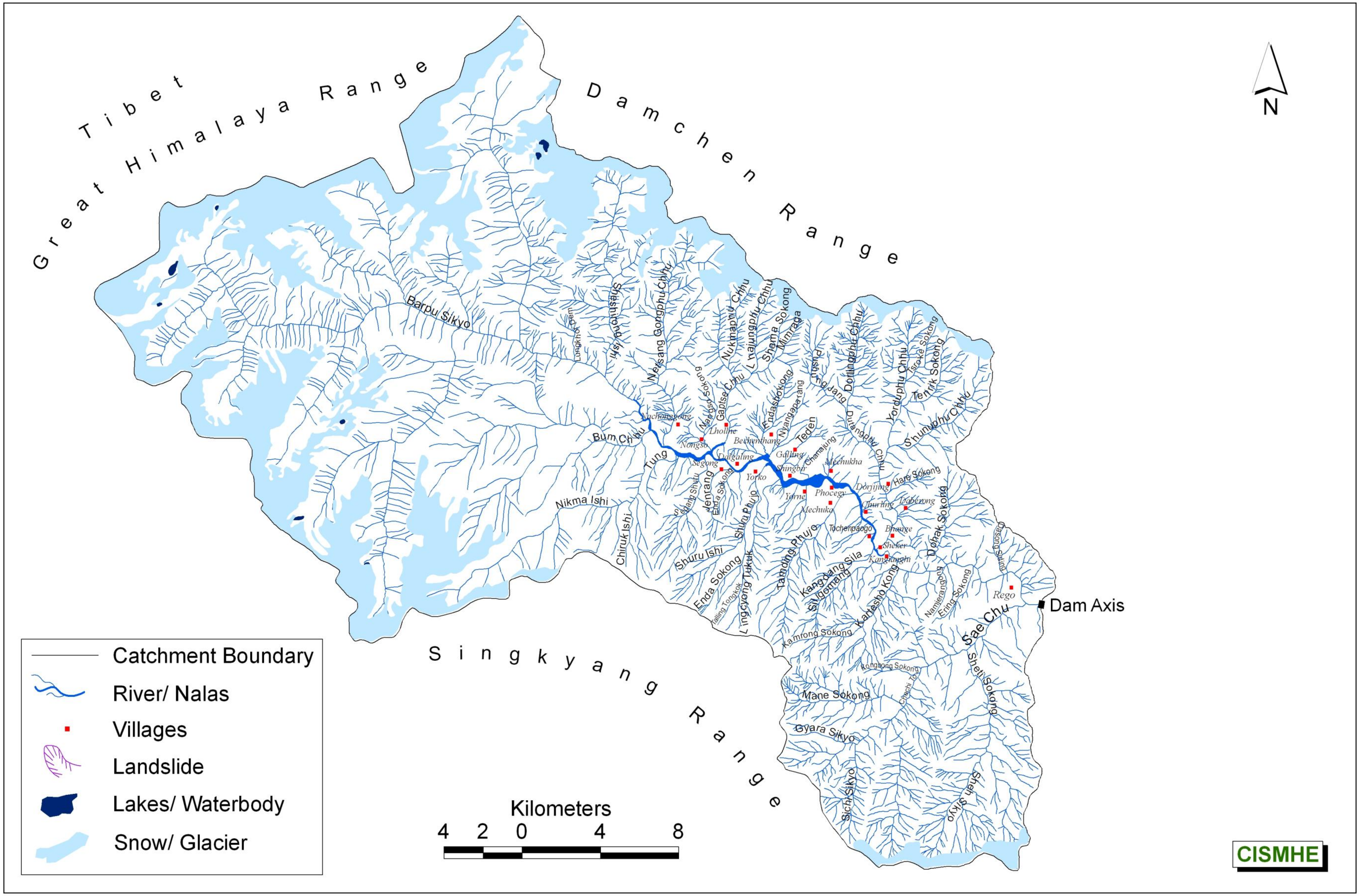


Fig.3.2.1.1 Drainage map of Yarjep Chhu in the catchment area of the proposed Pauk H.E. Project up to the proposed dam site

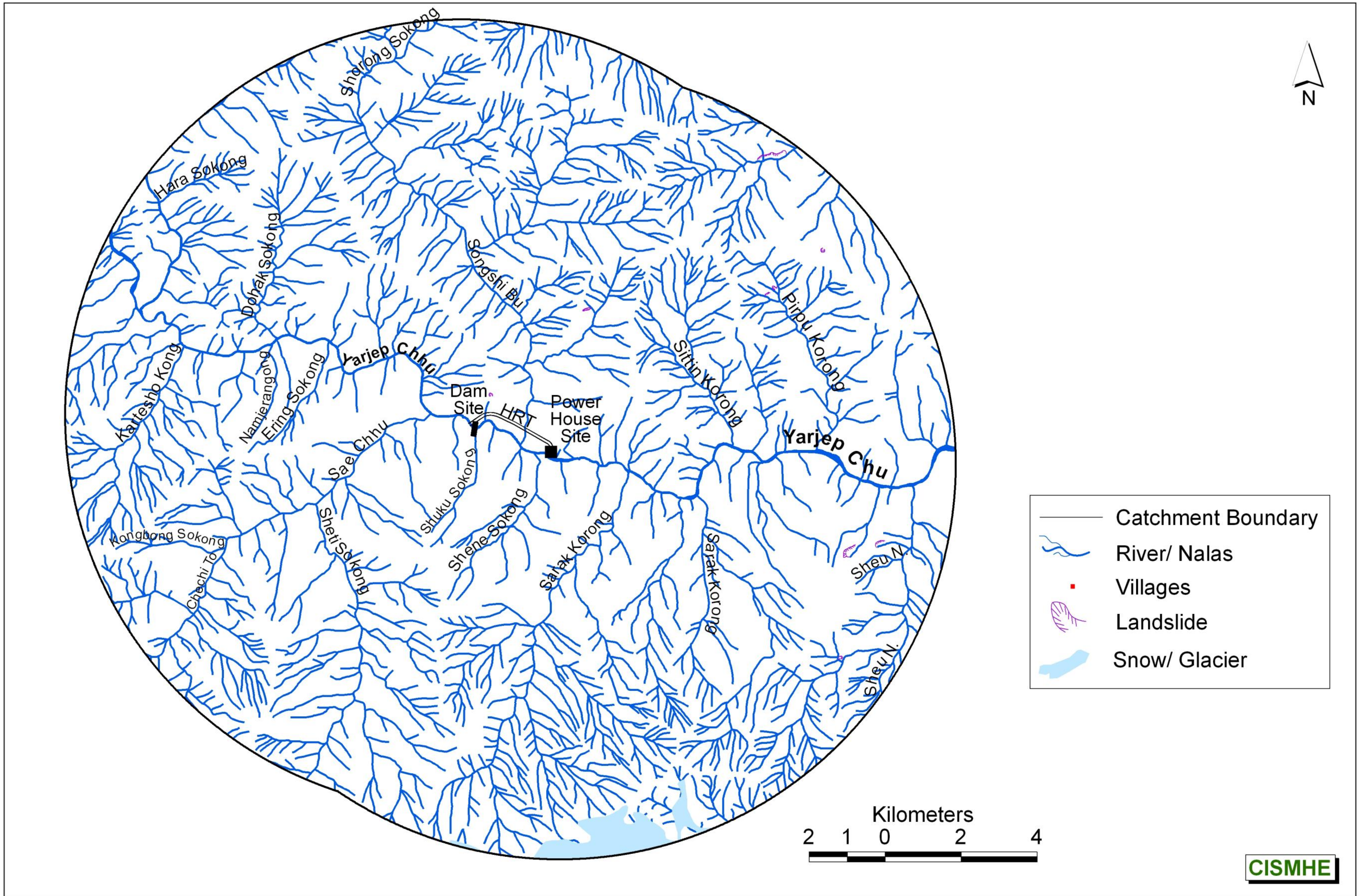


Fig.3.2.1.2 Drainage map of Yarjep Chhu in the influence zone of the proposed Pauk H.E. Project

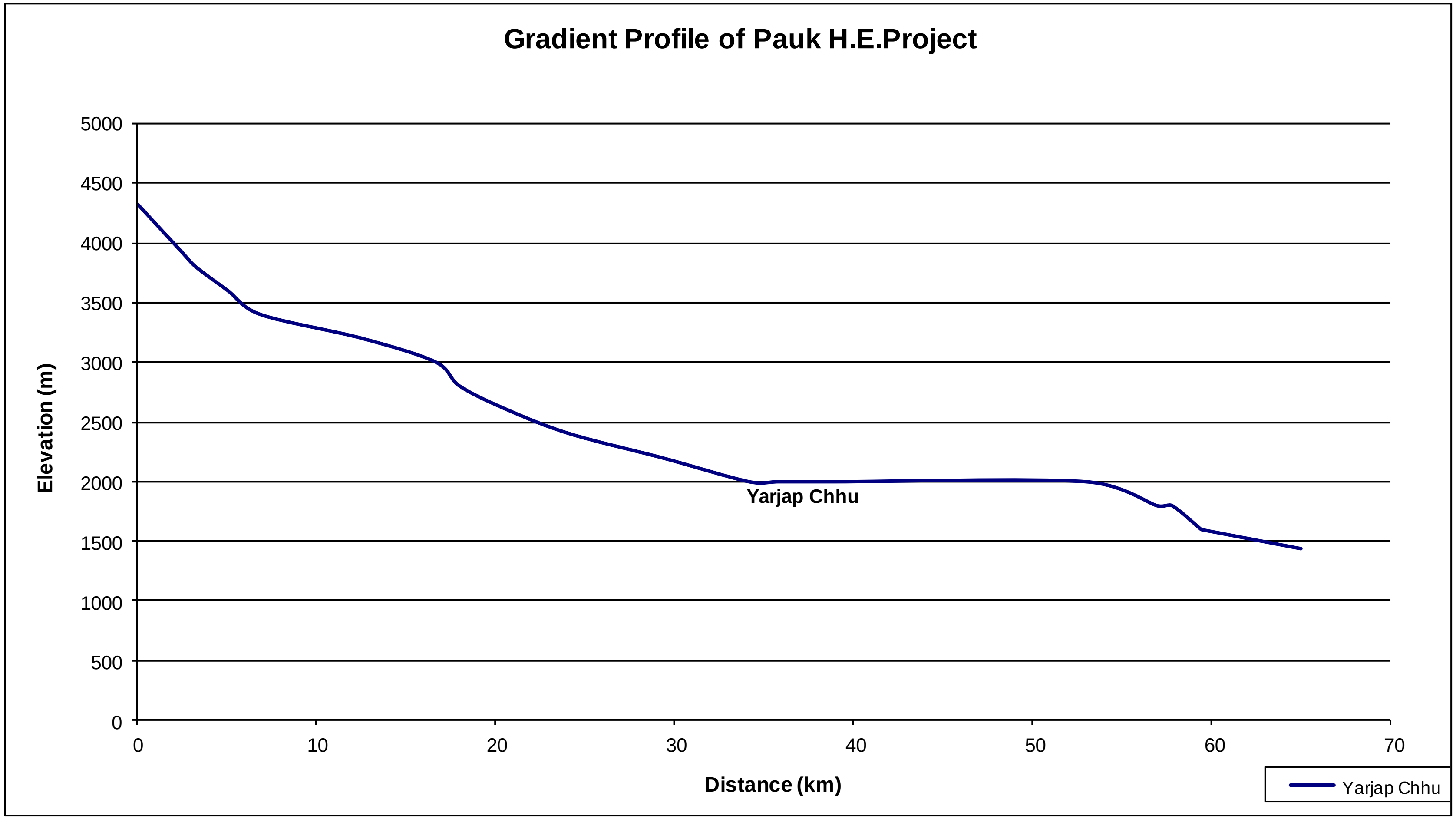


Fig. 3.2.1.3 Gradient profile of Yarjep Chhu up its proposed dam site

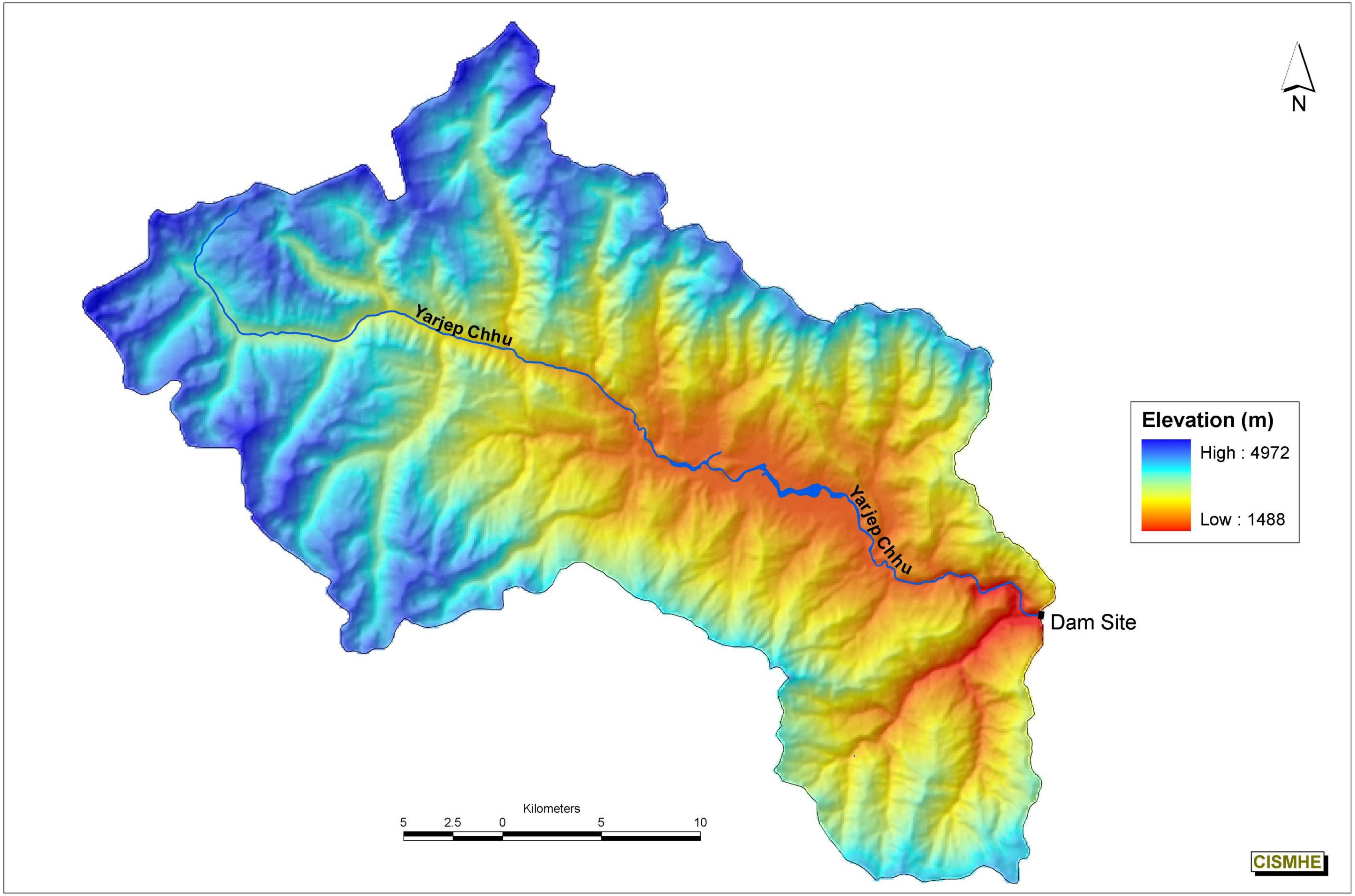


Fig. 3.2.1.4 Digital Elevation Map of the Yarjep Chhu catchment of Pauk H.E. Project up to the proposed dam site

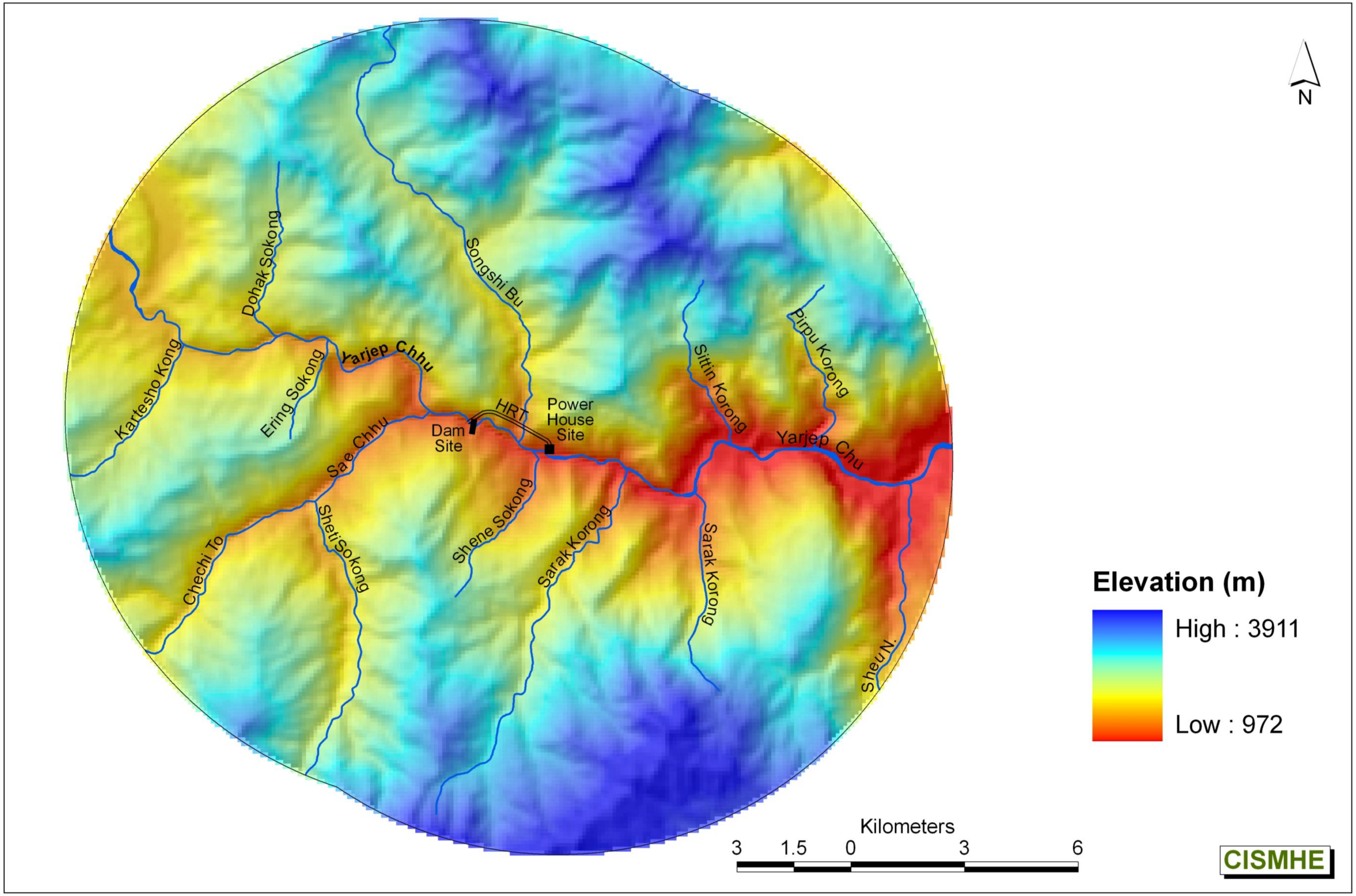


Fig. 3.2.1.5 Digital Elevation map of Yarjep Chhu in the influence zone of the proposed Pauk H.E. Project

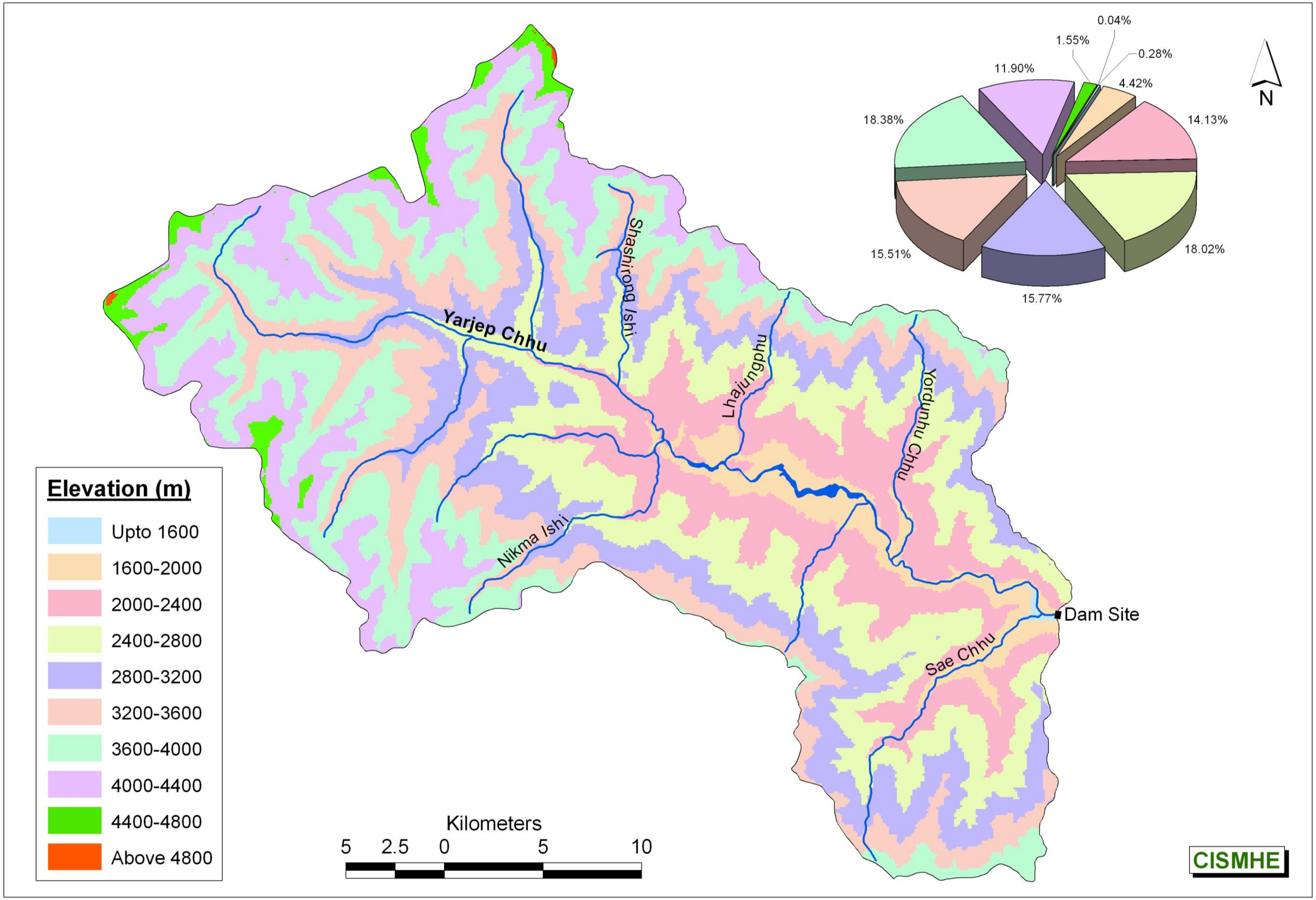


Fig. 3.2.1.6 Reilief map of the catchment area of Pauk H.E. Project up to the proposed dam site

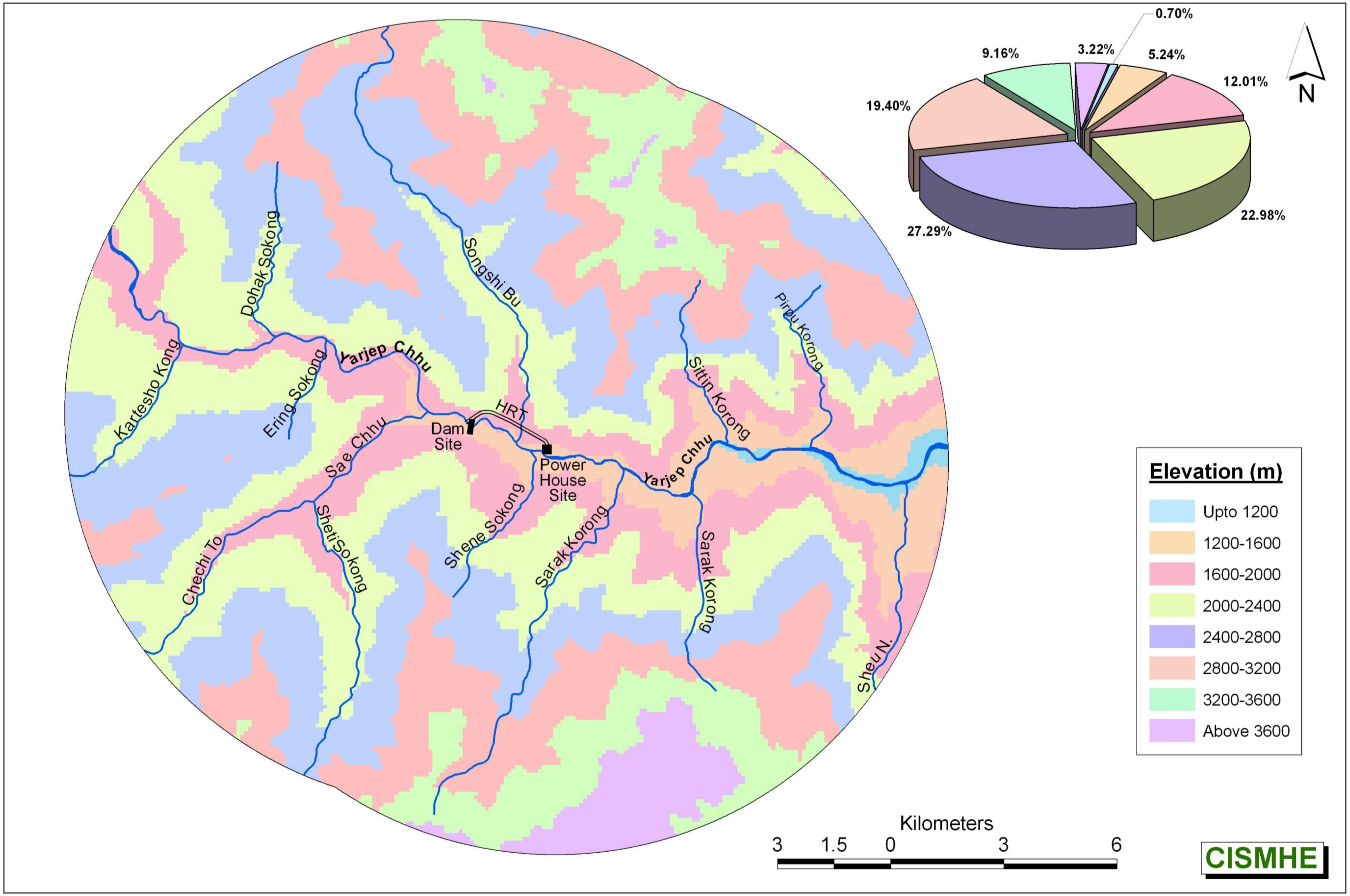


Fig. 3.2.1.7 Relief map of Yarjep Chhu in the influence zone of the proposed Pauk H.E. Project

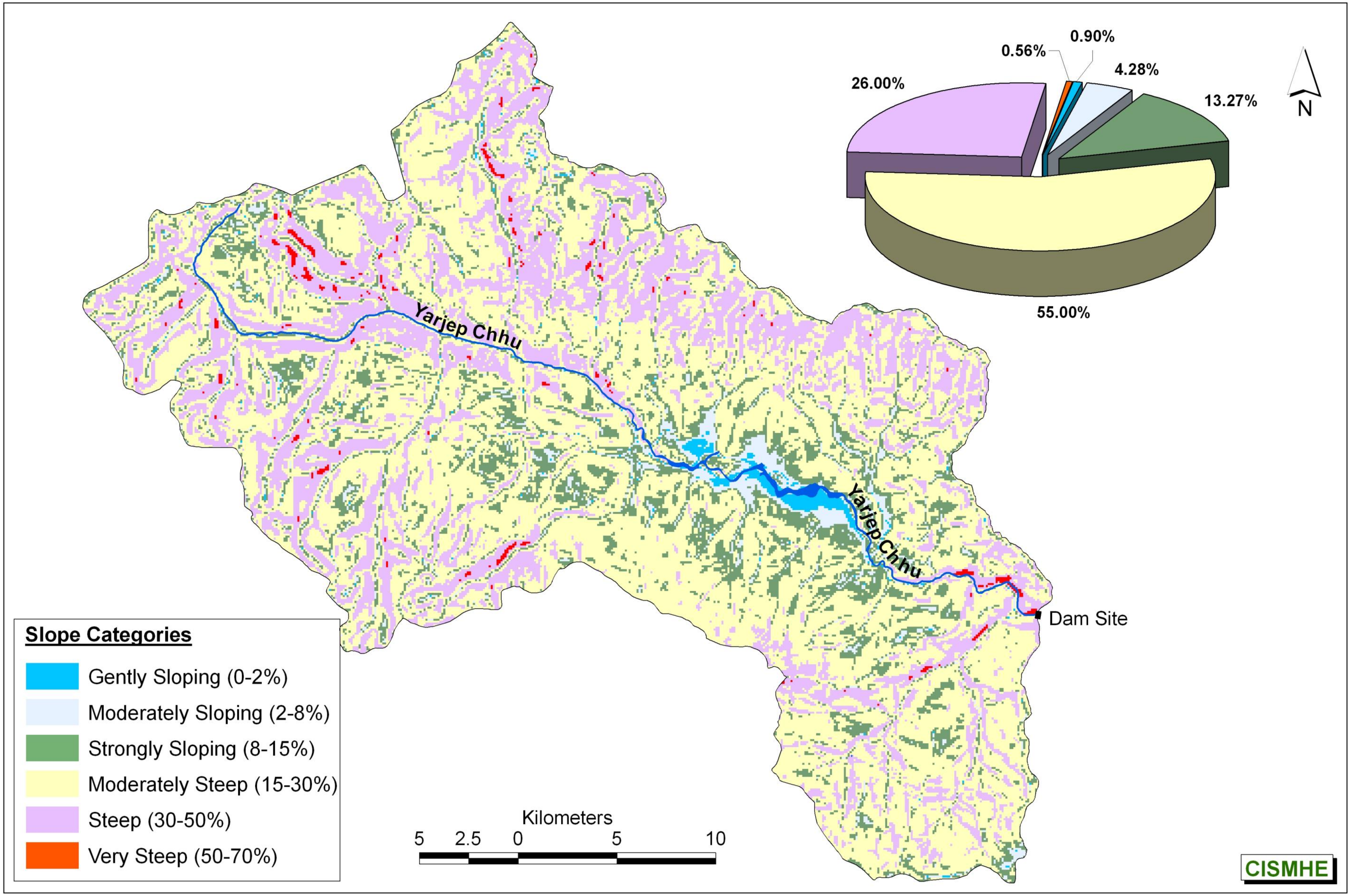


Fig. 3.2.1.8 Slope map of the Pauk H.E. Project up to the proposed dam site

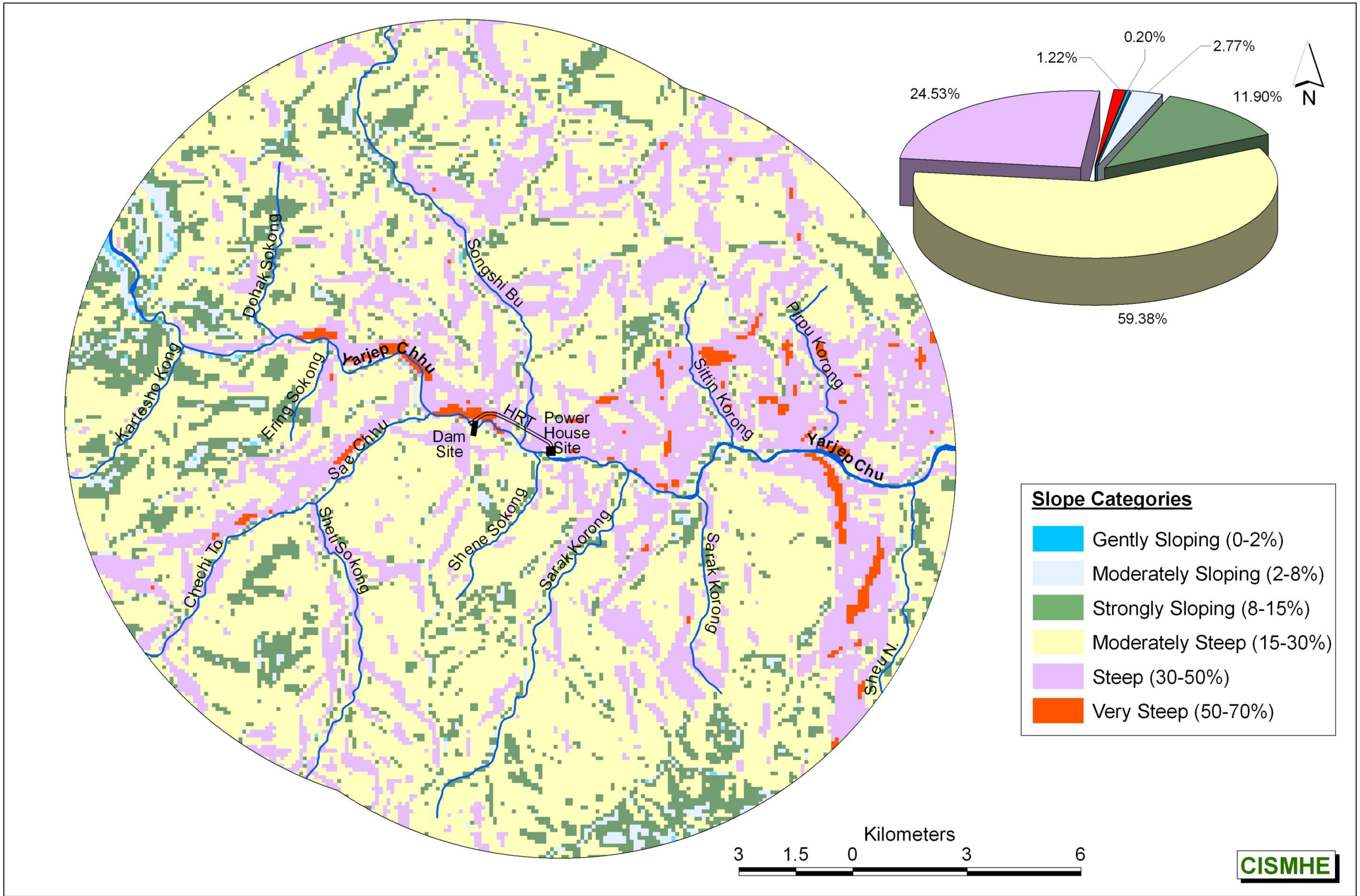


Fig. 3.2.1.9 Slope map of Yarjep Chhu in the influence zone of the proposed Pauk H.E. Project

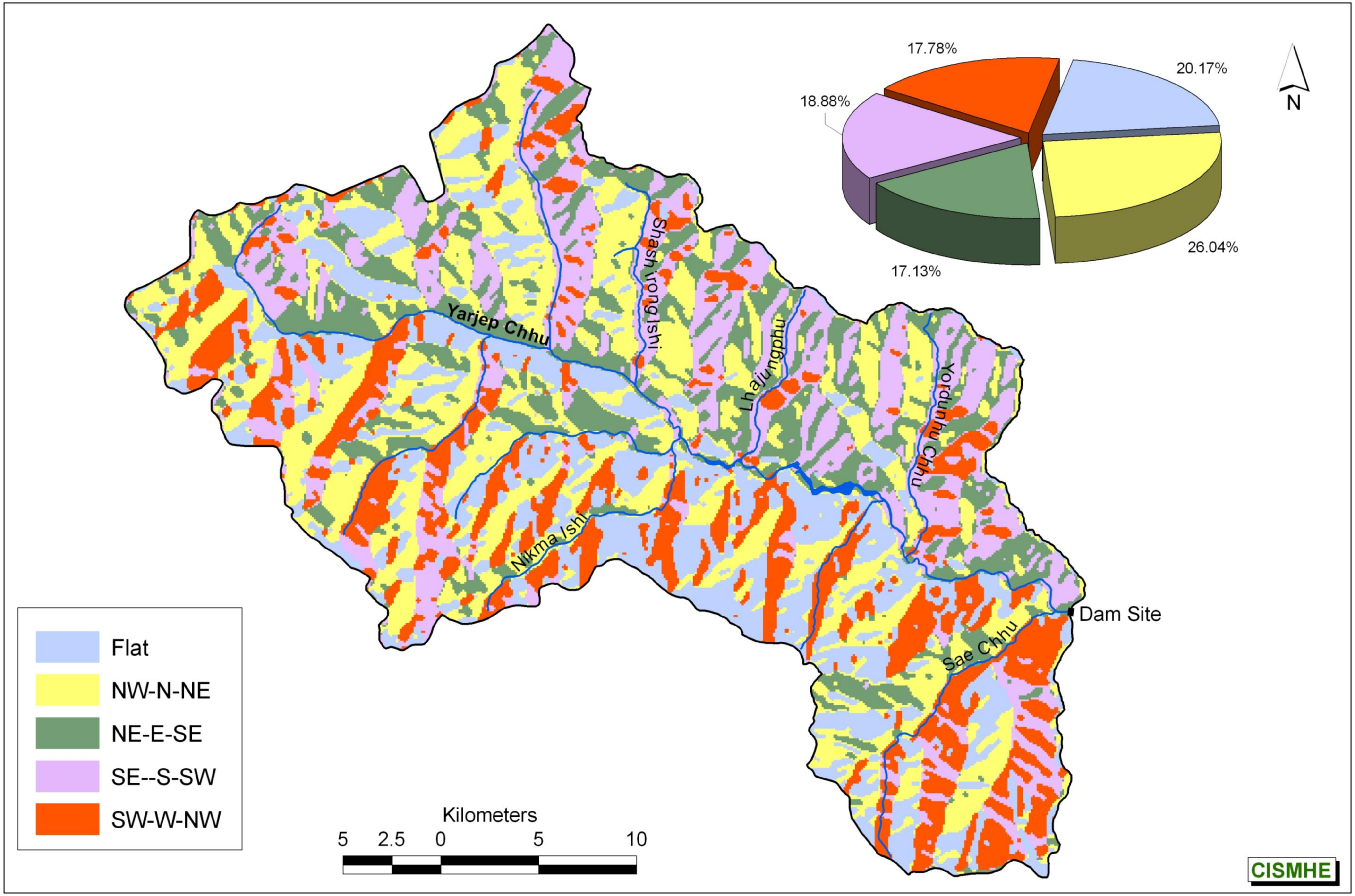


Fig.3.2.1.10 Aspect map of the catchment area of Pauk H.E. Project up to the proposed dam site

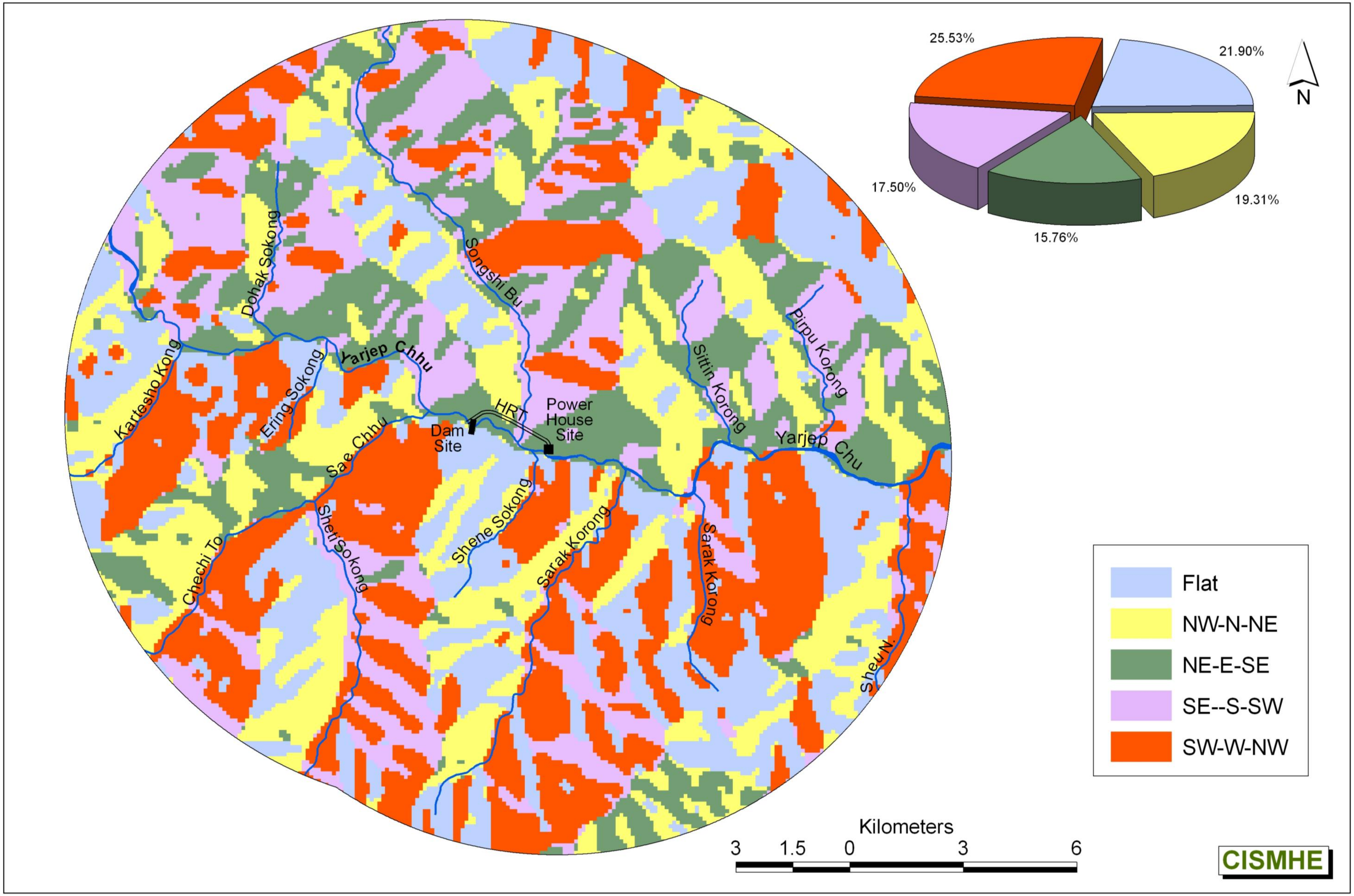


Fig. 3.2.1.11 Aspect map of Yarjep Chhu in the influence zone of the proposed Pauk H.E. Project

3.2.2 GEOLOGY & SEISMICITY

3.2.2.1 General

Study of geology is important for the development of a hydropower project because it not only deals with the rocks and their strength housing the appurtenant structures of the project but also examines the earth's internal and surfacial processes under a regional framework. Pauk H.E. Project is located on Yarjep River in Mechuka circle of West Siang district of Arunachal Pradesh. The proposed dam site is located between Latitude 28˚ 32' 46"N latitude and 94˚ 14' 43" E longitude. The project envisages a concrete arch dam of 110 m height above river bed level, a reservoir with a submergence of 34.1 ha, a head race tunnel of 2.2 km and a surface powerhouse. The proposed powerhouse is located between 28˚ 32' 22"N latitude and 94˚ 15' 58"E longitude. Total catchment area of the proposed project is 982 sq km. Total install capacity of the project is 145 MW.

3.2.2.2 Regional Geology

i) Stratigraphy

The Himalayan ranges continuing from NW India to NE India occurs as a "gigantic crescent" in this part of the country with its convex side towards south and extends from the Western border of Bhutan to Lohit valley in the east and is divisible into four linear zones namely the Tibetan Himalaya, Higher Himalaya, Lesser Himalaya, and Sub Himalaya abutting against the Trans Himalayan range, and the Mishmi Hills famously known as the Eastern Syntaxial Bend (ESB) (**Fig. 3.2.2.1**). The Himalayas constituting the northern fringe of the Indian Plate abuts against the Tibetan Plate along Indus-Tsangpo suture in the north and in the east by Indo-Burmese Plate along the Tiding Suture. Mishmi hills are considered to be part of the Burmese Plate, an extension from Myanmar. The Naga-Patkoi ranges define the southern limit of the Upper Brahmaputra plain abut against the Mishmi Hills along Mishmi thrust in the part forms part of Assam-Arakan basin. The ophilite belt of Nag-Chin separates it from the Naga metamorphics in the east. The Brahmaputra plain lies between Shillong Plateau and Naga-Patkoi ranges in the south and Himalaya in the north, Mishmi Hills in the east. This is essentially made up of quaternaries and rest over the basement of Precambrian or Paleogene-neogene sediments.

Rocks of Arunachal Pradesh belong to Proterozoic. Based on stratigraphy, degree of metamorphism and associated igneous activities they have been classified into three sequences (**Fig. 3.2.2.2**) as enumerated below:

Supersequence –I Sela Group of rocks –Early Proterozoic

Supersequence-II Bomdila- Middle to late Proterozoic

Supersequense–III Dirang and Lumla Formations –Mesoproterozoic age

The general Proterozoic succession is provided in the Table:

Proterozoic	**Neo Proterozoic**	
	Meso Proterozoic	Granite Gneiss **Dirang Formation; Lumla Formation**
Palaeo Proterozoic		Biotite granite gneiss Ultramafic dykes/sills
		Bomdila Group Chillepiam Formation Tenga Formation Ketabari Formation **Se La Group** Galensiniak Formation Tahila Formation

The Sela Group is the oldest, comprises polyphase deformed metasediments varying from green schist to amphibolite facies and well exposed in Se La pass and occurs in the higher Himalayas close to the border with Bhutan. The southern limit is defined by Main Central Thrust (MCT) which separates it from the younger Dirang Formation. The Bomdila group extensively developed and exposed in the Lesser Himalayas from Siang Valley in the east to Kameng Valley in the West and further continues into Bhutan. Dirang formation unconformably overlays the Bomdila Group. As the sequence has been differently classified different nomenclature has been adopted by different workers and correlated differently. In view of the unconformable relation the Dirang formation is distinguished as a different identity from the upper most formation Chilliepam Formation of the Bomdila Group and is not considered part of the sequence.

The Mesoproterozoic rocks unconformably overlie the Bomdila Group of Rock and Ziro gneisses in Lesser Himalayabto constitute Dirang formation and over the Se La group in Higher and Tethyan Hiamalayas to form Lum La Formation.

The project area falls in Dirang formation resting over the Se La group of rocks. The formation comprises a thick sequence of low grade metasedimentaries comprising garnet-muscovite schist, phyllite, sericite- quartzite, calc silicate and tremolite-actinolite marble, truncated in the north by MCT.

3.2.2.3 Geology of the Project Area

i) ***Dam site***

The dam site is located in a narrow and deep gorge. Upstream of the dam site a major tributary of Yarjep River flows into the river. 10 km upstream of the upstream extremity of Pauk reservoir, the valley enlarges widely, in the plain of Mechuka. The geology of the dam site consists essentially of gneiss with thin bands of schist (**Fig. 3.2.2.3**). The fluvial morphology of Yarjep River exhibits deep gorges, narrow valleys and a steep gradient of the river itself. In the river bed, deposit of sand, gravel cobbles and boulders (dia >3m) are frequent. However, in the vicinity of the dam site, the river flows directly on the rock. Sound rock is accessible on both banks (**Plate 3.2.2.1**), a few decades of meters upstream. The slopes of the abutment of dam are very steep to near vertical. Rock (quartzitic or quartzo-feldspathic gneiss) is visibly (from right bank) exposed on the left bank abutment throughout the entire height of the dam. The slope is relatively steeper on the right bank

The different lithologies occur not as separate mappable entities but as intercalated sequence as a sequel to which bulk lithological assemblages have been described. The foliation of the country rock trends N54E to E – S54W to W and dips at 30 to 50 in the direction of N36W to W. The major discontinuities present in the rockmass of the country rocks are as provided in Table 3.2.2.1.

Table 3.2.2.1 Prominent Discontinuities sets recorded in Country Rock

Joint (Dip direction / amount)	Type	Continuity	Roughness	Frequency
40° -50° / N 40°-50° W	Foliation Joint	Long continuity up to more than 10m Sp: 10 cm to 1m	Smooth/Planar	Very frequent
50°: S 30°W	Steep Oblique Joint	6 m -7 m, Sp: 1m – 1.5m	Smooth/Planar	Frequent

40° : N 74°E	Oblique Joint	4- 5 m, Sp > 2m	Smooth/Curvi-linear	Occasional

The foliation and other discontinuities present at the site extend across the valley as in the case of lithology of the country rock thereby indicating no structural dislocation along the riverbed.

ii) ***Intake Structure***

A tunnel intake structure has been proposed taking off from the right flank of the dam. Left Bank is not accessible at present. Access will be done at later stage when the developer will be authorized by Government to build roads and infrastructures. Since left bank is not accessible, no site investigations have been achieved. Investigations have been essentially carried out on the right bank at the time of the report. The river bed is accessible in the vicinity of the intake structure. The drifting exploration showed that rock is mainly gneissic with thin schist bands. The geological survey of the exploratory drift shows schistosity dipping moderately NNW, around 330/30 (dip direction/dip).

Core drill analysis confirmed this statement on the entire height of the dam up to the foundation level. It is assumed that the geological continuity on both banks, which has been evidenced along the valley, will be there at Pauk dam site: it is assumed that the geology encountered on the right bank is almost the same on the left bank as far as the abutment of the dam is concerned and in the vicinity of the intake structure. By continuity, the rock is supposed to be sound and suitable for underground excavation. Satellite imagery analysis has confirmed this assessment.

iii) ***Head Race Tunnel***

The proposed Head Race Tunnel (HRT) alignment passes through a rough and rugged terrain with very difficult access on the left bank of Yarjep River. The tunnel as per the proposals is 2.3 km long with a diameter of 5.9 m, horseshoe and has a gradient of 1 in 300. The tunnel is almost in a straight line, except for a small kink in the initial reaches from the Intake, and in general is aligned in NE-SW direction.

In view of inhospitable terrain and also due to scarcity of outcrops and thick forest cover along the actual alignment, the geological details gathered on the mapping details of road section on the right bank and outcrops map of the tunnel alignment area had to be inevitably relied upon were used for interpreting the anticipated geological setting along the tunnel alignment. Mapping details at the powerhouse site and results of explorations have supplemented to develop the geological section along the tunnel alignment to make a forecast of the rock groups to be met along the tunnel alignment and the probable rock mass characteristics have been worked out to design the support systems.

The geological mapping carried out and correlation of other data indicates that the tunnel will encounter the following rock units/groups in general.

I. Schistose Gneisses

II. Marble (Calc gneisses?) and banded gneisses (dominant) with schistose bands and basic rock layers.

In the tunnel alignment following is broadly the distribution of the rock units along the tunnel alignment starting from the inlet side: in the initial reaches, the tunnel is aligned in NE direction from the dam site. In this stretch and beyond, the tunnel will be excavated through schistose gneisses inter bedded with marble bands. It is expected that a number of shear zones in the poorer schistose zones are anticipated and may be filled with clayey and other rock flour material.

In the final portion, the tunnel is aligned in northeasterly direction and is expected to be driven through mainly gneiss group of rocks with the foliation strike of the rocks across the tunnel alignment making it a favorable direction for tunneling. The schists in thin layers in the gneisses show a puckering effect and form weak zones in the surrounding competent rocks and these vary in thickness from a few centimeters to about 2 meters.

iv) ***Power House Site***

The site is located downstream of very steep cliffs. The predominant rock type at selected site is gneiss. In **Plate 3.2.2.3**, a wide area with gentle slope is shown. A village has settled there, where agriculture is easy. This is a landslide. The Power House site is located at the toe of this landslide, on the upstream extremity.

The thickness of loose deposits could exceed 15 – 20 m in the central part of the inferred slide. However, field observations indicated that this thickness can be reduced to 5 – 10 m at the selected

Power House location. Just upstream of this location, good quality gneiss outcrop allows anticipating good conditions regarding excavations and foundation for the structures.

Two morphologic lineaments highlighted on **Plate 3.2.2.3** could correspond to near E-W trending faults or major fractures. The low slope between the two lineaments reflects lower strength of the rock mass. Consequently, the design should contemplate the location of surge shaft and penstock away from this zone, relatively weaker.

3.2.2.4 Seismo-Tectonics and Seismicity

Himalayas as a whole have undergone intense folding and faulting during different phases of Himalayan Orogeny. The Northeast India in particular has witnessed sedimentation from Paleozoic to Tertiary and has undergone subsequent tectonic events. Four physiographic divisions viz. Tethys, Higher, Lesser and Sub Himalayas of Arunachal Pradesh described above have imprints of different tectonic episodes and differ markedly in their intensity. The important structural features of Arunachal are described below. Seismotectonic map of the region is shown in **Figure 3.2.2.4**.

Folds

Each division has witnessed different tectonic episodes and depicts different patterns of folding. A brief description of various generation folds described in literature is given below.

a). The first generation folds (F1) are isoclinal to reclined parallel to bedding (S_0) and of local extent which were developed during first generation of metamorphism (garnet – amphibolite facies) and are largely recorded in Se La Group of rocks.

b). The second generation folds (F2) are superimposed over F1, moderately tight to open and of regional dimension. These are conspicuously developed in Se La and Bomdila Group of rocks and trend in ENE – WSW direction if not refolded during subsequent episodes. These are not traceable in younger rocks e.g. Dirang and late successions and therefore, are believed to be associated with late Palaeo - Proterozoic orogenic movements. Further, these are associated with large scale acid intrusions which gave rise to various granitic gneisses i.e. tourmaline gneiss, biotite granite gneiss etc. in this region. One such axis of regional fold, overturned plunging anticlinal is found running between MCT and MBF following same regional trend i.e. ENE – WSW within Palaeo – Proterozoic gneisses occurring between both tectonic features.

c) The third generation folds (F3) are isoclinal, reclined or asymmetrical with axial plane running in NNE – SSW or NE – SW and plunging towards north. Their imprints are found in Bomdila Group, Dirang Group and younger sequence of rocks.

d). The fourth generation (F4) is asymmetrical upright to overturned folds having ENE – WSW trending axial plane and dipping towards north. These folds are recorded in Lower Gondwana sequence, west of Siang valley. Eastern Syntaxial Bend is the result of this tectonic event of deformation. Their imprints are well traceable in Bomdila Group as well.

e). The last and final phase of deformation resulting in fifth generation (F5) folds which are generally open, broad asymmetrical with axial plane trending NNW – SSE to NW- SE. These folds have affected Yingiang Group and older succession but have not affected MBF and Siwalik Group of rocks. It therefore, seems that they are the result of strong compression forces possibly during initiation of Himalayan orogeny when Gondwana Plate collided with Asian Plate along Indus Tsangpo Suture on one side and Central Burmese Plate along Tiding Suture on the other side along Tidding Suture.

ii) ***Fault / Thrust***

a) *Main Central Thrust*

The MCT separates the high grade metamorphic rocks (Se La Group) with low to medium grade metamorphic rocks (Dirang Formation). It is traceable in Diggin valley near Rama Camp, upper reaches of Kamla River and near Taliha in Subansiri river section.

b) *Main Boundary Fault*

The Main boundary Fault (MBF) is northerly dipping, steep fault which demarcates Main Himalaya in the north and Sub Himalaya in the south. It is traceable from near Bhutan boarder in the west, through north of Itanagar it extends in ENE – WSW direction to Roing in Dibang valley and ends up against Roing Fault.

c) *Bame Fault*

Bame Fault runs N – S in central Arunachal Pradesh and demarcates Bomdila Group of rocks and Lower Gondwana rocks. Along this fault, Yang Sangchu Formation which occurs between Lohit

Thrust and Tidding Suture terminates in Sigang valley. This fault is traceable from Sigang valley in the north to near Basar in the south and it terminates along MBF.

d) *Roing Fault*

Roing Fault runs parallel to Tiding Suture and Lohit Thrust in central Arunachal Pradesh in the NW – SE direction and like them it also abuts against Mishmi Thrust. Main Boundary Fault also gets terminated near Roing along this fault.

e) *Tidding Suture*

The word suture is normally referred to plate boundaries and therefore is important regional lineaments. The Tidding suture is NW – SE trending suture zone or the zone of subduction where Indian Plate is believed to be subducting beneath the Burmese plate along this lineament. It extends from Dhapa Bum (southern part of Lohit valley) to south of Tuting in Siang valley in northwest. It abuts against Mishmi Thrust in the south.

f) *Lohit Thrust*

It is also NW – SE trending feature which separates Tiding and Mishmi Formations. It was first identified by (Nandy, 1976). It is traceable from north of Tuting in Siang valley till Mishmi Thrust in the south where it is abutting against it.

g) *Mishmi Thrust*

It is located in the south east part of the Arunachal Pradesh near Myanmar boarder. The western part of this thrust trends E – W while it takes NW – SE trend as it moves towards eastern side following the trend of Naga Patkoi Hill ranges.

3.2.2.5 Seismicity and Earthquakes

i) *General*

The dam site is defined by co-ordinates 28° 32’ 46” N and 94° 14’ 43” E and lies in the West Siang district of Arunachal Pradesh. The area falls in Seismic Zone V as adumbrated in the Indian Standard Criteria for Earthquake Resistant Design of structures IS: 1893-Part I, 2002 (**Fig. 3.2.2.5**).

The Zone corresponds to Intensity IX of the MSK scale (1964). IS code quoted above also iterates that detailed site specific studies are to be carried out for determination of design earthquake parameters based on the seismotectonics of a given area, the response at site and seismogenic capability of the tectonic elements etc, a review of the past and present earthquake incidences etc.

The catalogue of earthquakes of the region containing information of source parameters, size, focal mechanism, time of occurrence are gathered through the published information of the Geological Survey of India (Seismotectonic Atlas of India-2000) and the table is appended with this report. (Table 3.2.2.2)

ii) *Seismotectonic Milieu*

Regionally, Arunachal Pradesh comprises four geotectonic blocks viz., 1) The Himalaya 2). The Mishmi Hills 3) Naga-Patkoi ranges of the Arakan Yoma Mountain and 4) The Brahmaputra Plain separated from each other by major tectonic fabric, characterized by distinct stratigraphy with different orogenic episodes and geological history (G.Kumar 1997).

The major structural elements of the region are the MCT, which lies to the north of the project site, Baume–Tuting Fault in the east, Mishmi Thrust, Tiding Suture and the Lohit thrust. The Main Boundary Thrust and the Main Frontal thrust occurs to the South east part of the project complex. As reported by the GSI (Seismic Atlas 2000), variable pattern of seismic incidences have been registered in different tectonic domains and the Himalayan domain is considered sparsely seismic contrary to Indo-Burmese convergent margin tectonics. The Project area falls very close to Himalayan domain. A perusal of the appended drawing indicates that the project area manifests relatively fewer incidences of earthquakes and the focal mechanism of two fault plane solutions of two nearby events to the south indicates strike slip mechanism. A regional assessment also indicates thrust mechanism for deeper events and normal and strike slip mechanism for relatively shallow events (GSI).

A detailed Site Specific study for Design Earthquake Parameters for Pauk HEP, Arunachal Pradesh has been carried out by the Department of Earthquake Engineering, IIT, Roorkee. The analysis revealed that the horizontal seismic co-efficient is 0.31g and the vertical acceleration is as two thirds of horizontal seismic co-efficient.

Table 3.2.2.2 Chronological listing of earthquake data for magnitude > 4.9

SI. No.	Yr	Mo	Dt	Hr	Min	Sec	Lat	Long	Ms	Mb	Depth Km	Source
1	1927	3	15	16	56	32.0	24.50	95.00	6.50	6.00	130.00	GR
2	1930	9	22	14	19	11.0	25.00	94.00	6.30	5.90		GR
3	1932	8	14	4	39	32.0	26.00	95.50	7.00	7.00	120.00	ABE
4	1934	6	2	5	54	29.0	24.50	95.00	6.50	6.00	130.00	GR
5	1935	4	23	16	45	41.0	24.00	94.75	6.30	5.90	110.00	GR
6	1938	5	6	3	41	8.0	24.50	95.00	5.80	5.70	100.00	GR
7	1939	5	27	3	45	44.0	24.50	94.00	6.70	6.10	75.00	GR
8	1941	5	22	1	0	32.0	27.50	93.00	5.60	5.50		GR
9	1943	10	23	17	23	16.0	26.00	93.00	7.20	7.40		ABE
10	1950	8	26	6	33	6.0	26.80	95.00	6.00	5.80		ISS
11	1950	9	25	12	25	28.0	24.00	93.00	5.50	5.50		ISS
12	1951	2	8	21	14	15.0	27.50	95.60	5.80	5.70		ISS
13	1954	3	21	23	42	11.0	24.50	95.25		7.40	180.00	ABE
14	1955	9	8	4	45	26.0	25.00	95.00	5.70	5.60	150.00	ISS
15	1956	12	30	21	59	6.0	24.00	94.50	5.00	5.20		CGS
16	1957	5	28	5	31	68.0	25.42	95.03	5.80	5.70	61.00	ISS
17	1957	7	1	19	30	22.0	24.38	93.76	6.80	6.20	41.00	ISS
18	1959	4	9	17	8	33.0	25.70	94.76	5.10	5.30		ISS
19	1960	5	26	20	5	7.0	27.00	93.00	5.00	5.20		CGS
20	1961	2	4	8	51	48.6	24.80	95.30	5.40	5.40	135.00	CGS
21	1961	6	14	0	41	17.0	24.55	94.69	5.80	5.70	91.00	ISS
22	1963	6	26	17	21	57.3	24.30	95.10		5.40	79.00	CGS
23	1963	10	14	2	1	23.5	25.20	95.30		5.30	33.00	CGS
24	1964	3	27	4	30	36.1	25.82	95.71	4.70	5.30	115.00	ISC
25	1964	6	3	2	49	17.2	25.88	95.69		5.40	121.00	ISC
26	1964	7	12	20	15	58.8	24.88	95.31		5.50	152.00	ISC
27	1965	2	18	4	26	34.7	24.97	94.21		5.40	45.00	ISC
28	1965	5	30	8	48	19.7	25.93	95.80		5.30	101.00	ISC
29	1965	6	18	8	17	38.1	24.94	93.67		5.20	48.00	ISC
30	1966	9	11	15	55	19.4	26.90	95.60		4.90	26.00	ISC
31	1966	10	2	4	31	49.5	24.41	94.81		4.90	75.00	ISC
32	1966	10	18	20	34	37.4	24.28	94.87		4.90	86.00	ISC

33	1969	4	28	12	50	17.2	25.93	95.20		5.00	68.00	ISC
34	1970	2	19	7	10	61.5	27.40	93.96		5.40	12.00	ISC
35	1970	7	29	10	16	20.4	26.02	95.37		6.40	68.00	ISC
36	1970	7	29	10	30	47.4	26.04	95.33		5.00	33.00	ISC
37	1970	7	29	10	31	11.0	26.24	95.10		5.30	52.00	ISC
38	1971	6	26	2	16	36.9	24.60	94.78		5.00	74.00	ISC
39	1971	7	17	15	0	55.8	26.41	93.15	5.1	5.40	52.00	ISC
40	1971	12	29	22	27	3.5	25.17	94.73		5.60	46.00	ISC
41	1973	5	31	23	39	52.4	24.31	93.52	5.7	5.80	1.00	ISC
42	1973	10	9	4	1	47.4	27.69	93.60		4.90	33.00	ISC
43	1974	12	2	1	8	45.9	24.44	95.31		4.90	107.00	ISC
44	1975	11	4	19	27	58.5	24.09	95.11		5.20	98.00	ISC
45	1976	12	25	1	7	10.9	26.12	95.18		4.90	55.00	ISC
46	1977	11	13	21	2	31.8	26.51	93.00		5.10	52.00	ISC
47	1978	1	8	6	10	58.5	24.73	95.20		5.00	97.00	ISC
48	1979	5	29	0	39	52.1	24.50	94.74	4.6	5.20	82.00	ISC
49	1979	7	13	23	20	8.8	24.88	95.22	4.3	4.90	108.00	ISC
50	1979	8	11	20	32	7.9	24.20	94.93	3.9	5.00	113.00	ISC
51	1980	8	12	16	44	1.5	24.80	94.62		4.90	52.00	ISC
52	1981	4	25	11	32	23.0	24.89	95.34	5	5.70	146.00	ISC
53	1982	9	14	6	1	28.5	25.93	95.31		5.00	88.00	ISC
54	1982	11	26	13	26	29.1	27.78	94.87	4.4	5.10	29.00	ISC
55	1983	1	3	11	28	15.1	24.23	94.45		5.10	82.00	ISC
56	1983	1	13	23	0	11.9	24.67	95.00		5.40	109.00	ISC
57	1983	1	31	3	26	4.2	24.72	95.04		5.00	70.00	ISC
58	1983	8	23	12	12	17.5	25.55	95.12		5.20	126.00	ISC
59	1983	8	30	10	39	27.2	25.04	94.67		5.70	64.00	ISC
60	1983	9	23	20	18	8.5	24.77	95.12		4.90	115.00	ISC
61	1984	2	19	9	29	50.6	24.99	94.79		5.00	50.00	ISC
62	1984	3	5	21	26	42.6	24.52	94.62		5.20	70.00	ISC
63	1984	3	21	23	6	24.0	26.76	93.30		5.00	35.00	ISC
64	1984	4	25	14	58	41.5	26.03	95.70		5.00	107.00	ISC
65	1984	5	6	15	19	11.3	24.22	93.53	5.8	5.70	54.00	ISC
66	1985	3	5	10	10	58.4	27.72	94.08	4.9	4.30	52.00	ISC
67	1986	4	17	13	15	57.3	24.42	94.74		5.00	89.00	ISC
68	1987	4	29	5	15	34.6	24.07	94.64		5.00	106.00	ISC

69	1987	5	18	1	53	51.3	25.23	94.21	5.9	5.70	55.00	ISC
70	1987	9	6	23	38	54.1	26.64	93.41	4.3	5.20	49.00	ISC
71	1987	12	1	8	50	41.4	26.33	93.22		4.90	59.00	ISC
72	1988	2	17	17	52	14.0	24.33	94.40		4.90	111.00	ISC
73	1988	7	10	3	31	30.2	25.03	95.38		4.90	128.00	ISC
74	1988	8	6	0	36	25.5	25.13	95.15	7.2	6.60	108.00	ISC
75	1988	8	13	19	59	51.0	25.29	95.13		5.00	87.00	ISC
76	1988	8	21	13	16	30.2	25.27	95.10		4.90	89.00	ISC
77	1989	4	3	19	39	31.5	25.15	94.66	4.8	5.30	69.00	ISC
78	1989	8	9	16	1	24.6	24.51	94.55		5.10	80.00	ISC
79	1990	1	9	18	51	29.2	24.74	95.26		6.10	118.00	ISC
80	1990	1	10	6	37	54.9	26.46	94.63		5.30	82.00	ISC
81	1990	11	29	10	20	33.0	24.37	94.64		4.90	82.00	ISC
82	1991	1	23	6	7	8.6	24.72	95.22		5.40	114.00	ISC
83	1991	1	28	22	24	43.5	26.08	95.39	4.9	4.60	0.00	ISC
84	1991	3	11	10	24	39.0	25.80	94.70		5.00	33.00	ISC
85	1991	5	11	2	15	22.2	24.26	93.68	4.5	5.00	64.00	ISC
86	1991	6	23	10	4	1.7	26.59	93.19	4.4	5.40	35.00	ISC
87	1991	12	7	13	57	38.9	24.00	93.83	4.5	5.10	64.00	ISC
88	1991	12	20	2	6	5.2	24.69	93.12	4.9	5.30	41.00	ISC
89	1992	3	25	22	32	34.2	24.82	95.25		5.20	106.00	ISC
90	1992	4	15	1	32	11.3	24.27	94.93		5.50	116.00	ISC
91	1992	6	15	2	48	56.1	24.00	95.97	6.3	5.80	14.00	ISC
92	1992	3	27	9	42	58.5	24.64	95.02		4.90	117.00	ISC
93	1993	9	4	17	25	10.1	30.3	94.8		5.1	10	
94	1993	12	12	23	54	18.4	27.2	92		5.1	33	
95	1994	4	6	7	3	27.6	26.2	96.8		5.6	33	
96	1995	2	17	2	44	24.4	27.6	92.3		5.2	33	
97	1996	1	26	2	21	11.2	30.9	91.5		5.1	33	
98	1996	6	9	23	15	18.5	28.3	92.2		5.1	0	
99	1997	5	16	11	18	7.7	30.3	97		5.2	33	
100	1997	8	9	4	48	0.7	30.29	96.98		5.2	33	
101	1998	9	26	18	27	5.4	27.77	92.81		5.4	33	
102	1999	10	5	17	4	48	26.26	91.93		5.3	33	
103	2000	1	2	10	23	59.1	28	92.51		5.3	33	
104	2000	1	22	9	37	11.1	30.54	94.06		5.1	52	

105	2000	1	25	16	43	24.8	27.96	92.5		5.3	33	
106	2000	1	26	21	37	51.6	31.45	96.07		5.6	33	
107	2000	1	30	6	35	10.1	29	91.76		5.1	33	
108	2000	5	14	17	18	28.3	28.03	91.42		5.2	15	
109	2000	6	7	21	46	56.4	27.07	97.02		6.1	33	
110	2005	2	3	20	13	28.9	26.22	95.61		5.2	90	
111	2005	6	1	20	6	40.6	28.95	94.71		5.7	49	
112	2006	2	23	20	4	53.5	27.13	91.58		5.6	10	
113	2006	3	25	5	51	49.3	26.89	92.38		5.1	10	

3.2.2.6 Geotechnical Assessment

1. *Dam*

The Dam site is located in a country of gneiss with bands of schists. The appropriate support measures recommended for the class is toe ditch, spot or systematic bolting with spot shotcrete. The recommended measures will be carried out during execution of excavation.

2. *Head Race Tunnel*

The HRT geological mapping carried out and correlation of other data indicates that the tunnel will encounter the following rock units/groups:

I. Schistose Gneisses

II. Marble (Calc gneisses?) and banded gneisses (dominant) with schistose bands and basic rock layers.

Based on Assessment of the" Q" value and RMR value for the quartzite and banded Gneisses as per the Guidelines for excavation and support of Rock Tunnels in accordance with the Rock Mass Rating System (Bieniawski 1989), the support system will be as follows:

- Good Rock RMR 61-80…Locally bolts in crown 3m long spaced 2.5m with occasional wire mesh 50mm shotcrete on crown where required
- Fair Rock RMR 41-60 Systematic bolting 4m long spaced 1.5-2.5m in crown and walls with wire mesh in crown.50-100mm shotcrete on crown and 30mm on sides

- Poor Rock RMR 21-40 Systematic bolting 4.5m long spaced 1-1.5m on crown and wall with wire mesh Shotcrete 100-150mm on crown and 100mm on sides. Light steel set ribs spaced 1.5m where required.

Based on Grimstead and Barton (1993 on the tunneling quality index (Q) the support system for this 5.9m diameter tunnel, could be

- Systematic bolting or
- Systematic bolting with 40-100mm unreinforced shotcrete / fibershotcrete.

3. *Surge Shaft*

The area around the Surge Shaft is occupied mostly by quartzite with a thin cover of overburden and bushy vegetation. The gneiss exposures are interbedded with schist bands of variable thickness.

In view of the good quality of the rock no problems should occur during the excavations of the shaft. However, if the rock falls occur from the sides the same will be suitably stabilized with anchors and shotcreted before final lining with concrete. The all round lateral cover for the Surge Shaft is considered adequate.

Potential faults on upper side of the shaft location have been highlighted by the geologist during the site visit (see Geology Volume, Coyne-et-Bellier report, dated March 2011). A stress relief may be expected close to the cliff. To prevent any problem during the excavation of the shaft, an adequate support is foreseen, such as rock bolts and concrete lining were necessary.

4. *Pressure Shaft*

The surface ridge outline is occupied by fine to medium grained quartzites with thin schist bands RQD values indicates the quality of the rock mass to be Class II type and it may be of Class III for some stretch in the horizontal section.

Excavations of the pressure shaft should not pose problems both in the vertical as well as in the horizontal section taking precautions during excavations and providing rock bolts and shotcrete as dictated. However, potential faults on upper side of the shaft location have been highlighted by the geologist during the site visit (see Geology Volume, Coyne-et-Bellier report, dated March 2011). A stress relief may be expected close to the cliff. The design of the pressure shaft has been made to prevent any problem. First of all, its axis has been chosen to limit the risk to meet a fault during its excavation. It is steel lined to prevent from any squeezing.

5. *Power House*

Geological mapping and evaluation of power house explorations by geophysical surveys have proved that at the foundation sound rock is encountered.

The rock mass from data available is anticipated to be classified under Class III Fair rock and equivalent allowable bearing pressure capacity for the foundations rock. To seal the joints and weak zones consolidation grouting on a regular pattern will be provided for after necessary trial grouting. This has to be decided upon opening of the foundations by the geologist.

Since the powerhouse wall falls close to the river, a curtain grouting to prevent the river water entering the powerhouse pit will be provided in the rock mass to seal all the joints along with necessary drainage measures at the pit in the powerhouse. The power house is equipped of a dewatering system. Slope cuts of the hill slope behind the powerhouse are a prerequisite for stabilization of the back slopes. The rock slopes behind the northern side of the powerhouse will be stabilized by designed slope cuts with anchors and shotcreting in the detailed design stage.

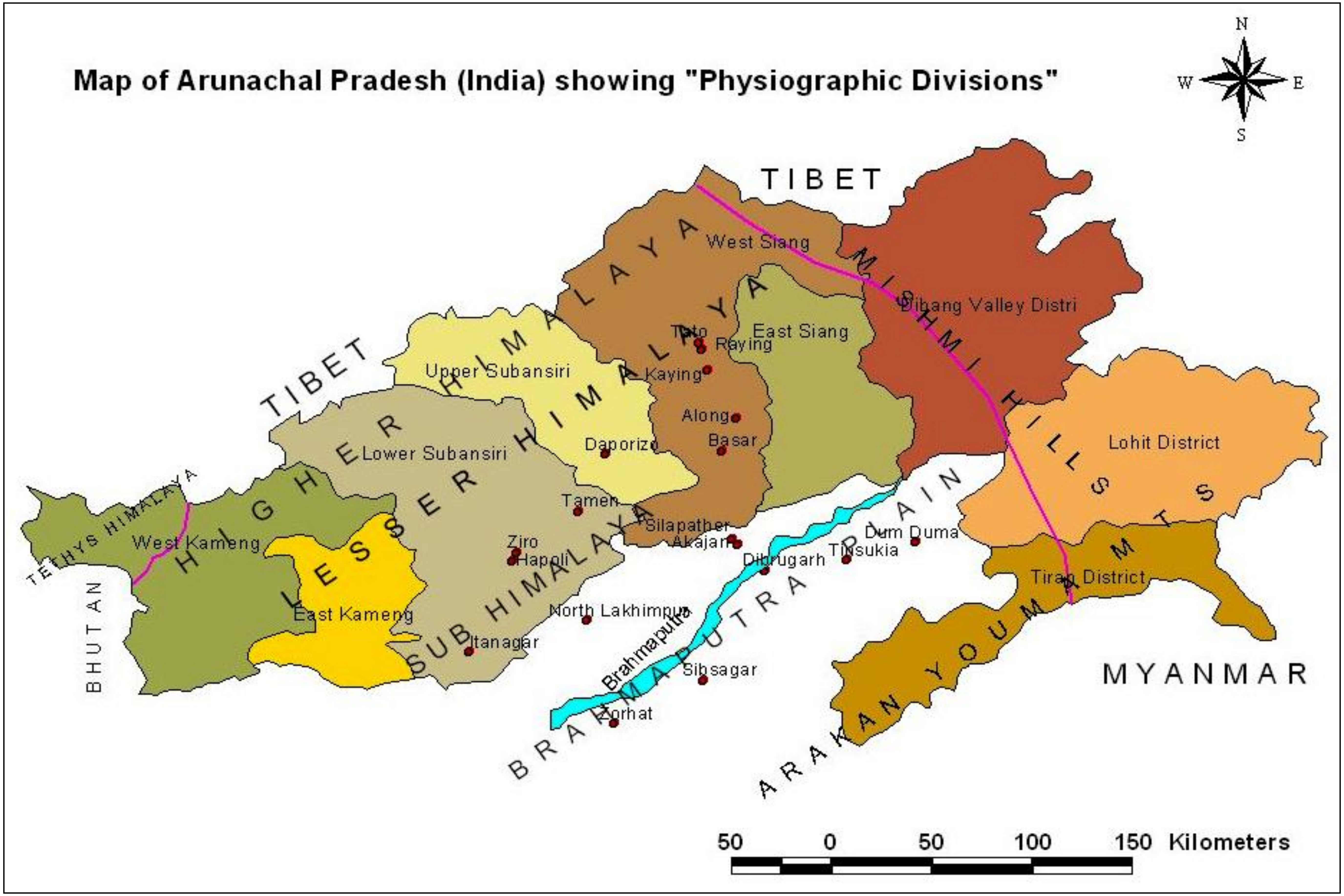


Fig. 3.2.2.1: Map showing physiographic divisions of Arunachal Pradesh

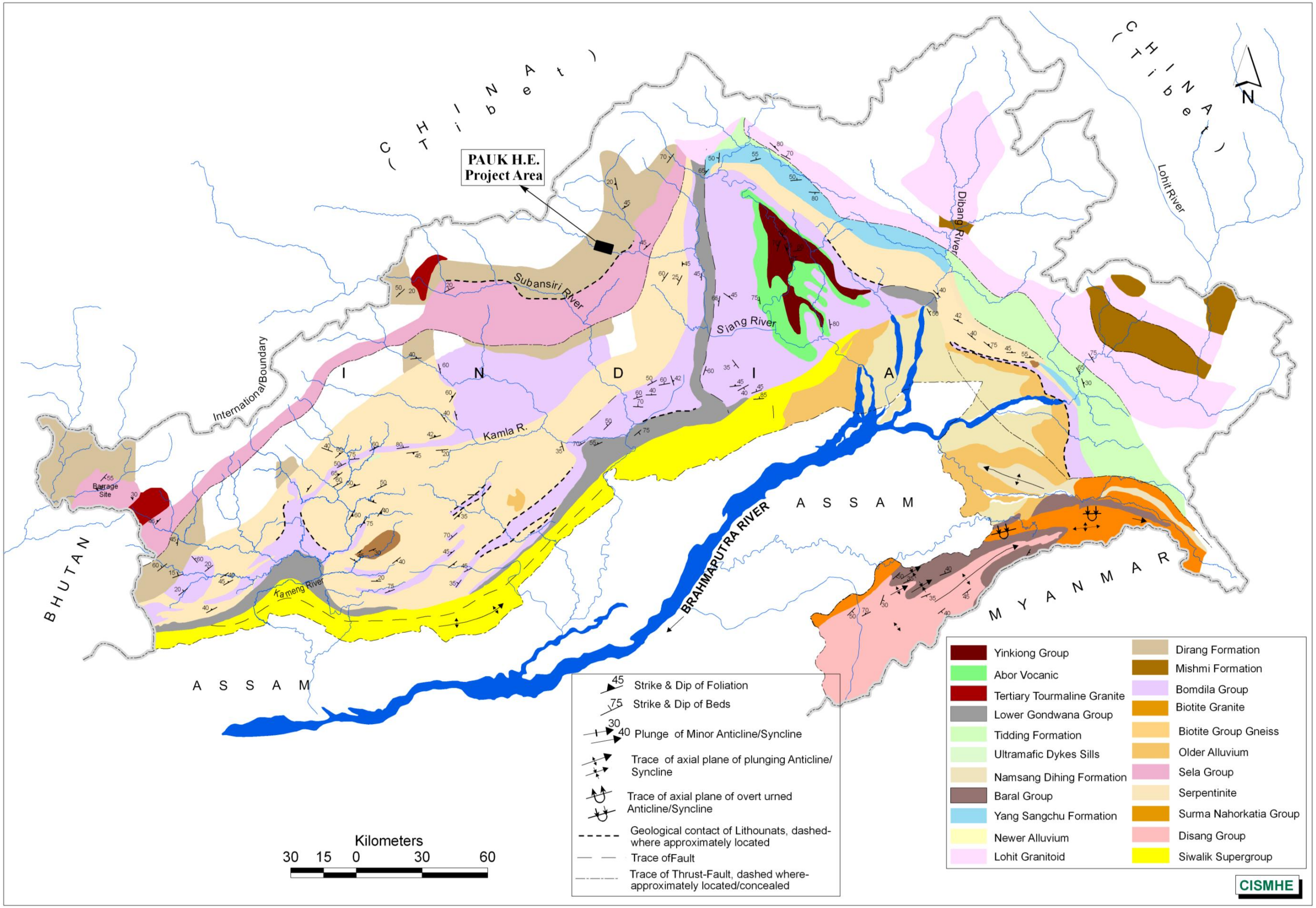


Fig. 3.2.2.2 Regional geology of the Arunachal Pradesh showing Pauk H.E. project area

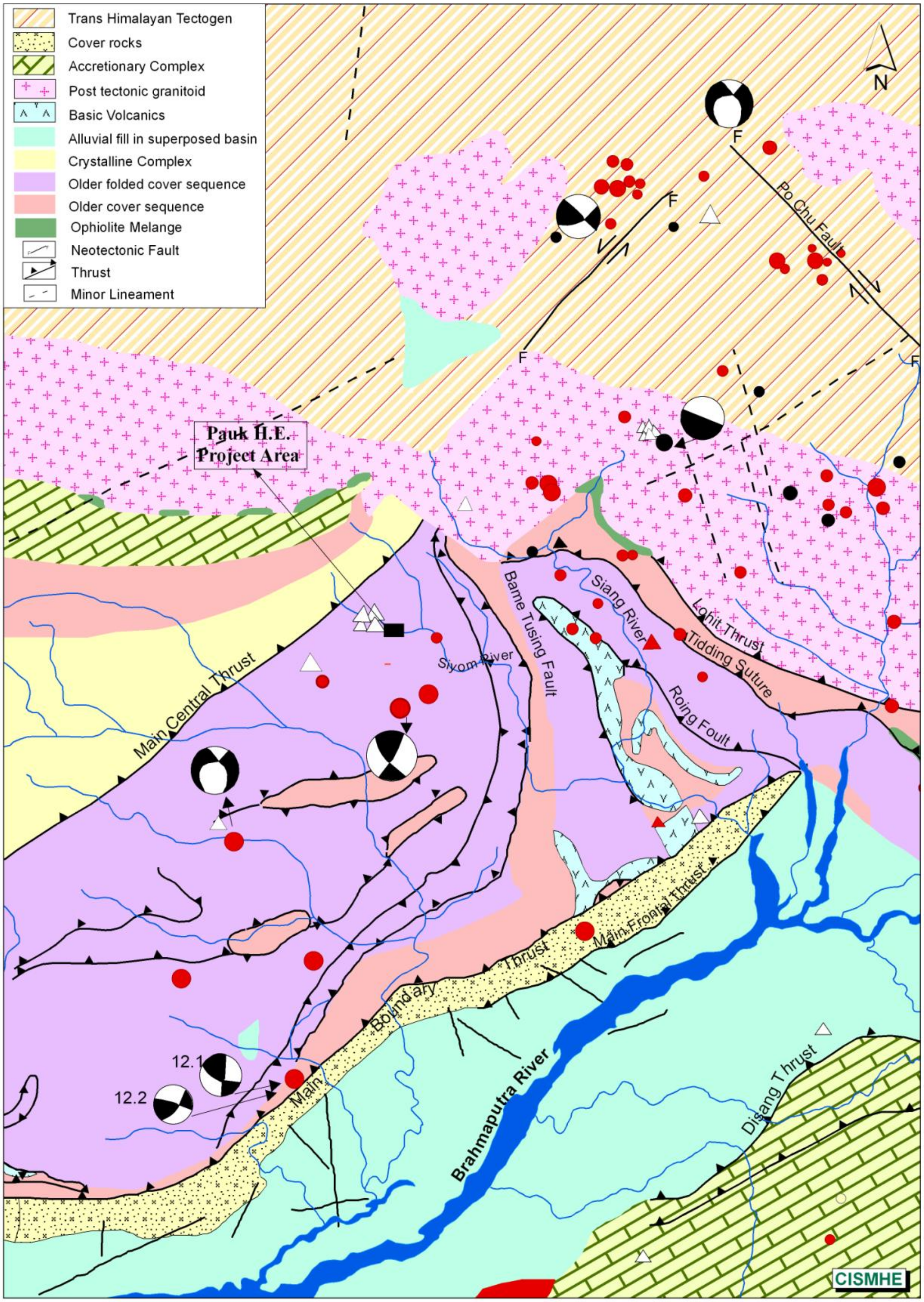


Fig.3.2.2.4 Seismotectonic map of Northeast India

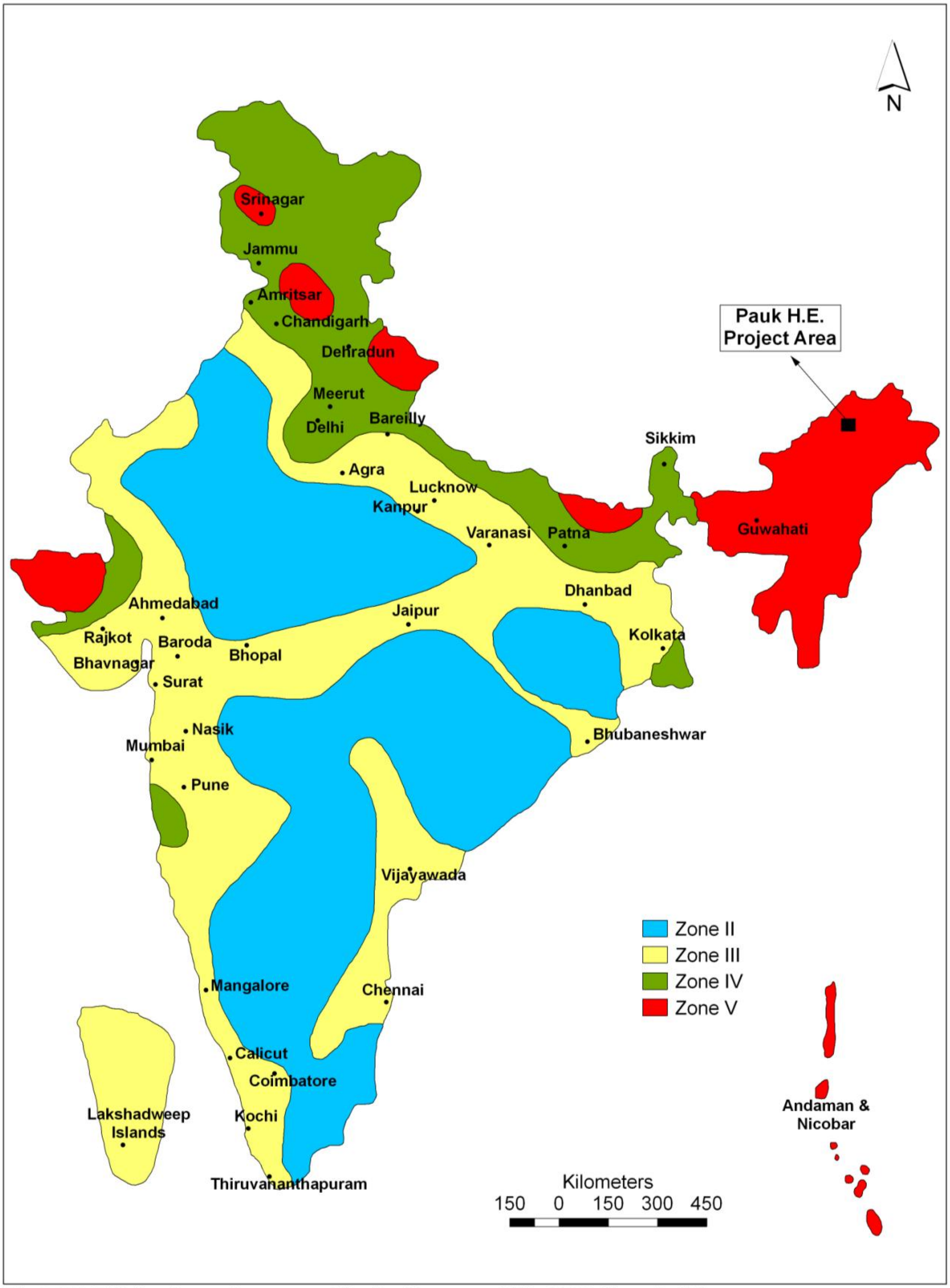


Fig.3.2.2.5 Seismic zoning map of India (Source : BIS, 2002, New Delhi)

Plate 3.2.2.1: **Exposed rock near dam axis on the road**

Plate 3.2.2.2: Exploratory drift, joints indicated by arrows. All joints are much less persistent than schistosity

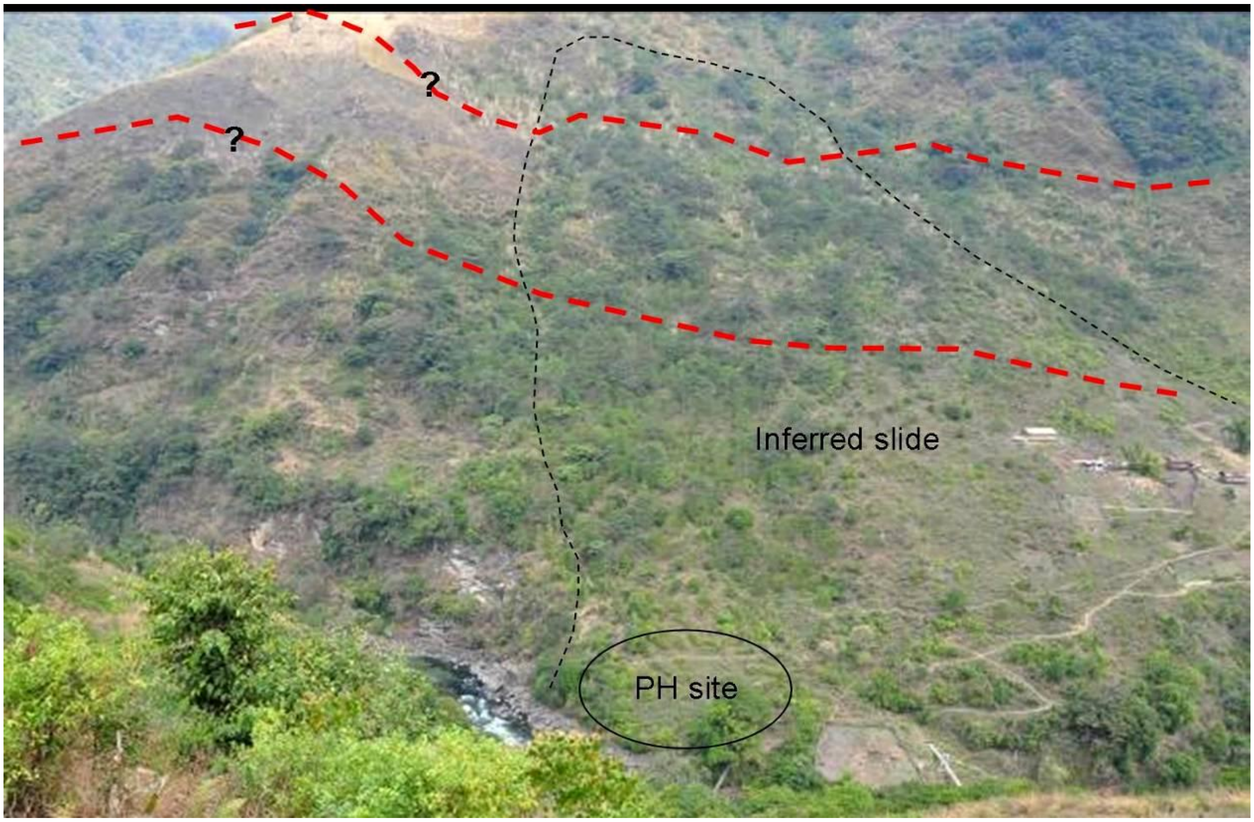


Plate 3.2.2.3: Location of the power house. Slide and fault branches are inferred from geomorphologic features.

3.2.3 SOIL

3.2.3.1 Introduction

Soil is a product of biochemical weathering of parent materials and its formation is influenced by the soil formation factors like climate, organisms, parent materials, relief and time (Brady, 1990). Soil has a unique morphology from surface down to parent material. Soil composition in one of the important determinants of the plant growth in a given area, and affects the terrestrial ecosystem largely. Apart from its life sustaining capacity, its structure, texture and erosion vulnerability affect the life support system in a larger area.

In recent years anthropogenic modification of land amounts to a major threat to its life sustaining property and results into soil contamination, soil erosion and induced land slides. In addition, the use of chemical fertilizers contaminates not only the soils but deteriorates the water quality due to leaching out of soils. The construction activities in a hydroelectric project are expected to include the excavation, quarrying, road construction, etc. in large scale which affect soil adversely. Also, soil erosions in the catchment have immense effects on the life of reservoir and other components. Considering these facts, Environmental Impact Assessment needs to address these issues properly.

Understanding the nature, characteristics, extent and distribution of different soils as well as their properties is helpful in the soil management and conservation, crop production, water control and structure support.

3.2.3.2 Soil Types

i) ***Catchment Area***

Catchment area of Pauk H.E. Project is covered with 6 soil associations in an area of 982 sq km. Soil association Lithic Udorthents – Dystrict Eutrochretps is predominant in the catchment area covering nearly 55.36% of the total area (**Fig. 3.2.3.1**). The soil is predominantly loamy skeletal, shallow and severe erosion associated with moderately deep and light stoniness (Table 3.2.3.1). The major part of the river Yarjep flows through this soil association. Smallest soil association Typic Udorthents – Typic Eutrochretpts covers only 0.08% of the total area. The snow cover area with rock outcrops is limited to upper catchment mainly on right bank of the river. It covers 12.1% of the total catchment.

ii) ***Influence Area***

The influence area of Pauk H.E. Project area is demarcated for 401 sq. km. It is covered with 5 soil associations (**Fig. 3.2.3.2**). Soil association Lithic Udorthents – Typic Udorthents is predominant in influence area covering 55.09% of the total area. Soil is loamy skeletal, shallow to moderately deep and prone to very severe to severe erosion (Table 3.2.3.1). This group of soil is limited basically in valleys and mid hills. Most upper areas of influence zone on right and left banks are dominated with Typic Udorthents – Dystrict Eutrochrepts and Lithic Udorthents – Typic Udorthents associations.

iii) ***Project Component Area***

All project components like dam, HRT, powerhouse colony area, etc of Pauk H.E. Project are located on soil association Lithic Udorthents – Typic Udorthents. Soil is loamy skeletal, shallow to moderately deep and prone to very severe to severe erosion.

Table 3.2.3.1 Soil groups and their characteristics in Catchment and influence areas of Pauk H.E. Project

Soil Series	Description	Sub-Group
S1	Shallow, excessively drained, loamy-skeletal soils on very steeply sloping hill summit having loamy surface with very severe erosion hazard and moderate stoniness: *associated with*:	Loamy-skeletal, Lithic Udorthents
	Moderately deep, somewhat excessively drained loamy-skeletal soils on moderately steeply sloping side slopes with severe erosion hazard and moderate stoniness	Loamy-skeletal Typic Udorthents
S2	Deep, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping summits having loamy surface with severe erosion hazard and moderate stoniness: *associated with*;	Loamy-skeletal, Entic Haplumbrepts
	Moderately shallow, excessively drained, sandy skeletal soils on steeply sloping summits with very severe erosion hazard and slight stoniness.	Sandy-skeletal, Typic Udorthents

S3	Shallow, excessively drained, loamy-skeletal soils on steeply sloping summits having loamy surface with severe erosion hazard and slight stoniness: *associated with*;	Loamy-skeletal, Lithic Udorthents
	Moderately deep, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping side slopes and slight stoniness	Loamy-skeletal, Dystric Eutrochrepts
S4	Shallow, excessively drained, loamy-skeletal soils on very steeply sloping summits having loamy surface with severe erosion hazard and strong stoniness: *associated with*;	Loamy-skeletal, Lithic Udorthents
	Moderately deep, somewhat excessively drained, sandy-skeletal soils with very severe erosion hazard and moderate stoniness	Sandy-skeletal Typic Udorthents
S5	Moderately shallow, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping side slope of hills having loamy surface with severe erosion hazard and strong stoniness: *associated with*;	Loamy-skeletal, Typic Udorthents
	Moderately deep, somewhat excessively drained, fine-loamy soils with moderate erosion hazard	Fine-Loamy, Typic Eutrochrepts
S6	Rocky mountains covered with perpetual snow and glaciers	

3.2.3.3 Soil Properties

i) *Physical and Chemical Characteristics*

Generally, physical and chemical properties of soil in nature are affected by soil texture and partly influenced by the vegetation cover and the activities of various animals and microorganisms living on and in it. The bio-chemical reactions and mechanical weathering of parent rock materials convert these into living soils, which is capable of supporting plant and microbial diversity. High percentage of silt and clay in soils is generally considered soils are rich in nutrient contents. The texture of the soil is one of the most important characteristics, which determines its porosity, permeability, erodibility and water holding capacity. In the present study, we recorded a considerable variation in the physical and chemical characteristics of the soil samples collected from the project and catchment areas (Table 3.2.3.2). Among the different grades of soil texture based on the International Systems of Soil Classification (1927) coarse sands recorded maximum percentage, followed by the medium sands and fine and very fine sands which clearly indicate high porosity and permeability of soils in the project and catchment areas. We recorded more than 2% silt and clay for majority of the samples collected from different sites (0.39 to 6.6%). The percentage of moisture content ranged from 5.51 % at S2 site during winter season to 81.17% for S1 site during monsoon season. Bulk density varied from 0.67 g/cc to 1.31 g/cc indicating soils are loosely compacted and suitable for vegetation growth. Water holding capacity of the soil samples for different sites ranged between 27% and 88.34 %. A higher value of electrical conductivity (147 μS/cm) was recorded for monsoon season at S4 site, whereas it was recorded low (34 μS/cm) winter season at S1 site.

The pH of soils under study showed nearly similar values of the soils from the plains. We recorded pH less than 7 ranging from pH 5.79 to pH 6.7 for the soil samples collected from different sites of the project area (Table 3.2.3.2). These pH values indicate soils fall under near neutral to slightly acidic in nature. However, Himalayan soils are generally of high to moderately acidic forms, deviation in the present result seems to be an exception to the above rule. A higher concentration of phosphate was recorded from the soils in comparison with chloride and nitrate (Table 3.2.3.2). We observed that soil samples collected from the different sites of the Pauk H.E. Project area are considerably rich in organic matters and organic carbon.

ii) ***Biological characteristics***

The biological characteristics were analysed for the microbes (fungal colony and bacterial colony) In terms of density. In general higher elevation recorded low density of microbes. It can be attributed with variation in temperature along the elevational gradient and forest cover. Site S1 (Mechuka) is covered with sparse vegetation and records low temperature. The minimum density of microbes were recorded from Mechuka (Table 3.2.3.3).

Table 3.2.3.2. Physical and chemical characteristics of soils retrieved from the influence area of Pauk H.E. project

	Winter				Pre-monsoon				Monsoon			
Parameters	**S1**	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**
Physical characteristics												
Soil Texture (%)												
Very Coarse sand	0	0.42	0.15	1.30	2.1	0	0	0.13	0.79	1.39	4.7	0.53
Coarse sand	24.4	33.2	44.73	53.40	38.25	66.64	31.85	54.12	37.17	14.32	28.23	49.18
Medium sand	37.99	29.1	33.65	32.70	29.59	27.27	18.60	32.27	28.2	42.18	43.11	10.00
Fine and very fine sand	33.09	24.6	16.12	6.67	19.23	4.65	1.47	12.56	29.93	41.1	20.52	34.28
Coarse silt	2.32	10.3	0.40	1.79	4.23	0.22	45.84	0.33	2.79	0.59	1.93	4.19
Fine, medium silt and clay	2.18	2.41	4.92	4.21	6.60	1.2	2.21	0.59	1.08	0.39	1.45	1.82
Moisture content (%)	20.01	5.51	15.75	19.71	15.26	18.04	10.36	15.49	81.17	16.96	41.94	29.17
Bulk Density (g/cc)	0.8	1.31	0.8	0.98	0.89	0.79	1.00	1.11	0.67	0.73	0.73	0.97
Water Holding Capacity (%)	67.07	40.4	77.1	77.93	72.35	82.22	55.1	88.34	33.33	14.035	44.71	27.00
Conductivity (µs)	34.00	99.00	83.00	81.00	72.00	71.00	31.00	120.00	70.00	63.0	147.00	110.00
Chemical Characteristics												
pH	5.90	6.27	6.04	5.89	5.91	6.08	5.84	6.01	5.79	6.70	5.83	6.18
Nitrate (mg/g)	0	0.04	0	0.03	0.05	0.05	0.07	0.03	0.021	0.01	0.039	0.03
Phosphate (mg/g)	0.48	0.63	0.39	0.31	0.04	0.045	ND	0.048	ND	0.08	0.09	0.19
Organic Matter (%)	2.49	1.39	4.48	6.18	4.23	1.31	1.64	7.46	3.91	0.9	4.01	1.95
Organic Carbon (%)	1.44	0.8	2.6	4.27	2.64	0.76	0.95	3.22	2.27	0.52	2.33	1.27
Chloride(mg/g)	0.074	0.06	0.047	0.07	0.12	0.146	0.066	0.091	0.21	0.048	0.051	0.06

S1 = Mechukha; S2 = Dam site; S3 = Uphill of Pyuring village; S4 = Rapum village

Table 3.2.3.3 Microbial density in soils retrieved from various sites

Season	Site S1	Site S2	Site S3	Site S4
Winter Season				
Fungal colony (mpn/ g^{-1})	0.80×10^3	23.00	3.16×10^4	0.90×10^4
Bacterial colony (cfu/ g^{-1})	2.27×10^4	2.33×10^3	4.90×10^4	1.32×10^5
Pre-monsoon Season				
Fungal colony (mpn/ g^{-1})	1300	1.43×10^4	1.79×10^4	3.60×10^4
Bacterial colony (cfu/ g^{-1})	4800	4.11×10^6	2.87×10^4	2.88×10^4
Monsoon Season				
Fungal colony (mpn/ g^{-1})	1.12×10^3	1.73×10^4	3.00×10^5	5.11×10^5
Bacterial colony (cfu/ g^{-1})	1.81×10^3	1.29×10^4	3.65×10^4	3.61×10^4

S1 = Mechukha; S2 = Dam site; S3 = Uphill of Pyuring village; S4 = Rapum village

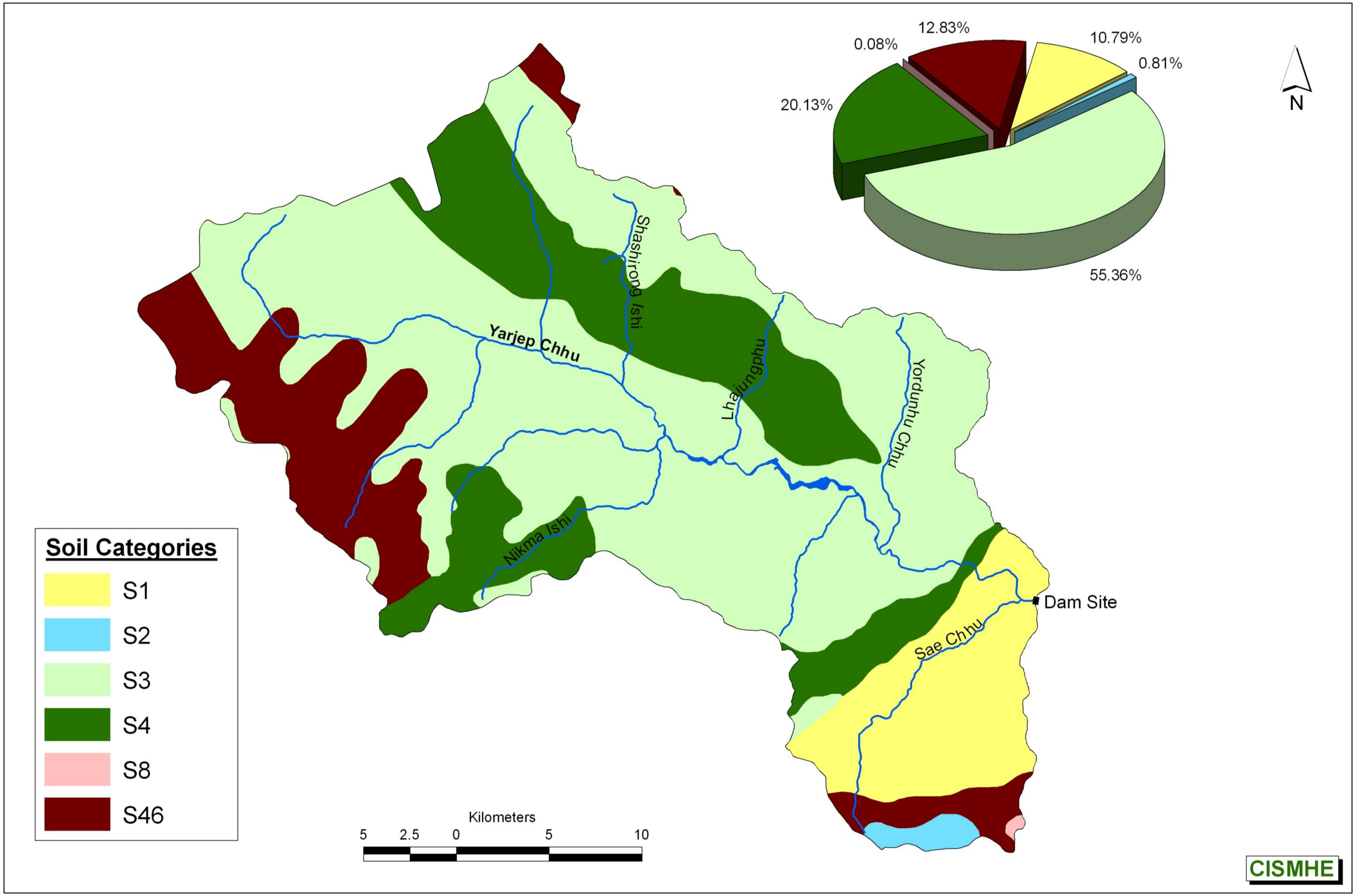


Fig.3.2.3.1 Soil map of the catchment area of Pauk H.E. Project up to the proposed dam site

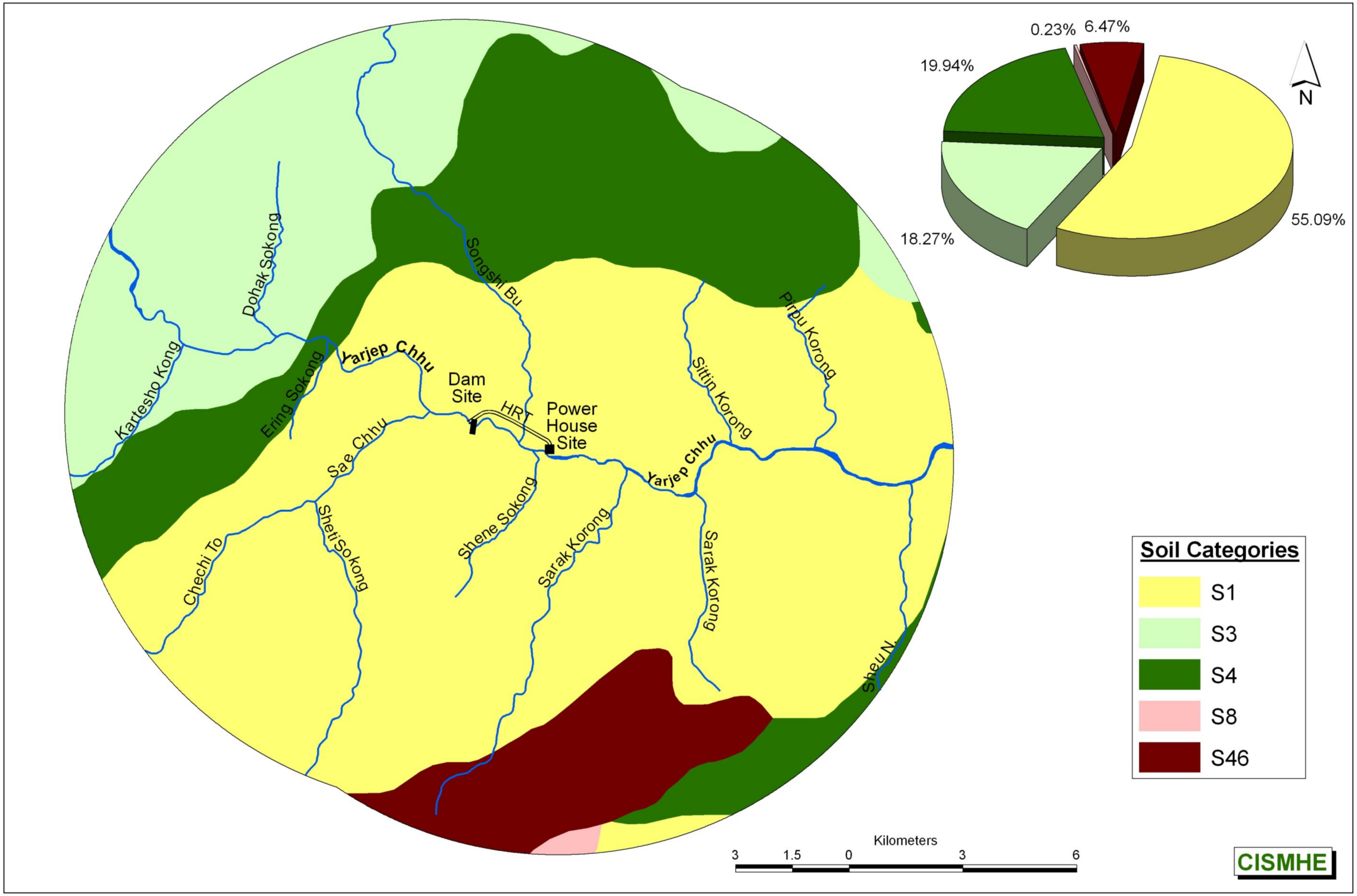


Fig. 3.2.3.2 Soil map of Yarjep Chhu in the influence zone of the proposed Pauk H.E. Project

3.2.4 LAND USE AND LAND COVER

3.2.4.1 Introduction

The land use relates to the human activity or economic function associated with a specific piece of land, while the term land cover relates to the type of feature present on the surface of the earth (Lillesand and Kiefer, 2000). Land use/ Land cover (LULC) maps are presently being developed for various purposes. Moreover it is being used for planning and management activities. Since the industrialization LULC changes has been a studied subject, such as deforestation, urban sprawl, etc. In the LULC mapping the use of multi-spectral bands and panchromatic band are being widely used since the emergence of satellite imageries in early 1970s. More recently, high spatial and spectral resolution satellite imageries such as quick bird sensors with spatial resolution of 0.50 meters are being utilized for more detail LULC mapping. Therefore, the satellite remote sensing technology has been widely accepted for rapid resource assessment and monitoring, particularly in the Developing World. National Aeronautical and Space Administration (NASA) of USA has made most significant contributions with satellite based remote sensing techniques. Since 1972, after the Landsat-1 was launched, remote sensing technology and its application has undergone a tremendous change in terms of sensing development, aerial flights with improved sensors, satellite design development and operations including data reception, processing, interpretation, and utilization of satellite images. All these advancements have strengthened the applicability of remotely sensed data in various areas, like forest cover, vegetation type mapping, and their changes on a regional scale. Global Land cover Facility (GLCF) mapping has now made all its satellite data sources freely available for research and LULC mapping. These data sources are of immense use for decision makers and policy makers therefore it is possible to carry out detailed forest inventories, monitoring of land use, protected area conservation and vegetation cover at various scales. The present work is an attempt of the same in Pauk H.E. Project area.

