ENVIRONMENTAL IMPACT ASSESSMENT OF TING TING H.E. PROJECT, SIKKIM

August 2010

Prepared for:
T.T. ENERGY PVT. LTD.

RSET Environmental Consulting

RS Envirolink Technologies Pvt. Ltd.

CONTENTS

LIST OF TABLES

LIST OF FIGURES Page No

CHAPTER-1

INTRODUCTION

1.1 GENERAL

Sikkim constitutes part of Eastern Himalaya and is situated between $27^0$00'46" to $28^0$07'48" N latitude and $88^0$00'58" to $88^0$55'25"E longitude, with an area of 7096 sq km and measuring approx. 112 km from the north to south and 90 km from east to west; the elevation ranges from 300 m to over 8540 m above sea level (Mt. Khangchendzonga). It has a human population of 5,40,493 as per Census, 2001, which constitutes only 0.05% of India's total population. The state is bounded in the north by the Tibetan plateau, by China (Tibet) on the north-east, by Pangolakha range of Bhutan on the south-east, by Darjeeling district of West Bengal on the south and Singalila range and Khanchendzonga on the west and north-west.

The state of Sikkim has been administratively divided into four districts *viz*. North Sikkim, South Sikkim, East Sikkim and West Sikkim using water divides of major and minor tributaries of Teesta River as criteria. The state capital is located at Gangtok in East Sikkim. Human population of Sikkim is comprised mainly of Nepali, Bhutia and Lepchas and main languages are also known by the same names i.e. Nepali, Bhutia and Lepcha. Majority of the population speaks Nepali, which is the main medium of instruction in educational institutions along with English. The inhabitants of the state are predominantly Buddhists. Majority of residents depend on agriculture and related activities for their livelihood. Maize, large cardamom, rice and wheat are principal crops grown in the state.

Sikkim is drained by large number of perennial rivers, which merge into two prominent rivers, the Teesta and the Rangit. River Rangit is a tributary of Teesta and joins it at Melli, the boundary between Sikkim and West Bengal.

Hydropower potential of the Sikkim was recognized in early seventies, before the state became part of Union of India in 1975.

1.2 MAJOR RIVERS IN SIKKIM

The River Teesta is one of the main Himalayan rivers, which originates in the glaciers of Sikkim at an elevation of over 8,500 m above mean sea level. The river rises in mountainous terrain and is formed mainly by the union of two hill streams Lachen Chhu and Lachung Chhu at Chungthang in North Sikkim. After the confluence of Lachen Chhu and Lachung Chhu, the river gradually increases in width and takes a wide loop flowing down to Singhik, dropping in elevation in the process from 1550m to 750m.

At Singhik, the river receives one of its major tributaries, the Talung Chhu on its right. Talung Chhu originates from the Talung glacier, which is a part of the Khangchendzonga range. From Singhik, the river flows south towards Dikchu in a very deep valley and drops from 750 m to 550 m. From Dikchu the river flows in a big curve again down to Singtam with a drop of about 200 m. The Rongni Chhu, which drains the slopes of Tsomgo lake, joins Teesta from left at Singtam and the river receives Rangpo Chhu at Rangpo. After Rangpo, Teesta starts widening rapidly and is joined by the Great Rangit river at Melli on Sikkim - West Bengal border. After flowing for a distance of about 40 km from Melli in hilly terrain, the river enters the plains of West Bengal at Sevoke. Further ahead, it fans out and attains the width of 4 to 5km at places.

The Rangit river and its tributaries originates from Talung glacier in West Sikkim and after flowing for about 60 km, joins Teesta below Melli. River Rangit is a major tributary of river Teesta. Major tributaries of Rangit are Rathong 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 is joined by Rathong Chhu, which originates from the Rathong glacier and is one of the major tributaries of river Rangit. The gradient of Rangit river up to its confluence with Rathong Chhu is of the order of 1 in 25. After the confluence, the river enters into area with gentler slopes with a gradient 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.

1.3 HYDRO-POWER POTENTIAL OF SIKKIM

Out of the country’s total hydro-power potential of 84,044 MW (at 60% load factor), 4286 MW (2.88%) is located in Sikkim. Out of this 13.86% (594 MW) is under operation, 44.77% is under construction (1919 MW) and 41.37% (1773 MW) is yet to be developed. Break up of the above figures along with data for all India is given at Table 1.1. The project wise break-up of operational project (594 MW) is given at Table 1.2.

Table-1.1: Status of Hydro-Power Potential of the North-eastern States

State	Identified Capacity as per Re-assessment Study	Capacity Developed		Capacity Under Construction		Capacity yet to be Developed	
	(MW)	(MW)	%	(MW)	(%)	(MW)	%
Sikkim	4286.00	594.00	13.86	1919.00	44.77	1773.00	41.37
All India	148701.00	32442.50	21.82	13574.00	9.13	102684.50	69.05

Source: Central Electricity Authority; www.cea.nic.in/hydro/Status%20of%20Hydroelectric%20Potential%20Development.pdf – updated as of August 31, 2008

Table-1.2: List of Operational HEPs in Sikkim with Capacity

Sl. No.	Project	Capacity (MW)
1	Lower Lagyap	12
2	Upper Rongni Chhu	8
3	Mayang Chhu	4
4	Rangit-III	60
5	Teesta - V	510
Total		**594**

Source: Central Electricity Authority; http://www.cea.nic.in/hydro/List of HE Station in thecountry.pdf updated as of August 31, 2008

As per the hydropower schemes identified by Central electricity Authority (CEA) in Sikkim, the river Teesta can be harnessed for hydro-power generation in six stages, as cascade development, as per the details given at Table 1.3 below.

Table 1.3: Hydropower Schemes on Teesta River

Sl.No.	Name of Project	Installed Capacity (MW)**
1	Teesta Hydel Project Stage-I	280
2	Teesta Hydel Project Stage-II	480
3	Teesta Hydel Project Stage-III	1200
4	Teesta Hydel Project Stage-IV	495
5	Teesta Hydel Project Stage-V*	510
6	Teesta Hydel Project Stage-VI	440
Total Installed Capacity (MW)		**3405**

*Operational Project
** Installed capacities are tentative and may change after completion of DPR

In addition, there are several other hydro power schemes in Sikkim for which PFRs have been prepared under Hon'ble Prime Minister's 50,000 MW initiative and also as self identified projects promoted by private developers. These projects are at different stages of survey and investigation. Some of the major such schemes are given at Table 1.4 below.

Table 1.4: Other Major Hydropower Schemes in Sikkim

Sl.No.	Name of Project	Installed Capacity (MW)**
1	Rolep H.E. Project	36
2	Ralang H.E. Project	40
3	Chakung Chhu H.E. Project	50
4	Chuzachen H.E. Project	120
5	Sada Mangder H.E. Project	71
6	Bhasmey H.E. Project	32
7	Rangit Stage-II H.E. Project	66
8	Rangit Stage-IV H.E. Project	90
9	Jorethang Loop HEP	96
10	Ting Ting HEP	99
11	Tashiding HEP	97
12	Jedang H.E. Scheme	185
13	Talem H.E. Scheme	75
14	Rongni H.E. Project	96
15	Ringpi H.E. Scheme	160
16	Dikchu H.E. Power Project	90
17	Lachen H.E. Scheme	210
18	Lingza H.E. Scheme	160
19	Rangyong H.E. Scheme	90
20	Rukel H.E. Scheme	90
21	Panan H.E. Scheme	300
Total Installed Capacity (MW)		**2253**

** Installed capacities are tentative and may change after completion of DPR

1.4 PROJECT DESCRIPTION

The Ting Ting HEP located in West Sikkim envisages the utilization of the flow of Rathong Chhu a tributary of Rangit River for the generation of electric power. The project area is located between Latitude 27°13’ N and Longitude 88°12’ E approximately.

Location map of Ting Ting HEP is given at Figure 1.1 and Project Layout is given at Figure 1.2. Project location along with locations of other projects under cascade development is given at Figure 1.3.

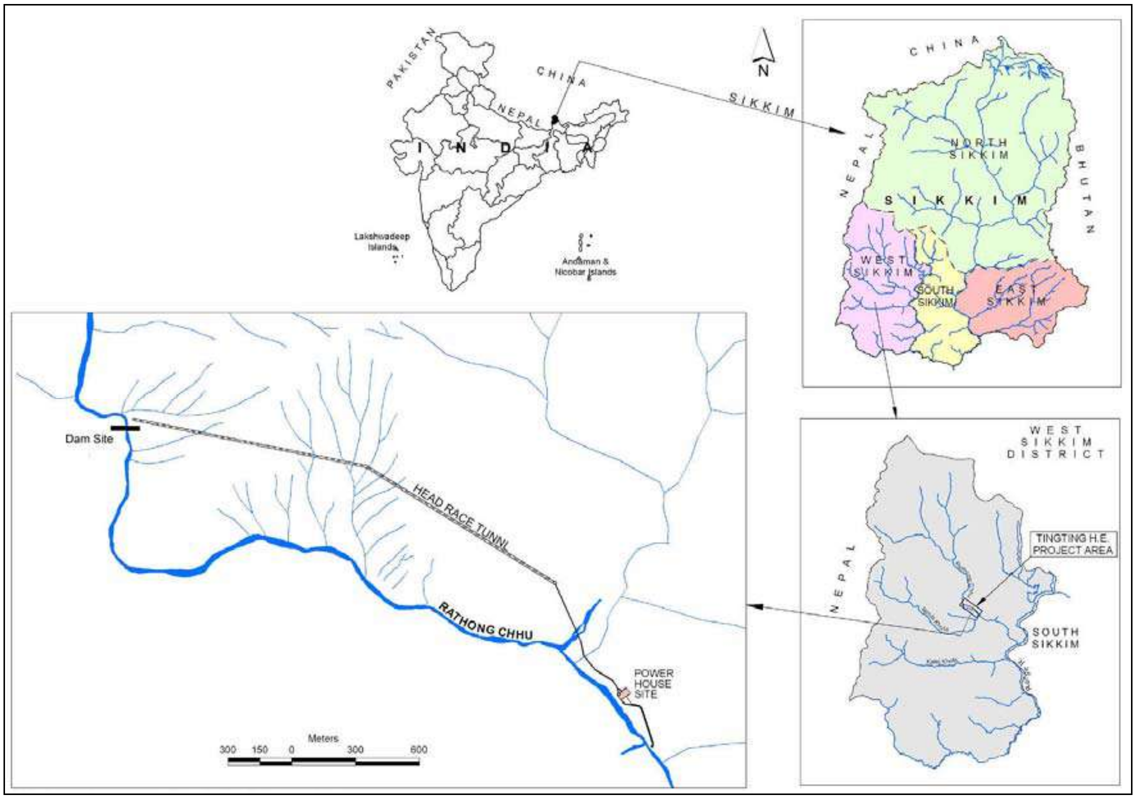


Figure 1.1: Location map of Ting Ting H.E. Project

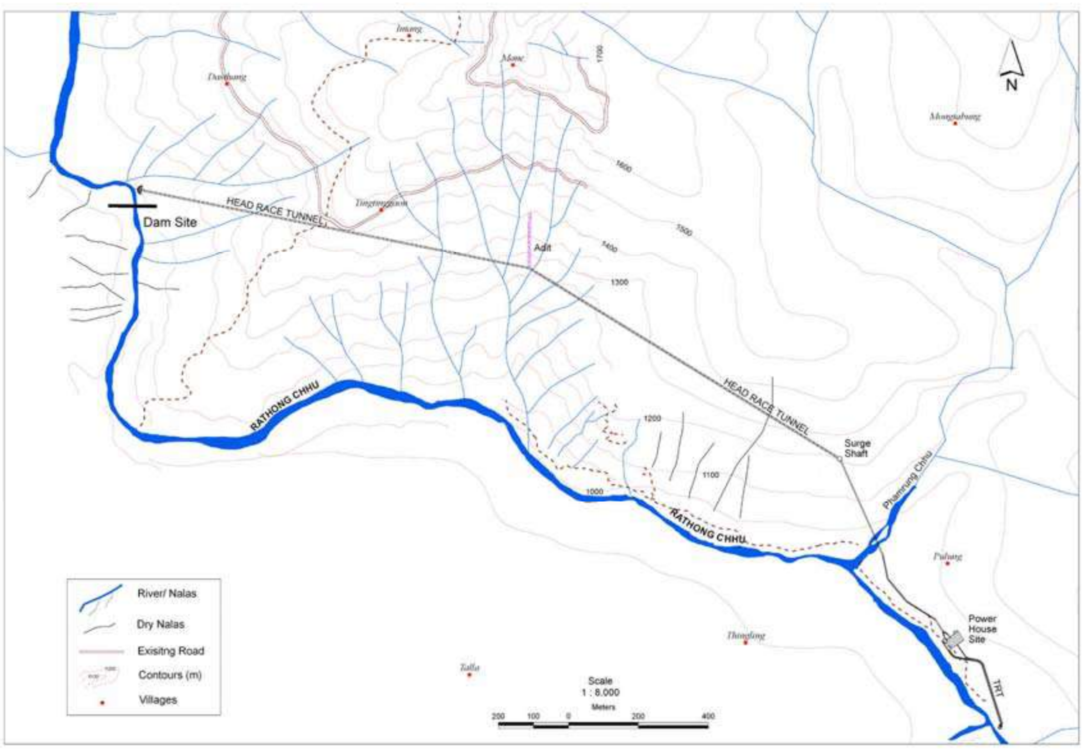


Figure 1.2: Layout Map of Ting Ting H.E. Project

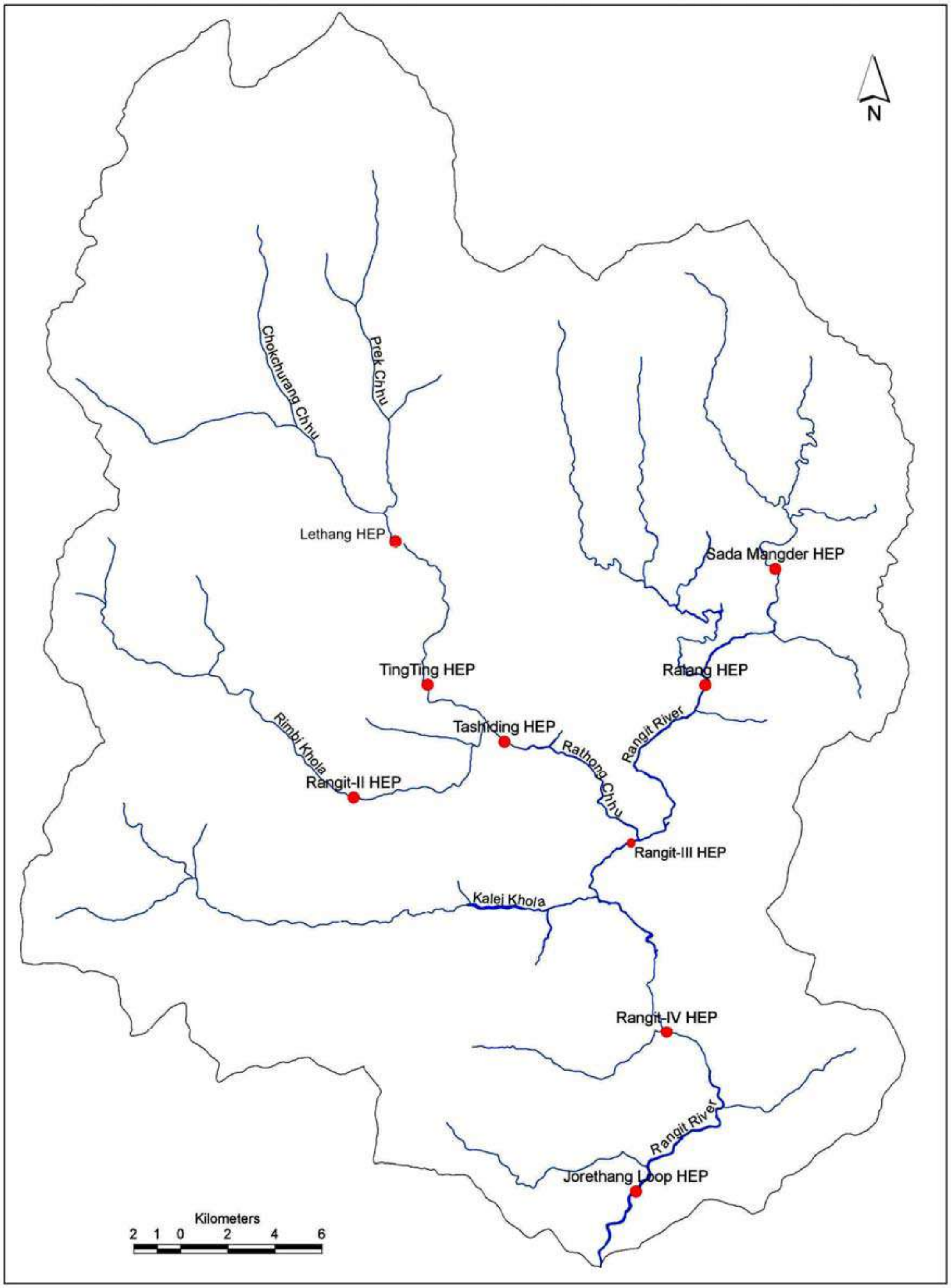


Figure 1.3: Ting Ting HEP's location vis-à-vis other hydropower projects in basin

The Project envisages utilization of a design discharge of 46 cumec through a gross head of 250 m., in order to generate a maximum of 99 MW of power. The scheme shall have a 55 m high Dam across approximately 9 kms upstream of Rathong Chhu's confluence with Rangit River; a 2.14 km head race tunnel and a surface power station with two Vertical Francis Turbine-driven generating units each of 49.5 MW (2 X49.5 MW) aggregating to 99 MW. The scheme has been envisaged as a Run-of-the-River scheme with adequate storage to meet the peaking requirements for a period of approximately 3 hrs.

On implementation of the 99 MW the Ting Ting HEP, Scheme will deliver annually 424 GWH of electrical energy in 90% dependable year.

1.4.1 Salient Features

Salient Features of the proposed Ting Ting HEP are tabulated below:

SALIENT FEATURES	
PROJECT LOCATION	
State	Sikkim
District	West
Stream	Rathong Chhu
Location (nearest village)	Yuksom
DAM	
Latitude	27^0 13' N
Longitude	88^0 12' E
HYDROLOGY	
Catchment area at Dam Site	372 sq km
Average Annual precipitation in snow fed catchment	1200 mm
Average Annual precipitation in rain fed catchment	2500 mm
Average Annual Inflow	2578 mm
Flood Discharge for River Diversion (~Q25) Non-Monsoon	125 Cumec
Standard Project Flood Discharge (SPF) (~Q 500)	1415 Cumec
Probable Maximum Flood Discharge (PMF)	1885 Cumec
DAM AND APPURTENANT STRUCTURES	
DAM	
Type	Concrete Gravity
Length of dam at top	98.5 m
Spillway Width	36 m
Spillway Crest Level:	1130
River Bed Level (Lowest)	1125.00 m
Minimum Draw Down Level	1143.00 m
Full Reservoir Level	1165.00 m
Top level of Dam	1169.00 m

Pondage above MDDL (Diurnal storage)	0.46 MCM
Submergence area at FRL (approx)	4.02 ha
Stretch of Reservoir	0.46 km
Spillway Gates	
Type	Radial
No. & Size	3.0 nos. of 6.0m(w) x 6.5m (H)
RIVER DIVERSION AT DAM	
Upstream Cofferdam	
Crest Elevation	EL 1142 m
Length	35.8 m
Downstream Coffer dam	
Crest Elevation	EL.1125.00 m
Length	63.1 m
Diversion Tunnel	
Shape & Size	D-Shape, 3.6 m
Length	131.0 m
Invert level at inlet	EL 1137.0 m
Invert level at outlet	EL 1122.4 m
INTAKE	
Location	On Left bank, 5.9 m upstream of Dam axis
Size of opening for trash rack	16 m x 6.02 m
Size of Intake opening	4.2 m(W) x 4.4 m(H)
Invert level of Intake at Entry	EL.1133.80 m
Design Discharge	46.13 Cumec
Velocity of flow through Trash racks	0.75 m/sec
Feeder Tunnel from Intake	One no. of 4.4 m Horse Shoe Shaped
Invert Level of Feeder Tunnel	EL.1134.40 m
No. Type & Dimension of Gates	One, Vertical lift gate, 4.2 x4.4 m
Trash Rack Units	8 panels of 4.0 m x 3.01m
HEADRACE TUNNEL – HRT	
Shape & Size	Horse Shoe, 4.4 m
Length	2141 m
Flow Velocity at Design Discharge	2.87 m/sec
Design Discharge	46.13 cumec
Lining Thickness (PCC)	200 mm to 300 mm
Adit to HRT	
Location	Just U/s of Surge shaft
Slope & Size	D-shaped, 4.5 m
Length	122 m
Level	El. 1120 m
SURGE SHAFT	
Vertical Shaft	Restricted Orifice Type
Internal Diameter	10 m
Height of shaft	63.9 m
Concrete lining thickness	Varying from 300mm to 600 mm

Lining Type	RCC Lining
Vertical Lift Gate size	3.4 m (W) x3.4 m (H)
Top of Surge shaft	El. 1188 m
Bottom of Surge shaft	El. 1124.1 m
Max. Surge level	El. 1185 m
Min. Surge level	El. 1127.80 m
Orifice dia	2.25 m
Adit to Surge Shaft Bottom	
Shape & Size	D-Shaped, 4.5 m
Entry Sill Level	EL1120.70 m
Length	77 m
PRESSURE SHAFT PENSTOCK	
Total Length upto Bifurcation	760 m
Number of anchor blocks	3
Diameter after Bifurcation	2.4 m
Branch penstock length	23.1 m & 32.6 m
Steel liner thickness	16 mm to 36 mm
Grade of Steel lining	ASTM 537 Class-II
POWERHOUSE	
Type	Surface Powerhouse
Size	48 m (L) x18 m (W)x44 m(H)
Number of units	Two (2)
Rated Discharge per unit	23.06 Cumec
Turbine Speed	500 rpm
Min. Tail Water Level	EL912.60 m
Normal Tail Water Level	EL 915.00 m
Max. Tail Water Level	EL 924.00 m
Gross Head (monsoon period)	EL 250 m
Net Rated Head	233.98 m
Installed Capacity	2x 49.5 MW
Annual Plant Load Factor (90 % year)	0.473
Inlet Valve Type	Spherical Valve
Number	2
Inlet Valve diameter	1.8 m
Turbine Axis Elevation	EL 904.60 m
Generator type	Suspended
Nominal Speed	500 rpm
Voltage / Frequency	11 kV /50 Hz
Power Factor	0.9
Draft Tube Gates, No & Size	Two, 4.71 m (W) x 3.764 (H)
TRANSFORMER	
Type and capacity	Single phase,11KV/220KV, 21.0 MVA, OFWF
Location	Outdoor on left bank of the river
Number	7
TAILRACE TUNNEL	
Type	Twin box, cut and cover tunnel

Length (Including tail pool)	140.8 m
No & Size	2nos. x 4.8 m x 3.5m
Bed Slope Gradient	Varying
Nominal Discharge	46.13 Cumec
River Bed Elevation	EL.912.00 m
SWITCHYARD	
Type	Outdoor
Location of Switchyard	Downstream of PH on right bank at El. 940.00 m
Bus bar Voltage	220 KV
TRANSMISSION LINE	Switch yard to pooling station
Type	Single Circuit 220 KV
ESTIMATED COST	
Civil Works (Including gates & hoists)	Rs. 226.61 Crore
E&M Works (including costs of	Rs. 167.83 Crore
transmission line to pooling station)	
Total Basic Cost	Rs. 394.44 Crore
Escalation during construction	Rs. 34.76 Crore
Interest during Construction	Rs. 59.93 Crore
Total (Generation Works)	Rs. 489.13 Crore
Cost per MW installed	Rs. 4.91 Crore
POWER BENEFITS	
Design Energy Generation (90% Dependable Year with 95% machine availability)	410.24 GWh
Annual Energy Generation in (90% Dependable Year)	424.09 GWh
Annual Energy Generation including additional energy utilizing high inflow (90% Dependable Year)	444.63 GWh
Design Energy Generation (90% Dependable	429.75 GWh
Year with 95% machine availability) including	
additional energy utilizing high inflow	
Annual Energy Generation including additional energy utilizing high inflow (50% Dependable Year)	478.77 GWh
FINANCIAL ASPECTS	
Levelized Tariff for Design Energy at 90% Dependable Year	Rs 2.15 /kWh
FIRR at Rs 2.22 /kWh tariff (35 years)	8.96%
FIRR at Rs 2.5 /kWh tariff (35 years)	11.09%
CONSTRUCTION PERIOD	
Construction Period in months (excluding pre-construction works)	30 months

1.4.2 Infrastructure

Ting Ting HEP located in West district of Sikkim about 13 Km from the Yuksom town, the first capital of Sikkim established in the year 1647, is being developed as a run of the river scheme on Rathong Chhu river, a tributary of Rangit River. The site is approachable by all weather road from Melli which is on NH-31A & connected to Siliguri / New Jalpaiguri / Bagdogra. The nearest Airport is at Bagdogra and rail head is at New Jalpaiguri / Siliguri.

Development of adequate infrastructure is a pre-requisite for timely implementation of the project. Establishment of proper infrastructure considering the existing facilities in the nearby area and the requirement of different worksites for various activities goes a long way in speedy execution of the works minimizing delays in project completion.

Transportation

Rail Head Facilities

The Power house site is 70 Km from Melli which is further connected by NH-31 with New Jalpaiguri (NJP) which is the nearest railhead of the Eastern Railway and is 160 Km from Power house site and 165 Km from Dam site. Steel, Heavy equipment and machinery shall be planned for transportation up to NJP by rail. From NJP all materials shall be transported by road to the project site.

Road Transport Facilities

The Dam site and Power house site are connected through Melli, situated on NH 31-A, by an all weather road connecting Pelling & Yuksom. The National Highway and the state Highway from Melli to Legship are capable of carrying all construction material & heavy machinery required for the project. These roads have been used by NHPC in the construction of Rangit-III HEP which was commissioned in the year 2000. Further from Legship to Power House site some of the bridges and culverts required to be upgraded to bear the loads of heavy machinery which are to be transported for the Project.

Infrastructure Facilities

Following infrastructure facilities will be required for construction of the Project

- Access roads in the Project area to various work sites, camps, offices, muck disposal area, job facility sites etc.
- Bridges and cross-drainage works.
- Residential buildings for the Project staff & offices including their electricity & provision of water supply, sanitation & drainage works.
- Non-residential buildings
- Telecommunication net work
- Construction Power

Access Roads & Bridges

Ting Ting Dam site is located on Rathong Chhu river about 13 Km before Yuksom town on the Melli-Pelling-Yuksom State Highway and the Power house is about 5 Km further downstream. The state highway from Pelling after crossing the Rimbi Khola runs along the right bank and crosses over to the left bank about 3 Km upstream of Dam site. The requirement of access roads to the work sites from the existing state highway shall be as under.

Dam site road on left bank of Rathong Chhu river

The proposed Ting Ting dam site is approachable from the same Pelling – Yuksom SPWD road, which is located at an elevation of 1250m (approx.). About 100m after crossing the bridge on Rathong Chhu, an approach road of 1.8 km was constructed more than 10 years back by the SPWD on the left bank of Rathong Chhu river, upto 300m from Dam axis. The road is presently in very poor condition and shall be reconstructed /improved for access to dam site. A temporary bridge will be provided u/s of the dam for access to the right bank. Diversion tunnel portals, u/s and d/s coffer dams and borrow areas shall be connected by road from this temporary bridge.

Surge shaft / Penstock roads

The road to Dam top (El. 1169 m) shall be extended further approximately. by 2.97 km length to reach the surge shaft top (El. 1187 m). This road shall be negotiating few drains through culverts/ bridges on its way to surge shaft top. From this road a bifurcations shall be taken at El. 1145 m to provide access road to surge shaft bottom at El. 1120.70 m.

Power House

The proposed Ting Ting surface power house, on the left bank of Rathong Chhu, is approachable from the Pelling– Yuksom SPWD road, which runs at a high elevation of around 1160m. Approach road for power house site is possible from the left bank of Rimbi khola close to its confluence with Rathong Chhu from the existing Pelling – Yuksom road. An Iron foot bridge on river Rathong Chhu is presently exists at El. 930 m u/s of the confluence of Rathong Chhu & Rimbi Khola. This will be replaced with a permanent bridge connecting left bank for approach to the Powerhouse site. The cost of this approach road upto the bridge and bridge over Rathong Chhu will be shared by the

Tashding HEP which is located immediately downstream of Ting Ting HEP Power House as they will be using the same road for construction of their project components.

After the bridge on Rathong Chhu near Power House area, access roads shall be further extended upto the Pressure shaft top at elevation EL 1002m connecting the power house and dumping area on its way on the left bank of Rathong Chhu and crossing over the Phamrung Chhu through a temporary bridge.

Other Approach Roads

- Approach roads to quarry sites/borrow areas
- Haul roads to dumping areas for muck disposal
- Approach roads to explosive magazine, crusher, B&M plant, stores, workshops penstock fabrication yard, sheds etc.

Construction and improvement of the roads, bridges and cross - drainage works will be a priority and are to be completed during the pre-construction stage. Details of the project road are as follows:

Sr. No.	**Description**	**Length (m)**
1	From Existing Road To Dam Top	2100
2	From Dam Top To Surge Shaft Top	2978
3	Diversion Road to Surge Shaft Bottom	365
4	Road to Pressure Shaft Top from Power House	770
5	Road to Power house bridge	3340
6	Road from bridge to Power house area	240
8	Other Misc. Roads	1000
	Total	**10793**

Colonies & Construction Camp Sites

The total number of permanent operating and maintenance staff required for the project is estimated to be about 15. However, during construction stage the staff requirement shall be more and shall be provided accordingly.

It is planned to execute the project through two EPC contracts, one for Civil and HM and the other for E&M works. Adequate accommodation for the contractors staff engaged in Civil, Hydro-mechanical and Electro-mechanical works will be required to be provided by the Contractor. The total no. of engineers, officers and workers of various disciplines to be deployed by the Contractor’s will be planned commensurate with the construction programme. For the contractor staff the area will be provided near project site. Labour to be deployed during construction stage will also be accommodated near work sites.

Land Requirement

Land would be required for the construction of the project components, approach roads, submergence, muck disposal and residential and non-residential buildings.

The land requirement, as worked by project developer, is summarized in the Table 1.5 below.

Table-1.5: Details of Land Requirement

Sr.No.	Description	Area (ha)
1	Dam & Reservoir Area	9.30
2	Powerhouse Area	5.66
3	Surge shaft Area	0.10
4	Batching Plant and Dumping area near Surge shaft	1.50
5	HRT & Adits Area	2.29
6	Pressure Shaft Area	0.54
7	Surface Penstock Area	0.35
8	Roads	10.80
9	Penstock fabrication/Electrical Equipment Storage Area	0.20
10	Magazine Area	0.05
	Total	**30.79**

Construction of Residential Structures

It is proposed to construct about 100 units of residential accommodation in permanent structures together with about 250 temporary units for use solely during the construction period of the project. Temporary facilities at appropriate locations, including colonies for contractors, will be required during the construction of the project.

Water and Power Supply

Water for construction will be taken from the Rathong Chhu River, which is perennial. Electric power required is about 3.0 MW for construction and other areas and will be taken from SPDC's nearest Substation at Yuksom, and for this transmission lines, transformers etc. will be provided. The Contractor will also have Diesel Generating sets with a total capacity of about 500 kVA for use in emergencies and when there is breakdown in the main supply.

1.5 POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

The Ministry of Environment & Forests (MoEF), Government of India is the nodal agency in the administrative structure of the Central Government, for the planning, promotion, co-ordination and overseeing the implementation of environmental and forestry programs. MoEF formulates environmental policies and accords environmental clearance for the projects. A Comprehensive Environmental Impact Assessment (CEIA) report is a prerequisite for environmental clearance.

Under the Environment Protection Act (EPA), 1986, various rules have been promulgated to control pollution and manage environmental issues. EIA Notification, 2006 imposes certain restrictions and prohibitions on new projects or activities, or on the expansion or modernization of existing projects or activities based on their potential environmental impacts. These project categories are listed in the notification and clearance process defined based on their capacities to obtain prior environmental clearance.

State Pollution Control Boards issue NOCs and "Consent" under Air and Water Act to various projects. Hydroelectric projects are considered as Red Category projects by SPCB. Forest and Fisheries Department of Sikkim have also issued specific notification covering Catchment Area Treatment (CAT) and Fisheries management applicable on hydroelectric projects in state.

EIA Notification, 2006

96 MW Ting Ting HEP is a Category A projects (> 50 MW), as per item 1 (c) of Schedule attached to EIA notification of September 2006 and required environmental appraisal from the Ministry of Environment & Forests (MoEF), Government of India. The appraisal process involves three stages:

1. Scoping
2. Public Consultation
3. Appraisal

Scoping: An application for scoping was submitted to MoEF in the month of December 2006 for issuance of Terms of Reference (TOR) to undertake EIA study. The application consists of Pre-feasibility Report (PFR), Project Allotment Letter/MoU with State Government and duly filled in Form 1 with proposed TOR. On completion and submission of application, a technical presentation was made before the Expert Appraisal Committee (EAC) for River Valley and Hydroelectric Projects for scoping. Approval for pre-construction activities was accorded by MoEF vide letter no. J. 12011/65/2006-IA.I dt. 09.01.2007 (Refer Annexure I).

On approval of Scoping EIA study was undertaken with extensive field data collection during three different seasons, data preparation and analysis, impact assessment and preparation of Environmental Management Plan (EMP) as per the TOR. A draft report is prepared incorporating all the above for other two stages viz. Public Consultation and Appraisal.

Public Consultation: On completion of draft EIA report and its executive summary, Public consultation will be conducted through stipulated public consultation process to be organized by Sikkim State Pollution Control Board (SPCB). Outcome of the Public Consultation process in the form of report detailing the proceedings and video of the entire event will be submitted to MoEF by SPCB.

Appraisal: On completion of Public Consultation process, incorporation of suggestions, if any during the public consultation, final report will be prepared, submitted and presented to the Expert Appraisal Committee at MoEF for final approval.

Diversion of Forest Land under Forest Conservation Act (1980)

The "in principle" approval for diversion of Forest Land required for the project under FCA (1980) has already been obtained from State Forest Department vide letter no. 1090/FCA/FEWMD/17 dt. 6.4.2010 (Refer Annexure-II).

No Objection from National Board of Wild Life

As the proposed falls within 10 km radius of Khangchendzonga National Park, it is mandatory to obtain NOC from National Board of Wild Life (NBWL).

State Level Clearances

The State Forest Department has made it mandatory to seek the approval of the Environmental Impact Assessment and monitoring of Environment Management Plan prepared by the Project Proponents. A Nodal Committee constituted by the department with members from State Pollution Control Board, Forest Department, Fisheries Department, etc. reviews all the EIA reports before they go for Public Consultation as per EIA Notification of September 2006. Therefore, on completion of the draft report, first step is to submit the report to State Forest Department for state level appraisal.

No Objection Certificate is required from the State Fisheries Department for the proposed Ting Ting H.E project.

1.6 SCOPE OF THE EIA STUDY

The scope of EIA study includes:

- Assessment of the existing status of physico-chemical, ecological and socio-economic aspects of environment
- Identification of potential impacts on various environmental components due to activities envisaged during construction and operational phases of the proposed hydro-electric project.
- Prediction of significant impacts on major environmental components
- Delineation of Environmental Management Plan (EMP) outlining measures to minimize adverse impacts during construction and operational phases of the proposed project.
- Formulation of environmental quality monitoring programs for construction and operational phases.
- Formulation of Catchment Area Treatment (CAT) Plan and Disaster Management Plan (DMP).

1.7 OUTLINE OF THE REPORT

The Comprehensive EIA report for the proposed Ting Ting hydroelectric project has been presented in two volumes – Volume I contains the findings of EIA study and the second part includes various mitigation measures under the Environmental Management Plan. The contents of Volume - I of the document are organized as follows:

Volume I : Environmental Impact assessment

Chapter-1 The Chapter gives an introduction to the area, project description and policy, legal and administrative framework for environmental clearance.

Chapter-2 Outlines of the methodology adopted for conducting the Comprehensive EIA study.

Chapter-3 Covers the environmental baseline of physical aspects of environment. The baseline study involved both field work and review of existing documents necessary for identification of data which already may have been collected for other purposes.

Chapter-4 Presents biological aspects of environment. The study is based on collection of data from various secondary data sources. As a part of the Comprehensive EIA study, detailed ecological survey was conducted for various seasons. The findings of the study were analyzed and ecological characteristics of the study area have been described in this Chapter.

Chapter-5 Covers socio-economic aspects of the project study area i.e. villages covered in the study area, their demography and amenities available at present based on primary survey in the area and Census of India, 2001 data.

Chapter-6 Describes the anticipated positive and negative impacts as a result of the construction and operation of the proposed hydro-power project. It is essentially a process to forecast the future environmental conditions of the project area that might be expected to occur as a result of the construction and operation of the proposed project. An attempt was generally made to forecast future environmental conditions quantitatively to the extent possible. But for certain parameters, which cannot be quantified, the general approach has been to discuss such intangible impacts in qualitative terms so that planners and decision makers are aware of their existence as well as their possible implications.

Volume-II: Environmental Management Plan

Volume-II of the report deals with different Environmental Management Plans prepared to mitigate the adverse environmental impacts. The contents of the Part-II are organized as follows:

Chapter-1 delineates the Biodiversity Conservation and Management Plan for mitigation of anticipated adverse impacts likely to accrue as a result of the proposed project. The approach for formulation of Biodiversity Conservation Plan is to maximize the positive environmental impacts and minimize the negative ones. After suggesting environmental mitigation measures, the cost required for implementation of various measures is also estimated.

Chapter-2 Catchment Area Treatment (CAT) plan is outlined in this Chapter. Silt yield Index (SYI) Method has been used for categorization of sub-watersheds into erodibility classes. Treatment measures for very high and high erosion categories of sub-watersheds have been formulated. Cost required for implementation of CAT Plan too has been estimated.

Chapter-3 describes the various measures to be undertaken for the Conservation & Management of the fish fauna.

Chapter-4 This chapter on Public Health Delivery System deals with the basic health care facilities available in the area and setting up of new infrastructure as well as improvement of existing infrastructure along with the cost estimates.

Chapter-5 This chapter describes various solid waste disposal problems that are likely to accrue during the construction period and also the formulation of management plan for the same.

Chapter-6 It deals with the Forest Conservation Plan covering energy conservation measures, landscaping and restoration of construction areas and creation of green belt.

Chapter-7 It deals with the problem of muck that is likely to be generated during the construction of various project components and also suggests measures for both engineering and biological measures for rehabilitation of muck disposal sites.

Chapter-8 Dam Break Analysis using DAMBRK model has been conducted. The results of the modeling exercise are outlined in this Chapter. Disaster Management Plan (DMP) too has been outlined for implementation in case of Dam Break.

Chapter-9 This chapter covers various environmental concerns that are foreseen during the construction on air, water, soil and noise environment in the project area and also deals with mitigation measures during the construction and operational phase.

Chapter-10 This chapter provides details of the project construction schedule, methodology for construction of various structures like dam, diversion arrangements, head race tunnel and equipment planning, etc.

Chapter-11 This Chapter discusses various aspects of Compensatory Afforestration Programme to be implemented by the State Forest Department.

Chapter-12 The Resettlement and Rehabilitation Plan for Project Affected Families has also been formulated as a part of this Chapter.

Chapter-13 Environmental Monitoring Programme for implementation during project construction and operation phases has been presented in this Chapter. The environmental monitoring programme has been suggested to assess the adequacy of various environmental safeguards, and to compare the predicted and actual scenario during construction and operation phases. This will be the responsibility of project proponent to formulate remedial measures not foreseen during the planning stage but arising during these phases and to generate data for further use.

Chapter-14 Summarizes the cost required for implementation of the Environmental Management Plan (EMP) and the Environmental Monitoring Programme.

CHAPTER-2

METHODOLOGY

2.1 ENVIRONMENT IMPACT ASSESSMENT

The importance given to environmental considerations in order to achieve sustainable and successful development is increasingly gaining acceptance among various developmental experts and institutions. Understanding the consequences of development and forecasting its impact on the basic life support system - land, water and air - is referred to as the Environment Impact Assessment or EIA. New dimensions have also been added to the EIA studies encompassing impacts on the ethnic diversity, socio-cultural and socio-economic aspects including displacement, resettlement and rehabilitation of human societies where developmental activities are undertaken.

EIA is a location specific study; with a common basic structure of understanding the baseline status of relevant environmental components and impact prediction due to proposed development. However, the process varies from project to project based on the location, type and magnitude of operations. EIA studies give emphasis on the assessment and prediction of impacts of development on natural ecosystems and their species along with concentrating on geophysical features, which mostly cover reversible impacts. The main aim of having EIA studies carried out is to understand and prioritize the impact of development activity on the natural life support systems and processes with main emphasis on the continuation of ecosystem processes and functions, so that adequate remedial/mitigating measures are taken right from the design stage. .

Typically in a hydro-power scheme, whose sustenance and continuity largely depends on the quality of ecosystems in the catchment of its river and reservoir, biological health of the catchment will control not only the quality and quantity of water in the river but also the life of reservoir. There is only one way to generate hydro-power on sustainable basis and that is by maintaining the natural ecosystems in the catchment. Hydro-power is a direct benefit of natural ecosystem functions, which are controlled by the biodiversity.

2.2 METHODOLOGY

Standard methodologies of Environment Impact Assessment were followed for conducting the CEIA study for the proposed Ting Ting hydroelectric project. A brief account of the methodologies and matrices followed in the present study is given below under different headings. All the methods were structured for the identification, collection and organization of baseline environmental data, assessment of developmental component and their impacts on the baseline environment. The information thus gathered has been analyzed and presented in the form of a number of visual formats for easy interpretation and decision-making.

2.2.1 Study Area

Study area for environmental study has been delineated as:

- Project area or the direct impact area within 10 km radius of the main project components like dam, power house, etc. and also area within 10 km upstream of reservoir tail.
- Submergence Area
- Intermediate catchment between dam site and power house and the river stretch downstream of dam up to power house.
- Catchment area up to the dam site

A map of the study area prepared based on the above criteria is given at Figure 2.1.

2.2.2 Scoping Matrix

Scoping is a tool which gives direction for selection of impacts due to the project activities on the environment. As part of the study, scoping exercise was conducted selecting various types of impacts which can accrue due to hydroelectric project. Based on the project features, site conditions, various parameters to be covered were selected. The results of scoping analysis are presented in Table-2.1.

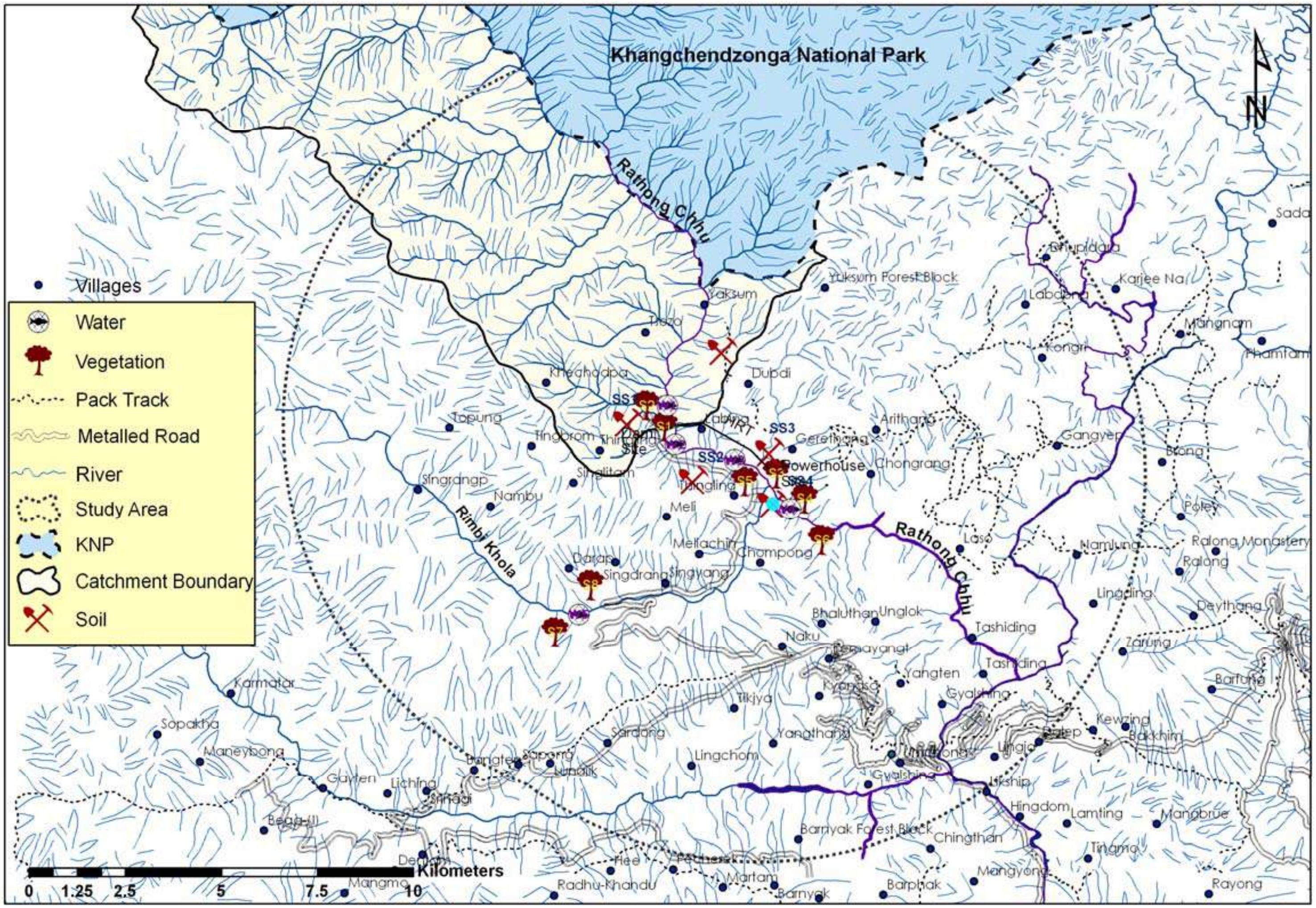


Figure 2.1 Map of Rathong Chhu Catchment Area showing Study Area and Sampling Locations

Table-2.1: Scoping for EIA study

Aspects of Environment	Likely Impacts
Land Environment	
Construction phase	• Increase in soil erosion • Pollution by construction spoils • Acquisition of land for construction works colonies • Solid waste from construction works colonies
Operation phase	• Acquisition of land for various project appurtenances • Change of landuse
Water Resources and Water Quality	
Construction phase	• Increase in turbidity of nearby receiving water bodies • Degradation of water quality due to disposal of wastes from construction works colony and construction sites
Operation phase	• Disruption of hydrologic regime • Sedimentation and siltation risks • Impacts on D.O. due to reservoir stratification • Risk of eutrophication • Reduced flow impacting downstream users
Aquatic Ecology	
Construction phase	• Increased pressure on aquatic ecology as a result of indiscriminate fishing. • Reduced productivity due to increase in turbidity and pollution of the river body
Operation phase	• Impacts on migratory fish species • Impacts on spawning and breeding grounds • Degradation of riverine ecology Increased potential for reservoir fisheries
Terrestrial Ecology	
Construction phase	• Increased pressure from construction works to meet their fuel wood and timber requirements • Adverse impacts due to increased accessibility of the area
Operation phase	• Impacts on wildlife movement • Loss of forest area • Impact on RET species, if any

Aspects of Environment	Likely Impacts
Socio-Economic Aspects	
Construction phase	• Improved employment potential during the project construction phase • Development of allied sectors leading to greater employment • Pressure on existing infrastructure facilities • Friction between the construction works and the native population
Operation phase	• Loss of lands • Loss of private properties • Increased revenue from power generation
Public Health	
Construction phase	• Impacts due to disposal of untreated sewage from construction works camps
Operation phase	• Increased incidence of vector borne disease due to increase in water spread area.
Air Environment	
Construction phase	• Emissions due to fuel combustion in construction equipment • Increased vehicular movement • Entrainment of fugitive emissions
Noise Environment	
Construction phase	• Increased noise level due to operation of various equipment • Increased vehicular movement.

Based on the Scoping matrix, the environmental baseline data have been collected and the project details superimposed on environmental baseline conditions to understand the beneficial and deleterious impacts due to the construction and operation of the proposed project.

2.2.3 Field Surveys

The field surveys commenced from January 2008 and were conducted in different seasons of the year i.e. winter, monsoon and post monsoon to collect data/ information on flora, fauna, forest types and ecological parameters as well as sociological aspects. In addition, surveys and studies were also conducted for understanding aquatic ecology and fish diversity of Rathong Chhu. Following seasons have been covered for collection of baseline data in the study area (Table 2.2).

Field surveys in the study area were also conducted for the purpose of ground truthing and augmenting the remote sensing data. For this purpose various attributes such as land features, rivers, forest and vegetation types were recorded on the ground.

Table 2.2: Sampling Frequency for Various Environmental Parameters

Particulars	Winter (Lean)	Monsoon	Post-monsoon
Vegetation sampling	Jan, 2008	Jul-08	Oct., 2008
Faunal surveys	Jan, 2008	Jul-08	Oct., 2008
Water sampling & aquatic biology	Jan, 2008	Jul-08	Oct., 2008
Air Environment	Jan, 2008	---	Oct., 2008
Noise Environment	Jan, 2008	Jul-08	Oct., 2008
Socio-economic-surveys	Oct.-Dec., 2008		

2.2.4 Physiography

The spatial database on physiographic features like drainage, roads, settlements and villages, etc. was created from maps of Survey of India (SOI) topographic sheets and satellite data followed by data analysis with Geographic Information System (GIS) tools. Contours of study area including that of catchment area have been digitized from SOI topo sheets to calculate slope category for the entire catchment. Percent area under various slope categories namely gently sloping, moderately sloping, strongly sloping, moderately steep to steep, steep, very steep and escarpments were also calculated for the entire catchment.

2.2.5 Geology

The regional geology around the project area highlighting geology, stratigraphy and structural features were based on the existing information on these aspects contained in Detailed Project Report (DPR) of the project. In addition the important parameters of seismicity were assessed using published literature on seismic history and seismo-tectonic nature of the regional rock types in the area.

2.2.6 Meteorology

Meteorological factors like precipitation, temperature and evapo-transpiration are important, as they have a profound impact on the water availability, cropping pattern, irrigation and drainage practices, soil erosion and public health, etc.

Meteorological data have been collected and analyzed as part of the DPR preparation and same have been used during the preparation of the EIA study.

2.2.7 Hydrology

Hydrological data for river Rathong Chhu as available in the Detailed Project Report was collected and suitably incorporated in the EIA study.

2.2.8 Landuse and Landcover

Land use and land cover maps of the study area as well as catchment was prepared from the latest satellite data. Digital data of IRS-P6, LISS III Path/Row 107/052 of 2-01-2006 was used for the present studies and the project area was extracted from the full scenes. For the secondary data, Survey of India topo sheets on 1:50,000 scale were referred for the preparation of base map and drainage map.

For the collection of ground truth a reconnaissance survey was carried out in the study area during field visits. For the preparation of environment management plans like catchment area treatment, land use/ land cover maps and related thematic maps were prepared and classified on 1:50,000 scale. Different forest density classes were identified and the degraded areas and scrubs were also delineated for the purpose of erosion mapping along with settlements and agricultural areas. The non-forest land cover in the form of barren land, river, etc. was also delineated for the calculation and classification of erosion intensity.

2.2.9 Soil

The soil samples were collected from various locations in the project study area. The monitoring was conducted at different locations during field visits. For the preparation of soil map of the catchment, free draining catchment and the project study area, soil maps prepared by NBSS & LUP, Kolkata for Carrying Capacity studies of Teesta Basin in Sikkim were referred to.

2.2.10 Water Quality and Aquatic Biology

The existing data on water quality has been collected to:

- Assess the quantitative and qualitative nature of effluent discharges to river
- Evaluate river water quality on upstream and downstream of the project site.

The water quality was monitored for three seasons and analyzed for physico-chemical and biological parameters.

2.2.11 Ambient Air Quality

The ambient air quality was monitored at two locations in the study area. Monitoring was conducted for two seasons namely winter, and post monsoon. The frequency of monitoring in each season was twice a week. The parameters monitored were SPM, RPM, SO_2, and NOx. SPM and RPM have been estimated by gravimetric method. Modified West and Gaeke method (IS-5182 Part-II, 1969) has been adopted for estimation of SO_2. Jacobs Hochheiser method (IS5182 Part-IV, 1975) has been adopted for the estimation of NOx.

2.2.12 Ambient Sound Levels

As a part of the EIA study sound levels were monitored at various locations in the study area during field visits. At each station, hourly sound levels were monitored using hand held digital sound level meter near the source of sound,

2.2.13 Forest Types and Forest Cover

The details on forest types and forest cover in the catchment area were based on field surveys in the area supplemented with the working plans of the forest divisions of the study area. The major forest types, sub-tropical, temperate, sub-alpine and alpine, encountered in the area were described based on the classification of Champion and Seth (1968), Negi (1989, 1996), Srivastava and Singh (2005).

2.2.14 Vegetation Structure/ Floristic

The detailed account of flora, floristic ecology and plant communities has been described based on the primary surveys in the catchment area of the project. These surveys were undertaken during different seasons of the year to account for most of the floral elements found in the area. Quadrats were laid for the analysis of distribution pattern of plants in the catchment. The data on vegetation were quantitatively analysed for abundance, density and frequency. The distribution pattern of different species was studied using the ratio of abundance to frequency (Whitford, 1956). Plant diversity was also analysed for the region using Shanon Wiener (1963) Index. The complete inventorisation of flora was carried out after consulting the existing literature on the flora of these areas. For the compilation of floral accounts of the project area, data was collected from various secondary sources also.

2.2.15 Faunal Elements

Since observations of fauna and wildlife take long time, primary surveys were limited to field visits and direct and indirect sightings of animals. The presence of wildlife was also confirmed from the local inhabitants depending on the animal sightings and the frequency of their visits in the catchment area. In addition to these, secondary sources mainly literature was referred for preparing checklists and other analysis in the study of animals and wildlife in the region.

2.2.16 Aquatic Ecology

Water resources projects have beneficial as well as adverse impacts on fish production. The data on the prevailing fish species was collected from Fisheries Department of State Government and through literature review as well. Fishing was done at various sites in the project area and river stretches, both upstream and downstream of the project site to ascertain the disposal pattern of fish species. Identification and measurements of all the fish catch was done and an inventory of the fish species was also prepared. Various migratory species and the species to be affected due to conversion of lotic to lentic conditions as a result of commissioning of the proposed project were also identified.

Water samples from Rathong Chhu were also collected as a part of field studies. The density and diversity of phytoplankton, species diversity index and primary productivity etc. were also studied.

2.2.17 Demographic Characteristics

The demographic and socio-economic characteristics of the submergence area as well as the study area were compiled through field surveys as well secondary sources. Detailed socio-economic census survey was conducted in all the villages likely to be affected by the proposed project. Collection of data was completed at two levels - at village and individual household level. (Refer Annexure III and IV for Questionnaires). The socio-economic survey at the village level was aimed at finding out the status and extent of amenities and resources available in villages. Based on the assessment of demographic profile of Project Affected Families (PAFs), using guidelines and norms as per National Policy on Resettlement and Rehabilitation (2007), Resettlement and Rehabilitation Plan was formulated.

2.2.18 Infrastructure Facilities

The present status of infrastructure facilities, status and availability of electricity, drinking water, communication and mode of transportation, commercial, educational and health facilities, veterinary services, etc. was collected using secondary data sourced from Census of India, 2001.

2.2.19 Public Health

Development of water resources could have both beneficial and adverse effects on the health of the people in and around the project area. In order to assess the existing status of public health, the following data on public health status has been collected from Public Health Department:

- prevalent vectors in the area
- prevalence of malaria and other water and vector-borne diseases in the area

2.3 IMPACT PREDICTION

Prediction is essentially a process to forecast the future environmental conditions of the project area that might be expected to occur because of implementation of the project. Impacts of project activities have been predicted using overlay technique (super-imposition of activity on environmental parameter). For intangible impacts qualitative assessment has been done. The environmental impacts predicted are as follows:

- Loss of cultivable land and forests
- Impacts on landuse pattern

- Displacement of population, if any, due to acquisition of private and community properties
- Impacts on hydrologic regime
- Impacts on water quality
- Increase in incidence of water-related diseases including vector-borne diseases
- Effect on riverine fisheries including migratory fish species
- Increase in air pollution and noise level during project construction phase
- Impacts due to sewage generation from construction works camps
- Impacts due to acquisition of forest land
- Impacts on terrestrial and aquatic ecology due to increased human interferences during project construction and operation phases

2.4 ENVIRONMENTAL MANAGEMENT PLAN AND COST ESTIMATES

Based on the environmental baseline conditions and project inputs, the adverse impacts were identified and a set of measures have been suggested as a part of Environmental Management Plan (EMP) for their mitigation.

The management measures have been suggested for the following aspects:

- Biodiversity Conservation and Management Plan
- Action Plan for Catchment Area Treatment
- Fisheries Conservation & Management Plan
- Public Health Delivery System
- Solid Waste Management Plan
- Muck Disposal Plan
- Landscaping and Restoration of Quarries and Construction sites
- Forest Protection Plan
- Resettlement & Rehabilitation Plan
- Mitigation Measures for Air, Noise and Water Environment
- Compensatory Afforestation Programme
- Construction Methodology and Equipment Planning

The expenditure required for implementation of R&R Plan, CAT Plan and other components of EMP shall be estimated and proposed as part of the study report.

2.5 DAM BREAK ANALYSIS AND DISASTER MANAGEMENT PLAN

The dam break analysis was carried out using DAMBRK model for this project in the following stages:

- Developed inflow hydrograph for the reservoir at the time of failure
- The hydrograph was routed through reservoir
- Estimated the outflow hydrograph after the dam break. Model was developed to asses the movement of flood wave downstream its travel time, maximum water level etc.

The Disaster Management Plan (DMP) to cater for the exigencies in case of a dam break has been suggested. It outlines the actions to be taken in the event of a dam break.

2.6 ENVIRONMENTAL MONITORING PROGRAMME

It is necessary to continue monitoring of certain parameters to verify the adequacy of various measures outlined in the Environmental Management Plan (EMP) and to assess the implementation of mitigative measures. An environmental monitoring programme including monitoring frequency for critical parameters has been suggested for implementation during project construction and operation phases. The staff, necessary equipment and agencies to be involved for implementation of the Environmental Monitoring Programme and costs have also been indicated.

CHAPTER-3

ENVIRONMENTAL BASELINE STATUS-PHYSICO-CHEMICAL ASPECTS

3.1 GENERAL

Before start of any Environmental Impact Assessment study, it is necessary to establish the baseline levels of relevant environmental parameters which are likely to be affected as a result of the construction and operation of the proposed project. A similar approach has been adopted for conducting the EIA study for the proposed Tingting Hydroelectric Project. A Scoping Matrix as outlined in Chapter-2 was formulated to identify various issues likely to be affected as a result of the proposed project. Based on the project location and features, special focus areas requiring attention during impact assessment have been short-listed. Thus, planning of baseline survey commenced with the shortlisting of impacts and identification of parameters for which the baseline data needed to be collected.

The baseline status has been evaluated under the following three categories:

- Physico-chemical aspects
- Biodiversity/ Ecology
- Socio-Economic and ethnographic aspects

The baseline setting for physico-chemical aspects have been covered in this Chapter.

3.2 PHYSIOGRAPHY

Sikkim state being a part of inner mountain ranges of Himalaya is mostly hilly. The altitude above mean sea level varies from 230 m in the south to above 8,500 m in the north and the hill slope generally ranges between 4% in the flat valleys to 90% and characterised by undulating surface features. The habitable areas exist only up to the altitude of 2,100 m constituting only 20% of the total area of the state.

The hill tops are in the North, East and West and covered with perpetual snow which feed the two major rivers, the Teesta and the Rangit traversing through the state from North to South. The highest portion of Sikkim lies in its North-West direction, which includes Mt. Khangchendzonga, the third highest peak in the world at an elevation of

8,598 m. A number of glaciers descend from the eastern slopes of Khangchendzonga where snow line is found above 5,300 m. The biggest amongst them is Zemu.

The geographical area of the proposed Tingting hydroelectric project site falls in West Sikkim district. The West district with an area of 1,166 sq km has a rectangular shape with North-South elongation. The elevations vary from 350 m at Jorethang in the south to 7,000 m near Pandim in the north. The district has only one glaciated basin known as the East Rathong basin located west of Teesta River. This basin has a total of 36 glaciers of different sizes covering an area of 57.8 sq km.

.

The catchment area map of Tingting HE project is shown in Figure 3.1.

Rathong Chhu is the major tributary of Rangit river in West Sikkim and originates at an elevation of 4900 m from Rathong Glacier. Rathong Chhu is formed by the confluence of two streams i.e. Prek Chhu and Chokchurang Chhu (see Figure 3.1). Prek Chhu stream originates from Onglakthang glacier (4,200m). It receives water from number of glacial lakes like Tikuchia Pokhari (4,800 m), Chamliya Pokhari (4,600 m) and Sungmoteng Chho (4,280 m) whichlocated on the lateral moraines on the left flank of Onglakthang glacier. Prek Chhu flows for about 12km up to an El. 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 for another 10 km up to El. 2,175 m where Chokchurang Chhu drains into it on the right bank. Chokchurang Chhu originates from East Rathong glacier at 4,600 m from where it flows for about 7 km up to El. 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. After this it flows for another 2.3 km and receives water from Koklung Chhu on its right bank which traverses a distance of about 7 km from its origin at 5,000 m. Downstream of this confluence the river flows 1.7 km where Gomathang Chhu joins 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 for about 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 for another 1.2 km to join Prek Chhu on its right bank at 2,175 m. After their confluence it is known as Rathong Chhu. Rathong Chhu then traverses a distance of

1.7 km up to 1,970 m and receives water from Pongmirang Chhu on its right bank. Thereafter it flows down about 9 km up to the proposed Tingting dam site.

