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1.0 INTRODUCTION

The Himalayan State of Sikkim, which in 1975 has elected to join the India Union is one of the most picturesque regions of Asia. The bowl like mountain girdled state in the eastern Himalayas bordered on the west by Nepal, on the north by Tibet, on the east by Bhutan and on the south by the Darjeeling district of West Bengal lies between 27^o to 28^o north latitudes and 88^o to 89^o east longitude. Sikkim is surrounded by important mountain ranges. The chola range of mountains on its east forms the watershed between it and Bhutan on one side and Chumbi valley of Tibet on the other. The well known Singalila ridge separates Sikkim from Nepal. The northern boundary is formed by the convex arch of the great Himalayan peaks.

The total geographical area of Sikkim state is about 7096 sq km, The maximum horizontal length from north to south is about 112 km whereas the maximum width from east to west is 90 km. The Tibetan Plateau on the north, Nathula and other passes on the north-east, Bhutan on the south-east, Darjeeling district of West Bengal on the south and Singalila range of Nepal on the west from the boundaries of this picturesque Himalayan State. It is a hill-state having no plain area. The altitude above mean sea level varies from 213m in the south to about 8500m in the north-west. The Mount Kanchendzonga, the third highest peak in the world iat an elevation of about 8598 m. adorns the state with its beautiful range covered with shining snow. Gangtok, the capital is about 1677 m above mean sea level. The northern part of the state is cut into deep escarpments. The northern part is not populated except in Lachung and Lachen valleys. Southern Sikkim is, however, more open and fairly well cultivated.

Sikkim is drained by large number of perennial rivers, which merge into two prominent rivers, the Teesta and the Rangit. Rest of other streams eventually joins one or the other. Rangit also joins the Teesta just near the boundary between Sikkim and West Bengal.

The Rangit river and its tributaries originate in the Talung glacier in West Sikkim and after flowing for about 60 km, joins Teesta below Malli near the border of Sikkim with West Bengal. River Rangit is a major tributary of river Teesta from the Western Sikkim.

Major tributaries of Rangit are Rathang Chhu, Rimbi Khola, Kalej Khola, Ramam Khola and the little Rangit. The Rangit river in its early reaches flows through very high valleys and steep slopes till it joins with Rathang Chhu which originates from the Rathang glacier and is one of the major tributaries of river Rangit. The slope of the river Rangit up to its confluence with Rathang Chhu is of the order of 1 in 25. After the confluence, the river enters into somewhat flatter area with a slope of 1 in 85. After joining Ramam Khola and little Rangit near Naya Bazaar, the river enters the plains and widens out till it meets Teesta.

1.1 RANGIT – ii he Project

Rangit-II H.E. project is located on river Rimbi Khola, a tributary of Rathong Chhu. Rathong Chhu and Rimbi Khola then meet to form Rangit river in West Sikkim district. (Fig.1). The Rangit-III has been constructed by N.H.P.C. on river Rangit. The confluence of Rathong Chhu and Rangit river is located upstream of dam of Rangit H.E. project Stage-III which is under operation by NHPC. The location of power house of Rangit Stage-II is proposed near Chong jong village on left bank of Kalej Khola, which is about 11 km from Gyalzing. The surge shaft is located near Linchyum village which is about 7km from Gyalzing (Fig. 2 & 3). The salient features of the project are given in the Table – 1.

Table 1.2 Salient features of the proposed Rangit-II H. E. project

1.	**LOCATION**	
	Country	India
	State	Sikkim
	District	West Sikkim
	River	Rimbi Khola
	River Basin	Brahmaputra
	Diversion site	
	Longitude	88^{o} 10’ 32’’E
	Latitude	27^{o} 18’ 46’’N
	Nearest airport	Bagdogra – 145 km
	Nearest rail head	New Jalpaiguri (BG) – 130 km
2.	**TYPE OF PROJECT**	
	Type	Run-of-River
	Installed Capacity	66 MW (2x33)
	Annual Energy Generation	296.21 MU (90% dependable year)
3.	**HYDROLOGY AND CLIMATE**	
	Catchment area (up to headworks)	120 sq km
	Average yield 90% dependable	393 MCum
	Maximum	1155 MCum
	Maximum daily rainfall	363.9 mm
	Minimum daily rainfall	9.8 mm
	Maximum design flood	1152 cumec
	Portable maximum flood	1152 cumec
	Maximum/ Minimum temperature	30.5ºC / 6ºC
	Seismic factors	
	Horizontal direction	0.23 g
	Vertical direction	0.15 g
4.	**DIVERSION ARRANGEMENT**	
	Diameter of Diversion tunnel	3.40 m
	Tunnel length	120.57 m

	Open channel	118.73 m
5.	**DAM**	
	Type of Dam	Concrete gravity dam
	Height of Dam	40 m
	Top level of Dam	1365 m
	F.R.L	1360 m
	M.D.D.L	1352 m
	M.W.L	1362.5
	Dead Storage Level	1340 m
	Gross Storage Capacity	2.25 MCum
	Live Storage (between FRL and MDDL)	0.223 MCum
	Number of Spillways	3
	Size of Spillway Gate	6.00m x 6.00 m
	Crest Elevation (Sluice)	1340.00 m
	Type of Sluice Gate	Radial
	Number of Overflow Bays	1
	Size of (ungated) overflow Bay	6.00 m
	Crest Elevation of ungated (Ogee Spillway)	1360.5 m
	Length of the dam at top	96.22 m
	Width of the dam at top	7.5 m
	Free Board for FRL	3 m
	Maximum Tail Water Level	1341 m
	River Bed Level	1334 m
	Expected Foundation Level	1325 m
	Energy dissipation device	Ski Jump Bucket
	Intake Structure	1 No. with invert at El. 1343 m and of Size 3 m width and 6 m height
6.	**SUBMERGENCE**	
	Area under Submergence	4.0 Ha
	Number of villages affected	
	Fully	Nil
	Partially	Nil
	Number of families / persons to	

	be rehabilitated	
	Urban	Nil
	Rural	Nil
7.	**DESILTING CHAMBER**	
	Type	Underground
	Number of Desilting Chambers	1
	Length (including transaction)	120.00 m
	Width	7.00 m
	Height (up to Hopper)	11.50 m
	Size of silt particle to be removed	0.20 mm and above
	Flow through Velocity	20.00 cm/sec.
	Flushing out let at R.L.	1326
	Length of flushing conduct	143.87 m
8.	**HEAD RACE TUNNEL**	
	Type of Head Race Tunnel	Horse Shoe
	Diameter of Head Race Tunnel	3.40 m (finished)
	Length	5182 m
	Slope	1 in 275
	Design discharge	12.46 cumec
	Number of intermediate Adits	1
9.	**SURGE SHAFT**	
	Type	Vertical Shaft with riser
	Size	10.00 m diameter
	Maximum Upsurge Level	1374.00 m
	Maximum Down Surge Level	1332.00 m
	Top Elevation of Surge Shaft	1375.50 m
	Bottom Elevation of Surge Shaft	1323.30 m
10.	**PENSTOCK**	
	Type	Burried Inclined
	No. of Penstock	One-bifurcated into two
	Diameter	1.70 m
	Length of Penstock	1852.00 m
	Thickness of Plates	10 mm to 34 mm

11. POWER HOUSE

Type of Power House	Surface
Length of Power House	52.50 M
Width of Power House	16.00 m
Centre to centre spacing of units	17.50 m
Length of Service Bay	17.50 m
Distance between B line to C line	7.50 m
Distance between C line to D line	8.50 m
Centre Line of Turbine	El. 734.00 m
Turbine Floor Level	El. 737.00 m
Upper Generator Floor Level	El. 742.00 m
Service Bay Level	El. 747.00 m
Top Elevation of Roof Truss	763.50
No. of Units	Two
Type of Turbine	Pelton Wheel
Rated Unit Capacity	33 MW
Excitation System	Static
Heaviest component to be transported	50 MT
Power House Crane	1 No. 125/ 25 T
Maximum Gross Head	626.00 m
Rated Net Head	600.00 m
Design Discharge	12.46 cumec

12. TAIL RACE CHANNEL

Size of Tail Race Channel	170x2.00 m x 3.30 m
Length	50.00 m (Approx.)
Type	Free Flow
Tail Race Bed Level	724.50 m

13. SWITCH YARD

Location	On the bank of Kalej Khola
Number of Bays	2
Size	80.00 m x 70.00 m
Voltage Level	132 KV
Type of Switchyard	Outdoor

14.	**CONSTRUCTION PERIOD**	36 Months
15.	**PROJECT COST**	
a)	Total estimated cost at Jan. 2007 price level	
	i) Gross	Rs. 358.63 crore
b)	Civil works	Rs. 166.29 crore
c)	Electrical & Mechanical works (including Transmission Lines)	Rs. 114.08 crore
d)	Cost / MW Installed	Rs. 5.43 crore
e)	Cost of Energy Generation per Kwh at Bus bar for 90% dependable year	
	i) Tariff per unit for first year (90% dependable year)	Rs. 2.57/ kWh
	ii) Average (for 5 years)	Rs. 2.47/ kWh

2.0 PHYSIOGRAPHY

The geographical area of the proposed Rangit-II hydroelectric project site is spread in the Gyalzing subdivisions of West Sikkim. The proposed dam is located on Rimbi Khola near Dharap village.

Rangit basin is a rectangular shaped basin in which majority of its tributaries flow in canoe shaped basin. The drainage pattern in Rangit basin is mostly dendritic, however, towards the mouth of the major tributaries, rectangular drainage pattern is well observed, which indicates structural control on the drainage network.

Rangit river originates as Rangit Chhu from 4,080m ridge dividing watersheds of Rangit river and Talung Chhu (Fig. 3.1). Kayam Chhu, a major tributary of Rangit Chhu, has its head water in Narsingh glacier at 5,825 m. Rangit river meanders for a distance of 8.4 km up to the confluence of Barme Chhu on the left bank. Then after flowing a distance of 3.8 km, the river is joined by Rel Chhu on its right bank. Rel Chhu has its headwaters in Narsingh glacier. It flows for 4 km up to 3,880 m where Leduwa Chhu, flowing 4.8 km from 4,900 m

(also fed by Narsingh glacier), joins it on the right bank. Rel Chhu travels in southward direction and receives water from a number of streams joining it on either side before it confluences with Rangdong Chhu. After this confluence Rel Chhu receives water from Nar Khola on its left bank at 1,300 m. From here downstream, Rel Chhu exhibits distinct rectangular drainage pattern and joins Rangit Chhu on its right bank. Rangit Chhu hereafter is known as Rangit river and receives water from a number of streams like Chil Khola, Sangrung Khola and Bania Khola. After their confluence, Rathong Chhu, the largest tributary of Rangit river confluences with the river at 602 m on the right bank.