3.2.4.2 Objective and Study Area

The objective of the present work is to produce land use and land cover map using hybrid digital classification technique. Also, to produce land cover data set appropriate for wide variety of applications like Catchment Area Treatment (CAT) planning.

3.2.4.3 Database

The details of primary data in the form of digital data on CDROMs for interpretation and analysis are given in Table 3.2.4.1. The mask of the entire Pauk catchment area including the project site was generated from the IRS-P6 data which was acquired on 5th December 2006 with 95% cloud free atmosphere.

Table 3.2.4.1 Database used for land use and land cover mapping of the Pauk catchment

Satellite	Sensor	Path/Row	Date	Data type & Bands
IRS-P6	LISS-IV	112/51	05-12-2006	Digital (1,2,3,4)

In addition Survey of India (SOI) toposheets (82L2-82L3-82L6-82L7) with 1:50,000 scale were used for the preparation of base and drainage maps. The field information, collected by CISMHE and / or provided by Velcan Energy was also used in order to study the Project Area.

3.2.4.4 Methodology

Land use and land cover mapping of the Pauk H.E. Project was carried out by standard methods like digital image processing (DIP) supported by ground truthing. For this purpose digital data on CDROMs was procured from National Remote Sensing Agency (NRSA), Hyderabad DIP of the satellite data, preparation of various thematic maps, and their interpretation were achieved at Computer GIS Lab, CISMHE using Erdas Imagine 9.0 of Leica Geosystems. Before image processing, image enhancement, transformation and classification, pre-processing was done for multi-spectral band. Different bands were downloaded into the workstation using Erdas Imagine 9.0. The images were checked for occasional shortcomings in the quality of radiometric and line dropouts. Band separation and windowing of the study area with the help of Survey of India (SOI) toposheets was performed. The registration of image was performed using the nearest neighbour resampling algorithm. The scene was geometrically corrected with toposheets using proper identification of Ground control points (GCPs) with a root-mean-square (RMS) error of 0.0002 to 0.003 pixels. Indian Remote Sensing data was radiometrically corrected using dark pixel subtraction technique. They were then co-registered with SOI toposheets using UTM Zone–46 N WGS84 projection systems. Geo-referencing of the composite image was done using digital vector layer of drainage, road network, water bodies, and other permanent ground features extracted from SOI toposheets. Distinguishable Ground Control Points (GCPs) both on image and vector database were identified. By using these GCPs the image was resample and geo-coded. Sub-pixel image to map registration accuracy was achieved through repeated attempts. The image enhancement techniques like edge detection, filters, manipulation of contrast and brightness, histogram equalization etc. was performed by using different combinations for best image contrast. Standard false color composite (FCC) image of the catchment area was prepared using bands 2, 3 and 4 of IRS-P6 (**Fig. 3.2.4.1**) and discrimination of features was made by visual interpretation on this image. The interpretation key was based on the relationships between ground features and image elements like texture, tone, shape, location and pattern. A flow chart indicating the general procedure for land use and land cover classification is shown in the **Figure 3.2.4.2**.

In order to provide higher resolution of base image (IRS-P6 LISS III), panchromatic (PAN) image was fused with MSS LISS –III image. In this process, a portion of high resolution PAN band, which corresponds to an area of interest (AOI) in the multi-spectral LISS – III image was extracted. Thereafter, both the images were co-registered and LISS-III image was resampled for merging with PAN image. Merging or image fusion was done by special enhancement module in Erdas Imagine 9.0. The digital vector layers like contour, drainage network, snow, glacier, forest, settlements etc. of the Pauk H.E Project site were prepared from the SOI toposheet in 1:50,000 scale. The vector layers were also prepared for nearby free-draining catchment areas. Further, the drainage network was classified into various sub-watersheds based on stream order (Horton, 1945, Strahler, 1952, 1957).

In the preliminary analysis, image classification was done by unsupervised classification method by performing ISODATA training. It helped in assigning the classification of the image into land use categories. However, the boundaries of water bodies were separately mapped from SOI toposheets for image classification. The doubtful areas or wrongfully interpreted areas owing to various physical features controlling the study area were marked for ground truth collection. Consequently following the ground truth collection, supervised classification was assigned for the final image classification. The classified map was regrouped and merged. The classified raster map thus prepared, was then converted to vector format for GIS analysis, and the preparation of required thematic maps using ArcGIS 9.1 and GeoMedia Professional 5.2. Supervised and Unsupervised classification methods are statistical models which enable the user to classify land features in land uses and land covers.

3.2.4.5 False Colour Composite (FCC)

FCC image generated from IRS-P6 (band 2, band 3 and band 4) LISS-III of Pauk catchment area is presented in the **Figure 3.2.4.1**. Based on visual interpretation on FCC image, several geomorphological features have been identified in the catchment area. Areas covered with snow and glacier is marked by white colour and they are situated towards the northwestern part of the catchment. Areas occupied by forest lands are marked by deep red to brown colour in FCC and most part of the catchment is occupied by this features. Areas of less vegetation and no vegetation (barren land) are displayed by light red and brown colours respectively, while areas covered with thick vegetation is marked by deep red colour. Most part of the catchment area is occupied by this unit. Surface water bodies are displayed by deep blue to bluish black colour. Cultivation lands and settlement areas are displayed by grey and cyan colours respectively. These features are commonly distributed near the main river courses. There are many lineaments observed in the catchments. Several geological structures, like thrusts, faults and lineaments have also been identified on the FCC image. Distribution of straight river channels is marked as lineaments and is common along the main river courses and its tributaries. The presence of thrusts and faults are marked by tonal variation.

3.2.4.6 Classification Scheme

Keeping in mind the objectives of preparation of environment management plan (EMP), action plan for watershed management and catchment area treatment (CAT) plan, the classification scheme adopted for the preparation of land use/land cover maps on 1:50,000 scale is described below. Vegetation density classification was made by Normalized Difference Vegetation Index (NDVI) technique where band 2 and band 3 were used in extracting the vegetation index.

$$NDVI= (\lambda_{1-} \lambda_2) /(\lambda_{1+} \lambda_2).$$

Where λ_1 is near infrared channel and λ_2 is near visible band channel. In NDVI algorithm vegetated areas will generally yield high values because of their relatively high near-infrared reflectance and low visible reflectance in contrast to water, clouds, and snow have larger visible reflectance than near-infrared reflectance. Thus, these features yield negative index values. Therefore NDVI values are a measure for the presence and condition of green vegetation density (Lillesand and Kiefer, 1999).

From the NDVI assessment two forest density classes were interpreted for the forest cover mapping. The forests with >40% canopy cover were delineated as dense forests and between 10%

and 40% crown density as open forest. Furthermore, degraded forests and scrubs were also delineated for the purpose of erosion mapping. The cropland was also delineated. The non-forest land cover in the form of barren/ rocky land, glaciers, lakes, etc. was also classified for the calculation of erosion intensity classification in Catchment area treatment plan.

An interpretation key was prepared based on the relationships between ground features and image elements like texture, tone, shape, location, and pattern. Image interpretation was done for the entire Yarjep River basin. Interpreted details (polygons) were then transferred to base map. Since satellite data is geo-coded there was not much error in the geometry of the data and wherever necessary, local matching was done while transferring the details.

3.2.4.7 Land Use/Land Cover in the Catchment Area

The total catchment area for the proposed project up to the dam site is about 98200 ha. The project site lies under Pauk catchment which includes its major tributaries like the Nikma Ishi, Sheshirong, Nukmaphu Chhu, Shama Sokong, Sae Chu, Kartesho Kong. The land use/ land cover of the catchment area consists of 9 categories (**Fig. 3.2.4.3**), out of which maximum area of about 35803.72 ha i.e., (36.46%) is under Dense forest (Table 3.2.4.2). Open forest and degraded forest together accounts for 11.8%, Scrub/Alpine scrub 10762.72 ha (10.96%). Barren/ rockyland with moraines together occupy 17921.5 ha (18.25%) of the total catchment area. Snow/ glacier contributes 16959.14 ha (17.27%) in the catchment, while cultivations and settlement covers 4919.82 ha i.e., 5.01% of the total catchment. River and sand body together contributes 255.32 ha (0.26%) of the total catchment area.

Table 3.2.4.2 Areas of different categories of land use/ land cover of the Pauk Lower H.E. Project

Land cover/Land use	Area (Ha)	Percent
Dense Forest	35803.72	36.46
Open Forest	7914.92	8.06
Scrub	10762.72	10.96
Degraded Forest	3672.68	3.74
Cultivation/settlement	4919.82	5.01
Moraines	7198.06	7.33

Barren	10723.44	10.92
River	255.32	0.26
Snow	16959.14	17.27
Total	**98200**	

3.2.4.8 Land Use/Land Cover of Influence Zone

Additionally, MoEF has been following a general practice of baseline data to be collected in a 10 km radius of a project while conducting EIA studies. A base map was developed to demarcate the submergence zone and influence zone of the Pauk H.E Project. Therefore land cover and land use maps will be further studied within the 10 km radius of power house and barrage site. It is called as the study area (Influence zone and the submergence area).

From the **Figure 3.2.4.4** the influence area has 40155.74 ha of land. Dense Forest has maximum area coverage of 44.86% of the study area. It is prevalently spread along both banks of Yarjep Chhu. Open forest is more predominant along the left bank of the Yarjep Chhu, it accounts for 18.34% of the total influence zone. Alpine Scrub covers 17.19% of the total area whereas degraded forest is spread on 14.12% of the total area of study area. The remaining land cover and land use accounts for mere 5.49% of the total area i.e., Moraines and barren land, Cultivation and settlement, Snow and water bodies including river.

3.2.4.9 Land Use/Land Cover of Submergence area

The total reservoir area around the dam site is about 34.1 ha. The land use/ land cover around the reservoir area consists of 5 categories (**Fig. 3.2.4.5**), out of which about one fourth is covered by the riverbed. Degraded forest is the most prevalent class covering 39.04%. Dense forest covers about 13.5% of the reservoir area, and the remaining land use/land cover is open forest and scrub, with an area of about 9% and 6% respectively.

3.2.4.10 Land Use/Land Cover of Project area

The dam area, in the vicinity of Chengrung village, is mostly covered by dense and open forest to degraded forest and scrubs. No areas under cultivation or settlements are affected by the project.

The muck disposal area and its access road are located in an area mostly covered with dense to open forest, while the power house area, around Purying and Hiri villages, is characterized by mostly open to degraded forest and scrubs. The dense forest in this area is negligible compared to the rest of the power house area. There are also a few places of cultivation and settlement with a relatively small footprint nearby the project area.

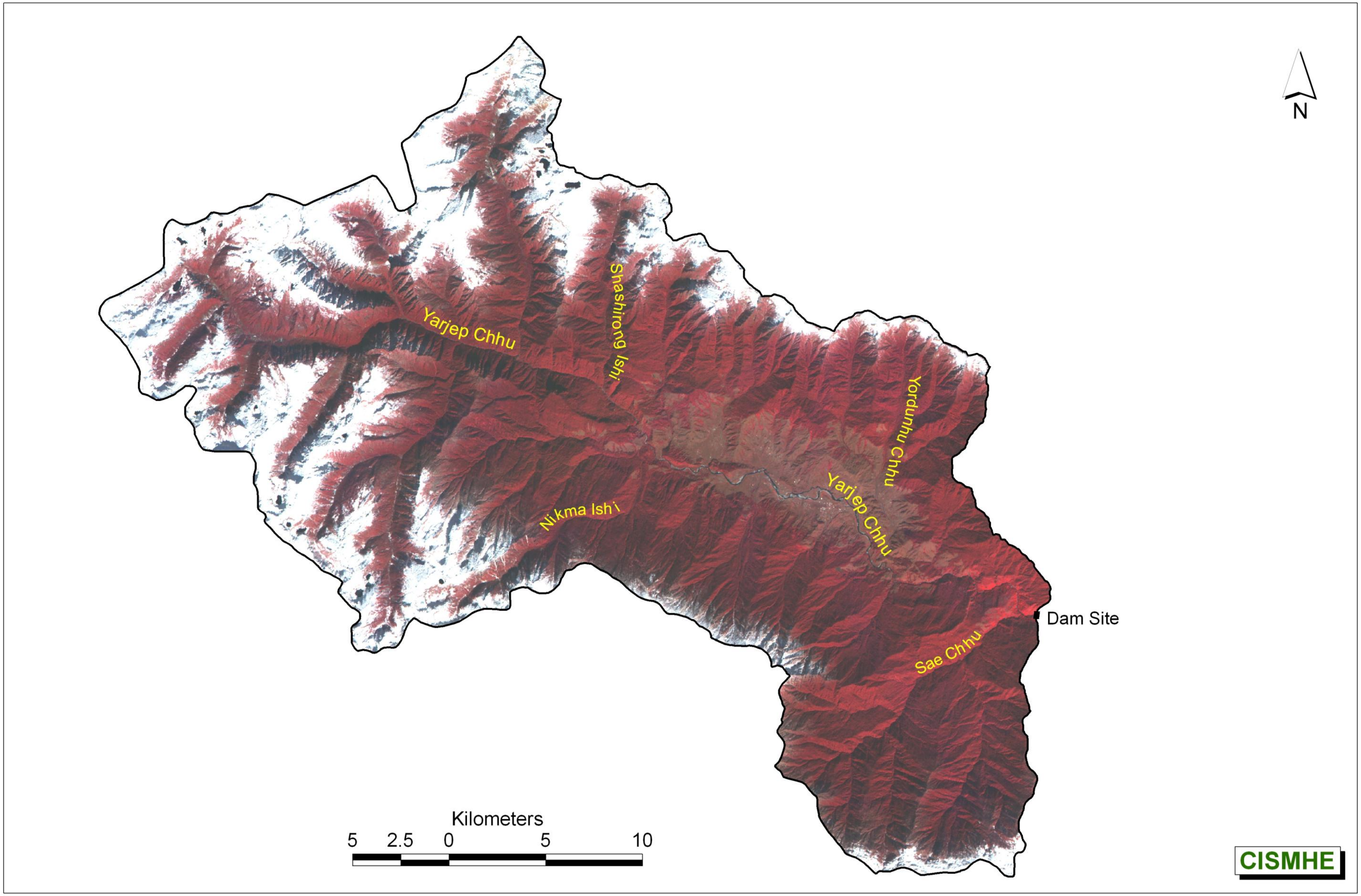


Fig.3.2.4.1 False Colour Composite (FCC) generated from IRS-P6 LISS-III, 2006 of the proposed Pauk H.E. Project

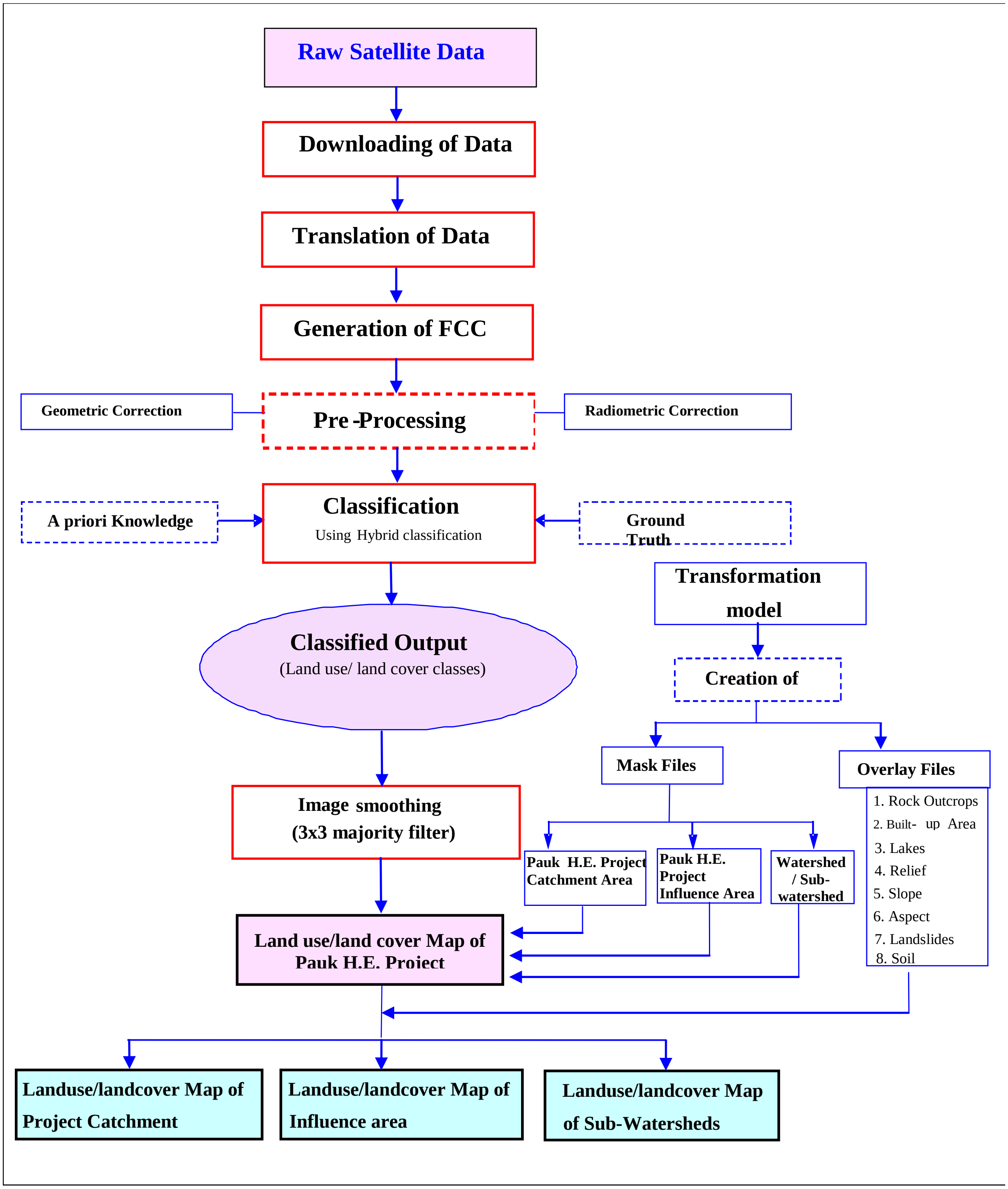


Fig. 3.2.4.2 Flow diagram for land use/ land cover classification

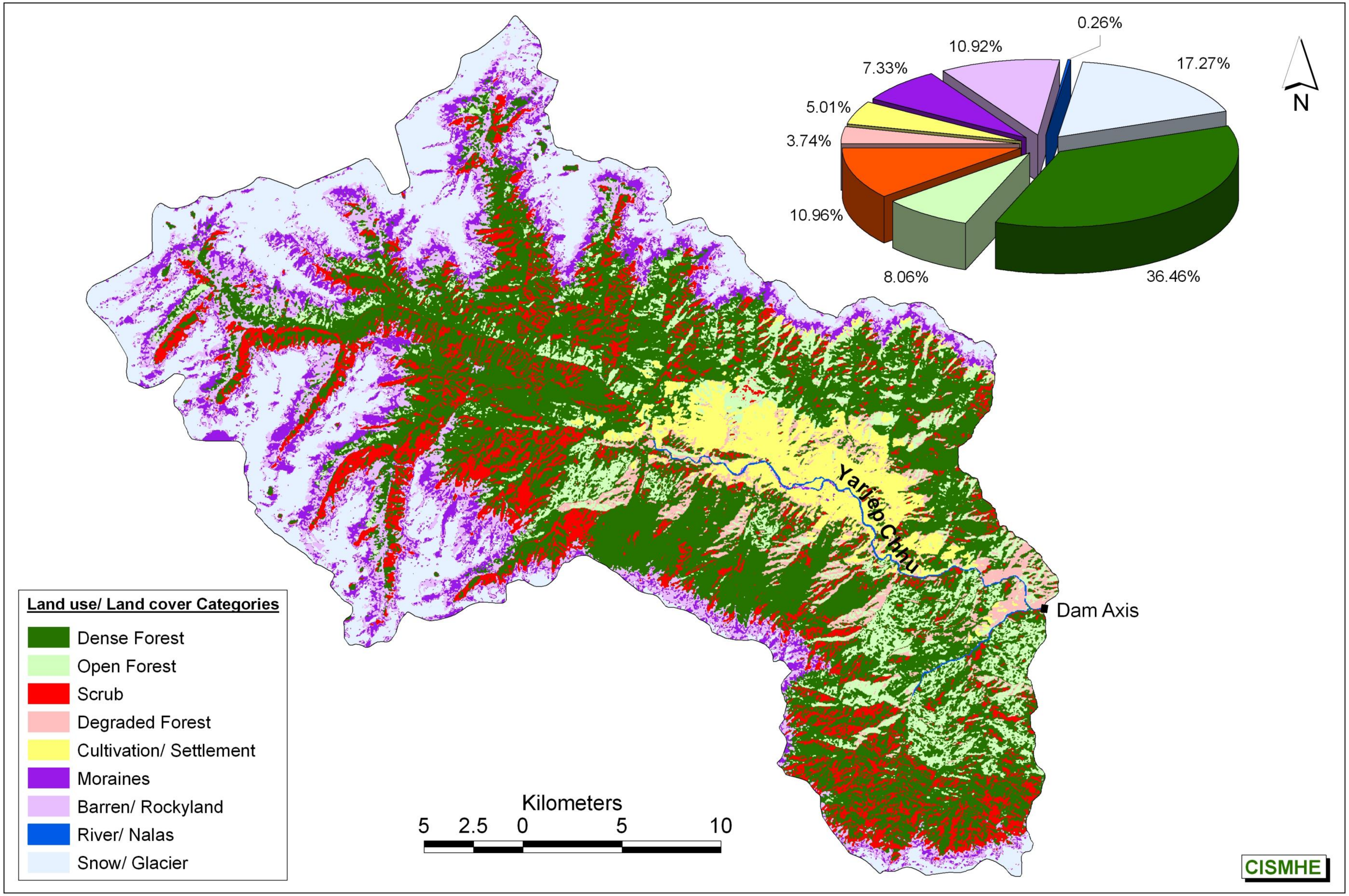


Fig. 3.2.4.3 Land use/ land cover map of the Yarjep Chu catchment of the proposed Pauk H.E. Project

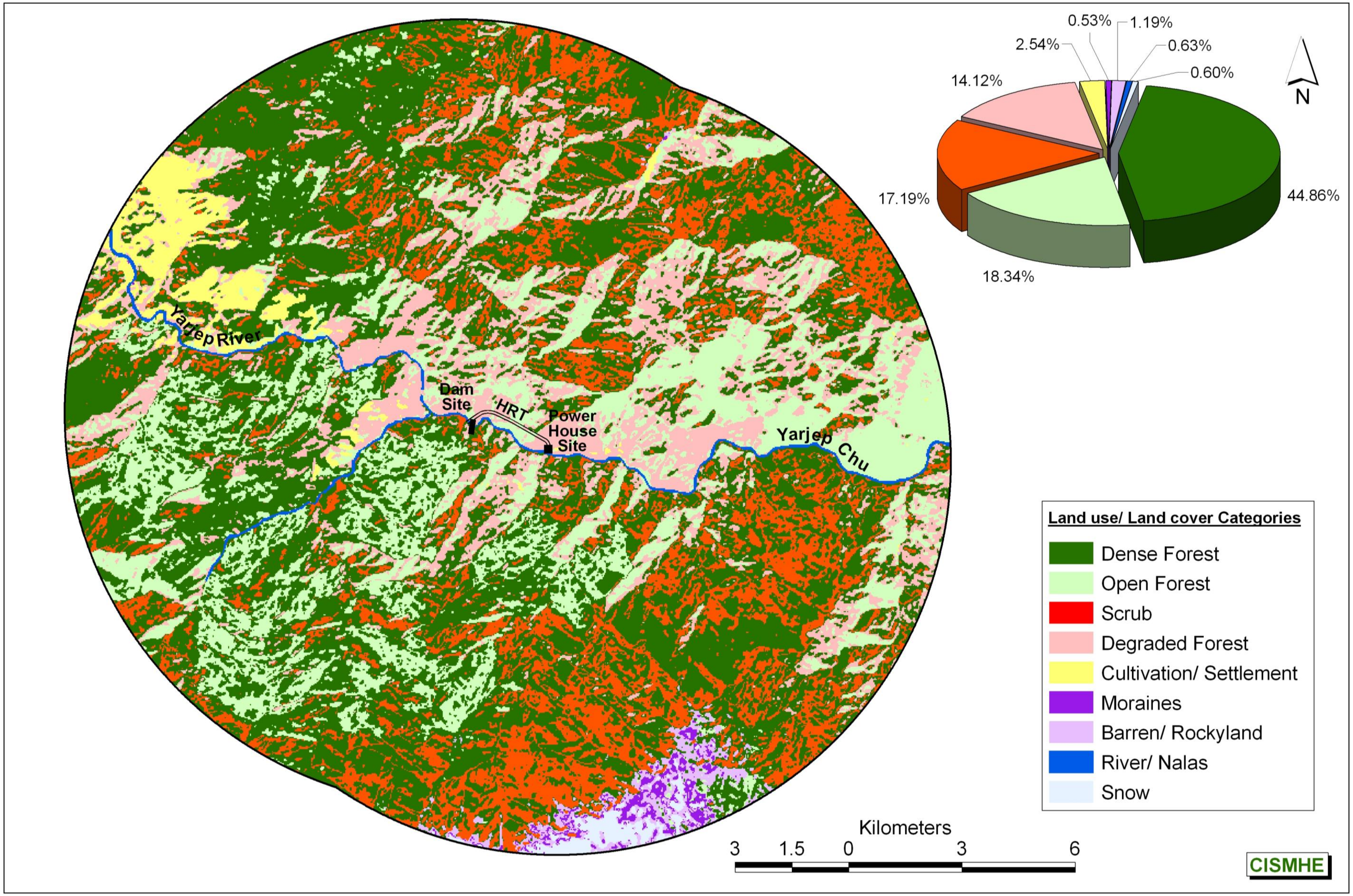


Fig. 3.2.4.4 Land use/ Land cover map of Yarjep Chhu in the influence zone of the proposed Pauk H.E. Project

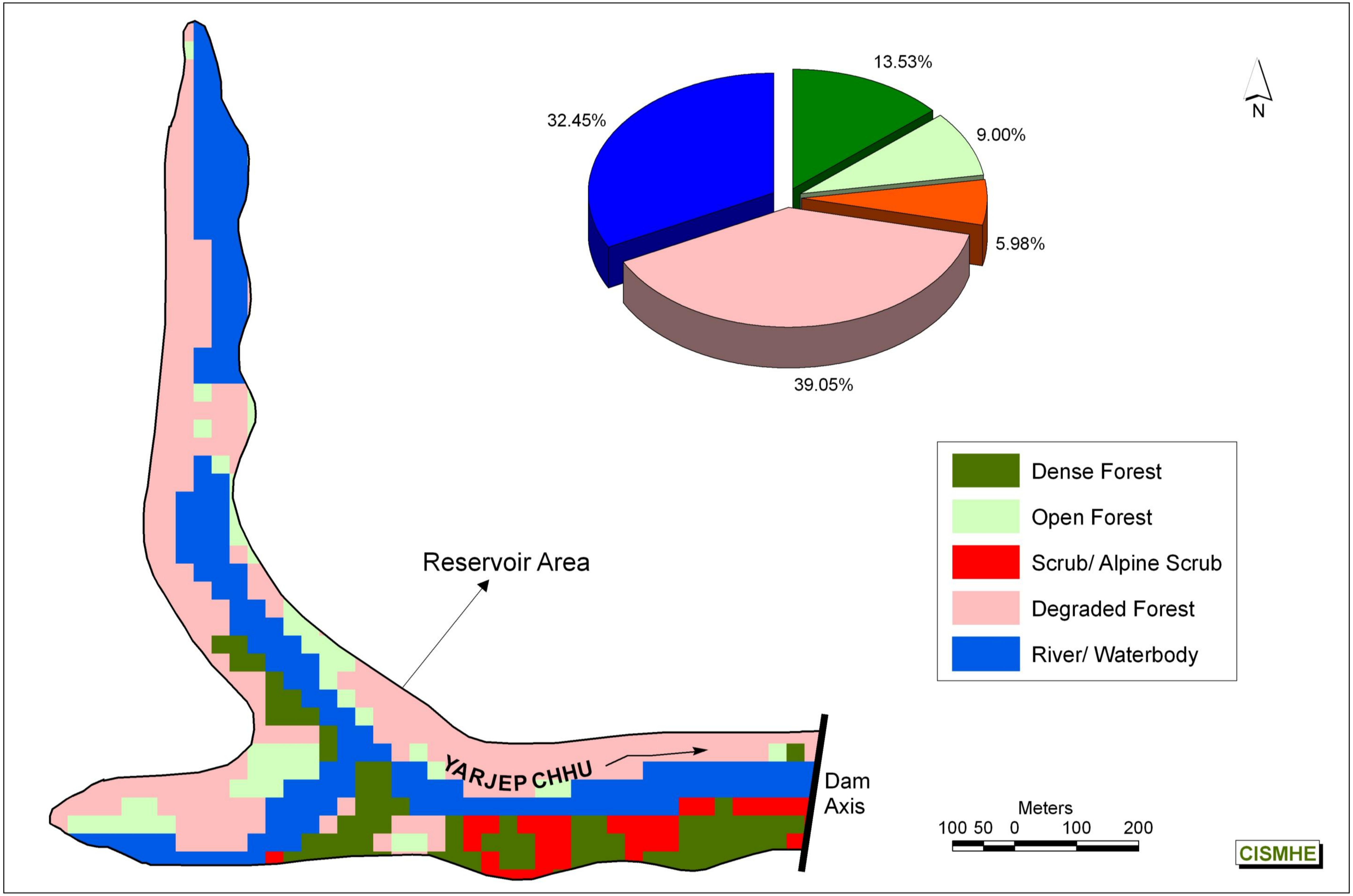


Fig. 3.2.4.5 Land use/ land cover map of submergence area of the proposed Pauk H.E. Project

3.3 WATER ENVIRONMENT

3.3.1 HYDROLOGY

3.3.1.1 General

Hydrology is the basis of hydro-electric project, it deals with the transfer of water and energy between the land surface and the lower atmosphere. The hydrological attributes of basin include rainfall, water discharge, snow cover area and sedimentation. These parameters are generally used while studying the power potential studies. The main drivers of hydrological attributes are temperature, climatic conditions, geological and topographic position of the basin.

The baseline data on the hydrology in the impact assessment are helpful not only for the power potential studies but it provides the understanding of impact prediction. When a dam is constructed across the it leads to many changes in the flow regime in the downstream and upstream. Also, many environmental consequences are associated with the change in the hydrology. This chapter attempts to discuss some aspects of hydro-meteorological system in the Yarjep basin with reference to the development of the proposed Pauk HE Project near Chengrung village.

3.3.1.2 Rainfall

The average monthly rainfall data for rain Gauge stations at Mechuka, Monigong, Raying, Kaying, Aalo and Tato are shown in **Figure 3.3.1.1** and Table 3.3.1.1. The rainfall data for various rain gauge stations are used from the Hydrology of detailed project report (Velcan Energy, DPR, 2011) provided by Velcan Energy. Two data were being used for Mechuka. One of the data was developed from the external source which is named as Mechuka (ext) and data acquired through Velcan Energy named as Mechuka (int). Maximum rainfall was recorded at Raying and Kaying with an annual precipitation of 4658 mm and 4374 mm. The intensity of the rainfall is high during the monsoon period (June-September) whereas it is low during lean (December-March).

Machuka and Tato are nearest rain gauge stations, where annual rainfall records stand for 2627 mm (Mechuka ex), 2459 mm (Mechuka int) and 3031 mm (Tato). Monthly rainfall ranges from 27 mm to 460 mm, 21 mm 431 mm and 21 mm to 683 mm. Minimum rainfall occurs in December and January while maximum in June July. The monsoon rain decreases at the end of September. The rainfall received during October at all sites ranges from 104 to 288 mm and it is gradually reduced up to onset of winter in December. During lean season maximum rainfall is received in the month of March, ranging from 104 mm to 325 mm. The maximum rainfall received during monsoon (July) is 908 mm at Raying.

3.3.1.3 Seasonal Distribution of rainfall

The seasonal distribution of rainfall is given in Table 3.3.1.1 and **Figure 3.1.1.2**. During monsoon the rainfall is high in Kaying, Raying, Tato and Aalo. These four stations record around 60% of the annual precipitation during the monsoon season at their respective stations (June-Sept). At Monigong and Mechuka (int) the monsoonal precipitation amounts to 54% and 50% of the yearly rainfall. However, the precipitation during the post-monsoon (Oct-Nov) season amounts to 7% to 12% of the total annual precipitation, where maximum of 12% at Monigong and Minimum of 7% at Aalo were recorded. During lean season minimum precipitation is received at Aalo with 11% of the total annual precipitation. Kaying receives maximum precipitation during lean season scaling up to 325 mm, and Tato receives maximum lean seasonal precipitation which amounts to 16% of the total annual rainfall there. A fifth (~13-25%) of the total annual rainfall is received during the pre-monsoon months (Apr-May) at most of the stations.

3.3.1.4 Water Discharge and Water Availability

i) Discharge pattern at intake site

The average of 10-daily discharge for dam site in the basin is shown in **Figure 3.3.1.3**. The discharge starts increasing in the month of May. The onset of monsoon is in the beginning of June. The average 10-daily flows near Chengrung (June 1978 to May 1994 and June, 2000-May, 2009) was computed on flow series data from DPR of Pauk H.E project (Velcan Energy, 2011). CWC has approved such flow series in July 2010. Average 10-daily discharges computed at the dam site has been plotted and the same is shown in **Figure 3.3.1.3**. During July and August the water discharge in the river is high. The peak discharge is in the month of July. The average discharge in Yarjep River during the monsoon months (June to Sept) vary from 128 to 194 cumec at dam site respectively. During the monsoon season (Jun to Sept), the minimum and maximum water discharge for 25 years were 64 cumec in the middle of September 2005 and 410 cumec in the end of July, 2007, respectively. The water discharge during post-monsoon (Oct-Nov) period ranges from 16 cumec in the middle to end of November 2004 to 236 cumec at the beginning of October, 2003. Lean season (December to March) discharge for 25 years ranges from 9 cumec in the middle of January, 2005 to

Table 3.3.1.1 Seasonal Distribution of rainfall in the vicinity of Pauk H. E Project.

Station/Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mechuka (ext)*	69	97	153	198	338	460	373	342	316	188	66	27
Mechuka (int)*	21	157	125	244	383	220	431	393	186	224	40	35
Monigong	42	85	146	170	188	250	287	285	195	174	45	16
Raying	111	193	250	363	470	688	908	641	632	288	63	51
Kaying	156	153	325	353	396	712	755	624	535	246	69	50
Aalo	41	58	104	158	196	411	397	229	298	104	33	17
Tato	21	66	248	132	249	533	683	469	237	180	73	140

61 cumec in the end of March, 2007 iii) Pre-Monsoon (Apr-May) were 247 cumec in the end of May, 2007 and 15 cumec in the beginning of April, 1993 and 1994.

ii) Water availability and Optimization study

The changing pattern of total annual yield at the proposed Pauk dam site for the water years 1978-79 to 1993-1994 and 2000-2001 to 2008-2009 is shown in **Figure 3.3.1.4**. The optimization studies for the Pauk H.E Project have been conducted on the basis of the 10 daily discharge data for 25 years. The criteria of dependable years signify the maximum quantum of energy which could be generated in a 90 % and 50% dependable years. The 90% and 50% dependable years are years in which the annual energy generation has a 90% and 50% probability to occur over the considered period of 25 years. The average 10-daily water discharge in Yarjep River at the dam site for 90% dependable year (1978-1979) and 50% dependable year (2003-2004) as shown in **Figure 3.3.1.5**. The peak discharge in the 90% dependable year was 224 cumec at the end of June. On the other hand, the peak discharge in the 50% dependable year was 295 cumec in the beginning of July. The minimum discharge was 11 cumec for both the 90% and 50% dependable years.

3.3.1.5 Flood Peaks in the River

The variation pattern of flood peaks shows that the peaks attain high level every 5 to 6 years for dam site axis. The data for the flood variation was available for 25 years (1978-79 to 1993-1994 and 2000-2001 to 2008-2009) provided by Velcan Energy (DPR, 2011). As seen in **Figure 3.3.1.4** maximum discharge at the dam site was attained in the 2007-08 with a total cumulative discharge of 3348.432 Mcum. Based on daily records over 20 years, and probabilistic Gumbel Distribution methodology, full year floods have been estimated.

FLOOD ESTIMATION - Full Year	
TR (yr)	Q
2	1 025 m^3/s
5	1 453 m^3/s
10	1 736 m^3/s
25	2 095 m^3/s
50	2 360 m^3/s
100	2 624 m^3/s
500	3 233 m^3/s
1000	3 496 m^3/s
SPF	3 000 m^3/s
PMF	**3 700 m^3/s**

Table 3.3.1.2   50% and 90% Dependable Years

		50% Dependabe Year 2003-04	90% Dependabe Year 1978-79
Jun	I	91	116
	II	128	161
	III	198	224
Jul	I	295	136
	II	240	148
	III	146	143
Aug	I	122	140
	II	208	109
	III	135	72
Sep	I	184	129
	II	144	161
	III	137	133
Oct	I	236	111
	II	98	85
	III	77	74
Nov	I	33	36
	II	31	29
	III	32	36
Dec	I	20	24
	II	26	21
	III	25	19
Jan	I	12	16
	II	11	14
	III	12	14
Feb	I	11	13
	II	11	11
	III	12	17
Mar	I	18	17
	II	18	17
	III	28	24
Apr	I	16	25
	II	22	29
	III	30	31
May	I	49	98
	II	54	89
	III	77	70

3.3.1.6 Sedimentation

The slopes on both the banks of the reservoir are steep. It has been assessed that the Mechuka plain plays a critical role in a sediment point of view. Since the valley at Mechuka is very wide and slopes of the flanks gentle on their lower levels, the valley acts as a desilting basin (**Plate 3.3.1.1**). Water is cleared from silts while it flows through the Mechuka plain. Even during high flood events, hydraulic model shows that sand and silt deposits are not put in motion again: water velocity does not increase significantly even during extreme flood event. The Pauk reservoir (11.5 Mm^3 and 34 ha submergence area) will also be acting as a desilting basin. The water velocity in the reservoir will fall down to less than 0.05 m/s, whereas the water velocity is never less than 0.2 m/s even in a desilting basin. Even very small particles of sediments (<0.3mm) will basically deposit into Pauk Reservoir and the Power house will be protected from silt concentrated water

3.3.1.7 Environmental Implication

The stretch up to dam site requires special attention for the purpose of catchment area treatment in case of soil erosion and high siltation during the monsoon period. In addition instantaneous flood peaks are expected. PMF has been taken into account for the design. PMF determination is based on critical heavy rainfall calculated by IMD. An appropriate disaster management plan is necessary and proposed under appropriate section of the EMP (Chapter 5.12) for the purpose of catastrophic events like dam break failure. Continual release of certain cumec into the downstream stretch will help to maintain and sustain the ecological functions in this region. The project has no impact on the high peak in discharges occurring during the monsoon season. Then, flood regime of the river will be maintained during the entire monsoon season, allowing the ecological regeneration of the river life.

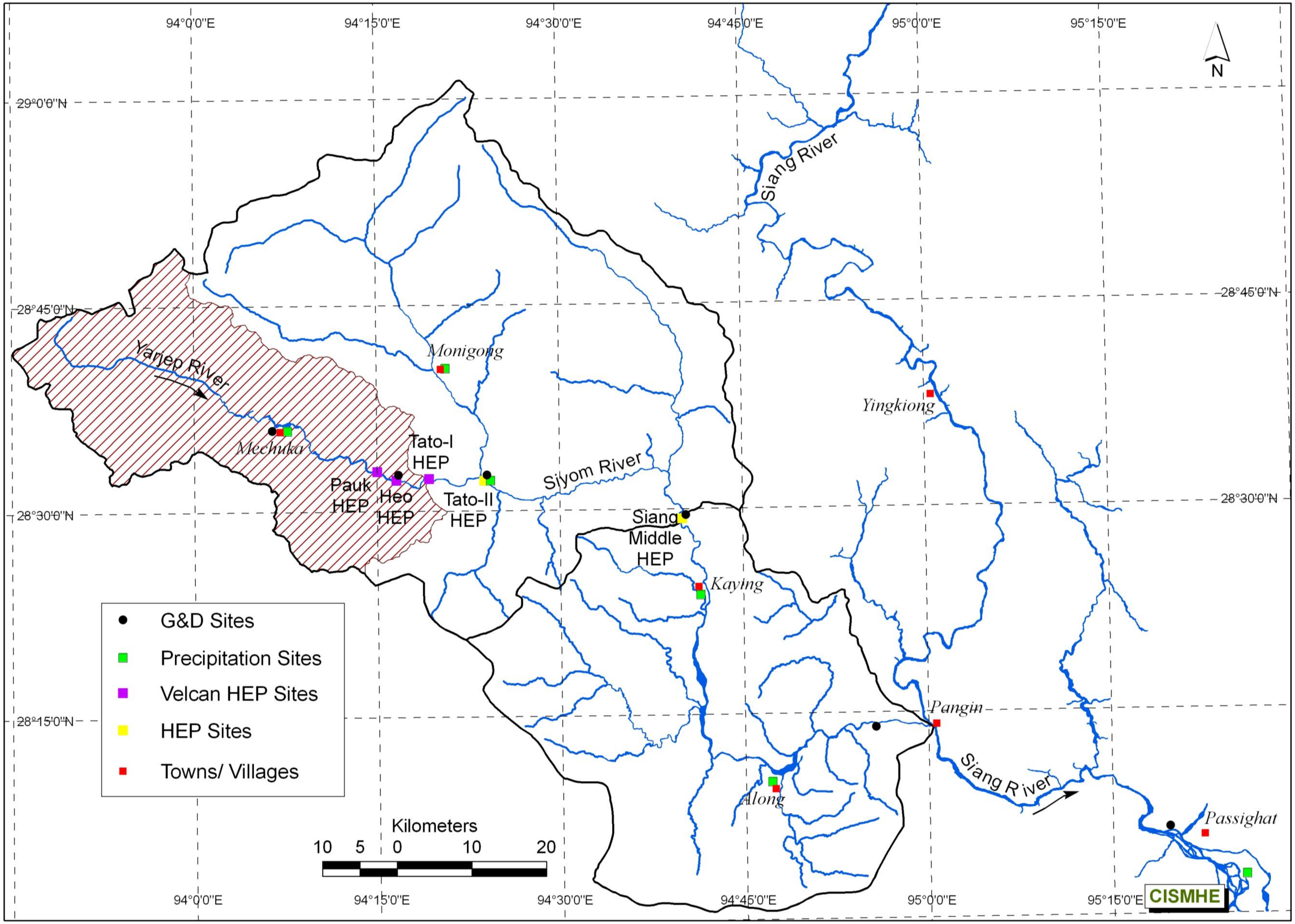


Fig. 3.3.1.1 Locations of G&D sites and Rain Guage Stations

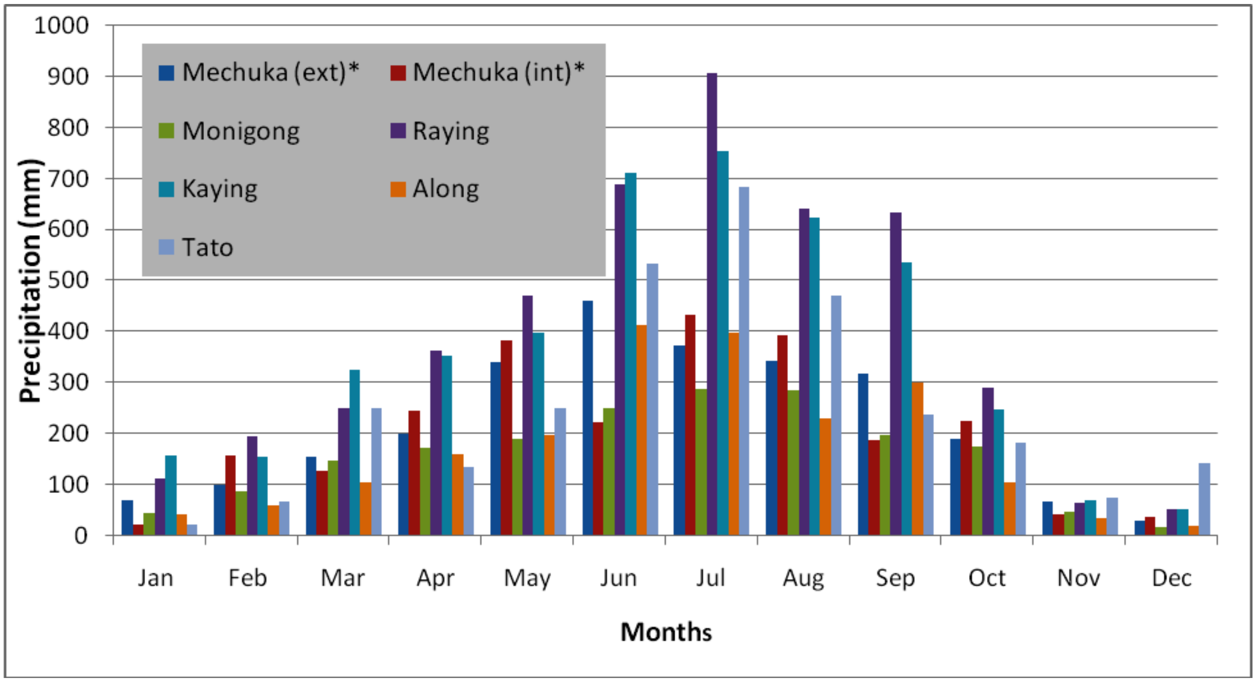


Figure 3.3.1.2: Precipitation for seven rain gauge station

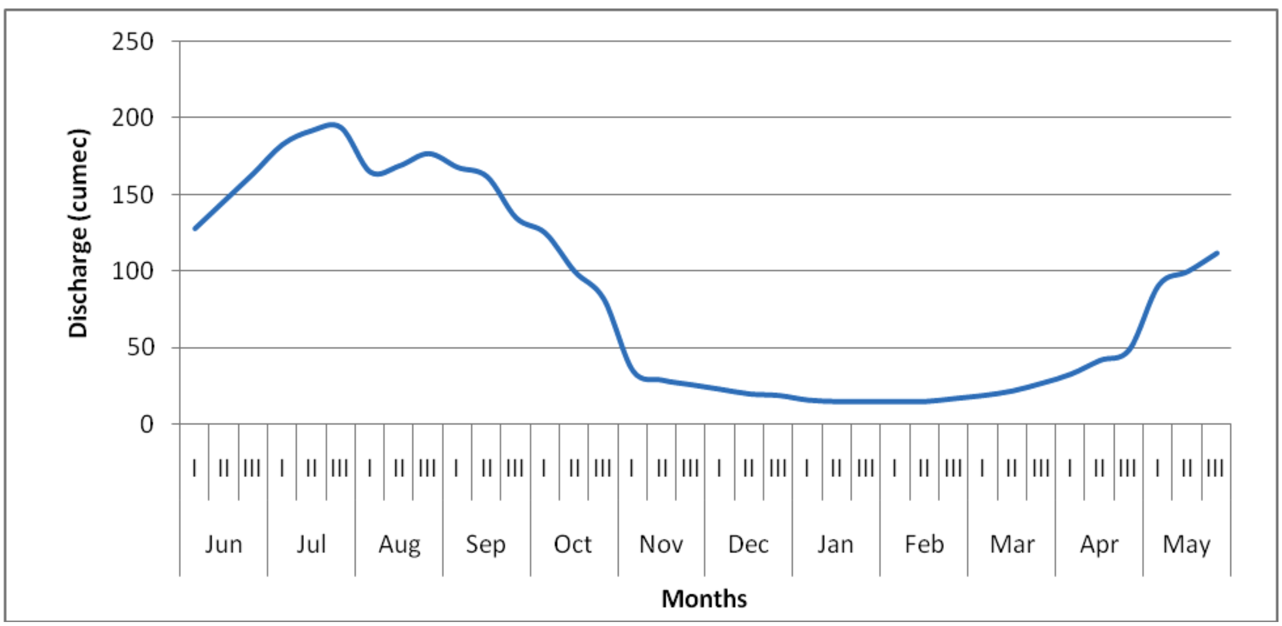


Figure 3.3.1.3 Average 10 daily discharge at barrage site

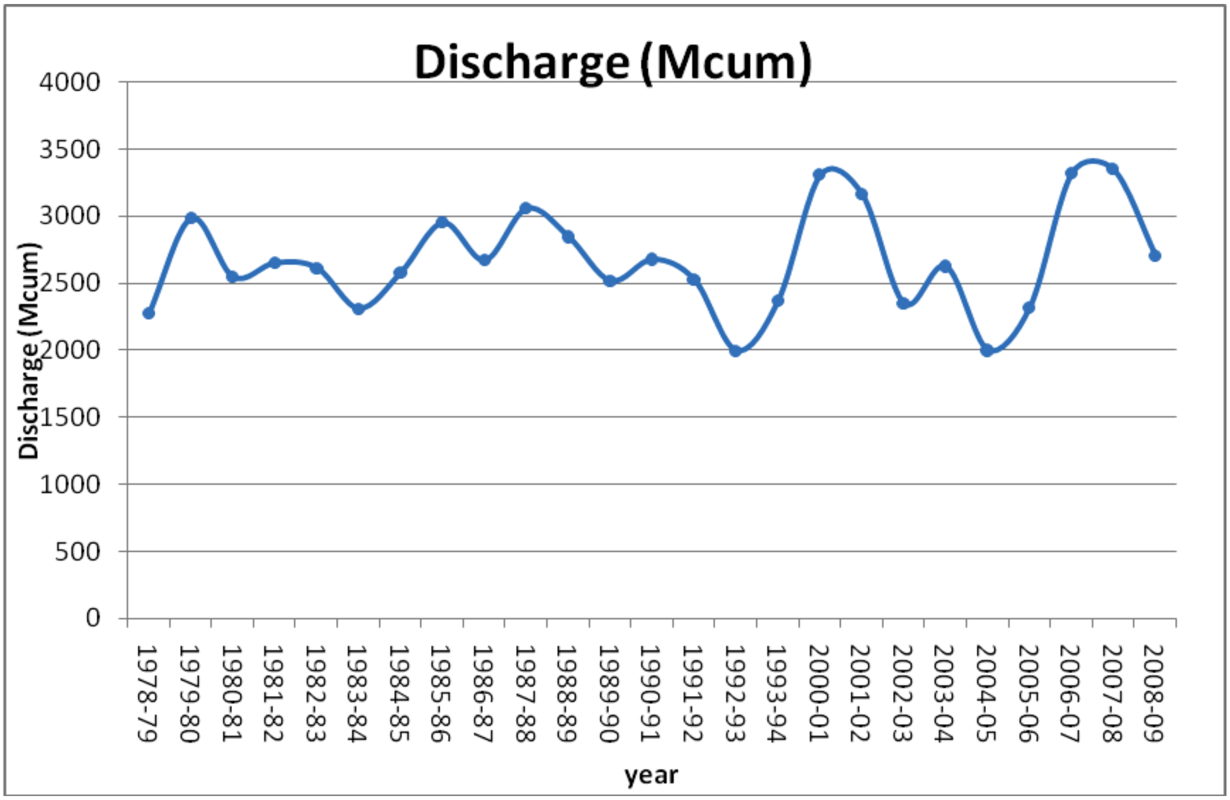


Figure 3.3.1.4: Discharge pattern for 25 years at the barrage site

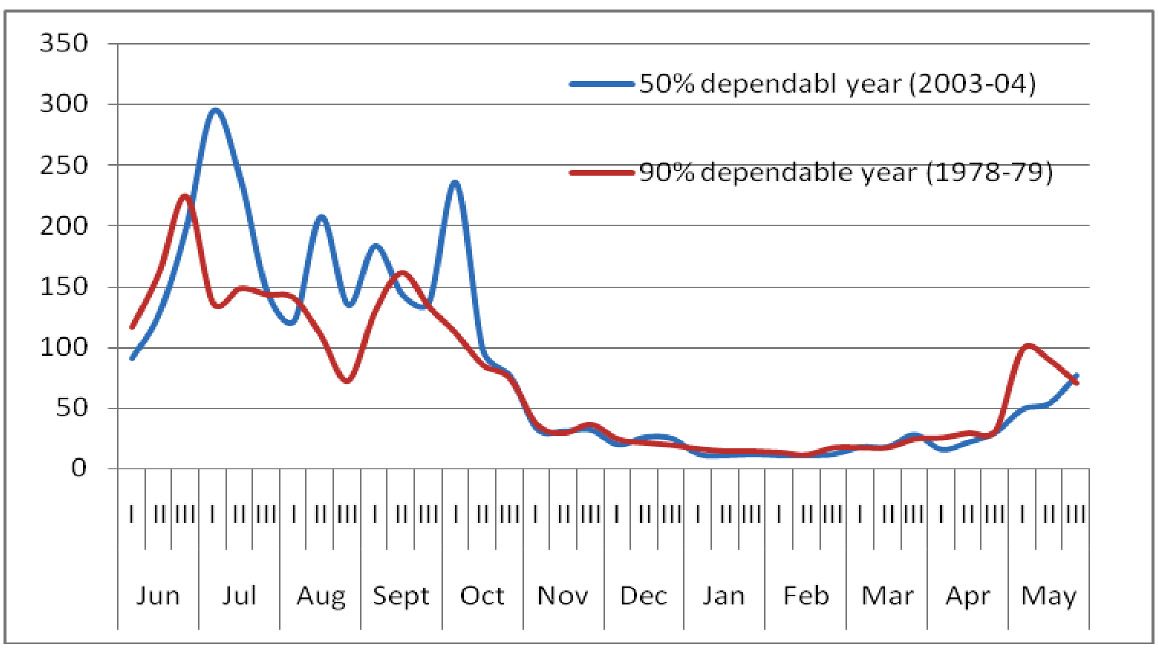


Figure 3.3.1.5 10 daily discharge for 50% dependable year and 90 % dependable year

Plate 3.3.1.1: Mechuka plain – View of upstream Mechuka bridge

3.3.2 WATER QUALITY & AQUATIC ECOLOGY

3.3.2.1 General

The rapid population growth and urbanization in developing countries like India has led to significant increase in energy consumption. The traditional modes of power generation are being found insufficient to cater to the rapidly increasing energy demands. Therefore, the alternative methods of power generation like solar power and hydropower are being looked upon to fulfill the gap between demand and supply. India, especially the Himalayan region is rich in water resources, therefore, the area is being used to harness the energy from flowing waters to generate electricity. It is considered as a renewable source, and relatively nonpolluting, and reliable energy source. When it is developed in accordance with good environmental and social practices, hydropower plants have the advantage of producing power that is both renewable and clean, as they emit less greenhouse gases than traditional fossil fuel plants and do not emit polluting suspended particulate matter (from the high ash-content of indigenous coal). However, dams represent one of the most significant human interventions in the hydrological cycle. They have both intended and unintended impacts, which can be positive or negative. It is unlikely to find intended negative impacts, though positive impacts can be both intended and unintended. Each of these types of impacts can be inevitable in their entirety, reducible or totally avoidable.

In addition to economic, the socio-economic benefits of dams are numerous. In addition to huge social impacts, large dams directly impact rivers in a variety of physical and biological ways. The most significant is the alteration of a river's flow, which affects downstream ecosystems and the landscape through which the river flows. Dams change the hydrology of the river and disturb the seasonal fluctuations. This can be particularly damaging in seasonal floodplains as dam also holds back sediments that would naturally replenish downstream ecosystems. Thus, dams create obstacles in the longitudinal exchanges along fluvial systems. The most significant consequence of this disruption is that, it tends to fragment the riverine ecosystem, isolating population of species living up and downstream of the dam and cutting off migrations and other species movements (McCully, 2001; Dynesius and Nilsson 1994 and Postel, 1998).

Identification of impacts is primary activity in the Environmental Impact Assessment (EIA) studies of developmental projects. These studies help in formulating methods to avoid or mitigate the adverse environmental impacts caused by the projects. The present study was conducted in Yarjep chhu in West Siang district in Arunachal Pradesh to assess the aquatic ecology and water quality with special reference to hydro- electric project.

3.3.2.2 Aquatic Ecology

i) ***Physical and chemical characteristics***

Details of physical and chemical characteristics are given in Tables 3.3.2.1 and 3.3.2.2. The water quality affecting the physical, chemical and biological characteristics of the lotic systems depend on the seasonal fluctuations in the water discharge. One of the most important factors governed by the water discharge is the water current velocity. Velocity gradients produce shearing forces that resist the organism's ability to cling to the available substratum. They also determine how well-stirred an organism's environment is with respect to delivery of nutrients and food particles, and removal of wastes or allelo-chemicals (Vogel 1981). Water current velocity in Yarjep River ranged from 0.48 m/s at site W1 (most upstream site) in winter to 2.73 m/s at site W4 (most downstream site) in pre- monsoon season (Table 3.2.2.1). In tributaries it ranged from 0.4 to 1.81 m/s (Table 3.2.2.2). Water temperature is another physical factor which exerts direct as well as indirect influences on abiotic and biotic characteristic of aquatic ecosystems. Water temperature ranged from 9^{o} C at sites W1 and W2 (dam site) in winter to 15^{o}C in monsoon at W3 (power house site) during the monsoon season. No considerable variation in the water temperature between main river and tributaries was observed.

The pH of river is an important factor for the aquatic fauna living within them. In Yarjep River and its tributaries, it falls in alkaline range. Water pH was recorded to range from 6.76 at site W3 (Power house site) in pre- monsoon season to 8.40 at site W2 in monsoon season. Dissolved oxygen (DO) is a most important characteristic, which support the aquatic fauna in the water body. Turbulent flow and aquatic flora is the main source of dissolved oxygen in the water while water temperature is main controlling factor (Hynes, 1970). Dissolved oxygen was recorded minimum (6.23 mg/l) at site W2 in pre- monsoon to 9.70 mg/l at site W2 in winter season. The high Dissolved oxygen content in winter is due to low water temperature and low turbidity, which results in increased transparency. All these factors together contribute in increased dissolved oxygen content in winter season. Biochemical Oxygen Demand (BOD) is the most essential parameter to assess the water quality. In present study area its concentration ranged from 0.12 at site W2 (dam site) in Winter to 2.10 mg/l at site W2 in pre-monsoon season indicating less organic pollution in the area. In tributaries it was absent for pre-monsoon and monsoon seasons (Table 3.2.2.2).

Electrical conductivity ranged from 7.00 µS/ cm^2 at site W3 in pre- monsoon season to 72 µS/ cm^2 at site W3 in winter season. Total dissolved solids were recorded to be minimal at site W3 in pre- monsoon season (5.33 mg/l) and maximal at site W3 in winter season (36.66 mg/l). Low TDS and electrical conductivity in pre- monsoon season can be attributed to dilution of river water due to snow- melt. Total alkalinity ranged from 10 mg/l to 26 mg/l. Water in Yarjep Chhu is soft as the values for total hardness are low. Total hardness was recorded minimum at site W3 in pre- monsoon season (4 mg/l) and maximum at site W2 site in Winter season (44 mg/l). Calcium was the main component of water hardness. Calcium hardness ranged from 6 mg/l at site W3 in pre-monsoon season to 21 mg/l at site W3 in Winter. Calcium ions followed the similar trend. Magnesium hardness was not recorded in pre- monsoon season. Minimum Magnesium hardness recorded to be 1.60 mg/l at site W3 in monsoon season and maximum at site W1 in winter season (23.20 mg/l). Nutrient concentrations were found low as the study area has minimal anthropogenic activities which are considered to be the primary source of nutrient enrichment in aquatic systems. Among the nutrients, chloride ranged from 5.99 mg/l to 14.99 mg/l. Nitrate concentration ranged from 0.11 µg /l to 0.35 µg/l. Phosphate ranged from 0.17 µg /l at site W2 in monsoon season to 2.45 µg/ l at site W3 in winter season.

Comparing tributaries with main river, Shongsh Bu and Shene Korong showed different patterns, especially in chemical characteristics. Shongsh Bu recorded higher concentrations of Electrical conductivity, TDS, alkalinity and hardness as compared to that of main river. On the other hand Shene Korong recorded considerably low concentration of same characteristics as compared to that of main river and Shongsh Bu. The variation in the chemical characteristics between main river and tributaries can be attributed to the different geological features of the watershed.

Table 3.3.2.1. Physical and chemical characteristics of Yarjep river and its tributary in and around Pauk H.E. Project

Parameters	Winter			Pre-Monsoon			Monsoon		
	W1	W2	W3	W2	W3	W4	W1	W2	W3
Physical Characteristics									
Water current velocity (m/s)	0.48	1.92	0.81	2.24	2.35	2.73	1.23	2.16	1.73
Water Temperature (ºC)	9.00	9.00	11.00	14.00	12.00	11.50	11	14	15
Chemical Characteristics									
pH	6.91	7.85	7.06	7.55	6.76	6.85	8.13	8.40	7.36
Dissolved Oxygen (mg/l)	9.63	9.70	8.43	6.23	8.93	8.43	7.54	8.48	8.36
BOD (mg/l)	1.12	0.12	0.87	2.10	1.11	0.15	1.34	1.30	0.13
Electrical Conductivity (µS/cm²)	55.33	59.66	72.00	24.33	7.00	7.66	17.00	18.00	21.00
Total dissolved Solids (mg/l)	30.00	30.00	36.66	15.33	5.33	6.33	10.00	10.00	10.00
Total alkalinity (mg/l)	10.00	10.00	11.00	20.00	20.00	20.00	26.00	22.00	22.00
Total hardness (mg/l)	40.00	44.00	40.00	8.00	4.00	8.00	14.00	12.00	10.00
Calcium Hardness (mg/l)	16.80	21.00	21.00	8.00	6.00	8.00	6.30	6.30	8.40
Calcium ion (mg/l)	6.72	8.41	8.41	3.20	2.40	3.20	2.52	2.52	3.36
Magnesium Hardness (mg/l)	23.20	23.00	19.00	0.00	0.00	0.00	7.70	5.70	1.60
Magnesium ion (mg/l)	5.63	5.58	4.61	0.00	0.00	0.00	1.87	1.38	0.38
Chloride (mg/l)	7.99	5.99	6.99	14.99	12.99	12.99	7.99	7.99	5.99
Nitrate (mg/l)	0.13	ND	ND	0.11	0.15	0.35	0.00	0.00	0.00
Phosphate (mg/l)	2.00	1.86	2.45	ND	0.25	ND	0.98	0.17	0.51

W1 (upstream of proposed dam site); W2 (proposed dam site); W3 (proposed power house site); W4 (downstream of proposed power- house site)

Table 3.2.2.2 Physical and chemical characteristics of tributaries join Yarjep river

Characteristics	Winter		Monsoon		Post monsoon	
	SB	SK	SB	SK	SB	SK
Water current velocity (m/s)	1.66	0.40	1.17	0.89	1.81	1.04
Water temperature (ºC)	7.00	7.00	12.00	15.00	16.00	17.00
Turbidity (ntu)	8.00	3.00	342.00	412.00	20.00	35.00
pH	8.36	6.88	8.75	7.48	8.51	7.52
Dissolved oxygen (mg/l)	8.46	8.96	7.30	9.00	7.90	8.43
BOD (mg/l)	0.46	0.18	ND	ND	ND	ND
E. Conductivity (µS/cm)	240.33	18.33	92.00	6.00	169.00	14.67
Total dissolved Solids (mg/l)	148.33	11.66	70.16	4.97	106.00	10.00
Total alkalinity (mg/l)	76.00	28.00	80.00	36.00	64.00	24.00
Total hardness (mg/l)	172.00	58.00	82.00	24.00	140.70	29.40
Calcium Hardness (mg/l)	115.50	23.10	33.60	21.00	92.40	8.40
Calcium ion (mg/l)	46.25	9.25	13.45	8.41	37.00	3.36
Magnesium hardness (mg/l)	56.50	34.90	48.40	3.00	48.30	21.00
Magnesium ion(mg/l)	13.72	8.47	11.76	0.72	11.73	5.1
Chloride (mg/l)	20.99	20.99	18.99	26.99	22.99	17.99
Nitrate (mg/l)	0.84	0.14	0.00	0.10	ND	ND
Phosphate (mg/l)	1.54	0.22	0.14	0	ND	ND

SB = Shonsh Bu, SK = Shene Korong

ii) Biological characteristics:

The biological community in a river is a product of the various physical and geomorphologic forms and processes of the river. Biological communities reflect overall ecological integrity (i.e., chemical, physical, and biological integrity) as the very existence of these communities represents the integration of conditions around them (Karr and Chu, 1999). Therefore, biological results are useful in assessing the ecological quality of aquatic ecosystems. River water is rich in planktonic, benthic and macro invertebrates' populations. Zooplanktons formed a minor portion of planktonic community. Zooplankton density ranged from 11 individuals/ l to 275 individual/ l (Table 3.3.2.3). Highest zooplankton density was recorded in pre- monsoon season at W2 (dam site). Phytoplankton or suspended algae formed an important component of aquatic flora as they are the primary producers in aquatic ecosystem. Diatoms formed the major component of phytoplankton as well as of phytobenthos. Phytoplankton density showed seasonal variation and was recorded minimum (11 cells/ lit.) in monsoon season and maximum was recorded (76658 cells/ lit.). Phytobenthos density was also recorded minimum in monsoon season (9 cells/lit.) and maximum (115395 cells/ cm²) in winter season. Lowest density in monsoon season is recorded as the high water discharge in monsoon season scour off the phytobenthos. Macro- invertebrate density ranged from 122 individual/ m^2 to 2022 individual/ m^2 with minimum at W1 site in monsoon season and maximum at W2 site in monsoon season. Shongsh Bu nallah showed lowest density for phytobenthic and phytoplanktonic communities except for zooplankton density. In Shongsh Bu nallah, zooplankton formed the major portion of planktonic community.

iii) *Community Composition*

a) *Algae*

Algal biomass and species composition are considered to be valuable parameters of environmental health of freshwater ecosystem. *Ulothrix*, sp. *Spirulina* sp. and *Lyngbye* sp. represented the chlorophyceae and Cynophyceae in Yarjep River. In the Bacillariophyceae (diatom), a total of 83 taxa were recorded from all sites in three seasons, which were divided into 66 and 51 species in benthic and planktonic forms. Diatom taxa occurring exclusively in planktonic form were 17, while taxa recorded exclusively in benthic form were 32. A total of 34 taxa were common to both forms (Table 3.3.2.4). Among the diatom community, *Achnanthidium linearis* was the most abundant taxon. It was recorded at all sites followed by *Achnanthidium conspicua, Achnanthidium exilis, Achnanthidium exilis, Fragilaria vaucheriae, Planothidium lanceolata, Gomphonema intricatum, Gomphonema longiceps* and *Gomphonema sphaerophorum.* These taxa were found in both planktonic as well as benthic form. Taxa found exclusively in benthic forms were *Achnanthidium Boyei, Achnanthidium construens, Achnanthidium laeniata, Achnanthidium laterostrata, Achnanthidium marginulata, Achnanthidium affinis, Cymbella amphicephala, Cymbella nagpurensis, Cymbella parva, Cymbella turgidula, Gomphonema bohemicum, Gomphonema intricatum* var. *pumilum, Gomphonema olivaceum, Navicula cari, Gomphonema parvulum* var. *microples, Gomphonema* sp., *Navicula radiosa* var. *tenella, Synedra ulna* var. *amphirhynchus and Tabellaria flocculus.* Taxa found exclusively in planktonic forms were *Planothidium lanceolata* f. *ventricosa, Navicula cryptocephala* var. *veneta, Melosira junergensii, Gomphonema parvulum* var. *calcarea, Fragilaria pinnata* f. *subrotunda, Fragilaria rumpens* var. *fragilaroides, Melosira junergensii, Navicula cryptocephala* var. *veneta, Navicula radiosa* var. *Planothidium lanceolata* f. *ventricosa.* As the density of phytoplanktons and phytobenthos were low in monsoon season, the numbers of diatom taxa were also less. A few of the diatom taxa found in monsoon season were *Achnanthidium linearis, Planothidium lanceolata and Gomphonema parvulum.* Diatom assemblage composition indicates the pristine water quality of river water in Yarjep Chhu.

Table 3.3.2.3 Densities of various biotic communities in Yarjep River and its tributary.

	Winter				Pre-monsoon				Monsoon			
Biological Characteristics	**W1**	**W2**	**W3**	**SB**	**W2**	**W3**	**W4**	**PN**	**W1**	**W2**	**W3**	**PN**
Coliforms (A/P)	A	A	A	P	A	A	P	A	A	A	A	A
Zooplanktons (indiv/lit.)	54	11	24	740	275	29	19	51	15	11	19	14
Phytoplankton (cells/lit.)	52900	64247	76658	1327	377	19	184	66	0	16	11	10
Phytobenthos (cells/cm²)	112492	110427	115395	157	105360	17	78	131	0	9	18	102
Macro- invertebrates (indiv/m²)	144	333	287	444	400	866	1244	1554	122	2022	877	587

W1 (upstream of proposed dam site); W2 (proposed dam site); W3 (proposed power house site); W4 (downstream of proposed power- house site); SB = Shongsh Bu

Table 3.3.2.4 Algal composition in Yarjep River and tributary in and around Pauk H.E. Project

	Phytobenthos						Phytoplankton					
	Winter			Pre- Monsoon			Winter			Pre- Monsoon		
Taxa name	**W1**	**W2**	**W3**	**W2**	**W3**	**W4**	**W1**	**W2**	**W3**	**W2**	**W3**	**W4**
Achnanthidium affinis	5.21	3.12	-	-	-	-	-	0.59	5.44	5.79	9.41	12.5
A. austriaca	0.86	-	-	-	8.33	-	-	0.59	-	2.17	-	-
A. Boyei	0.86	-	-	-	-	-	-	-	-	-	-	-
A. conspicua	1.73	3.12	-	31.63	-	-	-	1.19	5.94	3.62	-	-
A. construens	-	-	-	1.69	-	-	-	-	-	-	-	-
A. exigua	-	-	-	-	-	-	-	-	-	-	-	4.16
A. exilis	1.73	1.56	4.6	-	-	-	7.69	1.19	4.95	0.72	-	-
A. Grimmei	6.95	-	2.3	-	-	-	-	1.19	1.48	0.72	-	-
A. Hauckiana	-	-	-	-	-	-	-	-	0.49	0.72	-	-
A. hungarica	1.73	2.6	5.52	2.25	-	-	-	-	6.93	2.17	1.17	-
A. laeniata	0.82	-	-	-	-	-	-	-	-	-	-	-
A. lapidosa	-	-	-	-	-	-	-	0.59	-	-	-	-
A. laterostrata	-	-	-	-	12.5	-	-	-	-	-	-	-
A. linearis	9.5	5.2	3.22	40.67	8.33	-	38.46	19.04	18.81	28.98	21.17	12.5
A. marginulata	0.86	-	-	-	4.16	-	-	-	-	-	-	-
A. microcephala	-	3.12	5.06	-	-	-	7.29	-	8.41	-	-	-
A. minutessima	-	0.52	2.3	-	-	-	7.69	11.3	2.47	2.17	7.05	4.16
A. nodosa	1.73	-	-	-	-	-	-	-	-	0.72	-	-
A. saxonica	1.73	0.52	1.38	0.56	-	-	-	4.76	-	0.72	1.17	-

A. subsalsa	0.82	-	4.14	-	-	-	-	-	-	-	-	-
A. suchlandti	-	0.52	-	0.56	-	-	-	1.19	0.99	-	-	-
A.affinis	-	-	0.92	-	-	-	-	-	-	-	-	-
Cymbella amphicephala	-	-	-	1.12	-	-	-	-	-	-	-	-
C. delicatula	-	-	1.38	-	-	-	-	0.59	-	-	1.17	-
C. hungarica var. signata	-	-	-	-	-	-	-	-	-	-	1.17	-
C. Laevis	0.86	0.52	1.84	0.56	-	-	-	-	0.99	-	1.17	-
C. nagpurensis	1.73	-	-	-	-	-	-	-	-	-	-	-
C. parva	-	-	0.46	-	-	-	-	-	-	-	-	-
C. perpusila	-	-	0.92	-	-	-	-	-	0.99	-	-	-
C. pusila	-	-	-	-	-	-	-	-	-	-	1.17	-
C. turgidula	0.86	-	-	-	-	-	-	-	-	-	-	-
C. ventricosa	2.6	-	-	-	-	-	-	1.19	-	-	1.17	-
Coconeis placentula	-	1.56	-	-	-	-	-	4.16	1.48	-	3.52	-
Coconeis placentula var. *euglypta*	-	-	-	-	-	50	-	-	-	-	-	-
Diatoma hiemale	1.73	5.2	-	-	-	-	-	0.59	0.49	-	11.76	8.33
Eunotia camelus var. gibbosa	-	-	-	-	-	-	-	-	-	0.72	-	-
Eunotia exigua	-	-	-	-	-	-	-	-	-	-	-	4.16
Fragilaria bicapitata	9.56	0.52	-	-	-	-	-	-	-	0.72	-	-
F. brevistrata	2.6	-	-	-	-	-	-	-	-	-	-	-
F. Capucina	1.73	-	1.38	0.56	-	-	-	-	-	-	-	-
F. inflata	-	-	-	-	8.33	-	-	-	-	-	-	-
F. intermedia	1.73	-	-	-	-	-	-	-	-	-	-	-

F. leptostauron	-	2.08	-	-	-	-	-	-	-	-	-	-
F. pinnata	-	-	-	-	-	-	-	-	-	-	-	4.16
F. pinnata f. *subrotunda*	-	-	-	-	-	-	-	-	-	-	3.52	-
F. rumpens var. *fragilaroides*	-	-	-	-	-	-	-	-	-	-	1.17	-
F. vaucheriae	-	31.25	11.52	8.47	4.16	-	23.07	30.95	13.86	2.17	3.52	4.16
Fragilaria sp.1							-	-	-	-	-	12.5
Fragilaria sp.2	4.34	-	-	3.38	45.83	-	-	4.76	9.9	26.08	9.41	-
Gomphonema bohemicum	0.86	3.64	4.6	0.56	-	-	-	0.59	-	-	-	-
G. gracile	-	-	0.46	-	-	-	-	-	-	-	-	-
G. intricatum	0.86	1.04	-	-	-	-	-	-	-	-	-	-
G. intricatum var. *pumila*	4.34	6.77	13.36	1.12	-	-	-	4.16	1.98	2.17	2.35	4.16
G. intricatum var. *pumilum*	2.6	6.77	13.82	-	-	-	-	-	-	-	-	-
G. longiceps var. *subclavata*	-	0.52	2.76	0.56	-	-	-	4.16	1.48	2.17	3.52	-
G. olivaceoides	-	0.52	2.3	-	-	-	-	1.78	0.99	2.17	-	4.16
G. olivaceum	4.34	5.2	9.21	-	-	-	-	-	-	-	-	-
G. olivaceum var. *Calcarea*	-	2.6	-	1.12	-	-	-	-	-	-	-	-
G. olivaceum *var. minutessima*	0.82	-	0.92	-	-	-	-	1.78	-	-	-	-
G. parvulum	-	-	-	4.51	-	-	7.69	1.78	4.95	5.07	3.52	-
G. parvulum var. *calcarea*	-	-	-	-	-	-	-	-	-	0.72	-	-
G. parvulum var. *exilissimum*	0.86	-	-	-	-	-	-	-	-	0.72	-	-
G. parvulum var.*micropl*es	0.86	-	-	-	-	-	-	-	-	-	-	-
G. sphaerophorum	4.34	1.56	-	-	8.33	-	7.69	1.19	2.47	0.72	-	-
Gomphonema sp.	3.47	-	-	-	-	-						

Hannaea arcus	-	0.52	-	-	-	-	-	-	-	0.72	-	-
Hannaea arcus var. *amphioxys*	-	-	2.3	-	-	-	-	0.59	-	0.72	-	-
Hannaea arcus var. *linearis*	-	-	-	0.56	-	-	-	-	-	-	1.17	-
Melosira junergensii	-	-	-	-	-	-	-	-	-	0.72	-	-
Navicula cari	-	-	0.46	-	-	-	-	-	-	-	-	-
N. cryptocephala var. *veneta*	-	-	-	-	-	-	-	-	-	-	1.17	-
N. minima var. *atomoides*	0.86	-	-	-	-	-	-	-	-	-	-	-
N. radiosa	-	-	-	-	-	-	-	-	0.99	-	-	-
N. radiosa var. *minutissima*	-	-	-	-	-	50	-	-	-	-	-	-
N. radiosa var. *terella*	0.86	-	-	-	-	-	-	-	-	-	-	-
Pinnularia microstauron var. *brebissone*	-	-	0.46	-	-	-	-	-	-	-	-	-
Planothedium lancedata	2.6	4.16	1.84	0.56	-	-	-	-	2.47	4.34	4.7	16.66
Planothidium lanceolata f. *ventricosa*	-	-	-	-	-	-	-	-	-	-	1.17	-
Rameria sinuata	-	0.52	0.46	-	-	-	-	-	-	-	-	-
Synedra ulna aequalis	-	2.6	-	-	-	-	-	-	1.48	-	-	-
Synedra ulna var. *amphirhynchus*	9.56	2.6	-	-	-	-	-	-	-	-	-	-
Tabellaria flocculasa	0.86	-	0.46	-	-	-	-	-	-	-	-	-
Tetracyclus lacustris	-	-	-	-	-	-	-	-	-	-	-	4.16
Total	**38**	**29**	**29**	**18**	**8**	**2**	**7**	**24**	**24**	**26**	**23**	**13**

W1 (upstream of proposed dam site); W2 (proposed dam site); W3 (proposed power house site);

b) *Macro-invertebrates*

Benthic fauna plays a major role in maintaining the equilibrium of aquatic ecosystems. The factors which affect the distribution of benthic fauna are temperature, velocity, and availability of substrates (Hynes, 1970). Macro- invertebrates in the present study area comprised of six orders viz. Diptera, Coleoptera, Ephemeroptera, Plecoptera, Tricoptera and Odonata. Diptera was the most diverse order with six families (Chironomidae, Tipulidae, Simulidae, Rhagionidae, Ceratopogonidae and Psychodidae) followed by Coleoptera (Chrysomelidae, Elmidae and Dystiscidae), Ephemeroptera (Heptageniidae, Baetidae and Ephemeridae). Plecoptera (Perlidae and Periodidae) and Tricoptera (Hydroptilidae and Hydropsychidae) were represented by two families. Odonata was represented by single family Gomphidae. Families Heptageniidae (*Cinygmula*, *Stenonema* and *Epeorus*) and Chironomidae (*Chironomus*, *Ablabesmyia* and *Tendipes*) were represented by 3 genera each. Hydroptilidae (*Hydroptila* and *Ochrotrichia*) and Elmidae (*Narpus* and *Hetrlimnius*) were represented by two genera each. Rest of the families was represented by one genus. *Cinygmula*, *Ablabesmyia* and *Baetis* were the most abundant genera found almost at all sites in all three seasons (Table 3.3.2.5).

Table 3.3.2.5 Macro-invertebrate composition (individual/m²) in Yarjep River and its tributary in and around Pauk H.E. Project

	Winter			Pre-Monsoon			Monsoon		
Taxa Name	**W1**	**W2**	**W3**	**W2**	**W3**	**W4**	**W1**	**W2**	**W3**
Ephemeroptera									
Heptageniidae									
Cinygmula	44	100	33	133	33	-	22	56	-
Stenonema	-	-	-	-	67	33	-	-	-
Epeorus	-	-	-	-	-	-	-	300	156
Baetidae									
Baetis	-	22	-	100	44	100	22	56	44
Epehmerelidae									
Ephemerella	-	-	-	-	-	11	-	-	-
Others	-	33	144	-	-	-	-	-	-
Plecoptera									
Perlidae									
Acroneuria	-	-	-	22	100	11	-	22	33

Periodidae									
Isoperla	-	-	-	-	-	-	-	-	22
Trichoptera									
Hydroptilidae									
Hydroptila	-	11	-	11	33	11	-	-	-
Ochrotrichia	-	-	-	-	*22*	-	-	-	-
Hydropsychidae									
Hydropsyche	-	-	-	-	-	-	-	33	56
Diptera									
Chironomidae									
Chironomus	-	-	-	56	178	356	-	-	-
Ablabesmyia	67	167	44	67	367	622	78	1444	555
Tendipes tentans	-	-	22	-	-	-	-	-	-
Tipulidae									
Antocha saxicola	-	-	11	11	-	-	-	-	-
Simulidae									
Simulium pictipes	-	-	-	-	-	78	-	111	-
Rhagionidae									
Atherix variegata	11	-	-	-	-	-	-	-	-
Ceratopogonidae									
Culicoides variipennis	-	-	11	-	-	-	-	-	-
Psychodidae									
Psychoda	11	-	-	-	-	-	-	-	-
Coleoptera									
Chrysomelidae									
Donacia hirlicollis	-	-	-	-	11	-	-	-	-
Elmidae									
Narpus	-	-	-	-	11	11	-	-	-
Heterlimnius	-	-	22	-	-	-	-	-	-
Dytiscidae									
Agabinus glabrellus	11	-	-	-	-	-	-	-	-
Odonata									
Gomphidae									
Ophiogomphus	-	-	-	-	-	11	-	-	11
Density (individual/ m²)	**144**	**333**	**287**	**400**	**866**	**1244**	**122**	**2022**	**877**

W1 (upstream of proposed dam site); W2 (proposed dam site); W3 (proposed power house site

3.3.2.3 Assessment of Water Quality

Water quality of the river water can be assessed using physical, chemical and biological characteristics of the water. Among the physical and chemical parameters, dissolved oxygen (DO), Bio-chemical Oxygen Demand (BOD), pH and concentration of heavy metal are important parameters for the water quality monitoring. High concentration of DO, low concentration of BOD, non detectable heavy metal and optimum alkaline range of pH in Yarjep waters indicate a good water quality. The local inhabitants generally use the spring water for drinking purpose. Though, Shongsh Bu recorded higher concentration of alkalinity, hardness, total dissolved solids, but remain under the desirable limit. The present investigation reveals that quality of surface water and drinking water is good and stand under the desirable limit as per IS:10500 except turbidity (Table 3.3.2.6).

Table 3.3.2.6. Drinking water quality standards (as per IS:10500)

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)	300	600
Total alkalinity (mg/l)	200	600
Chloride (mg/l)	250	1000
Nitrate (mg/l)	45	100
Calcium (mg/l)	75	200
Magnesium (mg/l)	30	100
Copper (mg/l)	0.05	1.5
Iron (mg/l)	0.30	1.0
Lead (mg/l)	0.05	No relaxation
Cadmium (mg/l)	0.01	No relaxation

There was no point source triggering the organic pollution in the vicinity. None of the effluents that were recorded measured the various parameters as per Table 3.3.2.7. Inland surface water standards indicate that the water of Yarjep and its tributaries is conducive for drinking, agricultural and fisheries purpose.

Table 3.3.2.7 Tolerance Limits for Inland Surface Waters (as per IS:2296)

SN	Parameter and Unit	Class-A	Class-B	Class-C	Class-D	Class-E
1.	Colour (Hazen Units)	10300	300	-	-	
2.	Odour	Unobject	-	-	-	-
3.	Taste	Tasteless	-	-	-	-
4.	pH (max) (min:6.5)	8.5	8.5	8.5	8.5	8.5
5.	Conductivity (μS/cm□)	-	-	-	1000	2250
6.	Do (mg/L) (min)	6	5	4	4	-
7.	BOD (3 days at 27^oC) (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 C_6H_5OH)	0.002	0.005	0.005	-	-
16.	Total Hardness (mg/L as $CaCO_3$)	300	-	-	-	-
17.	Chloride (mg/L as CI)	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
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.

In the biological parameters coliforms were absent at most of the sites of river and tributary waters investigated during different seasons. It can be explained on the basis of sparse human population and absence of any point source of organic pollution in the catchment. Most of the algal species (*Achnanthidium linearis, Achnanthidium conspicua, Achnanthidium exilis, Fragilaria vaucheriae, Planothidium lanceolata, Gomphonema longiceps* etc.) and macro-invertebrates taxa like *Cinygmula, Stenonema* and *Epeorus* were intolerant of the organic pollution indicating the status of river water. MWQI value ranges from 0.35 to 0.87 in Yarjep River. In winter season water quality was good to very good (see Bhatt & Pandit, 2008). In Monsoon season, it was poor to good quality at various sites. The poor water quality in monsoon season can be attributed to the high turbidity in water, which lasted in post monsoon season and reflected in the poor to fair water quality (**Fig. 3.3.2.1**).

3.3.2.4 Change in Flow Regime

Change in the flow regime may have many environmental consequences. In addition, there are many unseen impacts of changed environmental flow. About 2.6 km river stretch would undergo through scarcity of water, though a few small nalahs join Yarjep River. Shongshi Bu having a total catchment area of 71.5 sq km. joins Yarjep River at 1.8 km downstream of proposed dam while Shene Sokong joins it at 2.3 km downstream. The monthly variation in water discharge in these nalahs is given in Table 3.3.2.8. The nalahs would contribute to minimize some of the negative impacts like the scarcity of water and would help the natural regeneration of the river.

Table 3.3.2.8 10-daily water discharge in downstream tributaries

Months		Songshi Bu	Shene Sokong
Jun	I	9.37	1.63
	II	10.64	1.85
	III	11.59	2.01
Jul	I	13.31	2.31
	II	13.97	2.43
	III	14.12	2.45
Aug	I	12.06	2.09
	II	12.31	2.14
	III	12.92	2.24
Sep	I	12.23	2.12
	II	11.80	2.05
	III	9.89	1.72
Oct	I	9.12	1.58
	II	7.31	1.27
	III	6.01	1.04
Nov	I	2.53	0.44
	II	2.11	0.37
	III	1.89	0.33
Dec	I	1.66	0.29
	II	1.49	0.26
	III	1.36	0.24
Jan	I	1.18	0.21
	II	1.11	0.19
	III	1.09	0.19
Feb	I	1.09	0.19
	II	1.07	0.19
	III	1.22	0.21
Mar	I	1.38	0.24
	II	1.65	0.29
	III	1.99	0.35
Apr	I	2.42	0.42
	II	3.06	0.53
	III	3.56	0.62

May	I	6.64	1.15
	II	7.27	1.26
	III	8.19	1.42

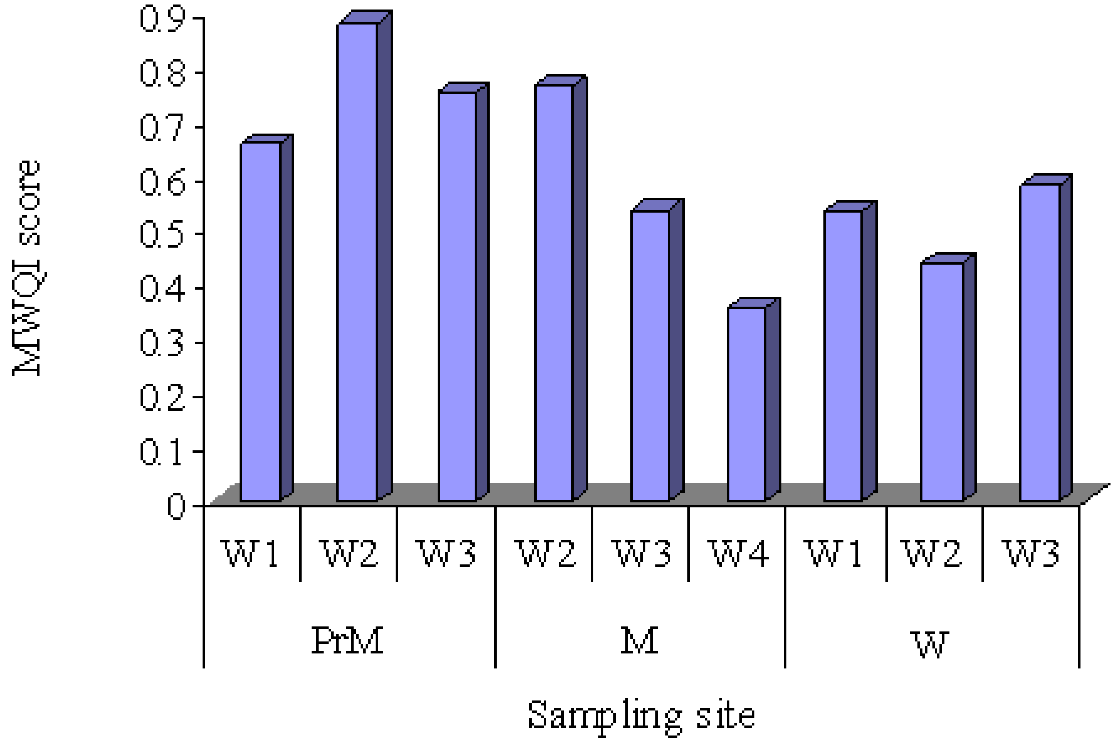


Fig. 3.3.2.1 Macro-invertebrates Water Quality Index proposed by Bhatt & Pandit (2010)

3.3.3 FISH & FISHERIES

3.3.3.1 Introduction

Flow is the major determinant of physical habitat in the rivers, which directly affects the biotic communities. Flow modification is directly related to the habitat loss and fragmentation which is one of the greatest threats to biodiversity worldwide, and this certainly holds true for riverine fishes. It is thus almost certain that disturbances, generated for example by dams, weirs, reservoirs for water supply, diversion etc all creating direct or indirect decreases in habitat availability, will endanger or extinguish many freshwater fish species in the future.

In general, suggested environmental flow in the river would rely on the nature and magnitude of the impacts of the flow modification on the aquatic communities and downstream users of water (Bunn and arthington, 2002). Considering the biotic communities of the river, fish are largest species in the Himalayan river systems, therefore, it may be considered as main target group while taking the environmental flow assessment into account. It is assumed that the quantity of flow conducive for fish will be sustainable for other biotic communities of the river. Also, the maintenance of flow is focused towards the key fish species considering their spawning habit, migration, hatching habit (e.g. Alfredsen, et al., 2011).

In order to formulate an environmental flow in the downstream of Pauk dam, fish was considered as main interest group, therefore, detailed surveys were carried out on the fish and fisheries in Yarjep river and its contributing tributaries for three seasons.

3.3.3.2 Fish Composition & Conservation Status

Ichthyofauna in the Yarjep river and its tributaries comprises of 6 species belonging to 4 families (Table 3.3.3.1). *Schizothorax richardsonii* (**Plate 3.3.3.1a**) and *Garra nagenensis* are widely distributed and prefer to inhabit main river like Yarjep river. Other species like *Nemacheilus multifasciatus*, *Schistura rupecola*, *Botia berdmorei* and *Glyptothorax annandeli* are bottom dwellers and prefer to inhabit tributaries. During the primary surveys, *Schizothorax richardsonii*, *Garra naganensis*, *Nemacheilus multifasciatus* and *Glyptothorax annandeli* were recorded from Yarjep river during all seasons. In Songshi Bu, a tributary of Yarjep River, fingerlings of *Schizothorax richardsonii* and adult *Nemacheilus multifasciatus* and *Glyptothorax annandeli* were recorded in all seasons while juveniles *Schizothorax richardsonii* (**Plate 3.3.3.1b**) were found only in monsoon season. In Shene Korong tributary, unidentified fish fry were collected only in monsoon season, indicating that this stream is also used as spawning ground by some species.

Out of 6 species 5 have been assessed for their conservation status by CAMP (1997) workshop. Two species are endangered as three are vulnerable. In the IUCN criterion, *Schizothorax richardsonii* has been categorized as vulnerable species.

Table 3.3.3.1 Fish composition in Yarjep river and its tributaries

Scientific Name	Yarjep R.	Songsh Bu	Shene Korong
Cyprinidae			
Schizothorax richardsonii	+	+*	-
Garra naganensis	+	-	-
Balitoridae			
Nemacheilus multifasciatus	+	+	-
Schistura rupecola	+	-	-
Cobitidae			
Botia berdmorei	+	-	-
Sisoridae			
Glyptothorax annandeli	+	+	-

* only fingerlings and juveniles in monsoon season were recorded from Songsh Bu

3.3.3.3 Fisheries

During the primary survey *Schizothorax richardsonii* was landed during winter, pre-monsoon and monsoon seasons in Yarjep river between proposed dam and power house site. Its Juveniles and fingerlings were recorded from a tributary of Yarjep river in study area especially in monsoon season. *Glyptothorax annandeli* was landed in winter season from Yarjep river while in monsoon season it was recorded from right bank tributary near dam site.

In different seasons no fisherman was found to land fish in the river stretch between proposed dam site and power house site. In order to know the catch per unit effort in specified area we hire fishermen for each season. A two hour fish catch in winter season ranged from 1.5 to 3.0 kg. It decreased to a range of 1.0 to 2.5 kg in pre-monsoon season while it was around 0.3 kg in monsoon season. In monsoon season fish were landed from tributaries only. Cast net and hooks are main fishing gears used in the vicinity of the project. Fishing can not be attributed to be one of the means of livelihood of inhabitants. To fulfill their protein diet, inhabitants generally prefer hunting rather than fishing.

The inhabitants of the surrounding areas are non vegetarian in food habit but it does not reflects in the fishing activities as confirmed by the very low capture and disorganized fishing in the region. *Schizothorax richardsonii* is predominant in Yarjep river, most capture fishery depends on it.

3.3.3.4 Fish Migration

No long route migratory fish was observed in Yarjep river. Only *Schizothorax richardsonii* is found to perform local migration. It finds its breeding ground in nearby tributaries, evidenced by the presence of fingerlings and juveniles in the tributaries (**Plate 3.3.3.1b**). Other species are bottom dwellers and are not supposed to migrate for long distance.

(a) Adult *Schizothorax richardsonii*

(b) Juvenile *Schizothorax richardsonii*

Plate 3.3.3.1 Predominant fish species in Yarjep river and Tributaries. Adult has been captured from Yarjep river while juvenile was landed from a tributary

3.4 AIR ENVIRONMENT

3.4.1 METEOROLOGY

3.4.1.1 General

The Himalayan mountain region is observed by four distinct seasons: i) Pre-monsoon (April-May), ii) Monsoon (June-September), iii) Post-Monsoon (October-November); and iv) winter season (December-March). Overall climatic conditions in Himalaya vary along the seasonal gradient. The Himalayan climate varies to that of the plains in India (Das, 2002). The marked difference among the various seasons can seen between monsoon and winter seasons. Monsoon season is characterized by high rainfall while winter season by low temperature and snow fall in high elevation. These characteristics affect the various characteristics of ambient air quality.

3.4.1.2 Temperature, Humidity and Wind Chill

The temperature and relative humidity in high mountainous regions like Himalaya is influenced by the change in altitude. At about 2,000 meters, the average summer temperature is near 18°C. The summer temperature in valleys reaches between 32°C and 38°C. The latitudinal variation in Himalaya also controls the rainfall, temperature and humidity. The Eastern Himalaya receives heavy rainfall, and therefore, the variation pattern of temperature and relative humidity of this region is different from that of Western Himalaya. The temperature and humidity data available for the project area are shown in the Table. 3.4.1.1.

Temperature, humidity, wind speed and wind chill were directly assessed by CISMHE during our field visits in (2009) recorded at three sites. The Yarjep basin experience cold temperature during the winter months from December to January. The maximum temperature recorded was 28.7°C during monsoon season at site S2 (Chengrung) whereas the minimum temperature was 5°C recorded during winter at Mechuka (S1). Relative humidity was highest during the pre-monsoon period for site S1 with 86.7%. The relative humidity during the winter scales down to37.8% Rapum (S3). Wind chill were also assessed for all the sites. It was highest during the monsoon with a temperature of 28.7°C at site S2 site. The lowest wind chill temperature was recorded 4.9°C at site S1 site during winter. Besides wind speed was also recorded and the maximum speed was recorded during the winter season at S3 site with a wind speed of 20 km/h. In addition heat index, dew point, wet bulb, barometer and density altitude were also directly assessed with the help of weather instruments. Details of the weather variables assessed are given in the Table 3.4.1.1.

Table 3.4.1.1 Meteorological data for Pauk H.E Project.

	Winter			Pre- Monsoon		Monsoon	
	S1*	**S2***	**S3***	**S1***	**S2***	**S1***	**S2***
Wind (Km/h)	1.7	0.5	20	1.5	1.3	6.6	17.8
Temperature (ºC)	5	16.6	18.3	20	17.6	26	28.7
Wind Chill (ºC)	4.9	16.6	19.1	20	16.6	26	28.7
Humidity (%)	73.3	72.5	37.8	86.7	14.4	61.1	43.4
Heat index (ºC)	5.6	17.5	16.8	19.1	15.4	26.2	27.5
Dew Point (ºC)	6.7	12	3.8	16.6	14.7	17.6	14.8
Wet bulb (ºC)	7.3	13.5	10.5	16.8	13.3	19.9	18.2
Barometer (hPa)	847.8	81.8	895.6	881	892.2	866.9	835.6
Density Altitude (M)	2140	1940	1926	1995	1755	2455	2983

* S1 = Mechuka; S2 = Chengrung village; S3 = Rapum

3.4.2 AIR ENVIRONMENT

Deterioration of air quality is a major problem, which is an alteration of atmospheric chemistry by air pollutants from natural and anthropogenic sources. The air pollution cannot be regarded as a local phenomenon but it includes a vast area due to transboundary movement of air pollutants. In general, the sources of deterioration of air quality are different. For instance, the emission of SO_2 from volcanoes, O_3 from lightning, particulate and CO2 from naturally occurring fires, wind storm, the construction activities in large scales, vehicular movement, power plants, metal smelters etc. Thus, it largely depends on the location, topography of the region.

Regarding the surroundings of Pauk H.E. Project all the natural and anthropogenic activities are not prevalent so that the level of air pollution is anticipated very low. The only source of air and noise pollution in the area is sparse traffic density, slash and burning and domestic fuels. However, the air quality is, to some extent, determined by the behaviour of air as a result of the interaction of topography such as mountains and valleys; weather such as wind, temperature, air turbulence, air pressure, rainfall and cloud cover; physical and chemical properties of pollutants; and by the emission sources themselves. The area is know to have dense forest cover, and relatively high rainfall, which are considered as factors amelioration of air quality. However, the air and noise quality assessment in EIA study is an important aspect, which would be useful in monitoring the ambient air quality during the construction phase of Pauk H.E.

project. A number of activities during construction phase of the project may add or increase air pollutants viz., SPM, volatile organic compounds (VOCs), NO_2, SO_2 etc. to some degree. Various anthropogenic activities such as transport system, changes in land use and industries etc. also pollute air mostly in immediate vicinities. Notes on thee traffic density, air quality and noise level in and around the project component areas are described in the following paragraphs.

3.4.2.1 Traffic Density

In the vicinity of Pauk H.E. Project a single road connects the surrounding villages and Mechuka and Tato towns. Due to sparse population in the region transport services on this road is low, therefore, these facilities are facilitated by private owned light vehicles. Mechuka is the biggest settlement in the catchment area, therefore, traffic density was also recorded at a particular point at Mechuka. Values of traffic density in and around the project area are given in Table 3.4.1.2. Survey revealed that Mechuka town recorded maximum traffic density, maximum of those are from army owned vehicle. The traffic density on the Tato - Mechuka road near proposed project site is very low.

Table 3.4.1.2 Traffic density in and around Pauk H.E. Project

Location	Date and time vehicles	Vehicular Traffic/ hour		
		Heavy vehicles	Light wheelers	Two
Winter Season				
Tato Mechuka Road	February, 12:00 - 14:00	1	2	1
Mechuka	February, 9:00 – 11:00	5	3	2
Pre-monsoon				
Tato-Mechuka Road	25 May, 10.00 - 12:00	1	2	0
Mechuka	25 May, 8:00 – 9:00	3	1	1
Mechuka	25 May, 16:00 – 17:00	7	2	3
Mechuka	26 May, 12:00 – 14:00	8	3	2
Monsoon				
Tato-Mechuka Road	23 August, 11.00- 12:00	1	0	0
Mechuka	23 August, 9:00-10:00	6	1	3
Mechuka	23 August, 14:00-15:00	7	2	4
Mechuka	24 August, 12:00-14:00	6	3	0

3.4.2.2 Air Quality

Major sources of outdoor air pollution in the project area at Pauk H.E. Project are vehicular traffic in and around, Jhum cultivation fire, and road construction activities. The source of indoor air pollution is burning of fuel wood. The region receives high rainfall and is covered with dense vegetation. In addition, the open agricultural fields in the region are covered with vegetation during fallow seasons. Soils are not exposed and there is little possibility of any dust storms contributing in air pollution owing to the pervasive structure of vegetation cover. Different air pollutants are described as under the following headings.

i) ***Suspended particulate matter (SPM)***

Concentration of SPM levels in and around project location is anticipated to be lower than its values at Aalo vary from 83.61 to 311.00 $\mu g/ m^3$ (Table 3.4.1.3). Except in winter season, these values are generally lower than the standard values prescribed in NAAQS approved by the Ministry of Environment & Forests, GOI (Table 3.4.1.4). The average value of SPM was recorded lowest during the monsoon season, which may be ascribed due to settling down of the particles. The main sources of SPM in the region are vehicular traffic, occasional open degraded land areas and land slides. Forest fire was not observed in the region during the survey. The entire region is virtually covered with thick vegetation which plays a significant role in ameliorating the load of suspended particulate matters in air. Based on our field records of ambient air quality at Aalo we suggest that the levels of SPM, RSPM and NRSPM will remain much lower at the project site (Pauk H.E. Project) than the values recorded at Aalo. Since the human population density in the region is comparatively lower than that of Aalo and the number of vehicles plying on the road is also low at the project site as a result the ambient air quality is at healthy level.

Table 3.4.1.3 Air quality characteristics recorded at Aalo and projected for the project areas

Parameters	Winter(a)	Winter(b)	Pre-monsoon	Monsoon
SO_2 (µg/m³)	9.83	0.0	0.0	0.0
NOx (µg/m³)	0.0	1.79	1.22	1.35
TSPM (µg/m³)	311.00	272.60	92.13	83.61
RSPM (µg/m³)	137.61	79.24	13.75	31.25
NRSPM (µg/m³)	173.39	193.36	78.38	52.36

Note: Sampling was carried out twice in winter season, therefore, depicted as a and b

ii) ***NOx***

NOx is the generic term for a group of highly reactive gases which contain compound of nitrogen and oxygen in varying proportions. Most of the nitrogen oxide gases are colourless and odourless gases except nitrogen dioxide (NO_2), which is reddish brown. These gases are produced during combustion especially at high temperature. The main sources of NOx are vehicles and industries. In Aalo region there is no industry and vehicles are the main source of NOx. A very low concentration of NO_2 was recorded at Aalo (Table 3.4.1.3) which is negligible compared to the values of NAAQS approved by Ministry of Environment & Forests (see Table 3.4.1.4). Maximum level of NO_2 recorded at Aalo was 1.79 μg/ m^3 during winter season. Extrapolating the above observation we anticipate that NO_2 at the project sites will remain lower than the recorded value of NO_2 at Aalo (1.79 μg/ m^3).

iii) ***Sulphur Dioxide (SO_2)***

Sulphur dioxide is a colourless gas smelling pungent irritating odour. The main source of SO_2 is volcanoes, industrial processes and combustion of fuels such as oil and coal. Besides, coal and petroleum contain sulphur compounds and upon their combustion results in generating sulphur dioxide unless the sulphur compounds are removed before burning the fuel. SO_2 forms H_2SO_4 in the presence of a catalyst such as NO_2 that results in acid rain. Sulphur dioxide emissions are also a precursor to formation of particulates in air. The highest level of SO_2 recorded in the region was 9.83 μg/ m^3 (see Table 3.4.1.3). This value is significantly lower than the values of NAAQS approved by Ministry of Environment & Forests (see Table 3.4.1.4).

Table 3.4.1.4 National Ambient Air Quality Standards approved by Ministry of Environment & Forests

Pollutants	**Time**	**Concentration in Ambient Air**		**Method of Weighted**
	Ecological	**Industrial, Sensitive areas**	**Measurements Residential , Rural & Other Areas**	
Sulphur Dioxide (SO_2)	Annual Average 24 hour	20 μg m^{-3} 80 μg m^{-3}	50 μg m^{-3} 80 μg m^{-3}	Improved West and Greek Method Ultraviolet flourescence
Oxides of Nitrogen (NO_x)	Annual 24hour	30 μg m^{-3} 80 μg m^{-3}	40 μg m^{-3} 80 μg m^{-3}	Modified Jacob Hochheises (Na-Arsenite) Chemiluminescence

Particulate Matter (size less than 10 μg)	Annual	60 μg m^{-3}	60 μg m^{-3}	Gravimetric TOEM
	24 hour	100 μg m^{-3}	100 μg m^{-3}	Beta attentuation
Particulate Matter Matter (Size < 2.5 μg)	Annual	40 μg m^{-3}	40 μg m^{-3}	Gravimetric TOEM
	24hour	60 μg m^{-3}	60 μg m^{-3}	Beta attentuation

3.4.3 NOISE LEVEL

Major source of noise around the project areas is turbulent flow of the river. It is pronounced in the area because no other major sound is produced in and around. However, it can not be considered as noise pollution because it is not an unwanted sound or unpleasant. Merely vehicular movement contributes little to the sound level. Sound level in the region ranged from 41.3± 2.53 to 69.1 ± 5.30 dBA in the influence area (Table 3.4.1.5). Apparently higher sound levels were recorded from the barrage and power house sites; attributed to the flow of river. At Mechuka sound levels were recorded in the morning, day time and at night. Lowest sounds were recorded at night. The recorded noise levels in the project area were within the range limits as approved by the national standard, Government of India (Table 3.4.8).

Table 3.4.1.5. Noise levels at various sites in the vicinity of Pauk H.E. Project

Location	Date and time	Sound level dB(A)
Winter		
Rego (S1)	10 Feb, 2009; 11:00	46.4 ± 2.46
Dam site (S2)	10 Feb, 2009; 12:00	61.0 ± 4.73
Power House (S3)	10 Feb, 2009; 14:00	58.6 ± 3.24
Road site (S4)	10 Feb., 2009; 10:00	48.0± 3.69
Mechuka (S5)		
Morning	10 Feb., 2009; 9:00	45.2± 5.09
Day time	-	
Night	10 Feb., 2009; 20:00	41.3± 2.53
Pre-monsoon		
Rego (S1)	25 May, 2009; 11:00	43.9 ± 3.00
Dam site (S2)	25 May, 2009; 13:00	66.6 ± 3.60
Powerhouse site (S3)	25 May, 2009; 14:00	69.1 ± 5.30

Road site (S4)	25 May, 2009; 10:00	50.2 ± 4.32
Mechuka (S5)		
Morning	25 May, 2009; 8:30	48.9 ± 3.21
Day time	25 May, 2009; 16:20	51.3± 3.85
Night	25 May, 2009; 20:25	42.5± 3.53
Monsoon		
Rego village (S1)	23 August, 2009; 10:30	50.3 ± 3.65
Dam site (S2)	28 August, 2009; 13:00	61.7 ± 2.36
Powerhouse site (S3)	-	
Road site (S4)	23 August, 2009; 11.00	51.5 ± 3.27
Mechuka (S5)		
Morning	23 August, 2009; 9.00	44.9 ± 6.73
Day time	23 August, 2009; 14.00	49.1 ± 6.52
Night	23 August, 2009; 20.00	42.3 ± 2.58

The magnitude of noise depends on the type of machine, time of operation etc. Table 3.4.1.6 and 3.4.1.7 give the details of machines and sound produced by them. These tables would guide only the readers' eyes.

Table 3.4.1.6 Sound level produced by different instruments while in operation

Sl. No.	Equipments	Sound Level (dBA)
1.	Truck Mounted Crane	76-83
2.	Un-silenced scraper/grader	82
3.	Generator	82
4.	Un-silenced pile diver	110
5.	Un-silenced compressor	80
6.	Un-silenced pneumatic drill	90
7.	Heavy duty bulldozer	91-107
8.	Light duty bulldozer	93-101

Source: Kerr *et al.*, 2002

Table 3.4.1.7 Sound level at different distance from the source

Distance (m)	Ambient noise Level (dB)	Probable noise level due to activity	Increase in noise level (dB)
100	50	70	20
200	50	68	18
500	50	60	10

1000	50	55	5
1500	50	52	2
2000	50	50	-
2500	50	49	-
3000	50	47	-

Source: Tato II H.E. Project

Note:

1. Day time is reckoned in between 6.00 AM and 9.00 PM
2. Night time is reckoned in between 9.00 PM and 6.00 AM
3. Silence zone is defined as areas up to 100 m around such premises as hospitals, educational institutions and courts. The silence zones are to be declared by competent authority.

3.4.4 CONCLUSION

The quality of air in the region is good as there are no point sources of air and noise pollution. The status of noise in the region is good and noise pollution in and around the region almost nil. Vehicular movement is very poor while the practice of slash and burning is not prevalent as compared to lower reaches of the West Siang District. The ambient air pollutants were recorded at Aalo, which must be significantly lower at the project sites as compared.

The baseline data of air environment would be useful in preparing the mitigation measures of air quality during the construction phase. All the parameters are anticipated to increase significantly during the construction phase.

Table 3.4.1.8. Ambient noise levels as per CPCB

Area code	**Category of Area**	**Limits in dB (A) Leq**	
		Day time	**Night Time**
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Zone	50	40

3.5 BIOLOGICAL ENVIRONMENT

3.5.1 FLORAL ELEMENTS

3.5.1.1 Introduction

Arunachal Pradesh, the easternmost part of the Himalaya, is the largest state areawise in the Northeast region covers an area of 83,743 sq km. It shares international boundary with Myanmar, China and Bhutan. The area is mostly mountainous and the elevation of the hills ranges from 200m (Siwalik formations) to 7,750m (in the inner Himalayas) along the Tibet-China border. The climate of the state varies from temperate in the northern part to warm and humid in the southern part with average annual rainfall ranging from 2000 mm to 8000 mm. The temperature in the state varies below zero to 31^0c. The wide range of altitudinal variation, unique phytogeographical position, topography, high degree of precipitation and microclimatic condition, have supported to the characteristic, rich and diverse flora in Arunachal Pradesh. The five major forest types occurring in the state are tropical semi-evergreen, subtropical wet hill and pine, wet temperate forest and sub-alpine and alpine forest. Each forest type depicting its own characteristic biodiversity, therefore, the area is considered to be one of the bio-diversity 'Hot Spot' of the world. Takhtajan (1969) has regarded it as the cradle of flowering plants. Over 5000 species of flowering plants and 400 pteridophytes have been identified from 60% area of the state explored.

Arunachal Pradesh has remained less explored in the past as compared to other regions within the Eastern Himalaya possibly due to tough and inaccessible terrain. H. Wilcox was the first botanist who for the first time explored the Mishmee hills in 1826. Subsequently, Griffith in 1836 botanized this region and his "Flora of Mishmi Hills" enumerates 900 species of flowering plants and 22 species of ferns and fern allies. With advent of 20th Century, plant explorations in this region gained momentum which resulted in the publication of some important floristic accounts of this region such as "On the Botany of Abor Expedition" by Burkill (1924-25); "Botanical Expedition in the Mishmi Hills" by Kingdom-Ward (1929-1931); "Lohit Valley" by Kingdon Ward (1953) and "A sketch of the vegetation of Aka Hills" based on the collections of Bor (1931-1934) which enumerates 1549 species of flowering plants, 9 species of gymnosperms and 58 species of ferns and fern allies. With the inception of the Eastern Circle of Botanical Survey of India at Shillong, various parts of Arunachal viz. Kameng, Subansiri, Siang, Lohit, Tirap, etc. were surveyed for its vegetational wealth, of which Rao and Panigrahi (1961); Deb (1961); Rao (1974); Sahni (1981), Chowdhery (1996) are worth mentioning.

3.5.1.2 Forest Types

The forest cover of Arunachal Pradesh, based on satellite data of November- December 2004 and Ferbruary 2005, is 67, 777 km^2, which constitutes 80.93 percent of geographic area under forest cover and includes very dense, moderately dense and open forests (FSI, 2005). The forest of Arunachal Pradesh fall under five major categories of vegetation viz., tropical, sub-tropical, temperate broad-leaved and temperate coniferous, sub-alpine and alpine forests. Detailed accounts of floristics of these forests are found in Champion & Seth (1968) and Kaul and Haridasan (1987). The catchment area of the proposed Pauk HE Project covers almost all types of these forests. However, the concerned project area which is stretched around 5 km and covers sub-tropical wet hill forests, wet temperate broad-leaved and dry temperate coniferous forest. The forests in the project area fall in Mechuka range of Aalo Forest Division.