Phamrong Chhu and Rimbi Khola are two signicant tributaries downstream of the dam site in the project study area (Figure 3.2). Phamrang Chhu flowing 7.5 km from El. 2,900 m joins it on the left bank near Pulung. Immediately downstream of this point, Rimbi khola drains into Rathong Chhu on the right bank at 907 m.

Rimbi Khola a major tributary of Rathong Chhu and 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. 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 then joins Rangit River on its right bank at 602 m. From this confluence Rangit river is fed by Kalej Khola on the right bank. Rimbi Khola joins the Rathong Chhu about 150 m downstream of the proposed powerhouse site of the project.

3.2.1 Gradient Profile of Rathong Chhu

Longitudinal profile of Rathong Chhu drawn from the 1:50,000 SOI toposheets is given in Fig.3.3 up to the confluence of major right bank tributary downstream, Rathong Chhu flowing as Prek Chu in initial stretch of 4km has a very steep gradient of about 1:1. Thereafter average gradient is 1:8.1 up to the proposed dam site.

3.2.2 Slope

To generate the slope model for the catchment area of Tingting H.E. project the contours at an interval of 40m from 1:50,000 Survey of India toposheets were digitized with the help of ArcGIS 9.0. From the digital data, Digital Elevation Model (DEM) for entire project catchment as well as for sub-watersheds was also generated using ArcGIS 9.0 (Fig. 3.4). Subsequently, the TIN models for all the constituent sub-watersheds of Tingting H.E. project catchment for the preparation of Catchment Area Treatment Plan were also generated. The results of this analysis are presented in the form of thematic maps for slope and elevation-relief in Figures 3.4 and 3.5, respectively. Percent area under each slope category is shown in the pie-chart as inset in Fig.3.4.

The slope map indicates that the maximum area in the catchment is under steep slopes which are about 46% of the total catchment. Moderately steep slopes also cover quite a large extent (31%) of the catchment whereas area under very steep slopes covers more than 9% of the area. Very steep slopes are characteristic of higher ridges and their slopes.

The study area also is characterized by steep slopes comprising more than 59% of area while moderate slopes cover about 27% of area (Figure3.5). Very steep slopes cover area nearly 9% of area.

3.2.3 Elevation & Aspect

The elevation-relief and aspect maps were also generated from the Digital Elevation Model (DEM) (Figure 3.6). The digital elevation model for Tingting H.E. project catchment is shown in Figure 3.7. The area (on catchment area proportionate basis) covered by each elevational band is shown in pie-chart inset in Figure 3.6.

Starting from the bed level of about 1125 m at the dam site up to Rathong glacier the catchment area covers 372 sq km. The catchment has been divided into ten elevational bands (Figure 3.7). Barring the lowest and highest elevation bands, each intermediate band covers an altitude range of 400 m. The lowest elevation band covers area up to 1200 m elevation, whereas the highest band extends beyond 7,200 m.

Most of the the catchment lies in the elevational band of 4000-4800 m covering nearly 38 % of catchment area. Other bands of significant coverage are 3600-4000 m (46.17 sq km, 12.41%) and 4800-5200 m (48.76 sq km, 13.11%).

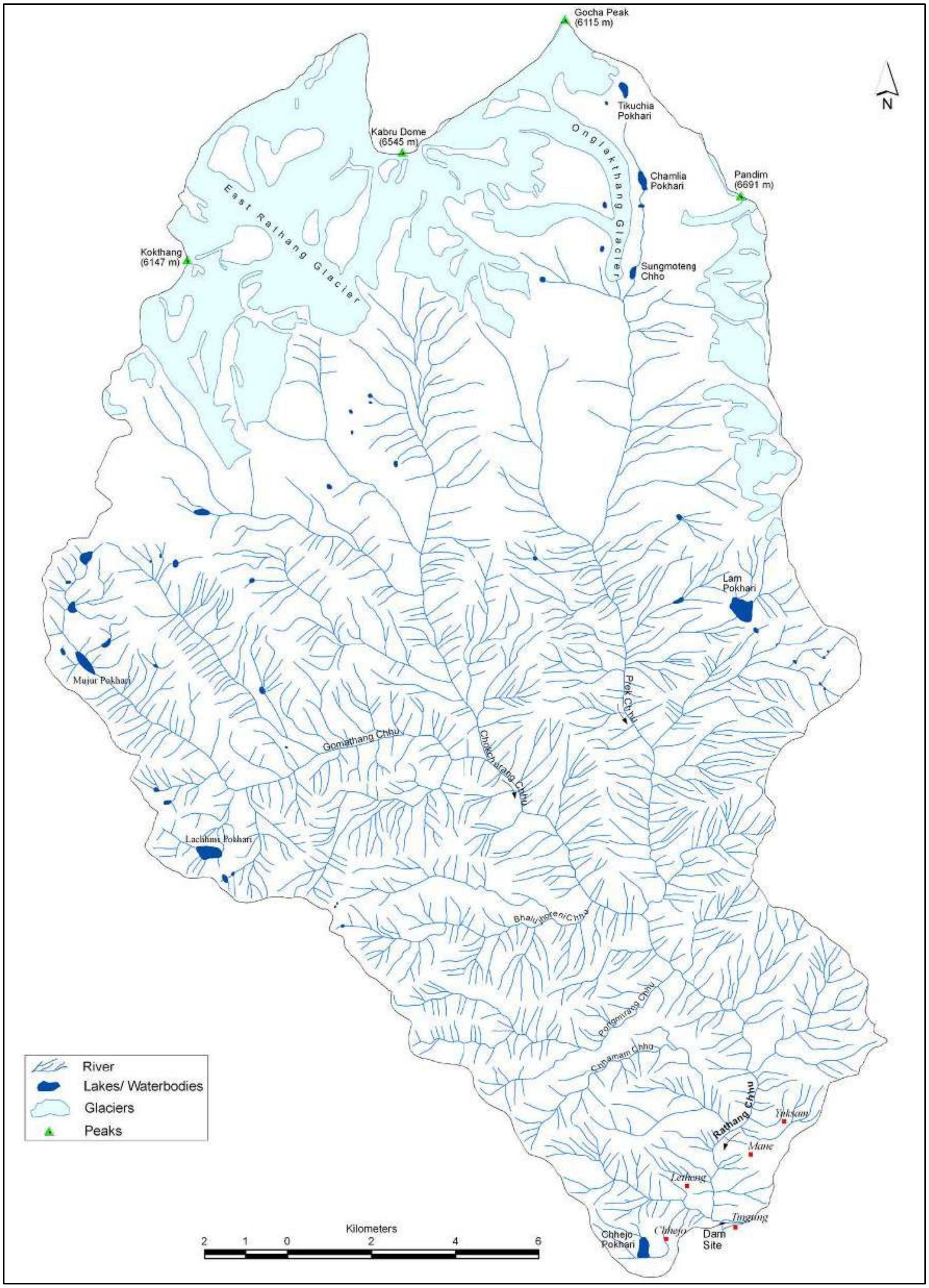


Figure: 3.1: Drainage map of Rathong Chhu catchment up to Tingting HE project

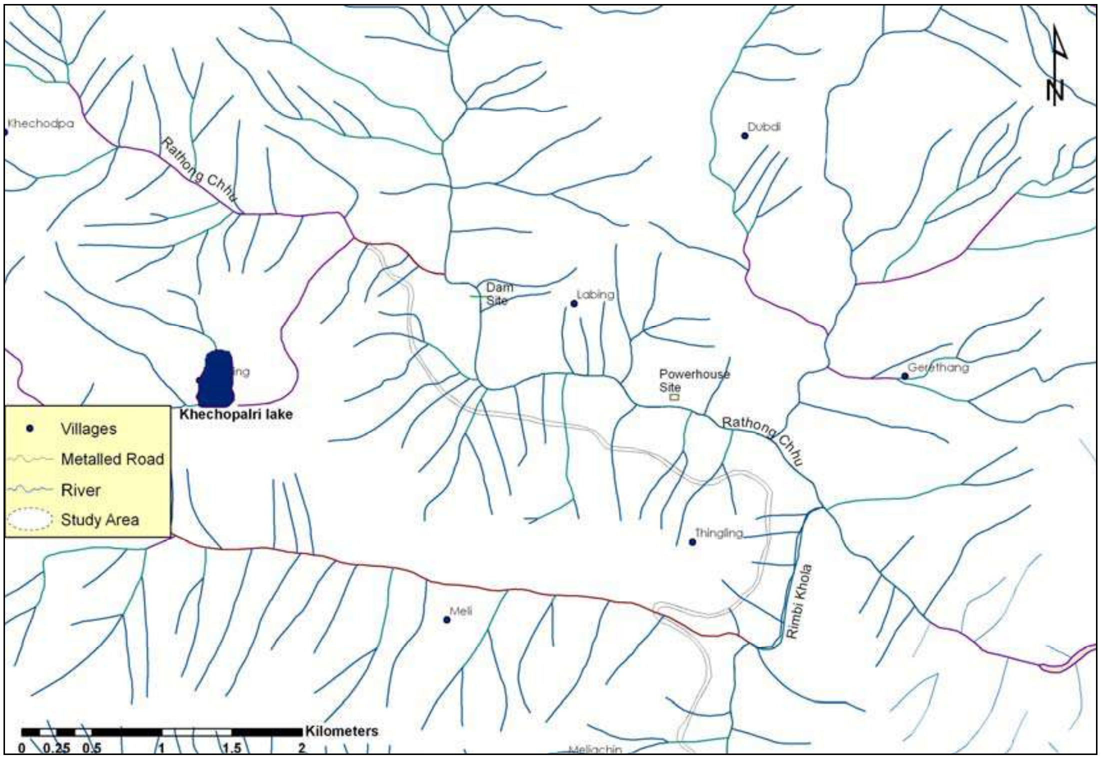


Figure 3.2: Drainage map of Tingting HE project study area

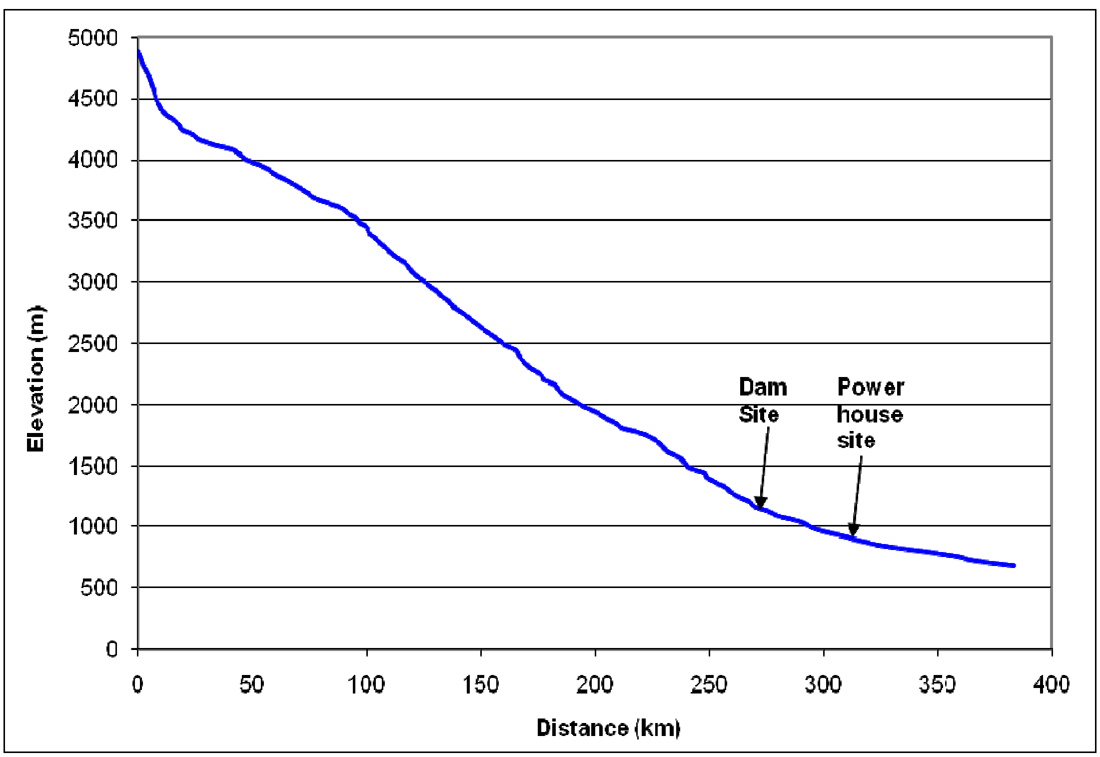


Figure 3.3: Gradient profile of Rathong Chhu

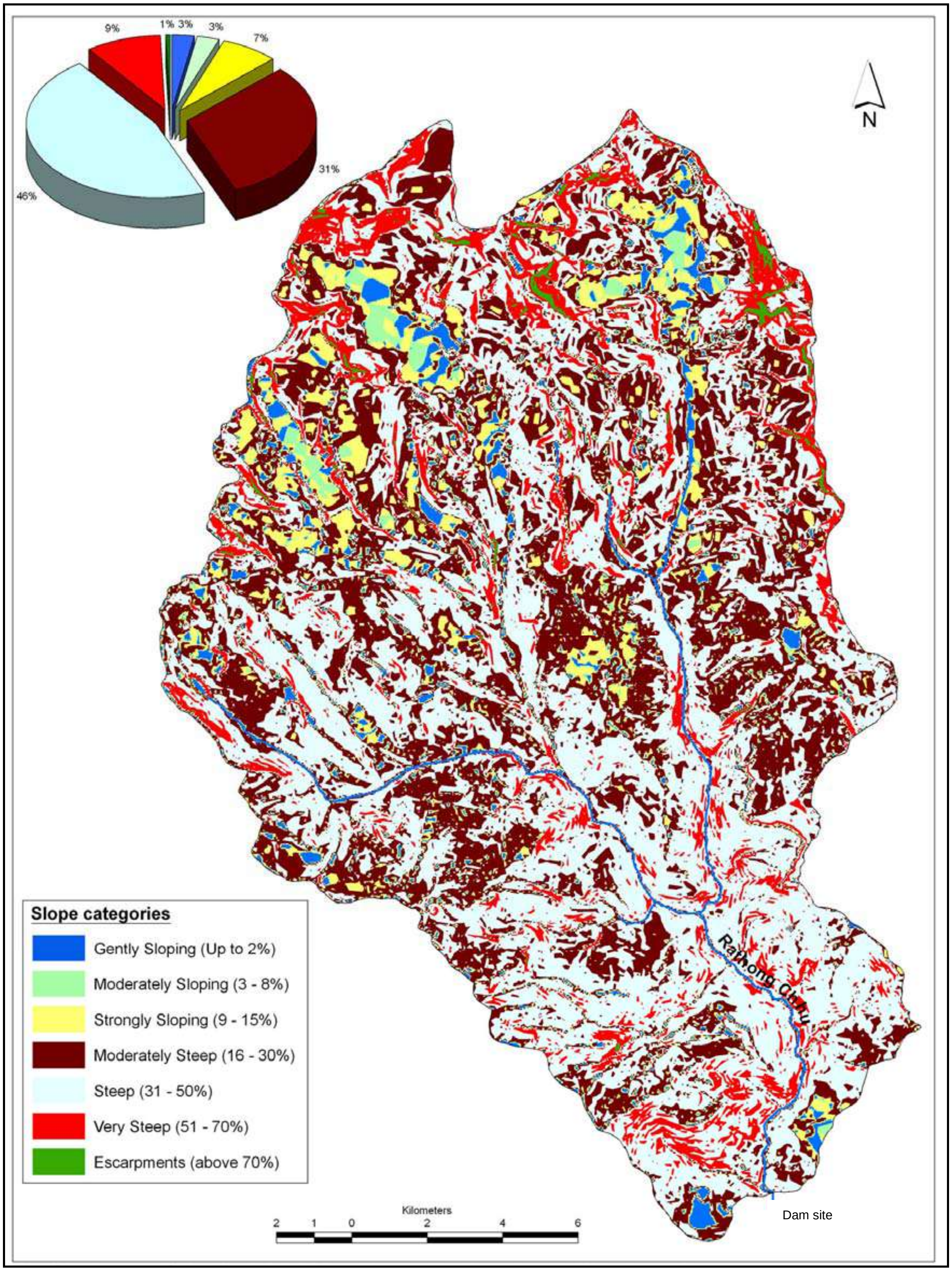


Figure 3.4: Slope map of Rathong Chhu catchment up to Tingting dam site

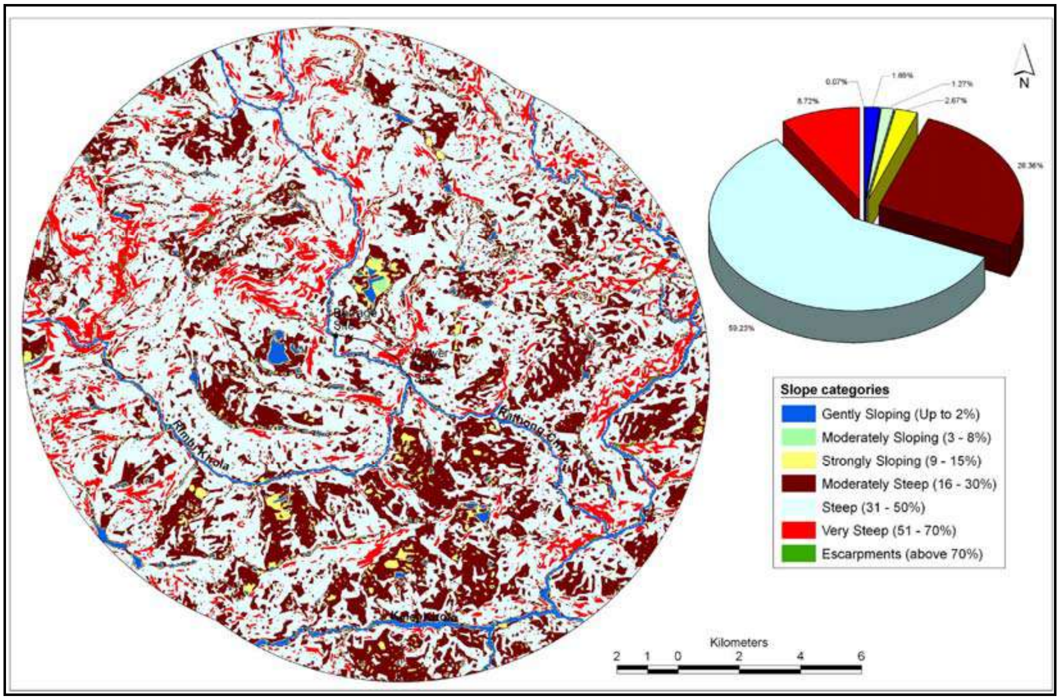


Figure 3.5: Slope map of Tingting HE project study area

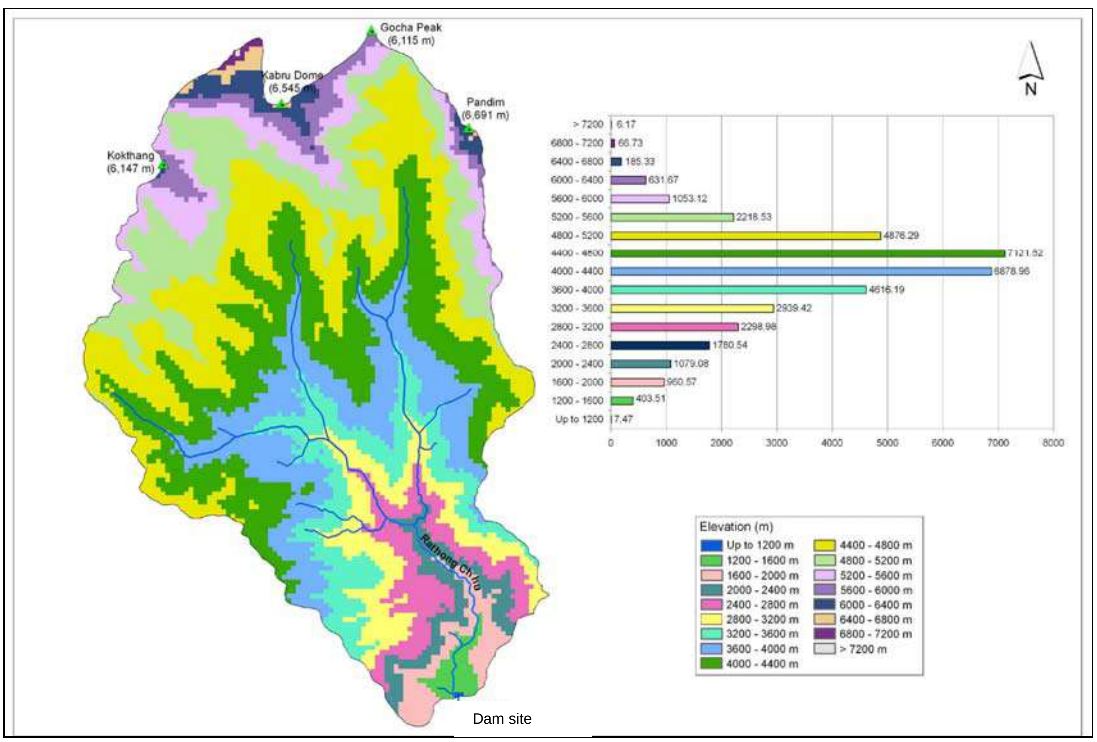


Figure 3.6: Relief map of Tingting HE project study area

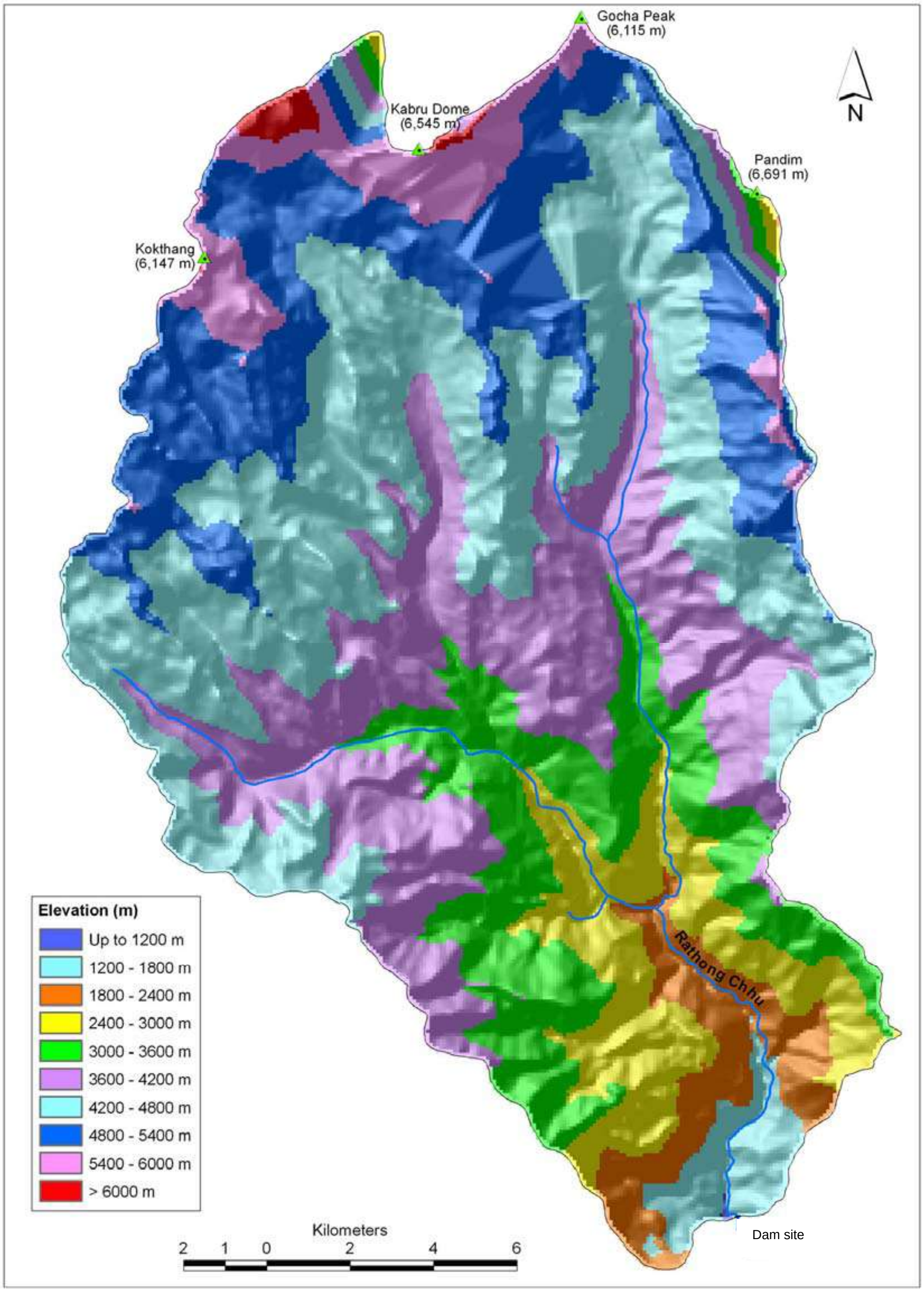


Figure 3.7: DEM of Tingting HE project catchment

3.3 REGIONAL GEOLOGY & STRATIGRAPHY

Sikkim Himalaya has been subdivided into distinct geotectonic domains like other sectors, which are separated from one another by thrust faults (e.g. Acharya and Shastry, 1979; Ray, 1976; Sinha Roy, 1982; Catlos *et al*., 2004; Dasgupta *et al*., 2004) (Figures 3.8 & 3.9). They are described as follows.

Sub-Himalayan Domain

This domain lies in the south and consists of mollase type deposits of the Siwaliks (Mio-Pliocene), and is separated from the lesser Himalayan domain (LHD) in the north by the Main Boundary Thrust (MBT).

The Lesser Himalayan Domain

The LHD consists of a thin strip of Gondwana rocks (Carboniferous-Permian), carbonate rocks (Buxa Formation) and a thick meta-sedimentary sequence of dominantly pelites with subordinate psammite and wacke (Daling Group).

Higher Himalayan Domain

The higher Himalayan domain (HHD) overlies the LHD and is composed of medium to high-grade crystalline rocks, commonly referred to as the higher Himalayan crystallines (HHC). These are dominantly of pelitic composition, with sporadic quartzites, calc-silicate rocks, metabasics and small bodies of granite. The HHC is separated from the lesser Himalayas by the Main Central Thrust (MCT). The exact location of this thrust has been controversial in many areas, including Sikkim (Lal *et al*., 1981; Sinha Roy, 1982).

The Tethyan Belt

A thick pile of fossiliferous Cambrian to Eocene sedimentary rocks belonging to the Tethyan Belt (Tethyan Sedimentary Sequence) overlie the HHC on the hanging wall side of a series of north-dipping normal faults constituting the South Tibetan Detachment System (STDS) in the extreme north of Sikkim.

3.3.1 Stratigraphy

A comprehensive stratigraphic framework along a south-north traverse from the foothills of Darjeeling-Himalaya to the northernmost part of the Sikkim Himalaya is established by Ray (1989) and shown in Table 3.1. The repetitive nature of the three units, namely the Gorubathan, the Reyang and the Baxa of the Daling Group as also the two units, the Rangit Pebble Slate and the Damuda of the Gondwana Group, within a tectonic section has been shown from Darjeeling-Sikkim Himalaya (see Table 3.1).

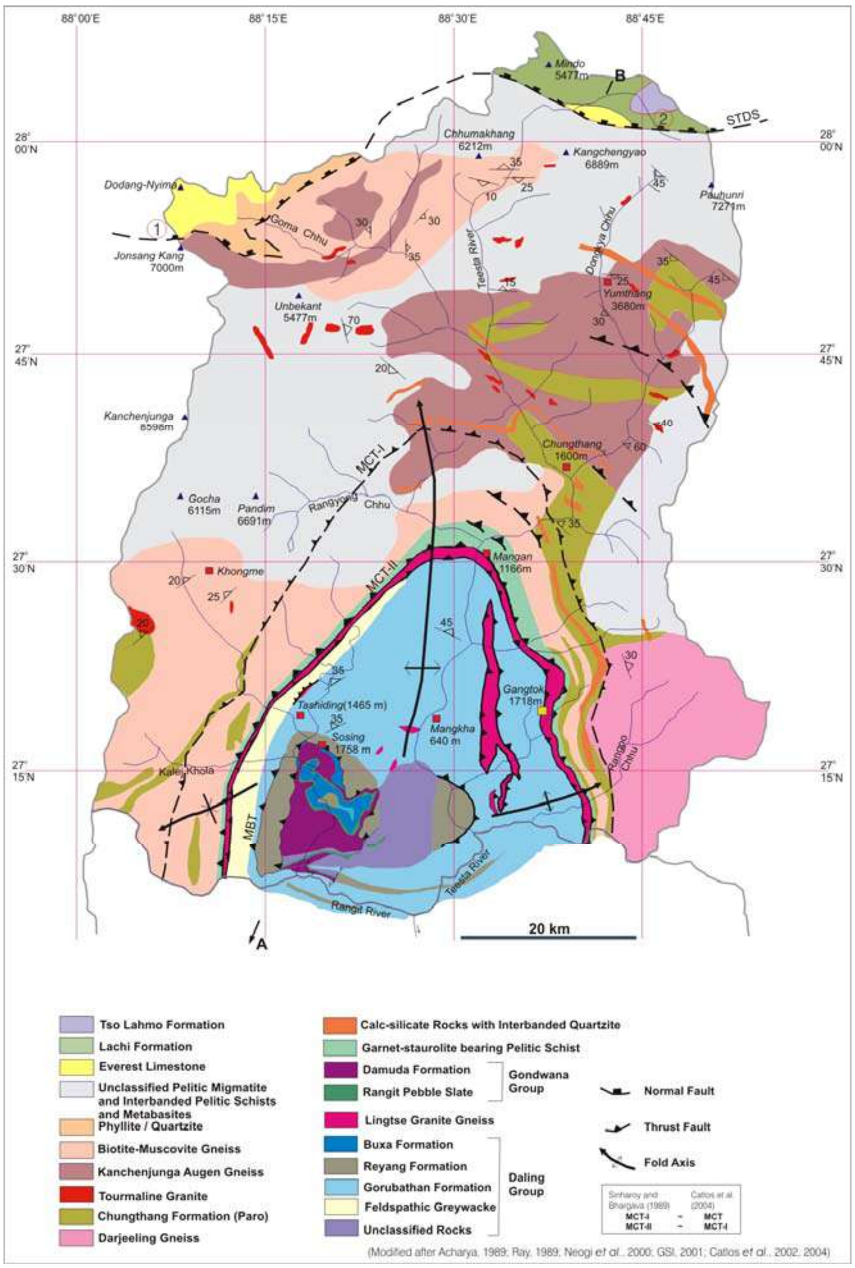


Figure 3.8 Geology and stratigraphy of Teesta basin in Sikkim

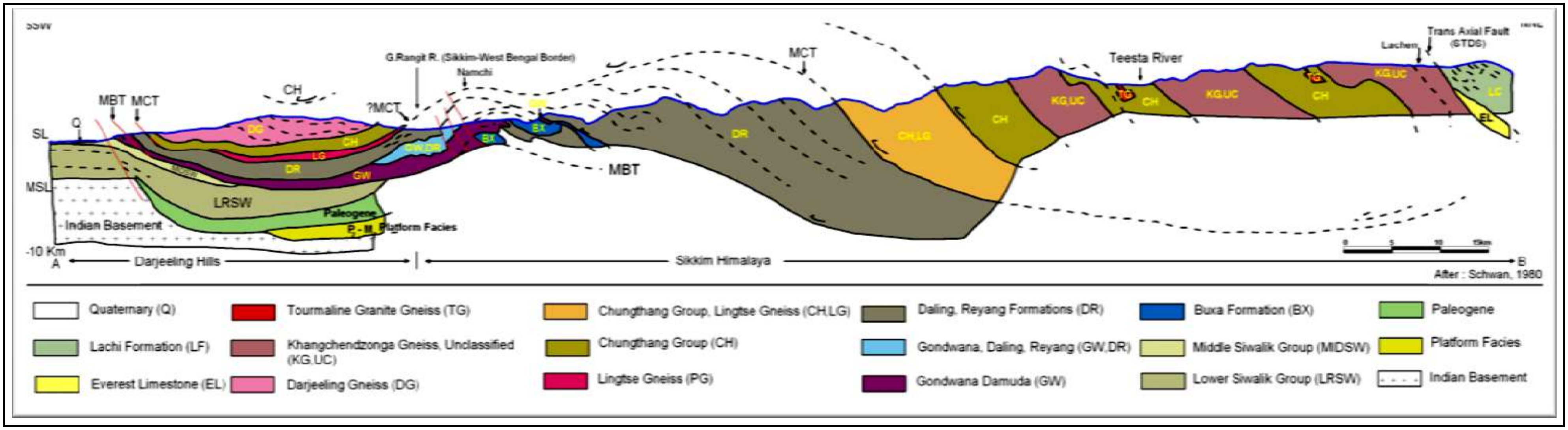


Figure 3.9: Geological section along A – B of Figure 3.8

Table 3.1: Tectono-stratigraphic Succession along South-North Darjeeling-Sikkim Himalayan Section (after Ray, 1989, GSI, 2000)

North ⇧

TETHYAN GROUP

4. Tso Lhamo Formation
3. Lachi Formation
2. Mt. Everest Limestone
1. Mt. Everest Pelitic Formation

__________ *TRANS AXIAL THRUST* __________

SIKKIM GROUP

Darjeeling Gneiss, Khangchendzonga Gneiss and Chungthang (=Paro) Subgroup with Lachen Leucogranite (and its Equivalents)

__________ *SIKKIM (MAIN CENTRAL) THRUST* __________

DALING GROUP

Gorubathan Subgroup
(with Lingtse Granite Sheets at different Structural Levels)
(Syngenetic Fe-Cu-Pb-Zn Mineralisation)

__________ *KALET CHHU-LEGSHIP THRUST* __________

DALING GROUP

Reyang Subgroup
Buxa Subgroup — Gondwana Group
Gorubathan Subgroup

__________ *PAJOK THRUST* __________

A Zone of pile of thin scales of
Daling Group (Gorubathan-Reyang-Buxa Subgroups)
and Gondwana Group (Rangit Pebble Slate -
Damuda Formations)

__________ *NORTH TATAPANI THRUST* __________

GONDWANA GROUP

2. Damuda Formation
1. Rangit Pebble Slate

DALING GROUP

3. Buxa Subgroup
2. Reyang Subgroup
1. Gorubathan Subgroup

__________ *NAYA BAZAR THRUST* __________

A Zone of Pile of thin Scales of
Daling Group (Gorubathan-Reyang-Baxa Subgroups)
and Gondwana Group (Rangit Pebble Slate -
Damuda Formations)

__________ *KITAM-MANPUR KHOLA THRUST* __________

DALING GROUP

2. Reyang Subgroup
1. Gorubathan Subgroup

__________ *SIM JHORA THRUST* __________

DALING GROUP

Gorubathan Subgroup
(With Lingtse Granite Sheets)

__ *NORTH DARJEELING (BARNESBERG-BADAMTAM) THRUST* __

SIKKIM GROUP	Chungthang Subgroup, Darjeeling Gneiss, Khangchendzonga Gneiss (? Middle Cenozoic Pegmatite Aplite Formation and small Granite Bodies)
SOUTH DARJEELING THRUST	
DALING GROUP	Gorubathan Subgroup (Intruded, Metasomatically Replaced and Technically Emplaced Lingtse Granite) (Syngenetic Fe-Cu-Pb-Zn Mineralisation)
DEORALI-RONGCHONGTHRUST	
DALING GROUP	2. Reyang Subgroup (with slices of Gorubathan Subgroup) 1. Gorubathan Subgroup (with slices of Rangit Pebble Slate and Damuda Formation in Basal Portion)
DALING THRUST	
GONDWANA GROUP	2. Damuda Formation 1. Rangit Pebble Slate (Slices of Daling Group)
TINDHARIA THRUST	
GONDWANA GROUP	Damuda Formation
MAIN BOUNDARY THRUST (SOLE OF NAPPE)	
SIWALIK GROUP	2. Geabdat Formation 1. Chunabhatti Formation (Intermixed with Damuda Slices in Rangtong Thrust)
RANGTONG (IMBRICATE) THRUST	
SIWALIK GROUP	3. Murti Boulder Bed 2. Parbu Grit 1. Geabdat Formation
UNCONFORMITY/FAULT	
QUATERNARY GROUP	Alluvium Terrace Boulder Beds

⇩
SOUTH

The project area lies in the lesser Himalaya, a part of Geo-dynamically active Himalayan orogen which provides an excellent correlation with the subduction and collision related mountain building processes with the ongoing crustal deformation as uplift of this chain. The Lesser Himalayan Meta sedimentaries including the Daling and Gondwana Group of rocks (restricted to Sikkim Himalayas in the Rangit Window), where the metamorphism is restricted to garnet grade, which are tectonically succeeded by rocks of higher grade metamorphism starting from staurolite at the base to Silliminite grade at higher structural level showing inverted metamorphism. The boundary between these two contrasting litho assemblages has been marked by the Main Central Thrust (MCT). On the basis of order of superimposition of stratigraphic sequences which has been considerably modified by intense tectonic deformation during different episodes of tectonic history, a generalized stratigraphic succession of the project area is given below:

Group/Formation	Age	Lithology
Godwana Group	Upper carboniferous to Lower Cretaceous	Damuda-sub group comprises of Grey coloured Sandstone, Carbonaceous slates, plant fossils, coal seams and Lamprophyre sills
------------Tectonised--------		
		Rangit pebble/ conglomerate slates carbonaceous matrix, rhythmites, Volcanoclastics and marl also named as Basal diamictite
------------Tectonised---------		
Daling group	Upper Proterozoic	**Buxa Formation**–comprised of Dolostone, limestone, quartzites, phylites and slates **Reyang formation**: Quartzites **Gurubathang formation**: Monotonous thick assemblage of green slate, cholitic feldspathic grey wacke with intrusive epidorites
Central Crystallines	Pre-cambrian	**Lingtse granitic gneiss**: A streaky sheared gneiss separating the Dalings from high grade Darjeeling Gneiss. **Darjeeling Formation**: Medium to high grade metamorphics **Chungthang formation**: Highly deformed metamorphic rocks consisting of calc silicates, quartzites, granulites gneisses and graphitic schist, granites and pegmatites **Kanchenjunga Formation**: augen gneiss, quarzites, amphibolites and migmatitic gneisses intruded by leuco granites & pegmatites

The description of different group/formation with their chronological order is discussed below:

Gondwana Group

The basal diamictite comprises pebbly and gritty slates and lithicwackes, quartzites, pyritous and carbonaceous phyllites, rhythmites, volcanoclastics and marl. The lower & upper contacts of the Rangit pebble slates are usually tectonised. Based on the local nature of the phyroclasts derived from the subjacent and adjacently exposed pre-Gondwana rocks, an uncomfortable relation is usually assumed.

This pebble slate sequence is comfortably overlain by the Damuda subgroup as recorded at a number of places in Rangit Window. The Damuda subgroup is represented by fine to coarse grained, almost gritty sandstones with intercalations of carbonaceous shale, occasional bands of calcarenite and then bands of limestone.

The sandstones are dark gray to greenish blue in colour, hard and well bedded and at places massive and highly jointed. These are composed of sub-angular to rounded grains of quartz, plagioclase, muscovite, biotite and some opaque minerals. Some of the feldspar grains are completely serictised and muscovite & biotite grains show alteration to clay minerals. Gangamopteris and Glossopteris and Vertebraria are the plant fossils recorded from the carbonaceous slates from this unit.

Bands of calcarenite and thin limestone are noted, associated with grit and sandstone in the Rishi Khola section as well as the main Rangit valley north of Rishi village. The cacarenite bands are about 2 m thick, but the limestone bands are rarely more than 15 cm thick.

Daling Group

Three litho-cum tectono stratigraphic units have been recognized within the moderately metamorphosed Pre- Gondwana formations. Dolostone, pyritous slate and cherty quartzite represents the youngest facies (Buxa- formation). The middle facies comprise pink and purple quartzite (Buxa formation) key beds with gray purple slates, phyllites and minor limestone and epidiorites. The quartzites are frequently protoquartzitic, occasionally conglomeratic, rippled and cross bedded (Reyang formation) A monotonous thick assemblage of green slate bedded and intrusive epidiorite and chloritic feldspathic greywacke comprise of basal part of the Daling group. This basal assemblage is named as Gurubathang formation.

Central Crystallines

The Daling group of Rocks in the east-west and north are thrust by the Darjeeling group of rocks comprised of migmatitic gneisses, kyanite-sillimanite schists and gneisses, staurolite garnet schist form the lower member of the Darjeeling formation depicting prominent effects of retrogression, shearing and mylonitisation supporting inverted metamorphism. The contact between the underlying Dalings is tectonised and marked by the Main Central Thrust which is polyphasedly deformed and the thrust slices are known as MCT – I, MCT – II and MCT – III South East of the project area. These lithounits like Chhungthang formation comprised of calc granulite gneisses are equivalent of Paro group of rocks of Bhutan and are exclusively exposed in North Sikkim along with the Kanchenjunga formation in the inner Himalayas zone which displays leucogranitic and pegmatite intrusives, probably of Tertiary affinity. Lingtse granite gneiss (streaky) is recorded in various litho assemblages in Dalings as well as Darjeeling Gneisses. The litho assemblages described in this para belong to the Central Crystallines and are exposed in the project area.

3.3.2 Regional Geology & Tectonic Setup

The project lies in the lesser Himalaya, a part of geodynamically active Himalayan orogen which provides an excellent correlation with the subduction and collision related mountain building processes with the on going crustal deformation as uplift of this chain and current occurrence of earthquakes of different magnitudes. The Himalaya, in transverse profile, from south to north and lower to higher structural levels, have been divided in four physiographic cum tectonic domains namely the Sub– Himalayan/Outer Himalayan Tectonic Belt, Lesser Himalayan Tectonic Belt, the Great Himalayan Belt and the Trans Himalayan Sedimentary Belt with the characteristic Tethyan fauna merging with Tibetan plateau in the north. On the basis of metamorphism, the Himalayan Metamorphic Belt (HMB) encompassing the lesser Himalayas and Great Himalaya has two distinct domains; one constituted of quartzites, psammite - pelite alternations, gneiss and minor amounts of meta volcanics with metamorphism largely remaining within chlorite to biotite grade, and the other the Higher Himalayan Crystallines (HHC) where in the meta metamorphism varies from garnet to sillimanite-k-feldspar grades. The HMB is comprised of southward verging large nappes, which are thrust over the lesser Himalayan Proterozoic sedimentary zone due to continental collision tectonics along large intra-continental Main Central Thrust (MCT) and its various plays. (Figure 3.10).

In the Darjeeling-Sikkim region, the Daling Group forming the lesser Himalayan metamorphics consists of chlorite – Sericite phyllite, quartzite and orthogneiss. The Paro and. Darjeeling groups of HHC comprise medium to higher grade gneiss, amphibolites and quartzite in which the metamorphism increases from stauralite at the base to sillimanite grade at higher levels, showing inverted metamorphism. The repetition of these units in the Darjeeling Sikkim region has been recorded in the form of ‘klippe’ and ‘window’ structure like the Darjeeling “klippe” and “Ranjit window” which exposes the Gondwana group of rocks over the Dalings with gradational as well as tectonic contacts (Figure 3.11).

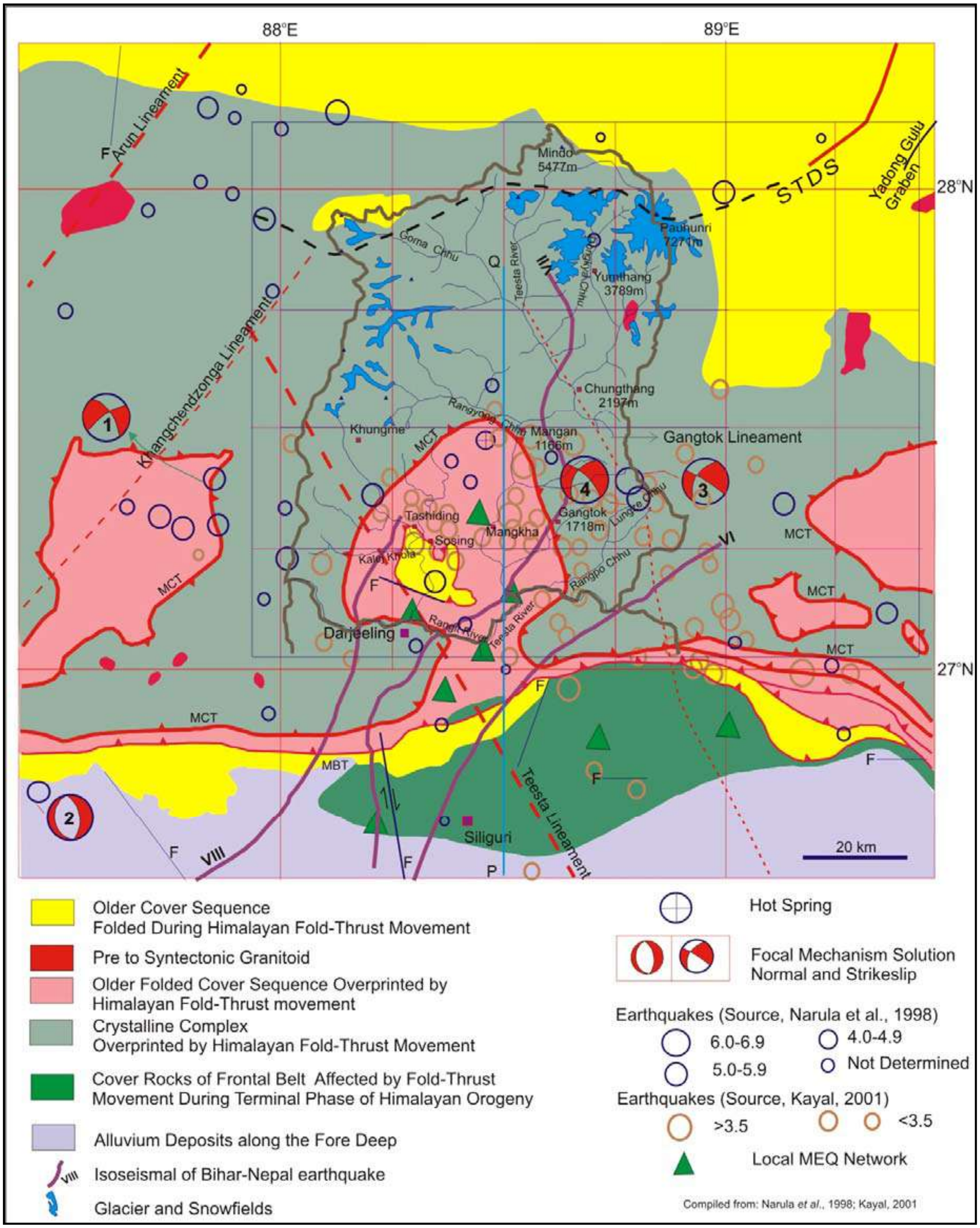
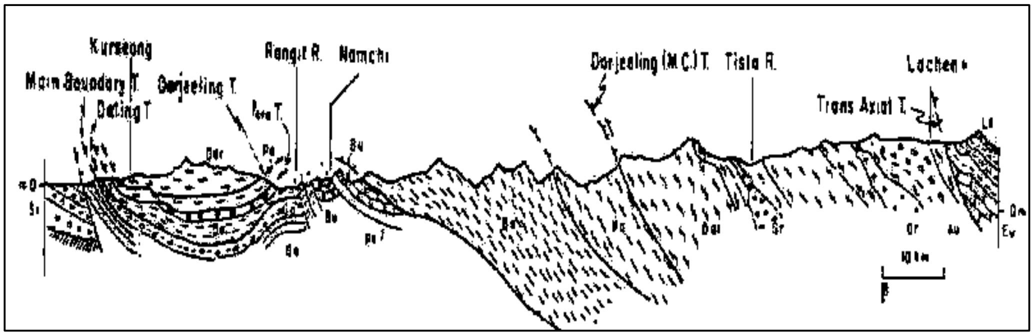


Figure 3.10: Regional geological setup & seismicity pattern in the vicinity of the project



Bu = Bux Gr = Granite Dar = Darjeeling Gneiss Pa = Paro Da = Damuda
La = Lachi Go = Gondwana Si = Siwalik

Figure: 3.11 Tectonic components of Sikkim Himalaya

The Daling phyllites, slates and quartzites, have thrust over the Gondwana Group of rocks along a thrust, the ‘Tendong thrust’, which displays moderate to steep dips, is marked by a zone of shearing and crushing. In the Rishi Khola section of the project area, the low angle dipping phyllites of Daling have come in juxtaposition with steeply dipping Gondwana rocks (Raina 1976). This thrust which has been traced for a length of about 40 km has also been considered by some workers as one of the splays of the main central thrust and named as MCT-III.

The Lesser Himalayan Meta sedimentaries including the Daling and Gondwana Group of rocks (primarily restricted to Sikkim Himalayas in the Rangit Window), where the metamorphism is restricted to garnet grade, are tectonically succeeded by rocks of higher grade metamorphism starting from staurolite at the base to Silliminite grade at higher structural level showing inverted metamorphism. The boundary between these two contrasting litho assemblages has been marked by the Main Central Thrust (MCT), a conspicuous and consistent tectonic surface, considered to have controlled significant crustal convergence between Asia and India during the Cenozoic collision, responsible for the sculpture of the lofty Himalaya. Because of abrupt break in metamorphism more than one tectonic surface has been named as MCT by different workers. In view of this, some workers like (Pecher 1977) thought it prudent to call it a thick zone of Main Central Thrust which includes all the replays of MCT, like the Munshiari thrust and Vaikrita in Western Himalaya and the Darjeeling thrust, Chhungthang thrust and the Tendong thrust in the Sikkim Himalaya, as splays of MCT and named as MCT I, MCT II and MCT III.

From above discussions, it is apparent that the order of superimposition of stratigraphic sequences has been considerably modified by intense tectonic deformation during different episodes of tectonic history.

Important Tectonic Surfaces

Design of the Great Himalaya, Main Central Thrust and other tectonic surfaces in Sikkim.

- The Great Himalaya constituted of metamorphics and forming the basement of the Trans Himalayan Tethyan sediments is a thick homoclinal structure. The Central Crystalline Axis or the Axial Bell, representing the core of this tectogene, is composed of various types of gneisses, migmatites, calc granulites and intrusive bodies of biotite-tourmaline granites. In Sikkim Himalaya, the Tethyan rock sequences of the Trans-Axial Belt are separated by Trans-Axial Thrust. In addition to this thrust, Interformational thrust sheets have also been recognized within this thick metamorphic pile represented in this area as Kanchenjunga Formations, the Chhungthang Formations, the Darjeeling Formation which show repetition because of these thrust sheets.

- The Main Central Thrust (MCT) which has been traced all along the Himalayan Belt, constitutes the southern boundary of the Great Himalaya – a plane of abrupt change in the grade of metamorphism from the higher amphibolite facies to the greenschist facies of the Lesser Himalayan assemblage of Proterozic age. This zone of strong mylonitization is a tectonic surface related to the southward progradation related thrust structure after the collision of the Indian Plate with the Eurasian Plate.

In Sikkim Himalaya, the MCT II forms a re-entrant with eastern side oriented in the NNW-SSE direction while the western trace is oriented in the NNE-SSW direction from the general east-west trend of this structure in Nepal and Bhutan. This trend conforms to the N-S Antiformal structure of the Teesta River. It has also been interpreted that these re-entrant structures may be related to basement strike slip faults.

- This important tectonic surface wraps round the Rangit window which exposes Gondwanas which have been thrust over by Daling Group of Rocks. This thrust is locally known as Tedong thrust (MCT III). N-S trending faults with limited outcrop lengths have been recorded from the project area. Strike faults like the Great Rangit fault and Ramam Fault with E-W trends are also common.

In addition to a number of transverse faults several lineaments, cutting across the Himalayan belt have been recorded from the vicinity of the Sikkim Himalaya. These lineaments exhibit northeasterly as well as northwesterly trends. Most conspicuous of which are the northeasterly trending Kanchenjunga lineament and the northwesterly trending Teesta and Gangtok lineaments, which in certain limited stretches are representing faults. It has also been postulated that the actual disposition of MCT might have been influenced by the deep seated NW-SE as well as NE-SW faults.

3.3.3 Geological Setup of Project Area

The project is located northwest of the Rangit Window. La Touche (1900) was probably the first to report the presence of sedimentary rocks in Rangit valley in otherwisepredominantly known as metamorphic domain. Ghosh (ibid) was first to postulate a window structure, which crops out in the re-entrant of Rangit River. Major tectonic surfaces in the Sikkim Himalaya wrap round this re-entrant. The sedimentaries in the Rangit window belong to Precambrian Daling and Buxa with overlying PermianGondwanas which have been terminated by the Tendong Thrust (MCT-III) which has brought the Daling rocks in juxtaposition with Gondwanas. The Daling meta-sedimentaries displaying low grade metamorphism are exposed in a wide zone along the Rangit valley but in the Rathong Chhu Valley these rocks have been terminated by the Main Central Thrust (MCT-II) which has brought higher grade metamorphic rocks of Darjeeling Group in juxta position with the Daling rocks. The trace of this tectonic surface passes very near to Peling, cuts across the Rathong Chu downstream of the proposed power house of the Ting Ting project and rises on the left bank slopes to cross the Tashiding - Yuksom road.

The Darjeeling Group of rocks are higher grade gneisses belonging to the Central Crystalline Gneissic Complex (CCGC) having intra-bands of meta-sedimentaries represented by cafe silicate / quartzite, high grade schists which in some areas are mapped as Chungthang Formation and at other places it then occur as enclaves in the high grade gneisses. The gneisses vary in composition from gneiss in which feldspar is predominant with respect to quartz, to quartz biotite gneiss in which feldspar is almost absent. The former type is well foliated with streaks of biotite and the latter is compact and poorly foliated. In the project area, calc silicate / quartzite are exposed in the Rimbi River section which is located in the downstream of the powerhouse site of the project. The structural fabric elements in these rocks are predominated by high-grade litho facies which have undergone polyphase deformation and metamorphism. The primary structures include compositional banding which could be attributed to metamorphic differentiation. Bedded characters are observed only in the silicate quartzite bands. The high-grade litho facies have undergone polyphase deformation and metamorphism. The primary structures include compositional banding which could be attributed to metamorphic differentiation. Bedded characters are observed only in the calc silicate quartzite bands. The high-grade schists also show compositional banding of alternate quartz rich and calc silicate rich bands. The secondary structures include gneissic foliations, schistosity and fracture cleavage. The gneissic foliation forms the most prominent fabric element of high-grade metamorphic tectonics. The gneissic foliation in the area generally a trend NE - SW with moderate dips in the NW direction.

In the project area, granitic gneisses are exposed at the dam site, which continue up to the turn point in the Headrace Tunnel. The gneissic rock is underlain by a major Quartzite band, gneisses and quartz gneiss which extend to nala. From the confluence of this nala with Rathong Chu well-foliated quartzite, brittle gneisses and schist are exposed right upto the powerhouse site. The detailed description of these litho units along with the recent cover sediments is given in subsequent paragraphs where geotechnical assessment of the appurtenances has been made. .

a) Geology of Dam Site

A 55 m high concrete gravity dam has been proposed on the Rathong Chhu at latitude 27^0 13’ N longitude 88^0 12’ 30” E. It is named after a small village called Tingting on the left bank of the Rathong Chhu.

The intake structure for this project has been located downstream of the proposed Lethang HE Project of Kalpan Hydro Company and the power house of which is located on the left bank of the Rathong Chhu on a terrace below Dasthang village. The tail water level for this proposed powerhouse is at El.1167m level. This terrace is located over the east west bend in the N-S flowing river. The river takes a right angle bend at a distance of about 150 m downstream of this proposed powerhouse site. From this location, the river once again flows in N-S direction for a length of about 700m. The Intake structure has been so planned so as to keep the FRL of the proposed Tingting project well below the Tail water level of upstream Lethang HE Project. To have reasonable storage for peaking purposes, the diversion structure has been located on the d/s N - S arm of the river.

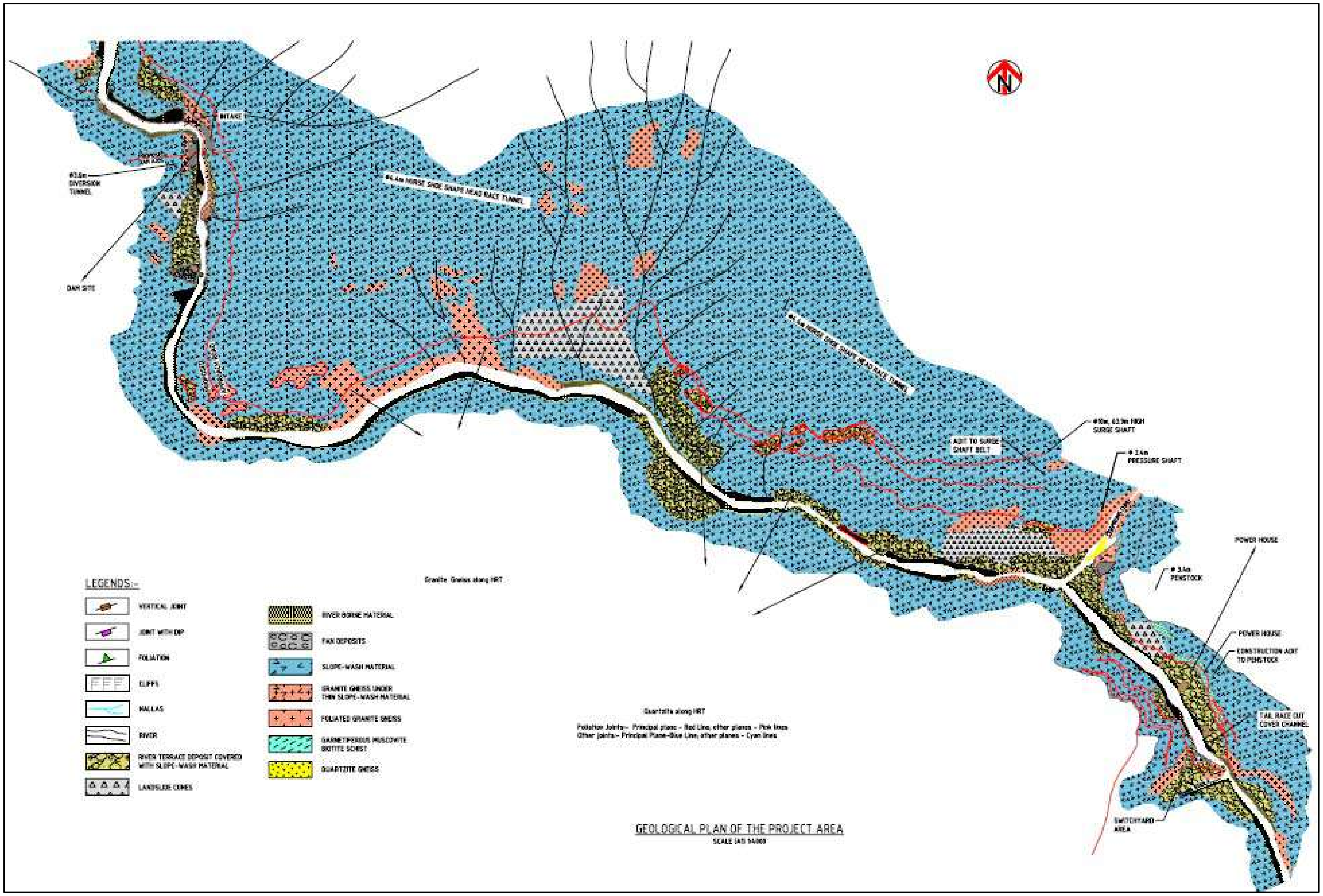


Figure 3.12: Geological Map of Project Area

In general granitic gneisses are exposed with thin to moderate slope wash cover on both the abutments near the dam site up to levels much above the proposed top of the structure (+1170 m level). At this site, the valley opens out towards downstream direction and the banks of the river are occupied by terrace material as well as coluvium covered slopes. The strike of foliation of the rocks varies from N50°E - S50° W to almost E-W with moderate to low angle (250-400) dips in the north-west to northerly direction (upstream). The rocks are transected by following sets of joints:

i) Strike N - S to N10° W - S10°E with 60° to 70° in the easterly direction
ii) Strike N80° W - S80°E to E - W with 70° to 85° in the northerly as well as southerly direction
iii) Strike N15°E - S15°W to N40°E - S40° W with 45° to 75° dip in the northwesterly direction

The detailed geological mapping of the dam site covering all the appurtenances has been carried out earlier on 1:1000 scales and it has been reproduced in geological plan of dam site.

b) Geology of River Section

Geological traverses taken in this section of the river has designated that the rocky outcrops of Granitic gneisses near the river level are available only for a length of ±90 m on the right bank and ±75m on the left abutment. These rock out crops extend on both the abutments to levels much above 1165m mandatory level for FRL of the proposed diversion structure. Locating the diversion structure in this section of the river is an economically viable proposition. Further downstream, the valley opens out and the banks of the river are occupied by terrace material as well as debris covered slopes. The rocky outcrops are seen only where the river again takes an east-west turn near the suspension bridge. In this section of the river a diversion structure is not an economically feasible proposition due to steep gradient of the river, the river level at this bridge site falls to ±1060m compared to a level at the end of upstream east west bend where the river level is ± 1130m. If the complete head from the Tail Race of the U/s Rathong Chu project is to be harnessed it is obligatory that the diversion structure is located in the rocky outcrop zone after the bend downstream of the Rathong Chu H.E. Project. The Dam Axis is very near the bend. The very steep gradient along the river restricts the storage capacity for peaking purposes.

c) Geology of Right Abutment

The right abutment rises continuously up to El. 1170m at an angle of about 550 to 600 and then flattens to 250 due to turn in contours. A rocky outcrop has been observed at the proposed diversion site above El. 1135m with moderate cover of slope wash and vegetation and below El.1135m the abutment is occupied by river borne deposits and slope wash. Further downstream, the valley opens out and the banks of the river are occupied by terrace material as well as colluviums cover. The strike of the formations is almost in E-W direction which is nearly normal to the river flow.

d) Geology of Left Abutment

The left abutment rises continuously at an angle of 700 to 750 at the curve portion and afterward in downstream at an angle of about 500. Sound rock is seen exposed which is mostly strong to very strong, fresh to slightly weathered, fine to medium grained, moderately jointed granitic gneiss with moderate cover of slope wash material.

e) Optimization of the Dam Location & Geotechnical Assessment

The river at the proposed diversion site flows in N-S direction about 75 meter through a narrower portion after it takes a right angle curve in upstream, afterwards the valley opens out and the banks of the river are occupied by terrace material as well as debris covered slopes. Initially the site was examined for locating the dam and intake near the curve portion were vertical cliff / sound rock are exposed on the banks but it was observed that the foliation gets exposed and distressed in this upstream arm of the river as strike of the foliation is almost parallel to the slope and dipping towards river side. Destressing of the rock mass has been noticed in the form of wide open joints which are dipping towards the river. This opening is more on the right abutment because of the undercutting along the foliation in the u/s direction where the river flows at an acute angle with the strike of foliation. In this case, it was felt necessary to increase the rock ledge existing between the dam axis and acute curve of river in upstream, which is potential and susceptible for planner as well as wedge failures, particularly during rapid draw down between FRL and MDD period. It was also observed that the location of earlier proposed Intake on the left bank was facing directly in to the river flow which also materializes the problem of siltation in the water conductor system. Due to above mentioned reasons; the dam axis is located about 45m downstream from the existing upstream right angle river curve in view of increased rock ledge between the dam axis and river bend on the right bank and relocate the intake in improve way. With this option it is possible to increase in length of dam in the downstream side because the valley opens out in the downstream direction. The site examination indicates thin cover of colluviums on both site of valley and as such no deep cut in the slope wash material is anticipated.

f) Geology of Intake

The proposed intake is located on left bank on a straight reach of the river to avoid any siltation problem in water conductor system. At the proposed location bedrock is exposed on a moderate slope up to an elevation of EL.1165 m with thin to moderate cover of colluviums. The foliation strike of the bedrock is N80^{O}E – S80OW with 25^{O} dip in the northwesterly direction. Two prominent sets of joints, one striking in N30^{O}E-S30^{O}W and the other striking E-W with 55^{O} dip in southeasterly direction and 60O due south have been recorded. These features have been projected in the geological section along the Intake structure. The Intake is located at 1133.8 m level. Proper cuts with slope protection measures by means of rock anchors and shotcrete will have to be provided.

g) Geology of Diversion Tunnel

About 140 m long and 5m finished dia (D- Shaped section) has been proposed through the right abutment loop with invert level at EL 1137 m at Intake and 1120 m at the outlet portal giving a steep gradient of 1:8.