Rathong Chhu is comprised of two forks i.e. Prek Chhu and Chokchurang Chhu. Prek Chhu originates from Jemathang (4,740 m) and its headwater lies in Onglakthang glacier. It receives water from glacial lakes *viz*. Tikuchia Pokhari (4,800 m), Chamliya Pokhari (4,600 m) and Sungmoteng Chho (4,280 m) located on the lateral moraines lying on the left flank of Onglakthang glacier. Prek Chhu flows 11.7 km up to 3840 m where it receives water from a stream named Kokchhurong, which is fed by glacier at the base of Forked Peak (6,220 m). From this confluence Prek Chhu flows 9.9 km up to 2,175 m where Chokchurang Chhu confluences with it on the right bank. Chokchurang Chhu originates from East Rathong glacier at 4,600 m from where it flows for 6.9 km up to 3,780 m where Rungli Chhu (> 4,000 m) joins it on the right bank. From here the stream flows 1km up to 3,770 m and receives water from Tikip Chhu on its right bank. Then it flows for another 2.3 km and receives water from Koklung Chhu which flows 7.2 km from its origin at 5,000 m on its right bank. From this confluence the river flows 1.7 km where Gomathang Chhu confluences it on the right bank at 3140 m. Gomathang Chhu has its headwaters in a glacial lake complex. Mujur Pokhari (4,260 m), Simana Pokhari (4,540 m), Lachhmi Pokhari (4,320 m) and Thumlo Jumle Pokhari (4,400 m) are some of the glacial lakes in this region that contribute significantly to the discharge of Gomathang Chhu. Gomathang Chhu after receiving water from Dhop Chhu on the right bank drains into Chokchurang Chhu on its right bank at 3,140 m. After flowing 4.5 km from this confluence

Chokchurang Chhu receives water from Baliajhore Chhu (4,300 m) on its right bank at 2340 m and then flows 1.2 km to join Prek Chhu on its right bank at 2,175 m. From this confluence Prek Chhu travels 1.7 km up to 1,970 m and receives water from Pongmirang Chhu on its right bank. Then the stream flows down 11 km up to 920 m as Pathang Chhu where Phamarong Chhu flowing 7.5 km from 2,900 m joins it on the left bank near Pulung. Immediately downstream of this point, Rimbi khola confluences with Pathang Chhu on the right bank at 907 m.

Rimbi Khola originates from Lachhmi Pokhari and Lam Pokhari lakes as Chhinjyum Khola and drains the forested areas through Pale Khola on its left bank and Longman Khola on its right bank (see Fig. 3.1). From this point, the stream flows as Rimbi Khola and receives water from a number of streams like Thar Khola, Heri Khola near village Rimbi, Nambu Khola and Lingsur Khola on either side. After this confluence, it flows as Rathong Chhu. Rathong Chhu after flowing 6.6 km joins Rangit river on its right bank at 602 m. From this confluence Rangit river flows 3.9 km up to 499 m where Kalej Khola joins it on the right bank.

Kalej Khola originates from 3,898 m peak as Barmo Khola where Yam Khola joins it on the right bank (see Fig. 3.1). Along its 34 km traverse in WE direction, it receives water from a number of tributaries on either side. Mardom Khola, Simpok Khola, Simchar Khola, Bega Khola, Dentam Khola, Hi Khola and Rangsang Khola are some f the main streams that join Kalej Khola in this stretch. Kalej Khola ultimately drains into Rangit river on its right bank at 499 m. Rangit river flows 4.2 km up to 460 m where Rayong Khola joins it on the left bank. Further downstream Rishi Khola joins it on the right bank at 421 m. From this confluence downstream Rangit river receives water from Change Khola, Rinchhu Khola and Roathok Khola. Ramam (or Rangbang) Khola is another tributary that joins Rangit river on its right bank. Ramam Khola drains from forested areas through smaller streams like Ribdi Khola, Riyong Khola and Rani Khola. After the confluence of Rani Khola, Ramam Khola flows for another 10.8 km and joins Rangit river. Rangit river changes its course towards east thereafter. After this

the river is also known as Great Rangit river and defines the inter-state boundary between West Bengal and Sikkim. Manpur Khola is only significant tributary on its left bank in this stretch before Rangit river finally merges with Teesta river at Melli Bazar.

3.0 HYDRO-METEOROLOGY

Rangit river and its tributaries originate in the Talung glacier in West Sikkim and it flows for about 61 km before joining the Teesta near Melli at the border of Sikkim with the West Bengal. Rimbi Khola at higher reaches flows through high valleys and steep slopes till it joins with the Rothang Chhu, which originates from Rathong glacier and is one of the major tributaries of the river Rangit. The slope of river Rimbi Chhu up to its confluence with Rathong Chhu is of the order of 1 in 25. The terrain is very steep and provides an excellent opportunity for development of hydropower. The total catchment area of Rimbi Khola above the proposed dam site is 120 sq km. The catchment is of small size and fan shaped.

The climate in the region is fairly humid and moist. The steep variation in altitude is mainly responsible for changes in climatic conditions and aided by the complex topography. The area experiences frequent rainfall of varying intensity and duration. The normal annual temperature is below 20^{o}C.

In Rangit basin, monsoon normally sets in the third week of May and withdraws in second week of October. The catchment being hilly and the river flowing in steep gradient, hevy rain in upper and middle catchment has an immediate effect of rendering the slopes to flash floods. The normal rainfall of the Rangit basin is about 2,800m.

The West district has an opposite trend of the air temperature with the minima observed during May to August. In the west District the maximum temperature vary between 20-30°C throughout the year. The humidity ranges

from 50 to 90% in a year. The maximum humidity is experienced in the months of June to August.

Detailed hydrological studies for developing the water availability series for Rangit-IV H.E. project have been carried out using the long term observed 10-daily discharges for the period from 1976 to 2003 of Rangit-III H.E. Project, which is under operation by NHPC.

After applying consistency checks for all these data sets different synthetic flow series were derived from Rangit-II HEP using Rishi Khola, Rangit-IV and Teesta-II datasets. A G&D site at dam site on Rimbi Khola river had been set up and is under operation. The observed 10-daily flow data is available for about two years for the period from Sep, 2004 to Oct, 2006. In absence of any other long time data, this observed data for one hydrological year has been used for consistency check of the transposed data sets.

The 50% dependable year (1993-94) had inflow of 320.6 Mcum and the 90% dependable year (1985-86) had inflow of 243.33 Mcum. The dataset also reveals that over the past 26 years the inflow in the basin has increased.

The water availability in the river is maximum during monsoon period (June-Sept.). The maximum water flow is of the order of 80 cumec and the minimum is about 10 cumec during this period. In the lean season the maximum water flow is only 10 cumec.

4.0 SOIL

The soil in the catchment area is comprised of 13 soil series associations belong to 13 soil families. Total area of the catchment is 12,0,12 ha, in which soil series Lachung–Puchikongma–Byuma of Lithic Udorthents group is most pre-dominant, covering about 26.6% of the total catchment (Fig. 5.1). This association is very shallow, full of gravels and light in texture. In the lower reaches Sajong-Tarnu series of Humic Dystrudepts group is dominant. It is

developed on the granite gneiss and prone to the severe erosion. These soils are marginally suitable for the terraced cultivation. The proposed dam site is located on the Chongrang – Legship-Singgyang series of Entic Hapludolls. The soils are coarse loamy, acidic and excessively drained. It requires proper conservation measures and diversification of drainage lines to protect soils from landslides.

The stretch from proposed dam site to the power house site and 2-3 km periphery was considered for the study of soils of project area (Fig.5.2). It covers a total area of 9132 km. The soils of this area belong to 19 series of 12 families. The entire head race tunnel passes through Maling – Rayong, Tumin-Phong-Chautare, Singgyang-Maniram-Damthang, Chakung-Tumin-Sajong, Doling-Khediand and Samdur-Khedi-Bhusuk series. The nature of these soils suggests adequate measures for the conservation. The proposed power house is located on the Dharamdin-Martam-Karfecter series of Fluventic Eutrudepts family. Soils rare deep, fine texture with good water holding capacity.

5.0 GEOLOGY AND SEISMICITY

The project area is located in the Lesser Himalaya, characterized by very rugged hills. The project area is also dissected by narrow 'V' shaped valleys and escarpments. The Rimbi Khola is a perennial, rain and glacial fed river and is one of the main tributary of Rangit river. It originates in Western Himalaya from the glaciated slopes of Kabru and Khangchendznga ranges at about 6,500 m to 8,500 m. The drainage pattern in the project area is coarse dendritic with some of the stream courses controlled by joints and fractures.

The project area is represented by Daling and Darjeeling Formations with predominantly medium to high grade metamorphic group of rocks comprising Biotite-Granite-Gneiss, Schists, and Phyllites & Quartzite. The Gneissic rocks contain bands of quartz-felspathic and mafic rich minerals with intrusive bands of pegmatite and some patches of Schist and Phyllites bands. Gneissic rocks belonging to Central Crystalline Gneissic Complex (CCGC) of Proterozoic Age

will be present at the dam and desilting sites. The HRT will pass through gneissic rocks at the initial stage followed by Mica schist, Quartzite, Phyllites, and Phyllites Quartzite of Daling Group. It is likely to cut across Main Central Thrust (MCT). The Surge Shaft and Power House complex will be housed in Daling Group of rocks.

The project area is mainly constituted by Darjeeling and Daling Formations, predominantly medium to high grade metamorphic rocks like Biotite/ Granite Gneiss with inter bands of Quartzite, Schists and Phyllites. The intrusive bands of Pegmatite and Quartz veins with variable thicknesses are seen along and across the foliation.

The geology of the dam site comprises mainly of Biotite-Granite-Gneiss rocks. These rocks generally trend from NE-SW to N70°E – S70°W with variable dip amount of 30° to 45° towards NW to NNW direction. The rocks out crops are distinctly visible on the left bank and in bottom section of both the abutments in and around dam axis. Sound Gneissic rocks are expected in the dam foundation and both the abutments of dam area.

Head Race Tunnel with about 5.2 km length and 3.4 m finished diameter will be on right bank of Rimbi Khola and will pass through the hill with maximum rock over burden depth of 825 m. Most of the tunnel is likely to be excavated in 'Good' Gneissic rocks along with zones of closely foliated 'Fair to Poor' Phyllites and Schist rocks as well as jointed quartzite rocks. Small weak zones of crushed/ sheared materials are also expected intermittently.

The surge shaft is likely to be constructed in over burden material underlain by Gneissic rocks. The alignment of Penstock is likely to follow the gentler and stable hill slope.

The surface power house is located on left bank of Kalej khola over a large terrace deposits. The depth of terrace is likely to be shallow in power house area with sound gneissic rock below it.

The area where Rangit Hydro Electric Project (Stage-II) is located falls under active seismologic area. As such, seismological studies are required to be carried out for finalization of designs for major Project Components. In general Rangit-II HEP area falls within Himalayan Seismic Belt and lies in ZONE-IV in Seismic Map as recommended by Indian Standard Code of Practice IS: 1893-1984.

6.0 LAND USE / LAND COVER

Land use and land cover mapping of Rimbi Khola catchment up to the proposed Rangit-II H.E. project dam site was carried out by standard methods of analysis of remotely sensed data, followed by ground truth collection and digital image processing of satellite data. For this purpose digital data on CDROMs was 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 R.S. Envirolink Technologies using ERDAS Imagine 8.7 of Erdas Inc.

The study deals with the natural and managed ecosystems of Rimbi Khola catchment which forms one of the major tributary catchments of Teesta river basin in Sikkim in Eastern Himalaya. The region is characterized by extensive Tropical moist deciduous and riverine semi-evergreen forest, Sub-tropical broad-leaf hill forest, Temperate wet forest and Mixed coniferous forests. Landslide activity at some regions also changes the landscape features.

Rimbi Khola catchment has a good forest cover. About 8094.95 ha of the catchment area up to the proposed dam site is covered with forest. Of the total forest land, major part (49.78%) is covered with open forest. Dense forest covers only 17.56% of the total forest area of the total catchment up to the dam

site. Alpine scrub covers 9.37% while 5.97% is under scrub of the total catchment. A large part (11.17%) of the catchment is under barren/ rockyland and snow/ glaciers covers very part on the above area (0.24 ha). There are few lakes viz. Lachhami Pokhari, Lam Pokhari, Sukia Pokhari and Ghuniah Pokhari are famous, covers only 0.16 ha of the catchment. About 4.49% of the catchment area is under moraines cover. The settlements and cultivated land cover only 196.73 ha of the catchment (1.64%).

The land use/ land cover of different sub-watersheds was extracted from the thematic land use/ land cover map prepared for the entire catchment. These land use/ land cover layers were used for erosion mapping in different sub-watersheds.