The vegetation in these forests comprises sub-tropical wet hill forests in the lower valleys of the project area, while wet temperate broad-leaved and dry temperate coniferous forests in the mid and upper hills. In the entire valley of the catchment, the area is either covered by dense forests along the river banks or degraded open forests interspersed with settlements in upper reaches. The forests present in the catchment area have been grouped into different forest types following the classification of Champion & Seth (1968), Negi, (1989, 1996), Chowdhery (1996) and Muddgal & Hajra (1999). The major forest types found in this catchment are discussed below.

i) ***8B/CI East Himalayan Sub-tropical wet hill forests***

These forests occur on hilly terrain between 1000-2000 m and are largely dominated by a number of evergreen species, though some deciduous trees also occur in the top canopy. Many of the tropical genera like *Bischofia, Duabanga, Pterospermum, Tetrameles,* etc are absent and more temperate genera like *Alnus*, *Lithocarpus, Lyonia* and *Quercus* appear. These forests were observed in Hiri, Padusa and Purying areas. The top canopy is comprised of *Albizia odoratissima, Alnus nepalensis*, *Altingia excelsa*, *Castanopsis indica*, *Engelhardtia spicata*, *Macaranga denticulata*, *Ostodes paniculata*, *Phoebe hainsiana*, *Schima wallichii,* etc. The second storey is represented by some evergreen tree species like *Alangium chinense, Brassiopsis aculeata, Ficus oligodon, Garcinia* *pedunculata, Gynocardia odorata, Oroxylum indicum, Rhus chinensis*, etc. The third storey consists of shrubs and climbers. Among shrubs are *Boehmeria macrophylla, Clerodendrum griffithianum, Debregeasia longifolia, Dendrocalamus hamiltonii, Eurya acuminata, Leea aequata, Maesa chisia, Oxyspora paniculata, Saurauia nepalensis*, etc. Epiphytes and climbers are abundant. Climbers belong to the species of *Canvalia, Cissus, Caesalpinia, Clematis, Dioscorea, Rhaphidophora, Rubia* and *Stephania*. Epiphytes are represented by ferns viz., *Colysis, Lepisorus, Vittaria* and orchids such as *Bulbophyllum, Cymbidium, Dendrobium,* etc. The prominent herbs are *Ageratum conyzoides, Anaphalis busua, Anemone vitifolia, Aster mollisculus, Bidens bipinnata, Cardamine hirsuta, Crassocephalum crepidioides, Impatiens* sp., *Persicaria capitata, P. barabata, Setaria glauca, Saccahraum longisetosus, Spiranthes sinensis, Themeda arundinacea, Thysanolaena latifolia, Viola betonicifolia,* etc.

ii) *11B/C1 East Himalayan wet temperate forests*

These forests occur between 1800-2700m elevations on the higher hills of Mechuka range of West Siang district. The oaks contribute the greater part of top canopy with some laurels. The top canopy is represented by *Acer acuminatum, Castanopsis tribuloides, Litsea sericea, Magnolia pterocarpa, Michelia doltsopa, Prunus cerasoides, Quercus semiserrata Q. lamellosa* and *Tetradium fraxinifolium.* The middle storey is dominated by moderate sized trees and shrubs like *Eurya acuminata, Ilex dipyrena, Lyonia ovalifolia, Prunus rufa, Rhododendron arboreum, Symplocos thaefolia, Viburnum cotnifolium,* etc. Other associates of middle storey are *Berberis asiatica, B. wallichiana, Myrsine semiserrata, Rubus niveus, Spiraea canescens* and *Thamnocalamus spathiflorus*. Climbers and twiners are extremely rare except for the species of *Clematis, Rubus* and *Vitis*. These forests were observed in the upper reaches of Rapum and Rego areas. The ground flora is consist of herbaceous species belonging to genera like *Anaphalis, Anemone, Cardamine, Campanula, Circium, Carduus, Fragaria, Plantago, Persicaria, Potentilla, Pilea, Rorippa, Sedum, Stellaria* and *Viola.*

iii) *12/1S1 Alder forest*

These forests are pure forests present along the banks of streams and water courses. These forests are mostly the primary colonizers of degraded lands, particularly the landslides. These forests are very dense with a very thin understorey. These forests were commonly observed near Meyning, Purying and Rego areas.

iv) ***13/C6 East Himalayan dry temperate coniferous forest***

This is a mixed coniferous forest type found in the inner valleys of Mechuka Reserve forest. These forests are characterized by the predominant conifers blue pine (*Pinus wallichiana*) as the principal species. The tall trees of blue pine are more or less open in nature. 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, Prunus cerasoides*, *Quercus lamellosa*, *Rhododendron arboreum* and *Salix wallichiana*. Shrubby layer is represented by *Berberis wallichiana*, *Cotoneaster microphyllus, Eurya acuminata, Indigofera heterantha, Rosa brunonii*, *Rubus niveus* and *Viburnum cotnifolium*. The ground flora consists of some terrestrial ferns, herbs and grasses belonging to the genera such as *Anaphalis, Anemone, Artemisia, Circium, Dicranopteris, Digitaria, Dryopteris, Fragaria, Lycopodium, Potentilla, Pilea, Pteridium, Rumex, Stellaria*, etc.

v) ***12/C3. East Himalayan mixed coniferous forests***

This type of evergreen forest occurs on the high altitudinal zone of West Siang District, with predominating oak and Rhododendrons. Hemlock (*Tsuga dumosa*) makes appearance as a dominant tree species between 2100 m and 2700m elevations. *Cephalotaxus griffithii* is a typically associated with wet temperate broad-leaved and dry temperate coniferous forests in the Mechuka area. Blue pine (*Pinus wallichiana*) also formes dense patchy populations in the forest. Besides *Pinus wallichiasna*, there are some oak mixed deciduous tree species such as *Acer, Corylus, Magnolia, Michelia* and *Rhododendron* that are found in moist and damp places. These forests were observed in Yorkuand Sengong areas. A dense undergrowth of many evergreen shrubs species like *Berberis, Cotoneaster, Lonicera, Salix, Rhododenron, Thamnocalamus,* etc were found in the understorey. Most of the tall trees and shrubs are loaded with many epiphytic mosses and lichens.

vi) ***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 Yarlong area. The main associates are *Betula utilis, Rhododedron campanulatum, Rosa sericea,* and *Viburnum nervosum*.

vii) ***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 stunted scrubs and some herbs like *Betula utilis, Cotoneaster sanguineus*, *Lonicera angustifolia*, *Rosa sericea*, *Salix wallichiana*, etc. Common herbs are *Aconitum, Anemone, Polygonatum, Ranunculus, Senecio, Viola*, etc., which have a very short growing season.

viii) ***15/C3 Alpine pastures***

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

3.5.1.3 Vegetation Profile in the Influence Zone

The description of vegetation of the project area has been presented in terms of zones which correspond to topographic/elevational class within the 10 km radius influence zone of the project. These are as follows:

i) Area between Purying village and Rapum village
ii) Area between Rapum village and Rego village
iii) Area between Rego village and Mechuka town
iv) Area beyond Mechuka and its environ

i) ***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 Yarjep 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*, etc. along with some 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, Rhus chinensis*, etc.

Some dense bamboo (*Bambusa pallida*) thickets and tall grasses like *Themeda arundinacea* and *Setaria palmifolia* were seen in Jhum area at 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 thyrsiflora*, *Debregeasia longifolia*, *Elaeagnus parviflora*, *Leea asiatica*, *Oxyspora paniculata*, *Vernonia vokameriifolia*, etc. The tree trunks are often loaded with a number of epiphytic mosses, ferns and orchids. Notable epiphytic plants like *Aeschynanthus parasiticus* and *Polygonatum oppositifolium* were seen on the trunks of *Engelhardtia spicata*. Herbs include *Ageratum, Arisaema, Artemisia, Crowfurdia, Hydrocotyle, Impatiens, Malva, Oxalis, Rumex, Saccharum, Sida* and *Themeda*.

ii) ***Area between Rapum village and Rego village***

There are dense alder, wet temperate broad-leaf and dry mixed coniferous forests above Rapum village. In the vicinity of Rapum area, the natural vegetation comprises *Albizia odoratissima, Alnus nepalensis, Altingia excelsa, Castanopsis hystrix, Cinnamomum tamala, Schefflera impressa* and *Tetradium fraxinifolium.* Shrubs are *Ardisia thrysiflora, Brassiopsis aculeata, Dichroa fabrifuga, Elaeagnus parviflora, Leucosceptrum canum, Maesa chisia, Oxyspora paniculata, Rubus ellipticus*, etc. 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*, *Ptridium, Persicaria*, *Potentilla, Spiranthes sinensis*, etc.

The vegetation around Rego village is characterized by mixed coniferous forest. Top canopy is represented by tall trees like *Cephalotaxus griffithii, Eurya acuminata, Magnolia campbellii, Michelia doltsopa, Pinus wallichiana, Quercus lamellosa, Rhododendron arboreum, Shefflera 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* with other shrubs. Important shrubs are *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*.

iii) *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 campbellii, Michelia* spp., *Pinus wallichiana, Rhododendron arboreum, 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 hookerii, Cotoneaster bacilaris, 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 hookerii, Cotoneaster bacilaris, Magnolia campbellii, Schima wallichii,* etc. 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*.

iv) *Area beyond Mechuka and its environ*

Beyond Mechuka, the vegetation up to Hanuman Camp is represented by mixed coniferous forest with a few evergreen oaks and Rhododendrons in the middle and lower stories. Common tree associates include *Acer acuminatum, Castanopsis tribuloides, Litsea sericea, Magnolia campbellii, Michelia velutina, Pinus wallichiana, Quercus lamellosa* and *Rhododendron arboreum*. Shrub elements are composed of *Cotoneaster bacilaris, Gaultheria fragrantissima, Pieris formosa, Rhododendron* spp., *Rosa sericea, Rubus niveus, Salix wallichiana, Thamnocalamus spathiflorus,* etc. 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, Circium, Fragaria, Potentilla, Scirpus, Senecio,* etc. Above Yorko Hemlock (*Tsuga dumosa*) makes appearance as a dominant tree species with other tree associates like *Acer, Quercus, Pinus*, etc. In the Gurudwara area dense mixed coniferous forest is 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*).

3.5.1.4 Floristics of Project Area

The present ecological study in the project area of Pauk HE Project was undertaken with the objectives of preparing a checklist of flora in the submergence area and locations where project components are proposed and its adjoining areas; listing of rare/endangered, economically important and medicinal plant species; determination of frequency, abundance and density of different vegetation components.

The field survey for all the above aspects of the ecological study pertaining to winter, premonsoon and monsoon seasons was conducted during different seasons of the year 2009 i.e. Feb, April and September, respectively. Besides the primary surveys in the catchment area of the project, we sourced our data on the floral diversity of this region from the literature cited above. The database has been pooled to present the results in terms of vegetation of submergence area, dam area and powerhouse area.

i) ***Vegetation in Submergence Area***

The submergence area is located upstream of the Chengrung hamlet area along Yarjep river. The area in the vicinity of the proposed project comprised of temperate mixed broad-leaved forest on the lower reaches, while dry temperate mixed coniferous forest in the upper reaches of the submergence area (**Plate 3.5.1.1a**). At right bank, the top canopy is represented by few tall trees like *Albizia odoratissima, Alnus nepalensis, Altingia excelsa, Castanopsis tribuloides, Cinnamomum glaucscens, Macaranga denticulata, Quercus glauca* and *Saurauia punduana*. Second storey is comprised of *Acer thomsonii, Eurya acuminata, Litsea kingii, Schefflera impressa*, etc. Understorey is occupied by few small trees and shrubs. Epiphytes are abundant, comprising of variety of fern species like *Asplenium, Drynaria, Lepisorus, Pyrrosia, Vittaria*, etc. and orchid species like *Bulbophyllum* and *Dendrobium*, etc. Climbers include species of *Clematis, Dicentra, Dioscorea, Smilax, Rubia, Stephania* etc. Herbaceous flora is represented by some terrestrial ferns, herbs and grasses. About 64 plant species of flowering plants are recorded from the submergence area (Table 3.5.1.1). Based on habit wise classification 20 are trees, 12 shrubs, 8 climbers and 23 herbs were recorded in the submergence area during survey (**Plate 3.5.1.1b,c**). Terrestrial and epiphytic ferns are few like *Pteris subquinata*, *Pteridium aquilinum*, *Selaginella indica*, etc (Table 3.5.1.2) (**Plate 3.5.1.1d**).

Table 3.5.1.1 List of flowering plants in Submergence area

Species	Local name	Family
Trees		
Actinodaphne obovata	Pajihuta	Lauraceae
Albizia odoratissima	Kalo Siris	Mimosaceae
Alnus nepalensis	Utis	Betulaceae
Altingia excelsa	Singri	Hamamelidaceae
Brassiopsis aculeata	-	Araliaceae
Castanopsis indica	1Hinguri	Fagaceae
C. tribuloides	Musre Katus	Fagaceae
Cinnamomum glaucescens	Gonsoroi	Lauraceae
Dysoxylum excelsum	Lahasune	Meliaceae
Eurya acuminata	Murmura	Theaceae
Exbucklandia populnea	-	Hamamlidiaceae
Ficus semicordata	-	Moraceae
F. oligodon	-	Moraceae
Macaranga denticulata	Malata	Euphorbiaceae
Milletia pulchra	-	Papilionaceae
Pinus wallichiana	Blue Pine	Pinaceae
Rhus chinensis	Bhakimilo	Anacardiaceae
Saurauia punduana	Paniposala	Actinidiaceae
Schefflera impressa	-	Araliaceae
Sloanea tomentosa	-	Elaeocarpaceae
Shrubs		
Aconogonum molle	Thothney	Polygonaceae
Arditia thyrsiflora	-	Myrsinaceae
Boehmeria macrophila	Kamli	Urticaceae
Buddleja asiatica	-	Loganiaceae
Debregeasia longifolia	Tusare	Urticaceae
Leea asiatica	-	Leeaceae
Maesa chisia	-	Myrsinaceae
Melocalamus compactiflorus	Daral	Poaceae

Neillia thyrsiflora	-	Rosaceae
Oxyspora paniculata	-	Melastomataceae
Rubus ellipticus	Hisalu	Rosaceae
R. burkillii	-	Rosaceae
R. niveus	-	Rosaceae
Climbers		
Clematis gouriana	-	Ranuncuaceae
Dioscorea bulbifera	-	Dioscoreaceae
Hedera nepalensis	-	Araliaceae
Rhaphidophora decursiva	-	Araceae
Rubia sikkimensis	-	Rubiaceae
Smilax aspera	-	Smilacaceae
Stephania glandulifera	-	Menispermaceae
Tetrastigma obovatum	-	Vitaceae
Herbs		
Anaphalis busua	-	Asteraceae
Anemone vitifolia	-	Ranunculaceae
Begonia nepalensis	-	Begoniaceae
Capillipedium assimile	-	Poaceae
Carex cruciata	-	Cyperaceae
C. filicina	-	Cyperaceae
Commelina benghalensis	-	Commelinaceae
Dicentra scandens	-	Fumariaceae
Elatine ambigua	-	Elatinaceae
Elatostema platyphyllum	-	Urticaceae
Gerardinia diversifolia	-	Urticaceae
Hedychium spicatum	-	Zingiberaceae
Hydrocotyle nepalensis	-	Apiaceae
Lecanthus peduncularis	-	Urticaceae
Molineria capitulata	-	Hypoxidaceae
Musa balbisiana	-	Musaceae
Oxalis corniculata	-	Oxalidaceae
Persicaria chinensis	-	Polygonaceae
Pilea umbrosa	-	Urticaceae
Pollia hasskarlii	-	Commelinaceae

Saccharum rufipilum	-	Poaceae
Setaria palmifolia	-	Poaceae
Urtica parviflora	-	Urticaceae

Table 3.5.1.2 Some of the common terrestrial pteridophytes of submergence area of Pauk HE Project

Sl.No.	Species	Family	Habit	Altitude (m)
1.	*Equisetum diffusum*	Equisetaceae	herb	Up to 3000
2.	*E. ramosissimum*	Equisetaceae	herb	up to 3000
3.	*Selaginella indica*	Selaginellaceae	herb	1000-2800
5.	*Alsophila spinulosa*	Cyatheaceae	herb	Up to 1500
7.	*Lygodium salcifolium*	Lygodiaceae	herb	Up to 2000
8	*Adiantum lunulatum*	Adiantaceae	herb	up to 1500
9.	*Pteris subquinata*	Pteridaceae	herb	1000-1500
10.	*Ptridium aquilinum*	Pteridiaceae	herb	Up to 2000

ii) *Vegetation around dam site*

Vegetation in the vicinity of the dam site is patchy and consists of wet temperate broad-leaved forest at lower reaches. Some trees of dry pine (*Pinus wallichiana*) can be seen on mid and upper reaches. On the right bank, the tree layer is represented by few tree species viz., *Actinodaphne obovata*, *Albizia odoratissima*, *Alnus nepalensis*, *Altingia excelsa*, *Brassiopsis aculeata*, *Cinnamomum glaucescens*, *Ficus semicordata*, *Macaranga denticulata*, *Quercus glauca*, *Saurauia punduana* and *Sloanea tomentosa*. Understorey is represented by some small trees and shrubs. *Aconogonum molle*, *Boehmeria macrophylla*, *Debregeasia longifolia*, *Leucosceptrum canum*, *Maesa chisia*, *Melocalamus compactiflorus* and *Rubus ellipticus* are common shrubs. Climbers and epiphytes are not common. *Cuscuta reflexa*, *Parthenocissus thomsonii*, *Rhaphidophora decursiva*, *Rubia sikkimensis*, *Stephania glandulifera*, etc are some twiners. Among herbs are *Artemisia nilagirica*, *Begonia nepalensis*, *Commelina benghalensis*, *Coniogramme caudata*, *Elatine ambigua*, *Equisetum ramosssimum*, *Hedychium spicatum*, *Imperata cylindrica*, *Pollia hasskarliii*, *Saccharum longisetosum*, and *Thysanolaena latifolia*.

The left bank has a more dense forest in the lower reaches compared to the right bank. The dominant tree species include *Albizia odoratissima, Alnus nepalensis, Cinnamomum glaucescens, Macaranga denticulata* and *Saurauia punduana*.

iii) ***Power House site***

A surface powerhouse has been proposed on the left bank of river Yarjep near Purying Basti. An open degraded sub-tropical mixed forest occurs in the vicinity of the project area (**Plate 3.5.1.2**). The important tree associates in the vicinity include *Albizia odoratissima, Alnus nepalensis, Altingia excelsa, Brassiopsis aculeata, Celtis tetrandra, Engelhardtia spicata, Juglans regia, Macaranga denticulata* and *Rhus chinesis*. The next storey consists of few small trees and shrubs. *Bambusa tulda, Boehmeria macrophylla, Brassiopsis griffithii, Chromolaena odoratum, Debregeasia longifolia, Ficus oligodon, Leea asiatica, Rubus ellipticus,* etc are common in the understorey. Climbers and epiphytes are not common. *Cissus repens, Melocalamus compactiflora, Piper pedicellatum, Raphidophora decursiva, Tetrastigma obovata, Smilax aspera,* etc. are important twiners. Epiphytes are mostly represented by many species of fern and orchid species like *Bulbophyllum, Cymbidium, Dendrobium,* etc. The epiphytic ferns are represented by species of *Colysis, Lepisorus, Pyrrotia, Vittaria,* etc. The ground floor is occupied by seasonal herbs and grasses like *Achyranthes aspera, Artemisia nilagirica, Capillipedium assimile, Commelina benghalensis, Hedychium spicatum, Oplismenus compositus, Persicaria capitata, Pilea umbrosa, Saccharum longisetosum* and *Thysanolaena latifolia*.

3.5.1.5 Community Structure

Community is an assemblage of organisms living in a particular area or physical habitat or it is an aggregation of organisms which form a distinct ecological unit. Before going to expel any idea related to numerical strength of the species in the community, it is prerequisite to understand the community quantitatively. Thus the phytosociological data gives an idea about the numerical strength of the species in a particular community. During our surveys (January, 2008 to Sept., 2008) two sites viz., dam site and powerhouse site were selected for vegetation structure study on the basis of the presence of forest patches in the area. For sampling of various strata of vegetation, Nested Quadrat Sampling method was followed.

i) ***Density and Basal area***

The maximum number of tree species was recorded at dam site (V1) as compared to powerhouse site (Table 3.5.1.3). Similarily, the herb layer was poor in both the sites and seasons except in monsoon at powerhouse site (Table 3.5.1.4). Table 3.5.1.5 gives the number of herb species occurring on each site in different seasons.

On the dam site (Chengrung, right bank of Yarjep River), the tree strata was dominated by *Albizia odoratissima* having maximum density (80 trees/ha) and frequency (60%). The associated species in the tree canopy were *Sloanea tomentosa, Saurauia punduana, Ficus semicordata, F. oligodon, Dysoxylum excelsusm, Quercus glauca, Alnus nepalensis, Macaranga denticulata, Brassiopsis aculeata* and *Actinodaphne obovata*. In the sapling layer *Saurauia punduana, Schefflera impressa, Ficus oligodon* and *Dysoxylum excelsum* were present. *Elatostema sessile* was found as the most dominant shrub species with high density in the shrub layer. The dominance of *Elatostema sessile* may be due to its non palatable nature and capability to grow in the shaded areas. Other competing species in the understorey were *Melocalamus compactiflorus, Boehmeria macrophylla, Strobilanthes extensa, Maesa chisia, Oxyspora paniculata, Neillia thyrsiflora, Aconogonum molle* and *Alphonsea spinulosa* (Table 3.5.1.3). The complete absence of seedlings of all dominant tree species in a forest is attributed to high human encroachment and shade in the area.

At the power house site (Purying, left bank of Yarjep River), the tree and sapling strata were dominated by *Engelhardtia spicata* having maximum density and frequency. The associated species in the layer were *Brassiopsis aculeata, Celtis tetrandra, Ficus semicordata, Rhus chinensis, Xylosma longifolium, Viburnum cylindricum, Alnus nepalensis, Albizia odoratissima* and *Pinus wallichiana*. In the shrub layer *Maesa chisia* was found as most dominant species with high density. Other competing species in the understorey were *Ardisia khasiana, Leucosceptrum canum, Pentapanax leschenaultii, Oxyspora paniculata, Arenga sacchrifera, Rubus burkilii, Debrgeasia longifolia, Rubus ellipticus* and *Zanthoxylum acanthopodium* (Table 3.5.1.3).

Total tree density ranged from 300 trees/ha (at power house site) to 370 trees/ha (dam site). The sapling density was higher (1000 plants/ha) in power house site as compared to the dam site (560 plants/ha). The total density of shrubs varied from 1920 to 3480 individuals ha^{-1}. It was comparatively higher in the dam site (3480 individual ha^{-1}) as compared to power house site. The maximum individual shrub density was recorded for *Elatostema sessile* (1200 individual ha^{-1}), while minimum values were recorded for *Aconogonum molle* and *Alphonea spinulosa* at the dam site and *Zanthoxylum acanthopodium* (40 individual ha^{-1}) at power house site, respectively (Table 3.5.1.3).

The total basal cover ranged from 72.247 m^2/ha on power house site to 246.805 m^2/ha on dam site. The lowest mean basal area was recorded for *Actinodaphne obovata* (0.0778 m^2/tree) at the dam site, whereas the highest was recorded for *Albizia odoratissima* (1.447m^2/ tree) at the same site. *Engelhardtia spicata* was the single dominant tree species at the power house site with an IVI of 101.081. Similarily, *Albizia odoratissima* was the dominant species at the dam site with an IVI of 91.624 (Table 3.5.3).

Among herbs, on proposed dam site, *Carex cruciata* was the dominant species having maximum density (25000 plants/ha) during winter. It was followed by *Oplismenus compositus* (23000 plants/ha) and *Lecanthus peduncularis* (20000 plants/ha). *Oplismenus compositus* was the dominant species (24000 plants/ha) during premonsoon and *Elatostema platyphyllum* was dominant species (37000 plants/ha) during monsoon (Table 3.5.1.4). As per IVI value, *Gerardinia diversifolia* was the dominant species (75.740) during winter (Table 3.5.1.4). *Oplismenus compositus* was the dominant species (76.804) during premonsoon. The lowest IVI of 2.800 was recorded in *Oxalis corniculata* during monsoon.

At power house site, *Capillipedium assimile* was the dominant species having maximum density (68000 plants/ha) during winter. It was followed by *Imperata cylindrica* (40000 plants/ha), *Artemisia nilagirica* (34000 plants/ha) and *Isachne albens* (20000 plants/ha). *Hydrocotyle nepalensis* (78000 plants/ha) was the dominant species during monsoon (Table 3.5.4). Maximum value of IVI was observed in *Artemisia nilagirica* (114.446) followed by *Capillipedium assimile* (59.764) and *Imperata cylindrica* (25.038) during winter. *Thysanolaena latifolia* was the dominant species (74.596) during monsoon. The minimum IVI of 1.871 was noted for *Pimpinella diversifolia* during monsoon.

ii) ***Species Diversity***

The species diversity (H) in the tree stratum ranged from 1.967 (power house site) to 2.210 (dam site). The species diversity for sapling and shrub strata ranged from 0.944 to 1.277 and 1.691

to 2.019, respectively (Table 3.5.1.6). The diversity for tree layer decreased from dam site (right bank) to power house (left bank). The shrub species richness and diversity was higher at the power house site as compared to the dam site. The herb species diversity weas also higher at the powerhouse site (Table 3.5.1.6).

Table 3.5.1.3 Various ecological attributes of woody vegetation in Pauk HE Project

	Species	Frequency (F%)	Density(ha^{-1})	TBC(m^2ha^{-1})	IVI
	Trees				
V1 Dam site (Chengrung, right bank of Yarjep) 1525m					
1	*Sauarauia punduana*	40	50	26.909	39.801
2	*Alnus nepalensis*	10	10	9.499	10.397
3	*Dysoxylum excelsum*	30	30	29.016	31.403
4	*Albizia odoratissima*	60	80	115.813	91.624
5	*Brassiopsis aculeate*	10	10	2.826	7.694
6	*Sloanea tomentosa*	20	70	30.091	38.803
7	*Ficus oligodon*	30	30	4.769	21.579
8	*Schefflera impressa*	10	10	0.855	6.895
9	*Macaranga denticulate*	10	10	4.069	8.198
10	*Quercus glauca*	10	20	10.686	13.581
11	*Actinodaphne obovata*	10	10	0.779	6.864
12	*Ficus semicordata*	20	40	11.493	23.160
		260	370	246.805	
	Sapling				
1	*Schefflera impressa*	40	160	5.024	103.868
2	*Ficus oligodon*	20	80	3.925	60.611
3	*Saurauia punduana*	20	240	6.104	102.565
4	*Dysoxylum excelsum*	10	80	1.231	32.956
		90	560	16.284	
	Shrubs				
1	*Elatostema sessile*	30	1200	10.386	83.158
2	*Boehmeria macrophylla*	40	680	7.687	63.656
3	*Melocalamus compactiflorus*	20	800	0.393	33.404

4	*Aconogonum molle*	10	40	0.359	6.908
5	*Alphonsea spinulosa*	10	40	2.921	15.550
6	*Oxyspora paniculata*	20	80	1.608	16.814
7	*Maesa chisia*	40	160	1.809	28.882
8	*Strobilanthes extensa*	40	400	3.799	42.495
9	*Neillia thyrsiflora*	10	80	0.679	9.136
		220	3480	29.640	
V2 Powerhouse site(Purying,left bank of Yarjep)1320m					
	Trees				
1	*Brassiopsis aculeate*	30	40	13.886	47.553
2	*Celtis tetrandra*	30	40	3.419	33.066
3	*Engelhardtia spicata*	60	110	24.864	101.081
4	*Alnus nepalensis*	10	10	0.794	9.432
5	*Albizia odoratissima*	10	10	0.804	9.446
6	*Ficus semicordata*	10	20	19.694	38.926
7	*Rhus chinensis*	10	20	2.035	14.483
8	*Xylosma longifolium*	20	20	2.267	19.805
9	*Viburnum cylindricum*	10	20	1.658	13.962
10	*Pinus wallichiana*	10	10	2.826	12.245
		200	300	72.247	
	Saplings				
1	*Engelhardtia spicata*	50	560	8.616	136.811
2	*Macaranga denticulate*	60	320	6.271	110.490
3	*Saurauia punduana*	10	120	7.124	52.698
		120	1000	22.011	
	Shrubs				
1	*Pentapanax leschenaultia*	10	160	4.299	21.080
2	*Rubus burkillii*	10	80	0.831	10.876
3	*Leucosceptrum canum*	30	280	13.738	54.289
4	*Ardisia khasiana*	40	360	3.235	45.435
5	*Arenga saccharifera*	10	120	9.288	27.683
6	*Maesa chisia*	50	560	19.944	90.204
7	*Zanthoxylum acanthopodium*	10	40	0.804	8.746

8	*Debregeasia longifolia*	10	80	0.981	11.138
9	*Oxyspora paniculata*	10	160	1.809	16.745
10	*Rubus ellipticus*	10	80	2.512	13.803
		190	1920	57.440	

TBC = Total basal cover; IVI = Importance value Index

Table 3.5.1.4 Various ecological attributes of herbaceous vegetation in Pauk HE Project

Species	Winter		Premonsson		Monsoon	
	Density	IVI	Density	IVI	Density	IVI
V1 Dam site (Chengrung, right bank of Yarjep) 1525m						
Oplismenus compositus	23000	45.406	24000	76.804	-	-
Carex cruciata	25000	52.136	-	-	-	-
Lecanthus peduncularis	20000	65.511	-	-	-	-
Pollia subumbellata	3000	20.954	-	-	-	-
Urtica parviflora	5000	40.242	-	-	-	-
Gerardinia diversifolia	2000	75.740	-	-	-	-
Elatostema platyphyllum	-	-	10000	46.176	37000	43.413
Pteris wallichiana	-	-	2000	18.343	2000	3.967
Molineria capitulata	-	-	1000	42.506	2000	9.418
Carex filicina	-	-	5000	26.256	-	-
Lecanthus peduncularis	-	-	10000	29.269	6000	8.288
Pollia hasskarlii	-	-	4000	28.994	15000	30.112
Urtica parviflora	-	-	3000	18.830	5000	8.671
Commelina benghalensis	-	-	2000	12.814	-	-
Pilea umbrosa	-	-	-	-	23000	24.104
Crassocephalum crepedioides	-	-	-	-	2000	6.348
Dicentra scandens	-	-	-	-	1000	2.810
Setaria palmifolia	-	-	-	-	4000	4.857
Persicaria chinensis	-	-	-	-	6000	11.353
Commelina paludosa	-	-	-	-	20000	21.053
Equisetum ramossimum	-	-	-	-	15000	20.808
Solanum nigrum	-	-	-	-	1000	3.073
Impatiens chinensis	-	-	-	-	6000	10.827

I. violaeflora	-	-	-	-	4000	5.021
Musa balbisiana	-	-	-	-	2000	76.470
Begonia nepalensis	-	-	-	-	2000	6.606
Oxalis corniculata	-	-	-	-	1000	2.800
V2 Powerhouse site(Purying, left bank of Yarjep) 1320m						
Drymaria diandra	10000	9.131	4000	5.825	-	-
Oplismenus compositus	4000	6.167	14000	12.704	-	-
Persicaria capitata	2000	5.070	14000	15.291	24000	11.576
Girardinia diversifolia	1000	4.953	-	-	-	-
Carex longipes	5000	10.708	2000	4.958	-	-
Achyranthes aspera	4000	6.533	5000	10.671	-	-
Lecanthus peduncularis	6000	7.362	-	-	-	-
Molineria capitulata	3000	16.194	2000	21.274	-	-
Isachne albens	20000	14.519	24000	21.879	-	-
Artemisia nilagirica	34000	114.446	20000	84.885	22000	27.515
Capillipedium assimile	68000	59.764	38000	39.818	50000	18.414
Elsholtzia strobilifera	4000	10.784	-	-	-	-
Senecio scandens	3000	9.331	3000	14.112	-	-
Imperata cylindrica	40000	25.038	20000	15.802	-	-
Urena lobata	-	-	5000	12.011	14000	15.321
Mimosa pudica	-	-	4000	5.825	14000	7.046
Arthraxon lancifolius	-	-	12000	13.904	-	-
Hydrocotyle nepalensis			12000	10.578	78000	30.564
Fimbristylis dichotoma	-	-	2000	4.637	4000	2.790
Setaria glauca	-	-	4000	5.825	5000	4.557
Bidens bipinnata	-	-	-	-	14000	13.545
Kyllinga brevifolia	-	-	-	-	28000	13.902
Pimpinella diversifolia	-	-	-	-	1000	1.871
Carex filicina	-	-	-	-	16000	14.789
Commelina benghalensis	-	-	-	-	6000	5.578
Arthraxon hispidus	-	-	-	-	37000	16.330
Melilotus indica	-	-	-	-	60000	18.992
Lespedeza juncea	-	-	-	-	6000	3.786
Impatiens chinensis	-	-	-	-	1000	2.340

Digitaria ciliaris	-	-	-	-	4000	2.693
Nepeta ciliaris	-	-	-	-	10000	5.594
Arenaria neelgheriensis	-	-	-	-	10000	4.144
Desmodium caudatum	-	-	-	-	4000	6.187
Athyrium sp.	-	-	-	-	4000	2.827
Hedychium spicatum	-	-	-	-	2000	4.395
Fagopyrum esculentum	-	-	-	-	4000	3.190
Murdania divergens	-	-	-	-	1000	1.875
Pilea umbrosa	-	-	-	-	2000	2.207
Thysanolaena latifolia	-	-	-	-	70000	74.596

Table 3.5.1.5 Number of herb species encountered on two project sites in different seasons

Seasons	No. of species	
	Site V1	Site V2
Winter	6	14
Premonsoon	9	17
Monsoon	19	27

Table 3.5.1.6 Species Diversity Indices (H) for different vegetation components at different sampling sites in Pauk HE Project

Vegetation component	Shannon's Index (H)		
	Winter	Premonsoon	Monsoon
Dam site (Chengrung, right bank of Yarjep)			
Trees	2.210	2.210	2.210
Saplings	1.277	1.277	1.277
Shrubs	1.691	1.691	1.691
Herbs	0.469	1.783	2.406
Power House site			
Trees	1.967	1.967	1.967
Saplings	0.944	0.944	0.944
Shrubs	2.019	2.019	2.019
Herbs	1.981	2.474	2.983

iii) *Plant Biodiversity*

A total of 93 species of plants were recorded under the ecological investigation during different sampling seasons. Out of which 18 were trees, 17 shrubs and 58 herbs. The ground vegetation comprised of ephemeral, annual and perennial species of grasses, sedges, legumes and non legume forbs.

iv) *Lower Plant Diversity (Cryptogams)*

Cryptogamic flora of Arunachal Pradesh is very rich with a diverse species composition. However, studies on this component of the flora are largely lacking. As many as 54 species of algae belonging to 23 genera have been reported from the area. The lichen flora of Arunachal Pradesh is also rich in species composition with nearly 331 species of lichens belonging to 72 genera and 41 families. Pteridophytes are important constituents of the vegetation of Arunachal Pradesh (Plate 3.5.1.3). The Botanical Survey of India has recorded about 452 species of fern and fern allies from Arunachal Pradesh Himalaya.

v) *Taxonomic diversity*

The proposed Pauk HE. Project area extends from Purying to Chengrung village. Out of the total number of about 17000 flowering plant species estimated to occur in India about 4,156 species of flowering plants are reported from Arunachal Pradesh Himalaya (Mudgal & Hajra, 1999; BSI, 2006). Nearly 340 species of angiosperms have been recorded in the free deraining catchment of Pauk H.E. Project encompassing the valleys of Yarjep River and its major tributaries i.e. Purying and Rego Nalas. These species belong to 240 genera and 79 families. Out of 79 families represented in the area, 63 are dicots and 16 are monocots. The dicotyledons are represented by 240 plant species belonging to 170 genera, while the monocotyledons are represented by 70 genera and 100 species. Gymnosperms are represented by 3 families, 3 genera and 3 species. The ratio of monocot to dicot species is 1:2.4 (100 monocots and 240 dicots). For monocots, family to genera, family to species and genera to species ratios are 1: 4.37, 1: 6.25 and 1: 1.42, respectively. The genus to species ratio for this region is around 1: 1.42 which is not too far from that of Arunachal Pradesh (1:3.17) (BSI, 2006). However, this ratio is much less in comparison to the corresponding ratio of 1:13 for the world and 1: 6 for India (Raizada and Saxena, 1978; Mudgal & Hajra, 1999). This result confirms the general view that within the same floral region flora of smaller areas has lower genus-species ratio.

Poaceae with 31 genera and 46 species and Asteraceae with 19 genera and 26 species are the largest families of monocots and dicots, respectively. Among Gymnosperms, Pinaceae is the dominant family represented by 2 genera and 2 species. The dominant genera represented by 5 or more species in the catchment area are *Rubus* (5), *Carex* (6) and *Cyperus* (6). Many of these species were observed during our field visits conducted between February, 2009, Apr., 2009 and Aug., 2009. Besides the primary surveys in the catchment area of the project, we sourced our data on the floral diversity of this region from the literature cited above.

vi) ***Rarity and Endemism***

As per IUCN red list, *Cephalotaxus griffithii* is a single "near threatened" plant species noticed in the influence area of the project (Fig. 3.5.1.4). However, there are around 4 species of flowering plants from low hills (in the altitudinal range of 300-1500 m elevation) of the state that have entered the Red Data Book of Indian Plants (Nayar and Sastry (1987, 1988 and 1990)(Table 3.5.7). Since the project falls within this altitudinal range there is possibility that some of these species may be present in the project area though they were not encountered during field sampling and survey.

Table3.5.1.7 Rare, vulnerable, endangered and endemic plants of low hills likely to be found in the Pauk HE project area

Species	Family	Altitude	Habit	Status (m)
Cephalotaxus griffithii	Cephalotaxaceae	1800-2000	Tree	Low Risk/ Near Threatened
Cymbidium eburnum	Orchidaceae	1000-1500	Herb	Vulnerable
Paphiopedilum fairrienum	Orchidaceae	1400-2000	Herb	Endangered
Psychotria aborensis	Rubiaceae	300-1200	Shrub	Endangered/Endemic
Xanthophyllum burkillii	Xanthophyllaceae	800-1400	Tree	Rare/Endemic

vii) ***Epiphytes***

Epiphytes are often attached to the trunks and branches of trees. Angiospermic epiphytes in the project area mostly belong to the families Orchidaceae and Araliaceae. A few epiphytic orchids belonging to the genera *Bulbophyllum, Cymbidium, Dendrobium,* etc. were observed on trees in the project area. Among epiphytic ferns are *Colysis pedunculata, Lepisorus nudus, Polypodioides wattii,* *Pyrrosia nuda*, *Vittaria* sp., etc. In addition to these, a large number of non vascular epiphytes such as a variety of mosses and lichens are also seen growing luxuriantly on the barks of many trees in the forests.

viii) ***Parasitic Flora***

During the field surveys in different areas of the proposed Pauk HE Project, a few parasitic plant species were observed belonging to the families Cuscutaceae and Loranthaceae. *Cuscuta reflexa* (Cuscutaceaae) was found growing on a wide range of hosts in the area such as, *Chromolaena odoratum, Eurya acuminata* and *Maesa chisia*, while *Scurrulla elata* was found growing on *Ficus semicordata* in the project area.

ix) ***Physiognomic Diversity***

The diversity of vegetation in the project sites at Chengrung and its adjacent areas was assessed in terms of the physiognomy of its floral elements. Some of the families that showed diverse habit forms of trees, shrubs and climbers include Rosaceae and Euphorbiaceae. Rosaceae, for example, was represented by *Potentilla nepalensis* (herb), *Rubus ellipticus* (shrub), *R. niveus* (climber) and *Prunus cerasoides* (tree). On the contrary, some of the families such as Magnoliaceae, Meliaceae, Bignoniaceae, Lauraceae, Betulaceae, Fagaceae, Pinaceae, etc. were represented by tree species only. Hydrangeaceae, Leeaceae, Caprifoliaceae, Myrsinaceae and Araliaceae are some of the families which were mostly comprised of shrubby species. Members of Menispermaceae, Cucurbitaceae, Vitaceae, Dioscoreaceae and Smilacaceae exclusively comprised of climbers. Herbaceous species formed the bulk of flora (59.47%) followed by shrubs (17.78%), trees (17.49%), climbers (5.53%) and stem parasites (0.58%).

Predominance of herbaceous species at the lower altitudes indicates that the biotic pressure has been responsible for arresting woodland formation. The ecosystems in the entire valley are highly disturbed due to anthropogenic activities like conversion of forests into agricultural fields (Jhuming), collection of fodder and firewood by local inhabitants, road construction and hydro-power projects activities. These activities result in the formation of degraded and secondary forests in the region.

x) *Phytogeography*

The floral elements in Pauk project area were analysed for their floristic similarities with other regions of the world and to find out the nature and composition of the flora. Clarke (1889) suggested that Eastern Himalaya and Assam are distinct sub areas based on his studies on the distribution of the family Cyperaceae. Hooker (1906) in his botanical divisions of India treated Eastern Himalaya as a separate area and merged parts of Assam, Shillong plateau, Naga and Manipur hills with Myanmar. Rao (1974) described close affinities between the flora of Assam and Myanmar and treated them as a part of the Eastern border lands. Takhtajan (1986) placed Arunachal Pradesh in the Eastern Himalayan Province within Eastern Asiatic region of Boreal sub-kingdom along with parts of Eastern Nepal in the west up to Kali river valley, Darjeeling, Sikkim, Bhutan, large parts of Assam Himalaya, certain south and southern parts of Tibet.

The flora of Arunachal Pradesh has close affinities with tropical South-East Asian-Malayan, temperate Himalayan-Chinese and Japanese floras and has some elements common with peninsular India, Sri Lanka, Tibet and Euro-Siberian region. Floral elements from South East Asian region, which include Myanmar, Thailand, Indo-China, Indonesia and Malaysia, were found in the subtropical forests of the proposed project area. These include many trees, shrubs and climbers such as *Brassiopsis aculeata, Engelhardtia spicata, Oroxylum indicum,* etc. Himalayan - Chinese-Japanese elements such as *Lyonia ovalifolia, Litsea sericea, Quercus* spp. are quite common in this region. There are some Pan Himalayan taxa distributed from NW to East Himalaya but absent from China and Japan are *Pandanus nepalensis, Potentilla nepalensis, Rhus chinensis* and *Tsuga dumosa*. The European and Mediterranean elements are represented by the species of *Anemone, Artemisia, Ranunculus,* etc. The New World elements are represented by weeds of cultivated lands, open forest areas and waste places such as *Ageratum conyzoides, Bidens bipinnata* and *Chromolaena odoratum*.

xi) *Economically Important Plants*

Arunachal abounds in many economically important plant resources. The majority of the population in the state is tribal and totally dependent on the forest. They use various wild plants in their daily life as food, medicine, fiber, fodder, fuel wood and timber and to some extent horticultural purposes. The usage of various plant species by the local tribes varies with the altitude and availability of resources in the surrounding areas. A comprehensive account of these plant resources is given below:

Medicinal Plants

The people inhabiting this remote state with their ingenious skills and close association with plants have accumulated knowledge related to the utilization of plants surrounding their settlements. Some of the important medicinal plants like *Achyranthes aspera, Acorus calamus, Artemisia nilagirica, Bergenia ciliata, Clerodendrum bracteatum, Hedychium spicatum, Molineria capitulata* and *Viola betonicifolia* are quite common in the sub-tropical parts of proposed project area. *Cephaloptaxus griffithii, Clematis montana, Lyonia ovalifolia, Prunus cerasoides, Thalictrum foliolosum,* etc. are important medicinal plants occurring in the temperate areas. The list of some medicinally important plant species found in the project area is given in Table 3.5.8.

Table 3.5.1.8 Some important medicinal plants of project area

Sl. No.	Bot. name	Family	Vern./ Local	Altitude (m)	Part/s used
1.	*Achyranthes aspera*	Amaranthaceae	Chir-chita	Up to 2400	whole plant
2.	*Acorus calamus*	Acoraceae	Kilatolyo	1600-2000	Rhizome
3.	*Artemisia nilagirica*	Asteraceae	Tite pati	Up to 1800	Twigs
4.	*Bergenia ciliata*	Saxifragaceae	Pasanved	Up to 1600	Tuber
5.	*Centella asiatica*	Apiaceae	Brahmi	900- 2400	Whole plant
7.	*Cuscuta reflexa*	Cuscutaceae	AkasBel	Up to 1600	Stem
8	*Hedychium spicatum*	Zingiberaceae	Ruksana	600-1600	Roots
9	*Lyonia ovalifolia*	Ericaceae	Angeri	1400-2500	Leaf
10	*Molineria capitulata*	Hypoxidaceae	-	Up to 1500	Roots
11	*Polygonatum oppositifolium*	Liliaceae	-	Up to 1600	Whole plant
12	*Zanthoxylum acanthopodium*	Rutaceae	Yokhung	Up to 1800	Whole plant

Food Plants

The important crops of the region are finger millets, rice, maize, potato etc. Many wild vegetables and fruits are also consumed locally. Among the wild edible plants consumed are the leaves and young twigs of *Aconogonum molle, Amaranthus spinosus, Fagopyrum esculentum, Girardinia diversifolia, Rumex nepalensis,* etc. The tubers and rhizomes of *Colocasia esculenta* and *Dioscorea bulbifera* are commonly consumed as vegetables. Fruits of *Prunus cerasoides, Rubus ellipticus, Saurauia punduana,* etc. are eaten after ripening.

Fodder Plants

The human population of the area depends essentially on naturally growing trees, shrubs, herbs and grasses for the fodder requirements of their cattle and livestock. Some fodder trees like *Celtis tetrandra, Ficus auriculata, Morus laevigata* and *Quercus glauca* are grown as fodder plants in the proposed project area. In addition to these, there are many herbs and shrubs viz., *Capillipedium assimile*, *Digitaria ciliaris*, *Eleusine coracana*, *Oryza sativa*, *Setaria palmifolia*, *Thamnocalamus spathiflorus*, etc that are also used for this purpose.

Timber Trees and Fuelwood

The wood used for timber include *Altingia excelsa* (Jutli), *Castanopsis indica* (Hingori), *Pinus wallichiana* (Blue pine), *Quercus lamellosa* (Aule Katus), *Schima wallichii* (Chilone), *Tsuga dumosa*, etc. (**Plate 3.5.1.5**). In addition to these trees, some woody bamboos such as *Thamnocalamus spathiflorus* are also used for this purpose.

Miscellaneous uses

The local inhabitants make use of many plant species for various purposes. A list of some commonly occurring plant species and their miscellaneous uses are given in Table 3.5.9.

Table 3.5.9 List of some common useful plant species of the project area

Sl.No.	Plant species	Miscellaneous uses
1	*Brassiopsis aculeata*	Leaves of plants are used to feed domestic animals.
2	*Calamus erectus*	Stems are durable and used for furniture making.
3	*Colocasia esculenta*	Tubers of this plant are cooked as vegetables.
4	*Eleusine coracana*	Cultivated for seeds in Jhum areas.
5	*Hedychium spicatum*	Planted on pots for ornamentation purposes.
6	*Macaranga denticulata*	Foliage is used as cattle fodder.
7	*Molineria capitulata*	Ripe fruits are edible
8	*Pinus wallichiana*	Cones are kept houses for decoration.
9	*Rubus ellipticus*	Ripe fruits are edible.
10	*Saurauia punduana*	Ripe fruits are edible.

Plate 3.5.1.1(a) Submergence area (a panoramic view)

Plate 3.5.1.1(b) ***Elatine ambigua*** **(aquatic flowering plant from submergence area)**

Plate 3.5.1.1c ***Arditia thyrsiflora (*****flowering plant species from the near submergence area)**

Plate 3.5.1.1d. Epiphytic plants from the submergence area (mosses and pteridophytes)

Plate 3.5.1.2. Sub-tropical wet hill forest near powerhouse site

Plate 3.5.1.3 Lower plant diversity from the influence area (*Lycopodium* sp.)

Plate 3.5.1.4 Threatened plant species from the influence area (*Cephalotaxus griffithii*)

Plate 3.5.1.5 Timber yielding tree species from the influence area (*Altingia excelsa*)

3.5.2 FAUNAL ELEMENTS

3.5.2.1 General

The state of Arunachal Pradesh (83,743 km²) in North-East India is situated in the transition zone between the Himalayan and Indo-Burmese regions (Mani, 1974; Rodgers and Panwar, 1988). Arunachal Pradesh falls within the Eastern Himalaya global biodiversity hotspot (Myers *et al*., 2000) and is also among the 200 globally important ecoregions (Olson and Dinerstein, 1998). Arunachal Pradesh in India is one of the richest zones in floral and faunal diversity, in spite of the fact that a large portion of the state is unexplored due to inaccessibility, tough topography and harsh climatic conditions.

The entire state of Arunachal Pradesh including West Siang area (study area) is a unique abode of tribal populations, which are closely associated with forests, forest products and wildlife. The customary hunting in the state and fondness of tribal people towards trophies are considered to be one of the major threats to the wildlife. In recent years burgeoning developmental activities like road building, hydro-electric projects etc. also add pressure on the wildlife.

The proposed Pauk H.E. Project is located on the Yarjep River (a tributary of Siyom River) in the West Siang district of Arunachal Pradesh. Many projects on the Siang-Siyom basin are likely considered to lead immense effects on the wildlife of the basin. The catchment area of the proposed project comprises of sub-tropical wet hill forests, wet temperate broad-leaved and dry temperate coniferous forests and are known to harbour threatened faunal species especially mammals. The influence zone harbours subtropical and temperate forests and rich in biodiversity. The baseline data on faunal elements with respect to EIA of Pauk H.E. Project was collected from the catchment area, influence zone and project area.

Affinities: The Abor hills, where the proposed project is located, forms a phytogeographic node for the mingling of Chinese, Malaysian and Himalayan flora. 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.

3.5.2.2 Catchment and Influence Areas

i) *Mammals*

Mammalian fauna of the catchment and influence areas comprises of langur, macaque, cat, dog, bear, mongoose, civet, deer, gaur, bat, squirrel, marmot, rat, mice etc. The catchment is represented nearly by 26 species while influence area harbours about 27 species (Table 3.5.2.1). A total of 21 species are common in both areas. A few species like *Panthera uncia* (Snow leopard), *Muschus chrysogaster* (Musk deer), *Budorcas taxicolor* (Takin) and *Marmota himalayana* (Himalayan marmot) are restricted to the catchment area *Nycticebus coucang* (Slow loris), *Prionailurus bengalensis* (Leopard cat) and bat species are distributed in the lower reaches (up to 1500 m.). A detailed account on the diversity, distribution and conservation status of different orders is given below.

Primates

Order primate is represented by 4 species in the catchment and influence areas. Capped langur mainly inhabits the lower area of the project influence area, however, its rare presence in the catchment area has also been confirmed with the help of local people. Assamese and Rhesus macaque are found in and around the project area up to 2000 m. Slow Loris inhabit dense forest and are rarely spotted.

Conservation Status: Capped langur and Slow Loris have been categorized as Schedule I (WPA, 1972) and 'vulnerable' species (ZSI, 1994). Others are Schedule II species.

Carnivora

Carnivora is comprised of 12 species classified under 6 families. Felidae is largest family followed by Canidae (Table 3.5.2.1). *Panthera uncia* is restricted in the upper catchment while *Prionailurus bengalensis*, *Herpestes javanicus* and *Lutra lutra* are distributed in lower part (below 1500 m.) of the influence area. Presence of hides and trophies in the households indicates the common appearance of *Panthera pardus*, *Prionailurus bengalensis*, *Herpestes javanicus* and *Ursus thibetanus* in the catchment and influence areas. *Canis aureus* is also a common species, though it is rarely spotted and hunted. Some of the species like *Neofelis nebulosa*, *Cuon alpinus*, *Viverricula indica* and *Vulpes bengalensis* dwell inner part of the forest, therefore, rarely spotted by hunters.

Conservation Status: A total of 6 species of carnivore are Schedule I and 5 are Schedule II. Of the Schedule species, one is restricted to the catchment area while two in the influence area (Table 3.5.2.1). As per the criterion of ZSI (1994) 4 species are categorized as 'threatened' of which 3 are 'vulnerable' and one is 'endangered'. IUCN (2010) mentions two species under 'endangered' category and one species under 'vulnerable'.

Artiodactyla

Artiodactyla is represented by 7 species of three families (Table 3.5.2.1). Of seven species two namely *Muschus chrysogaster* and *Budorcas taxicolor* are distributed above 3000 and 2500 m, respectively. *Sus scrofa cristatus*, *Muntiacus muntjak*, *Bos frontalis* and *Nemorhaedus goral* are most common species in and around the project area, confirmed by the presence of hides, horns and trophies of these in the tribal households. These species are mostly hunted for food, and trophies. *Bos frontailis* is the most common and semi domesticated animal, slaughtered in large number at the occasion of festivals and other ceremonies.

Conservation Status: As per WPA (1972) criterion each of Schedule I and III category mentions 3 species while status of *Bos frontailis* is not assessed. Only *Capricornis sumatraensis* has been mentioned as 'Vulnerable' category while 2 are categorized under 'insufficient known' category as per ZSI criterion. In IUCN categorization *Capricornis sumatraensis* and *Budorcas taxicolor* are 'vulnerable' species while other species are 'least concerned' and 'near threatened'.

Chiroptera

Chiroptera comprises of two species namely *Cynopterus brachyotis* and *Rousettus leschenaultia*. Both species are absent in the catchment area inhabiting lower reaches of the influence area.

Conservation Status: Former species is categorized as Schedule V species while the other is considered as 'least concerned' as per IUCN criterion.

Rodentia

Rodentia in the catchment and influence area comprises of squirrels and rats. Except *Marmota himalayana* all species are common in the catchment and influence areas. Squirrels are arboreal and inhabit dense forest, while rat species are common in settlement and agricultural fields.

None of the species is ‘vulnerable’ or ‘endangered’ as per the criteria of different institutions. IUCN (2010) categorized most of the species as ‘least concerned’.

Table 3.5.2.1 Mammalian species and their conservation status in the catchment and influence areas of Pauk H.E. Project.

Scientific name	English name	WPA (1972)	ZSI (1994)	IUCN (2010)	Distribution CA	IA
Cercopithecidae						
Semnopithecus pleateus	Capped Langur	I	VU	LC	+	+
Macaca assamensis	Assames macaque	II	-	NT	+	+
M. mulatta	Rhesus macaque	II	-	LC	+	+
Loridae						
Nycticebus coucang	Slow loris	I	IK	VU	+	+
Felidae						
Panthera pardus	Common leopard	I	VU	NT	+	+
Panthera uncia	Snow leopard	I	VU	EN	+	-
Neofelis nebulosa	Clouded leopard	I	EN	VU	+	+
Prionailurus bengalensis	Leopard cat	I	VU	LC	-	+
Felis chaus	Jungle cat	II	-	LC	+	+
Canidae						
Cuon alpinus	Wild dog	II	-	EN	+	+
Canis aureus	Jackal	II	-	LC	+	+
Vulpes bengalensis	Indian fox	II	-	LC	+	+
Viverridae						
Viverricula indica	Small Indian Civet	II	-	LC	+	+
Herpestidae						
Herpestes javanicus	Small Indian mongoose	IV	-	LC	-	+
Mustelidae						
Lutra lutra	Common otter	I	-	NT	-	+
Ursidae						
Ursus thibetanus	Black bear	I	-	VU	+	+
Suidae						
Sus scrofa cristatus	Wild boar	III	IK	LC	+	+

Cervidae						
Muntiacus muntjak	Barking dear	III	-	LC	+	+
Muschus chrysogaster	Musk deer	I	-	EN	+	-
Bovidae						
Bos frontalis	Guar	-	-	-	+	+
Nemorhaedus caudatus	Goral	III	-	NT	+	+
Nemorhaedus sumatraensis	Mainland Serow	I	VU	VU	+	+
Budorcas taxicolor	Takin	I	IK	VU	+	-
Pteropodidae						
Cynopterus brachyotis	-	V	-	LC	-	+
Rousettus leschenaultia	Fulvous fruit bat	-	-	LC	-	+
Sciuridae						
Tamiops macclellandi	Himalayan stripped squi.	-		LC	+	+
Hylopetes alboniger	Particolored flying squir.	-	-	LC	+	+
Dremomys lokriah	Orange-bellied Himalayan squir		-	LC	+	+
Marmota himalayana	Himalayan marmot	-	-	LC	+	-
Belomys pearsonii	Hairy footed flying squirrel	-	-	-	+	+
Muridae						
Mus booduga	Indian field mouse	V		LC	+	+
Mus musculus	House mouse	V	-	LC	+	+
Rattus rattus	House rat	V	-	LC	+	+

LC = least concerned, NT = near threatened, VU = vulnerable, EN = endangered, IK = insufficient known

ii) *Avifauna*

More than 500 species of bird species dwell the land of Arunachal Pradesh. Avifauna comprises of Himalayan forms, southeast forms from Myanmar and western forms from Bhutan. More than 150 species are expected to inhabit the catchment area of Pauk H.E. Project, however, 75 species belonging to more than 25 families could be confirmed with the help of primary and secondary sources in the study area (Table 3.5.2.2). Generally birds are widely distributed, therefore, majority of the species are common in the catchment and influence areas.

Only *Lophophorus sclateri*, *Tragopan temminckii* and *Lerwa lerwa* are confined in the catchment area above 3000 m. while species like *Gracula religiosa* and *Picus chlorolophus* are found in the lower part of the influence area. Sylviidae and Timalidae are largest families represented by 14% and 11% of the total species. About 44.8% of the total species are sparse residents while 37.7% are widespread residents. A detailed account on the distribution pattern and conservation status of different taxa is described in the following headings. None of the species was migratory and vagrant in the study area.

Galliformes in the study area is represented by a single family Phasianidae, comprises of 4 species. Out of 4 species three (*Lophophorus sclateri*, *Tragopan temminckii*, *Lerwa lerwa*) are restricted to the upper catchment (above 3000 m) while *Lophura leucomelana* is found in the influence area. Except *Lerwa lerwa* all species are widespread residents in distribution. Three species fall under the Schedule I while IUCN red list includes three species under the 'least concerned' threat category (Table 3.5.2.2).

In the Falconiformes the presence of only 2 species belonging to family Accipitridae could be confirmed in the catchment and influence areas. *Accipiter nisus* is a sparse resident and sparse winter visitor while *Ictinaetus malayensis* is a widespread resident species. The former species are categorized as Schedule I and 'least concerned' species as per the criteria of WPA (1972) and IUCN (2010), respectively.

Only one species of hornbill (*Anthracoceros albirostris*) belonging to order Bucerotiformes could be confirmed in the study area. It is a sparse resident and categorized under Schedule I. It is the most hunted bird species in the area, hunted mainly for its unique beak used by tribes as trophy. Similarly, each of the orders Upupiformes, Coraciformes and Strigiformes are represented by a single species, none of them is threatened and Schedule I species.

Passeriformes is the largest group, accounting for 77% of the total species in the catchment and influence areas. Out of 17 families Sylviidae and Timalidae are largest accounting for 18.9% and 13.7% of the total species. About 53% of the total species are sparse residents followed by widespread residents (25.8%). A single species - *Zoothera wardii* (Pied Ground Thrush) is a sparse summer visitor in the catchment area. A total of 19 species are considered as 'least concerned' as per IUCN (2010) criterion. Besides, Beautiful Nuthatch (*Sitta formosaesi*) and *Parus nuchalis* (White-napped Tit) have been placed under the 'vulnerable' category by Birdlife International (2000).

Table 3.5.2.2 Avifaunal composition and their conservation status in the catchment and influence areas of the proposed Pauk H.E. Project

Scientific name	Common Name	Status				
		Distribution			Conservation	
		Habit	CA	IA	WPA	IUCN
Phasianidae						
Lophophorus sclateri	Scalater's monal	R	+	-	I	-
Lophura leucomelana	Kaleej pheasant	R	+	+		LC
Tragopan temminckii	Temminck's Tragopan	R	+	-	I	LC
Lerwa lerwa	Snow partridge	r	+	-	I	LC
Accipitridae						
Accipiter nisus	Northern Sparrow Hawk	rw	+	+	I	LC
Ictinaetus malayensis	Black Eagle	R				
Columbidae						
Columba hodgsoni	Speckled Wood Pigeon	r	+	+	IV	LC
Streptopelia chinensis	Spotted Dove	R	+	+	IV	-
Cuculidae						
Cuculus micropterus	Indian Cuckoo	R	+	+	IV	-
Eudynamys scolopacea	Indian Koel	R	+	+	IV	-
Bucerotidae						
Anthracoceros albirostris	Great Indian Pied Hornbill	r	+	+	I	LC
Picidae						
Picoides macei	Indian Fulvousbreasted	R	+	+	IV	-
Picus chlorolophus	Lesser Yellownape	R	-	+	IV	LC
Megalaimidae						
Megalaima virens	Great barbet	R	+	+	IV	LC
M. asiatica	Blue-throated Barbet	R	+	+	IV	LC
Upupidae						
Upupa epops	Hoopoe	R	+	+	IV	-
Meropidae						
Nyctionornis athertoni	Blue-bearded bee eater	R	-	+	IV	LC
Strigidae						
Glaucidium cuculoides	Barred Owlet	r	+	+	IV	-
Pittidae						
Pitta nipalensis	Bluenaped Pitta	r	+	+	IV	

Hirundinidae						
Hirundo rustica	Eastern Swallow	RW	+	+	IV	LC
Delichon nipalensis	Nepal House martin	r	+	+	IV	-
Corvidae						
Corvus macrorhynchos	Jungle Crow	R	+	+	IV	-
Dicrurus aeneus	Bronzed Drongo	r	+	+	IV	LC
Cissa chinensis	Green Magpie	r	+	+	IV	LC
Dendrocitta formosae	Himalayan Treepie	R	+	+	IV	LC
Sturnidae						
Gracula religiosa	Hill Myna	r	-	+	IV	LC
Pycnonotidae						
Pycnonotus jacosus	Redwhiskered Bulbul	R	+	+	IV	LC
P. leucogenys	Whitecheeked Bulbul	R	+	+	IV	-
Laniidae						
Lanius schach	Long-tailed Shrike	R	+	+	IV	-
L. tephronotus	Grey-backed Shrike	rW	+	+	IV	-
Sylviidae						
Phylloscopus proregulus	Pallas Leaf Warbler	rW	+	+	IV	LC
P. trochiloides	Greenish Leaf Warbler	rW	+	+	IV	-
P. chloronotus	Lemon-rumped Warbler	rW	+	+	IV	LC
Seicercus castaniceps	Chestnut-headed Flycatcher	r	+	+	IV	-
S. burki	Spectacled Warbler	rW	+	+	IV	-
S. xanthoschistos	Grey-hooded Warbler	rW	+	+	IV	-
Yuhinia nigrimenta	Black-chinned Yuhina	R	+	+	IV	-
Y. gularis	Striped-throated Yuhina	R	+	+	IV	-
Y. occipitalis	Rufous-vented Yuhina	r	+	+	IV	-
Heterophasia picaoides	Long-tailed Sibia	r	+	+	IV	-
Actinodura egertoni	Rusty-fronted Barwing	r	+	+	IV	-
Timaliade						
Garrulax striated	Striatus Laughing Thrush	r	+	+	IV	-
Garrulax albogularis	White-throated Laughing Thrush	R	+	+	IV	-
Alcippe castaneceps	Chestnut-headed Tit-babbler	r	+	+	IV	-
Alcippe nipalensis	Nepal Quaker Babbler	r	+	+	IV	LC
Pteruthius melanotis	Black-eared Shrike Babbler	r	+	+	IV	-
Pellorneum ruficeps	Puff-throated Babbler	r	+	+	IV	

Stachyris ruficeps	Pygmy Wren Babbler	r	+	+	IV	
S. nicriceps	Grey-throated Babbler	r	+	+	IV	
Cisticolidae						
Prinia hodsonii	Ashy Grey Wren Warbler	R	+	+	IV	-
P. criniger	Himalayan Brown Hill Warbler	R	+	+	IV	-
Turdidae						
Myophonus caeruleus	Blue Whistling Thrush	R	+	+	IV	-
Zoothera wardii	Pied Ground Thrush	s	+	+	IV	LC
Turdus albocinctus	Whitecollared Blackbird	r	+	+	IV	LC
T. boulboul	Greywinged Black Bird	r	+	+	IV	LC
Muscicapidae						
Muscicapa rubecoloides	Bluethroated Flycatcher	R	+	+	IV	-
Eumyias thalassina	Verditer Flycatcher	R	+	+	IV	-
Rhyacornis fuliginosus	Plubeous Redstart	r	+	+	IV	-
Chaimarrornis leucocephalus	White Capped Redstart	r	+	+	IV	-
Cinculus pallasii	Himalayan Brown-dipper	r	+	+	IV	-
Enicurus scouleri	Little Forktail	r	+	+	IV	-
Paridae						
Parus monticolus	Greenbacked Tit	r	+	+	IV	-
*P. nuchalis**	White napped Tit	r	+	+	IV	LC
Sittidae						
Sitta himalayensis	Himalayan Whitetailed Nuthatch	r	+	+	IV	-
*Sitta formosaes**	Beautiful Nuthatch	r	+	+	IV	-
Certhiidae						
Tichodroma muraria	Wall Creeper	rw	+	+	IV	LC
Nectariniidae						
Dicaeum ignipectus	Firebreasted Flowerpecker	r	+	+	IV	LC
Aethopyga saturate	Black-throated Sunbird	r	+	+	IV	-
Passeridae						
Passer montanus	Tree sparrow	R	+	+	IV	LC
Anthus hodgsoni	Olive-backed pipit	W	+	+	IV	-
A. godlewiskii	Blyth's Pipit	w	+	+	IV	-
Fringillidae						
Carduelis spinoides	Himalayan Greenfinch	R	+	+	IV	LC
Carpodacus rubescens	Blanford's Rosefinch	r	+	-	IV	-

C. thura femininus	Yunan Whitebrowed Rosefinch	r	+	-	IV	LC
Pyrrhoplectus epaulette	Goldheaded Black Finch	r	+	+	IV	-
Haematospiza sipahi	Scarlet Finch	r	+	-	IV	LC

R = Resident, r = Local resident, W = Widespread winter visitor, w = Sparse winter visitors, s = sparse summer visitors

iii) ***Herpetofauna: Distribution & Conservation Status***

Herpetofauna in Arunachal Pradesh is comprised of 78 species (12 families) of reptiles (Sanyal and Gayen, 2006) and 39 species (6 families) of amphibians (Sarkar and Ray, 2006). Out of the 78 species of Reptilia, 6 are common in West Siang district while out of 39 species of Amphibia only three occur in the district. Primary surveys for three seasons also indicate poor diversity of herpetofauna in the catchment and influence areas. The reported species are mainly confined in lower parts of the influence area. *Hemidactylus brookii* (reptilian) and *Bufo Himalayan* and *Rana cyanophlyctis* (Amphibia) are common herpetofaunal species of the influence area. In the snakes *Bungarus nigers* is reported near the settlement. Other species of herpetofauna includes *Ahaetulla prasinus*, *Xenochrophis piscator*, *Amphiesma stolata*, *Psammodynastes pulverulentus* and *Rana limnochari*. Among these species *Xenochrophis piscatori* (Checkered Keelback) is placed under the Schedule II, while *Rana* spp. is categorized as Schedule IV. None of the species inhabiting the catchment is threatened as per criterion of ZSI.

iv) ***Invertebrates***

Other invertebrates in the catchment and influence areas of Pauk H.E. Project comprise protozoan, crab, nematods, insects, leeches, oligochaets etc. *Giardia lamblia*, *Plasmodium vivax*, *P. falciparum Assulina muscorum* and *Eimeria* are predominant species in the study area. Crustacean fauna in the region comprises crabs only. They are dominated in lower part of the influence area. They are represented by *Carcinus* sp., *Portunus* sp. etc. Annelids in the region comprise of leeches and earthworms. The common leech species of project and catchment areas are *Haemadipsa montana*, *H. sylvestris* and *H. montivindicus* (Mandal, 2006). They are found up to 3000 m. Insecta is the largest group, comprising of more than 1000 species in Arunachal Pradesh. The important groups in the study area are Diptera, Coleoptera, Hymenoptera, Lepidoptera, Hemiptera, Odonata, Ephemeroptera, Plecoptera, Trichoptera etc. Lepidoptera is the largest group followed by Diptera. The project areas and catchment area have a good share of insect diversity. Lepidoptera comprises nearly 15 species, out of which *Pieris canidia* and *Delias aglaias* are the most common in the study area. Among the Diptera sp., *Culusium* spp., *Simulium* spp. *Limonia* spp. *Gonomyia* spp. and *Conosia irrorata* are predominant species of the catchment area. Ephemeroptera is represented abundantly by *Cynigmula* sp. *Heptagenia* spp. and *Baetis* spp. etc. Plecoptera and Trichoptera are dominated by *Perla* spp. and *Hydropsychae* spp., respectively. Hymenoptera in the catchment comprises mainly of ants and spiders. *Tiphia* spp. and *Camponotus* spp. *Solenopsis geminate, Ampules* spp. are common Hymenopterans of the region. Coleoptera are mainly represented by *Epilachna bipunctata* and *Acanthosese decipiens*.

3.5.2.3 Project Areas

i) *Mammals*

Survey team did not come across the direct sighting of mammalian species from the project component areas, however, a household survey and interaction with tribal people revealed that the project components areas are visited frequently by Common leopard (*Panthera pardus*), Black bear (*Ursus thibetanus*), Barking deer (*Muntiachus muntjak*), Wild boar (*Sus scrofa*), Assamese Macaque (*Macaca assamensis*), Serow (*Capricornis sumatraensis*), Goral (*Nemorhaedus caudatus*), and Hairy footed flying squirrel (*Belomys pearsonii*) (**Plate 3.5.2.1a, b**). After hunting, tribal inhabitants generally preserve the body parts like skull, teeth, jaws, hides, fur etc and use them as trophies, case etc.

ii) *Avifauna*

Avifauna of project component area comprises of pheasant, pigeon, dove, owlet, nap, woodpeckers, pittta, bulbul, flycatcher, redstart, dipper, thrushes, laughing thrushes, yuhina, sparrow, finches etc. A total of 31 species grouped under 15 families were found in the project component areas (Table 3.5.2.3). Sclater's Monal species was indirectly spotted during three season surveys. Sclater's Monal was spotted by the presence of its feather in a household of tribes. *Streptopelia chinensis*, *Pycnonotus jacosus*, *P. Leucogenys*, *Rhyacornis fuliginosus*, *Cinculus pallasii*, *Enicurus scouleri***,** *Yuhinia nigrimenta* and *Passer montanus* are most common species of the project area, of which *Passer montanus* (4.6 – 9.5%) and *P. leucogenys* (4.9 – 8.2%) were most abundant. All species are either widespread residents (47.5%) or sparse residents (52.3%).

Table 3.5.2.3 Species composition and distribution pattern in the avifauna of the surrounding area of the proposed Pauk H.E. Project

Scientific Name	Common Name	Distribution	Seasons W	Seasons PrM	Seasons M
Phasianidae					
Lophophorus sclateri	Sclater's Monal*	R	-	-	-
Columbidae					
Columba hodgsoni	Speckled Wood Pigeon	r	-	+	+
Streptopelia chinensis	Spotted Dove	R	+	+	+
Strigidae					
Glaucidium cuculoides	Barred Owlet	r	-	+	+
Picidae					
Picoides macei	Indian Fulvousbreasted	R	+	+	+
Picus chlorolophus	Lesser Yellownape	R	+	+	-
Pittidae					
Pitta nipalensis	Bluenaped Pitta	r	+	+	+
Pycnonotidae					
Pycnonotus jacosus	Redwhiskered Bulbul	R	+	+	+
P. leucogenys	Whitecheeked Bulbul	R	+	+	+
Timaliade					
Garrulax striated	Striatus Laughing Thrush	r	+	+	+
Garrulax albogularis	White-throated Laughing Thrush	R	-	+	-
Seicercus castaniceps	Chestnut-headed Flycatcher	r	+	+	-
Stachyris ruficeps	Pygmy Wren Babbler	r	-	+	-
Alcippe nipalensis	Nepal Quaker Babbler	r	+	+	-
Pteruthius melanotis	Black-eared Shrike Babbler	r	-	-	+
Pellorneum ruficeps	Puff-throated Babbler	r	+	+	+
Muscicapidae					
Chaimarrornis leucocephalus	White Capped Redstart	r	+	+	+
Rhyacornis fuliginosus	Plubeous Redstart	r	+	+	+
Cinculus pallasii	Himalayan Brown-dipper	r	+	+	+
Enicurus scouleri	Little Forktail	r	+	+	+
Sylviidae					
Yuhinia nigrimenta	Black-chinned Yuhina	R	+	+	+
Y. gularis	Striped-throated Yuhina	R	+	+	+
Paridae					
Parus nuchalis	White napped Tit	r	-	+	-
Passeridae					

Anthus hodgsoni	Olive-backed pipit	W	-	+	+
Passer montanus	Tree sparrow	R	+	+	+
Nectariinidae					
Dicaeum ignipectus	Firebreasted Flowerpecker				
Aethopyga saturate	Black-throated Sunbird				
Fringillidae					
Carduelis spinoides	Himalayan Greenfinch	R	-	+	+
Carpodacus rubescens	Blanford's Rosefinch	r	+	+	+
Fringilliade					
Carpodacus rubescens	Blanford's Rosefinch	r	-	-	+
Haematospiza sipahi	Scarlet Finch	r	+	+	-

R = Widespread resident, r = sparse resident, W = Widespread winter visitor, w = sparse winter visitor

* not sighted, only trophy was recorded

iii) *Butterfly*

Influence area is poor in lepidopteran diversity. Only 13 species could be located during three seasons studies, in which most of them were confined to the lower part of the influence area. The maximum diversity was observed during pre-monsoon season while in winter season only five species were observed (Table 3.5.2.4.). Indian cabbage white (*Pieris canidia*), Himalayan fivering (*Ypthima sacra sacra*), Indian red admiral (*Vanessa indica indica*), Sullied Sailer (*Neptis som*) Common sailer (*N. hylas varmona*) were the most common species of the study area. Indian cabbage white (*Pieris canidia*), Tabby and Commodore (*Limenitis danava*) were recorded from the upper area of the influence area (**Plate 3.5.2.1c,d**). Common sailer (*N. hylas varmona*) and Indian cabbage white (*Pieris canidia*) were the most common species of surroundings; they accounted for 25.3% and 19.6% in winter season, 12.8% and 8.6% in pre-monsoon season and 12.1% and 11.8% in monsoon season, respectively.

Table 3.5.2.4. Butterfly species at various sites of influence area of Pauk H.E. Project

Families/Comon name	Scientific name	Conservation status (WPA, 1972)	Seasons W	PrM	M
Papilionidae					
Redbreast	*Priceps alcmentor*	-	-	+	-
Pieridae					
Great blackvein	*Aporia agathon*	-	-	-	-
Tree yellow	*Gandaca harina assamica*	-	+	-	+

Indian cabbage white	*Pieris canidia*	-	+	+	+
Lycaenidae					
Purple sapphire	*Heliophorus epicles indicus*	-	-	+	-
Metallic cerulean	*Jamides alecto eurysaces*	II	-	+	+
Pointed line blue	*Nacaduba helicon*	-	-	+	-
Nymphalidae					
Tabby	-	-	-	+	+
Commodore	*Limenitis danava*	-	-	+	
Himalayan fivering	*Ypthima sacra sacra*	-	+	+	+
Indian red admiral	*Vanessa indica indica*	II	-	+	+
Sullied Sailer	*Neptis soma*	-	+	+	+
Common sailer	*N. hylas varmona*	-	+	+	+

3.5.2.4 Tribal Population and Biodiversity

The surrounding area of Pauk H.E. Project is inhabited by 'Adi', and its sub tribes. They are unique in culture and customs and dwell forested areas and are dependant on the forest resources for their livelihood. Hunting intensity is low in upper part of influence area of Pauk H.E. Project as compared to the influenced area of other projects like Heo, Tato I and Tato II. Hunting pressure in the area is considered to be one of the reasons of declining wildlife. Generally, Barking deer, Black bear, Chinese goral, Common leopard, Wild boar etc are hunted for the purpose of food, hides and trophies. However, we observed the body parts of other small animals like squirrels, Himalayan marten, Jungle cat, civet etc from the tribal households.

Hunting is executed in all seasons in the area and there are a number of regular hunters. However, the hunting intensity increases during the festivals, marriage ceremonies, and scarification. Licensed guns are main hunting tools of hunters, however, they also use traps and *gulel* to land the small animals and birds.

3.5.2.5 Conclusion

The influence area of Pauk H.E. Project is covered with sub tropical and temperate forests. Surrounding areas of Pauk H.E. Project house rich faunal and floral diversity. Customary hunting is considered as one of the major threats to biodiversity in the region because enforcement of forest rules is not strict in these areas because of the customary rights of the people on the forest and forest products. Tribes have a vast traditional knowledge of biodiversity and wildlife. They are well aware of food habit, shelters, and habitat preferences of wild animals. They are able to identify the species of animals especially mammals and birds with the help of their calls. The traditional knowledge of tribes could be used in formulating the appropriate biodiversity management plan. Considering the traditional knowledge of tribal population on forest and forest resources, their involvement is warranted in any strategic plan of biodiversity conservation. In addition, conservation planning would require a comprehensive awareness programme and some alternatives, which could fulfill the fondness of tribes towards the ornaments and trophies. The artificial trophies made out of fiber glass may be one of the alternatives.

(a). Tail of Hairy footed flying squirrel

(b). Head parts of Chinese goral

(c). Green Comodore (*Limenitis daraxa)*

(d). Tabby (*Pseudergolis wedah*)

Plate 3.5.2.1. Plate showing common species in the influence area of Pauk H.E. project

3.6 SOCIAL ENVIRONMENT

3.6.1 INTRODUCTION

Hydro-electric projects have significant impacts (negative as well as positive) on the local communities and are generally long term in nature. The impacts may be positive or/and negative, therefore, there are proponents as well as opponents among the communities for such activities. The baseline data on the demography, education, culture, ethnography, life standard, etc. of the inhabitants in the periphery of project would be helpful in predicting the impact of the project and in formulating the community and peripheral development plans. The developmental plan is aimed to strengthen the infrastructures in the area and to empower the communities and vulnerable groups. The mitigation measures must take the peoples aspiration and needs into account and must avoid the very adverse impacts.

Pauk H.E. Project is located in the Mechuka circle of West Siang district of Arunachal Pradesh. The influence area of the proposed project covers mainly Mechuka circle and partly Tato circle. Socio-economic profile of concerned administrative units (Arunachal Pradesh, West Siang district, Mechuka, Tato circles) is described briefly while a detailed account on the demography, education, occupation, culture, ethnography etc. of influence area, affected villages and affected families is given in the following paragraphs.

3.6.1.1 Arunachal Pradesh

Arunachal Pradesh covers an area of 83,743 sq. km and lies between latitudes 26^0 28’ to 29^0 30’ N and longitudes 91^0 30’ to 97^0 30’ E. Arunachal Pradesh is bordered by Bhutan in the west, China in the north and north-east, Myanmar in the southeast, and the Indian State of Assam in the south. Total population of Arunachal Pradesh is 13,82,611 with a sex ratio of 920 (females to 1000 males) (Census, 2011). The average population density is 16.5 persons per sq km. Average literacy in Arunachal Pradesh is 57.09% with maximum in males (69%). Administratively, Arunachal Pradesh is divided into 16 districts, namely Tawang, West Kameng, East Kameng, Papum Pare, Lower Subansiri, Upper Subansiri, West Siang, East Siang, Upper Siang, Dibang valley, Lohit, Changlang, Tirap, Lower Dibang Valley, Anjaw and Kurung-Kumey. Itanagar is the State capital of Arunachal Pradesh, which is located in Papum Pare district.

3.6.1.2 West Siang District

The proposed Pauk H.E. Project is located in the West Siang district of Arunachal Pradesh. Prior to 1970 West Siang was a part of Siang Frontier Division and was recognized as Siang district after 1971. Later on Siang district was divided into West Siang and East Siang districts. District West Siang is divided into 6 sub-divisions, 10 blocks, 20 administrative circles and 397 villages. The district headquarter of West Siang is located at Aalo. As per Census (2011) the total population of West Siang district is 1,12,272 with sex ratio of 916 (females to 1,000 males), which is marginally lower than the State average of 920. The population density of the district is 12 individuals per sq. km, nearly same as that of the State (14 person/sq km). West Siang district is one of the districts which recorded lowest decadal growth of 8%. The scheduled tribe (ST) population accounts for 81.7% of the total population in the district. The district recorded a total literacy rate of 59.47%, which is slightly higher than the state average.

3.6.1.3 Mechuka Circle

Mechuka sub-division of the West Siang district is comprised of four circles including Tato, Mechuka, Pidi and Monigong circles. The proposed project is situated in the Mechuka circle. The total population of Mechuka subdivision is 9,973 with a significantly better sex ratio of 995 compared to the district and the State averages (Census 2001). The average literacy rate in Mechuka circle is 35.8% with considerably higher rates in males (45.4%), but overall literacy in the Circle is rather significantly lower compared to the state average of 54%. The age group of 0-6 year accounts for 19.3% of total population. About 42% of the total population is of worker category in which 24% are males and 18% are females. Of the total workforce, main workers are about 91%. Most of the workers are cultivators.

3.6.1.4 Tato Circle

The total population of Tato Circle is 2132 with a sex ratio of 925. The sex ratio is marginally lower than the figures of the Sub-division, but better than the State average. The average literacy rate of Tato circle is 37.23% with maximum in males (44.95%). These figures are significantly lower than the literacy rates of the State. Age group of 0-6 year constitutes 22.6% of total population. Total workers account for 47.6% of the population of which 26.6% are males and 21% are females. Of the total workforce, main workers are about 82%.

Tato Circle is catered to by one middle and five primary schools. The Circle lacks educational institution of secondary or college level. The health facilities comprise of one primary health centre and a pharmacy located in Tato village.

3.6.2 INFLUENCE AREA

Influence area of the Pauk H.E. Project includes a total of 20 villages in which 19 come under the jurisdiction of Mechuka circle and a single village is under Tato circle. Detailed socio-economic profiles of these villages are given in following paragraphs.

3.6.2.1 Demographic Profile

Total population of villages of influence area is 1382 associated with 232 households (Table 3.6.1.1) (Census, 2001). Average sex ratio in these villages is 1044. Age group 0-6 year accounts for 21.6% of the total population. All villages are inhabited by 100% scheduled tribe population.

Table 3.6.1.1 Demographic profile of villages located in 10 km radius of proposed Pauk H.E. Project as per Census 2001

		Population Structure								
Village	**HH**	**Total**	**Male**	**Female**	**T 0-6**	**M 0-6**	**F 0-6**	**Sex Ratio**	**SC**	**ST**
Mechuka Circle										
Gauchi	16	85	50	35	18	14	4	700	0	85
Churling	7	61	27	34	10	5	5	1259	0	61
Bumji Panga	22	140	64	76	37	16	21	1188	0	140
Taching Panga	1	10	4	6	1	1	0	1500	0	10
Kadasila	3	16	5	11	2	1	1	2200	0	16
Karte	5	20	8	12	4	0	4	1500	0	20
Lingdungloti	4	18	10	8	5	2	3	800	0	18
Dorjeeling	41	300	143	157	67	38	29	1098	0	300
Sekor	13	81	33	48	20	7	13	1455	0	81
Rego	18	97	48	49	30	14	16	1021	0	97
Rapum	16	100	51	49	13	5	8	961	0	100
Hiri	7	27	14	13	3	1	2	929	0	27
Purying	10	65	31	34	10	5	5	1097	0	65
Lipusi	3	17	6	11	2	1	1	1833	0	17
Padusa	10	51	26	25	12	6	6	962	0	51

Gapo	25	127	64	63	32	19	13	984	0	127
Meying*	4	21	11	10	6	1	5	909	0	21
Chengrung	10	58	32	26	16	10	6	813	0	58
Pauk	5	30	14	16	2	2	0	1143	0	30
Tato Circle										
Heyo	12	58	35	23	9	4	5	657	0	58
Total	**232**	**1382**	**676**	**706**	**299**	**152**	**147**	**1044**	**0**	**1382**

SC=Scheduled Castes, ST=Scheduled Tribes

* In Census 2001, Meying was not considered as a revenue village and its figures were included in Gapo's figures. For the purpose of clarity, Gapo's and Meying's population were split in the above table, keeping in mind the same final figures.

3.6.2.2 Education Profile

Nearly half of the villages have facilities of primary education. For secondary education Mechuka and Tato are the nearest centres. On the whole educational infrastructures in the influence area are very poor, which is reflected in the average literacy rate. Average literacy rate in these villages is 47.5%, considerably higher in male (57.4%) (Table 3.6.1.2).

Table 3.6.1.2. Educational profile of the village located in the vicinity of Pauk H. E. Project

	Literates			Literacy Rates		
Village	**T**	**M**	**F**	**T**	**M**	**F**
Mechuka Circle						
Gauchi	31	21	10	46.3	58.3	32.3
Churling	24	13	11	47.1	59.1	37.9
Bumji Panga	60	34	26	58.3	70.8	47.3
Taching Panga	6	2	4	66.7	66.7	66.7
Kadasila	2	0	2	14.3	0.0	20.0
Karte	8	5	3	50.0	62.5	37.5
Lingdungloti	2	2	0	15.4	25.0	0.0
Dorjeeling	106	61	45	45.5	58.1	35.2
Sekor	26	15	11	42.6	57.7	31.4
Rego	39	20	19	58.2	58.8	57.6
Rapum	51	29	22	58.6	63.0	53.7
Hiri	9	5	4	37.5	38.5	36.4
Purying	24	17	7	43.6	65.4	24.1

Lipusi	4	2	2	26.7	40.0	20.0
Padusa	10	9	1	25.6	45.0	5.3
Gapo	41	21	20	43.2	46.7	40.0
Meying	2	2	0	13.3	20	0.0
Chengrung	30	19	11	71.4	86.4	55.0
Pauk	14	8	6	50.0	66.7	37.5
Tato Circle						
Heyo	25	16	9	51.0	51.6	50.0
Total	**514**	**301**	**213**	**47.5**	**57.4**	**38.1**

(Source: Census of India 2001)

3.6.2.3 Occupation and Cropping Pattern

Nearly 45% of the total population is engaged in the various works, of which more than 44% are main workers. Female population accounts for higher work force as compared to male population (Table 3.6.1.3). Most of the inhabitants are involved in cultivation followed by road building activities. Millets, rice and maize are main crops in the area. Non worker population (about 55%) also includes the population of age group 0-6years.

3.6.2.4 Other Amenities

The villages of influence zone under Mechuka circle like Churling, Sekor, Rego, Hiri, Gapo, Padusa, etc. are connected to the national highway. The villagers of some of the villages move 2-8 km to approach the highway. Most of the villages have facilities of tap water, supplied from springs. The water is not treated. To avail the facilities of bank, post office, secondary school and primary health facilities, Mechuka and Tato are the main centers in the region.

Table 3.6.1.3 Occupation pattern in the village located in the vicinity of Pauk H. E. Project

Village	Work Force											
	Total Workers			Main Workers			Marginal Workers			Non Workers		
	T	M	F	T	M	F	T	M	F	T	M	F
Mechuka Circle												
Gauchi	35	18	17	35	18	17	0	0	0	50	32	18
Churling	20	9	11	20	9	11	0	0	0	41	18	23
Bumji Panga	46	24	22	45	24	21	1	0	1	94	40	54
Taching Panga	6	2	4	4	2	2	2	0	2	4	2	2
Kadasila	12	4	8	10	3	7	2	1	1	4	1	3
Karte	10	4	6	10	4	6	0	0	0	10	4	6
Lingdungloti	8	4	4	8	4	4	0	0	0	10	6	4
Dorjeeling	129	62	67	129	62	67	0	0	0	171	81	90
Sekor	39	17	22	39	17	22	0	0	0	42	16	26
Rego	39	19	20	39	19	20	0	0	0	58	29	29
Rapum	45	22	23	45	22	23	0	0	0	55	29	26
Hiri	18	10	8	18	10	8	0	0	0	9	4	5
Purying	39	21	18	39	21	18	0	0	0	26	10	16
Lipusi	8	2	6	8	2	6	0	0	0	9	4	5
Padusa	26	10	16	26	10	16	0	0	0	25	16	9
Gapo	69	32	37	69	32	37	0	0	0	58	32	26
Meying	11	7	4	11	7	4	0	0	0	10	4	6
Chengrung	23	11	12	23	11	12	0	0	0	35	21	14
Pauk	16	7	9	16	7	9	0	0	0	14	7	7
Tato Circle												
Heyo	22	14	8	19	13	6	3	1	2	36	21	15
Total	**621**	**299**	**322**	**613**	**297**	**316**	**8**	**2**	**6**	**761**	**377**	**384**

Source: Census 2001

3.6.3 AFFECTED VILLAGES

The lands near four villages namely, Chengrung, Rapum, Hiri and Purying are affected due the various components of the project. The dam site would be located near Chengrung village. The power house site is proposed near the Hiri and Purying villages. The socio-economic profile of these villages is given in the following paragraphs. Hiri and Purying villages areas are also impacted by Heo HEP components and structures. In order to avoid any double counting in the EMP plans of Heo and Pauk HE Projects, Hiri and Purying villages will be considered as affected villages exclusively for the Heo H.E. Project, and Chengrung and Rapum villages will be considered as affected villages exclusively for the Pauk H.E, for the purpose of Rehabilitation and Resettlement plan.

3.6.3.1 Demography

Total population of affected villages is 250 people belonging to 43 households (Census 2001). The average sex ratio is 953 (Table 3.6.1.4). Age group 0-6 year accounts for 16.8%. The entire population of affected villages belong to Scheduled tribes, 'Adi' and their sub tribes.

Table 3.6.1.4 Demographic profile of the affected villages of Pauk H.E. project as per Census 2001

		Population Structure								
Village	**HH**	**Total**	**Male**	**Female**	**T 0-6**	**M 0-6**	**F 0-6**	**Sex Ratio**	**SC**	**ST**
Hiri	7	27	14	13	3	1	2	929	0	27
Purying	10	65	31	34	10	5	5	1097	0	65
Chengrung	10	58	32	26	16	10	6	813	0	58
Rapum	16	100	51	49	13	5	8	961	0	100
Total	**43**	**250**	**128**	**122**	**42**	**21**	**21**	**953**	**0**	**250**

Source: Census 2001

3.6.3.2 Education Profile

Average literacy rate in the affected villages 54.8%, which is similar to the state and district averages. Low literacy can be related to the poor infrastructure. Male population records considerably high literacy rate as compared to that of female (Table 3.6.1.5).

Table 3.6.1.5. Educational profile of the affected villages of Pauk H.E. Project

Village	Literates T	Literates M	Literates F	Literacy Rate % T	Literacy Rate % M	Literacy Rate % F
Hiri	9	5	4	37.5	38.5	36.4
Purying	24	17	7	43.6	65.4	24.1
Chengrung	30	19	11	71.4	86.4	55.0
Rapum	51	29	22	58.6	63.0	53.7
Total	**114**	**70**	**44**	**54.8**	**65.4**	**43.6**

Source: Census 2001

3.6.3.3 Occupation and Cropping Patterns

About 50% of the total population of affected villages is employed in various works. All of them are main workers. The main workers form the majority of the population in these villages (Table 3.6.1.6). Cultivation, including jhum, is main occupation in these villages. Shifting cultivation is main practice in these villages. Non workers including age group 0-6 account for half of the total population. Millets, rice maize and pulses are main crops in the region.

Table 3.6.1.6. Occupation pattern in the affected villages of Pauk H. E. Project

	Work Force											
	Total			Main			Marginal			Non- Wor.		
Villages	T	M	F	T	M	F	T	M	F	T	M	F
Hiri	18	10	8	18	10	8	0	0	0	9	4	5
Purying	39	21	18	39	21	18	0	0	0	26	10	16
Chengrung	23	11	12	23	11	12	0	0	0	35	21	14
Rapum	45	22	23	45	22	23	0	0	0	55	29	26
Total	**125**	**64**	**61**	**125**	**64**	**61**	**0**	**0**	**0**	**125**	**64**	**61**

Source: Census 2001

3.6.3.4 Other Amenities

Hiri and Chengrung are located on the right bank of the river, alongside the national highway connecting Aalo and Mechuka. Rapum village is linked to the road by a footpath. Though, transportation facilities are very poor, they are mainly facilitated by light vehicles. Tato and Mechuka are main centers of secondary education, primary health facility and telecommunication for these villages. The villages are not electrified. The water is supplied by springs, which is untreated.

3.6.4 AFFECTED FAMILIES

The ultimate purpose of identifying Affected Families is to properly implement a well targeted Rehabilitation plan. A total of four villages are directly affected due to the Pauk H.E. Project. In order to avoid double counting of the families in the EMP plans of several projects, the villages deemed affected by the Pauk H.E. Project are Chengrung and Rapum villages.

Therefore the families belonging to the Communities of Chengrung and Rapum villages areas or having holding rights on such lands (or from whom individual land is to be acquired under the project land requirement, if any) will be considered affected families of the Pauk H.E. Project. A detailed socio-economic profile of the affected families of these Communities is given below.

A detailed social survey will be performed again during the procedure for land acquisition, and before the time of implementation of the plan in order to have the most up to date information and in order to implement the most targeted and efficient R & R plan.

3.6.4.1 Demographic Profile

A total of 202 persons come from 24 households (55 families) are affected in Pauk H.E. Project (Social Survey). The sex ratio in the project affected families is 961. Age group 0-6 year accounts for 21.1%. All project affected persons belong to Scheduled Tribe (Table 3.6.1.7).

Table 3.6.1.7. Demographic profile of project affected families of Pauk H.E. Project

Villages	HH	Total	Male	Female	0-6 yrs	ST	SC	Sex ratio
Chengrung	5	39	21	18	11	39	0	857
Rapum	19	163	82	81	23	163	0	988
Total	**24**	**202**	**103**	**99**	**34**	**202**	**0**	**961**

3.6.4.2 Education Profile & Occupation Pattern

Average literacy rate in the project affected families is 53.6% (Table 3.6.1.8). The education level extends from primary to graduate level.

Table 3.6.1.8. Educational profile of the affected families of Pauk H.E. Project

Village	P	M	HS	SS	Grad	PG	Total	Literacy (%)
Chengrung	8	6	2	2	1	0	20	71.4
Rapum	27	23	9	6	4	0	70	50.0
Total	**35**	**29**	**11**	**8**	**5**	**0**	**90**	**53.6**

About 31.7% of the affected families are employed in various works. About 30% are engaged in cultivation mainly slash and burning while a few are employed in the government jobs (Table 3.6.1.9). Millets, rice, maize are main crops of the affected families.

Table 3.6.1.9. Occupation pattern of the affected families of Pauk H. E. Project

Village	Govt	Pensioner	Cultivation	Business	Labour	Total	%age
Chengrung	0	0	11	0	0	11	28.2
Rapum	1	0	50	2	0	53	32.5
Total	**1**	**0**	**61**	**2**	**0**	**64**	**31.7**

3.6.4.3 Livestock Population

Livestock population comprises of cows, mithuns, goats, pigs and chicken. Cows are the main source of milk in the area while mithun, pigs, and chicken are used as food. Mithuns are rarely reared in Rapum and Chengrung as compared to that of the villages of lower reaches.

3.6.4.4 Vulnerable Families

All project affected families are Scheduled Tribe, thus considered as vulnerable group. Among these families 5 are categorized as BPL (below poverty level) while 4 persons are widow.

3.6.4.5 Fuel Use Pattern

Only two families have facility of LPG connection while 6 families from Chengrung and Rapum are users of kerosene. All families use fuel wood for cooking and other purposes.

3.6.5 LIVING STANDARD

Among the project affected villages, Chengrung and Hiri villages are connected to the highway, however, transport facilities are very poor in the region. The State Transport buses and private light vehicles are main means of transport. The majority of the families in the area owns *kaccha* houses, consisting of bamboo poles thatched grasses. A few inhabitants located along the road sides own *pucca* houses. Aalo, district head quarters, is the main market, located more than 150 km away. Majority of the households are not electrified. Villages are connected to the tap water facilities with few common points. The water is tapped from nearby springs which are untreated. Regarding the education, health, telecommunication, and transportation, the infrastructure facilities are very poor in the influence zone. Regarding the other amenities like access to telephone, television and other goods only a few families have such facilities. Living standard of inhabitants is not satisfactory and entire area needs strengthening in infrastructure facilities and empowerment.

3.6.6 CULTURAL ENVIRONMENT

3.6.6.1 Brief History

Well documented history of Arunachal Pradesh starts with 16th century, when Ahom kings ruled the region. The population comprised mostly of Tibeto – Burmese linguistic origin. In 1826 British took over Assam after Yanlaboo treaty. Before 1962 Arunachal Pradesh was known as North Eastern Frontier Agency (NEFA) and was constitutionally a part of Assam State. It was administered by the Indian Ministry of External Affairs until 1965 and subsequently by the Ministry of Home Affairs through Governor of Assam. On 20th January 1972 it was declared as Union Territory and renamed as Arunachal Pradesh. On 20 February 1987, it became 24th State of the Indian Union.

Before 1970 West Siang was a part of Siang Frontier Division, which was recognized as Siang district after census 1971. Later on Siang district was divided into West Siang and East Siang districts. On the 23rd November, 1994 Upper Siang district was formed by carving out a few administrative circles from East Siang district. The head quarter of West Siang district is located at Aalo.

3.6.6.2 Ethnography

The 'Galo' and 'Adi' are the major tribal groups constitutionally reorganized in West Siang District of which former is the dominant group in the district. They both have their respective dialects also called Galo and Adi, respectively. However, they both belong to a common origin and ancestor known as Abo/ Abu Tani. Mopin and Solung, respectively are their main festivals. The traditional village panchayat of 'Galo' and 'Adi' locally called Keba and Kebang respectively is a Judico-administrative body consisting of mature and influential elders, generally presided over by "Gaon Budha". They look after the administration of justice by settling all matters of dispute. They are very fond of handicrafts, which can be seen in their cane and bamboo works like basket, trays, mats headgears etc.

The surrounding areas of the Pauk HE project are inhabited by the Pailibo Ramo and Memba subgroups. These people worship "Donyipoolo" barring the Memba, who are Mahayana Buddhists by faith. Fairs and festivals like 'Podi Barbi', Losar, etc reflect their rich cultural heritage. In general the dances are performed in groups.

The arranged marriages with mutual consent are prevalent among the tribes. The offer for alliance is made would be from groom side. Gifts are exchanged between both the sides during the marriage. After marriage, the elder sibling separate in appropriate time and establish a new family while the younger stays with parents to look after.

Among the Adi and Galo, last rite is completed in the graveyards where all required personal belongings of the deceased are also buried with ceremonial programme. The ceremonial programme, if required is organized by the family members of the deceased after one year or so. The Buddhist sub group however follows their universally well-known customs.

Chapter 4

ENVIRONMENTAL IMPACT

4
ASSESSMENT OF IMPACTS

4.1 INTRODUCTION

Impact prediction and assessment of the impacts often constitute a most important part in EIA studies. Indeed the whole EIA exercise is about identification and prediction of impacts and is needed at the earliest stages when the project, including alternatives, is being planned and designed. The impacts depend on the nature, scale and location of proposed activity; it includes the effects on the natural resource base i.e. quality of air, water, biological and socio-economic components of the environment which determine the cost of environment. These impacts can be classified variously as primary/secondary, direct/indirect, positive/negative, permanent/temporary, local/regional, reversible/irreversible, short term/long term.

The Impact assessment document is a provision for considering interactions among actions and effects. The effects are identified, predicted, measured and evaluated and finally linked to the alternatives and mitigation analyses. The evaluation of impacts incorporates qualitative as well as quantitative information and various methodologies have been adopted for this purpose that range from intuitive to the analytical and from formal to informal. The mitigation of adverse impacts is aimed to avoid, reduce, remedy or compensate, to restore or partially restore for various impacts due to the project actions. Here, the impacts of various project activities associated with Pauk H.E. Project are highlighted, quantified and communicated.

4.2 IDENTIFICATION OF IMPACTS

In hydro-electric projects, various activities like excavation, dam building, tunneling for HRT, quarrying, road construction, blasting, etc lead to impacts on the various ecosystems. The impacts are identified for the following environment.

4.2.1 Land Environment

The total land required for various construction activities like dam, colony, dumping areas, road constructions etc. is 91.7 ha, out of which 3.3 ha of the land is underground and remaining 88.4

ha land excluding 9.3 ha river bed area would be required for the surface work. Total submergence area is about 34.1 ha.

All the project components are located along the Yarjep (Shi) river and the total river stretch of the proposed project is more than 5 km. The influence area is either degraded (Jhum) or dense patchy forest in lower reaches along the both banks of Yarjep (Shi), Wet temperate, dry temperate and mixed coniferous forests are found at higher altitudes. Some tall trees of blue pine (*Pinus wallichiana*) can be observed in project areas along with alder and mixed broad-leaved tree species. The dam and submergence area has a fairly dense broad-leaved forest while power house area has only patchy forest. Though the lower reaches of the catchment are highly disturbed and under jhum cultivation, this area harbors most of threatened plant species of lower elevation. The high altitudes of the catchment and influence zone are ecologically more sensitive as inhabited by most of the threatened and scheduled species of fauna.

4.2.2 Geophysical Environment

A head race tunnel of 2.2 km would pass through a few nalahs. In addition, quarrying and road construction and power house complex would require frequent blasting activities. The likely impacts of construction activities on natural springs, activation of land slides, impacts on the settlement areas, underground water table have been identified in the influence area.

4.2.3 Water environment

The possible impacts of diversion of water, inundation, generation of solid waste by migrant population, effects of dumping area etc. on the water bodies have been taken into account. The changes in flow patterns of water in upstream and downstream areas and its impacts on the physical, chemical and biological characteristics of water and fish and fisheries were evaluated. These activities have been identified as the catalysts of changes in the water quality, potability, and species composition.

4.2.4 Air Environment

During the construction phase, a large number of equipment like loaders, compressors, cranes, DG sets etc. will be installed at working sites. In addition, vehicular movements would increase significantly in the areas. The burning of fossil fuels (oil) due to the deployment of heavy machines and a large number of heavy and light vehicles are anticipated to increase the air pollutants and to produce high sound levels. The impacts of pollutants, noise pollution and vehicular movement were assessed on the human health, animal movement and wildlife habitats.

4.2.5 Social Environment

The temporary demographic changes, new threats to locals due to diseases, social evils and cultural conflictions are likely adverse impacts due to migrant population. The threat to the natural resources by project workers has also been assessed. On the other hand, positive impacts due to project activities and migrant workers like employment opportunities to locals, peripheral development plan, and improvement in the living standard and lifestyle of the inhabitants were also taken into account.

4.2.6 Downstream Impacts

The diversion of water through HRT would lead various downstream impacts not only on aquatic ecosystem and flow regime but livelihood of the natives and riparian vegetation. The impacts of scarcity of water in the downstream were assessed on physical, chemical and biological components of the river water.

4.2.7 Anthropogenic Impacts

A large number of outside workers may exert the additional pressure on the natural resources. The anthropogenic pressures are identified for the wildlife, plant species, water quality etc.

4.3 PREDICTION OF IMPACTS

Using the base line information the adverse and beneficial impacts on the various environmental components have been evaluated. The likely impacts of the project activities are described for the following environment.

4.3.1 Land Environment

Project activities would have a direct impact on 79.1 ha surface land (including 8.8 ha of riverbed), which is proposed for the acquisition for various project components like submergence of surface land area, dam complex area, access road, colonies, labour camps, dumping areas, etc. The area includes unclassified state forest land, community and private land. The multifarious project activities will have both positive as well as adverse impacts on the environment are mentioned here.

4.3.1.1 *Change in Land Use and Habitat Destruction*

The proposed project envisages construction of 110.0 m high dam near Chengrung village, which will result in the submergence of around 25.3 ha of surface land (total submergence area being 34.1 ha including 8.8 ha of river bed). The forest area will be cleared for the purpose, which would result into land use and land cover changes. The project components would lead to the adverse impact on the floral diversity of the region and habitat shrinkage of the wildlife.

4.3.1.2 *Submergence Area*

The vegetation in the vicinity of submergence area is covered with dense/open broad-leaved forests. Including the river area a total of 34.1 ha land would be required for the submergence. A significant number of trees would likely come under the submergence. The area harbors some economically and medicinally important plant species like *Albizia odoratissima, Alnus nepalensis, Altingia excelsa, Castanopsis tribuloides, Cinnamomum glaucscens, Quercus glauca, Saurauia punduana* (Trees) *Eurya acuminata, Boehmeria macrophylla, Melocalamus compactiflorus, Schefflera impressa* (shrubs), *Anaphalis busua, Begonia nepalensis, Hedychium spicatum, Molineria capitulate, Musa bulbisiana, Pteridium aquilinum, Urtica parviflora* (herbs), etc. We did not come across any threatened and scheduled plant species in the submergence during our primary surveys. The impacts are permanent, negative and reversible.

4.3.1.3 *Other construction Area*

Apart from the submergence, there would be requirement of nearly 54.3 ha of land for dam complex area (that include 0.5 ha of riverbed), dumping, road, power house, quarry, etc. The surrounding areas house fairly dense mixed forest in upper reaches and degraded forest in valley area. The dominant trees in the area are *Actinodaphne obovata, Altingia excelsa, Alnus nepalensis, Cinnamomum glaucescen*colonies, *Saurauia punduana* and *Sloanea tomentosa*. The predicted number of tress come under these activities would be 11,000. There would be permanent changes in the land use and land cover.

4.3.1.4 ***Anthropogenic pressure***

Approximately 1550 persons would be deployed for the project works, which would come from different parts of Arunachal Pradesh and India. Migrant population constitutes a bigger population than the inhabitants of influence (census 2001) area and would therefore exert the additional pressure on the natural resources. Migrant population is supposed to lead the negative, temporary and reversible impacts on the natural resources. The magnitude of impacts would be high during the construction phase.

4.3.1.5 ***Impacts on wildlife***

The catchment area of the proposed project stretches from 1500 m to 2700 m elevational bands. The area has mountainous landscape characterized by dense wet temperate, dry temperate and mixed coniferous forest. The various physical activities of the projects and their ancillary impacts like human and vehicular movements, blasting, running of equipment etc. would disturb the wildlife movement and lead to the habitat fragmentation and shrinkage. The most affected animal species in the surroundings are Common leopard, Leopard cat, Jungle cat, Barking deer, Wild boar, Rhesus macaque etc. The majority of the impacts are temporary because the activities and human population would last up to the construction period. The activities like blasting, vehicular movement and high noise level would lead negative impacts on the breeding habit of the animals. The possible mitigation measures for the protection of wild animals from such types of impacts are precautionary. Project authorities are advised to devise the activity schedule keeping animal behavior, i.e., breeding season of many vertebrates and their feeding in the mind. One of the better ways of controlling noise is to manage it at source. The equipment used, for example, will meet minimum safe guards for natural areas and could have silencers and cause minimum ground vibrations during construction period.

4.3.1.6 ***Loss of species***

The various activities like creation of reservoir, quarry, road construction, colony, etc. would have direct impacts on the habitat and plant species. The plant species of submergence area as well other construction areas are widely distributed in the surrounding areas (influence zone) in abundance and thus, permanent loss of any species is not anticipated. The economically important plant species in and around the construction sites are mentioned in the report. However, there will be loss of riverine vegetation for the time being, which will regenerate in the reservoir periphery in due course of time.

4.3.1.7 *Phyto-retardation*

High concentration of suspended particulate matter (SPM) would lead to the phyto-retardation in and around the activity areas, which reduce the physiological process in the plant species. Phyto-retardation in plant species results into biodiversity as well as economic loss. Many plant species are intolerant of the phyto-retardation and may be wiped out from the area. Such impacts are short term (construction phase) and reversible in the nature. Regarding the Pauk H.E. project no orchards and other commercially important plant species are present in the surrounding area, therefore, such types of impacts are not anticipated.

4.3.1.8 *Introduction of Invasive Species*

Invasive species are highly tolerant of physical disturbance and thrive well in turmoil conditions. Also, migrant workers are foreseen to carry such species as ornamental plants and with food grains. The alien species lead to the loss of biodiversity, dominate the construction and degraded sites.

4.3.1.9 Generation of Solid Wastes

A total population of around 1550 persons would generate 265 tons of solid waste comprising of plastic, metals, papers, domestic garbage and others. The wastes spread over the landscape would result into loss of biodiversity, deterioration of water quality, loss of scenic beauty and would become obnoxious. In order to handle the solid waste project authorities would formulate an effective waste management plan for Pauk H.E. Project.

4.3.2 Geophysical Environment

Around the project area the rock units belong to Lumla Formations, which are consisting of schistose quartzite, schist, marble, gneiss with augen gneiss. These gneisses are good tunneling media and are likely to come under “Fair” to “Good” category. The HRT would not pass through major nallahs. However, very rare possibilities for damage of underground water tables occur. No major land slide was observed in the nearest surroundings. However, the construction activities like excavation, road construction, quarrying may trigger the small landslides and slips.

Apart from the environmental consequences, the care must be taken for structural aspects because MCT (Main Central Thrust) passes from a nearby locality Yapuik. The blasting activities may lead to regular vibration in the area, however, no settlements are identified along the HRT alignment. The reservoir of Pauk H.E. Project would be of 34.1 ha and would be used as active storage also for the 2 other projects developed downstream of Pauk HEP by the same agency (Heo and Tato-1 HEP). A reservoir can induce the seismicity.

4.3.3 Aquatic Environment

4.3.3.1 *Deterioration of Water Quality*

During construction, the likely impacts will arise from inappropriate disposal of muck, effluents from crushers and other sources and sewage from labour camps and colonies. The muck will come essentially from road building activities, tunneling and other activities. Since all the dumping areas are located along side the river, therefore, fair possibilities of leaching of soils occur directly from the dumping sites and during the transportation. The soils would increase the turbidity of river water and consequently would reduce the photosynthetic efficiency of primary producers in the river and as a result the biological productivity will be greatly reduced. Thus prolonged turbid conditions would have negative impacts on the aquatic life.

4.3.3.2 *Generation of Waste Water*

A large number of workers would camp alongside the river. Also, many equipment and machineries would be stationed at working area. This may result in production of domestic waste and human excreta, which if discharged into the river directly could affect the quality of river water. A total of 1,55,000 liters of water per day is expected to be generated from the 1550 migrant population. These activities would exert the pressure on water quality, lessen the dissolved oxygen, pH, and increase the BOD, coliform concentrations. The deterioration of water would decrease its potability.

4.3.3.3 *Habitat/Species composition*

During construction, flow regime would be changed in a small stretch of the Yarjep (Shi) river, which is supposed to trigger changes in algal and macro-invertebrates. But in operation phase it would occur considerably due to the diversion of water from main river channel. A dearth of water in the main channel is not expected to have rich diversity and to sustain column feeder fish species like *Garra* sp., and *Schizothorax* sp. Low water discharge in downstream would destroy the breeding grounds of fish species unless a minimum is released in the river at the Dam site.

4.3.3.4 *Fish & Fisheries*

Schizothorax richardsonii and *Garra naganensis* are two important column feeder species of fish that take a long course of movement. A dam of 110 m height is expected to hamper the fish movement and exert a negative impact on the fish fauna. In addition, reservoir would also be non conducive and act as area of fragmentation for bottom dwellers. After the construction and diversion, fisheries would be affected adversely in the downstream. It would affect the local fishermen. In the absence of large size species, fishermen may land small sized species.

On the other hand, proposed reservoir would increase the possibilities of reservoir fisheries, therefore, it is considered as positive impact. A submergence area of nearly 34 ha would provide fair possibilities of fish culture. These impacts are foreseen in the operational phase of the projects. The impacts are positive and permanent in nature.