Most part of the tunnel will be driven through granitic gneisses, which dip at moderate angles in the upstream direction. At the Inlet Portal location, the foliation dips are towards the river and any cuts at angles steeper than foliation dips would need necessary protection in the form of rock anchors and shotcrete.

The conservative “Q” rating for the rock mass is expected to be between about 04 to 12 which categorizes the rock mass as fair to good for tunneling (after Boston 1998). With such value, systematic rock boltingwith thin layer of shotcrete (if required) should be adequate for the support system.

Initial 10m of the section on the inlet as well as outlet portals may require steel arches at 0.5 m center to center spacing because of low rock cover. On the outlet portal side overburden material comprised of debris and river borne material, which would need cut

& cover or open excavation with proper side slope cuts and stability measures for locating the portal.

h) Geology along Head Race Tunnel Alignment

The water from the diversion dam is proposed to be conducted through about 2.2 km long Head Race Tunnel from the Intake structure located about few meter upstream of the dam axis to a Surge Shaft on the right abutment slopes of Phamrung Chu near the confluence of this deeply incised nala with Rathong Chhu in the vicinity of Tongong village. A straight alignment of the HRT was not possible because of inadequate cover in the middle reach of the tunnel and thus a swing in the alignment became obligatory.

Geological mapping of the area, covering the tunnel alignment has been carried out on 1:5000 scale covering the whole slope on the left bank of Rathong Chhu. Since most of the tunnel alignment and vicinity is covered with overburden and rock outcrops are scanty, the available exposure along the river bank has been made use of in projecting the tunneling media. The tunnel is aligned normal to slightly skew to the general trend of the rock foliation, which is a favorable condition for tunnelling. It is seen from the geological map of the area that in the initial reaches of the tunnel granitic gneisses would be encountered up to the tunnel length of about 1150m afterward a thick band of quartzites is expected .The contact between the overlying granitic gneisses and the quartzites is expected to be sheared and faulted because of change in the dip and strikeof the rocks in the quartzites and presence of a number of landslides in the vicinity of the projection of this contact. The quartzite member is again underlain by gneisses, quartzite, quartzitic gneisses bands. Rocks of this area are closely to moderately jointed (3 plus random sets) and the joint planes are likely to get tight with depth, during the excavation which may cause wedge failure. The rock mass has an estimated joint volume number (Jv) of ± 26 giving rise to irregular and small blocks.

The foliation in granitic gneisses varies from N50 ^{0}E - S50 ^{0}W to N70 ^{0}E - S70^{0}W with 25^{O} to 35^{O} dip in the northerly direction. Because of the intense folding/faulting, considerable variation in the attitude and persistence of the joint sets is noticed at the project site.

Following sets of joints have been recorded in addition to the foliation joint:
- Strike N30^{O} W-S30 ^{O}E with 35^{O} to 55^{O} dip is north easterly direction.
- Strike N-S with 85^{O} dip in the easterly direction.
- Strike E-W with 50^{O} to 85^{O} dip in the northerly direction.

- Strike N40^{O}E-S40^{O}W to N50^{O}E – S50^{O}W with 70^{O} to 85^{O} dip in the south easterly direction.

On the basis of persistence and roughness of joints, their spacing etc., it is estimated that in general the "Q" value of the rock mass along the tunnelling direction is expected to be in between 4 and 12 indicating that the rock mass is fair to good tunneling media. This category of rock mass would be encountered up to RD 1150m. The same lithology is expected for another 20-40m but the rock mass in this reach is expected to be shattered and sheared because of its proximity to faulted contact between the granitic gneisses and underlying quartzites. The total width of sheared rock mass is expected for a length of about 120m in quartzite. In the reaches of shear/shattered zones, "Q" values of less/equal than 1 may also be expected. This feature may involve tunnelling problems which would become further aggravated where the rock mass is charged with water. High seepage / inflow of water can be expected in some reaches. In such conditions probe holes would need to be drilled in advance of excavated face to study the geological condition. In this zone, the quartzites strike in the N10^{O} E–S10^{O} W with 7^{O} - 75^{O} dip in the westerly direction which is in variance from the general dip of the rocks in the area, which are expected up to RD 2070 m. On the basis of limited data obtained from the rocky outcrops the "Q" value between 1 to 4 is expected in this rock and classified as poor to fair tunneling condition. The quartzite member is again underlain by gneisses, quartzite, quartzitic gneisses bands and from RD 2070m to the Surge Shaft at RD 2222 m granitic gneisses are expected again which are fair to good tunneling media.

i) Geology of Surge Shaft

The Surge Shaft is located in granitic gneisses exposed on the right bank of Phamrung Chu nala under very thin cover of debris material in isolated locations. This surge shaft location was finalized in the initial stages of project investigations.

The site was also examined for locating the surge shaft on the left bank of Phamrung Chhu, with this option head race tunnel has to cross the deeply incised Phamrung Chu nala and to cross this nala, tunnel alignment would have to be shifted upstream for obtaining adequate cover at the crossing, in which case the length of the HRT would increase considerably. And also after crossing the phamrung chu, the slopes at the Surge Shaft level are occupied by debris material and suitable location for Surge Shaft is not available in this part. Considering these facts, the Surge Shaft location has been fixed on the right bank slope of Phamrung Chhu which will have to be negotiated by the penstock/ pressure shaft.

j) Geology along Penstock Alignment & Powerhouse Site

i) Location of Pressure shaft / Penstock and Power house option

Initially the site was examined for locating an underground Powerhouse on the right bank of Phamrung Chhu below the Surge Shaft so that the length of Pressure Shaft would be reduced and the Tail Water could be conducted through a Tail Race Tunnel crossing Phamrung Chhu at the desired location (level of ± 906m). Near the confluence of Phamrung Chhu and Rathong Chhu, the river level is 935m. The left bank slopes of Rathong Chhu are occupied by river borne material covered by thick accumulation of debris material which rises up to ± 1050m level and as such any approach from the main Rathong Chhu side through over burden material would be hazardous, particularly in view of damages which could be caused by flash floods - as borne out by one such flood in 1980 which wiped out whole of the village. Only possibility of approaching the underground cavity would be from hard rock exposures available at level ± 940m. With the deepest foundation grade being minus 900m, the approach would be long and circuitous to reach the foundation grades / Service Bay level/ and top of power house.

Because of complicated approaches for an underground structure and very high cost, the option for underground power house has not been considered preferential. Due to limitation of topography and geological conditions discussed above, an alternative site has been identified for the surface power house on the terrace on the left bank of the Rathong Chhu, located about 250m u/s of the existing steel bridge. At this location, a wide terrace is available which varies from 925m to 930m level while the river level is at ± 920 m. As similar terrace is not available in the downstream direction, it would be obligatory to locate a medium deep set power house at this location with about 100m long Tail Race channel to join the river at 912m level. Under this scheme, the penstocks would be about 800m long, would involve crossing of Phamrung Chu nala with underground pressure shaft/penstocks and rest length of the penstocks would be surface seated located on the right bank of Phamrung Chhu below the Surge Shaft on the slope. The option for surface penstocks only was also examined; in this case considerable length of the penstocks would be aligned on parallel to hill slope and river borne material covered by thick accumulation of slide debris material which involves huge significant slope treatment and has not been considered preferential. Finally the option for surface power house with partly surface and partly underground penstocks has been preferred on the techno- economic considerations and thus has been adopted for detailed geo-technical assessment.

ii) Geology along Penstock Alignment

It is proposed to conduct the water from Surge Shaft to the Power house by a 800m long and 3.4m dia Penstock, aligned partly along the right bank slopes of Phamrung Chhu (150m length) and the remaining length (due to anticipated difficulties in crossing the penstock across the deep incised Phamrung Chhu) of the penstocks has been proposed crossing the nalla underground through pressure shaft. The right bank of the Phamrung Chhu is mostly occupied by granitic gneisses under very thin cover of debris material. All the anchor blocks for the surface penstocks would be founded on the bedrock comprising of granite gneisses.

iii) Geology of Surface Power House Site

The proposed Ting-Ting surface power house is approachable from the Pelling – Yuksom SPWD road, which is located at higher elevation around 1300m. At the location of proposed power house site on the left bank of the Rathong Chu River about 250 m u/s from the existing steel bridge, the area is occupied by terrace material which is about 40- 70m wide. The layout of the surface Power House has been optimized keeping in view without infringing too much on the rock portion and avoid under cutting of overburden material above the rocky outcrop. As the overburden extends to great heights, any cutting below the same might make the slopes above unstable. At the proposed Powerhouse site the width of the terrace is about 70m. The wider terrace location has been chosen so that the powerhouse and its appurtenances including seepage control and flood protection measures are possible.

3.3.4 Seismo-tectonics of Project Area

Sikkim Himalaya is a part of Alpide-Himalaya seismic belt known for high seismicity mostly concentrated between the MBF on the south of MCT in the north. The vicinity of this belt has experienced great magnitude earthquakes, the one to the east is the epicentre of Great Indian Earthquake of magnitude 8.7 and to the southwest was the Bihar-Nepal Earthquake of magnitude 8.3 located within a distance of about 200 km from the southern boundary of Sikkim, where intensity VIII has been experienced. In the seismic zoning Map of India, this area falls in Zone IV which also reflects that Peak Ground Acceleration equivalent to intensity VIII has to be provided for seismotectonic evaluation of area leading to identification of possible earthquake sources. The distances of these sources and the expected motions at the appurtenances of the project would be evaluated and provided for aseismic design of structures.

Sikkim Himalaya and its vicinity has been witness to a number of seismic events of magnitude varying between magnitude 4.5 and 5.5 (Table 3.2) most of which are shallow focus events but a few events intermediate focal depths have also been recorded, the most conspicuous of which was the 1980 event of magnitude MS 3.3 with focal depth of 47 km.

Table 3.2: Chronological listing of Earth Quake of magnitude ≥ 4.5m between Lat: 26.5 to 28.5 N and long: 87.5 to 89.5 E

Year	Month	Dt	Hr	Min	Sec	Lat	Long	Ms	Mb	Depth (km)	Source
1935	5	21	4	22	31	28.8	89.3	6.3	5.9	140	GR
1960	8	21	3	29	4.9	27	88.5	5.5	5.5	29	CGS
1964	2	1	11	28	19.4	27.3	87.8	-	5.1	33	ISC
1964	3	27	23	3	41.1	27.1	89.4	-	5	29	ISC
1964	8	30	2	35	7.3	27.4	88.2	-	5.1	21	ISC
1965	1	12	13	32	24.1	27.4	87.8	-	5.8	23	ISC
1965	1	12	13	55	18.1	27.3	87.7	-	5.2	18	ISC
1966	12	28	3	59	7	28	89	-	5.2	-	ISC
1971	12	4	8	38	0.2	27.9	88	-	5.2	29	ISC
1972	8	21	14	4	33.9	27.3	88	-	4.5	33	ISC
1972	8	21	18	55	7.2	27.2	88	-	5.1	33	ISC
1975	1	23	1	37	42.9	27.4	88.4	-	4.5	33	ISC
1975	2	6	6	39	44.6	28	87.7	-	4.7	63	ISC
1975	6	24	15	38	27.8	27.7	87.5	-	4.8	33	ISC
1975	11	26	15	2	31.1	28.2	87.8	-	5	33	ISC
1979	6	19	16	29	8.4	26.7	87.5	4.6	5.2	20	ISC
1979	11	16	17	17	27.7	27.9	88.7	-	4.6	39	ISC
1980	11	19	0	0	45	27.4	88.8	6.1	6	47	ISC
1982	4	5	19	19	41.2	27.4	88.8	4.6	5	9	ISC
1985	5	25	28	28	18.7	27.6	88.5	-	4.6	33	ISC
1986	1	7	20	20	0.4	27.4	88.4	-	4.7	41	ISC
1986	2	10	56	56	23	28.2	87.9	-	4.7	67	ISC
1988	5	26	30	30	5.5	27.5	88.6	-	4.7	42	ISC
1988	9	27	10	10	10	27.2	88.4	4.6	5	23	ISC
1988	12	27	56	56	1.8	28	87.9	-	4.6	38	ISC
1991	12	21	52	52	45.1	27.8	88	-	4.7	65	ISC

It has been opined by Narula (1991-92) that the Main Himalayan seismic Belt with predominantly thrust type of Mechanism could be divided into discrete tectonic blocks delimited by transverse fundamental fractures which would decide the earthquake generating capabilities. The transverse tectonic surfaces which are generally the strike slip faults have also acted as sources for discrete seismic events which has been demonstrated by the focal mechanism of some of the events for which focal mechanism studies have been done are tabulated in Table 3.3.

Table 3.3: Focal Mechanism Solutions

Plot. no	Yr	Mo	Dt	NP 1		NP 2		P-Axis		T-Axis		B-Axis		Source
				St	Dip	St	Dip	P1	Az	P1	Az	P1	Az	
1	1965	1	12	233	76	326	72	23	192	3	281	66	14	Dasgupta *et al* (1987)
2	1979	6	19	350	57	179	34	78	243	11	84	4	353	Dziewonski *et al* (1988)
3	1980	11	19	209	51	301	89	28	172	25	68	51	302	-Do-
4	1982	4	5	206	48	314	72	43	178	14	74	42	330	Nandy & Dasgupta

Earthquake Intensities recorded in Sikkim Himalaya by earthquakes of Great Magnitude and type of Moderate Magnitudes

On the basis of damage patterns in the southern Sikkim, the Isoseismal map prepared by Geological Survey of India (Fig 3.13) (Memoir Vol. 73, 1939) it is seen that Isoseismal VIII passes very close to the confluence of Teesta and Great Rangit and closes towards Jorethang. It is reported that Dak bungalows at Namchi and Dentam further west collapsed to the plinth along with out houses. Both these localities are included in the Isoseist-VIII

The description of damages at a few places like Rhenok, Snigtam, Rangpo, Gangtok and Samdong in Teesta valley are indicative of intensity VII. Mostly the stone wall houses show cracks in all walls and partial collapse of such buildings. Thus, during the 1934 earthquake except for the southern part north of Darjeeling Hills the Sikkim state experienced damages of intensity VII. During the 1988 earthquake of magnitude 6.4 located in near vicinity of 1934 event, the intensity reached in the area of interest was near VII (Fig 3.14).

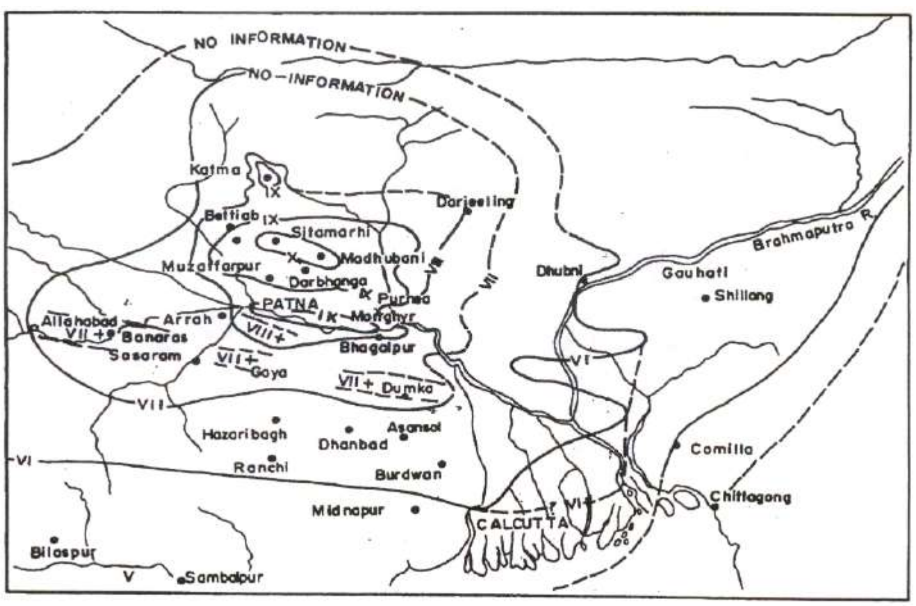


Figure 3.13: Iso-seismal map of Bihar-Nepal earthquake 1934

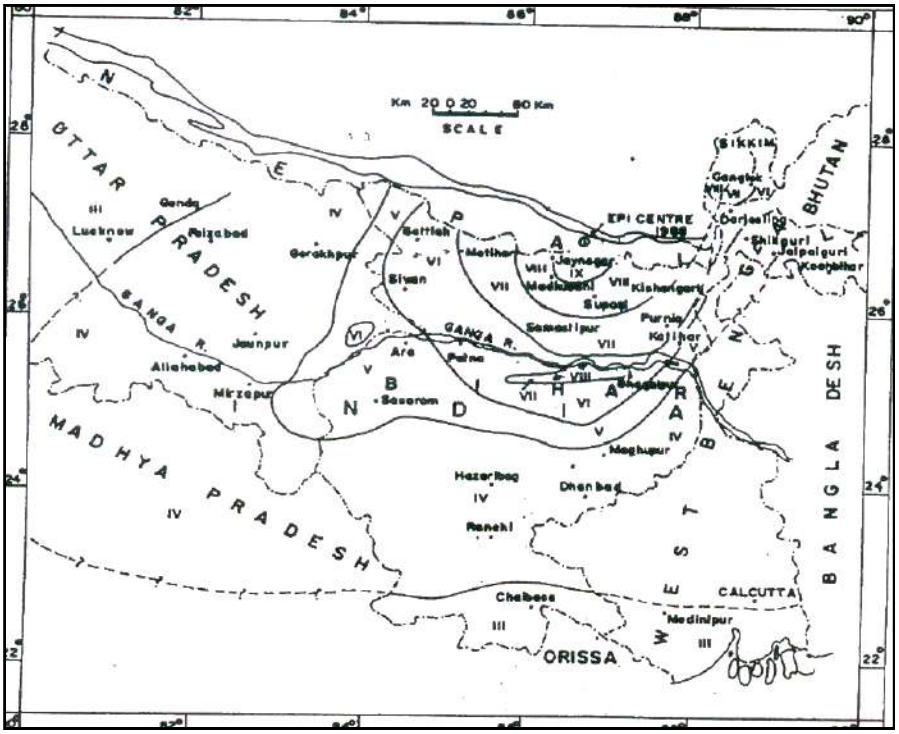


Figure 3.14: Iso-seismal map of Bihar-Nepal earthquake 1988

According to empirical relationships between intensity and peak ground acceleration the intensity VII corresponds to PGA of 75-140 cm/sec^2 while the intensity VIII corresponds to PGA of 140/sec^2 to 260cm/sec^2. Thus the maximum acceleration experienced in the project area was of the order of 140 cm/sec^2 (Table 3.4).

Table 3.4: Average Peak Ground Acceleration (Horizontal component)
(as a function of Earth Quake intensity (MM Scale) from different empirical relations)

Intensity MM scale	Acceleration as a function of *g*					
	Empirical Relations					
	1	2	3	4	5	6
V	0.015	0.032	0.031	0.021	0.022	0.032
VI	0.032	0.064	0.061	0.046	0.053	0.056
VII	0.068	0.13	0.12	0.1	0.13	0. 10
VIII	0.146	0.26	0.24	0.23	0.3	0.18
IX	0.314	0.54	0.48	0.52	0.72	0.32

Empirical relations

- Gutenberg and Richter, 1956
- New mann, 1954
- Trifunac and Brady 1977
- New mann, 1977 (Revised by Murphy and O' Brien 1977)
- Murphy and O' Brien 1977

i) Micro-Seismicity Surveys

Micro-seismicity surveys have been conducted in the vicinity of the area in different episodes. During 1992-95 the local area network was run by the Geological Survey of India which had shown the cluster of micro events north of MBT and the events originated from a depth range of 10-40 km, indicating that a few events fall below the detachment surface.

Subsequently a network was run in the eastern part (De, 2000) is seen that during the later episode the micro earthquake events were concentrated in the vicinity of N-S swing of the MCT from its general E-W trend. It has been postulated that this swing may be related to N-S trending basement fracture, the trace of which is exposed further south, which has displaced the MBT. The composite fault plane solution of these events show strike slip style of deformation, one nodal plane of which strikes in the NNE-SSW direction.

ii) Neotectonic Activity

The evidence of imperceptibly slow and secular as well as episodic crustal movements have been recorded in the Himalayan Fold Belt as well as the formtal Deidmont and alluvial tract during the Quaternary Period. These are manifest in the form of movement of rock masses along faults, subsidence and rise of the ground as well as certain peculiar geomorphic changes and episodic and rise of the ground as well as certain peculiar geomorphic changes and episodic release of strain manifest as seismicity. The most important tectonic surface, which displays direct evidences of over riding of older rocks on Quaternary sediments along the whole of Himalayan Front, is the MBT (MBF). Contemporary or younger movements along transverse features trending in the NNW-SSE as well as NNE-SSW directions displacing the MBT have also been recorded. The area of such profuse eotectonic activity is located in the Sub-Himalaya fold thrust Belt south of the project area. The alluvial tract south of this belt is also marked with conspicuous tectonic lineaments along which neotectonic activity has been recorded. These lineaments many of which are basement fractures have sculptured the basement configuration. South of Sikkim and Darjeeling Himalaya is located the Rangpur Ridge (Burried) which is delimited by Malda-Kishanganj Fault on the west and Teesta Fault on the east. Several subsidiary faults parallel to NNW-SSE trending Teesta Fault, forming grabens, in which Gondwana sedimentation took place, are reported.

The Teesta Fault is known for neotectonic activity, in fact because of downward movement along this fault towards east caused the change of the Teesta River being a tributary of Ganga before 1787 and because tributary of Brahamputra river. Teesta River after entering the plains follow this tectonic lineament from its general N-S course in the Hilly terrain of Sikkim where it flows along N-S trending antiform.

Based on study of Teesta River morphology it has been observed (SS Roy 1980) that there are thick points above the river course which have been correlated with the tectonic surfaces enter the one near the Singtam which has been related to the NE-SW trending fault along Rongni Chhu.

From the above observations it is evident that adjustments have taken place along discrete tectonic surfaces during the Quaternary period which may be secular in nature or episodic into the seismic activity.

iii) Seismotectonic Model

In order to explain the seismocity patterns, the deformation styles of the events recorded, correlation of seismic events with the tectonic surfaces along which episodic stress release has taken place, it has been postulated that the seismic activity in the Himalaya and its vicinity is related to under thrusting of Indian sub continent along a detachment (decollemont) surface dipping at low angles towards north. (Seeber & Armbunster 1981) (Fig 3.15). The northern portion of which dips at steeper angle near the interacting slabs. The steeper portion of this detachment surface near the interacting slabs has been locale for moderate earthquakes (6.5 to 7 magnitudes) occurring in the northern part of lesser Himalaya albeit at differing tectonic levels in different sectors of the Himalaya. When the accumulated strain reaches a certain level, the southern part of the detachment is activated generating large magnitude earthquakes. The seismicity patterns of the Sikkim Himalaya indicates that the moderate magnitude earthquakes are concentrated in a linear E-W Belt north of the MCT, irrespective of the wedge in the MCT in Sikkim Himalaya, which might have been created by transverse NNW-SSE and NNE-SSW tectonic surfaces based on the energy release contour patterns. (Pande & Das Gupta 2005) have inferred and EW basement discontinuity (around Lat. $27^0$15’ N having an extension of about 210 km. This surface with northerly dip could be the source of this moderate activity related to the Basement thrust Front. It has been postulated by various workers that the 1984 earthquake was in the outer portion of the detachment surface which caused the 8.3 magnitude Bihar-Nepal Earthquake. Though the epicentre of this event is located 200 km southwest of the project area, a portion of the detachment surface in front of Sikkim Himalaya could also have been involved in the activity.

In addition to these two types events, the focal mechanism studies carried out for discrete seismic events like the 1988 Bihar-Nepal Event and two Gangtok events of 1965 and 1980 have shown that tectonic surfaces trending in the NNE-SSW and NNW-SSE have also been source of discrete earthquakes. These tectonic surfaces extend from the southern alluvial tract and cut across the Himalaya tectonic grain. These events might be related to strain partitioning along some basement fractures in response to the northward under thrusting of the upper crust below the sedimentary wedge.

Based on the seismotectonic model discussed above, following possible earthquake sources, along with their maximum magnitude, generating capabilities, have been considered for evaluating the earthquake hazard for the Ting Ting Hydro-electric Project in Sikkim Himalaya. For this purpose ICOLD Guidelines (1989) have been considered.

iv) Detachment related thrust type source:

According to the Seismotectonic model of the Himalayan, the great earthquakes of magnitude +-98 are related to the under thrusting of Indian Crust (Upper) below the sedimentary wedge along a low northerly dipping angle decolement surface, located south of the Basement Thrust Front (Seber and Armbruster, 1981). The Basement Thrust Front where the curst disposal steeper angles, is located at different structural locations in different parts of the Himalaya. As discussed earlier, this source of large magnitude earthquakes in Sikkim Himalaya, is located south of Rangit Fault, almost along the Great Rangit River. This area is parallel to Rangit River tectonic Flux Fault, postulated by Pande and Guptasharma (2005).

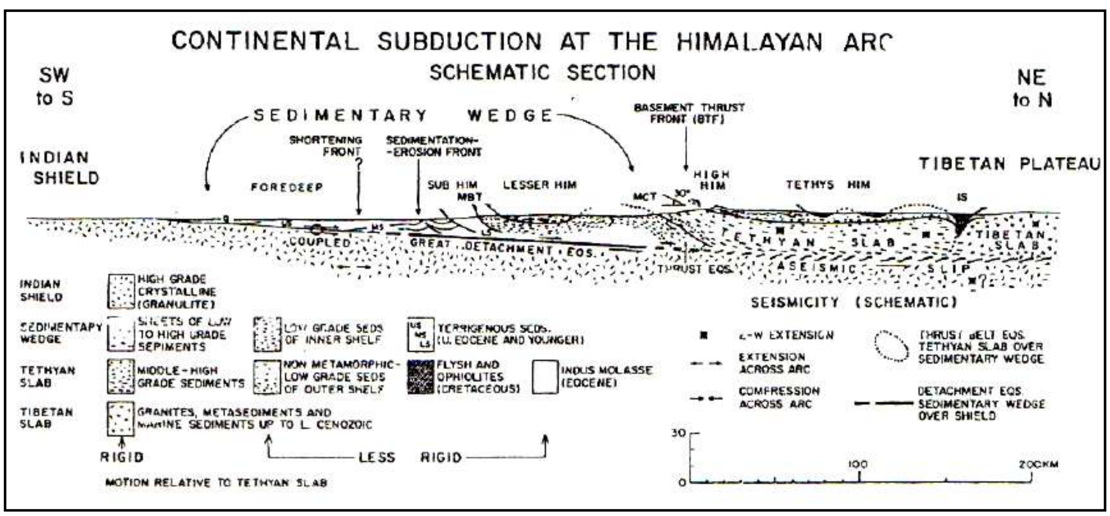


Fig 3.15: Continental subduction at the Himalayan Arc : Schematic

v) Seismotectonic Units/Surfaces Considered For Earthquake Hazard for the Project Site

It is inferred that the source of great magnitude earthquake would be located further south of the project area. As a most conservative consideration the focus of this event could be at a distance of 35 Km, even if it is considered that the source of great magnitude earthquake is at the same location as the Basement Thrust Front.

There is a concentration of moderate magnitude in a 30 km wide E_W domain located north of the Rangit River. Majority of the events of magnitude >4.5 magnitude listed in Table 3.5 are allocated within this domain. The maximum magnitude recorded is 6.3 and a few events are recorded from the project area itself. The Maximum magnitude assigned to this source is 7.0, the epicentral distance of zero and Hypocentral distance of 20 km.

The MCT in the project area has two arms are disposed in the NNE-SSW direction and the other disposed NNW-SSE. The former with steep dips in the westerly direction is located very near (about 1.5 km d/s of the powerhouse site) to the project area. It has been interpreted that the arms of the entrant of MCT is because of existence of transverse strike slip faults and a few focal mechanism solutions have proved so. These transverse features are capable of generating 6.5 to 7 magnitude earthquakes. Hence these have been assigned the status of possible earthquake faults.

The NNW-SSE trending other arm is located at a distance of 40 Km as such because of larger distance the PGA values for the same would be much less than the NNE-SSW are as such this source alternation has not been included in the table for PGA alculations.

A number of transverse lineaments starting from the Indian Shield area cut across the Himalayan trend. One such treatment is the Teesta fault, the neotectonic activity along which has been established. This feature, continuing for a length of 250 km, is capable of generating a 7 magnitude earthquake (by strike slip mechanism) passes very close to the project area. As such the same has been assigned the status of a capable fault. For alternation, only focal depth has been considered as the distance from the project area is negligible. Other possible source like the Kanchenjunga Fault, the Gangtok lineament, the Arun lineament, and the Chhungthang Fault are located at quite large distance with possible 6.5 to 7 magnitude earthquakes originating from these sources would give much less PGA values than the sources considered, PGA values for the same have not been estimated. The computed motions for the above four sources considered for the Project are included in Table 3.5 below.

Table 3.5: Computed Motions of the Four Sources considered for the Project

No	Seismic Source	Hypo Central Distance	Type	Magnitude	PGA Values
					Campbell 1997
1	Main Himalayan Sesmic Source, the detachment surface	15 km	Thrust	8	0.46g
2	Basement thrust Front	20 km	do	7	0.25g
3	NNE-SSW trending area of MCT	15 km	Strike Slip	6.5	0.27g
4	Teesta Lineament	20 km	do	7	0.25g

It is seen form the above table that the most conservative worst scenario earthquake would give PGA value of 0.49g. Such an event would have long recurrence intervals. If it is assumed that during the 1934 earthquake, this source was involved, the same may not repeat in the life span of the project. Thus this event at best could be assigned the status of Maximum credible (considered) Earthquake (MCE). According to the ISI code is 1893 (Prt-1)-2002 on Indian Standard Criteria for Earthquake resistant Design of Structure, Bureau of Indian Standard, New Delhi, and the Design Base Earthquake (DBE), which has to used for a seismic design, should be 50% of the MCE value. Thus PGA for DBE for this project would 0.25g. Interestingly the other sources considered, with shorter recurrence interval, give PGA values in this range only. Thus the DBE of 0.25g is recommended for the project and the design spectra would be developed at the detailed engineering stage.

Tingting Hydroelectric Project is located on Rathong Chhu, a tributary of Rathong Chhu, and emerges from the Rathong glacier on the southern side of Khangchendzonga peak. The dam site of this project is located south of Yuksom, a heritage township where the coronation of first “Chogyal” of Sikkim took place in AD 1641. The Powerhouse site of this run of the river scheme is located just upstream of the confluence of Rimbi Khola with Rathong Chhu. The project area falls in Zone IV of the Seismic Zoning Map of India (Figure 3.16) included in the Bureau of Indian Standards Code 1S 1893 (Part I) 2002. The Zone IV corresponds to a PGA of 0.25g (intensity VIII on MMI Scale). It is stipulated in the above-referred code that these motions should be used only for preliminary design of Hydro electric projects but for the detailed designs site specific motion characteristics may be evaluated. These studies are carried out utilizing deterministic as well as probabilistic approaches.

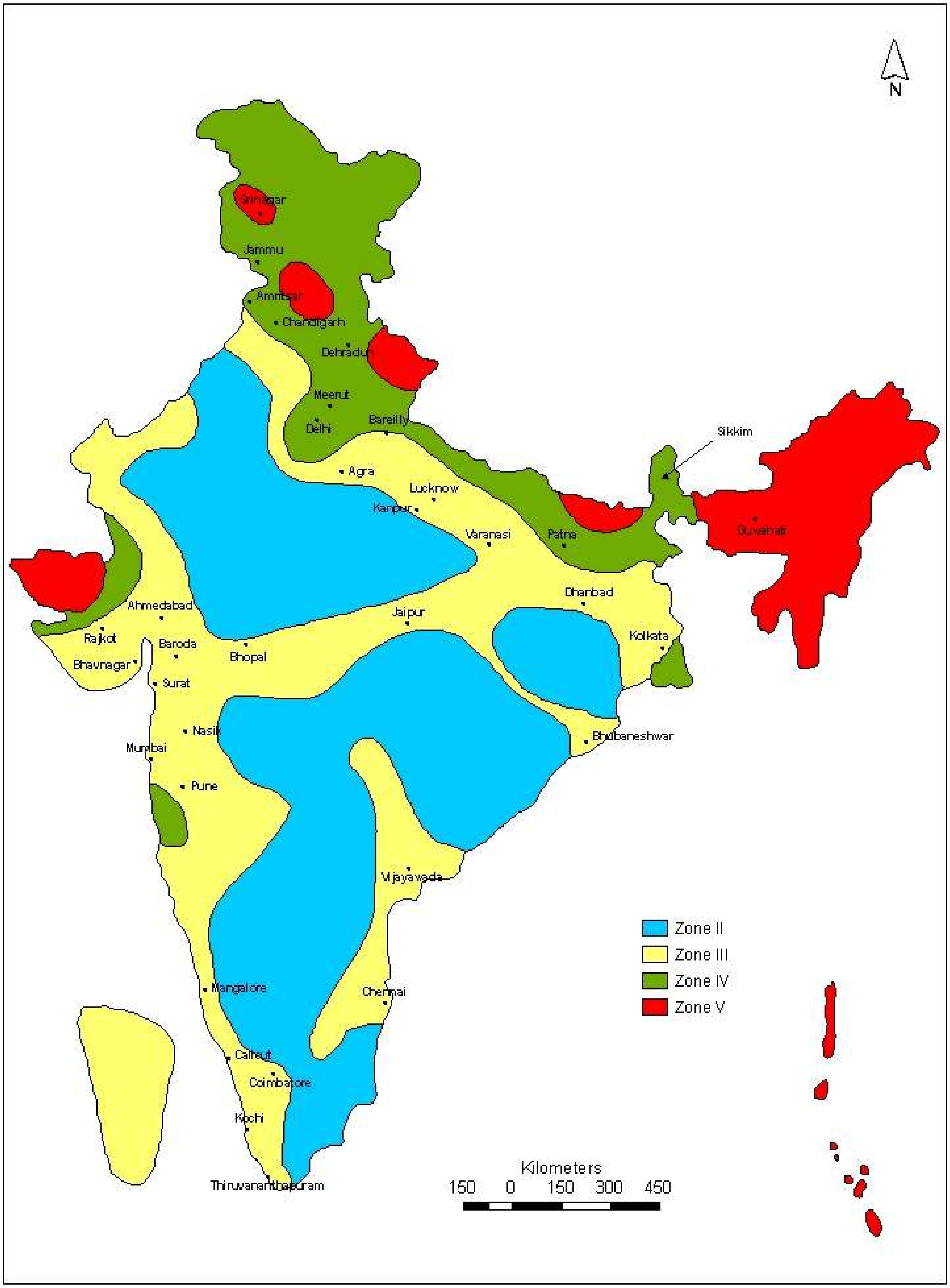


Figure 3.16: Seismic Zoning map of India (Source: BIS, 2001, New Delhi)

Conventionally for Indian scene deterministic approach is followed based on the Seismotectonic evaluation of the project area, identifying the possible source faults and computation of motion characteristics adopting appropriate attenuation relationships. This report covers the Seismotectonic evaluation of the project area and preliminary computation of Peak Ground Acceleration (PGA) values for the DPR stage design of studies against the dynamic forces generated by earthquakes. For the Detailed Design Stage these values will have to be re-validated along with generation of design spectra and the time histories. This report deals with the regional geological and tectonic set up, identification of seismicity, effect of past major earthquakes, Neotectonic activity and postulation of 'Seismotectonic Model' and identification of possible source Faults which have to be considered for generation of earthquake motions. Preliminary assessment of the PGA values has also been made for MCE and DBE conditions.

3.4 MINERAL RESOURCES

This district has great potential in terms of mineral resources and mineral based industries. The district has appreciable deposits of dolomite and limestone in a relatively undisturbed situation. There is scope for development of building stone/ polished shale (gneiss, marble, quartzite) industry, ceramics (clay horizons).

The major non-metallic mineral reported from west Sikkim are dolomite and graphite. Minor occurrences of soapstone or talc, magnesite and asbestos etc. have also been recorded but all, except talc, are till now of uneconomic quantity. Occurrences of sulphide mineralisation have been located in Chakum, Soreng, Chongbong, Roathak, Bum and Legship.

i) *Dolomite*

Both high-grade massive and low-grade flaggy type dolomites have been located in Rishi area, in the southeastern part of the district, west of Jorthang-Legship state highway. On either banks of Rishi Khola, adjacent to Rishi village (27^{o} 13' N; 88^{o} 46' E), four dolomite-bearing blocks have been delineated. Massive dolomites are light grey in colour, fine grained with high percentages of MgO (18-22%), CaO (ca. 30%) and insoluble (1.5-3 %). A total reserve of more than one million tonnes has been estimated down to a depth of 30 m.

ii) *Graphite*

Graphite both lumpy and flaky types, associated with graphite schist, marble and limonitised pegmatite of High Grade Gneiss, has been located at Chitre (27^{o}16'20"N :

88^{o}02'10"E) and Dareli (27^{o}17'N: 88^{o}03'E) of West Sikkim. The graphite bands occur even at depths of 2 to 3 m below the surface and the thickness varies from 30-80 cm. An estimated reserve of about 6,000 tonnes of graphite has been computed from Chitre sector. The IBM has conducted beneficiation test on this graphite, which indicated good liberation of graphite in finer fraction. However, impersistent and pocketry nature of graphite occurrences, their inaccessibility and location at high altitude (3,000-4,000 m) near India-Nepal border, have rendered these occurrences uneconomic in view of the high cost of exploration, mining and transportation of the materials.

iii) ***Coal***

Thin coal seams occurring within the carbonaceous shale-sandstone sequence of Gondwana Group have been located around Put Khola, Roathak Khola and Rinchingpong area of the district. The coal is black to grayish black in colour, powdery in nature, semi-anthracitic with high ash, low volatile matter and high (?) moisture.

iv) ***Asbestos***

Near Tashiding, bluish grey short matted, harsh fibre type of asbestos associated with acicular tremolite and actinolite crystals have been located within the Dalling Phyllites.

v) ***Limestone***

Grey limestone interbanded with green phyllites is observed in Rishi Khola, south of Namgaon. An exposure of limestone, about 30 m thick is traceable over a strike length of 60 m near Rishi Khola. It contains CaO (42-46%), MgO (1.22-2.20%) and insoluble (12-14%). Pink limestone with shales is exposed at Nayabazar. Limestone is massive, hard and breaks with conchoidal to semi-conchoidal fracture. Selected portion of limestone horizon have 42-44% CaO, 1.22-1.6 % MgO and 11- 18% insoluble.

vi) ***Talc***

Talc occurrences have been located in Rani Khola, Rishi Khola, and Roathak Khola within the metamorphic rocks of Daling Group. Talc is found as pockets within the phyllite and is intimately associated with an inrtrusive quartz vein in Rani Khola area.

vii) ***Magnesite***

In the metasediments and metabasics of Rangit valley, magnesite occurrences have also been located.

viii) ***Rock Phosphate***

Occurrences of rock phosphate in stromatolitic dolomite near Tatapani and Subuk area within the Daling Group have been reported in the eastern part of the district. The phosphate-bearing horizon are very thin and impersistent in nature.

ix) *Sillimanite*

Sillimanite along with kyanite occurs either as needles or as fibrous aggregates within the quartz cummingtonite-quartz schists forming a part of high-grade biotite gneiss. A few sillimanite enriched zones were located between Sardung and Dentam villages. The most promising occurrence is at Sardung area, which has a thickness of 50m and strike length of 250m prospected by trenching and sampling. Chemical analysis of five samples show very low Al_2O_3 (5-15 %) content. Therefore, this silimanite deposit does not seem to be of economic importance.

x) *Quartzite*

Occurrences of quartzite within the Daling Group of rocks has been reported from Mansari-Malbashe-Chakung and Bardang-Singrep-Jhum-Roathak areas. Extensive exposures of pure white/milky white massive and flaggy variety of quartzite at Mansari has some economic potential.

xi) *Sulphide Mineralisation*

Base metal occurrences containing chalcopyrite with pyrite, in the form of veins, stringers and disseminations have been located at Jugdum, Roathok, Sisni, Sirbong, Sontali, Chugbung, Legship and Bum.

a) Jugdum (27^{o}11' N : 88^{o}14'48" E): The copper mineralisation is associated with quartz veins and occurs within the thick greenish chlorite phyllite of Daling Group over a length of 215 m. A few lenses of chlorite schist and phyllite containing mineralized quartz vein also occur in this area. There are three main mineralized quartz veins in the main zone. Copper mineralisation present between the vertical depths of 49 m and 57 m. Copper content of core sample was between 0.21 – 0.64%. At Jugdum, the Daling phyllites and schists have a NNE-SSW regional strike with foliation dipping towards WNW.

b) Roathak Khani (27^{o}09'50" N : 88^{o}15'18" E): The Roathak Khani occurrence is located at the confluence of Khani Khola and Roathak Khola and is about 1.6 km NE of Chakung village. Sulphide mineralisation containing chalcopyrite and pyrite is noted over a length of about 500 m on the right bank of Khani Khola. The copper mineralisation is mainly associated with quartz veins and slates of Daling Group.

c) Sisni (27^{o}15’N : 88^{o}14’23" E): Sisni deposit is located about 90 m upstream of the Sisni Khola from its confluence with Roathak Khola and about 2 km NW of Chakung village. The copper mineralisation with 0.15 to 0.35% Cu is associated with quartz veins in Daling slates. The main band has a thickness ranging from 0.8 m to about 2 m over an exposed length of about 44 m.

d) Shribong (27^{o}10’20" N: 88^{o}16’E): Chalcopyrite and pyrite is exposed in quartz veins associated with slaty phyllite of Daling Group. The quartz veins have widths ranging from 0.61 m to 1.83 m and are exposed on the bed of Shribong Khola, 1.6 km NNE of Roathak Khani.

e) Sontali: Copper mineralisation noticed in association with quartz veins within the sericitic phyllites, slates and chlorite schists of Daling Group. Three mineralized quartz veins were identified with widths ranging from 0.3 m to 0.6 m.

f) Chongbong (27^{o}7’30" N : 88^{o}15’ E): Chongbong occurrence is located on the southern slope of Chakung ridge at an elevation of about 900 m on steep scarp face and the left side of Chongbong Khola. Poorly mineralized quartz veins with total width of 1.3m occur within the slaty phyllite striking NE and dipping NW.

g) Legship (27^{o}17’ N : 88^{o}17’ E): In Legship area the basemetal mineralisation is observed in the northern bank of Bania nala, near its confluence with Rangit River. Sulphide minerals *viz*. pyrite, pyrrhotite, chalcopyrite, bornite and galena occur as disseminations and thin hairline fracture filling in quartz veins. The copper content ranges from 1200 ppm to <100 ppm.

h) Bum (27^{o}13’ N : 88^{o}15’ E): The mineral occurrences are observed both in phyllite and quartzite and are exposed on either banks of Rishi Khola near the Bum bridge. Pyrite, chalcopyrite, bornite, galena and pyrrhotite are seen in association with vein quartz stringers, varying in thickness from less than 1cm to 13cm. Sample from a 115 cm thick quartz vein from this area has yielded 3.41-4.50% copper, but it does not show persistent strike.

At present quartzite and talc are being mined from Mansari in West Sikkim. Previously dolomite was being mined from Rishi by private agencies. They used to crush the dolomite into powder and sale to the State Government of Sikkim for distribution to the farmers for spreading on cultivated lands for neutralizing the acidic soil. Only Dolomite may have some future potential for use in steel industry.

3.5 SOIL

It is very essential to assess the soil quality of the region for proper planning of a project, whether hydroelectric, road, construction and agricultural or afforestation. The soil quality can be defined as “capacity of a specific kind of soil to function”. It is generally assessed by measuring a minimum data set of soil properties to evaluate the soil’s ability to perform basic functions (i.e. maintaining productivity, regulating and partitioning of water solute flow, filtering and buffering against pollutants and storing and cycling nutrients). Evaluation of physical and chemical characteristic is essential for measuring the soil quality of a particular region or area and it has also been done for the project area Tingting H.E. project on Rathong Chhu.

3.5.1 Soil Series Classification

The basic data of soil classification done by the National Bureau of Soil Survey and Land Use Planning (Indian Council of Agriculture Research), Nagpur for Carrying Capacity studies of Teesta basin has been referred to for the preparation of soil maps of project area and catchment (Figures 3.17 & 3.18, Table 3.6).

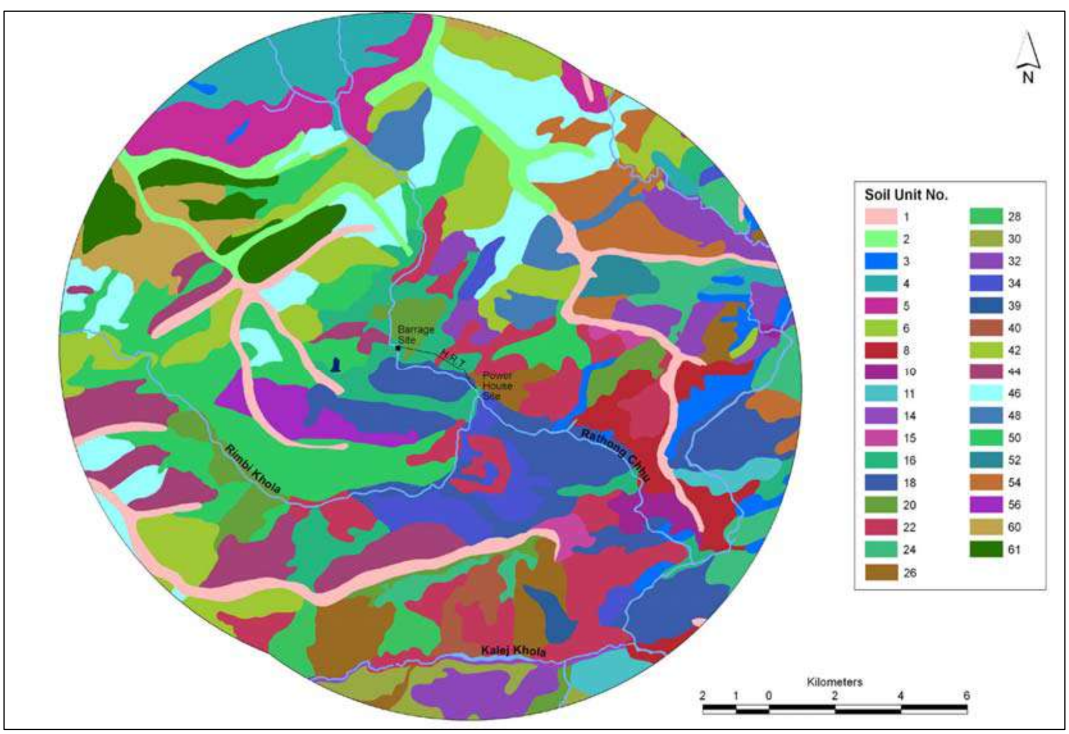


Figure 3.17: Soil map of Ting Ting H.E. project study area
(For legend of soil units refer to Table 3.6)

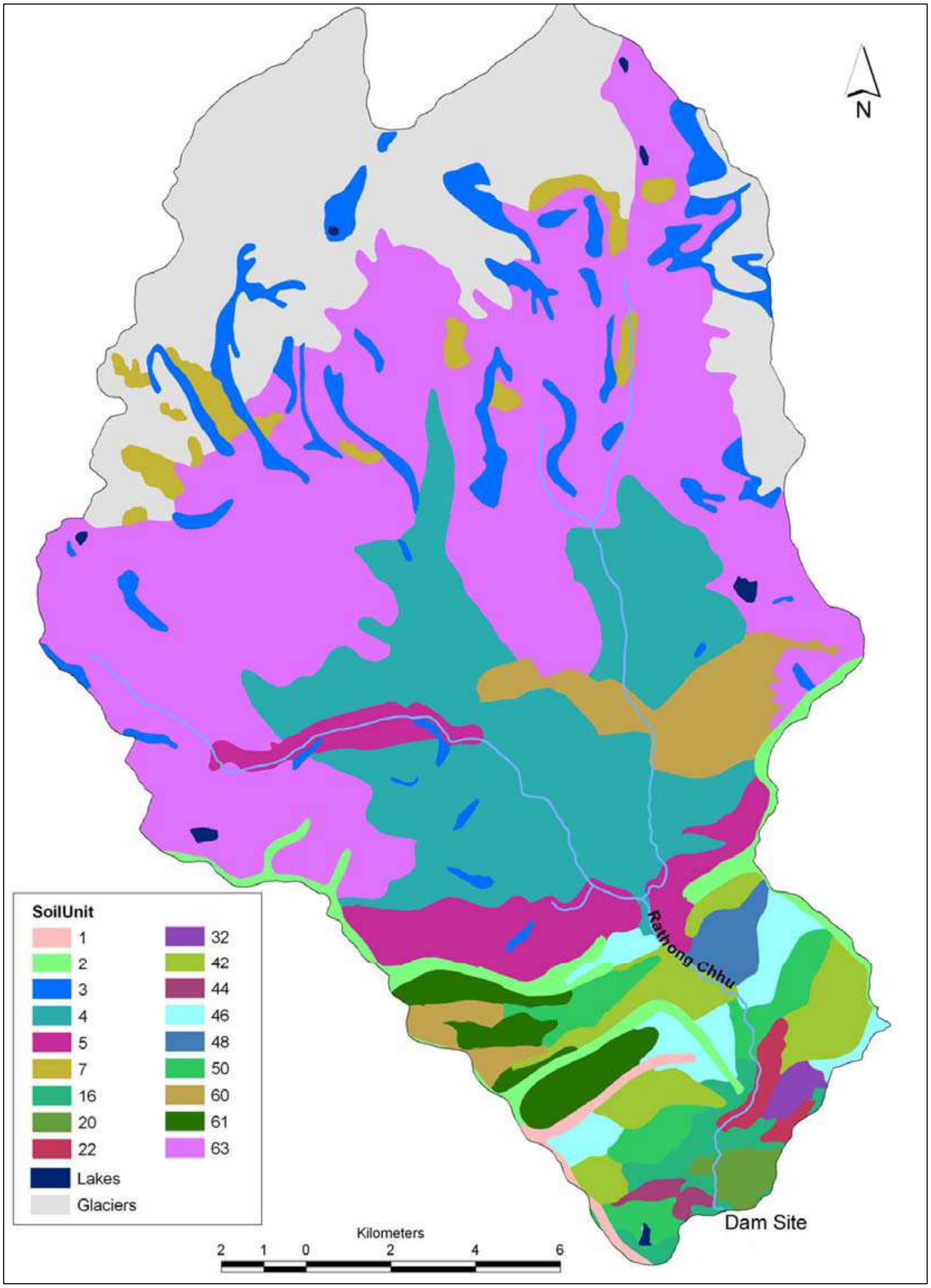


Figure 3.18: Soil map of Ting Ting H.E. project catchment area (Source: NBSS&LUP) – For legend of soil units refer to Table 3.6

Table 3.6: Legend to the Soil Units in Figures 3.17 & 3.18

Soil Unit No.	Soil Series	Description	Taxonomic Classification
1	Maling-Rayong	Moderately shallow, somewhat excessively drained, coarse-loamy over fragmental soils on steep slope (30-50%) with loamy surface, slight surface stoniness and moderate erosion; associated with shallow, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate stoniness and moderate erosion.	Coarse-loamy over fragmental, thermic Typic Haplumbrepts Coarse-loamy, thermic, Lithic Udorthents
2	Rubam-Salem	Deep, moderately well drained, fine soils on steep steep slope (30-50%) with loamy surface, slight stoniness and moderate erosion; associated with moderately deep, well drained, fine-silty soils with loamy surface, slight stoniness and moderate erosion.	Fine, thermic Typic Haplumbrepts Fine-silty, thermic, Typic Haplumbrepts
3	Rockoutcrops – Jorpul	Deep, well drained, fine-loamy soils on steep slope (30-50%) with loamy surface, slight stoniness and moderate erosion; associated with deep, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate stoniness and moderate erosion.	Fine-loamy, thermic Pachic Haplumbrepts Coarse-loamy, thermic Entic Haplumbrepts
4	Hilley-Singrep – Chatten	Moderately deep, well drained, fine-loamy soils on steep slope (30-50%) with loamy surface, slight stoniness and moderate erosion; associated with moderately shallow, somewhat excessively drained, loamy skeletal soils with gravelly loamy surface, moderate stoniness and severe erosion	Fine-loamy, thermic Typic Haplumbrepts, Loamy-skeletal, thermic Umbric Dystrochrepts
5	Bhusuk – Karporang - Tibik	Moderately deep, somewhat excessively drained, coarse loamy soils on steep slope (30-50%) with loamy surface, moderate erosion and slight stoniness; associated with deep, well drained, fine soils with loamy surface, moderate erosion and slight stoniness.	Coarse-loamy, thermic Typic Haplumbrepts Fine, thermic Umbric Dystrochrepts
6	Karporang - Hilley	Deep, well drained, fine-loamy soils on moderately steep slope (15-30%) with loamy surface, moderate erosion and slight stoniness; associated with moderately deep, excessively drained, coarse-loamy soils with sandy surface, severe erosion and slight stoniness.	Fine-loamy, thermic Typic Hapludolls Coarse-loamy, thermic Typic Udorthents

Soil Unit No.	Soil Series	Description	Taxonomic Classification
7	Kalep - Rockoutcrop	Moderately deep, somewhat excessively drained, fine-loamy soils on moderately steep slope (15-30%) with loamy surface, moderate erosion and slight stoniness; associated with moderately deep, somewhat excessively drained, loamy-skeletal soils with loamy surface, moderate erosion and slight stoniness.	Fine-loamy, thermic Cumulic Haplumbrepts Loamy-skeletal, thermic Typic Udorthents
8	Bhasme – Chautare - Legship	Deep, excessively drained, fine-loamy soils on moderately steep slope (15-30%) with loamy surface, moderate erosion and slight stoniness; associated with moderately deep, excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness.	Fine-loamy, thermic Pachic Haplumbrepts Coarse-loamy, thermic Typic Haplumbrepts
10	Chalumthang – Rorethang - Bhasme	Deep, somewhat excessively drained, fine-loamy soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness; associated with moderately deep, somewhat excessively drained, coarse-loamy over fragmental soils with loamy surface, moderate erosion and slight stoniness.	Fine-loamy, thermic Typic Haplumbrepts Coarse-loamy over fragmental, thermic Typic Udorthents
11	Mangjing – Singrep - Rorethang	Deep, somewhat excessively drained, coarse-loamy soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness; associated with deep, somewhat excessively drained, coarse-loamy over fragmental soils with loamy surface, moderate erosion and slight stoniness.	Coarse-loamy, thermic Typic Hapludolls Coarse-loamy over fragmental, thermic Entic Hapludolls
14	Dharamdin – Lingtse - Karfecter	Moderately deep, well drained, fine-loamy soils on very steep slope (>50%) with loamy surface, severe erosion and slight stoniness; associated with deep, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness.	Fine-loamy, thermic Typic Dystrochrepts Coarse-loamy, thermic Typic Haplumbrepts
15	Mangreg – Karfecter - Mangjing	Deep, somewhat excessively drained, coarse-loamy soils on very steep slope (>50%) with loamy surface, severe erosion and moderate stoniness; associated with deep, somewhat excessively drained, coarse-loamy soils with gravely loamy surface, severe erosion and moderate stoniness.	Coarse-loamy, thermic Typic Hapludolls Coarse-loamy, thermic Dystric Eutrochrepts

Soil Unit No.	Soil Series	Description	Taxonomic Classification
16	Tumin – Phong – Chautare	Moderately deep, somewhat excessively drained, coarse-loamy over fragmental soils on very steep slope (>50%) with loamy surface, moderate erosion and moderate stoniness; associated with shallow, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness.	Coarse-loamy over fragmental, thermic Typic Udorthents Coarse-loamy, thermic Lithic Haplumbrepts
18	Phong – Khedi - Maniram	Moderately deep, somewhat excessively drained, coarse-loamy soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness; associated with deep, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness.	Coarse-loamy, thermic Entic Hapludolls Coarse-loamy, thermic Dystric Eutrochrepts
19	Pakel – Tibik - Rockoutcrop	Deep, somewhat excessively drained, coarse-loamy soils on very steep slope (>50%) with loamy surface, severe erosion and moderate stoniness; associated with deep, somewhat excessively drained, dark brown to brown, moderately acidic coarse-loamy soils with loamy surface, moderate erosion and slight stoniness.	Coarse-loamy, thermic Typic Hapludolls Coarse-loamy, thermic Entic Hapludolls
20	Chakung – Tumin - Sajong	Moderately deep, somewhat excessively drained, coarse-loamy soils on very steep slope (>50%) with loamy surface, severe erosion and slight stoniness; associated with deep, somewhat excessively drained, fine-loamy soils with loamy surface, severe erosion and slight stoniness.	Coarse-loamy, mesic Typic Haplumbrepts Fine-loamy, mesic Umbric Dystrochrepts
21	Singhik – Tibik - Lingthem	Deep, somewhat excessively drained, coarse-loamy soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness; associated with moderately shallow, somewhat excessively drained, loamy-skeletal soils with gravelly loamy surface, severe erosion and slight stoniness.	Coarse-loamy, thermic Typic Hapludolls Loamy-skeletal, thermic Entic Hapludolls
22	Chongrang – Legship - Singgyang	Moderately shallow, somewhat excessively drained, loamy-skeletal soils on very steep slope (>50%) with gravelly loamy surface, severe erosion and moderately stoniness; associated with moderately deep, somewhat excessively drained, coarse-silty soils with loamy surface, moderate erosion and slight stoniness.	Loamy-skeletal, mesic Entic Hapludolls Coarse-silty, thermic Typic Hapludolls
23	Singhik – Ruglo - Rapung	Moderately deep, somewhat excessively drained, coarse-loamy soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness; associated with shallow, somewhat excessively drained, coarse-loamy soils with loamy surface, severe erosion and moderate stoniness.	Coarse-loamy, thermic Typic Haplumbrepts Coarse-loamy, thermic Lithic Udorthents

Soil Unit No.	Soil Series	Description	Taxonomic Classification
24	Doling - Khedi	Moderately deep, somewhat excessively drained, loamy-skeletal soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness; associated with moderately shallow, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness.	Loamy-skeletal, mesic Typic Haplumbrepts Coarse-loamy, thermic Typic Udorthents
25	Gyer – Manul – Lema	Moderately deep, somewhat excessively drained, coarse-loamy soils on very steep slope (>50%) with loamy surface, moderate erosion and slight stoniness; associated with moderately shallow, somewhat excessively drained, coarse-loamy soils with gravelly loamy surface, severe erosion and moderate stoniness.	Coarse-loamy, thermic Typic Haplumbrepts Coarse-loamy, thermic Typic Udorthents
26	Dikling - Hilley	Shallow, somewhat excessively drained loamy-skeletal soils on high relief glaciated land (>50%) with loamy surface, severe erosion and moderate stoniness; associated with moderately shallow, somewhat excessively drained, loamy-skeletal soils with gravelly loamy surface, moderate erosion and slight stoniness.	Loamy-skeletal, isofrigid Lithic Cryorthents Loamy-skeletal, isofrigid Typic Cryorthents
27	Nung – Lingthem	Moderately shallow, excessively drained, coarse-loamy soils on very steep slope (>50%) with gravelly loamy surface, severe erosion and moderate stoniness; associated with moderately shallow, excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness.	Coarse-loamy, mesic Entic Haplumbrepts Coarse-loamy, mesic Typic Haplumbrepts
28	Samdur – Khedi – Bhusuk	Moderately shallow, somewhat excessively drained coarse-loamy soils on escarpments with loamy surface, severe erosion and slight stoniness; associated with moderately shallow, somewhat excessively drained, loamy-skeletal over fragmental soils with loamy surface, severe erosion and strong stoniness.	Coarse-loamy, thermic Umbric Dystrochrepts Loamy-skeletal over fragmental, thermic Entic Hapludolls
29	Lingthem – Lema – Singhik	Moderately deep, somewhat excessively drained, coarse-loamy soils on escarpments with loamy surface and moderate erosion; associated with deep, somewhat excessively drained, fine-loamy soils with loamy surface and moderate erosion.	Coarse-loamy, thermic Typic Hapludolls Fine-loamy, thermic Umbric Dystrochrepts
30	Rumtek - Tumin	Moderately deep, excessively drained fine-loamy soils on escarpments with gravelly loamy surface and moderate erosion; associated with moderately deep, excessively drained, loamy-skeletal soils with loamy surface and severe erosion.	Fine-loamy, thermic Umbric Dystrochrepts Loamy-skeletal, thermic Entic Haplumbrepts

Soil Unit No.	Soil Series	Description	Taxonomic Classification
31	Bitchu – Ruglo - Pakel	Deep, somewhat excessively drained, fine-loamy soils on escarpments with loamy surface and moderate erosion; associated with moderately deep, excessively drained, sandy soils with loamy surface and severe erosion.	Fine-loamy, thermic Umbric Dystrochrepts Thermic Typic Udipsamments
32	Bhusuk – Pirik – Namchi	Moderately shallow, excessively drained, loamy-skeletal soils on escarpments with loamy surface and moderate erosion; associated with deep, somewhat excessively drained, fine-loamy soils with loamy surface and moderate erosion.	Loamy-skeletal, thermic Typic Udorthents Fine-loamy, thermic Typic Dystrochrepts
33	Manul – Gyer – Rockoutcrop	Moderately deep, excessively drained, loamy skeletal soils on escarpments with gravelly loamy surface and severe erosion; associated with moderately deep, excessively drained, loamy-skeletal soils with gravelly loamy surface and severe erosion.	Loamy-skeletal, thermic Typic Udorthents Loamy-skeletal, thermic Entic Hapludolls
34	Namchi – Synggyang	Moderately deep, excessively drained, coarse-loamy soils on escarpments with loamy surface and moderate erosion; associated with moderately shallow, excessively drained, coarse-loamy soils with loamy surface and moderate erosion.	Coarse-loamy, thermic Umbric Dystrochrepts Coarse-loamy, thermic Entic Hapludolls
39	Daragoan – Gaucharan – Dharamdin	Moderately shallow, somewhat excessively drained, coarse-loamy over fragmental soils on very steep slope (30-50%) with gravelly loamy surface, moderate erosion and moderate stoniness; associated with deep, somewhat excessively drained, coarse-loamy over fragmental soils with loamy surface, moderate erosion and slight stoniness.	Coarse-loamy over fragmental, mesic Entic Haplubrepts Coarse-loamy over fragmental, mesic Pachic Haplumbrepts
40	Dharamdin – Martam – Karfecter	Moderately shallow, somewhat excessively drained, coarse-loamy soils on steep slope (30-50%) with loamy surface, moderate erosion and moderate stoniness; associated with moderately deep, well drained, fine-loamy soils with loamy surface, moderate erosion and slight stoniness.	Coarse-loamy, thermic Cumulic Haplumbrepts Fine-loamy, thermic Typic Haplumbrepts
42	Damthang – Chongrang – Rockoutcrop	Deep, somewhat excessively drained, loamy-skeletal soils on steep slope (30-50%) with gravelly loamy surface, severe erosion and moderate stoniness; associated with moderately shallow, somewhat excessively drained, loamy-skeletal soils with gravelly loamy surface, severe erosion and moderate stoniness.	Loamy-skeletal, thermic Umbric Dystrochrepts Loamy-skeletal, thermic Typic Dystrochrepts
44	Singgyang – Maniram – Damthang	Moderately shallow, well drained, fine-silty soils on steep slope (30-50%) with loamy surface, moderate erosion and slight stoniness; associated with moderately deep, well drained, fine-loamy soils with loamy surface, moderate erosion and slight stoniness.	Fine-silty, thermic Typic Haplumbrepts Fine-loamy, thermic Umbric Dystrochrepts

Soil Unit No.	Soil Series	Description	Taxonomic Classification
46	Maniram – Damthang – Jorpul	Deep, well drained, fine-loamy soils on steep slope (30-50%) with loamy surface, moderate erosion and slight stoniness; associated with deep, well drained, fine-loamy soils with gravelly loamy surface, moderate erosion and slight stoniness.	Fine-loamy, thermic Typic Argiudolls Fine-loamy, thermic Cumulic Hapludolls
48	Martam – Tarnu – Sajong	Deep, somewhat excessively drained, loamy-skeletal soils on steep slope (30-50%) with gravelly loamy surface, moderate erosion and slight stoniness; associated with shallow, somewhat excessively drained, coarse-loamy soils with gravelly loamy surface, severe erosion and moderate stoniness.	Loamy-skeletal, thermic Typic Hapludolls Coarse-loamy, thermic Lithic Udorthents
50	Sajong – Tarnu	Shallow, somewhat excessively drained, coarse-loamy soils on steep slope (30-50%) with gravelly loamy surface, severe erosion and moderate stoniness; associated with moderately shallow, somewhat excessively drained, loamy-skeletal soils with gravelly loamy surface, severe erosion and moderate stoniness.	Coarse-loamy, mesic Lithic Haplumbrepts Loamy-skeletal, mesic Typic Udorthents
52	Khedi – Maniram – Rongnek	Deep, somewhat excessively drained, fine-loamy soils on steep slope (30-50%) with loamy surface, moderate erosion and slight stoniness; associated with deep, somewhat excessively drained, fine loamy surface, moderate erosion and slight stoniness.	Fine-loamy, thermic Typic Hapludolls Fine-loamy, thermic Typic Argiudolls
54	Rongnek – Sajong	Deep, somewhat excessively drained, coarse-loamy soils on steep slope (30-50%) with loamy surface, moderate erosion and slight stoniness; associated with moderately deep, somewhat excessively drained, coarse-loamy soils with gravelly loamy surface, severe erosion and moderate stoniness.	Coarse-loamy, thermic Pachic Haplumbrepts Coarse-loamy, thermic Typic Udorthents
56	Khedi – Dikling	Moderately deep, somewhat excessively drained, coarse-loamy soils on steep slope (30-50%) with loamy surface, moderate erosion and slight stoniness; associated with moderately shallow, excessively drained, loamy-skeletal soils with gravelly loamy surface, moderate erosion and slight stoniness.	Coarse-loamy, mesic Typic Haplumbrepts Loamy-skeletal, mesic Pachic Haplumbrepts
60	Lachung – Puchikongma – Byuma	Moderately deep, somewhat excessively drained, coarse-loamy soils on moderately steep slope (15-30%) with loamy surface, moderate erosion and slight stoniness; associated with deep, well drained, fine-silty soils with loamy surface, moderate erosion and slight stoniness.	Coarse-loamy, thermic Cumulic Haplumbrepts Fine-silty, thermic Cumulic Haplumbrepts

Soil Unit No.	Soil Series	Description	Taxonomic Classification
61	Yumthang – Thangu – Kalep	Deep, well drained, fine-loamy soils on moderately steep slope (15-30%) with loamy surface, moderate erosion and slight stoniness; associated with shallow, somewhat excessively drained, coarse-loamy soils with loamy surface, moderate erosion and slight stoniness.	Fine-loamy, thermic Fluventic Eutrochrepts Coarse-loamy, thermic Lithic Hapludolls
63	Thangu - Rockoutcrop	Moderately shallow, somewhat excessively drained, coarse-loamy soils on moderately steep (15-30%) slope with gravelly loamy surface, moderate erosion and slight stoniness; associated with shallow, somewhat excessively drained, loamy-skeletal soils with loamy surface, moderate erosion and slight stoniness.	Coarse loamy, mesic Typic Haplumbrepts Coarse-loamy, mesic Lithic Haplumbrepts

Soils collected from the adit site belong to the Singgyang-Maniram-Damthang and Sajong –Tarnu soils series. These soils are susceptible to severe erosion. Very fine sand comprises its major portion. High proportion of very fine sand and low gravels and pebbles can be coincided with high moisture contents and bulk density. The soil is acidic with high concentration of ions as recorded high electrical conductivity. These soils recorded low nutrients and organic matter.