Rimbi Khola watershed comprising the project area i.e. area within 10 km radius of the project, has a good forest cover. Major part of the project area along Rimbi Khola on higher elevations from the dam site up to the proposed powerhouse site is covered with dense (14.11%) and open (41.44%) forests (Fig.7.5). However, at lower elevations, there is concentration due to human settlements all along the river valley as cultivation and settlement areas (1022.62 ha; 11.13%) are mostly clustered near the floodplains and depositional landforms. At the higher elevations, barren/ rockyland and moraines covers more than 9.93%. All the area around the settlements is under intensive agriculture.

7.0 FOREST TYPES

The forests present in the Rangit II project and adjoining area, have been grouped into different forest types following the classification of Champion & Seth (1968), Hajra & Das (1982), Negi, (1989, 1996), Hajra & Verma (1996), Srivastva (1998). The major forest types found in this catchment are discussed below.

a) 3C/C3 b East Himalayan tropical moist deciduous forest

These low hill forests are found near the powerhouse site area and found up to 900m elevation. The soil is well derained and rainfall is heavy up to 500cm annually. The trees are mostly deciduous and become leafless during the hot weather. The important tree associates include *Albizia chinensis, Bombax ceiba, Canarium strictum, Castanopsis indica, Duabanga grandiflora, Ficus semicordata, Gynocardia odorata, Millettia glaucescens, Syzygium formosum, Terminalia myriocarpa, Toona ciliata*, etc. Shrubs are *Abroma angusta, Boehmeria macrophylla, Clerodendrum serratum, Dendrocalamus hookeri, Lantana camara, Leea aequata, Musssaenda roxburghii, Rubus ellipticus* and *Saurauia roxburghii*. Epiphytes and climbers are abundant. Important twiners are *Bauhinia vahlii, Celastrus monospermuss, Cryptolepis buchanani, Dioscorea bulbifera, Piper pedicellatum, Rhaphidophora decursiva* and *Stephania glabra*. Common epiphytic orchids include *Bulbophyllum affine, Cymbidium elegans, Dendrobium chrysanthum, Liparis dentata,* etc. Some riverine semi-evergreen trees such as *Bischofia javanica, Oroxylum indicum, Rhus chinensis*, etc also occur along the river banks. The other riverine elements are tall grasses like *Imperata cylindrical, Phragmites australis, Saccharum spontaneum* and *Thysanolaena latifolia*.

b) 8B/C1 East Himalayan sub-tropical wet hill forest

These forests are found on hilly terrain between elevations of 900m and 1700m and formed of dominant evergreen species. At some places deciduous species like Chir (*Pinus roxburghii*) is found as scattered tree in upper area. The forest of this group can be divided into two sub-types according to rainfall. Warm broad leaved hill forest occur at higher altitudes with low rainfall and contain a mixture of evergreen and deciduous species viz., *Alnus, Lyonia* and *Quercus*. This type of forest is observed along Rimbi Khola and Likon Khola in West Sikkim. Cool broad leaved forest develops above the warm broad leaved forests. This forest is more mixed forest in which *Quercus* spp. is less common and other

trees like *Litsea, Michelia, Persea, Phoebe, Schima, Semingtonia,* etc. are more abundant. This type of wetter cool broad leaved forest is found along Limni Nala and Pailing areas. The drier type, cool broad leaved forest contains a dominance of evergreen species like *Lyonia*, *Quercus* and *Rhododendron*. This type of forest is found in upper reaches of Gyalzing, Pailing and Yoksum areas. Understorey is dense mixed and formed by bamboos thickets, shrubs and climbers. Predominant shrubs are *Berberis asiatica, Brassiopsis mitis, Callicarpa arborea, Eurya acuminata, Maesa chisia, Mussaenda roxburghii, Oxyspora paniculata, Rhamnus nepalensis* and *Rubus ellipticus*. Bryophytes, ferns and species of orchids constitute epiphytic flora. Most of the trees of this forest are laden with some epiphytic ferns such as *Antrophym obovatum, Colysis pedunculata, Polypodioides lachnopus* and *Pyrrotia obovata*. Among climbers are species of *Cissus, Creptolepis, Dioscorea, Parthenocissus, Piper, Raphidophora* and *Smilax.* Some weeds like *Ageratina adenophora* and *A. ligustrina* grow profusely in lower reach of the forest.

c) 11 B/C1 East Himalayan wet temperate forests

These forests are found between 1800m and 3000m elevations and divided into three sub-types according to altitudinal zones. Towards higher altitudes they merge with sub-alpine forests. The forests of this group are comprised of following types:

d) 11B/C1a Lauraceous forest

This zone occurs between 1800 and 2100m elevations. The forests are mixed evergreen with medium sized trees. There are many deciduous tree species mixed with evergreen oaks and laurels. These forests are found in upper ridges of Rimbi, Pailing and Yoksum areas. *Acer campbellii, Betula alnoides, Carpinus viminea, Castanopsis hystrix, Cinnamomum glanduliferum, Ilex dipyrena, Litsea elongata, Michelia kisopa, Prunus nepalensis, Quercus thomsoniana, Symplocos ramosissima,* etc. are frequently met up to 2100m. The oaks and

laurels are covered with many epiphytic mosses and ferns. *Alnus nepalensis* grows mainly along streams and water courses in these forests. These forests are very thick with abundant shrubs and climbers. The common epiphytic ferns on trees are *Lepisorus nudus, Microsorium membranaceum, Pyrrosia nuda* and *Vittaria sikkimensis*. Among shrubs are *Berberis asiatica, Boehmeria macrophylla, Debregeasia longifolia, Mahonia napaulensis, Rhamnus nepalensis, Rubus ellipticus*, etc.

e) 11B/C1b Buk oak forests

This zone occurs from 2100m to 2400m elevation and is dominated by buk oak (*Quercus lamellosa*). Important associates of the tree canopy are *Acer campbellii, Betula alnoides, Castanopsis hystrix, Lithocarpus elegans, Litsea doshia, Michelia velutina, Symplocos theifolia*, etc. Shrubs are *Berberis asiatica, Merilopanax alpinus, Pieris formosa, Rhododendron arboreum, Rubus niveus, Thamnocalamus aristatus* and *Viburnum erubescens*. These forests are found in upper ridges of Gezing, Pailing and Yoksum areas. Climbers are few and are represented by species of *Clematis, Parthenocissus, Rubus, Smilax*, etc. Epiphytes are abundant and are loaded on the trunks of trees and shrubs. The common pteridophytic epiphytes are *Colysis hemionitidea, Lepisorus subconfluens, Pyrrosia manii* and *Vittaria sikkimensis*.

f) 11B/C1c High level Oak forests

These forests occur between 2400m and 2700m elevations. Tree canopy is comprised of *Acer campbellii, Betula alnoides, Castanopsis tribuloides, Lithocarpus pachyphylla, Quercus lamellosa, Rhododendron arboreum* and *Taxus baccata*. The shrubs are represented by species of *Berberis, Cotoneaster, Lonicera, Rhododendron, Salix* and *Viburnum*. These forests are found above Sarjon and Prek Chhu areas. Climbers are few and represented by species of *Clematis, Herpetospermum, Rubus* and *Smilax*. There are some terrestrial ferns like *Athyrium, Dryopteris*, *Pteris* and *Selaginella* on the ground floor. In addition

to these, some interesting lichens which found on the bark of trees and on stones are *Parelia, Peltigera, Ramalina, Usnea*, etc. Herbs are represented by *Aconogonum molle, Anaphalis busua, Anemone obtusiloba, Artemisia indica, Carex baccans, C. filicina, Calamagrostis emodensis, Persicaria amplexicaule, Ranunculus diffusus, Rumex nepalensis,* etc.

g) 12/C3 East Himalayan mixed coniferous forests

The forests of this zone are dense evergreen, with predominating oak and rhododendrons. Hemlock (*Tsuga dumosa*) makes appearance in the upper reaches as a dominant tree species especially on the drier ridges above 2700m elevations. These forests are found in Bakhim and Tsoka areas. At the higher elevations Hemlock gives way to Silver fir (*Abies densa*). Fir forest is characterstic of the highest forest ridges and reached up to 3,600m. Apart from conifers, some oak mixed deciduous tree species such as *Acer, Betula, Magnolia, Populus* and *Rhododendron* are found in the forests. Undergrowth is represented by some evergreen shrubs such as *Berberis, Cotoneaster, Mahonia, Rhododendron, Salix, Thamnocalamus* and *Viburnum*. Most of the shrubs are loaded with many epiphytic mosses and lichens. The common lichens include *Cladonia furcata, Parmelia wallichiana, Peltigera dolichorrhiza, Usnea baileyi,* etc.

h) 14/C2 East Himalayan Sub-alpine birch/fir forest

This sub-alpine forest is found above elevations of 3000m. These are a typically dense growth of small crooked trees and some large shrubs. *Rhododendron* spp. cover large areas in the forest. Important tree species in the forest are *Abies densa, Betula utilis, Magnolia campbellii, Rhododendron thomsonii, R. lanatum,* etc.

i) 15/C1 Birch / Rhododendron moist alpine scrub forest

This is low evergreen forest dominated by Rhododendron and some deciduous species. Important associates are *Betula utilis, Rhododedron lanatum, R. thomsonii, R. anthopgon, Sorbus foliolosa* and *Viburnum nervosum*.

j) 15/C2 Deciduous alpine scrub

This is a low deciduous scrub formation forming a cover over gentle alpine slopes. The climate is too cold and severe for tree growth. The scrubs found just below the snowline are *Betula utilis, Berberis umbellata*, *Rosa macrophylla*, *Salix daltoniana*, etc. There are some herbs which have very short growing season along meadows.

k) 15/C3 Alpine pastures

These are meadows lying below the snowline where the tree lines ends. The gentle mountain slopes or meadows are composed of many perennial mesophytic herbs and some grasses. Important herbs are species of *Aconitum, Allium, Anemone, Caltha, Fragaria, Fritillaria, Geum, Gentiana, Juncus, Potentilla, Primula, Ranunculus* and *Rheum*.

8.0 VEGETATION STRUCTURE

Rangit-II H.E. Project area extends from Chungjong village (near Kalej Khola) to Rimbi along the Rimbi Khola. In all 457 species of angiosperms and gymnosperms were recorded from Rangit II project areas. Out of ca 17,500 flowering plant diversity in India and 4,500 species of flowering plants in Sikkim Himalaya (Mudgal & Hajra, 1997; Singh & Chauhan, 1999), about 452 species of angiosperms are harboured in Rangit II project area in the region between Kalej Khola to Rimbi and Rimbi to Yoksum and Yoksum to Tsoka (along Rathong Chhu and Prek Chhu) in the West Sikkim. About 110 families represented in these areas 95 are dicots, 15 are monocots. The dicotyledons are represented by 307 species belonging to 229 genera and 95 families, while the

monocotyledons are represented by 15 families, 84 genera and 145 species. Gymnosperms are represented by 3 families, 4 genera and 5 species.

No endemic species reported in the project area. However, during the EIA study some local endemics as well as Eastern Himalayan endemics were observed from the catchment area. Some species growing are *Adgaria darjeelensis, Angelica sikkimensis, Aster sikkimensis, Pimpinella wallichii* and *Salvia sikkimensis*.

No rare and endangered species reported in the area. However, some of the plants observed in the surrounding area belonging to vulnerable (VU) plant category are *Panax sikkimensis* and *P. bipinnatifidus*.

The diversity of vegetation in Rimbi and its adjacent areas was assessed in terms of physiognomy of its floral elements. Some of the families that showed diverse habit forms of trees, shrubs and climbers include Euphorbiaceae, Fabaceae, Mimosaceae and Rosaceae.