4.3.4 Air & Noise Environment

4.3.4.1 *NO2 and SO2 Level*

Impacts of project activities on air environment are only restricted to the construction period. During the construction phase, the operation of large number of machines, equipment like DG sets, loaders, cranes, compressors, vehicular movement is foreseen to increase the level of NOx, SOx and CO. It exerts negative impacts on the human health especially on the workers of the project. It is temporary and reversible impacts. The level of these chemical is expected to increase nearly by 10 times during day time. The level would stay for 5 times in construction phase. During the operation phase level may decrease significantly.

4.3.4.2 *Suspended Particulate Matter (SPM)*

The actions like excavation, tunneling, quarrying, dumping and vehicular movement would lead to the high concentration of SPM in air quality. The high concentration of SPM would have adverse effects on the human as well as plant health. The level of SPM is expected to increase 100 times at day time and would stay for 20 times more than present status during construction phase.

4.3.4.3 *Noise Level*

No point source of noise was observed in the entire Yarjep (Shi) valley. During the construction phase blasting, vehicles, operation of machines like compressor, loader, roller, bulldozers would increase the sound level significantly. The magnitude of noise depends on the type of machine, time of operation etc. Table 4.1.1.1 and 4.1.1.2 give the details of machines and sound produced by them. These tables would guide only the readers' eyes. These activities would disturb the human population as well as wildlife. Such negative impacts would remain for short time during construction phase only. The impacts are temporary and reversible in nature.

Table 4.1.1.1 Sound level produced by different instruments while in operation

Sl. No.	Equipments	Sound Level (dBA)
1.	Truck Mounted Crane	76-83
2.	Un-silenced scraper/grader	82
3.	Generator	82
4.	Un-silenced pile diver	110
5.	Un-silenced compressor	80
6.	Un-silenced pneumatic drill	90
7.	Heavy duty bulldozer	91-107
8.	Light duty bulldozer	93-101

Source: Kerr *et al.*, 2002

Table 4.1.1.2 Sound level at different distance from the source

Distance (m)	Ambient noise level (dB)	Probable noise level due to activity noise	Increase in level (dB)
100	50	70	20
200	50	68	18
500	50	60	10
1000	50	55	5
1500	50	52	2
2000	50	50	-
2500	50	49	-
3000	50	47	-

Source: EIA report of Tato II H.E. Project

Note:

1. Day time is reckoned in between 6.00 AM and 9.00 PM
2. Night time is reckoned in between 9.00 PM and 6.00 AM
3. Silence zone is defined as areas up to 100 m around such premises as hospitals, educational institutions and courts. The silence zones are to be declared by competent authority.

4.3.4.4 *Visual Impact*

During the construction phase SPM are clearly visual in the air. The dust particles lead to the phytoretardation and affect not only the physiological process of plant species but deteriorate the aesthetic values. It becomes irritating and obnoxious in a wider range. It affects the human health adversely.

4.3.5 Human Environment

For construction work, there will be considerable number of outside labourers and project staff that would enter the area. The outsider workers would have various effects, described below.

4.3.5.1 *Demographic Changes*

About 1550 persons including family members of workers are expected to come in the area. The human population density in the surrounding areas is very low. (Total population in influence areas is 1382 as per Census, 2001. Calculating decadal growth, total population would nearly be 1700) therefore, prominent increase in the human population would take place. During the construction phase the outsiders would account for nearly than 100% of the total population of influence area. The demographic changes have many beneficial and harmful impacts. Though, it is a temporary phenomenon and after construction period, the most of the migrants would be homed.

4.3.5.2 *Cultural Confliction*

Change in the demography may trigger the cultural confliction between natives and outsider because the area is dominated by ‘Adi’ and its sub tribes. These tribes are unique in their culture, customs and their traditions. The high number of migrant population may bring the anxiety among the tribes, which may result in the confliction.

4.3.5.3 *Social Evils and threats to new disease*

The sometimes outsider population is associated some social evils. The natives may be affected adversely. In addition, the migrant population is expected to be carrier of new diseases.

4.3.5.4 *Interaction*

An interaction between natives and migrant population is anticipated to facilitate an exposure to natives. Such types of exposure would have positive impacts on the local population.

4.3.5.5 Small Scale Business

The migrant population would provide a fair possibility of a surplus income for the natives. The local people could start small scale business for daily needs in the area.

4.3.6 Downstream Impacts

4.3.6.1 *Habitat/species loss, Deterioration of Water quality, Fish*

The diversion of river water from main channel during operation phase is foreseen to trigger the habitat loss, changes in species composition, water quality, fish and fisheries. The scarcity of the water in downstream would decrease the self purify capacity of water and most of the physical and chemical characteristics like dissolved oxygen, BOD, pH, hardness, TDS etc would be affected adversely. These impacts are anticipated in operational phase, they are long term, permanent and irreversible.

4.3.6.2 *Change in Flow Regime*

Change in the flow regime may have many environmental consequences, which are described above. In addition, there are many unseen impacts of changed environmental flow. About 5 km river stretch would undergo through scarcity of water, though a few small nallahs join Yarjep (Shi) near on right bank. Shongshi Bu having a total catchment area of 71.5 sq km. joins Yarjep (Shi) river at 2.08 km downstream of proposed dam while Shene Korong join it at 2.5 km downstream. The monthly variation in water discharge in these nallah is given in Table 4.1.1.3.

Table 4.1.1.3 daily water discharge in downstream tributaries

		Downstream tributaries				
Nalahs (90% DY)		**Total (cumecs)**	**Shuku Sokong**	**Songshi Bu**	**Shene Sokong**	**Other**
Jun	**I**	**10**	0.2	8.4	0.9	0.5
	II	**14**	0.3	11.7	1.2	0.7
	III	**19**	0.4	15.9	1.7	1.0
Jul	**I**	**11**	0.3	9.2	1.0	0.6
	II	**12**	0.3	10.0	1.1	0.6
	III	**12**	0.3	10.0	1.1	0.6
Aug	**I**	**12**	0.3	10.0	1.1	0.6
	II	**9**	0.2	7.5	0.8	0.5
	III	**6**	0.1	5.0	0.5	0.3
Sep	**I**	**11**	0.3	9.2	1.0	0.6
	II	**14**	0.3	11.7	1.2	0.7
	III	**12**	0.3	10.0	1.1	0.6
Oct	**I**	**9**	0.2	7.5	0.8	0.5
	II	**7**	0.2	5.8	0.6	0.4
	III	**7**	0.2	5.8	0.6	0.4
Nov	**I**	**3**	0.1	2.5	0.3	0.2
	II	**3**	0.1	2.5	0.3	0.2
	III	**3**	0.1	2.5	0.3	0.2
Dec	**I**	**2**	0.0	1.7	0.2	0.1
	II	**2**	0.0	1.7	0.2	0.1
	III	**1**	0.0	0.8	0.1	0.1
Jan	**I**	**1**	0.0	0.8	0.1	0.1
	II	**2**	0.0	1.7	0.2	0.1
	III	**1**	0.0	0.8	0.1	0.1
Feb	**I**	**1**	0.0	0.8	0.1	0.1
	II	**1**	0.0	0.8	0.1	0.1
	III	**1**	0.0	0.8	0.1	0.1
Mar	**I**	**1**	0.0	0.8	0.1	0.1
	II	**2**	0.0	1.7	0.2	0.1

	III	**2**	0.0	1.7	0.2	0.1
Apr	**I**	**2**	0.0	1.7	0.2	0.1
	II	**2**	0.0	1.7	0.2	0.1
	III	**2**	0.0	1.7	0.2	0.1
May	**I**	**8**	0.2	6.7	0.7	0.4
	II	**8**	0.2	6.7	0.7	0.4
	III	**6**	0.1	5.0	0.5	0.3

4.3.6.3 *Livelihood*

The livelihood of people do not depends on the river water. Only small scale fisheries are executed. In the downstream stretch no irrigation land falls and river water is not used for the drinking purpose. Thus. no adverse impacts on the livelihood are anticipated.

4.3.6.4 *Bank Erosion*

After the diversion of water. the possibility of bank erosion increases because downstream channel would receive turbid free water from tail race channel. The turbid free water has more eroding capacity.

4.3.6.6 *Riparian Vegetation*

Low water flow in the downstream channel is anticipated to affect the riparian vegetation adversely. Number of bryophytes. pteridophytes and herbs grow in the downstream and would be affected adversely.

4.3.7 Economic Upliftment

In order to mitigate or to avoid adverse impacts predicted project authorities would implement many mitigation measures related to environment and societies. There would be good share of employment for local people. subject to eligibility. In addition to direct employment in the project activities. the inhabitants would be benefited indirectly like for example with small contract. etc. There will significant changes in the infrastructure facilities like transportation. education. health. etc. The Rehabilitation and Resettlement Plan in EMP report is directly related to the local people and their upliftment. In addition to the relief package. project authorities would implement a peripheral or social development plan. The provisions would have been made towards local participation in the project activities. infrastructure development like school. health centre. adoption of village. scholarship scheme. play ground. development of small scale business. etc. The social development plan would play an important role in empowering the vulnerable groups of the region. It would put in positive impacts on the tribal community for long time and would be strategic in the nature.

4.4 IMPACT INFORMATION

The interaction of activities and their impacts vary between construction and operational phase. Regarding the hydro-electric project. major activities occur in the construction phase. therefore major impacts are anticipated during construction. In Pauk H.E. project various impacts have been discussed keeping their nature in view. Some of the impacts will be of short duration particularly during construction phase. whereas some impacts will be long lasting. Each impact was analyzed under the categories mentioned above and quantified using modified Leopold matrix. Each impact was assigned with a score using a scale of 1-5. depending on the magnitude and potential. The magnitude. potential and significance of an impact was assessed on the basis of nature of impact (short term/long term. reversible/irreversible. local/regional. direct/indirect. minor/major) A positive or negative sign was provided for beneficial and harmful nature of the impacts. The rows' totals of matrix- reflects the total impacts of an action on the various environmental components while the columns' totals reflect the impact of all actions on one environmental variable.

Table 4.1.1.4 indicates relative comparison of impacts of various actions on the different environmental components during the construction as well as operation phases.

Table 4.1.1.5 shows relative impacts on the various environmental and social components. Details are provided in the **Matrix 4.1 and 4.2**. Majority of the impacts is negative but minor in their consequences. Notably, the magnitude of negative impacts decreases considerably in the operational phase of the project. In the construction phase, total score is -80 of which 102 stands for negative impacts and 22 for positive impacts. During the operational phase total score decrease to – 30 of which negative impacts score for 45 and positive for 15. Considering the project actions during construction phase excavation/tunneling, quarrying and migrant population are major activities which pose major impacts on the environmental and social components while community development is most positive impact. In the operation phase, diversion of water leads to maximum negative impacts. The downstream impacts are long lasting and permanent in the nature.

Table 4.1.1.4 Summary of impacts of various actions in construction and operation phases

Actions	Construction Phase		Operation Phase	
	Negative	Positive	Negative	Positive
Dam structure	1	0	5	0
Road construction	10	1	2	2
Submergence	0	0	4	1
Power house	5	0	2	0
Adits	3	0	2	0
Dumping	11	0	3	0
Excavation/ Tunnel	20	0	1	0
Quarrying	14	0	0	1
Colony	5	2	4	2
Diversion	0	0	11	0
Migrant population	15	5	6	1
Construction method	9	2	0	0
Vehicular Movement	7	2	5	2
Community Development	0	10	0	6
Total	**102**	**22**	**45**	**15**

Wildlife and ambient air quality are most adversely impacted environmental variables while employment opportunities and basic amenities of development are the most benefited social components.

Table 4.1.1.5 Summary of impacts on various environmental variables in construction and operation phases

Environmental/ Social variables	Construction Phase		Operation Phase	
	Negative	Positive	Negative	Positive
Land use /land cover	7	0	2	1
Habitat loss/ Degradation	4	0	2	0
Wild life	10	0	6	0

Phytoretardation	4	0	1	0
Exploitation of resource	2	0	0	0
Invasion	3	0	1	0
Ground Water Level	2	0	3	0
Weathering	3	0	0	0
Landslides/slip	7	0	1	0
Stability	2	0	0	0
Deterioration of Water	10	0	4	0
Species/Habitat loss	4	0	1	0
Fish Movement	0	0	5	0
Fisheries	1	0	0	2
NO_2. SO_2 Level	4	0	2	0
SPM	11	0	2	0
Noise Level	8	0	1	0
Visual Impact	7	0	2	0
Demographic changes	1	0	1	0
Cultural confliction	2	0	1	0
Social evils	2	0	0	0
Interaction	0	2	0	1
Health Hazards	8	0	1	0
Downstream Impact*				
Habitat /species loss/	0	0	5	0
Flow regime	0	0	3	0
Livelihood	0	0	1	0
Drinking water	0	0	0	0
Bank erosion	0	0	1	0
Riparian vegetation	0	0	1	0
Employment	0	7	0	1
Social values	0	3	0	3
Basic amenities	0	8	0	6
Marketing	0	2	0	2
Total	**102**	**22**	**45**	**15**

4.5 IDENTIFICATION OF MITIGATION MEASURES

After the identification, prediction and evaluation of impacts, some mitigation measures are identified to ameliorate the negative impacts. Some of the important mitigation measures which are warranted to conserve the environment are listed below:

i). Adequate safeguard measures for wildlife conservation and preservation of biodiversity

ii). The activity like blasting must be scheduled and controlled taking the animal behaviour like movement time, Breeding, Corridor, etc. into account

iii). Afforestation in degraded land and catchment area

iv). Adequate engineering measures at construction sites, catchment area, dumping areas, landslides to arrest the soils

v). Restoration of quarry sites, colony area, road sites and other construction sites

vi). Maintenance of water quality, air quality and noise level

vii). Fish and Fishery development

viii). Regular monitoring of migrant population to ensure the overexploitation of forest resources, poaching, crime, social evils and cultural confliction

ix). Development of infrastructure in the surrounding area towards education, health, transportation, etc.

x). Adequate measures for disposal of waste

xi). Suitable mitigation measures for downstream impacts

All mitigation measures are taken into account in the Environment Management plan of Pauk H.E. Project.

4.6 CUMULATIVE IMPACT ASSESSMENT

Generally assessment of the impacts is addressed in isolation considering a particular project. Sometimes it becomes insignificant when there are other existing or/and proposed projects in the close vicinity. Therefore, in order to achieve the aim evaluation of impacts is carried out in context of combined effects of all past, present and reasonably foreseeable future activities. Cumulative impact assessment also provides valuable and important inputs particularly in monitoring of environmental sustainability impacts. Thus, the process of analyzing cumulative effects is an enhancement of the traditional environmental assessment components: (i) scoping. (ii) describing the affected environment. and (iii) determining the environmental consequences.

The cumulative impacts are broadly divided into two categories namely additive cumulative impacts and synergistic cumulative impacts. In this contribution. synergistic cumulative impacts are described because the combined effects of the projects are considerably larger than the impact of an individual project. The present contribution deals with the impact assessment of cascade development on the Yarjep (Shi) river in West Siang district of Arunachal Pradesh.

Though. there are other projects like Tato-II. Tato-I. Heo. Pauk. Rego. Tagurshit projects proposed in the basin but hence. a cumulative impact assessment for three projects. namely Tato-I. Heo. and Pauk H.E. projects is formulated. These projects are owned by a same agency so that the main purpose of cumulative impact assessment is to mitigate the adverse impacts of the projects under the comprehensive and coordinated system. The mitigation measures for these projects are given separately. However, an approach of coordination for the implementation of the various management plan has been followed.

4.6.1 Brief Description of the Projects

The cumulative impacts of three projects on the surrounding environment are addressed in this contribution. Prior to highlight the identification and prediction of impacts, an account of comparative salient features of these projects is given in Table 4.1.1.6.

Table 4.1.1.6 Salient features of the projects proposed on Yarjep (Shi) river in cascade

	Tato I HEP	Heo HEP	Pauk HEP
Location of Intake/dam/barrage			
Latitude	: 28˚ 32’ 32”	28°32’20’’N	28˚ 32’ 46”N
Longitude	: 94˚ 18’ 43”	94°16’31’’E	94˚ 14’ 43”E
Location of Power House			
Latitude	: 28˚ 31’ 53”	28°32’32’’N	28˚ 32’19”N
Longitude	: 94˚ 21’ 31”	94°18’43’’E	94˚ 16’ 01”E
Catchment area at dam site	: 1154 sq km	1065 sq. km	985 sq km
Design Flood	: 3400 cumecs	3200 cumecs	3700 cumecs
Weir/dam top	: 1195.5 m	1400 m	1550 m
River Bed Level at Intake site	: 1188 m	1385 m	1445 m
Height of dam/weir (above river bed level)	: 7.5 m	15 m	115 m
Design discharge	: 133 cumecs	130.2 cumecs	118 cumecs

Submergence	: 3 ha	8.4 ha	34.1 ha
Length of HRT	: 3.9 km	3.55 km	2.8 km
PH Type	: Surface	Surface	Surface
Installed capacity	: 186 MW	240 MW	145 MW
Construction period	: 4 Years	4 years	4 years
Total land to be acquired	: 52.8 ha	55.7 ha	91.7 ha

4.6.2 Identification & Prediction of Cumulative Impacts

Cumulative impact assessment is a part of strategic environmental assessment. provides better scope than project level impact assessment. Such types of studies address the impacts of development on environment and helpful in assessing the effect of policy. plan and programme on the environment. This section deals with the identification of impacts of Pauk, Heo and Tato I H.E. projects on the surroundings. Table 4.1.1.7 summarizes the various actions of three projects cumulatively during construction phase and operational phase.

4.6.2.1 *Construction phase*

Various activities mentioned in the Table 4.1.1.7 would lead to cumulative impacts on the various environments like biological, social, human, air environments with different magnitudes in construction and operational phases. Nature of all impacts are same for all projects. However, magnitude of impacts would increase while considering cumulatively. Major adverse impacts on the flora and fauna are anticipated in the construction phase. Apart from the ecosystem services provided by plant species, many species of economic importance like *Actinodaphne obovata, Albizia odoratissima, Alnus nepalensis, Altingia excelsa, Brassiopsis aculeate, Cinnamomum glaucscens, Castanopsis tribuloides, Casearia glomerata, Engelhardtia spicata. Eurya acuminata*. *Ficus semicordata, F. Oligodon, Garcinia cow, Lyonia ovalifolia, Macaranga denticulata, Saurauia Schefflera bengalensis, Schima wallichi, Xylosma longifoli, Carpinus viminea. Quercus glauc*, etc. will be under the direct influence of the project.

Table 4.1.1.7. Combined actions of three projects in Yarjep (Shi) valley of Arunachal Pradesh

Parameters	Construction Phase	Operation Phase	Nature of Impact
Land Environment			
Influence Area	581 sq. km	581. sq. km	-
Land use Changes			Negative. Permanent. Irreversible
Submergence	-		Negative. Permanent
Generation of Solid Waste	1868 kg/day	373 kg/day	Negative. Temporary. Reversible
Quantity of Muck to be generated	28.27.293 m^3	-	Negative. Permanent. Reversible
Water Environment			
Hydraulic Changes	-	14 km d/s	Negative. Permanent. Irreversible
Generation of Waste Water	4.00.000 lit/day	80.000 lit/day	Negative. Temporary. Reversible
No. of Intermediate Tributaries	08	08	Positive. Permanent
Anthropogenic Pressure			
Total Migrant Population	4000	/	Negative. Temporary. Reversible
Biological Environment			
No of Trees Affected (approx.)	40.000	-	Negative. Temporary. Reversible
Social Environment			
Villages in Influence Area (Census. 2001)	29	29	-
Total Population of Influence Areas (idem)	2899		-
No of Affected Villages	10	-	Negative. Temporary. Reversible
No. of Affected Families/HH (Social Survey)	209/144	-	Negative. Temporary. Reversible
Population of Affected Families (Social Survey)	733	-	-
Geophysical Environment			

Total Length of HRT	6.8 km	6.8 km	Negative. Permanent. Irreversible
Total Land required for Road	45.3 ha	-	Negative/Positive. Permanent. Irreversible
Total Area required for Quarry Sites	2.6 ha	-	Negative. Permanent. Irreversible
Total No of Nalahs Crossed By HRT	-	4	Negative. Temporary. Reversible

Project activities have direct as well as indirect impacts on the wild animals. Generally activities of river valley project are concentrated in the lower reaches of valley but cascade development covers a larger area thus, leads to adverse impacts on the faunal species in large area. The important animal species like Panthera pardus. *Prionailurus bengalensisCanis aureus*¸ *Neofelis nebulosa*. *Macaca assamensis*. *Felis chaus*. *Lutra lutra*. *Sus scrofa cristatus Muntiacus muntjak*. *Lophura leucomelana* will be directly affected due to activities of all three projects. In addition. project activities during construction and operational phases are described below.

Total expected population of migrant workers would be that the existing population of influence area. The various professional and social activities of migrant workers are anticipated to lead the negative as well as positive impacts on the local population. These impacts in construction phase can be identified and predicted as demographic changes. cultural confliction. extraction of natural resources. social evils. threats to heath etc. The generation of solid waste and waste water is secondary impact of migrant population. On the other hand high population and ancillary activities would provide fair possibilities of development of small scale business. The additional requirement of food grains. milk. white goods. and other daily needs can provide a source of surplus income for locals.

Air quality is anticipated to be affected most adversely as compared to other parameters of environment. The ambient air pollutants are more concentrated at the source and their concentration decreases along the peripheral gradient. In case of cascade development, there would be many source of these pollutants. Therefore, Yarjep (Shi) valley up to Mechukha would be affected. The obnoxious clouds of dust are foreseen to be visible in the valley. The air pollutants have impacts on human health and plant species, described earlier. Table 4.1.1.8 gives a summary of activities, their impacts and nature of impacts in the construction phase.

Table 4.1.1.8 Construction activities and their impacts

Construction Phase	**Activity**	**Potential Environmental Impact**
a) Site work / other facilities.	i) Cleaning and grading	Deforestation
	ii) Temporary facilities. such as sheds. approach roads.	Dust emission and change in traffic intensity

	sanitary facilities	
	iii) Earth work comprising of excavation and trenches	Soil erosion. run off. increase in traffic. dust emission
	iv) Foundation work. piling and construction of check dams	Dust. visual and noise pollution
	v) Construction of permanent structures like roads. colony. etc.	Dust and noise pollution Deforestation
	vi) Mechanical erection and utility systems	Dust. noise and visual impact
b) Construction of approach roads tunneling works and foundations	i) Excavation	Dust. soil erosion. wastewater generation and noise
	ii) Drilling & Blasting	Dust. noise and health hazards. change in the course of course of water source. Wildlife disturbances
c) Disposal of muck	i) Dumping	Dust. noise and visual
	ii) Transportation	Dust. noise and visual
d) Socio-economic disturbances	iii) Excavation iv) Road Construction i). Due to rehabilitation and resettlement aspects ii) Due to labour influx	Dust. SPM level Dust. SPM level. Noise Impact on human health. cultural. aesthetics. etc. Various social. cultural changes
e) Installation of Equipment like loader. cranes. crushers. compressors. heavy vehicle. DG sets f) Other works	i) Operation ii) Running i) Lighting ii) Landscaping iii) Solid waste disposal	Increase in NOx. SOx and CO_2 Disturbance to wildlife Add to social services Adverse impacts on flora. entomo-fauna Visual impact. beautification Soil pollution. visual impact

	iv) Finishing activities like removal of temporary works	Generation of solid waste. visual impact

4.6.2.2 ***Operational Phase***

Permanent acquisition of land. downstream and upstream activities are major impacts which would remain during the operational phase. After the construction phase. most of the project activities would cease. thus. magnitude of associated impacts would decrease significantly. There would be no more removal of plant species. In case of wild animal species permanent impacts like habitat fragmentation and habitat shrinkage due to structural units. vehicular movement would occur but the source of high noise (blasting. tunneling) would come to end. Major part of the vehicles and machines running in the area will be removed. Similarly. most of the migrant workers (about 90%) will be homed. All the labour camps and temporary colonies will be dismantled and the project authorities would carry out the phytoremediation of those sites. The degraded habitats will be stabilized during the operational phase. The pressure on the aquatic ecosystem will reduce due to the decreasing anthropogenic pressure. Air pollutants will decrease due to closing of construction activities.

The diversion of water is the major impact during the operational phase. which would result into the scarcity of water from nearly 14 km river stretch. Paucity of water in downstream stretch would have adverse impacts on ichthyofauna. and other biotic communities. Diurnal variation in the flow would destabilize biotic communities of the river.

The implementation of local area development and community development plans is expected to be most beneficial activity of the project. Such types of plans work in the construction as well as operational phases. A joint efforts of all project is expected to help a large area in West Siang district. The provisions of schools. health centres. footpaths. roads. income generation schemes. training programme etc. would put in to empowerment of society and development of infrastructure.

Most of the management plans suggested to restore the environment are implemented in the operational phase of the project. Table 4.1.1.9 gives a summary of activities. their impacts and nature of impacts in the operation phase.

Table 4.1.1.9 The major impacts identified during the operational phase

Operational Phase	Activity	Potential Environmental Impact
a) Site work / other facilities.	i) Creation of reservoir	i) Leads to submergence of a large number of plant. causes habitat shrinkage and fragmentation. helpful in fishery development
	ii) Construction of permanent structures like roads. colony. etc.	ii) Sewage outfall. vehicular movement. which would disturb wild animals.
	iii) Dam structure	iii) Hampers fish migration
b) Construction of footpath	i) in affected villages	i) It will help the local people in the transportation
c) Downstream impacts	i) There will be reduction in the water from 14 km stretch	i) It would cause habitat fragmentation for fish and provide new corridors for wildlife ii) Low dilution of pollutants would lead to deterioration of water quality
d) Socio-economic impacts	i) Amenities	i) The establishment of new schools. health centres and market complex. provision of drinking water. electricity etc. would empower the tribal population. improve the quality of life in the region and provide fair job opportunities
e) Implementation of EMP	CAT Biodiversity Management Fisheries Landscaping Etc.	Reduce the negative impacts

Matrix 4.1 Modified Leopold Matrix to study the environmental impacts in construction phase

Environmental effects / Developmental Activities	Land Environment						Geophysical Environment				Aquatic Environment				Air Environment & Noise				Human Environment					Downstream Environment						Economic Upliftment				**Total**
	Land use /land cover	Habitat loss/ Degradation	Wild life	Phytoretardation	Exploitation of resource	Invasive Species	Ground Water Level	Weathering	Landslides/slip	Stability	Deterioration of water	Species/Habitat loss	Fish Movement	Fisheries	NO_2, SO_2 Level	SPM	Noise Level	Visual Impact	Demographic changes	Cultural confliction	Social evils	Interaction	Health hazards	Habitat /species loss	Flow regime	Livelihood	Drinking water	Bank Erosion	Riparian vegetation	Employment	Social value	Basic amenties	Marketing	
Dam	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-1**
Road construction	-1	0	-1	0	0	-1	0	-1	-2	0	-1	0	0	0	0	-2	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**-9**
Submergence	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-1**
Power house	-1	-1	-1	0	0	0	0	0	-1	0	0	0	0	0	-0	-0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-5**
Adits	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-2**
Dumping	-1	-1	0	-1	0	0	0	0	0	0	-2	-1	0	0	-1	-2	0	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	**-11**
Excavation/Tunnelling	0	0	-2	-1	0	0	-2	-2	-2	-2	-1	-1	0	0	0	-2	-2	-1	0	0	0	0	-2	0	0	0	0	0	0	0	0	0	0	**-20**
Quarrying	-2	-1	-1	-1	0	0	0	0	-2	0	0	0	0	0	0	-3	0	-2	0	0	0	0	-2	0	0	0	0	0	0	0	0	0	0	**-14**
Colony	-1	-1	-1	0	0	0	0	0	0	0	-1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	**-3**
Diversion	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Migrant population	0	0	-1	0	-2	-2	0	0	0	0	-2	-1	0	-1	0	0	0	0	-1	-2	-2	2	-1	0	0	0	0	0	0	1	0	1	1	**-10**
Construction method/	0	0	-2	-1	0	0	0	0	0	0	-2	0	0	0	0	-1	-3	-1	0	0	0	0	-1	0	0	0	0	0	0	2	0	0	0	**-9**
Vehicular Movement	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	-3	-1	-1	0	0	0	0	0	-1	0	0	0	0	0	0	0	1	1	0	**-7**
Community Development	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	4	1	**10**
Total	**-7**	**-4**	**-10**	**-4**	**-2**	**-3**	**-2**	**-3**	**-7**	**-2**	**-10**	**-4**	**0**	**-1**	**-4**	**-11**	**-8**	**-7**	**-1**	**-2**	**-2**	**2**	**-8**	**0**	**0**	**0**	**0**	**0**	**0**	**7**	**3**	**8**	**2**	**-80**

Matrix 4.2 Modified Leopold Matrix to study the environmental impacts in operation phase

Environmental effects / Developmental Activities	Land Environment						Geophysical Environment				Aquatic Environment				Air Environment & Noise				Human Environment					Downstream Environment						Economic Upliftment				**Total**
	Land use /land cover	Habitat loss/ Degradation	Wild life	Phytoretardation	Exploitation of resource	Invasive Species	Ground Water	Weathering	Land Slide/slips	Stability	Deterioration of Water	Species/Habitat Loss	Fish Movement	Fisheries	NO_2, SO_2	SPM	Noise Level	Visual Impacts	Demographic change	Cultural confliction	Social evils	Interaction	Health hazards	Habitat /species loss/	Flow regime	Livelihood	Drinking water	Bank Erosion	Riparian vegetation	Employment	Social value	Basic amenities	Marketing	
Dam	0	0	0	0	0	0	0	0	0	0	0	0	-3	0	0	0	0	0	0	0	0	0	0	-2	0	0	0	0	0	0	0	0	0	**-5**
Road construction	0	-1	-1	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	**-1**
Submergence	0	-1	-1	0	0	0	0	0	0	0	-1	0	-2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-3**
Power house	0	0	-1	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-2**
Adits	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-2**
Dumping	-1	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-3**
Excavation/Tunnel.	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**-1**
Quarrying	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Colony	0	0	-1	0	0	0	0	0	0	0	-2	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	**-2**
Diversion	-1	0	-1	0	0	0	0	0	0	0	*	*	0	0	0	0	0	0	0	0	0	0	0	-3	-3	-1	0	-1	-1	0	0	0	0	**-11**
Migrant population	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	-1	-1	-1	0	-1	-1	0	1	0	0	0	0	0	0	0	0	0	0	1	**-5**
Construction method	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Vehicular Movement/Equipment	0	0	-1	-1	0	0	0	0	0	0	0	0	0	0	-1	-1	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	1	1	0	**-3**
Community Development	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	3	1	**6**
Total	**-1**	**-2**	**-6**	**-1**	**0**	**-1**	**-3**	**0**	**-1**	**0**	**-4**	**-1**	**-5**	**2**	**-2**	**-2**	**-1**	**-2**	**-1**	**-1**	**0**	**1**	**-1**	**-5**	**-3**	**-1**	**0**	**-1**	**-1**	**1**	**3**	**6**	**2**	**-30**

BIBLIOGRAPHY

BIBLIOGRAPHY

Ali, S. and Ripley, S.D. (2001). *Handbook of the birds of India and Pakistan* Vol 1 to 10. Oxford University Press, New Delhi.

Bisset, R. (1987). *EIA Methods: A selective survey with case studies. In: Environmental Impact Assessment for Developing Countries*, A.K. Biswas and Qu Geping (eds.). Tycooly International, London.

Biswas, A.K. and Qu Geping (Chu, Ko-Ping) (editors) (1987). *Environmental Impact Assessment for Developing Countries*. Tycooly International , Oxford.

Burkill, I. H. (1925). *The Botany of Abor expedition*. Rec. Bot. Surv. India 10 (1).

Champion, H.G. and Seth, S. K. (1968). *A revised survey of the forest types of India*. Department of Forest, Govt. of India publication.

Chowdhery, H.J., Giri, G.S., Pal, G. D., Pramanik, A and Das, S.K. (1996). *Materials for the Flora of Arunachal Pradesh.* (eds.) Hajra et al. B.S.I., Kolkata.

CISMHE (1993). *Environmental Sensitivity of Himalayan River Basins*. CISMHE, Univ. of Delhi, Delhi. Sponsored by NHPC Ltd., New Delhi.

CISMHE (1998). *Environmental Sensitivity of Tuivai River basin and Environmental Impact Assessment of Tuivai Hydro-electric Project*. CISMHE, Univ. of Delhi, South Campus, New Delhi.

Clark, B.D., et al, (1981). *A Manual for the Assessment of Major Development Proposals*, London: Her Majesty's Stationery Office.

Curtish, J.T. and Cottom, G. (1956). *Plant Ecology Work Book: Laboratory Field Reference Manual.* Burgess Publishing Com., Minnesota. pp.193.

Curtish, J.T. and McIntosh, R. P. (1950). The interrelations of certain analysis and synthetic phytosociolgical characters. Ecology, 31:434-455.

Dee, N. et al., (1979). *Environmental Evaluation System for Water Resources Planning*. Columbus, Ohio: Battelle Columbus Laboratories.

Duke, K.M. et al., (1979). *Environmental Quality Evaluation Procedure Implementing Principles and Standards for Planning Water Resources Programs.* Draft Report. Washington, DC: US Water Resources Council.

Dutta, B.B. and Roy, S.B. (2006). *Aves. In: Fauna of Arunachal Pradesh*, State Fauna Series, 13 (Part 1), 69-245. Zool. Surv. India.

Dynesius M. and Nilsson C. (1994). *Fragmentation and flow regulation of river systems in the northern third of the world.* Science 266: 753-762.

Edmondson, W. T. (1959). *Freshwater Biology (2nd edition).* John Wiley & Sons, New York. 1248 pp.

FSI. (2003). *State of Forest Report*. Forest Survey of India, Dehradun, pp. 182.

Ghosh, S.R., Ghosh, B., Biswas, A., & Ghosh, R.K. (2004). *The Pteridophytic Flora of Eastern India* Vol.- I, Botanical Survey of India, Kolkata, pp.1-591.

Grewal, B., Harvey, B. and Pfister, O. (2002). *A Photographic Guide to The Birds of India*. Periplus Editions (HK) Ltd. Singapore, pp 512.

Hynes, H. B. N. (1970). *The ecology of running waters.* University of Toronto Press, Toronto

Hynes, H.B.N. (1970). *The Ecology of Running Waters*. University Toronto Press, Toronto.

Hooker, J.D. (1906). *A sketch of Flora British India*. London

Jackson, M. L. (1958*). Soil Chemical Analysis*. Prentice Hall, Inc. Engle Wood Cliffs, New Jersey, U.S.A.

Jensen J.R. (1996*). Introductory Digital Image Processing: A Remote Sensing Perspective*, Prentice-Hall Inc., Upper Saddle River, NJ.

Karr, J.W. & Chu, E.W. (1999). *Restoring life in running waters: better biological monitoring*. Island press, Washington DC, USA; pp 1-2.

Kaul R. N. and Haridasan K. (1987). *Forest types of Arunachal Pradesh- a preliminary study*. Journal of Economic and Taxonomic Botany 9: 383-389.

Kayal, J. R.. (2008). *Microearthquake seismology and seismotectonics of South Asia*. New Delhi: Capital Publishing Company.

Kingdom –Ward, F. (1953). *The Lohit valley in 1950*. Proc. Linn. Soc. London 164: 2-8

Kumar, G (1997): *Geology of Arunachal Pradesh*, Geol Soc. India. Ind. 214p.

Leopold, L. *et al.* (1971) *A procedure for evaluating Environmental Impact*. US Geological survey Circular 645. Washington, DC: US Geological Survey.

Mani, M.S. (1974) *Ecology and Biogeography in India*. Dr.W. Junk b.v. Publishers, The Hague, The Netherlands. Program that aims to secure the cooperation of tribal

McCully, P. (2001). Rivers *No More: The environmental effects of large dams; an excerpt from Silenced Rivers: The Ecology and Politics of Large Dams*, Zed Books, London, UK.

Mudgal, V. & Hajra, P. K. (1999). *Floristic Diversity and Coservation Strategies in India*. Botanical Survey of India, Kolkata.

Myers, N., Mittermeier, R.A., Mittermeier, C.A., da Fonseca, G.A.B. & Kent, J. (2000) *Biodiversity hotspots for conservation priorities. Nature*, **403**, 853–858.

Nayar, M. P. and Sastry, A. R. K. (1987): *Red Data Book of Indian Plants*. Botanical Survey of India, Howrah. Vol. I.

Nayar, M. P. and Sastry, A.R.K. (1988): *Red Data of Indian Plants.* Botanical Survey of India, Howrah. Vol. II.

Nayar, M. P. and Sastry, A.R.K. (1990): *Red Data of Indian Plants.* Botanical Survey of India, Howrah. Vol. III.

Negi, S. S. (1989). *Forest types of India, Nepal and Bhutan*. Periodical experts book Agency, Delhi.

Negi, S. S. (1996). *Forest types of India. In: S.S. Negi* (ed.) Manual of Indian Forestry Vol I. pp.180-243. Bishen singh Mahendra Pal singh, Dehra Dun.

Postel, S. L. (1998). *Water for food production: Will there be enough in 2025?*. BioScience 48: 629-637

Rabeni, C.F. and Jacobson, R.B. (1993). *The importance of fluvial hydraulics to fish habitat restoration ion low gradient alluvial streams. Freshwater Biology*, 29,211-220.

Rodgers, W.A. & Panwar, H.S. (1988). *Planning a Wildlife Protected Area Network in India, Volume I & II). A Report Prepared for the Department of Environment, Forests & Wildlife,Government of India*. Wildlife Institute of India, Dehradun, India.

Sanyal, D.P. and Gayen, N.C. (2006). *Reptilia. In: Fauna of Arunachal Pradesh,* State Fauna Series, 13 (Part 1), 247-284. Zool. Surv. India.

Sarkar, A.K. and Ray, S. (2006). *Amphibia. In: Fauna of Arunachal Pradesh,* State Fauna Series, 13 (Part 1), 285-316. Zool. Surv. India.

Sarod, P. T. & Kamat, N. D. (1984). *Fresh Water Diatoms of Maharashtra*. Saikripa Publications, Aurangabad. 338 pp.

Sassaman, R.W. (1981). *Threshold of Concern: A Technique for Evaluating Environmental Impacts and Amenity Values.* J. of Forestry, 79(2), pp.84-6.

Sen, T. K. (2006). *Pisces. In: Fauna of Arunachal Pradesh.* Part 1. Edited by J.R.B. Alfred, Zoological Survey of India, Kolkata.

Talwar, P. K. and Jhingran, A. G. (1991). *Inland fishes of India and adjacent countries,* Vol.1 & 2, Oxford.

Takhtajan, A. (1986). *Floristic regions of the world.* Univ. California Press. Berkeley.

Vogel, S. (1981). *Life in moving fluids*. Princeton University Press, Princeton, New Jersey.

ANNEXURES

Annexure I

QUESTIONNAIRE FOR SOCIO-ECONOMIC SURVEY OF AFFECTED VILLAGES DUE TO PROJECT RELATED ACTIVITIES OF PROPOSED PAUK H.E. PROJECT, ARUNACHAL PRADESH

1. Village Name ____________________

   a) District ______________ b) Development Block ________

   b) Tehsil ______________ d) Panchayat ____________

2. Area (ha) ____________________

3. Number of households ____________________

4. Population Profile:

   Total population:

   a) Male ____________________

   b) Female ____________________

   c) Scheduled Castes ____________________

   d) Scheduled Tribes ____________________

5. Workers:

   a) Main workers ____________________

   b) Farmers ____________________

   c) Marginal workers ____________________

   d) Others ____________________

6. Total Cultivable area (ha) ____________________

7. Net Sown area (ha) ____________________

8. Net Irrigated area (ha) ____________________

9. Cropping Pattern:

   Area (ha) under principal crops and yield (per ha) ____________________

Cereals

a) Wheat ____________________

b) Maize ____________________

c) Rice ____________________

d) Others ____________________

Pulses

Rajmah ____________________

Others ____________________

10. Horticulture:

Area (ha) under principal crops and annual production

a) ____________________

b) ____________________

c) ____________________

d) ____________________

11. Medical Facilities:

a) Allopathic institutions	No.	No. of Beds	No. of Doctors	Other Staff
1) Hospitals				
2) Community Health Centres				
3) Primary Health Centres				
4) Dispensary				
5) Health Sub-centre				

b) Ayurvedic Institutions: Nos. No. of Beds

1) Hospitals ______________________

2) Dispensary ______________________

c) Health & Hygiene:

Prevalent Diseases ______________________

Endemic Diseases ______________________

Epidemic Diseases ______________________

12. Educational Institutions:	Number	Student Strength	No. of Teachers
a) Primary schools			
b) Middle schools			
c) High / Higher Secondary schools			
d) Colleges			

If there is no school, then nearest school and distance from the village.

13. Veterinary Facilities:

a) Hospitals ______________________

b) Dispensary ______________________

c) Artificial Insemination Centres ______________________

14. Sewage & Sanitation Facilities, if any ______________________

____

15. Whether Electrified Yes / No

– Any electrical sub-station ______________________

– If not electrified, then the nearest electrified village ______________________

16. Roads Length (km)

   a) Unmetalled ______________________

   b) Metalled ______________________

   c) Jeepable ______________________

   d) If not connected by any road, then the nearest road head (distance)

   ____

17. Post Office Yes / No

   If the answer is 'No', then the location and distance of nearest post office

   ____

18. Telegraph Office ______________________

19. Banks ______________________

20. Police Post ______________________

21. State Government Employees ______________________

22. Central Govt. Employees ______________________

23. Drinking water availability:

   Source ______________________
   (River, Well, Hand-pump, Tap, Public Standpost, springs and others)

   Quality : Satisfactory : Yes/ No
   (Nature of problem, if No)

   Quantity : Adequate/ Inadequate For drinking water (litres)
   For other use (litres)
   Any other specific drinking water problem
   If the water is not fit for drinking, how do you purify it.
   (filtering through cloth, boiling, alum treatment, disinfectant, decantation) etc.

   Water borne diseases, if any
   (Dysentary, Diarrhoea, Jaundice, Gastroenteritis, others, etc.)

24. Livestock:

- Sheep ________________ Buffaloes ________________
- Goat ________________ Horses & Mules ________________
- Cows ________________________________

25. Co-operative Societies & NGOs ________________________________

26. Village Panchayat ________________________________

27. Fair Price Shop ________________________________

28. Tourist/Recreational Spot ________________________________
(Religious place, historical monument, sanctuary, others, etc.)

29. Fertilisers used and consumption ________________________________

30. a) Forest Range/Division ________________________________

Forest Check Post/s ________________________________

b) Forests & Forest Produce:

Forests:

Reserve Forest ________________________________

Protected Areas ________________________________

Revenue Forest ________________________________

Forest produce:

Medicinal herbs ________________________________

Misc. ________________________________

31. Natural Water Sources:

a) Springs ________________________________

b) Brooks ________________________________

c) Water Quality ________________________________

32. Literacy ____

33. Income Pattern:

a) Farming ____

b) Salaried:

- Government ____

- Private ____

c) Businessman/Shops/Trading ____

34. Government Schemes (Both Central & State Govt.) like IRDP, etc.

____

____

35. Vocational Training Centres, if any ____

____

36. Meteorological Data:

a) Rainfall
i) Average Annual ________________ ii) Daily (mm) ________________

b) Temperature Mean: __________ Max. ______ °C Min. ________ °C

Daily record, if available ____

c) Snowfall ____

d) Hailstorms a) Intensity ________________ b) Frequency ____________

e) Flashfloods a) Historical ________________ b) Frequency ____________

37. Fishery Resources:

Type of Fish ____

Licenced Fisherman, if any ____

Fish catch ______

38. Small Scale Industries:

a) Medicinal herbs collection ______

b) Handicrafts ______

c) Shawl making ______

d) Carpet weaving ______

e) Paper Machie ______

f) Wooden carving ______

g) Apiary ______

h) Others ______

39. Mode of transport : ______

40. Vehicles:

a) Bicycles ______

b) Tractors ______

c) Scooters/Bikes ______

41. Marketing Facilities:
Local Trading Centre ______

42. Non-conventional Energy Sources:

Solar lighting etc. ______

43. Recreational facilities ______
(Library, Club, TV, Cinema, etc.)

44. Wastewater
How do you dispose-off watewater ______
(Drainage, Sewer, Soak pit, No organised system, etc.)

Any specific problem related to waterwater ______

Suggestions for improvement ______

45. Sanitation and Health

No. of families : Latrine proper sanitation facilities

Soakpit : ______________ Septic tank : ______________ Any other : ______________

(If No, where do you go for defecation)

Open space: Field: Road side: Public latrine:

46. Solid waste disposal:

(Unused land, road side, community dustbin, composting, any other)

Annexure II

QUESTIONNAIRE FOR SOCIO-ECONOMIC SURVEY OF AFFECTED FAMILIES DUE TO PROJECT RELATED ACTIVITIES OF PROPOSED PAUK H.E. PROJECT, ARUNACHAL PRADESH

Village Name ____________________

a) District ____________ b) Development Block ____________

b) Tehsil ____________ d) Panchayat ____________

1. Name of the head of the family ____________________

2. Religion of the family ____________________

3. Caste of the family: General ________ SC ________ ST ________ OBC ________

4. Number of Family Members ____________________

5. Age group of the family members: Adults ____________________

   Children (0-6) ____________________

   Children (6-17) ____________________

6. Number of earning members

7. Number of non-earning members Male [ ] Female [ ]

8. Number of dependants & relationship with head of the family

   Male ____________________

   Female ____________________

   Children: (Male : 0-6) ____________________

   (Female : 0-6) ____________________

9. Marital status of dependants : Married : Male [ ] Female [ ]

   Unmarried : Male [ ] Female [ ]

10. Occupation of family members:

    Father ____________________

    Mother ____________________

    Children : Daughter ____________________

    Son ____________________

    Others ____________________

11. Occupation details:

Service Governmetn/ Non-government

Agriculture ______________________

Business ______________________

Any other ______________________

12. Educational qualifications of family members:

Primary ______________________

Higher Secondary ______________________

Graduate ______________________

Post-graduate ______________________

and above ______________________

13. Homestead Land:

	No. of house/houses	Area (Acres)
a) Owner	______________	______________
b) Tenant	______________	______________

14. No. of houses affected due to construction of project ______________________

15. No. of houses left ______________________

16. Land holding:

Total ______________ Acres/ hectare/ any other ( )

Land under cultivation ______________ Acres

Location of land Same village ______________ (Area in acres/ha/any other)

Other village ______________ (Area in acres/ha/any other)

17. Land self tilled or by labourers ______________________

18. Whether living in village or not, permanently/temporarily ______________________

19. No. of shops/mills to be acquired/affected

20. No. of shops left

21. No. of animals : Sheep ______________________
    Goat ______________________
    Cow ______________________
    Bull ______________________
    Horse ______________________
    Pig ______________________
    Others ______________________

22. Income:
    a) Source/s ______________________
    b) Total annual income including agriculture, self employment, salaries, casual wages, etc. ______________________
    ____

22. Cropping Pattern ______________________

23. Income /expenditure Pattern ______________________

24. Details of government grants, if availed under Indian Rural Developmental Programme (IRDP) or other such schemes ______________________
    ____

25. Health Status:
    - Name major diseases by which family members fell sick in last 3 years ______________________
    - Type of treatment, family generally avails ______________________ (allopathy, homoeopathy, ayurvedic, unani, etc.)
    - Does family knows preventive measures ______________________ of the above diseases (Immunisation, water treatment, personal hygiene, do not know, etc.)
    - Where does family go for treatment ______________________ (Household treatment, Pvt. medical practitioner, Govt. hospital, PHC, etc.)

- Have any member got vaccinated in the last one year ______________________
  (Cholera, Jaundice, any other)

26. Land aquisition

    a) Total land of the owner____

    b) Land to be acquired (ha) ____

    c) Land left (ha) ____

    d) Type of land acquired (ha)- Landuse ___________________________________

    e) Type of land left (ha) - Landuse ______________________________________

    f) Estimated loss due to loss of agricultural land, if any _______________________

    ____

27. Immovable Properties:

    a) Houses ____

    b) Wells ____

    c) Ponds ____

    d) Water- mills ____

    e) Others ____

28. Willingness to Accept:

    a) Willing to accept the loss of land (homestead/agricultural) Yes/No

    b) Is ready to accept the proper compensation offered Yes/No
       for the loss as per the State policy

    c) If answers to above questions are No, then give reasons ____________________

    ____

29. Would you welcome the project. Yes/ No
    (If No, give reasons)

Surveyor Name: ______________________ ______________________
Signature of the respondent

Date : ___________________

Annexure-III

List of Flowering plants in influence area of Pauk HE Project

Gymnosperms				
Family	**Genus**	**Species**	**Habit**	**Altitudinal occurrence (m)**
Pinaceae	*Pinus*	*wallichiana*	tree	to 2000
Cephalotaxaceae	*Cephalotaxus*	*griffithii*	tree	1900-2400
Pinaceae	*Tsuga*	*dumosa*	tree	to 2700
Cupressacesae	*Juniperus*	*recurva*	shrub	to 2900
Angiosperms				
Dicots				
Ranunculaceae	*Anemone*	*vitifolia*	herb	1500-2700
	Clematis	*buchananiana*	climber	800-1600
	Clematis	*gouriana*	climber	to 2000
	Ranunculus	*cantoniensis*	herb	1000-2500
	Thalictrum	*foliolosum*	herb	to 1800
	Thalictrum	*javanicum*	herb	to 2100
Magnoliaceae	*Magnolia*	*pterocarpa*	tree	1500-2500
	Magnolia	*campbellii*	tree	1600-2000
	Michelia	*doltsopa*	tree	1300-1700
	Michelia	*glabra*	tree	300-1200
	Michelia	*oblonga*	tree	1200-1800
	Michelia	*punduana*	tree	1000-1500
	Michelia	*velutina*	tree	1500-2000
Menispermaceae	*Stephania*	*elegans*	climber	to 1800
	Stephania	*glandulifera*	climber	450-1700
Fumariaceae	*Dicentra*	*scandens*	climber	1500-2500
Berberidaceae	*Berberis*	*asiatica*	shrub	1000-2000
	Berberis	*hookeri*	shrub	2400-3400
Brassicaceae	*Brassica*	*nigra*	herb	to 1500
	Brassica	*juncea*	herb	1000-1200
	Cardamine	*scutata*	herb	1800-2500
Violaceae	*Viola*	*betonicifolia*	herb	800-1500
	Viola	*canescens*	herb	1500-2500
	Viola	*diffusa*	herb	1600-3200
Caryophllaceae	*Arenaria*	*neelgherrensis*	herb	Up to 1700
	Arenaria	*orbiculata*	herb	15-2600
	Brachystema	*calycinum*	herb	1100-2500
	Stellaria	*decumbens*	herb	1000-1600
Hypericaceae	*Hypericum*	*elodeoides*	herb	1100-3000
	Hypericum	*japonicum*	herb	1700-1800
Theacee	*Camellia*	*caudata*	shrub	1000-1800
	Camellia	*kissi*	shrub	1100-1800
	Eurya	*siangensis*	shrub	1150-1800
	Eurya	*acuminata*	tree	900-1500
	Eurya	*cerasifolia*	tree	1500-1800
	Eurya	*nitida*	tree	1000-2000
	Schima	*wallichii*	tree	1200-2000

Actinidiaceae	*Saurauia*	*punduana*	tree	900-1800
	Saurauia	*roxburghii*	tree	Up to 1000
Malvaceae	*Urena*	*lobata*	herb	to 1500
Elaeocarpacdeae	*Sloanea*	*tomentosa*	tree	1400-1600
Malpighiaceae	*Hiptage*	*benghalensis*	climber	to 1800
Geraniaceae	*Geranium*	*polyanthes*	herb	1500-2500
Balsaminaceae	*Impatiens*	*angustiflora*	herb	1000-1500
	Impatiens	*arguta*	herb	900-2130
	Impatiens	*drepanophora*	herb	600-1500
	Impatiens	*racemosa*	herb	1500-2000
Oxalidaceae	*Oxalis*	*corniculata*	herb	to 2800
Rutaceae	*Zanthoxylum*	*acanthopodium*	shrub	1000-2500
Aquifoliaceae	*Ilex*	*dipyrena*	tree	1000-1800
Aquifoliaceae	*Ilex*	*sikkimensis*	tree	1500-2000
Celastraceae	*Ilex*	*theifolius*	sherb	1500-2500
Rhamnaceae	*Berchemia*	*floribunda*	sherb	1400-1700
Vitaceae	*Cissus*	*japonica*	climber	to 1500
Aceraceae	*Acer*	*campbellii*	tree	1600-1800
	Acer	*acuminatum*	tree	1500-2500
Anacardiaceae	*Rhus*	*succadanea*	tree	to 1650
	Rhus	*chinensis*	tree	to 2000
Papilionaceae	*Crotolaria*	*cajan*	shrub	to1500
	Desmodium	*microphyllum*	herb	to 1600
Caesalpiniaceae	*Bauhinia*	*purpurea*	tree	to 1500
	Bauhinia	*variegata*	tree	to 1750
Mimosaceae	*Albizia*	*odoratissima*	tree	to 1500
Rosaceae	*Cotoneaster*	*acuminatus*	herb	2000-3000
	Cotoneaster	*bacillaris*	shrub	1600-2000
	Photinia	*cuspidata*	tree	1500-2200
	Fragaria	*nubicola*	herb	1800-2500
	Potentilla	*nepalensis*	herb	1500-2500
	Potentilla	*sundersiana*	herb	1800-3600
	Prunus	*cerasoides*	tree	1200-3000
	Prunus	*persica*	tree	800-1500
	Rubus	*burkillii*	shrub	
	Rubus	*hamiltonii*	shrub	900-1500
	Rubus	*ellipticus*	shrub	1500-1800
	Rubus	*lineatus*	shrub	to 2000
	Rubus	*niveus*	shrub	to 1100
	Rosa	*brunonii*	shrub	to 2599
Saxifragaceae	*Bergenia*	*ciliata*	herb	
	Dichroa	*febrifuga*	shrub	to 2500
Hydrangeaceae	*Hydrangea*	*robusta*	shrub	to 2500
Hamamelidaceae	*Altingia*	*excelsa*	tree	800-1600
	Exbucklandia	*populnea*	tree	to 2000
Melastomataceae	*Melastoma*	*erythrophylla*	shrub	600-1500
	Melastoma	*malabathricum*	shrub	400-1400
	Osbeckia	*normale*	shrub	to 2000
	Osbeckia	*chinensis*	shrub	
	Oxyspora	*paniculata*	shrub	1000-2000

Onagraceae	*Ludwigia*	*octavalvis*	herb	to 900
Cucurbitaceae	*Cucumis*	*melo*	climber	
Apiaceae	*Centella*	*asiatica*	herb	to 1700
	Hydrocotyle	*nepalensis*	herb	to 1600
	Pimpinella	*diversifolia*	herb	1500-2200
Araliaceae	*Brassiopsis*	*aculeata*	tree	1500-2000
	Hedera	*trifoliatus*	shrub	1000-1200
	Hedera	*nepalensis*	climber	1500-2500
	Schefflera	*venullosa*	shrub	800-1500
	Schefflera	*impressa*	tree	
	Schefflera	*wallichiana*	sh/tree	1500-1800
Alangiaceae	*Alangium*	*chinense*	tree	1500-2000
Caprifoliaceae	*Viburnum*	*colebrookianum*	shrub	to 1000
	Viburnum	*cylindricum*	shrub	Up to 2000
Rubiaceae	*Galium*	*asperuloides*	herb	200-2000
	Luculia	*pinceana*	shrub	1100-1800
	Mussaenda	*roxburghii*	shrub	to 1500
	Ophiorrhiza	*glabra*	shrub	600-1500
	Paederia	*foetida*	shrub	800-1200
Valerianaceae	*Valeriana*	*jatamansi*	herb	2000-3000
Asteraceae	*Artemisia*	*nilagirica*	herb	to 2500
Asteraceae	*Aster*	*molliusculus*	herb	
	Aster	*albescens*	herb	1700-2700
	Conyza	*bonariensis*	herb	to 2450
	Conyza	*japonica*	herb	900-2500
	Conyza	*candensis*	herb	1500-2500
	Dichrocephala	*integrifolia*	herb	
	Circium	*wallichii*	herb	
	Carduus	*edelbergii*	herb	
	Sonchus	*oleraceus*	herb	1900-2400
	Ageratum	*conyzoides*	herb	to 2000
	Ageratina	*adenophora*	herb	to 2900
	Chromolaena	*odoratum*	shrub	to 2000
	Bidens	*bipinnatus*	herb	to 2000
	Eclipta	*prostrata*	herb	to 1500
	Galinsoga	*parviflora*	herb	to 2500
	Inula	*cappa*	herb	to 2400
	Anaphalis	*busua*	herb	600-3300
	Anaphalis	*contorta*	herb	2100-4000
	Anaphalis	*triplinervis*	herb	1800-4000
	Gnaphalium	*affine*	herb	1200-3000
	Gnaphalium	*hypoleucum*	herb	1500-2400
	Duhaldea	*rubricaulis*	herb	1700-1900
	Duhaldea	*gossypina*	herb	1200-2400
	Tagetes	*minuta*	herb	to 2000
	Vernonia	*cinerea*	herb	to 1500
Campanulaceae	*Campanula*	*sylvatica*	herb	to 1800
	Campanula	*pallida*	herb	1200-3000
Ericaceae	*Gaultheria*	*nummularioides*	shrub	1200-2400
	Gaultheria	*trichophylla*	shrub	2100-2900

	Pieris	*formosa*	shrub	1800-3000
	Leucothoe	*griffithiana*	tree	2070
	Vaccinum	*retusum*	shrub	2100-3050
	Lyonia	*ovalifolia*	tree	1500-2500
	Rhododendron	*arboreum*	tree	1700-4000
	Rhododendron	*grande*	tree	2100-3000
	Rhododendron	*falconeri*	shrub	2500
	Rhododendron	*hodgsonii*	shrub	2900
	Rhododendron	*barbatum*	tree	2100
Primulaceae	*Primula*	*denticulata*	herb	1800-4000
Myrsinaceae	*Maesa*	*chisia*	shrub	900-1800
	Myrsine	*semiserrata*	shrub	1000-2700
Symplocaceae	*Symplocos*	*ramosissima*	tree	1000-2000
	Symplocos	*theifolia*	tree	1500-2800
Oleaceae	*Jasminum*	*humile*	climber	1000-3000
	Jasminum	*multiflorum*	climber	to 1500
Apocynaceae	*Cryptolepis*	*buchanani*	climber	1000-1800
Loganiaceae	*Buddleja*	*paniculata*	shrub	900-2000
	Buddleja	*asiatica*	shrub	800-1500
Boraginaceae	*Cynoglossum*	*glochdiatum*	herb	1200-2400
Gentianaceae	*Crawfurdia*	*speciosa*	climber	1500-2100
Convolvulaceae	*Ipomoea*	*purpurea*	climber	to 1700
	Ipomoea	*carnea*	shrub	to 1500
Cucutaceae	*Cuscuta*	*reflexa*	climber	800-2400
Solanaceae	*Solanum*	*nigrum*	herb	800-1600
	Datura	*stramonium*	shrub	to 1400
	Physalis	*minima*	herb	to 1500
Scrophulariaceae	*Verbascum*	*thapsus*	herb	to 1900
	Mazus	*surculosus*	shrub	to 1600
	Mazus	*pumilus*	herb	1200-2400
	Lindera	*antipoda*	herb	1200
	Scrophularia	*urticifolia*	herb	1250
	Mimulus	*nepalensis*	herb	1800-3000
	Veronica	*anagallis-aquatica*	herb	
Gesneraceae	*Aeschynanthus*	*gracilis*	herb	2100
	Chirita	*pumila*	herb	to 1500
	Didymocarpus	*andersonii*	herb	800-1700
	Didymocarpus	*pulcher*	herb	800-1600
Begnoniaceae	*Oroxylum*	*indicum*	herb	900-2500
Acanthaceae	*Thunbergia*	*coccinea*	tree	to 1550
	Strobilanthes	*extensa*	climber	800-2200
	Strobilanthes	*hamiltoniana*	shrub	800-1900
	Dicliptera	*bupleuroides*	shrub	to 1500
Plantaginaceae	*Plantago*	*erosa*	herb	to 1800
Caprifoliaceae	*Lonicera*	*angustifolia*	herb	800-2400
	Lonicera	*obovata*	shrub	2200-3000
	Leycestera	*formosa*	shrub	
Lamiaceae	*Ocimum*	*gratissimum*	shrub	1500-3000
	Plectranthus	*barbatus*	herb	to 2000
	Anisochilus	*pallidus*	herb	1400-2200

	Elsholtzia	*fruticosa*	herb	900-1600
	Elsholtzia	*ciliata*	shrub	2100-3000
	Elsholtzia	*strobilifera*	herb	1600-2800
	Perilla	*frutescens*	herb	2100-2700
	Salvia	*plebeia*	herb	to 2300
	Scutellaria	*plectranthoides*	herb	ca 1525
	Anisomeles	*discolor*	herb	1200-2400
	Colquhounia	*indica*	herb	800-2400
	Leucosceptrum	*canum*	herb	800-2300
	Ajuga	*macrosperma*	shrub	1500-2500
Amaranthaceae	*Deeringia*	*celosioides*	herb	1200-3000
	Amaranthus	*spinosa*	herb	to 2500
	Cyathula	*prostrata*	herb	to 2000
	Achyranthes	*aspera*	herb	to 1800
	Alternanthera	*sessilis*	herb	to 1800
	Gomphrena	*celosoides*	herb	to 1500
Chenopodiaceae	*Chenopodium*	*album*	herb	800-1700
	Chenopodium	*aromaticum*	herb	800-2100
Polygonaceae	*Polygonum*	*plebium*	herb	800-2400
	Persicaria	*barbata*	herb	to 1500
	Persicaria	*posumbu*	herb	800-2000
	Persicaria	*capitata*	herb	800-1500
	Persicaria	*chinense*	herb	800-2600
	Aconogonum	*molle*	herb	800-2600
	Fagopyrum	*esculentum*	shrub	1000-2000
	Rumex	*nepalensis*	herb	1500-2800
Piperaceae	*Pepromia*	*heyneana*	herb	1000-3000
	Pepromia	*reflexa*	herb	to 1800
Lauraceae	*Phoebe*	*hainesiana*	herb	to 1890
	Cinnamomum	*tamala*	tree	800-1600
	Cinnamomum	*glauscescens*	tree	1400-1700
	Litsea	*kingii*	tree	to 1200
	Litsea	*sericea*	tree	2100-2900
	Actinodaphne	*obovata*	tree	1600-2400
Loranthaceae	*Loranthus*	*odoratus*	tree	to 1400
	Scurrula	*elata*	shrub	to 1500
Euphorbiaceae	*Euphorbia*	*hirta*	climber	to 2000
	Euphorbia	*stracheyi*	herb	to 1200
	Macaranga	*denticulata*	herb	1500-2500
Moraceae	*Morus*	*laevigata*	tree	to 1800
	Ficus	*semicordata*	tree	to 2000
	Ficus	*oligodon*	tree	to 1500
	Ficus	*auriculata*	tree	to 1400
Urticaceae	*Urtica*	*parviflora*	tree	to 1500
	Urtica	*ardens*	herb	to 1600
	Gerardinia	*diversifolia*	herb	2000-2600
	Pilea	*umbrosa*	herb	to 2000
	Lecanthus	*peduncularis*	herb	to 1600
	Elatostema	*sessile*	herb	to 1600
	Elatostema	*sesquifolium*	herb	to 1500

	Boehmeria	*platyphyllum*	shrub	to 1600
	Boehmeria	*macrophylla*	shrub	to 1400
	Debregeasia	*longifolia*	shrub	to 1800
Juglandiaceae	*Engelhardtia*	*spicata*	shrub	to 1800
Betulaceae	*Carpinus*	*viminea*	tree	to 2300
	Alnus	*nepalensis*	tree	to 2600
Fagaceae	*Quercus*	*semiserrata*	tree	1500-2200
	Quercus	*glauca*	tree	1600- 2300
	Quercus	*leucotrichophora*	tree	1200-1800
	Quercus	*lamellosa*	tree	1200-2600
	Lithocarpus	*elegans*	tree	1700-2700
	Lithocarpus	*pachyphyllus*	tree	900-2200
	Castanopsis	*indica*	tree	1500-2300
	Castanopsis	*hystrix*	tree	800-1500
	Castanopsis	*tribuloides*	tree	2000-2300
Salicaceae	*Salix*	*wallichiana*	tree	1200-2400
	Populus	*australis*	tree	1700-2700
			tree	Up to 2000
Monocots				
Hydrocharataceae	*Vallisneria*	*spiralis*		
	Hydrilla	*verticillata*	herb	to 1400
Orchidaceae	*Bulbophyllum*	*affine*	herb	to 1400
	Dendrobium	*porphrochilum*	epiphtic Herb	1200-2000
	Dendrobium	*longicornu*	epiphytic herb	1000-2000
	Spiranthes	*sinensis*	epiphytic herb	1000-1500
	Calanthe	*ovalis*	herb	Up to 2300
	Eria	*elegans*	epiphytic herb	800-1800
	Malaxis	*cathcartii*	epiphytic Herb	1500-2500
	Galeola	*lindlayana*	herb	1600-2500
Zingiberaceae	*Amomum*	*aromaticum*	herb	1800-2300
	Curcuma	*aromatica*	herb	to 1400
	Hedychium	*spicatum*	herb	to1500
	Hedychium	*coccinneum*	herb	to1800
	Zingiber	*offiinale*	herb	to1502
Musaceae	*Musa*	*bulbisiana*	herb	cult.
Dioscoreaceae	*Dioscorea*	*oppositifolia*	herb	to 1500
Smilacaceae	*Smilax*	*glabra*	climber	to 2000
	Smilax	*aspera*	climber	to 1700
Liliaceae	*Polygonatum*	*oppositifolium*	climber	to 1700
Hypoxidaceae	*Molineria*	*capitulata*	herb	to 1400
Araceae	*Pothos*	*cathcartii*	herb	to 2300
	Colocasia	*esculenta*	climber	to 1400
	Arisaema	*tortuosum*	herb	to 1800
	Arisaema	*concinum*	herb	1000-2400
Acoraceae	*Acorus*	*calamus*	herb	1200-2400

Commelinaceae	*Commelina*	*benghalensis*	herb	1200-2700
	Murdania	*scapiflorum*	herb	to 1700
	Murdania	*nudiflorum*	herb	to 1600
	Cyanotis	*cristata*	herb	to 1700
	Floscopa	*scandens*	herb	to 1500
	Pollia	*hasskarlii*	herb	to 1400
Juncaceae	*Juncus*	*inflexus*	herb	to 1600
Arecaceae	*Calamus*	*erectus*	herb	to 1800
Eriocaulaceae	*Eriocaulon*	*viride*	shrub	to 1500
Cyperaceae	*Kyllinga*	*brevifolia*	herb	to 1500
	Bulbostylis	*densa*	herb	to 1700
	Cyperus	*niveus*	herb	1500-2700
	Cyperus	*squarosus*	herb	800-2000
	Cyperus	*compressus*	herb	800-2300
	Cyperus	*cyperoides*	herb	800-2000
	Cyperus	*densa*	herb	to 1500
	Cyperus	*irria*	herb	to 1700
	Fimbristylis	*dichotoma*	herb	to 1500
	Fimbristylis	*junciformis*	herb	to 2000
	Scirpus	*teratanus*	herb	300-2400
	Schoenoplectus	*mucronatus*	herb	to 1700
	Schoenoplectus	*triqueter*	herb	to 1800
	Rhynchospora	*rugosa*	herb	to 1800
	Eriophorum	*comosum*	herb	1600-2300
	Carex	*nubigena*	herb	300-3000
	Carex	*longipes*	herb	1500-4000
	Carex	*myosurus*	herb	1000-3000
	Carex	*cruciata*	herb	1200-2000
	Carex	*filicina*	herb	to1500
	Carex	*decora*	herb	1000-1800
Poaceae	*Saccharum*	*spontaneum*	herb	Up to 1200
	Saccharum	*longisetosus*	herb	to 1500
	Saccharum	*rufipilus*	herb	to 1600
	Paspalum	*scrobiculatum*	herb	1800-2200
	Paspalum	*paspalodes*	herb	to 2000
	Isachne	*logiflora*	herb	to 2000
	Isachne	*albens*	herb	to 1700
	Panicum	*sumatrense*	herb	to 2000
	Thysanolaena	*latifolia*	herb	to1500
	Oplismenus	*compositus*	herb	to 1500
	Setaria	*glauca*	herb	to 2000
	Setaria	*verticillata*	herb	to 2000
	Setaria	*palmifolia*	herb	to 1500
	Zea	*mays*	herb	to 1700
	Imperata	*cylindrica*	herb	to 2000
	Digitaria	*ciliaris*	herb	to 2300
	Digitaria	*cruciata*	herb	to 1700
	Arthraxon	*hispidus*	herb	to 2300
	Apluda	*mutica*	herb	to 1600
	Capillipedium	*assimile*	herb	to 1600

	Chrysopogon	*gryllus*	herb	to 1500
	Chrysopogon	*acicularis*	herb	to 1500
	Themeda	*arundinacea*	herb	to 1400
	Themeda	*anathera*	herb	to 1700
	Sporobolus	*diander*	herb	to 1700
	Agrostis	*micrantha*	herb	to 1800
	Agrostis	*vinealis*	herb	to 2000
	Agrostis	*gigantea*	herb	to 1900
	Muhlenbergia	*viridissima*	herb	to 2000
	Calamagrostis	*emodensis*	herb	to 1600
	Cynodon	*dactylon*	herb	to 1900
	Eleusine	*indica*	herb	to 2300
	Eleusine	*coracana*	herb	to 1500
	Brachiaria	*ramosa*	herb	to 2100
	Oryzopsis	*munroi*	herb	to 1500
	Helictotrichon	*parviflorum*	herb	to 1800
	Arundo	*donax*	herb	to 1600
	Eragrostis	*nigra*	herb	to 1500
	Eragrostis	*pilosa*	herb	to 2400
	Eragrostis	*tenella*	herb	to 1800
	Poa	*annua*	herb	to 1800
	Brachypodium	*sylvaticum*	herb	to 2800
	Bambusa	*tulda*	herb	1800-1900
	Melocalamus	*compactiflora*	shrub	to 1500
	Thamnocalamus	*spathiflorus*	shrub	to 1400
			shrub	1800-2300

DRAFT FINAL REPORT
JUNE 2012

ENVIRONMENTAL IMPACT ASSESSMENT OF PAUK HYDROELECTRIC PROJECT, Arunachal Pradesh

Volume-II
Management Plan

Prepared for:
Pauk Hydro Power Pvt. Ltd., New Delhi

CENTRE FOR INTER-DISCIPLINARY STUDIES OF MOUNTAIN & HILL ENVIRONMENT
University of Delhi, Delhi

CONTENTS

LIST OF TABLES

LIST OF FIGURES

5.1
CATCHMENT AREA TREATMENT PLAN

5.1.1 INTRODUCTION

The increase of the population has led to the degradation of natural resources by over exploiting the natural resources in developing infrastructures to meet the energy demand, food supply etc. This is more so in the case of exploitation of water resource to cater to increased demands of energy, irrigation and water supply. The majority of the river valley developmental projects are followed by a number of related activities such as deforestation, and urbanization, etc. which cause degradation of the catchment and watershed which also represent an ecological functional unit. These developmental activities damage soil environment which ultimately leads to rapid erosion and sedimentation of reservoirs. Accelerated soil erosion in the catchment areas of the reservoirs and transport of detached material through the drainage network gives rise to a series of problems, notably depletion of flow capacity, steady loss of storage capacity, consistent drop in hydro-electric power generation and frequent floods. The loss of dead and live storage leads to heavy economic losses due to reduced life span of reservoirs. Therefore, extensive soil conservation and watershed management programmes are needed to minimize the damage to the catchment area and to mitigate soil erosion problems.

For any soil conservation programme or catchment area treatment plan watershed is chosen as the basic unit for implementation of such schemes. This is necessary because watershed is a natural hydrological and geographic unit. It covers a specific aerial expanse of land surface from which the rainfall-run off flows to a defined drain, channel, stream or river at any particular point. It is delineated by a line joining the highest points on the boundary of drainage basin with reference to specific point drainage. However, watershed below the ground surface does not always coincide with the surface watershed. The boundary between two adjacent watersheds is the drainage line. Delineation of the watershed depends on the catchment drainage pattern of the watershed. This in turn depends on the relief of the area considered.

As watershed characterizes optimum interaction and synergistic effects of land and water resources, its management primarily involves collection of basic information on a wide range of parameters of static and dynamic nature related to geology, hydrology, soil, geomorphology, topography, drainage conditions, land use, land cover, climate, etc.

5.1.2 CATCHMENT AREA TREATMENT PLAN

The proposed Pauk H.E Project catchment receives lesser precipitation in the form of snowfall in the upper catchment, but a higher rainfall, mainly received in the middle and lower parts. The terrain comprises moderately steep slopes to very steep slopes. These two factors are responsible for soil erosion by way of sheet erosion, rill erosion, gully erosion, bank erosion by streams and glacier erosion. In addition to these natural erosion processes that are active in the region, various project related construction activities are likely to accentuate the erosion process. One or several combinations of all these factors are known to cause landslides in the rainy season. Recurrent blasting for tunneling, etc. during the construction period are also likely to trigger off minor slips/ landslides due to the reduction of shear strength of rock material.

In view of the above, the catchment area treatment (CAT) plan for the free-draining catchment area has been formulated with the main objective of arresting soil erosion in the catchment area up to the dam site. The CAT has been limited to the free-draining catchment area because of an upstream river valley project, namely Rapum H.E Project, which is being developed by another developer. Based on the topographic factors, soil type, climate, land use/vegetation cover in the catchment area, various measures, both engineering/mechanical and biological are being proposed to be undertaken with the aim to check the soil erosion, prevent/check siltation of reservoir and to maintain its storage capacity in the long run. The engineering measures will comprise construction of a number of check dams/walls, retaining walls, wire crates, etc. for gully control, stabilization of flood prone streams, landslides/slopes, river banks, roads, etc.

5.1.2.1 Objectives

The Pauk H.E. Project catchment area treatment plan has been prepared with the following objectives:

i) Checking soil erosion and land degradation by proposing adequate and effective soil conservation measures in erosion prone areas (very severe and severe) in the catchment.
ii) Rehabilitation of degraded forest areas through afforestation and facilitating natural regeneration.

iii) Rehabilitation of degraded slopes and landslide prone areas, wherever necessary and possible.

5.1.3 ESTIMATION OF SOIL EROSION

In order to formulate appropriate soil conservation measures, it is essential to estimate the extent of soil erosion and its spatial context in the catchment area. A brief description of various factors that are responsible for soil erosion are being discussed below.

5.1.3.1 Drainage

The Yarjep Chu catchment area up to the barrage site is 98200 ha and the drainage network of the catchment area of Yarjep Chu is shown in **Figure 5.1.1**. The river is called as Barpu Sikyo in the head water region of the catchment. Barpu Sikyo is joined by large numbers of the snow fed, spring fed, glacial fed and seasonal rivers. These streams flow in the elevational region between 4000 to 4430 m. Yarjep chhu is a spring fed, snow fed and lake fed river. Small stream is also fed by four lakes on its left bank, which lie above 4000 m. In the middle stretch, Yarjep Chu runs from WNW to ESE and a number of tributary streams flowing from north hills to south and southern hills to north join this river in the Indian part of the catchment. The area of free draining up to the barrage site is about 15222.59 ha.

Left Bank Stream

Dasong Siding

It is a small springfed stream which flows from the steep southern slope of Shing Duk range. There is thick forest cover on these slopes. The stream course is marked by a 61 m high waterfall. The river flows for 1.6 km before it drains into Yarjep Channel before the dam site.

Right Bank Stream

Sae Chhu

As shown in the map given in **Figure 5.1.1** Sae Chu is one of the largest tributary systems of the Yarjep Chhu and moreover the largest tributary along the right bank of the Yarjep Chhu. It is a snowfed and springfed stream which flows towards northeast and confluences with Yarjep Chhu at 1428 m a.s.l. In its upper stretch it is also known as Chechi To. The river traverses an approximately 16 km stretch before it drains into the main river channel of Yarjep Chhu near Rego village before the barrage site. Mane Sokong, Gyara Sikyo, Shichi Sikyo, Sheh Sikyo and Sheti Sokang are important tributary streams of Sae Chhu. All these tributary systems form a several sub-watersheds of Sae Chu. The Northern slopes of Sae Chhu are almost vertical cliffs whereas the southern slopes are gentle.

5.1.3.2 Delineation of Sub-watersheds

For the demarcation of sub-watersheds, hierarchical delineation system developed by AIS & LUS (AIS&LUS Technical Bulletin 9) was followed in this study. The codification system as given in Watershed Atlas of India (AIS&LUS) was followed for Yarjep river watershed at 1:50,000 scale. Based on this delineation scheme, Yarjep River for Pauk H.E free draining area comprised of 12 sub-watersheds, which have been designated as Sc1 to Sc12 (**Fig. 5.1.2**). The catchment treatment plan has been limited to the free-draining catchment of the proposed Pauk H.E. Project as mentioned earlier. Therefore, for the preparation of CAT plan, all the twelve sub-watersheds have been delineated in the free-draining catchment area only as per the codification system given in Watershed Atlas of India (AIS&LUS) (see **Fig. 5.1.3**).

5.1.3.3 Slope

The slope has major influence on the soil loss and water from the watershed and thereby it influences the land use capability. The slope percentage determines the erosion susceptibility of the soil depending on its nature. This helps in classifying various lands for suitable capability classes, which enables us to formulate suitable conservation measures for the prevention of soil erosion. The following slope classes and ranges are recommended by All India Soil & Land Use Survey (AIS&LUS) and the same have been followed here in this study.

SLOPE CLASS	SLOPE RANGE	DESCRIPTION
A	0 - 2%	Gently sloping
B	2 - 8%	Moderately sloping
C	8 - 15%	Strongly sloping
D	15 - 30%	Moderately steep
E	30 - 50%	Steep
F	50 - 70%	Very steep
G	Above 70%	Escarpments

The slope model for the proposed Pauk H.E. Project area was generated from the contours of Survey of India (SOI) toposheets at 1:50,000 scale following a 40 m contour interval. The contours were digitized using ArcGIS 9.0 and wherever SOI toposheets were not available, DEMs were generated from the SRTM data obtained from Global Land Cover Facility at University of Maryland (www.glcf.umiacs.umd.edu). From the digital data, Digital Elevation Model (DEM) was also generated for the entire project area as well as for the sub-watersheds using ArcGIS 9.1. From these thematic maps, sub-watershed were extracted and digitized (see **Fig. 5.1.3**) with the help of free-draining catchment area only as per the codification system given in Watershed Atlas of India (AIS&LUS) followed by slope of the free-draining catchment area of Pauk H.E. Project (**Fig. 5.1.4**). These thematic maps were then used for erosion mapping and the forest cover mapping.

Our analysis reveals that about 86% of the free draining catchment area of the proposed Pauk H.E. project falls under two slope categories, *viz*. Moderately steep (63.93%) and Steep (22.98%) (see **Fig. 5.1.**4, Table 5.1.1). A small part (10.05%) of the free draining area falls in the strongly sloping category. Very steep slope and moderately sloping areas cover only a minor part 0.82% and 2.10% of the free draining area respectively. Along most part of the Yarjep River course steep slopes are present on either bank. For further details of slope distribution in the sub watersheds please refer to Table 5.1.1.

Table.5.1.1 Area (ha) under different slope categories of Pauk H.E project catchment area

Sub Watershed/ Slope	Gently Sloping	Moderately Sloping	Strongly Sloping	Moderately Steep	Steep	Very Steep
Sc1	0	4.45	46.28	529.01	302.63	3.07
Sc2	1	29.15	162.36	681.8	378.88	2
Sc3	0	6.36	85.33	629.01	129.56	0
Sc4	0	26.44	100.12	622.65	217.21	0
Sc5	1	28.27	144.49	1183.56	302.09	0
Sc6	1	13.08	199.85	775.98	62.32	0
Sc7	1.16	19.29	74.7	555.76	243.34	
Sc8	4.99	16.45	66.11	538.15	80.99	0
Sc9	3.01	70.32	159.01	755.53	220.69	0
Sc10	2.82	35.65	231.25	1346.53	432.82	0
Sc11	1	23.67	124.78	1241.34	558.74	46.2
Sc12	4	45.81	135.32	871.85	568.34	73.99

5.1.3.4 Land use/ land cover

Land use and land cover mapping was carried out by standard methods of analysis of remotely sensed data followed by ground truth collection and interpretation of satellite data. For this purpose digital data on CDROMs were procured from National Remote Sensing Agency, Hyderabad. Digital image processing of the satellite data and the analysis of interpreted maps were carried out at the Computer Centre at CISMHE using ERDAS Imagine 8.7.

Digital data of IRS P6 LISS-3 and Landsat-7 full scene were used for image processing and thematic map preparation (see Table 5.1.2) (**Fig.5.1.5**). For the secondary data, Survey of India toposheets on 1:50,000 and 1:25,000 were referred to for the preparation of base map and drainage map.

Table 5.1.2 Details of satellite sensor sources, path/row and date of image acquisition

Satellite	Sensor	Path/Row	Date	Data type & Bands
IRS P6	LISS-III	112/51	05-12-2006	Digital (1,2,3,4,5,7)

Classification Scheme

With the objective of preparing the environment management plan and an action plan for watershed management and a free draining catchment area treatment, the classification scheme adopted for the preparation of land use/ land cover maps and related thematic maps on 1:50,000 scale is as follows. Two forest density classes were interpreted for the forest cover mapping. The forests with >40% canopy cover were delineated as dense forests and between 10% and 40% crown density as open forest. Furthermore, degraded forests (with <10% canopy cover) and scrubs were also delineated for the purpose of erosion mapping. The cropland (agriculture) was also delineated for the calculation of erosion intensity classification. The non-forest land cover in the form of glaciers, lakes, moraines, etc. was also delineated.

The base map, drainage map and land use/land cover map prepared using the satellite data were digitized on computer for further processing and analysis using combination of ArcGIS 9.0 and GeoMedia Professional 5.2. The sub-watershed boundaries were then overlaid on the drainage map and land use map of the Yarjep river watershed up to the dam site in order to extract the drainage and land use of the sub-watersheds, which were further used for overlay analysis by Geographic Information System (GIS) techniques.

Yarjep river free-draining catchment of Pauk H.E Project has a prevalent forest cover. About 67% of the catchment area up to the proposed barrage site is covered with forest (dense and open forest) (Table 5.1.3, **Fig 5.1.6**). These forests belong mainly to Sub-tropical forest and Semi evergreen forest types. Of the total forest land (10193.49 ha), major part (49.36%) is covered with dense forest. Degraded forest covers 6.92% of the total forest area up to the dam site. Open forests cover 17.60% of the total catchment. However, Barren, Moraines, Snow & River account only for 9.10% of the total free draining area. Only 0.59% area is under agriculture & settlements (built-up areas). The scrub covers large area up to 16.42% of the free-draining catchment area. For further details of land use land cover distribution along the sub watersheds refer to Table 5.1.3.

Table 5.1.3 Area (ha) under different land use/ land cover categories in free-draining catchment area of Pauk H.E. Project

Sub Water-shed	Dense Forest	Open Forest	Scrub/ Alpine Scrub	Degraded Forest	Cultiva-tion	Moraines	Barren/ Rocky land	River/ Water-body	Snow
Sc1	496.48	101.34	186.34	0	0.17	36.03	64.42	0	0.67
Sc2	605.45	321.71	251.12	76.51	0	0	0	0.39	0
Sc3	514.72	48.54	204.32	0.63	0	24.68	57.36	0	0
Sc4	524.51	6.48	313.50	0	0	21.70	81.24	0	18.98
Sc5	896.12	37.17	454.67	17.16	0	38.44	108.78	0	107.05
Sc6	494.01	477.58	43.13	13.31	0	0	0	24.19	0
Sc7	451.03	33.50	176.92	0	0	42.14	75.21	0	115.45
Sc8	222.09	0	198.09	0	0	54.87	102.31	0	129.32
Sc9	609.29	47.83	335.05	1.68	0	15.79	54.21	0	144.71
Sc10	1091.06	601.97	215.24	140.31	0	0	0.06	0.43	0
Sc11	978.77	585.57	70.21	280.31	48.10	0	0	32.7	0
Sc12	630.78	417.46	50.91	524.20	41.47	0	0	34.51	0

5.1.3.5 Soils

The soils of the proposed Pauk H.E Project catchment comprise 6 main groups having 6 sub-groups associated to 6 soil units (see **Fig. 5.1.7** and Table 5.1.4). Loamy-Skeletal, Lithic-Udorthents soil is predominant in the free-draining catchment covering about 70% of the total area (Table 5.1.5). Among the different units, unit 1 comprises Loamy-Skeletal-Lithic Udorthents group associated with Typic Udorthents sub-group is the most dominant soil. It is characterized by the shallow with moderately deep soil. Almost entire stretch of Yarjep river and its major tributary of free draining area come under the soil unit 1 (S1). The second predominant form of soil unit is the S4 soil unit with area coverage of 9% of the total free draining area up to the barrage site. It is composed of Lithic Udorthents associated with Typic Udorthents, excessively drained and it is susceptible to very severe erosion. A detail classification of soil class along the sub-watersheds is given in the Table 5.1.5.

Table 5.1.4 Legend for soil series and their description in the free-draining catchment of Pauk H.E. Project

Soil Series	Description	Sub-Group
S1	Shallow, excessively drained, loamy-skeletal soils on very steeply sloping hill summit having loamy surface with very severe erosion hazard and moderate stoniness: associated with:	Loamy-skeletal, Lithic Udorthents
	Moderately deep, somewhat excessively drained loamy-skeletal soils on moderately steeply sloping side slopes with severe erosion hazard and moderate stoniness	Loamy-skeletal Typic Udorthents
S2	Deep, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping summits having loamy surface with severe erosion hazard and moderate stoniness: associated with;	Loamy-skeletal, Entic Haplumbrepts
	Moderately shallow, excessively drained, sandy skeletal soils on steeply sloping summits with very severe erosion hazard and slight stoniness.	Sandy-skeletal, Typic Udorthents
S3	Shallow, excessively drained, loamy-skeletal soils on steeply sloping summits having loamy surface with severe erosion hazard and slight stoniness: associated with;	Loamy-skeletal, Lithic Udorthents

	Moderately deep, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping side slopes and slight stoniness	Loamy-skeletal, Dystric Eutrochrepts
S4	Shallow, excessively drained, loamy-skeletal soils on very steeply sloping summits having loamy surface with severe erosion hazard and strong stoniness: associated with;	Loamy-skeletal, Lithic Udorthents
	Moderately deep, somewhat excessively drained, sandy-skeletal soils with very severe erosion hazard and moderate stoniness	Sandy-skeletal Typic Udorthents
S8	Moderately shallow, somewhat excessively drained, loamy-skeletal soils on moderately steeply sloping side slope of hills having loamy surface with severe erosion hazard and strong stoniness: associated with;	Loamy-skeletal, Typic Udorthents
	Moderately deep, somewhat excessively drained, fine-loamy soils with moderate erosion hazard	Fine-Loamy, Typic Eutrochrepts
S46	Rocky mountains covered with perpetual snow and glaciers	

Table 5.1.5. Soil classes in the free draining area with area coverage (areas in ha)

Sub Watershed /Soil Class	S1	S2	S3	S4	S8	S46
Sc1	56.56	0	161.26	667.61	0	0
Sc2	1117.83	0	0	137.35	0	0
Sc3	709.04	0	130.44	10.78	0	0
Sc4	633.87	11.49	0	0	0	321.06
Sc5	1033.67	253.24	0	0	0	372.5
Sc6	1052.23	0	0	0	0	0
Sc7	396.37	281.64	0		0	216.24
Sc8	20.69	260.21	0	0	0	425.8
Sc9	656.4	0	0	0	81.97	470.19
Sc10	2049.08	0	0	0	0	0
Sc11	1775.15	0	0	220.58	0	0
Sc12	1199.09	0	153.1	347.14	0	0

The soil and soil-depth of the free-draining catchment has been given in **Figure 5.1.8** and Table 5.1.6. About 82% of the free-draining catchment area of the proposed Pauk H.E. Project is characterized by shallow soil. However, there are certain pockets and areas in the sub-watersheds located in the southern part with rocky mountain and moderately shallow classes.

Table 5.1.6 Soil depth classes in the free draining area with area coverage

Sub watershed	Deep	Shallow	Moderately Shallow	Rocky Mountain
Sc1	0	885.44	0	0
Sc2	0	1255.18	0	0
Sc3	0	850.26	0	0
Sc4	11.49	633.87	0	321.06
Sc5	253.24	1033.67	0	372.5
Sc6	0	1052.23	0	0
Sc7	281.64	396.37	0	216.24
Sc8	260.21	20.69	0	425.8
Sc9	0	656.4	81.97	470.19
Sc10	0	2049.08	0	0
Sc11	0	1995.74	0	0
Sc12	0	1699.33	0	0

5.1.3.6 Erosion Intensity Mapping

A Composite Erosion Intensity Unit (CEIU) map on 1:50,000 scale was prepared using the spatial factors of slope, drainage, soil and land use. In Table 5.1.7 different conditions and weightage are given to assess the soil erosion intensity mapping. This composite map was then superimposed on the drainage map with sub-watershed boundaries in order to obtain sub-watershed-wise CEIU maps. As shown in **Figure 5.1.9** the different erosion intensity classes in the free draining area.

Table 5.1.7 Legend for the Composite Erosion Intensity Unit

Erosion	Slope Land cover	Land use/ depth	Soil DR Unit	Weightage/ Intensity
Very Severe (a)	Very very steep >50%	Open forest, scrub forest	Shallow	20/0.95
Severe	Steep to very	Open forest,	Moderately	18/0.90

(b)	steep 25 -50%	scrub, cultivation	shallow	
Moderate to slight (c)	Strongly sloping to moderately steep 10-25%	Dense forest, open forest, cultivation	Moderately deep	13-15/0.90
Slight to Negligible (d)	Gently sloping to moderately sloping 5-10%	Dense forest, open forest	Deep	11/0.85

As given in Table 5.1.8 and shown in **Figure 5.1.9** severe erosion class is prevalently spread in the free draining area with coverage of 55.4% of the total free draining area. Very severe is spread in an area of 3.4% of the free draining area. It is spread in the small pockets of Sc1, Sc3, Sc4, Sc5, Sc7, Sc8, and Sc9. All these sub-watersheds form the headwater region of Sae Chu and its tributaries. Small patches of very severe erosion classes are also spread in the pockets of Sc11 and Sc12. See **Table 5.1.8** for further erosion classes and area details.

Table 5.1.8. Soil erosion classes in free draining area

Sub Watershed	Slight	Moderate	Severe	Very Severe	River	Snow
Sc1	0	334.66	496.96	53.16	0	0.67
Sc2	0	510.11	744.52	0.17	0.39	0
Sc3	0	447.73	392.28	10.26	0	0
Sc4	0	299.52	550.58	97.34	0	18.98
Sc5	0	613.64	879.09	59.63	0	107.05
Sc6	0	534.21	493.82	0	24.19	0
Sc7	0	265	474.14	39.65	0	115.45
Sc8	0	108.95	398.52	69.91	0	129.32
Sc9	0	357.18	656.48	50.19	0	144.71
Sc10	0	950.53	1098.12	0	0.43	0
Sc11	0	689.56	1206.88	66.52	32.77	0
Sc12	0	537.04	1048.49	79.28	34.51	0

5.1.3.7 Sediment Yield Index

To calculate the sediment yield index, methodology developed by All India Soil & Land Use Survey (Department of Agriculture, Govt. of India) was followed, where each erosion intensity unit is assigned a weightage value. When considered collectively, the weightage value represents approximately the relative comparative erosion intensity. A basic factor of K = 10 was used in determining the weightage values. The value of 10 indicates a static condition of equilibrium between erosion and deposition. Any addition to the factor K (10+X) is suggestive of erosion in ascending order whereas subtraction, i.e. (10-X) is indicative of deposition possibilities.

Delivery ratios were adjusted for each of the erosion intensity unit. The delivery ratio suggests the percentage of eroded material that finally finds entry into dam/reservoir or river/stream. Area of each composite unit in each sub-watershed was then measured.

Sediment yield index (SYI) was calculated using following empirical formula (for SYI of individual sub-watersheds see Annexure-I).

$$SYI = \frac{\sum (A_{ei} \times W_{ei} \times DR)}{AW} \times 100$$

where,

SYI	=	Sediment yield index
A_{ei}	=	Area of composite erosion intensity unit
W_{ei}	=	Weightage of composite erosion intensity unit
DR	=	Delivery ratio
AW	=	Total area of the sub-watershed

5.1.3.8 Erosion Intensity and Delivery Ratio

Determination of erosion intensity unit is primarily based on the integrated information on soil characters, physiography, slope and land use/land cover. This is achieved through super-imposition of different thematic map overlays. Based on the ground-truth, carried out during the field work, weightage value and delivery ratio were assigned to each erosion intensity unit.

Delivery ratio, which depends on the type of material, soil erosion, relief length ratio, land cover conditions, etc. were assigned to all erosion intensity units depending on their distance from the nearest stream. The criteria adopted for assigning the delivery ratio are as follows:

Nearest Stream	Delivery ratio
0 - 0.9 km	1.00
1.0 - 2.0 km	0.95

2.1 - 5.0 km	0.90
5.1 - 15.0 km	0.80
15.1 - 30.0 km	0.70

5.1.3.9 Prioritization of Sub-watersheds for Treatment

Only the area under very severe and severe erosion has to be considered for treatment in free draining catchment, which is around 8966 ha. Out of 8966 ha, only 5954.20 ha will be treated, because they come below 3000 m elevation and are made of slopes of less than 45^{o}. The remaining 3011.8 ha are not suitable for treatment, either due to too high elevation (above 3000 m) or too steep slopes (slopes above 45%).

Based on the Sediment Yield Index (SYI), sub-watersheds that require treatment measures were prioritized using the simple rule that the sub-watersheds with a higher SYI were ranked higher in priority for treatment (Table 5.1.9). The sub-watersheds Sc1, Sc8, Sc9 etc would be treated on priority basis in the treatment scheme to be followed (Table 5.1.9). An index map giving physical targets of the year-wise treatment measures to be undertaken in different sub-watersheds prepared according to their priority ranking for treatment was prepared and is given in **Figure 5.1.11**.

Table5.1.9 Prioritization of sub-watersheds for catchment area treatment measures

Sub-watershed	Area (ha)	Silt Yield Index*	Priority Ranking
Sc1	885.45	1428.77	1
Sc2	1255.19	1334.89	4
Sc3	850.27	1319.19	7
Sc4	966.42	1321.67	6
Sc5	1659.41	1324.27	5
Sc6	1052.22	1239.74	10
Sc7	894.24	1263.64	8
Sc8	706.70	1377.50	2
Sc9	1208.56	1343.35	3
Sc10	2049.08	1219.97	12
Sc11	1995.73	1221.98	11
Sc12	1699.32	1243.11	9

* For details see Annexure – I

The areas having Silt Yield Index values (SYI) above 1300 have been categorized as very high prioritized areas for the treatment. These areas are prone to very severe erosion (Table 5.1.10). The other category which has been considered for the treatment is high prioritized areas. The SYI values for these areas range from 1200 – 1299. These areas are prone to severe erosion.

Table 5.1.10 Prioritized SYI value of erosion intensity rates with sub-watershed code

Priority Category		SYI Values	Sub-watershed Code
1.	Very High	> 1300	Sc1, Sc2, Sc3, Sc4, Sc5, Sc8, Sc9
2.	High	1200-1299	Sc6, Sc7, Sc10, Sc11, Sc12
3.	Medium	1100-1199	–
4.	Low	1000-1099	–
5.	Very Low	< 1000	–

5.1.3.10 Area to be taken up for Soil Conservation Measures

The prioritized areas in the different sub-watersheds of the free-draining catchment of Pauk H.E. Project that require treatment were delineated and their areas calculated from the composite erosion intensity unit map. For this, a number of simple as well as complex spatial queries were run in a step-wise manner using GIS softwares (ArcGIS 9.0 & GeoMedia Professional 5.2). These queries included different attributes of parameters that have been defined earlier in the chapters, *viz*. slope, soil, land use, etc. For executing these queries all the thematic maps of different attributes and parameters were geo-referenced to maintain the accuracy of the resultant outputs. In case of slope, the spatial queries were undertaken for different slope categories ranging from gently sloping category to escarpments with different soil classes like shallow soils, deep soils, etc. The subsequent queries were executed with resultant outputs from the first level queries with different attributes of land use/ land cover. In all more than 150 such spatial queries were executed for the purpose. From these queries a thematic map of areas susceptible to erosion in the entire free-draining catchment area was prepared. The area under different erosion intensity categories is given in Table 5.1.8. From the thematic map of erosion intensity, areas that require treatment measures were extracted with the help of further spatial queries. Areas which were classified as inaccessible, i.e. areas with more than 45^o (100%) slope and areas above 3,000 m with natural ecosystems having little human interference were excluded from the treatment measures even though these areas may have ranked high in prioritization for treatment. After taking out the areas where it is not feasible to carry out treatment, the total area that will require treatment under this CAT plan is of the order of 5954.19 ha (Table 5.1.11). The total area earmarked for the treatment comprises more than 39.11% of the free-draining catchment area.

Table 5.1.11 Sub-watershed-wise area (ha) requiring treatment measures in free-draining catchment of Pauk-H.E. Project

Sub Watershed	Area (ha)
Sc1	155.53
Sc2	682.78
Sc3	152.77
Sc4	189.76
Sc5	310.49
Sc6	464.64
Sc7	149.84
Sc8	133.36
Sc9	276.73
Sc10	1059.37
Sc11	1251.15
Sc12	1127.77
Total	**5954.19**

5.1.3.11 Year-wise Treatment of Watersheds

Silt yield index (SYI) has been calculated for all the 12 sub-watersheds, following the All India Soil and Land Use Survey (AISLUS) method and accordingly prioritized for treatment. Maximum area of 1895.02 ha (around 31.83% of the total treatment area) has been taken in the second year for treatment and in the seventh year total treatment area is around 1748.65ha (29.37 % of the total treatment area). The maximum estimated SYI value of 1428.77 is recorded for Sc1 sub-watershed and the minimum value of 1219.97 is in Sc10 sub-watershed. The area from sub-watersheds 1, 8, 9, 2, 5 and 4, (1748.65 ha) will be taken for treatment in the first year because of high silt yield index in these water sheds (see Table 5.1.12).

Table 5.1.12 Year-wise prioritization of the sub-watersheds

Years	Sub-watershed Name	SYI	Priority Ranking	Treatment Area (ha)
Ist	Sc1	1428.77	1	155.53
	Sc8	1377.50	2	133.36
	Sc9	1343.35	3	276.73
	Sc2	1334.89	4	682.78
	Sc5	1324.27	5	310.49
	Sc4	1321.67	6	189.76
Total				**1748.65**
IInd	Sc3	1319.19	7	152.77
	Sc7	1263.64	8	149.84
	Sc12	1243.11	9	1127.77
	Sc6	1239.74	10	464.64
Total				**1895.02**
IIIrd	Sc11	1221.98	11	**1251.15**
IVth	Sc10	1219.97	12	**1059.38**
Grand Total				**5954.20**

5.1.4 ACTIVITIES TO BE UNDERTAKEN

For undertaking soil conservation measures in the Pauk H.E. Project catchment area up to the dam site various indirect or preventive measures like biological measures and direct or remedial measures like engineering measures (Table 5.1.13) have been discussed in the following paragraphs. Even if suggestions have been made regarding certain specific treatment measures to be undertaken in a particular sub-watershed, these measures, however, may require further micro-planning during the implementation stage.

5.1.4.1 Preventive Measures

It is always better to undertake preventive measures than to mitigate the factors that ultimately lead to soil erosion. Such preventive measures will indirectly help to conserve soil in the long run, keeping in view the importance of integrating eco-restoration strategy with socio-economic needs of the local community wherein both ecology and economics are developed. The preventive measures that are suggested for the project area have been discussed below.

a) ***Afforestation***

In the upland region like this project area, the trees and vegetation cover play an important role in the conservation of soil and ecology and thus prevent from soil erosion and soil degradation. Afforestation programme would be taken up in such forest areas that contain large patches of barren grassy slopes and are generally devoid of trees and are honey-combed by cultivation. In critically degraded areas, plantation of locally useful, diverse and indigenous plant species such as *Alnus nepalensis, Altingia excelsa,Bauhinia purpurea, Lithocarpus elegans, Schima wallichii,* etc. would be undertaken. Afforestation measures would be taken up under catchment area treatment plan on 1522.45 ha. An outlay of **Rs 669.88 lakhs** (including maintenance) has been provided to cover various areas under afforestation in different sub-watersheds.

Afforestation Programme

Different types of plantations would be undertaken under afforestation programme according to the methodology described below. The plantations that would be undertaken in the forest (scrub/degraded forest) would have a planting density of 1600 plants per ha and vegetative hedge in contour trenches. Contour planting conserves soil and enhances moisture regime and adverse effect of surface run off of rain water is reduced considerably. Trenches, pits and plants along the contour reduce velocity of water, increase soil moisture and facilitate seepage of water in soil and reduce soil loss resulting in better growth of plants. Hence, soil working and planting along contours would be strictly followed in the project.

In the afforestation areas, the digging of trenches and pits would be along the contour. About 20 to 30 m long contour trenches would be dug leaving a space of 50 cm (septa) between the two consecutive trenches. Soil would be dug on the lower side of the trench and after removing pebbles and weeds, the trench to be half refilled with soil and remaining soil would be collected to form berm on lower side of trench. On the berm, seeds of shrubs/hedges like *Arenga saccharifera, Ardisia thyrsiflora, Calamus* spp, *Lecosceptrum canum, Melocalamus compactiflorus*, etc. would be sown to raise vegetative barrier. The size of pits would be 45 cm^3. The contour trenches would be at an interval of 5 m.

Table 5.1.13 Watershed-wise details of various activities

Sl. No.	Sub-watershed No.	Brushwood Checkdams	DRSM Checkdams	Contour Bunding	Bench Terracing/ Bally Benching	Afforestation	Assisted Natural Regeneration	NTFP Regeneration/ Medicinal Plants	Pasture Improvement	Total
		Nos.	**Nos.**	**ha**	**ha**	**ha**	**ha**	**ha**	**ha**	
1	Sc1	12	15	25.50	40.45	20.33	15.25	20.25	33.75	**155.53**
2	Sc2	16	14	75.25	225.35	160.80	80.50	72.70	68.18	**682.78**
3	Sc3	12	17	35.50	48.70	21.45	10.60	16	20.52	**152.77**
4	Sc4	8	9	40.30	55.75	15.82	20.00	35.35	22.54	**189.76**
5	Sc5	21	28	55.25	40.30	105.45	27.00	50.59	31.90	**310.49**
6	Sc6	29	30	88.35	75.25	95.85	40.17	82.45	82.57	**464.64**
7	Sc7	15	11	25.65	21.00	35.10	18.00	22	28.09	**149.84**
8	Sc8	8	15	22.00	50.35	30.50	5.75	12	12.76	**133.36**
9	Sc9	19	18	27.45	42.35	65.50	45.50	30.50	65.43	**276.73**
10	Sc10	45	30	170.75	245.40	315.50	95.00	120.33	112.40	**1059.38**
11	Sc11	48	28	195.00	260.70	345.65	115.50	185.15	149.15	**1251.15**
12	Sc12	42	37	155.57	245.20	310.50	88.25	225	103.25	**1127.77**
	Total	**275**	**252**	**916.57**	**1350.8**	**1522.45**	**561.52**	**872.32**	**730.54**	**5954.20**

For digging 1600 pits per ha, pits would be dug 15 cm uphill side from the contour trenches. The spacing of pits along contour trench will not be closer than 1.25 m. In afforestation areas soil working would be started in October-November and would be completed by March. It is important that filling of pits and half filling of trenches is completed before the onset of monsoon, otherwise dug soil will be washed away by rains leaving only stones and pebbles near the pit. Extreme care would be taken in transporting the plants from nurseries to the plantation site to avoid any damage. Planting would be completed before the monsoon period is over. With a view to conserve not only soil and water but also for fuelwood production, it is important to raise the vegetative barrier of hedge plants. The seeds of hedges like *Calamus*, *Debregeasia*, *Melocalamus*, *Mussaenda*, etc. will be sown in contour trenches before the onset of monsoon. When the water of surface run-off reaches the line of hedges its speed is checked and silt is stopped by the hedge plants and only percolated water passes down slowly. Hedges spread and grow well in the silt left behind and form a natural terrace. The plants planted in the pits near contour trenches get more moisture and grow fast.

Choice of Species

The species for plantations would be selected after considering altitude, aspect, biotic pressures, soil depth, moisture, etc. As there is pressure of cattle grazing, non-fodder/ fuelwood species would also be planted in suitable proportion in between the fodder species. The tree species that would be planted under this programme are: *Alnus nepalensis*, *Altingia excelsa* (Jutli), *Castanopsis indica* (Hingori), *Cinnamomum tamala* (Tej Pata), *Rhododendron* spp, *Tetradium fraxinifolium (Khankpa)*, etc.

There are many shrubby plant species which are suitable for fodder/ fuelwood plantations which are**:** *Bambusa tulda, F. semicordata, Sinarundinaria* sp, and *Morus alba.* The important legumes and grasses that would be planted are, *Lespedeza juncea*, *Trifoliun ripens*, Kans *(Sacchaurm longisetosum*, Brome grass (*Thysanolaena latifolia*) and Thatch grass (*Themeda arundinacea*) among grasses and White clover (*Trifolium repens*), Red clover (*Trifolium pratense*), Vetch (*Vicia villosa*), and Caucasian clover (*Trifolum ambiguum*) among legumes.

The plant species suitable for avenue and ornamental purposes are: *Altsonia scholaris*, *Bauhinia variegata*, *Bougainvillea spectabilis*, *Cassia fistula*, *Delonix regia*, *Erythrina stricta*, *Hibisicus rosasinensis*, and *Polyalthia longifolia*.

Fencing

Stone wall 120 cm high and 45 cm wide or 4 strand barbed wire fencing would be erected during first year along with soil working. The cooperation of local villagers would be sought for the success of the plantation programmes.

Weeding and Mulching

Weeding, hoeing and mulching would be carried out during October-November. Weeding and loosening of soil by hoeing breaks the capillary action in soil and thus reduces the moisture loss. Mulching reduces evaporation and conserves soil moisture and adds humus to soil. Cut and uprooted weeds and grasses used as mulching material would be spread around the plant.

Watch and Ward and Fire Protection

Protection of plantation is the greatest challenge in hills as villagers and their livestock damage the plantation before it is established. Hence the protection of plantation particularly in the juvenile stage is of paramount importance and watchmen/ chowkidars would be engaged from the nearby villages for the required job. Besides the above, other appropriate measures would be adopted to ward off these potential threats.

b) ***Assisted Natural regeneration in existing forest***

In some of the forest areas, conditions are conducive to natural regeneration provided some sort of assistance is provided. Such areas shall be taken up under this component. The areas shall be closed to exclude biotic interference. Forest floor will be cleared of slash; debris and felling refuse to afford a clean seedbed to the falling seed. At certain places some soil raking may also have to be done to facilitate germination of seeds. Where natural regeneration is found deficient, it will be supplemented by artificial planting. Patch sowing in suitable areas may also be done. Bush cutting & cleaning operations are done depending on necessity. Up to 800 plants or patches per hectare will be planted /sown to hasten the process of regeneration in the area uniformly. An outlay of **Rs 67.45 lakhs** (including maintenance) has been made to cover 561.52 ha (see Table 5.1.16).

c) ***NTFP Regeneration***

Arunachal Pradesh Forests are rich in a variety of non timber forest produce (NTFP). However, because of over-exploitation of NTFP in the past there has been depletion of this valuable resource. Therefore, in order to augment natural stock of NTFP in the forests, it is proposed to take up planting of NTFP and establishing nurseries. An outlay of **Rs 379.14 lakhs** @ Rs.36,563/- per ha has been suggested to cover about 872.32 ha for establishing (Rs 318.95 lakhs) and its maintenance Rs 60.19 lakhs for five years (see Table 5.1.16).

d) ***Grazing Land/Pasture Improvement***

The livestock especially Mithuns owned by the local communities exert significant pressure on the natural habitats. In order to improve the grazing areas/pastures and to make these sustainable, the degraded areas, particularly among community lands will be taken up for treatment under silvi-pastoral model. An outlay of **Rs 150.07 lakhs** has been earmarked for this purpose and it will cover about 730.54 ha of land for development at a cost of Rs 145.63 lakhs and its maintenance will cost Rs 4.43 lakhs (see Table 5.1.16).

e) ***Forest infrastructure development***

For efficient management of forest resources, it is essential that field infrastructure of the State Forest Department of the area is adequately developed. Given the rugged mountainous terrain, there is a need to improve the existing forest roads and paths. Jeepable roads would be avoided in the forests of the catchment area as this would lead to habitat fragmentation, degradation and increased siltation. Only bridle paths, inspection paths and footbridges shall be constructed or improved for which an amount of **Rs 65.45 lakhs** has been earmarked (Table 5.1.14).

5.1.4.2 Treatment Measures: Engineering Measures

Gully erosion is one of the concerned soil erosion in the slope and hilly areas. The gullies would be treated with the help of engineering/ mechanical as well as vegetative methods. Check dams would be constructed in some of the areas to promote growth of vegetation that will consequently lead to the stabilization of the slopes/area and prevention of further deepening of gullies and erosion. For controlling the gullies, the erosive velocities are reduced by flattening out the steep gradient of the gully. This is achieved by constructing a series of checks which transform the longitudinal gradient into a series of steps with low risers and long flat treads. Different types of check dams would be required for different conditions comprising different materials depending upon the site conditions and the easy availability of material at local level. The following types are recommended for this area:

i) Brushwood checkdam (see **Plate 5.1.1**)

ii) DRSM (Dry Rubble Stone Masonry) - Check dams with stones available at the site (see **Plate 5.1.2**)

iii) Combination of DRSM and crate works. For moderate to deep gullies with stones available at the sites

In addition to the vegetative measures used for stabilization of gullies, temporary or permanent mechanical measures will be used as supplementary measures to prevent the washing away of young plantations by large volume of run off. The gullies get stabilized over a period of time with the establishment and growth of vegetation cover. With the passage of time mechanical structures weaken and vegetative measures get strengthened.

For engineering measures following types of checkdams are suggested.

a) ***Brushwood checkdams***

The main advantage of brushwood checkdams is that they are quick and easy to construct and are inexpensive as they are constructed by using readily available materials at the site. In brushwood checkdams, small branches preferably of coppiceable species are fixed in two parallel rows across the gully or nalah and packed with brushwood between the rows of these vertical stakes. The vertical stakes are tied down with wires or fastened with sticks across the top. The important consideration in erecting brushwood checkdams is to pack the brushwood as tightly as possible and to secure it firmly. This type of checkdam is generally constructed over small gullies or at the starting stretch of gullies. In all, 275 brushwood checkdams/ vegetative spurs would be constructed to check gully erosion, stream bank protection and slope stabilization works.

b) ***Dry Rubble Stone Masonry (DRSM) checkdams***

The site where DRSM checkdams are to be constructed is cleared and the sides are sloped 1:1. The bed of gully is excavated for foundation to a uniform depth of 0.45 m to 0.60 m and dry stones are packed from that level. Over the foundation, DRSM super structure of check dam is constructed. The stones are dressed and properly set in with wedges and chips. The width of checkdam at the base should be approximately equal to maximum height and successive courses are narrower so the section is roughly a trapezium. It is common to find upstream face of checkdams vertical with all slopes on the downstream face but while there is sound engineering reason for this in case of large checkdams but it is not of any consequence in small gully control dams. In the centre of the dam portion sufficient waterway is allowed to discharge the maximum run off. The dry stone work should go up to 0.30m to 0.60m in the stable portion of the gully side to prevent end-cutting. Sufficient apron is provided to prevent scouring of the structure. The thickness of the apron packing would be about 0.45 m and gully sides above the apron have to be protected with packing to a height of at least 0.30 m above the anticipated maximum water level to prevent side scour being formed by the falling water. For gully control measures 252 numbers of DRSM checkdams would be constructed.

c) ***Slope modification by Stepping/Bench Terracing***

Bench terracing is one of the most popular mechanical soil conservation practices adopted by farmers in India and other many countries. It is constructed in the form of step like fields along contours by half cutting and half filling and would result in the conversion of the original slope into leveled fields. Thus, hazards of erosion are eliminated and manure and fertilizers applied are retained in the leveled fields. The sloping fields in the valley need to be bench terraced by cutting and filling with the latter supported by retaining stone wall. While making bench terraces, care will be taken not to disturb the top soil by spreading earth from the lower terraces to higher terraces. The vertical intervals between the terraces will not be more than 1.5 m and cutting depth would be kept at 50 cm. The minimum average width of the terrace would be 4 to 5 m to enable the usage of prolong hinge. The shoulder bunds of 30 x 15 cm would also be provided. The excess water from the terraces will be drained off by staggered channels. An area of 1350.80 ha will be covered under this plan.