Soils collected from proposed power house site belong to Dharamdin-Martam-Karfecter soil series of Fluventic Eutrudepts. ‘Very fine sand’ is the major portion in the soil texture. These soils have relatively low moisture content but good water holding capacity and bulk density. The soil is strongly acidic but low prone to soil erosion. Relatively these soils have high organic matter.

3.5.2 Physico-chemical Characteristics

The soil samples were collected from 4 locations viz. proposed dam site (SS1), Adit site (SS2), proposed dumping site (SS3) and proposed Power house site (SS4) (see Fig.2.1). The soils samples were collected in triplicate at each site during lean season.

The physical properties of soil like water holding capacity, bulk density and texture were analysed as per the methods given in Jackson (1958). Chemical characteristics of soil were determined by analysing pH, electrical conductivity, potassium, magnesium, phosphate, nitrate and organic matter. Soil pH and conductivity were measured by the instruments pHScan and TDScan 3 (Oakton, Eutech Instruments), respectively. Phosphate and nitrate were determined by the ion specific meter (Hanna Instruments). Organic matter was determined by Walkley’s method (Walkley, 1947).

Bulk density of all the soil samples ranged from 1.02 to 1.06 g/cc. Electrical conductivity ranged from low of 181 to high of 244 µS/cm. The soils of different locations in the project area were acidic in nature with pH ranging from 5.5 to 5.8 (Table 3.7). Organic content in the soils was quite high varying between 4.46% and 12.77% and all the sampling locations showed sandy-silt texture indicating good percolation capacity.

Table 3.7: Physico-chemical Analysis of Soil Samples

Soil Samples	SS1	SS2	SS3	SS4
Physical Parameters				
Bulk Density (gm/cc)	1.02	1.03	1.06	1.04
Water holding capacity, %w/w	54.97	54.25	44.2	54.28
Texture				
• Sand,%w/w	38.89	28.32	40.29	54.87
• Clay,%w/w	7.28	13.82	6.47	10.42
• Silt,%w/w	53.83	57.86	53.24	34.71
Electrical Conductivity (µS/cm)	183	228	181	244
Chemical Parameters				
pH	5.6	5.8	5.5	5.8
Organic matter, %w/w	10.43	4.46	12.77	5.21
Nitrate (as NO_3), ppm	107	95	146	98
Phosphates (as P), ppm	34	24	19	24
Potassium (as K), ppm	119.22	97.21	243.72	175.67
Magnesium (as Mg), mg/kg	151.32	68.05	159.53	92.23

SS1=Dam site; SS2 = Adit site; SS3 = Dumping site; SS4 = Power house site

3.6 HYDROLOGY

Hydrological analysis has been carried out to:

- Assess the availability of water for power generation i.e., establish long-term stream flow series.
- Assess design floods.
- Assess sediment exclusion provisions.

3.6.1 Rangit River Basin

The River Rangit originating at an approximate elevation of 4900 is the major tributary of River Teesta in West Sikkim. The upper portion of the catchment area is rocky and partly covered with glaciers. It remains under snow during the winter months. The middle portion is covered with forest and the lower portion is covered partially with forest and partially with cultivation. The Rangit River and its tributaries originate in the Talung

Glacier in West Sikkim and it flows for about 61 km before joining the Teesta below the valley at the border of Sikkim with the West Bengal. The Rangit River in early reaches flows through very high valleys and steep slopes till it joins with the Rathong Chhu, which originates from Rathong Glacier and is one of the major tributaries of the river Rangit. The slope of the river Rangit up to its confluence with Rathong Chhu is of the order of 1 in 25. After the confluence, the river enters into the flat area with a slope of 1 in 85. The slope just below the confluence of Rathong Chhu with Rangit is of the order of 1 in 40. Further downstream, it joins with little Rangit at Naya Bazar and then the river acquires a flatter slope and becomes wider till it meets the Teesta near Melli. The catchment area up to proposed diversion site is assessed as 372 sq km. The catchment is both snow fed as well as rain fed. The proposed diversion site is 18 km upstream of existing Rangit HE Stage-III Project (60 MW), being operated by NHPC. The catchment area of the Rangit at various locations is given in Table 3.8.

Table 3.8: Catchment Area of the Rangit River

Location	Catchment Area (sq km)		
	Snowfed	Rainfed	Total
Ting Ting Dam	51	321	372
Stage-III Dam	262	700	962
Jorethang Loop HEP	262	1122	1384

3.6.2 Climate, Rainfall and Seasons

Sikkim lies in the sub-tropical and temperate zone. The region is subjected to heavy rainfall due to its location in the direct path of the monsoon. There is a high degree of variation in climate and vegetation, which ranges from subtropical to alpine depending upon the altitude. Altitude is the main factor controlling the climate and weather conditions of the state. Relief features such as high mountains act as barriers for the movements of monsoon winds. Low temperature, high rainfall on windward slopes, and comparatively dry on leeward side, and heavy precipitation in the form of snow at the mountaintops are the main features of the climate in Sikkim. Due to great variation in sharp edged mountains, there is a large variation in rainfall and temperature in the state.

Mean annual precipitation varies from 1250 mm in the snow fed catchment to 2,500mm in the rainfed catchment with intensity of rain varying from drizzling showers in low altitude areas to torrential rain at higher altitudes. In the dry upper valleys of Lachung and Lachen annual rainfall is about 1,250 mm. Sikkim falls within the high rainfall zone of the country. During the monsoon, which lasts from the beginning of June to almost the middle of October, the state witnesses a very high precipitation in all its parts.

Temperature varies with altitude and slope aspects. The temperature usually varies from a maximum of 22 to 23 degrees centigrade in July and August to a minimum of 3 to 5 degrees centigrade in December and January, as recorded by the Meteorological Station at Gangtok.

Rainfall is heavy and well distributed during the months from May to early October. July is the wettest month in most of the places. The intensity of rainfall during South-West monsoon season decreases from South to North, while the distribution of winter rainfall is in the opposite order. The highest annual rainfall for the individual station may exceed 5000 mm and average number of rainy days with rain of 2.5 mm. or more ranges from 100 days at Thangu to 184 days at Gangtok.

3.6.3 Precipitation Data

There are six rain gauge stations in the Project region viz., at Yuksom, Gyaling, Rangit Dam Site, Pelling, Dentam and Damthong. Monthly and annual normals based on data of these stations have been analysed.

Rainfall normals and Seasonal distribution of annual precipitation in Himalayan mountain region is given in Table 3.9 and Table 3.10. It is observed that, for hydroelectric power development, catchments in Sikkim and Arunachal are better placed than the catchments in the other Himalayan mountain regions and a higher runoff per sq km of catchment in Sikkim can be expected.

Table 3.9: Rainfall Normals

	Rainfall Normal (mm) at					
Station	**Yuksom**	**Pelling**	**Gyalzing**	**Rangit Dam Site**	**Dentam**	**Damthang**
Month	**(6 Yrs)**	**(3Yrs)**	**(14 Yrs)**	**(11 Yrs**	**5 Yrs)**	**(12 Yrs)**
Jan	34	36	13	20	10	24
Feb	22	47	16	19	41	29
Mar	53	90	55	49	66	63
Apr	110	67	108	108	180	110
May	198	308	190	206	340	249
Jun	350	465	428	459	552	545
Jul	551	436	462	462	606	626
Aug	489	458	425	384	503	582
Sep	567	363	408	366	405	425
Oct	189	173	162	146	153	97
Nov	65	78	16	20	25	28

Dec	14	9	21	21	38	25
Annual	2642	2530	2304	2261	2918	2804
Monsoon (May-Oct)	2344	2202	2075	2024	2558	2524
Non- Monsoon (Nov-Apr)	298	327	230	237	360	280

Table 3.10: Seasonal distribution of precipitation in Himalayan Mountain region

Himalayan mountain region (Location)	Seasonal Distribution of Precipitation (%)				
	Snowfall Season (Dec-Feb)	Snowmelt Season (Nov-Apr)	Monsoon Season (Oct-May)	Post Monsoon Season (Jun-Sep)	Annual Precipitation (mm)
Kashmir	22.1	22	53.6	2.3	970
Himachal	11.9	8.1	78.4	1.6	1200
Garhwal	6	3.6	87.8	2.6	1750
Nepal(West Central)	3.9	2.9	88	5.2	1850
Nepal(East)	2.9	6.8	85	5.3	2000
Arunachal	2.4	25.7	65.8	6.1	3000
Sikkim	2	16.5	74.6	6.9	2800
Project Region	2.8	2.5	79.1	15.6	2650

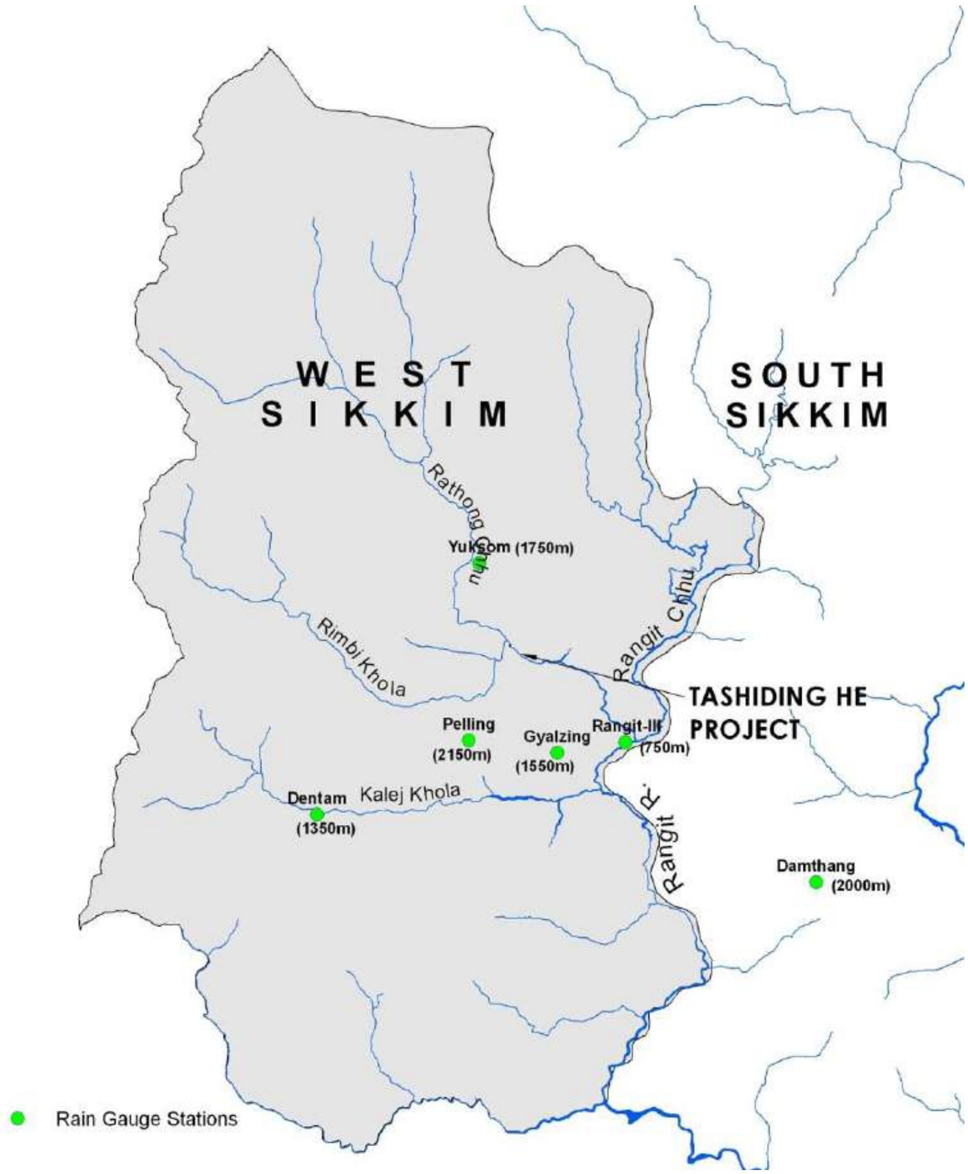


Figure 3.19: Location of Rain Guage Stations in Rangit Catchment

3.6.4 Temperature & Humidity

There is no temperature record available at the diversion dam site. Record available is for Gangtok and Kalimpong stations situated outside the catchment. Mean temperature over major part of the project basin varies:

13.2^{0}C in winter season (January),
22.1^{0}C during summer (April),
23.9^{0}C in rainy season (July) and
20.5^{0}C towards end of monsoon (October)

The relative humidity is generally high in the monsoon season, being over 80%. In the post-monsoon and in winter season, the humidity is less. The summer is generally the driest part of the year.

3.6.5 Stream Flow Records

Stream flow records (10-daily) of the Rangit River at 4 gauge sites are available as indicated in Table 3.11:

Table 3.11: Rangit catchment – Stream flow Records

Site	Catchment Area (sq km)	Period of Data Available
Rangit – Leg Ship Bazaar	1141	Jan 1990 – May 2002
Rangit – Leg Ship Weir	926	Jan 1977 – Dec 1991
Rangit Stage III Dam	962	June 1975 to April 2000
Rangit Stage III (based on power gen. data)	962	May 2000- April 2006

3.6.6 Stream Flow Series

Based on the above data sets, long term stream flow series (31yrs) at Rangit Stage – III Dam site (1975-2006) has been obtained. This series has been checked for consistency and after eliminating obvious inconsistencies, rational stream flow series (10-daily) of Rangit –III Dam site are given in Table 3.12.

i) Annual, monsoon and non-monsoon runoff data (May 1975 – Apr 2006) of the Rangit River at Rangit – III Dam site (after filling the few gaps in data) are given in

Table 3.12 (Series A). The quality of stream flow data for 6 years (2000-01 to 2005-06) based on power generation data is considered to be of high accuracy and acceptable.

ii) Runoff during 6 years (1994-95 to 1999-2000) is found to the considerably high when compared to the annual rainfall. Further, the average annual runoff during these 6 years (4477mm) is about 1.75 times the average annual runoff during the remaining 25 years (2533 mm).

iii) Stream flow series of these 6 years (1994-95 to 1999-2000) is scaled down (dividing by 1.75) making them consistent with the remaining 25 years data (vide series B in Table 3.12).

iv) Annual Precipitation normal over the snow fed catchment being (1250 mm) half of that (2500 mm) of rain fed catchment, weighted annual perception normal would be:

Site	**Catchment Area (sq km)**		**Annual Normal Perception volume**
	Snow fed	**Rainfed**	
Rangit- III Dam Site	262	700	2.500 x 831 M cum
Ting Ting Dam Site	51	321	2.500 x 346.5 M cum
Ratio of Annual normal Precipitation Volumes			1 : 0.417

Assuming that the stream flow is proportional to the annual normal percipitation volume, steam flow (10-dalily) series of Ting Ting Dam site based on the stream flow (10-daily) series of Rangit–III Dam Site is obtained using a conversion factor of 0.417. The adopted 10-daily discharge series for TingTing HEP is attached as Annexure VI

Table 3.12: Seasonal and Annual Runoff at Rangit III Dam Site (CA = 962 sq km)

Series A - Before Review				**Series B - After Review**			
Year	**Monsoon**	**Non-monsoon**	**Annual**	**Year**	**Monsoon**	**Non-monsoon**	**Annual**
	May-Oct (mm)	**Nov-Apr (mm)**	**May-Apr (mm)**		**May-Oct (mm)**	**Nov-Apr (mm)**	**May-Apr (mm)**
1975-76	1935.3	425.12	2360.42	1975-76	1935.3	425.12	2360.42
1976-77	1649.77	358.37	2008.14	1976-77	1649.77	358.37	2008.14
1977-78	1924.25	441.61	2365.86	1977-78	1924.25	441.61	2365.86
1978-79	1770.53	422.61	2193.14	1978-79	1770.53	422.61	2193.14
1979-80	2006.55	684.24	2690.79	1979-80	2006.55	684.24	2690.79
1980-81	2007.85	406.74	2414.58	1980-81	2007.85	406.74	2414.58
1981-82	2083.9	647.87	2731.77	1981-82	2083.9	647.87	2731.77
1982-83	1893.25	597.74	2490.99	1982-83	1893.25	597.74	2490.99
1983-84	1961.85	407.96	2369.81	1983-84	1961.85	407.96	2369.81
1984-85	1981.54	610.52	2592.06	1984-85	1981.54	610.52	2592.06

1985-86	1802.14	278.19	2080.33
1986-87	1453.39	487.89	1941.28
1987-88	1760.22	426.4 2	186.63
1988-89	1785.47	614.56	2400.03
1989-90	2135.4	662.09	2797.49
1990-91	2227.9	734.76	2962.66
1991-92	2557.13	792.63	3349.75
1992-93	2430.26	741.23	3171.49
1993-94	1982.9	696.24	2679.14
2000-01	2547.77	343.99	2891.76
2001-02	2171.34	392.47	2563.81
2002-03	2434.36	400.82	2835.18
2003-04	2535.79	424.35	2960.14
2004-05	2086.27	400.58	2486.85
2005-06	1900.63	399.65	2300.28
25 years			
Average	2041.03	511.95	2552.98
Std.Dev	288.2	148.5	356.61
CV	0.14	0.29	0.14
1994-95	2660.37	753.2	3413.56
1995-96	3363.35	809.14	4172.49
1996-97	3417.2	773.11	4190.31
1997-98	3230.06	635.13	3865.19
1998-99	4945.21	724.14	5669.35
1999-00	4836.84	714.44	5551.28
6 years			
Average	3742.17	734.86	4477.03
Std. Dev	930.3	59.66	922.59
CV	0.25	0.08	0.21

1985-86	1802.14	278.19	2080.33
1986-87	1453.39	487.89	1941.28
1987-88	1760.22	426.4 2	186.63
1988-89	1785.47	614.56	2400.03
1989-90	2135.4	662.09	2797.49
1990-91	2227.9	734.76	2962.66
1991-92	2557.13	792.63	3349.75
1992-93	2430.26	741.23	3171.49
1993-94	1982.9	696.24	2679.14
1994-95	1508.43	427.06	1935.49
1995-96	1907.02	458.78	2365.8
1996-97	1937.55	438.35	2375.9
1997-98	1831.45	360.12	2191.56
1998-99	2803.94	410.59	3214.52
1999-00	2742.49	405.09	3147.57
2000-01	2547.77	343.99	2891.76
2001-02	2171.34	392.47	2563.81
2002-03	2434.36	400.82	2835.18
2003-04	2535.79	424.35	2960.14
2004-05	2086.27	400.58	2486.85
2005-06	1900.63	399.65	2300.28
31 years			
Average	2056.67	493.5	2578.14
Std. Dev	337.45	138.91	390.26
CV	0.16	0.28	0.15

3.6.7 Rainfall-Runoff co-relation

From the available data, the average annual runoff is higher than the average rainfall over the catchment. The reason for this is either that the runoff is over estimated or the rainfall is very sparse and not a true representation of the mean precipitation over the catchment. Attempt has been made to co-relate the rainfall measured in the catchment with the measured runoff. There is only one rainguage station in the entire catchment area of 372 sqkm and only six stations in the complete Rangit river basin for more than 1400 sqkm. The precipitation in the Himalayas has high spatial and temporal variability and such a sparse network of rainfall measurements is not sufficient to give a reasonable representation of the average precipitation over the catchment. Many studies have been done previously on the precipitation pattern in the himalayas which have concluded that there is high spatial variability in the Himalayas and for most catchments, it is observed that the runoff is greater than rainfall (*Himalayan Rivers: Water Avaliability Studies for Hydel Power Projects by Dr. P R Rao and Niranjan Sahoo,* *National Seminar on Recent Advances in Hydrology for Water Resources Development and Management, Association of Hydrologists of India, Jan 2009).*

The runoff data observed at Rangit III from year 2000 onwards is based on highly accurate measurements from the power station and dam site and is highly reliable. Moreover, it is observed that the average annual runoff at Rangit III from year 2000 is higher than the average of the discharge series prior to 2000. This information gives enough confidence that the adopted 10-daily discharge series is in order and is not over estimated. Hence, the 10-daily discharge series measured by CWC from 1975-2000 and the 10-daily discharge series from the Rangit III Power Station and Dam Site post 2000 have been used in the power potential studies.

3.6.8 Hydrological Measurements at Site

Three guage and discharge measurement sites were set up at the project site to ascertain the flows in the Rathong Chu River at Ting Ting Dam site. Measurements are being taken twice daily since Nov 2008. The three G&D sites have been placed at the following three strategic locations so that the data could be corrected and to reduce discrepancies in the measured discharge data:

a. On Rathong Chu river at Ting Ting Dam Site (Catchment Area = 372 sqkm)
b. On Rathong Chu river 2.5 km downstream of Ting Ting Dam Site (Catchement Area = 533 sqkm)
c. On Rimbi Chu river just before its confluence with Rathong Chu river (Catchment Area = 145 sqkm)

One Rainguage station has been established at Ting Ting Dam Site in April 2010. The precipitation data from this station would be useful to plan the construction activities. A minimum of 30-40 rain guage stations would be required to get a true representation of catchment precipitation. It is much easier to maintain and record three G&D sites which give more accurate information of catchment run-off and hence more emphasis has been laid by project developers on establishing G&D sites over raingauge stations.

The average runoff based on site measurements at Ting Ting Dam Site is very close to the average runoff in the 90% dependable year. However, it is hard to ascertain if the current year in question is a 90% or lower dependable year.

3.6.9 Design Flood Assessment & Prescription

Diversion dam on the Rangit River near Ting Ting village falls under the category of Minor Structures, as per IS: 6966 (1989): Criteria for Hydraulic Design of Barrages and

Weirs are IS: 11223 (1985): Guidelines for fixing Spillway Capacity. Since no storage is envisaged at the diversion structure of the Ting Ting HE Project (except diurnal storage), design of spillway for a flood of 500-years return period of SPF would be in order. The safety of the structure has to be checked for PMF with a minimum freeboard of 20 cm. The following flood peaks are recommended for design of hydraulic structures of the project.

Return Period	Flood Peak (Cumec)
2.33 – yrs flood peak	590
5 – yrs flood peak	720
10 – yrs flood peak	830
25 – yr flood peak	950
50 – yr flood peak	1060
100 – yr flood peak	1170
Standard Project Flood (SPF)/500-yr flood is:	1405
Probable Maximum Flood (PMF) is	1880

Design floods assessed through Unit Hydrograph approach are appropriate and conservative enough for design purposes. Accordingly the spillway is designed to safely pass the SPF/500-yr flood of 1415 cumec and nominal freeboard of 20 cm is provided for PMF of 1885 cumec.

A study of maximum daily discharges observed during October to November months and during December to April months (construction period) indicated that maximum daily discharge is not more than 200 cumec and 100 cumec respectably as seen from the generation data of Rangit III Power House (2000-2006). Diversion arrangements during construction at Ting Ting dam site may be made to cater for a discharge of at least 125 cumec on a proportionate catchment assessment.

3.6.10 River Sediment Studies

Suspended sediment data collected by CWC at three stations viz., Chungthang (downstream of confluence of Lachen Chu and Lachung Chu) for May 1983 to Dec 1996, Dikchu (Teesta Stage V dam site) for the period Jan 1986 to Oct 1991 and at Sirwani (near Teesta Stage V Power House Site) for the period Jan 1986 to Dec 1996 have been analyzed. Further, suspended sediment data of the Rangit River at Stage III dam site available for two years prior to the commissioning of the Rangit Stage-III Power House has been studied. These studies indicate that coarse sediment fraction is much more than medium/fine fractions at Dikchu because the banks on either side experience major landslides during monsoon period. Further, over 70% of the total annual sediment is carried during the three monsoon months (June - Aug). Taking bed load as 20% of suspended silt load, average annual silt load at Dikchu was assessed as 5.97 M cum or 0.1385 Ha-m/ sq km/ year for Teesta Stage V project catchments of 4307 sq km. It has been observed that river sediment inflow was less than 200 ppm for 9 months (Sept to May) and was more than 5000 ppm for only 2 days in the year 1998.

Referring to CBI & P - Pub. No. 89 (1995): Capacity Survey of Storage Reservoir, it is seen that the form of sediment rating is generally considered to be :

S = k An

where S = Annual Sediment Volume in Ha-m

A = Catchment Area is sq km

k and n are constants.

For Indo-Gangetic Plain region, the relationship is given as:

$S = 1.55\ A^{0.763}$ ………………. Eqn (1)

Annual sediment load assessed for the Teesta Catchment of 4307 sq km being 5.97 MCM based on field data, annual sediment load for the Ranjit Catchment of 372 sq km (up to Ting Ting HE Project diversion) works out to:

5.97 * (372 / 4307) 0.763 = 0.93 MCM/yr as against 1.42 MCM given by eqn (1).

While eqn (1) may have simplicity, the relationship between annual runoff to sediment rate would be more rational and realistic:

s = k * qn

where s = annual sediment rate in Ha-m/ 100 sq km

q = annual runoff in cumec days per 100 sq km

k and n are constants.

For Indo-Gangetic Plain region, the relationship for q = 100 to 2000 is:

$s = 0.00627\ q^{1.185}$ …………… Eqn (2)

or $s = 0.00627\ (q_{mm} / 0.864)^{1.185} * A/100$ Ha-m / yr

where q_{mm} is annual runoff in mm. As sediment is associated mainly with monsoon runoff of the rainfed catchment of 321 sq km with monsoon rainfall normal of 2057 mm, annual sediment volume estimate is:

$s = 0.00627\ (2057/0.864)^{1.185} \times 3.21 = 202$ Ha-m = 2.02 MCM/yr

Garde & Kothyari (NIH publication No. INCOH/SAR-6/1995) have prepared a map showing iso-erosion rate which indicates sediment rate of 2500 tonnes / sq km / year for the project region. Unit weight of the sediment is estimated using the following equation:

r = Wc Pc + Wm Pm + Ws Ps , where r = unit weight in lbs/cft, Pc, Pm, Ps = % of clay, silt and sand respectively of the incoming sediment. Wc, Wm, Ws = coefficient of clay, silt and sand respectively obtained from the following table:

Reservoir Type	Wc	Wm	Ws
I	26	70	97
II	35	71	97
III	40	73	97
IV	60	73	97

Ting-Ting Project reservoir is Type – I. Taking the grain size distribution as:

clay 23% silt 40% and sand 37%

r = 26 * (0.23) + 70 * (0.40) + 97 * (0.37)

= 70 lbs/cft = 1121 kg/m^3

Sediment Volume = 2500 x 372 x 103/1121 m^3 = 0.83 MCM/yr

Thus, annual sediment volume estimates for the Ting Ting catchment vary from 0.83 to 2.02 MCM with mean of 1.30 MCM. It is assumed that the average annual sediment load would be 0.90 MCM, mainly confined to six monsoon months.

3.6.11 Resevoir Survey – 2006

Topographic survey of the Reservoir area has been carried out in May 2006 using the State-of-the art technology. Elevation–Area–Capacity curves of the reservoir have been developed using the grid generated from XYZ file. Values of capacity corresponding to reservoir elevation are given in Table 3.13.

Table 3.13: Elevation vs Capacity of Ting Ting HEP Reservoir

Elevation	Cumulative Volume (Cum)
El. 1130	0
El. 1135	9140
El. 1140	29420
El. 1145	65638
El. 1150	122588
El. 1155	209168
El. 1160	328763
El. 1161	356736
El. 1162	386615
El. 1163	418685
El. 1164	453487
El. 1165	491026
El. 1170	718129

3.6.12 Sediment Exclusion Provision

The project is a run-of-the-river scheme with nominal diurnal storage for 3-hr peaking. In the case of run-of-the-river schemes, where most of the floodwaters with high sediment concentration are let down, loss of storage would be much less. Considering that the volume of water diverted for power generation is 30% of average monsoon runoff, loss of gross storage during the monsoon months could be taken as 30% of S i.e., 27 Ha-m (1/3 in live storage and 2/3 in dead storage). MDDL is fixed at El.1143 m, where the capacity is 5 Ha-m.

Average reservoir sediment deposit in a month below MDDL works out to:
27*(2/3) / 6-months or 3 Ha-m/ month, indicating that the sediment deposit in the reservoir needs to be flushed out at least once a month during the monsoon season to recover the storage loss.

Referring to Table – 5.7, Reservoir capacity at MDDL 1143 m = 5.0 Ha-m
at FRL 1165 m = 49.1 Ha-m

Live storage capacity available = 44.1 Ha-m

This live storage capacity is adequate for 3-hour peaking operation twice daily. Spillway sluices provided in the body of the dam below MDDL will ensure removal of sediment deposits in the river stretch by flushing during monsoon (when maximum sediment load is expected). The river fetch of 0.75 km would also function as sedimentation chamber located upstream of the dam such that top layers of silt-free water only would enter the water conductor system. Further, the crest level of the Intake is kept sufficiently high above crest level of sluices to enable to draw top layers of water with low velocity to exclude coarse and medium fractions of suspended sediment. The diversion tunnel with appropriate gated intake and lining could also be considered, if necessary, to bypass coarse sediment fractions. With these arrangements, sedimentation is not expected to create any serious problem. However, considering riverbank erosion and landslides, reservoir needs to be managed during flood season by flushing frequently through the sluices provided in the body of the dam to pass the prescribed design flood.

3.7 AMBIENT AIR, NOISE AND TRAFFIC DENSITY

3.7.1 Ambient Air Quality

In a water resource project, impacts on air quality are marginal and limited only during construction phase. In order to assess the existing status of air quality ambient air quality monitoring was undertaken at two locations in the project area. The monitoring stations are located at dam site and power house site. The monitoring was done during three seasons namely winter season, summer and post monsoon season. The baseline data of ambient air environment was generated for the following parameters:

- Suspended Particulate Matter (SPM)
- Respirable Particulate Matter (RPM)
- Sulphur dioxide (SO_2)
- Oxides of Nitrogen (NOx).

The techniques used for monitoring of various parameters are given in Table-3.14.

Table 3.14: Techniques Used for Ambient Air Quality Monitoring

Parameter	Technique	Technical Protocol
Suspended Particulate Matter (SPM)	Respirable Dust Sampler (Gravimetric method)	IS-5182 (Part-IV)
Respirable Particulate Matter (RPM)	Respirable Dust Sampler (Gravimetric method)	IS-5182 (Part-IV)
Sulphur Dioxide (SO_2)	West and Gaeke	IS-5182 (Part-II)
Nitrogen Oxide (NOx)	Jacob & Hochheiser	IS-5182 (Part-IV)

The proposed Tingting HE project on Rangit river does not come in the category of air polluting projects. The air environment of the region is also very clean. The project is in Gyalzing sub-division of West Sikkim. There is no major industry in the district. Traffic is also very low in the district. The proposed project is near the Yuksom - Gyalzing road. Only light vehicles and army trucks ply on this route. Main source of air pollution in the region could be kitchen fuel, which is mainly wood. The region is totally covered with forest (82% of Sikkim is covered with forest), so the chances for air pollution from agricultural fields and open area is also very low. The levels of SPM, RPM, NO_x and SO_2 were assessed using High Volume Air Sampler (APM 460 BL). Ambient Air Quality monitoring was carried out at three different locations viz. Gyalzing (A1), Dam Site (A2) and Power House site (A3). Data is given at Table 3.15.

Table 3.15: Ambient Air Quality Data

PARAMETERS		A1	A2	A3
RPM **$\mu g/m^3$**	Max Min Avg.	42.0 15.0 21.0	24.0 12.0 17.0	27.0 9.0 19.0

SPM **μg/m^3**	Max Min Avg.	135.0 78.0 96.0	121.0 67.0 89.0	115.0 65.0 79.0
SO_2 **μg/m^3**	Max Min Avg.	8.9 6.2 7.2	7.8 6.0 6.9	7.6 6.0 6.8
NOx **μg/m^3**	Max Min Avg.	15.0 9.2 11.2	12.5 7.9 9.5	13.8 7.5 9.0

A1: Gyalzing, A2: Dam Site; A3: Power house site

i) *Suspended particulate matter (SPM)*

Suspended particulate matter (SPM) is defined as any dispersed matter, solid or liquid range in size from 0.0001 microns to 10,000 microns. Suspended particulate matter, based on size and ability of these particles to enter in the respiratory track of human, is divided into respirable suspended particulate matter (RSPM) with diameter less than 10 micron and non-respirable suspended particulate matter (NRSPM) – particle diameter above 10 micron. Average seasonal concentration of particles in the range of 100 to 200 micro grams per cubic meter in presence of sulphur dioxide of around 80 μg per cubic meter increases incidences of bronchitis and aggravates asthma. However, at various sites in the West Sikkim, the ambient level of the SPM ranged from a minimum of 65 μg/m^3 to 135 μg/m^3 (Table 3.15).

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 (CPCB, see Table 3.16). The sources of SPM in the region were mainly moving vehicles on the roads.

ii) *NO_x*

In the project area the average NO_x levels were negligible as compared to the standards of CPCB (see Table 3.16). The level of NO_x in area ranged from 7.5 to 15.0 μg/m^3 (see Table 3.15). Other locations reported even lower values.

iii) *SO_2*

The main source of SO_2 is fuels such as oils and coals. The levels of sulphur dioxide in the region were also observed to be quite low (see Table 3.15). At all the three locations the observed levels of SO_2 were well below the standards given by CPCB.

Table 3.16: National Ambient Air quality standards as per CPCB

Pollutants Weighted Average	Time	Concentration in Ambient Air: Sensitive Area	Industrial Area	Residential, Rural & Other Areas	Method of measurement
Sulphur Dioxide (SO_2)	Annual Average 24 hour	15 $\mu g\ m^{-3}$ 30 $\mu g\ m^{-3}$	80 $\mu g\ m^{-3}$ 120 $\mu g\ m^{-3}$	60 $\mu g\ m^{-3}$ 80 $\mu g\ m^{-3}$	Improved West and Greek Method
Oxides of Nitrogen (NO_2)	Annual 24hour	15 $\mu g\ m^{-3}$ 30 $\mu g\ m^{-3}$	80 $\mu g\ m^{-3}$ 120 $\mu g\ m^{-3}$	60 $\mu g\ m^{-3}$ 80 $\mu g\ m^{-3}$	Jacob Hochheiser Modified (Na-Arsenite) method
Suspended Particulate Matter (SPM)	Annual 24 hour	70 $\mu g\ m^{-3}$ 100 $\mu g\ m^{-3}$	360 $\mu g\ m^{-3}$ 500 $\mu g\ m^{-3}$	140 $\mu g\ m^{-3}$ 200 $\mu g\ m^{-3}$	High Volume Sampling (Average flow rate not less than 1.1/ m^3 minute
Respirable Particulate Matter (RPM), (Size < 10^3 m)	Annual 24hour	50 $\mu g\ m^{-3}$ 75 $\mu g\ m^{-3}$	120 $\mu g\ m^{-3}$ 150 $\mu g\ m^{-3}$	60 $\mu g\ m^{-3}$ 100 $\mu g\ m^{-3}$	Respirable Particulate matter sampler
Lead (Pb)	Annual 24 hour	0.5 $\mu g\ m^{-3}$ 0.75 $\mu g\ m^{-3}$	1 $\mu g\ m^{-3}$ 1 $\mu g\ m^{-3}$	0.75 $\mu g\ m^{-3}$ 1 $\mu g\ m^{-3}$	ASS method after sampling using EPM 2000 or equivalent Filter paper
Carbon Monoxide (CO)	8 hour 1 hour	1 mg m^{-3} 2 mg m^{-3}	5 mg m^{-3} 10 mg m^{-3}`	2 mg m^{-3} 4 mg m^{-3}	Non dispersive infrared spectroscopy

Noise levels were recorded at various places, inside the deep forest, riverside and in the villages. The traffic data was taken near the dam site along the Pelling road and near powerhouse site.

3.7.2 Noise Levels

Noise monitoring is carried out during post-monsoon season at various sampling location along the river and near villages. The sampling location includes submergence area, dam site, power house site and downstream of the powerhouse site. The project area is almost silent mostly the noise is from river, water falls and local vehicles (generally jeeps). The noise level varied from 62.41 to 74.4 dBA along the river whereas near villages, it ranged from 37.1 to 55.7 dBA (Table 3.17).

Table 3.17: Sound level recorded in the proposed project area

S.No.	Sites	Time	Min-Max	Average (dBA)
	Project Area			
1	Dam Site	8:00 a.m – 6.00 p.m.	70.9 - 72.2	71.45

2	Power house Site	8:00 a.m – 6.00 p.m.	70.3 – 72.6	71.69
3	Rimbi Khola	8:00 a.m – 6.00 p.m.	61.2 – 63.1	62.41
4	Rimbi Khola & Rathong Chhu confluence	8:00 a.m – 6.00 p.m.	73.5 – 75.4	74.40
5	Submergence	8:00 a.m – 6.00 p.m.	69.4 – 70.0	69.60
	Near villages			
6.	Thingling -1	8:00 a.m – 6.00 p.m.	35.2 – 39.9	37.10
7.	Thingling -3	8:00 a.m – 6.00 p.m.	36.7 – 60.2	44.88
8.	Dosthang village	8:00 a.m – 6.00 p.m.	54.5 – 55.7	55.10

3.7.3 Traffic Density

Major towns around the project area of Ting Ting H.E. Project are Gyalzing and Yuksom. Gyalzing-Yuksom is the main traffic routes in the region. The traffic is seasonal, peak traffic is observed during May-October, when tourists visit various places like Pelling and Yuksom. During tourist season, different types of vehicles ply on this road. Table 3.18 shows the traffic density in the region during the month of October. During off-season (with respect to tourist flow) only local vehicles and few small trucks ply in the region. Buses are also few and they ply in the morning and evening hours only. In Sikkim light vehicles are the main transport mode on the roads. Under heavy vehicle category buses are very few. Though all types of vehicles were observed, however majority were of small vehicles like Marshal, Jeeps and Maruti vans. The traffic data was taken near villages along the study area of proposed project.

Table 3.18: Traffic density recorded in the proposed project area

Vehicle Data					
Date	**Time**	**Site**	**Heavy Vehicles**	**Light Vehicles**	**Two Wheelers**
15.10.08	8:00 - 9:00 a.m	Thingling 1	0	4	0
15.10.08	1:00 - 2:00 p.m	Thingling 3	1	6	1
16.10.08	8:00 - 9:00 a.m	Thingling 3	0	3	0
17.10.08	9:00 - 10:00 a.m	Dosthang	0	3	0
17.10.08	1:00 - 2:00 p.m	Dosthang	0	4	1

CHAPTER-4

ENVIRONMENTAL BASELINE STATUS - BIODIVERSITY ASPECTS

The baseline setting for ecological aspects are outlined in the present Chapter. As a part of the EIA study, a detailed Ecological survey was conducted for three seasons. The surveys were conducted in monsoon, post-monsoon and winter seasons during the year 2008. The objectives of the ecological survey were to:

- Prepare inventory of flora in the project area.
- Assess the presence of rare/endangered, economically important and medicinal plant species.
- Determine frequency, abundance and density of different vegetation components.Estimate density and volume of the trees with height above 8 m.
- List wildlife in the project area, based upon field surveys as well as literature survey.
- Determine frequency, abundance and density of phytoplanktons and zooplanktons.

4.1 LAND USE/ LAND COVER

Landuse provides details of various categories of land uses e.g. for agriculture, settlement, forest, whereas land cover provides the details such as vegetation, rocks or buildings that are present on the surface. Accurate landuse and landcover identification is the key to most of the planning processes.

The landuse pattern of the project and catchment area has been studied through digital satellite imagery data. Digital IRS LISS-III and satellite data was procured from National Remote Sensing Agency (NRSA), Hyderabad. The data was processed through ERDAS IMAGINE software.
Ground truthing studies were conducted in the project area to validate various signals in the satellite images and correlate them with different landuse domains. As a part of field studies ground truthing was conducted in the project as well as the study area. The image was then classified using the prominent signatures extracted based on the past experience. The False Color Composite (FCC) and classified image of the catchment and study area is shown in Figures-4.1, 4.2 and 4.3.

Area under different landuse/ landcover categories in the project catchment as well as study area has been given in given in Tables-4.1 & 4.2.

The major land use category in the study area is forest land, which accounts for more than 66.00% of the total study area. This includes dense forest (22.55%) with crown cover density > 40% and open forest (43.79%) with crown cover density < 10%. Area under scrubs is about 14.58%. Other major land use land cover categories are agricultural land and settlements (6.36%) and barren area (7.52%).

Table 4.1: Land use classification for Rathong Chhu catchment at diversion site

Landuse/Landcover	Area in percentage	Area in sq km
Moraines	10.24	38.083
Barren Rockyland/Alpine Barren Area	34.06	126.708
Open Forest	29.79	110.820
Dense Forest	3.99	14.827
Lakes/Waterbodies	0.31	1.153
Cultivation	0.47	1.737
Alpine Area	8.70	32.387
Snow Covered Area	8.92	33.192
Glaciers	2.79	10.387
Scrub	0.74	2.764
Total	**100.00**	**372.057**

Table 4.2: Landuse Pattern in the Study Area

Landuse Categories	Area (ha)	Area in percentage
Dense Forest	8389.65	22.55
Open Forest	16289.89	43.79
Scrub	5424.13	14.58
Alpine Scrub	1185.70	3.19
Cultivation/ Settlements	2364.46	6.36
Barren/ Rockyland	2795.91	7.52
Moraines	746.40	2.01
Snow/ Glaciers	7.88	0.02
Total	**37204.02**	

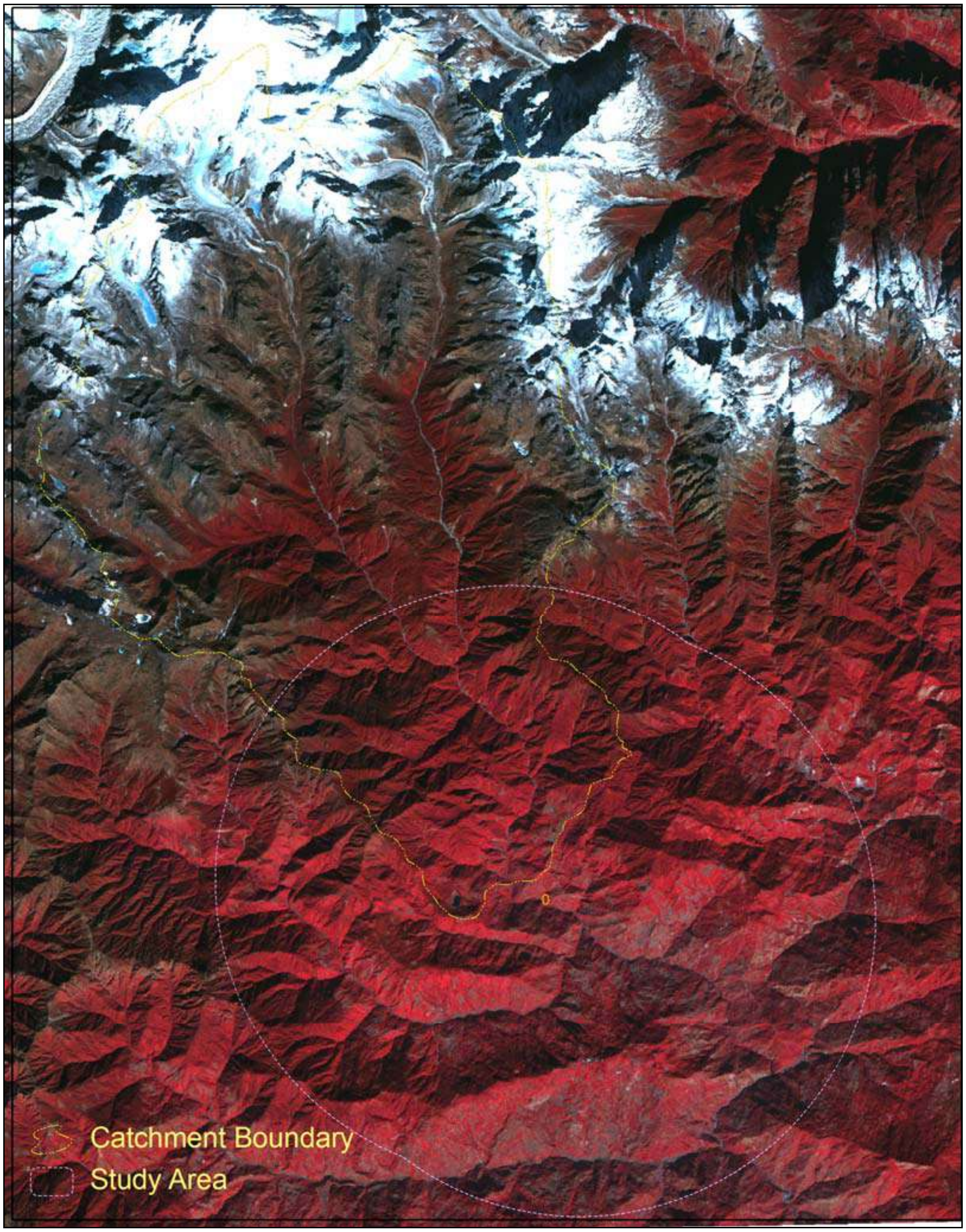


Fig.4.1: FCC of Ting Ting HE Project Aatchment Area and Study Area

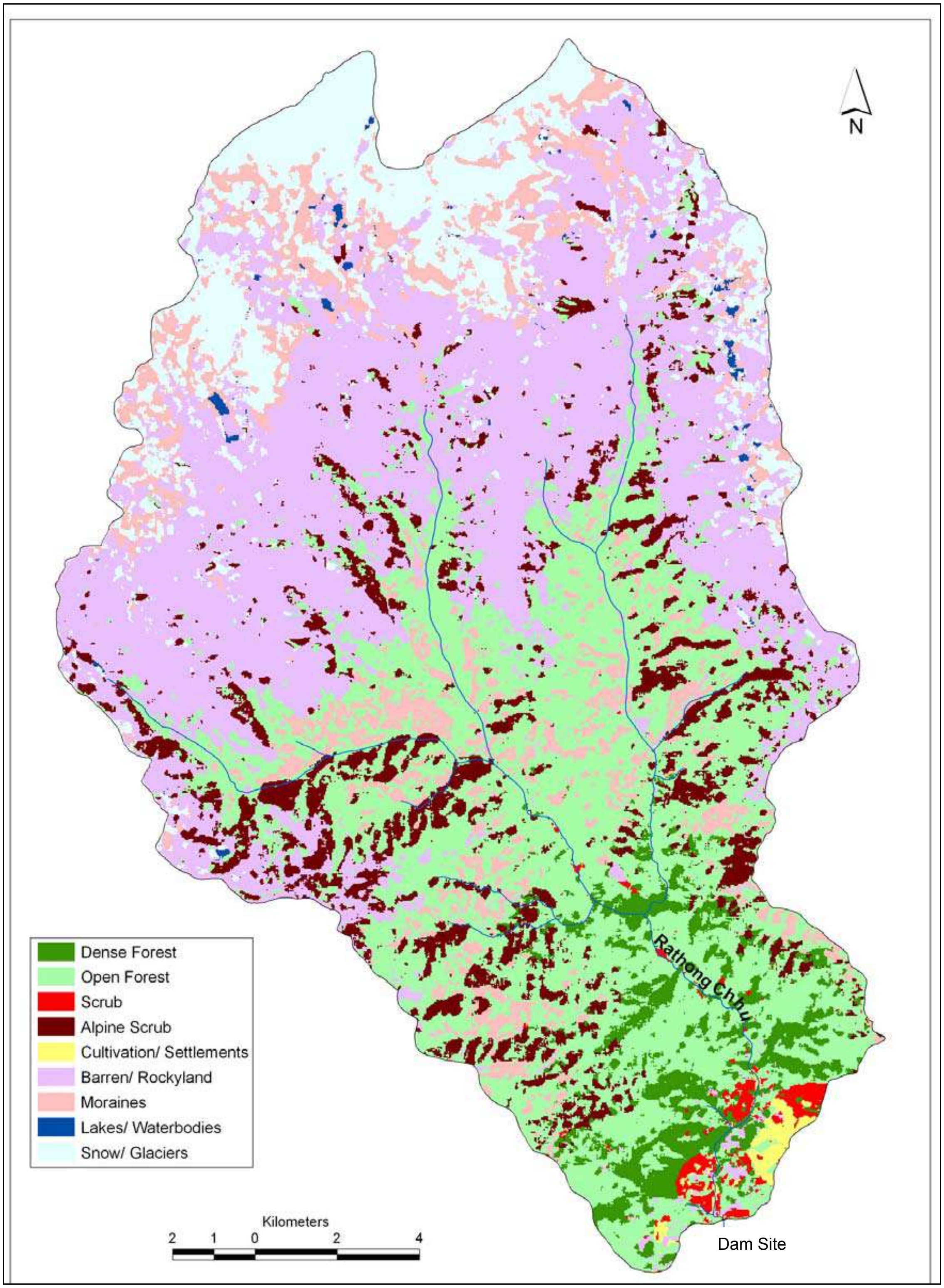


Fig.4.2: Land use/ land cover map of Ting Ting HE Project catchment area

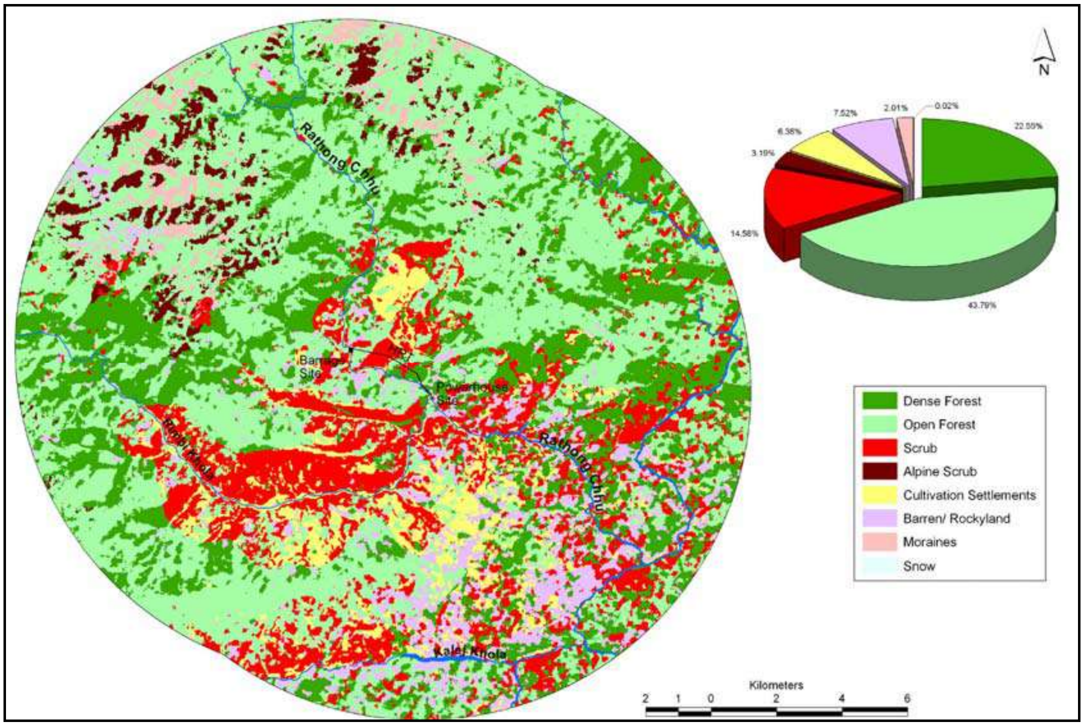


Fig.4.3: Land use/ land cover map of Ting Ting HE Project study area

4.2 FOREST TYPES

The forests present in the Tingting project study area and catchment 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.

3*C/C3 b* East Himalayan tropical moist deciduous forest

These low hill forests are found up to 900m elevation. 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, Mussaenda roxburghii, Rubus ellipticus* and *Saurauia roxburghii.* Epiphytes and climbers are abundant. Important twiners are *Bauhinia vahlii, Celastrus monospermus, 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 cylindrica, Phragmites australis, Saccharum spontaneum* and *Thysanolaena maxima.*

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 patches of Chir pine (*Pinus roxburghii*) are found as scattered trees. The forest of this group can be divided into two sub-types according to rainfall. Warm Broad leaved hill forest occurs at higher altitudes with low rainfall with an admixture of evergreen and deciduous species of genera like *Alnus, Lyonia* and *Quercus*. This type of forest is observed along Rimbi Khola and Likon Khola in the project area. Cool broad leaved forest is found above the warm broad leaved forests. This type of forest is more of 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 in and around Pelling. The drier type, cool broad leaved forest have abundance of evergreen species like *Lyonia*, *Quercus* and *Rhododendron*. This type of forest is found in upper reaches of Gyalzing, Pelling and Yuksom areas. Understorey is comprised of dense mixed bamboo 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 epiphytic ferns such as *Antrophym obovatum, Colysis pedunculata, Polypodioides lachnopus* and *Pyrrotia obovata*. Among climbers are species of *Cissus, Cryptolepis, Dioscorea, Parthenocissus, Piper, Raphidophora* and *Smilax.* Some weeds like *Ageratina adenophora* and *A. ligustrina* grow profusely at lower elevations of the forest.

11 B/C1 East Himalayan wet temperate forests

This type of forest is found between 1800m and 3000m elevations and is comprised of three sub-types varying with altitude. Towards higher altitudes they merge with sub-alpine forests. The forests of this group are comprised of following types:

11B/C1a Lauraceous forest

This type 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, Pelling and Yuksom 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 2100 m. 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 abundance of 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.

11B/C1b Buk oak forests

This forest sub-type 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 theaifolia*, 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 Gyalzing, Pelling and Yuksom 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*.

11B/C1c High level Oak forests

This forest type occurs between 2400m and 2700m elevations. Tree canopy is comprised of *Acer campbellii, Betula alnoides, Castanopsis hystrix, 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.