The parasitic plant species belonged to families Cuscutaceae and Loranthaceae. *Cuscuta reflexa* was found growing on wide range of hosts in the area *Loranthus odoratus* and *Scrulla elata* were observed parasitic on *Lithocarpus elegans* and *Quercus leucotrichophora.*

Many orchids such as *Coelogyne nitida, Cymbidium elegans, Dendrobium porphyrochilum* and some pteridophytes like species of *Colysis, Lepisorus* and *Polypodioides* were observed in this group. A large number of non-vascular epiphytes such as lichens, a variety of mosses and ferns were also cover large space on the bark of the trees in the forest.

The floral elements in Rangit-II 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. Floral elements from South East Asian region, which included Myanmar, Thailand, Indo-China, Indonesia and Malaysia were found in the tropical and subtropical forest of project area.

Sikkim is very rich in plant resources. Large numbers of wild plants of medicinal value are distributed in the area altitudinally. Some of the herbs like *Achyranthes aspera, Acorus calamus, Artemisia indica, Bergenia ciliata, Cissampelos pareira, Cyperus rotundus, Hedychium spicatum, Houttuynia cordata, Oroxylum indicum, Viola betonicifolia,* etc are quite common in tropical and sub-tropical parts of project area. *Angelica sikkimensis, Betula utilis, Origanum vulgare, Panax sikkimensis, P. bipinnatifidus, Pleurospermum album, Rubia manjith, Swertia agustifolia,* etc are important medicinal plants of high altitude zones.

The region is important for crop plants such as rice, finger millet, maize, large cardmom, and many wild vegetables and fruits. Among wild food plants include leaves and Young twigs of *Aconogonum molle* (Thotney), leaves of *Fagopyrum esculentum* (Jungaly Phaper), *Giradinia diversifolia* (Bhangrey Shisnu), tuber of *Dioscorea glabra* (Ban Tarul), young shoots of *Dendrocalamus hamiltonii* (Tama), roots of *Manihot esculenta* (Semal tarul), flower bud of *Bauhinia purpurea* (Koiralo), fruits of *Persea robusta* (Kawla), *Ficus auriculata* (Kabra), *Musa balbisiana* (Ban Kera).

Some fodder trees like *Bauhinia purpurea*, *Celtis tetrandra, Debregeasia longifolia, Ficus auriculata* and *Morus alba* are used in low altitude areas. In upper areas few wild trees like *Ilex, Quercus* and small bamboos (*Thamnocalamus aristatus*) are used for fodder.

In lower areas, the wood used for timber includes *Bischofia javanica, Castanopsis indica, Canarium strictum, Garuga pinnata, Schima wallichii, Terminalia myriocarpa, Toona ciliata,* etc. In addition to these, some tall

bamboos like *Bambusa tulda* and *Dendrocalamus hamiltonii* are also used for this purpose.

At higher altitudes oaks and conifers are used for the timber and fuel wood purposes. Important timber yielding trees include *Abies densa, Juglans regia, Lithocarpus elgans, Quercus lamellosa* and *Tsuga dumosa*.

8.1 VEGETATION COMPOSITION IN AND AROUND THE PROJECT AREA

8.1.1 Submergence Area

The dam site is located upstream of Rimbi village in the district of West Sikkim. The area in the vicinity of proposed project comprised of fairly dense mixed sub-tropical wet hill forest with few semi- evergreen riverine plant species. The left bank of Rimbi Khola has sparse forest canopy interspersed with agricultural fields. *Albizia chinensis, Alnus nepalensis, Bischofia javanica, Engelhardtia spicata, Erythrina arborescens, Ficus auriculata, Juglans regia, Macaranga denticulata, Persea robusta, Schima wallichii, Toona ciliata,* etc. constitute the tree canopy. Second storey is comprised of some tall spreading shrubs and bamboos. *Brassiopsis mitis, Denrocalamus hamiltonii, Edgeworthia gardneri, Mussaenda roxburghii, Neillia thyrsiflora, Oxyspora paniculata, Rubus ellipticus,* etc were noticed in the understorey. Climbers and epiphytes were few. *Cissus repens, Cryptolepis buchanani, Cuscuta reflexa, Porana racemosa, Rhaphidophora glauca, Stephania elegans,* etc are important trailing species. Herbaceous flora was represented by some pteridophytic plants, grasses and weeds. Among terrestrial pteidophytes are species of *Adiantum, Athyrium, Lygodium, Pteris* and *Selaginella*. Angiospermic herbs include *Ageratum conyzoides, Ageratina adenophora, Artemisia indica, Arthraxon hispidus, Capillipedium assimile, Commelina benghalensis, Galinsoga parviflora, Hydrocotyle nepalensis, Impatiens hirsuta, Imperata cylindrica, Lecanthus peduncularis, Oxalis corniculata, Physalis minima, Pilea scripta, Pogonatherum paniceum, Saccharum spontaneum, Rumex nepalensis* and *Solanum nigrum.*

The vegetation of right bank is dense in comparision to the left bank. *Albizia chinensis, Alnus nepalensis, Altingia excelsa, Bauhinia purpurea, Juglans regia, Persea robusta* and *Schima wallichii* are important trees in the canopy. Some terrestrial ferns and weeds are found abundantly in shaded and damp areas. Second storey is also dense mixed and comprised of shrubs and lianas. *Brassiopsis mitis, Celastrus monospermus, Mussaenda roxburghii, Oxyspora paniculata, Rhamnus paniculata, Saurauia nepalensis,* etc. in the under storey. Among herbs are *Aconogonum molle, Ageratum conyzoides, Aster mollisculus, Bidens bipinnatus, Carex baccans, Centella asiatica, Chenopodium album, Cyperus rotundus, Digitaria ciliaris, Galium aprine, Impatiens exilis, Persicaria barbata, Pilea scripta, Saccharum rufipilum* and *Thysanolaena latifolia*.

8.1.2 Power House site

A surface powerhouse has been proposed on the left bank of Kalej Khola near Chungjong village. Sparse tropical moist deciduous forest occurs in the vicinity of powerhouse area. Important tree associates in the canopy include *Albizia chinensis, Alnus nepalensis, Bombax ceiba, Canarium strictum, Erythrina arborescens, Ficus semicordata, Oroxylum indicum, Rhus chinensis, Schima wallichii,* etc. Second storey is also very sparse comprised of shrubs and small trees like *Ageratina ligustrina, Boehmeria macrophylla, Colebrookea oppositifolia, Mussaenda roxburghii, Rubus ellipticus,* etc. Climbers and epiphytes are few at this bank. *Cissus repens, Cissampelos pareira, Mimosa himalayana, Stephania glabra,* etc are found trailing on the trees in the forest. Among herbs are *Ageratum conyzoides, Arthraxon hispidus, Arundinella nepalensis, Bidens bipinnatus, Dichanthium annulatum, Moghania fruticosa, Neyraudia arundinacea, Paspalum paspalodes, Pilea scripta, Pogonatherum paniceum, Saccharum spontaneum* and *Thysanolaena latifolia.*

8.2 Community Structure

8.2.1 Abundance and Density

The maximum number of tree species were recorded at upper stretch (left and right bank of dam sites) as compared to lower and middle stretch (Powerhouse and Adit site).

On the Lower stretch (V1, powerhouse site, left bank of Kalej Khola) the tree strata was dominated by *Schima wallichii* having maximum density 700 plants ha^{-1}) and frequency (40%). It was followed by *Alnus nepalensis* having maximum density. The associated species in the tree layer were *Bombax ceiba, Albizia chinensis, canarium strictum, Bischofia javanica, Ficus semicordata* and *Engelhardtia spicata*. In the shrub layer *Ageratina ligustrina* was found as most dominant species with high density. The dominance of *Ageratina ligustrina* may be due to its non palatable nature and capability to grow in open degraded areas. Other competing species in the understorey were *Mussaenda roxburghii, Colebrookea oppositifolia, Rubus ellipticus, Oxyspora paniculata* and *Buddleja asiatica*. The absence of saplings and seedlings of the important species is attributed to high human encroachment in the area.

At the middle stretch (V2, Adit site, left bank of Limni Khola), the tree strata was dominated by *Alnus nepalensis.* The associated species of the tree layer were *Engelhardtia spicata, Macaranga denticulata, Ostodes paniculata, Ficus oligodon, Albizia chinensis, Juglans regia, Brassiopsis glomerulata* and *Schima wallichii*. No saplings and seedlings of the important trees were recorded in the tree layer. In the shrub layer *Dendrocalamus hamiltonii* was found as the most dominant species with high frequency and density. Other competing species of the shrub strata were *Boehmeria*

macrophylla, Dichroa febrifuga, Rubus ellipticus, Rhamnus purpurea, Brassiopsis mitis and *Leea aequata.*

On the upper stretch I (V3, Right bank of dam site), *Juglans regia* was found as the most dominant tree species having maximum frequency and density. The associated species of tree layer were *Alnus nepalensis, Bauhinia purpurea, Albizia chinensis, Persea robusta, Macaranga denticulata, Erythrina arborescens, Oroxylum indicum, Schima wallichii* and *Ficus oligodon*. No saplings and seedlings of the important trees were recorded in the area. *Dendrocalamus hamiltonii* was found as most dominant shrub species with high density. Other competing species of shrub strata were *Brassiopsis mitis, Rhamnus purpurea, Mussaenda roxburghii, oxyspora paniculata* and *Celastrus monospermus.*

At the upper stretch II (V4, left bank of dam site), the tree strata was dominated by *Schima wallichii*. The associated species of tree layer were *Ficus auriculata, F. virens, Albizia chinensis, Alnus nepalensis, Macaranga denticulata, Persea robusta, Juglans regia, Castanopsis indica, Engelhardtia spicata* and *Eurya acuminata*. No saplings and seedlings of the important trees were recorded in the area. *Dendrocalamus hamiltonii* was found as most dominant shrub species in the understorey. Other competing species of shrub strata were *Neillia thyrsiflora, Brassiopsis mitis, Oxyspora paniculata, Mussaenda roxburghii, Edgeworthia gardneri* and *Rubus ellipticus.*

Across all the stretches the total tree density ranged from 2200 trees/ha at upper stretch II (left bank of dam site) to 3000 trees/ha at lower stretch (powerhouse site). The total absence of saplings and seedlings is attributed to high encroachment of human settlements near the boundary of forests.

The total basal cover ranged from 2128.29 m^2/ha at middle stretch (Adit site) to 3793.01 m^2/ha on lower stretch (powerhouse site). The lowest mean

basal area (0.0778 m^2/tree) were recorded for *Alangium chinense* at middle stretch and the highest was shown by *Ficus virens* (3.0372 m^2/tree) at the upper stretch II. *Juglans regia* was the dominant species with an IVI of 102.72 at upper stretch I, whereas *Alnus nepalensis* was the dominant species with an IVI of 89.65 at middle stretch (Adit site). Low total density and also low total basal cover indicated greater disturbances at middle stretch (i.e. proposed Adit site).

Among herbs *Bidens bipinnata* was dominant species having maximum density (2.3 plants m^{-2}) at lower stretch (V1, powerhouse site). It was followed by *Cynodon dactylon, Saccharum spontaneum, Persicaria capitata, Paspalum paspalodes, Oxalis corniculata, Digitaria ciliata, Euphorbia hirta, Artemisia indica, Arthraxon hispidus, Eragrostis japonica, Juncus concinnus, Pogonatherum paniceum* and *Conyza japonica* in term of density. When abundance values were considered, *Saccharum spontaneum* was recorded highest value (6.0), followed by *Bidens bipinnata* (5.8)*, Cynodon dactylon* (5.0) and *Euphorbia hirta* (4.0). As per the IVI values, *Bidens bipinnata* was the dominant species (62.769) followed by *Saccharum spontaneum* (47.100)*, Cynodon dactylon* (24.514), *Artemisia indica* (21.102), *Paspalum paspalodes* (20.205), *Persicaria capitata* (18.911), *Galinsoga parviflora* (15.201), *Digitaria ciliaris* (14.556) and *Oxalis corniculata* (14.772). The lowest IVI of 4. 476 was recorded in *Gnaphalium affine*.