5.1.4.2.1 *Administrative Setup*

The catchment area treatment (CAT) project involves intensive and highly technical operations, which require the expertise of technical personnel. It is, therefore, recommended that the existing forest staff of Arunachal Pradesh Forest Department in the area will look after all the works to be carried out under the CAT plan including plantation and maintenance as all the areas to be covered under CAT plan fall under these divisions. However, temporary staff may be engaged for the purpose during the project implementation period, i.e. for about 5 years.

a) ***Nursery Development***

Nursery development allied services, like drip irrigation or micro-irrigation, will be crucial for successful execution of CAT plan. It will be important to prepare a stock of plant material for the supply of saplings for afforestation programme and various other activities. Hence a provision of main nursery has been developed already in the CAT plan of downstream H.E project of Tato-I. Therefore the services such as saplings, plants etc will be available at Tato-I H.E Project and will be provided for the upstream projects of Heo and Pauk H.E Projects.

b) Forest Infrastructure Development

The works of the catchment area treatment plan will be executed by the Forest Department, Government of Arunachal Pradesh. These works will be an added responsibility for the Forest Department that may not have adequate facilities and infrastructure to execute the work as suggested in the plan. Provision has, therefore, been made in the CAT plan to develop the infrastructure of Forest Department in the region and accordingly a budget of Rs **65.45 lakhs** is proposed for this purpose (Table 5.1.14).

Table 5.1.14 Budget for development of State Forest Department infrastructure

		Amount (Rs. in lakhs)		
S.No.	**Components**	**Establishment**	**Running Cost**	**Total**
1.	Forest Office Establishment (One Office)	20	-	20
2.	Forest Fire Fighting System	10	-	10
3.	Road and Foot Path Development	10	-	10
4.	*Office Equipment and Stationery	6.45	-	6.45
5.	*Office Vehicle	10	2	12
6.	Contingency	4	3	7
	Total	**60.45**	**5**	**65.45**

Item at S.N.4 & 5 shall be provided by project proponent in kind to forest department.

*Office Equipment and Stationery
-Computers : 3 no. @ Rs.45,000/no : Rs.1,35,000.00
-Laptops : 3 no. @ Rs.50,000/no : Rs.1,50,000.00
-Photocopiers : 3 no. @ Rs.1,00,000/no : Rs3,00,000.00
-Digital Cameras : 5 no. @ Rs.12,000/no : Rs.60,000.00
TOTAL= Rs. 6,45,000.00

*Office Vehicles : 2 no.@ Rs.5,00,000/unit : **Rs.10,00,000.00**

5.1.4.2.2 *Eco-tourism*

The project area is rich in cultural diversity as well as bio-diversity. Culturally rich tribes such as Adi sub tribes, including Ramos, and Memba dwell in the region. Although some of the 'Adi' communities have embraced Christianity in recent years, other 'Adi' tribes are worshiper of Dony Polo (Sun and Moon) while Membas predominantly follow Tibetan Buddhism. A well-known Tibetan Buddhist temple, Mechuka Gompa, is located in the western part of the Memba-speaking region. Biodiversity is equally rich in the free draining catchment with semi evergreen forests found along the lower right bank of Yarjep River. Sub-tropical wet hill forests are found in the middle stretch of the free draining catchment. Along the upstream ridges wet temperate and dry temperate coniferous forest (blue pine), mix coniferous and sub alpine rhododendron forest are found.

The State of Arunachal Pradesh follows an inner-line permit system for the visitors. This may be seen as acting as a deterrent for the tourist industry. However, in Arunachal Pradesh eco-tourism has a vast potential and so is in this area which can attract domestic as well as foreign tourists. Eco-tourism activities such as hiking and trekking along the existing traditional trails can be promoted at state, national as well as at international levels. The involvement of local communities in eco-tourism activities would greatly help them in generating new income sources. This peoples' involvement will go on a way in the maintenance of the local culture as well the biodiversity of the region. The natural landscapes such as higher ridges with semi dense forest and along the riparian woodlands in the sub-watershed are suitable areas for such recreational sites.

5.1.4.2.3 *Eco-restoration and Local Area Development*

There is urgent need to reduce the dependency of local population on the forest and other natural resources which are under severe pressure. The eco-restoration works and other activities related to area development and employment regeneration are suggested and should be carried out through community welfare committees (CWC) of local villages. These should include the following measures, which would help in rejuvenating the ecosystems and in reducing the soil erosion in the region.

1. Plantation in the degraded patches of community/civil/ forest land.
2. Water conservation and harvesting in the villages.
3. Soil conservation measures in village areas.
4. Improvement in agricultural and horticultural practices.

5. Technical and financial support for harnessing alternate energy sources such as micro-hydel and non-conventional energy (solar power and solar heating) to reduce pressure on the forest for fuel wood
6. Rural technology support programmes.
7. Awareness programmes for conservation of wildlife and natural resources.
8. Promotion of income generating schemes like ecotourism.

The total cost estimate for these activities is proposed as **Rs 17.77 lakhs** (1% of total cost of treatment measures).

5.1.5 SCHEDULE OF TREATMENT PLAN

The total time schedule for the execution of the planned CAT works has been kept at 4 years. Accordingly, areas from each sub-watershed have been prioritized for treatment and a year-wise plan has been assigned (**Fig 5.1.8**). Zero year has been kept for the development of nursery and raising sapling for plantation. Sc1, Sc2, Sc4, Sc5, Sc8 and Sc9 sub-watersheds have been suggested to be taken up for treatment in the first year and accordingly area for treatment is allotted. Maximum area for treatment will be taken up in second year and minimum will be taken up in the fourth year. In the first and second years the areas taken up for treatment are 1748.65 ha and 1895.02 ha, respectively. In the remaining years the area for treatment is 1059.38 ha (4th year) and 1251.15 ha in the third year (**Fig 5.1.11**). One year time is given for the maintenance of the executed work in the catchment. Accordingly, a separate budget for the maintenance is given in Table 5.1.15.

5.1.5.1 Micro-planning

A separate budget of is **Rs 53.53 Lakhs** is allocated for the micro-planning. This will help in designing a suitable treatment type, biological or engineering measure, required for a particular location.

5.1.5.2 Monitoring and Evaluation

Monitoring and evaluation will be developed as in built part of the project management. Thus, a process of self-evaluation at specified intervals of time will ensure the field worthiness and efficacy of the CAT plan.

Annual work plan for each sub-watershed would be prepared well in advance specifying physical and financial targets, sites, locations and beneficiaries of each component of the project activity. Month-wise work scheme of various items of each component for the financial year would also be prepared in advance and its timely implementation would be ensured. Monthly progress report on all activities would be submitted by the Range Officers to Divisional Forest Officer for its subsequent submission to the project authorities and Ministry of Environment & Forests, Government of India. The monitoring committee appointed for this purpose would also monitor on a regular basis the quality and quantity of works carried out in the area.

For monitoring, reference points of silt load observation in the river are suggested to install silt recording station upstream of dam site in Yarjep River to evaluate the impact of the soil conservation measures. A sum of is **Rs 30 Lakhs** has been provided for monitoring and evaluation.

5.1.6 PERIOD AND SCHEDULE OF IMPLEMENTATION

The execution of CAT plan in Pauk-H.E. project area would require extensive efforts on the part of executing agencies. Keeping in view the local topography and climate, it is being estimated that the entire treatable area would require at least 4 years to be completed. However, the maintenance of plantations would continue from IInd year to Vth year and accordingly CAT plan has been prepared for 5 years. All these works would have to start with the pre-construction activities especially the studies in respect of micro-planning for each sub-watershed, which would require further detailed investigations. Based on the silt yield index of the sub-watersheds, the conservation measures would be first taken up in sub-watershed Sc1, Sc8, Sc9 etc. (For detail see Table-5.1.12). The year-wise index map of schedule of implementation of different conservation measures under CAT plan has been given in **Figure 5.1.11** & Table 5.1.16 gives the year-wise physical details of various engineering and biological treatment measures to be undertaken.

5.1.7 COST ESTIMATES

The total estimated cost of catchment area treatment plan to be spent over a period of five years is **Rs 2,156.36 lakhs**. The details of cost estimates and physical work schedule as well as phasing of expenditure are given as follows in Tables 5.1.15. All the costs towards the administration during the implementation work have been included in the cost estimates of CAT (Table 5.1.15).

Table 5.1.15 Component-wise cost estimate for catchment area treatment works

Sl. No.	Item of Work			Unit	Qty.	Rate (Rs.)	Amount (Rs. in lakhs)
A.	**Engineering Measures**						
1.	Gully Control						
	a)	Brushwood checkdams		Nos.	275	26,000/-	71.50
	b)	DRSM checkdams		Nos.	252	33,281/-	83.87
	c)	Contour Bunding		ha	916.57	25,000/-	229.14
2.	Bench terracing			ha	1350.80	7,500/-	101.31
	Total (1+2)						**485.82**
	Add 5% for maintenance of structures						24.29
	Sub-total (A)						**510.11**
B.	**Biological Measures**						
1.	Afforestation						
	1.)	i)	Creation	ha	1522.45	39,000/-	593.76
2.)		ii)	Maintenance			5,000/-	76.12
2.	Assisted natural regeneration in existing forests						
	i)	Creation		ha	561.52	11762/-	66.05
	ii)	Maintenance				250/-	1.40
3.	NTFP Regeneration						
	i)	Creation		ha	872.32	36,563/-	318.95
	ii)	Maintenance				6900/-	60.19
4.	Pasture development						
	i)	Creation		ha	730.54	19,935/-	145.63
	ii)	Maintenance				607/-	4.43
	Sub-total (B)						**1,266.53**
	Sub-Total (A+B)						**1,776.64**
C.	**Micro-planning @ 3% of (A+B)**						**53.30**
D.	**Establishment Cost @ 7%**						**124.37**
E.	**Forest Infrastructure**						**65.45**
	Vehicles, machinery & equipment, paths, etc.						
F.	**Eco-restoration @ 1%**						**17.77**
G.	**Contingency @ 5%**						**88.83**
H.	**Monitoring and evaluation**						**30.00**
	Grand Total (A to H)						**2,156.36**

Table 5.1.16 Physical and Financial layout plan of Catchment Area Treatment for Pauk H.E. Project

(Amount in lakhs)

S. No.	Item	Unit	0th Year Phy	0th Year Fin	Ind Year Phy	Ind Year Fin	IIrd Year Phy	IIrd Year Fin	IIIth Year Phy	IIIth Year Fin	IVth Year Phy	IVth Year Fin	Vth Year Phy	Vth Year Fin	Total Phy	Total Fin
A.	**ENGINEERING MEASURES**															
1.	**Gully Control**															
a)	Brushwood Check Dams	Nos.			80	20.80	88	22.88	58	15.08	49	12.74	-	-	**275**	**71.50**
b)	DRSM Check Dam	Nos.			73	24.30	81	26.96	53	17.64	45	14.97	-	-	**252**	**83.87**
c)	Contour Bunding	ha			265.81	66.45	293.30	73.32	192.48	48.12	164.98	41.25	-	-	**916.57**	**229.14**
2.	Bench Terracing/ Bally Benching	ha			391.73	29.38	432.26	32.42	283.67	21.28	243.14	18.23	-	-	**1350.80**	**101.31**
Total (1+2)																**485.82**
Add 5% for maintenance of structures																**24.29**
Sub-total (A)																**510.11**
B.	**BIOLOGICAL MEASURES**															
1.	Afforestation															
i)	Creation	ha			441.51	172.19	487.18	190.00	319.72	124.69	274.04	106.88	-	-	**1522.45**	**593.76**
ii)	Maintenance		-	-	-	-	-	22.08	-	24.36	-	15.98	-	13.70	-	**76.12**
2.	Assisted Natural Regeneration in existing forests															
i)	Creation	ha			162.84	19.15	179.69	21.14	117.92	13.87	101.07	11.89	-	-	**561.52**	**66.05**
ii)	Maintenance		-	-	-	-	-	0.41	-	0.45	-	0.29	-	0.25	-	**1.40**
3.	NTFP Regeneration															
i)	Creation	ha			252.97	92.49	279.14	102.06	183.19	66.98	157.02	57.42	-	-	**872.32**	**318.95**
ii)	Maintenance		-	-	-	-	-	17.45	-	19.26	-	12.64	-	10.84	-	**60.19**
4.	Pasture Development															
i)	Creation	ha			211.86	42.23	233.77	46.60	153.41	30.58	131.50	26.22	-	-	**730.54**	**145.63**
ii)	Maintenance		-	-	-	-	-	1.29	-	1.42	-	0.92	-	0.80	-	**4.43**
	Sub-total (B)															**1,266.53**
	Total (A+B)															**1,776.64**
C.	**Micro-Planning & Overhead expenditure @ 3%**				-	5.26	-	16.07	-	13.36	-	10.66	-	7.95	-	**53.30**
D.	**Establishment Cost @ 7%**				-	12.27	-	37.48	-	31.18	-	24.87	-	18.57	-	**124.37**
E.	**Forest Infrastructure** Vehicles, Machinery & equipment, plants, etc.				-	10	-	20	-	20	-	10	-	5.45	-	**65.45**
F.	**Eco-restoration @ 1%**				-	1.75	-	5.36	-	4.46	-	3.55	-	2.65	-	**17.77**
G.	**Contingency @ 5%**				-	8.76	-	26.77	-	22.27	-	17.77	-	13.26	-	**88.83**
H.	**Monitoring and Evaluation**				-	3.00	-	9.00	-	7.50	-	6.00	-	4.50	-	**30.00**
GRAND TOTAL (A to H)																**2,156.36**

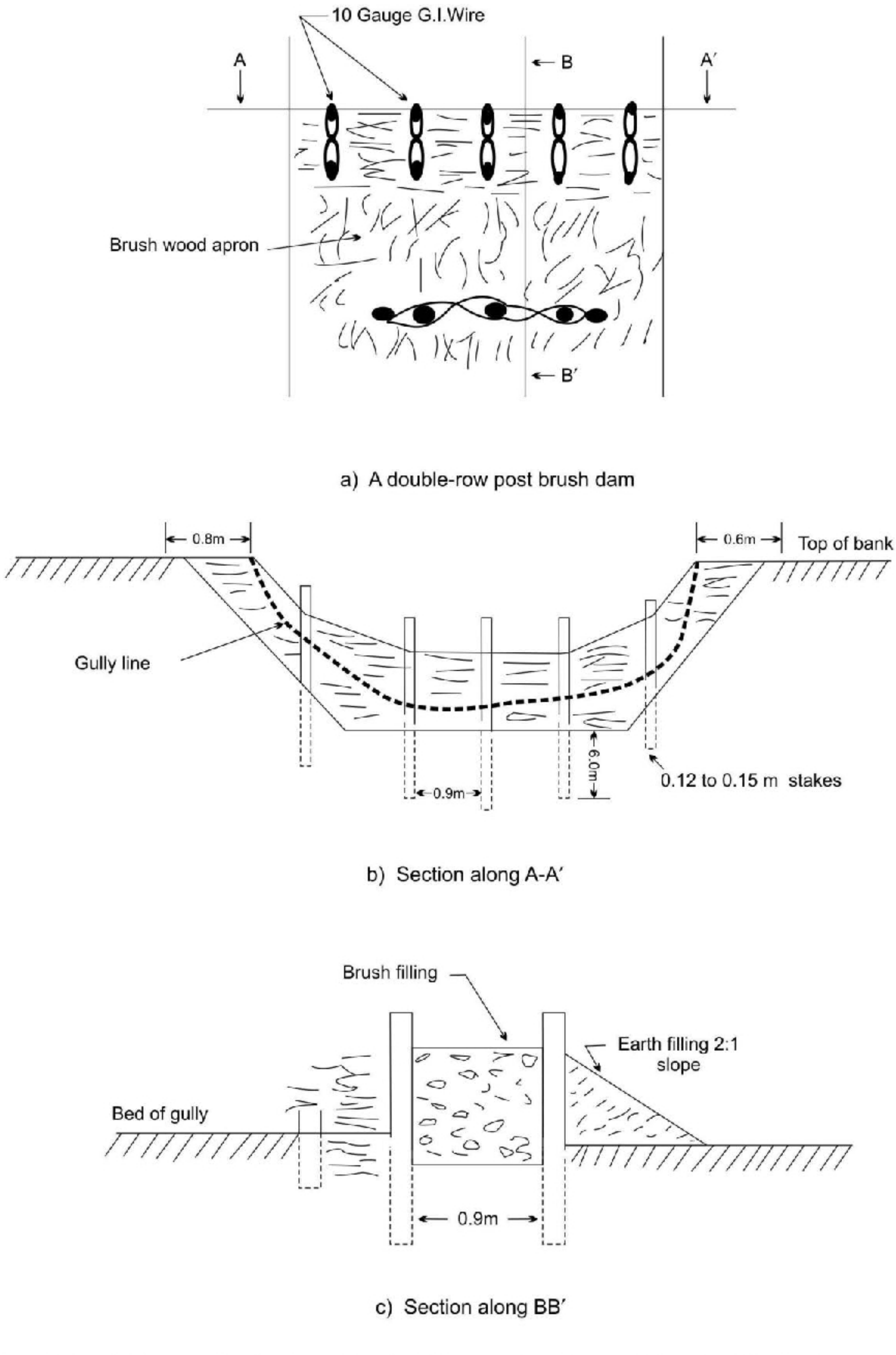


Plate 5.1.1 A Schematic diagram of a double row brush wood check (a) and its cross section along the dam A-A′ (b) and across the dam (c).

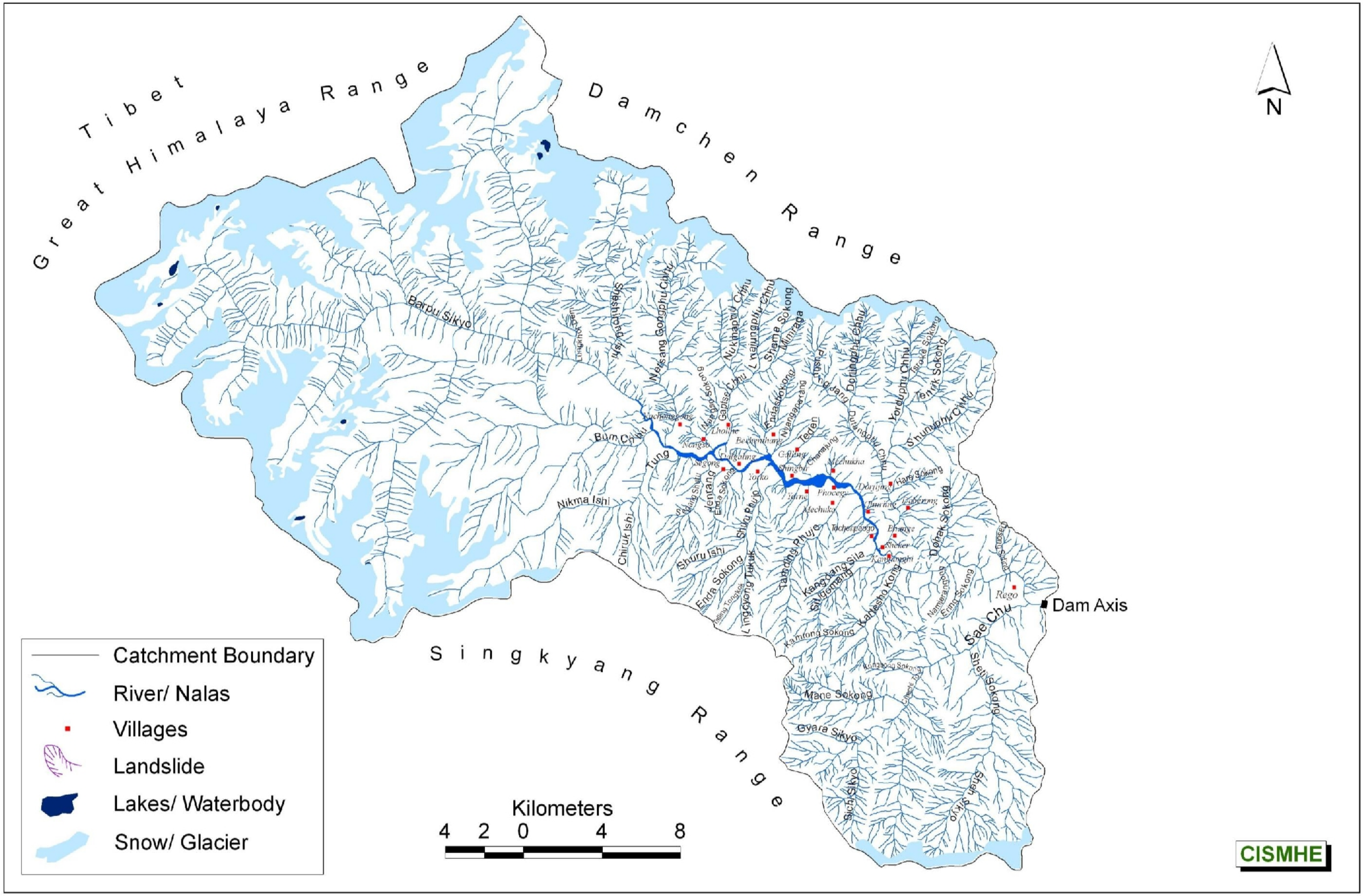
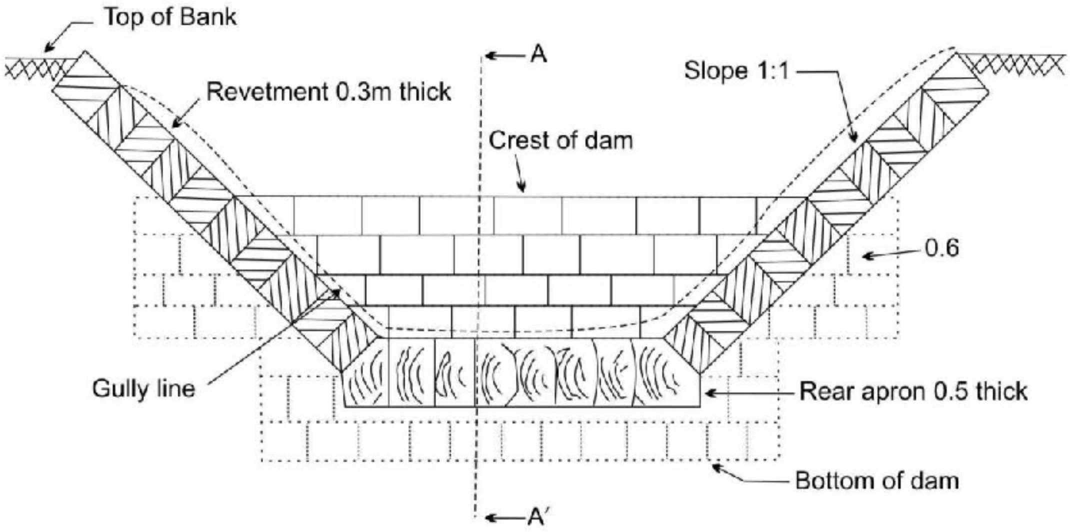
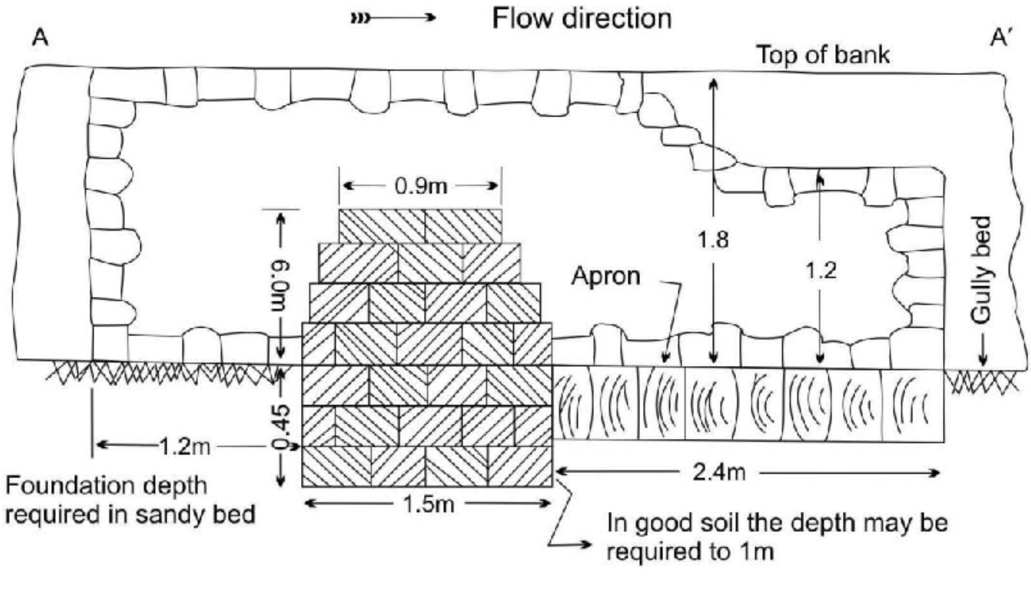


Fig. 5.1.1 Drainage map of Yarjep Chhu in the catchment area of the proposed Pauk H.E. Project up to the proposed dam site



a) Section of Dry rubble stone check dam along the structure



b) Section across the structure on A A′

Plate 5.1.2 A Schematic diagram of a Dry rubble stone check dam showing section along the dam looking up gully (a) and section along A-A′ on diagram(b) .

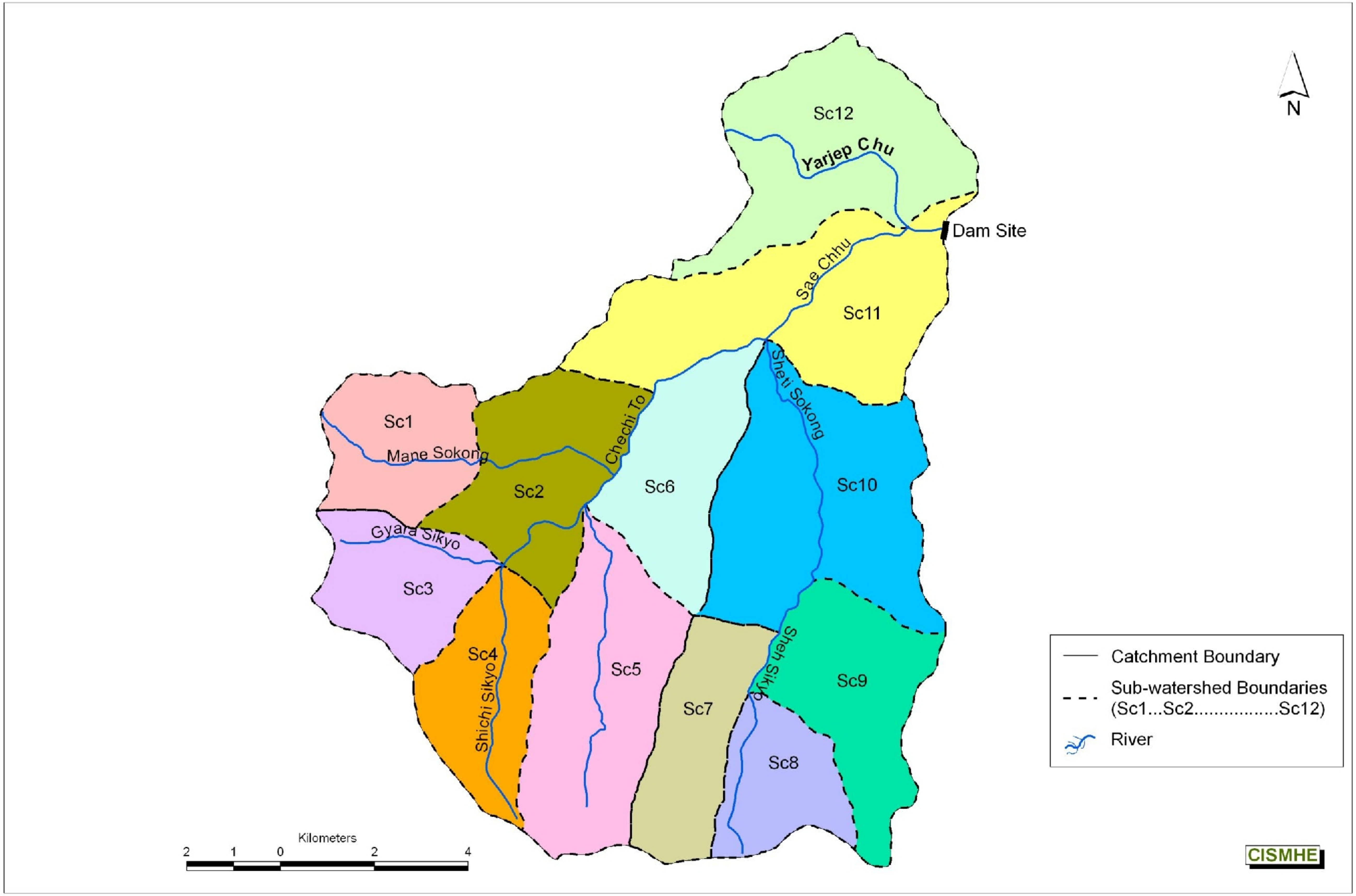


Fig.5.1.2 Index map of free-draining area of Pauk H.E. project

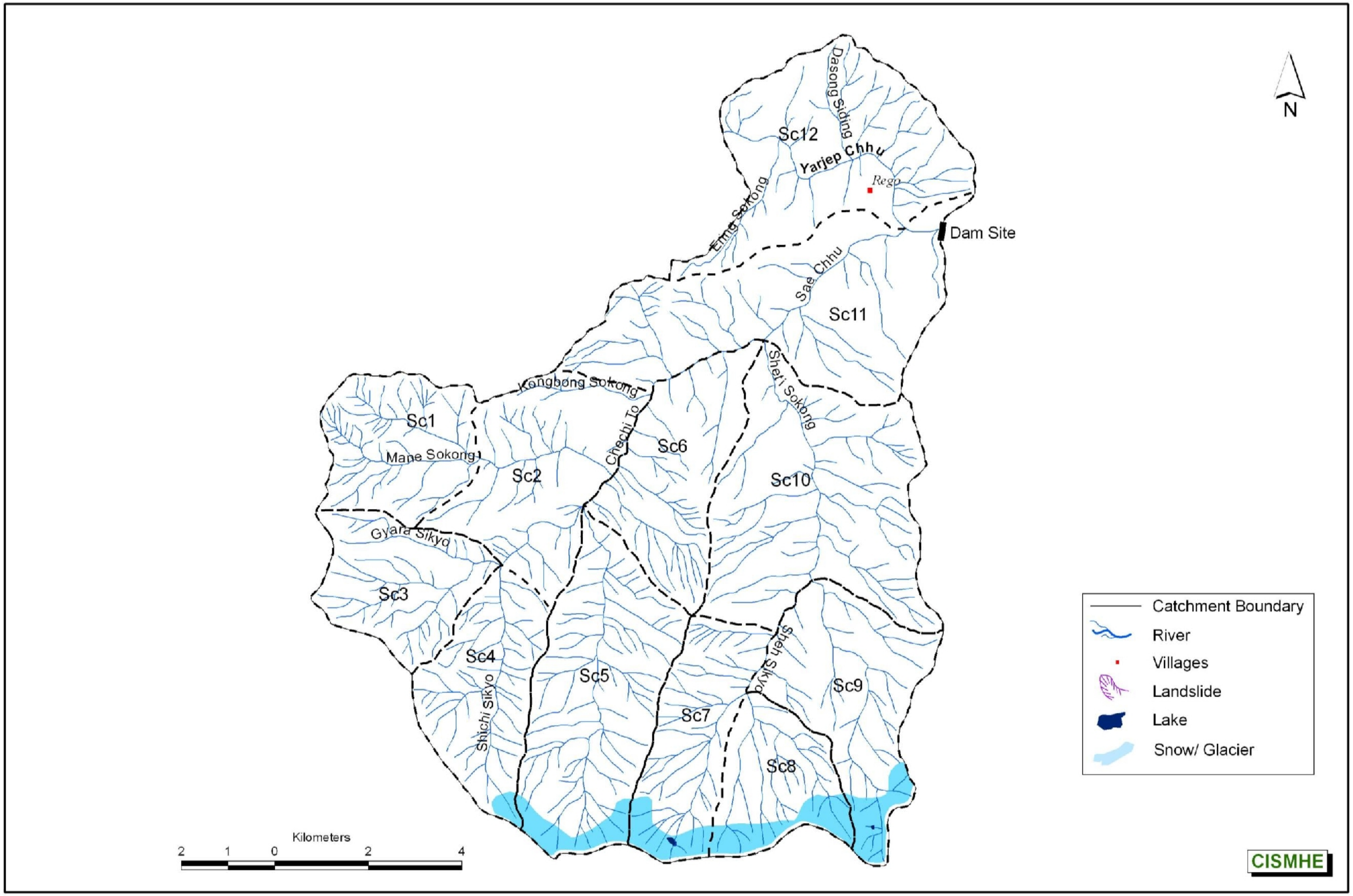


Fig.5.1.3 Drainage map of Yarjep Chhu in the free-draining of the proposed Pauk H.E. project

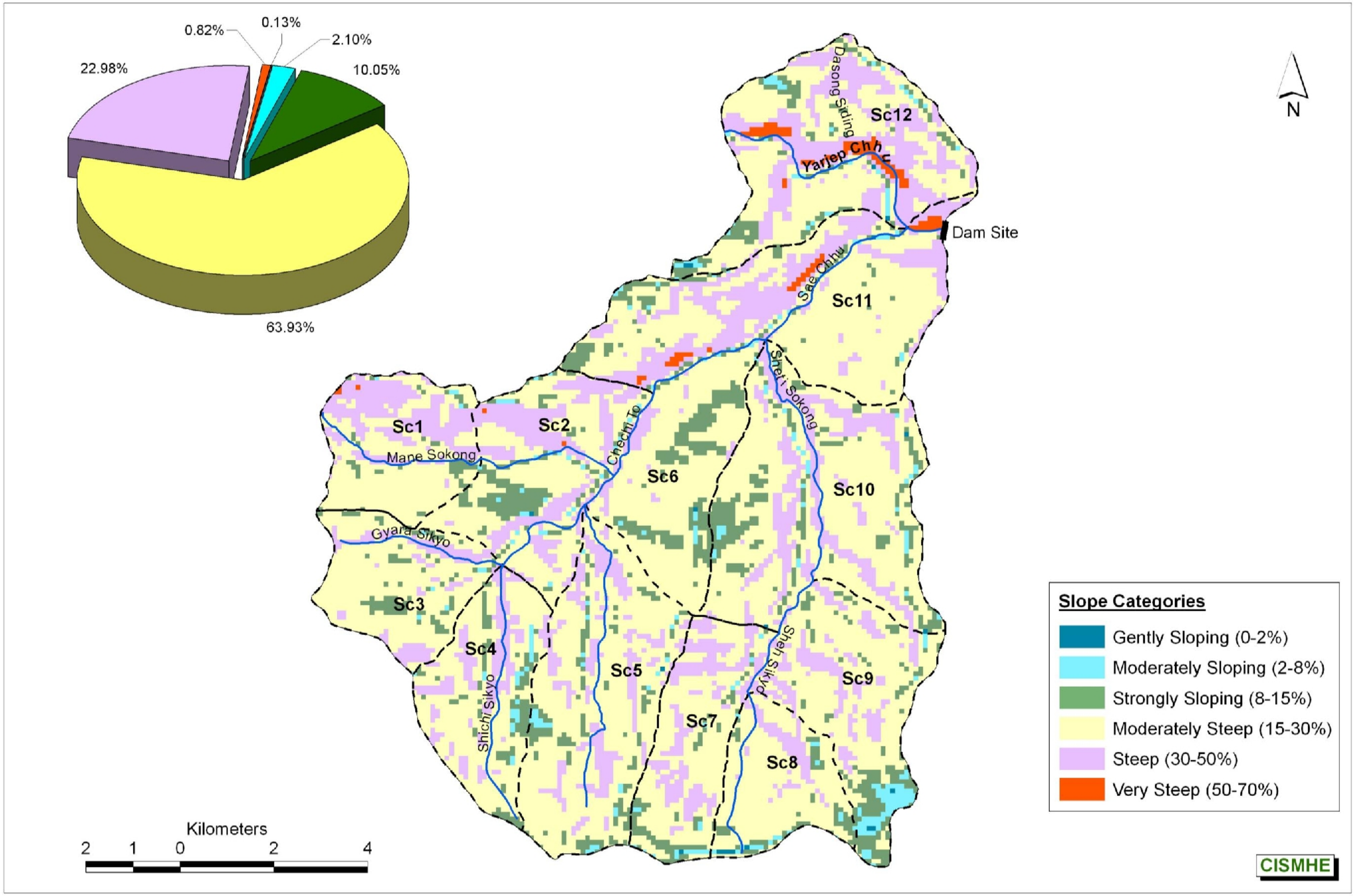


Fig.5.1.4 Slope map of Yarjep Chhu in the free-draining catchment of the proposed Pauk H.E. project

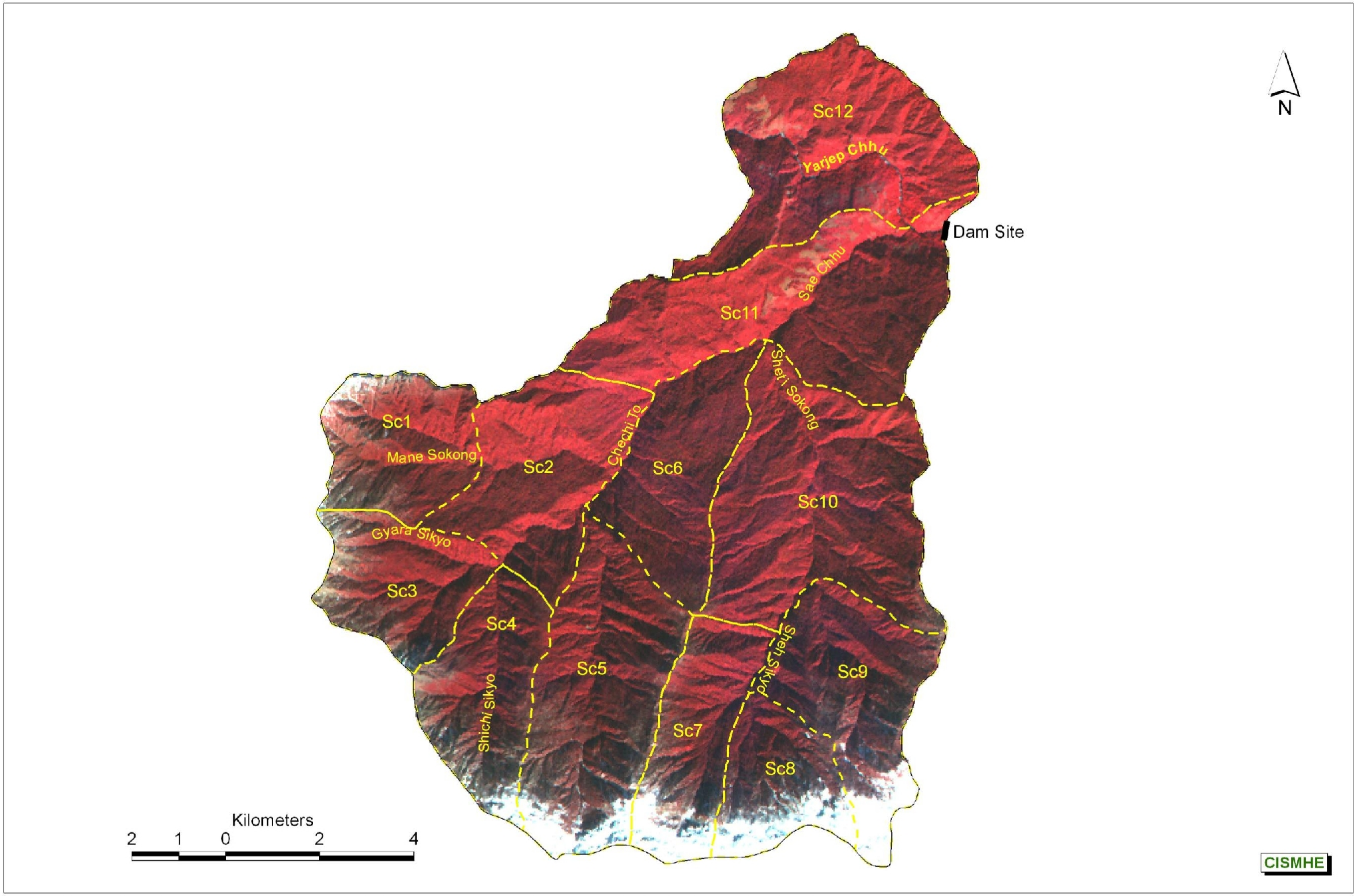


Fig.5.1.5 False Colour Composite (FCC) generated from IRS-P6 LISS-III, 2006 of the proposed Pauk H.E. project

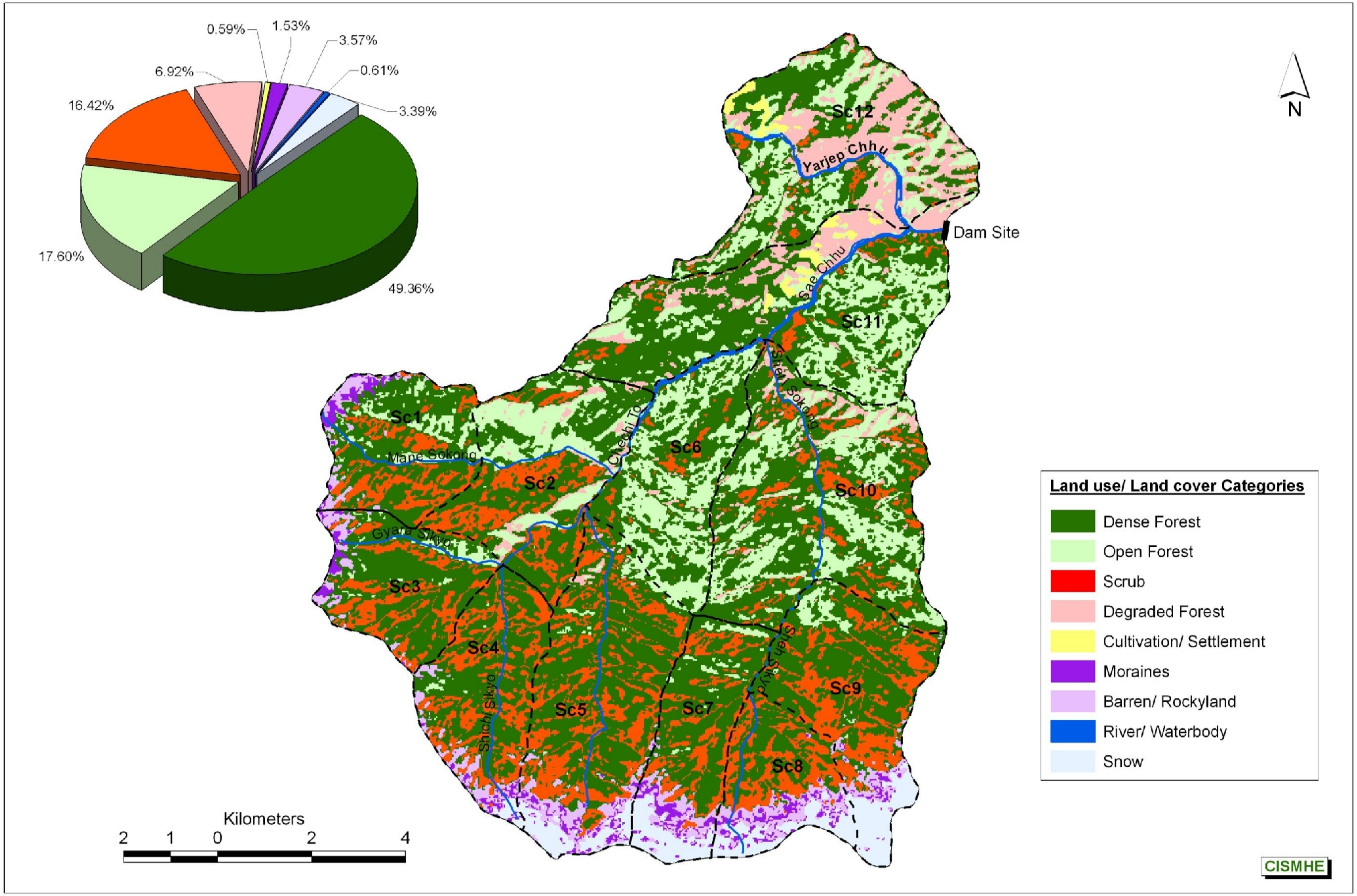


Fig.5.1.6 Land use/ land cover map of free-draining catchment of the proposed Pauk H.E. project

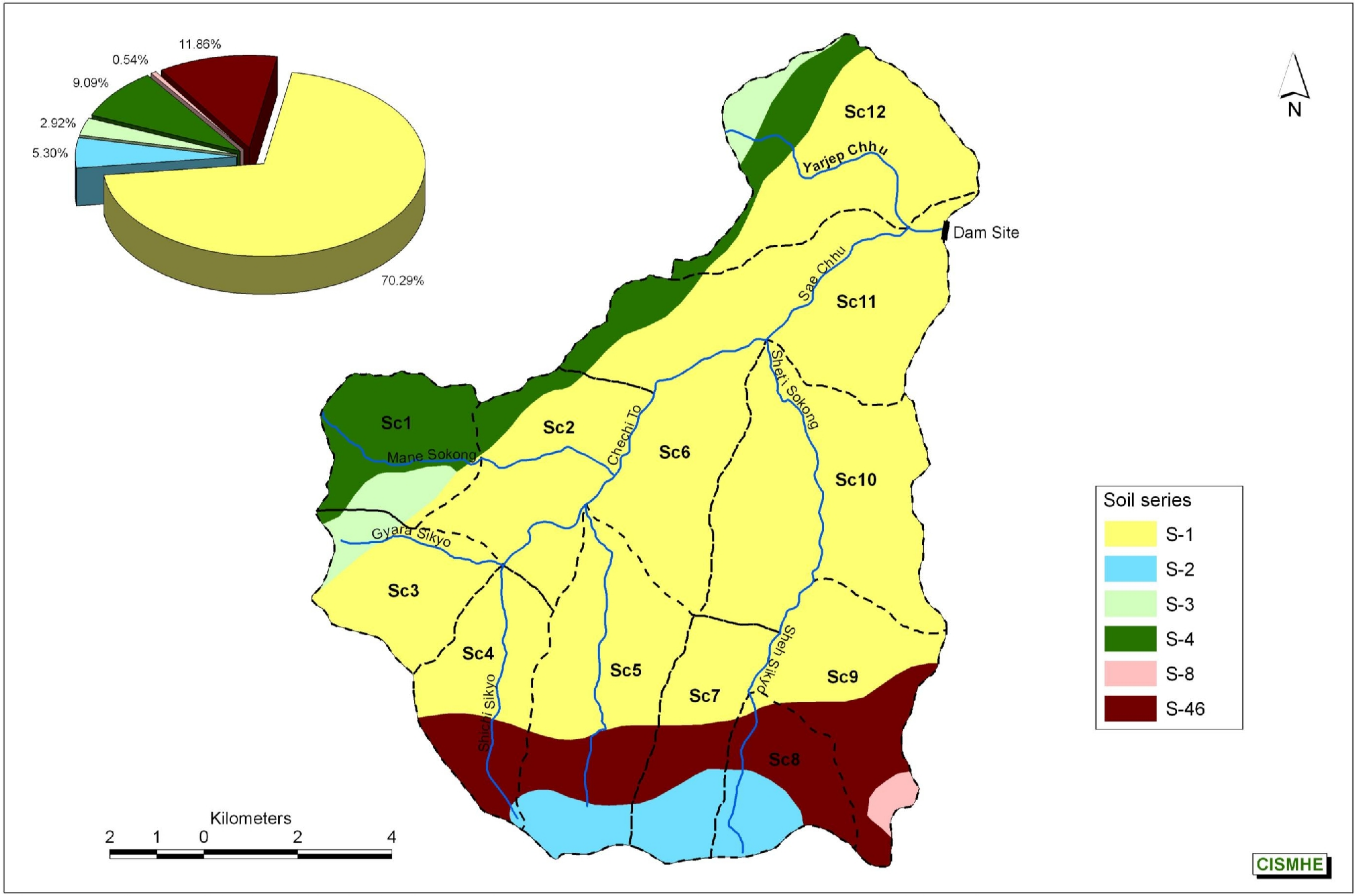


Fig.5.1.7 Soil map of Yarjep Chhu in the free-draining catchment of the proposed Pauk H.E. project

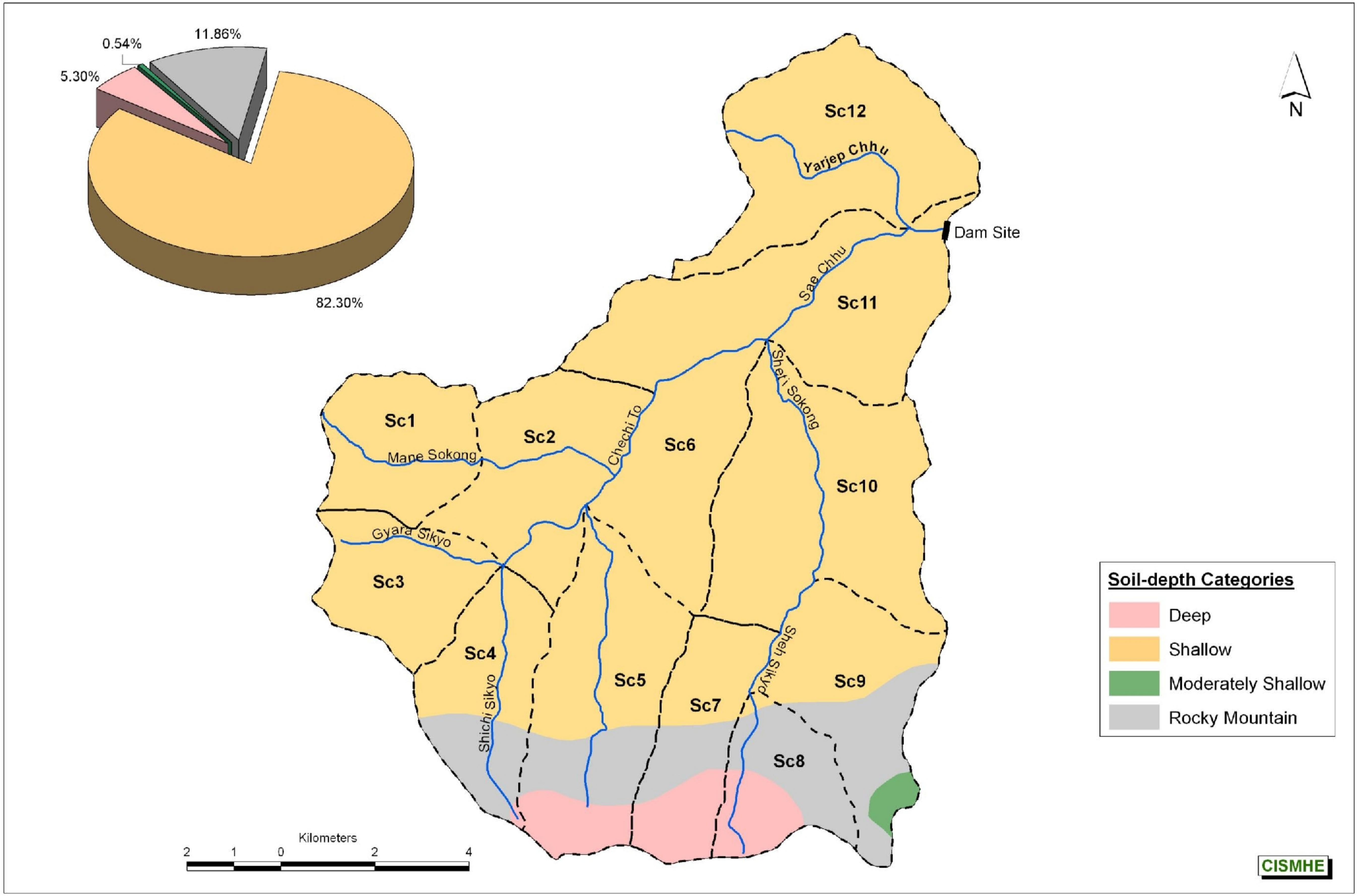


Fig. 5.1.8 Soil-depth map of Yarjep Chhu in the free-draining catchment of the proposed Pauk H.E. project

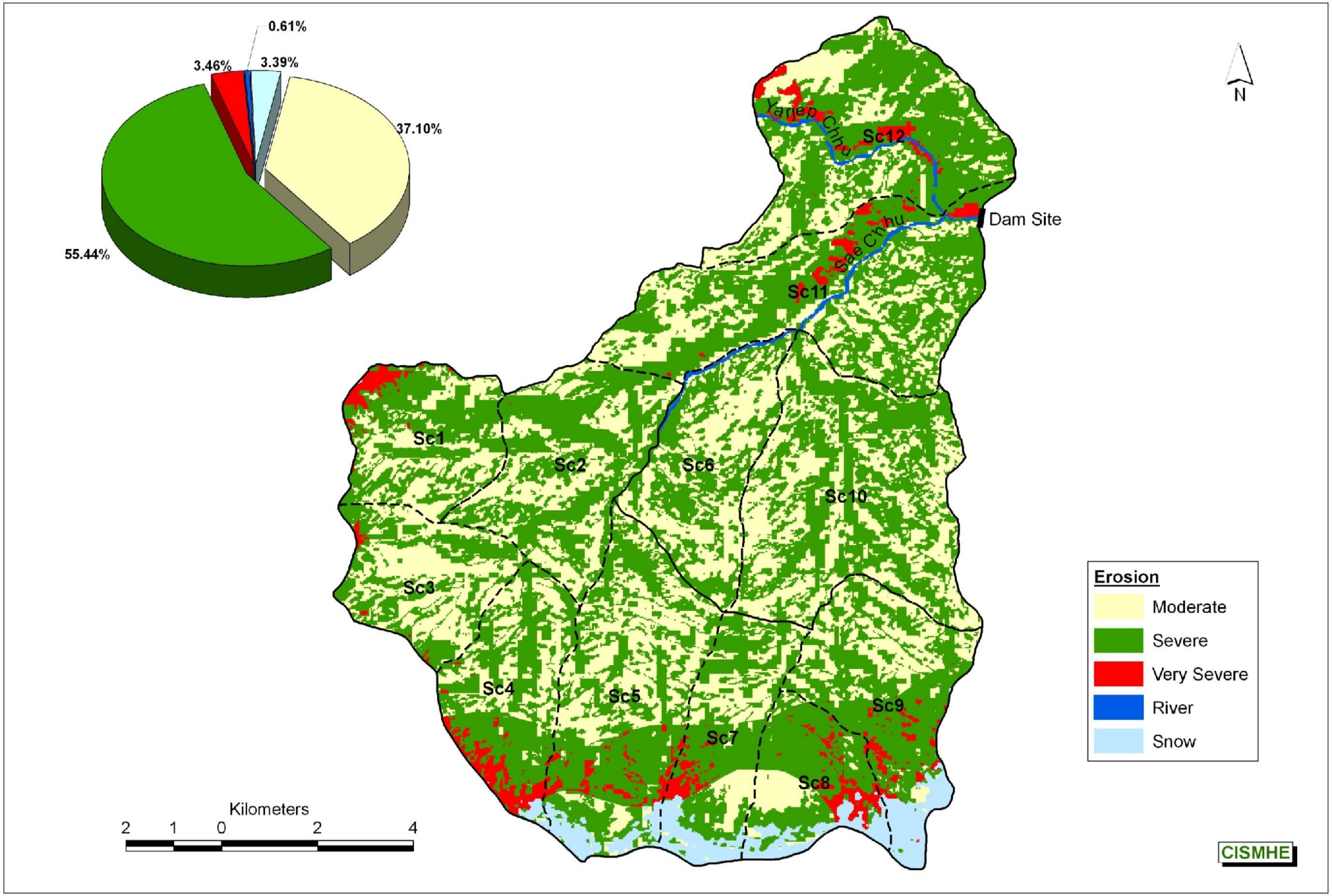


Fig. 5.1.9 Erosion intensity map of free-draining catchment of the proposed Pauk H.E. Project

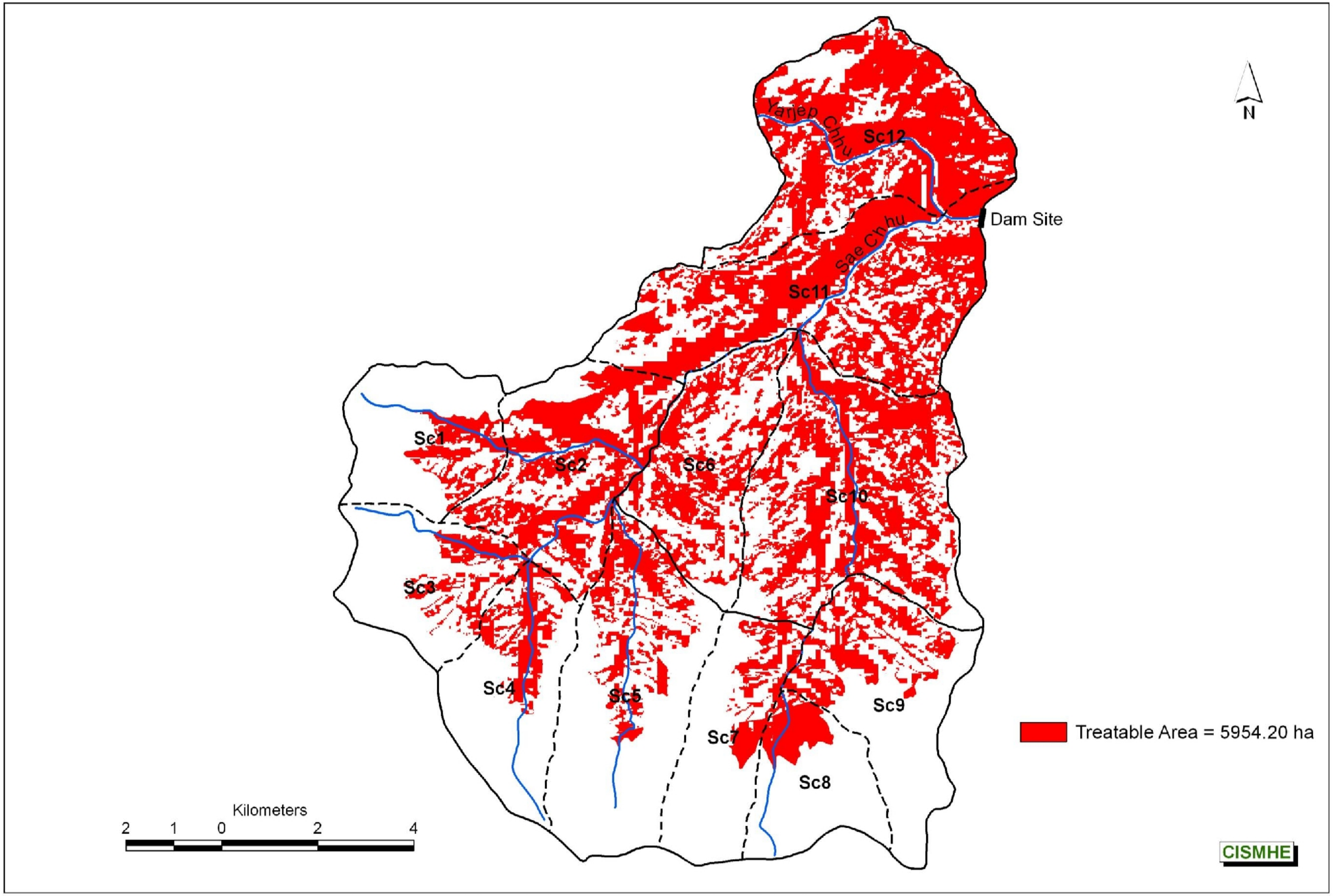


Fig.5.1.10 Treatment map showing treatable area of free-draining catchment of Pauk H.E. Project

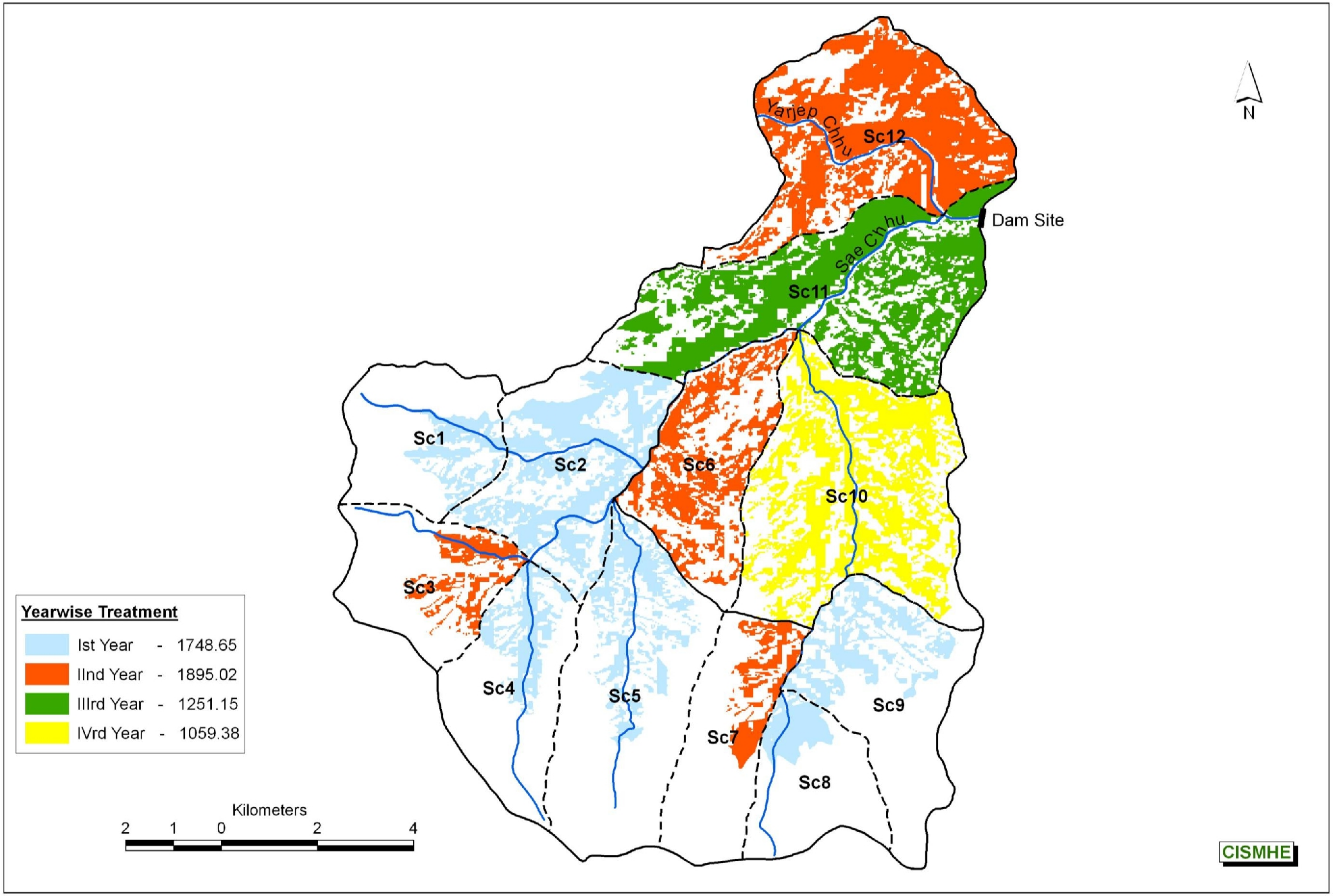


Fig.5.1.11 Yearwise treatment map of free-draining catchment of Pauk H.E. Project

5.2
BIODIVERSITY MANAGEMENT AND WILDLIFE CONSERVATION PLAN

5.2.1 INTRODUCTION

The conservation refers to the management of a natural resource so that it can be sustained for long. The natural resources are the goods and services supplied by our environment and can be made useful to humans to meet their needs and wants. However, with increasing human population, natural resources are declining both in quantity and quality on a global scale. Therefore, it becomes important to prevent further exploitation of natural resources and manage them to ensure their sustainable utilization. Natural conservation involves proper management of natural wealth, places that sustain these resources besides the human pressure that affect the resources. The need for conservation, preservation and management of biological diversity arises on account of threats to natural terrestrial and aquatic ecosystems by anthropogenic activities. In the present project threats may arise as a result of dam construction and associated activities of the proposed hydroelectric project. The likely disruptive activities include road construction, blasting, excavation for tunnels, quarrying, dumping of excavated material and human population pressure on land and biological resources.

Biodiversity also has social, cultural and spiritual values distinct from bio resources. The surroundings of proposed project experience with similar condition (rich in habitat diversity, biodiversity, agro-biodiversity and customary rights of tribes over natural resources). The preparation and execution of biodiversity management and wildlife conservation plan in the region is a challenging job as livelihood, customs, spirit etc. of tribes conflict with them.

In view of the foreseen disturbance and degradation of natural ecosystems, complementary strategies will be followed in biodiversity conservation and management plan. The entire catchment of Pauk hydroelectric project is a store house of the large array of diversity in timber, fuel, food, fodder, vegetables, medicinal plants which are naturally and artificially growing in the region. The important strategies are *in Situ* conservation strategy, *ex Situ* conservation strategy, reduction of anthropogenic pressure and rehabilitation of threatened species.

5.2.2 OBJECTIVES

The main objectives of the Biodiversity Management and Wildlife Conservation Plan for Pauk H.E. Project are given below.

i. To maintain a sustainable approach between customs and culture of tribes and biodiversity conservation,
ii. To establish inventory for the voucher specimen of threatened, new and endemic plant species,
iii. Special efforts for conservation of critical/important plant/animal species, if any, affected by the project,
iv. To maintain data on ‘vaids’ (Kennapanna) and traditional knowledge on medicines,
v. To provide incentives for research, training and public education to increase awareness with respect to biodiversity.
vi. To prepare a Forest Protection Plan

5.2.3 STATUS OF BIODIVERSITY IN THE SURROUNDINGS

The vegetation in these forests comprises sub-tropical wet hill forests in the lower valleys of the project area, while wet temperate broad-leaved and dry temperate coniferous forests in the mid and upper hills. There are nearly 340 species of angiosperms and gymnosperms plants. The angiosperms are represented by about 79 families in these areas of which 63 are dicots and 16 are monocots. The dicotyledons are represented by 240 plant species belonging to 170 genera, while the monocotyledons are represented by 70 genera and 100 species. Gymnosperms are represented by three families, three genera and three species. The ratio of monocot to dicot species is 1:2.4 (100 monocots and 240 dicots). Detailed description of flora of the influence area has been provided under chapter 3.5 of the EIA.

The faunal diversity of influence area is represented by 27 species of mammals, 75 species of birds, 9 species herpetofauna (6 reptiles and 3 amphibians) and 13 species of butterflies. A total of 11 species were scheduled I while 8 species were vulnerable or endangered as per IUCN criterion (2010). Common leopard (*Panthera pardus*), Black bear (*Ursus thibetanus*), Barking deer (*Muntiachus muntjak*), Wild boar (*Sus scrofa*), Assamese Macaque (*Macaca assamensis*), Serow (*Capricornis sumatraensis*), Goral (*Nemorhaedus caudatus*) are common species of the influence area. In the avifauna, a total of five bird species were schedule I. A total of 31 species of birds could be located during the primary surveys in three seasons. Area is poor in Lepidopteran diversity, only 13 species of butterfly were observed in influence area.

Customary hunting is considered as one of the major threats to biodiversity in the region because enforcement of forest rules is not strict in these areas because of the customary rights of the people on the forest and forest products. Tribes have a vast traditional knowledge of biodiversity and wildlife. They are well aware of food habit, shelters, and habitat preferences of wild animals. They are able to identify the species of animals especially mammals and birds with the help of their calls. The traditional knowledge of tribes could be used in formulating the appropriate biodiversity management plan. Detailed description of fauna of the influence area has been provided under chapter 3.5 of the EIA.

5.2.4 PROPOSED PLAN

The proposed biodiversity management plan has been formulated in view of the scope of other projects in the area. Some of the mitigation measures have been covered in other projects, owned by the same project authorities and therefore not provided in the Pauk H.E. Project as the influence areas are overlapping. Similarly, the measures suggested in this section under the Pauk HEP will be implemented in the influence areas of other projects.

5.2.4.1 Definitions

In view of the biodiversity conservation we have used a few terms, mentioned in the Biological Diversity Act (2002). Only those terms are defined in the following section, which are relevant to the proposed biodiversity Management Plan.

i.) “Biological diversity” means the variability among living organisms from all sources and the ecological complexes of which they are part of and includes diversity within species or between species and of ecosystem.

ii.) “Biological resources” means plants, animals and micro-organisms or parts thereof, their genetic material and by-products (excluding value added products) with actual or potential use or value but does not include human genetic material.

iii.) "Bio-survey" means survey or collection of species, sub species, genes, components, and extract of biological resources for any purpose and includes characterization, inventorisation and bioassay.

iv.) "Local bodies" means panchayats, and municipalities.

v.) "Cultivar" means a variety of plant that has originated and persisted under cultivation or was specifically bred for the purpose of cultivation.

vi.) "Folk variety" means a cultivated variety of plant that was developed, grown and exchanged informally among farmers.

vii.) "Land race" means primitive cultivar that was grown by ancient farmers and their successor.

5.2.4.2 Management Measures

Following measures for the biodiversity management and conservation plan are proposed in Pauk H.E. Project.

5.2.4.2.1 *Establishment of a Botanical Garden*

In the goal of conserving important (folk varieties, landraces, medicinal and endemic plant) species, a botanical garden is proposed in the vicinity of the project. The garden is proposed to be located on the right bank of the river, near Rapum village (an degraded area). The proposed garden would act as a repository and would be of special interest to biodiversity conservation, scientific research, education and environmental awareness. The area of garden would be enclosed in a land of about 5 ha, which shall be provided by the State Government. The project authority would provide the funds for establishment and maintenance of botanical gardens for five years. In addition to folk varieties, land races and threatened species, some flowering fruit bearing plants will be included in the botanical garden. These species would attract the butterflies and bird species. To attract the bird species wooden nesting boxes would be established in the canopy of trees. The breakup of the total financial outlay for the botanical gardens including development of a nursery, collection of seeds and plant species, small laboratory and staff for five years is given below. After five years the garden would be handed over to State Forest Department. The plan will be implemented through State Forest Department. Land for the botanical garden would be provided by State Government. Total financial outlay for establishment of a Botanical Garden would be **Rs. 97 lakhs (Rs. Ninety Seven Lakhs).** Break up of budget is given in Table 5.2.1.1.

Table 5.2.1.1 Break up of the budget for botanical garden

Particulars	Amount (in Lakhs)
Salaries/wages*	
Research Scientist (1)	25.00
Curator (1)	16.00
Gardener (1)	10.00
Peon (1)	10.00
Collection of seeds and plant species	2.00
Development of a garden (including fencing)	15.00
Development of a nursery	2.00
Plantation	5.00
Water supply system	2.00
Equipment	5.00
Contingency (including outsourcing of expertise, research, travel etc)	5.00
Total	**97.00**

*In the salary head, lump sum amount for 5 years has been allocated considering the revised pay scale

5.2.4.2.2 ***Natural Resource and Skill Management***

Arunachal Pradesh has a rich tradition in crafts such as weaving, pottery, smithy work and basketry. Their designs reflect the social and religious system from which they emanate. Motifs are drawn from everyday life, myths and legends. The intricate motifs and designs, the combination of colours all reflects the social status and ethnic origins of the people. The loom that is traditionally used is the loin loom and the colours used are organic colours, prepared largely from the plants that grow in the forests. Like other traditional crafts, weaving also requires an ecological knowledge.

In the influence area weaving as one of the areas where tribal women can make some progress. Though most women are skilled weavers, there are very few women engaged in weaving on a part time or full time basis. This is because this activity is largely in the non formal sector. Tribal women are the custodians of this knowledge, to the elaborate process of spinning, dying and weaving. So if weaving is to be a livelihood option in the area as micro enterprises, it will require financial and marketing support as well as training and design inputs. Therefore, the involvement of tribal men and women in biodiversity conservation shall be crucial. The natural resource management can be achieved by joint forest management involving tribes through local NGOs and coordinated efforts of project proponents and the government. This joint work participation programme should be carried at various levels like awareness programmes, incentives to villagers, awareness about importance of local fiber yielding plants and their products. The participating NGO would run awareness, teaching and training programmes (method of extraction) for the local communities. With implementation of this plan, overexploitation of natural resources could be prohibited. The project proponent (Pauk Hydro Power Pvt. Ltd.) would provide the finances for supporting the activities of NGO for at least 5 years. Total financial outlay for the natural resource and skill management would be **Rs. 40, 00,000 /- (Fourty lakhs**).

5.2.4.2.3 *Butterfly Park*

Butterflies are extremely good indicators of environmental conditions and respond immediately to the disturbance caused due to alteration of their habitat. Purying, Rapum and Rego are well endowed habitats for butterflies. During the primary surveys Indian cabbage white (*Pieris canidia*), Tabby and Commodore (*Limenitis danava*) was recorded from the upper area of the influence area. Common sailer (*N. hylas varmona*) and Indian cabbage white (*Pieris canidia*) were most common species of surroundings. Field survey also revealed that a number of flowering plants like *Aconogonum molle, Azeratum conyzoides, Albizia odoratissima, Chromolaena odoratum, Ficus semicordata, Maesa chisia, Saurauia punduana, Saccharum spontaneum* and *Thysanolaena latifolia* are preferred food plants of a varieties of butterflies. In order to conserve these butterflies, two parks are suggested on the degraded land (near Rapum and Rego). The area of each park would be around 2 ha. Moist damp places and stream beds are the most suitable places for the butterflies. The flowering and fruit bearing plant species like *Artemisia indica*, *Begonia* spp., *Buddleja asiatica*, *Cathranthus roseus, Clerodendrum bracteatum, Circium wallichii, Ficus auriculata, Tegetus indica*, etc are suggested for the proposed butterfly parks. The break of budget including fencing, plantation, salaries, maintenance grant and contingency for butterfly parks is given in below amounting to **Rs. 42,00,000 /- (Forty Two lakhs)**. Break up for the budget earmarked for butterfly park is given in Table 5.2.1.2.

Table 5.2.1.2 Break up of the budget for butterfly parks

Particulars	Amount (Rs. in lakhs)
Salaries*	
Curator (2)	20.00
Fencing	5.00
Plantation	5.00
Maintenance grant @ Rs. 1.00 per year/park	8.00
Contingency (includes travels etc.)	4.00
Total	**42.00**

*In the salary head, lump sum amount for 5 years has been allocated considering the revised pay scale

5.2.4.2.4 *Identification of Invasive Species and recovery of susceptible species*

Though proposed project area is not under sever anthropogenic pressure, *Ageratina adenophora*, *Ageratum conyzoides*, *Bidens bipinnata*, *Chromolaena odoratum* are some of the invasive species that have been introduced unintentionally in this area. The increased human activity and disturbance in natural ecosystem is the main cause of the spread of invasive species. This trend may prove to be adverse for the native plant diversity leading to decline in number of endemics in future. In order to understand this problem and manage it successfully the following measures are suggested:

(i) Identify the areas where biological invasions have occurred and are threatening.
(ii) Identify the exotic invasive plants that are invading these habitats.
(iii) Identify the institutions/experts who can undertake inventorisation and researches to suggest management measures to control this negative impact of invasives.
(iv) Inventorise the native species which are threatened by invasions and that require rehabilitation and management.
(v) Removal of exotic invasive plant species and obnoxious weeds.

This plan will be implemented by the Environment Cell of project authorities in consultation with State Forest Department. Since the same plan has been suggested in Heo HEP so that the provision of separate budget has not been made for this project.

5.2.4.2.5 *Wildlife conservation & forest protection plan*

The surrounding area of the proposed project (Purying-Rapum and Rego- Mechuka) represent a habitat heterogeneity which has conservation significance. However, the area does not have the minimum basic amenities for wildlife conservation and forest protection such as road and communication network. The wildlife protection force is not adequately equipped with watching towers, wildlife personnel and other field work facilities. Considering all these facts various activities which are necessary for the forest protection plan are described in the following paragraphs:

i). For the improvement of vigilance and measures to check poaching, check posts and watch towers will be needed. In order to strengthen the working capacity the officers of the State Forest/Wildlife Department they must be provided with necessary equipment such as a camera, wireless, binoculars and other minor equipment (altimeter, spotscope, search lights, sleeping bags, health kits, etc.) that would increase their capability and efficiency.

ii). Under the reward for informers programme it is proposed to engage the workers of task force who are well acquainted with the area and are resourceful in gathering information for anti-poaching (particularly of butterflies, medicinal herbs and endangered species) and better vigilance. These youth could be hired on a contractual basis.

iii) The construction of bridges, inspection paths for more effective and meaningful patrolling of the staff should be undertaken.

iv). Improvement of vigilance by procurement of field vehicles and motorbikes.

v). Creation of veterinary facilities and rescue camps for healthcare of wild animals and for controlling diseases. For this purpose it is essential to maintain a stock of medicines in addition to setting up of a *mobile-rescue-cum-publicity-van*.

vi). Provision of fire lines within critical areas to protect the forest from accidental fires

vii). Organizing occasional public awareness programmes, conducting training camps, preparation of research documents, pamphlets, brochures, etc.

It would be a joint venture of proposed task force and State forest department. Project authorities would provide funds to State Forest Department. This plan would be implemented in the free draining catchment of Pauk H.E. Project. Total financial outlay under this head would be **Rs. 45,00,000/- (Forty five Lakhs**) only. The break-up of budget is given below.

Particulars	Total Amount (in lakhs)
i. Equipment (Camera, health kit, search light, binocular, etc)	12.00
ii. Watch Tower, patrolling path, bridges	15.00
iii. Veterinary facilities	05.00
iv. Mobile-rescue-cum-publicity-van	03.00
v. Reward for informers	10.00
Total	**45 .00**

5.2.5 SAFEGUARD MEASURES

Various adverse impacts on the wildlife are anticipated in the surrounding areas of the proposed project in terms of increased noise levels, land vibrations during tunneling and blasting, release of air and water pollutants, etc. Mammals are the most vulnerable group affected by these negative impacts, which affect their movement, behaviour and breeding habit. To avoid and minimize the negative impacts from these activities project authorities are advised to prepare strict guidelines as follows.

i. Strict restrictions shall be imposed on the workers at project sites to ensure that they do not harvest any species/produce from natural forests and cause any danger or harm to the animals and birds in the wild.

ii. Each worker shall be provided with identity card and would not be allowed access to forest areas without permission.

iii. Possession of firearms to project workers shall strictly be prohibited.

iv. Minimum levels of noise during construction activities will be maintained and no activity shall be carried out nights and early mornings in the vicinity of dense forest area.

v. To avoid the deterioration of water quality and release of pollutants into river, project authorities would provide proper sanitation facilities and garbage disposal bins to the workers/ colony areas.

vi The interference of human population would kept to a minimum in the adjacent forested areas.

vii The project authorities will be bound by the rules and regulations of Wildlife Protection Act (1972) or any such agency of the State, which may exist or will be promulgated from time to time for the preservation of habitats and protection of wild animals.

5.2.6 BIODIVERSITY MANAGEMENT COMMITTEE (BMC)

In order to monitor the progress of biodiversity management and wildlife conservation plan, a Biodiversity Management Committee (BMC) is proposed for Pauk H.E. Project. The committee will follow the guidelines of National Biodiversity Authority, State Biodiversity Conservation Strategy Action Plans (SBCSAP) and State Forest Department to implement, monitor and evaluate the Biodiversity Management Plan of the proposed project. The activities of BMC shall be under the direct administrative control of the Chief Wildlife Warden/Principal Chief Conservator of Forests, Arunachal Pradesh. The BMC will comprise of following members.

i.	Chief Wildlife Warden/Principal Chief Conservator of Forests, Arunachal Pradesh	Chairman
ii.	Chief (Environment), Pauk HE Project	Member Secretary
iii.	DFO (s) (wildlife) of the concerned Division	Member(s)
iv.	Two experts form University or renowned R & D Institutions	Member
v.	Local Body's Representatives from at least 3 villages on a rotational basis	Member
vi.	Representative of a well known local NGO	Member

The Chairman of the committee will have the right to assign various activities to various members for proper functioning and result-oriented tasks. The committee will monitor the progress of the proposed plan for all three projects, viz. Tato I, Heo and Pauk H.E. projects. The major share of budget for the BMC is provided in the Tato I H.E. projects, however, an amount of **Rs. 3.00 Lakhs (Three lakhs)** only has been separately provided for Pauk H.E. Project.

5.2.7 FINANCIAL OUTLAY

Total budget for Biodiversity Management and Wildlife Conservation Plan would be **Rs.227.00 lakhs**. The breakup is given below:

Head	Amount (in Lakhs)
i. Establishment of a Botanical Garden	97.00
ii. Natural Resource and Skill Management	40.00
iii. Butterfly Parks	42.00
iv. Identification of invasive Species/recovery of susceptible species	
v. Wildlife conservation & Forest Protection Plan	45.00
vi. Biodiversity Management Committee	3.00
Total	**227.00**

5.3
MUCK DISPOSAL PLAN

5.3.1 INTRODUCTION

Dumping of muck and its rehabilitation is a real challenge in the hydro-electric project as a huge quantity of muck is excavated from different structural units. All ancillary activities of muck dumping like excavation, transportation, relocation and rehabilitation have adverse impacts on the life support system and landscapes. Therefore, among all mitigation measures, relocation and rehabilitation of muck are addressed primarily in EIA studies. The nature of excavated muck varies significantly from the natural soils, therefore, its unsound disposal is considered to contaminate not only the water quality, air quality but soils and vegetation of surrounding areas. Though, no firm government policies have been formulated for the disposal of muck generated from the earth works, however, relocation of muck would require certain guidelines and regulations from its source to rehabilitation. A muck disposal plan would take the calculation of muck to be generated, swelling factors, reutilization of muck, dumping areas and their characteristics, mitigation measures including engineering and biological and their uses, if possible into account. The proposed muck disposal plan deals with the earthwork of Pauk H.E. Project in West Siang district of Arunachal Pradesh.

5.3.2 SELECTION OF DUMPING SITES

During the selection of the dumping sites the following criteria were given preference from the environment as well as economic point of view:

i) The dumping sites shall be located nearby the structures to be excavated to avoid the long distance transportation.

ii) The sites shall be free from active land slides or creeps and care shall be taken so that the sites do not have a possibility of toe erosion related slope failure.

iii) The base levels of the sites shall be at higher elevation than the maximum flood level.

iv) There shall not be any channel of small streams flowing through the dumping sites. If it is not avoidable, adequate care shall be taken so that there would be no contact between the muck and the stream. A suitable plan shall be proposed for the same.

v) These sites shall not be pristine habitats containing threatened species.

The dumping sites chosen by the developer in the DPR meets the requirements mentioned above.

5.3.3 GENERATION OF MUCK

The total quantity of muck to be generated from the different components of Pauk H.E. Project would be around 8,18,020 cum (Table 5.3.1.1). Considering the swelling factors (20% for underground and rock excavations, 10% for common excavations), the volume of muck to be rehabilitated would increase to about 9,76,449 cum. The muck will be generated mainly from surface earth work and underground work. A part of the muck generated will most probably be used for construction material purpose and therefore, only a part of the 9,76,449 cum will require rehabilitation in adequate dumping sites. However, as a cautious approach it has been decided to consider that the entire muck generated will have to be dumped so that in practice there will be a capacity margin.

Table 5.3.1.1 Quantities of Muck (in cum) to be generated and rehabilitated from the different components of Pauk HE Project

Components	**Qty. of material excavated (in m^3)**			**Qty. Of muck to be rehabilitated (with swelling factor) in m^3**
	Common	**Rock**	**Underground**	
Cofferdam	6,000	-	-	6,600
Dam Site	14,915	260,266	-	329,206
Access	2,404	27,148	87,075	139,712
Waterways HRT	-	-	106,969	128,363
Waterways DS	-	15,275	13,302	34,292
Powerhouse	28,427	255,839	-	338,276
TOTAL	**51,746**	**558,928**	**207,346**	**976,449**

5.3.4 MUCK DUMPING AREA (MDA)

Only one dumping site has been identified for the disposal of muck. The MDA is located at half distance between Chengrung and Rapum villages with a total area of 5.1 ha. This site is proposed to rehabilitate the muck of the whole Pauk H E Project (**Fig. 5.3.1.1**). Three cross sections have been prepared to describe the salient features of the dumping area. The base of dumping area is stretches elevationally from 1575 m to 1650 m while the highest flood level (HFL) at this site is maximum 1440 m asl (**Fig. 5.3.1.1**). Altitudinally, the minimum height between the dumping site and HFL is 135 m while it is 180 m horizontally. Total capacity of the muck dumping area is 10,34,900 cum.

5.3.5 REHABILITATION OF DUMPING AREAS

Considering the elevational (135m) and horizontal distances (180.9 to 260.7m) of dumping area from highest flood level, the possibility of soil erosion and other impacts of loose soils on the river water is relatively low. However, other adverse impacts of dumping on ambient air quality, surrounding vegetation and human health cannot be overlooked. Considering all environmental consequences of dumping area, the rehabilitation measures in Pauk HE project are described below.

5.3.5.1 Engineering Measures

5.3.5.1.1 *Compaction*

The compaction of dumping piles compresses and reduces the volume of muck considerably. The compaction also makes it suitable for the plantation and other biological measures. Top surface would be leveled and graded to make the alternative use. Total budget for the compaction would be **Rs. 6.0 lakhs** only.

5.3.5.1.2 *Precautionary measures*

All precautionary measures will be followed during the dumping of muck. All dumpers must be well maintained so that loose soil could be well protected during the transportation. All routes should be wetted prior to the dumping. Dumping would be avoided during the high speed wind, so that suspended particulate matters (SPM) level could be maintained. After the dumping, the surface of dumps must be wetted with the help of sprinklers. Care should be taken so that the loose soil could not be leached out in the nearby water body. To protect the loose soils from wind erosion, wind barriers of with suitable porosity will be established from three sides of dumping piles.

5.3.5.1.3 *Construction of retaining walls*

Carefully packed rock toe of 3 m height with side slope of 1.5:1 is enough to withstand the stress caused by the muck. However, the natural ground terrain varies from gentle to semi slope and steep slope. Hence, Random Rubble masonry in cement mortar 1:5 is proposed to be constructed 2.5 m high continuous wall along the edge of rock dump towards the river side.

The total length of retaining wall the dumping site has nearly been calculated to be 747.5 m including the side walls at a few places. The average height of walls would be 2.5 m, including a 1 m foundation wall (**Fig. 5.3.1.2**). The wall will be filled with plum concrete, provided with stone masonry of grade M15 (1:2:4). The foundation of retaining walls structures shall be of cement concrete of grade M10 (1:3:6). A stone filled layer will be placed at the side facing the dumped materials. They should catty weep holes for the discharge of surface water during rainy season. These holes will be provided with filters. Total estimated volume of the excavated materials for the foundation would be around 1121.25 cum and volume of retaining wall would be around 1,734 cum (906 cum for foundation wall + 828.20 cum). Total financial outlay for the retaining walls is **Rs. 94.98 lakhs,** given in Table 5.3.1.2.

Table 5.3.1.2 Cost estimates for retaining walls at the dumping sites in Pauk H.E. Project. It includes the labourers' wages

S.No.	Particular	Volume (cum)	Rate per cum	Cost in Lakhs
1	Earth work excavation for foundation	1121.25	500.00	5.61
2.	Cement concrete for foundation	906	4000.00	36.24
3	Cement concrete for retaining wall	828.20	4000.00	33.13
4	Stone filling and filter	Lumpsum	-	20.00
Total				**94.98**

5.3.5.1.4 *Fencing*

The fencing of dumping site would protect it from human interference, wild and domestic animals. In order to protect the dumping sites, temporary fencing will be implemented in the periphery of dumping site. After rehabilitation of dumping area, the fencing will be dismantled. Barbed wire strands with two diagonal strands, clamped to wooden/ concrete posts placed 3 m distance are proposed around the dumping piles. Approximately 1000 m barbed wire with 4 strands horizontal and two strands diagonal would be required for the fencing. Project authorities are suggested to establish temporary wind barrier around 3 sides of the dumps, if the area is close to the settlement area. Total cost for the fencing will be **Rs. 2.50 lakhs** only.

5.3.5.2 Biological Measures

After the construction of the retaining wall and the concrete tunnel, dumping and compaction, a total available surface area including tops and slopes of all dumping area would be left with about 4 ha. This area will be used for the plantation so that vegetation cover could control the mechanical and hydrological effects on the slopes and would give the permanent stability to the muck. The biological measures include the following measures.

5.3.5.2.1 *Soil treatment*

Generally the excavated soils are not fertile, if not treated vegetation cannot be grown properly on such soil surfaces. In order to make it nutrient rich, the following Integrated Biotechnological Approach' is required.

i) Analysis 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.
v) Use of locally available manure and compost.

The project authorities are suggested to consult a well reputed organization for implementation of VAM (Vascular Arbuscular Mycorrhiza) technology, which can supply the strains of mycorrhizal fungi, rhizobium, azotobacter and phosphate solubilizers (biofertilizers inoculum). The important institutions are IMTECH, Chandigarh and IARI, New Delhi. The total cost for the soil treatment would be **Rs. 3.00 Lakhs** only.

5.3.5.2.2 *Selection of species*

To stabilize the muck and restore the disposal site, fast growing plant species are suggested. The grasses are suited to bind loose soil and shrub and trees hold soil up to deeper level. Taking the climate, soil and drainage conditions of the sites into account, selection of local plant species is generally preferred. Important tree species which can be used to rehabilitate the loose soil are *Alnus nepalensis, Altingia excelsa, Brassiopsis aculeata, Castanopsis indica, Erythrina arborescens, Gymnema arborea, Saurauia punduana* and *Schima wallichii*. Shrubs that can be useful as soil binders are *Bambusa tulda, Boehmeria macrophylla, Debregeasia longifolia, Hydrangea robusta* and *Oxyspora paniculata*. Among tuft forming and fast growing grasses useful in soil binding are *Chrysopogon gryllus, Digitaria setigera, Eleusine coracana, Eragrostis nigra, Eulaliopsis binata, Saccharum longisetosum* and *Thysanolaena latifolia*.

5.3.5.2.3 *Use of Geo-textile*

After treatment of soils, mats of coir jute will be spread over the dumping slopes and wetted suitably. Use of geo-textiles is an eco-friendly practice and considered as good for plant growth. Geo-textile mats increase the water holding capacity of soils and retain the water.. After decomposition, they increase the fertility of soils. Likewise other projects, such types of geo textiles methodology will be adopted for the dumping site of Pauk HEP. Total budget for the use of geo textiles would be **Rs. 4.00 lakhs** only.

5.3.5.2.4 *Plantation*

The selected species will be planted after their nurseries have been developed. The dumping area is very small, therefore, separate nursery would not be required. The nurseries developed for the implementation of CAT plan can be used for the rehabilitation of dumping areas. Nearly 1-2 years old saplings would be used for the plantation. The plantation can 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. Plant saplings would be raised in biodegradable pots and transplanted as such. The plantation should be done in the monsoon season. Pits of 0.45 x 0.45 x 0.45 m will be dug and filled with some nutrients rich soil. The compost from local organic waste can be used.

An area of approximately 4 ha would be required for phyto-remediation measures. A total of nearly 4000 plant saplings (@1000 plants per ha) including trees and herbs will be planted at the dumping site. Total cost estimates for the biological measures are given in Table 5.3.1.3. This cost includes the cost of turfing of slopes, preparation of ground, spreading of manure, etc., providing 5 cm of soil cover and transportation and carriage. It also includes the cost of watch and ward and irrigation, etc. The total cost for the biological measures would be **Rs. 10.52 lakhs**.

The methodology consists in developing the formation width in half cutting and half filling, so that the materials obtained from cutting are utilized in filling. The excavation on hill side will be done to get a stable slope for the materials encountered. At places where there is a problem of retaining the hill slope, breast walls, gabion walls shall be constructed in natural slope to retain the fill materials.

Table 5.3.1.3 Financial requirements for the biological measures to rehabilitate dumping sites of Pauk H.E. Project

Sl.No.	Item	Quantity	Rate	Amount (Rs. in lakhs)
1.	Pitting	4,000 pits	Rs. 33.08/pit	1.32
2.	Raising of plants (including nursery cost, manure, transport, etc.)	4,000 plants	Rs. 30.00/plant	1.20
3	Turfing, spreading of manure etc	Lump sum	-	4.00
4	Maintenance, watering, transport, etc	lump sum		4.00
	Total			**10.52**

5.3.6 COST ESTIMATES

The total financial outlay for the relocation of muck and rehabilitation of the dumping sites including engineering and biological measures would be **Rs. 121 lakhs** only. Break-up of the budget is given Table 5.3.1.4.

Table 5.3.4 Break down of overall cost for muck disposal plan for Pauk H.E. Project

S.No	Particulars	Total cost (Rs. In lakhs)
1	Compaction	6.00
2	Cost of retaining wall	94.98
3	Fencing	2.50
4	Soil treatment	3.00
5	Geo Textile	4.00
6	Plantation	10.52
Total		**121**

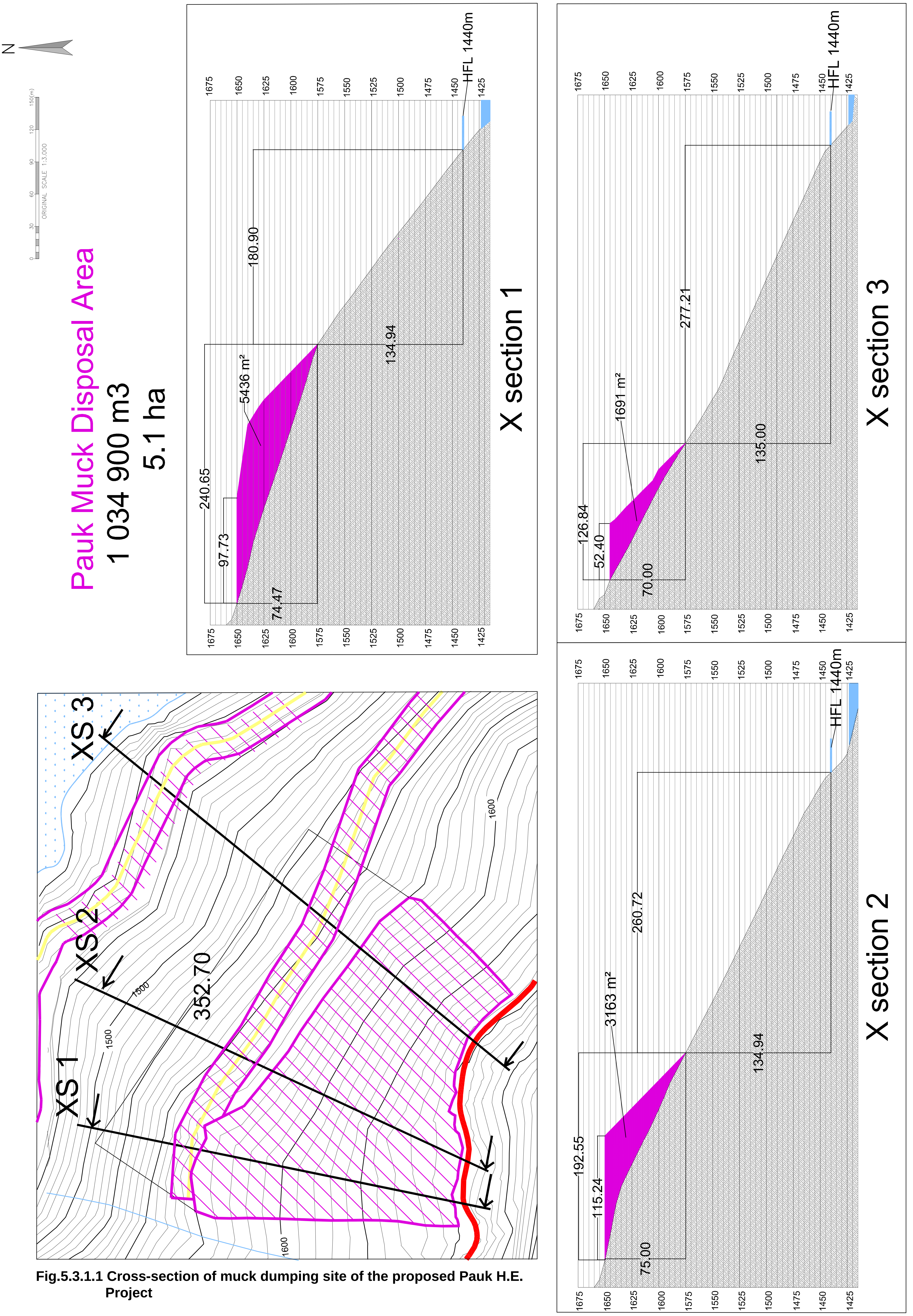


Fig.5.3.1.1 Cross-section of muck dumping site of the proposed Pauk H.E. Project

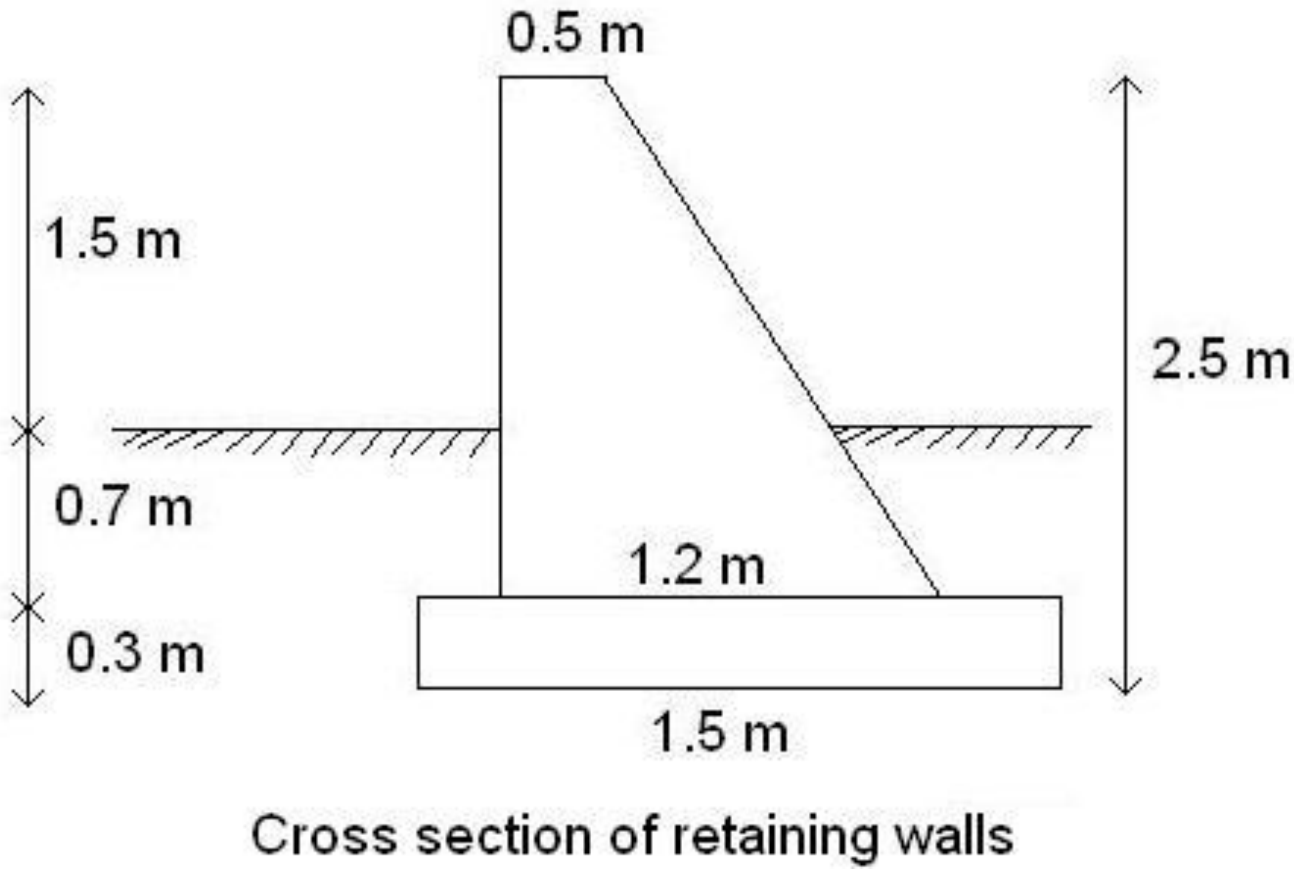


Fig. 5.3.1.2 Cross section of proposed retaining wall for Pauk H.E. Project

5.4
RESTORATION OF CONSTRUCTION AREAS AND LANDSCAPING

5.4.1 INTRODUCTION

The process of restoration of an area to its former state depends on the level of knowledge of former system, availability of biota for restoration, soil and geomorphology, cost and availability of funding, public policy and socio-cultural values. Therefore, a complete data set should be collected on natural resources in the vicinity of a disturbed site.

The proposed Pauk HE Project would involve construction of colonies for staff and laborers, roads linking to various components of project, offices, etc. During construction, these activities could also result in accumulation of large amount of unused material at various sites which require proper restoration measures. Total area likely surface area to be disturbed due to these activities is around 88.4 ha. This land also includes areas likely to be disturbed due to quarries and dumping of unused muck, dam complex area and powerhouse area. At present, the proposed project area is covered with dense/open forest particularly at dam storage and power house sites. This existing landscape will be totally changed or modified due to proposed project. Therefore, all areas disturbed by construction activity including access roads will be landscaped to reflect natural contours, restore suitable drainage paths and encourage the reestablishment of vegetation.

5.4.2 DISTURBED SITES AND THEIR RESTORATION

Around 79.1 ha of surface land (excluding river bed area) will be directly disturbed due to various construction activities of the proposed project, like access roads, muck dumping sites, quarry sites, colonies, offices, etc which will change the existing land cover in the region. After completion of the construction work, it is required to restore the disturbed area to its original conditions wherever it is possible. Submergence, Dam and Power House civil structures cannot be restored in their original shape, but Quarry sites, Colony and Office Complex and road (partly) can. These areas can benefit from restoration measures, even though their entire areas cannot be restored in their original shape. Restoration of dumping sites area has been described separately in the chapter 5.3 of the EMP. Here restoration of quarry sites, colony area, office complex and roads is discussed and a detailed plan is given for the landscaping of the region. Various engineering and biological measures have been suggested for the restoration of these areas. Proposed mitigation measures will also help to arrest soil erosion in the region.

5.4.3 RESTORATION OF QUARRY SITES

The quarry sites (QS1& QS2) are located in the vicinity of the proposed reservoir and power house areas for the excavation of land and rock material. Total area of the proposed quarry sites is around 1.2 ha. After excavation of the required material, these quarry sites will require restoration. Appropriate engineering, bio-engineering and biological methods are proposed for effective restoration of the quarry sites.

Removal of rocks from the quarry sites for different construction works will result in the formation of depression and craters. These will be filled up by the dumping materials consisting of boulders, rock, gravel and soil from nearby sites. To achieve this, appropriate measures would be adopted at various sites in the project area so that the restoration work will be scientifically executed. Various biological, bio-engineering and engineering measures are proposed for the restoration of the quarry sites and their costs are presented in the cost estimates of the EMP plan (Table 5.4.3).

5.4.3.1 Removal of Top Soil

The top soil (top 6-12 inch soil) should be removed before excavating the sand or rocks from the quarry sites. This soil contains all microbes (including earth worms) and important nutrients and organic matters which will be required at the time of restoration of these quarry sites.

5.4.3.2 Filling of Depressions

Removal of rocks from quarry sites for different construction works will result in formation of depression and/or craters. These depressions will be filled up by the dumping materials consisting of boulders, rock, gravel and soil from the nearby sites. After filling these craters, the top soil collected prior to quarrying will be spread as top layer. The top soil then should be covered with geo-textiles like coir, jute or by other locally available bio-degradable material. This will protect the top soil from erosion.

5.4.3.3 Diversion of Run-off

Effective drainage system will be provided to avoid the infiltration of run-off and surface waters into the ground of quarry sites.

5.4.3.4 Construction of Retaining Walls

Retaining walls will be constructed at the filled up depressions of quarry sites to provide necessary support particularly where there are moderately slopes.

5.4.3.5 VAM Fungi for Soil Reclamation

Top soil obtained from the project sites, before the start of quarrying activity would be reclaimed by using VAM fungi. The saplings of trees and shrubs should be raised using microbial inoculum like, VAM (Vesicular-arbuscular mycorrhiza), bacterial and fungal strains. The steps for raising plant saplings with mycorrhizal colony are given below:

A brief description of the procedure to be followed for the colonization of seedlings with VAM fungi and other soil microbes is given below:

1) Top soil collection from quarry sites before start of quarrying.
2) This soil which is rich in microbes should be used for the preparation of seed beds and should also be filled in polybags for raising saplings.
3) Isolation of VAM from the roots of juvenile seedlings particularly dominant tree species which are available in the region.
4) Suitable strain of VAM and other microbe can also be obtained from IARI, New Delhi and/or IMTECH, Chandigarh.
5) Preparation of mother culture and their appropriate dilution.
6) Growing of plant species which will be inoculated by specific and efficient strains,
7) Mixing the soil with the VAM inoculum and filling in the polybags.
8) Planting of saplings in the polybags two days after inoculating the soil with fungal microbial strains.
9) After thirty days of inoculation these saplings can be planted at the quarry sites.

5.4.3.6 Revegetation

In addition to the use of VAM fungi isolated from the roots of plant species growing in these areas and organic manure for enrichment of the top soil, revegetation of quarry sites would require the initial establishment of fast growing grasses like *Cynodon dactylon*, *Pennisetum antidotale* and *Saccharum longisetosum*. These grasses spread by creeping rootstocks and will also help in binding soil. Perennial species such as *Chrysopogon gryllus, Eulaliopsis binata, Coix lacryma-jobi* and *Themeda arundinacea* will be established subsequently by seeding and planting them directly into the annual crop residue.

Along with annuals and perennials, nitrogen fixing herbaceous legumes (*Trifolium repens*, *Lespedeza juncea*) and non legume shrubs like *Dichroa fabrifuga* will be planted at quarry sites to increase the nitrogen levels of soil. *Trifolium repens* and *Lespedeza juncea* are also desirable food plants and are less aggressive and persistent as compared to other herbaceous legumes. These legumes with dense cover will retard or prevent the invasion and establishment of native plant species. Temporary crop cover of annuals and perennials will thus help in stabilization of the quarry sites, which will take approximately 5-6 years.

Once the initial establishment of perennials is complete and quarry sites are stabilized, the sites would be ready for plantation of tree species. *Alnus nepalensis, Carpinus viminea, Terminalia myriocarpa,* etc would be first among tree species that would be planted. In open areas mixed perennial shrubs and herbs such as *Bambusa pallida*, *Leucosceptrum canum*, *Saccharum longisetosum, Themeda arundinacea* and *Thysanolaena latifolia* will be planted which grow well on rocks and on open slopes.

5.4.4 RESTORATION OF COLONY AND OFFICE COMPLEX

Out of 79.1 ha, around 2.8 ha of land will be disturbed due to construction of dam storage and colony area, office complex, dam complex area, power house office and colony, etc. (Table 5.4.1.1). Office and colony complexes will occupy 4.8 ha and are located on the right bank of Yarjep River near Chengrung and Purying villages. The land will be cleared of vegetation for the movement of heavy equipments required for different project related activities which would lead to degradation of slopes.

Table 5.4.1.1 Areas of colonies in the proposed Pauk H.E. Project

Sl. No.	Site specification	Area
1	Dam storage and colony area	3.5 ha
2	PH office and colony	1.3 ha

Engineering and biological measures are suggested for the stabilization and beautification of the disturbed area. Following measures should be adopted for the restoration and landscaping of colony areas and construction sites.

1) Proper roads and lanes would be provided inside the colony area. Open area should be covered with vegetation. Ornamental plants and avenue trees should be planted along the roads and lanes.
2) The choice of the tree species for plantation will depend on agro-climatic conditions of the area.
3) Retaining walls should be built to avoid landslides and slips. Proper drainage would be provided inside colony for the outlet of the domestic/rain water.
4) Parks and play grounds would be developed.
5) After the completion of all the construction activities, the construction sites and other temporary settlements would be covered with the top soil which would support the growth of plant species.

Engineering Measures: During the construction phase, some locales in the right bank area are likely to be prone to soil erosion. Construction of retaining walls would be necessary to stabilize the slopes. The budget kept for the construction of retaining walls and for other engineering measures is around **Rs. 8.00 lakhs**.

Biological Measures: The project construction would involve congregation of large labour and staff population. To meet the requirement of fuel and material for construction, dependency on forest resources is inevitable. These activities would also involve substantial clearing of forest land unless proper arrangement for fuel supply is done. Therefore, significant adverse impacts on terrestrial flora are anticipated if proper mitigation measures are not taken. There is a possibility that after construction, these degraded forests existing in the area will be further destroyed or damaged.

Plantation of tree species and shrubs are suggested in the colony area. Some of the local plant species are mentioned in Table 5.4.1.2. Total budget allocated for this purpose is around **Rs. 8.00 lakhs** which includes maintenance cost also (see Table 5.4.1.3).

5.4.5 ROADS

Most of the project components are located away from the Border road connecting Tato village to Mechuka and there is a requirement of about 7 km of additional roads to access the project sites. At the new road areas, plantation of tree seedlings grown in nurseries will be done in rows alternating with rows of herbaceous plants. The growth of trees, shrubs and herbaceous species will provide adequate erosion control and provide the habitat for wildlife, birds and insects. Around 21.4 ha of land will be disturbed due to the construction of new roads. Due to construction of roads, the region will be disturbed and may also trigger minor slips and downfall movement of soil aggregates. Various measures are suggested for the stabilization of the disturbed area.

***Engineering Measures**:* Road construction in the proposed project will disturb the hill slopes and result in excavated material (muck). Retaining walls and wire crate walls are proposed in the region to avoid slippage and land slides.

Biological Measures: Even though a muck disposal plan has been proposed, some of the excavated mucks are likely to form thin apron on mountain slopes along the road. Provisions are made to cover such slopes with vegetation. Tree saplings and shrubs should be planted along the road. Seeds of herbs and grass species should be spread over the loose soil. Some plants for plantation are suggested in the Table 5.4.1.2.