12/C3 East Himalayan Mixed coniferous forests

The forest of this type is dense evergreen, with predominance of oaks and rhododendrons. Hemlock (*Tsuga dumosa*) is found at the higher elevations as a dominant tree species. These forests are found commonly in and around 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 is found 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.

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 webbiana, Betula utilis, Magnolia campbellii, Rhododendron thomsonii, R. lanatum,* etc.

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, Rhododendron lanatum, R. thomsonii, R. anthopogon, Sorbus foliolosa* and *Viburnum nervosum*.

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.

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*.

Forest type map of the project catchment as well as project study area is given at Figures 4.4 and 4.5.

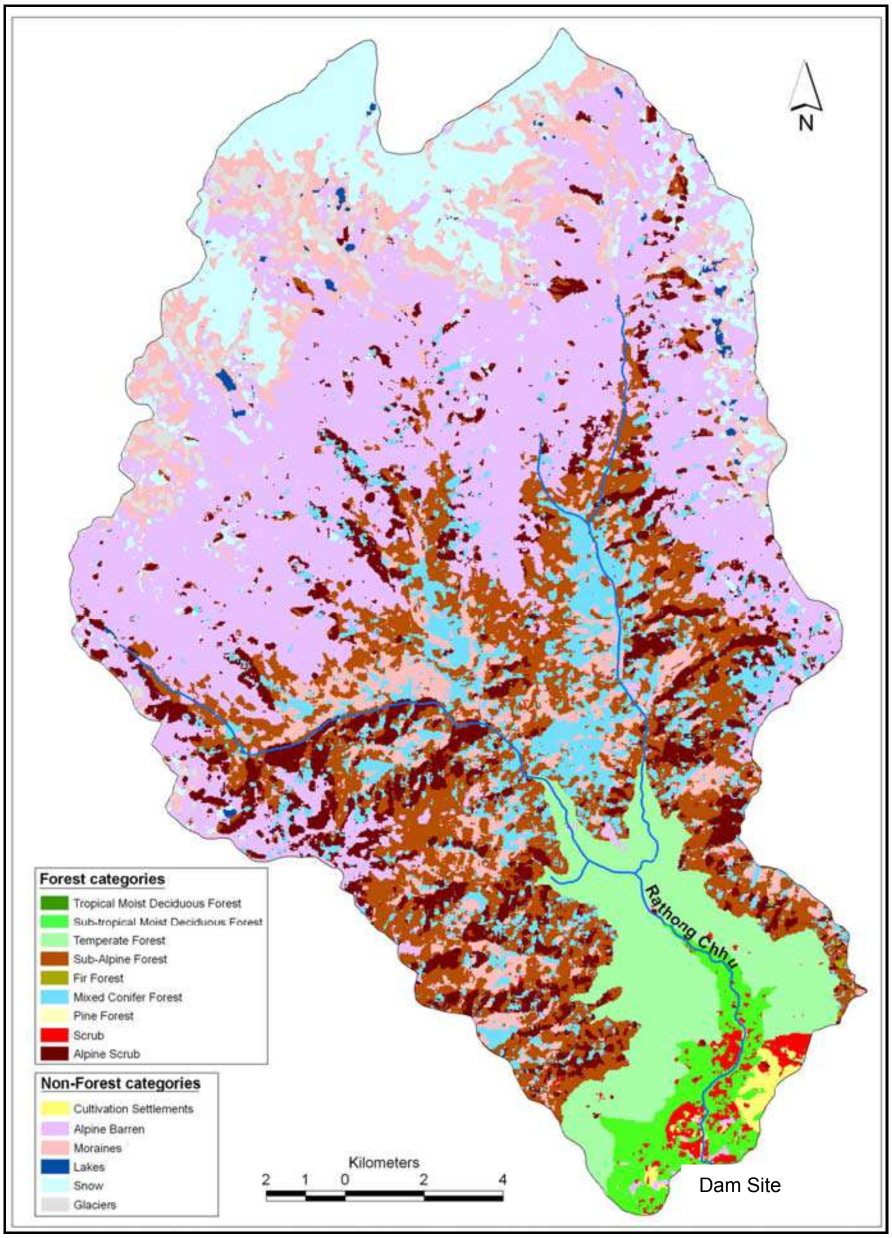


Fig.4.4: Forest type map of Ting Ting HE Project Catchment Area

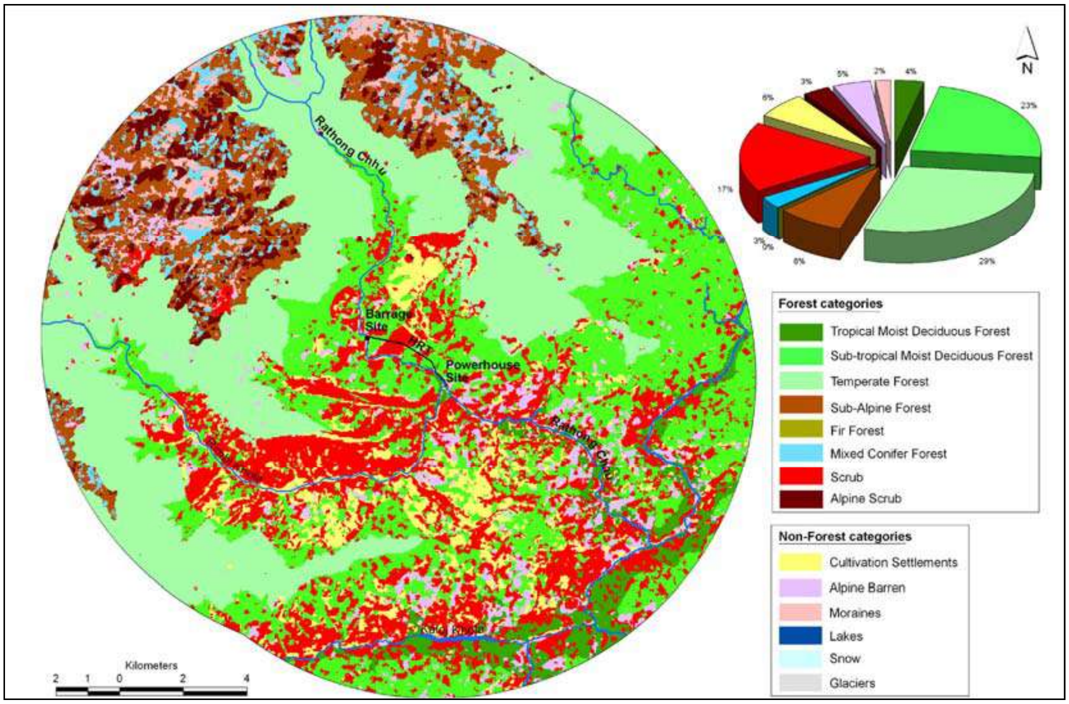


Fig.4.5: Forest type Map of Ting Ting HE Project Study Area

4.3 ECO-ZONES

West Sikkim is well known for its natural primary forests, wildlife and tourism. Khangchendongza Biosphere Reserve covers large area of the district and harbours a number of endemic and endangered species of the plants. As altitude changes, the vegetation changes from sub-tropical to sub-temperate and afterwards the vegetation becomes distinctly temperate. The primary forests are mostly found in upper slopes of the temperate zone. Agricultural activities are found in low altitude slopes of the area. The high altitude hills of the area have mixed coniferous forest, rhododendron forest, scrubs and pasture. The vegetation in each climatic zone is characterized by the seasonal precipitation, temperature regimes and humidity. Lower hills enjoy a tropical and sub-tropical climate, warm in winter, hot and very humid in summer. A generalized scheme of vegetation profile in the catchment of Tingting is presented in Fig.4.6. This figure clearly indicates that West Sikkim is dominated by tropical and sub-tropical broad-leaved hill forests in southern parts and dense to open mixed coniferous forests in the uphills and alpine scrubs and meadows towards higher reaches. Project study area lies in three different vegetational zones i.e. tropical, sub-tropical and warm temperate, based on the elevation and characterstics of vegetation.

4.3.1 Tropical Zone

The vegetation is constituted of moist deciduous broad-leaved forest with some riverine semi-evergreen elements and occurs up to 900m elevation. Climbers and epiphytes are abundant. Important tree associates include *Albizia chinensis, Bischofia javanica, Bombax ceiba, Canarium strictum, Duabanga grandiflora, Ficus semicordata, F. benghalensis, Gynocardia odorata, Rhus chinensis, Syzygium formosum, Terminalia myriocarpa* and *Toona ciliata.* Shrubs are *Boehmeria macrophylla, Brassiopsis mitis, Buddleja asiatica, Clerodendrum serratum, Leea aequata, Mussaenda roxburghii* and *Vitex negundo*. At some places in dry areas *Oroxylum indicum, Pandanus nepalensis, Phoenix humilis* can be seen thriving well in the forest. These forests occur in lower parts of Rangit valley and in Kalej Khola.

4.3.2 Sub-tropical Zone

The vegetation is dense mixed and found between 900m to 1800m elevations. These forests are characterised by mainly dominant evergreen tree species. Along the lower stretches of Kalej Khola, Rimbi Khola and Rathong Chhu, important tree associates include *Albizia chinensis, Alangium salviifolium, Bischofia javanica, Engelhardtia spicata, Erythrina arborescens, Ficus semicordata, Persea robusta, Rhus chinensis, Schima wallichii* and *Toona ciliata*. *Alnus nepalensis* often grows along streams and water courses in these forests. The undergrowth is scanty. *Boehmeria macrophylla, Celastrus monospermus, Dichroa febrifuga, Edgeworthia gardneri, Rhamnus nepalensis, Rubus ellipticus,* etc are found in the understorey. The climbers and epiphytes are abundant. *Cissampelos pareira, Cissus repens, Dioscorea bulbifera, Piper pedicellatum, Rhaphidophora glauca, Smilax aspera, Stephania elgans,* etc. are common twiners.

4.3.3 Temperate Zone

This zone falls between 1800 and 3300m altitudes and comprises two main vegetation types- temperate wet broad-leaved and mixed coniferous forests. Most part of the catchment in its upper reaches is covered with coniferous forests. Above 2700m *Tsuga dumosa* grows in abundance. *Abies densa* occurs in pure formations in the upper reaches of Tsoka and Bakhim areas. Other tree associates are *Acer campbellii, Castanopsis tribuloides, Lithocarpus pachyphylla, Populus ciliata, Prunus nepalensis, Quercus lamellosa* and *Rhododendron arboreum*. These forests are thick and have enough amount of moisture for the ground flora. Besides, dwarf bamboos (*Thamnocalamus aristatus*) other shrubs such as *Berberis umbellata, Deutzia compacta, Pieris formosa, Rhododendron campanulatum* and *Viburnum erubescenes* form understorey.

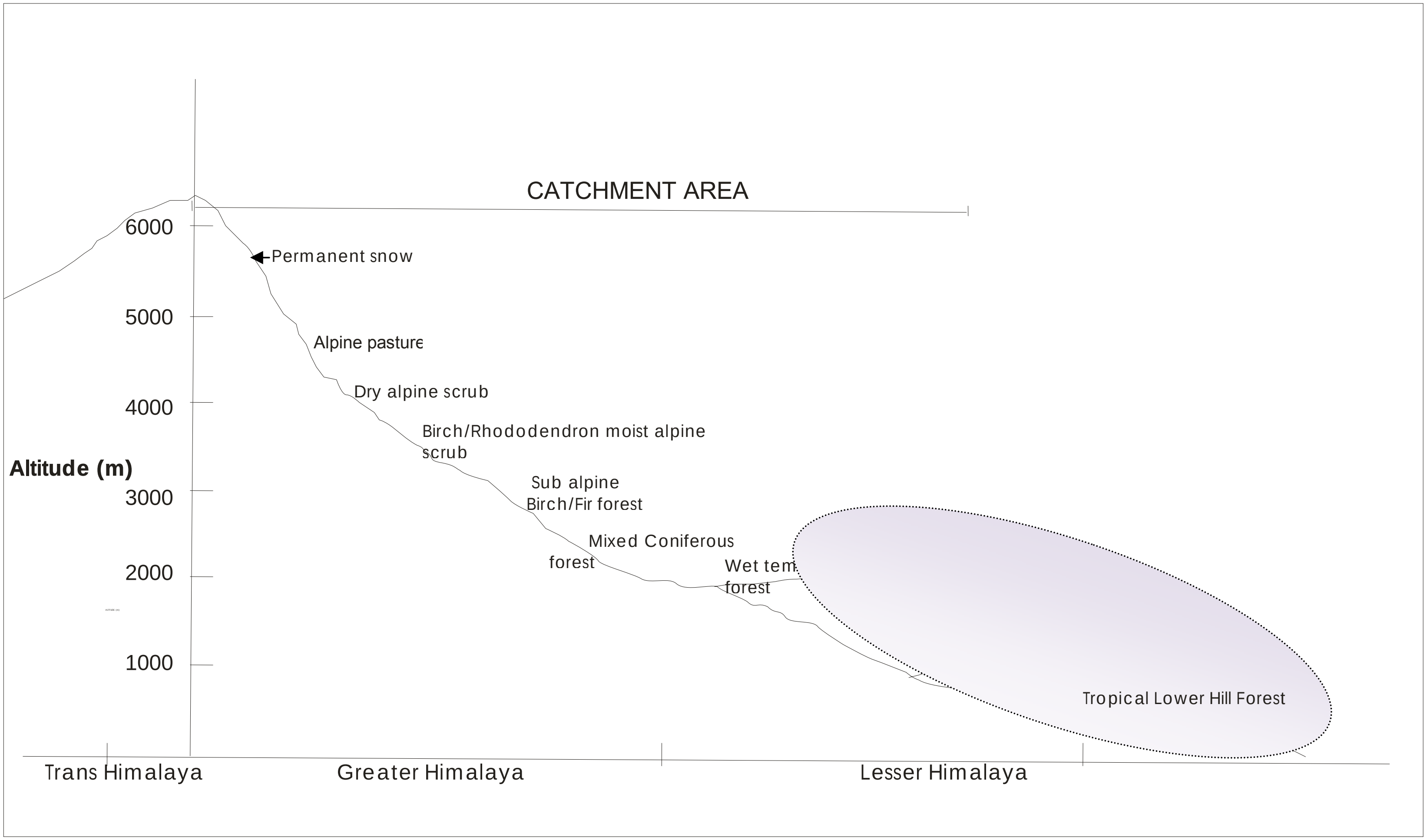


Fig.4.6: Vegetation profile along the altitude in Ting Ting HE project area

4.3.4 Sub-alpine and Alpine Zone

The sub-alpine vegetation consists of some stunted trees of birch, juniper, fir and rhododendrons above 3,300m elevation. Other woody associates are species of *Cotoneaster, Gaultheria, Rosa, Salix, Viburnum*, etc. In open meadows, many herbaceous species are represented by the genera like *Anemone, Arenaria, Corydalis, Fritillaria, Gentiana, Meconopsis, Pedicularis, Primula, Ranunculus* and *Saxifraga.*

The entire vegetation of the catchment is being affected by clear felling, road construction, grazing, trekking, etc. The various types of biotic influences and edaphic conditions have lead to the preponderance of conifer or mixed conifer communities in the uphill forests. In the middle hills *Quercus lamellosa* is the climax. *Lyonia ovalifolia* and *Rhododendron arboreum* have persisted because of poor fuel value and being non-edible to cattle. At lower altitude much of the forest has been cleared for conversion to agricultural fields and survive as open mixed deciduous forest. Areas of Rimbi, Gyalzing and along Kalej Khola are highly disturbed in West Sikkim. The forests get degraded in all the stages of their succession, through biotic influences such as lopping for fodder, fuel, grazing, unregulated and non-scientific felling for timber, etc.

4.4 VEGETATION COMPOSITION

The botanical explorations and floristic studies in Sikkim dates back to the early nineteenth century since Griffith's visit in 1843. The famous botanist J. D. Hooker visited Sikkim during 1848-49 and made one of the most comprehensive and descriptive account of the flowering plants of most parts of the Sikkim. Subsequently, numerous botanists such as G. King, C.B. Clarke, G.H. Cave, W.W. Smith and J.M. Cowan visited during later part of the 19^{th} century and early 20^{th} century and gave an account of the floristic wealth of Sikkim. In the post 1940 period, little collection was made except for K.P. Biswas, B.N. Ghosh, R.S. Rao, B.D. Sharma, B.Ghosh, Hara *et.al*. With establishment of the Sikkim Himalayan Circle (SHC) of the Botanical Survey of India at Gangtok in December 1979, the exploration work gained momentum. In the post 1979 period, P.K. Hajra, P. Chakaraworty, B. Krishna, A.K. Verma, D.C.S. Raju, R.C. Srivastava, S. Kumar, M. Sanjappa, D. G. Long collected plants from different areas of the state including the Dzongu area. In recent times the floristic information has been updated by Grierson & Long (1983-1991) Hajra & Verma (1996), Srivastava (1998), Rai (2002), Singh & Chauhan (2002), Singh & Dash (2002), Subba (2002) and CISMHE (2007).

4.4.1 Taxonomic Diversity

Ting Ting H.E. Project area extends from Legship village near the confluence of Rathong Chhu with Rangit river up to Yuksom village and beyond in Buffer zone-IV of Khangchendzonga Biosphere Reserve in the valley of Rathong Chhu. In all 457 species of angiosperms and gymnosperms were recorded from Tingting study area. Out of estimated 17,500 flowering plant species in India and nearly 4,500 species of flowering plants in Sikkim Himalaya (Mudgal & Hajra, 1997; Singh & Chauhan, 1999), about 450 species of angiosperms were recorded from Ting Ting H.E. project study area in the region between confluence of Rathong Chhu with Rangit river and Rimbi Khola confluence with Rathong Chhu to Yuksom and Yuksom to Tsoka (along Rathong Chhu and Prek Chhu) in West Sikkim (see Annexure-V). In all 110 flowering plant families are represented in this area of which 95 are dicots, 15 are monocots. The dicotyledons are represented by 315 species belonging to 231 genera and 95 families, while the monocotyledons are represented by 15 families, 84 genera and 135 species. Gymnosperms are represented by 3 families, 4 genera and 5 species. The ratio of monocot to dicot species is 1:2.33 (135 monocots and 315 dicots). For monocots, family to genera, family to species and genera to species ratios are 1: 5.6, 1: 9.0 and 1: 1.61, respectively. The genera to species ratio for this region (1:1.72) is lower in comparison to the corresponding ratio 1:13 for the world and 1: 6 for India (Raizada and Saxena, 1978; Mudgal & Hajra, 1999).

Poaceae with 30 genera and 46 species and Asteraceae with 20 genera and 28 species are the largest families of monocots and dicots, respectively. Among Gymnosperms, Pinaceae is the most dominant family represented by 3 genera and 3 species. Among dominant genera represented by 5 or more species in the project area are *Carex* (8), *Desmodium* (5), *Ficus* (5), *Rosa* (5) and *Rubus* (6). These species were recorded during the field visits conducted during from Jan, 2008 to November, 2008. For additional information on identification and nomenclatural changes recent books, research papers, and monographs were consulted.

4.4.2 Physiognomic Diversity

The diversity of vegetation in the project study area 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. Fabaceae for example was represented by *Parochetus communis* (herb), *Desmodium triflorum* (shrub), *Shuteria hirsuta* (climber) and *Erythrina arborescens* (tree). On the contrary, some of the families such as

Fagaceae, Lauraceae, Magnoliaceae, Meliaceae, Theaceae, etc were represented by tree species only. Araliaceae, Berberidaceae, Caprifoliaceae, Ericaceae, Leeaceae, Rhamnaceae are some of the families which were mostly comprised of shrubby species. Members of Cucurbitaceae, Dioscoreaceae, Menispermaceae and Vitaceae were exclusively climbers. Herbaceous species formed the bulk of flora (60.17%) followed by shrubs (17.50%), trees (16.63 %), climbers (5.68%) and parasites (0.65%).

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

4.4.3 Parasitic Flora

During the survey and collection in the different areas in the project, few parasitic plant species were observed. These plant species belonged to families Cuscutaceae and Loranthaceae. *Cuscuta reflexa* was found growing on wide range of hosts in the area. *Loranthus odoratus* and *Scurulla elata* were observed parasitic on *Lithocarpus elegans* and *Quercus leucotrichophora*.

4.4.4 Epiphytes

Epiphytes often grow attached to the trunks and branches of forest trees. Some flowering plants and ferns form this group. 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 covering large space on the bark of the trees in the forest.

4.4.5 Orchids

An inventory of orchids occurring in the project area was prepared. Total of 15 species of orchids were recorded from the area and list of the same has been given in Annexure-V.

4.4.6 Bamboos

Among the bamboos 5 diiferent species were recorded from the study area. A list of the same has been given in Annexure-V under Poaceae.

4. 5 ECONOMICALLY IMPORTANT PLANTS

The economic dependence of local people is essentially on the plant resources growing in the catchment area. These include plants of medicinal value, food plants, fodder, fuel wood and timber. The usage of various plant species by the local inhabitants varies with the altitude and availability of resources in the surrounding areas. A comprehensive account of these plant resources given below:

Medicinal Plants

The tribes are mainly Sikkimense and Bhutias in the area with their different system of practice. The practice of using herbs is broadly of three types i.e. the Nepalese, Lepcha and Tibetan traditional systems (FRLHT, 2003). There are a large number of traditional healers – *Baidya, Dhami* and *Jhankri* in the Nepali community, *Amji* and *Pow* in the Bhutia community and *Bongthing* in the Lepcha community. For these powerful faith healers, '*jhar phuk'* is the key word and the first step in an interestingly complicated but expensive course of treatment. Earlier the traditional healers were the only medical practitioners in the village. However with the creation of hospitals and improvement in the literacy rate allopathic treatment started getting increasingly accepted by the villagers. This has led to a greater recourse to allopathic government hospitals namely the PHCs and PHSCs.

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 angustifolia,* etc are important medicinal plants of high altitude zones. These plants are used internally for treating stomachic diarrhoea, dysentery, cough, cold, fever and asthma and externally for rheumatism, skin diseases, cuts, boils and injuries. Sikkim has the potential to become a major supplier of 'crude-drugs' for the pharmaceutical industry, a potentially major source of revenue and critical public goods.

Some of the wild plant species used locally for medicinal purposes are depleting from the area due to many anthropogenic activities. The list of some medicinally important plant species found in the project is given in Table 4.3.

The Govt. of Sikkim, Dept. of Forests, Environment & Wildlife Department, Gangtok has created a State Medicinal Plants Board vide Notification No. 100/E&WD dated 10.6.2002. The main function of the State Medicinal Plants Board is co-ordination with Departments / Organisations working in the state for development of medicinal plants in general. However some of the specific activity fields are listed below:

Table: 4.3: Some important medicinal plant species recorded from the study area

	Botanical Name	Family	Local Name	Altitude (m)	Plant part used
1	*Cissampelos pareira*	Menispermaceae	Akanadu	Up to 1000	Leaf
2	*Lyonia ovalifolia*	Ericaceae	Anyar	1000-3000	Leaf
3	*Achyranthes aspera*	Amaranthaceae	Chir-chita	Up to 2400	Whole plant
4	*Aconogonum molle*	Polygonaceae	Thotne	Lower hill forest	Young Shoots
5	*Acorus calamus*	Acoraceae	Bojho	1000-2000	Rhizome
6	*Ageratum conyzoides*	Asteraceae	Osari	Up to 2600	Leaves
7	*Alnus nepalensis*	Betulaceae	Utis	1000-2600	Bark
8	*Bauhinia purpurea*	Caesalpiniaceae	Tanki	Up to 1500	Flower bud
9	*Bischofia javanica*	Bischofiaceae	Kainjal	Middle hill forest	Leaves & bark
10	*Buddleja asiatica*	Loganiaceae	Bhinsenpatee	Up to 1200	Leaves, flower, stem
11	*Centella asiatica*	Apiaceae	Gora taprey	Upper hill forest	Leaf
12	*Cinnamomum tamala*	Lauraceae	Tejpata	Up to 1600	Leaves
13	*Clematis buchnaniana*	Ranunculaceae	Pinaasey lahara	Lower hill forest	Root
14	*Costus speciosus*	Zingiberaceae	Keu	Up to 1500	Stem
15	*Datura stramonium*	Solanaceae	Datura	Up to 1500	Seed
16	*Dichroa febrifuga*	Hydrangeaceae	Basak	Middle hill up to 1800	Root, leaves
17	*Dioscerea bulbifora*	Dioscoreaceae	Gittha	Up to 1200	Tuber
18	*Edgeworthia gardeneri*	Thymelaeaceae	Argaily	1200-2200	Shrub
19	*Engelhardtia spicata*	Juglandaceae	Silapoma	500-2100	Bark
20	*Ficus religiosa*	Moraceae	Peepal	Up to 1200	Whole plant
21	*Garuga pinnata*	Burseraceae	Dubdabey	Lower hill forest	Bark, root
22	*Gynocardia odorata*	Flacourticeae	Gantey	Up to 1200	Seed
23	*Houttuynia cordata*	Saururaceae	Nombaring	1000-2400	Leaves
24	*Juglans regia*	Juglandaceae	Okhar	Up to2300	Bark
25	*Oroxylum indicum*	Bignoniaceae	Totola	Lower hill up to 700	Bark, root
26	*Ostodes paniculata*	Euphorbiaceae	Byapari	Up to 1000	Leaves
27	*Rubia cordifolia*	Rubiaceae	Majito	1200-2100	Root, fruits
28	*Rubus ellipticus*	Rosaceae	Aeiselu	Middle hill forest	Root, fruits
29	*Schima wallichii*	Theaceae	Chilaune	300-2000	Stem
30	*Thysanolaena latifolia*	Poaceae	Amliso	Up to 1800	Roots
31	*Woodfordia fruticosa*	Lythraceae	Dhayeroo	Lower hill forest	Flower, bark
32	*Zingiber officinale*	Zingiberaceae	Adrak	Up to 1200	Rhizome

- Advise concerned Departments/ Organisations on matters relating to schemes and programme for development of medicinal plants
- Provide guidance in the formulation of proposals, schemes and programmes etc. to be taken up by agencies having access for cultivation and infrastructure for collection, storage and transportation of medicinal plants
- Identification, inventorisation and quantification of medicinal plants
- Promotion of *ex situ* / *in situ* cultivation and conservation of medicinal plants
- Promotion of co-operative efforts among collectors and growers and assisting them to transport and market their produce effectively
- Setting up of data-base system for inventorisation, dissemination of information and facilitate the prevention of Patents being obtained for medicinal use of plants which are in the public domain.

The development of medicinal plants in the project area under the Biodiversity Conservation Plan for the proposed project will be implemented under the guidance of State Medicinal Plants Board.

Food Plants

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), *Girardinia 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), *Tetradium fraxinifolium* (Khankapa), etc.

Fodder Plants

The human population of the catchment depends essentially on naturally growing trees, shrubs, herbs and grasses for the fodder requirements of their cattle and livestock. 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, Acer, Sorbus* and small bamboos (*Thamnocalamus aristatus*) are used for fodder.

Timber Trees and Fuelwood

At lower elevations, the wood used for timber includes *Alnus nepalensis*, *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, rhododendrons and conifers are used for the timber and fuel wood purposes. Important timber yielding trees include *Abies densa, Juglans regia, Lithocarpus elegans, Machilus* sp., *Quercus lamellosa* and *Tsuga dumosa*.

Plants of Religious Significance

Artemisia nilagirica C.B. Clarke (Asteraceae)
Local Name: Tuk-ril-koong
The Lepchas worship the twigs of this plant in every religious ceremony.
Lycopodium japonicum Thunb. (Lycopodiaceae)
Local Name: Nagbelli
The 'Bungthing' perform rituals with this plant. They have the belief due to this plant persons attacked by demon can be removed.
Thysanolaena maxima (Roxb.) Kurz. (Poaceae)
Local Name: Pusore
Leaf (teeth marked) used in performing religious ceremony.

Miscellaneous Uses

Some of the plant species in the project area are used by the local inhabitants for various purposes. A list of some commonly occurring plant species and their miscellaneous uses are given in Table 4.4.

Table 4.4: List of commonly used plant species for miscellaneous purposes

	Plant species	Miscellaneous uses
1.	*Aconogonum molle*	Relished as vegetable and pickle
2.	*Acorus calamus*	Rhizome paste is useful for treating pigs itching
3.	*Artemisia indica*	Leaves and flowering tops used for flavouring alcoholic drinks
4.	*Cardamine hirsuta*	Leaves are eaten as vegetables
5.	*Dendrocalamus hamiltonii*	Young culms are used for pickles and vegetables.
6.	*Edgeworthia gardeneri*	As a fish poison
7.	*Gynocardia odorata*	Pulp of the fruit is eaten after boiling.
8.	*Juglans regia*	Twigs and barks are used for tooth cleaning and insecticidal purposes, as a dye
9.	*Macaranga denticulata*	Foliage used as a cattle fodder
10.	*Maesa chisia*	Young shoots and fruits are eaten

11.	*Oroxylum indicum*	Seeds used in ceremonial worship, also eaten as vegetable
12.	*Terminalia myriocarpa*	Planted for landscaping
13.	*Thysanolaena latifolia*	Flowering culms are used for broom preparation

4.6 VEGETATION COMPOSITION IN AND AROUND THE PROJECT AREA

4.6.1 Submergence Area

The dam site is located upstream of Tingting village. The area in the vicinity of proposed project comprised of fairly dense mixed sub-tropical wet hill forest. The vegetation on both the bank of Rathong Chhu is comprised of patches of open to dense canopy forests interspersed with agricultural fields. *Alnus nepalensis* and *Schima wallichii* are the predominant tree species in the area. Other prominent trees are: *Albizia chinensis, Bischofia javanica, Engelhardtia spicata, Ficus semicordata, Macaranga denticulata, Grewia tiliaefolia, Castanopsis hystrix, Schima wallichii, Alangium chinense,* etc. Common shrubs are *Oxytropis paniculata, Dendrocalamus hamiltonii, Artemisia indica, Saurauia roxburghii, Solanum indicum, Triumfetta rhomboidea, Rubus ellipticus* and *Musa* sp. etc. Herbaceous flora was represented by some grasses and weeds. Terrestrial pteidophytes are represented by species of *Athyrium, Pteris* and *Selaginella*. The herbaceous flora include: *Ageratum conyzoides, Aconogonum molle, Bidens bipinnatus, Lecanthus peduncularis, Oxalis corniculata, Pouzolzia sanguinea, Pilea scripta, Pogonatherum paniceum* and *Solanum nigrum.*

4.6.2 Power House site

Dense to open canopy Tropical moist deciduous forest occurs in the vicinity of powerhouse area. Important trees in the forest canopy include *Albizia chinensis, Alnus nepalensis, Engelhardtia spicata, Schima wallichii,* etc. *Dendrocalamus hamiltonii, Boehmeria macrophylla, Oxytropis paniculata, Rubus ellipticus,* etc. are the most commonly found shrubs in this area. Among the common herbs are *Ageratum conyzoides, Bidens bipinnatus, Dichanthium annulatum, Lecanthus peduncularis, Paspalum paspaloides, Pilea scripta, Pogonatherum paniceum* and *Pouzolzia sanguine.*

4.7 COMMUNITY STRUCTURE

In order to understand the community structure, vegetation sampling was done at different locations in the project area. The sampling in the study area was conducted at least 8 locations viz. S1-Dam site (Right bank of Rathong Chhu), S2-Submergence Area, S3-Powerhouse (Right bank of Rathong Chhu), S4-Downstream of powerhouse, S5-Powerhouse (Right bank of Rathong Chhu), S6-Near powerhouse, S7-Darap area in Rimbi Khola catchment and S8-Rimbi Khola catchment (Table 4.5). The sampling was done in three different seasons i.e. Monsoon, Post-monsoon and Winters.

4.7.1 Methodology

For sampling various strata of vegetation, nested belt transect sampling mode was followed. For sampling 10m x 1m line transects for trees were laid in increasing altitudinal gradient on each of the sampling sites. Within each transect for trees, 5m x 1m nested transects/ quadrats for shrubs were laid. Similarly 1m x 1m quadrats were laid for herbs at all the sampling sites. The number of quadrats used for the study of different vegetation components at each sampling site is given in table below.

Number of Transects/Quadrats used for Vegetation Structure

Sampling Sites	No. of transects/ Quadrats Studied		
	Trees	Shrubs	Herbs
Dam site (Right bank of Rathong Chhu)	10	10	20
Submergence Area	10	10	20
Powerhouse (Right bank of Rathong Chhu)	10	10	20
Downstream of powerhouse	10	10	20
Powerhouse (Right bank of Rathong Chhu)	10	10	20
Near powerhouse	10	10	20
Darap area in Rimbi catchment	10	10	20
Rimbi Khola catchment	10	10	20

During the survey, number of plants of different species in each quadrat was identified and counted. The CBH (Circumference at Breast Height) of all trees with height more than 8 m was measured.

Based on the quadrat data, frequency, density and cover (basal area) of each species were calculated.

a) Importance Value Index (IVI)

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

The data on vegetation were quantitatively analysed for abundance, density, frequency (Curtis & McIntosh, 1950). The tree basal area was also determined as an index of dominance as:

$$\text{Basal area} = \pi r^2 = C^2/4\pi$$

Where C= Circumference at breast height

r = Radius

b) Shanon-Wiener Diversity Index

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

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

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

c) Evenness Index

The Evenness Index was calculated as follows:

Evenness index (E) = H/ log (S),

Where H = Shanon Weaver Diversity Index

S = No. of species

d) Simpson's Diversity Index

Simpson's diversity was calculated as follows:

Simpson Diversity Index (D): $D = \frac{\Sigma n (n - 1)}{N (N - 1)}$

where N = the total number of individuals of all species *and*

n = the total number of individuals of a particular species

Table 4.5: Characterstics of sampling locations

Site	Location	Altitude (m)	Forest Type
S1	Dam site (Right bank of Rathong Chhu)	1400	Sub-tropical wet hill
S2	Submergence Area	1150	-do-
S3	Powerhouse (Right bank of Rathong Chhu)	950	Tropical
S4	Downstream of powerhouse	700-900	Tropical
S5	Powerhouse (Right bank of Rathong Chhu)	950	Sub-tropical wet hill
S6	Near powerhouse	700-900	Tropical
S7	Darap area in Rimbi catchment	1300	Sub-tropical wet hill
S8	Rimbi Khola catchment	1300	Sub-tropical wet hill

4.7.2 Density & Distribution

The maximum number of tree species were recorded at Site-IV (downstream of proposed powerhouse site) while minimum number was recorded at Site-II i.e. in the submergence area (Table 4.6). Maximum numbers of herbaceous species were recorded from Site-III (Near Powerhouse) (see Table 4.7).

Alnus nepalensis was the most dominant tree species at Sites-1, 2 & 3 whereas it was *Schima wallichii* (Tables 4.6 & 4.7; Fig.4.7 & 4.8) which was dominant tree at sites S4 & S6. *Albizia chinensis, Ficus auriculata* and *Juglans regia* were the predominant trees at Sites S5 & S8 and S7, respectively.

Dendrocalamus hamiltonii was most dominant shrub at all the sampling sites except at site S6 where another bamboo genus *Bambusa* sp. Is dominant (Tables 4.6 & 4.7; Fig.4.7)

Amongst the herbs *Ageratum conyzoides* is the most common and dominant species at sites S1, S7 and S8 (Tables 4.5 & 4.6; Fig.4.3)

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).

Table: 4.6: Ecological attributes of various tree and shrub plant species

SITE-S1

S. No.	Species Name	Density per ha	Frequency (%)	Basal Area (Sq m/ha)
	TREES			
1	*Engelhardtia spicata*	40	30	0.606
2	*Schima wallichi*	120	20	2.497
3	*Alnus nepalensis*	300	50	81.020
4	*Albizia chinensis*	10	10	0.067
5	*Ficus semicordata*	20	10	0.414
6	*Grewia tiliaefolia*	40	30	0.341
7	*Castanopsis hystrix*	10	10	0.124
8	*Lithocarpus elegans*	20	10	0.440
9	*Terminalia myriocarpa*	10	10	0.048
10	*Alangium chinense*	20	10	0.034
11	*Bombax ceiba*	10	10	0.124
12	*Castanea sativa*	20	10	0.105
13	*Macaranga denticulata*	60	30	1.072
SHRUBS				
1	*Eupatorium cannabinum*	1400	20	0.2411
2	*Eupatorium odoratum*	280	5	0.0161
3	*Boehmeria platyphylla*	520	10	0.0232
4	*Musa* sp.	60	5	0.0963
5	*Artemisia indica*	260	10	0.0154
6	*Oxytropis paniculata*	480	20	0.1651
7	*Dendrocalamus hamiltoni*	280	5	1.6123

8	*Saurauia roxburghii*	40	5	0.0026
9	*Rubus ellipticus*	280	15	0.0413
10	*Melastoma* sp.	300	15	0.0259
11	*Debregeasia longifolia*	160	15	0.0154
12	*Triumfetta rhomboidea*	200	15	0.0109
13	*Anisomeles indica*	60	5	0.0008

SITE-S2

S. No.	Species Name	Density/ ha	Frequency (%)	Basal Area (Sq m/ha)
TREES				
1	*Alnus nepalensis*	280	50	50.160
2	*Macaranga denticulata*	20	10	0.041
3	*Schima wallichii*	70	20	2.963
4	*Albizia chinensis*	10	10	0.076
5	*Engelhardtia spicata*	10	10	0.115
SHRUBS				
1	*Grewia vestita*	1020	10	0.0207
2	*Oxytropis paniculata*	2240	25	0.0999
3	*Rubus ellipticus*	1120	10	0.0250
4	*Artemisia indica*	2060	25	0.0845
5	*Eupatorium odoratum*	4580	25	0.4175
6	*Solanum indicum*	560	5	0.0062
7	*Musa* sp.	2960	10	0.1744
8	*Dendrocalamus hamiltonii*	9400	10	1.7588
9	*Indigofera heterantha*	440	10	0.0039
10	*Eupatorium cannabinum*	440	5	0.0039

SITE-S3

S. No.	Species Name	Density per ha	Frequency (%)	Basal Area (Sq m/ha)
TREES				
1	*Ficus semicordata*	20	20	0.290
2	*Schima wallichi*	70	20	2.963
3	*Mangifera indica*	40	10	4.844
4	*Toona ciliata*	10	10	0.062
5	*Engelhardtia spicata*	100	60	5.752
6	*Castanopsis hystrix*	60	20	3.210
7	*Rhus chinensis*	10	10	0.048
8	*Bauhinia purpurea*	40	30	0.538
9	*Alnus nepalensis*	160	30	13.045
10	*Macaranga denticulata*	20	10	0.037
11	*Albizia chinensis*	10	10	0.062
12	*Lithocarpus elegans*	10	10	0.156
13	*Terminalia myriocarpa*	10	10	0.048
14	*Alangium chinense*	40	10	0.920
SHRUBS				
1	*Boehmeria macrophylla*	2000	20	0.0796
2	*Dendrocalamus hamiltoni*	21100	15	8.8617
3	*Eupatorium cannabinum*	5300	45	0.5591
4	*Eupatorium odoratum*	940	5	0.0176
5	*Flemingia strobilifera*	560	5	0.0062
6	*Inula cappa*	2180	20	0.0946
7	*Artemisia indica*	580	15	0.0067
8	*Triumfetta rhomboidea*	840	5	0.0140
9	*Rubus ellipticus*	240	5	0.0011

S. No.	Species Name	Density per ha	Frequency (%)	Basal Area (Sq m/ha)
10	*Indigofera heterantha*	760	5	0.0115
11	*Oxytropis paniculata*	2800	20	0.1561
12	*Trevesia palmata*	420	5	0.0035
13	*Pandanus nepalensis*	360	5	0.0026
14	*Debregeasia longifolia*	920	15	0.0168
15	*Musa* sp.	4900	10	0.4779
16	*Girardinia diversifolia*	140	5	0.0004
17	*Erythrina arborescens*	280	5	0.0016
18	*Woodfordia fruticosa*	240	5	0.0011
19	*Callicarpa vestita*	480	5	0.0046
20	*Urtica dioica*	360	5	0.0026

SITE-S4

S. No.	Species Name	Density per ha	Frequency (%)	Basal Area (Sq m/ha)
TREES				
1	*Lithocarpus elegans*	30	20	0.378
2	*Grewia tiliaefolia*	10	10	0.062
3	*Engelhardtia spicata*	10	10	0.072
4	*Castanopsis hystrix*	80	40	3.011
5	*Schima wallichii*	100	40	12.203
6	*Albizia chinensis*	10	10	0.067
7	*Terminalia myriocarpa*	10	10	0.351
8	*Bauhinia purpurea*	50	30	0.568
9	*Bombax ceiba*	10	10	0.089
10	*Duabanga grandiflora*	20	20	0.392
11	*Rhus chinensis*	10	10	0.103
12	*Alnus nepalensis*	40	10	0.841
13	*Alangium chinense*	10	10	0.037
14	*Emblica officinalis*	10	10	0.036
15	*Mallotus philippensis*	20	10	0.034
SHRUBS				
1	*Triumfetta rhomboidea*	200	10	0.0029
2	*Solanum indicum*	80	5	0.0020
3	*Urtica dioica*	40	5	0.0004
4	*Boehmeria macrophylla*	1480	45	0.3249
5	*Eupatorium odoratum*	1280	40	0.3121
6	*Eupatorium cannabinum*	200	5	0.0103
7	*Musa* sp.	40	5	0.0115
8	*Debregeasia longifolia*	180	15	0.0176
9	*Oxytropis paniculata*	640	35	0.2466
10	*Rubus ellipticus*	160	15	0.0077
11	*Datura stramomium*	20	5	0.0003
12	*Inula cappa*	140	15	0.0046
13	*Dendrocalamus hamiltonii*	200	5	0.9204
14	*Melastoma* sp.	80	5	0.0018
15	*Artemisia indica*	80	10	0.0022
16	*Smilax aspera*	60	10	0.0008
17	*Callicarpa vestita*	100	10	0.0154
18	*Indigofera heterantha*	100	5	0.0168
19	*Flemingia strobilifera*	60	5	0.0018

SITE-S5

S. No.	Species Name	Density/ ha	Frequency (%)	Basal Area (Sq m/ha)
TREES				
1	*Albizia chinensis*	70	40	4.575
2	*Alangium chinense*	10	10	0.034
3	*Bauhinia purpurea*	40	30	0.358
4	*Mangifera indica*	10	10	0.826
5	*Artocarpous chaplasa*	20	10	0.199
6	*Toona ciliata*	20	10	0.034
7	*Grewia tiliaefolia*	30	10	0.351
8	*Castanopsis hystrix*	30	10	0.765
9	*Erythrina indica*	10	10	0.034
10	*Lithocarpus elegans*	20	10	0.054
11	*Schima wallichii*	10	10	0.046
12	*Rhus chinensis*	10	10	0.051
SHRUBS				
1	*Cannabis sativa*	560	5	0.0062
2	*Urtica dioica*	880	15	0.0154
3	*Artemisia indica*	3200	35	0.2038
4	*Cassia occidentalis*	480	10	0.0046
5	*Bambusa* sp.	6400	5	0.8153
6	*Eupatorium odoratum*	1280	10	0.0326
7	*Buddleja asiatica*	1080	10	0.0232
8	*Debregeasia longifolia*	480	10	0.0046
9	*Melastoma* sp.	440	5	0.0039
10	*Oxytropis paniculata*	1880	20	0.0704
11	*Boehmeria macrophylla*	1240	15	0.0306
12	*Rubus ellipticus*	500	10	0.0050
13	*Musa* sp.	1480	10	0.0436
14	*Triumfetta rhomboidea*	460	10	0.0042
15	*Callicarpa vestita*	440	5	0.0039
16	*Sida cordifolia*	280	5	0.0016
17	*Dendrocalamus hamiltonii*	6400	5	0.8153

SITE-S6

S. No.	Species Name	Density/ ha	Frequency (%)	Basal Area (Sq m/ha)
TREES				
1	*Castanopsis hystrix*	120	50	6.406
2	*Schima wallichi*	170	50	15.762
3	*Mallotus philippensis*	20	10	0.034
4	*Emblica officinalis*	10	10	0.036
5	*Bauhinia purpurea*	20	20	0.407
6	*Duabanga grandiflora*	20	20	0.328
7	*Bombax ceiba*	20	20	0.272
8	*Albizia chinensis*	10	10	0.041
9	*Lithocarpus elegans*	30	20	0.297
10	*Engelhardtia spicata*	30	20	0.338
11	*Alnus nepalensis*	20	10	0.093
12	*Alangium chinense*	10	10	0.034
13	*Grewia tiliaefolia*	10	10	0.031
14	*Terminalia myriocarpa*	10	10	0.039
SHRUBS				
1	*Eupatorium odoratum*	3040	25	0.1839
2	*Grewia vestita*	480	15	0.0046
3	*Indigofera heterantha*	1160	10	0.0268

S. No.	Species Name	Density/ ha	Frequency (%)	Basal Area (Sq m/ha)
4	*Flemingia strobilifera*	300	5	0.0018
5	*Boehmeria macrophylla*	960	10	0.0183
6	*Smilax aspera*	240	10	0.0011
7	*Debregeasia longifolia*	880	10	0.0154
8	*Rubia manjith*	520	5	0.0054
9	*Artemisia indica*	740	10	0.0109
10	*Psidium guajava*	360	5	0.0026
11	*Triumfetta rhomboidea*	320	5	0.0020
12	*Musa* sp.	2240	5	0.0999
13	*Debregeasia salicifolia*	240	5	0.0011
14	*Oxytropis paniculata*	520	15	0.0054
15	*Rubus ellipticus*	240	5	0.0011
16	*Datura stramomium*	400	10	0.0032
17	*Eupatorium cannabinum*	2320	25	0.1071
18	*Inula cappa*	500	5	0.0050
19	*Emblica officinalis*	560	5	0.0062
20	*Bambusa* sp.	8600	5	1.4721

SITE-S7

S. No.	Species Name	Density/ ha	Frequency (%)	Basal Area (Sq m/ha)
TREES				
1	*Albizia chinensis*	20	20	464.47
2	*Juglans regia*	80	50	1168.39
3	*Macaranga denticulata*	29	10	56.52
4	*Oroxylum indicum*	12	10	15.20
5	*Bauhinia purpurea*	40	20	128.61
6	*Persea robusta*	25	20	27.69
7	*Ficus oligodon*	20	10	200.96
8	*Schima wallichii*	20	10	50.24
9	*Alnus nepalensis*	60	20	186.87
10	*Altingia excelsa*	10	10	28.26
11	*Erythrina arborescens*	20	10	66.33
SHRUBS				
1	*Mussaenda roxburghii*	1200	50	24.12
2	*Brassiopsis mitis*	3000	70	38.58
3	*Celastrus monospermus*	400	10	12.56
4	*Dendrocalamus hamiltonii*	6800	30	58.85
5	*Rhamnus purpureus*	1600	20	18.09
6	*Oxyspora paniculata*	1200	20	10.99

SITE-S8

S. No.	Species Name	Density/ ha	Frequency (%)	Basal Area (Sq m/ha)
TREES				
1	*Schima wallichii*	40	30	700.86
2	*Ficus virens*	35	30	911.17
3	*Albizia chinensis*	20	20	401.92
4	*Macaranga denticulata*	18	10	8.55
5	*Alnus nepalensis*	20	10	427.43
6	*Ficus auriculata*	50	20	415.27
7	*Persea robusta*	10	10	8.04
8	*Juglans regia*	10	10	379.94
9	*Castanopsis hystrix*	15	10	379.94

10	*Engelhardtia spicata*	18	10	103.82
11	*Litsea cubeba*	10	10	8.29
12	*Eurya acuminata*	10	10	7.89
SHRUBS				
1	*Brassiopsis mitis*	1600	50	60.79
2	*Rubus ellipticus*	200	10	6.28
3	*Neillia thyrsiflora*	2000	10	17.31
4	*Oxyspora paniculata*	1200	20	13.56
5	*Edgeworthia gardeneri*	400	10	6.15
6	*Mussaenda roxburghii*	800	10	7.32
7	*Dendrocalamus hamiltonii*	3600	10	31.16

Table 4.7: Ecological attributes of herbaceous species

SITE-S1

S. No.	Species Name	Density per ha	Frequency (%)	Basal Area (Sq m/ha)
1	*Bidens bipinnatus*	14286	14	--
2	*Lecanthes peduncularis*	4286	14	--
3	*Pouzolzia sanguinea*	15714	14	--
4	*Stellaria media*	39286	29	--
5	*Ageratum conyzoides*	30000	29	0.03468
6	*Inula cappa*	7143	7	0.00115
7	*Crassocephalum crepidiodes*	3571	14	0.00080
8	*Euphorbia hirta*	11429	7	--
9	*Achyranthes aspera*	13571	14	--
10	*Cyperus rotundus*	4286	7	--
11	*Ipomoea nil*	1429	7	--
12	*Cyanotis vaga*	10000	7	--
13	*Paspalum paspaloides*	4286	7	--
14	*Kylinga* sp.	7857	14	--
15	*Wulfenia nepalensis*	9286	7	--
16	*Pilea scripta*	16429	29	--
17	*Peristrophe bicalyculata*	25714	21	--
18	*Impatiens exilis*	2857	7	--
19	*Aconogonum molle*	8571	7	0.00815
20	*Pteris* sp.	2857	7	--
21	*Polygonum dumetorum*	15714	14	--

SITE-S2

S. No.	Species Name	Density per ha	Frequency (%)	Basal Area (Sq m/ha)
1	*Aconogonum molle*	15625	19	0.03901
2	*Peristrophe bicalyculata*	53750	44	--
3	*Scutellaria linearis*	3125	13	--
4	*Pteris* sp.	5625	19	--
5	*Rubia manjith*	1250	6	--
6	*Amomum subulatum*	16250	13	0.00920
7	*Cyanotis vaga*	3750	6	--
8	*Pouzolzia sanguinea*	25000	25	--
9	*Stellaria media*	40625	25	--
10	*Elsholtzia densa*	625	6	--
11	*Bidens bipinnatus*	11250	13	--

12	*Ageratum conyzoides*	11250	6	--
13	*Paspalum paspaloides*	16250	6	--
14	*Impatiens exilis*	6250	13	--
15	*Begonia picta*	1875	6	--
16	*Achyranthes aspera*	8125	13	--
17	*Crassocephalum crepidioides*	1875	6	--
18	*Rubia sikkimensis*	6250	6	--
19	*Galinsoga parviflora*	10000	6	--
20	*Ipomoea nil*	1250	6	--

SITE-S3

S. No.	Species Name	Density per ha	Frequency (%)	Basal Area (Sq m/ha)
1	*Bidens bipinnatus*	15000	13	--
2	*Ageratum conyzoides*	14375	19	--
3	*Commelina benghalensis*	3750	6	--
4	*Crassocephalum crepidiodes*	1250	6	--
5	*Stellaria media*	45000	31	--
6	*Pouzolzia sanguinea*	7500	6	--
7	*Swertia* sp.	7500	6	--
8	*Hedychium spicatum*	3125	6	--
9	*Cissampelos pariera*	625	6	--
10	*Persicaria capitata*	8750	6	--
11	*Euphorbia hirta*	2500	6	--
12	*Cyanotis vaga*	8125	13	--
13	*Conyza canadensis*	10000	6	--
14	*Galinsoga parviflora*	15000	6	--
15	*Lecanthes peduncularis*	6250	6	--
16	*Pilea scripta*	10000	6	--
17	*Peristrophe bicalyculata*	6250	6	--
18	*Amomum subulatum*	10000	6	0.01612
19	*Polygonum dumetorum*	8750	6	--
20	*Flemingia strobilifera*	96875	19	--
21	*Paspalum paspaloides*	1875	6	--
22	*Digitaria ciliaris*	53125	6	--
23	*Impatiens exilis*	3125	6	0.00115
24	*Wulfenia nepalensis*	6875	13	0.00538
25	*Kylinga* sp.	1875	6	--

SITE-S4

S. No.	Species Name	Density per ha	Frequency (%)	Basal Area (Sq m/ha)
1	*Ageratum conyzoides*	6250	19	--
2	*Bidens bipinnatus*	8750	19	--
3	*Stellaria media*	35000	38	--
4	*Kylinga* sp.	2500	6	--
5	*Amomum subulatum*	8125	6	0.01541
6	*Persicaria capitata*	8750	13	--
7	*Cissampelos pariera*	1250	6	--
8	*Hydrocotyle nepalensis*	13750	6	--
9	*Impatiens exilis*	2500	6	0.00080
10	*Crassocephalum crepidiodes*	1250	6	0.00039
11	*Plantago major*	5000	6	0.00258
12	*Clinopodium umbrosum*	10000	19	--

13	*Lecanthes peduncularis*	16250	19	0.02866
14	*Pouzolzia sanguinea*	15000	31	0.02071
15	*Achyranthes aspera*	7500	6	--
16	*Pteris* sp.	40000	19	--
17	*Peristrophe bicalyculata*	15000	25	0.00920
18	*Galinsoga parviflora*	15000	13	--
19	*Rubia manjith*	15000	6	--

SITE-S5

S. No.	Species Name	Density per ha	Frequency (%)	Basal Area (Sq m/ha)
1	*Kylinga* sp.	5714	7	--
2	*Euphorbia hirta*	7143	14	0.00051
3	*Ageratum conyzoides*	15714	21	--
4	*Ocimum indicum*	11429	7	0.01150
5	*Bidens bipinnatus*	11429	29	--
6	*Stellaria media*	41429	36	--
7	*Polygonum recumbens*	17143	14	--
8	*Crassocephalum crepidiodes*	3571	14	0.00051
9	*Colocasia esculenta*	2857	7	0.00080
10	*Pouzolzia sanguinea*	6429	14	--
11	*Lecanthes peduncularis*	4286	7	--
12	*Amaranthus hybridus*	4286	7	0.00115
13	*Galinsoga parviflora*	47143	21	--
14	*Tridax procumbens*	10000	7	0.00080
15	*Digitaria ciliaris*	12857	7	--
16	*Cyperus rotundus*	8571	7	--
17	*Rubia manjith*	4286	7	--
18	*Cyanotis vaga*	2857	7	0.00013
19	*Polygonum dumetorum*	11429	7	--

SITE-S6

S. No.	Species Name	Density per ha	Frequency (%)	Basal Area (Sq m/ha)
1	*Amomum subulatum*	16429	14	0.04969
2	*Pteris* sp.	10714	14	--
3	*Peristrophe bicalyculata*	4286	14	0.00079
4	*Dioscorea bulbifera*	2143	7	0.000510
5	*Vigna* sp.	3571	14	0.00114
6	*Digitaria ciliaris*	15714	7	--
7	*Cyperus rotundus*	12857	7	--
8	*Stellaria media*	49286	43	--
9	*Achyranthes aspera*	20000	14	--
10	*Bidens bipinnatus*	5000	21	--
11	*Ageratum conyzoides*	12857	21	0.01145
12	*Cissampelos pariera*	1429	7	--
13	*Hedychium spicatum*	2143	7	0.00111
14	*Clinopodium umbrosum*	1429	7	0.00013
15	*Plantago major*	10000	7	0.00538
16	*Persicaria capitata*	1429	7	--
17	*Ipomoea nil*	4286	7	--
18	*Lecanthes peduncularis*	8571	7	0.00531
19	*Pouzolzia sanguinea*	7143	7	0.00385
20	*Galinsoga parviflora*	12857	7	--
21	*Hydrocotyle nepalensis*	11429	7	--
22	*Impatiens exilis*	2143	7	0.00028

SITE-S7

S. No.	Species Name	Density per ha	Frequency (%)	Basal Area (Sq m/ha)
1	*Ageratina adenophora*	42000	50	0.08550
2	*Aconogonum molle*	28000	60	0.04007
3	*Lecanthus peduncularis*	4000	10	0.00050
4	*Apluda mutica*	4000	10	0.00020
5	*Elatostema platyphyllum*	2000	10	0.00127
6	*Pilea scripta*	32000	20	0.00226
7	*Impatiens exilis*	6000	10	0.00231
8	*Pilea umbrosa*	46000	30	0.00578
9	*Dichrocephala chrysanthemifolia*	6000	20	0.00091
10	*Bidens bipinnata*	12000	20	0.00151
11	*Fagopyrum esculentum*	4000	10	0.00177
12	*Carex baccans*	4000	10	0.00028
13	*Achyranthes aspera*	2000	10	0.00025
14	*Persicaria barbata*	6000	10	0.00042
15	*Stellaria media*	10000	10	0.00031
16	*Viola betonicifolia*	4000	10	0.00015
17	*Gnaphalium affine*	4000	10	0.00014

SITE-S8

S. No.	Species Name	Density per ha	Frequency (%)	Basal Area (Sq m/ha)
1	*Persicaria capitata*	11000	30	0.00078
2	*Hydrocotyle nepalensis*	17000	20	0.00083
3	*Cynodon dactylon*	14000	20	0.00053
4	*Oxalis corniculata*	11000	30	0.00028
5	*Gnaphalium affine*	2000	10	0.00011
6	*Centella asiatica*	15000	20	0.00680
7	*Rumex nepalensis*	17000	30	0.00307
8	*Ageratum conyzoides*	19000	30	0.00239
9	*Setaria palmifolia*	7000	20	0.00043
10	*Bidens bipinnata*	16000	20	0.00181
11	*Cynoglosum glochidiatus*	2000	10	0.00049
12	*Solanum nigrum*	3000	10	0.00059
13	*Artemisia indica*	6000	20	0.00301
14	*Colocasia affinis*	8000	10	0.00353
15	*Digitaria ciliaris*	7000	20	0.00022
16	*Commelina benghalensis*	8000	20	0.00122
17	*Galium aparine*	12000	20	0.00031
18	*Aster molliusculus*	22000	30	0.00069
19	*Arthraxon hispidus*	10000	10	0.00028

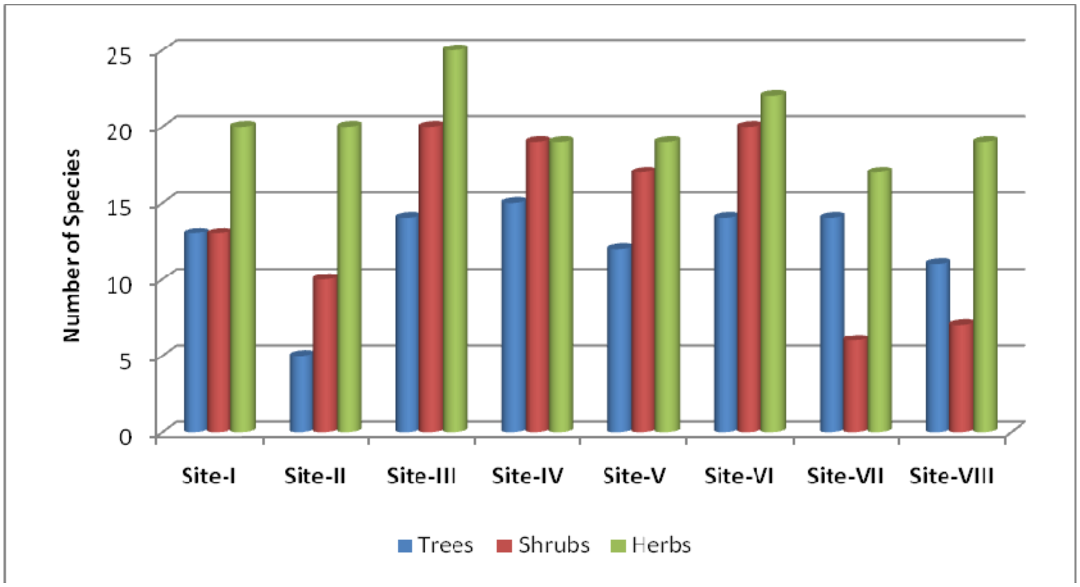


Figure: 4.7 Number of species recorded at different sampling locations

4.7.3 Species Diversity

Importance Value Index of all the plant species recorded from the study area at all locations is given at Annexure-VI.

Alnus nepalensis and *Schima wallichii* are the most dominant tree species recorded from most of the sampling locations. *Alnus nepalensis* was most dominant tree species at sites S-I, S-II and S-III an IVI of more than 150 and had an IVI of 216 at site S-II (Figure 4.8). *Schima wallichii* was most dominant at sites S-IV and S-VI with IVI of 107 and 118, respectively. *Engelhardtia spicata* was another predominant species at site S-III with IVI of 166. At sites S-VII and S-VIII there was almost equal distribution of species like *Albizia chinensis, Alnus nepalensis*, *Altingia excelsa, Bauhinia purpurea, Erythrina indica* and *Juglans regia*. Amongst the shrubs *Dendrocalamus hamiltonii* was the most dominant with maximum IVI of 139 at site S-III (Figure 4.9) and was found at all the sampling location except at site S-VI. *Oxytropis paniculata* was recorded from all the locations while *Eupatorium odoratum, Artemisia indica* and *Musa* sp., were the other dominant shrub species (Figure 4.9) indicating the disturbed nature of vegetation.
Amongst the herbs *Ageratum conyzoides* was present at all the sites and was the most dominant species at sites S-I and S-VII IVI value of 101 and 95 respectively, at these sites (Figure 4.10). *Bidens bipinnatus* was also recorded at al the sampling locations. *Aconogonum molle* was most dominant at sites S-II and S-VII, *Amomum subulatum* at sites S-III and S-VI, and *Stellaria media* at site S-V (Figure 4.10).

Shannon Weiner species diversity index (H) in the tree stratum ranged from 0.89 at sit S-2 to 2.33 at site S-4 (Table 4.8, Figure 4.11). The species diversity for shrub strata ranged from 1.445 (S-VII) to 2.33 (S-V). The value of species diversity (H) for the herbaceous layer ranged from 2.327 (S-VII) to 2.796 (S-VIII).

The evenness index indicated that at the majority of sites the trees as were evenly distributed except at site S-II where it was low (Table 4.8). The distribution of shrubs was more or less even at all the sites except at site S-III. The distribution of herbs was more or less even at all the sites.

Simpson's Diversity index (1-D) also showed pattern similar to Shannon Weiner diversity index at all the sampling locations.