At the middle stretch (V2, Adit site), out of 17 species, *Bidens bipinnata* was the dominant species having maximum density (2.4 plants m^{-2}). It was followed by *Thysanolaena latifolia, Oxalis latifolia, Eragrostis nigra, Ageratina adenophora, Cyperus rotundus, Capillipedium assimile, Persicaria barbata* and *Cyrtococcum accrescens* in term of density. *Thysanolaena latifolia* was recorded higest abundance value (20.0), followed by *Bidens bipinnata* (8.0) and *Oxalis latifolia* (5.0). Maximum value of IVI was recorded in *Thysanolaena latifolia* (60.853) followed by *Bidens bipinnata* (40.434)*, Ageratina adenophora* (27. 626), *Eragrostis nigra* (19.122), *Capillipedium assimile* (17.254) and *Oxalis latifolia* (17.276). The minimum IVI of 5.70 was noted for *Cyperus squarrosus*.

At the upper stretch I (i.e.V3, right bank of dam site), again 17 species of herbs were recorded. *Pilea umbrosa* was found to be the dominant herb having maximum density (4.6 plants m^{-2}) and abundance (15.3). It was followed by *Ageratina adenophora, Pilea scripta, Aconogonum molle* and *Bidens bipinnata* in term of density. The frequency of occurrence was highest in *Aconogonum molle* followed by *Ageratina adenophora* and *Pilea umbrosa*. As per IVI, *Ageratina adenophora* was the dominant species (72.705) followed by *Aconogonum molle* (60.720), *Pilea umbrosa* (42.696) and *Pilea scripta* (25.942). The lowest IVI of 4.755 was for *Achyranthes aspera*.

At the upper stretch II (V4, left bank of dam site) maximum number of herbs (19) was recorded. *Aster molliusculus* was found to be the dominant herb having maximum density (2.2 plants m^{-2}). It was followed by *Ageratum conyzoides*, *Rumex nepalensis, Hydrocotyle nepalensis, Centella asiatica, Galium aparine, Arthraxon hispidus, Commelina benghalensis* and *Colocasia affinis* in term of density. *Hydrocotyle nepalensis* recorded the highest abundance value (8.5), followed by *Bidens bipinnata* (8.0), *Centella asiatica* (7.5), *Aster molliusculus* (7.3) and *Cynodon dactylon* (7.0). Maximum vaue of IVI was observed in *Rumex nepalensis* (30.570) followed by *Ageratum conyzoides* (28.298), *Colocasia affinis* (23.112), *Artemisia indica* (22.340) and *Aster molliusculus* (21.772). The lowest IVI of 4.136 was recorded in *Gnaphalium affine*.

The analysis of distribution pattern of ground flora indicated that all populations were contagiously distributed. The general preponderance of contagious distribution in vegetation has also been reported by several other workers (Kershaw, 1973; Singh and Yadava, 1974; Kunhikannnan *et al*., 1998).

b) Species Diversity

The value of species diversity (H) in the tree stratum ranged from 1.930 at lower stretch (powerhouse site) to 2.311 at upper stretch II (left bank of dam site). The species diversity for shrub strata ranged from 1.271 (middle stretch) to 1.660 (upper stretch II). The diversity indice for shrubs were higher on the upper stretch (dam site) as compared to middle and lower stretch. The value of species diversity (H) in the herb layer ranged from 2.327 (upper stretch I) to 2.796 (upper stretch II).

9. FAUNAL ELEMENTS

The proposed hydro-electric project is located in the lower altitudes, which is one of the densely populated areas in the Sikkim. The project area is characterized by high hills with altitudes more than 1,300 m. The forest comprises of Tropical moist deciduous in valleys and Sub-tropical broadleaved forests at the higher elevations. During the field surveys about 37 common species could be spotted. These species with their status and behavior are listed. Of the 37 species, found in the vicinity of the project site (from powerhouse site to barrage site) about 30 species are resident. However, many of them perform vertical movement. A total of 5 species are altitudinal migrant (AM) while 2 species are winter visitors. On the basis of Wildlife Protection Act (1972) all species of birds with the exception of *Corvus splendens* are placed in Schedule-IV. Only two species *viz*. *Aceros nipalensis* and *Pavo cristatus* are found to be threatened (Vulnerable) (ZSI, 1994).

A large number of species of birds (74%) are common resident (R) in the area (Fig. 10.3). However, most of them are subject to altitudinal as well as horizontal movement. The winter visitors (WV) and summer visitors (SV) to Himalaya comprise about 8.5% and 5.5%, respectively of total species. About 7.5% bird species perform altitudinal migration. In addition, local migrants and partial migrants also constitute a small portion of bird species. *Bubulcus ibis* and *Cacomentis merulinus* are only migratory birds (0.37%) in the catchment area. The vagrant birds (*Ardea goliath* and *Pluvialis apricaria*) also comprise a small

percentage (0.37%) of total species occurring in the region.

About 372 species reported from the catchment area are categorized in Schedule-IV on the basis of Wildlife Protection Act (1972). About 12 species *viz.* Creasted goshowk, Bersa, Eurasian sparrow hawk, Jorden's baza, Black baza, Himalayan monal, Sikkim blood pheasant, Blacknecked crane, etc. are considered as Schedule-I. Only House crow is placed in Schedule-V. A total of 13 species of birds are threatened in the catchment (ZSI, 1994). The Black necked crane is 'critically endangered' while the species like Shaheen falcon, Tibetan snowcock, Himalayan monal and Great hornbill belong to 'endangered category'. The species with the exception of Great hornbill, are found in higher altitudes of catchment. There are two 'rare' species while remaining 6 species are categorized as 'vulnerable'. The threatened species of Hornbills and Indian pea-fowl occupy lower altitudes of catchments.

About 21 species belonging to 8 families have been recorded from Sikkim (CISMHE, 2007). The Ranidae is the most dominant group of Amphibia followed by Rhacophoridae. The altitudinal zone of 900 – 1,800 m is highly rich in amphibian diversity, which harbour about 19 species.

Reptiles of the catchment are comprised of more than 60 species belonging to 11 families viz. *Testudinidae, Agamidae, Gekkonidae, Scincidae, Anguidae, Varanidae, Typhlopidae, Boidae, Colubridae, Elapidae and Viperidae.*

10. AQUATIC ECOLOGY AND WATER QUALITY

The present study was carried out for a proposed hydro-electric project Rangit-II in West Sikkim district. A 40 m high concrete gravity dam is proposed across the river Rimbi Khola at an elevation of 1334 m. Water from the main river would be diverted through a 5.2 km long head race tunnel (HRT) into Kalej Khola in another watershed. The major reduction in water discharge would

occur from about 6 km river stretch of Rimbi Khola. Here, a major tributary Lingsor Khola joins it from right bank. Thereafter, river traverses about 2 km and joined by Pathang Chhu from right bank. It carries major discharge. After confluence, it is popularly known as Rathang Chhu.

The samplings for the physical, chemical and biological characteristics were carried out at proposed dam site in Rimbi Khola (W1), river Rangit near confluence (W2) and Kalej Khola (W3) where water of Rimbi Khola would join. The samples were retrieved from three locations at each site and pooled.

Turbidity was recorded less than 10 ntu in winter and post-monsoon season in all rivers but it increased in monsoon season vis-à-vis water discharge. The temperature at Kalej Khola water was higher than that of Rimbi Khola due to difference in altitudes. The pH of water ranged from 7.95 to 9.66 in all the streams. Optimum concentration of dissolved oxygen was observed in these rivers. Dissolved oxygen was directly correlated with water temperature. It is lower during monsoon season when temperature is higher. River Rangit recorded slightly higher electrical conductivity and total dissolved solids as compared to that of Rimbi Khola and Kalej Khola. Similarly, higher alkalinities were recorded in the river Rangit. The maximum alkalinity were recorded during the winter season in all streams.

The water of all rivers is soft; total hardness ranging from 12.30 to 66.00 mg/l. River Rangit recorded higher hardness as compared to Rimbi Khola and Kalej Khola. Calcium content was chief component of total hardness comprising calcium hardness. Nutrients concentrations, viz. chloride, nitrate and phosphate did not show a definite pattern temporally and spatially.

River Rangit showed high conductance, TDS, hardness, alkalinity and nutrient concentrations as compared to that of other streams, which can be attributed to its larger catchment area of this stream.

10.2 Biological Characteristics

Total coliforms were absent at the most of the sites. It was observed from river Rangit in winter and Post-monsoon seasons while water discharge was very low. The presence of colliforms in the river Rangit can be coincided to with low water discharge and human settlement. Major water from the main river channel is diverted through a head race tunnel of an existing dam. Similarly, there are human settlements in the immediate vicinity of Kalej Khola. Relatively, more intensive farming is practiced in these areas.

All the rivers were rich in the algal density in phytoplanktonic as well as phytobenthic communities. Phytoplankton density ranged from 2034 to 111799 cells/lit with minimum in the river Rangit during monsoon season

The algal composition comprised of about 6 species of filamentous algae and more than 60 species of diatoms, in which 46 diatom species were common in planktonic and benthic forms. Rimbi Khola recorded 4 species of chlorophyceae and 26 species of Bacillariophyceae. Chlorophyceae were recorded. Aquatic community in Kalej Khola was comprised of 4 species of Chlorophyceae. (*Spirullina* sp., *Hormidium* sp., *Ulothrix* sp.) and 33 species of Bacillariophyceae.

The rivers are rich in the macro-invertebrates composition. Macro-invertebrates densely ranged from 242-1265 individuals/m^2 with maximum in Kalej Khola.

11. FISH AND FISHERIES

The present study was carried out for in the proposed hydro-electric project area in West Sikkim. As water from the Rimbi Khola would be diverted through a 5.2 km long head race tunnel (HRT) to Kalej Khola, an adjacent watershed, the studies of fish and fisheries of both the streams i.e. Kalej Khola and Rimbi Khola. Kalej Khola is right bank tributary of Rangit while river Rimbi Khola is a left bank tributary of Rathong Chhu, which joins river Rangit on the right bank at Legship town. Both streams are snowfed, harbouring cold water fish. The river stretch of Kalej khola studied falls in the tropical zone while study area of Rimbi Khola falls in tropical and sub-tropical zones as well.

Ichthyofauna comprised of about 20 species in Kalej Khola and 15 in Rimbi Chhu belonging to Families Salmonidae, Cyprinidae, Sisoridae, Cobitidae and Schilbeidae. Though, during the course of survey only 13 species could be landed in both rivers. A total of 11 species were common in both streams. Exotic trout (Salmo trutta fario) has earlier been introduced in the Rimbi Chhu (CISMHE, 2007), though, it could not be landed from the Rimbi Chhu during the survey. *Schizothorax richardsonii* and *Schizothoraicthys progastus* were common species in both streams and account for major capture fishery in this area (Plate 12.2). They were landed by the hooks. *Acrossocheilus hexagonolepis* was also important species of Kalej Khola. It was not recorded from Rimbi Chhu. These all species take upstream movement during the monsoon season. The species like *Garra, Glyptothorax, Nemacheilus, Crossocheilus* are rarely found in the catch by traditional method, therefore, they are not of fishery interest in these areas.

Caste nets and hooks are common fish gears used by the fishermen in these streams. Cultural fisheries are totally absent in these areas whereas capture fishery depends mainly on the *Schizothorax richardsonii* and *Schizothoraicthys progastus* in Rimbi Khola and *S. richardsonii, S. progastus* and *Acrossocheilus hexagonolepis* in Kalej Khola. Average catch per hour/fishermen was observed to be 750 g approximately in both streams during winter season. The maximum fishing activities occur from October to April. In monsoon season

only hooks are used to land the fish. The average catch/fishermen/hour was about 150 g.