Table 5.4.1.2 Some important plant species for plantation in the colony area/office complex, and along the road sides

	Botanical name	Local name	Family	Use
1.	**Colonies/ Office complex**			
Trees				
1	*Albizia lebbeck*	Siris	Mimosaceae	landscaping
2	*Altingia excelsa*	Singri	Hamamelidaceae	landscaping
3	*Beilschmiedia roxburghiana*	Bonjolockia	Lauraceae	landscaping

4	*Citrus aurantium*	Ribosinking	Rutaceae	landscaping
5	*Elaeocarpus sphaericus*	Rudraksh	Elaeocarpaceae	landscaping
6	*Exbuclandia populnea*	-	Hamamelidaceae	landscaping
7	*Gmelina arborea*	Gomari	Verbenaceae	landscaping
8	*Magnolia hodgsonii*	-	Magnoliaceae	landscaping
9	*Michelia champaca*	Tita Sopa	Magnoliaceae	landscaping
10	*Polyalthia longifolia*	Asok	Anonaceae	landscaping
11	*Prunus domestica*	Plum	Rosaceae	landscaping
12	*Pyrus communis*	Naspati	Rosaceae	landscaping
Shrubs				
1	*Ardisia macrocarpa*	-	Myrsinaceae	landscaping
2	*Asparagus racemosus*	Satvari	Liliaceae	landscaping
3	*Bambusa tulda*	Bijli	Poaceae	landscaping
4	*Calamus erectus*	Jati bet	Arecaceae	landscaping
5	*Mussaenda roxburghii*	-	Rubiaceae	landscaping
6	*Zanthoxylum acanthopodium*	Yokhung	Rutaceae	landscaping
Herbs				
1	*Achyranthes aspera*	Chirchita	Amaranthaceae	landscaping
2	*Anemone vitifolia*	-	Ranunculaceae	landscaping
3	*Centella asiatica*	Brahmi	Apiaceae	landscaping
4	*Crowfurdia speciosa*	-	Gentiniaceae	landscaping
5	*Eleusine coracana*	Finger millet	Poaceae	landscaping
6	*Hedychium spicatum*	Ruksana	Zingiberaceae	landscaping
7	*Molineria capitulata*	Wurdo lago	Hypoxidaceae	landscaping
8	*Musa bulbisiana*	Kargok	Musaceae	landscaping
9	*Ocimum sanctum*	Tulsi	Lamiaceae	landscaping
10	*Pennisetum purpureum*	Fox tail	Poaceae	landscaping

2 Roadside/Avenues

Trees

1	*Albizia. odoratissima*	Kalo Siris	Mimosaceae	landscaping
2	*Alnus nepalensis*	Utis	Betulaceae	landscaping
3	*Castanopsis indica*	Katus	Fagaceae	landscaping
4	*Dysoxylum excelsum*	Lahsune	Meliaceae	landscaping

5	*Engelhardtia spicata*	Mahwa	Juglandaceae	landscaping
6	*Exbucklandia populnea*	-	Hamamelidaceae	landscaping
7	*Juglans regia*	Okhar	Julandaceae	landscaping
8	*Lannea coromandelica*	Jia	Anacardiaceae	landscaping
9	*Phyllanthus emblica*	Aonla	Euphorbiaceae	landscaping
10	*Prunus persica*	Aru	Rosaceae	landscaping
11	*Quercus glauca*	Musre Phalant	Fagaceae	landscaping
12	*Terminalia myriocarpa*	Panisaj	Combretaceae	landscaping
Shrubs				
1	*Alsophila spinulosa*	Tree fern	Cyatheacae	landscaping
2	*Calamus floribundus*	-	Arecaceae	landscaping
3	*Dichroa febrifuga*	-	Saxifragaceae	landscaping
4	*Hydrangea robusta*	-	Hydrangeaceae	landscaping
5	*Oxyspora paniculata*	-	Melastomataceae	landscaping
6	*Schefflera bengalensis*	-	Araliaceae	landscaping
Herbs				
1	*Achyranthes aspera*	-	Apiaceae	landscaping
2	*Chrysopogon gryllus*	-	Poaceae	landscaping
3	*Cymbopogon jwarancusa*	-	Poaceae	landscaping
4	*Cynodon dactylon*	Doob	Poaceae	landscaping
5	*Eulaliopsis binata*	-	Poaceae	landscaping
6	*Panicum antidotale*	-	Poaceae	landscaping
7	*Pennisetum purpureum*	-	Poaceae	landscaping
8	*Saccharum longisetosum*	-	Poaceae	landscaping
9	*Tagetus erecta*	Genda	Asteraceae	landscaping
10	*Themeda arundinacea*	-	Poaceae	landscaping

5.4.6 COST ESTIMATES

Cost estimates for different components of the landscaping and restoration are given in the Table 5.4.1.3. Around **Rs. 72.20 lakhs** would be required to restore the disturbed area to its near original state.

Table 5.4.1.3 Cost estimates for Restoration Works and Landscape Designing

S.No.	Item of Work	Amount (Rs.In lakhs)
A.	**Quarry Sites**	
	(i) Engineering measures	
	a) Removal of top soil (transplantation and stockpiling)	5.00
	b) Filling of crates with muck, stones, etc.	6.00
	c) Retaining walls, diversion channels	10.00
	(ii) Bio-engineering measures	
	a) Carpeting with geo-textiles (coir, jute and other local fibers)	3.20
	b) Mulching	2.40
	(iii) Biological measures	
	(a) Planting of herbs and grass species	1.40
	(b) Planting of trees and shrubs (@ Rs. 18.64/plant (1600plants/ha) Including maintenance and transportation	0.36
	Total (A)	**28.36**
B.	**Colony Area, Office Complexes**	
	(i) Engineering measures	
	(a) Retaining walls	6.00
	(b) Leveling the area	2.00
	(c) Development of parks, etc. (suggested in Muck disposal chapter)	Nil
	(ii) Biological measures	
	(a) Planting of trees and shrubs (@ Rs. 18.64/plant (1600plants/ha) Including maintenance and transportation	1.43
	(b) Planting of flowering plants and other herbs	3.00
	Total (B)	**12.43**
C.	**Roads**	
	Engineering	
	(i) (a) Retaining walls (260 m3 @ 1211/m^3)	3.15
	(b) Wire crates (3 x 2 x 1.5 Cum 35 / 2400.00)	7.56
	(ii) Biological measures – Planting trees, shrubs and herbs	5.70
	Total (C)	**16.41**

D.	**Development of Nursery**		
	(i)	Infrastructure including land cost (provision has been made under the CAT plan)	Nil
	(ii)	Collection of seeds (Lumpsum)	3.00
	(iii)	Raising of plants (Lumpsum)	8.00
	(iv)	Manpower to maintain the nursery (Lumpsum)	4.00
	Total (D)		**15.00**
Total (A + B + C + D)			**72.20**

5.5
GREEN BELT DEVELOPMENT PLAN

5.5.1 INTRODUCTION

Development of green belt around the project sites of hydroelectric power is generally proposed as the construction process emanates lot of dust due to excavation works, crushing of material and batching of aggregates. In addition, air pollution also takes place due to vehicular movement during construction and operation phases. The green canopy has the inherent capacity not only to absorb air pollution but also to increase water retention by soil and decrease sediment transport. To minimize the impact of different kind of pollutions and avoid land slips from the direct draining catchment into the reservoir, the creation of a green belt in and around the project area is urgently needed.

Selection of local plants is always advantageous for success of green belt development. The green belt developed along the project site, roads, colonies and other infrastructural facilities also adds to the aesthetic environment. Pauk HE Project envisages the construction of a 110 m high dam over the Yarjep River, downstream of the Chengrung village, and will create a submergence of 25.3 ha of surface land in addition to 8.8 ha of river, hence a reservoir of 34.1 ha total area (at FRL 1540 m elevation). During the 4 years construction period, the area will be disturbed, vegetation in the impacted land will be destroyed and soil will become prone to erosion. Plantation of suitable species along the reservoir periphery will serve many purposes, such as it will protect the area from soil erosion and shall provide a shelter to birds and wildlife.

5.5.2 DEVELOPMENT OF GREEN BELT

The green belt is proposed to be developed within the project area at the following places viz., along the network of approach roads, dam sites, power house site and around the periphery of reservoir, wherever these components are not already naturally surrounded by trees and local flora. Different kinds of strategies will be necessary for developing a green belt around different components of the project. The general considerations for green belt plan are:

- Planting of trees should be undertaken in appropriate encircling rows around the project sites wherever the forest is not already present.
- Generally local/indigenous fast growing trees should be planted.
- The trees should be protected by plantation of non palatable shrub species to avoid browsing by animals.
- Placement of Bamboo/ Iron tree guards around the trees.
- The Plantation should be at a spacing of 2.5m x 2.5m and about 1600 trees per hectare should be planted.

5.5.3 SPECIES TO BE PLANTED

A nursery has been proposed under the plan of Tato-1 HE Project. It will furnish the plants needed for plantation for the three projects developed by the developer. A list of indigenous tree, shrubs and herbs was made after identification of species suitable for raising in nurseries and for development of a green belt around the project area and along the periphery of the reservoir. The species wise details of the plant are presented in Table 5.5.1.1 (a, b and c) indicating their season of flowering and method of propagation and other characteristics.

Some important precautions have to be taken during the plantation as under Polyculture. Species mentioned as special should be planted in sufficient numbers so as to increase their population size in the area. Multipurpose species should be planted in large numbers, so as to provide direct benefit like extraction of fodder, fruits or medicines, to people living around.

5.5.4 GREEN BELT DEVELOPMENT

5.5.4.1 Road side Plantation

One row of each tree, shrub and biofencing has been proposed with a spacing of 2.5 m x 2.5 m for trees and 2m x 2m for shrubs (to take care of the mortality in the next season). The pit size has been recommended as 45 cm x 45 cm x 45 cm for trees and 30 cm x 30 cm for shrubs. Along the access roads, plantation will be done on both sides wherever feasible. The budget for planting trees along the road sides is given in chapter 5.4 (Landscaping and restoration of construction area).

5.5.4.2 Green belt around dam site

Plantation at the dam site for about 2 ha has been proposed for control of erosion and siltation of the reservoir and aesthetic importance. The total cost of planting 3200 saplings @ Rs. 24.38 (including transportation) per sapling works out to be Rs. 0.78 lakhs.

5.5.4.3 Green belt around power house

Plantation around powerhouse need to be done in 3 lines i.e. first line of only flowering herbs/shrub, second line should be of shrub/hedge in close spacing and along the road of powerhouse a row of small trees. The planting cost of 2000 saplings @ Rs. 24.38 works out for Rs. 0.48 lakhs.

5.5.4.4 Green belt around reservoir periphery

Total area for the creation of green belt around the reservoir rim is around 56.86 ha which is divided into two layers/zones for the purpose of plantation taking into consideration the microclimatic condition that will develop after the creation of a reservoir in the region (see **Fig. 5.5.1.1**). Degraded forest and scrub of each layer need plantation. These forests land together constitute about 50% of the green belt area shown in **Figure 5.5.1.1**, corresponding to an area of 28.42 ha.

The green belt will start from the immediate vicinity of the reservoir rim on both banks wherever moderately steep slopes are available for plantation. In the proposed green belt, area has been divided into two layers for plantation of plant species depending upon the microclimatic condition that will develop after creation of the reservoir in the region (**Fig.5.5.1.1**). The bottom layer (G1), which starts above the water level (at 1580 m contour line) and considered up to 1620 m contour line is around 28.19 ha in area. The upper layer (G2) is considered between contour lines 1620-16620 m with total area 28.67 ha (**Fig. 5.5.1.1**). Out of the total 56.86 ha, plantation will be done only on 28.42 ha of degraded forest (the balance are being covered with existing and sufficiently dense forest). Water and high humidity loving plants like *Actinodaphne obovata, Albizia odoratissima, Oroxylum indicum, Populus ciliata, Saurauia punduana*, and many shrubs and herbs have been suggested for plantation in the bottom (G1) layer. The upper layer (G2) will be planted with species of mesic habitats such as *Altingia excelsa*, *Castanopsis indica, Engelhardtia spicata, Lithocarpus elegans, Michelia chamapaca, Terminalia myriocarpa* and many shrubs and herbs. In all 45,472 plants over a stretch of 28.42 ha on both the flanks of the periphery of the reservoir will be done by planting 1600 saplings per ha. The planting cost for 45,472 saplings works out for Rs. 15.09 lakhs @ 24.38/sapling (Table 5.5.1.2).

Table 5.5.1.1(a) Species wise details of trees indicating planting techniques and their usages

Sl. No.	Botanical name	Common name	Furit/seed collection season	Seed longevity	Pre sowing seed treatment	Sowing season	Germ inatio n %	Age of normal planting stock (months)	Planti ng season	Method of Planting	Uses
1	2	3	4	5	6	7	8	9	10	11	12
1	*Actinodaphne obovata*	Pajihuta	April-May	Short lived (1-6 months)	Not required	Soon after collection	50	12-24	June-July	Direct sowing, entire planting	Timber, fuel-wood
2	*Aglaia spectabilis*	Amari	Sept.-Oct.	Short lived (1-6 months)	Not required	Soon after collection	60	12-24	June-July	Direct sowing, entire planting	Timber
3	*Albizia lebbeck*	Siris	January-Februrary	Very long lived (2years)	Scarification Hot water	March-July	60-90	12-24	July	Direct sowing, entire planting	Timber, fuel
4	*A. lucida*	Moz	January-Februrary	Very long lived(2years)	Scarification Hot water	March-July	70-80	12-24	July	Direct sowing, entire planting	Timber, fuel
5	*Altingia excelsa*	Singri	May-June	Short lived (1-3 months)	Not required	Soon after collection	40-50	12-24	July	Direct sowing, entire planting	Timber
6	*Artocarpus lacucha*	Deb chali	April-May	Short lived (1-6 months)	Not required	Soon after collection	50-60	12-24		Direct sowing, entire planting	Timber; fruits edible
7	*Bauhinia variegata*	Kanchon	May-June	Moderate long lived	Not required	May	95	2-3	June-July	Direct sowing, entire planting	Flower bud edible, fodder
5	*Castanopsis indica*	Hingori	May	Moderate long lived	Not required	June	90	2-3	June - July	Direct sowing, entire planting	Nuts edible; Timber, fodder
6	*Engelhardtia spicata*	Tongtamasok	April-May	Short lived (1-6 months)	Not required	Soon after collection	60	12-24	June - July	Direct sowing, entire planting	Timber, fuel

7	*Juglans regia*	Thitcha	April-May	Moderate long lived	Not required	soon after collection	80	12-24	June - July	Direct sowing, entire planting, Stump planting	Seeds, Timber, medicinal
8	*Kydia calycina*	Pichola	Feb.-March	Short lived (1-6 months)	Not required	Soon after collection	60	12-24	June-July	direct sowing, entire planting	Timber, fuel , ornamental
9	*Lannea coromandelica*	Jia	May-June	Short lived (1-6 months)	Not required	Soon after collection	50	12-24	July-August	direct sowing, entire planting	Timber, fuel , ornamental
10	*Magnolia grandiflora*	Boromthuri	March-May	Short lived (1-6 months)	Not required	Soon after collection	60-70	12-18	July	Direct sowing, entire planting, branch cutting	Ornamental
11	*Mesua assamica*	Sia-Nahar	May-June	Short lived (1-6 months)	Not required	Soon after collection	70	12-24	July	direct sowing, entire planting	Ornamental
11	*Morus alba*	Sahtut	April-May	Short lived (1-6 months)	Not required	Soon after collection	40	12-15	June-July	Direct sowing, entire planting, branch cutting	Fodder, fuel , ornamental
12	*Phoebe hainesiana*	Bola Bonsum	May	Short lived (1-6 months)	Not required	Soon after collection	50	12-24	June-July	direct sowing, entire planting	Timber
13	*Pinus wallichiana*	Blue pine	March-May	Very long lived (2years)	Scarification	June-July	70	12-24	Aug.-Sept.	Direct sowing, entire planting	Timber, fuel, ornamental
14	*Pterospermum acerifolium*	Hathipayle	Feb-March	Very long lived(2years)	Not required	soon after collection	60-70	12-24	July-August	Direct sowing, entire planting, branch cutting	Timber, fuel, ornamental
15	*Schima wallichii*	Chilone	Oct.-Dec.	Very long lived(2years)	Not required	soon after collection	75	12-24	June-July	Direct sowing, entire planting, branch cutting	Timber, fuel, ornamental
16	*Terminalia myriocarpa*	Panisaz	Oct.-Nov.	Very long lived(2years)	Not required	soon after collection	75	12-24	June-July	Direct sowing, entire planting	Timber, fuel, ornamental

Table 5.5.1.1 (b) Species wise details of shrubs indicating planting techniques and their usages.

Sl. No.	Botanical Name	Common name	Plantation method	Plantation time	Uses
1	*Bambusa pallida*	Makal	Through seeds, cuttings, root-shoot cutting	Aug.-Sept.	Afforestation of forest lands
2	*Bambusa tulda*	Shingane Bans	Through seeds, cuttings, root-shoot cutting	In any season	Culms are used for construction; leaves as fodder
3	*Boehmeria macrophylla*	Kamli	Through seeds, cuttings, root-shoot cutting	In rainy season	Soil conservation, fencing, fuelwood
4	*Calamus erectus*	Bent	Through seeds, cuttings	In rainy season	Soil conservation, fencing, furniture
5	*Debregeasia longifolia*	Tusare	Through seeds, cuttings	In any season	Fodder, fuel wood
6	*Desmodium caudatum*	-	Through seeds, cuttings	In any season	Fodder, fuel wood
7	*Luculia pinceana*	-	Through seeds, cuttings	In rainy season	Ornamental, fuel wood
8	*Mahonia acanthifolia*	-	Through seeds, cuttings	In rainy season	Reforestation of forest lands
9	*Melastoma malabathricum*	Key Sengs	Through seeds, cuttings, root-shoot cutting	In any season	Ornamental
10	*Mussaenda roxburghii*	Tengmeng	Through seeds, cuttings	In any season	Ornamental, leaves used as vegetables
11	*Rubus ellipticus*	Jellying	Through seeds, cuttings	In rainy season	Reforestation of forest lands
12	*Zanthoxylum acanthopodium*	Yokhung	Through seeds, cuttings	In any season	Medicinal

Table 5.5.1.1 (c) Species wise details of medicinal plants indicating planting techniques and their usages

Sl. No.	Botanical name	Family	Flowering time	Fruiting time	Parts used for curing the disease
1	*Achyranthes aspera*	Amaranthaceae	June-Aug.	Spt.-Oct.	Plant is used as medicinal; diuretic and purgative.
2	*Acorus calamus*	Acoraceae	Aug. -Sept.	Sept.-Nov.	Rhizomes/roots are medicinal
3	*Agave sisalana*	Agavaceae	Feb.-March	March-April	Leaf juice is used as insecticide
4	*Aloe vera*	Liliaceae	Feb.-March	Apr. -May	Leaves juice used in skin teatment; facial
5	*Asaparagus racemosus*	Liliaceae	Apr.-May	July-Aug.	Roots are medicinal; root bark has antibacterial and antifungal properties.
6	*Centella asiatica*	Apiaceae	May-July	July-Aug.	Leaf juice is used as a tonic; intellect promoting for childrens.
7	*Costus speciosus*	Araceae	Sept. -Oct.	Nov.-Dec	Rhizome is used in gout; as stimulant.
8	*Curcuma longa*	Zingeberaceae	Aug.-Sept.	Oct-Nov.	Rhizome/root powder is useful in wound healing.
9	*Cynodon dactylon*	Poaceae	May-June	Aug.-Sept.	Decoction of leaf juice is given in piles disease
10	*Datura stramonium*	Solanaceae	Aug.-Sept.	Set.-Oct.	Flowers are showy; Seeds are narcotic.
11	*Hedychium spicatum*	Zingeberaceae	Sept. -Oct.	Oct.-Nov.	Roots are medicinal.
12	*Molineria capitulata*	Hypoxidaceae	May-June	Sept.-Oct.	Roots are medicinal; fruits are edible.
13	*Musa bulbisiana*	Musaceae	Jan. -Feb.	Oct.-Nov.	Fruits are nutitious and edible
14	*Osbeckia stellata*	Melastomiaceae	May-oct.	Oct.-Nov.	Flowers are aesthetic; roots are medicinal.
15	*Rubia cordifolia*	Rubiaceae	June-Aug.	Aug.-Sept.	Plant juice is taken in skin diseases.
16	*Sida rhombifolia*	Malvaceae	June-Aug.	Sept.-Oct.	Roots are medicinal.
17	*Viola betonicifolia*	Violaceae	June-Aug.	Sept-Oct.	Whole plant is medicnal; cough and asthma.

Table 5.5.1.2 Physical and financial break up for the creation and maintenance of green belt around the periphery of reservoir of Pauk HE Project

Item		Ist layer (G1) (12-24 months) area: 14.09 (ha)	IInd layer (G2) (24-48 months) area: 14.33 (ha)
Biological measures (Afforestation and Maintenance)			
1.	Raising plants		
i)	Physical (Nos) (@1600 plants/ha)	22,552	22,936
ii)	Financial (Rs. in lakhs) (@Rs. 24.38/plant)	5.50	5.59
2.	Watering, maintenance and transport (Rs. in Lakhs)	2.00	2.0
	Total (Rs. lakhs)	**7.50**	**7.59**
Grand Total (Rs. lakhs) (G1+G2)		**15.09**	

5.5.4.5 Schedule

The construction period of the project is 43 months. All engineering measures like retaining walls, wire crate walls, etc to stabilize landslips around reservoir will be carried out under the CAT plan. Plant saplings will be required for biological treatment measures. Plantation and maintenance will be carried out starting 12th month from the date of inception of the project. Between 1-12 months all the engineering measures for stabilization of slopes will be carried out under the proposed CAT plan.

5.5.5 BUDGET

The overall cost of green belt development is **Rs. 24.63 lakhs** (Table 5.5.1.3). The budget also includes maintenance of the executed work.

Table 5.5.1.3 Summary of cost for green belt development

S.No.	Component	Cost (in Lakhs)
1.	Cost of planting of sapling around dam site	0.78
2	Cost of planting of sapling around power house areas	0.48
3.	Maintenance cost for 3 years-2 supervisor @150.00/day	3.28
4.	Cost of planting of sapling along reservoir periphery (including maintenance cost)	15.09
5.	Celebration of World Environment Day, etc	3.00
6.	Contingency	2.00
	Total	**24.63**

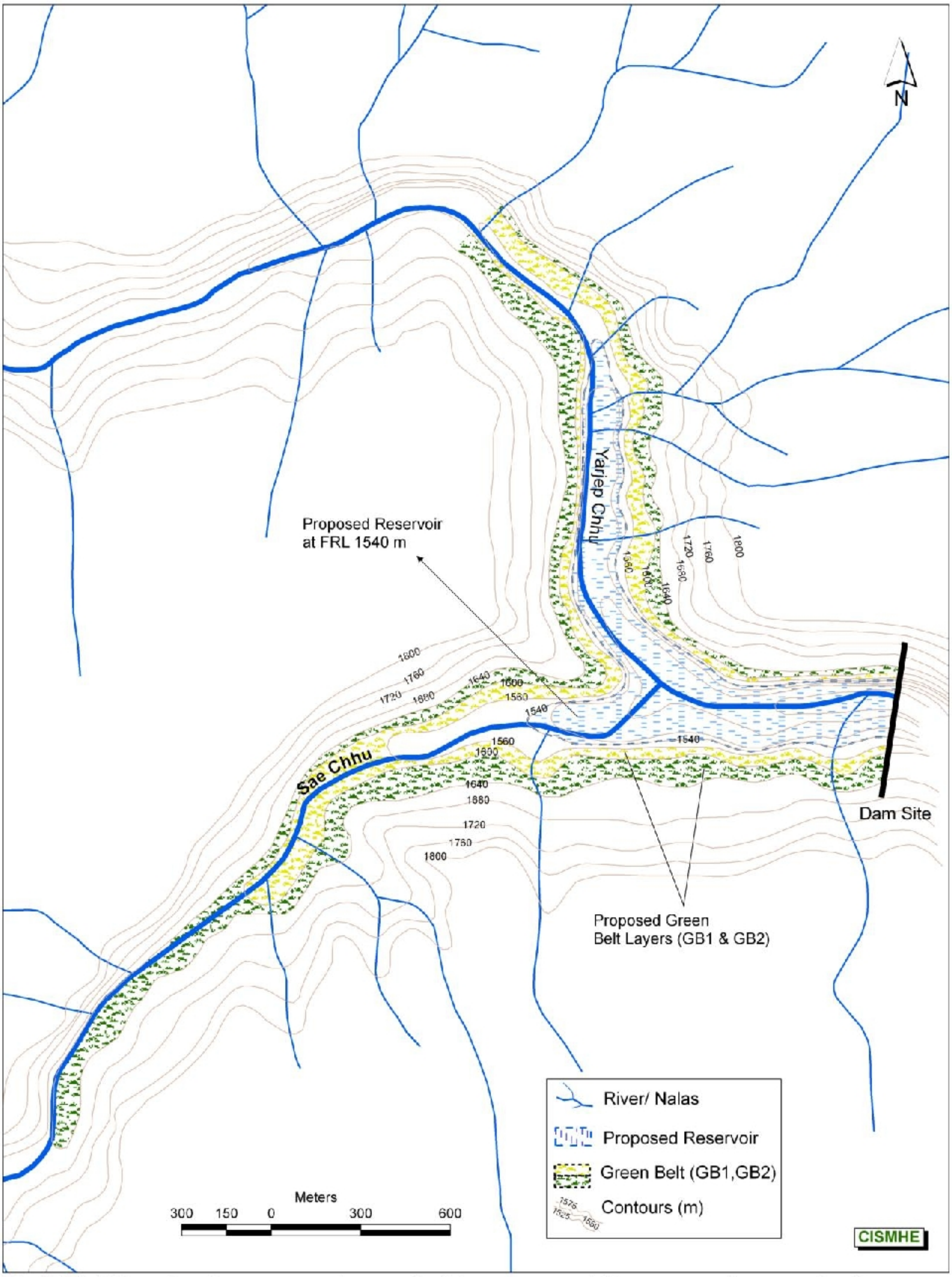


Fig.5.5.1.1 Map showing proposed green belt layers around the proposed reservoir of Pauk H.E. Project

5.6
FISHERY DEVELOPMENT & DOWNSTREAM MANAGEMENT PLAN

5.6.1 INTRODUCTION

In practice, the water resources are not equally protected as compared to land resources. The capture fishery is extensively done in seas and inland water bodies and it is considered as one of the source of livelihood. With unprecedented rise in the global population, aquatic resources have depleted at a steady rate especially in freshwater system. Also, deterioration of river waters due to pressure of multiple use, pollution and habitat degradation have exerted pressure on the ichthyofauna. Moreover, rivers are often managed for hydroelectric power and flood mitigation; their flow is channelized or controlled having detrimental effects on fish.

In Himalaya all major rivers are either under regulation or proposed for the regulation for hydro-electric projects. Thus, fishery resources are considered to be maximally affected by such types of projects. The present contribution deals with the proposed hydro-electric projects on Yarjep river (a tributary of Siyom river) in West Siang district of Arunachal Pradesh. The river is proposed for cascade development, which is expected to lead notable to adverse impacts on the fish and fisheries of the rivers. It would require a comprehensive fishery management plan focusing the conservation of indigenous species and fishery development for the livelihood of local people. The suggested plan has been formulated by keeping the same plans of other downstream and upstream projects in view. The fishery conservation and development plan has been formulated for Pauk H.E. Project that is one of the projects of cascade development.

5.6.2 PAUK H.E. PROJECT

The Pauk HE Project is proposed to harness the potential in Yarjep River which is a major tributary of river Siyom. Pauk H.E. Project involves a 110 m high concrete arch dam with installed capacity of 145 MW. In order to generate energy it would utilize 140 m head on the Yarjep River. Pauk H.E. Project is the first scheme of a cascade development, located upstream of Heo H.E. Project and Tato-I H.E. Project. Thus, considering the project planning, river flow and fish composition in Yarjep River, a sustainable approach has been adopted in the fishery development plan of Pauk HE Project. In order to avoid any repetition in the implementation of the plans of the projects, the same plans of both downstream projects were taken into account.

5.6.3 FISH & FISHERIES

Ichthyofauna in the catchment and influence areas of Pauk H.E Project comprises of 6 species belonging to 4 families. *Schizothorax richardsonii* (Snow trout) and *Garra nagenensis* are widely distributed in the catchment and influence areas. They prefer to inhabit the main rivers, like Yarjep and Siyom. Other species like *Nemacheilus multifasciatus*, *Schistura rupecola*, *Botia berdmorei* and *Glyptothorax annandeli* are bottom dwellers and prefer to inhabit tributaries. Only *Schizothorax richardsonii* is of fishery interest and contributes in most capture fishery in the area.

Fishing intensity is very low in the area under discussion. In different seasons, during the field survey, no fisherman was found to land fish in the river stretch between the proposed dam site and the power house site and in tributaries joining in between. The door to door social survey of affected families has also confirmed that fish is not widely used for food by the local people.

5.6.4 PROPOSED PLAN

Pauk H.E. Project includes the establishment of hatchery for indigenous species. This hatchery can supply the seeds for reservoirs of Pauk H.E and farmers of affected families and villages of Pauk projects with similar facilities and conditions as suggested for Heo and Tato I H.E. projects. Other provisions for these projects are training programmes and financial assistance to fishermen, downstream management plan and reservoir fishery. These plans are project specific, therefore, same will be proposed in Pauk H.E. Project also. The height of dam of Pauk H.E. project is more than 100 m so that fish ladders are not proposed for Pauk considering its feasibility. The measures suggested in Heo and Tato I H.E. projects were not included in the plan of Pauk H.E. Project to avoid any repetition because the three projects are owned by the same developer. Regarding the downstream management plan, the three projects stand for the same types of measures.

5.6.4.1 Development of Reservoir Fishery

Main objective of the development of reservoir fishery is to restore the livelihood of fishermen of influence area and affected villages. Also, the inhabitants exploit bush meat from the forest to fulfill their protein diet, the reservoir fishery could substitute it and reduce the pressure on the forest resources.

i) ***Reservoir***

A reservoir of 34.1 ha surface area is proposed to be used for reservoir fisheries. The stocking of reservoir will be carried out by State Fishery Department with the aid of project authorities. It would be stocked by ova, fry and fingerlings of indigenous fish species, supplied from the hatchery proposed for Pauk H.E. Project. Nearly 4000 to 5000 fry or 400 to 500 fingerlings per ha would be required for the stocking. Thus, total requirement of spawn or fingerlings in first year would be 100,000 to 126,000. The reservoir will be stocked for every year considering the mortality rate of fish. After establishment of self sustaining populations of fish species, the process of harvesting will be started. This process could take 4 to 5 years after creation of reservoir. Total cost for the stocking would be **Rs. 3.00 lakhs** only

ii) ***Management of reservoir***

Total surface area of reservoir is nearly 34.1 ha. In order to manage the fishing activities, the reservoir would be divided into 4 parts, each having water spread area of 8.0 ha. The villages of influence areas of all three projects would be divided into 4 groups and each group will be assigned a part, so that fishermen of these villages could fish in concerned part. In order to ensure proper functioning, State fishery Department would establish a committee of fishermen. The committee would be headed by an officer of State Fishery Department. Department would issue the license of fishing to fishermen of influence villages at nominal charges whereas, following the guidelines of Rehabilitation and Resettlement (NPRR) policy of Arunachal Pradesh, the license to fishermen belonging to affected families would be provided at no cost.

iii) ***Training***

Fishermen in the surrounding area are not customary of reservoir fishery. Prior to the harvesting of reservoir, Project authority in consultation with state fishery department would provide training of fishing in reservoir to local fishermen. The training will be focused on the types of fishing gears, boating, time of fishing etc. For this purpose a contractor will be appointed, preferably from the project affected families or affected villages. The contractors would provide the fishing boat to fishermen at nominal charges. Total cost towards training programme would be **Rs. 2.00 Lakhs** only.

iv) *Marketing*

State Fishery Department would appoint a contractor on the basis of competitive bid. The inhabitants of influence area and affected families would participate in the bidding on the priority basis. If the people of influence area and affected families would not be available to participate in this process, it would be open for others. The contractors would receive the fish from fishermen and supply to the markets.

5.6.4.2 Training for Fish Farming

Inhabitants would be encouraged for fish farming. In order to implement this plan, project authorities in consultation with State Fishery Department would propose training programmes for fish farming. The project authorities would furnish the application forms. The interested persons would apply for the training in prescribed form and submit to office of the project authorities. This programme would be run for 3 years and 5 applicants will be selected every year. If the training facilities are not available in Arunachal Pradesh, it will be facilitated to outside the state. The project affected persons will be given preferences. The budget for the training including training fee, accommodation, travel, etc. will be borne by the project authorities. Total budget for the purpose would be **Rs. 5.00 lakhs** only.

5.6.4.3 Financial Assistance for Fish Farms

The farmers interested for fish culture will be provided with financial assistance towards the construction of fish farms. This assistance will be given to trained people, which have got training under the scheme of project authorities or from other sources. This scheme will be run for four years and 5 farmers will be selected every year. Project affected persons will be given preferences. If the candidates are not available among the affected persons, it will be extended to project affected villages and, to the influence area. Each farmer will be provided with an amount of **Rs. 50,000** for the construction materials and other accessories with the conditions that if the work is not satisfactory the amount will be withdrawn from the beneficiary. The prescribed amount will be sanctioned after a detailed evaluation on feasibility of the site, availability of water channel in nearby place and adequacy of water, etc. Project authorities would evaluate the progress of construction of fish farm. After the completion of fish farm, fish seeds or ova would be supplied from the nearby hatchery, proposed for Heo H.E. Project at no cost. If, there would be other farmers, which are engaged in fish culture at their own, fish seeds would also be supplied by them at no cost. The beneficiaries would provide the land for the fish farm at no cost. Total cost for the plan would be **Rs. 10.00 lakhs** only.

5.6.5 DOWNSTREAM MANAGEMENT PLAN

5.6.5.1 Maintenance of Flow

The diversion of water from the downstream stretch would directly affect about 2.6 km of river stretch that would undergo the paucity of water unless proper measures are undertaken. The scarcity of water in the downstream stretch may lead to various adverse impacts on the biotic communities of the river, water quality, society, and livelihood of the people. Field investigation reveals that the major impacts are foreseen for the biotic communities especially fishes of Yarjep River, as no agricultural land depending on the river water falls in the downstream stretch. Also, fishing activities are very low, therefore, major impacts on the fishermen communities are not anticipated.

In order to mitigate the anticipated adverse impacts in the downstream environment, a minimum environmental flow, which will be able to maintain ecosystem integrity and can sustain the life, will be required. In order to conserve the fish fauna of Yarjep River, a minimum flow will be maintained from the proposed dam site of Pauk H.E. Project. For this reason, a dedicated environmental flow study of Pauk H.E. Project is under progress. The recommended flow must have adequate water discharge, water current velocity and depth of water column to sustain both column and bottom feeder species. The final recommendation will be approved by the Ministry of Environment and Forests, New Delhi.

In addition to suggested flow a few tributaries like Shuku Sokong, Songshi Bu and Shene Sokong join Yarjep River at 0.3 km, 1.8 km and 2.3 km downstream of the dam. These tributaries contribute to certain amount of water which will be taken into account in a separate minimum flow study.

5.6.5.2 River Channelization

River channel in terms of gradient and slope varies from the dam site to the power house site, which result in the variation of water current. Despite the suggested minimum flow in the downstream stretch and contribution of tributaries to the main River, there are possibilities of insufficient depth, width and water current velocity at a few sites. Such types of obstacles may cause problems to the integrity of the ecosystem. These sites would require a few engineering measures like river channelization. It would include removal of large boulders and cutting to provide sufficient water current velocity and channel depth. Total budget for this measure would be **Rs. 15.00 lakhs** only.

5.6.5.3 Maintenance of Pools

If water flow reduces significantly in the downstream stretch, it triggers isolation of many pools, which may be of breeding importance. In the Yarjep River, a detailed survey was carried out to find out the potential breeding pools. Though, breeding pools could not be encountered during the survey but fry and fingerlings were observed from the shallow water zones indicating Yarjep River as spawning ground. Probably fry and fingerlings belonged to *Schizothorax richardsonii*. In addition, fry and fingerlings were observed from tributaries. These findings reveal that there should be certain pools where fish lay their ova. The project authorities are suggested to mark these pools after a detailed survey and to maintain them through engineering measures. The isolated pools would be connected to regular and adequate water currents. The total financial outlay for this measure would be **Rs. 10.00 lakhs** only.

5.6.5.4 Maintenance of Tributaries

The deformation of the main river channel due to low flow results into the deposition of sand bar at the mouth of tributaries, which may hamper the movement of fish into tributaries. The removal of sand bars is an engineering solution, though it would be a regular practice because in every monsoon season, sand bar deposition would occur. Alternatively, the main river channel can be diverted in such a manner that it could confluence with tributary at its mouth so that sand bar deposition could be prevented. Total budget for this exercise would be **Rs. 10.00 lakhs**.

5.6.6 BUDGET

Total budget for the fishery development and downstream management plan would be **Rs.55.00 lakhs** only.

Table 5.6.6.1 Summary of cost for fisheries management plan

S.No.	Component	Cost (in Lakhs)
1.	Reservoir	5

2	Training for fish farming	5
3.	Financial assistance for fish farms	10
4.	Downstream management plan	
	River channelization	15
	Maintenance of pools	10
	Maintenance of tributaries	10
	Total	**55**

5.7
PUBLIC HEALTH DELIVERY SYSTEM

5.7.1 INTRODUCTION

Healthcare is one of the fastest growing sectors in India, in terms of revenues and employment. The Increasing population, rising economy, poverty and rising diseases are attributed to driving factors of health care market in India. However, health care facilities, especially in India are not well correlated with its scope (Health Care in India; Emerging market Report). The health delivery profile in rural area is significantly deteriorated as compared to that of urban areas. As per the report of Review of Health Care in India (2005) there are only 9.8 beds, 0.36 hospital and 1.49 dispensaries in rural area over 1 lakh population as compared to 178 beds, 3.6 hospitals and 3.6 dispensaries in urban area for the same population. In order to improve the health care infrastructure in rural areas, Government of India has launched the National Health Mission 2005-2012 in 2005.

Arunachal Pradesh has also been covered under the National Health Mission. Our survey revealed that majority of the people especially illiterates in influence area of Pauk H.E. project were not aware of this mission, which can be attributed to the fact that the implementation of this programme is difficult due to mountainous topography and poor infrastructures. Participation of developmental agencies in strengthening the health delivery system is considered as one of the best alternatives. Increasing number of hydro-electric projects in Arunachal Pradesh including present study area might play a vital role in improving the health care facilities. Proposed health care plan for Pauk H.E. project has been finalized in view of other projects in the area like Rego, Rapum, Heo, Tato I and Tato II H.E. Projects. In these projects, Heo, Tato-1 and Pauk H.E. Projects are being owned by same agency.

5.7.2 EXISTING FACILITIES

Most of the villages in the surroundings of Pauk are lacking instant health facilities because villages are not connected to the roads and tele-communication facilities. Nearby health centre is located in Mechukha whereas a Primary Health Sub Centre (PHSC) is located at Tato, HQ of circle. None of the affected village has primary health centre and primary health sub centre. To access hospital facilities people living in the rural areas have to move to Aalo which is more than 150 km from the project site.

5.7.3 HEALTH DELIVERY SYSTEM IN HEO AND TATO I H.E. PROJECTS

A hospital and a primary health centre are suggested in the management plan of Tato I and Heo H.E. Projects, respectively. These units would extend their facilities to the project affected families and affected villages of Pauk H.E. project also. In addition, other medical facilities like immunization programmes, organizing medical camps, facilities of mobile van, distribution of first aid box, etc. are also proposed in these projects. However, considering the size of project, some of the plans which are project specific are also suggested in Pauk H.E. Project.

5.7.4 PROPOSED PLAN

5.7.4.1 Child Welfare Centre

At least three child welfare centres are proposed in influence area. These centres will also cater to the influence area of Tato I and Heo H.E. Projects. The location of these centres will be decided by project authorities in consultation with State Health Department. However, project affected villages or remotely located villages will be given preferences. Project authorities would appoint trained staff in the centres. Project authorities would finance these centres for 4 years, thereafter, these will be handed over to state government. Land for the Child welfare centre would be provided by the State Government. Total cost for child welfare centre would be **Rs. 45 lakhs**. It includes salaries, medicines, and other infrastructures etc.

5.7.4.2 Health Workers

NRHM reported the shortage of health workers in rural areas of many states of India. This problem is more adverse in Arunachal Pradesh. In the line of the objectives of National Rural Health Mission, project authorities are advised to appoint qualified health workers in the area, directly or through a recognized NGO. These facilities would cater to influence areas of all three projects. At least three health workers are proposed for the project. Project authorities would provide salaries and other facilities to health workers for 4 years only. The financial outlay for health workers would be **Rs. 30.00 lakhs** only.

5.7.4.3 Immunization Programme

Immunization and vaccination programme will be run in the surrounding villages, especially in those villages, which are not covered under the same plan of Heo H.E. or Tato-1 project. Since a portion of influence area of Pauk H.E. Project will be covered under the Heo and Taot-1 H.E. project, therefore, this programme will be extended only to the villages selected for the peripheral development plan. The programme will be run in co-ordination with district administration in the surrounding villages that would be fixed for a particular day (Health day) of the month. Vaccines also follow a specific time schedule that must be strictly adhered to for effective immunity to be conferred on an individual. The immunization and vaccination programmes will follow the schedule prescribed by the Govt. of India under the Expanded Programme of Immunization (EPI) and the Indian Academy of Pediatrics (IAP) and also given for Heo H.E. Project. The work would be carried out by two teams with the help of village *Anganwari* workers in coordination with State Government. These teams will be based in the nearby health centres or hospital. The medical teams would also conduct the regular pre- and post-natal check-ups in the villages. The project authorities would provide funds for this immunization programme. A total amount estimated under this plan for four years would be **Rs. 15.00 lakhs**. This programme will run at least for four years.

5.7.4.4 Distribution of First Aid Boxes

The standard first aids kits of durable plastic boxes, fabric pouches or in wall-mounted cabinets would be distributed in the affected villages and surrounding villages which are not covered by the same plan of Heo and Tato I H.E. projects. This plan could be extended to other villages, which do not fall in the influence area. The trained fellows of villages will be provided with such first boxes. The fellows would receive medicines from nearby health centre after submitting utilization records of the medicines used. The trained fellows will be paid a nominal amount as incentive. All kits to be stored in a clean, waterproof container to keep the contents safe and aseptic and the kits should also be checked regularly and restocked, if any items are damaged or expired out of date. Project authority would provide funds to the State Health Department for four years. The project authorities are suggested to provide ORS packs with first aid boxes at each village. Total budget allocated for the distribution of the first aid boxes and ORS is around **Rs. 10.00 lakhs.**

5.7.5 SAFEGUARD MEASURES

In order to maintain a hygeinic environment and to minimize the incidence of vector borne diseases following measures will be followed in the project area.

i) Before joining the project, the migrant labourers and technical staff will have to pass through medical check up, which would be arranged by the project authorities.

ii) Adequate arrangements should be in place to dispose storm water from the labour colonies.

iii) Adequate vaccination and immunization facilities to be provided for the workers at the construction sites.

iv) Rapid deployment of sanitary inspectors and teams to disinfect an area of concern.

v) The labour camps and resettlement site to be located sufficiently away from any water body.

vi) Training and regular reorientation are emphasized as ways to remove some of the deficiencies in service delivery especially in remotest area.

vii) The project authorities are advised to address environmental sanitation and personal hygiene to the project workers and to the local people to reduce vector-borne diseases taking helps from exports.

5.7.6. FINANCIAL OUTLAY

Total Financial outlay for health delivery system proposed for Pauk H.E. project would be **Rs. 100 Lakhs** only. The break up of budget is given below :

Particulars	**Total Amount (in lakhs)**
Child Welfare Centres	45.00
Health Workers	30.00
Immunization Programme	15.00
Distribution of First Aid Boxes	10.00
Total	**100.00**

5.8
WASTE MANAGEMENT PLAN

5.8.1 INTRODUCTION

Generation of the waste is directly related to the human civilization, the higher the human consumption and more the waste materials. Both solid and liquid wastes have been increasing gradually along the population gradient worldwide. The wastes include not only the solids and liquids but liquefied gas. Major sources of solid and liquid wastes are mining or excavation, agriculture, industry, municipalities and sewage sludge. This contribution in EMP report addresses the municipal wastes to be generated from the working camps and colonies; the mitigation of other wastes like excavation/mining has been given separately in this report.

As far as municipal waste concern, urban areas produce nearly 5 times more waste than rural areas, in which 13 to 20 % is recyclable wastes (UNEP 2001). With the improvement in living standards, the nature of wastes is changing in the composition; more non biodegradable wastes such as metal, plastic and glass are being produced as compared to the amount of the organic waste.

The concerns of waste management in the developmental projects are due to the construction activities, establishment of new settlement (temporarily or permanently) and increasing human population etc. in pristine ecosystem. The improper handling of wastes and their disposal promote not only the water pollution, soil pollution but also growth of microorganisms, which lead to adverse impact on human health. Also, improper disposal of the waste including the solid and liquid waste is expected to harm the aesthetic beauty and clean environment of the region.

This chapter deals with the management of waste that would be generated by the migrant population and other project activities with proper system or procedure of collection, transport, processing, recycling or disposal and monitoring of waste materials.

5.8.2 MIGRANT POPULATION

The construction of the proposed Pauk H.E. Project would take about 4 years to complete. The number of required labourers and technical staff for the project would keep on changing each year depending upon the construction phase. Even though all of them will not spend the 4 years of construction period on site, approximately 550 migrant labourers, including technical staff, will be required for the Pauk H.E. Project. Some of the workers are expected to camp along their family thus, this will more than double the total population of the influence area (Influence Area population being 1382 persons as per Census 2001). Considering the periodic requirement of labourers for the construction of the proposed project, expected migrant population has been estimated following the assumptions given below.

(i) It is assumed that 50% of labourers and 50% technical staff are likely to have Families and the remaining 50% will be single workers,

(ii) 80% of the married labourers will comprise of both husband and wife, both working for project related works and counted as workers.

(iii) 50% of the technical staff will come with their families, and only husband will work,

(iv) 2% of the total migrating population are assumed as service providers, and

(v) 50% of service providers will have families.

(vi) The average family size of labourers and technical staff is assumed to be of five persons.

Details of the expected migrant population in the region are provided in Table 5.8.1.1. Calculation following the above assumption, a total population of nearly 1,600 is expected to come in the region. This figure is more than the existing population of the villages of the influence area (census 2001) and the migrants would likely reside in the region at any given time of construction phase of the project.

Table 5.8.1.1 Total migrant population (peak time) expected for the Pauk H.E. Project

S.No.	Particulars	Family/ Population
A	**Migrant workers**	
i)	Peak migrant workers	480
ii)	Single migrant workers (50% of 480)	240
iii)	Married migrant workers (50% of 480)	240
	iv) Husband and wife both working (80% of 240)	192
	v) Husband working + wife not working (20% of 240 x 2)	96
iv)	Number of dependent family members @ 3/- family (240 x 3)	720

Total Population of A = ii + iv + v + iv		**1248**
B.	**Migrant Technical staff**	
i)	Total migrant technical staff	70
ii)	Single technical staff (50% of 70)	35
iii)	Married migrant technical staff + wife (50% of 70 x 2)	70
iv)	Number of dependent family members @ 3/- family (35 x 3)	105
Total population of B = ii + iii + iv		**210**
C.	**Service Providers**	
i)	Total service provider (2% of the total population, i.e., A+B)	30
ii)	Single persons (50% of 30)	15
iii)	Married service providers + wife (50% of 30 x 2)	30
iv)	Number of dependent members (15 x 3)	45
Total population of C = ii + iii + iv		**90**
Grand Total of A + B + C =		**1,548**

5.8.3 GENERATION OF WASTE

In the region of the proposed Pauk H.E. Project all the expected migrant individuals, estimated to be 1,548 persons, would stay for, at least, a period of two years and maximum a period of four years. To keep a cautious approach of the estimates for waste generation, it has been considered that the entire migrant population would stay at site for 4 years. These migrant populations would definitely generate a large quantity of wastes, which are to be disposed off in a sound manner without polluting the land, air and water resources of the region. In India, the average dry weight per capita solid waste generated per day in urban area is reported to be around 468 g (Singhal and Pandey, 2001). In order to take the maximum safeguard measures into account, generation of per capita solid waste per day as per urban area has been taken into account. For the proposed Pauk H.E. Project, the annual generation of solid wastes by a migrant population of 1,548 persons is estimated to be approximately of 265 tons (0.468 x 1,548 x 365 days). It is suggested that the project authorities would ensure the proper collection and disposal of this large amount of wastes, besides providing proper sanitary facilities to the labour colonies in the project area.

In urban India, it is reported that the consumption of water per capita per day is nearly 135 litres including water for drinking, cooking, bathing and washing etc... Of these, nearly 100 litres of consumed water goes into sewage in the form of unusable water body and finally it is released into the river system. The total wastewater (unusable water) produced by the migrant population is calculated to be 1,54,800 litres per day that would drain into the rivers. It is suggested that the project authorities would ensure treatment of this wastewaters (unusable water) before releasing it into the water body.

5.8.4 WASTE MANAGEMENT AND DISPOSAL PLAN

For the disposal of all types of wastes including the solid waste generated in the labour camps, project colonies, offices and other sites of the proposed project a suitable management plan has been put forward for consideration. Following measures are suggested in and around the project areas for the management of the wastes.

5.8.4.1 Solid Waste

Improper handling of solid wastes leads not only to the air, water and soil pollution but makes an obnoxious state in the surroundings of project. Prior to the treatment of solid waste, it needs proper segregation of waste at the source. Considering the quantity of different types and composition of waste, a proper solid waste management plan has been prepared. The following quantity of the waste is expected to be generated daily in the Pauk project by the total migrant population.

Type of waste	**Quantity (in kg)**
Metal	14.5
Glass	14.5
Plastic	29.0
Papers	43.5
Compostable waste	305.0
Others waste	319.4
TOTAL	**725.9**

Source: World Bank Development Sector, Unit Solid Waste Management in Asia, 1999).

5.8.4.1.1 *Placement of dustbins*

In order to segregate the solid waste, dustbins are proposed for the colony area, working sites, roadside. The movable dustbins of good and long-lasting quality, marked with recyclable (plastic, glass, paper and other garbage) and compostable garbage (organic) separately will be installed at colony area and working sites while permanent dustbins (made up of concrete) will be established along the roadsides. A total of 20 movable dustbins and 10 permanent dustbins are proposed for the Pauk H.E. Project. All dustbins will be emptied on daily basis; recyclable waste will be stored at store room and will be sent for recycling. The organic wastes will be dumped to compost pits. Total cost for the dustbins would be **Rs. 2.90 lakhs** only.

5.8.4.1.2 *Establishment of Compost Pits*

The compostable waste would be dumped at compost pits. The compost pits will be established in the affected and surrounding villages and project nursery sites. A total of 20 compost pits will be established at these sites; the land for compost pits proposed at village sites will be provided by the respective villages. The capacity of each compost pit would be 200 m^3. The manure of compost pits, established in the villages would be used by villagers while manur of compost pits in nursery areas would be used for the CAT plan. Total cost for the construction and maintenance of compost pit would be **Rs. 10.00 lakhs** only.

5.8.4.1.3 *Dumpers and wheelbarrows*

Dumpers and wheels barrows will be required for the collection and transportation of garbage from one spot to another in the colony area, working sites and roadsides. One dumper and six wheelbarrows (double wheel) are proposed in the plan. Total estimated cost would be **Rs 13.50 lakhs**, which includes purchase and maintenance of dumpers and wheelbarrows. Salary estimated for the driver of dumper for four years would be **Rs 6.50 lakhs**.

5.8.4.1.4 *Landfills*

Large quantity of waste generated is of mixed nature and can not be segregated properly. Such types of wastes will be dumped at landfills area that will be located at environmentally sound place and adequately away from the settlement area. The landfill area will be fenced properly to prevent it from stray and wild animals. The process of combustion will be applied in the landfill area at regular interval. Project authority would apply all measures to prevent the leachate from the landfill area. After the construction of project (4 years) most of the workers would be homed, the project authority would ensure the closure and restoration of landfills in environmentally sound manner. Total budget for the landfill areas would be **Rs. 3.00** lakhs only.

5.8.4.2 Liquid Waste

5.8.4.2.1 *Septic tanks (Soak pits)*

The piped sewage system does not seem feasible in the mountain area, therefore, septic tanks are proposed for the project workers. In this system, sewage is collected in the septic tank and allowed to decompose in it. The septic tank is used for treating domestic sewage from individual households both in suburban and rural areas, wherein a piped-sewage system (i.e., a public sewer) is unavailable. In the septic tank, solid particles in sewage settle down to the bottom of the tank by means of sedimentation and partial or complete digestion of the sludge with the help of bacterial activities before its disposal. Standard municipal design septic tanks would be developed in the colonies of the project area by the project authorities. Usually, septic tanks of not less than 25 m^3 would be developed at appropriate sites in the colony areas. The generated organic wastes in the septic tanks would be decomposed and used as manure for landscaping the project area. However, non degradable waste would be incinerated. At least one septic tanks or soak pits are suggested for each set of toilet. A total estimated cost allocated for the purpose is **Rs. 33.00 lakhs**.

5.8.4.2.2 *Community toilets*

In the region, urination and defecation in open areas should be prohibited. The project authorities would make provisions for community toilets in the labour colonies. For the colony sites of the labourers, a total of around 45 low cost public toilet sets have been proposed. In addition to this, around 15 sets of temporary toilet facilities should also be provided at the working sites, which must be furnished with a proper water facility. Each set will have 8 to 10 seats (WCs) depending on the number of users. A total estimated outlay under this plan is about **Rs 35.00 lakhs**.

5.8.4.2.3 *Bathrooms and washing places*

Bathrooms and washing places are necessary for migrant workers. Proper facilities of bathing and clothes washing should be provided in the colony areas. A total of around 20 bathrooms/ washing places fitted with the proper water supply system are proposed for the 2 colony areas. Under this plan, a total budget of **Rs 13.00 lakhs** is estimated.

5.8.4.2.4 *Sewage treatment plant*

A small sewage treatment plant has been proposed for the Dam site colony area. Wastewater released from the kitchens, bathrooms and washing places drain off in the nearby streams or river channels if it is not managed properly, which can cause severe pollution in water ecosystem.

Properly treated water should either be reused or released into the draining channels. The total budget for setting up one sewage treatment plants is estimated to be around **Rs 40.00 lakhs**. The running cost for 4 years is calculated to be around **Rs 12.00 lakhs**. The Power House site colony will use the Sewage treatment proposed at nearby Heo HEP Dam site.

5.8.4.2.5 ***Service staff***

Maintenance, cleaning and upkeep of various facilities/ services at various places like colony areas, construction sites, etc. is required. Operating staff for garbage collection, dumping, sewage treatment plant and incinerators has been included under this plan. Salary for the staff who would keep the project area clean for the period of four years is estimated to be **Rs 19.00 lakhs**.

5.8.4.2.6 ***Water and toilet facilities for communities***

Four villages namely, Chengrung, Rapum, Hiri, and Purying comprising of 43 households with a total population of 250 individuals will be directly affected by the proposed project (census 2001). In these villages, majority of the households do not have access to proper sanitation. The proposed facilities like community toilets, septic tanks, dustbin would be extended to these affected villages. In addition, the project authorities would provide adequate water supply and sanitary facilities to these villages. This will go a long way in extending the help and assistance of the local population and enhance the acceptability of developmental projects among them. Providing services of these kinds, development activities or facilities to the affected communities would play an important role in local development Therefore, a separate budget of **Rs 37.50 lakhs** has been included under this plan for the purpose of water supply schemes.

At various places, in the project area, community toilets are lacking and the provision for this facility has been included under this plan. Around 10 sets of public toilets are proposed for these villages; however, the number of seats in each set may vary according to the number of users in the villages. A total cost calculated for the setting up of these facilities including maintenance charges for the period of four years is around Rs. 4.50 lakhs.

It is to be noted that among the affected villages in the proposed Pauk H.E. Project, Hiri and Purying villages also fall under the affected villages in Heo H.E. Project. To facilitate and rationalize the provision of water and toilet facilities, the project authorities may consult with the developer of the Heo H.E. Project for setting up the common infrastructures.

5.8.5 TOTAL COST

A total amount of **Rs 225.40 lakhs** is proposed under the solid waste management plan. The estimates for the solid waste management for Pauk H.E.P. are given in Table 5.8.1.2.

Table 5.8.1.2 Estimated cost (rupees in lakhs) for the solid waste management

Particulars	Number	Installation	Maintenance	Total cost
1. Dustbin (@ Rs. 5000 to 15000 per dustbin)				
a) Labour colonies	10	0.50	0.20	0.70
b). Colony area	10	0.50	0.20	0.70
c). Roadside	10	1.20	0.30	1.50
2. Compost Pits (@ Rs. 0.50 laks per pit)	20	6.00	4.00	10.00
3. Dumper				
a) All project sites	1	9.00	3.00	12.00
4. Wheel Barrows				
a) All project sites	6	1.50	-	1.50
5. Driver for Dumper				
Salary for 4 years @ Rs 11716/ + AI 1 Person		6.50	-	6.50
6. Landfill	1	2.00	1.00	3.00
7. Septic tanks and soak pits (@ Rs. 0.45 lakh per pit)				
a) Labour colony at Barrage site	60 pits	27.00	6.00	33.00
8. Community toilets				
a) Labour colonies at Barrage site (@ Rs. 0.45 lakh per set (one set with 8 to 10 seats)				
	45 sets	20.25	6.00	26.25
b) Community toilets at construction site (@ Rs. 0.45 lakh per set (one set 8-10 seats)				
	15 sets	6.75	2.0	8.75
9. Bathrooms and washing places (@ Rs. 0.50 lakh per bath room)				
a) Labour colonies at Barrage site	20 sets	10.00	3.0	13.00
10. Sewage treatment plant				
a) Labour colonies at barrage site	1	40.00	12.00	52.00
11 Staff for cleaning and maintenance				
(Salaries and wages for 4 years)	6	19.00	-	19.00
12. Facilities extended to affected villages including septic tanks, community toilets				
Vats and water supply system	02	37.50	-	37.50
Total		**187.7**	**37.7**	**225.40**

5.9
FUEL WOOD ENERGY MANAGEMENT & CONSERVATION

5.9.1 INTRODUCTION

In order to execute the construction of the project, a large number of labourers and project staff, would be required at project sites; many of them are expected to come along with their families. Due to increase in the population at the working sites, threats to forest resources like fuel wood is apparently foreseen, if not managed properly. Usually it can be observed that in remote areas of India food is cooked over an open fire or simple traditional cook stoves, which would require fuel wood. Fuel wood is required not only for the cooking purpose but it is also needed for heat during cool evenings and for additional heat in cooler regions. Also, fuel wood conservation is given less attention in remote areas. Fuel wood is the only source of energy in more than 95% households of influence area of Pauk H.E. Project. The area is poor in infrastructure facilities like road, electricity, transport, etc., therefore, inhabitants mostly depend on fuel wood for energy. The fuel wood is used with low efficiency and no programme has been running in the area to minimize the fuel wood consumption.

The fuel wood and energy conservation plan is proposed to include not only the incoming labourers and project staff but it will also be implemented in the influence area of Pauk H.E. Project. The proposed plan includes the provision of alternative fuel, improved wood utilization technologies and other efficient measures. The plan has been formulated in view of other projects like Heo H.E. Project and Tato I H.E. Project because all these projects are owned by same agency and developed in cascade in the same area. The main objective of taking all projects into account is to avoid overlapping of execution of the plan and to cover more area under this plan.

5.9.2 PROVISIONS MADE FOR HEO AND TATO I H.E. PROJECTS

A LPG depot has already been proposed at Gapo village or nearby area under the Tato I H.E. project. It will cater to all projects for the purpose. Besides, there are provisions for LPG connection, Kerosene depot, Community kitchens/ canteens, installation of solar panels, distribution of Chulahs and solar cookers, kerosene depots and Community kitchens/ canteens. All projects are located in the same vicinity, therefore, influence areas overlap each other. Considering this, beneficiaries in influence area of proposed project have been well defined.

5.9.3 BENEFICIARIES

Considering the same plan for Heo H.E. Project, the proposed plan will be implemented in the upper part of influence area. This area covers nearly 10 villages (Gauchi, Churling, Bumji Panga, Taching Panga, Kadasila, Karte, Lingdungloti, Dorjeeling, Sekor and Rego). Total population of these villages, as per Census 2001 is 828 from 130 households (extrapolated to be nearly 1025 person from 160 households as per Census 2011, not yet released). However, some of these villages are also covered under the plan of Heo H.E. project, Therefore, project authorities are suggested to carry out a detailed survey during the implementation with the precaution to avoid the same family being benefited by two projects for same facility in order to extend this plan in other areas beyond influence area, especially in case of tribal and BPL families.

5.9.4 PROPOSED PLAN

5.9.4.1 LPG Depot and Distribution of LPG Connections

A LPG depot has already been proposed in Tato-I H.E. Project. The services of the depot can be extended to the villages of the surroundings of Heo and Pauk H.E. Projects. Therefore, no separate depot is proposed for the Pauk H.E. Project. The project authorities are suggested to provide one time grant for LPG connection including chullahs to the inhabitants of the influence area of the Pauk H.E. Project. A total of 232 households are located in the influence area (Census 2001), most of which also fall under the Heo H.E Project influence area. Considering the fact there is provision of nearly 200 LPG connections excluding the beneficiaries of Heo H.E. Project. In addition, migrant workers having families would also be provided with these connections. Total budget for nearly 500 LPG connections would be **Rs. 20 Lakhs.**

5.9.4.2 Kerosene Depot

The project authority would open three kerosene depots at central places so that all villagers could access to these depots. The cost estimated for the plan would be **Rs. 3.00 lakhs**.

5.9.4.3 Community Kitchens/ Canteens

Community kitchen is an efficient way of energy conservation, which not only saves time but also increases working efficiency of the workers. The community kitchens / canteens are proposed for areas such as colony, camp and hostel. Project authority would provide all necessary infrastructures for the community kitchens/ canteens while ownership of the kitchen/canteen would be given at contract basis for a time period. Total cost allocated under this plan would be **Rs. 5.00 lakhs**.

5.9.4.4 Distribution of Energy efficient Chullahs

Fuel wood in among the inhabitants of influence area is required for heat especially in winter season; LPG is not a substitute for the purpose. People in the area use traditional chullahs, which are not energy efficient and hygienic as they exhaust much smokes. In order to conserve fuel wood and maintain a hygienic environment, project authorities would distribute improved and smokeless chullahas in the area. The beneficiaries of same facility provided by other projects would not be covered under this plan. The chullahs would be distributed to the households located in the influence zone and labourers of the project works. Also, this facility could be extended beyond the influence area. Total budget for this purpose would be **Rs. 4.00 lakhs** (for 500 chullahs @Rs. 800 only).

5.9.4.5 Distribution of dish Solar Cooker

Solar cooker is one of energy efficient measures. The solar cookers would be distributed to the households located in influence area. The provision of nearly 50 dish solar cookers would made for the households of influence area and projected affected villages and families. The priority would be given to BPL tribal families and project affected familes. In addition, the provision has been made for more families so that this plan could be extended in larger area. Total cost of solar cookers would be **7.50 lakhs** (@Rs 15,000 per solar cooker including servicing charges).

5.9.4.6 Training on Biogas Production

Biogas production for domestic purpose is one of the energy conservation measures. Project authority would ensure a training programme for biogas production with the help of renowned expertise. The training will be provided to the inhabitants of influence area. In addition, 5 biogas units will be installed at affected and influence area villages for the demonstration purpose. Total budget for this plan would be **Rs 10.00 lakhs** only.

5.9.5 FINANCIAL OUTLAY

Total financial outlay for the provision of fuel wood conservation would be **Rs. 49.5 lakhs**. The financial break up of this plan is given in Table 5.9.1.1.

Table 5.9.1.1 Budget allocation for fuel wood energy management and conservation of the Pauk H.E. Project area

S.No.	Particulars	Amount (Rs. in Lakhs)
1	LPG connections	20.00
2.	Kerosene Depots (3 No.)	3.00
3.	Community Kitchens / Canteens (3 Nos.)	5.00
4.	Energy efficient Chulahs	4.00
5.	Solar Cookers	7.50
6.	Training on Biogas Production	10.00
TOTAL		**49.50**

5.10
MANAGEMENT OF AIR, WATER QUALITY AND NOISE LEVEL

5.10.1 INTRODUCTION

Water and air and noise are prominent physical components of environment, which play significant role in maintaining the life support system. All project activities like excavation, blasting, regular vehicular movement, operation of machines and project workers lead direct impacts on the water, air and noise level of surrounding areas. The impacts affect the biota adversely, decrease the potability of water, create health problems, make atmosphere obnoxious and increase the noise level. In order to minimize the impacts under discussion, it requires not only a proper management plan but regular monitoring of these parameters. Majority of suggestive measures are precautionary and would not require separate funds.

5.10.2 WATER QUALITY MANAGEMENT

Some of the aspects of water management especially liquid wastes are properly addressed in other chapter (Waste Management Plan) in EMP report. However, there are some precautionary measures, which will be followed by the project authorities. The following mitigation measures are suggested to be followed during the construction of the project.

i. Project authorities are suggested to follow the Guidelines of CPCB and National Water Policy (2002) to maintain the sound water quality. The guidelines shall be issued to the contractors from the project authorities.
ii. Exploitation of ground water would be restricted in the project area.
iii. Accumulation of oil wastes in depressions should be minimized in order to avoid possible contamination of the ground water system.
iv. Adequate river water shall be secured to meet the requirements of riparian people, livestock, and wild animals and to sustain the aquatic ecosystem.
v. Direct drain of effluents into natural water bodies shall be prohibited. Surface runoff from oil handling areas/devices should be treated for oil separation before discharge into the river. If oil wastes are combined with sanitary sewage, oil separation will be necessary at the wastewater treatment facility.

vi The impact due to the suspended solids may be minimized by controlling discharge of wastes that contain suspended solids; this includes sanitary sewage and other wastes. Also, all activities that increases erosion or contributes nutrients to water (thus stimulating algal growth) should be minimized.

vii. Project authorities shall ensure that workers are not involved in illegal fishing activities and that the use of hazardous chemical, damming and blasting for fishing shall be prohibited strictly.

viii. Fish production in the reservoir will be monitored for any possible decrease. If any unexpected negative impact occurs, fish will be restocked. Technical support will be provided to the fish farming activities in the reservoir.

ix. The growth of aquatic weeds is to be monitored in the reservoir and excess weeds will be removed.

x. The open defecation must be prohibited strictly. The project authorities would establish toilets at various public places.

xi. The Project authority would ensure clean and treated potable water to workers.

xii. Project authorities shall ensure the regular monitoring of water quality in rivers and its tributaries.

5.10.3 AIR QUALITY MANAGEMENT

Combustion of petroleum fuel due to vehicular movement and operation of machines, DG sets etc, excavation, quarrying and transportation of muck are main drivers of deterioration of air quality in the project area. In this connection, details management plan are proposed for the rehabilitation of muck, however, there is need of various precautionary measures to reduce the air pollution in the region. Some important measures are described below.

i. Project authorities are suggested to ensure the norms and guidelines of The Air (Prevention and Control of Pollution) Act, 1981 and all statutory bodies like CPCB, State Pollution Control Boards.

ii. There should be a proper system to check the pollution. It should be mandatory for each vehicle and equipment to take a clearance certificate at a regular interval.

iii. The contractor(s) will be responsible for maintaining properly functioning construction equipment to minimize exhaust.

iv. Construction equipment and vehicles will be turned off when not used for extended periods of time.
v. Unnecessary idling of construction vehicles to be prohibited.
vi. Pre wetting of the ground to the depth of anticipated cuts should be followed.
vii. The grading operation shall be suspended when the speed of wind is very high.
viii. The roads near the residential areas, if any, shall be paved.
ix. All storage piles shall be adequately wetted or covered with plastic to ensure that no visible dust crosses the residential areas.
x. The wind barriers of 50% porosity shall be installed three sides of all storage piles.
xi. The project authority should ensure that all workers must have dust mask. The project authorities and contractor would provide the funds to workers for these masks.
xii. Regular monitoring of air pollution is warranted to ensure the effective management of air quality. The fund for monitoring will be provided by project authorities and monitoring will be carried out by independent agency, preferably State Pollution Control Board.

5.10.4 NOISE LEVEL MANAGEMENT

During the construction phase, the noise level would likely increase many times in the close vicinity of working sites due to heavy machines like compressors and DG sets, blasting operation, vehicular movement etc. The high noise pollution would lead to adverse effects not only on the human health but on wild life also. In order to minimize the noise pollution in the area following precautionary measures are suggested below:

i. Project authorities would follow the guidelines of the Noise Pollution (Regulation and Control) Rules, 2000.
ii. The work hours should be limited depending on convenience of the local people especially in case of nearby resident.
iii. The construction equipments must be designed and have a high quality muffler system.
iv. All stationery noise generating equipment such as air compressor, power generator should be away from the residential area.
v. Regular monitoring of equipment and vehicles shall be carried out.
vi. The total sound power level, Lw, of a DG set should be less than, $94+10 \log_{10}$ (KVA), dB(A) as per standard norms.

vii. Noise from the DG set should be controlled by providing an acoustic enclosure or by treating the enclosure acoustically.

viii. The Acoustic Enclosure should be made of CRCA sheets of appropriate thickness and structural/ sheet metal base. The walls of the enclosure should be insulated with fire retardant foam so as to comply with the 75 dBA at 1m sound levels specified by CPCB, Ministry of Environment & Forests.

ix. The DG set should also be provided with proper exhaust muffler with insertion loss of minimum 25 dB(A).

x. Proper efforts to be made to bring down the noise levels due to the DG set, outside its premises, within the ambient noise requirements by proper siting and control measures.

xi. A proper routine and preventive maintenance procedure for the DG set should be set and followed in consultation with the DG set manufacturer which would help prevent noise levels of the DG set from deteriorating with use.

All the measures are precautionary, therefore, no special budget has been provided for the maintenance of water quality, air quality and noise level. Project authorities would appoint an officer not below the Senior Manager level to look after the progress of the precautionary measures. Total budget for this work would be **Rs. 40 lakhs**. In addition, a regular monitoring work would be carried out for these parameters by an independent agency e.g. State Pollution Control Board. The provision of monitoring is given in other chapter of EMP report.

5.11
REHABILITATION & RESETTLEMENT PLAN

5.11.1 INTRODUCTION

Socio-cultural and economic aspect in EIA is addressed primarily because developmental project affects various groups differently so that there are proponents and opponents of the project among the people. The Rehabilitation and Resettlement plan is the most important measure that can maintain the harmonious and good relation between local inhabitants and project developers. The R & R plan involves the consideration of project affected families, villages, and a larger influence area. The main components of the R & R plan are provision of relief packages to project affect families, rehabilitation of displaced families, if any, provision of employment to local people, and implementation of a developmental plan for improvement of infrastructures in a larger influence area. Considering the fact that the influence zone and affected villages are inhabited by "Adi" tribes, having strong reservations on customs, culture, tradition and are not rich in living standards, the proposed plan is framed out to minimize the negative impacts of the project, improve living standards to the benefit of affected families or persons, to compensate the loss of livelihood of people, if any, to consider all cultural, traditional and social aspects and to furnish infrastructure development in the project area.

In order to provide the best packages to project affected families and to implement a sound developmental plan, Government of India has framed out detailed guidelines in the form of National policy on Rehabilitation and Resettlement (2007). This is a general policy and is considered across the nation. However, it does not highlight the regional issues, which are relevant to a particular area. Therefore, a few states of India including Arunachal Pradesh, where the proposed project is located, have formulated separate policies on Rehabilitation and Resettlement suggesting better packages and addressing regional issues imperatively. The Government of Arunachal Pradesh has issued a new policy named as Rehabilitation and Resettlement Policy of Arunachal Pradesh Government (2008). The guidelines of this policy have been followed in preparing R & R Plan of Pauk H.E. project.

The proposed plan for Pauk H.E. Project has been formulated considering the cascade development. There are two other projects immediately downstream which are owned by the same company (Heo and Tato-I H.E. Projects). Therefore, any repetition in the implementation of R & R plan has been avoided and/or minimized.

5.11.2 GENERAL METHODOLOGY

Because of the absence of land revenue records in the area The survey was carried out taking the community lands into account. Families belonging to the concerned communities were considered as affected families. The land impacted by the project was ascertained by the project authority and the concerned communities were identified with the help of panchayat members, Gram Budha and local people of concerned villages/areas.

Door to door socio-economic survey of the project-affected families was conducted to collect the base line data which has been used in preparation of the R&R plan. Discussion was held with all project affected families/persons, who have expressed their willingness to accept project. The detailed existing socio-economic profile of the project-affected area has been given in the EIA report Chapter 3.6.

In order to improve the accuracy of the data and information on socio-economic profile of local people and to implement a most efficient R&R plan, a detailed social survey will be performed again during the procedure of land acquisition, and before the time of implementation of the plan in order to have the most up to date information and in order to implement the most targeted and efficient R & R plan.

The Developer has applied to the State Government for acquisition of land and has requested the State Government to conduct a property survey. The procedure for land acquisition will be conducted under the exclusive authority and jurisdiction of the State Government. In any case, the mitigation measures and various compensations under this plan will be applied to all the concerned families whenever their land holdings have been impacted by the Project, whether the rights of the said families over such land are community rights, customary rights over forest or agricultural lands or individual rights.

The land required for project construction falls under the communities of the four directly affected villages, i.e Chengrung, Rapum, Hiri and Purying villages.

Land of Hiri and Purying villages areas are also impacted by Heo HEP components and structures. In order to avoid any double counting and repetition in the EMP plans of Heo and Pauk HE Projects, Hiri and Purying villages will be considered as affected villages exclusively for the Heo H.E. Project, for the purpose of Rehabilitation and Resettlement plan of the EMP. Therefore the families belonging to the Communities of Chengrung and Rapum, villages (or from whom individual land is to be acquired under the project land requirement, if any) will be considered affected families of the Pauk H.E. Project.

5.11.3 BRIEF SOCIO-ECONOMIC PROFILE

Pauk H.E. Project is the uppermost project of a cascade of 3 schemes developed by Velcan Energy Group. The influence area of Pauk H.E. Project falls under the administrative boundary of Tato and Mechuka circles in West Siang district of Arunachal Pradesh. The detailed socio-cultural and economic profile of the region, affected villages and affected families is given in EIA report (chapter 3.6). In this contribution, a brief discussion on socio-economic profile of the influence area that is relevant to R & R plan is given in the following paragraphs.

Influence area: Influence area of Pauk H.E. Project is inhabited by a total of 20 villages in which 19 come under the jurisdiction of Mechuka circle and one is under Tato circle. The total population of villages of influence area is 1382, coming from 232 households (Census 2001). Average sex ratio in these villages is 1044, that is higher than state average. All villages are inhabited by 100% scheduled tribe. Educational infrastructures are poorly developed in the villages of influence area. The nearest centers for secondary education are located at Mechuka and Tato. Average literacy rate in these villages is 47.5%.

The majority of the main workers are involved in cultivation including jhum. maize, millets and rice are main crops in these villages. Very rare are involved in households industry and government services. Nearly 45% inhabitants are employed in various works. The villages of influence zone under Mechuka and Tato circles like Churling, Sekor, Rego, Hiri, Gapo, Padusa, etc. are connected to the national highway. The villagers of other villages have to move 2 to 8 km to approach the road. Most of the villages have facilities of tap water, supplied from springs. The water is not treated. To avail the facilities of bank, post office and secondary school and primary health facilities Mechuka and Tato are main centers in the area.

Affected Villages: Land near four villages, viz. Hiri, Purying, Chengrung and Rapum are affected by the various project components. Hiri and Purying villages will be also affected by the implementation of the downstream Heo HEP, as the Pauk HEP Power House and the Heo HEP dam will share the same site around Purying and Hiri villages. However, Hiri and Purying and their inhabitants will benefit from the R&R and Peripheral Plans under the Heo HEP only to avoid overlapping and double count The total population of affected villages is 250 belong to 43 households (Census 2001). The average sex ratio is 953. The entire population of affected villages belongs to Scheduled tribes. Average literacy rate in the affected villages is 54.8%. Male population records considerably high literacy rate as compared to that of female.

About 50% of the total population of affected villages is employed in various works. All of them are main workers. The main workers form the majority of the population in these villages. Cultivation, including jhum, is the main occupation in these villages. Shifting cultivation is the main practice in these villages. Non workers including age group 0-6 year account for 50% of the total population. Millets, rice maize and pulses are main crops in the region. Hiri and Chengrung are located alongside the national highway connecting Aalo and Mechuka and Rapum is connected to such Highway by a foot track. Though, transportation facilities are very poor, and they are mainly facilitated by light vehicles. Tato and Mechuka are main centers of secondary education, primary health facility and telecommunication for these villages. The villages are not electrified. The tap water is supplied by springs, which is untreated.

Affected Families: Lands near four villages are directly affected due to the Pauk H.E. Project. However, the communities of Hiri and Purying villages areas are considered under the R&R plan of Heo H.E. Project. Therefore, in order to avoid double counting, only communities of Chengrung and Rapum villages are considered as affected families in Pauk H.E. Project R&R plan. Therefore the families belonging to the Communities of Chengrung and Rapum villages areas, or having individual holding rights on such lands, if any, will be considered affected families of the Pauk H.E. Project.

A total of 202 persons come from 24 households (55 families) are affected in Pauk H.E. Project. The sex ratio in the project affected families is 961. Average literacy rate in the project affected families is 53.6%. About 31.7% of the affected families are employed in various works. Livestock population comprises of cows, mithuns, goats, pigs and chicken. Cows are the main source of milk in the area while mithun, pigs, and chicken are used as food. All project affected families are Scheduled Tribe, thus considered as vulnerable group. All families use fuel wood for cooking and other purposes.

A detailed social survey will be performed again during the procedure for land acquisition, and before the time of implementation of the plan in order to have the most up to date information and in order to implement the most targeted and efficient R & R plan

5.11.4 AREA OF EXECUTION OF PERIPHERAL DEVELOPMENT PLAN

The influence area of Pauk overlaps with that of Heo and Tato-I H.E Projects. In order to avoid overlapping of R & R plan and peripheral development plan, the area of implementation of these plans has been demarcated. The villages which will be included under the plan of Pauk H.E Project are Gauchi, Churling, Bumji Panga, Taching Panga, Kadasila, Dorjeeling, Rapum, Chengrung and Rego. Total population of these villages is 867 belonging to 134 households (Census 2001).

5.11.5 PROPOSED PLAN

The proposed plan is described under three sections

- Rehabilitation & Resettlement Plan
- Rights & Privileges
- Peripheral Development Plan

5.11.5.1 Rehabilitation & Resettlement Plan

Resettlement and Rehabilitation plan for Pauk H.E. Project is based on the Rehabilitation and Resettlement policy of Arunachal Pradesh Government (2008) which has been supplemented by National Policy on the Resettlement and Rehabilitation (2007).

However the Project land requirement does not require any displacement of families, and therefore the Plan proposed by the Developer involves only Rehabilitation measures. Such measures aim at compensating the concerned families whenever their land holdings will be impacted by the Project, whether the rights of the said families over such land are community rights, customary rights over forest or agricultural lands or individual rights.

It is to be understood that the various compensations under this rehabilitation plan will be provided in addition to the rightful compensation to be made as per the Land Acquisition Act (1894) under the exclusive authority of the State Government, or any equivalent applicable regulation as the case may be, whenever applicable.

The proposed rehabilitation measures also aim at directly improving the socio-economic situation of the affected families.

5.11.5.1.1 *Definitions*

The various terms which are relevant to the proposed project are described in the following paragraphs. The definition of the various expressions used in this policy is the same as defined under the chapter III of NPRR (2007) except 'community', 'Affected area', 'Affected Villages' and 'Jhum'.

The definition of the "Affected Families" is also larger in this R&R plan than in the National R&R policy: in order to take into account the particularities of the tribal areas of Arunachal Pradesh, the definition includes the families members of a community / clan, in case of acquisition of community land (which belongs collectively to a clan).

(a) *"Administrator for Rehabilitation and Resettlement"* means an officer not below the rank of District Collector or commissioner in a State appointed for the purpose of rehabilitation and resettlement of affected persons.

(b) *"Affected family"* means:

(i) a family whose primary place of residence or other property or source of livelihood is adversely affected by the acquisition of land for a project or involuntary displacement for any other reason or

(ii) any tenure holder, tenant, lessee or owner of other property, who on account of acquisition of land (including plot in the *abadi* or other property) in the affected area or otherwise, has been involuntarily displaced from such land or other property; or

(iii) any agricultural or non-agricultural labourer, landless person (not having homestead land, agricultural land, or either homestead or agricultural land), rural artisan, small trader or self-employed person; who has been residing or engaged in any trade, business, occupation or vocation continuously for a period of not less than three years preceding the date of declaration of the affected area, and who has been deprived of earning his livelihood or alienated wholly or substantially from the main source of his trade, business, occupation or vocation because of the acquisition of land in the affected area or being involuntarily displaced for any other reason.

(iv) Any family member of a community / clan, to whom community land is acquired (case of acquisition of community land, i.e which belongs collectively to a clan).

(v) Any family which is permanent inhabitant of Chengrung or Rapum Villages for a period of not less than three years preceding the date of declaration under section 4 of the Land Acquisition Act, or any equivalent declaration as per applicable regulations from time to time

(c) *"Affected area"* means area of village or locality notified by the state government as affected by the Project. ;

(d) *"Agricultural labourer"* means a person primarily resident in the affected area for a period of not less than three years immediately before the declaration of the affected area who does not hold any land in the affected area but who earns his livelihood principally by manual labour on agricultural land therein immediately before such declaration and who has been deprived of his livelihood.

(e) "A*gricultural land*" includes lands being used for the purpose of

(i) agriculture or horticulture;

(ii) dairy farming, poultry farming, pisciculture, breeding of livestock or nursery growing medicinal herbs;

(iii) raising of crops, grass or garden produce; and

(iv) land used by an agriculturist for the grazing of cattle, but does not include land used for cutting of wood only;

(f) *"Appropriate Government"* means,-

(i) in relation to the acquisition of land for the purposes of the Union, the Central Government;

(ii) in relation to a project which is executed by the Central Government agency or undertaking or by any other agency on the orders or directions of the Central Government, the Central Government;

(iii) in relation to the acquisition of land for purposes other than (i) and (ii) above, the State Government; and

(iv) in relation to the rehabilitation and resettlement of persons involuntarily displaced due to any other .reason, the State Government;

(g) *'BPL family* The below poverty line (BPL) families shall be those as defined by the Planning Commission of India from time to time and included in a BPL list for the time being in force.

(h) *"Commissioner for Rehabilitation and Resettlement"* means the Commissioner for Rehabilitation and Resettlement appointed by the State Government not below the rank of Commissioner' or of equivalent rank of that Government.

i) *"family"* includes a. person, his or her spouse, minor sons, unmarried daughters, minor brothers, unmarried sisters, father, mother and other relatives residing with him or her and dependent on him or her for their livelihood; and includes *"nuclear family"* consisting of a person, his or her spouse and minor children.

(j) *"Holding"* means the total land held by a person as an occupant or tenant or as both.

(k) *"Land acquisition"* or *"acquisition of land"* means acquisition of land under the Land Acquisition Act, 1894 (1 of 1894), as amended from time to time, or any other law of the Union or a State for the time being in force.

(l) *"Notification"* means a notification published in the Gazette of India or, as the case may be the Gazette of a State.

(m) *"Occupiers"* means members of the Scheduled Tribes in possession of forest land prior to the 13thday of December, 2005;

(n) *"requiring body"* means a company, a body corporate, an institution, or any other organisation for whom land is to be acquired by the appropriate Government, and includes the appropriate Government if the acquisition of land is for such Government either for its own use or for subsequent transfer of such land in public interest to a company, a body corporate, an institution, or any other organization, as the case may be, under lease, license or through any other system of transfer of land;

(o) “community” means the residents of a village as a whole, clan, sub-clan or kindred.

(p) “Jhum Land” means jhum land as defined in Section 2(b) of the Balipara/Tirap/Sadiya Frontier Tract Jhum Land Regulation.

5.11.5.1.2 ***Applicable policies***

In addition to the rightful compensation related to the acquisition of Land (Section 23 of Land Acquisition Act and mentioned in Para 7.2.1 of R & R policy of State Government) whenever applicable, the following Rehabilitation and Resettlement Packages for the affected families are proposed in the applicable policies under discussion depending on the situation of each families.

(a) Any affected family owning houses and whose house has been acquired or lost shall be allotted free of cost house and a plot for the house site to the extent of actual loss of area of the acquired house but not more than 250 square meter of land in rural area or 150 sq. m. in urban area

or

The family which opts not to take the house offered at the resettlement site, shall get one time financial assistance for house construction and the amount shall be **Rs. 2,00,000/-**

(b) Each BPL family which is without homestead land and which has been residing in the affected zone for a period of not less than 3 years preceding the date declaration of the affected area and which has been involuntary displaced from such area shall be entitled a house of minimum 100 sq. m in rural and 50 sq. m in urban areas

or

The BPL family which opts not to take the house offered at the resettlement site, shall get one time financial assistance for house construction and the amount shall be **Rs. 75,000.** .

(c) Each affected family owning agricultural land in the affected area and whose entire land has been acquired or lost may be allotted agricultural land or cultivable waste land to the extent of actual lost, subject to a maximum of 1 ha of irrigated land or 2 ha of cultivable unirrigated land

or

Family shall be paid as one time grant of **Rs. 1,75,000/-** per ha. If the family is rendered landless after acquisition, the family shall be paid an extra grant of **Rs. 50,000/-** for one time.

(d) Each of the affected families who are left with less than 1 ha of land after acquisition shall be paid an additional grant of Rs. **40,000/-** In case of allotment of degraded or cultivable waste land, the adult member in the household shall get an amount of **Rs. 25,000/-** per ha for land development. In case of allotment of agricultural land, the adult member in the household shall get an amount of **Rs. 20,000/-** per ha for agricultural production.

(e) **Compensation for trees**: compensations for trees standing on the acquired agricultural land would be payable to the owners families as per valuation done by the State horticulture department.

(f) **Livelihood grant**: (i) The rendered landless family, who has been not provided employment shall get 1000 day minimum agricultural labour wage or **Rs. 1,00,000**/-

(ii) The family is left with less than 1 ha land after acquisition shall get 750 day agricultural wages or **Rs. 75,000/-**

(g) Each affected person who is a rural artisan, small trader, or self –employed person and has been displaced shall get one time financial assistance of **Rs. 25,000**/- for construction of shop.

(h) **Transportation grant**: Each displaced family shall get financial assistance of **Rs. 20,000**/- for transportation of the household goods, cattles etc.

(i) **Cattle shed grant**: Each displaced family shall get financial assistance of **Rs. 15,000**/- for construction of cattle shed.

(j) **Recruitment and Award of work /skill development:** The companies setting up hydro projects shall reserve the following categories of posts for the local tribal people, subject to the incumbents fulfilling the job requirement and subject to the availability as per the criteria given below

(i) Managerial /Professional post	25%
(ii) Clerical post	50%
(iii) Skilled jobs	25%
(iv) Unskilled jobs	75%

The preferences shall be given to project affected families or local people for jobs and contract etc.

(k) **Subsistence allowances**: Each affected family which is involuntary displaced shall get a monthly subsistence allowance equivalent to 25 day agricultural wages or **Rs. 2500**/- per month for a period of one year.

(l) **Pension for life to vulnerable person**: A vulnerable person shall get Rs. 500/- per month for life.

(m) **Compensation against Diversions of Unclassified State Forest and Reserve Forest**: Community shall be compensated **@ Rs. 1.56 Lakhs/Ha** for loss of customary rights and privileges of tribal people to collect and use forest produce (traditional land use) from Unclassified State Forests (USF) and @ Rs 0.78 Lakhs/Ha from Reserved Forest Land. In addition to this, the community will be paid a sum equivalent to 25 percent of Net Present Value (NPV) of the USF, as decided by the government of India from time to time, in case of diversion of USF as compensation towards extinction of their traditional rights over USF land use. Community land without forest cover and land under WRC (Watershed Research Cooperative) will be paid @ **Rs 1.75 lakhs/ha**. Compensation for crops will be paid @ Rs 1.25 lakhs/ha for land under jhum cultivation and Rs 1.5 lakhs/ha for land under WRC.

(n) **Scheduled Tribe Grant**: Each affected family belonging to Scheduled Tribe shall be compensated @Rs.50,000/- only

5.11.5.1.3 *Land Requirement*

Total land required for the construction of various components of Pauk H.E. Project is 91.7 ha. 88.4 ha is surface land and rest is underground land. Out of the total surface land 9.3 ha land accounts for river area while other belong to Unclassified State Forest (USF) (Table 5.11.1.1).

Table 5.11.1.1Breakup of the land to be acquired for various components in Pauk H.E. Project

Purpose wise break-up of total land Required for PAUK HEP					
S No	**Project Component**	**Surface Area (Ha)**		**Underground Area (Ha)**	**Total Area (Ha)**
		Surface Land	**River Bed**		
1	Submergence area	25.3	8.8		34.1
A	**Surface Structures**				
2	Dam complex area	3.5	0.5		4
3	Dam storage area and Colony area	3.5			3.5
4	Dam Quarry site	1.0			1.0
5	Dam Access Road	2.4		1.1	2.4
	Diversion Tunnel			0.2	0.2
6	Power house area (including penstocks and Tail Race)	16.8			16.8
7	muck disposal	5.1			5.1
8	PH Storage Area, Office and colony	1.3			1.3
9	PH Quarry site	0.2			0.2
10	PH Access Road	3.1			3.1
11	Surge Shaft Access Road	3.3			3.3
12	Muck Access Road	12.6		0.3	12.6
13	Ta Explosive storage area	1.0			1.0
	Total of surface areas	**79.1**	**9.3**	**1.6**	**88.4**
B	**Under Ground Structures**				
14	Head Race Tunnel			1.7	1.7
	Total	88.4		3.3	91.7

Important observation: The total submergence area is 34.1 ha, including 8.8 Ha of River bed. Hence the balance submerged land area to be acquired is 25.3 ha.

5.11.5.1.4 *Eligible Persons*

The Pauk H.E. Project being the most upstream project of a cascade of 3 H.E.P, the Pauk HEP Power Site is also the site of the immediately upstream Heo HEP Dam. Because of such site sharing between the 3 projects, it is necessary to allocate the different Community villages holdings project wise, in order to avoid repetition and wrong double counting Only the families from the Communities of Chengrung or Rapum villages (or from whom individual land is to be acquired under the project land requirement, if any) are eligible to the rehabilitation grant under the Pauk He Project, as provided under by the definition under 5.11.5.1.1 (b).

Pauk HE Project does not involve any displacement of family, and therefore none of the concerned families is losing its home. In the same way no family is rendered landless.

Project authorities have decided to consider all Affected Family for a onetime grant of Rs 75,000, such amount being equivalent to 750 days of agricultural minimum wage (equivalent to the livelihood grant under to the provision under 5.11.5.1.2.(f)).

In addition, the communities will receive appropriate compensations against the loss of their customary rights on USF land.

The summary of land to be acquired and eligible persons is given below:

Total land to be acquired (Community Land)	79.1 ha
Total No. of households affected	24
Total No. of family affected	55
Total No. of Scheduled Tribe family	55
Total No. of BPL family	5
Total No of vulnerable persons	5

It is to be noted that the land requirement has been defined based on the latest project features used for DPR and same land details have been submitted in forest application for diversion of forest land. The legal status is given as per the findings of the survey carried out so far. However the actual and final location of project components, the land requirement and the final ownership status may change as per various future procedural requirements as the requirements of the Techno-Economic Clearance, the assessment of the State Land Acquisition officer (SLAO) and as per the provision of Forest Conservation Act–1980.

Another property and social survey will be carried out by the State Government during the land acquisition procedure in order to confirm/update the features and status of the Land required for the Project and number of affected families.

The final actual compensations shall be paid as per the final procedures of the State Government, using the package per family described below.

5.11.5.1.5 *Relief Package*

Relief and rehabilitation package for the affected families for the project affected families are given in Table 5.11.1.2.

Table 5.11.1.2 Relief package for the affected families of proposed Pauk H.E. Project

	Particulars		**Amount (in Rs.)**
i)	Total No. of project affected households	24	
ii)	Total No. of project affected families	55	
iii)	Eligible person family grant		
	All affected families @ Rs 75,000	55	**41,25,000**
v).	Scheduled Tribe Grant		
	Total Number	55	**27,50,000**
	@ Rs. 50,000/-		
vi)	BPL Family grant		
	Total number	5	
	@ Rs. 75,000		**3,75,000**
vii)	Pension for vulnerable persons		
	Total number	5	
	@ Rs. 500 per person for lifetime (lump sum grant)		**12,00,000**
viii)	Free Electricity grant		
	100 units per month for PAFs for 10 year		
	No. of families	55	
	@Rs. 5.00/unit (lump sum rate) (100 x 5 x 45 x 12 x 10)		**33,00,000**
	GRAND TOTAL		**117,50,000**

5.11.5.1.6 *Application for Grant and Grant Distribution*

The Deputy Commissioner/ District magistrate or his/her representative not below the rank of ADM/ SDM from West Siang district will be the sanctioning authority for the rehabilitation grant, which shall be provided by the project authorities. Each family will be eligible for one package only, and will not be entitled to apply for a package under the Pauk HEP relief programs if it has already applied for such package under the relief programs of the Tato-I HEP or the Heo HEP. Affected family/ persons will apply on a general prescribed format, which will furnish the information of the village, details of community or individual land acquired, family and community status, and any other document required by project authorities, etc. The form will be submitted to the project office and evaluated by Land Acquisition Officer and General Manager of the Requiring Body. After receiving the list of PAFs by Deputy Commissioner, the options, if any, will be invited from head of the affected family on stamp paper and this will be rooted through SDM concerned. Deputy Commissioner/District Magistrate shall be the final authority to sort out the disputes between affected families and the project authorities. All stamp duty and fees of registration shall be borne by the project developers. After submitting all necessary document R&R cell would disburse the compensatory amount to the affected persons, upon the completion of the land acquisition. If there is any dispute between affected person and the project, Deputy Commissioner / DM can interfere to sort the disputes out.

5.11.5.2 Rights and Privileges – Compensation for USF Community land

In addition to relief packages, the concerned Communities will receive appropriate compensations against the loss of their customary rights on USF land.

The process of community land procurement required by the project authorities will be dealt between requiring body, affected families and Government of Arunachal Pradesh. The Affected families shall be compensated as per the norm of State Government.

In order to compensate against rights and privileges, the tribal communities shall be compensated **@ Rs. 1.56 Lakhs/ha** for the loss of their customary rights and privileges to collect and use forest produce (traditional land use) from unclassified state forests (USF). In addition to this, the community will be paid a sum equivalent to **25** percent of Net Present Value (NPV) of the USF, as decided by the government of India from time to time, in case of diversion of USF as compensation towards extinction of their traditional rights over USF land use. For that purpose, the project developer shall provide a total amount of **Rs. 291 Lakhs -**(subject to changes that may occur in NPV rates as per Government of India or in the findings and final results of the application of diversion of Forest under the Forest Conservation Act–1980)**.**

5.11.5.3 Peripheral Development Plan

5.11.5.3.1 *Scope and principles*

Peripheral Developmental Plan would play a positive role in the social and economic upliftment of the local inhabitants of the influence area. The effective implementation of the peripheral development ensures the participation of local inhabitants in the developmental activities and maintains a harmonious relationship between project authorities and locals. Taking the Heo H.E. Project and Tato-I H.E. Project into consideration, the proposed plan will be implemented in 9 villages as listed under paragraph 5.11.4 of this chapter.

The project authorities directly as well as through their contractors would ensure that local population gets good number of jobs. The jobs, however, would be determined by the qualifications and experience of the persons wanting to be employed. It will also provide an opportunity to many unskilled youth to become skilled. By gaining technical knowledge and experience, their chances of gainful employment will be greatly enhanced. Enhancing the local people’s skills and opportunities for employment the project would result in uplifting the standard of living and the existing quality of life of the local inhabitants. This would go a long way in making the area economically self-sustaining. Besides generating local employment for the skilled and un-skilled labourers, the project would also provide an opportunity for the local people to compete for various contracts related to the project works, depending on their economic status. The participation in this process would, however, be guided by the usual process of tendering. The project authority would ensure as far as possible, to engage local labourers in various skilled/non-skilled jobs depending on a candidate’s qualifications and experience. In addition, local people would be beneficiaries of the following facilities, established in the periphery.

The area is poor in the education facilities. The project authorities would establish educational institutions in the area for the children/wards of their project employees. At some places, grants would be provided for the maintenance and upgrade of existing educational institutions which would be a great benefit for the local residents. The project authorities would establish healthcare facilities in terms of healthcare centers and primary health centre at a few affected villages and for their employees. These centers shall extend services to the local people. Details of proposed health care facilities are given in Chapter 5.7 of EMP report. Project authorities would provide mobile vans for emergency services in the area.

The project authorities would construct and establish club/playgrounds for the project employees/ sports competitions and sports meets would be organized between the local players and project employees which would ensure the local participation. This will also provide them with the necessary facilities for excelling in sports of their choice. These facilities would go a long way in honing and nurturing the local talent in the field of sports and competitive games. In addition to education, health and sports facilities, the requiring body would play a vital role in strengthening the communication and transportation facilities. The various other programmes like skill up gradation, merit scholarship programme, training programme etc. will be run in the area. Provision of green belt in the periphery of the reservoir, landscaping and establishment of botanic gardens will enhance the scenic beauty and tourist spots of the area and attract the local and outside tourists. The influx of outside labourers would provide fair possibilities of marketing and small scale business in the area. These activities would add surplus income of local inhabitants.

5.11.5.3.2 *Grants for Peripheral Development*

(i) Merit Scholarship Programme

As per the clause 7.13.1(c) of NPRR (2007), requiring body shall offer scholarships and other skill development opportunities to the eligible persons from the families of influence area per the criteria fixed by the appropriate Government. To improve and encourage the literacy and educational standards in the project affected area and to create a pool of potential candidates, Requiring Body will introduce a Merit Scholarship Scheme for the wards of the inhabitants of the influence area. The wards of the project affected families will be given preference. The wards should be studying in school, college or any other educational institute recognized by State or Central government or a reputed private institution. The students should not be receiving any other scholarship of State and Central governments.

A total of 10 students (preferable from 134 households of the selected villages, discussed under paragraph 5.11.4) every year will be selected for the scholarship on the merit basis. The scholarship would be divided on the basis of standards and disciplines, viz, senior secondary school (3 students), vocational training (3 students), diploma (2 students) and Degree in science, engineering, medical etc. (2 students). The scholarship for an individual will last for the tenure of course. The scholarship @ Rs.1000/-, Rs.1500/-, Rs.2000/- and Rs.2500/- per month would be provided to the students of secondary school, vocational training, diploma and degree, respectively. The project authorities are suggested to run this scheme at least for 5 successive years. After completion of the scheme, Requiring Body reserves the right to restart or terminate this scheme.

The eligible students may apply for the grant of scholarship as per the format given by the project authorities (Annexure II). The amount of the scholarship shall be released on a half-yearly basis. The submission of application for scholarship shall not guarantee the grant of scholarship. Requiring body management shall reserve the right to accept or reject any or all application without assigning any reasons. Requiring Body also reserves the right to reduce/ increase the number of beneficiaries or change the number of beneficiaries in different standards depending upon availability of the students.

The eligible candidate shall apply on the prescribed form printed by Requiring Body. Duly completed application form should be submitted along with attested copies of marks sheets of previous annual examinations, various certificates as may be required and two passport size photographs attested by the principal/head of the institute. Total budget for the Merit scholarship including increment would be **Rs. 30.00 lakhs**.

(ii) Training Programme

Following the clause 7.13.2 of NPRR, the affected persons shall be offered the necessary training facilities for development of entrepreneurship, technical and professional skills for self-employment. Training on the mushroom cultivation, computer courses, apiculture, vermiculture, eco-tourism, poultry farming, dairy farming, knitting, sewing etc. could open new areas of self employment in the region.

Requiring body would invite trainees among the affected families mentioned above for the training on various courses. The requiring body would select 10 trainees every year for the period of 5 years (training period for a batch is one year). If the applicants are not available among the affected families the training programme can be extended to the affected villages and/or villages located in the 10 km radius as described above. The applicants can obtain application form at no cost from the office of requiring body (Annexure III). Applicant would submit application form along with certificate of domicile or certificate of land acquired, as the case may be, from the LAO (Land Acquisition Officer) of Requiring Body, income certificate from DC/SDM, certificates of educational qualification, caste certificate issued by an officer not below the rank of executive magistrate and verification certificate of the concerned Gram Pradhan/Panchayat member. The scheme is a welfare measure for the PAF's and inhabitants of the influence area. If the requiring body is not able to develop all infrastructural facilities for all the training programmes, it may consult the concerned department of the state to facilitate training to the applicants. The requiring body would bear all expenditure including accommodation, travel etc. of the trainees and charges of the concerned department. Total financial out lay for the training programme would be **Rs. 18.00 lakhs** (@ Rs. 3000/- per month for a trainee).

(iii) Education Facilities

The area is poor in having the education facilities. Considering the fact that one middle school and two primary schools are proposed under the EMP plans of Heo and Tato-I HE Projects respectively, a middle school is proposed under the plan of Pauk HE Project. The project authorities are advised to select a village for the school which is not covered under the same scheme of other projects and having no existing schools. Also, the selected village must be located at the central place and/or remotely located village within influence area. The project authorities would finance all the infrastructure, salaries and maintenance grants for the school for at least five years. The land for the school buildings would be provided by the State government. After five years, the funding of the school will be handed over to the State Government, if the requiring body desires. In addition to the establishment of a school, the requiring body would provide the funds for strengthening of existing schools, if required. Total budget for the proposed school including buildings, salaries and maintenance would be **Rs. 106 lakhs**. The break up of the budget is given below

	Components	Amount (In lakhs)
A.	Salaries/wages	
	Middle School teacher (No. 06) (Basic pay @ Rs. 11,170/ pm + Annual increment)	40.00
	Peon (No. 01) (Basic pay Lump sum @ Rs. 9000/- + Annual increment)	6.50
Sub total A		**46.50**
B.	School buildings (1 middle school)	15.00
C.	Play grounds	2.00
D.	Maintenance grant	7.50
E.	Miscellaneous grant	10.00
F.	Budget for strengthening the existing schools	25.00
Total (A+B+C+D+E+F)		**106.00**

(iv) Community Welfare Centres

In order to strengthen the infrastructure in the villages, the community centres are proposed in the villages wherever they are needed. A few villages already have this facility. Therefore, a total of 4 community centres are proposed for Pauk H.E. Project. The community centres will be provided with electricity, water supply and furniture. Total cost of community centres including construction cost, electricity, water supply and furniture would be **Rs. 15.00 Lakhs** only.

(v) Adoption of a Model Village

In order to establish harmonious relationship between project authorities, State Government and local people, requiring body would adopt a village to develop it as a model village. The selection of village will be decided by the project authorities in consultation of the State government, considering the same plan of other upstream and downstream projects. The village would have school, health, telecommunication, water supply, sanitation, road or footpath facilities. Also, the activities of landscaping and beautification will be carried out in the adopted village. Total budget for the adopted village would be **Rs. 102.00 Lakhs**. The break up of the budget is given below:

Particulars	Amount (Rs. in lakhs)
School (already exist or proposed above)	-
Health centre (proposed in Health Delivery System)	00.00
Sanitation (toilet and bathroom at each households for households)	15.00
Construction of *Pucca* houses	40.00

Construction of footpath (lump sum)	4.00
Electrification (at each house hold and street light)	10.00
Water supply (each household will be connected to tap water)	15.00
Provision of dust bins	2.00
Community hall	2.00
Plantation	2.00
Beautification	2.00
Miscellaneous budget	10.00
Total	**102.00**

Maximum 40 households have been considered for the model village

(vi) Construction of Rain shelters and Footpath

Requiring body shall provide rain shelters along Tato-Mechuka road for 15 km. The remaining stretch will be covered under the peripheral developmental plan of Tato I and Heo H.E. Projects. The area is sparsely populated and there are no other means for the purpose. About 15 rain shelters are proposed along side the road. In addition, to provide easy access to the road, *pucca* footpaths from village to nearest road are also proposed. The villages like Gauchi, Churling, Bumji Panga, Taching Panga, Kadasila and Dorjeeling would require footpaths (2 to 3 km each). Total length of footpath to be constructed is estimated to be 20 km. The cost of footpaths is calculated to be **Rs. 27.00 lakhs** only. Total budget for rain shelters and footpath is estimated to be **Rs. 35.00 lakhs** only.

(vii) Provision of Sanitation Facilities

Each household of the selected villages as under para 5.11.4 above shall be provided with a toilet set and bathroom. Taking the decadal growth rate into consideration, this facility would be facilitated for nearly 133 households (Total households are 106 as per Census 2001). Total budget for the sanitation would be **Rs. 50.00 lakhs** (@Rs. 37,500/set).

(viii) Contribution towards Cultural, Religious & Sports Activities

Provision has been kept for **Rs. 30.00 lakhs** to contribute towards cultural, sports and religious activities for the project affected areas.

(ix) Crafts and Skill Upgradation

The industrial training is an important mean for the development of effective work habits and methods of work. The development of infrastructure and training are proposed to preserve and revitalize the traditional indigenous handicrafts, handlooms and sericulture products. The project authorities are suggested to allocate **Rs. 30.00 lakhs** for the one handloom unit and one training centre in the area. Ministry of Agriculture of State would be the implementing agency.

(x) Horticultural and Agricultural Support

Maize, millets, and vegetables are main crops in the area. In order to improve the quality of these a support unit will be established at a central location. This unit will be established by the project authority in consultation with the concerned state department. Thus, it will be implemented by the state department. A total financial outlay for this purpose would be **Rs. 30.00 lakhs** only.

5.11.5.4 Financial Outlay

Total financial outlay for Peripheral Development Plan is **Rs. 584 Lakhs** only (Five hundred eighty four lakhs only). The break up of the budget is given below.

S.N.	Head	Amount (Rs. in Lakhs)
(i)	Merit Scholarship Programme	30.00
(ii)	Training Programme	18.00
(iii)	Education Facilities	106.00
(iv)	Community Welfare Centres	15.00
(v)	Adoption of a Model Village	102.00
(vi)	Construction of Rain shelters and Footpath	35.00
(vii)	Provision of Sanitation Facilities	50.00
(viii)	Contribution to Cultural, Religious & Sports Activities	30.00
(ix)	Crafts and Skill Upgradation	30.00
(x)	Horticultural and Agricultural Support	30.00
Total		**446.00**

5.11.6 DEVELOPER MESSAGE

The Pauk H.E. Project is a midsized Run-Off-the River HEP, which involves only a small reservoir and a small submergence area (25.3 ha of surface land to be submerged). The Project does not require any displacement of people. The Pauk H.E. Project has been developed right from the beginning with the cooperation of local inhabitants on the field investigations and feasibility studies, and compensations and benefits have been allocated through sponsoring, welfare activities and employment even before the start of Project construction. Due to a small submergence area (34.1 ha including 8.8 ha of river bed, being a net submergence impact of 25.3 ha) and a small land requirement (net surface land impact 79.1 ha), the Pauk H.E Project is having a small impact on local inhabitants, and the number of Project Affected Families remain very low (55 estimated families).

A total budget of **Rs 884.50 Lakhs** has been allocated for Rehabilitation measures, Rights and Privileges, Peripheral Development Plan and Monitoring (do not include the compensations per the Land Acquisition Act, which will be paid in addition whenever applicable).

5.11.7 MONITORING & EVALUATION

In order to sort out the land acquisition and compensation issues, an independent committee is required for evaluation and monitoring, especially the Rehabilitation and Resettlement Plan. The State Government shall constitute a standing Rehabilitation and Resettlement Committee under the chairmanship of the Deputy Commissioner of West Siang district to monitor the progress of Rehabilitation and Resettlement plan. The composition, powers and function and other matters relating to the functioning of Rehabilitation and Resettlement Committee shall be prescribed by the State Government. Any affected person, if aggrieved, for not being offered the benefits admissible, may move a petition for redress of his/her grievances arising out of the matters covered under the policy. Any disputes related to the compensation will be disposed of as per applicable rules. The proposed R & R committee for Pauk H.E. Project would comprises of the following members

i)	Deputy Commissioner, West Siang District	Chairman
ii)	Managing Director, Pauk Hydro Power Pvt Ltd	Member
iii)	General Manager (Project), Pauk Hydro Power Pvt Ltd	Member
iv)	Head of R & R Cell (project), Pauk Hydro Power Pvt Ltd	Member Secretary
v)	A representative from Corporate Finance Deptt.	Member
vi)	Head, Corporate Social Responsibility Cell	Member
vii).	Panchayat members of affected villages	Members
iv.	Woman (social worker) from the affected area	Members

v. Representative of well known NGO in the area Member

The financial budget for the day to day expenditure of the committees would be **Rs. 30.00 lakhs** only.

For the effective implementation of R & R plan and peripheral development plan project authorities are advised to constitute Rehabilitation & Resettlement Cell (R & R Cell) of the Project and Corporate Social Responsibility Cell (CSRC). R & R Cell will be responsible for the effective implementation of R & R plan and rights and privileges issues while CSRC will take the responsibility of peripheral development. Both will assist Rehabilitation and Resettlement Committee in the monitoring and evaluation.

5.11.8 TOTAL BUDGET

Total budget for the Rehabilitation and Resettlement Plan and Peripheral Development Plan would be **Rs. 884.50 Lakhs** (Eight hundred Eighty Four Lakhs and fifty thousand only). The break up of budget is given below.

S.N.	Plan	Amount (Rs. in lakhs)
i).	Rehabilitation & Resettlement Plan	117.50
ii).	Rights and Privileges	291
iii).	Peripheral Development Plan	446.00
iv)	Monitoring and Evaluation	30.00
Total		**884.50**

5.12
GOOD PRACTICE

Safeguard and precautionary measures can play a vital role in protecting the environment and social values in and around the project. There are a large number of small but important issues, for which separate management plans are not required but necessary for implementation. Such types of measures are included in good practice. Also, the various mitigation measures suggested in the EMP report can be supplemented and strengthened through good practice. These measures are helpful not only in maintaining a sound environment but also in maintaining a harmonious relationship between project authorities and local inhabitants.

5.12.1 Environmental Training for the project Workers

Project authorities and contractors would prepare a training plan to their workers emphasizing the work scenario, the importance of environmental conservation and social values of the area, maintaining a good relationship with local inhabitants, waste management, health care, use of explosive, chemicals and other equipment.

5.12.2 Awareness Programme

Project authorities would organize awareness programmes regarding the environment and society values and their role in the development of project. The workers of project and local people would participate in the programmes.

5.12.3 Rules and Guidelines

The project authorities would issue guidelines related to the environment protection and social relation in the area. There must be provision of penalties on violation of rules and guidelines.

5.12.4 Conservation of Natural Resources and Biodiversity

Project authorities and contractors would take the responsibility of their workers not to damage the forest and streams, not to be involved in forest firing, fishing, poaching and hunting. A detailed guideline would be issued by the authorities to the workers. All workers must be provided with an identity card, and should not be allowed in the forest areas without permission or/and any valid reason. There should be provision of rules and penalties.

5.12.5 Waste Management

The project authorities would ensure the maintenance of surface water quality and terrestrial ecosystem. Open defecation alongside the roads, river and improper dumping of garbage would be strictly prohibited. Authorities would deploy a few persons among the labourers at various sites to monitor these issues.

5.12.6 Health Aspects

Project authorities/contractors shall follow a strict quarantine procedure for their labourers coming from outside. Each labourer should pass through a proper check up to avoid any possibility of spread of communicable diseases. In addition, the workers involved in excavation, tunneling, dumping etc. activities should be provided with breathing masks. All safety measures for the workers should be strictly followed. All workers must be registered under the contractor or project authority with their full address. During the appointment in the project, he/she must pass through proper checking.

5.12.7 Social Aspects

There is always a possibility of cultural confliction between locals and migrants. To avoid any confliction due to culture, social evils etc. suitable measures will be taken by the project authorities. There should be a clear demarcation of the project construction area. All project workers must be provided with identity cards by contractors or project authorities. The workers should not be allowed access to villages or forest area without permission or/and without valid reason. The permanent addresses of workers must be verified by local police. Project authorities would ensure that none of the worker was involved in any illegal activity.