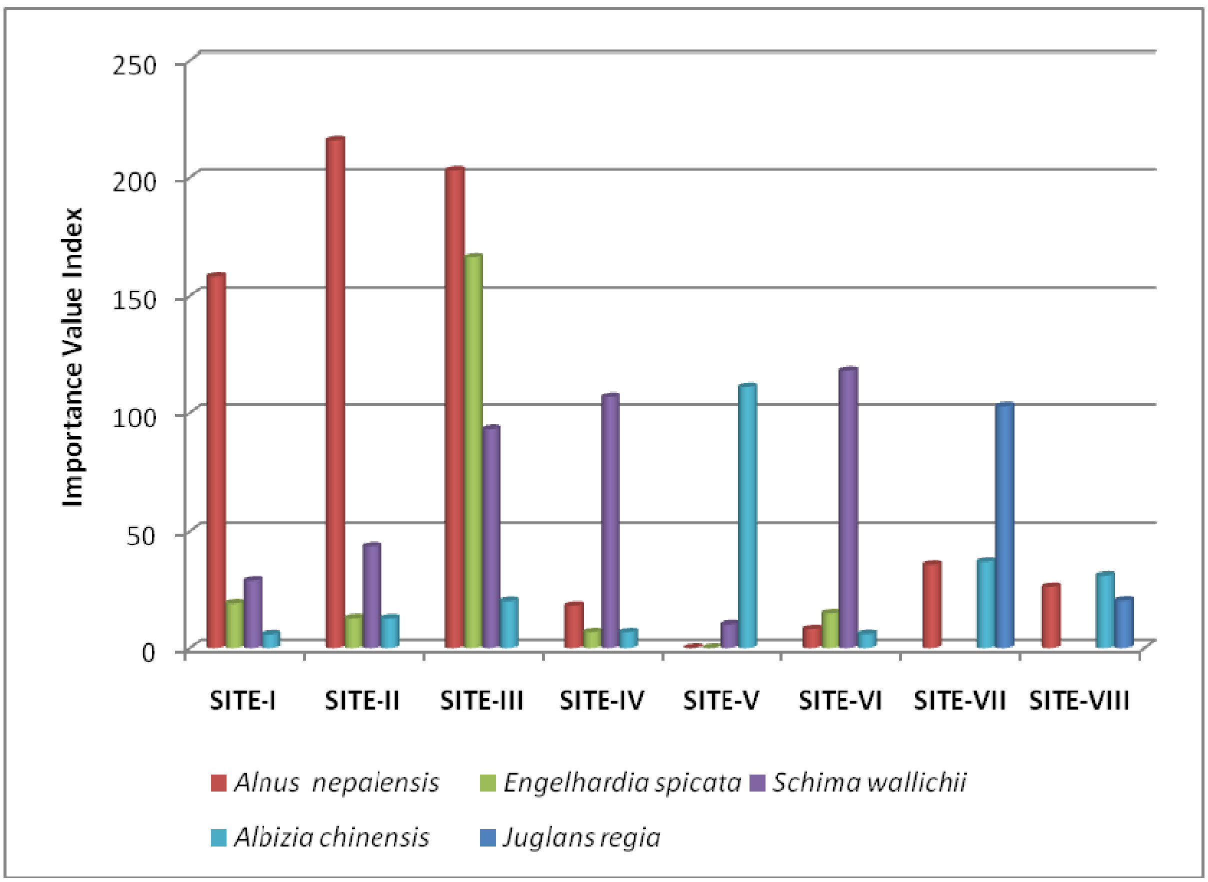


Figure 4.8: IVI of dominant tree species at different sampling locations

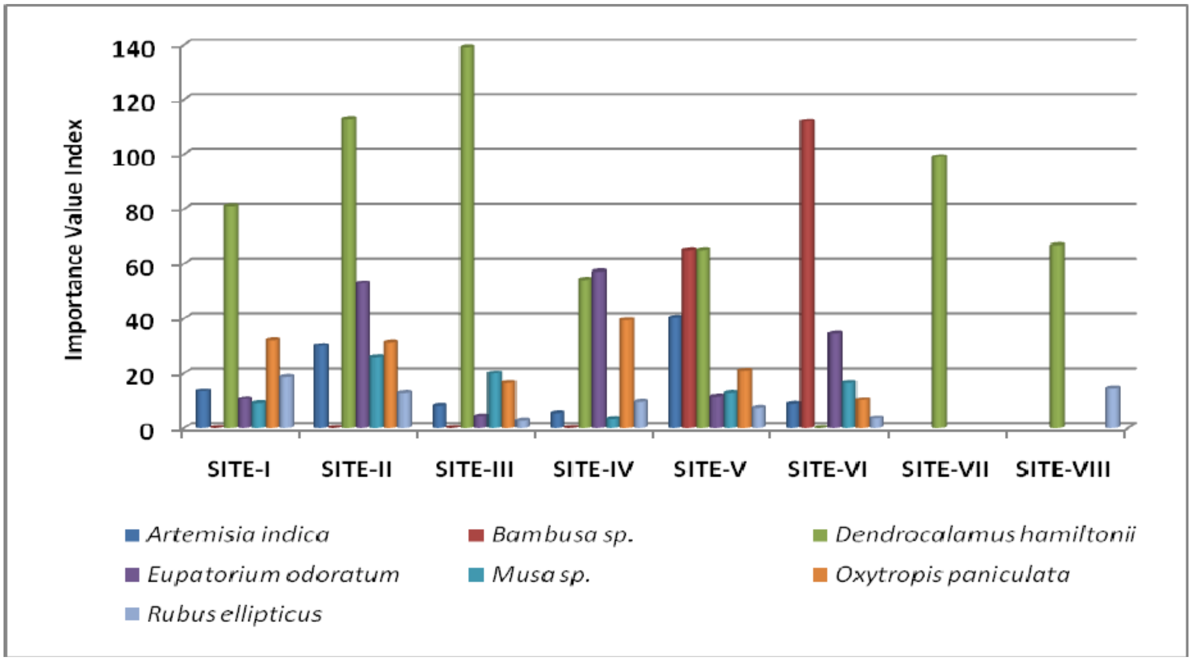


Figure 4.9: IVI of dominant shrub species at different sampling locations

Table 4.8: Diversity indicies of various tree and shrub plant species

Shannon-Weiner Diversity Index	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**
Trees	1.88	0.89	2.24	2.33	2.26	2.08	2.203	2.236
Shrubs	2.18	1.86	1.97	2.22	2.33	2.26	1.445	1.66
Herbs	2.76	2.49	2.54	2.63	2.58	2.68	2.327	2.796
Evenness Index								
Trees	0.73	0.55	0.85	0.86	0.91	0.79	0.919	0.936
Shrubs	0.85	0.81	0.66	0.75	0.82	0.85	0.807	0.853
Herbs	0.91	0.83	0.79	0.89	0.88	0.87	0.821	0.949
Simpson's Diversity Index (1-D)								
Trees	0.755	0.448	0.861	0.870	0.872	0.810	0.870	0.887
Shrubs	0.843	0.788	0.748	0.830	0.861	0.836	0.698	0.773
Herbs	0.922	0.887	0.870	0.910	0.896	0.905	0.868	0.933

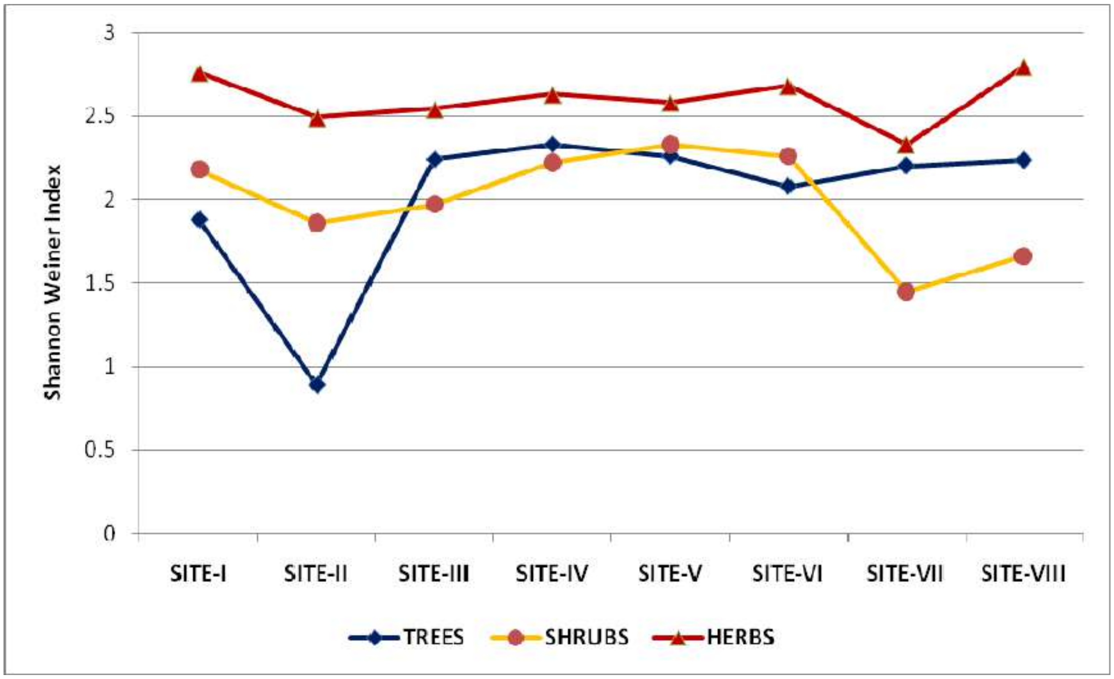


Figure 4.10: Shannon Weiner Diversity Index of plant species

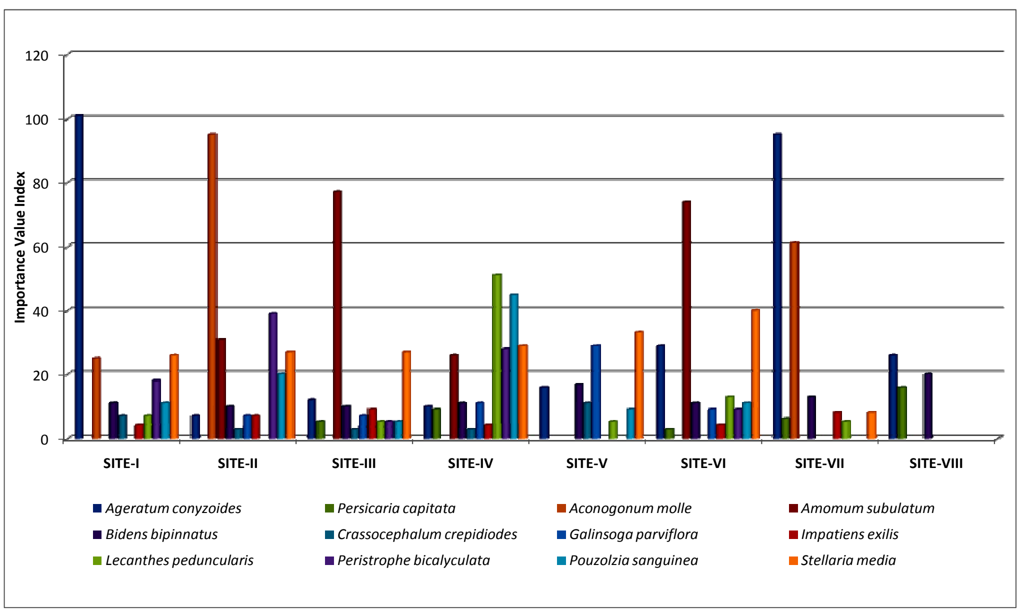


Figure 4.11: IVI of some dominant herbaceous species

4.8 CONSERVATION STATUS

The catchment area of Tingting HE project area has a rich and diverse flora including many economically important plants such as timber trees, medicinal herbs and also some attractive and interesting horticultural groups such as Orchidaceae, Primulaceae and Ericaceae.

4.8.1 Monotypic Genera

A number of monotypic genera distributed over different habitats were observed in the study area. Some of these taxa are *Bischofia javanica* (Bischofiaceae), *Gynocardia odorata* (Flacourtiaceae), *Houttuynia cordata* (Saururaceae), *Herpetospermum pedunculosum* (Cucurbitaceae), *Parochetus communis* (Fabaceae) and *Schima wallichii* (Theaceae).

4.8.2 Endemics

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

Some of the East Himalayan endemics represented in Sikkim are *Abies densa, Agapetes sikkimensis* and *Maddenia himalaica*.

4.8.3 Phytogeographical Affinities

The floral elements in Ting Ting HE 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 forests of project area. These include many trees, shrubs and climbers such as *Bischofia javanica, Bombax ceiba, Brassiopsis glomerulata, Duabanga grandiflora, Engelhardtia spicata, Lithocarpus elegans, Oroxylum indicum, Simingtonia populnea,* etc. Sino-Japanese elements such as *Lyonia ovalifolia, Quercus* spp. And *Schima wallichii* are quite common in this region. The European and Mediterranean elements are represented by the species of *Allium, Anemone, Artemisia, Gentiana, Ranunculus,* etc. Some species like *Geranium nepalense, Houttuynia cordata, Lyonia ovalifolia* and

Quercus leucotrichophora are present from Western Himalaya to Japan. The New world elements are exhibited by weeds of agricultural lands, open forest areas and waste places such as *Ageratina adenophora* and *A. ligustrina* (Clarke, 1898; Hooker, 1904, Willis, 1982, Takhtajan, 1986.

4.8.4 Threatened Flora

Rare and endangered species were identified referring to the Red Data Book of India and other available literature, flora and herbarium pertaining to the rare/ endangered species of Sikkim.
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*.

In addition to Vulnerable (VU) plants, there are a number of plants in the area that are not listed in Red Data Book such as *Adgaria darjeelensis, Angelica sikkimensis, Aster sikkimensis, Pimpinella wallichii, Taxus baccata*, etc but are getting lost due to habitat destruction.

4.9 PTERIDOPHYTES, BRYOPHYTES & LICHENS

4.9.1 Pteridophytes

Number of plants belonging to the group Pteridophyta were recorded from the project study and a list of them is given below.

List of Pteridophytes Recorded from Study Area

S. No.	Plant Name
1	*Adiantum capillus-veneria*
2	*Cheilanthes bicolor*
3	*Cyathea spinulosa*
4	*Dicranopteris linearis*
5	*Dryoathyrium boryanum*
6	*Dryopteris filix-max*
7	*D. fillixanus*
8	*Equisetum diffusum*
9	*Glaphylopteriopsis erubescens*
10	*Lycopodium clavatum*
11	*Nephrolepsis cordifolia*
12	*Polypodium decorum*
13	*Pteris cretica*
14	*Selaginella nepalensis.*

4.9.2 Bryophytes

An inventory of bryophytes found in the project study area was prepared based upon literature survey as well as field survey collections. Total 18 species were recorded from the area and the same has been given in a table below.

List of Bryophytes Recorded from Study Area

S. No.	Species Name
1	*Fissidens* sp.
2	*Frullania nepalensis*
3	*F. retusa*
4	*Funaria hygrometrica*
5	*Jungermannia obliquifolia*
6	*J. sikkimensis*
7	*J. truncata*
8	*Lejeunea* sp.
9	*Marchantia nepalensis*
10	*M. polymorpha*
11	*Plagiochasma articulatum*
12	*P. intermedium*
13	*P. pterospermum*
14	*Plagiochila flexuosa*
15	*P. microphylla*
16	*Polytrichum* sp.
17	*Porella caespitans*
18	*Riccia kashayapii*

4.9.3 Lichens

Survey and collection of lichens in Sikkim commenced with Sir J. D. Hooker and later his collections were worked out by Nylander (1860, 1863). Subsequently, Asahina (1966) and Awasthi (1965, 1988, 1991) recorded lichens from Sikkim. Based on earlier collections about 155 species were known from Sikkim. The exploration work on lichens from different localities of Sikkim was made possible with the establishment of Botanical Survey of India, Sikkim Himalayan Circle, Gangtok (Chauhan, 1998).

On the basis of altitudinal and climatic variation, lichen vegetation of the area is classified into 4 major types i.e. Tropical lichen vegetation, sub-tropical, temperate and alpine lichen vegetation.

Tropical lichen vegetation

This type of lichen vegetation is found up to 900 m elevation in the vicinity of dam site, Yuksom, and catchment of Rimbi Khola. The trunks of *Bischofia javanica, Bombax ceiba, Schima wallichii* etc. support the growth of crustose lichens belonging to the families like Anthoniaceae, Caliciaceae, Graphidaceae, Lecanoraceae, Pertusariaceae, Pyrenocarpaceae and Verrucariaceae. Some foliose lichens such as *Bulbothrix setschwanesis*, *Dirinaria* sp., *Heterodermia diademata*, *Parmotrema praesorediosum*, etc. grow in moist open places. Fruticose forms are absent except *Usnea baileyi*.

Sub-tropical lichen vegetation

This type of vegetation occurs between 900-1800m elevations in the vicinity of dam site, submergence area, powerhouse and other project areas. There is a rich diversity of both crustose and foliose forms. Crustose lichens include *Graphis duplicata*, *G. scripta, Pertusaria* sp., *Phaeographis* sp., etc. on the trunks of *Alnus nepalensis, Eurya acuminata, Prunus cerasoides, Schima wallichii* and *Toona ciliata* with many foliose forms. Among foliose lichens are *Bulbothrix isidiza, Everniastrum nepalense, Heterodermia diademata, Parmelina wallichiana, P. xantholepis, Parmotrema sancti-angelii, P. reticulatum, P. tinctorum* and *Pseudocyphellaria aurata*. Many fruticose lichens like *Ramlina subcomplanata, Usnea baileyi* and *U. orientalis* grow on tree trunk while *Cladonia* sp. and *Stereocaulon* sp. are found on rocks.

Temperate lichen vegetation

This vegetation of lichen occurs in the upstream areas between 1800-3600m in the catchment of Rathong Chhu. The climate of the area offers the favourable condition for luxuriant growth of foliose and fruticose forms. The trunks of *Acer campbellii, Betula utilis, Castanopsis hystrix, Quercus lamellosa, Rhododendron arboreum*, etc provide suitable habitat for growth of *Cetrelia braunsiana, Coccocarpia erythroxylii, Everniastrum cirrhatum, E. nepalense, Heterodermia comosa, Lobaria retigera, Parmelaria thomsonii* and *Sticta neocaledonica*. Crustose forms are fewer and belong to the genera like *Anthracothecium, Diploschistes, Micobilimbia, Pertusaria,* etc which grow on the ground, exposed boulders and tree trunk. Some fruticose forms like *Bryoria himalayana, Salcria sulcata, Usnea himalayana* and *U. thomsonii* are seen pending from trees. Among foliose taxa *Lobaria kurokawae, L. pseudopulmonaria, peltigera canina, P. dolichorrhiza, Sticta nylanderiana, S. orbicularis, S. platyphylloides,* etc grow on the dead wood fallen on the ground.

4.10 FAUNAL ELEMENTS

The state of Sikkim lies within the biogeographic province-2C, the Central Himalaya (Rodgers & Panwar, 1988). The Province stretches from the Gandak river in central

Nepal to the Sankosh river in central Bhutan. Indian component of this zone comprise all of Sikkim and the northern part of West Bengal.

The overall habitat in the immediate vicinity of project is generally degraded. Large scale plantation of large cardamon, interspersion of human habitations and encroachment of land for cultivation are the major factors.

To collect the data on faunal composition field surveys were undertaken in different locations in different seasons during 2008. In addition to field surveys the data from secondary sources was also collected (CISMHE, 2007; Subba, 2002; Negi, 1994; ZSI, 1994, Prater, 1993; and Ali and Ripley, 1983).

4.10.1 Mammals

Out of more than 460 species of mammals in the world, 372 are reported from India (including aquatic and terrestrial species). Among all the states of India, state of Sikkim is one of the richest in biodiversity. It harbours more than 160 species of mammals. The mammalian fauna of Rangit river catchment comprises families like Bovidae, Cervidae, Moschidae, Suidae, Tragulidae, Ailuropodidae (Artiodactyla), Canidae, Felidae, Herpestidae, Mustelidae, Ursidae, Viverridae (Carnivora), Emballonuridae, Hipposideridae, Megadermatidae, Molossidae, Pteropodidae, Rhinolophidae (Chiroptera), Soricidae (Insectivora), Leporidae, Ochotonidae (Lagomorpha), Cercopithecidae (Primates), Muridae, Pteromyidae (Rodentia), etc. The Chiroptera is largest order of mammals in Sikkim, followed by Rodentia. The order Perissodactyla is represented by a single species.

Distribution

In the project area, human settlements and agricultural practices are confined to lower (< 800 m) altitudinal regions. Mixed forests with Large cardamon plantations occur in the altitudinal zone 900-1,800 m. The zones above 1,500 m are inhabited by Mixed broadleaved evergreen forests, followed by conifer forests, sub-alpine forests and alpine pastures. Such variations in topography, climatic conditions, forests and landuse pattern play a vital role in the distribution of animals. In addition, food habit of animal determines the habitat. More than 50% species of order Artiodactyla inhabit the area between 3,000 and 4,000 m (Table 4.9). Unlike Artiodactyla most of the carnivore species *viz*., Jackal, Wolf, Leopard, Small cats, Mongoose, Civets, Himalayan marten, etc. inhabit lower elevations Table 4.9). They are nocturnal and feed on the domestic animals also. However, many carnivores like Snow leopard, bears, Red panda are found at high altitudes (above 2,500 m). Most of the species of Chiroptera (bats) are distributed in lower regions of catchment while rodents have wide range of distribution. Bats depend on the wild as well as domestic fruits plants while rodents especially rats feed on the house wastes. For there reasons only they are distributed near the human settlements. Order Perrisodactyla is represented by a single species of Kiang. It is found above 4,000 m. It inhabits mainly the alpine pastures. Among the primates, three species are known from Sikkim. Rhesus macaque (*Macaca mulatta*) and Assamese macaque (*Macaca assamensis*) are found up to 2,000 m. They are found in groups, generally found along the road sides.

Table 4.9: Composition of mammals, their distribution and status in the catchment area

Common name	Scientific name	Distribution range (m)	WPA (1972)	Status ZSI
ARTIODACTYLA				
Himalayan tahr	*Hemitragus jemlahicus*	2500-4000	I	EN
Goral	*Naemorhedus goral*	900-2000	III	*
Blue sheep – Bharal	*Pseudois nayaur*	4000-5500	I	VU
Nayan, argali	*Ovis ammon*	3000-5000	I	IK
Tibetan gazelle	*Procapra picticauda*	Above 4000	I	IK
Barking deer	*Muntiacus muntjak*	1500-2400	III	*
Musk deer	*Moschus chrysogaster*	3000-5000	I	EN
Musk deer	*M. fuscus*	3000-5000	I	*
Indian wild boar	*Sus scrofa*	Up to 1300	III	*
Mouse deer	*Moschiola meminna*	Up to 1800	III	*
CARNIVORA				
Red panda	*Ailurus fulgens*	1800-3800	I	EN
Jackal	*Canis aureus*	Up to 3000	II	*
Dhole	*Cuon alpinus*	2000-3000	II	*
Tibetian fox	*Vulpes montanus*	Above 2500	II	*
Leopard	*Panthera pardus*	300-1500	I	VU
Snow leopard	*P. uncia*	3660-3965	I	EN
Clouded leopard	*Neofelis nebulosa*	1500-2500	I	EN
Marbled cat	*Felis marmorata*	-	I	EN
Jungle cat	*F. chaus*	Up to 1500	II	*
Golden cat	*F. temminckii*	-	I	EN
Common mongoose	*Herpestes edwardsii*	Up to 1000	IV	*
Crab-eating mongoose	*H. urva*	Up to 700	IV	*
Clawless otter	*Aonyx cinerea*	Up to 1000	II	VU
Hog badger	*Arctonyx collaris*	-	II	-
Himalayan marten	*Martes flavigula*	1220-2745	II	-
Beech marten	*M. foina*	Up to 1525	II	-
Himalayan stoat	*Mustela erminea*	3200-4200	II	-
Burmese ferret badger	*Melogale personata*	-	II	-
Yellow-bellied weasel	*Mustela kathiah*	Up to 1000	II	-
Himalayan weasel	*M. sibirica*	1525-4880	II	-
Striped-backed weasel	*M. strigidorsa*	-	II	-
Himalayan black bear	*Ursus thibetanus*	1500-4000	I	-
Sloth bear	*Melursus ursinus*	Up to 600	I	-
Brown bear	*Ursus arctos*	Above 3000	I	EN
Binturong	*Arctictis binturong*	Above 3000	I	EN

Common name	Scientific name	Distribution range (m)	WPA (1972)	Status ZSI
Small-toothed palm civet	*Arctogalidia trivirgata*	-	-	-
Himalayan palm civet	*Paguma larvata*	Up to 1500	II	-
Spotted linsang	*Prionodon pardicolor*	150-1850	II	-
Small Indian civet	*Viverricula indica*	Up to 900	II	-
Large Indian civet	*Viverra zibetha*	500-1000	-	-
CHIROPTERA*				
Naked-rumped tomb bat	*Taphozous nudiventris*	-	-	-
Great Himalayan bat	*Hipposideros armiger*	-	V	-
Fulvous leaf-nosed bat	*H. fulvus*	-	V	-
Andersen's Leaf-nosed bat	*H. pomona*	-	V	
Indian false vampire bat	*Megaderma lyra*	-	-	-
Asian false vampire bat	*M. spasma*	-	-	-
European free-tailed bat	*Tadarida teniotis*	-	V	-
Wrinkled-lipped bat	*T. plicata*	-	-	-
European free-tailed bat	*T. teniotis*	-	V	-
Short-nosed fruit bat	*Cynopteris sphinx*	-	V	-
Dawn bat	*Eonycteris spelaea*	-	-	-
Greater long-tongued bat	*Macroglossus sobrinus*	-	V	-
Niphan's fruit bat	*Megaerops niphanae*	-	-	-
Indian flying fox	*Pteropus giganteus*	-	V	-
Fulvous fruit bat	*Rousettus leschenaultia*	-	V	-
Mountain fruit bat	*Sphaerias blanfordi*	-	V	-
Great Eastern bat	*Rhinolophus luctus*	-	-	-
Greater horseshoe bat	*R. ferrumequinum*	-	V	-
Horsfield's horseshoe bat	*R. pearsoni*	-	-	-
Rufous horseshoe bat	*R. rouxii*	-	-	-
Trefoil horse-shoe bat	*R. trifoliatus*	-	-	-
Least horse-shoe bat	*R. pusillus*	-	-	-
Little horse-shoe bat	*R. lepidus*	-	-	-
Eastern barbestelle bat	*Barbastella leucomelas*	-	-	-
Northern serotine bat	*Eptesicus nilssoni*	-	-	-
Silky serotine bat	*E. serotinus*	-	-	-
Sombre bat	*E. tatei*	-	-	-
Hairy winged bat	*Harpiocephalus harpia lasyurus*	-	-	-
White bellied bat	*Murina leucogaster*	-	-	-
Round eared bat	*M. cyclotis*	-	-	-
Peter's tube nosed bat	*M. huttoni*	-	-	-
Scully's tube nosed bat	*M. tubinaris*	-	-	-
Little tube nosed bat	*M. aurata*	-	-	-
Painted bat	*Kerivoula picta*	-	-	-
Hardwicke's bat	*K. hardwickei*	-	-	-
Nepalese whiskered bat	*Myotis muricola*	-	-	-

Common name	Scientific name	Distribution range (m)	WPA (1972)	Status ZSI
Nepal bat	*M. mystacinus*	-	-	-
Hodgson's bat	*M. formosus*	-	-	-
Mandelli's bat	*M. sicarius*	-	-	-
Small-toothed whiskered	*M. siligorensis*	-	-	-
Himalayan noctule	*Nyctalus montanus*	-	-	-
Common noctule	*N. noctula*	-	-	-
Babu pipistrelle	*Pipistrellus babu*	-	-	-
Indian pipistrelle	*P. coromandra*	-	-	-
Himalayan pipistrelle	*P. javanicus*	-	-	-
Pegu pipistrelle	*P. peguensis*	-	-	-
Brown longeared bat	*Plecotus auritus*	-	-	-
Harlequin bat	*Scotomanes emarginatus*	-	-	-
Bamboo bat	*Tyloylonycteris pachypus*	-	-	-
Asian/Eastern barbestell	*Barbastella leucomela*	-	-	-
INSECTIVORA				
Himalayan water shrew	*Chimmarogale himalayica*	-	-	-
Szechuan water shrew	*Nectogale elegans*	-	-	-
Asiatic shrew	*Soriculus caudatus*	-	-	-
Indian long-tailed shrew	*S. leucops*	-	-	-
Small long-tailed shrew	*S. macrurus*	-	-	-
Sikkim large-clawed shrew	*S. nigrescens*	1800-3800	-	-
Tibetian shrew	*Sorex thibethanus*	Up to 4000	-	-
House shrew/Musk shrew	*Suncus murinus*	Up to 4000	-	-
Asian white toothed shrew	*Crocidura fulginosa*	Up to 1000	-	-
Blyth's mole	*Talpa leucura*	-	-	-
Eastern mole	*T. micrura*	-	-	-
Tree shrew	*Tupaia belangeri*	Up to 2000	-	-
LAGOMORPHA				
Woolly hare	*Lepus oiostolus*	-	IV	-
Blacknaped hare	*L. nigricollis*	1000-2400	IV	-
Black-lipped pika	*Ochotona curzoniae*	-	IV	-
Forrester's pika	*O. forresti*	-	IV	-
Large eared pika	*O. macrotis*	-	IV	-
Mountain pika	*O. tibethana*	Above 4000	IV	-
Nubra pika	*O. nubrica*	-	IV	-
Himalayan pika	*O. royeli*	3400-4300	IV	-
PERISSODACTYLA				
Kiang	*Equus kiang*	Above 4000	I	EN
PHOLIDOTA				
Chinese pangolin	*Manis pentadactyla*	-	I	IK
PRIMATES				
Assamese macaque	*Macaca assamensis*	Up to 1500	II	-
Rhesus macaque	*M. mulatta*	Up to 2000	II	-
Himalayan Nepal langur	*Semnopithecus entellus*	2000-3000	II	-
RODENTIA*				

Common name	Scientific name	Distribution range (m)	WPA (1972)	Status ZSI
Himalayan crestless porcupine	*Hystrix brachyuran/hodgsoni*	-	II	-
Indian porcupine	*H. indica*	1000-2400	III	-
Miller's wood mouse	*Apodemus rusiges*	-	V	-
Wood mouse	*A. sylvaticus*	-	V	-
Wroughton's wood mouse	*A. wardi*	-	V	-
Indian mole rat	*Bandicota bengalensis*	-	V	-
Bandicoot rat	*B. indica*	-	V	-
Bay bamboo rat	*Cannomys badius*	-	V	-
Large-toothed giant rat	*Dacnomys millardi*	-	V	-
Edward's giant rat	*Leopolda edwardsii*	-	V	-
Sikkim Vole	*Microtus sikkimensis*	-	V	-
Indian field mouse	*Mus booduga*	-	V	-
Fawn-coloured mouse	*M. cervicolor*	-	V	-
House mouse	*M. musculus*	-	V	-
Sikkim mouse	*M. pahari*	-	V	-
Short-tailed bandicoot rat	*Nesokia indica*	-	V	-
Smoke bellied rat	*Niviventer eha*	-	V	-
Chestnut rat	*N. fulvescens*	Up to 2800	V	-
Langbian rat	*N. langbianis*	-	V	-
White-bellied rat	*N. niviventer*	-	V	-
Himalayan rat	*Rattus nitidus*	-	V	-
Brown rat	*R. norvegicus*	-	V	-
Common house rat	*R. rattus*	-	V	-
Sikkim rat	*R. sikkimensis*	-	V	-
Turkestan rat	*R. turkestanicus*	-	V	-
Long-tailed tree mouse	*Vandeleuria oleracea*	-	V	-
Chinese birch Mouse	*Sicista concolor*	-	V	-
Woolly flying squirrel	*Eupetaurus cinereus*	Up to 1800	V	-
Particoloured flying squirrel	*Hylopetes alboniger*	Up to 1800	-	-
Grey-headed flying squirrel	*Petaurista elegans*	Up to 1800	-	-
Hodgson's flying squirrel	*Petaurista magnificus*	Up to 900	-	-
Noble giant flying squirrel	*P. nobilis*	Up to 900	-	-
Giant red flying squirrel	*P. petaurista*	Up to 1800	-	-
Hairy-footed flying squirrel	*Belomys pearsonii*	Up to 900	III	-
Himalyan marmot	*Marmota himalayana*	4300-5500	-	-
Eastern red marmot	*M. hemachalanus*	-	-	-
Malayan Giant squirrel	*Ratufa bicolor*		II	-
Red-bellied tree squirrel	*Callosciurus erythraceus*	Up to 1800	-	-
Hoary-bellied Himalaya squirrel	*C. pygerythrus*	Up to 1500	II	-
Orange-bellied Himalayan squirrel	*Dremomys lokriah*	1500-2800	-	-
Pernyi's ground squirrel	*D. pernyi*	Up to 1800	-	-

Common name	Scientific name	Distribution range (m)	WPA (1972)	Status ZSI
Red-cheeked squirrel	*Dremomys rufigenis*	Up to 1800	-	-
Five-striped palm squirrel	*Funambulus pennantzi*	Up to 900	-	-
Himalayan striped squirrel	*Tamiops mcclellandii*	Up to 900	-	-

*Most of the species of Chiroptera are distributed in low altitudes while rodents have wide range of distribution.
- Data not available; EN = Endangered; CR = Critical; R = Rare; VU = vulnerable
LR = lower risk; LC/lc = least concern; NT/nt = near threatened; VU = vulnerable

Conservation Status

Total of 22 species reported from the project area and project catchment have been placed in Schedule-I. The highest number of Schedule-I species is found among the Carnivora, followed by Artiodactyla (Fig.4.12). The important species placed under Schedule-I are, Musk deer, Himalayan tahr, Serow, Red panda, Leopard, Marbled cat, Fishing cat, Black bear, Brown bear, Kiang, etc. Out of 12 species of Artiodactyla, 6 have been placed in different threatened categories Himalayan tahr and Musk deer are categorized as 'endangered' species while rest are 'vulnerable' and 'insufficiently known' (IK) (ZSI, 1994.). Among the Carnivora, Red panda, Snow leopard, Clouded leopard, Marbled cat, Golden cat, Brown beer and Binturong belong to 'endangered' category. Besides these, Kiang (Perrisodactyla) and Chinese Pangolin (Pholidota) are the Schedule-I species. About 24 species of mammals are categorized as Schedule-II, which includes 17 species of carnivores, 3 species of primates and 3 species of rodents. There are only 6 species in Schedule-III. The whole group of Lagomorpha (8 out 11 species) in Rangit river catchment has been placed in Schedule-IV. The Schedule-V, also called as 'Vermin' comprises of 11 species of Chiroptera and 26 species of rodents. None of the species of rodents and Chiroptera is categorized as threatened species in the project catchment area.

4.10.2 Avifauna

Composition and Distribution

Owing to wide altitudinal variation, the catchment area of Rathong Chhu is characterized by wide variation in the forest cover and composition. These characteristics of catchment area reflect in the rich species diversity of avifauna. The avifauna of the catchment area comprises of cormorants, egrets, herons, ducks, teals, eagles, vultures, hawks, pheasants, partridges, quails, doves, pigeons, cuckoos, cranes, woodpeckers, kingfishers, lapwings, wagtails, crows, magpies, tree pies, jays, flycatchers, drongos, bulbuls, sparrows, babblers, warblers, thrushes, bays, finches, buntings etc. These species belong to 17 orders. Order Passeriformes is the largest group of birds, which contributes about 65% to total species diversity of the catchment area (Fig.4.13). The Passeriformes is followed by Falconiformes (6.1%), Galliformes (4.7%) and Piciformes (4.7%). Trogoniformes is the smallest order, represented by a single species.

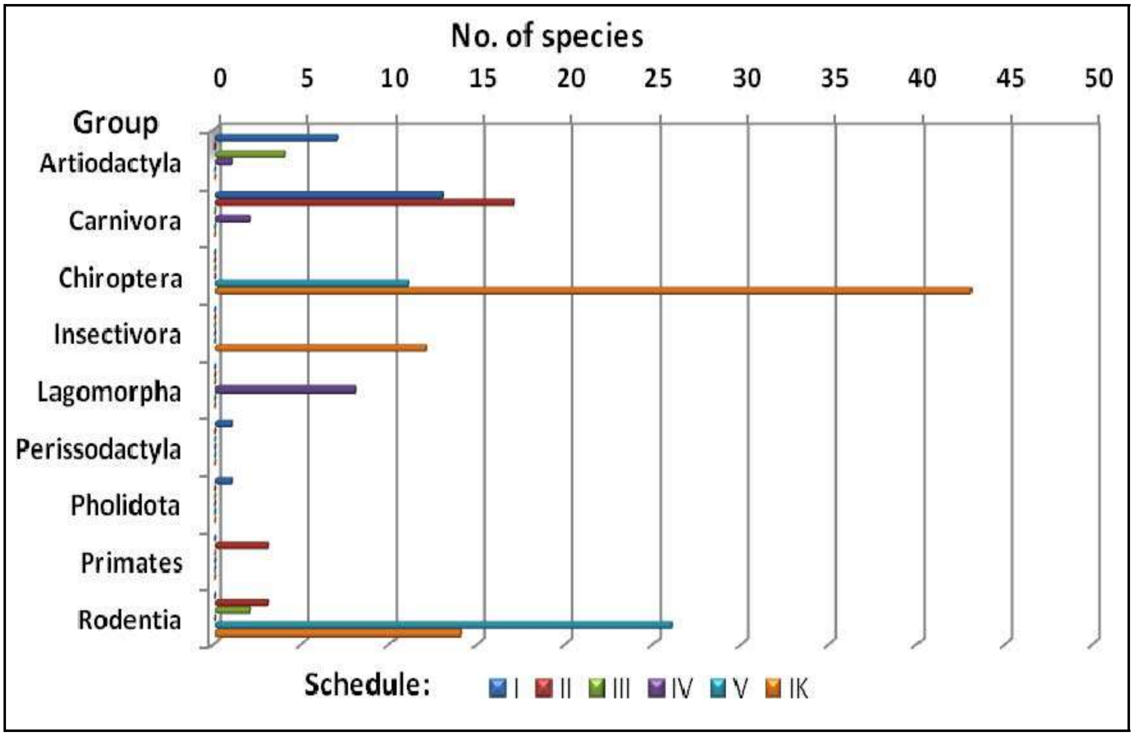


Figure 4.12: Conservation status of different species of mammals as per the WPA

A large number of species of birds (74%) are common resident (R) in the area (Fig. 4.14). 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.

The species richness in three lower zones i.e. I (<900 m), II (900 – 1,800 m) and III (1,800-2,800 m) is more or less similar. The zones-II and III are relatively rich in bird diversity. The species richness decreases gradually in upper zones (IV and V). The lower most zone is dominated by woodpeckers, drongos, bulbuls, buntings, and kingfishers; zone-II by doves, sunbirds and minivets. The zone-III harbours mostly babblers, warblers and thrushes. Zone-IV (2,800-3,800 m) and zone-V (>3,800 m) are represented with pheasants, vultures and eagles.

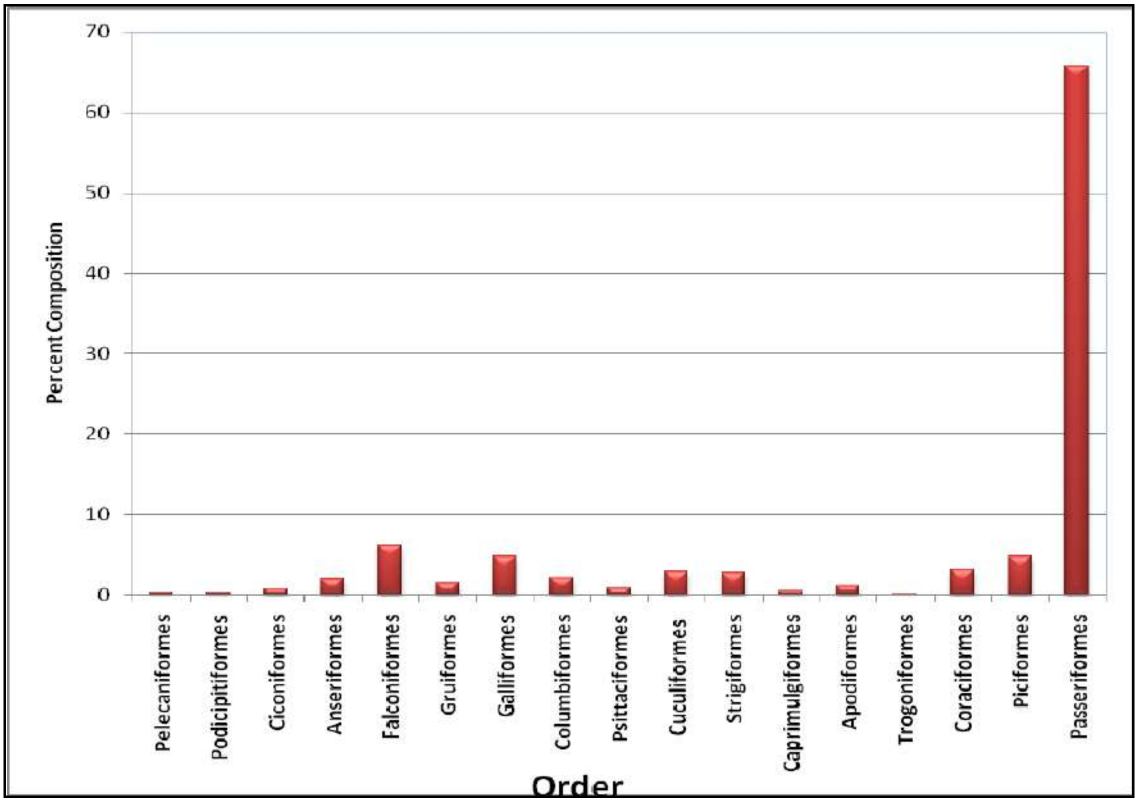
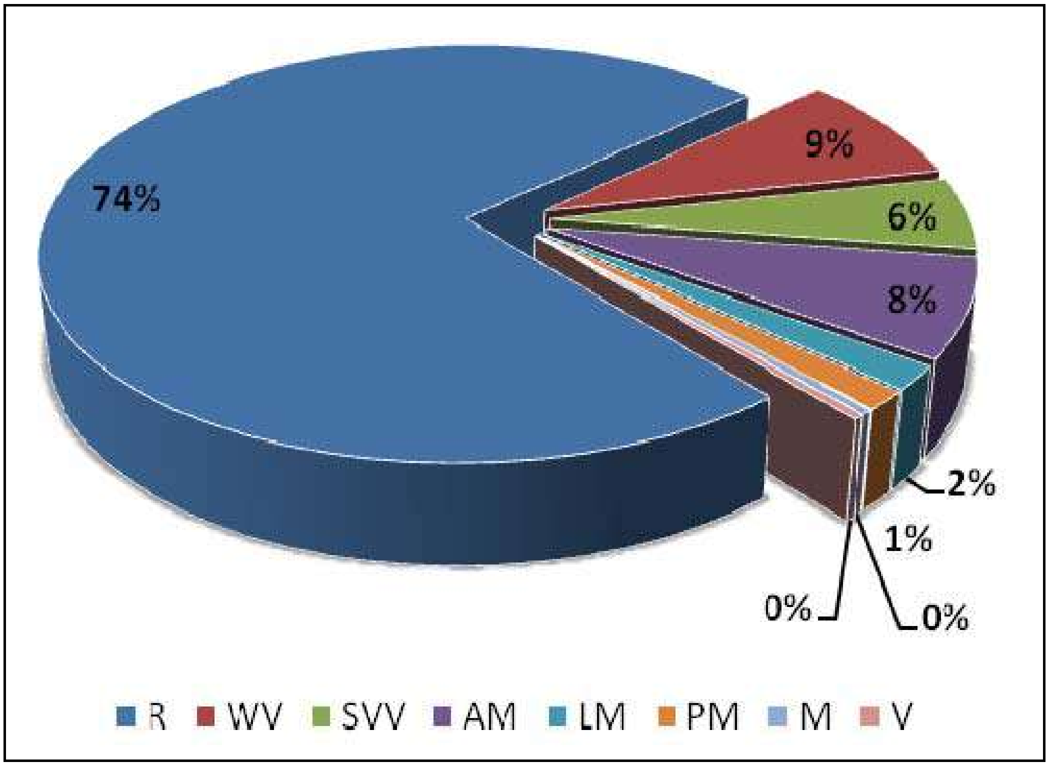


Figure 4.13: Composition of different groups of birds in the catchment area



(R = resident, WV = winter visitor, SV = summer visitor, AM = altitudinal migrant, PM = partial migrant, LM local migrant, M = migrant and V= vagrant)

Figure 4.14: Classification of birds on the basis of their migration pattern

Conservation Status

About 372 species reported from the catchment area are categorized in Schedule-IV on the basis of Wildlife Protection Act (1972) and 12 species *viz.* Creasted goshowk, Bersa, Eurasian sparrow hawk, Jorden's baza, Black baza, Himalayan monal, Sikkim blood pheasant, Blacknecked crane, etc. have been placed in Schedule-I. Only House crow is placed in Schedule-V. A total of 13 species of birds are threatened (Table 4.10) 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 like Hornbills and vulnerable species like Indian pea-fowl occupy lower altitudes of catchments.

In all 6 species found in Sikkim are endemic to Eastern Himalaya (Table 4.10). Of these species Chestnut-breasted hill partridge and White napped yuhina have wide range of distribution (up to 2,800 m) and Rusty-bellied shortwing is found at high altitude (2,800-3,800 m). The rest are mid-altitude species.

Table 4.10: Threatened and endemic species of birds reported from Khangchendzonga National Park in the catchment of Ting Ting H.E. project

Common Name	Scientific Name	Conservation Status		Endemic to Eastern Himalaya
		ZSI (1994)	WPA (1972)	
Goliath heron	*Ardea goliath*	R		-
Himalayan beared vulture	*Gypaetus barbatus*	R		-
Ospray	*Pondian haliatus*	VU		-
Shaheen falcon	*Falco peregrinus*	EN		-
Chestnut-breast partridge	*Arborophila mandellii*	–		+
Tibetan snowcock	*Tetraogallus tibetanus*	EN		-
Blood pheasant	*Ithaginis cruentus*	VU		-
Satyr tragopan	*Tragopan satyra*	VU		-
Himalayan monal	*Lophophorus impejanus*	EN		-
Indian pea-fowl	*Pavo cristatus*	VU		-
Black necked crane	*Grus nigricollis*	CR		-
Rufous-necked hornbill	*Aceros nipalensis*	VU		-
Great hornbill	*Buceros bicornis*	EN		-
Oriental pied hornbill	*Anthracoceros albirostris*	VU		-
Broad-billed fly warbler	*Tickelli hodgsoni*	–		+
Hoary-throated barwing	*Actinodura nipalensis*	–		+
Rusty-bellied shortwing	*Brachypterix hyperythra*	–		+
Wedge-billed wren-babler	*Sphenocichla humei*	–		+
White-naped yuhina	*Yuhina bakeri*	–		+

EN = Endangered; CR = Critical; R = Rare; VU = vulnerable

4.10.3 Faunal Species Recorded from Study Area

The proposed hydro-electric project is located in one of the densely populated areas in West Sikkim. During the field surveys 37 common occurring species were spotted. These species with their status and behavior are listed in Table 4.11. Of the 37 species, found in the the project study area 30 species are resident. Many of them perform vertical movement while 5 species are altitudinal migrants (AM) and 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 under the threatened (Vulnerable) (ZSI, 1994).

Table 4.11: Species composition and their conservation status

Common Name	Scientific Name	WPA (1972)	Behaviour
Falconiformes			
Mountain hawk eagle	*Spizaetus nipalensis*	IV	R
Galliformes			
Kaleej pheasant	*Lophura leucomelanos*	IV	R
Indian pea-fowl	*Pavo cristatus*	IV	R
Chestnut breasted hill partridge	*Arborphila mandellii*	IV	R
Charadriformes			
River lapwing	*Vanellus duvaucelii*	IV	WV

Red-wattled lapwing	*V. indicus*	IV	AM
Blackbacked Forktail	*Enicurus immaculatus*	IV	R
Cuculiformes			
Chestnut winged cuckoo	*Clamator coromandus*	IV	R
Himalayan griffon	*Gyps himalayensis*	IV	R
Columbiformes			
Rock pigeon	*Columba livia*	–	R
Wedge tailed green pigeon	*Treron sphenura*	IV	AM
Brown dove	*Streptopelia senegalensis*	IV	AM
Oriental turtle-dove	*S. orientalis*	IV	AM
Bartailed cuckoo dove	*Macropygia unchall*	IV	R
Strigiformes			
Barred owlet	*Glaucidium cuculoides*	IV	AM
Collard owlet	*G. brodiei*	IV	R
Oriental bay owl	*Phodilus badius*	IV	R
Coraciformes			
Common hoopoe	*Upupa epops*	–	SV
Rufousnecked hornbill	*Aceros nipalensis*	IV	R
Piciformes			
Blyth's kingfisher	*Alcedo hercules*	IV	R
Blue-eared kingfisher	*A. meninting*	IV	R
Passeriformes			
House sparrow	*Passer domesticus*	–	R
Tree sparrow	*P. montanus*	–	R
Indian myna	*Acridotherus tristis*	IV	R
Blue whistling thrush	*Myophonus caeruleus*	IV	R
Lesser neck laughing thrush	*Garrulax monileger*	IV	R
Yellowbreasted bunting	*Emberiza aureola*	IV	WV
House crow	*Corvus splendens*	V	R
Green magpie	*Cissa chinensis*	IV	R
Yellowbilled blue magpie	*C. flavirostris*	IV	R
Whitecheeked bulbul	*Pycnonotus leucogenys*	IV	R
Red –vented bulbul	*P. cafer*	IV	R
Grey tit	*Parus major*	IV	R
Green-backed tit	*P. monticolus*	IV	R
Brown shrike	*Lanius cristatus cristatus*	–	R
Longtailed shrike	*L. schach tricolor*	–	R
Striped tit babbler	*Macronous gularis*	IV	R
Crested bunting	*Melophus lathami*	IV	R

(R = resident, WV = winter visitor, SV = summer visitor, AM = altitudinal migrant, PM = partial migrant, LM local migrant, M = migrant and V= vagrant)

4.11 HERPETOFAUNA

4.11.1 Amphibians

The altitudinal zone of 900 – 1,800 m in West Sikkim as well as South Sikkim is quite rich in amphibian diversity comprised of 19 species. The lower elevation zone, where proposed project is located, harbours 10 species. All amphibian species except *Ichtjyophis sikkimensis* are categorized as Schedule-IV. *Ichtjyophis sikkimensis* is a Schedule-I species and is distributed in the mid-altitudes zone from 900 to 1,800m (Table 4.12). *Rana* spp. and *Bufo melanostictus* are other common species occurring in the project area. Only *Tylototrioton verrucosus* is an endangered species and is found in the upstream catchment area. It is distributed from 900 to 2,800 m altitudes.

4.11.2 Reptiles

There are more than 60 reptilian species reported from the catchment of the project belonging to 11 families *viz*. Testudinidae, Agamidae, Gekkonidae, Scincidae, Anguidae, Varanidae, Typhlopidae, Boidae, Colubridae, Elapidae and Viperidae. The lower altitudes are relatively rich in species composition and harbour 34 species. The number of species gradually decreases towards higher elevations. A large number of reptilian species (>50) are included in the Schedule-IV. There are 4 species like *Varanus bengalensis, Xenochrophis piscator, Naza kaouthia*, and *Vipera russelli* of Schedule-II. Only *Python molurus* is a Schedule-I species. *Calotes versicolor, Hemidactylus garnoti, H. flaviviridis, Varanus bengalensis, Naza kaouthia* and *Ophiophagus hannah* are found commonly in the study area. Common Indian monitor (*Varanus bengalensis*) and Rock python (*Python molurus*) are 'endangered' species. They are found at lower altitudes (<900 m) of the catchment.

Table 4.12: List of herpetofauna and their conservation status

Common name	Scientific name	WPA (1972) Category
Common toad	*Bufo melanostictus*	IV
Common frog	*Rana* spp.	IV
Indian python	*Pythonconicus molurus*	I
Common Indian krait	*Bungarus caerules*	IV
Indian cobra	*Naja naja*	IV
Rat snake	*Ptycs macosus copo*	II
Himalayan pit viper	*Ancistrodon himalayanus*	IV
Common chameleon	*Calotes versiclor*	IV
Common India monitor lizard	*Varanus monitor*	II
Common lizard	*Agama tuberculata*	IV
Common house gecko	*Hemidactylus brooki*	IV

4.11.3 Butterflies

Sikkim is well known for butterflies and harbours about 689 species. The number of species of butterflies gradually decrease along the altitudinal gradient. Due to increasing biotic interference, they have been under tremendous stress. Unlike birds and herpeto-fauna there are 29 species in Schedule-I, 92 species in Schedule-IV and only 8 species in Schedule-IV. Good forest cover interspersed with agricultural field and fallow land with water regime, act as suitable habitats for high butterfly species in lower altitudes. List of butterflies reported from the project area is given in Annexure-VII.

4.12 KHANGCHENDZONGA BIOSPHERE RESERVE

The proposed project is located within 7 km of Bufer Zone-IV of Khangchendzonga Biosphere Reserve (KBR). The KBR is spread across West, South and North districts of Sikkim State with a total area of 2655.26 sq km. It is comprised of 2 Core Zones i.e. Khangchendzonga National Park and Maenam Wildlife Sanctuary with total area of 1819.34 sq km and four buffer zones covering on area of 835.92 sq km (Figure 4.15). The Biosphere Reserve is in the altitude ranging form 1220m to over 8550 m.

Main features of the Khangchendzonga Biosphere Reserve are:

i) it contains unique geomorphic features with some of the lofty picturesque and beautiful peaks of heights ranging from 5825 m to over 8550 m asl., glaciers, high altitude lakes and is endowed with one of the world's highest ecosystems,

ii) it covers varying eco-clines from sub-tropical to arctic areas (1220-8550m) and several major North-South and west South trans-boundary watersheds,

iii) it is of a high religious significance. Mountains, Lakes, rocks and caves are sacred to the local people and are worshipped by them.

The Khanchendzong Biosphre Reserve includes only the Government Reserved Forests, forest set aside for grazing (Goucharan) and for the purpose of public utility (Khasmal), thus the boundary of the Biosphere Reserve runs all along the Reserved Forest boundary in places where villages are contiguous to the forests. It does not include any other village settlement except two small eco-villages.

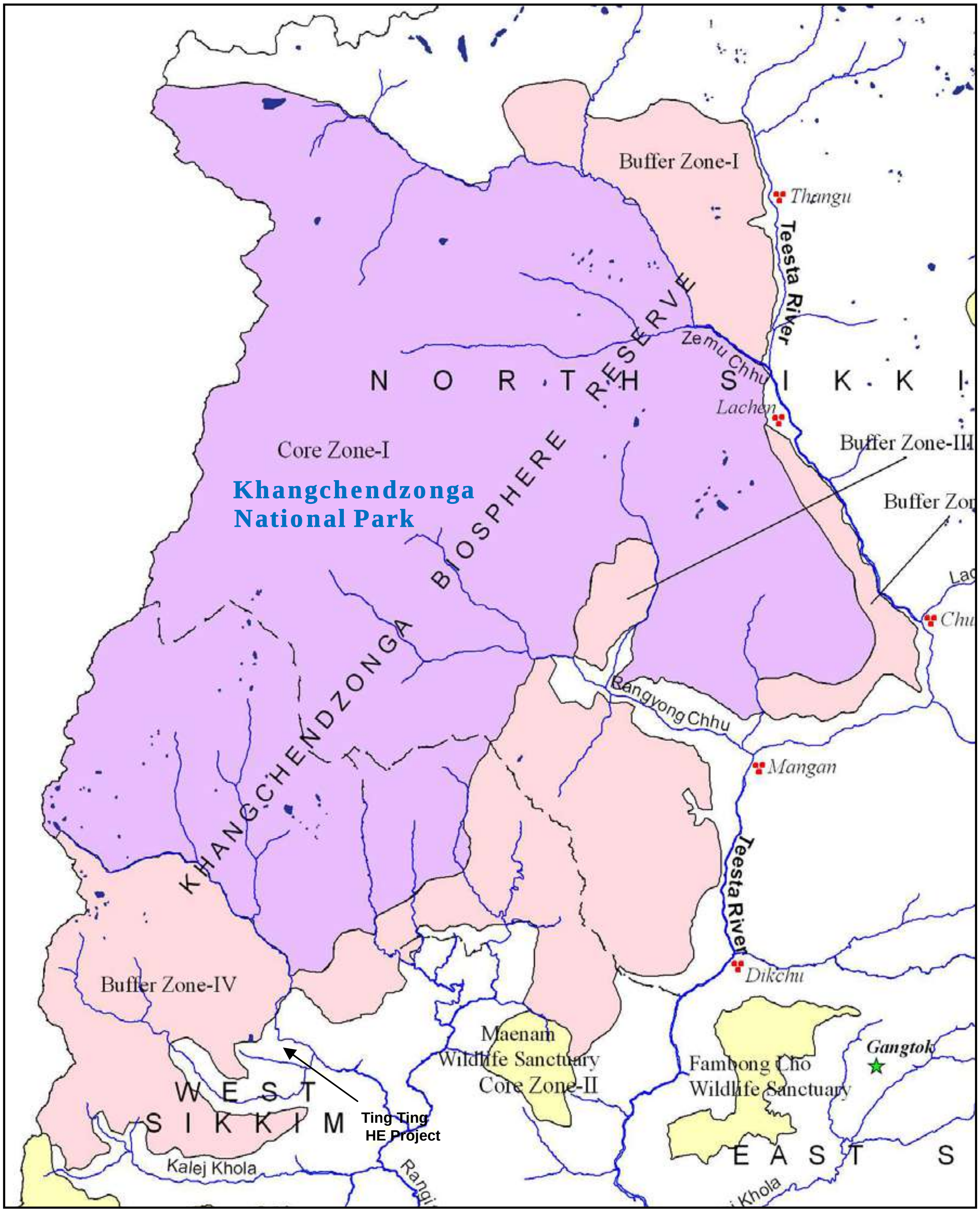


Figure 4.15: Map of Khangchendzonga Biosphere Reserve vis-à-vis Ting Ting H.E. project

The Reserve is surrounded by rural villages. The population consists of Lepchas (early settlers), Bhotiyas and Nepalese. Nepalese are represented by Brahmin, Chettri, Newar, Tamang, Gurung, Rai, Sherpa, Limbu, Mangar, Bhujel, Kami, Damai, and Sharki. The rural economy is mostly a mixed economy of agriculture, horticulture and animal husbandry.

Biodiversity of KBR

Khangchendzonga Biosphere Reserve is rich in floristic wealth. The forests represent diverse plant communities which include diverse vegetational types corresponding to variation of climatic and edaphic factors. Main vegetation types in the Biosphere Reserve based as per Champion and Seth (1986 are: Sub-tropical broad-leaved hill forest, Himalayan wet temperate forests, Temperate broad-leaved hill forest, Himalayan wet temperate forests, Temperate broad-leaved forests, Mixed coniferous forests, Sub-alpine forests, Moist Alpine Forests, and Dry Alpine Forests.

The faunal wealth is also equally rich in contents. The important threatened flora of the Reserve is listed below.

Threatened flora of the KBR

Aconitum spp.	*P. tibetacum*	*Rubia manjith*
Rhododendron spp.	*P.himalaicum*	*Lancea tibetica*
Meconopsis spp.	*Cordyceps sinensis*	*Onosma hookeri*
Costus speciosus	*Heracleum wallichi*	*Aristolochia* spp.
Taxus baccata	*Picrorhiza kurrooa*	*Dioscorea deltoidea*
Swertia chirata	*Orchis latifolia*	*Lilium polyphyllum*
Gynocardia odorata	*Panax pesudo-ginseng*	*Calenthe whitana*
Paphiopedilum venustum	*Trichosanthes palmata*	*Nardostachys jatamasi*

Some of the threatened fauna of the KBR

Common name	**Scientific name**
Mammals	
Leopard cat	*Felis bengalensis*
Jungle cat	*Felis chaus*
Panther or leopard	*Panthera pardus*
Snow leopard	*Uncia uncia*
Musk deer	*Moschus chrysogaster*
Himalayan tahr	*Hemitragus jemlahicus*
Tibetan wolf	*Canis lupus*
Clouded leopard	*Neofelis nebulosa*
Serow	*Capricornis sumatraensis*
Red panda	*Ailurus fulgens*
Nayan	*Ovis ammon hodgsoni*
Birds	
Himalayan golden eagle	*Aquila chrysaetos daphanea*

Himalayan bearded-vulture	*Gypaetus barbatus*
Satyr tragopan	*Tragopan satyra*
Himalayan monal pheasant	*Lophophorus impajanus*
Tibetan snow cock	*Tetraogallus tibetanus*
Tibetan horned or eagle-owl	*Bubo bubo tibetanus*
Forest eagle-owl	*Bubo nepalensis*
Black eagle	*Ictinactus malayensis*

People living in far flung areas close to the Biosphere Reserve are often devoid of the benefits of modern infrastructure. The economy is based on marginal agriculture, forestry and small herd of domesticated animals. They know judicious use of natural resources. Keeping socio-economic factors and age old rights of local people in view, in the project development programme, people-oriented schemes will be formulated to provide alternative means of employment in the project.