At various sites in the West Sikkim, the ambient level of the SPM ranged from a minimum of 89.6 $\mu g/m^3$ to 120.15 $\mu g/m^3$ at Gyalzing. Gyalzing, the district head quarter of West Sikkim is the biggest and most busy town of West Sikkim. The place also has more traffic than other places in the district. The number of vehicles per hour at Gyalzing ranged from 43 to 49 in January, 2007. At all the locations, the SPM level in the ambient air was quite lower then the national standards level given by Central Pollution Control Board. The sources of SPM in the region were mainly moving vehicles on the roads.

In the project area the average NO_2 levels were negligible as compared to the standards of CPCB. The level of NO_2 in Gyalzing area ranged from 1.7 to 6.41 $\mu g/m^3$.

The main source of SO_2 is fuel such as oils and coals. The levels of sulphur dioxide in the region were low. At Gyalzing the observed levels of SO_2 were quite lower than the standards given by CPCB.

The project area is almost like a silent zone. Except the gurgling sound of Rimbi Khola and Rangit river, there is no significant noise generating activity in the valley. Occasionally vehicles disturb the silence of the region. At the riverbank near dam site, the sound levels ranged from a minimum of 59.6 to 78.8 dBA (day time observations).

13. SOCIO-ECONOMIC PROFILE

The West Sikkim is the second largest (1,166 sq km) among the four districts and having the population of 1,23,256 persons according to Census 2001. The sex-ratio is 929. The district covers nearly 16% of the total land area

of the state. The density of population in the district is 105 persons per sq km. It consists of two sub-divisions, namely Gyalzing and Soreng.

13.1 Gyalzing Sub-Division

The villages where the families whose land or house is likely to be affected by the proposed project activities have been categorized as affected villages. A total 6 villages namely Yangthang, Lingchom, Nambu, Tapong, Darap and Timrong are likely to be affected due to various components of proposed Rangit-II H.E project. All the 6 villages come under the jurisdiction of District West Sikkim under sub-division Gyalzing.

The total population of the affected villages, is comprised of 7213 which belong to 1379 households. The average family size is around 5 persons per family. Out of the total population, the number of males and females is 3742 and 3471, respectively, which means that the number of females per 1000 males is 928. The age group 0-6 yrs accounts for 16.22% of the total population. The Scheduled Tribes population accounts for 10.51% and Scheduled Castes account for only 3.33% of the total population. The affected villages are inhabited mostly by the Hindu communities.

Total 64.50 ha of land is likely to be acquired by the project authorities for the different components of the project *viz*. submergence, dam structure, colonies and dumping areas, etc. It includes only 2.28 ha of forest land and 59.34 ha of private and 2.88 ha of Govt. land would be acquired for the different activities. Only 4.0 ha of area is likely to be submerged. The private land is likely to be acquired which belong to 6 villages. Total 38.79 ha of land would be acquired on lease while balance 25.71 ha is to be acquired permanently.

13.5 Project Affected Families

. Total population of the affected families, according to the survey, is comprised of 1354 which belong to 145 surveyed households. The average family size is around 9 persons per family. Out of the total population, the number of males and females is 606 and 545, respectively, which means that the number of females per 1000 males is 899. The age group 0-6 years account for 13.71% of the total population. The population of Scheduled Tribes accounts for 93.55% (1248) and Other Backward Classes and General account for 6.45% (86) of the total population. There are no Scheduled Castes families among the project affected families.

Average literacy rate among the surveyed PAFs is 57.09%. Among the affected families. Darap village has maximum literacy (67.94%) while Tapong (46.85%) has lowest literacy rate.

About 34.33% of the total population of affected families comes under the workers category. The most of the working population is engaged in agriculture (87.12%) followed by government sector (10.04%) and business (1.97%). Only 0.87% people are pensioners including ex-service men and old age citizens.

Village Timrong having highest working participation rate of around 44.52%. About 95.65% of the working population of village Timrong is engaged in agriculture.

The livestock population in the affected families comprises of sheep, goats, cow, bull and buffallo. The cows, bulls, goats and sheeps are main components of livestock population. Cows are main source of milk in these villages.

13.6 Public Perception About the Project

During field survey of the affected families of the Rangit-II H.E. project it was observed that people are aware of the upcoming project. People gave positive as well as negative opinions about the proposed project.

About 100% of the people surveyed feel that upcoming project would bring development to their area as it would improve educational and medical facilities, while 93% of the people also feel that it would increase better transportation facility. Almost all the respondents suggested that their area can become a tourist spot because of the dam and powerhouse and most of the people are of the opinion that it would increase their welfare facilities and development. On the other hand, 36% of people surveyed felt that irrigational facilities would not improve because of this project.

Around 79% of the people surveyed informed that their agricultural land will be lost due to acquisition and 79% of them feel that this will bring loss to their agricultural crops and this will further lead to decrease in crop production. According to 93% there would be an increase in population. Only 50% of the people feel that they will not be paid adequate compensation. About 29% residents surveyed feel that there would be more landslides and loss of their natural water resources located in the project area.

One important aspect is displacement and relocation of the affected families and is of great concern. About 57% of the people are ready for it while 43% of the people surveyed were still not in favour of displacement and relocation.

14. IMPACT ASSESSMENT AND EVALUATION

The environmental impacts of the proposed Rangit-II H.E. project are being forecast in light of the activities that would be undertaken during the construction of dam, coffer dam, drilling and blasting during tunneling for head race tunnel, adits, roads, construction of permanent and temporary housing and labour colonies, quarrying for construction material and dumping of muck generated from various project works and other working areas. The likely impacts have been considered on ecosystems, both aquatic and terrestrial, as a whole, and also on individual critical species, if any. Impacts have also been assessed on the geophysical environment of the area which may lead to serious negative consequences. An attempt has also been made to understand the impact on the sociological environment in terms of social and socio-economic structure of the areas directly and/or indirectly concerned with the proposed project activities.

14.1 Impact on Terrestrial Environment

(a) Impact of Acquisition of land for project components

The proposed Rangit-II H.E. project involves construction of 40 m high dam leading to submergence of about 4.0 ha of area near Rimbi village which is mainly comprised of agricultural fields as well as degraded/ open forests. In addition 60.05 ha of land, required for building and construction purposes, has been marked for acquisition, which may lead to disruption of flora and fauna due to these activities.

(b) Impact due to submergence

The dam site is located upstream of Rimbi village in the district of West Sikkim. The area in the vicinity of proposed project comprised of fairly dense mixed sub-tropical wet hill forest with few semi- evergreen riverine plant species. The left bank of Rimbi Khola has sparse forest canopy interspersed with

agricultural fields. *Albizia chinensis, Alnus nepalensis, Bischofia javanica, Engelhardtia spicata, Erythrina arborescens, Ficus auriculata, Juglans regia, Macaranga denticulata, Persea robusta, Schima wallichii, Toona ciliata,* etc. constitute the tree canopy. Second storey is comprised of some tall spreading shrubs and bamboos. *Brassiopsis mitis, Denrocalamus hamiltonii, Edgeworthia gardneri, Mussaenda roxburghii, Neillia thyrsiflora, Oxyspora paniculata, Rubus ellipticus,* etc were noticed in the understorey. Climbers and epiphytes were few. *Cissus repens, Cryptolepis buchanani, Cuscuta reflexa, Porana racemosa, Rhaphidophora glauca, Stephania elegans,* etc are important trailing species. Herbaceous flora was represented by some pteridophytic plants, grasses and weeds. Among terrestrial pteidophytes are species of *Adiantum, Athyrium, Lygodium, Pteris* and *Selaginella*. Angiospermic herbs include *Ageratum conyzoides, Ageratina adenophora, Artemisia indica, Arthraxon hispidus, Capillipedium assimile, Commelina benghalensis, Galinsoga parviflora, Hydrocotyle nepalensis, Impatiens hirsuta, Imperata cylindrica, Lecanthus peduncularis, Oxalis corniculata, Physalis minima, Pilea scripta, Pogonatherum paniceum, Saccharum spontaneum, Rumex nepalensis* and *Solanum nigrum.*

The vegetation of right bank is dense in comparison to the left bank. *Albizia chinensis, Alnus nepalensis, Altingia excelsa, Bauhinia purpurea, Juglans regia, Persea robusta* and *Schima wallichii* are important trees in the canopy. Some terrestrial ferns and weeds are found abundantly in shaded and damp areas. Second storey is also dense mixed and comprised of shrubs and lianas. *Brassiopsis mitis, Celastrus monospermus, Mussaenda roxburghii, Oxyspora paniculata, Rhamnus paniculata, Saurauia nepalensis,* etc. in the under storey.

(c) Impact due to road construction

The alignment of proposed has been planned keeping in mind the stability and steepness of slopes, due to presence of steep slopes at some places, the construction of roads would lead to minor slips and downhill

movement of soil aggregates. Further, the removal of trees and disturbance of slopes nearby the roads might result in erosion leading to formation of gullies, etc. and landslides.

(d) Impact due to Muck Disposal

The project proposes to utilize only some part of the muck to be generated as construction material in various project structures. Therefore, most of the muck is proposed to be dumped at pre-identified locations. The dumping sites are mostly located downstream of the proposed reservoir, therefore, no negative impacts on the life of reservoir are foreseen due to this activity. The muck is proposed to be dumped in an environmentally sound manner in pre-identified dumping sites, which are proposed to be rehabilitated subsequently in an environmentally sound manner for which appropriate environmental management plan has been prepared. Generally during the construction phase and also during the disposal of muck, there is a possibility of washing away of this muck into the main river which might cause some negative impacts on the aquatic ecosystem of the river.

(e) Anthropogenic pressure

The threat of habitat disturbance, degradation and fragmentation may not only come from the constructional activities, but from the large labour population that is generally employed in such developmental projects. The presence of human population in large numbers in such areas is known to exert tremendous pressure on the natural ecosystems around the project activity sites. These pressures are foreseen in terms of increase in fuel-wood collection, rearing of livestock and the grazing pressure on the surrounding natural forest ecosystems, killing and poaching of animals for consumption and commerce, pressure on medicinal plant species and other minor forest produce that are critically endangered, degradation of habitat through tree felling and negative

changes in aesthetic quality of landscape by overcrowding beyond its carrying capacity.

Serious impacts outlined and envisaged above may not result at all the sites of project activity as the labour intensive activities and labour and office colonies are concentrated in areas away form pristine natural ecosystems.

f) Impacts on wildlife

The present proposed project envisages a 40 m high dam, which would result in inundation of only 4.0 ha of area and would not store large quantity of water; therefore, serious negative impacts on migration and movement of fauna are not envisaged. The proposed project site is not along the path of migratory animals. The proposed project activities like drilling, blasting, etc. would lead to increased noise levels in the area, which may cause disturbance to the wildlife in the area. Therefore, project authorities would be advise to devise the activity schedule keeping in mind the animal behaviour i.e. breeding season, etc.

14.2 Impact on Aquatic Environment

The most obvious impact of hydro-electric projects in the upstream inundation of terrestrial ecosystems and , in the river channel, the conversion of lotic to lentic systems. They also alter the downstream flow regime.

Downstream of the dam, reduction in sediment load in the river can result in increased erosion of river-banks and beds and loss of floodplains (through erosion and decreased over-bank accretion). Removal of fine material may leave coarser sediments that ‘armour’ the riverbed, protecting it from further scour. In some circumstances, material entrained from tributaries cannot be moved through the channel system by regulated flows, resulting in aggradations.

(b) Impact on Water Quality and Aquatic Biology

The likely impacts on the water quality arise from inappropriate disposal of muck, effluents from crushers and other sources and sewage from labour camps and colonies.

The major impact on the water quality arises when the muck is disposed along the river bank. The project authorities have identified suitable muck disposal sites which are located near the river channel. The muck will essentially come from the road-building activity, tunneling and other excavation works. The unassorted waste going into the river channel will greatly contribute to the turbidity of water continuously for long time periods. The high turbidity is known to reduce the photosynthetic efficiency of primary producers in the river and as a result, the biological productivity will be greatly reduced. Therefore, the prolonged turbid conditions would have negative impact on the aquatic life.