5.12.8 Storage, Handling and Emergency Response for Hazardous Chemicals and Explosives

There should be a proper management for the storage of hazardous chemicals and explosives. The storage of fuel, oil and chemicals should not be permitted within 100 m of river water. In case of an accidental spill overflow, release of fluid occurs into the stream open surface, emergency measures should be followed by the contractors and project authorities. There will be appropriate rules and regulations and penalties towards the misuse of chemicals and explosives.

5.12.9 Cultural Meet & Renovation of Cultural Sites

Project authorities shall organize cultural meet at least once a year. Also, financial help will be provided for the local festivals in the area. Project authorities would take care of cultural sites in the area.

5.12.10 Establishment of Creche

It was observed that labourers do have their families, stationed alongside the road. Their infants do not have facilities of nursery and primary education. Therefore, project authorities are suggested to open creches to look after and to educate them.

5.12.11 Control of Polythene and Plastic Carry Bags

Project authorities would ensure the ban on carry bags and package materials made up of plastic and polythene within the project boundaries. The awareness programmes for the same practice would be run in the surrounding villages.

5.12.12 Videography

It was observed that people were concerned about the blasting operation in the tunnels, which leads to vibration and cracks in the houses and damage the natural springs lying on the HRT alignment. Though there are not much *pucca* houses along the HRT alignment, however, project authorities are suggested to conduct videography of all houses and natural springs fall near the HRT prior to the construction works. If such types of adverse impact would occur during the construction phase the project authorities would provide the compensation.

5.12.13 Public Relation Cell

Project authorities would open a public relation cell to sort out complains of locals towards workers, construction activities, etc. It would be helpful in maintaining the harmony between project authorities and locals.

The project authorities are suggested to establish their Environment Cell and Corporate Social Responsibility Cell as suggested earlier. All the good practices will be executed and monitored by the Environment Cell and Corporate Social Responsibility Cell. There is provision of financial outlay of **Rs. 25.00 lakhs** to implement the good practice in the area.

5.13 IMPLEMENTATION & MONITORING PROGRAMMES

5.13.1 INTRODUCTION

Construction activities in the developmental projects are anticipated to lead the adverse impacts on the various parameters of the environment. In order to maintain an approach of sustainable development, the adverse impacts need proper mitigation measures and monitoring. Environmental monitoring describes the process and activities that need to take place to characterize and monitor the quality of environment. Also, the management of the environment relies on the formulation of suitable plans and their implementation and monitoring.

Monitoring shall be performed all stages of project to ensure that the impact are no greater than predicted and to verify the impact prediction and identification Care should be taken to classify, analyse and store data for easy retrieval, so that it can be used as a reference data for other assessments. Therefore, a monitoring programme should address the objectives, stages of implementation, practical methodologies, adequate funding, clear responsibilities and regular reporting. If adverse effects beyond those anticipated in the original environmental impact assessment become apparent, remedial actions must be taken.

In this chapter a detailed implementation and monitoring programme is suggested for the Pauk H.E. project in purview of the other projects, proposed on the same river.

5.13.2 ENVIRONMENT CELL & CORPORATE SOCIAL RESPONSIBILITY CELL

Project developers are suggested to constitute an Environment Cell (EC) and a Corporate Social Responsibility Cell (CSRC) for the project. The function of the EC and CSRC would be to monitor and evaluate various sub plans and be a part of action based monitoring committees. EC will be associated to the environmental related activities while CSRC will be associated to the social works.

5.13.3 IMPLEMENTATION

Table 5.13.1.1 gives the details of actions, implementing agencies and monitoring team. Various agencies of State government and project authorities are involved in the implementation of mitigation measures.

5.13.4 MONITORING & EVALUATION

As above mentioned, there are many plans and actions to be implemented to mitigate and protect the environment. Various agencies will implement and monitor these measures in the region. However, it would require a proper coordination among these agencies for smooth functioning. For this reason, two committees are suggested for the monitoring and evaluation.

5.13.4.1 Independent Committee

The independent committee would be notified by the State Government. The committee will be headed by a senior state level officer, not below the rank of Deputy Commissioner or his/her representative. The committee will evaluate and monitor over all progress in the implementation of various plans. All sub committees, suggested for the various plan would submit their reports to the independent committee. The committee would comprise of following members

State Level Senior Officer (not below the rank of DC)	Chairman
Director of Project	Member Secretary
Deputy Commissioner or his/her representative	Member
Block Head	Member
Concerned MLA	Member
Renowned Ecologist	Member
Member of State Level NGO	Member

5.13.4.2 Project Level Committee

Project Level committee will assist the independent committee. The committee will arrange the meetings between various sub committees and independent committee. After the detailed evaluation and monitoring by the independent committee, all merits and demerits will be communicated to the project level committees to complete them in specified time. The committee would comprise of following members.

Table 5.13.1.1 Detailed implementation plan for Pauk H.E. Project

Plan	Actions	Agency	Responsibility/Monitoring
1. Biodiversity Management Plan	i. Botanical Garden	Research Team from a reputed institute/university	State Forest Department/ Environment Cell, project
	ii. Natural Resource and Skill Management	NGO reputed institute/university	State Forest Department/ Environment Cell, Project
	iii. Forest Protection plan	State Forest Department	State Forest Department
	iv. Safeguard Measures	Environment Cell	Environment Cell
2. CAT Plan	i. Construction of Check dams/ Brushwood, etc	State Forest Department	State Forest Department
	ii. Terrace Benching	State Forest Department	State Forest Department
	iii. Afforestation	State Forest Department	State Forest Department
3. Public Health Delivery System	i. Immunization/vaccination,	State Health Department	CSRC, Project
	ii. Distribution of first aid box	State Health Department	CSRC, Project
4. Fishery Development & Downstream Management	i. Fishery Development	Project authority	State Fishery Department
	ii. Downstream Management	Project authority	State Pollution Control Board
5. Waste Management	Construction of compost pit, Septic tanks, Community toilets, Bathrooms, sewage treatment plant	Planning Division, Project	State Pollution Control Board
6. Energy Conservation	i. Solar Pannel	Planning Division, Project	GM/Ditrector, Project
	ii. Distribution of LPG	CSRC, Project	GM/Director, Project
	iii. Distribution of improved Chullahs, solar cockers, etc.	CSRC, Project	GM/Director, Project
	iv. Community Kitchen	Planning Division, Project	GM/Director, Project

7. Management of Air, Water & Noise	i. Precautionary Measures	EC, Project	State Pollution Control Board
	ii. Regular Monitoring	State Pollution Control Board	State Pollution Control Board
8. Rehabilitation of Muck	i. Construction of retaining wall	Civil Division, Project	GM/Director, Project
	ii. Plantation	EC, Project	EC, Project
	iii. Precautionary measures	EC, Project	GM/Director, Project
	iv. Transportation of muck	Project authorities	State Pollution Control Board
9. Landscaping & Restoration	i. Rehabilitation of disturbed site	EC, Project	GM/Director, Project
10. Restoration of quarry sites	i. Rehabilitation of quarry sites	EC & Civil division	GM/Director, Project
11. Green Belt	i. Biological measures	EC, Project	GM/Director, Project
12. R & R Plan	i. Relief package for PAFs	R & R cell, Project/ District Administration	DC, West Siang District
	ii. Developmental activities in project areas	R & R Cell, Project	Chairman, R & R Monitoring Committee
	iii. Peripheral development	R & R Cell, Project	Chairman, R &R Monitoring Committee
13. Disaster Management Plan	i. Telecommunication	Planning Division, Project	Planning Division, Project
	ii. Emergency Action Plan	Planning Division, Project/ District Administration	District Magistrate
	iii. Rescue Operation	District Administration	District Magistrate
	iv. Rehabilitation	R & R cell, Project District Administration	District Magistrate
14. Environmental Monitoring	i. Implementation & Monitoring	Various agencies	Project Level Committee/ Independent Committee

Director, Project	Chairman
Head, Environment Cell, Project	Member Secretary
General Manager, Project	Member
Head, Corporate Social Responsibility Cell	Member
Circle(s) Head	Member(s)
Heads of Panchayat of Affected Villages	Members
Social Activist of Affected Zone	Member

5.13.5 MONITORING SCHEDULE

Various environmental variables like water, noise, air, etc are critical and would require a regular monitoring to avoid deterioration of quality while others actions as mitigation measure need sound evaluation. Table 5.13.1.2 gives details of work, schedule and agencies, which will be involved in the monitoring and evaluation.

Table 5.13.1.2 Detailed plan for evaluation and monitoring of various environmental variables and mitigation measures

S.N.	Parameters	Time Schedule	Agency
1.	Monitoring of water quality (pH, temperature, DO, BOD, Alkalinity, Hardness, TDS, Nutrients, Sulphates, Silicates, Heavy metals, coliforms, etc)	Quarterly	State Pollution Control Board
2.	Monitoring of Air Quality (SOx, NOx, CO, SP)	At an interval of 15 days	State Pollution Control Board
3.	Monitoring of Noise Level	Randomly	State Pollution Control Board
4.	Evaluation of Waste Management	Quarterly	State Pollution Control Board
5.	Monitoring of Afforestation	Quarterly	Environment Cell, Project
6.	Transportation and Dumping of	Monthly Board	State Pollution Control Muck
7.	Distribution of relief package	All days during Implementation	District Magistrate or his/her representative
8.	Progress in peripheral development	Randomly Committee (R & R)	Evaluation and Monitoring
9.	Water level in downstream	Randomly	State Pollution Control Board

5.13.6 BUDGET

The budget would be required for the routine meetings between various committees and project authorities. The project authorities are suggested to provide an office for the scheduled meetings. It would include the financial outlay for furniture, stationeries, travel, etc. Total cost estimates for this purpose would be **Rs. 40.00 lakhs** only. In addition, various other agencies are involved in the monitoring and evaluation of some of the mitigation measures. For most of the agencies budgets have been allocated, however, a budget of **Rs. 20.00 lakhs** has been earmarked for a few agencies like State Pollution Control Board. Total Financial outlay for the monitoring and evaluation would be **Rs. 60.00 lakhs** only.

7
SUMMARY OF COST ESTIMATES

The environment management plan, proposed for Pauk H.E. Project is useful during and after its development. It embodies 14 different management plans viz. biodiversity conservation management plan, catchment area treatment plan, rehabilitation and resettlement plan, muck disposal plan, fishery development plan, disaster management plan, solid waste management plan and some other important plans. It is believed that implementation of all these plans would ameliorate the condition of the environment that is likely to be resulted due to negative impacts during and after the development of the proposed project and also bring in socio-economic development of the region. The total financial layout proposed to meet the measures suggested in various management plans is **Rs. 4158.19 Lakhs only** (Rupees Four thousand one hundred fifty eight lakhs and nineteen thousand).

Table 7.1 Cost estimates for the implementation of EMP*

Sl.No.	Plans	Amount (Rs. in lakhs)
1.	Catchment Area Treatment Plan	2156.36
2.	Biodiversity Management and Wildlife Conservation Plan	227.00
3.	Muck Disposal Plan	121.00
4.	Restoration of Construction Areas and Landscaping	72.20
5.	Green Belt Development Plan	24.63
6.	Fishery Development and Downstream Management Plan	55.00
7.	Public Health Delivery System	100.00
8.	Waste Management Plan	225.40
9.	Fuel Wood Energy & Bio-Resource Conservation	49.50
10.	Management of Air & Water Quality and Noise Level	40.00
11.	Rehabilitation and Resettlement Plan	884.50
12.	Good Practice	25.00
13.	Implementation & Monitoring Programme	60.00
14.	Disaster Management Plan	117.60
	Total	**4158.19**

* This does not include the cost for Compensatory Afforestation and cost of land to be acquired.

Chapter 6

DAM BREAK MODELING & DISASTER MANAGEMENT PLAN PAUK HE PROJECT

Prepared for:

VELCAN ENERGY

Prepared by:

R. S. Envirolink Technologies Pvt. Ltd.

402, RADISSON SUITES COMMERCIAL PLAZA,
B-BLOCK, SUSHANT LOK-I, GURGAON

Ph: +91-124-4295383 : **www.rstechnologies.co.in**

CONTENTS

LIST OF TABLES

LIST OF FIGURES

6.1

INTRODUCTION

6.1.1 DAM BREAK PHENOMENON

The construction of dams in rivers can provide considerable benefits; however the consequences which would result in the event of their failure could be catastrophic. They vary dramatically depending on the extent of the inundation area, the size of the population at risk, and the amount of warning time available.

Dam break may be summarized as the partial or catastrophic failure of a dam leading to the uncontrolled release of water. Such an event can have a major impact on the land and communities downstream of the breached structure. A dam break may result in a flood wave up to tens of meters deep traveling along a valley at quite high speeds. The impact of such a wave on developed areas can be sufficient to completely destroy infrastructure. With such destructive force comes an inevitable loss of life, if advance warning and evacuation was not possible.

Though, there have been great advancements in design methodologies, failures of dams and water retaining structures continue to occur. Failure of the Malpasset concrete dam in France in 1959 led to 433 casualties and eventually prompted the introduction of dam safety legislation into France. In October 1963, 2000 people died in Italy, when a landslide fell into the Vaiont reservoir creating a flood wave some 100 m high that overtopped the dam and flooded into the downstream valley. In July 1985, about 90% of the 300 people living in Stava near the Stave Dam in Italy also died when this mine tailings dam failed. More recently, in May 1999, a dam failed in Southern Germany causing 4 deaths and over 1 billion Euro of damage. In Spain 1997, failure of a dam on the Guadalquivir river, not far from Sevilla, caused immense ecological damage from the release of polluted sediments into the river valley. Similarly, in Romania earlier this year, failure of a mine tailings dam released lethal quantities of cyanide into the river system, polluting the environment and a major source of drinking water for both Romania and Hungary.

In India, the breaching of Kodaganar Dam (Tamil Nadu) in year 1977 caused a huge loss of property in downstream area. About 2000 people died due to breaching of Machhu II dam (Gujarat) in year 1979 and the flood wave of order of 10 m caused a heavy devastation in Morvi town and nearby villages. In year 2005, the failure of Nand Gavan dam in Maharashtra and Pratapura dam in Gujarat caused severe flooding in downstream area.

The above instances of dam breaks establish that hazard posed by dams, large and small alike, is very real. As public awareness of these potential hazards grows, and tolerance of catastrophic environmental impact and loss of life reduces, managing and minimizing the risk from individual structures is becoming an essential requirement rather than a management option.

6.1.2 NEED FOR DAM BREAK MODELING

The first European Law on dam break was introduced in France in 1968 following the earlier Malpasset Dam failure that was responsible for more than 400 injuries. Since then many countries have also established requirements and in others, dam owners have established guidelines for assessment. In India, Risk assessment and disaster management plan has been made a mandatory requirement while submitting application for environmental clearance in respect of river valley projects. Preparation of Emergency Action Plan after detailed dam break study has become a major component of dam safety programme of India.

The extreme nature of dam break floods means that flow conditions will far exceed the magnitude of most natural flood events. Under these conditions, flow will behave differently to conditions assumed for Normal River flow modeling and areas will be inundated, that are not normally considered. This makes dam break modeling a separate study for the risk management and emergency action plan.

The objective of dam break modeling or flood routing is to simulate the movement of a dam break flood wave along a valley or indeed any area downstream that would flood as a result of dam failure. The key information required at any point of interest within this flood zone is generally:

- Travel time of flood water
- Peak water level – extent of inundation
- Peak discharge
- Duration of flooding

The nature, accuracy and format of information produced from a dam break analysis will be influenced by the end application of the data.

Emergency Planning

To reasonably prepare an emergency plan, it will be necessary for the dam break analysis to provide:

- Inundation maps at a scale sufficient to determine the extent of and duration of flooding
- Timing of the arrival and peak of the flood wave

Development Control

Development control will focus mainly on the extent of possible inundation resulting from different failure scenarios. Consideration may also be given to the characteristics of the population at risk.

6.1.3 PRESENT DAM BREAK MODELING STUDY

The present study for the Pauk H.E. Project comprises of the following hydrodynamic simulations due to occurrence of:

- PMF with Dam break with initial reservoir level at top of the dam
- PMF without dam in place (virgin condition)

The study comprises of:

1. Prediction of outflow hydrograph due to dam breach
2. Routing of dam breach flood hydrograph through the downstream valley to get the maximum water level and discharge along with time of travel at different locations of the river downstream of the dam
3. Routing the design flood hydrograph through the reservoir and downstream valley without dam breach to get the maximum discharge and water level at different locations of the river downstream of the dam
4. Channel routing the design flood hydrograph through the downstream valley in the virgin condition of Yargyap Chu i.e. without Pauk Dam to get the maximum discharge and water level at different locations of the river downstream of the dam

6.2

DAM BREAK MODELING PROCESS

6.2.1 INTRODUCTION TO DAM BREAK MODELING

Generally, dam break modeling can be carried out by either i) scaled physical hydraulic models, or ii) mathematical simulation using computer. A modern tool to deal with this problem is the mathematical model, which is most cost effective and reasonably solves the governing flow equations of continuity and momentum by computer simulation.

Mathematical modeling of dam breach floods can be carried out by either one dimensional analysis or two dimensional analysis. In one dimensional analysis, the information about the magnitude of flood, i.e., discharge and water levels, variation of these with time and velocity of flow through breach can be had in the direction of flow. In the case of two dimensional analysis, the additional information about the inundated area, variation of surface elevation and velocities in two dimension can also be assessed.

One dimensional analysis is generally accepted, when valley is long and narrow and the flood wave characteristics over a large distance from the dam are of main interest. On the other hand, when the valley widens considerably downstream of dam and large area is likely to be flooded, two dimensional analysis is necessary. In the instant case, as the Narmada valley is long and the flood wave characteristics over a large distance from the dam are of main interest, one dimensional modeling was adopted.

6.2.2 HYDRODYNAMIC MODELING

The essence of dam break modeling is hydrodynamic modeling, which involves finding solution of two partial differential equations 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;

A_0 = 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.

6.2.3 SELECTION OF MODEL

Selection of an appropriate model to undertake dam break flood routing is essential to ensure the right balance between modeling accuracy and cost (both in terms of software cost and time spent in developing & running the model). In the instant case, MIKE 11 model developed by Danish Hydraulic Institute has been selected for the present study because of its wide acceptability in India and abroad.

6.2.4 MIKE 11 MODEL

The core of the MIKE 11 system consists of the HD (hydrodynamic) module, which is capable of simulating unsteady flows in a network of open channels. The results of a HD simulation consist of time series of water levels and discharges. MIKE 11 hydrodynamic module is an implicit, finite difference model for unsteady flow computation. 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 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 cannot 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. The solution algorithm for the different flow descriptions is identical in the inner programme structure, implying that the user does not have to distinguish between the different computational levels, when running the program. In the instant case, dynamic wave approach was adopted for a better simulation.

Hydrodynamic module utilizes a space staggered grid consisting of alternating **h** and **Q** points, i.e., points where water levels (**h**) and discharges (**Q**) are computed sequentially. Topographic data are entered at the **h** points, and discharge relations are evaluated at **Q** points. During simulations, the complete non-linear equations of open channel flow are solved numerically at the grid points at specified time intervals for the given boundary conditions.

6.2.4.1 Solution Technique

In order to obtain a stable solution to the finite difference scheme, two conditions viz. (i) Velocity condition and (ii) Courant condition have to be satisfied.

(i) Velocity condition: $(V.\Delta t/\Delta x) \leq 1\text{-}2$

(ii) Courant condition: $C_r = [(V+\sqrt{(g.d)}).\Delta t]/\Delta x \leq 10\text{-}15$

$\mathbf{C_r}$ is the Courant number, **v** is the cross-sectional mean velocity, **g** is the acceleration due to gravity, **d** is the mean depth, **Δt** is the time step, **Δx** is the space step (the distance between adjacent **h**-points)

The most important considerations determining the selection of space and time steps for a particular model application are the expected wave lengths and duration of the wave period, and the ability to adequately resolve the channel topography. The space step length must be chosen ensuring a sufficient number of points along the channel axis to resolve the expected waves. The wavelength is determined by the wave period and the speed of propagation. A second concern is the adequate resolution of rapid changes in topography along the channel axis, and this may require extra grid points. The time step must be selected so that all expected significant wave periods are adequately resolved in time. As the duration of tidal waves is generally shorter than flood waves, the time step of a hydrodynamic model, which simulates tidal flows requires a shorter time step than that used in flood wave computations.

The solution to the combined system of equations at each time step is performed in a computational grid consisting of alternative **Q**-point and **h**-point, i.e. points where the discharge "Q" and water level "h" respectively, are computed at each time step. A typical layout of channel section with computational net is shown in **Figure 6.2.1**.

The computational grid is generated by the model on the basis of the user requirements. Q-points are always placed midway between neighbouring h-points, while the distance between h-point may differ. The discharge will, as a rule, be defined as positive in the positive x-direction (increasing chainage).

6.2.4.2 Boundary conditions in general

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, (iii) internal inflows, and (iv) wind friction. 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.

The structure description combines a wide range of elements covering weirs, narrow cross-sections, flood plains, reservoirs operations, etc., and which can be regarded as an internal boundary condition. The description is obtained by replacing the momentum equation with an h-Q-h relation or an h-Q relation. The grid to be used to describe a structure will consist of **h**-point on both side, and a **Q**-point at the structure.

Lateral inflows can also be accommodated in MIKE 11 Hydrodynamic module (HD). The lateral inflows are specified at **h**-points, and are included in the continuity description.

6.2.4.3 Topographical requirement and discretization

MIKE 11 HD is a physical modeling system, and hence, data related to the detailed physical characteristics of the study area must be obtained, if realistic results are to be expected. Topographic data are necessary to provide an adequate geometrical and topographical description of the river system, flood plains, and all important structures.

First, the layout of the channel network is determined, and all significant channels identified, including the locations of the main channel confluences and bifurcations. Flood cells subject to inundation must be delimited, and the network of discharge exchange between the flood cells and the main river channels need to be identified.

Cross-sections are required at regular intervals along the river. These must extend up to the river bank to encompass any natural or man-made river embankments. In the model schematization, the available cross-sections are placed at **h**-points. The cross-sections should be representative of the entire channel reach between the adjacent **Q**-points. Hence, channels which exhibit highly irregular cross-sectional variations require denser grid, and hence, have greater data requirements.

The equations of one dimensional flow assume a horizontal water level surface across the channel section. Where flow occurs over wide flood plains, which are separated from the main river channel by natural levees or manmade embankments, a purely one dimensional description is no longer adequate. The description of such areas, called flood cells, is readily accommodated by MIKE 11 module through linking of the individual cells via an appropriate discharge formulation. For example, where the flood cell boundary constitutes a road or flood embankment, the discharge relation describing the exchange of flows between the cells by overtopping of the embankment is a simple weir formulation. Where flood cells are interconnected by road culverts, the standard culvert formulation of MIKE 11 HD may be used.

Longitudinal profiles along the flood cell embankments, which lie directly adjacent to the main river are also required to establish the locations and levels at which overbank spilling may occur. Similar profiles are required along the embankments or roads, which separate the individual flood cells, if overbank spilling is possible. Topographic input for flood cells consists of a flooded area / water level elevation relation, such that the storage characteristics for each cell may be identified.

Possible sources of data for the topographical input include contour maps, hydrographic charts, aerial photographs, satellite imagery, etc. However, in the majority of cases, sufficiently detailed information can only be obtained from controlled field surveys. It is essential that all topographical data levels relate to a common fixed reference level, preferably mean sea level.

Besides topographic data, hydrometric data are necessary to enable the model to be calibrated against actual events, and thus, provide a basis for verification of the chosen schematization. Hydrometric data are also required at the model boundaries for any subsequent operation of the model. The main types of hydrometric data required are water levels and discharges.

6.2.5 MIKE 11 Model set-up

The Dam Break Module in MIKE 11 simulates the outflow hydrograph resulting from the failure of a dam. The model set-up consists of a single or several channels, reservoirs, dam break structures and other auxiliary dam structures such as spillways, bottom outlets etc. As the flood propagation due to the dam break will be of highly unsteady nature, the river course needs to be described accurately through the use of as many cross-sections as possible, particularly where the cross-section is changing rapidly. Further, the cross-sections should extend as far as possible to cover the highest modelled water level, which normally will be in excess of the highest recorded flood level. If the modelled water level exceeds the highest level in the cross-section for a particular location, MIKE 11 will extrapolate the processed Data as a vertical wall, and this will give conservative results.

6.2.5.1 River channel set-up

The river channel set-up for dam break modeling is the same as for the HD model except that the dam break structure is located in a separate reservoir branch, which contains 3 calculation points, i.e., two h-points and one Q-point. If a spillway is added to the dam, it can be described as a separate branch with 3 calculation points. The dam and spillways are located at a Q-point. The river set-up with a dam and, with dam and spillway are shown in **Figure 6.2.2** and **Figure 6.2.3** respectively.

6.2.5.2 Description of reservoir and appurtenant structures

<u>**Reservoir**</u>

To obtain an accurate description of the reservoir storage characteristics, the reservoir is normally modelled as a single **h**-point in the model. This will usually correspond to the upstream boundary of the model, where also the inflow hydrograph is also specified.

The description of the reservoir storage is entered in the processed data. The surface storage area of the dam is described as a function of the water level and it is entered as additional flooded area. The lowest water level given for the reservoir should be somewhere below the final breach elevation of the dam.

The cross-sectional area is set to a large finite value and is used only for calculating the inflow head loss into the breach. The inflow head loss can be calculated as :

$$\Delta H = (V_s^2 / 2g)\, C_i \,[1-(A_s / A_{res})]$$

Where, V_s = Velocity through the breach
C_i = Inflow head loss coefficient
A_s = Flow area through the breach, and
A_{res} = Cross-sectional area of the reservoir

In order to obtain a reasonable head loss description it is only necessary that $A_{res} >> A_s$ so that $[1-(A_s / A_{res})] = 1$. The hydraulic radius is set to any non-zero value.

The total surface area of the reservoir is calculated as:

$$A_{total} = b.2\Delta x + \text{Additional flooded area}$$

Since the total surface area is already described by the additional flooded area, the first term should be equal to zero. Therefore, the width b should be set to zero.

Dam

At the **Q** point, where the dam break structure is located, the momentum equation is replaced by an equation, which describes the flow through the structure. As the momentum equation is not used at the **Q** point, the Δx – step is of no relevance. The maximum Δx for the river branch, where the dam is to be placed should, therefore, be greater than the distance between two cross-sections in the reservoir branch, so that no cross-section is interpolated between the actual cross-sections.

<u>**Spillways and other structures**</u>

At the node, where two branches meet (Fig 8) the surface flooded area is taken as the sum of the individual flooded areas specified at the **h**-points. Therefore, if the reservoir storage has already been specified at the reservoir **h**-point, the spillway **h**-point should not contain any flooded areas. Both the width b, and the "additional flooded area" should be set to zero and other parameters such as the cross-sectional area and hydraulic radius should be the same as for the reservoir.

Boundary conditions for dam break modeling

The boundary conditions must be specified at both upstream and downstream limits of the model. The upstream boundary will generally be an inflow into the reservoir at the first reservoir **h**-point. The downstream boundary will generally be a stage-discharge relationship at the last cross section of the set up.

6.2.6 SPECIFICATIONS OF DAM BREAK STRUCTURES

The following information relating to dam break structures need to be specified:

(i) Geometrical specifications
(ii) Breach characteristics
(iii) Failure moment, and
(iv) Failure mode

6.2.6.1 Breach development

Earth and Rockfill dams usually do not collapse instantaneously, but they develop breaches, which increase gradually. The failure time may vary between a few minutes up to a few hours, depending on amongst other, the dam geometry and the construction material. The development of the breach determines the breach outflow hydrograph, and an accurate description of the breach development is, therefore, required in "near field" dam breach studies. In the "far-field" studies, an accurate flood routing procedure is of more importance, because the outflow variation is rapidly damped out as the flood propagates downstream.

6.2.6.2 Failure modes

The dam break module of MIKE 11 allows selection of one of various breach development modes. Either linear failure mechanism or an erosion based formulation may be selected. The linear failure mode assumes a linear increase in the breach dimensions in time between specified limits. In the erosion based mode, the increase in breach dimensions is calculated from the prevailing hydraulic conditions in the breach, and from the given geometrical data. For both modes, limits of the final breach width and level are specified. These may be determined, for example, by the original valley embankments.

a) Linear failure modes

The necessary data required to fully specify a linear dam failure are shown in **Figure 6.2.4**. In addition, the user specifies the duration of the breach development and whether the failure is to commence at a given time, or is initiated by overtopping of the dam. This facility has applications in simulating the cascading failure of several dams located on the same river.

b) Erosion based failure

The enlargement of the breach in earth fill dams from erosion of the dam core material may also be determined from sediment transport considerations. Erosion based breach formulations are based on sediment continuity equation for the breach. Numerous sediment transport formulae are available, of which two have been implemented in the breach formulation, being those of Engelund-Hansen (1967), and Meyer-Peter and Muller (1947). Modeling of the variation of the width of the breach is more difficult to relate to the classical theories of sediment transport. Due to the development of a wall boundary layer along the often very steep side walls of the breach, the theories for bed load and suspended load do not apply. As an approximation, the sediment transport at the sloping walls is assumed to be proportional to that in the central part of the breach. The coefficient of proportionality (side erosion index) is of the order of 0.5 – 1.0.

6.2.7 INITIAL CONDITIONS

Though in many cases, dam failure may occur on a dry river bed downstream of the dam, but such conditions are not possible in MIKE 11, which require a finite depth of water, in order to ensure “the continuity” of the finite difference algorithm. Therefore, before a dam break is actually simulated, it is necessary to create a steady state “hot-start” file, which can be used for all subsequent dam break simulation. This file is created by:

(i) Giving a lateral inflow at the first **h**-point in the river
(ii) Setting the inflow into the reservoir to zero, and
(iii) Specifying the dam break structure to fail by overtopping, ensuring that the dam crest level is greater than the specified reservoir level.

Initial conditions (water level and discharge) must be specified in HD parameter file, including the reservoir level, at which the dam break simulation should commence. The set-up should be run until a steady state condition is reached (i.e., Q=constant=lateral inflow up to the downstream boundary).

6.2.8 DAM BREAK SIMULATIONS

The dam break simulation may be carried out using the hotstart file generated as mentioned above, specifying the upstream boundary as the inflow hydrograph. The time step depends upon the slope of the river bed and should be selected of the order of 0.5 to 5 minutes according to the slope.

6.3

PAUK HYDRO-ELECTRIC PROJECT

6.3.1 SALIENT FEATURES OF THE PROJECT

The salient features of the Pauk HE Project are given below;

I.	**Location**	
i)	State	Arunachal Pradesh
ii)	District	West Siang
iii)	River	Yargyap Chu
iv)	Latitude	$94^0$14’ 43” E
v)	Longitude	28^0 32’ 46” N
II.	**Hydrology**	
i)	Total catchment area	982 sq.km
ii)	Maximum design flood	3665 cumec
iv)	Probable Maximum Flood (PMF)	3665 cumec
III.	**Reservoir**	
i)	FRL	El. 1540 m
ii)	MWL	El. 1548.5 m
iii)	MDDL	El. 1520 m
iv)	Water spread area at FRL	34 Ha
v)	Total storage	11.5 M Cum
vi)	Active Storage	5.7 M Cum
IV.	**Arch Dam**	
i)	Length at top	150 m
ii)	Non-overflow	31.95 m
iii)	Top of dam	El. 1550 m
iv)	Foundation level	1445 m

v)	River bed level at dam site	1475 m

V. Spillway

i)	Type	Free Ogee Spillway
ii)	Maximum discharge capacity	3700 cumec
iii)	Crest elevation (Ogee)	El. 1540 m
iv)	Length of spillway	73.2

VI. Power house

i)	Type	Surface
ii)	Installed capacity	3 x 48.3 MW
iii)	Type of turbine	Vertical Francis
iv)	Head race tunnel	2350 m length, 119 cumecs design discharge

6.4

INPUT DATA AND MODEL SETUP

6.4.1 INPUT DATA REQUIREMENT

Dam break flood analysis requires a range of data to depict accurately to the extent possible the topography and hydraulic conditions of the river course and dam break phenomenon. The important data required are;

(i) Cross sections of the river from dam site and up to location downstream of the dam to which the study is required

(ii) Elevation-surface area relationship of the reservoir

(iii) Rating curve of spillway and sluices

(iv) Salient features of the all hydraulic structures at the dam site and also in the study reach of the river

(v) Design flood hydrograph

(vi) Stage-discharge relationship at the last river cross section of the study area

(vii) Manning’s roughness coefficient for different reaches of the river under study

(viii) Rating curve of all the hydraulic structures in the study reach of the river

For the present study, the following data supplied has been used;

6.4.1.1 River cross sections

For dam break studies of Pauk HE Project, the Yargyap Chu for a length of 92.784 km downstream of the dam site has been represented in the model by numerous cross sections taken at a suitable interval. In the case of extreme floods the flood water spreads beyond the normal course of the river, where the resistance to flow will be high due to presence of bushes, vegetation etc. Considering the above the Manning's roughness coefficient for the entire study reach of the river has been taken as 0.040.

6.4.1.2 Reservoir and dam

The reservoir has been represented in the model by a separate reservoir branch and its elevation-surface area relation, which has been specified at Chainage “0” km of the reservoir branch, is given in **Table 6.4.1**. The dam has been places at Chainage 500 m of the reservoir branch and dam breach parameters specified therein.

Table 6.4.1: Elevation-Area relationship of the reservoir

Elevation (m)	Surface area (ha)
1445.00	0.00
1514.00	19.50
1517.00	20.90
1520.00	22.50
1523.00	23.90
1526.00	25.30
1529.00	27.40
1532.00	29.10
1535.00	31.60
1538.00	33.80
1540.00 (FRL)	**34.80**
1541.00	35.30
1544.00	37.70
1547.00	39.80
1550.00	42.80

6.4.1.3 Spillway

The spillway has been represented in the model by number and size of spillway gates. The same has been specified at Chainage 500 m of the spillway branch. Rating curve has been shown below:

6.4.1.4 Design Flood Hydrograph

The design flood hydrograph which is the PMF for the present case has been used as for the upstream boundary of the dam break model set up. The same applied at chainage "0" km of the reservoir branch in the model set up, is given in **Table 6.4.2.**

Table 6.4.2: Design Flood Hydrograph (PMF)

Time (hr)	PMF Ordinate (m^3/s)
0	49
1	52
2	57
3	66
4	90
5	171
6	273
7	407
8	600
9	799
10	874
11	966
12	1072
13	1204
14	1387
15	1772
16	2219
17	2690
18	3246
19	3665
20	3419
21	2940

Time (hr)	PMF Ordinate (m^3/s)
22	2437
23	1979
24	1575
25	1228
26	955
27	762
28	595
29	455
30	352
31	277
32	206
33	157
34	114
35	71
36	57
37	52
38	49

6.4.1.5 Downstream boundary

In order to avoid its influence in the study reach normally the downstream boundary should be applied at a distant location from the last river cross section of study reach. The same has been worked out using Manning's equation and applied at a location 93 km downstream of Pauk HE Project dam site, as given in **Table 6.4.3**.

Table 6.4.3: Stage-discharge relationship - downstream boundary of MIKE11 model set up

Stage (m)	Discharge (cumec)
260.07	0.00
261.43	154.28
262.78	1019.90
263.02	1294.79
263.27	1638.79
263.51	2029.65
266.21	10105.22
267.44	15844.98
268.66	23021.67
270.75	38753.50
272.83	58794.74

274.48	77888.23
276.13	100295.63
279.43	155234.51
282.73	223503.72
286.03	305117.02
289.33	400322.91
292.62	509220.84
299.22	766110.43
305.82	1071518.17
312.42	1423154.42
319.02	1819585.49
325.62	2259727.43
332.21	2742867.47
338.81	3269512.82
345.41	3840318.75
352.01	4455818.68
358.61	5116539.94
365.20	5823005.88
371.80	6575832.21
378.40	7375798.16

6.4.1.6 Upstream Elevation View

Upstream Elevation view of the dam has been shown in Plate 6.1.

6.5

DAM BREAK AND OTHER HYDRO-DYNAMIC SIMULATIONS

6.5.1 SELECTION OF DAM BREACH PARAMETERS

Estimation of the dam break flood will depend on time of failure, extent of overtopping before failure, size, shape and time of the breach formation, etc., which are called dam breach parameters. The breach characteristics that are needed as input to the existing dam break models are i) Initial and final breach width; ii) Shape of the breach; iii) Time duration of breach development, and iv) Reservoir level at time of start of breach. The predominant mechanism of breach formation is, to a large extent, dependent on the type of dam and the cause due to which the dam failed.

A study of the different dam failures indicate that concrete arch and gravity dams breach by sudden collapse, overturning or sliding away of the structure due to inadequate design or excessive forces that may result from overtopping, earthquakes and deterioration of the abutment or foundation material.

As per the *UK Dam Break Guidelines and U.S. Federal Energy Regulatory Commission (FERC) Guidelines*, *in the case of* ***concrete gravity dams****, the breach width should be taken 0.2-0.5 times the crest length of the dam. The breach development time for gravity dam should be about 0.2 hour. The breach depth can been taken corresponding to the relatively weaker locations in the dam such as galleries etc or the zero storage elevation of the reservoir.*
For the present case the gross storage of the reservoir is only 11.5 million cubic meter hence in case of any dam breach the storage is not capable to further increase the size of breach, as the reservoir will get emptied instantly. Considering this fact it is appropriate to assume a breach width corresponding

to approximately 0.2 times of the crest length. Accordingly the breach parameter given in Table-6.5.1 has been selected for the dam break study.

Table 6.5.1 Breach parameters

Breach Level (m)		**Breach Width (m)**	**Breach Slope**	**Breach Development Time (Minutes)**	**Remarks**
Initial	Final				
1550	1486	35	0	10	The final breach level at El 1486 m has been taken at gallery

6.5.2 CRITICAL CONDITIONS FOR DAM BREAK STUDY

The critical condition for a dam break study is when the reservoir is at FRL and design flood hydrograph (PMF) is impinged. Accordingly, in the present study, first the reservoir routing has been carried out by impinging the PMF in to the reservoir, assuming that the water level in reservoir is at FRL of 1540 m and the spillway gates are fully open. During the reservoir routing the MDDL has been restricted corresponding to EL 1520 m. The maximum water level reached in the reservoir routing is 1540.30 m, which occurs 19 hours 3.5 minute after the application of PMF. Further, since the top of the dam is at El 1550 m, no overtopping of the dam will occur. Hence for the hypothetical case of dam break simulation and also to get the maximum dam breach flood peak it would be appropriate to assume the starting of the breach, when the reservoir level is at El 1540.30 m.

6.5.3 DAM BREAK SIMULATION (BREACH WIDTH 35M, BREACH DEPTH 64M, BREACH DEVELOPMENT TIME 10 MINUTES)

Taking the above breach parameter and critical condition of para 6.5.2 the dam break condition has been simulated. In the simulation the dam has been assumed to breach 19 hours 3.5 minutes after the impingement of the PMF, when the water level in the reservoir is at EL 1540.30 m. The dam breach flood hydrograph just downstream and 500 m downstream of the dam is given in **Fig-6.5.1**.

The peak of the dam breach flood just downstream of the dam is 4098.562 cumec which includes about 3665 cumec due to PMF itself. Hence the contribution of reservoir storage in the dam breach flood peak is only 433.562 cumec. The maximum discharge, water level and their time of occurrence at different locations of the Yargyap Chu downstream of the dam are given in Table 6.5.2 and 6.5.3 respectively.

Table 6.5.2: Maximum discharge due to dam breach flood (breach width 35m and breach depth 64m)

The breach has been assumed to start on 18-05-2012 07:03:30 hours		
Chainage (m) d/s of Pauk dam	*Maximum discharge (cumec)*	*Time of occurrence (Date:hours:Minutes:seconds)*
YARGYAP CHU 250.00	4098.562	18-05-2012 07:10
YARGYAP CHU 750.00	4093.726	18-05-2012 07:10
YARGYAP CHU 1250.00	4093.241	18-05-2012 07:10
YARGYAP CHU 1750.00	4077.946	18-05-2012 07:10
YARGYAP CHU 2250.00	4067.356	18-05-2012 07:11
YARGYAP CHU 2750.00	4054.766	18-05-2012 07:11
YARGYAP CHU 3250.00	4033.673	18-05-2012 07:12
YARGYAP CHU 3750.00	4024.529	18-05-2012 07:12
YARGYAP CHU 4250.00	4014.224	18-05-2012 07:13
YARGYAP CHU 4750.00	4010.259	18-05-2012 07:13
YARGYAP CHU 5250.00	4010.295	18-05-2012 07:13
YARGYAP CHU 5681.00	4009.127	18-05-2012 07:13
YARGYAP CHU 6181.00	4008.296	18-05-2012 07:14
YARGYAP CHU 6750.00	4004.840	18-05-2012 07:14
YARGYAP CHU 7291.00	4002.582	18-05-2012 07:14
YARGYAP CHU 7791.00	3982.327	18-05-2012 07:15
YARGYAP CHU 8197.50	3980.832	18-05-2012 07:15
YARGYAP CHU 8676.85	3976.669	18-05-2012 07:16
YARGYAP CHU 9305.05	3968.898	18-05-2012 07:16
YARGYAP CHU 9795.35	3952.500	18-05-2012 07:17
YARGYAP CHU 10281.75	3947.441	18-05-2012 07:18
YARGYAP CHU 10812.10	3931.579	18-05-2012 07:19
YARGYAP CHU 11250.00	3930.561	18-05-2012 07:19
YARGYAP CHU 11750.00	3929.788	18-05-2012 07:19
YARGYAP CHU 12250.00	3928.815	18-05-2012 07:20
YARGYAP CHU 12750.00	3927.279	18-05-2012 07:20
YARGYAP CHU 13250.00	3927.281	18-05-2012 07:20
YARGYAP CHU 13750.00	3924.486	18-05-2012 07:20

YARGYAP CHU	14250.00	3920.348	18-05-2012 07:21
YARGYAP CHU	14750.00	3916.652	18-05-2012 07:21
YARGYAP CHU	15321.80	3912.021	18-05-2012 07:22
YARGYAP CHU	15770.25	3911.226	18-05-2012 07:22
YARGYAP CHU	16198.45	3910.083	18-05-2012 07:23
YARGYAP CHU	16750.00	3898.238	18-05-2012 07:23
YARGYAP CHU	17250.00	3895.205	18-05-2012 07:24
YARGYAP CHU	18000.00	3887.365	18-05-2012 07:25
YARGYAP CHU	18750.00	3886.549	18-05-2012 07:25
YARGYAP CHU	19250.00	3879.969	18-05-2012 07:26
YARGYAP CHU	19750.00	3879.131	18-05-2012 07:26
YARGYAP CHU	20250.00	3877.638	18-05-2012 07:27
YARGYAP CHU	20750.00	3871.474	18-05-2012 07:27
YARGYAP CHU	21250.00	3870.736	18-05-2012 07:28
YARGYAP CHU	21750.00	3868.202	18-05-2012 07:28
YARGYAP CHU	22250.00	3866.075	18-05-2012 07:29
YARGYAP CHU	22750.00	3865.253	18-05-2012 07:29
YARGYAP CHU	23250.00	3855.019	18-05-2012 07:30
YARGYAP CHU	23750.00	3850.810	18-05-2012 07:31
YARGYAP CHU	24250.00	3844.373	18-05-2012 07:31
YARGYAP CHU	24750.00	3841.270	18-05-2012 07:32
YARGYAP CHU	25500.00	3832.706	18-05-2012 07:33
YARGYAP CHU	26250.00	3829.695	18-05-2012 07:34
YARGYAP CHU	26750.00	3827.518	18-05-2012 07:35
YARGYAP CHU	27500.00	3823.167	18-05-2012 07:36
YARGYAP CHU	28250.00	3810.505	18-05-2012 07:37
YARGYAP CHU	28657.85	3809.589	18-05-2012 07:37
YARGYAP CHU	29221.15	3806.535	18-05-2012 07:38
YARGYAP CHU	29813.30	3805.096	18-05-2012 07:39
YARGYAP CHU	30250.00	3804.817	18-05-2012 07:39
YARGYAP CHU	30750.00	3804.596	18-05-2012 07:40
YARGYAP CHU	31215.60	3804.213	18-05-2012 07:40
YARGYAP CHU	31715.60	3802.172	18-05-2012 07:41
YARGYAP CHU	32500.00	3799.122	18-05-2012 07:42
YARGYAP CHU	33500.00	3795.081	18-05-2012 07:43
YARGYAP CHU	34500.00	3793.686	18-05-2012 07:44
YARGYAP CHU	35500.00	3791.365	18-05-2012 07:45
YARGYAP CHU	36500.00	3789.707	18-05-2012 07:45
YARGYAP CHU	37500.00	3788.813	18-05-2012 07:46
YARGYAP CHU	38500.00	3784.970	18-05-2012 07:47
YARGYAP CHU	39500.00	3781.107	18-05-2012 07:49
YARGYAP CHU	40500.00	3780.221	18-05-2012 07:49
YARGYAP CHU	41500.00	3777.543	18-05-2012 07:50
YARGYAP CHU	42500.00	3775.756	18-05-2012 07:51
YARGYAP CHU	43500.00	3769.972	18-05-2012 07:53
YARGYAP CHU	44500.00	3765.031	18-05-2012 07:54

YARGYAP CHU	45500.00	3761.198	18-05-2012 07:56
YARGYAP CHU	46500.00	3757.878	18-05-2012 07:57
YARGYAP CHU	47420.20	3754.423	18-05-2012 07:59
YARGYAP CHU	48260.60	3751.814	18-05-2012 08:00
YARGYAP CHU	48941.80	3749.383	18-05-2012 08:01
YARGYAP CHU	49463.80	3747.708	18-05-2012 08:02
YARGYAP CHU	50136.68	3743.820	18-05-2012 08:03
YARGYAP CHU	50960.45	3739.542	18-05-2012 08:05
YARGYAP CHU	51784.21	3736.438	18-05-2012 08:06
YARGYAP CHU	52625.50	3735.375	18-05-2012 08:08
YARGYAP CHU	53484.30	3731.719	18-05-2012 08:09
YARGYAP CHU	54332.90	3728.634	18-05-2012 08:11
YARGYAP CHU	55171.30	3727.140	18-05-2012 08:12
YARGYAP CHU	56009.70	3723.931	18-05-2012 08:14
YARGYAP CHU	56838.38	3722.479	18-05-2012 08:15
YARGYAP CHU	57657.32	3721.150	18-05-2012 08:16
YARGYAP CHU	58440.55	3720.321	18-05-2012 08:18
YARGYAP CHU	59188.05	3719.807	18-05-2012 08:19
YARGYAP CHU	59935.55	3717.735	18-05-2012 08:20
YARGYAP CHU	60687.00	3716.008	18-05-2012 08:21
YARGYAP CHU	61442.40	3715.479	18-05-2012 08:22
YARGYAP CHU	62197.80	3714.875	18-05-2012 08:23
YARGYAP CHU	62976.38	3707.919	18-05-2012 08:26
YARGYAP CHU	63778.13	3705.773	18-05-2012 08:27
YARGYAP CHU	64559.29	3703.601	18-05-2012 08:29
YARGYAP CHU	65319.85	3701.785	18-05-2012 08:30
YARGYAP CHU	66080.41	3699.879	18-05-2012 08:32
YARGYAP CHU	66931.98	3698.470	18-05-2012 08:34
YARGYAP CHU	67874.52	3696.122	18-05-2012 08:35
YARGYAP CHU	68784.07	3693.847	18-05-2012 08:37
YARGYAP CHU	69660.60	3690.392	18-05-2012 08:39
YARGYAP CHU	70537.13	3686.440	18-05-2012 08:41
YARGYAP CHU	71311.84	3682.481	18-05-2012 08:43
YARGYAP CHU	71984.70	3680.674	18-05-2012 08:45
YARGYAP CHU	72657.57	3679.554	18-05-2012 08:46
YARGYAP CHU	73328.59	3678.862	18-05-2012 08:47
YARGYAP CHU	73997.75	3678.259	18-05-2012 08:48
YARGYAP CHU	74666.91	3677.140	18-05-2012 08:49
YARGYAP CHU	75341.80	3675.046	18-05-2012 08:51
YARGYAP CHU	76022.40	3673.433	18-05-2012 08:52
YARGYAP CHU	76703.00	3672.056	18-05-2012 08:54
YARGYAP CHU	77383.34	3671.379	18-05-2012 08:55
YARGYAP CHU	78063.41	3668.911	18-05-2012 08:57
YARGYAP CHU	78743.48	3665.792	18-05-2012 08:59
YARGYAP CHU	79581.54	3661.225	18-05-2012 09:02
YARGYAP CHU	80577.60	3653.904	18-05-2012 09:05

YARGYAP CHU 81409.87	3646.304	18-05-2012 09:09
YARGYAP CHU 82078.34	3643.122	18-05-2012 09:12
YARGYAP CHU 82746.82	3641.891	18-05-2012 09:14
YARGYAP CHU 83451.78	3641.758	18-05-2012 09:15
YARGYAP CHU 84193.22	3639.869	18-05-2012 09:17
YARGYAP CHU 84934.66	3608.208	18-05-2012 09:20
YARGYAP CHU 85793.94	3550.857	18-05-2012 09:29
YARGYAP CHU 86771.06	3522.383	18-05-2012 09:42
YARGYAP CHU 87717.45	3513.252	18-05-2012 09:51
YARGYAP CHU 88633.09	3512.188	18-05-2012 09:54
YARGYAP CHU 89426.55	3511.822	18-05-2012 09:56
YARGYAP CHU 90097.83	3511.463	18-05-2012 09:58
YARGYAP CHU 90769.10	3510.994	18-05-2012 10:00
YARGYAP CHU 91524.60	3510.504	18-05-2012 10:02
YARGYAP CHU 92364.34	3510.248	18-05-2012 10:04

From the Table 6.5.3 it can be seen that the rise in water level along the reach of the river is about 3.5 m to 12.3 m.

Table 6.5.3: Maximum water level due to dam breach flood (breach width 35m and breach depth 64m)

Note : YARGYAP CHU 500.00 means location of Yargyap chu 500 m d/s of Pauk dam axis. The same way all other locations may be read			
Chainage (m) d/s of Pauk dam	Bed Level (m)	*Maximum water level (m)*	*Time of occurrence (Date:hours:Minutes:seconds)*
YARGYAP CHU 0.00	1475.820	1479.319	18-05-2012 07:10
YARGYAP CHU 500.00	1473.750	1478.883	18-05-2012 07:10
YARGYAP CHU 1000.00	1463.712	1467.538	18-05-2012 07:10
YARGYAP CHU 1500.00	1431.766	1437.994	18-05-2012 07:10
YARGYAP CHU 2000.00	1420.311	1425.677	18-05-2012 07:11
YARGYAP CHU 2500.00	1405.073	1409.944	18-05-2012 07:11
YARGYAP CHU 3000.00	1391.427	1397.452	18-05-2012 07:12
YARGYAP CHU 3500.00	1385.692	1393.365	18-05-2012 07:12
YARGYAP CHU 4000.00	1384.200	1390.957	18-05-2012 07:13
YARGYAP CHU 4500.00	1382.000	1388.220	18-05-2012 07:13
YARGYAP CHU 5000.00	1376.690	1380.718	18-05-2012 07:13
YARGYAP CHU 5500.00	1346.350	1351.777	18-05-2012 07:13
YARGYAP CHU 5862.00	1336.388	1340.812	18-05-2012 07:14
YARGYAP CHU 7000.00	1300.679	1304.880	18-05-2012 07:14
YARGYAP CHU 7582.00	1255.575	1262.373	18-05-2012 07:15
YARGYAP CHU 8000.00	1252.197	1257.154	18-05-2012 07:15
YARGYAP CHU 8395.00	1219.948	1224.711	18-05-2012 07:16
YARGYAP CHU 8958.70	1195.480	1202.926	18-05-2012 07:16

YARGYAP CHU 9651.40	1176.690	1187.025	18-05-2012 07:17
YARGYAP CHU 9939.30	1176.557	1185.271	18-05-2012 07:18
YARGYAP CHU 10624.20	1169.690	1176.179	18-05-2012 07:19
YARGYAP CHU 11000.00	1160.960	1168.786	18-05-2012 07:19
YARGYAP CHU 11500.00	1148.880	1157.452	18-05-2012 07:19
YARGYAP CHU 12000.00	1135.390	1144.392	18-05-2012 07:19
YARGYAP CHU 12500.00	1102.717	1112.368	18-05-2012 07:20
YARGYAP CHU 13000.00	1091.290	1096.569	18-05-2012 07:20
YARGYAP CHU 13500.00	1053.000	1057.486	18-05-2012 07:20
YARGYAP CHU 14000.00	1034.095	1041.502	18-05-2012 07:21
YARGYAP CHU 14500.00	1031.259	1038.292	18-05-2012 07:21
YARGYAP CHU 15000.00	1020.715	1028.609	18-05-2012 07:22
YARGYAP CHU 15643.60	1013.590	1017.786	18-05-2012 07:22
YARGYAP CHU 15896.90	985.188	990.534	18-05-2012 07:22
YARGYAP CHU 16500.00	959.000	966.519	18-05-2012 07:23
YARGYAP CHU 17000.00	957.960	963.610	18-05-2012 07:24
YARGYAP CHU 17500.00	943.291	949.096	18-05-2012 07:25
YARGYAP CHU 18500.00	913.480	919.505	18-05-2012 07:25
YARGYAP CHU 19000.00	886.391	894.930	18-05-2012 07:26
YARGYAP CHU 19500.00	882.395	887.043	18-05-2012 07:26
YARGYAP CHU 20000.00	868.385	873.936	18-05-2012 07:27
YARGYAP CHU 20500.00	853.543	862.204	18-05-2012 07:27
YARGYAP CHU 21000.00	852.810	858.316	18-05-2012 07:28
YARGYAP CHU 21500.00	833.316	840.217	18-05-2012 07:28
YARGYAP CHU 22000.00	824.000	832.678	18-05-2012 07:29
YARGYAP CHU 22500.00	820.995	826.226	18-05-2012 07:29
YARGYAP CHU 23000.00	800.280	808.967	18-05-2012 07:30
YARGYAP CHU 23500.00	799.525	806.027	18-05-2012 07:31
YARGYAP CHU 24000.00	787.600	799.385	18-05-2012 07:32
YARGYAP CHU 24500.00	787.500	797.965	18-05-2012 07:32
YARGYAP CHU 25000.00	785.244	795.565	18-05-2012 07:33
YARGYAP CHU 26000.00	782.626	790.072	18-05-2012 07:34
YARGYAP CHU 26500.00	772.432	778.380	18-05-2012 07:34
YARGYAP CHU 27000.00	758.887	767.312	18-05-2012 07:35
YARGYAP CHU 28000.00	751.360	763.636	18-05-2012 07:37
YARGYAP CHU 28500.00	753.930	762.299	18-05-2012 07:38
YARGYAP CHU 28815.70	749.406	757.189	18-05-2012 07:38
YARGYAP CHU 29626.60	740.900	752.326	18-05-2012 07:39
YARGYAP CHU 30000.00	744.478	750.901	18-05-2012 07:39
YARGYAP CHU 30500.00	728.905	732.776	18-05-2012 07:40
YARGYAP CHU 31000.00	701.129	707.372	18-05-2012 07:40
YARGYAP CHU 31431.20	695.789	701.817	18-05-2012 07:41
YARGYAP CHU 32000.00	690.330	696.472	18-05-2012 07:42
YARGYAP CHU 33000.00	676.172	682.615	18-05-2012 07:43
YARGYAP CHU 34000.00	661.445	665.756	18-05-2012 07:44
YARGYAP CHU 35000.00	625.855	633.236	18-05-2012 07:44

YARGYAP CHU 36000.00	606.972	613.442	18-05-2012 07:45
YARGYAP CHU 37000.00	*	578.041	18-05-2012 07:46
YARGYAP CHU 38000.00	538.750	545.047	18-05-2012 07:47
YARGYAP CHU 39000.00	525.260	530.388	18-05-2012 07:49
YARGYAP CHU 40000.00	*	516.599	18-05-2012 07:49
YARGYAP CHU 41000.00	493.210	502.698	18-05-2012 07:50
YARGYAP CHU 42000.00	*	488.520	18-05-2012 07:51
YARGYAP CHU 43000.00	472.075	479.375	18-05-2012 07:53
YARGYAP CHU 44000.00	460.460	468.690	18-05-2012 07:54
YARGYAP CHU 45000.00	449.460	458.199	18-05-2012 07:56
YARGYAP CHU 46000.00	442.722	448.659	18-05-2012 07:57
YARGYAP CHU 47000.00	420.200	426.604	18-05-2012 07:59
YARGYAP CHU 47840.40	*	417.473	18-05-2012 08:00
YARGYAP CHU 48680.80	400.540	408.850	18-05-2012 08:01
YARGYAP CHU 49202.80	*	405.857	18-05-2012 08:02
YARGYAP CHU 49724.80	392.370	403.982	18-05-2012 08:04
YARGYAP CHU 50548.57	*	401.383	18-05-2012 08:05
YARGYAP CHU 51372.33	*	399.174	18-05-2012 08:07
YARGYAP CHU 52196.10	388.560	396.469	18-05-2012 08:07
YARGYAP CHU 53054.90	*	393.001	18-05-2012 08:09
YARGYAP CHU 53913.70	384.330	390.692	18-05-2012 08:11
YARGYAP CHU 54752.10	*	386.537	18-05-2012 08:12
YARGYAP CHU 55590.50	*	383.737	18-05-2012 08:14
YARGYAP CHU 56428.90	374.250	381.979	18-05-2012 08:15
YARGYAP CHU 57247.85	*	376.345	18-05-2012 08:16
YARGYAP CHU 58066.80	364.290	371.142	18-05-2012 08:17
YARGYAP CHU 58814.30	*	367.294	18-05-2012 08:18
YARGYAP CHU 59561.80	*	365.149	18-05-2012 08:20
YARGYAP CHU 60309.30	354.770	362.092	18-05-2012 08:21
YARGYAP CHU 61064.70	*	356.119	18-05-2012 08:22
YARGYAP CHU 61820.10	*	350.228	18-05-2012 08:23
YARGYAP CHU 62575.50	340.462	346.743	18-05-2012 08:26
YARGYAP CHU 63377.25	*	344.930	18-05-2012 08:28
YARGYAP CHU 64179.00	334.740	342.260	18-05-2012 08:29
YARGYAP CHU 64939.57	*	338.772	18-05-2012 08:30
YARGYAP CHU 65700.13	*	335.879	18-05-2012 08:32
YARGYAP CHU 66460.70	324.520	332.611	18-05-2012 08:33
YARGYAP CHU 67403.25	*	327.658	18-05-2012 08:35
YARGYAP CHU 68345.80	314.310	323.250	18-05-2012 08:37
YARGYAP CHU 69222.34	*	320.406	18-05-2012 08:40
YARGYAP CHU 70098.87	*	318.763	18-05-2012 08:42
YARGYAP CHU 70975.40	304.430	316.715	18-05-2012 08:44
YARGYAP CHU 71648.27	*	314.898	18-05-2012 08:45
YARGYAP CHU 72321.13	*	312.955	18-05-2012 08:46
YARGYAP CHU 72994.00	299.320	310.484	18-05-2012 08:47
YARGYAP CHU 73663.16	*	307.682	18-05-2012 08:48

YARGYAP CHU 74332.34	*	305.160	18-05-2012 08:50
YARGYAP CHU 75001.50	294.820	303.114	18-05-2012 08:51
YARGYAP CHU 75682.10	*	301.552	18-05-2012 08:53
YARGYAP CHU 76362.70	*	299.928	18-05-2012 08:54
YARGYAP CHU 77043.30	291.210	297.723	18-05-2012 08:55
YARGYAP CHU 77723.37	*	294.535	18-05-2012 08:58
YARGYAP CHU 78403.44	*	293.319	18-05-2012 09:00
YARGYAP CHU 79083.51	285.450	291.524	18-05-2012 09:03
YARGYAP CHU 80079.57	*	289.482	18-05-2012 09:07
YARGYAP CHU 81075.63	279.670	288.242	18-05-2012 09:11
YARGYAP CHU 81744.11	*	287.198	18-05-2012 09:13
YARGYAP CHU 82412.59	*	285.767	18-05-2012 09:14
YARGYAP CHU 83081.06	275.370	283.562	18-05-2012 09:15
YARGYAP CHU 83822.50	*	279.002	18-05-2012 09:19
YARGYAP CHU 84563.94	*	276.709	18-05-2012 09:50
YARGYAP CHU 85305.38	267.690	276.504	18-05-2012 09:53
YARGYAP CHU 86282.50	*	276.433	18-05-2012 09:53
YARGYAP CHU 87259.62	265.990	276.297	18-05-2012 09:54
YARGYAP CHU 88175.27	*	275.875	18-05-2012 09:55
YARGYAP CHU 89090.92	263.960	274.509	18-05-2012 09:56
YARGYAP CHU 89762.20	*	272.317	18-05-2012 09:59
YARGYAP CHU 90433.47	*	270.586	18-05-2012 10:01
YARGYAP CHU 91104.74	261.630	269.140	18-05-2012 10:02
YARGYAP CHU 91944.47	*	267.047	18-05-2012 10:03
YARGYAP CHU 92784.20	260.080	264.005	18-05-2012 10:04

** cross sections interpolated by MIKE11*

Note: The dates shown are relative dates as used in MIKE11 model simulation

6.5.4 MAXIMUM DISCHARGE AND WATER LEVEL IN YARGYAP CHU DUE TO OCCURRENCE OF PMF WITHOUT DAM BREACH

To know the maximum discharge and water levels at different locations of Yargyap Chu downstream of the dam due to occurrence of PMF, when reservoir is at FRL, but without any dam breach, the simulation has been run. The maximum discharge and water level obtained at the different locations along the river reach is given in Table-6.5.4 and 6.5.5 respectively.

Table 6.5.4 : Maximum discharge due to occurrence of PMF without dam breach

The PMF has been impinged in the reservoir on 17-05-2012 at 12:00:00 hr		
Chainage (m) d/s of Pauk dam	*Maximum discharge (cumec)*	*Time of occurrence (Date:hours:Minutes:seconds)*
YARGYAP CHU 250.00	3664.073	18-05-2012 07:03
YARGYAP CHU 750.00	3663.722	18-05-2012 07:03
YARGYAP CHU 1250.00	3663.701	18-05-2012 07:03
YARGYAP CHU 1750.00	3663.121	18-05-2012 07:04
YARGYAP CHU 2250.00	3662.753	18-05-2012 07:04
YARGYAP CHU 2750.00	3662.302	18-05-2012 07:05
YARGYAP CHU 3250.00	3661.446	18-05-2012 07:05
YARGYAP CHU 3750.00	3661.023	18-05-2012 07:06
YARGYAP CHU 4250.00	3660.596	18-05-2012 07:06
YARGYAP CHU 4750.00	3660.438	18-05-2012 07:07
YARGYAP CHU 5250.00	3660.441	18-05-2012 07:07
YARGYAP CHU 5681.00	3660.389	18-05-2012 07:07
YARGYAP CHU 6181.00	3660.360	18-05-2012 07:07
YARGYAP CHU 6750.00	3660.213	18-05-2012 07:07
YARGYAP CHU 7291.00	3660.122	18-05-2012 07:08
YARGYAP CHU 7791.00	3659.068	18-05-2012 07:08
YARGYAP CHU 8197.50	3658.995	18-05-2012 07:09
YARGYAP CHU 8676.85	3658.772	18-05-2012 07:09
YARGYAP CHU 9305.05	3658.340	18-05-2012 07:10
YARGYAP CHU 9795.35	3657.278	18-05-2012 07:11
YARGYAP CHU 10281.75	3656.975	18-05-2012 07:11
YARGYAP CHU 10812.10	3656.027	18-05-2012 07:12
YARGYAP CHU 11250.00	3655.974	18-05-2012 07:13
YARGYAP CHU 11750.00	3655.933	18-05-2012 07:13
YARGYAP CHU 12250.00	3655.887	18-05-2012 07:13
YARGYAP CHU 12750.00	3655.799	18-05-2012 07:14
YARGYAP CHU 13250.00	3655.801	18-05-2012 07:14
YARGYAP CHU 13750.00	3655.634	18-05-2012 07:14
YARGYAP CHU 14250.00	3655.370	18-05-2012 07:15
YARGYAP CHU 14750.00	3655.148	18-05-2012 07:15
YARGYAP CHU 15321.80	3654.862	18-05-2012 07:16
YARGYAP CHU 15770.25	3654.816	18-05-2012 07:16
YARGYAP CHU 16198.45	3654.753	18-05-2012 07:16
YARGYAP CHU 16750.00	3653.903	18-05-2012 07:18
YARGYAP CHU 17250.00	3653.711	18-05-2012 07:18
YARGYAP CHU 18000.00	3653.189	18-05-2012 07:19
YARGYAP CHU 18750.00	3653.140	18-05-2012 07:19
YARGYAP CHU 19250.00	3652.672	18-05-2012 07:20
YARGYAP CHU 19750.00	3652.618	18-05-2012 07:21
YARGYAP CHU 20250.00	3652.511	18-05-2012 07:21

YARGYAP CHU 20750.00	3652.041	18-05-2012 07:22
YARGYAP CHU 21250.00	3651.989	18-05-2012 07:22
YARGYAP CHU 21750.00	3651.801	18-05-2012 07:23
YARGYAP CHU 22250.00	3651.638	18-05-2012 07:23
YARGYAP CHU 22750.00	3651.585	18-05-2012 07:24
YARGYAP CHU 23250.00	3650.550	18-05-2012 07:25
YARGYAP CHU 23750.00	3650.103	18-05-2012 07:25
YARGYAP CHU 24250.00	3649.280	18-05-2012 07:26
YARGYAP CHU 24750.00	3648.903	18-05-2012 07:27
YARGYAP CHU 25500.00	3648.010	18-05-2012 07:28
YARGYAP CHU 26250.00	3647.729	18-05-2012 07:29
YARGYAP CHU 26750.00	3647.508	18-05-2012 07:30
YARGYAP CHU 27500.00	3646.893	18-05-2012 07:31
YARGYAP CHU 28250.00	3645.291	18-05-2012 07:33
YARGYAP CHU 28657.85	3645.186	18-05-2012 07:33
YARGYAP CHU 29221.15	3644.836	18-05-2012 07:34
YARGYAP CHU 29813.30	3644.670	18-05-2012 07:35
YARGYAP CHU 30250.00	3644.639	18-05-2012 07:35
YARGYAP CHU 30750.00	3644.615	18-05-2012 07:35
YARGYAP CHU 31215.60	3644.567	18-05-2012 07:36
YARGYAP CHU 31715.60	3644.306	18-05-2012 07:36
YARGYAP CHU 32500.00	3643.932	18-05-2012 07:37
YARGYAP CHU 33500.00	3643.399	18-05-2012 07:39
YARGYAP CHU 34500.00	3643.222	18-05-2012 07:39
YARGYAP CHU 35500.00	3642.909	18-05-2012 07:40
YARGYAP CHU 36500.00	3642.686	18-05-2012 07:41
YARGYAP CHU 37500.00	3642.569	18-05-2012 07:42
YARGYAP CHU 38500.00	3642.014	18-05-2012 07:43
YARGYAP CHU 39500.00	3641.429	18-05-2012 07:45
YARGYAP CHU 40500.00	3641.295	18-05-2012 07:45
YARGYAP CHU 41500.00	3640.878	18-05-2012 07:47
YARGYAP CHU 42500.00	3640.580	18-05-2012 07:48
YARGYAP CHU 43500.00	3639.486	18-05-2012 07:49
YARGYAP CHU 44500.00	3638.534	18-05-2012 07:51
YARGYAP CHU 45500.00	3637.774	18-05-2012 07:52
YARGYAP CHU 46500.00	3637.149	18-05-2012 07:54
YARGYAP CHU 47420.20	3636.424	18-05-2012 07:56
YARGYAP CHU 48260.60	3635.852	18-05-2012 07:57
YARGYAP CHU 48941.80	3635.255	18-05-2012 07:58
YARGYAP CHU 49463.80	3634.787	18-05-2012 07:59
YARGYAP CHU 50136.68	3633.708	18-05-2012 08:01
YARGYAP CHU 50960.45	3632.517	18-05-2012 08:02
YARGYAP CHU 51784.21	3631.702	18-05-2012 08:04
YARGYAP CHU 52625.50	3631.421	18-05-2012 08:05
YARGYAP CHU 53484.30	3630.367	18-05-2012 08:07
YARGYAP CHU 54332.90	3629.551	18-05-2012 08:09

YARGYAP CHU	55171.30	3629.123	18-05-2012 08:10
YARGYAP CHU	56009.70	3628.179	18-05-2012 08:12
YARGYAP CHU	56838.38	3627.774	18-05-2012 08:13
YARGYAP CHU	57657.32	3627.396	18-05-2012 08:14
YARGYAP CHU	58440.55	3627.156	18-05-2012 08:16
YARGYAP CHU	59188.05	3626.982	18-05-2012 08:17
YARGYAP CHU	59935.55	3626.336	18-05-2012 08:18
YARGYAP CHU	60687.00	3625.818	18-05-2012 08:20
YARGYAP CHU	61442.40	3625.666	18-05-2012 08:21
YARGYAP CHU	62197.80	3625.439	18-05-2012 08:21
YARGYAP CHU	62976.38	3622.858	18-05-2012 08:24
YARGYAP CHU	63778.13	3622.086	18-05-2012 08:26
YARGYAP CHU	64559.29	3621.323	18-05-2012 08:28
YARGYAP CHU	65319.85	3620.666	18-05-2012 08:29
YARGYAP CHU	66080.41	3619.971	18-05-2012 08:31
YARGYAP CHU	66931.98	3619.465	18-05-2012 08:32
YARGYAP CHU	67874.52	3618.552	18-05-2012 08:35
YARGYAP CHU	68784.07	3617.566	18-05-2012 08:36
YARGYAP CHU	69660.60	3615.967	18-05-2012 08:38
YARGYAP CHU	70537.13	3614.162	18-05-2012 08:40
YARGYAP CHU	71311.84	3612.328	18-05-2012 08:43
YARGYAP CHU	71984.70	3611.459	18-05-2012 08:44
YARGYAP CHU	72657.57	3610.966	18-05-2012 08:46
YARGYAP CHU	73328.59	3610.664	18-05-2012 08:47
YARGYAP CHU	73997.75	3610.391	18-05-2012 08:48
YARGYAP CHU	74666.91	3609.875	18-05-2012 08:49
YARGYAP CHU	75341.80	3608.900	18-05-2012 08:51
YARGYAP CHU	76022.40	3608.147	18-05-2012 08:53
YARGYAP CHU	76703.00	3607.502	18-05-2012 08:54
YARGYAP CHU	77383.34	3607.174	18-05-2012 08:55
YARGYAP CHU	78063.41	3605.883	18-05-2012 08:57
YARGYAP CHU	78743.48	3604.216	18-05-2012 08:59
YARGYAP CHU	79581.54	3601.648	18-05-2012 09:02
YARGYAP CHU	80577.60	3597.367	18-05-2012 09:06
YARGYAP CHU	81409.87	3592.793	18-05-2012 09:11
YARGYAP CHU	82078.34	3591.099	18-05-2012 09:14
YARGYAP CHU	82746.82	3590.520	18-05-2012 09:16
YARGYAP CHU	83451.78	3590.495	18-05-2012 09:17
YARGYAP CHU	84193.22	3589.013	18-05-2012 09:19
YARGYAP CHU	84934.66	3562.865	18-05-2012 09:23
YARGYAP CHU	85793.94	3519.447	18-05-2012 09:35
YARGYAP CHU	86771.06	3498.429	18-05-2012 09:46
YARGYAP CHU	87717.45	3490.944	18-05-2012 09:55
YARGYAP CHU	88633.09	3490.018	18-05-2012 09:58
YARGYAP CHU	89426.55	3489.694	18-05-2012 10:00
YARGYAP CHU	90097.83	3489.379	18-05-2012 10:01

YARGYAP CHU 90769.10	3488.967	18-05-2012 10:03
YARGYAP CHU 91524.60	3488.530	18-05-2012 10:06
YARGYAP CHU 92364.34	3488.301	18-05-2012 10:08

From the Table 6.5.5 it can be seen that the rise in water level along the reach of the river is about 3.2 m to 12.2 m.

Table 6.5.5 : Maximum water level due to occurrence of PMF without dam breach

Chainage (m) d/s of Pauk dam	*Bed Level (m)*	*Maximum water level (m)*	*Time of occurrence (Date:hours:Minutes:seconds)*
YARGYAP CHU 0.00	1475.820	1479.028	18-05-2012 07:03
YARGYAP CHU 500.00	1473.750	1478.562	18-05-2012 07:03
YARGYAP CHU 1000.00	1463.712	1467.288	18-05-2012 07:03
YARGYAP CHU 1500.00	1431.766	1437.691	18-05-2012 07:04
YARGYAP CHU 2000.00	1420.311	1425.458	18-05-2012 07:04
YARGYAP CHU 2500.00	1405.073	1409.701	18-05-2012 07:04
YARGYAP CHU 3000.00	1391.427	1397.161	18-05-2012 07:05
YARGYAP CHU 3500.00	1385.692	1392.988	18-05-2012 07:05
YARGYAP CHU 4000.00	1384.200	1390.617	18-05-2012 07:06
YARGYAP CHU 4500.00	1382.000	1387.911	18-05-2012 07:06
YARGYAP CHU 5000.00	1376.690	1380.500	18-05-2012 07:06
YARGYAP CHU 5500.00	1346.350	1351.495	18-05-2012 07:07
YARGYAP CHU 5862.00	1336.388	1340.573	18-05-2012 07:07
YARGYAP CHU 7000.00	1300.679	1304.656	18-05-2012 07:07
YARGYAP CHU 7582.00	1255.575	1262.077	18-05-2012 07:08
YARGYAP CHU 8000.00	1252.197	1256.914	18-05-2012 07:09
YARGYAP CHU 8395.00	1219.948	1224.537	18-05-2012 07:09
YARGYAP CHU 8958.70	1195.480	1202.594	18-05-2012 07:10
YARGYAP CHU 9651.40	1176.690	1186.752	18-05-2012 07:11
YARGYAP CHU 9939.30	1176.557	1185.018	18-05-2012 07:11
YARGYAP CHU 10624.20	1169.690	1175.957	18-05-2012 07:12
YARGYAP CHU 11000.00	1160.960	1168.447	18-05-2012 07:12
YARGYAP CHU 11500.00	1148.880	1157.088	18-05-2012 07:13
YARGYAP CHU 12000.00	1135.390	1144.027	18-05-2012 07:13
YARGYAP CHU 12500.00	1102.717	1112.154	18-05-2012 07:14
YARGYAP CHU 13000.00	1091.290	1096.349	18-05-2012 07:13
YARGYAP CHU 13500.00	1053.000	1057.289	18-05-2012 07:14
YARGYAP CHU 14000.00	1034.095	1041.213	18-05-2012 07:14
YARGYAP CHU 14500.00	1031.259	1038.089	18-05-2012 07:15
YARGYAP CHU 15000.00	1020.715	1028.426	18-05-2012 07:16
YARGYAP CHU 15643.60	1013.590	1017.658	18-05-2012 07:16
YARGYAP CHU 15896.90	985.188	990.382	18-05-2012 07:16
YARGYAP CHU 16500.00	959.000	966.321	18-05-2012 07:17

YARGYAP CHU 17000.00	957.960	963.453	18-05-2012 07:18
YARGYAP CHU 17500.00	943.291	948.883	18-05-2012 07:19
YARGYAP CHU 18500.00	913.480	919.279	18-05-2012 07:19
YARGYAP CHU 19000.00	886.391	894.661	18-05-2012 07:20
YARGYAP CHU 19500.00	882.395	886.875	18-05-2012 07:20
YARGYAP CHU 20000.00	868.385	873.731	18-05-2012 07:21
YARGYAP CHU 20500.00	853.543	861.957	18-05-2012 07:22
YARGYAP CHU 21000.00	852.810	858.144	18-05-2012 07:22
YARGYAP CHU 21500.00	833.316	839.992	18-05-2012 07:23
YARGYAP CHU 22000.00	824.000	832.486	18-05-2012 07:23
YARGYAP CHU 22500.00	820.995	826.060	18-05-2012 07:23
YARGYAP CHU 23000.00	800.280	808.797	18-05-2012 07:25
YARGYAP CHU 23500.00	799.525	805.815	18-05-2012 07:25
YARGYAP CHU 24000.00	787.600	799.157	18-05-2012 07:27
YARGYAP CHU 24500.00	787.500	797.759	18-05-2012 07:27
YARGYAP CHU 25000.00	785.244	795.369	18-05-2012 07:28
YARGYAP CHU 26000.00	782.626	789.865	18-05-2012 07:29
YARGYAP CHU 26500.00	772.432	778.210	18-05-2012 07:30
YARGYAP CHU 27000.00	758.887	767.141	18-05-2012 07:31
YARGYAP CHU 28000.00	751.360	763.497	18-05-2012 07:33
YARGYAP CHU 28500.00	753.930	762.169	18-05-2012 07:33
YARGYAP CHU 28815.70	749.406	757.043	18-05-2012 07:34
YARGYAP CHU 29626.60	740.900	752.173	18-05-2012 07:35
YARGYAP CHU 30000.00	744.478	750.802	18-05-2012 07:35
YARGYAP CHU 30500.00	728.905	732.672	18-05-2012 07:35
YARGYAP CHU 31000.00	701.129	707.215	18-05-2012 07:36
YARGYAP CHU 31431.20	695.789	701.663	18-05-2012 07:36
YARGYAP CHU 32000.00	690.330	696.323	18-05-2012 07:37
YARGYAP CHU 33000.00	676.172	682.486	18-05-2012 07:38
YARGYAP CHU 34000.00	661.445	665.659	18-05-2012 07:39
YARGYAP CHU 35000.00	625.855	633.120	18-05-2012 07:40
YARGYAP CHU 36000.00	606.972	613.352	18-05-2012 07:41
YARGYAP CHU 37000.00	*	577.946	18-05-2012 07:42
YARGYAP CHU 38000.00	538.750	544.907	18-05-2012 07:43
YARGYAP CHU 39000.00	525.260	530.276	18-05-2012 07:44
YARGYAP CHU 40000.00	*	516.500	18-05-2012 07:45
YARGYAP CHU 41000.00	493.210	502.560	18-05-2012 07:46
YARGYAP CHU 42000.00	*	488.428	18-05-2012 07:47
YARGYAP CHU 43000.00	472.075	479.283	18-05-2012 07:49
YARGYAP CHU 44000.00	460.460	468.524	18-05-2012 07:51
YARGYAP CHU 45000.00	449.460	458.040	18-05-2012 07:52
YARGYAP CHU 46000.00	442.722	448.548	18-05-2012 07:54
YARGYAP CHU 47000.00	420.200	426.536	18-05-2012 07:55
YARGYAP CHU 47840.40	*	417.395	18-05-2012 07:57
YARGYAP CHU 48680.80	400.540	408.739	18-05-2012 07:58
YARGYAP CHU 49202.80	*	405.736	18-05-2012 07:59

YARGYAP CHU 49724.80	392.370	403.867	18-05-2012 08:01
YARGYAP CHU 50548.57	*	401.265	18-05-2012 08:03
YARGYAP CHU 51372.33	*	399.067	18-05-2012 08:04
YARGYAP CHU 52196.10	388.560	396.376	18-05-2012 08:05
YARGYAP CHU 53054.90	*	392.929	18-05-2012 08:07
YARGYAP CHU 53913.70	384.330	390.623	18-05-2012 08:08
YARGYAP CHU 54752.10	*	386.469	18-05-2012 08:10
YARGYAP CHU 55590.50	*	383.665	18-05-2012 08:12
YARGYAP CHU 56428.90	374.250	381.901	18-05-2012 08:13
YARGYAP CHU 57247.85	*	376.269	18-05-2012 08:14
YARGYAP CHU 58066.80	364.290	371.069	18-05-2012 08:15
YARGYAP CHU 58814.30	*	367.230	18-05-2012 08:16
YARGYAP CHU 59561.80	*	365.089	18-05-2012 08:18
YARGYAP CHU 60309.30	354.770	362.031	18-05-2012 08:19
YARGYAP CHU 61064.70	*	356.066	18-05-2012 08:20
YARGYAP CHU 61820.10	*	350.172	18-05-2012 08:22
YARGYAP CHU 62575.50	340.462	346.670	18-05-2012 08:25
YARGYAP CHU 63377.25	*	344.855	18-05-2012 08:26
YARGYAP CHU 64179.00	334.740	342.181	18-05-2012 08:27
YARGYAP CHU 64939.57	*	338.692	18-05-2012 08:29
YARGYAP CHU 65700.13	*	335.807	18-05-2012 08:31
YARGYAP CHU 66460.70	324.520	332.546	18-05-2012 08:32
YARGYAP CHU 67403.25	*	327.588	18-05-2012 08:35
YARGYAP CHU 68345.80	314.310	323.175	18-05-2012 08:37
YARGYAP CHU 69222.34	*	320.322	18-05-2012 08:39
YARGYAP CHU 70098.87	*	318.684	18-05-2012 08:42
YARGYAP CHU 70975.40	304.430	316.631	18-05-2012 08:44
YARGYAP CHU 71648.27	*	314.813	18-05-2012 08:45
YARGYAP CHU 72321.13	*	312.877	18-05-2012 08:46
YARGYAP CHU 72994.00	299.320	310.409	18-05-2012 08:47
YARGYAP CHU 73663.16	*	307.605	18-05-2012 08:48
YARGYAP CHU 74332.34	*	305.089	18-05-2012 08:50
YARGYAP CHU 75001.50	294.820	303.048	18-05-2012 08:52
YARGYAP CHU 75682.10	*	301.488	18-05-2012 08:53
YARGYAP CHU 76362.70	*	299.869	18-05-2012 08:54
YARGYAP CHU 77043.30	291.210	297.670	18-05-2012 08:55
YARGYAP CHU 77723.37	*	294.485	18-05-2012 08:58
YARGYAP CHU 78403.44	*	293.273	18-05-2012 09:01
YARGYAP CHU 79083.51	285.450	291.476	18-05-2012 09:04
YARGYAP CHU 80079.57	*	289.437	18-05-2012 09:09
YARGYAP CHU 81075.63	279.670	288.201	18-05-2012 09:13
YARGYAP CHU 81744.11	*	287.157	18-05-2012 09:14
YARGYAP CHU 82412.59	*	285.729	18-05-2012 09:15
YARGYAP CHU 83081.06	275.370	283.530	18-05-2012 09:16
YARGYAP CHU 83822.50	*	278.977	18-05-2012 09:22
YARGYAP CHU 84563.94	*	276.688	18-05-2012 09:53

YARGYAP CHU 85305.38	267.690	276.481	18-05-2012 09:56
YARGYAP CHU 86282.50	*	276.409	18-05-2012 09:57
YARGYAP CHU 87259.62	265.990	276.274	18-05-2012 09:58
YARGYAP CHU 88175.27	*	275.854	18-05-2012 09:59
YARGYAP CHU 89090.92	263.960	274.490	18-05-2012 10:00
YARGYAP CHU 89762.20	*	272.298	18-05-2012 10:02
YARGYAP CHU 90433.47	*	270.566	18-05-2012 10:04
YARGYAP CHU 91104.74	261.630	269.121	18-05-2012 10:06
YARGYAP CHU 91944.47	*	267.032	18-05-2012 10:07
YARGYAP CHU 92784.20	260.080	263.998	18-05-2012 10:08

- *cross sections interpolated by MIKE11*

6.5.5 MAXIMUM WATER LEVEL IN THE VIRGIN CONDITION OF THE YARGYAP CHU DUE TO OCCURRENCE OF PMF

To know the maximum discharge and water level due to occurrence of PMF in the virgin condition of the Yargyap Chu the necessary simulation has been run. In this case, the PMF has been impinged at chainage “0” of the Yargyap Chu (just d/s of Pauk dam site) without considering the Pauk dam. The maximum discharge and water level obtained at the different locations along the river reach is given in Table 6.5.6 and 6.5.7 respectively.

Table 6.5.6 : Maximum discharge due to occurrence of PMF in virgin river condition

The PMF has been impinged at chainage "0" of Yargyap Chu on 17-05-2012 at 12:00:00 hr		
Chainage (m) d/s of Pauk dam	*Maximum discharge (cumec)*	*Time of occurrence (Date:hours:Minutes:seconds)*
YARGYAP CHU 250.00	3664.888	18-05-2012 07:03
YARGYAP CHU 750.00	3664.328	18-05-2012 07:03
YARGYAP CHU 1250.00	3664.308	18-05-2012 07:03
YARGYAP CHU 1750.00	3663.568	18-05-2012 07:03
YARGYAP CHU 2250.00	3663.114	18-05-2012 07:04
YARGYAP CHU 2750.00	3662.598	18-05-2012 07:04
YARGYAP CHU 3250.00	3661.677	18-05-2012 07:05
YARGYAP CHU 3750.00	3661.237	18-05-2012 07:05
YARGYAP CHU 4250.00	3660.788	18-05-2012 07:06
YARGYAP CHU 4750.00	3660.619	18-05-2012 07:06
YARGYAP CHU 5250.00	3660.623	18-05-2012 07:06
YARGYAP CHU 5681.00	3660.569	18-05-2012 07:07
YARGYAP CHU 6181.00	3660.537	18-05-2012 07:07
YARGYAP CHU 6750.00	3660.382	18-05-2012 07:07
YARGYAP CHU 7291.00	3660.287	18-05-2012 07:07
YARGYAP CHU 7791.00	3659.199	18-05-2012 07:08
YARGYAP CHU 8197.50	3659.126	18-05-2012 07:09
YARGYAP CHU 8676.85	3658.896	18-05-2012 07:09
YARGYAP CHU 9305.05	3658.455	18-05-2012 07:10
YARGYAP CHU 9795.35	3657.377	18-05-2012 07:10
YARGYAP CHU 10281.75	3657.070	18-05-2012 07:11
YARGYAP CHU 10812.10	3656.110	18-05-2012 07:12
YARGYAP CHU 11250.00	3656.056	18-05-2012 07:12
YARGYAP CHU 11750.00	3656.016	18-05-2012 07:13
YARGYAP CHU 12250.00	3655.967	18-05-2012 07:13
YARGYAP CHU 12750.00	3655.879	18-05-2012 07:13
YARGYAP CHU 13250.00	3655.880	18-05-2012 07:13
YARGYAP CHU 13750.00	3655.713	18-05-2012 07:14
YARGYAP CHU 14250.00	3655.446	18-05-2012 07:14
YARGYAP CHU 14750.00	3655.222	18-05-2012 07:15
YARGYAP CHU 15321.80	3654.934	18-05-2012 07:16
YARGYAP CHU 15770.25	3654.887	18-05-2012 07:16
YARGYAP CHU 16198.45	3654.825	18-05-2012 07:16
YARGYAP CHU 16750.00	3653.968	18-05-2012 07:17
YARGYAP CHU 17250.00	3653.776	18-05-2012 07:18
YARGYAP CHU 18000.00	3653.251	18-05-2012 07:19
YARGYAP CHU 18750.00	3653.200	18-05-2012 07:19
YARGYAP CHU 19250.00	3652.730	18-05-2012 07:20

YARGYAP CHU 19750.00	3652.676	18-05-2012 07:20
YARGYAP CHU 20250.00	3652.568	18-05-2012 07:21
YARGYAP CHU 20750.00	3652.096	18-05-2012 07:22
YARGYAP CHU 21250.00	3652.043	18-05-2012 07:22
YARGYAP CHU 21750.00	3651.855	18-05-2012 07:22
YARGYAP CHU 22250.00	3651.692	18-05-2012 07:23
YARGYAP CHU 22750.00	3651.637	18-05-2012 07:23
YARGYAP CHU 23250.00	3650.600	18-05-2012 07:25
YARGYAP CHU 23750.00	3650.152	18-05-2012 07:25
YARGYAP CHU 24250.00	3649.325	18-05-2012 07:26
YARGYAP CHU 24750.00	3648.947	18-05-2012 07:27
YARGYAP CHU 25500.00	3648.053	18-05-2012 07:28
YARGYAP CHU 26250.00	3647.770	18-05-2012 07:29
YARGYAP CHU 26750.00	3647.549	18-05-2012 07:29
YARGYAP CHU 27500.00	3646.932	18-05-2012 07:31
YARGYAP CHU 28250.00	3645.326	18-05-2012 07:32
YARGYAP CHU 28657.85	3645.221	18-05-2012 07:33
YARGYAP CHU 29221.15	3644.871	18-05-2012 07:34
YARGYAP CHU 29813.30	3644.705	18-05-2012 07:35
YARGYAP CHU 30250.00	3644.674	18-05-2012 07:35
YARGYAP CHU 30750.00	3644.648	18-05-2012 07:35
YARGYAP CHU 31215.60	3644.602	18-05-2012 07:36
YARGYAP CHU 31715.60	3644.339	18-05-2012 07:36
YARGYAP CHU 32500.00	3643.966	18-05-2012 07:37
YARGYAP CHU 33500.00	3643.432	18-05-2012 07:38
YARGYAP CHU 34500.00	3643.254	18-05-2012 07:39
YARGYAP CHU 35500.00	3642.941	18-05-2012 07:40
YARGYAP CHU 36500.00	3642.717	18-05-2012 07:41
YARGYAP CHU 37500.00	3642.600	18-05-2012 07:42
YARGYAP CHU 38500.00	3642.043	18-05-2012 07:43
YARGYAP CHU 39500.00	3641.458	18-05-2012 07:45
YARGYAP CHU 40500.00	3641.324	18-05-2012 07:45
YARGYAP CHU 41500.00	3640.906	18-05-2012 07:46
YARGYAP CHU 42500.00	3640.608	18-05-2012 07:47
YARGYAP CHU 43500.00	3639.513	18-05-2012 07:49
YARGYAP CHU 44500.00	3638.560	18-05-2012 07:51
YARGYAP CHU 45500.00	3637.799	18-05-2012 07:52
YARGYAP CHU 46500.00	3637.174	18-05-2012 07:54
YARGYAP CHU 47420.20	3636.448	18-05-2012 07:55
YARGYAP CHU 48260.60	3635.875	18-05-2012 07:57
YARGYAP CHU 48941.80	3635.278	18-05-2012 07:58
YARGYAP CHU 49463.80	3634.809	18-05-2012 07:59
YARGYAP CHU 50136.68	3633.730	18-05-2012 08:00
YARGYAP CHU 50960.45	3632.538	18-05-2012 08:02
YARGYAP CHU 51784.21	3631.722	18-05-2012 08:04
YARGYAP CHU 52625.50	3631.441	18-05-2012 08:05

YARGYAP CHU 53484.30	3630.386	18-05-2012 08:07
YARGYAP CHU 54332.90	3629.569	18-05-2012 08:09
YARGYAP CHU 55171.30	3629.141	18-05-2012 08:10
YARGYAP CHU 56009.70	3628.197	18-05-2012 08:12
YARGYAP CHU 56838.38	3627.792	18-05-2012 08:13
YARGYAP CHU 57657.32	3627.413	18-05-2012 08:14
YARGYAP CHU 58440.55	3627.173	18-05-2012 08:16
YARGYAP CHU 59188.05	3626.999	18-05-2012 08:16
YARGYAP CHU 59935.55	3626.352	18-05-2012 08:18
YARGYAP CHU 60687.00	3625.835	18-05-2012 08:19
YARGYAP CHU 61442.40	3625.682	18-05-2012 08:21
YARGYAP CHU 62197.80	3625.455	18-05-2012 08:21
YARGYAP CHU 62976.38	3622.873	18-05-2012 08:24
YARGYAP CHU 63778.13	3622.101	18-05-2012 08:26
YARGYAP CHU 64559.29	3621.337	18-05-2012 08:27
YARGYAP CHU 65319.85	3620.680	18-05-2012 08:29
YARGYAP CHU 66080.41	3619.985	18-05-2012 08:31
YARGYAP CHU 66931.98	3619.478	18-05-2012 08:32
YARGYAP CHU 67874.52	3618.565	18-05-2012 08:34
YARGYAP CHU 68784.07	3617.579	18-05-2012 08:36
YARGYAP CHU 69660.60	3615.979	18-05-2012 08:38
YARGYAP CHU 70537.13	3614.174	18-05-2012 08:40
YARGYAP CHU 71311.84	3612.339	18-05-2012 08:43
YARGYAP CHU 71984.70	3611.470	18-05-2012 08:44
YARGYAP CHU 72657.57	3610.977	18-05-2012 08:46
YARGYAP CHU 73328.59	3610.674	18-05-2012 08:47
YARGYAP CHU 73997.75	3610.401	18-05-2012 08:48
YARGYAP CHU 74666.91	3609.886	18-05-2012 08:49
YARGYAP CHU 75341.80	3608.910	18-05-2012 08:51
YARGYAP CHU 76022.40	3608.157	18-05-2012 08:52
YARGYAP CHU 76703.00	3607.512	18-05-2012 08:54
YARGYAP CHU 77383.34	3607.184	18-05-2012 08:55
YARGYAP CHU 78063.41	3605.892	18-05-2012 08:57
YARGYAP CHU 78743.48	3604.225	18-05-2012 08:59
YARGYAP CHU 79581.54	3601.656	18-05-2012 09:02
YARGYAP CHU 80577.60	3597.374	18-05-2012 09:06
YARGYAP CHU 81409.87	3592.799	18-05-2012 09:10
YARGYAP CHU 82078.34	3591.105	18-05-2012 09:14
YARGYAP CHU 82746.82	3590.526	18-05-2012 09:16
YARGYAP CHU 83451.78	3590.500	18-05-2012 09:17
YARGYAP CHU 84193.22	3589.018	18-05-2012 09:19
YARGYAP CHU 84934.66	3562.861	18-05-2012 09:23
YARGYAP CHU 85793.94	3519.431	18-05-2012 09:35
YARGYAP CHU 86771.06	3498.411	18-05-2012 09:46
YARGYAP CHU 87717.45	3490.925	18-05-2012 09:55
YARGYAP CHU 88633.09	3490.000	18-05-2012 09:57

YARGYAP CHU 89426.55	3489.675	18-05-2012 10:00
YARGYAP CHU 90097.83	3489.361	18-05-2012 10:01
YARGYAP CHU 90769.10	3488.949	18-05-2012 10:03
YARGYAP CHU 91524.60	3488.512	18-05-2012 10:05
YARGYAP CHU 92364.34	3488.283	18-05-2012 10:07

The rise in water level along the reach of the river downstream of the dam is about 3.21 m to 12.2 m.

Table 6.5.7: Maximum water level due to occurrence of PMF in virgin river condition

Chainage (m) d/s of Pauk dam	*Bed Level (m)*	*Maximum water level (m)*	*Time of occurrence (Date:hours:Minutes:seconds)*
YARGYAP CHU 0.00	1475.820	1479.029	18-05-2012 07:03
YARGYAP CHU 500.00	1473.750	1478.562	18-05-2012 07:03
YARGYAP CHU 1000.00	1463.712	1467.289	18-05-2012 07:03
YARGYAP CHU 1500.00	1431.766	1437.692	18-05-2012 07:03
YARGYAP CHU 2000.00	1420.311	1425.458	18-05-2012 07:04
YARGYAP CHU 2500.00	1405.073	1409.701	18-05-2012 07:04
YARGYAP CHU 3000.00	1391.427	1397.161	18-05-2012 07:05
YARGYAP CHU 3500.00	1385.692	1392.988	18-05-2012 07:05
YARGYAP CHU 4000.00	1384.200	1390.617	18-05-2012 07:06
YARGYAP CHU 4500.00	1382.000	1387.911	18-05-2012 07:06
YARGYAP CHU 5000.00	1376.690	1380.500	18-05-2012 07:06
YARGYAP CHU 5500.00	1346.350	1351.495	18-05-2012 07:06
YARGYAP CHU 5862.00	1336.388	1340.573	18-05-2012 07:07
YARGYAP CHU 7000.00	1300.679	1304.656	18-05-2012 07:07
YARGYAP CHU 7582.00	1255.575	1262.077	18-05-2012 07:08
YARGYAP CHU 8000.00	1252.197	1256.914	18-05-2012 07:08
YARGYAP CHU 8395.00	1219.948	1224.537	18-05-2012 07:09
YARGYAP CHU 8958.70	1195.480	1202.594	18-05-2012 07:09
YARGYAP CHU 9651.40	1176.690	1186.752	18-05-2012 07:10
YARGYAP CHU 9939.30	1176.557	1185.018	18-05-2012 07:11
YARGYAP CHU 10624.20	1169.690	1175.957	18-05-2012 07:12
YARGYAP CHU 11000.00	1160.960	1168.448	18-05-2012 07:12
YARGYAP CHU 11500.00	1148.880	1157.088	18-05-2012 07:12
YARGYAP CHU 12000.00	1135.390	1144.027	18-05-2012 07:13
YARGYAP CHU 12500.00	1102.717	1112.154	18-05-2012 07:13
YARGYAP CHU 13000.00	1091.290	1096.349	18-05-2012 07:13
YARGYAP CHU 13500.00	1053.000	1057.289	18-05-2012 07:14
YARGYAP CHU 14000.00	1034.095	1041.213	18-05-2012 07:14
YARGYAP CHU 14500.00	1031.259	1038.089	18-05-2012 07:15
YARGYAP CHU 15000.00	1020.715	1028.426	18-05-2012 07:15

YARGYAP CHU 15643.60	1013.590	1017.658	18-05-2012 07:16
YARGYAP CHU 15896.90	985.188	990.382	18-05-2012 07:16
YARGYAP CHU 16500.00	959.000	966.321	18-05-2012 07:17
YARGYAP CHU 17000.00	957.960	963.453	18-05-2012 07:18
YARGYAP CHU 17500.00	943.291	948.883	18-05-2012 07:19
YARGYAP CHU 18500.00	913.480	919.280	18-05-2012 07:19
YARGYAP CHU 19000.00	886.391	894.661	18-05-2012 07:20
YARGYAP CHU 19500.00	882.395	886.875	18-05-2012 07:20
YARGYAP CHU 20000.00	868.385	873.731	18-05-2012 07:21
YARGYAP CHU 20500.00	853.543	861.958	18-05-2012 07:21
YARGYAP CHU 21000.00	852.810	858.144	18-05-2012 07:22
YARGYAP CHU 21500.00	833.316	839.992	18-05-2012 07:22
YARGYAP CHU 22000.00	824.000	832.486	18-05-2012 07:23
YARGYAP CHU 22500.00	820.995	826.060	18-05-2012 07:23
YARGYAP CHU 23000.00	800.280	808.797	18-05-2012 07:25
YARGYAP CHU 23500.00	799.525	805.815	18-05-2012 07:25
YARGYAP CHU 24000.00	787.600	799.157	18-05-2012 07:26
YARGYAP CHU 24500.00	787.500	797.760	18-05-2012 07:27
YARGYAP CHU 25000.00	785.244	795.369	18-05-2012 07:28
YARGYAP CHU 26000.00	782.626	789.866	18-05-2012 07:29
YARGYAP CHU 26500.00	772.432	778.210	18-05-2012 07:29
YARGYAP CHU 27000.00	758.887	767.141	18-05-2012 07:30
YARGYAP CHU 28000.00	751.360	763.497	18-05-2012 07:32
YARGYAP CHU 28500.00	753.930	762.170	18-05-2012 07:33
YARGYAP CHU 28815.70	749.406	757.043	18-05-2012 07:34
YARGYAP CHU 29626.60	740.900	752.173	18-05-2012 07:34
YARGYAP CHU 30000.00	744.478	750.802	18-05-2012 07:35
YARGYAP CHU 30500.00	728.905	732.672	18-05-2012 07:35
YARGYAP CHU 31000.00	701.129	707.215	18-05-2012 07:35
YARGYAP CHU 31431.20	695.789	701.663	18-05-2012 07:36
YARGYAP CHU 32000.00	690.330	696.323	18-05-2012 07:37
YARGYAP CHU 33000.00	676.172	682.486	18-05-2012 07:38
YARGYAP CHU 34000.00	661.445	665.659	18-05-2012 07:39
YARGYAP CHU 35000.00	625.855	633.120	18-05-2012 07:40
YARGYAP CHU 36000.00	606.972	613.352	18-05-2012 07:41
YARGYAP CHU 37000.00	*	577.946	18-05-2012 07:41
YARGYAP CHU 38000.00	538.750	544.907	18-05-2012 07:43
YARGYAP CHU 39000.00	525.260	530.276	18-05-2012 07:44
YARGYAP CHU 40000.00	*	516.500	18-05-2012 07:45
YARGYAP CHU 41000.00	493.210	502.560	18-05-2012 07:46
YARGYAP CHU 42000.00	*	488.428	18-05-2012 07:47
YARGYAP CHU 43000.00	472.075	479.284	18-05-2012 07:49
YARGYAP CHU 44000.00	460.460	468.524	18-05-2012 07:51
YARGYAP CHU 45000.00	449.460	458.040	18-05-2012 07:52
YARGYAP CHU 46000.00	442.722	448.548	18-05-2012 07:53
YARGYAP CHU 47000.00	420.200	426.536	18-05-2012 07:55

YARGYAP CHU 47840.40	*	417.395	18-05-2012 07:57
YARGYAP CHU 48680.80	400.540	408.739	18-05-2012 07:58
YARGYAP CHU 49202.80	*	405.736	18-05-2012 07:59
YARGYAP CHU 49724.80	392.370	403.867	18-05-2012 08:01
YARGYAP CHU 50548.57	*	401.265	18-05-2012 08:02
YARGYAP CHU 51372.33	*	399.067	18-05-2012 08:04
YARGYAP CHU 52196.10	388.560	396.376	18-05-2012 08:05
YARGYAP CHU 53054.90	*	392.929	18-05-2012 08:07
YARGYAP CHU 53913.70	384.330	390.623	18-05-2012 08:08
YARGYAP CHU 54752.10	*	386.469	18-05-2012 08:10
YARGYAP CHU 55590.50	*	383.665	18-05-2012 08:12
YARGYAP CHU 56428.90	374.250	381.901	18-05-2012 08:13
YARGYAP CHU 57247.85	*	376.269	18-05-2012 08:14
YARGYAP CHU 58066.80	364.290	371.069	18-05-2012 08:15
YARGYAP CHU 58814.30	*	367.230	18-05-2012 08:16
YARGYAP CHU 59561.80	*	365.089	18-05-2012 08:18
YARGYAP CHU 60309.30	354.770	362.031	18-05-2012 08:19
YARGYAP CHU 61064.70	*	356.066	18-05-2012 08:20
YARGYAP CHU 61820.10	*	350.172	18-05-2012 08:21
YARGYAP CHU 62575.50	340.462	346.670	18-05-2012 08:25
YARGYAP CHU 63377.25	*	344.855	18-05-2012 08:26
YARGYAP CHU 64179.00	334.740	342.181	18-05-2012 08:27
YARGYAP CHU 64939.57	*	338.692	18-05-2012 08:29
YARGYAP CHU 65700.13	*	335.807	18-05-2012 08:31
YARGYAP CHU 66460.70	324.520	332.546	18-05-2012 08:32
YARGYAP CHU 67403.25	*	327.588	18-05-2012 08:34
YARGYAP CHU 68345.80	314.310	323.175	18-05-2012 08:37
YARGYAP CHU 69222.34	*	320.322	18-05-2012 08:39
YARGYAP CHU 70098.87	*	318.684	18-05-2012 08:42
YARGYAP CHU 70975.40	304.430	316.631	18-05-2012 08:44
YARGYAP CHU 71648.27	*	314.813	18-05-2012 08:45
YARGYAP CHU 72321.13	*	312.877	18-05-2012 08:46
YARGYAP CHU 72994.00	299.320	310.409	18-05-2012 08:47
YARGYAP CHU 73663.16	*	307.605	18-05-2012 08:48
YARGYAP CHU 74332.34	*	305.089	18-05-2012 08:49
YARGYAP CHU 75001.50	294.820	303.048	18-05-2012 08:51
YARGYAP CHU 75682.10	*	301.488	18-05-2012 08:53
YARGYAP CHU 76362.70	*	299.869	18-05-2012 08:54
YARGYAP CHU 77043.30	291.210	297.670	18-05-2012 08:55
YARGYAP CHU 77723.37	*	294.485	18-05-2012 08:58
YARGYAP CHU 78403.44	*	293.273	18-05-2012 09:01
YARGYAP CHU 79083.51	285.450	291.476	18-05-2012 09:04
YARGYAP CHU 80079.57	*	289.437	18-05-2012 09:09
YARGYAP CHU 81075.63	279.670	288.201	18-05-2012 09:12
YARGYAP CHU 81744.11	*	287.157	18-05-2012 09:14
YARGYAP CHU 82412.59	*	285.729	18-05-2012 09:15

YARGYAP CHU 83081.06	275.370	283.530	18-05-2012 09:16
YARGYAP CHU 83822.50	*	278.977	18-05-2012 09:21
YARGYAP CHU 84563.94	*	276.688	18-05-2012 09:53
YARGYAP CHU 85305.38	267.690	276.481	18-05-2012 09:56
YARGYAP CHU 86282.50	*	276.409	18-05-2012 09:57
YARGYAP CHU 87259.62	265.990	276.274	18-05-2012 09:57
YARGYAP CHU 88175.27	*	275.854	18-05-2012 09:58
YARGYAP CHU 89090.92	263.960	274.490	18-05-2012 09:59
YARGYAP CHU 89762.20	*	272.298	18-05-2012 10:01
YARGYAP CHU 90433.47	*	270.566	18-05-2012 10:04
YARGYAP CHU 91104.74	261.630	269.121	18-05-2012 10:05
YARGYAP CHU 91944.47	*	267.032	18-05-2012 10:07
YARGYAP CHU 92784.20	260.080	263.998	18-05-2012 10:08

** cross sections interpolated by MIKE11*

6.6

RESULTS AND DISCUSSIONS

6.6.1 COMPARISON OF MAXIMUM DISCHARGE AND WATER LEVEL

For the different hydrodynamic scenario simulated so far, the maximum discharge and water level occurring at different locations of Yargyap Chu downstream of Pauk dam have been compared in Table 6.6.1 and 6.6.2 respectively.

Table 6.6.1: Comparison of maximum discharge obtained in different cases

Chainage (m) d/s of Pauk dam	Maximum discharge (cumec)		
	PMF and dam breach *(Table 5.2)*	PMF without dam breach *(Table 5.4)*	PMF in virgin condition *(Table 5.6)*
YARGYAP CHU 250.00	4098.562	3664.073	3664.888
YARGYAP CHU 750.00	4093.726	3663.722	3664.328
YARGYAP CHU 1250.00	4093.241	3663.701	3664.308
YARGYAP CHU 1750.00	4077.946	3663.121	3663.568
YARGYAP CHU 2250.00	4067.356	3662.753	3663.114
YARGYAP CHU 2750.00	4054.766	3662.302	3662.598
YARGYAP CHU 3250.00	4033.673	3661.446	3661.677
YARGYAP CHU 3750.00	4024.529	3661.023	3661.237
YARGYAP CHU 4250.00	4014.224	3660.596	3660.788
YARGYAP CHU 4750.00	4010.259	3660.438	3660.619
YARGYAP CHU 5250.00	4010.295	3660.441	3660.623
YARGYAP CHU 5681.00	4009.127	3660.389	3660.569
YARGYAP CHU 6181.00	4008.296	3660.360	3660.537
YARGYAP CHU 6750.00	4004.840	3660.213	3660.382
YARGYAP CHU 7291.00	4002.582	3660.122	3660.287
YARGYAP CHU 7791.00	3982.327	3659.068	3659.199
YARGYAP CHU 8197.50	3980.832	3658.995	3659.126
YARGYAP CHU 8676.85	3976.669	3658.772	3658.896
YARGYAP CHU 9305.05	3968.898	3658.340	3658.455
YARGYAP CHU 9795.35	3952.500	3657.278	3657.377
YARGYAP CHU 10281.75	3947.441	3656.975	3657.070

YARGYAP CHU	10812.10	3931.579	3656.027	3656.110
YARGYAP CHU	11250.00	3930.561	3655.974	3656.056
YARGYAP CHU	11750.00	3929.788	3655.933	3656.016
YARGYAP CHU	12250.00	3928.815	3655.887	3655.967
YARGYAP CHU	12750.00	3927.279	3655.799	3655.879
YARGYAP CHU	13250.00	3927.281	3655.801	3655.880
YARGYAP CHU	13750.00	3924.486	3655.634	3655.713
YARGYAP CHU	14250.00	3920.348	3655.370	3655.446
YARGYAP CHU	14750.00	3916.652	3655.148	3655.222
YARGYAP CHU	15321.80	3912.021	3654.862	3654.934
YARGYAP CHU	15770.25	3911.226	3654.816	3654.887
YARGYAP CHU	16198.45	3910.083	3654.753	3654.825
YARGYAP CHU	16750.00	3898.238	3653.903	3653.968
YARGYAP CHU	17250.00	3895.205	3653.711	3653.776
YARGYAP CHU	18000.00	3887.365	3653.189	3653.251
YARGYAP CHU	18750.00	3886.549	3653.140	3653.200
YARGYAP CHU	19250.00	3879.969	3652.672	3652.730
YARGYAP CHU	19750.00	3879.131	3652.618	3652.676
YARGYAP CHU	20250.00	3877.638	3652.511	3652.568
YARGYAP CHU	20750.00	3871.474	3652.041	3652.096
YARGYAP CHU	21250.00	3870.736	3651.989	3652.043
YARGYAP CHU	21750.00	3868.202	3651.801	3651.855
YARGYAP CHU	22250.00	3866.075	3651.638	3651.692
YARGYAP CHU	22750.00	3865.253	3651.585	3651.637
YARGYAP CHU	23250.00	3855.019	3650.550	3650.600
YARGYAP CHU	23750.00	3850.810	3650.103	3650.152
YARGYAP CHU	24250.00	3844.373	3649.280	3649.325
YARGYAP CHU	24750.00	3841.270	3648.903	3648.947
YARGYAP CHU	25500.00	3832.706	3648.010	3648.053
YARGYAP CHU	26250.00	3829.695	3647.729	3647.770
YARGYAP CHU	26750.00	3827.518	3647.508	3647.549
YARGYAP CHU	27500.00	3823.167	3646.893	3646.932
YARGYAP CHU	28250.00	3810.505	3645.291	3645.326
YARGYAP CHU	28657.85	3809.589	3645.186	3645.221
YARGYAP CHU	29221.15	3806.535	3644.836	3644.871
YARGYAP CHU	29813.30	3805.096	3644.670	3644.705
YARGYAP CHU	30250.00	3804.817	3644.639	3644.674
YARGYAP CHU	30750.00	3804.596	3644.615	3644.648
YARGYAP CHU	31215.60	3804.213	3644.567	3644.602
YARGYAP CHU	31715.60	3802.172	3644.306	3644.339
YARGYAP CHU	32500.00	3799.122	3643.932	3643.966
YARGYAP CHU	33500.00	3795.081	3643.399	3643.432
YARGYAP CHU	34500.00	3793.686	3643.222	3643.254
YARGYAP CHU	35500.00	3791.365	3642.909	3642.941
YARGYAP CHU	36500.00	3789.707	3642.686	3642.717
YARGYAP CHU	37500.00	3788.813	3642.569	3642.600

YARGYAP CHU 38500.00	3784.970	3642.014	3642.043
YARGYAP CHU 39500.00	3781.107	3641.429	3641.458
YARGYAP CHU 40500.00	3780.221	3641.295	3641.324
YARGYAP CHU 41500.00	3777.543	3640.878	3640.906
YARGYAP CHU 42500.00	3775.756	3640.580	3640.608
YARGYAP CHU 43500.00	3769.972	3639.486	3639.513
YARGYAP CHU 44500.00	3765.031	3638.534	3638.560
YARGYAP CHU 45500.00	3761.198	3637.774	3637.799
YARGYAP CHU 46500.00	3757.878	3637.149	3637.174
YARGYAP CHU 47420.20	3754.423	3636.424	3636.448
YARGYAP CHU 48260.60	3751.814	3635.852	3635.875
YARGYAP CHU 48941.80	3749.383	3635.255	3635.278
YARGYAP CHU 49463.80	3747.708	3634.787	3634.809
YARGYAP CHU 50136.68	3743.820	3633.708	3633.730
YARGYAP CHU 50960.45	3739.542	3632.517	3632.538
YARGYAP CHU 51784.21	3736.438	3631.702	3631.722
YARGYAP CHU 52625.50	3735.375	3631.421	3631.441
YARGYAP CHU 53484.30	3731.719	3630.367	3630.386
YARGYAP CHU 54332.90	3728.634	3629.551	3629.569
YARGYAP CHU 55171.30	3727.140	3629.123	3629.141
YARGYAP CHU 56009.70	3723.931	3628.179	3628.197
YARGYAP CHU 56838.38	3722.479	3627.774	3627.792
YARGYAP CHU 57657.32	3721.150	3627.396	3627.413
YARGYAP CHU 58440.55	3720.321	3627.156	3627.173
YARGYAP CHU 59188.05	3719.807	3626.982	3626.999
YARGYAP CHU 59935.55	3717.735	3626.336	3626.352
YARGYAP CHU 60687.00	3716.008	3625.818	3625.835
YARGYAP CHU 61442.40	3715.479	3625.666	3625.682
YARGYAP CHU 62197.80	3714.875	3625.439	3625.455
YARGYAP CHU 62976.38	3707.919	3622.858	3622.873
YARGYAP CHU 63778.13	3705.773	3622.086	3622.101
YARGYAP CHU 64559.29	3703.601	3621.323	3621.337
YARGYAP CHU 65319.85	3701.785	3620.666	3620.680
YARGYAP CHU 66080.41	3699.879	3619.971	3619.985
YARGYAP CHU 66931.98	3698.470	3619.465	3619.478
YARGYAP CHU 67874.52	3696.122	3618.552	3618.565
YARGYAP CHU 68784.07	3693.847	3617.566	3617.579
YARGYAP CHU 69660.60	3690.392	3615.967	3615.979
YARGYAP CHU 70537.13	3686.440	3614.162	3614.174
YARGYAP CHU 71311.84	3682.481	3612.328	3612.339
YARGYAP CHU 71984.70	3680.674	3611.459	3611.470
YARGYAP CHU 72657.57	3679.554	3610.966	3610.977
YARGYAP CHU 73328.59	3678.862	3610.664	3610.674
YARGYAP CHU 73997.75	3678.259	3610.391	3610.401
YARGYAP CHU 74666.91	3677.140	3609.875	3609.886
YARGYAP CHU 75341.80	3675.046	3608.900	3608.910

YARGYAP CHU 76022.40	3673.433	3608.147	3608.157
YARGYAP CHU 76703.00	3672.056	3607.502	3607.512
YARGYAP CHU 77383.34	3671.379	3607.174	3607.184
YARGYAP CHU 78063.41	3668.911	3605.883	3605.892
YARGYAP CHU 78743.48	3665.792	3604.216	3604.225
YARGYAP CHU 79581.54	3661.225	3601.648	3601.656
YARGYAP CHU 80577.60	3653.904	3597.367	3597.374
YARGYAP CHU 81409.87	3646.304	3592.793	3592.799
YARGYAP CHU 82078.34	3643.122	3591.099	3591.105
YARGYAP CHU 82746.82	3641.891	3590.520	3590.526
YARGYAP CHU 83451.78	3641.758	3590.495	3590.500
YARGYAP CHU 84193.22	3639.869	3589.013	3589.018
YARGYAP CHU 84934.66	3608.208	3562.865	3562.861
YARGYAP CHU 85793.94	3550.857	3519.447	3519.431
YARGYAP CHU 86771.06	3522.383	3498.429	3498.411
YARGYAP CHU 87717.45	3513.252	3490.944	3490.925
YARGYAP CHU 88633.09	3512.188	3490.018	3490.000
YARGYAP CHU 89426.55	3511.822	3489.694	3489.675
YARGYAP CHU 90097.83	3511.463	3489.379	3489.361
YARGYAP CHU 90769.10	3510.994	3488.967	3488.949
YARGYAP CHU 91524.60	3510.504	3488.530	3488.512
YARGYAP CHU 92364.34	3510.248	3488.301	3488.283

From the above table it can be seen that due to flash nature of flood contribution from reservoir in case of dam breach, the flood peak gets attenuated over the river reach. This is due to not much capacity of the reservoir and the model reach.