4.13 AQUATIC ECOLOGY

To study various parameters for aquatic ecology, survey was conducted and sampling was carried out at different sites of the proposed hydro-electric project on Rathong Chhu in post-monsoon, monsoon and lean (winter) seasons during 2008. The samples were taken in the replicates at each site of the river. The average value was calculated for the result. Physico-chemical and biological parameters were analyzed. The sites at which sampling was done are as follows:

Sampling Site	Location
W1	Submergence Area (Left bank of Rathong Chhu)
W2	Near Dam site (Right bank of Rathong Chhu)
W3	Power house site (Left bank of Rathong Chhu)
W4	Confluence of Rathong Chhu & Rimbi Khola (Left bank)
W5	Rimbi Khola (Left bank)

4.13.1 Methodology

a) Physico-Chemical Parameters

Several physico – chemical parameters of water necessary for the ecological studies were measured in the field with the help of different instruments. At each sampling site, pH, temperature, electrical conductivity, total dissolved solids and dissolved oxygen were measured in the field. The water temperature was measured with the help of graduated mercury thermometer. The pH, conductivity and total dissolved solids were recorded with the help of a pH, EC and TDS probes (Hanna instruments HI 98130) in the field. The water samples were collected in polypropylene bottles from the different sites in the field and brought to the laboratory for the further analysis. The two parameters such as, total silicates and nitrate were analyzed at the Spectro Analytical Labs Limited, Okhla, New Delhi. Total alkalinity, total hardness and phosphate (PO_4 – P) were measured as per APHA (1992) and Adoni (1980).For the analysis of turbidity, water samples were collected from the different sampling sites and brought to the laboratory for analysis. The turbidity was recorded with the help of Digital Turbidity meter. Dissolved oxygen was measured with the help of Digital DO meter (Eutech ECDO 602K) in the field. The water current velocities at all sites were measured by using the float method.

b) Biological Parameters

Sampling was performed across the width of the stream at the depth of 15 - 30 cm. The samples were taken from the accessible banks only. The cobbles of size 64 -128 mm, usually 4-5 in number, were picked from the riffle and pools, in apparently different flows such as stones above and below gushing waters, swift flow and slow flow conditions so as to obtain a representative sample. Diatom samples were collected by scratching the cobbles with a brush of hard bristles in order to dislodge benthos from crevices and minute cavities on the boulder surface from an area of 3 x 3 cm^2, using a sharp edged razor. The scrapings from each cobble were collected in a petri dish and transferred to storage vials.

Samples were preserved in 4% formaldehyde solution. Acid treatment according to Reimer (1962) method adopted earlier also (Nautiyal & Nautiyal 1999, 2002) was followed to process the samples for light microscopy. The treated samples were washed repeatedly to remove traces of acid. Samples with high organic content were treated with hydrogen per oxide to clean the diatom frustules. The permanent mounts were prepared in Naphrax for further analysis. They were examined using a BX-40 Trinocular Olympus microscope (10x and15x wide field eye-pieces) fitted with Universal condenser and PLANAPO 100x oil immersion objective under brightfield using appropriate filters to identify the species.

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

The dehydrated material was transferred to Xylol twice before finally mounting in Euparol.

Macro - invertebrate samples were collected from $1ft^2$ area by lifting of stones and sieving of substratum from the wadeable portion of the river. The material was sieved through 125 μm sieve and preserved in 70% ethyl alcohol. Standard keys were used for the identification of macro invertebrate samples (Pennek 1953; Edmondson 1959; Macan 1979, Edington and Hildrew 1995).

Table 4.13: Physico-Chemical Characteristics of River Water at various sampling locations

Characteristics	W1			W2			W3			W4			W5		
	W	M	PM	W	M	PM	W	M	PM	W	M	PM	W	M	PM
Water current velocity (m/s)	0.72	2.52	1.58	0.91	2.61	1.65	1.01	2.21	1.82	0.86	2.82	1.77	0.94	2.28	1.90
Water temperature (^{0}C)	5.0	13.0	11.3	6.00	15.0	8.0	5.7	14.00	8.50	7.6	15.00	7.00	7.0	16.00	10.00
Electrical Conductivity (µS/cm)	54	37	42	52	41	42	41	36	41	36	43	39	46	45	41
Turbidity (NTU)	5.66	18.87	14.01	4.11	18.52	12.11	5.22	19.14	18.48	4.55	15.52	10.11	8.22	19.14	18.08
pH	7.38	7.01	7.19	7.41	7.28	7.22	7.29	7.23	7.15	7.45	7.08	7.22	7.27	7.03	7.25
DO (mg/l)	8.80	8.10	9.55	8.92	8.00	9.80	8.49	8.20	9.30	8.74	8.55	8.50	8.18	8.00	9.10
Total Dissolved Solids (mg/l)	40.00	30.00	30.00	50.00	40.00	40.00	40.00	40.00	20.00	50.00	40.00	40.00	40.00	40.00	20.00
Total Alkalinity (mg/l)	22.00	22.00	20.20	42.00	28.00	26.60	24.00	24.00	20.40	42.00	28.00	26.60	24.00	24.00	20.40
Total Hardness (mg/l)	36.00	28.00	12.00	66.00	36.00	18.00	36.00	36.00	14.00	66.00	36.00	18.00	36.00	36.00	14.00
Chloride (mg/l)	5.99	5.99	5.49	8.99	6.33	6.54	5.99	5.99	5.79	8.99	6.33	6.54	5.99	5.99	5.79
Nitrates (mg/l)	0.097	0.022	0.004	0.013	0.071	0.008	0.004	0.094	0.022	0.002	0.071	0.048	0.001	0.004	0.002
Phosphate (mg/l)	0.070	0.021	0.041	0.041	0.021	0.031	0.060	0.030	0.041	ND	0.033	0.054	ND	0.009	0.019
Silica (as SiO_2),mg/l	0.021	0.041	0.48	0.48	0.021	0.031	0.61	0.030	0.041	0.77	0.021	0.031	0.41	0.030	0.041

W = Winter, M = Monsoon, PM = Post-monsoon, ND = Not Detectable

Table: 4.14 Densities of different biotic communities at different sampling locations

Characteristics	W1			W2			W3			W4			W5		
	W	M	PM	W	M	PM	W	M	PM	W	M	PM	W	M	PM
Coliforms (A/P)	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
Phytoplankton (cells/lit.)	33962	2136	6733	32345	2255	6412	42453	2670	8416	45849	2883	9089	121899	98016	63034
Phytobenthos (cells/cm^2)	72363	9106	21176	68917	8742	20168	90454	11382	26471	97690	12293	28588	154538	35063	123584
Macro-invertebrates (indiv./m^2)	1013	593	1036	965	565	987	1267	742	1295	1368	801	1399	1191	239	989

W = Winter, M = Monsoon, PM = Post-monsoon, A = Absent, P = Present

Table: 4.15 List of phytobenthos recorded at different sampling locations

Taxa/Sampling Site	W1	W2	W3	W4	W5
Chlorophyaeae					
Spirullina sp.	+	-	+	-	+
Hormidium sp.	+	+	-	+	+
Ulothrix sp.	+	-	+	-	-
Microspora sp.	-	+	+	+	+
Spirogyra sp.	+	+	+	+	-
Arthospira sp.	-	+	-	+	+
Bacillariophyceae	+	-	+	-	-
Diatoma hiemala	+	-	+	-	+
Fragilaria vaucheriae	+	+	+	+	+
Synedra ulna	+	+	-	+	+
S. ulna var. *oxyrhynchus*	+	-	-	-	-
S. rumpens	-	-	+	-	-
Hannaea arcus var. *linearis*	-	+	+	-	-
Eunotia sp.	+	+	+	-	-
Achnanthes affinis	-	+	+	+	+
A. biasolettiana	-	+	+	+	+
A. conspicua	+	+	-	+	-
A. fragilarioides	+	+	-	+	-
A. hauckiana	-	-	-	-	+
A. lanceolata	-	-	+	-	-
A. linearis	+	-	+	-	+
A. minutissima	-	+	+	+	+
A. saxonica	+	+	-	+	+
A. undata	+	+	-	+	+
Cocconeis placentula var. *euglypta*	+	-	+	-	+
Anomoeneis sp.	+	+	+	+	+
Navicula cryptocephala	+	-	+	-	+
N. dicephala	+	+	-	+	+
N. grimii	+	+	-	+	-
N. radiosa	+	+	+	+	+
N. rhynchocephala	+	-	+	-	-
Cymbella affinis	-	-	+	-	-
C. hustedtii	+	+	-	+	+
C. laevis	-	+	-	+	-
C. lata	-	+	-	+	-
C. obtusiuscula	+	-	-	-	+
C. nagpurensis	-	-	+	-	-
C. tumida	-	-	+	-	+
C. turgidula	+	-	-	-	-
C. ventricosa	-	+	+	+	+
Reimaria sinuata	+	+	+	+	+
Gomphonema angustatum	-	-	+	-	-
G. bohemicum	+	+	-	+	-
G. gracile	+	+	-	+	+
G. intricatum	-	+	+	+	+
G. olivaceum	-	-	-	-	-
G. olivaceoides	+	-	+	-	+
G. lanceolata	+	+	-	+	-
G. parvulum	-	+	+	-	+
G. sphaerophorum	+	-	+	+	-
Gomphonema sp.	+	+	-	+	+
Surirella sp.	-	-	-	-	+
Nitzschia amphibia	+	+	-	+	-
N. linearis	-	+	+	+	-

+ Present; - Absent

Table 4.16: Macro-invertebrates composition in the different streams in the project area

TAXA		W1			W2			W3			W4			W5		
		W	M	P	W	M	P	W	M	P	W	M	P	W	M	P
Ehemeroptera																
	Heptagenidae	332	100	334	222	266	211	388	211	277	222	266	211	259	221	282
	Baetidae	144	322	56	212	144	202	342	199	167	221	138	313	357	186	162
	Ephemerellidae	56	-	11	-	-	22	110	22	89	-	-	32	90	52	65
	Caenidae	22	22	-	77	-	11	-	-	75	61	-	11	-	-	80
Plecoptera																
	Isoperlidae	22	-	11	67	-	-	-	-	22	67	-	-	-	-	22
	Perlidae	-	-	-	-	-	44	-	-	22	-	-	44	-	-	22
Trichoptera																
	Hydropsychidae	56	-	444	234	-	-	-	33	22	221	-	-	-	39	22
	Leptophelbidae	552	110			31	256	311	33	324		30	217	300	33	281
Diptera																
	Chironomidae	77	-	87	110	101	110	44	22	122	110	101	105	42	27	92
	Culucidae	-	-	56	22	-	-	28	-	-	21	-	-	22	-	-
Coleoptera																
	Psephanidae	-	-	-	11	-	11	-	11	22	11	-	11	-	11	22
	Total	**1261**	**554**	**999**	**955**	**542**	**867**	**1223**	**531**	**1142**	**934**	**535**	**944**	**1070**	**569**	**1050**
	BMWP Score	**64**	**37**	**52**	**52**	**32**	**62**	**47**	**70**	**77**	**52**	**32**	**62**	**47**	**50**	**77**
	ASPT Score	**8.0**	**9.3**	**7.4**	**6.5**	**8.0**	**7.8**	**7.8**	**10.0**	**7.7**	**6.5**	**8.0**	**7.8**	**7.8**	**7.1**	**7.7**

W = Winter, M = Monsoon, PM = Post-monsoon, ND = Not Detectable

BMWP = Biological Monitoring Working Party

ASPT = Average Score Per Taxa

4.13.2 Physico-chemical Water Quality

Rathong Chhu is a glacier fed river. Water current velocity varied with season being maximum during the monsoon (Table 4.13). Turbidity was less than 10 NTU in winters at all the locations but it was more during monsoon season. The pH of water ranged from 7.01 to 7.45 at all the sampling sites in different seasons. Dissolved oxygen varied with water temperature and is lower during monsoon season when temperature is higher. Electrical conductivity varied from 36 to 54 and total dissolved solids from 20 to 50 ppm. Maximum alkalinity values were recorded during the winter season at W2 & W4.

The water at all the sampling locations is soft with total hardness ranging from 12.30 to 42.00 mg/l. Nutrients concentrations, viz. chloride, nitrate, phosphate and silicates did not follow a definite pattern at any particular location.

4.13.3 Biological Water Quality

a) ***Total coliforms***

Total coliforms were absent at all the sampling sites during all seasons (Table 4.14).

b) ***Algae***

All the rivers were rich in the algal density in phytoplanktonic as well as phytobenthic communities (Table 4.14). Phytoplankton density ranged from 2255 to 121899 cells/lit. with minimum during monsoon season (Table 4.14). The density of phytobenthic algae varied from 8742 to 154538 cells/cm^2 with minimum at site W2 area, the submergence during monsoon season.

The algal composition comprised of about 6 species of filamentous algae and more than 47 species of diatoms (Table 4.15). At dam site and submergence area 4 species of Chlorophyceae were recorded and 28 and 18 species of Bacillariophyceae were recorded at the respective sites. Chlorophyceae included *Spirullina* sp., *Hormidium* sp., *Ulothrix* sp., *Microspora* sp. and *Arthospira* sp. Among the Bacillariophyceae (diatoms) *Achnanthes minutissima* and *A. linearis* were predominant at sampling locations near powerhouse.

No serious stresses on Rathong Chhu or Rimbi Khola could be observed. Physical and chemical characteristics health of Rathong Chhu is directly related to the presence of settlements in the immediate vicinity. Among the biological characteristics, majority of the taxa in all streams were pollution intolerant, however, presence of a few pollution tolerant species like *Gomphonema sphaerophorum, Nitzschia amphibian*, *N. linearis* is indicative of slightly stressed condition.

c) Macro-invertebrates

Rathong Chhu is rich in the macro-invertebrates composition. Macro-invertebrates density ranged from 531 – 1261 individuals/m^2 (Table 4.16). Macro-invertebrates fauna comprised of 10 families, in which Heptageniidae and Baetidae were most common and dominant at all sampling locations. Higher water discharge during monsoon resulted in lower density of macro-invertebrates at all locations.

The **biological monitoring working party** (BMWP) procedure was employed for measuring water quality using species of macroinvertebrates as biological indicators (http://www.nethan-valley.co.uk/insectgroups.doc). A higher BMWP score is considered to reflect a better water quality. BMWP score for these rivers ranged from 37 to 77 while ASPT score varied from 6.5 to 10.

4.13.4 Glacial Lakes

The catchment of Rathong Chhu up to project site has a number of glacial lakes in the higher reaches. These are sacred lakes. The Rathong Chhu, itself considered a sacred river, is said to have its source in nine holy lakes at the higher elevations, close to the mountain peaks. Besides, the river in the Yuksom region itself is considered to have 109 hidden lakes. These visible and less obvious notional lakes identified by religious visionaries are said to have presiding deities, representing both good and evil. Propitiating these deities through various religious ceremonies is considered important for the welfare of the Sikkimese people.

Of more than 200 lakes in Sikkim, Khecheopalri Lake is the most sacred and is revered by the local people.

4.14 FISH AND FISHERIES

Of the 674 inland fish species of India, about 52 species are found in Sikkim. The rich surface water resource as river and lakes in the Sikkim Himalaya (potentially rivers) provides a great opportunity for the development of fish and fishery. River Rangit is the largest tributary of river Teesta in Sikkim. It originates from Mamprik Phuk ridge at 4,401 m and confluences with Teesta at 234 m near Melli. The great altitudinal variation in Rangit leads to variation in fish species also and about 37 fish species have been recorded from river Rangit, which belong to families Cyprinidae, Homalopteridae, Sisoridae, Cobitidae, Schilbeidae, Channidae and Anguilidae. The data on fish and fisheries were collected from field survey and sampling and secondary sources. The fish were landed with the help of local fishermen. They caught fish by cast nets and hooks.

4.14.1 Fish distribution and composition in Rathong Chhu

Fish composition changes along the altitudinal gradient of river Teesta and its tributaries like Rangit due to changes in physical and chemical characteristics of water. The water temperature plays a vital role in the distribution of fish and in Himalayan rivers. Like other Himalayan rivers, Rangit can be divided into three zones *viz*. upper most zone (above 1,400 m), middle zone (850-1,400 m) dominated by snow trout and lower zone (below 850 m) dominated by carp species (Sehgal, 1983). The distribution of important fish species is described in the following paragraphs.

a) Schizothorax richardsonii **(Snow trout)**

Snow trout is found throughout Himalaya. It is herbivorous and in Sikkim it is locally known as Asla. It is quite common in Rangit river and in its tributaries like Rimbi Khola, Rathong Chhu and Kalej Khola. It is found from 300m to 1,600 m (Table 4.17). It performs local migration from upstream to downstream. It is important contributor to the capture fishery in Rangit catchment.

b) Schizothoraicthys progastus **(Snow trout)**

This is one of the most common Himalayan species. In Sikkim, it is locally known as Chuche Asla. It is herbivorous and common in all the streams of Sikkim including Rangit. It is distributed mainly in tropical and temperate regions from El. 300 to 1,600 m.

c) Tor putitora **(Mahseer)**

Tor putitora is popularly known as Himalayan mahseer or Golden mahseer and is known as Shahar or mahseer in Sikkim. It is a migratory fish, which ascends from foothills to Teesta and Rangit river system during late summer to monsoon. In Rangit river the stretch from Meli to Legship near Rishi Khola confluence was as a known breeding ground for mahseer.

***d) Barilius* spp. (Hill trout)**

Barilius spp. are the most common fishes found in Rangit river. Locally they are called 'Khasrey' and commonly called hill trout. Two species of hill trout namely *Barilius bendelisis* and *B. vagra* were recorded from Rangit. They are distributed in lower stretch of river Rangit.

***e) Garra* spp.**

This group of fish is known as Budhna in Sikkim. The group comprises of 5 species in river Rangit (Table 4.17). *Garra gotyla* and *G. lamta* are common species of Rangit river while, other species are found rarely. Generally, the fish of this group are distributed from 300 to 900 m.

***f)* Other species**

In addition, many other fish species like *Noemacheilus* spp., *Glyptothorax* spp., *Euchiloglanis hodgarti*, *Pseudecheneis sulcatus*, *Balitora bruccei, Clupisoma* sp., *Bagarius bagarius*, *Laguvia ribeiroi* and *Chana orientalis* are known from river Rangit. They are not important from fisheries point of view in Rangit catchment. Their status and distribution is given in Table 4.17.

4.14.2 Migratory Fish in Rangit River System

Fish migration is a specific phenomenon and related to the breeding behaviour. Most of the species of fish are periodic in breeding and require specific ground through out the life. Mahseer (*Tor putitora*) is an important potamodromous fish in Himalayan rivers, which migrates from warmer plains to high reaches in cold water region. In Sikkim also, it is a true potamodromous migratory fish, ascending a long distance from warm waters of Teesta barrage (foothill) to cold waters of rivers Rangit, Teesta and Rangpo Chhu during late summer to monsoon months for breeding. The water turbidity, temperature and nature of river bed are considered to be important stimuli for the migration of mahseer (Bhatt *et al*. 2005). Most of the brooders of mahseer were found to prefer river Rangit for spawning. Adults after spending whole summer and monsoon in these streams return to warmer waters during September and mid-October along with juveniles. The stretch of Rangit river up to Jorethang is the breeding ground for mahseer. However, of late the migration of mahseer has been hampered due to the construction of Teesta Low Dam hydro-electric project (lower stretch of Teesta in West Bengal) impairing its migratory route. Therefore, mahseer presently is rarely captured in this stretch.

Acrossocheilus hexagonolepis and snow trout are the local migratory fishes. *A. hexagonolepis* migrates to small tributaries from the main stream while snow trout like *Schizothorax richardsonii, S. progastus* move downstream during summer to monsoon.

Table 4.17: Composition and distribution of fish species in Rangit River

Species	Local name	Occurrence	Status	Altitude (m)
Family Cyprinidae				
Tor putitora	Mahseer, Sahar	C	E	Up to 700
Labeo dero	Gardi	R		Up to 700
Surssocheilus hexagonolepis	Catli	A		Up to 850
Puntius clavatus	-	R	E	
Schizothorax richardsonii	Asla	A		Up to 1600
Schizothoraicthys progastus	Chuche asla	A		
Barilius bendelisis	Korang, Joia	C		Up to 850
B. bendelisis chedra	Korang, Joia	C		Up to 850
B. vagra	Chirkay	C		Up to 850
Danio aequipinnatus	Vhitti	R		
D. naganensis	Vhitti	R		
Garra gotyla gotyla	Budhna	C		Up to 900
G. gotyla stenorhynchus	Budhna	R		Up to 900
G. annandalei	Budhna	R		Up to 900
G. lamta	Budhna	C		
G. mcclellandi	Budhna	R		
Crossocheilus latius latius	Lohari	R		Up to 700
Family Homalopteridae				
Balitora bruccei	Teetai maccha	R		
Family Sisoridae				
Glyptothorax sinense sikkimensis	Kahray	-		
G. basnetii	Kahray	-		
G. bhutiai	Kahray	-		
Bagarius bagarius	Ganchha maccha	C		
Laguvia ribeiroi ribeiroi	Ganchha maccha	C		
L. ribeiroi jorethangensis	Ganchha maccha	R		
Family Cobitidae				
Nemacheilus butanensis	Gadela	R		
N. carletoni	Gadela	C		
N. corica	Gadela	C		
N. devdevi	Gadela	C		
N. sikkimensis	Gadela	C		
N. kanjupkhulensis	Gadela	C		

N. multifaciatus	Gadela	C		
N. spilopterus	Gadela	C		
N. bevani	Gadela	C		
Family Schilbeidae				
Clupisoma ontana	Jalkapoor	R		Up to 850
Family Channidae				
Channa gachua	Hilay	R		Up to 850
Family Anguilidae				
Anguilla bengalensis	Balm	A	E	Up to 650

A = Abundant, C = Common, R = Rare, E = Endangered

4.14.3 Fisheries Activities

Quite a large proportion of people of Sikkim are non-vegetarian in food habit. Despite the fact that Sikkim is rich in fish resources and legal fishing is allowed, the fish is not main source of their diet. However, the process of fisheries development is continuing in Sikkim. At present 13 fish farms have been functioning in Sikkim for different species.

In river Rangit capture fishery occurs mostly in lower stretch of the river up to 600 m during winter season. In monsoon it becomes significantly low due to heavy discharge and high velocity of water in the river. The important species, contributing capture fishery are *Acrossocheilus hexagonolepis* (Catli), *Schizothorax richardsonii* (Asla), *Schizothoraicthys progastus* (Chuche Asla), *Tor putitora* (mahseer) and *Anguilla bengalensis* (Bam). The fishermen have been issued licenses for fishing. They were found to use caste nets and hooks for fish landing. On one side the construction of Teesta Low Dam on Teesta river in West Bengal has lead to disruption of migration of mahseer upstream into Teesta river as well as Rangit river, while the proposed reservoir would encourage fisheries development in the area.

4.14.4 Fishery Survey in The Project Area

The present study was carried out in the proposed hydro-electric project area in West Sikkim. As water from Rathong Chhu would be diverted through a 2.14 km long head race tunnel (HRT) up to the proposed powerhouse. As Rathong Chhu is snowfed, it harbours cold water fishes. The river stretch below powerhouse falls in the sub-tropical zone.

Methodology

Fishing was carried out during the winter and monsoon seasons in Rathong Chhu. Local fishermen were employed to land fish. Number of fishermen were employed for fishing during winter as well as monsoon seasons. Fishermen used hooks and caste net to land fish and rarely did they use damming method to land the bottom dweller species. In addition information from fishermen were also used to collect the information on fish.

Fish Composition

Ichthyofauna comprised of 15 species in Rathong 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 (Table 4.18). A total of 11 species were common in both streams. Exotic trout (*Salmo trutta fario*) has earlier been introduced in the Rimbi Chhu (Carrying Capacity Studies, 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. 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. Occasionally, fishermen dam a part of stream, wherein all species are found in the catch.

4.14.5 Conservation Status & Fisheries

The criterion of BCPP CAMP workshop (1997) was followed to understand the conservation status of fishes of Himalaya. Out of 25 species 13 species have been assessed for their threat category. A total of 4 species of *Nemacheilus* and *Garra gotyla stenorhynchus* are placed under 'endangered' category while *Schizothorax ricahardsonii, Barilius vagra* and *G. gotyla gotyla* are 'vulnerable' (Table 4.18).

Caste nets and hooks are common fish gears used by the fishermen in Rangit river system. Cultural fisheries are totally absent in these areas whereas capture fishery depends mainly on the *Schizothorax richardsonii* and *Schizothoraicthys progastus* Rathong Chhu. Number of fishermen in the vicinity of project area are engaged in the fishing activities. Average catch recorded per hour/fishermen was 800 g approximately during winters. The maximum fishing activities occur in the months from October to April. In monsoon season only hooks are used to land the fish. The average catch/fishermen/hour was about 150 g.

Table 4.18: Composition and distribution of fish species in the waters of Kalej Khola and Rimbi Khola

S. No.	Species	Local name	Status
Family Salmonidae			
1	*Salmo trutta fario*	Trout	Exotic
	Family Cyprinidae		
2	*Schizothorax richardsonii*	Asla	VU
3	*Schizothoraicthys progastus*	Chuche Asla	LR/nt
4	*Garra gotyla gotyla*	Budhna	VU
5	*G. gotyla stenorhynchus*	Budhna	EN
6	*G. lamta*	Budhna	-
7	*Crossocheilus latius latius*	Lohari	DD
Family Sisoridae			
8	*Glyptothorax sinense sikkimensis*	Kahray	-
9	*Laguvia ribeiroi ribeiroi*	Ganchha maccha	LRnt
10	*L. ribeiroi jorethangensis*	Ganchha maccha	-
Family Cobitidae			
11	*Nemacheilus carletoni*	Gadela	EN
12	*N. corica*	Gadela	LR/nt
13	*N. devdevi*	Gadela	EN
14	*N. sikkimensis*	Gadela	EN
Family Schilbeidae			
15	*Clupisoma montana*	Jalkapoor	-

LR = low risk; LC/lc = least concern; NT/nt = near threatened; VU = vulnerable; EN = Endangered; DD = Data deficient

CHAPTER-5

SOCIO-ECONOMIC ASPECTS

5.1 GENERAL

Sikkim is a landlocked, smallest mountainous state in the Eastern Himalaya with a total area of 7,096 sq km. Sikkim is sparsely populated with a population density of 76 persons per sq km. About 11.10% of the total population of the state is urban. Scheduled Castes and Scheduled Tribes population constitute 5.02% and 20.59% respectively of the total population (see Table 5.1). Total literacy rate is nearly 70%, which is dominated by males. The sex ratio in the state is 875.The state is divided into four districts (North, South, East and West) and its capital Gangtok is located in East Sikkim. The districts are further sub-divided into sub-divisions, with nine sub-divisions in all, *viz*. Gangtok, Pakyong and Rongli in East Sikkim, Namchi and Ravong in South Sikkim, Gyalzing and Soreng in West Sikkim and Mangan and Chungthang in the North Sikkim. The population comprises of Lepchas, Bhutias and Nepalese.

Sikkim has a tremendous potential for successful tourism industry in all its four districts. The state is 113 km long from north to south and 64 km wide from west to east. Besides, there are numerous rivers and water channels in this state. They are a potentially rich source for the generation of hydel power and aquaculture.

Table 5.1 Sikkim at a Glance

Area	7096 sq km
Number of Districts	4
Number of Sub-divisions	9
Number of Towns	8
Population	540493
Urban Population	11.10%
Density of population	76 per sq km
Sex Ratio	875
Literacy Rate	69.68 (%)
Number of Gram Panchayats Units	166
Number of Revenue blocks	453

Development projects are planned based on the availability of exploitable natural resources and on commissioning they act on growth foci. This attracts flow of finances, investments, jobs and other livelihood opportunities, which brings in people from different cultural and social background. Such planned activities not only provide impetus to the local economy but also bring about a multi-dimensional economic, social and cultural change. Most often it has been observed that such development projects are commissioned in economically and socially backward areas, which are inhabited by some of the indigenous populations. Commissioning of development project invariably brings about a number of desired and undesired impacts along with it. The proposed project is located in West Sikkim district on Rathong Chhu, a tributary of Rangit river.

5.2 WEST SIKKIM

Gyalzing (a.k.a Geyzing) is the headquarters of West Sikkim district. The district is prominent place for trekkers and adventure lovers. It also harbours vast variety of fauna and flora and rhododendrons. Other important towns include Pelling, Yuksom and Jorethang. Yuksom once was the capital of Sikkim, it served as the capital in 1642 for almost 50 years until it was shifted to Rabtense. The district was under the occupation of the Nepalese for many decades in the 18th and 19th centuries. After the Gorkha War, the district was returned to Sikkim. The economy is mainly agrarian, despite most of the land being not suitable for cultivation owing to the precipitous and rocky slopes. The tourist attractions include the Khecheopalri lake which is a sacred lake and the Dubdi Monastery, the first monastery of the state. The people are mainly of Nepali descent. Other ethnic groups include the Lepcha and Bhutia communities. Nepali is the most widely spoken language in the district.

Khecheopalri lake is situated at 2000m and 34 km northwest of Pelling. Lake is known as the "Wishing Lake", it is sacred to the Lepchas (Buddhists) and the Hindus religions. Lake is surrounded by dense forests, it is believed that the birds do not allow even as single leaf to float on the lake. Khecheopalri village and the Gompa is just 3 km away from the lake, from the top of the ridge, excellent views of Mt Pandim (6,691m) can be seen.

The region has many power projects and enjoys almost uninterrupted electricity. Roads however, are in a poor condition owing to the frequent landslides.

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. The district also has 5 forest blocks. Gyalzing, the district headquarters is the only town in the district. About 98.5% of the total population is rural. The population of Scheduled Castes and Scheduled Tribes accounts for 4.66% and 19.33% of the total population, respectively. Total literacy rate in the district is 58.8%.

The population of West Sikkim primarily comprises of three main ethnic-groups,viz.,Lepchas who are the original inhabitants of the state; the Bhutias who migrated from Tibet during the 17th century and the Nepalese whose migration started in the 19th century. However, the present population of Sikkim includes a sizeable proportion of people from the plains as well apart from Nepalese,Lepchas and Bhutias.The Nepali population is dominant in the entire project area.The official and common language in the region is Nepali.

West Sikkim is comprised of 2 sub-divisions viz. Gyalzing and Soreng. The proposed project and its components fall in the sub-division Gyalzing.

GENERAL INFORMATION: WEST SIKKIM

Total Population	137,700
Scheduled Tribes	Male : 32,268 – Female : 30,119
Scheduled Castes	Male : 4,167 – Female : 3,974
Others	Male : 34,816 – Female : 32,356
0-6 years	17,901(CNA 2008)
Gyalzing CHC	1
No. of PHCs	7
No. of PHSC	41
No. of ICDS centers	205
No. of Gram Panchayats	55
Total number of households	23103
Total number of ASHAs	120
Total number of MSS	67
Total number of villages	205
Total number of schools	294

(Source: DHEO, Dept .of HCHS AND FW, District hospital,Gyalzing ,Govt.of Sikkim)

5.3 SOCIO-ECONOMIC STATUS IN THE STUDY AREA

The project study area is spread across two districts viz. West and South within only two sub-divisions viz. Gyalzing and Ravong. The total population of these two sub-divisions is 1,08,594. The literacy rate of Gyalzing and Ravong sub-division are 61.20 and 55.40, respectively.

A census survey of the population residing in the vicinity villages of the project area was carried out. This section deals with the overall village summary of the socio-economic standards and the amenities available to the local people living therein.

5.3.1 Socio-economic Profile of Sub-divisions : Gyalzing and Ravong

a) Demographic profile

Total population of Gyalzing sub-division is 64,419 which belong to 11,955 households and 65 villages (Table 5.2). Scheduled Castes (SC) and Scheduled Tribes (ST) constitute

4.82% and 21.19%, respectively of the total population. The population in the age group of 0-6 years accounts for 17.12% of the total population. The sex ratio in Gyalzing is 909.

Table 5.2: Demographic profile of Gyalzing & Ravong Sub-Division

Sub Division - West Sikkim										
Sub-Division	**No. of Villages**	**No. of Households**	**Population Structure**						**Sex Ratio**
			T	**M**	**F**	**SC**	**ST**	**0-6 yrs**	
Gyalzing	65	11955	64419	33744	30675	3110	13654	11036	909
Ravong	47	8396	44175	23162	21013	1444	10184	7472	927

T=Total, M=Male, F=Female, SC=Scheduled Castes, ST=Scheduled Tribes; (*Source*: Census, 2001)

b) Educational Profile

Total literacy rate is about 55.4% (Table 5.3) Literacy rate is considerably higher in the male population. More than 92% of the villages are having primary education facility in the sub-division. There is no college in the Gyalzing sub-division. Also, there is lack of middle, senior and senior secondary schools as compared to primary education facilities.

Table 5.3: Educational profile

Sl.No	**Literacy Rate (%)**			**No. of Educational Institutions**				
	Total	**Male**	**Female**	**P Sch**	**M Sch**	**SS**	**SSC**	**College**
Sub Division - West Sikkim								
Gyalzing	55.4	63.3	46.6	132	33	15	03	-
Sub Division – South Sikkim								
Ravong	67.31	74.29	59.72	110	29	10	02	-

PSch = Primary school, MSch = Middle School, SS = Secondary School, SSC = Senior Secondary School (*Source*: Census, 2001)

c) Health Care Facilities

There is one allopathic hospital in the entire Gyalzing sub-division while there are no ayurvedic and homeopathic hospitals (Table 5.4). In Gyalzing sub-division, there are 3 Primary Health Centers located in the villages Yuksom, Laso and Mangmo. In all 21 Primary Health Sub-Centers are located in the villages Gerethang, Thingle, Meli, Melliaching, Nambu, Darap, Singyang, Chongpung, Unglok, Kongri, Narkhola, Gangyep, Umchung, Lingchom, Bangten, Karmatar, Maneybung, Radu-Khandu, Hee, Barnyak and Chingthang. There is no maternity home or Family Welfare Center in the Gyalzing sub-division. There are 45 Child Welfare Centers that caters to the entire Gyalzing population.

Table 5.4 Number of hospitals and health centers

Sub-division	Allopathic	Ayurvedic	Homoeopathic	PHC	PHSC
Sub Division - West Sikkim					
Gyalzing	01	-	-	03	21
Sub Division – South Sikkim					
Ravong	-	-	-	2	15

(*Source*: Census, 2001)

d) Occupation Pattern

Agriculture has traditionally been the major feature of Sikkim's economy. Besides this the economy of the villages in the area depends mainly on the government and non-government services. Large Cardamom is the major cash crop while paddy, potato, cabbage, corn, etc., are the main crops in this area.

Table 5.5: Occupation pattern

Sub-Division	Work Force			Main Worker			Marginal Worker			Non Workers		
	T	M	F	T	M	F	T	M	F	T	M	F
Gyalzing	28976	17975	11001	24795	16384	8411	4181	1591	2590	35443	15769	19674
Ravong	3283	1994	1289	3002	1920	1082	281	74	207	3138	1399	1739

T = Total, M = Male, F = Female (*Source*: Census, 2001)

About 45% of the total population falls in the worker category in Gyalzing (Table 5.5). About 85.5% workers come under the main workers category. Marginal workers contribute 14.4% of the total work force, dominated by females. About 55% of the total population is in the non-worker category.

5.3.2 Socio-economic Profile of Villages in The Study Area

i) Demographic Profile

There are 55 villages that fall within the study area of the proposed Ting- Ting H.E. Project. The total human population of these villages is 51,781 of which 10,728 belong to Schedule Tribes which constitute 20.7 % of the total population. There are 9788 households in study area. Table 5.6 shows demographic profile of villages in study area.

Table 5.6: Demographic Profile of Study Area Villages

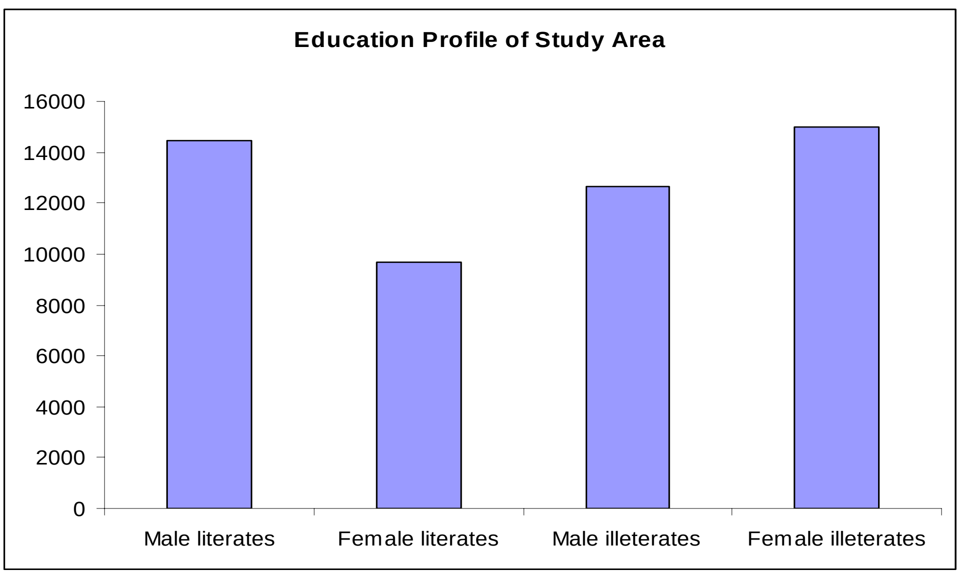
Sl.No	WEST DISTRICT (Gyalzing Sub-division)					
	Village	Households	Population			Sex Ratio
			M	F	T	

Sl.No	WEST DISTRICT (Gyalzing Sub-division)					
	Village	**Households**	**Population**			**Sex Ratio**
1	Arithang	141	451	396	847	878
2	Bangten	108	324	320	644	988
3	Barnyak	303	845	800	1645	947
4	Barnyak Forest Block	1	6	7	13	1167
5	Barthang	208	565	569	1134	1007
6	Chingthang	113	312	273	585	875
7	Chongpung	119	343	317	660	924
8	Chongrang	240	746	641	1387	859
9	Darap	256	711	687	1398	966
10	Dhupidara	76	247	246	493	996
11	Dubdi	69	217	185	402	853
12	Gangyep	99	334	293	627	877
13	Gerethang	176	553	473	1026	855
14	Gyalzing Forest Block	154	350	244	594	697
15	Hee	410	1140	1102	2242	967
16	Khechodpalri	114	269	287	556	1067
17	Kongri	71	239	203	442	849
18	Kyonsda	406	967	844	1811	873
19	Labing	179	567	476	1043	840
20	Laso	262	787	677	1464	860
21	Lingchom	345	917	877	1794	956
22	Lungzik	142	396	388	784	980
23	Martam	331	926	877	1803	947
24	Meli	116	332	291	623	877
25	Melliaching	109	293	296	589	1010
26	Naku	223	645	622	1267	964
27	Nambu	146	436	423	859	970
28	Pecherek	126	361	377	738	1044
29	Pemayangtse Monastery	3	13	6	19	462
30	Radu-Khandu	266	788	754	1542	957
31	Sapong	115	309	287	596	929
32	Sardong	115	348	358	706	1029
33	Sindrang	55	188	137	325	729
34	Singlitam	64	177	181	358	1023
35	Singyang	102	330	262	592	794
36	Srinagi	94	272	236	508	868
37	Tashiding	257	768	680	1448	885
38	Tashiding Forest Block	2	5	11	16	2200
39	Thingle I	138	340	287	627	844
40	Thingle II	118	342	303	645	886
41	Tikjya	190	549	520	1069	947
42	Tingbrum	91	220	200	420	909
43	Topung	52	154	132	286	857
44	Tsozo	89	270	206	476	763
45	Umchung	350	959	818	1777	853
46	Unglok	201	560	523	1083	934
47	Yangten	206	525	465	990	886

Sl.No	WEST DISTRICT (Gyalzing Sub-division)					
	Village	**Households**	**Population**			**Sex Ratio**
48	Yangthang	489	1304	1152	2456	883
49	Yuksom	364	1043	908	1951	871
SOUTH DISTRICT (Ravong sub-division)						
1	Lingdong	102	318	258	576	811
2	Namlung	149	462	427	889	924
3	Zarung	152	432	405	837	938
4	Dalep	138	359	357	716	994
5	Lingzo	126	347	321	668	925
6	Likship	717	1475	1260	2735	854

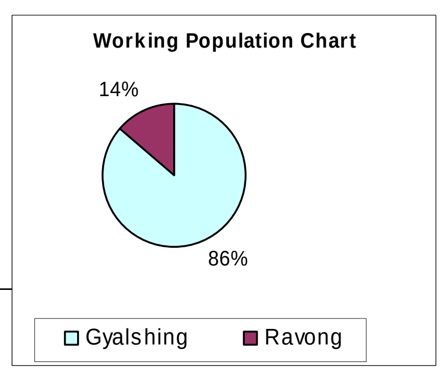
ii) Educational Profile

The educational profile of the people in the vicinity villages is average. In the entire population of 51781, 47 % of the people constitute the total population of literates. Of that, 60 % of literates are males and the rest 40% are females. The percentage of illiterate females is higher than that of the males. Among the 53 % of illiterates in the entire population, the population of illiterate females exceeds the males by 8%. The histogram below depicts the distribution of the literate and illiterate males and females among the villages in the vicinity area of the proposed project.



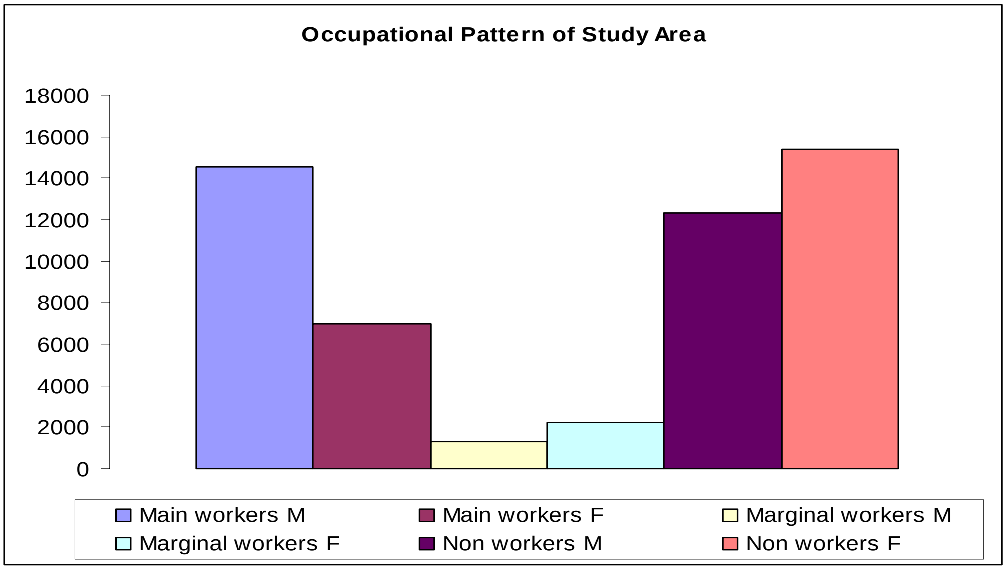
iii) Occupational Profile

The sampled working population chart below shows that the working people of Gyalzing exceed the working population of Ravong by 72%.The total number of villages included in the Ravong sub



district is very less compared to the Gyalzing sub-division.

Among the total population, 46 % of the people are working. In the working population of 24041 people, 85% of the people are the main workers and the rest of them are marginal workers . In the entire population, only 18% of females are working. It must be noted that in the entire working population of 24041, 38% is of working women. Other than that, in the entire sample of population taken, a total of 27740 are the non-workers.



5.4 SOCIO-ECONOMIC STATUS OF THE AFFECTED VILLAGES

The main aim of the study was to assess the socio-economic status of the villages likely to affected by the Ting Ting HEP.

- To compile socio-economic data for the villages in the study area from the secondary sources.
- Undertake a survey of the affected villages and population, i.e. villages falling within the submergence area and the working area of the project.
- Understand various socio-economic aspects of the affected population viz., profile of the affected villages, demographic characteristics and socio-economic conditions.

The secondary data was collected from the different officials of various administrative government departments in the district headquarter of Gyalzing. Primary information used in the report is gathered from various field visits to the study area. It mirrors the present social and economic status of the people living in the vicinity of the project area and their perspective towards the project. Questionnaires have been used to gather village–wise data from the Panchayat members of different villages including other local people. The perception of the people towards the project was also assessed through questionnaires.

Not just that, a number of suggestions for the improvement and enhancement in the availability of the amenities to people were also collected and discussed.

Few of the observations in the field are:

i) The people interviewed were mostly Nepali, Bhutia and few Lepchas.

ii) All the visited villages availed the regular supply of electricity except for occasional power cuts due to some maintenance problems at the electrified stations.

iii) The interviewed farmers of all 6 villages said that the entire area follows organic way of farming and uses farm yard manure for better yield.

iv) All interviewed people use LPG for cooking purposes. They occasionally bring firewood from the forest nearby.

v) The villages are acquainted with regular supply with water. People are also satisfied with the quality of the drinking water.

vi) The health facilities were not adequate in the surveyed villages. The villagers have to visit the district hospital at Gyalzing approximately 20 km away for medical aid. There is a primary health centre located in village Lobing and also at the constituency of Yuksom. Village Thingling has one dispensary and a Primary sub health center (PHSC).

vii) The educational facilities are comprised of 5 primary schools located in different villages. For children below 6 years of age, Integrated Child Development Services (ICDS) are being provided in Leythang, Lobing and Thingling. However, the need for secondary and higher secondary schools is felt by the villagers.

viii) Several SHG groups under different panchayat units have been established. Nearly all the villages had Self-Help Groups consisting of 10-15 persons with their emphasis on micro-finance through common management which was basically to promote savings among the villagers as there is dearth of banking facilities. There are 14 self help groups under the Yuksom constituencies.

ix) The villagers follow proper sanitation habits. Most of the households in the surveyed villages had their own septic tanks. However, few of the villages lacked facilities for safe disposal of wastes.

x) The community based organizations like Khangchendzonga Conservation Committee (KCC) is working with the villagers for the promotion of conservation and eco-tourism.

The committee imparts training on eco tourism to the local villagers under their project called Biodiversity Conservation and Sustainable Tourism Development.

The villages where the families whose land is likely to be acquired for the proposed project activities have been categorized as affected villages. A total of 5 villages (11 hamlets) will be affected due to various components of proposed Tingting H.E. Project. The list of these villages/hamlets is given below:

.

Village	Hamlets
Chozo	15 mile
	Lethang
Ting Ting	Khezek
	Khoksera
Lobing	Sardungthang
	Tongay
Thingling	Kendam
	Kamenkeun
	Aam Botay
	Doban
Mansabong	Fera

All the villages come under the jurisdiction of West Sikkim District. The socio- economic profile of these villages is discussed in the following text.

5.4.1 Profile of the Affected Villages

Chozo

The village Panchayat is Chojo at Kecheoperi. Population of this area comprises mainly of Lepchas and most of them are Buddhists .The total number of households is 36.The nearest PHC is at Khecheopalri.There are 2 primary schools in the village with 3 teachers in total.The post office is at Khecheoperi.The nearest police post is at village Yuksom.

Tingting

The total number of households in this village is 30. The village population belongs to Subba and Chhetri group. This entire population is of Hindu religion. The principal crops grown are millet, maize, cardamom and ginger. The fruits grown include orange, banana, guava and mango. These crops are sold in the local market of village Yaksum. The nearest primary health center and fair price shop is at village Yaksum.The recreational spots close to the village include Dubdi monastery and Phamrung falls.

Lobing

This village is close to the powerhouse site of Ting Ting H.E.P.The population of the village includes Buddhists,Hindus and 2-3 Christian families.The local population is a combination of Subbas, Chetri and Lepchas.The cropping pattern of the village like all other village is Terrace farming. Principal crops grown are cardamom, paddy, maize, millet and ginger. Horticulture includes production of Sikkim mandarin,guava,peach etc.The nearest market of the village is at Yuksom and Gerethang.That is where the local people sell their crops.The nearest dispensary ,fair price shop and police post is also at Gerethang.The village does not have a bank but the self help groups are promoting individual investment and savings.The closest tourist spot is Phamrung falls.The SHG groups working in the village are WELCOME, WABERI and Lobing Phamrang Village SHG.

Thingling

The village population consists of Subbas and Other Backward Classes such as Rai, Gurung and Chettri. The principal crops grown are Maize, millet, ginger, cardamom, and paddy. Fruits grown are guava, orange, pinapple, peach and banana.The village Thingling has one dispensary. The village has a primary school and a higher secondary school. The village has one post office. That village also has a fair price shop and a Multi-Purpose Cooperative Society.(MPCS). There is one post office in the village. The Panchayat of the village is Lachi Maya Subba. The important tourist spot of this village is Kanchenjunga falls. The villagers complained of the land subsidence incidences. The Ronum nallah near village Lungsung was learnt to encounter several landslides.

Mansabong

This village is close to the powerhouse site of Tingting H.E.P. The population of the village includes Buddhists, Hindus and some Christian families.The local population is a combination of Subbas, Chetri and Lepchas.The cropping pattern of the village like all other villages is terrace farming. Principal crops grown are cardamom, paddy, maize, millet and ginger. Horticulture includes production of Sikkim mandarin,guava,peach etc.The nearest market of the village is at Yuksom and Gerethang.That is where the local people sell their crops. The village does not have a bank but the self help groups are promoting individual investment and savings.The closest tourist spot is Phamrung falls.The SHG groups working in the village are WELCOME, WABERI and Lobing Phamrang Village SHG.

5.4.2 Local Economy

The local economy of the people depends mostly on the agriculture. The villagers grow various types of crops for both subsistence and for selling it to the local markets. The commercial crops grown are mainly maize,paddy,wheat,buckwheat,black gram,mustard and soyabean.The spices include large cardamom ,ginger and turmeric. The fruits grown are sikkim mandarin,pear,peach and plum. The vegetables include tomato, potato and choko which is locally known as Choyote. Besides that, the leafy vegetables grown are rai, cabbage, broccoli and chillies. All the visited villages were learnt to be following the organic way of farming. After the declaration of Sikkim as an organic state in the year

2003 ,every effort has been given to accelerate the organic production system in the entire district.Rural compost like farm yard manure is used for sustaining the fertility of the soil. Krishi Vigyan Kendra ,Geba near Gyalzing under the Food Security and Agriculture Development Department has various training programmes for the villagers on organic production of crops.

5.4.3 Dependency on Natural Resources

Flora: The wild medicinal plants are one of the major sources for local medical aid of the tribes of the study area. Many among these are eaten either raw or in boiled form for their medicinal value. The people of village Tingting use medicinal plants like kutki (*Picrorhiza kurrooa*) for fever and cough, chirato(*Swertia chirayita*) for fever,barhal (*Artocarpus chaplasha*) for boils.The small leaves of abijal (*Stellaria* media) are chewed to cure cough,the leaves of titipati (*Artemisia*) are useful for nose bleeding and the juice from the leaves of banmala (*Eupatorium*) is applied on cuts and wounds.

Fauna: Fish supplements the diet of the villagers. Among the various fishes Asala (*Schizothorax* sp.) sometimes called “Snow trout” are the common game fishes with which the fishermen are very much acquainted. Other fishes which the fishermen catch are Chuchey Asala (*Schizopyge progastus*),buduna (*Garra gotyla gotyla*) and kabray (*Glyptothorax* sp.)The fishing net used by the villagers is tied to the stones at the bottom and hurled into the flowing river. The fish swimming across get entangled and thereafter taken out.

5.5 PLACES OF TOURIST IMPORTANCE IN THE PROJECT AREA

The project area has various places of historical,religious and tourist importance like Dubdi monastery and the palace area of Rabdentse ,the second capital of Sikkim.The magnificent Phamrang falls is located between Yuksom and Gerethang and is the highest waterfall of the entire Sikkim.The ringing stone is situated at Lethang.The stone produces metallic sound when struck with another stone.

Another place of attraction is the Kanchanjunga Falls which is 500 meters away from village Thingling. Moreover, there is an attractive Hongry monastery situated in Upper Lobing.

5.6 PUBLIC PERCEPTION OF THE PROJECT

The socio-economic survey team visited the entire area going to be affected by the project and data regarding public perception and awareness of the project was collected by direct interaction with local people in the affected villages on the basis of structured questionnaires. The source of information about the project was mostly visual and the opinions were generally good. Several discussions were held with both the educated youth and the Panchayat Members of the affected villages regarding the submergence of their agricultural lands. It was observed during the field survey that the respondents whose land will be affected were aware about the project. Villagers of Thingling,Tingting and Lobing were even more supportive also because they were allowed to be a member of the village level project committee.

In general, people welcome the project as it will bring infrastructural development and progress in the area. Most of the respondents in the project area have a positive outlook towards the construction of the project; however, some of them still doubt that the compensation for the loss of livelihood and other properties may not be adequate. The educated youth in the area are looking forward to employment opportunities during construction and operation and hence have positive mindset about the development. They consider it as a positive step towards the path of development for the area as a whole; however, they showed concern that this development is at the cost of their ancestral land, other immovable properties and livelihood for which they should be properly compensated. The people in village Thingling suggested the establishment of a hospital and school for improvement. Villagers whose land is likely to be directly affected have asked for satisfactory compensation and regular participation in the project planning process. In Thingling, the villagers desperately required the facility of banks.

However, the members of the Khangchendzonga Conservation Committee (KCC) were not much in favor of the project as they have a perception that the construction of the project will bring a negative impact on the tourist activities.

It was observed that out of the total surveyed population, all the young respondents feel that due to this developmental project they will get more employment, which is the basic need for sustaining their lives. Infrastructure in terms of educational, transportation and medical facilities will improve. The people believe that the area can emerge as a tourist spot by the construction of this project leading to further improvement in infrastructure and development in the area.

People were equally concerned about the adverse impacts due to project related activities and are aware of the loss of their agricultural lands due to acquisition. They understand that this development will lead to influx of migratory population leading to change in their social attitude. They are also concerned about environmental impacts especially leading to more landslides and loss of their natural water resources lying in the project area. However the villagers are ready to give their cultivable land or homestead in exchange for adequate compensation.

The above findings and observations reveal that all the population of the project-affected area, most of the people, are in favor of the construction of this project. However efforts need to be made by the project developer and the administration that the indigenous people should not suffer but benefit from this developmental project.

CHAPTER-6

PREDICTION OF IMPACTS

6.1 GENERAL

The proposed Ting Ting hydroelectric project would lead to generation of number of environmental impacts owing to the activities that would be undertaken during the construction of various project appurtenances, such as dam and coffer dam, drilling and blasting for the construction of head race tunnel, adits, roads, etc.; 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 for various aspects of environment, including physico-chemical, ecological and socio-economic aspects.

Based on the project details and the baseline environmental status, potential impacts as a result of the construction and operation of the proposed Ting Ting Hydro-electric Project have been identified. Wherever possible, the impacts have been quantified and otherwise, qualitative assessment has been undertaken. This Chapter deals with the anticipated positive as well as negative impacts due to construction and operation of the proposed Ting Ting hydro-electric project.

6.2 IMPACTS ON LAND ENVIRONMENT

6.2.1 Construction Phase

Very few impacts of construction phase are permanent. Majority of the environmental impacts attributed to construction works are temporary in nature, lasting mainly during the construction phase and often do not extend much beyond the construction period. However, if these issues are not properly addressed, the impacts can continue even after the construction phase for longer duration. The time required for construction of the project has been estimated as about 36 months. Even though the impacts due to construction are temporary in nature, they need to be reviewed closely as they could be significant due to the nature and intensity of the impacts.

The major anticipated impacts during the construction phase are as follows:

- Impact of acquisition of land for project components
- Impact due to submergence
- Environmental degradation due to immigration of construction workers population
- Quarrying operations
- Operation of construction equipment

- Soil erosion/increased siltation
- Muck disposal
- Impacts due to construction of roads

Impact of acquisition of land for project components

The proposed Ting Ting H.E. project involves construction of 55 m high dam leading to submergence of about 4.02 ha of area. Overall 30.79 ha of land would be required for construction of dam and power house; construction of colonies and access roads; muck disposal area, etc. This also includes land required only during the construction phase for labour colonies, construction equipments, storage, magazine area, etc. Out of total 30.79 ha, 19.0251 ha is private land, 7.3482 ha is forest land and 4.4167 ha is government land. Break up of land requirement is given at Table 6.1 below.

Table 6.1: Land Requirement for Ting Ting HEP

Sr.No.	Description	Area (Ha)
1	Dam & Reservoir Area	9.30
2	Powerhouse Area	5.66
3	Surge shaft Area	0.10
4	Batching Plant and Dumping area near Surge shaft	1.50
5	HRT & Adits Area	2.29
6	Pressure Shaft Area	0.54
7	Surface Penstock Area	0.35
8	Roads	10.80
9	Penstock fabrication/Electrical Equipment Storage Area	0.20
10	Magazine Area	0.05
	Total	**30.79**

Acquisition of 29.4068 ha of land will have impact on land environment in terms of change of land use and land pollution due to various activities as per changed land use.

Environmental degradation due to immigration of Construction workers population

The schedule of labour requirements during the project construction period is given in Table 6.2. At the time of peak construction work in the project, maximum of 350 persons may be engaged. Around 50 labourers are expected to be from the local population. Around 100 or more of the work force, which will include technical, non-technical and service class, will come from outside. In the first year, 60% of the peak force is required and in the second year and third year 80% of the peak force is required.

Table 6.2: Periodic labour requirement during the construction of the project

Year of construction	No. of labourers	No. of skilled labourers and technical staff	Total
1st	150	60	210
2nd	200	80	280
3rd	250	100	350

The peak human manpower would be around 1010. Thus for worst scenario 1500 persons shall be taken. The other assumptions made for assessing human load are as under:

- Family size has been assumed as 5
- 80% laborers and technical staff are married,
- 80% of laborers both husband & wife will work.
- 50% of technical staff will come with their families and only husband will work
- 2% of total migrating population has been assumed as service providers
- 50% of service providers will have families

Based on these assumptions the peak migrant population has been calculated as 1010 persons (Table 6.3). This population is expected to reside in the project area at any given time.

Table 6.3: Calculation of total migrant population (Peak time)

Sl.No.		Workers	Population
A.	**Migrant workers**		
	i)	Married Families (80% of 250)	200
	ii)	Single (20% of 250)	50
	iii)	Husband and wife both working (80% of 200)	160
	iv)	Number of families where both husband-wife work (160/ 2)	80
	v)	Families where only husband is working (80/2)	40
	Total of 'A' [80 x 5 (Av. no. of family members) + 40 x 5 (Av. no. of family members) + 50]		**650**
B.	**Migrant Technical Staff**		
	i)	Married families (50 % of100)	50
	ii)	Single (50% of 100)	50
	Total of 'B' (50 x 5 +50)		**300**
Total A+B			**950**
C.	**Service**		
	i)	2% of total population (950)	19
	ii)	Number of service provider with families (50% of 19)	10
	Total 'C' (10x 5 + 10)		**60**
Grand Total of A+B+C (650 + 300 + 60)			**1010**

Separate accommodation and related facilities for workers, service providers and technical staff are to be arranged. The volume of labour force is most likely will create problems of sewage disposal, solid waste management and requirement of fuel etc. Appropriate mitigating measures have been suggested in EMP.

Quarrying Operations

The total quantity of coarse aggregate required for concreting and masonry in the proposed dam is about 111594 m^3 and quantity of fine aggregates required is m^3. The quarrying operations will be semi-mechanized in nature. Normally, in a hilly terrain like Sikkim, quarrying is done by cutting the hill face, and this leaves a permanent scar, once the quarrying activities are over with the passage of time, rock from the exposed face of the quarry under the action of wind and other erosional forces, slowly gets weathered and they become a potential source of landslide. Thus, it is necessary to implement appropriate slope stabilization measures to prevent the possibility of soil erosion and landslides at the quarry sites. In the proposed project, it is proposed to utilize material from river bed etc.

Operation of Construction Equipment

During the construction phase, various types of equipment will be brought to the site. These include crushers, batching plant, drillers, earth movers, rock bolters, etc. The siting of these construction equipments would require significant amount of space. In addition, land will also be temporarily acquired, i.e. for the duration of project construction; for storage of the quarried material before crushing, crushed material, cement, rubble, etc. Proper siting of these facilities is important so as to have minimum impact due to their location and operation. The various criteria for selection of these sites would be:

- Proximity to the site of use
- Sensitivity of forests in the nearby areas
- Wildlife, if any, in the nearby area
- Proximity from habitations

Efforts shall be made to select the site for locating the construction equipment in such a way that the adverse impacts on environment are minimal including that on residents of nearby villages.

During construction phase, there will be increased vehicular movement for transportation of various construction materials to the project site. Large quantity of dust is likely to be entrained due to movement of trucks and other heavy vehicles on unpaved road. Impact will be local and temporary, lasting only during construction phase and is not very significant due to absence of major habitations in the project area. However sufficient mitigation measures would be required to minimize the impact of dust on health of the people living in the vicinity and laborers working in the project area.

Soil Erosion/Increased Siltation

The runoff from the construction sites will have a natural tendency to flow towards river or its tributaries. For some distance downstream of major construction sites, such as dam, power house, etc. there is a possibility of increased sediment levels in river water resulting in reduction in light penetration and hence reduced photosynthetic activity to some extent. This is likely to have an adverse impact on the primary productivity of the affected stretch of river and its tributaries. River has sufficient flow throughout the year; therefore, impacts on this account are not expected to be significant. However, some adverse impacts are anticipated on the streams and nallahs which have low flow during lean season.

Muck Disposal

About 0.342 Mm^3 of muck is expected to be generated as a result of construction of Dam power house and other appurtenant works. The muck quantity expected to be generated from various work sites is tentatively assessed to be as under.

Sr. No.	**Structure**	**Approx. Muck Qty. Cum (Lakh)**
A	Upstream Structures i.e. Dam works, river diversion, intake, upstream stretch of HRT upto 0.8 Km	1.14
B	Surge Shaft ,D/s HRT, Adits, Part penstock	0.61
C	Pressure Tunnel, Power house, cut & cover tail race tunnel etc.	1.67

The project proposes to utilize some part of the muck to be generated as construction material in various project structures. Therefore, some part of the muck is proposed to be dumped at three pre-identified locations in line with the topographic conditions.

Two dumping sites for Dam and part HRT: Muck dumping sites for Dam and u/s HRT part will be on the left and right bank of Rathong Chhu downstream of dam site.

Dumping site for Surge shaft / Penstock & balance HRT: It will be slightly upstream of the bifurcation from where road towards Surge Shaft bottom takes off from the road towards surge shaft top.

Dumping site for Pressure Shaft, Power House & TRT:- Muck dumping area have been identified on left bank of Phamrung Chhu near its confluence with Rathong Chhu.

The muck is proposed to be dumped in an environmentally sound manner in pre-identified dumping sites, which are proposed to be rehabilitated. 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. Even though the negative impact is going to be a short term in this case, yet sufficient care would be taken during the construction to ensure that very little rubble/muck is allowed to be washed into the main channel.