The presence of labours and other work force, which are generally located near the river bank would lead to deterioration of the water quality in the stream. Therefore, in order to avoid any deterioration in water quality and subsequent changes in the aquatic biota, project authorities propose to have a proper sewage disposal system in and around various labour colonies to check the discharge of waste and refuse into the river. In absence of such measures there is bound to be deterioration in water quality and the subsequent changes in the aquatic biota. The degradation in water quality will mainly arises from discharge of waste and refuse into the river channel by the labour colonies and other temporary human habitations. The increased organic content in the river waters may result in eutrophication and change in the species composition.

If the human waste and refuse is directly drained into the river channel, total coliforms and other disease causing micro-organisms may increase leading to water borne diseases.

14.3 Impact on Human Environment

a) Impact on Demography

If the quantum of human population migrating from other areas is greater than the local human population in the area it would result in demographic changes and other repercussions that follow. Since the migrant workforce is generally from the different regions, diverse ethnic and cultural backgrounds and value systems, they are bound to affect the local socio-cultural and value systems. In addition, these migrants might be the probable carriers of new diseases hitherto unknown / unreported from the project area. Diseases like AIDS, VDS, Malaria, Gastro-entireties, etc. are some of the potential risks to human health. For these project authorities have proposed quarantine procedure for screening and detecting such cases. In addition, the existing medical facilites would also be strengthened and proper health delivery system to be proposed in the project area.

14.4 Impact on Air Environment

The impact of the project would be restricted during the construction period only. These are in the form of deterioration of ambient air quality and increased noise levels. The higher noise levels during the construction, would also lead to health problems, therefore, it is advisable to use equipment that create minimum noise and vibrations.

The construction of road, drilling, etc. would lead to increase in SPM levels in addition to increased NOx and SOx levels owing to increased traffic density in the project area, pollution due to consumption of fuel in DG sets and other construction equipment and emissions from crushers. Therefore, the project authorities are advised to use sprinklers, etc. to control the SPM levels in the air.

14.5 Impact on Geophysical Environment

The area lies in the seismically active Zone-V of the seismic zoning map of India and has witnessed micro-seismic activity. From the spatial disposition of the project area in the regional seismo-tectonic setup of Sikkim, it is evident that the project area is very close to seismically active zone in the vicinity of MCT. Therefore, it is essential to adopt suitable seismic coefficient in the design for various appurtenant structures of the project. Suitable design for the dam, tunnel, surge shaft and power house be adopted. The offices and colonies will be suitably designed to withstand any future devastating earthquake.

14.6 Impacts in the Downstream Stretch

The downstream impacts may vary in their magnitude, they may be beneficial or harmful and they may be different for different sectors viz. social, economic, environmental etc.

a) Changes in Hydraulic Regime

The proposed project on Rimbi Khola near Rimbi has been designed for a discharge of 12.46 cumec. Maximum water discharge in the 90% dependable year is 25 cumec whereas minimum is 1.77 cumec. It has been, therefore, recommended to maintain 10% of the minimum water discharge during the lean period recorded in the 90% dependable year. This discharge however, will be augmented by a number of streams that join Rimbi Khola in the downstream stretch up to its confluence with Rathong Chhu. There a small stretch of about 6 km only will be comparatively dry during the lean period / season. Most of the streams joining Rimbi Khola are perennial.

b) Changes in water quality

The self purifying capability of running water is directly related to its flow regime and water discharge. River regulation is able to alter the ecological characteristics including its purifying capacity. Creation of a reservoir would lead to desiltation, therefore, water in the downstream section would be less turbid

with much lower water current velocity as compared to the normal velocity. The shallowness of the water in this section during the lean season also leads to increase the water temperature, thereby would affecting the dissolved oxygen contents adversely. Dilution of organic pollutants, if any, also decreases and results in increase in concentration of pollutants in the river channel.

c) Impacts on ground water

The recharge function of river is destroyed due to lower flows, which would affect the ground water status. Moreover, tunnel alignment may also affect the ground water recharge, resulting in the reduction of ground water recharge and destruction and drying up of natural springs.

d) Fish and fisheries

Fishes, particularly brown trout has been observed in Rimbi Khola and Kalej Khola, these species also be go up in Rimbi Khola. construction of dam will hamper the local movement of these fishes in these two streams. Therefore, in the EMP, the maintenance of small pools is recommended between the dam site and powerhouse for survival, sustenance and movement of fishes in the river by maintaining minimum required water discharge in the river during the lean season.

e) Anthropogenic stresses on surface water quality

More than 300 labourers would likely to reside in the project area for different project works. In the absence of proper sanitation and sewerage facilities, river water would deteriorate due to lower flow rate. The reduced flow leads to lower capacity of self purification and dilution of pollutants. Therefore, a proper sewage disposal has been prepared to mitigate these impacts.

f) Socio-economic Impacts

There are 7 Revenue villages in the 7.7 km downstream stretch of Rimbi Khola between dam site and its confluence with Rathong Chhu which are which are dependent upon river water directly and indirectly. Most of the villages are on the right bank except Tarnu, Meli, Bajebung and Kendem. The population of this stretch is 5197 living in 934 households. Darap is the largest village with a population of 1398. During the surveys it was observed that people are not dependent on Rimbi Khola for drinking water but use water for irrigation. The local people are interested in commercial fishing. Though fishes are available in the river and the catch is not sufficient for commercial exploitation.

14.7 Impacts during Construction

The impacts due to the construction of Rangit-II H.E. project and powerhouse installation commence right from the start of exploration activities, construction of adit tunnels, head race tunnels and approach roads, etc. may continue up to generation of hydel power, with the nature and extent of impacts varying throughout the stages of project development.

Activities like site preparation, approach roads, excavation, drilling, blasting, foundation, tunneling, deployment of machinery, erection, transportation and dumping are taken up during construction phase. The likely impacts on the environment due to these activities are also listed. Tunneling and foundation works will involve land excavation, filling and concrete works effecting environment by noise and dust pollution. Structural, deployment of machinery, approach roads construction and erection work will also result in dust, noise pollution and vehicular traffic. Material handling and transportation may significantly increase noise pollution.

During the construction of tunnels, shaft and power house installations, surface water (river / gad water) may get polluted due to the generation of large quantities of suspended particulate matter at the time of transportation of much and wastewater (sewage) coming from temporary arrangements like offices, labour camp sheds etc.

The components of the project are mostly on agricultural land, barren land and or underground and large area of cultivable land is required for the project. The construction of the project facilities would involve deforestation. Thus the danger of erosion and disturbance to hill slopes is high. The construction of new roads and project components will involve felling of large number of trees and huge deposition of excavated material in the river and tributary streams would affect the environment adversely.

14.8 Impacts during Operation

Only a small number of maintenance and operation staff will be stationed in the area in a well planned colony with piped water supply and proper sewerage treatment plant. In the operation phase, around 30 families (total population of 150 persons) will be housed in the area. About 0.024 mld of sewage will be generated. The total BOD will be to the order of about 9 kg / day. It is proposed to provide adequate number of septic tanks and soak pits to properly manage sewage and portable sewerage treatment plants are to be provided wherever the concentration of construction population is high. Adequate care will be taken to locate these structures so as there are no leaches from this activity in natural water bodies.

14.9 Post Construction impacts

The post-construction phase consists of a major activity i.e. effective implementation of bringing the affected area to its original form as far as possible. In this process the activities involved are dumping the left over solid waste at suitable places and plantation of trees on the reclaimed area so as to

attain its original form. The main activities that may cause environmental impact on the surrounding environment during project completion are:

- Transportation of excessive solid waste material (muck)
- Dumping of solid waste material.
- Removal of temporary facilities, cleaning etc.
- During the project completion the likely potential environmental impacts are due to dust and noise.

14.10 Positive Impacts

a) Positive Impacts on Socio-Economic Environment

The following positive impacts are anticipated on the social-economic environment of the local people of villages of project are during the project construction and operation phases:

i) Expatriate constructors who would probably come from other parts of the country would undertake construction activities.

ii) A number of marginal activities and jobs would be available to the locals in the project improves the job opportunities during construction phase.

iii) Education will receive a shot in the arm. The advantage of education to secure jobs will quickly percolate through all sections of the population and will induce people to get their children educated.

iv) The availability of electricity to the rural areas will reduce the dependence of the locals on alternative energy sources namely forest.

v) With increased availability of electricity, small-scale and cottage industries are likely to come up in the area.

vi) The proposed project site is well connected by road. Efforts to be made to develop eco-tourism, which could earn additional revenue.

b) Negative Impacts on Socio-Economic Environment

Although, there are a number of positive impacts of the proposed project, one major negative impact is identified i.e. there will be loss of land due to the proposed project. None of the project affected families would become houseless and landless due to the project.

15. ENVIRONMENTAL MANAGEMENT PLAN

15.1 Biodiversity Management Plan

As the project is located in the vicinity of Buffer Zone-IV of Khangchendzonga Biosphere Reserve, the construction activities would affect the habitats of wildlife. Even though directly no rare or endangered plant or animal species are likely to be affected by the project activities and submergence, the existing natural ecosystems in areas constituting upstream catchment of the proposed project especially the Buffer Zone area need protection and further strengthening of conservation efforts. In order to ensure proper implementation of conservation policies and measures additional funding support will have to be provided to aid conservation efforts in the area. Since most of these areas are administered by the State Forest Department, it will be desirable to strengthen the existing set up of the Forest & Wildlife Department of the state with clear mandate of ensuring safety and conservation of wildlife in the region. In order to ascertain that there is enough interest and necessary funding support for the activities related to management and conservation of terrestrial ecosystems and various critical species, it is proposed to provide adequate funding support for activities of conservation and management of critical and important species and ecosystems in the region.

The specific issues discussed that are required to be dealt with are described below:

i) Poaching has been one of the major cause for destruction of wildlife. Besides poachers from the town and cities who kill these animals just for the sake of fun. The poaching is to be checked by regular patrolling

and deployment of anti-poaching parties and enforcement of the Wildlife Protection Act of 1978.

ii) The project area catchment is under heavy grazing pressure and is one of the main limiting factors for the wildlife because of following effects of grazing on wildlife.

a) Interference

b) Reduction in food availability for herbivores

c) Disease propagation

d) Reduction in area of wilderness needed for the wildlife

15.1.1 Guidelines for Conservation of Biota

(i) Strict monitoring of labourers and associated workers for any activity related to endangering the life or habitat of wild animals and birds.

(ii) Strict restrictions will be imposed on the workers at project sites to ensure that they do not harvest any produce from the natural forests and cause any danger or harm to the animals and birds in wild.

(iii) Minimum levels of noise during construction activities will be maintained and only restricted/essential activities will be carried out at night in areas where the project site is in the vicinity of animal/bird habitats.

(v) The firewood to the labourers will be provided from plantations meant for the purpose and/or the provision has been made for the supply of the free subsidized kerosene/LPG from the depots being set up for this purpose to avoid forest degradation and animal habitats.

(vi) The interference of human population would be kept to the minimum and it would be ensured that the contractors do not set up labour colonies in the vicinity of forests and wilderness areas.

(vii) A mix of incentives for protection of wildlife and their habitats and strict regulatory framework will be put in place to implement the conservation effort.

(viii) The project authorities will be bound by the rules and regulations of the Wildlife Protection Acts 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.