Table 6.6.2: Comparison of maximum water level obtained in different cases

Chainage (m) d/s of Pauk dam	Bed Level (m)	Maximum water level (m)		
		PMF and dam breach *(Table 5.3)*	PMF and dam breach *(Table 5.5)*	PMF and dam breach *(Table 5.7)*
YARGYAP CHU 0.00	1475.820	1479.319	1479.028	1479.029
YARGYAP CHU 500.00	1473.750	1478.883	1478.562	1478.562
YARGYAP CHU 1000.00	1463.712	1467.538	1467.288	1467.289
YARGYAP CHU 1500.00	1431.766	1437.994	1437.691	1437.692
YARGYAP CHU 2000.00	1420.311	1425.677	1425.458	1425.458
YARGYAP CHU 2500.00	1405.073	1409.944	1409.701	1409.701
YARGYAP CHU 3000.00	1391.427	1397.452	1397.161	1397.161
YARGYAP CHU 3500.00	1385.692	1393.365	1392.988	1392.988
YARGYAP CHU 4000.00	1384.200	1390.957	1390.617	1390.617
YARGYAP CHU 4500.00	1382.000	1388.220	1387.911	1387.911

YARGYAP CHU 5000.00	1376.690	1380.718	1380.500	1380.500
YARGYAP CHU 5500.00	1346.350	1351.777	1351.495	1351.495
YARGYAP CHU 5862.00	1336.388	1340.812	1340.573	1340.573
YARGYAP CHU 7000.00	1300.679	1304.880	1304.656	1304.656
YARGYAP CHU 7582.00	1255.575	1262.373	1262.077	1262.077
YARGYAP CHU 8000.00	1252.197	1257.154	1256.914	1256.914
YARGYAP CHU 8395.00	1219.948	1224.711	1224.537	1224.537
YARGYAP CHU 8958.70	1195.480	1202.926	1202.594	1202.594
YARGYAP CHU 9651.40	1176.690	1187.025	1186.752	1186.752
YARGYAP CHU 9939.30	1176.557	1185.271	1185.018	1185.018
YARGYAP CHU 10624.20	1169.690	1176.179	1175.957	1175.957
YARGYAP CHU 11000.00	1160.960	1168.786	1168.447	1168.448
YARGYAP CHU 11500.00	1148.880	1157.452	1157.088	1157.088
YARGYAP CHU 12000.00	1135.390	1144.392	1144.027	1144.027
YARGYAP CHU 12500.00	1102.717	1112.368	1112.154	1112.154
YARGYAP CHU 13000.00	1091.290	1096.569	1096.349	1096.349
YARGYAP CHU 13500.00	1053.000	1057.486	1057.289	1057.289
YARGYAP CHU 14000.00	1034.095	1041.502	1041.213	1041.213
YARGYAP CHU 14500.00	1031.259	1038.292	1038.089	1038.089
YARGYAP CHU 15000.00	1020.715	1028.609	1028.426	1028.426
YARGYAP CHU 15643.60	1013.590	1017.786	1017.658	1017.658
YARGYAP CHU 15896.90	985.188	990.534	990.382	990.382
YARGYAP CHU 16500.00	959.000	966.519	966.321	966.321
YARGYAP CHU 17000.00	957.960	963.610	963.453	963.453
YARGYAP CHU 17500.00	943.291	949.096	948.883	948.883
YARGYAP CHU 18500.00	913.480	919.505	919.279	919.280
YARGYAP CHU 19000.00	886.391	894.930	894.661	894.661
YARGYAP CHU 19500.00	882.395	887.043	886.875	886.875
YARGYAP CHU 20000.00	868.385	873.936	873.731	873.731
YARGYAP CHU 20500.00	853.543	862.204	861.957	861.958
YARGYAP CHU 21000.00	852.810	858.316	858.144	858.144
YARGYAP CHU 21500.00	833.316	840.217	839.992	839.992
YARGYAP CHU 22000.00	824.000	832.678	832.486	832.486
YARGYAP CHU 22500.00	820.995	826.226	826.060	826.060
YARGYAP CHU 23000.00	800.280	808.967	808.797	808.797
YARGYAP CHU 23500.00	799.525	806.027	805.815	805.815
YARGYAP CHU 24000.00	787.600	799.385	799.157	799.157
YARGYAP CHU 24500.00	787.500	797.965	797.759	797.760
YARGYAP CHU 25000.00	785.244	795.565	795.369	795.369
YARGYAP CHU 26000.00	782.626	790.072	789.865	789.866
YARGYAP CHU 26500.00	772.432	778.380	778.210	778.210
YARGYAP CHU 27000.00	758.887	767.312	767.141	767.141
YARGYAP CHU 28000.00	751.360	763.636	763.497	763.497
YARGYAP CHU 28500.00	753.930	762.299	762.169	762.170
YARGYAP CHU 28815.70	749.406	757.189	757.043	757.043
YARGYAP CHU 29626.60	740.900	752.326	752.173	752.173

YARGYAP CHU 30000.00	744.478	750.901	750.802	750.802
YARGYAP CHU 30500.00	728.905	732.776	732.672	732.672
YARGYAP CHU 31000.00	701.129	707.372	707.215	707.215
YARGYAP CHU 31431.20	695.789	701.817	701.663	701.663
YARGYAP CHU 32000.00	690.330	696.472	696.323	696.323
YARGYAP CHU 33000.00	676.172	682.615	682.486	682.486
YARGYAP CHU 34000.00	661.445	665.756	665.659	665.659
YARGYAP CHU 35000.00	625.855	633.236	633.120	633.120
YARGYAP CHU 36000.00	606.972	613.442	613.352	613.352
YARGYAP CHU 37000.00	*	578.041	577.946	577.946
YARGYAP CHU 38000.00	538.750	545.047	544.907	544.907
YARGYAP CHU 39000.00	525.260	530.388	530.276	530.276
YARGYAP CHU 40000.00	*	516.599	516.500	516.500
YARGYAP CHU 41000.00	493.210	502.698	502.560	502.560
YARGYAP CHU 42000.00	*	488.520	488.428	488.428
YARGYAP CHU 43000.00	472.075	479.375	479.283	479.284
YARGYAP CHU 44000.00	460.460	468.690	468.524	468.524
YARGYAP CHU 45000.00	449.460	458.199	458.040	458.040
YARGYAP CHU 46000.00	442.722	448.659	448.548	448.548
YARGYAP CHU 47000.00	420.200	426.604	426.536	426.536
YARGYAP CHU 47840.40	*	417.473	417.395	417.395
YARGYAP CHU 48680.80	400.540	408.850	408.739	408.739
YARGYAP CHU 49202.80	*	405.857	405.736	405.736
YARGYAP CHU 49724.80	392.370	403.982	403.867	403.867
YARGYAP CHU 50548.57	*	401.383	401.265	401.265
YARGYAP CHU 51372.33	*	399.174	399.067	399.067
YARGYAP CHU 52196.10	388.560	396.469	396.376	396.376
YARGYAP CHU 53054.90	*	393.001	392.929	392.929
YARGYAP CHU 53913.70	384.330	390.692	390.623	390.623
YARGYAP CHU 54752.10	*	386.537	386.469	386.469
YARGYAP CHU 55590.50	*	383.737	383.665	383.665
YARGYAP CHU 56428.90	374.250	381.979	381.901	381.901
YARGYAP CHU 57247.85	*	376.345	376.269	376.269
YARGYAP CHU 58066.80	364.290	371.142	371.069	371.069
YARGYAP CHU 58814.30	*	367.294	367.230	367.230
YARGYAP CHU 59561.80	*	365.149	365.089	365.089
YARGYAP CHU 60309.30	354.770	362.092	362.031	362.031
YARGYAP CHU 61064.70	*	356.119	356.066	356.066
YARGYAP CHU 61820.10	*	350.228	350.172	350.172
YARGYAP CHU 62575.50	340.462	346.743	346.670	346.670
YARGYAP CHU 63377.25	*	344.930	344.855	344.855
YARGYAP CHU 64179.00	334.740	342.260	342.181	342.181
YARGYAP CHU 64939.57	*	338.772	338.692	338.692
YARGYAP CHU 65700.13	*	335.879	335.807	335.807
YARGYAP CHU 66460.70	324.520	332.611	332.546	332.546
YARGYAP CHU 67403.25	*	327.658	327.588	327.588

YARGYAP CHU 68345.80	314.310	323.250	323.175	323.175
YARGYAP CHU 69222.34	*	320.406	320.322	320.322
YARGYAP CHU 70098.87	*	318.763	318.684	318.684
YARGYAP CHU 70975.40	304.430	316.715	316.631	316.631
YARGYAP CHU 71648.27	*	314.898	314.813	314.813
YARGYAP CHU 72321.13	*	312.955	312.877	312.877
YARGYAP CHU 72994.00	299.320	310.484	310.409	310.409
YARGYAP CHU 73663.16	*	307.682	307.605	307.605
YARGYAP CHU 74332.34	*	305.160	305.089	305.089
YARGYAP CHU 75001.50	294.820	303.114	303.048	303.048
YARGYAP CHU 75682.10	*	301.552	301.488	301.488
YARGYAP CHU 76362.70	*	299.928	299.869	299.869
YARGYAP CHU 77043.30	291.210	297.723	297.670	297.670
YARGYAP CHU 77723.37	*	294.535	294.485	294.485
YARGYAP CHU 78403.44	*	293.319	293.273	293.273
YARGYAP CHU 79083.51	285.450	291.524	291.476	291.476
YARGYAP CHU 80079.57	*	289.482	289.437	289.437
YARGYAP CHU 81075.63	279.670	288.242	288.201	288.201
YARGYAP CHU 81744.11	*	287.198	287.157	287.157
YARGYAP CHU 82412.59	*	285.767	285.729	285.729
YARGYAP CHU 83081.06	275.370	283.562	283.530	283.530
YARGYAP CHU 83822.50	*	279.002	278.977	278.977
YARGYAP CHU 84563.94	*	276.709	276.688	276.688
YARGYAP CHU 85305.38	267.690	276.504	276.481	276.481
YARGYAP CHU 86282.50	*	276.433	276.409	276.409
YARGYAP CHU 87259.62	265.990	276.297	276.274	276.274
YARGYAP CHU 88175.27	*	275.875	275.854	275.854
YARGYAP CHU 89090.92	263.960	274.509	274.490	274.490
YARGYAP CHU 89762.20	*	272.317	272.298	272.298
YARGYAP CHU 90433.47	*	270.586	270.566	270.566
YARGYAP CHU 91104.74	261.630	269.140	269.121	269.121
YARGYAP CHU 91944.47	*	267.047	267.032	267.032
YARGYAP CHU 92784.20	260.080	264.005	263.998	263.998

** cross sections interpolated by MIKE11*

From the Table 6.6.2, it can be concluded that:

i) The rise in water level above river bed due to dam breach varies from about 12.3 m to 3.5 m along the river reach

ii) The rise in water level along the river reach in dam breach condition is only about 0.1 m to 0.3 m more in comparison to non dam breach condition (col. 3&4)

iii) Due to not much capacity of the reservoir it does not much dampen the PMF peak and water level along the river reach in non dam breach condition and virgin river condition is not very different

The water levels given in Table 6.6.2 can be used for the preparation of inundation map. The plot of time series of water level due to dam breach flood at different locations of Yargyap Chu is given in **Figure 6.6.1** A to N. The same can be used for estimating the period of inundation corresponding to a particular elevation during the preparation of disaster management plan. The tables of few cross sections of the Yargyap Chu used have been given in Table 6.6.4. The maximum water level at these cross sections due to dam breach flood has also been superimposed over them.

6.6.2 DAM BREACH FLOOD HYDROGRAPH

The dam breach flood hydrograph of **Figure 6.5.1** has been reproduced in the tabular form and the same is given in **Table 6.6.3**. The peak of the hydrograph is 4098.562 cumec.

Table 6.6.3: Dam breach Flood hydrograph just d/s of Pauk dam

Time (Date: hours : minutes : seconds)	Discharge (cumec)
17-05-2012 12:00	0
17-05-2012 13:00	51.973
17-05-2012 14:00	56.94
17-05-2012 15:00	65.868
17-05-2012 16:00	89.579
17-05-2012 17:00	169.343
17-05-2012 18:00	270.604
17-05-2012 19:00	403.444
17-05-2012 20:00	594.874
17-05-2012 21:00	793.113
17-05-2012 22:00	871.566
17-05-2012 23:00	962.749
18-05-2012 00:00	1068.004
18-05-2012 01:00	1198.638
18-05-2012 02:00	1379.024
18-05-2012 03:00	1754.213
18-05-2012 04:00	2196.928
18-05-2012 05:00	2665.25

18-05-2012 06:00	3215.011
18-05-2012 07:00	3640.74
18-05-2012 07:10	4098.562
18-05-2012 08:00	3433.906
18-05-2012 09:00	2970.218
18-05-2012 10:00	2469.967
18-05-2012 11:00	2010.145
18-05-2012 12:00	1603.474
18-05-2012 13:00	1253.326
18-05-2012 14:00	975.626
18-05-2012 15:00	777.09
18-05-2012 16:00	608.51
18-05-2012 17:00	466.71
18-05-2012 18:00	360.9
18-05-2012 19:00	283.692
18-05-2012 20:00	212.541
18-05-2012 21:00	161.655
18-05-2012 22:00	118.212
18-05-2012 23:00	75.349
19-05-2012 00:00	58.46
19-05-2012 01:00	52.534
19-05-2012 02:00	49.333
19-05-2012 02:00	49.33
19-05-2012 02:00	49.314
19-05-2012 02:00	49.317
19-05-2012 02:00	49.317
19-05-2012 02:00	49.31
19-05-2012 02:00	49.299
19-05-2012 02:00	49.302
19-05-2012 02:00	49.301
19-05-2012 02:00	49.291
19-05-2012 02:00	49.287
19-05-2012 02:00	49.287
19-05-2012 02:00	49.285
19-05-2012 02:06	49.009

6.6.3 LONGITUDINAL PROFILE

The longitudinal profile of the Yargyap Chu for dam breach condition is given in **Figure 6.6.2**.

Table 6.4: Typical few river cross sections used for Yargyap Chu downstream of Pauk Dam

0 km			11 km			20 km			30 km			41 km	
0	2332.88		0	1705.773		0	1661.241		0	1127.623		0	730.17
52.788	2305.616		16.599	1686.359		3.314	1657.985		29.121	1120.824		55.458	719.79
122.505	2270.772		37.002	1671.319		7.189	1653.023		123.674	1099.728		78.512	714.635
147.848	2254.066		74.847	1646.574		13.003	1645.714		129.217	1097.969		104.728	714.4
176.965	2226.353		97.08	1624.389		39.369	1611.587		138.242	1094.126		113.467	714.426
192.822	2211.654		121.694	1605.153		55.208	1585.378		163.758	1081.363		129.447	713.027
242.965	2141.083		127.118	1599.8		67.086	1564.183		176.478	1073.159		178.552	706.439
297.667	2070.723		216.884	1551.058		111.481	1484.971		198.3	1059.085		211.289	701.803
298.213	2070.081		217.773	1550.498		121.169	1472.789		198.47	1058.961		230.874	696.547
298.574	2069.756		309.411	1480.574		140.944	1448.839		198.768	1058.722		251.1	695.794
339.909	2030.86		389.285	1424.81		160.719	1425.987		278.801	987.256		254.622	695.662
389.695	1988.812		397.467	1420.099		209.731	1371.613		291.42	974.579		325.867	689.467
403.772	1977.156		475.041	1392.655		278.688	1305.312		366.009	899.644		351.048	687.131
408.699	1972.516		487.583	1389.68		303.194	1282.974		405.549	864.17		443.38	683.628
446.263	1931.994		492.053	1387.083		317.898	1268.701		424.376	845.917		454.481	683.173
470.262	1893.779		496.679	1384.394		363.869	1222.587		459.563	819		460.031	683.379
487.806	1867.749		544.95	1362.085		378.742	1212.825		496.282	790.803		483.534	682.504
500.123	1848.045		553.766	1358.01		423.226	1181.041		543.715	763.035		518.788	679.876
512.25	1823.482		605.017	1336.544		444.75	1167.127		556.299	756.721		527.113	679.131
519.22	1809.365		617.967	1325.785		478.495	1145.313		601.12	747.69		550.616	674.401
561.067	1745.743		659.71	1300.889		544.147	1099.336		621.56	744.478		585.87	660.737
579.564	1701.471		667.816	1295.158		611.493	1038.709		647.34	746.823		591.42	658.545
594.377	1668.264		681.784	1281.331		612.922	1037.388		743.5	775.055		594.195	656.642
614.722	1620.138		715.509	1245.264		620.427	1026.864		746.253	775.818		623.574	633.869
625.394	1593.376		740.925	1214.758		688.754	935.27		747.522	776.103		636.141	621.878
642.858	1559.186		757.932	1197.378		716.085	903.054		750.964	777.164		678.088	576.857
647.217	1550.728		774.097	1192.161		721.089	897.018		752.718	777.66		720.034	539.026

649.881	1546.291		787.971	1190.999		722.908	895.453		836.218	793.67		791.72	514.13
675.167	1510.65		814.91	1172.75		741.102	884.898		902.767	806.052		801.66	509.38
690.862	1499.019		833.13	1164.89		764.355	871.677		946.174	832.019		829.81	504.62
707.109	1482.883		854.66	1160.96		770.169	871.328		979.622	849.62		872.88	493.21
719.87	1480.15		899.215	1190.957		807.622	868.385		1002.919	863.011		901.04	500.82
736.43	1477.12		960.99	1215.28		816.985	870.463		1054.593	892.714		930.85	508.42
763.25	1475.82		985.411	1225.407		832.591	875.464		1056.131	893.108		973.953	529.752
779.41	1479.72		1025.255	1243.28		889.635	887.418		1058.351	894.788		993.912	538.083
790.85	1482.11		1042.073	1250.283		904.702	894.557		1082.721	918.369		1058.219	577.387
801.89	1483.41		1131.94	1294.077		937.422	912.555		1096.38	929.944		1059.607	578.379
815.453	1489.349		1208.514	1335.578		940.757	915.778		1101.857	937.202		1060.995	579.703
835.873	1500.062		1234.083	1348.771		965.714	936.774		1138.971	986		1125.301	642.014
854.817	1509.487		1251.559	1360.114		976.813	949.531		1165.463	1006.702		1171.873	693.736
930.846	1567.826		1320.6	1404.087		989.497	965.753		1165.845	1007.022		1195.159	713.869
931.148	1568.027		1352.58	1424.455		1012.868	989.088		1166.087	1007.154		1197.15	715.977
932.139	1568.564		1388.746	1443.785		1035.854	1019.689		1169.594	1008.714		1230.087	750.837
969.986	1589.57		1435.779	1484.45		1048.924	1035.397		1227.707	1034.126		1326.547	843.345
980.375	1594.536		1478.862	1516.107		1067.222	1061.448		1259.901	1048.404		1328.53	845.496
1071.781	1629.634		1500	1526.282		1094.668	1088.471		1285.61	1058.132		1332.098	848.475
1094.016	1641.755					1110.488	1102		1320.027	1074.595		1351.683	866.285
1103.113	1646.714					1128.568	1108.059		1373.108	1101.999		1390.854	898.401
1152.299	1674.81					1137.9	1113.27		1386.396	1109.02		1397.098	904.203
1212.415	1707.25					1182.047	1137.922					1399.18	906.53
1289.871	1743.815					1197.021	1145.951					1441.126	951.864
1354.985	1786.212					1229.692	1171.272					1474.683	991.133
1356.15	1786.941					1289.727	1213.249					1495.64	1012.272
1360.472	1789.645					1317.255	1232.422					1500	1015.89
1383.794	1803.987					1325.875	1236.406						
1405.99	1819.392					1337.368	1241.347						
1500	1878.223					1391.721	1267.351						

						1409.479	1274.821						
						1434.988	1288.027						
						1438.943	1290.989						
						1466.628	1302.36						
						1500	1319.329						

52.196 km			62.575 km			72.994 km			81.075 km			92.784 km	
0	466.844		2.08	466.67		0	524.544		53.18	384.1		0	378.4
29.421	461.68		29.19	438.52		56.285	531.059		94.65	378.05		2.581	377.719
93.333	482.875		120.91	427.41		62.028	530.987		122.59	372.17		18.551	373.499
111.217	487.348		192.83	427.04		73.115	530.57		138.82	366.64		95.852	359.501
135.832	491.676		257.25	416.188		97.431	533.268		154.14	362.84		180.669	343.645
143.831	494.616		268.56	411.366		128.707	536.627		180.28	357.65		275.662	325.834
238.5	534.557		292.607	398.959		143.899	539.256		197.41	354.02		281.602	324.052
250.25	539.515		339.063	382.698		187.785	536.179		219.94	350.74		328.449	309.994
258.996	543.22		367.005	372.665		209.019	535.294		266.82	345.9		415.391	286.35
322.201	562.598		378.603	371.75		215.285	534.016		292.06	343.14		460.76	277.74
363.271	570.317		505.078	369.929		218.285	532.711		346.14	336.57		493.4	274.55
364.989	570.823		550.984	363.759		223.101	530.992		372.28	333.8		563.36	267.93
380.264	569.923		669.043	343.782		293.147	509.497		411.94	330.35		625.85	263.51
437.731	568.244		723.366	341.804		302.25	506.295		419.99	328.28		674.35	263.02
471.786	559.077		784.206	340.462		337.253	493.98		433.84	325.99		715.39	262.78
473.155	558.66		844.29	340.581		356.423	486.455		447.7	322.18		759.23	262.04
528.202	524.799		854.27	341.561		372.275	480.232		459.43	317.22		804	261.31
541.268	515.989		898.088	345.705		415.303	461.574		471.15	310.35		864.62	260.08
555.379	503.585		972.362	362.693		433.167	452.841		480.75	302.92		896.34	262.04
614.85	447.89		977.704	363.98		447.708	440.478		494.6	296.24		935.51	263.27
637.786	428.029		1070.635	388.622		480.501	410.595		515.92	289.75		965.36	266.21
659.83	419.89		1097.691	401.127		516.969	376.703		572.42	284.6		1020.39	267.93
685.41	406.95		1161.6	431.386		561.58	356.3		633.18	283.84		1043.7	268.66
705.66	395.37		1187.427	443.614		579.61	351.85		658.76	284.03		1068.89	271.36
721.65	391.28		1202.204	448.412		589.52	349.26		685.41	283.65		1082.88	272.34
748.3	388.56		1251.795	472.329		612.06	344.07		732.31	279.67		1097.8	272.83
766.42	389.24		1291.774	484.196		623.77	341.48		778.15	284.03		1111.79	273.08
797.34	392.64		1317.206	491.411		631.89	339.63		842.11	285.94		1135.11	273.57
835.71	404.9		1393.064	505.737		643.84	337.06		865.56	287.08		1164.02	274.55

870.89	413.76		1421.414	509.161		686.48	322.75		879.41	287.66		1182.68	275.29
895.4	420.57		1500	517.496		698.2	315.4		911.39	289.95		1218.12	277.98
917.79	427.38					706.73	307.22		962.56	295.48		1347.834	288.457
968.95	436.92					730.18	299.32		1002	299.48		1370.324	291.492
1007.33	445.78					750.43	302.72		1044.64	311.31			
1037.18	454.63					787.74	307.63		1061.86	319.63			
1086.526	467.054					814.39	315.4		1109.63	324.32			
1092.9	470.971					831.45	321.53		1170.93	327.53			
1110.3	484.89					873.49	321.48		1243.04	335.93			
1117.357	490.536					930.81	323.7		1245.75	338.15			
1127.488	499.206					986.06	327.41		1260.17	345.06			
1173.905	537.776					1013.16	328.52		1270.08	349.88			
1241.178	598.552					1043.39	328.89		1281.8	354.81			
1318.02	651.504					1101.76	331.48		1312.354	362.195			
1321.278	654.491					1119.48	331.11		1333.922	372.065			
1323.325	656.225					1179.93	333.33		1338.165	373.41			
1327.144	659.068					1202.87	334.81		1347.342	374.365			
1409.262	717.076					1240.39	335.19		1388.546	377.982			
1430.08	731.891					1305.02	342.96		1415.419	382.277			
1465.02	748.085					1336.29	348.15		1459.192	393.91			
1495.361	768.572					1357.13	355.19		1500	393.516			
1500	770.851					1419.67	381.11						
						1443.65	392.59						
						1487.43	412.22						
						1523.91	434.07						
						1542.67	450						
						1545.92	464.07						
						1563.52	467.41						
						1587.49	480						
						1611.47	488.52						

						1625.28	492.96						
						1660.46	504.07						
						1694.46	515.93						
						1724.95	523.7						

6.7
INUNDATION & DISASTER MANAGEMENT PLAN

6.7.1 PREPARATION OF INUNDATION MAP

An inundation map (**Figure 6.7.1**) is a map depicting the d/s areas vulnerable to inundation by the Dam break flood. The DAMBRK model computes maximum flood elevation at each original or interpolated cross-section. In present case, the cross-sections are available up to 92.784 km d/s of Dam. The profile of water levels below the Dam at all cross-sections (original and interpolated) is given as Table 6.5.3 in Chapter 6.5. From this profile, at locations below the Dam & their subsequent markings on the topographic maps, it can be seen which areas are likely to be submerged in case of Dam break.

It is clear from the inundation map that in case of Dam break, the flood will be confined within the gorge only and though there would be inundation of few lower areas adjacent to the river however no settlement or area will be affected.

6.7.2 DISASTER MANAGEMENT PLAN

From the result it is evident that up to about 92.784 km d/s of the Dam, time required in reaching the flood wave elevation to the maximum is of the order of three hour. It hardly leaves any possibility of any rescue or evacuation. Since the time available is very short, the Disaster Management Plan should concentrate on preventive actions. Also as evident from the inundation map, a flood wave remains confined to the narrow gorge only and doesn't affect adjacent areas to the river course; Disaster Management Plan is more of a precautionary measure.

Surveillance and monitoring programmes are required to be implemented during design and investigation, construction, first reservoir filling, early operation period and operation & maintenance phases of the life cycle of Dam. It is desirable that all gates, electricity, public announcement system, power generator backups etc are thoroughly checked before arrival of the monsoon. As it is clear from the results that u/s water level has significant effect on the Dam break flood, the following flood conditions may be considered for different level of alertness:

1) If u/s water level reaches at top of the Dam, it may be considered as an emergency. At this point only a few minutes are available for taking any action. All the staff from the Dam site should be alerted to move to a safe place. The district administration and the corporation's head office shall be informed about the possibility of Dam failure.
2) If u/s water level rises above the Dam top and Dam begins to fail, it may be considered as a disaster condition. At this stage, nothing can be done. Information in this regard should be given to the head office and district administration.

i) If upstream water level is at or below FRL and flood is of the order of 20% to 30% of PMF, it may be considered as **normal flood** condition and normal routine may be maintained.

ii) If upstream water level is rising above FRL, it may be considered as **Level-1 emergency**. In this condition at least four gates must be kept fully operational. All concerned officials should be alerted so that they may reach at the Dam site to take suitable actions. Preventive actions may be carried out simultaneously. A suitable warning and notification procedure may be laid. The local officials should be informed about the situation.

iii) If upstream water level reaches above MWL and still rising, it may be considered as **Level-2 emergency.** It is seen from the results that around four hour is available to carry out suitable action at this condition. All communication systems and safety measures should be operational now. Public announcement system or centralized siren system may be used. A flood warning may be issued to the public downstream so that they may reach a higher and safe place.

iv) If upstream water level reaches at the top of the Dam, it may be considered as **Level-3 emergency**. At this point only a few minutes are available for taking any action. All the staff from the Dam site should be alerted to move to a safe place. The district level office and the corporation's head office should be informed about the possibility of Dam failure.

v) If upstream water level is rising above the Dam top and Dam has started to fail. It may be considered as a **disaster** condition. Any information in this regard should be immediately provided to civil administration for necessary rescue operations.

The following measures can be taken to avoid the loss of lives and property:

- To establish an effective Dam Safety Surveillance and monitoring program including rapid analysis and interpretation of instrumentation and observation data; periodic inspection and safety reviews/evaluation by an independent panel of experts.
- To formulate and implement an Emergency Action Plan to minimize to the maximum extent possible, the probable loss of life and damage to property in the event of failure of Dam.

6.7.2.1 Surveillance

The surveillance and monitoring programs are required to be implemented during design and investigation, construction, early operation period and operation and maintenance phases of the life cycle of the Dam. An affective flood forecasting system is required by establishing hourly gauge reading at suitable upstream locations with real time communication at the top. An effective Dam safety surveillance, monitoring and observation along with periodic inspection, safety reviews and evaluation must be put in place. These programs will be implemented in five phases in the life cycle of a Dam *viz.*,

i) design and investigation phase,
ii) construction phase,
iii) first reservoir filling,
iv) early operation period, and
v) operation and maintenance phase.

6.7.2.2 Emergency Action Plan

An emergency is defined as a condition of serious nature which develops unexpectedly and endangers downstream property and human life and requires immediate attention. Emergency Action Plan shall include all potential indicators of likely failure of the Dam, since the primary concern is for timely and reliable identification and evaluation of potential emergency.

This plan presents warning and notification procedures to be followed in case of potential failure of the Dam. The purpose is to provide timely warning to nearby residents and alert key personnel responsible for taking action in case of an emergency.

6.7.2.3 Administrative and Procedural Aspects

The Administrative and Procedural Aspects of Emergency Action Plan consists of a flowchart depicting the names, addresses and telephone numbers of the responsible officials. In order of hierarchy, the following system will usually be appropriate. In the event of potential emergency, the observer at the site is required to report it to the Engineer-in-charge through a wireless system, if available, or by the fastest communication system available. The Engineer-in-charge shall be responsible for contacting the Civil Administration, *viz*. Deputy Commissioner. In order to oversee all the operations required to tackle the emergency situations, a centralized control room could be set up by the project authorities at Tato.

Each person would be made aware of his/her responsibilities/ duties and the importance of work assigned under the Emergency Action Plan. All the villages falling under the flood prone zone or on the margins would be connected through wireless communication system with backup of standby telephone lines. A centralized siren alert system would be installed at all the Village Panchayats so that in the event of a warning all villagers can be alerted through sirens rather than informing everybody through messengers which is not feasible in such emergency situations.

6.7.2.4 Preventive Action

Once the likelihood of an emergency situation is suspected, action has to be initiated to prevent a failure. The point at which each situation reaches an emergency status shall be specified and at that stage the vigilance and surveillance shall be upgraded. At this stage, a thorough inspection of the Dam shall be carried out to locate any visible signs of distress.

The anticipated need of equipment shall be evaluated and if these are not available at the Dam site, the exact locations and availability of these equipments shall be identified. A plan shall be drawn on priority for inspection of the Dam. The Dam, its sluices and non-overflow sections will be properly illuminated.

6.7.2.5 Communication System

An efficient communication system and a downstream warning system is absolutely essential for the success of an emergency plan especially in the present case because of inadequacy of time. The difference between a high flood and a Dam break situation shall be made clear to the downstream people. All of the villages falling under the flooding zone or on margins are required to be connected through wireless system backed by stand-by telephone lines. A centralized siren system is to be installed at Panchayats so that in event of a warning, all villagers can be alerted, through messengers which may not be possible in this case.

6.7.2.6 Merits of Satellite Communication System

Keeping the disaster scenario in mind, any terrestrial system such as land lines, etc. is likely to be the first casualty in earthquakes or floods. The restoration of such systems is time consuming. Moreover the maintenance of such lines becomes a great problem in emergency even for the technical personnel who are required to reach the site of fault, which may be struck by the disaster. So the system cannot be put back into operation soon. The fault repairs and restoration of communication services are usually not possible for a considerable period of time after the calamity has struck. Moreover, it is critical that the communication systems are restored at the earliest so that relief/medical teams and other personnel can be arranged at the earliest possible time. All the subsidiary help depends solely on the communication system. As this criteria is paramount, existing systems such as telephones and telex, etc. are practically of little use in case of such events and situations. Similarly, microwave links are expected to be down due to collapse of towers, etc. Restoration of towers and alignment of equipment is again a time consuming activity.

Keeping in view the urgency of services and their dependability during emergency relevant to the disaster conditions, satellite based systems present an ideal solution. The satellite based system usually comprises following components.

i) A small dish of approximately one meter diameter
ii) Associated radio equipment
iii) A power source

The deployment of the system is not dependent on the restoration of land routes. The existing satellite based communication systems are designed in such a manner that they are able to withstand fairly high degree of demanding environmental conditions. Secondly, the restoration of the satellite based system can be undertaken by carrying maintenance personnel and equipment by helicopters at a very short notice. Even the fresh systems could be inducted in a matter of an hour or so because most of these are designed for transportability by air. The deployment takes usually less than an hour. The power requirements are not large and can be met by sources such as UPS/batteries/ generators.

6.7.2.7 Financial Outlay for Installation of VSAT Communication System

The cost of deployment and maintenance of a telecommunication system in disaster prone areas is not as important as the availability, reliability and quick restoration of the system. The cost of both satellite bandwidth and the ground components of the satellite communication system has been decreasing rapidly like that of V-SAT (Very Small Aperture Terminal) based systems supporting a couple of voice and data channels. Some highly superior communication systems in VSAT without time delay are marketed by National agencies like HECL, HFCL and HCL Comet. There are two different types of systems with the above mentioned capabilities available in the market viz. SCPCDAMA and TDMA. However, the first one named SCPCDAMA has been recommended for the Pauk H.E. Project. Two such systems would be installed at suitable upstream and downstream locations. The estimated cost of installation of such a communication system has been given in Table 6.7.1.

6.7.2.8 Evacuation Plans

Emergency Action Plan includes evacuation plans and procedures for implementation based on local needs. These are:

- Demarcation/prioritization of areas to be evacuated.
- Notification procedures and evacuation instructions.
- Safe routes, transport and traffic control.
- Shelter areas
- Functions and responsibilities of members of evacuation team.

The flood prone zone in the event of break of Pauk Dam shall be marked properly at the village locations with adequate factor of safety. As the flood wave takes sufficient time in reaching these villages, its populace shall be informed well in time through wireless and sirens etc. so that people may climb on hills or to some elevated place beyond the flood zone which has been marked.

The Evacuation Team would comprise of:

i) D.M./ his Nominated Officer (To peacefully relocate the people to places at higher elevation with state administration)
ii) Engineer-in-Charge of the Project (Team Leader)
iii) S.P./Nominated Police Officer (To maintain law and order)
iv) C.M.O. of the area (To tackle morbidity of affected people)

v) Sarpanch/ Affected Village Representative to execute the resettlement operation with the aid of state machinery and project proponents

vi) Sub-committees at village level

The Engineer-in-Charge will be responsible for the entire operation including prompt determination of the flood situation from time to time. Once the red alert is declared the whole state machinery will come into swing and will start evacuating people in the inundation areas delineated in the inundation map. For successful execution, annually Demo exercise will be done. DM is to monitor the entire operation.

6.7.2.9 Notifications

Notification procedures are an integral part of any emergency action plan. Separate procedures shall be established for slowly and rapidly developed situations and failure. Notifications will include communications of either an alert situation or an alert situation followed by a warning situation. An alert situation will indicate that although failure or flooding is not imminent, a more serious situation can occur unless conditions improve. A warning situation will indicate that flooding is imminent as a result of an impending failure of the Dam. It will normally include an order for evacuation of delineated inundation areas. For a regular watch on the flood level situation, it is necessary that two or more people man the flood cell so that an alternative person is available for notification round the clock.

In addition, a few guidelines to be generally followed by the inhabitants of flood prone areas, which form part of public awareness for disaster mitigation include:

- Listen to the radio for advance information and advice.
- Disconnect all electrical appliances and move all valuable personal and household goods and all clothing out of reach of flood water.
- Move vehicles, farm animals and movable goods to the highest ground nearby.
- Move all dangerous pollutants and insecticides out of reach of water.

- Do not enter flood waters on foot, if it can be avoided.

6.7.3 COST ESTIMATES FOR DISASTER MANAGEMENT

The estimated total cost of execution of disaster management plan including the equipment would be **Rs. 117.60 lakh** and it is given in Table 6.7.1.

Table 6.7.1 Estimated cost of setting up of a satellite communication system & disaster management plan

Sl. No.	Product	Amount (Rs. in lakh)
A.	Setting up of V-SAT communication system	
1.	Product Name: SCPCDAMA (two sites) @ Rs.20.00 lakh per site	40.00
	a) Antenna 2 x 2.4 M	
	b) RF 2 x 2 W	
	c) Modem 2 x 1No.	
2.	Generators 2 No. (2 KVA)	6.00
3.	UPS 2 Nos. (2 KVA)	4.00
4.	Installation and maintenance of system, maintenance and running cost of UPS, generators, etc. @ 10% of the total cost for 6 years	21.60
B.	Installation of alert systems, Setting up of control room, etc.	10.00
C.	Notification and publication procedures, Miscellaneous etc	6.00
D.	Preparation of Disaster Management Action Plan	30.00
	Total	**117.60**

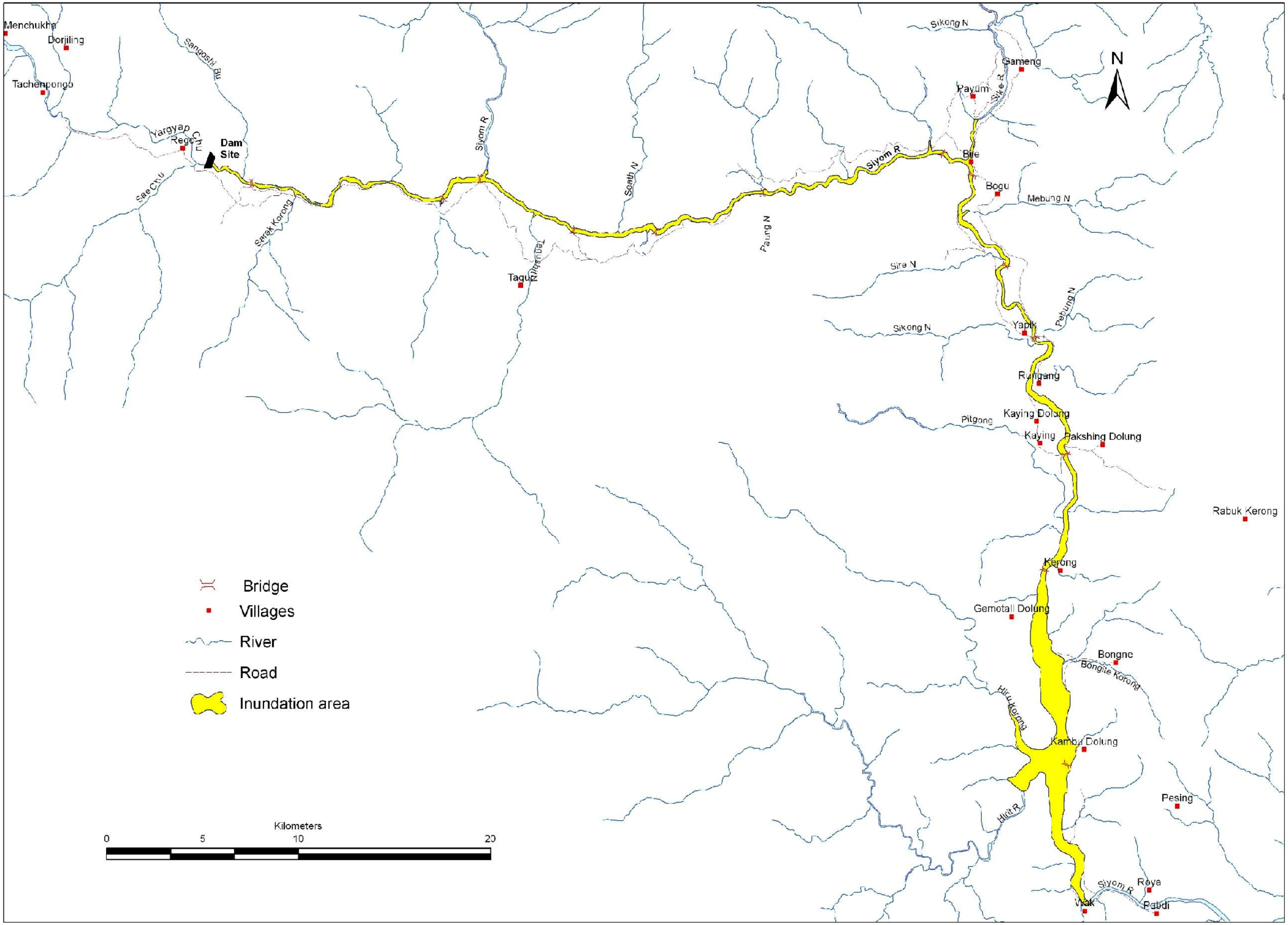


Figure 6.7.1: Inundation Map

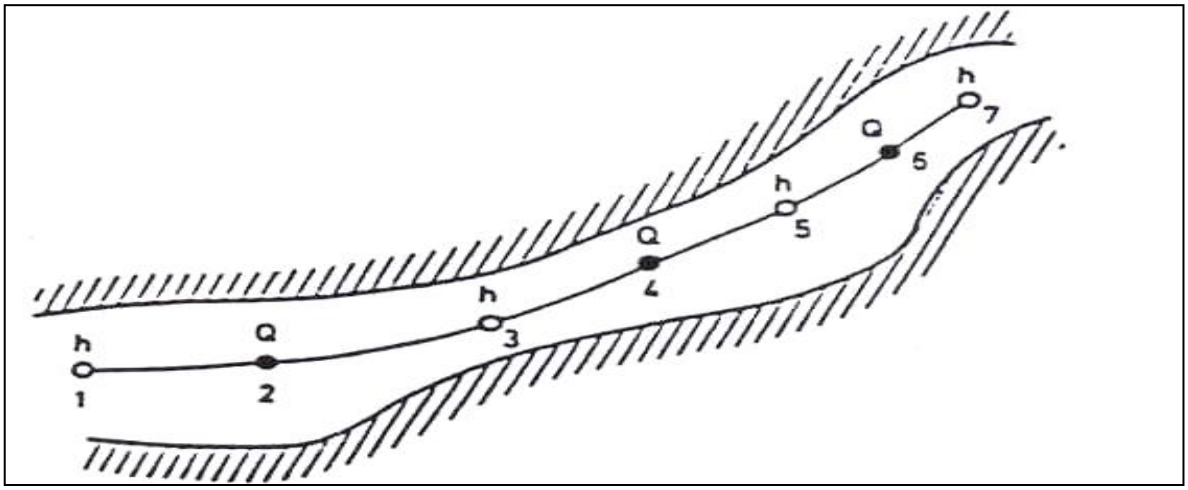


Figure 6.2.1: Layout of channel section with computational net

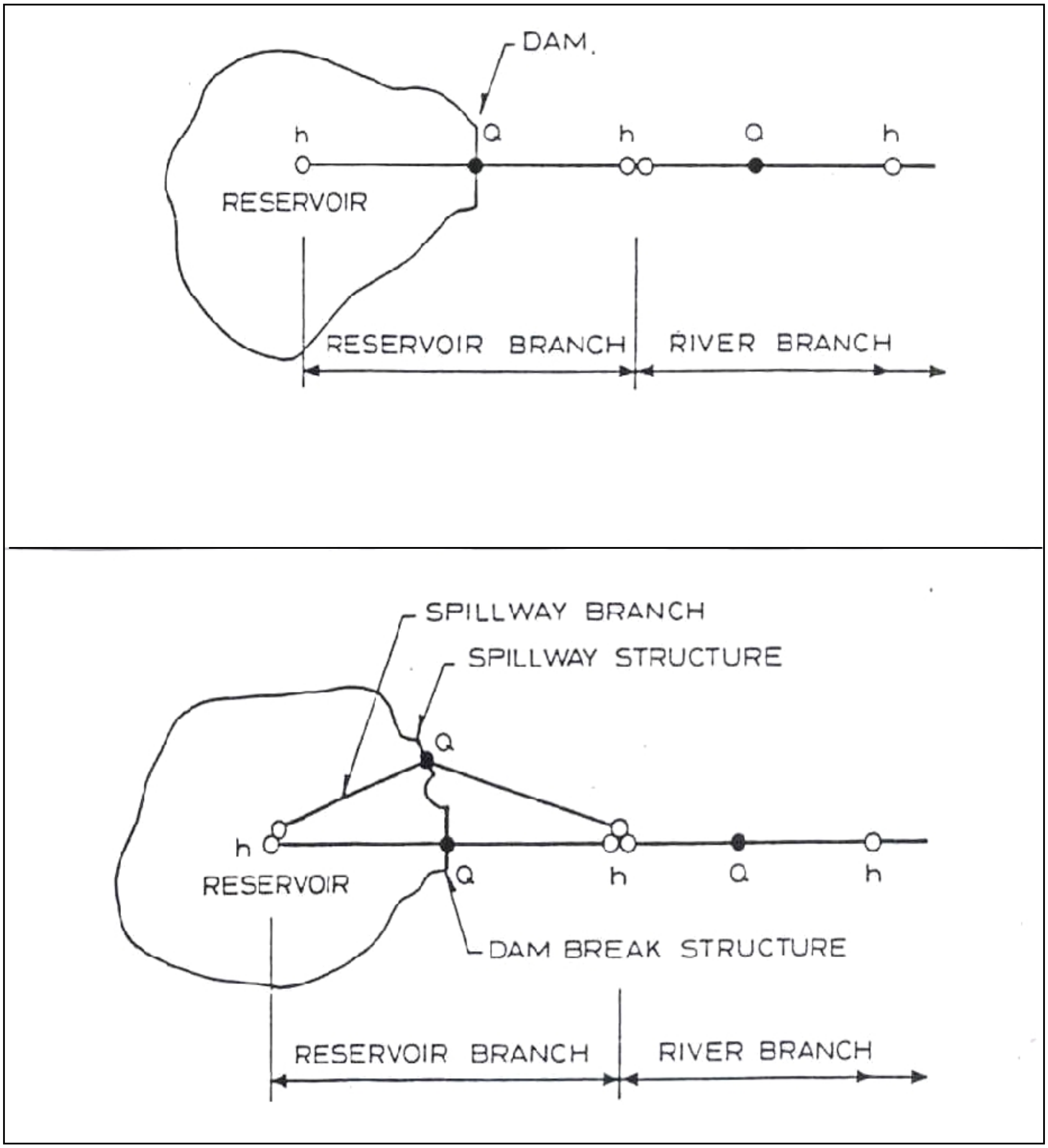


Figure 6.2.2 & 6.2.3: River set up with dam

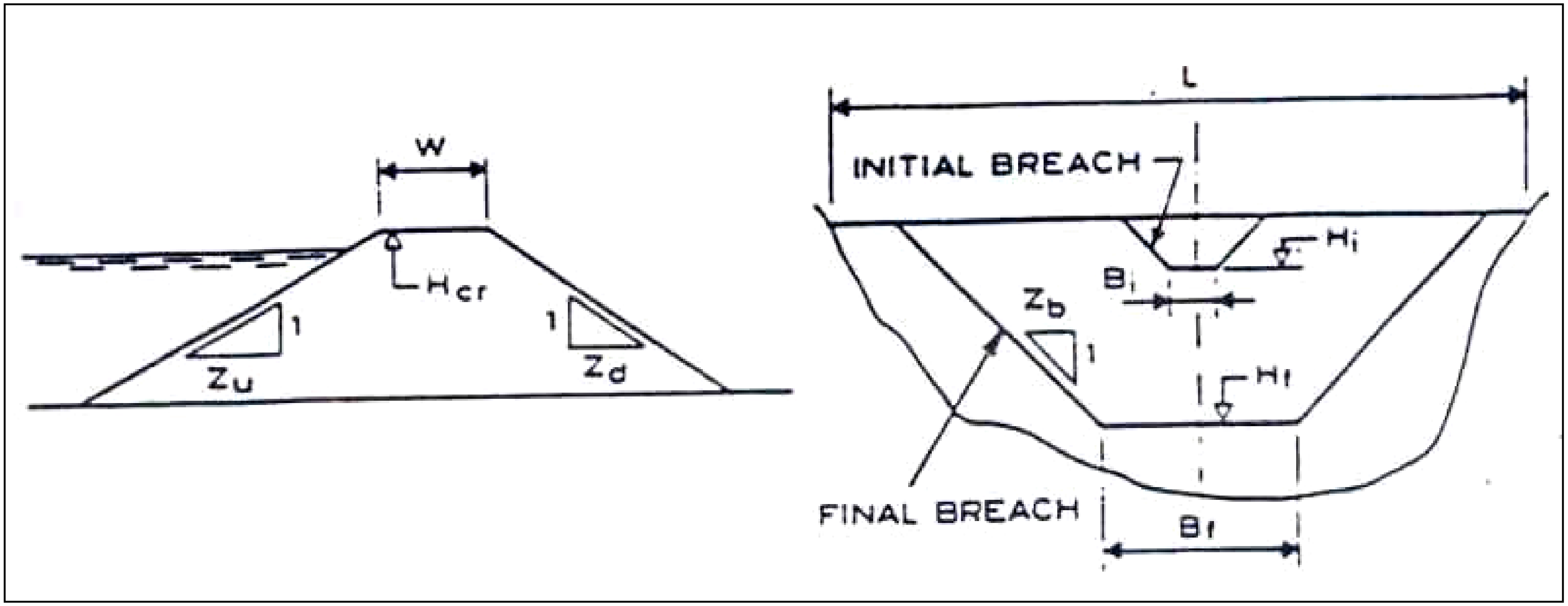
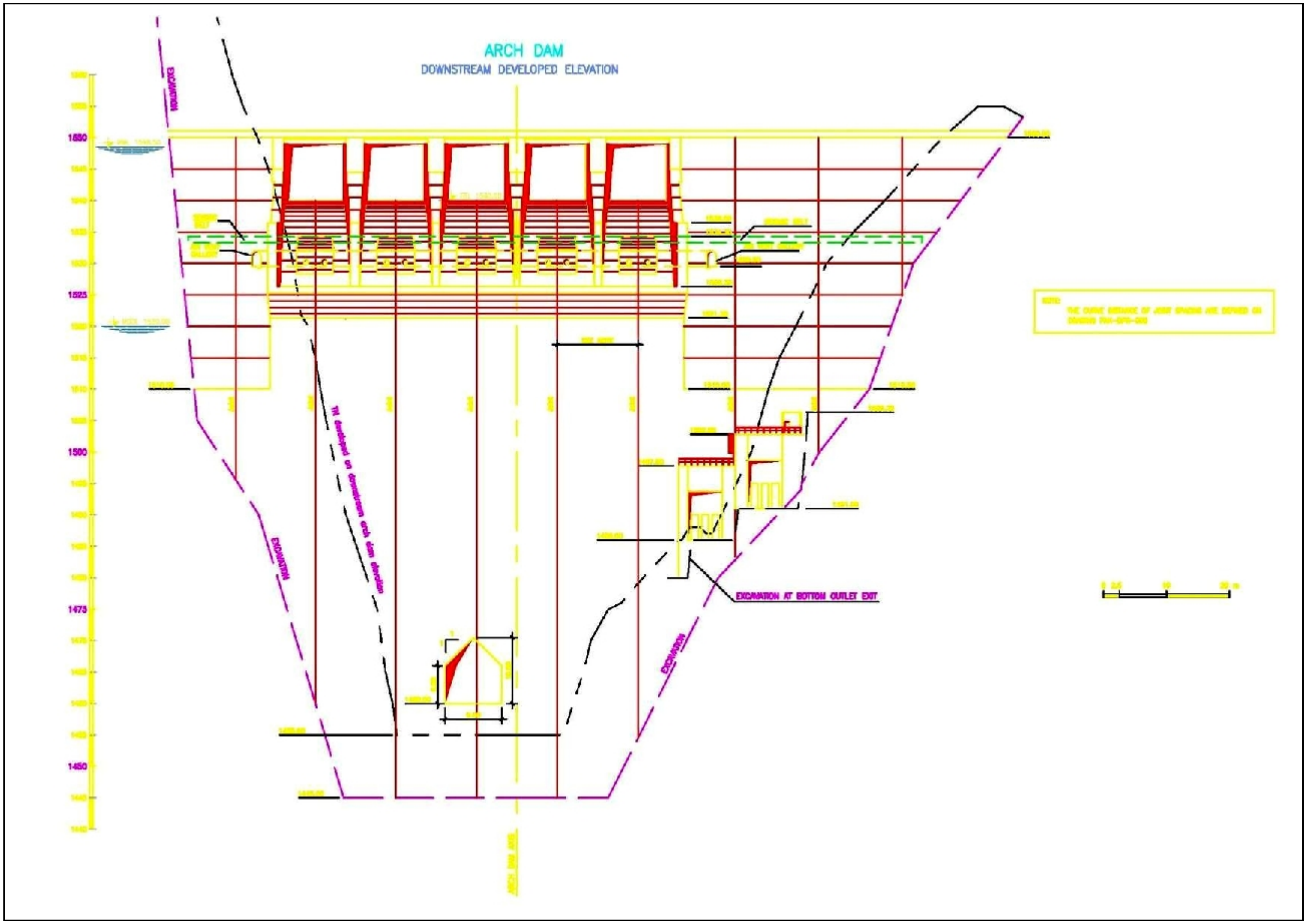
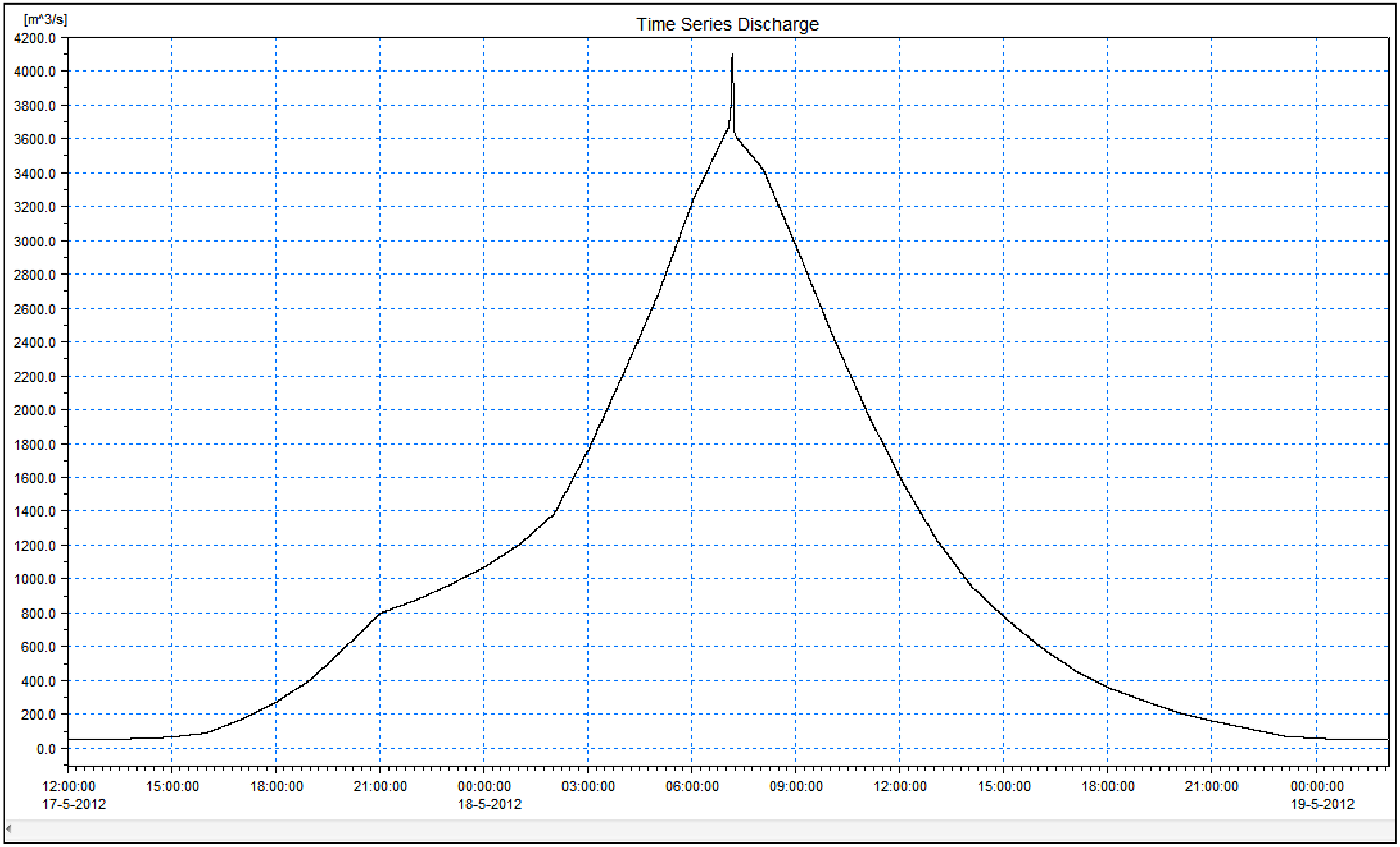


Figure 6.2.4: Breach parameters for linear mode

Plate 6.1

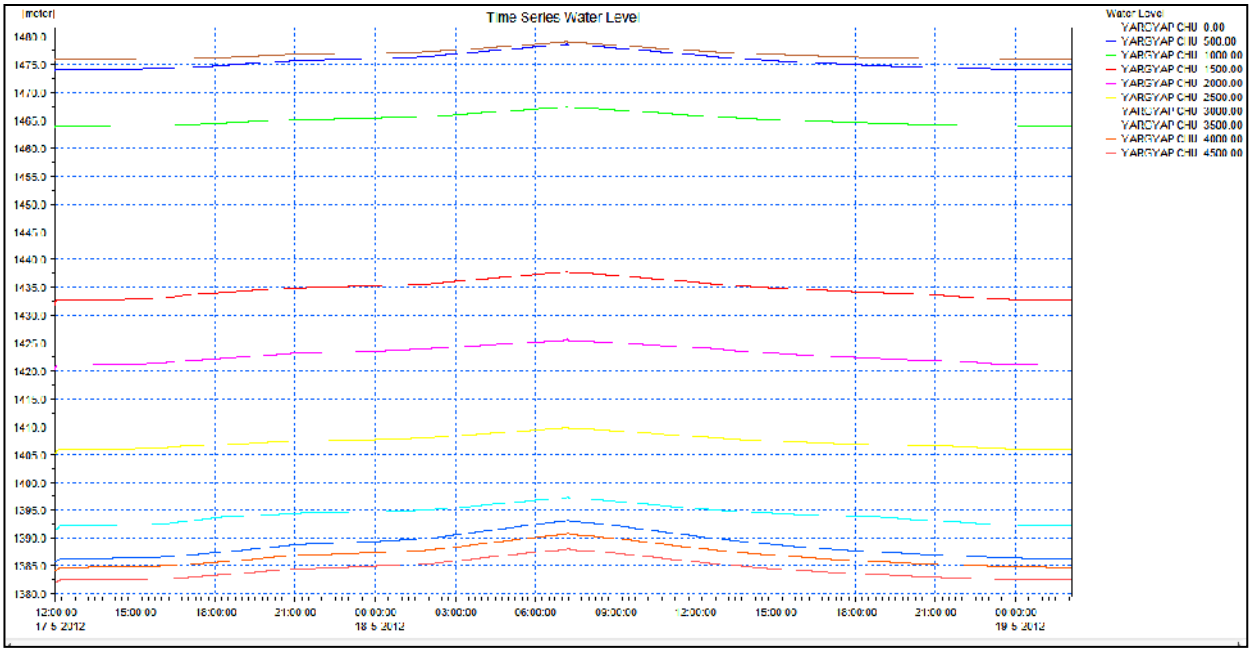


ARCH DAM
DOWNSTREAM DEVELOPED ELEVATION
EXCAVATION
EXCAVATION AT BOTTOM OUTLET EXIT

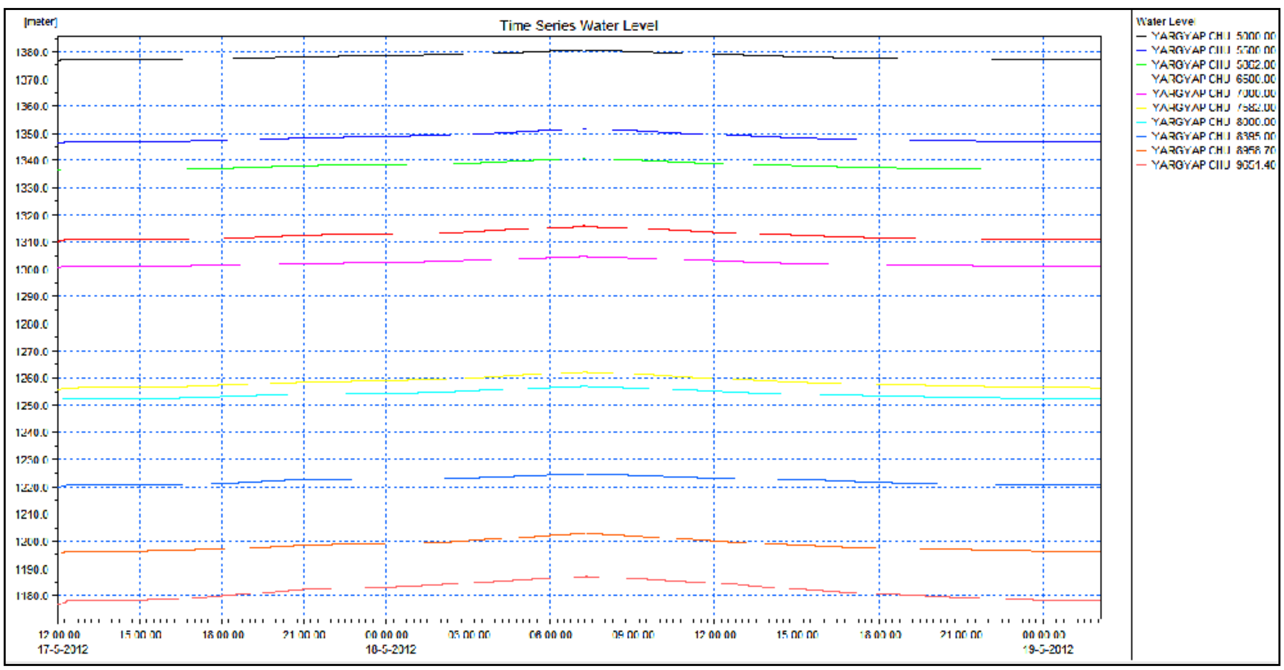


Note: The dates shown on the time axis of the plot are relative dates as used in MIKE11 model

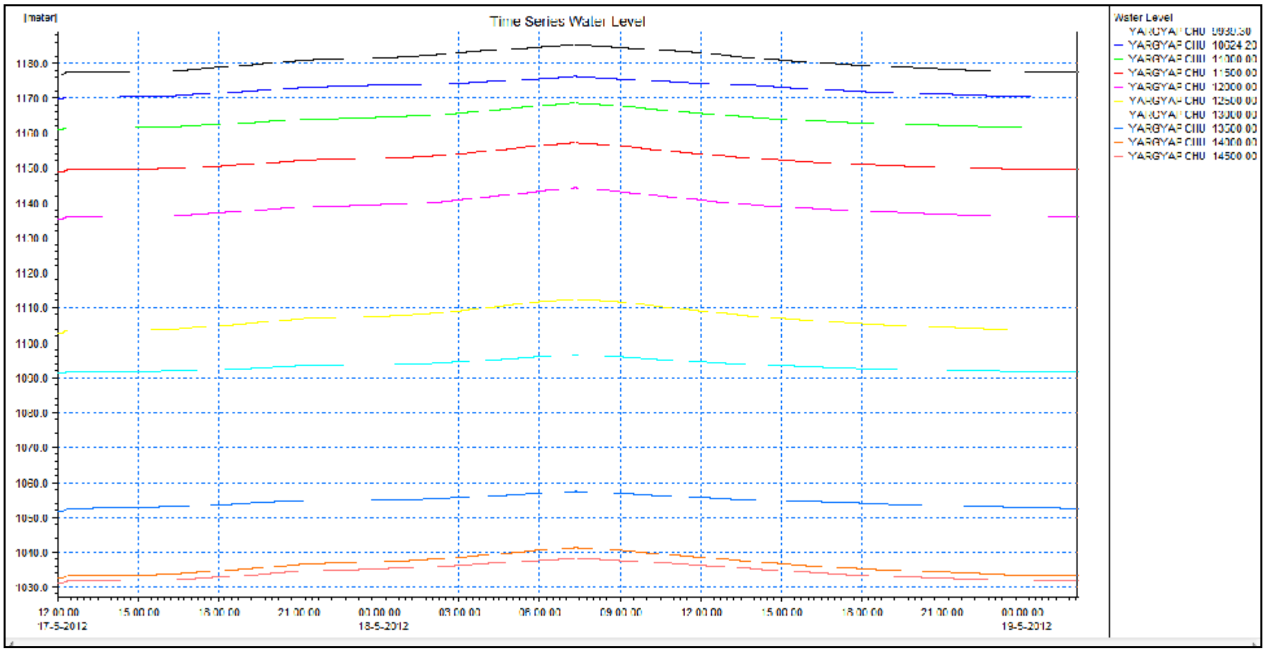
Fig. 6.5.1:The dam breach flood hydrograph

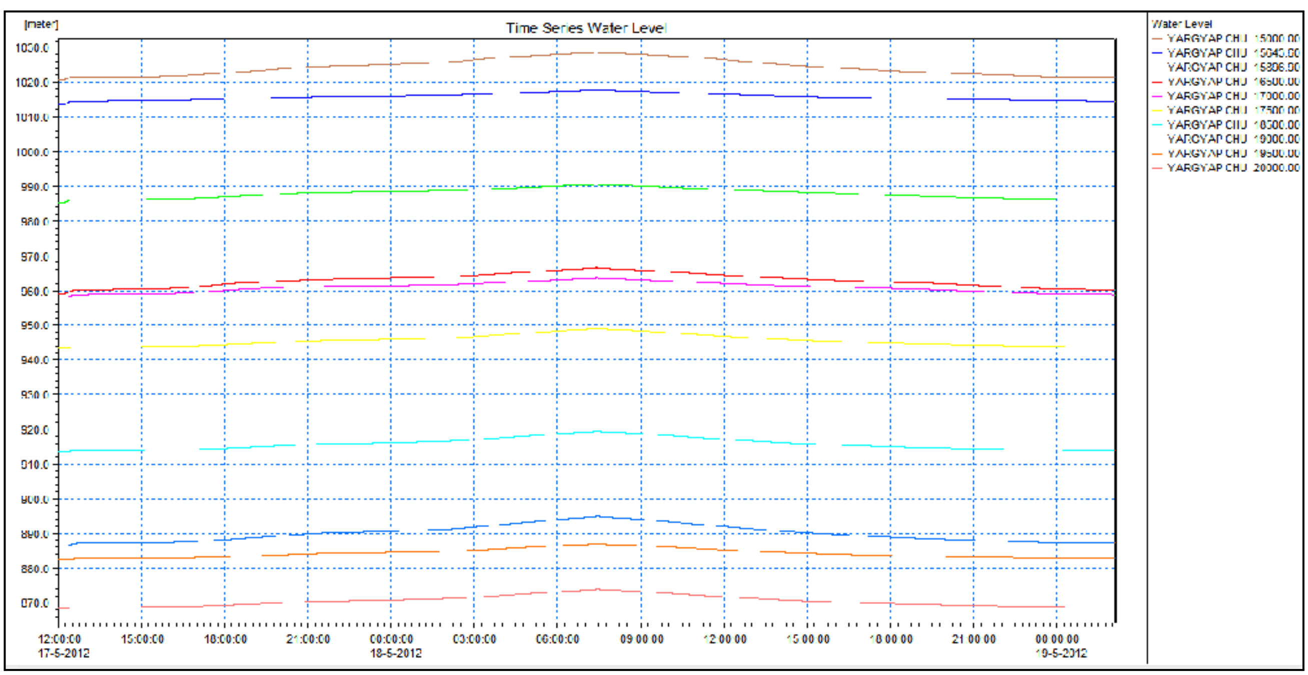


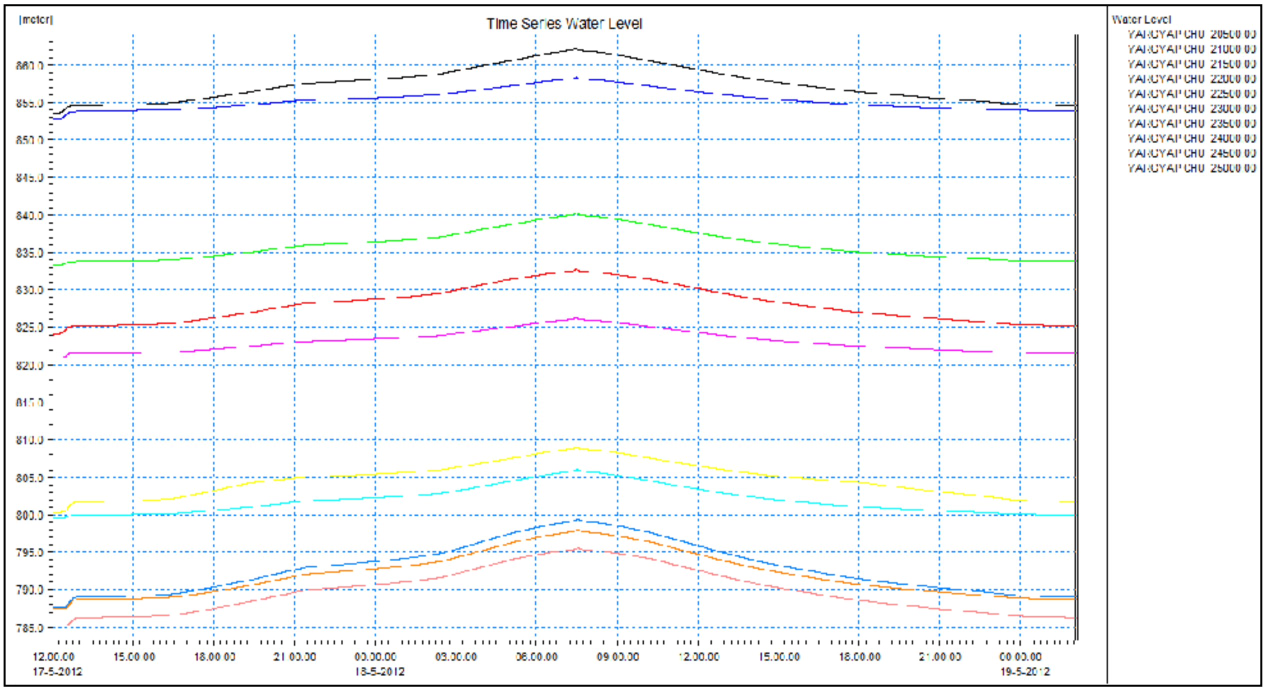
Time Series Water Level
[meter]
Water Level
YARGYAP CHU 0.00
YARGYAP CHU 500.00
YARGYAP CHU 1000.00
YARGYAP CHU 1500.00
YARGYAP CHU 2000.00
YARGYAP CHU 2500.00
YARGYAP CHU 3000.00
YARGYAP CHU 3500.00
YARGYAP CHU 4000.00
YARGYAP CHU 4500.00
12:00:00 17-5-2012
00:00:00 18-5-2012
00:00:00 19-5-2012

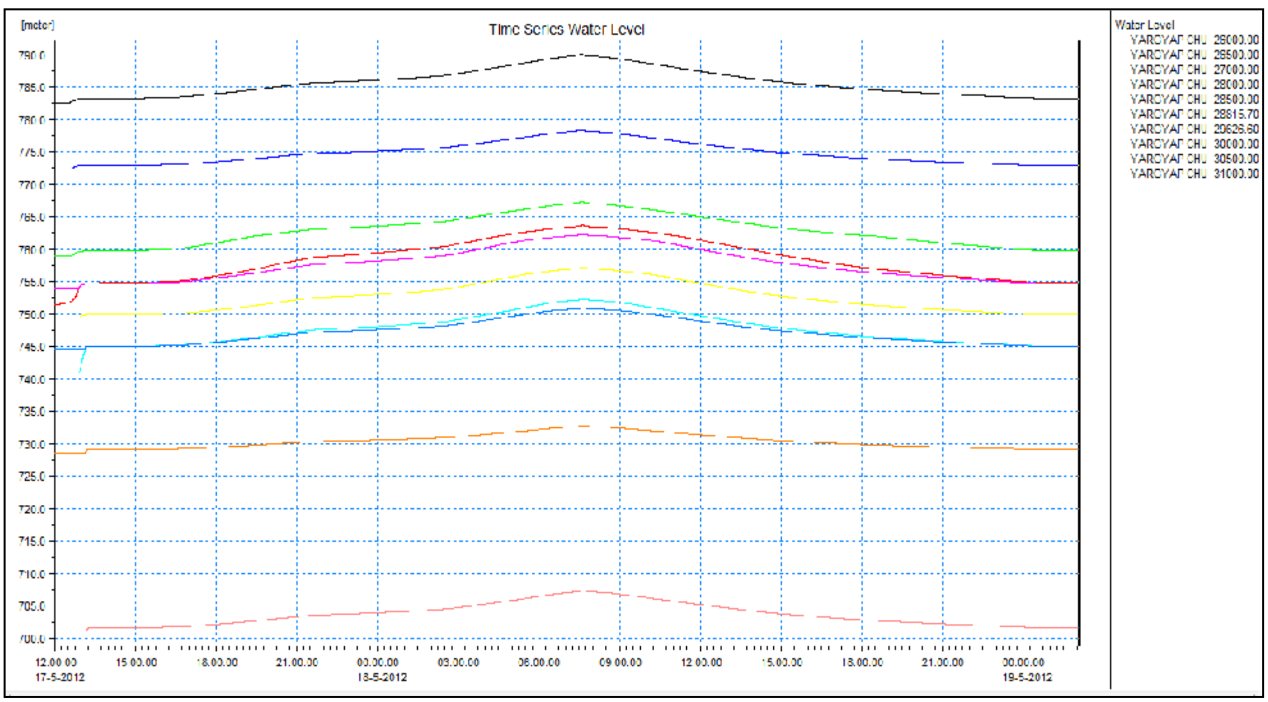


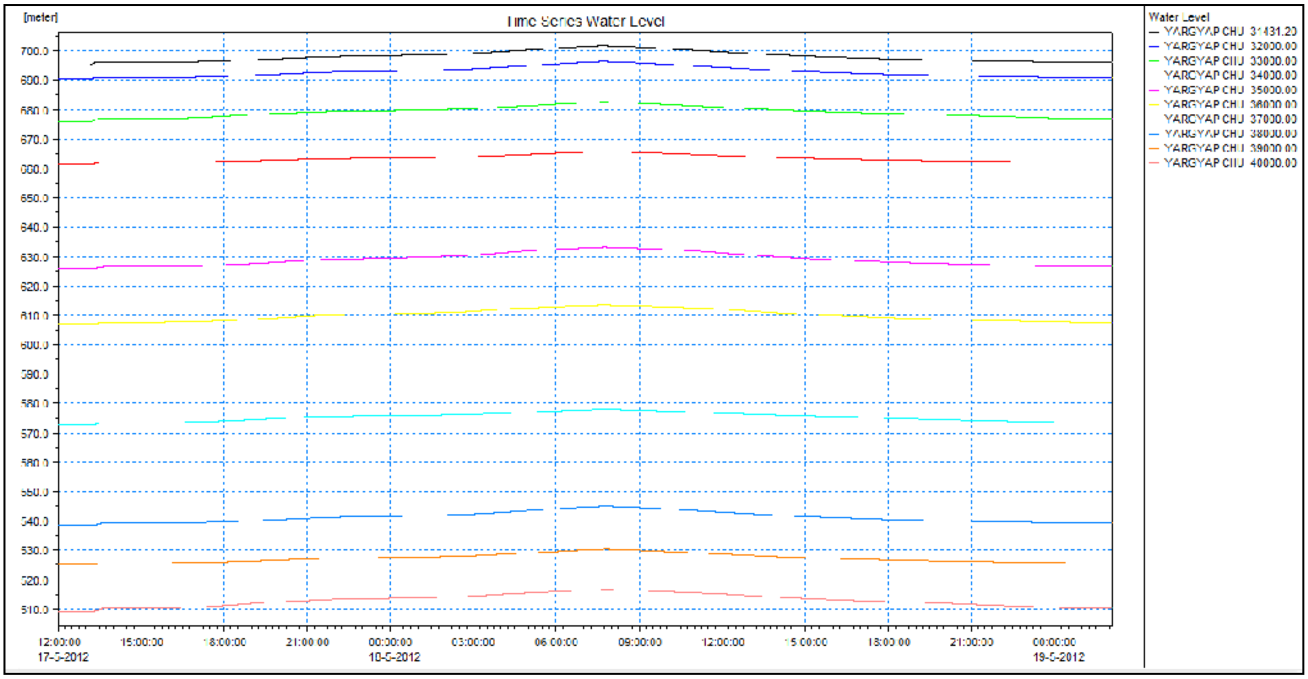
Time Series Water Level
[meter]
Water Level
YARGYAP CHU 5000.00
YARGYAP CHU 5500.00
YARGYAP CHU 5002.00
YARGYAP CHU 6500.00
YARGYAP CHU 7000.00
YARGYAP CHU 7582.00
YARGYAP CHU 8000.00
YARGYAP CHU 8395.00
YARGYAP CHU 8958.70
YARGYAP CHU 9051.40
12:00:00 17-5-2012
00:00:00 18-5-2012
00:00:00 19-5-2012


[meter]
Time Series Water Level
Water Level
YARGYAP CHU 10024.20
YARGYAP CHU 11000.00
YARGYAP CHU 11500.00
YARGYAP CHU 12000.00
YARGYAP CHU 12500.00
YARGYAP CHU 13000.00
YARGYAP CHU 13500.00
YARGYAP CHU 14000.00
YARGYAP CHU 14500.00
17-5-2012
18-5-2012
19-5-2012

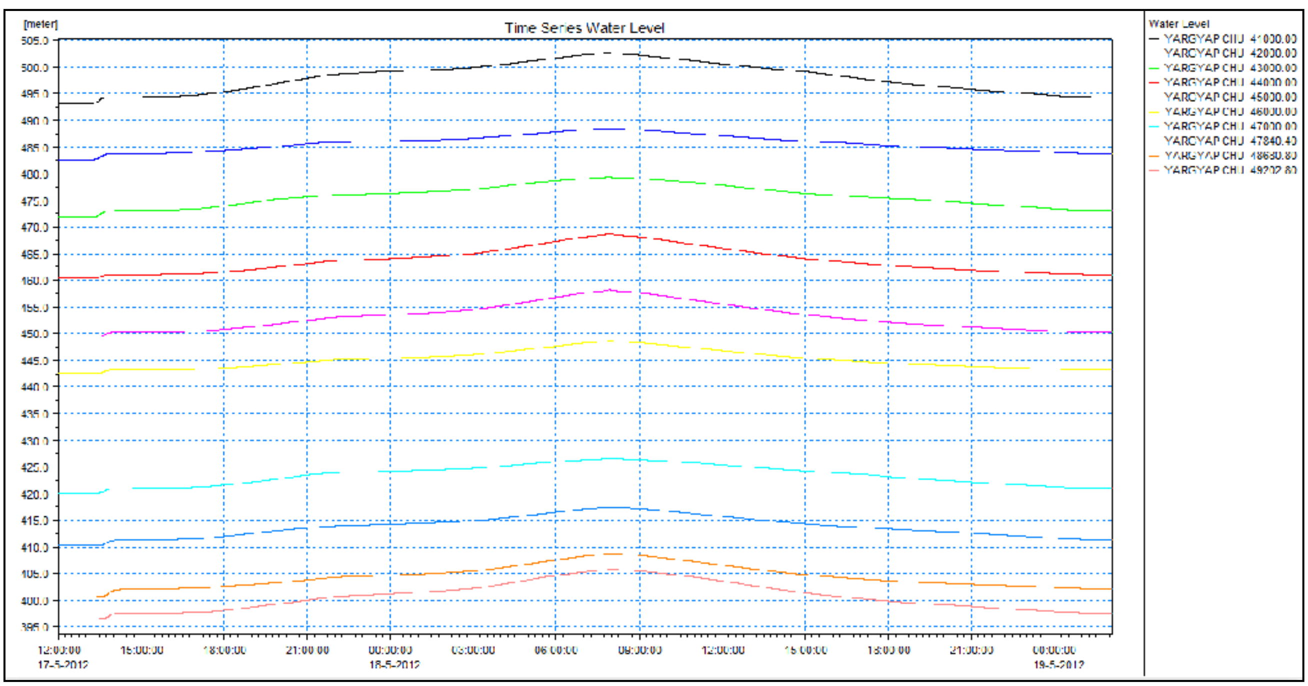

[meter]
Time Series Water Level
Water Level
YARGYAP CHU 15000.00
YARGYAP CHU 15040.00
YARGYAP CHU 15806.00
YARGYAP CHU 16500.00
YARGYAP CHU 17000.00
YARGYAP CHU 17500.00
YARGYAP CHU 18500.00
YARGYAP CHU 19000.00
YARGYAP CHU 19500.00
YARGYAP CHU 20000.00
17-5-2012
18-5-2012
19-5-2012


[meter]
Time Series Water Level
860.0
855.0
850.0
845.0
840.0
835.0
830.0
825.0
820.0
815.0
810.0
805.0
800.0
795.0
790.0
785.0
12.00.00 17-5-2012
15.00.00
18.00.00
21.00.00
00.00.00 18-5-2012
03.00.00
06.00.00
09.00.00
12.00.00
15.00.00
18.00.00
21.00.00
00.00.00 19-5-2012
Water Level
YARGYAP CHU 20500.00
YARGYAP CHU 21000.00
YARGYAP CHU 21500.00
YARGYAP CHU 22000.00
YARGYAP CHU 22500.00
YARGYAP CHU 23000.00
YARGYAP CHU 23500.00
YARGYAP CHU 24000.00
YARGYAP CHU 24500.00
YARGYAP CHU 25000.00

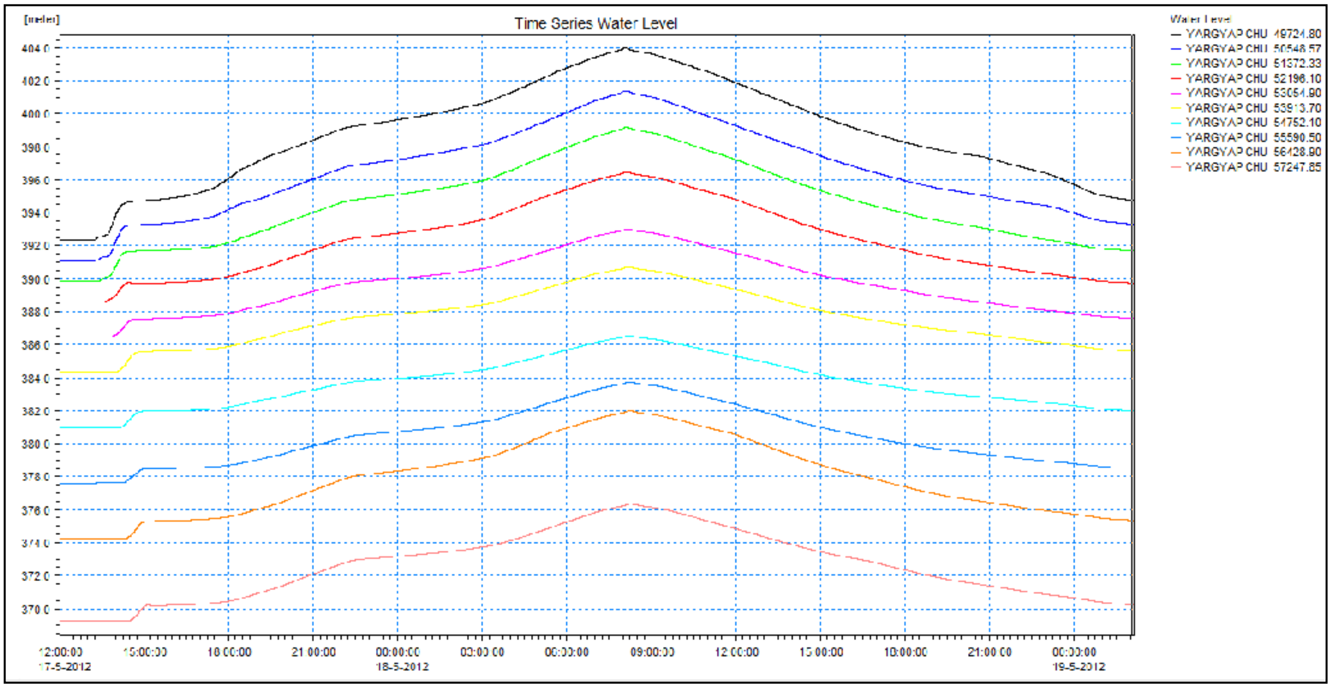

[meter]
Time Series Water Level
790.0
785.0
780.0
775.0
770.0
765.0
760.0
755.0
750.0
745.0
740.0
735.0
730.0
725.0
720.0
715.0
710.0
705.0
700.0
12.00.00 17-5-2012
15.00.00
18.00.00
21.00.00
00.00.00 18-5-2012
03.00.00
06.00.00
09.00.00
12.00.00
15.00.00
18.00.00
21.00.00
00.00.00 19-5-2012
Water Level
YARGYAP CHU 26000.00
YARGYAP CHU 26500.00
YARGYAP CHU 27000.00
YARGYAP CHU 28000.00
YARGYAP CHU 28500.00
YARGYAP CHU 28815.70
YARGYAP CHU 29626.60
YARGYAP CHU 30000.00
YARGYAP CHU 30500.00
YARGYAP CHU 31000.00



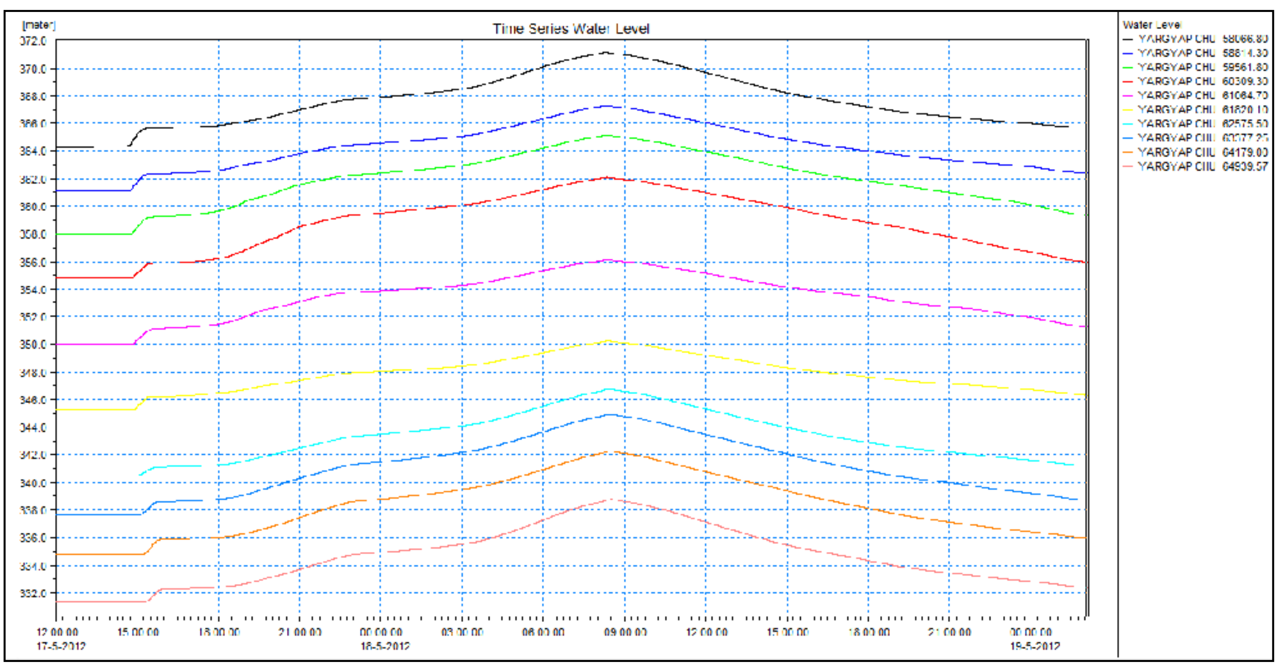
[meter]
Time Series Water Level
700.0
690.0
680.0
670.0
660.0
650.0
640.0
630.0
620.0
610.0
600.0
590.0
580.0
570.0
560.0
550.0
540.0
530.0
520.0
510.0
12:00:00
17-5-2012
15:00:00
18:00:00
21:00:00
00:00:00
18-5-2012
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
19-5-2012
Water Level
YARGYAP CHU 31431.20
YARGYAP CHU 32000.00
YARGYAP CHU 33000.00
YARGYAP CHU 34000.00
YARGYAP CHU 35000.00
YARGYAP CHU 36000.00
YARGYAP CHU 37000.00
YARGYAP CHU 38000.00
YARGYAP CHU 39000.00
YARGYAP CHU 40000.00



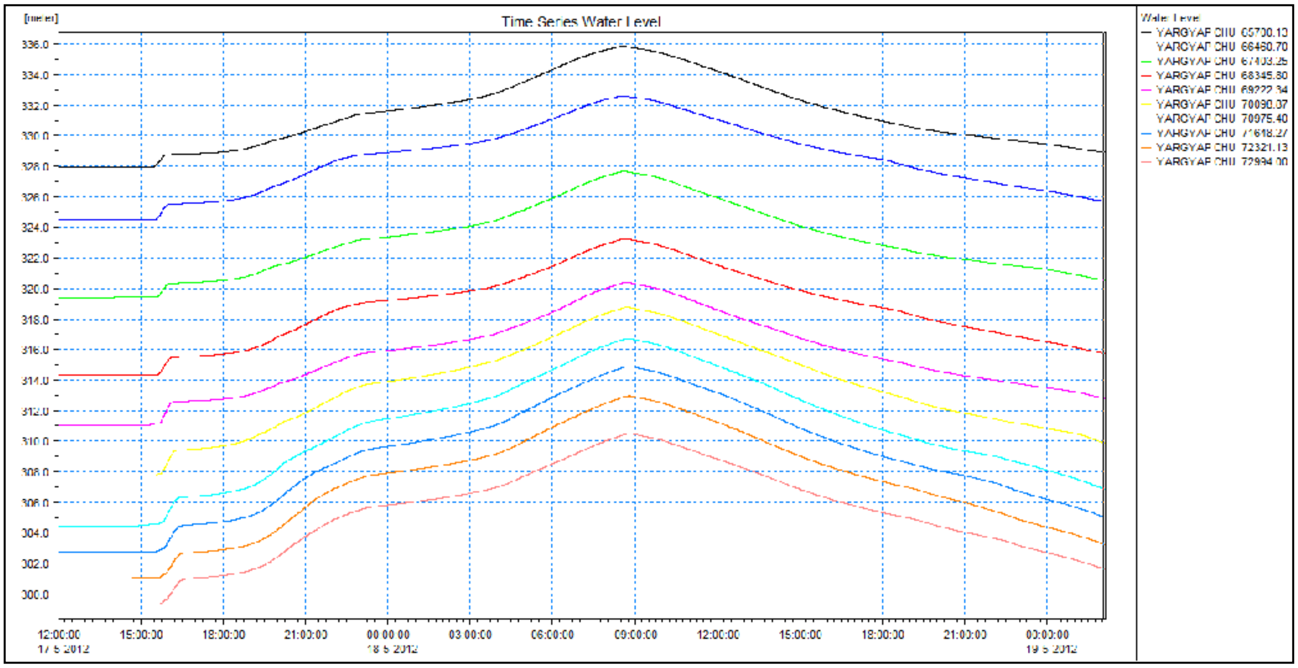
[meter]
Time Series Water Level
505.0
500.0
495.0
490.0
485.0
480.0
475.0
470.0
465.0
460.0
455.0
450.0
445.0
440.0
435.0
430.0
425.0
420.0
415.0
410.0
405.0
400.0
395.0
12:00:00
17-5-2012
15:00:00
18:00:00
21:00:00
00:00:00
18-5-2012
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
19-5-2012
Water Level
YARGYAP CHU 41000.00
YARGYAP CHU 42000.00
YARGYAP CHU 43000.00
YARGYAP CHU 44000.00
YARGYAP CHU 45000.00
YARGYAP CHU 46000.00
YARGYAP CHU 47000.00
YARGYAP CHU 47840.40
YARGYAP CHU 48680.80
YARGYAP CHU 49202.80

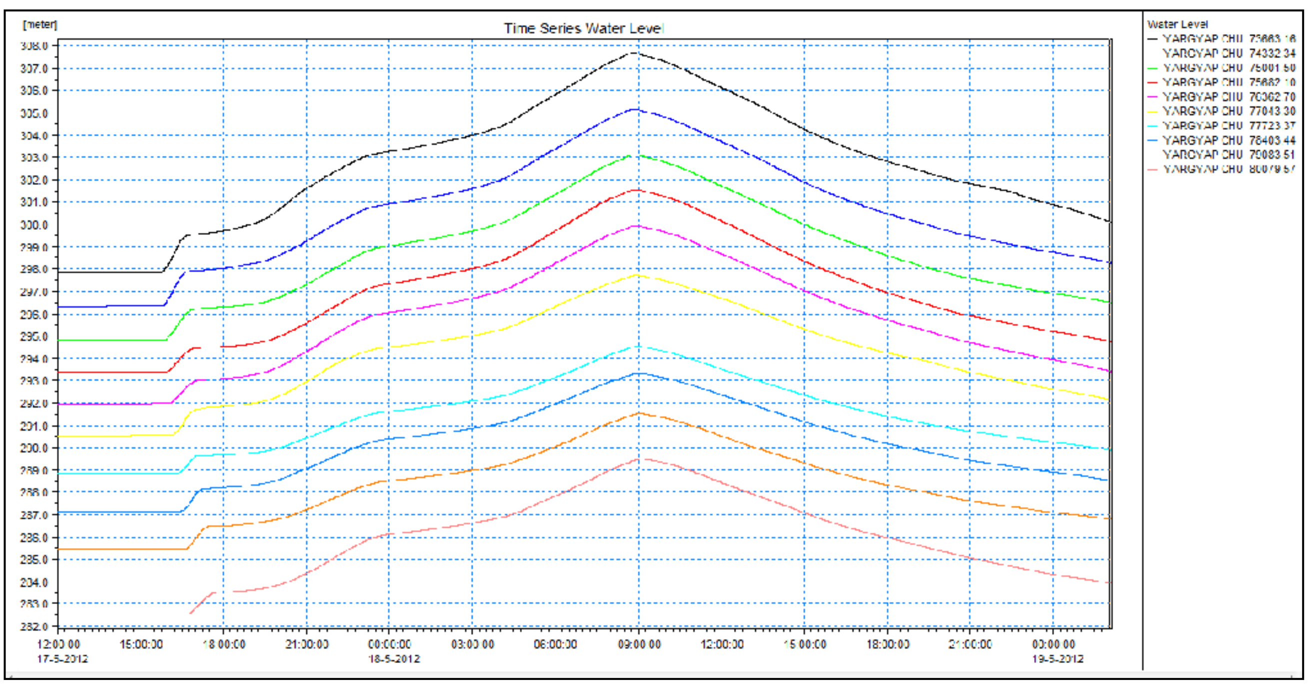


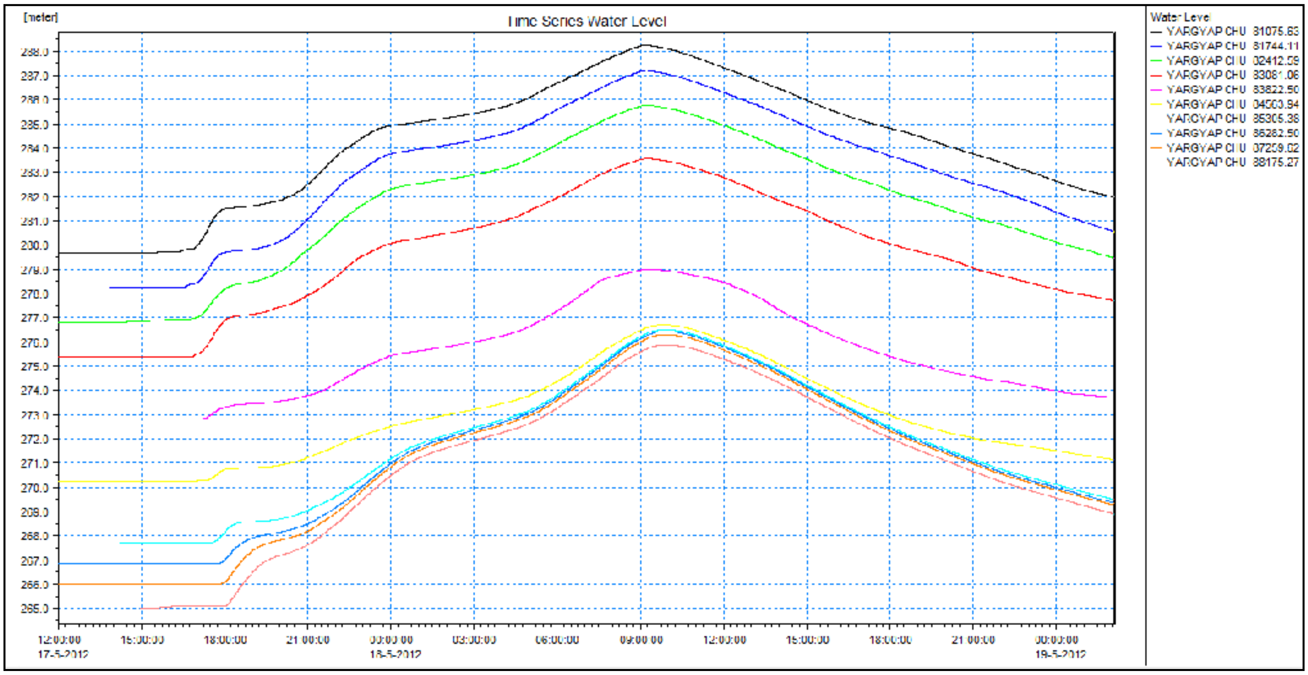
Time Series Water Level
[meter]
404.0
402.0
400.0
398.0
396.0
394.0
392.0
390.0
388.0
386.0
384.0
382.0
380.0
378.0
376.0
374.0
372.0
370.0
12:00:00
17-5-2012
15:00:00
18:00:00
21:00:00
00:00:00
18-5-2012
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
19-5-2012
Water Level
YARGYAP CHU 49724.80
YARGYAP CHU 50548.57
YARGYAP CHU 51372.33
YARGYAP CHU 52196.10
YARGYAP CHU 53054.90
YARGYAP CHU 53913.70
YARGYAP CHU 54752.10
YARGYAP CHU 55590.50
YARGYAP CHU 56428.90
YARGYAP CHU 57247.85



Time Series Water Level
[meter]
372.0
370.0
368.0
366.0
364.0
362.0
360.0
358.0
356.0
354.0
352.0
350.0
348.0
346.0
344.0
342.0
340.0
338.0
336.0
334.0
332.0
12:00:00
17-5-2012
15:00:00
18:00:00
21:00:00
00:00:00
18-5-2012
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
00:00:00
19-5-2012
Water Level
YARGYAP CHU 58066.80
YARGYAP CHU 58814.30
YARGYAP CHU 59561.80
YARGYAP CHU 60309.30
YARGYAP CHU 61064.70
YARGYAP CHU 61820.10
YARGYAP CHU 62575.50
YARGYAP CHU
YARGYAP CHU 64179.00
YARGYAP CHU 64939.57


[meter]
Time Series Water Level
336.0
334.0
332.0
330.0
328.0
326.0
324.0
322.0
320.0
318.0
316.0
314.0
312.0
310.0
308.0
306.0
304.0
302.0
300.0
12:00:00
17-5-2012
15:00:00
18:00:00
21:00:00
00:00:00
18-5-2012
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
03:00:00
19-5-2012
Water Level
YARGYAP CHU 65700.13
YARGYAP CHU 66460.70
YARGYAP CHU 67403.25
YARGYAP CHU 68345.80
YARGYAP CHU 69222.34
YARGYAP CHU 70090.07
YARGYAP CHU 70975.40
YARGYAP CHU 71618.27
YARGYAP CHU 72321.13
YARGYAP CHU 72994.00


[meter]
Time Series Water Level
308.0
307.0
306.0
305.0
304.0
303.0
302.0
301.0
300.0
299.0
298.0
297.0
296.0
295.0
294.0
293.0
292.0
291.0
290.0
289.0
288.0
287.0
286.0
285.0
284.0
283.0
282.0
12:00:00
17-5-2012
15:00:00
18:00:00
21:00:00
00:00:00
18-5-2012
03:00:00
06:00:00
09:00:00
12:00:00
15:00:00
18:00:00
21:00:00
03:00:00
19-5-2012
Water Level
YARGYAP CHU 73663.16
YARGYAP CHU 74332.34
YARGYAP CHU 75001.50
YARGYAP CHU 75682.10
YARGYAP CHU 76362.70
YARGYAP CHU 77043.30
YARGYAP CHU 77723.37
YARGYAP CHU 78403.44
YARGYAP CHU 79083.51
YARGYAP CHU 80079.57



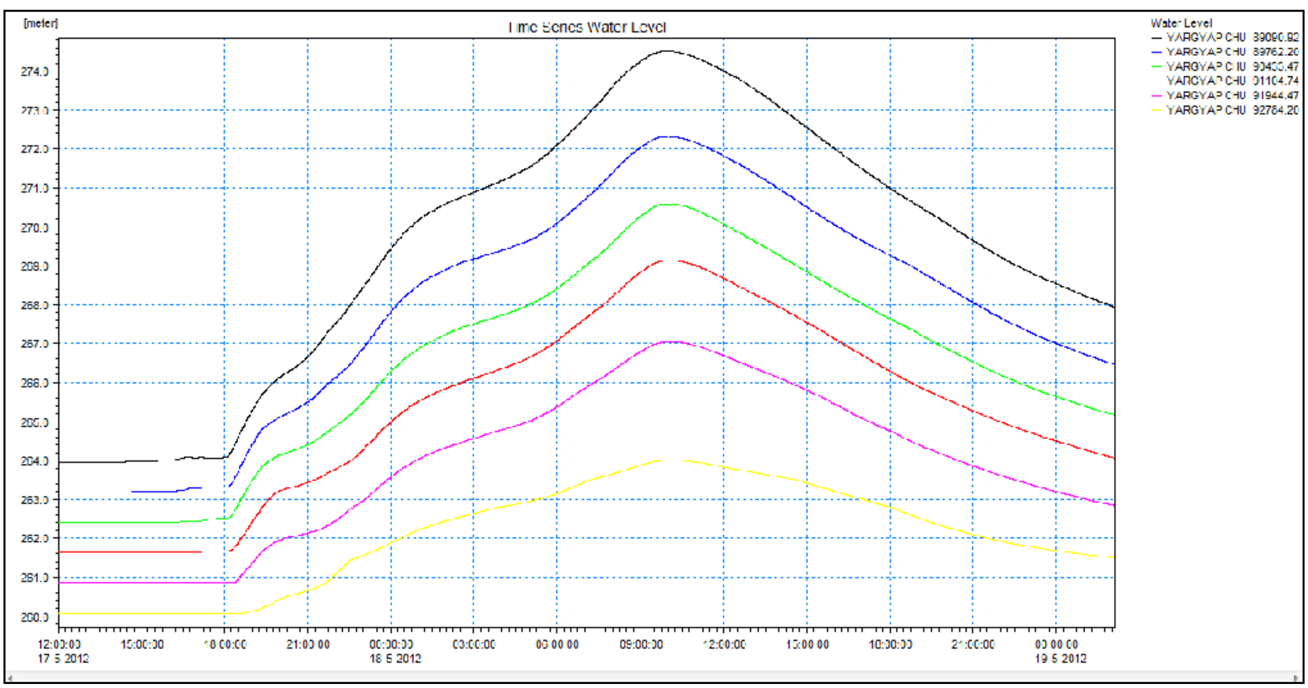


Figure 6.6.1 A to N: Time series of water level at different locations of Yargyap Chu downstream of Pauk dam due to dam breach

Note: YARGYAP CHU 500.00 means location of YARGYAP CHU 500 m d/s of Pauk dam axis. The same way all other locations may please be read

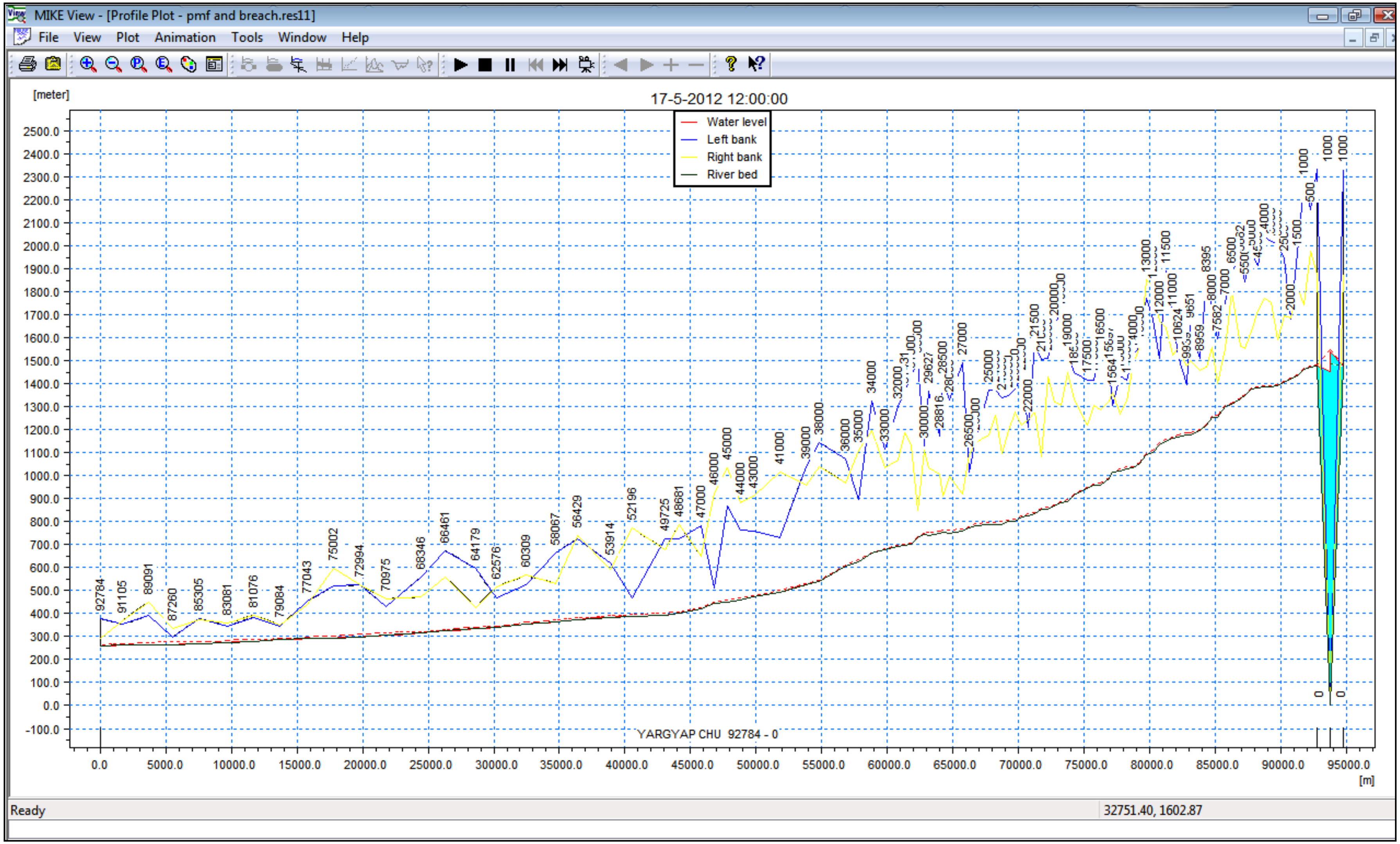


Figure 6.6.2: Profile of Yargyap Chu downstream of Pauk dam