15.1.2 Activities and Development works to be undertaken

i) Augmentation of water supply facilities for bunds, check dams, wells and for transportation of water, pumping of water, etc.

ii) Habitat improvement by way of plantation of trees, fodder plant species, fire protection measures, prevention of soil erosion and denudation of slopes; removal of weedy plant species.

iii) For the improvement of vigilance and measures to check poaching, boundary demarcation, wireless and other equipment is required.

iv) **Species Recovery Programme:** Afforstation of endangered and useful special would be given a thrust in he Biodiversity Management plan. Afforestation using the rate and endangered as well as less represented species of the concerned area will be the primary objective under the afforestation programme. Improvement of vigilance by procurement of field vehicle.

v) **Conservation and eco-**development efforts would be further strengthened with the help of establishing an arboretum. Natural Interpretation Centre, preparing a checklist of birds found in the area, by creating a webside dedicated to eco-tourism and

dissemination of printed material in the form of brochures and pamphlets.

vi) **Establishment of Arboretum:** The forest of the state exhibits diversified variety of flora and fauna and is a natural paradise for nature lovers, conservationists, botanists, zoologists and environmentalists. Sikkim being a high rainfall region encompasses within its narrow belt, a luxuriant floristic composition ranging from torpical screw pines to alpine primulas. There are more thant 4000 species of flowering plants, 300 species of ferns andits allies, 11 species of Oaks, 8 species of tree ferns and 22 species of Bamboos that grow at various altitudinal zones. Therefore, it is imperative to develop and arboretum to augment the conservation and information dissemination about rice and varied flora of the state.

vii) **Establishment of Nature Interpretation Centre (NIC) :** Nature interpretation is one of the many methods used to disseminate quality information to the visitors in a way that it supports the better management of the protected areas and encourages real appreciation for the protected area.

viii) **Preparation of Checklist of birds of the Area:** This would include preparation of checklist of birds of the project are and its catchments and would specifically summarize threats of habitat disturbances on birds in the region.

ix) **Creation of Website to boost Eco-tourism:** The state has great potential for eco-tourism development. Therefore, Environment Management Plan proposed to develop a website dedicated to boost the ecotourism in the region.

A provision of Rs.1081.89 lakhs has been made in Environment Management Plan for biodiversity management and conservation.

15.2 Action Plan for Catchment Area Treatment Plan

For the preparation of appropriate CAT plan, a detailed database on natural resources, terrain characteristics, soil type, land use and land cover is a pre-requisite. The terrain of free draining catchment of Rangit-II H. E. project is characterized by steep to very steep slopes. The terrain and geology of the area makes it susceptible to landslides and erosion. Bulk of the erosion takes place due to scouring action of water and surface run-off. All these two factors are responsible for soil erosion by way of sheet erosion, rill erosion, gully erosion, bank erosion by streams, glacier erosion and landslides.

Therefore, catchment area treatment plan has been formulated with the main objective of arresting soil erosion in the free draining catchment area up to dam site. Based upon 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 nallahs, landslides/ slopes, river banks, roads, etc.

15.2.1 Objectives

The Rangit-II H.E. project catchment area treatment plan has been prepared with the following objectives:

i) Checking soil erosion and land degradation by taking up adequate and effective soil conservation measures in erosion prone areas (very serve and serve).

ii) Rehabilitation of degraded forest areas through afforestation and facilitating natural regeneration.

iii) Rehabilitation of degraded slopes and landslide prone areas.

15.2.2 Delineation of Sub-Watersheds

For the demarcation of sub-watersheds, hierarchical delineation system developed by AIS & LUS (AIS&LUS Technical Bulletin 9) was followed. The codification system as given in Watershed Atlas of India (AIS&LUS) was followed for Teesta river watershed on 1:50,000 Survey of India toposheets. The sub-watersheds of catchment of the proposed Rangit-II H.E. project on Rimbi Khola are comprised of watersheds-3A1A7 (Rangit river). These are in turn part of Main Upper Most Teesta to Manas confluence (3A1) of Brahmaputra Right Bank up to Lohit confluence (3A) catchment as per the AISLUS, watershed Atlas of India. The sub-watersheds in the catchment were named according to their parent watersheds i.e. RrRk1-RrPk5 under Pale Khola sub-catchment in Teesta Lower sub-catchment as per AISLUS, Watershed Atlas of India. The treatment plan has been limited to entire catchment of Rangit-II H.E. project. Therefore, for the preparation of CAT paln, part of Upper Most Teesta catchment (3A1 as per AISLUS) comprising the catchment area was delineated into twenty eight sub-watersheds in Teesta Upper as per the Watershed Atlas of India as cited earlier. In all, **twenty eight** sub-watersheds have been delineated in the catchment area constituting an area of **11651.87 ha** as per the codification system as given in Watershed Atlas of India (AIS&LUS) on 1:50,000 Survey of India toposheets of the project area.

The areas in the different sub-watersheds of Rangit-II H.E. project that require treatment were 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 software (combination of ArcGIS 9.1 & GeoMedia Professional 5.2). From these queries a thematic map of areas prone to erosion in the entire free-draining catchment area was prepared. The area under different erosion intensity categories is given in Table 2.8. From the thematic map of erosion intensity, areas that require treatment measures were extracted with the help of further spatial queries. Areas which were found inaccessible i.e. areas with more than 45^{o} (50%) slope and areas above 4,000 m where the tree line starts with natural ecosystems with little human interference and tree line were excluded to arrive at those areas where appropriate treatment measures can be undertaken. Such areas were extracted for each individual sub-watershed. Finally the area required for different treatment measures for each sub-watershed was arrived at as follows. The entire area left after the above mentioned spatial queries under very severe and severe erosion intensity categories in all the sub-watersheds were included for treatment. In all total area of **1469.86 ha** would be taken up for treatment measures with **59.01 ha** under very severe category and **1410.85 ha** under severe erosion intensity category. The total area earmarked for treatment comprises more than **12.23% of the catchment area** and **30.68% of the total area under very severe and severe categories** in the catchment.

15.3 Fisheries Management

As the fishes will be affected by the change in the flow of the river like habitat fragmentation and conversion of riverine lotic environment to semi-lacustrine or lacustrine environment, appropriate management practices will be required to sustain their population. These measures are construction of check dams, maintenance of riffles and reservoir fishery.

15.4 Public Health Delivery System

During the project construction period there will be further increase in the population of this region, particularly around the project area. Around 350 workers will be coming from outside for the construction work. They will be accompanied with families and children. The peak labour force during the construction period will be around 1100. These migrant workers and their family members may be the potential carriers of new diseases hitherto unknown/unreported from the project area. Diseases like AIDS, VDS, malaria, gastroenteritis, etc are some of the potential risks to human inhabitants of this area. The present available health services in the area would be insufficient to cater to such a vast influx of outside population in this area. Therefore it would be mandatory for the project authorities and their contractors to have all the labourers including their family members registered and quarantined, vaccinated against common diseases like malaria, TB, etc. The project authorities will hold screening camps for the labourers, where rapid blood tests will be conducted for diseases like AIDS, TB, malaria, etc. Only after valid certification a labour or his family members will be registered with the contractor. The project authorities would ensure that the contractors follow this strict quarantine procedure and this clause would be included in the award of the contract/works. Adequate medical facilities would be provided by the project authorities for this purpose in addition to upgradation and strengthening of existing medical facilities in the area.

15.5 Solid Waste Management

In India average solid waste generated per capita per day is considered as 425 g (dry weight). Therefore, for about 1010 persons an estimated amount of about 156.68 tonnes (0.425 kg x 1010 individuals x 365 days = 156676 kg) per annum of solid waste will be generated annually. This waste would not be allowed to be dumped near any surface water body or a stream. The solid waste will be collected in masonry vats of at least 25 cum capacity constructed at suitable sites near the colony area. The garbage would be transported to the landfill sites located at least 500m away from the colony

area. The organic waste will be suitably processed to form compost, which can be used as manure. In addition to the above mentioned activities, proper sanitary facilities would also be provided at the labour colonies. There would be proper water facilities for drinking and cleaning for all the inhabitants of the colony. Septic tanks of appropriate size will be constructed. The wastewater generated from the colonies will be collected and disposed in specifically designed soak pits. The wastewater and sewage generated will not be allowed to flow into the rivers and streams of the area. The sanitary facilities at the colonies should be of standard municipal design for hill areas. One incineration is also proposed, which should be installed at a where maximum garbage is dumped. Particular care should be taken to burn the waste generated from the hospitals.

15.6 Forest Protection Plan

During construction phase of the hydroelectric project, migration of labour, quarrying activities, road development, etc. activities will be carried out. The migrant labourers may use forest wood for the fuel purpose. This will create biotic pressure on the forest. The quarrying and other construction activites will result either in the modification or destruction of the existing landscale of the area.

These are some of the following measures which will help in minimizing pressure on fores.

- **Energy Conservation Measures**

  Provision of free kitchen fuel like LPG and Kerosens, community kitchen and efficient cooking facilities have been made in Environment Management Plan. Captive fuel wood plantation of

local species would also be done to minimize pressure for fuel wood on forest.

- **Landscaping and restoration of construction areas**

The proposed Rangit – II HE Project would involve construction of plant area, residential and labour colonies, some bridges and access roads. These activities will result either in the modification or destruction of the existing land scale of the area. Therefore, revegetation through planting of trees, sowing of herbaceous plants and plantation of avenue trees have been proposed.

- **Green Belt Development**

A green belt around the reservoir will be created to avoid erosion of soil and prevention of land slips from the direct draining catchment into the reservoir. Most of the area in the vicinity of proposed reservoir of Rangit-II H.E. project is under dense to open forests. The creation of green belt on either side of the reservoir will ensure protection of the reservoir area from any minor slips due to fluctuation in the water level. The slopes on both the banks will be planted with suitable tree species for creation of a green belt around the reservoir rim.

15.7 Muck Disposal – Relocation and Rehabilitation

The total quantity / volume of material (muck) to be dug out or excavated during the construction of various project components is estimates to be 3,23,398 cubic meters. Of this excavated material, 1010,262 cubic meters will be utilized for construction and the rest 2,22,135 (including 40% swell factor) cubic meters of much will be required to be rehabilitated. Suitable engineering and biological measures would be taken for the stabilization of dumped much. The afforestation with suitable plant species of high ecological and economic

value which can adapt to local habitat will be undertaken with 1500-2000 plants per hectare depending upon the canopy cover required.

15.8 Disaster Management Plan

From the result it is evident that up to about 6 km d/s of the Rangit-II dam, time required in reaching the flood wave elevation to the maximum is of the order of few minutes. 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. The following measures have been suggested 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.

15.9 Environmental Monitoring Programme

Based on the findings of the Environmental Impact Assessment study various Environmental Management Plans *viz*. Catchment Area Treatment, Biodiversity Conservation & Management, Public Health Delivery System, Fisheries Development, Relocation & Rehabilitation of Dumping Sites, Landscaping and Restoration of Construction Area, Creation of Green Belt, etc. have been proposed. In order to monitor and impact and efficacy of these plans a number of parameters have been proposed during and after the completion of the management plans.

15.11 COST FOR IMPLEMENTATION OF EMP

An amount of **Rs. 1081.89 lacs** has been allocated for the implementation of different environment management plans. The summary of total cost estimates for the execution of different plans is given in Table below.

Cost estimates for the implementation of EMP*

Sl.No.	Plans	Amount (Rs. in lacs)
1.	Biodiversity Conservation Management Plan	151.50
2.	Action Plan for Catchment Area Treatment	385.01
3.	Fisheries Management	49.22
4.	Public Health Delivery System	42.00
5.	Solid Waste Management	59.80
6.	Forest Protection Plan	
	Energy conservation measures	21.35
	Landscaping and Restoration of construction areas	53.50
	Creation of Greenbelt	2.22
7.	Dumping Sites and Muck Disposal Plan	118.92
8.	Disaster Management Plan	28.31
11.	Resettlement and Rehabilitation Plan	144.96
12.	Environmental Monitoring Programme	25.00
	Total	**1081.88**

* The cost for Compensatory Afforestation and Net Present Value (NPV) not included. The cost of land to be acquired is also not included.