- Muck disposal can lead to impacts on various aspects of environment. Normally, the land is cleared before muck disposal. During clearing operations, trees are cut, and undergrowth perishes as a result of muck disposal.

- In many of the sites, muck is stacked without adequate stabilisation measures. In such a scenario, the muck moves along with runoff and creates landslide like situations. Many a times, boulders/large stone pieces enter the river/water body, affecting the benthic fauna, fisheries and other components of aquatic biota.

- Normally muck disposal is done at low lying areas, which get filled up due to stacking of muck. This can sometimes affect the natural drainage pattern of the area leading to accumulation of water or partial flooding of some area which can provide ideal breeding habitat for mosquitoes.

Thus, it is necessary to develop a proper muck disposal plan for amelioration of above referred impacts. The details of the same have been covered in Environmental Management Plan outlined in this Report.

Construction of Roads

The topography of the project area has steep slopes, which descend rapidly into narrow valleys. The conditions can give rise to erosion hazards due to downhill movement of soil aggregates. The project construction would entail significant vehicular movement for transportation of construction material and heavy construction equipment. Most of the roads in the project area would require widening apart from the new roads proposed to be constructed for this project. The details of the roads proposed to be constructed and improved are given below.

PROJECT ACCESS ROADS & BRIDGES

Ting Ting Dam site is located on Rathong Chhu about 13 Km before Yuksom town on the Melli-Pelling-Yuksom State Highway and the Power house is about 5 Km further downstream. The state highway from Pelling after crossing the Rimbi nallah runs along the right bank and crosses over to the left bank about 3 Km upstream of Dam site. The requirement of access roads to the work sites from the existing state highway shall be as under.

i) Dam site road on left bank of Rathong Chhu

The proposed Ting-Ting dam site is approachable from the same Pelling – Yuksom SPWD road, which is located at an elevation of 1250m (approx.). About 100m after crossing the bridge on Rathong Chhu, an approach road of 1.8 km was constructed more than 10 years back by the SPWD on the left bank of Rathong Chhu, upto 300m from Dam axis. The road is presently in very poor condition and shall be reconstructed /improved for access to dam site. A temporary bridge will be provided u/s of the dam for access to the right bank. Diversion tunnel portals, u/s and d/s coffer dams and borrow areas shall be connected by road from this temporary bridge.

ii) Surge shaft / Penstock roads

The road to Dam top (El. 1169 m) shall be extended further approximately. by 2.97 km length to reach the surge shaft top (El. 1187 m). This road shall be negotiating few drains through culverts/ bridges on its way to surge shaft top. From this road a bifurcations shall be taken at El. 1145 m to provide access road to surge shaft bottom at El. 1120.70 m.

iii) Power house

The proposed Ting-Ting surface power house, on the left bank of Rathong Chhu, is approachable from the Pelling– Yuksom SPWD road, which runs at a high elevation of around 1160m. Approach road for power house site is possible from the left bank of Rimbi Khola close to its confluence with Rathong Chhu from the existing Pelling – Yuksom road. An Iron foot bridge on river Rathong Chhu is presently exists at El. 930 m u/s of the confluence of Rathong Chhu & Rimbi khola. This will be replaced with a permanent bridge connecting left bank for approach to the Powerhouse site. The cost of this approach road upto the bridge and bridge over Rathong Chhu will be shared by the

Tashiding HEP which is located just downstream of Ting Ting Power House as they will be using the same road for construction of their project components.

After the bridge on Rathong Chhu near Power House area, access roads shall be further extended upto the Pressure shaft top at elevation El. 1002 m connecting the power house and dumping area on its way on the left bank of Rathong Chhu and crossing over the Phamrang Chhu through a temporary bridge.

iv) Other approach roads

- Approach roads to quarry sites/borrow areas
- Haul roads to dumping areas for muck disposal
- Approach roads to explosive magazine, crusher, B&M plant, stores, workshops penstock fabrication yard, sheds etc.

Construction and improvement of the roads, bridges and cross - drainage works will be a priority and are to be completed during the pre-construction stage. Details of the project road are as follows:

Sr. No.	Description	Length (m)
1	From Existing Road To Dam Top	2100
2	From Dam Top To Surge Shaft Top	2978
3	Diversion Road to Surge Shaft Bottom	365
4	Road to Pressure Shaft Top from Power House	770
5	Road to Power house bridge	3340
6	Road from bridge to Power house area	240
7	Other Misc. Roads	1000
	Total	**10793**

The major impacts likely to accrue as a result of construction of the proposed project are:

- Loss of forest and vegetation by cutting of trees
- Geological disturbance due to blasting, excavation, etc.
- Soil erosion as the slope cutting operation disturbs the natural slope and leads to land slips and landslides.
- Interruption of drainage and change in drainage pattern
- Disturbance of water resources with blasting and discriminate disposal of fuel and lubricants from road construction machinery
- Siltation of water channels/ reservoirs from excavated debris
- Effect on flora and fauna
- Air pollution due to dust from debris, road construction machinery, etc

The indirect impact of the construction of new roads is the increase in accessibility to otherwise undisturbed areas, resulting in greater human interference and subsequent adverse impacts on the ecosystem. Appropriate management measures required to mitigate adverse environmental impacts during road construction have been recommended. The details of the same have been covered in Environmental Management Plan outlined in this report.

6.2.2 Operation Phase

The Ting Ting HEP would result in the submergence of 4.02 ha of land area up to FRL of 1165 m. In addition to above land will be required for residential and for construction of the project, roads, stores and for the main project components such as Diversion dam, Surge shaft, Penstocks, Power house, cut and cover Tail Race Tunnel, switch yard etc. Muck dumping areas as identified will have to be acquired for dumping the material excavated from various sites. Break up of land requirement is given at Table 6.1

6.3 IMPACTS ON WATER RESOURCES

The construction of dam leads to the formation of reservoir. The passage of flood through a reservoir leads to the reduction in peak flow. The dry season flow in the river too is regulated. Thus, construction of the dam would lead to moderation in peak flood and delay in time lag as well. There are about six villages which fall between dam and power house with power house at Lobing village and who could be directly or indirectly dependent upon river. These are shown in Table 6.4. A small population resides in this stretch. During the surveys it was observed that people are not dependent on Rathong Chhu for drinking water however, they use this water for irrigation. They do get their drinking water supply from the river instead are dependent upon the streams that join the main river.

Table-6.4: Villages in the downstream stretch

Left Bank	Right Bank
Tingting	Thingling-I
Mansabong.	Thingling-II
Lobing (Power house site)	Thingling-III
	Lethang

There are some streams which meet Rathong Chhu between dam and power house site. The details of these are given in Table 6.5.

Table-6.5: Streams joining in the downstream stretch

S.No	Stream	Distance from dam	Left Bank/ Right Bank
1.	Sarangi Khola	0.4 km	Right bank
2.	Stream1	0.45 km	Right bank
3.	Stream2	0.5 km	Right bank
4.	Phamrang	2.7 km	Left Bank

Therefore there will be sufficient water available in the river for various uses.

Environmental flow release to sustain aquatic ecology

Environmental flow requirements for ecological needs have been worked out at the most critical location which is approximately 1000 m downstream of the diversion site. It has been observed that in the present situation (no project scenario), the water depth during the lean season months is around 75-80 cm and average width of the river is about 16-18 m. With the help of surveyed river cross sections at this critical location (1000 m downstream of diversion site), it has been calculated that 70 cm depth corresponds to flow of 6.59 cumec, which is average minimum flow for lean season (Dec-Feb) in 90% dependable year. A water depth of 75 cm corresponds to flow of 8.35 cumec, which is average minimum flow of last 31 years.

During the field studies in the river stretch and as per the interaction with local people and state government officials, it has been observed that a few fish species are found in Rathong Chhu and it has been noticed that out of these, only snow trout is migratory in nature and it too migrates locally and a water depth of 30-40 cm is needed for its habitat.

So, to maintain snow trout's habitat, minimum 50 cm depth of water in the river would require to be maintained which corresponds to minimum flow of 1.5 cumec as per calculations done with the help of surveyed river cross sections. So, in view of this a minimum flow of 1.5 cumec would be required to be maintained all the time in the river stretch, which is 22.5% of average minimum flow for lean season in 90% dependable year. This flow has been worked out at the most critical location which is about 1000 m downstream of the river and would be augmented with the runoff from intermediate catchment downstream.

Therefore, to ensure that water is available to sustain aquatic life in intermediate stretch, a minimum of 22.5% water flows will be released at all the times.

6.4 IMPACTS ON WATER QUALITY

6.4.1 Construction Phase

The major sources of water pollution during project construction phase are as follows:

- Sewage from Construction work camps/colonies
- Effluent from crushers
- Disposal of muck

Sewage from Construction worker Camps

The project construction is likely to last for a period of 3 years. The increase in the population is expected to be in the order of 1000. The domestic water requirement for the outside labour is in the order of 0.075 mld @ 70 lpcd. Assuming that about 80% of the water supplied will be generated as waste/ sewage. The BOD load contributed by domestic sources will be about 25 kg/ day. The minimum average flow in the Rathong Chhu is taken as 7 cumec and for the worst scenario the DO level is coming above 8 mg/l at a distance of 0.025 km from outfall and as such there will be no significant impact on stream water quality due to disposal of untreated sewage. Even then it is proposed to treat the sewage from labour camps before disposal. It is proposed to construct adequate number of septic tanks for treatment of sewage and portable sewerage treatment plants are to be provided wherever the concentration of construction labour is high.

Effluent from Crushers

During construction phase, at least one crusher is proposed to be commissioned at the dam site. The total capacity of the crusher is likely to be of the order of 120-150 tph. Water is required to wash the boulders and to lower the temperature of the crushing edge. About 0.1 m^3 of water is required per tonne of material crushed. The effluent from the crusher would contain high suspended solids. The quantum of effluent generated is of the order of 12-15 m^3/hr or 0.0033 to 0.0042 m^3/sec. The natural slope in the area is such that, the effluent from the crushers will ultimately find its way in river through natural drains. However, no major adverse impacts are anticipated due to small quantity of effluent and large volume water available for dilution in river. However, turbidity levels in small tributaries, especially, in lean season will increase. To minimize the impact, it is proposed to treat the effluent before disposal to ameliorate even if only the marginal impacts are likely to accrue on this account.

Disposal of Muck

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 unsorted 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.

6.4.2 Operation Phase

The various aspects covered as a part of impact on water quality during project operation phase are:

- Effluent from project colony
- Impacts on reservoir quality
- Eutrophication risks

Effluent from Project Colony

During the operation phase, due to absence of any large scale construction activity, the cause and source of water pollution will be much different. 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 the construction population is high. Adequate care will be taken to locate these structures so as there is no leaching from this activity in natural water bodies.

Impacts on Reservoir Water Quality

The flooding of previously forest and agricultural land in the submergence area will increase the availability of nutrients resulting from decomposition of the vegetative matter. Phytoplankton productivity can supersaturate the euphotic zone with oxygen before contributing to the accommodation of organic matter in the sediments. Enrichment of impounded water with organic and inorganic nutrients will be the main water quality problem immediately on commencement of the operation. However, this phenomenon is likely to last for a short duration of few years from the filling up of the reservoir.

Eutrophication Risks

Another significant impact observed in the reservoir is the problem of eutrophication which occurs mainly due to the disposal of nutrient rich effluents from the agricultural fields. The fertilizer use in the project area is negligible, hence, runoff at present does not contain significant amount of nutrients. Even in the post-project phase, the use of fertilizers in the project catchment area is not expected to rise significantly. Thus, in the post-project phase, problems of eutrophication, which is primarily caused by enrichment of nutrients in water, are not anticipated.

6.5 IMPACTS ON TERRESTRIAL FLORA

6.5.1 Construction Phase

The direct impact of construction activity for any water resource project in a mountainous terrain similar to that of proposed project is generally limited in the vicinity of the construction sites only. As mentioned earlier, a large population (1000) including technical staff, workers and other group of people are likely to congregate in the area during peak project construction phase. It can be assumed that the technical staff will be of higher economic status and will live in a more urbanized habitat, and will not use wood as fuel, if adequate alternate sources of fuel are provided. However, workers and other population groups residing in the area may use fuel wood (if no alternate fuel is provided) for whom firewood/coal depot could be provided. There will be an increase in population by about 1,000 of which about 800 are likely to use fuel wood. On an average, the fuel wood requirements will be of the order of (1.0 * 365 * 800 * 10^{-3}) 292 m^3. The wood generated by cutting one tree is 2.5-3.0 m^3. Thus, about 100-120 trees will be cut every year to meet the fuel wood requirements, which mean every year on an average about 0.5 to 0.6 ha of forest area will be cleared for meeting fuel wood requirements, if no alternate sources of fuel are provided. Hence, to minimize such impacts, it is proposed to provide alternate fuel for cooking e.g. Kerosene, LPG to the Construction Worker force. The other alternative is to provide community kitchens on a cooperative basis by the contractor. The details of the same have been covered in Environmental Management Plan.

The other major impact on the flora in and around the project area would be due to increased level of human interferences. The workers may also cut trees to meet their requirements for construction of houses, furniture. Normally in such situations, lot of indiscriminate use or wastage of wood is also observed, especially in remote or inaccessible areas. Thus, it is necessary to implement adequate surveillance to ameliorate the adverse impacts on terrestrial flora during project construction phase.

6.5.2 Operation phase

Acquisition of Forest Land

The total land required for the project is 29.12 ha of which 7.3482 ha is the land owned by the Forest Department, with or without forest cover. The tree density at various sampling stations is given in Table-6.6.

Table 6.6: Tree Density at Sampling Sites

Sampling site	No./ha
Site-S1	680
Site-S2	390
Site-S3	600
Site-S4	420
Site-S5	280
Site-S6	500
Site-S7	336
Site-S8	256

The tree density at various sampling sites in the land to be acquired for the project varied from 256 to 680 tree/ha. Normally in dense forest, the tree density is of the order of 800-1000 trees/ha. Thus, the tree cover in the project area indicates the degraded status of forests at some of the locations in the project area. Compensatory afforestation has been recommended as a part of EMP.

Impact due to submergence

The dam site is located upstream of Tingting village. The area in the vicinity of proposed project comprised of fairly dense mixed sub-tropical wet hill forest. The vegetation on both the bank of Rathong Chhu is comprised of patches of open to dense canopy forests interspersed with agricultural fields. *Alnus nepalensis* and *Schima wallichii* are the predominant tree species in the area. Other prominent trees are: *Albizia chinensis, Bischofia javanica, Engelhardtia spicata, Ficus semicordata, Macaranga denticulata, Grewia tiliaefolia, Castanopsis hystrix, Schima wallichii, Alangium chinense,* etc. Common shrubs are *Oxytropis paniculata, Dendrocalamus hamiltonii, Artemisia indica, Saurauia roxburghii, Solanum indicum, Triumfetta rhomboidea, Rubus ellipticus* and *Musa* sp. etc. Herbaceous flora was represented by some grasses and weeds. Terrestrial pteidophytes are represented by species of *Athyrium, Pteris* and *Selaginella*. The herbaceous flora include: *Ageratum conyzoides, Aconogonum molle, Bidens* *bipinnatus, Lecanthus peduncularis, Oxalis corniculata, Pouzolzia sanguinea, Pilea scripta, Pogonatherum paniceum* and *Solanum nigrum.*

It can be seen that species found in and around the submergence area are commonly occurring species and no rare or endangered species is found in this area, therefore no adverse impact of submergence is envisaged.

6.6 IMPACTS ON TERRESTRIAL FAUNA

6.6.1 Construction Phase

Disturbance to Wildlife

The total land required for the project is 29.4068 ha of which 4.02 ha comes under submergence, (including river bed) and 25.3868 ha is required for other project appurtenances. Based on the field survey and interaction with locals, it was confirmed that no major wildlife is reported in the proposed submergence area. It would be worthwhile to mention here that most of the submergence lies within the gorge portion. Thus, creation of a reservoir due to the proposed project is not expected to cause any significant adverse impact on wildlife movement. The project area and its surroundings are not reported to serve as habitat for wildlife nor do they are located on any known migratory route. Thus, no impacts are anticipated on this account.

During construction phase, a large number of machinery and construction Worker will have to be mobilized. This activity may have some disturbance to the wildlife population. The operation of various construction equipments is likely to generate significant noise, especially during blasting. The noise may scare the fauna and force them to migrate to other areas. Therefore, project authorities would be advised to devise the activity schedule keeping in mind the animal behaviour i.e. breeding season, etc. The equipment used should have silencers and cause minimum ground vibrations during the construction period. Likewise, siting of construction equipment, godowns, stores, Construction Worker camps, etc. may generally disturb whatever fauna is left in the area. However, no large-scale fauna is observed in the area. Thus, impacts on this account are not expected to be significant. However, few stray animals sometimes venture in and around the project site. Thus, to minimize any harm due to poaching activities from immigrant Construction worker population, strict anti-poaching surveillance measures need to be implemented, especially during project construction phase. The same have been suggested as a part of the Environmental Management Plan.

Impacts on Migratory Routes

The faunal species observed in the project area are not migratory in nature. The proposed project area is not the migratory route of wild animals. The construction of the proposed project will form a reservoir of about 4.02 ha, which is also not reported to be on the migratory route of any major faunal species.

6.6.2 Operation Phase

Species specific impacts, if any

The threats of loss and disappearance to species and populations generally arise from inundation, habitat destruction and fragmentation, direct removal and/or killing. The species populations that face maximum risk includes taxa with small population sizes, critically endangered, over-exploitation, endemic and restricted distribution. Our investigations have revealed that in the proposed project no such species have been recorded that may face extinction due to the project activities. However, species populations with small number of individual survivors and highly specialized niches may need special protection and care to avoid population extinctions. As already mentioned, the reservoir area, which proposes to inundate about 4.02 ha of land, does not contain any critically endangered species, therefore, there is no threat to any species at this site. Since majority of species occurring in the submergence zone are widely distributed in this region as well as other regions and are very common species, no negative impact is envisaged on the biota of this site.

During project operation phase, the accessibility to the area will improve due to construction of roads, which in turn may increase human interferences leading to marginal adverse impacts on the terrestrial ecosystem. Since significant wildlife population is not found in the region, no major adverse impacts are anticipated on this account.

6.7 IMPACTS ON AQUATIC ECOLOGY

6.7.1 Construction Phase

Impacts due to excavation of construction material from river bed

During construction phase, a large quantity of construction material like stones, pebbles, gravel and sand would be needed. Significant amount of material is available in the river bed just downstream of dam. It is proposed to extract construction material from the river bed. The extraction of construction material may affect the river water quality due to increase in the turbidity levels. This is mainly because the dredged material gets released during one or all the operations mentioned below:

- Excavation of material from the river bed.
- Loss of material during transport to the surface
- Overflow from the dredger while loading
- Loss of material from the dredger during transportation.

The cumulative impact of all the above operations is increase in turbidity levels. Good dredging practices can however, minimize turbidity. It has also been observed that slope collapse is the major factor responsible for increase in the turbidity levels. If the depth of cut is too high, there is possibility of slope collapse, which releases a sediment cloud. This will further move outside the suction radius of dredged head. In order to avoid this typical situation, the depth of cut may be restricted to:

γ H/C < 5.5, where,
γ - Unit weight of the soil
H - Depth of soil
C - Cohesive strength of soil

The dredging and deposition of dredged material may affect the survival and propagation of benthic organisms. The macro-benthic life which remains attached to the stones, boulders etc. gets dislodged and is carried away downstream by turbulent flow. The areas from where construction material is excavated, benthic fauna get destroyed. In due course of time, however, the area gets decolonized, with fresh benthic fauna. The density and diversity of benthic fauna will however, be less as compared with the pre-dredging levels.

The second important impact is on the spawning areas of fishes. Almost all the cold water fish breed in the flowing waters. The spawning areas of these fish species are found amongst pebbles, gravel, sand etc. The eggs are sticky in nature and remain embedded in the gravel and subsequently hatched. Any disturbance of stream bottom will result in adverse impacts on fish eggs. Even increase in fine solids beyond 25 ppm will result in deposition of silt over the eggs, which would result in asphyxiation of developing embryo and also choking of gills of young newly emerged fry. Thus, if adequate precautions during dredging operations are not undertaken, then significant adverse impacts on aquatic ecology are anticipated.

Impacts due to discharge of sewage from Construction Worker camp/colony

The proposed hydro-power project would envisage construction of temporary and permanent residential colonies to accommodate Construction Worker and staff engaged in the project. This would result in discharge of sewage which is usually discharged into the nearby water body. However, it is proposed to commission adequate number of septic tanks for treatment of domestic sewage before its disposal in to the river. Due to perennial nature of river, it maintains sufficient flow throughout the year which is sufficient to dilute the treated sewage from residential colonies. Therefore, as mentioned earlier, no adverse impacts on water quality are anticipated due to discharge of sewage from Construction worker camp/colony.

Impacts due to human activities

Accumulation of Construction Worker force in the project area might results in enhancement in indiscriminate fishing including use of explosives. The use of explosive material to kill fishes in the river in the project area would result in complete loss of fishes and other aquatic life making a river stretch completely barren. Indiscriminate fishing will reduce fish stock availability for commercial and sport fishermen. These aspects have been adequately covered in the Environmental Management Plan (EMP) outlined in this report.

6.7.2 Operation Phase

Impacts due to damming of river

The damming of river will result in creation of 4.02 ha of submergence area. The dam will change the fast flowing river to a quiescent lacustrine environment. The creation of a pond will bring about a number of alterations in physical, abiotic and biotic parameters both in upstream and downstream directions of the proposed dam site. The micro and macro benthic biota is likely to be most severely affected as a result of the proposed project.

The positive impact of the project will be the formation of a water body which can be used for fish stocks on commercial basis to meet the protein requirement of region. The commercial fishing in the proposed reservoir would be successful, provided all tree stumps and other undesirable objects are removed before submergence. The existence of tree stumps and other objects will hinder the operation of deep water nets. The nets will get entangled in the tree stumps and may be damaged.

The reduction in flow rate of river especially during lean period is likely to increase turbidity levels downstream of the dam. Further reduction in rate of flow may even create condition of semi-dessication in certain stretches of the river. This would result in loss of fish life by poaching. Hence, it is essential to maintain minimum flow required for sustenance of riverine fisheries till the disposal point of the tail race discharge.

The proposed project involves construction of a small dam only, with very little submergence and would not result in very adverse changes in the river ecosystem. However, the proposed diversion dam is expected to change the habitat conditions in the stretch immediately downstream of the dam site. Some portion of the river may become dry during lean season because of diversion, even though there are a number of small streams rivulets that meet the main channel downstream of the diversion structure. The river stretch of about 500 m downstream of the dam site would have very less flow during the lean season, thereafter other streams will join it. The project authorities have been advised to maintain sufficient amount of discharge during the lean period to maintain and sustain the aquatic ecosystem functions in this stretch. Some of the small streams will contribute to the flow of water in main channel and minimize negative impacts on the processes and structure of these aquatic ecosystems. For mitigating the downstream impacts, it is mandatory to release at least 10% of the lean season flow into the river.

Impacts on migratory fish species

Fish migration is a specific phenomenon and related to the breeding behaviour. Most of the species of fish are periodic in breeding and require specific ground throughout the life. Mahseer (*Tor putitora*) is an important potamodromous fish in Himalayan rivers, which migrates from warmer plains to high reaches in cold water region. In Sikkim also, it is a true potamodromous migratory fish, ascending a long distance from warm waters of Teesta barrage (foothill) to cold waters of rivers Rangit, Teesta and Rangpo Chhu during late summer to monsoon months for breeding. Most of the brooders of mahseer are found to prefer river Rangit for spawning. Adults after spending whole summer and monsoon in these streams return to warmer waters during September and mid-October along with juveniles. The stretch of Rangit river up to Jorethang is the breeding ground for mahseer. However, of late the migration of mahseer has been hampered due to the construction of Teesta Low Dam hydro-electric project (lower stretch of Teesta in West Bengal) impairing its migratory route. Therefore, mahseer presently is rarely captured in this stretch.

Acrossocheilus hexagonolepis and snow trout are the local migratory fishes. *A. hexagonolepis* migrates to small a tributaries from the main stream while snow trout like *Schizothorax richardsonii, S. progastus* move downstream during summer to monsoon.

In Rathong Chhu and the catchment of river Rangit capture fishery occurs mostly in lower stretch of the river up to 600 m during winter season. In monsoon it becomes significantly low due to heavy discharge and high velocity of water in the river. The important species, contributing capture fishery are *Acrossocheilus hexagonolepis* (Catli), *Schizothorax richardsonii* (Asla), *Schizothoraicthys progastus* (Chuche Asla), *Tor putitora* (mahseer) and *Anguilla bengalensis* (Bam). The fishermen have been issued licenses for fishing. They were found to use caste nets and hooks for fish landing. On one side the construction of Teesta Low Dam on Teesta river in West Bengal has lead to disruption of migration of mahseer upstream into Teesta river as well as Rangit river, while the proposed reservoir would encourage fisheries development in the area.

6.8 IMPACTS ON NOISE ENVIRONMENT

Noise due to Construction Equipment

In a water resource project, the impacts on ambient noise levels are expected only during the project construction phase, due to operation of various construction equipments. Likewise, noise due to quarrying, blasting, vehicular movement will have some adverse impact on the ambient noise levels in the area. The noise level due to operation of various construction equipments is given in Table-6.7.

Table-6.7: Noise level due to Construction Equipment

Equipment	Sound Level (dBA)
Unsilenced pile diver	110
Unsilenced scraper/grader	94
Unsilenced pneumatic drill	90
Unsilenced compressor	85
Cranes	82
Generator	82

Under the worst case scenario, considered for prediction of noise levels during construction phase, it has been assumed that all these equipment generate noise from a common point. The increase in noise levels due to operation of various construction equipments are given in Table-6.8.

Table-6.8: Increase in Noise due to Operation of Construction Equipment

Distance (m)	Average Ambient noise levels (dBA)	Noise levels due to construction activities (dBA)	Increase in ambient noise level due to construction activities (dBA)
100	48	76	28
200	48	70	22
500	48	62	14
1000	48	56	8
1500	48	52	4
2000	48	50	2
2500	48	49	1
3000	48	49	1

As per Table-6.8, increase in noise level shall be of the order of 8 dBA, within 1 km from the project area. However, it would be worthwhile to mention here that in absence of the data on actual location of various construction equipment, all the equipment have been assumed to operate at a common point. This assumption leads to over-estimation of the increase in noise levels.

It is a known fact that there is a reduction in noise level as the sound wave passes through a barrier. The noise transmission loss values for common construction materials are given in Table-6.9.

Table-6.9: Transmission Loss Values for Construction Materials

Material	Thickness (inches)	Decrease in noise level (dBA)
Light concrete	4	38
	6	39
Dense concrete	4	40
Concrete block	4	32
	6	36
Brick	4	33
Granite	4	40
Wood Bamboo		15

The walls of various houses will attenuate at least 15 to 30 dBA of noise. In addition there is attenuation due to the following factors.

- Air absorption
- Rain
- Atmospheric inhomogeneties and atmospheric turbulence.
- Vegetal foliage

Thus, no increase in noise levels is anticipated as a result of various activities, during the project construction phase. The noise is also generated due to blasting during tunneling operations. However, it is not likely to have any effect on habitations. No major wildlife is observed in and around the project site. Hence, no significant impacts on wildlife are anticipated as a result of blasting activities in the proposed project.

6.9 AIR POLLUTION

In a water resources project, air pollution occurs mainly during project construction phase. The major sources of air pollution during construction phase are:

- Pollution due to fuel combustion in various equipment
- Emission from various crushers
- Fugitive emissions from various sources.

Pollution due to fuel combustion in various equipments

The operation of various construction equipments requires combustion of fuel. Normally, diesel is used in such equipment. The major pollutant which gets emitted as a result of combustion of diesel is SO_2. The SPM emissions are minimal due to low ash content in diesel. The short-term increase in SO_2, even assuming that all the equipment are operating at same point of time, is quite low. Hence, no major impact is anticipated on this account on ambient air quality.

Emissions from various crushers

The operation of the crusher during the construction phase is likely to generate fugitive emissions, which can move even up to 1 km in predominant wind direction. During construction phase, one crusher is likely to be commissioned near proposed dam site. During crushing operations, fugitive emissions comprising mainly the suspended particulate will be generated. During layout design, care should be taken to ensure that the Construction Worker camps, colonies, etc. are located on the leeward side and outside the impact zone (say about 10 km in upwind direction) of the crushers.

Fugitive Emissions from various sources

During construction phase, there will be increased vehicular movement. Lot of construction material like sand, fine aggregate are stored at various sites, during the project construction phase. Normally, due to blowing of winds, especially when the environment is dry, some of the stored material can get entrained in the atmosphere. However, such impacts are visible only in and around the storage sites. The impacts on this account are generally, insignificant in nature.

6.10 IMPACTS ON SOCIO-ECONOMIC ENVIRONMENT

6.10.1 Construction Phase

A project of this magnitude is likely to entail both positive as well as negative impacts on the socio-cultural fabric of area.

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 various diseases not known so far in the region resulting in health risk for the local population. Some of the important impacts that can be foreseen on the socio-economic and socio-cultural aspects of human societies in the project area are enumerated below.

i) Changes in demographic profiles are known to bring about cultural invasions in the society. Such invasions will surely be expected here, though it may be a temporary phenomenon.

ii) The past experience has shown that projects where migrant population of this magnitude is concentrated, various social vices like drinking and trade in human flesh follow. This is an area of concern that the project authorities will have to seriously prepare for and tackle this problem with the help of local administration.

iii) Migrant workers might act as carriers of new diseases hitherto unknown/unreported from the project area. Diseases like AIDS, VDS, malaria, gastro-enteritis, etc. are some of the potential risks to human health. For these project authorities have proposed proper quarantine procedure for screening and detecting such cases. In addition the existing medical facilities would also be strengthened and proper health delivery system to be proposed in the project area.

Positive Impacts on Socio-Economic Environment

One of the main reasons for promoting hydroelectric schemes is their environmentally friendly character. This form of energy, unlike the energy from other conventional sources, entails no discharges of wastes or emission of toxic gases. It is virtually free from pollution and thus can be looked as “technology of the future” for the rural and remote areas. The following positive impacts are anticipated on the socio-economic environment of the local people of villages of project area 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.

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.

6.10.2 Operation Phase

The proposed project involves acquisition of lands. A total of 5 villages (11 hamlets) will be affected due to various components of proposed Tingting H.E. Project. The list of these villages/hamlets is given below:

.

Village	Hamlets
Chozo	15 mile
	Lethang
Ting Ting	Khezek
	Khoksera
Lobing	Sardungthang
	Tongay
Thingling	Kendam
	Kamenkeun
	Aam Botay
	Doban
Mansabong	Fera

The impacts due to acquisition of these lands have been covered in the Environmental Management Plan. A detailed R&R Plan for Project Affected Families has also been suggested as per the NRRP, 2007.

Socio-economic impacts

There are about six villages which fall between dam and power house and who could be directly or indirectly dependent upon river. These are

Right Bank---Thingling-I, Thingling-II,Thingling-III, and Lethang which is also called as Chozo.
Left Bank---Tingting and Mansabong whereas the Power house is located in Lobing.

During the surveys it was observed that people are not dependent on Rathong Chhu for drinking water however, they use this water for irrigation. The local people are interested in commercial fishing, however, the catch is not sufficient for commercial exploitation. Overall the decrease in the water discharge in the river will not have any severe impact on the economy and social life of the local people. This is because of the fact that small streams are sufficient to fulfill the daily water requirement of local population. However, river should be kept alive and the minimum discharge suggested above should always be released in the river.

6.11 INCREASED INCIDENCE OF WATER-RELATED DISEASES

The construction of a reservoir replaces the riverine ecosystem by a lacustrine ecosystem. The vectors of various diseases breed in shallow water areas not very far from the reservoir margins. The magnitude of breeding sites for mosquitoes and other vectors in the impounded water is in direct proportion to the length of the shoreline. The construction of the reservoir would increase the shoreline as compared to the pre-project shoreline of river under submergence. Thus, the construction of the proposed reservoir would enhance the potential breeding sites for various diseases vectors. There are chances that incidence of malaria may increase as a result of the construction and operation of the proposed project. In addition to the construction of the reservoir, the following factors too would lead to the increased incidence of malaria in and around the project area:

- aggregation of Construction Worker
- excavation, and
- inadequate & facilities in Construction Worker camp.

Aggregation of Construction Worker

About 350 laborers and technical staff will congregate in the project area during peak construction phase. The total increase in population is expected to be of the order of 1000. Most of the Construction Worker would come from various parts of the country.

The laborers would live in dormitories provided by the contractor. Proper sanitary facilities are generally provided. Hence, a proper surveillance and immunization schedule needs to be developed for the Construction Worker population migrating into the project area.

Excavations

The excavation of earth from borrow pits etc. is one of the major factor for the increase in prevalence of malaria. After excavation of construction material, the depressions are generally left without treatment where water gets collected. These pools of water, then serves as breeding grounds for mosquitoes. However, in the present case, the borrow areas are within the river bed, which in any case remain under water. Thus, no additional habitat for mosquito breeding is created due to excavation.

The flight of mosquito is generally limited up to 1 to 2 km from the breeding sites. Since, no residential areas are located within 1 km from the reservoir, periphery, increased incidences of malaria are not anticipated. However, Construction Worker camps, etc. could be vulnerable to increased incidence of malaria, if proper control measures are not undertaken.

Inadequate facilities in Construction Worker camps

Improperly planned Construction Worker camps generally tend to become slums, with inadequate facilities for potable water supply and sewage treatment and disposal. This could lead to outbreak of epidemics of water-borne diseases. Adequate measures for supply of potable water and sewage treatment have been recommended as a part of Environmental Management Plan.

6.12 IMPACTS DURING POST OPERATIONAL PHASE

The post-operational 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.

6.13 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. However, as the project does not involve impounding or storage of large volume of water being a small dam therefore, as such there will be little impact on the reservoir induced seismicity in the area. The old and new landslides in the project area should be taken into consideration during the construction of tunnel and safety measures, if required, be taken.

ANNEXURES

तार :
Telegram : PARYAVARAN,
NEW DELHI
दूरभाष :
Telephone : & Fax 2 436 2827
टेलेक्स :
Telex : W-66185 DOE IN
FAX : 4360678

Annexure-I

भारत सरकार
पर्यावरण एवं वन मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT & FORESTS
पर्यावरण भवन, सी. जी. ओ. काम्पलेक्स
PARYAVARAN BHAVAN, C.G.O. COMPLEX
लोदी रोड, नई दिल्ली-110003
LODHI ROAD, NEW DELHI-110003

o. J. 12011/65/2006-IA.I

Date ; 09.01.2007

Ir. David Tow
irector
MEC India Pvt. Ltd.
irst India Place,
B' ck, 2nd Floor, Vatika Building
eh uli-Gurgaon Road
urgaon-122002

ir,

Subject – Ting Ting Hydro-electric Project (90 MW) in Sikkim – Scoping regarding.

This has reference to your letter No. SMEC/Ting Ting HEP/MOEF/06 ated 5th December 2006 on the above mentioned subject. The proposal was onsidered by the expert committee at its meeting held on 20th December 006.The committee noted that the project is in the vicinity of Tashiding HEP. ie proposal envisages construction of a concrete gravity dam of about 50 m eight from deepest foundation across Rathong Chu river near village Yaksum west district of Sikkim for generation of 90 (2 x 45)MW hydro power. The ibmergence area at FRL(1,020m) is about 5 ha. Most of the submergence ea is falling in the gorge, No displacement of people and human settlements inv ed. The proposed site is about 5 km away from buffer zone of ia' ienzonga Biosphere Reserve. The cost of the project is Rs. 424 oresrun-of-the river scheme.

The Ministry of Environment and Forests hereby accords clearance for econstruction activities in the proposed sites , as per the provisions of ivironmental Impact Assessment Notification, 2006, along with the following rms of Reference(TOR) for preparation of EIA report. These TORs are in dition to the proposed TORs mentioned in the FORM 1.

i) Comprehensive EIA report should include three seasons data viz:- Pre-monsoon ,monsoon, and post-monsoon.

ii) A study of site specific earthquake design parameters for barrage site needs to be conducted.

iii) Detailed quantitative vegetation analysis for density, abundance and diversity to be carried out. Status of species to be shown clearly as per Red data book.

iv) Quantitative data on fauna also required (density, abundance and diversity schedule etc.),

v) Satellite imagery (FCC) and interpreted land cover map of 10 km radius area to be given

vi) Micro flora & fauna to be listed.

vii) River ecology to be appropriately described.

viii) Sedimentation rateshould be based on project site not on Teesta stage V HEP.

ix) Impact of emission from D G set on surrounding environment.

x) Details on tunneling aspect, such as machines to be employed, charge density etc.

xi) B:C ratio

Yours faithfully,

(Dr. S. Bhowmik)
Additional Director

Copy to;-

1. The Secretary, Ministry of Power, Shram Shakti, Bhawan, Rafi Marg, New Delhi-110001.
2. Secretary, Department of Power, Govt. of Sikkim. .Secretariat, Gangtok.
3. Secretary, Deptt. of Forest, Govt. of Sikkim, Secretariat, Gangtok.
4. The Regional Office, Ministry of Environment & Forests, Shillong.

Dr. S. Bhowmik)
Additional Director

Annexure-II

GOVERNMENT OF SIKKIM
OFFICE OF THE PRINCIPAL CHIEF CONSERVATOR OF FORESTS-CUM-SECRETARY
DEPARTMENT OF FORESTS, ENVIRONMENT AND WILDLIFE MANAGEMENT
FOREST SECRETARIAT, DEORALI, GANGTOK-737 102
[PHONE: 281261 (O), 281145 (O) FAX: 03592 – 281778, 281145]

Ref. No1090/FCA /FEWMD/117.............................. *Dated: 6.4.2010*

To,

The Engineer (Project),
M/s T.T. Energy Private Limited,
Development Area,
Gangtok Sikkim.

Sub: Proposal for diversion of 4.9381 Ha (Surface land =4.7350 Ha + Underground =0.2031 Ha) of forest land for construction of 99 MW Ting Ting Hydro Electric Project in West Sikkim by M/s T.T. Energy Pvt. Limited. - **Stage-I clearance regarding.**

Sir,

With reference to the proposal mentioned above. I am directed to convey the "in principle" approval (Stage-I) accorded by the Ministry of Environment & Forests, Government of India under Section 2 of the Forest (Conservation) Act, 1980 for diversion of 4.9381 Ha (Surface land =4.7350 Ha + Underground =0.2031 Ha) of forest land for construction of 99 MW Ting Ting Hydro Electric Project in West Sikkim by M/s T.T. Energy Pvt. Limited, subject to fulfillment & compliance of the conditions stipulated in the approval letter No. 3-SK B 009/2010-SHI / 2883-84 dated 08/03/2010 (a copy of which is enclosed for reference).

Therefore, you are requested to comply with the stipulated conditions and arrange to make the following payments separately in favour of Principal Chief Conservator of Forests-cum- Secretary, Department of Forest, Environment & Wildlife Management, Government of Sikkim, Gangtok by Demand Draft, drawn on Axis Bank / State Bank of India, Gangtok at the earliest:

1. **Amount of Compensatory Afforestation:** Rs. 28, 43,900=00 (Rupees Twenty eight lakhs forty three thousand and nine hundred) only.
2. **Amount of Net Present Value (NPV):** Rs 32, 44,332=00 (Rupees Thirty two lakhs forty four thousand three hundred and thirty two) only as per order of the Hon'ble Supreme Court dated 28/3/2008 and 9/5/2008.
3. **The payment of cutting / felling / extraction / transportation cost etc**. Rs. 26, 74,675=00 (Rupees Twenty six lakhs seventy four thousand six hundred and seventy five) only.

The Compliance Report shall be forwarded to the Ministry of Environment & Forest, Government of India only on fulfillment of the above conditions and mandatory Environmental Clearance is received for the project proposal cited above. **Diversion of forest land shall not be effected till the final approval to the proposal is granted by the Central Government.**

Yours faithfully,

(M.L. Srivastave, IFS)
CCF-cum-Nodal Officer (FCA),
Department of Forest, Environment & Wildlife Management
Government of Sikkim, Gangtok

GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT & FORESTS
NORTH EASTERN REGIONAL OFFICE
UPLAND ROAD, LAITUMKHRAH, SHILLONG - 793003
टेली/Tel: (0364) - 2227673, 2227929, 2502278, 2227047
GRAM : PARYAVARAN, SHILLONG
ईमेल/Email - mofner-meg@nic.in & moefner@dataone.in

भारत सरकार
पर्यावरण एवं वन मंत्रालय
पूर्वोत्तर क्षेत्रीय कार्यालय
अपलैंड रोड, लाइतुमुखरा, शिलांग - 793003
फैक्स/Fax: (0364) - 2227047
तार : पर्यावरण, शिलांग

No.3-SK B 009/2010-SHI/2083-84

March 08, 2010

To

The Principal Chief Conservator of Forests-
-cum Secretary Forests
Forest, Environment & Wildlife Management Department
Government of Sikkim
Gangtok

Sub: Proposal for diversion of 4.9381 ha (Surface land = 4.7350 ha + Underground = 0.2031 ha) of forest land for construction of 99 MW Ting Ting Hydro Electric Project in West Sikkim by M/s T.T. Energy Pvt. Ltd.

Sir,

Please refer to the State Government's letter No. FCA/FEWMD/1090/518 dt. 11.02.2010 on the subject mentioned above, seeking prior approval of the Central Government in accordance with section 2 of the FCA, 1980.

After careful scrutiny it has been observed that CA Scheme has not been approved by competent officer of State Govt. as per Rule/Guidelines of FC Act, 1980 No. 8-80/99-FC dt. 7-11-2001.

Hence, after due consideration of the proposal of the State Government of Sikkim, the Central Government hereby conveys its in-principle approval for diversion of 4.9381 ha (Surface land = 4.7350 ha + Underground = 0.2031ha) forest land for construction of 99 MW Ting Ting Hydro Electric Project in West Sikkim by M/s T.T. Energy Pvt. Ltd in West Sikkim, subject to the following conditions:

(i) The State Govt. shall make available the CA Scheme duly approved by Competent Officer of State Govt. as per FC Act, 1980 & Guideline as given above.

(ii) Demarcation of forest land to be done on the ground at project cost using four feet high reinforced cement concrete pillars with serial numbers, forward and back bearings and distance from pillar to pillar.

(iii) The User Agency shall transfer the cost of compensatory afforestation over 10.0 ha of degraded forest land identified at Chung R.F. under Yuksom Range in West Territorial Division with the State Forest Department.

(iv) The State Government shall charge the Net Present Value of the forest area diverted under this proposal from the User Agency as per the orders of the Hon'ble Supreme Court of India dated 30.10.2002 and 01.08.2003 and 04.08.2006 & 28.03.2008 & 9.05.08 in IA No. 566 in WP(C) No. 202/1995 and as per the guidelines issued by this Ministry vide letters No. 5-1/1998-FC(Pt-II) dated 18.09.2003 and 22.09.2003, as well as letter No. 5-2/2006-FC dated 03.10.2006 in this regard.

Contd...

(v) The User Agency shall furnish an undertaking to pay the additional amount of the Net Present Value (NPV) of the diverted forest land, if any, becoming due after finalization/revision of the same by the Hon'ble Supreme Court of India.

(vi) All the above funds received from the User Agency under the project shall be transferred to the CAMPA Fund (CAF) in **Account No CA 1605** of either Corporation Bank, Block 11, CGO Complex, Phase-I, Lodhi Road, New Delhi – 110 003 or Union Bank of India, Sunder Nagar Branch, New Delhi (A/c No. 344901010070128).

After receipt of the compliance report from the State Government on fulfillment of the conditions mentioned above, formal approval will be issued in this regard. Transfer of forest land shall not be effected by the State Govt. till final approval orders approving the diversion of forest land are issued by the Central Government.

Yours faithfully,

(Mrs. L. J. Syiemiong)
Dy. Conservator Forests (C)

Copy to:

1. The Nodal Officer , O/o The PCCF, Department of Forest, Env. & WL Management, Government of Sikkim, Deorali, Gangtok .

Dy. Conservator Forests (C)

ANNEXURE – III

QUESTIONNAIRE FOR SOCIO-ECONOMIC SURVEY OF AFFECTED VILLAGES DUE TO PROJECT RELATED ACTIVITIES OF PROPOSED TING TING H.E. PROJECT

1. Village Name ____________________

    a) District ____________ b) Development Block ______

    b) Tehsil ____________ d) Panchayat ____________

2. Area (ha) ____________________

3. Number of households ____________________

4. Population Profile:

    Total population:

    a) Male ____________________

    b) Female ____________________

    c) Scheduled Castes ____________________

    d) Scheduled Tribes ____________________

5. Workers:

    a) Main workers ____________________

    b) Farmers ____________________

    c) Marginal workers ____________________

    d) Others ____________________

6. Total Cultivable area (ha) ____________________

7. Net Sown area (ha) ____________________

8. Net Irrigated area (ha) ____________________

9. Cropping Pattern:

    Area (ha) under principal crops and yield (per ha) ____________________

Cereals

a) Wheat ______________________________

b) Maize ______________________________

c) Rice ______________________________

d) Others ______________________________

Pulses

Rajmah ______________________________

Others ______________________________

10. Horticulture:

Area (ha) under principal crops and annual production

a) ______________________________

b) ______________________________

c) ______________________________

d) ______________________________

11. Medical Facilities:

a) Allopathic institutions	No.	No. of Beds	No. of Doctors	Other Staff
1) Hospitals				
2) Community Health Centres				
3) Primary Health Centres				
4) Dispensary				
5) Health Sub-centre				

b) Ayurvedic Institutions: Nos. No. of Beds

1) Hospitals ______________________________

2) Dispensary ______________________________

c) Health & Hygiene:

Prevalent Diseases ______________________________

Endemic Diseases ______________________________

Epidemic Diseases ______________________________

12. Educational Institutions:	Number	Student Strength	No. of Teachers
a) Primary schools			
b) Middle schools			
c) High / Higher Secondary schools			
d) Colleges			

If there is no school, then nearest school and distance from the village.

13. Veterinary Facilities:

a) Hospitals ______________________________

b) Dispensary ______________________________

c) Artificial Insemination Centres ______________________________

14. Sewage & Sanitation Facilities, if any ______________________________

____

15. Whether Electrified Yes / No

– Any electrical sub-station ______________________________

– If not electrified, then the nearest electrified village ______________________________

16. Roads Length (km)

a) Unmetalled ______________________________

b) Metalled ______________________________

c) Jeepable ______________________________

d) If not connected by any road, then the nearest road head (distance)

____

17. Post Office Yes / No

If the answer is ‘No’, then the location and distance of nearest post office

____

18. Telegraph Office ______________________________

19. Banks ______________________________

20. Police Post ______________________________

21. State Government Employees ______________________________

22. Central Govt. Employees ______________________________

23. Drinking water availability:

Source ______________________________
(River, Well, Hand-pump, Tap, Public Standpost, springs and others)

Quality : Satisfactory : Yes/ No
(Nature of problem, if No)

Quantity : Adequate/ Inadequate For drinking water (litres)
For other use (litres)
Any other specific drinking water problem

If the water is not fit for drinking, how do you purify it.

(filtering through cloth, boiling, alum treatment, disinfectant, decantation) etc.

Water borne diseases, if any

(Dysentary, Diarrhoea, Jaundice, Gastroenteritis, others, etc.)

24. Livestock:

- Sheep ______________________ Buffaloes ______________________
- Goat ______________________ Horses & Mules ______________________
- Cows ______________________

25. Co-operative Societies & NGOs ______________________

26. Village Panchayat ______________________

27. Fair Price Shop ______________________

28. Tourist/Recreational Spot ______________________
(Religious place, historical monument, sanctuary, others, etc.)

29. Fertilisers used and consumption ______________________

30. a) Forest Range/Division ______________________

Forest Check Post/s ______________________

b) Forests & Forest Produce:

Forests:

Reserve Forest ______________________

Protected Areas ______________________

Revenue Forest ______________________

Forest produce:

Medicinal herbs ______________________

Misc. ______________________

31. Natural Water Sources:

a) Springs ______________________

b) Brooks ______________________

c) Water Quality ______________________

32. Literacy ____________________

33. Income Pattern:

a) Farming ____________________

b) Salaried:

- Government ____________________

- Private ____________________

c) Businessman/Shops/Trading ____________________

34. Government Schemes (Both Central & State Govt.) like IRDP, etc.

____

____

35. Vocational Training Centres, if any ____________________

____

36. Meteorological Data:

a) Rainfall
i) Average Annual ____________ ii) Daily (mm) ____________

b) Temperature Mean: ________ Max. ________ ^oC Min. ________ ^oC

Daily record, if available ____________________

c) Snowfall ____________________

d) Hailstorms a) Intensity ____________ b) Frequency ________

e) Flashfloods a) Historical ____________ b) Frequency ________

37. Fishery Resources:

Type of Fish ____________________

Licenced Fisherman, if any ____________________

Fish catch ____

38. Small Scale Industries:

a) Medicinal herbs collection ____________________________

b) Handicrafts ____________________________

c) Shawl making ____________________________

d) Carpet weaving ____________________________

e) Paper Machie ____________________________

f) Wooden carving ________________________________

g) Apiary ____

h) Others ____

39. Mode of transport : ___________________________________

40. Vehicles:

a) Bicycles ___________________________________

b) Tractors ___________________________________

c) Scooters/Bikes ___________________________________

41. Marketing Facilities:
Local Trading Centre ________________________________

42. Non-conventional Energy Sources:

Solar lighting etc.___________________________________

43. Recreational facilities ___________________________________
(Library, Club, TV, Cinema, etc.)

44. Wastewater
How do you dispose-off wastewater___________________________
(Drainage, Sewer, Soak pit, No organised system, etc.)

Any specific problem related to wastewater_____________________

Suggestions for improvement ______________________________

45. Sanitation and Health

No. of families : Latrine proper sanitation facilities

Soakpit :______________ Septic tank : ____________Any other :__________

(If No, where do you go for defecation)

Open space: Field: Road side: Public latrine:

46. Solid waste disposal:

(Unused land, road side, community dustbin, composting, any other)

ANNEXURE – IV

QUESTIONNAIRE FOR SOCIO-ECONOMIC SURVEY OF AFFECTED FAMILIES DUE TO PROJECT RELATED ACTIVITIES OF PROPOSED TING TING H.E. PROJECT

1. Name of the head of the family ______________________

2. Religion of the family ______________________

3. Caste of the family ______________________

4. Number of Family Members ______________________

5. Age group of the family members: Adults ______________________

   Children (0-6) ______________________

   Children (6-17) ______________________

6. Number of earning members

7. Number of non-earning members   Male [ ]   Female [ ]

8. Number of dependants & relationship with head of the family   Male ______________________

   Female ______________________

   Children: (Male : 0-6) ______________________

   (Female : 0-6) ______________________

9. Marital status of dependants : Married : Male [ ]   Female [ ]

   Unmarried : Male [ ]   Female [ ]

10. Occupation of family members:

    Father ______________________

    Mother ______________________

    Children : Daughter ______________________

    Son ______________________

    Others ______________________

11. Occupation details:

Service Government/ Non-government

Agriculture ______________________________

Business ______________________________

Any other ______________________________

12. Educational qualifications of family members:

Primary ______________________________

Higher Secondary ______________________________

Graduate ______________________________

Post-graduate ______________________________

and above ______________________________

13. Homestead Land:

	No. of house/houses	Area (Acres)
a) Owner	________________	________________
b) Tenant	________________	________________

14. No. of houses affected due to construction of project ________________

15. No. of houses left______________________________

16. Land holding:

Total ______________ Acres/ hectare/ any other (   )

Land under cultivation ________________ Acres

Location of land Same village__________ (Area in acres/ha/any other)

Other village __________ (Area in acres/ha/any other)

17. Land self tilled or by labourers ______________________________

18. Whether living in village or not, permanently/temporarily________________

19. No. of shops/mills to be acquired/affected

20. No. of shops left

21. No. of animals : Sheep ____________________

Goat ____________________

Cow ____________________

Bull ____________________

Horse ____________________

Pig ____________________

Others ____________________

22. Income:

a) Source/s ____________________

b) Total annual income including agriculture, self employment, salaries, casual wages, etc. ____________________

____

22. Cropping Pattern ____________________

23. Income /expenditure Pattern ____________________

24. Details of government grants, if availed under Indian Rural Developmental Programme (IRDP) or other such schemes ____________________

____

25. Health Status:

- Name major diseases by which family members fell sick in last 3 years ____________________

- Type of treatment, family generally avails ____________________ (allopathy, homoeopathy, ayurvedic, unani, etc.)

- Does family knows preventive measures of the above diseases ____________________ (Immunisation, water treatment, personal hygiene, do not know, etc.)

- Where does family go for treatment ____________________ (Household treatment, Pvt. medical practitioner, Govt. hospital, PHC, etc.)

- Have any member got vaccinated in the last one year ____________________
  (Cholera, Jaundice, any other)

26. Land aquisition

    a) Total land of the owner ____________________

    b) Land to be acquired (ha) ____________________

    c) Land left (ha) ____________________

    d) Type of land acquired (ha)- Landuse ____________________

    e) Type of land left (ha) - Landuse ____________________

    f) Estimated loss due to loss of agricultural land, if any ____________________

27. Immovable Properties:

    a) Houses ____________________

    b) Wells ____________________

    c) Ponds ____________________

    d) Water- mills ____________________

    e) Others ____________________

28. Willingness to Accept:

    a) Willing to accept the loss of land (homestead/agricultural) Yes/No

    b) Is ready to accept the proper compensation offered for the loss as per the State policy Yes/No

    c) If answers to above questions are No, then give reasons ____________________

    ____

29. Would you welcome the project. Yes/ No
    (If No, give reasons)

____
Signature of the respondent

Surveyor Name: ____________________

Date : ____________________

Annexure –V

List of Flowering Plant species

S. No.	Family	Genus	*Species*	Distribution (m)
1	Acanthaceae	*Strobilanthes*	*oligocephala*	1800-3000
2	Acanthaceae	*Thunbergia*	*coccinea*	800-1600
3	Aceraceae	*Acer*	*campbellii*	1500-2500
4	Aceraceae	*Acer*	*caudatum*	3500-4000
5	Acoraceae	*Acorus*	*calamus*	1700-2300
6	Actinidiaceae	*Saurauia*	*nepaulensis*	900-1500
7	Actinidiaceae	*Saurauia*	*roxburghii*	600-1700
8	Actinidiaceae	*Actinida*	*callosa*	1600-2600
9	Alangiaceae	*Alangium*	*chinense*	1500-2500
10	Amaranthaceae	*Deeringia*	*cordata*	Up to 1800
11	Amaranthaceae	*Amaranthus*	*hybridus*	ca. 2800
12	Amaranthaceae	*Achyranthes*	*aspera*	300-3500
13	Amaranthaceae	*Alternanthera*	*sessilis*	Up to 1500
14	Amaranthaceae	*Cyathula*	*tomentosa*	1000-2000
15	Amaryllidaceae	*Zepharanthes*	*candida*	1600-1800
16	Amaryllidaceae	*Crinum*	*amoenum*	700-2100
17	Anacardiaceae	*Rhus*	*chinensis*	900-2700
18	Anacardiaceae	*Rhus*	*succadanea*	600-2400
19	Anacardiaceae	*Dobinea*	*vulgaris*	1500-1900
20	Apiaceae	*Centella*	*asiatica*	600-2800
21	Apiaceae	*Angelica*	*sikkimensis*	800-2800
22	Apiaceae	*Bupleurum*	*candollii*	2500-4000
23	Apiaceae	*Carum*	*carvi*	2700-4000
24	Apiaceae	*Hydrocotyle*	*himalaicum*	1800-3200
25	Apiaceae	*Hydrocotyle*	*nepalensis*	Up to 2000
26	Apiaceae	*Heracleum*	*sublineare*	1600-2600
27	Apiaceae	*Pimpinella*	*wallichii*	1200-1800
28	Apocynaceae	*Trachelospermum*	*lucidum*	600-2100
29	Aquifoliaceae	*Ilex*	*dipyrena*	2000-3100
30	Araceae	*Arisaema*	*concinnum*	Up to 1800
31	Araceae	*Arisaema*	*griffithii*	2300-2900
32	Araceae	*Amorphophallus*	*nepalensis*	900-2100
33	Araceae	*Colocasia*	*esculenta*	600-1200
34	Araceae	*Raphidophora*	*decursiva*	1200-2000
35	Araceae	*Raphidophora*	*glauca*	1200-2000
36	Araliaceae	*Panax*	*pseudo-ginseng*	1500-3000
37	Araliaceae	*Brassiopsis*	*mitis*	1500-2100
38	Araliaceae	*Scheffeleria*	*elata*	1500-2130
39	Araliaceae	*Merrilopanax*	*alpinus*	1800-2800
40	Araliaceae	*Hedera*	*nepalensis*	1900-2600
41	Arecaceae	*Phoenix*	*acaulis*	Up to 1600
42	Arecaceae	*Pinanga*	*gracilis*	Up to 900
43	Asclepiadaceae	*Cynachum*	*auriculatum*	1800-3600
44	Asclepiadaceae	*Cryptolepis*	*buchnani*	Up to 2400

45	Asteraceae	*Ageratum*	*conyzoides*	Up to 2500
46	Asteraceae	*Ainsliaea*	*latifolia*	1500-3500
47	Asteraceae	*Anaphalis*	*busua*	1500-2800
48	Asteraceae	*Artemisia*	*indica*	3000- 3800
49	Asteraceae	*Artemisia*	*indica*	1500-2500
50	Asteraceae	*Anaphalis*	*margaritacea*	1800-3600
51	Asteraceae	*Anaphalis*	*triplinervis*	1800-3300
52	Asteraceae	*Artemisia*	*nilagirica*	600-3000
53	Asteraceae	*Aster*	*albescens*	2400-3600
54	Asteraceae	*Aster*	*mollisculus*	1500-2800
55	Asteraceae	*Aster*	*sikkimensis*	1800-3000
56	Asteraceae	*Erigeron*	*karvinckianus*	1600-2600
57	Asteraceae	*Bidens*	*bipinnatus*	600-2500
58	Asteraceae	*Bidens*	*pilosa*	1000-2000
59	Asteraceae	*Blumea*	*aromatica*	2700-3000
60	Asteraceae	*Cirsium*	*eriophoroides*	1600-2600
61	Asteraceae	*Cirsium*	*wallichii*	1500-3000
62	Asteraceae	*Dicrocephala*	*chrysanthemoides*	700-2100
63	Asteraceae	*Conyza*	*japonica*	1700-3700
64	Asteraceae	*Ageratina*	*adenophora*	Up to 2600
65	Asteraceae	*Chromolaena*	*odoratum*	600-2400
66	Asteraceae	*Galinsoga*	*parviflora*	1500-2500
67	Asteraceae	*Gerbera*	*piloselloides*	1500-3000
68	Asteraceae	*Inula*	*hookeri*	1550-2700
69	Asteraceae	*Myriactis*	*nepalensis*	1600-2800
70	Asteraceae	*Saussurea*	*heteromela*	Up to 2400
71	Asteraceae	*Senecio*	*scandens*	1800-3600
72	Asteraceae	*Taraxacum*	*officinale*	1500-3000
73	Balsaminaceae	*Impatiens*	*drepanophora*	Up to 1500
74	Balsaminaceae	*Impatiens*	*sulcata*	2850-3850
75	Balsaminaceae	*Impatiens*	*tripetala*	1900-2900
76	Begoniaceae	*Begonia*	*josephii*	600-1800
77	Begoniaceae	*Begonia*	*palmata*	1000-2850
78	Berberidaceae	*Berberis*	*umbellata*	3300-3900
79	Berberidaceae	*Berberis*	*concinum*	3300-3900
80	Berberidaceae	*Mahonia*	*napaulensis*	1500-3000
81	Betulaceae	*Alnus*	*nepalensis*	1000-3000
82	Betulaceae	*Betula*	*alnoides*	1500-2700
83	Betulaceae	*Betula*	*utilis*	2700-4300
84	Bignoniaceae	*Oroxylum*	*indicum*	Up to 1000
85	Bischofiaceae	*Bischofia*	*javanica*	600-1200
86	Bombacaceae	*Bombax*	*ceiba*	Up to 1500
87	Boraginceae	*Cynoglossum*	*lanceolatum*	1500-4000
88	Boraginceae	*Hackelia*	*uncinata*	2700-4200
89	Brassicaceae	*Arabidopsis*	*himalaica*	3400-4400
90	Brassicaceae	*Brassica*	*campestris*	Up to 1800
91	Brassicaceae	*Brassica*	*juncea*	Up to 1600
92	Brassicaceae	*Capsella*	*bursa-pastoris*	2000-3000

93	Brassicaceae	*Cardamine*	*impatiens*	1500-2750
94	Brassicaceae	*Cardamine*	*macrophylla*	2400-4100
95	Brassicaceae	*Roripa*	*benghalensis*	2700-6000
96	Brassicaceae	*Thalspi*	*andersonii*	3400-4500
97	Burseraceae	*Canarium*	*strictum*	Up to 1000
98	Caesalpiniaceae	*Bauhinia*	*purpurea*	250-1550
99	Campanulaceae	*Campanula*	*aristata*	3300-4500
100	Campanulaceae	*Cyananthus*	*pedunculatus*	3500-4000
101	Cannabaceae	*Cannabis*	*sativa*	600-2800
102	Caprifoliaceae	*Viburnum*	*erubescens*	1800-3000
103	Caryophyllaceae	*Arenaria*	*neelgheriensis*	Up to 2000
104	Caryophyllaceae	*Cerastium*	*glomeratum*	2400-3900
105	Caryophyllaceae	*Silene*	*indica*	2400-4000
106	Caryophyllaceae	*Stellaria*	*media*	1500-2400
107	Celastraceae	*Celastrus*	*paniculata*	600-2000
108	Chenopodiaceae	*Chenopodium*	*album*	600-3600
109	Chenopodiaceae	*Chenopodium*	*ambrosioides*	Up to 1600
110	Commelinaceae	*Commelina*	*benghalensis*	900-1600
111	Commelinaceae	*Commelina*	*paludosa*	ca 1800
112	Commelinaceae	*Murdania*	*divergens*	600-1600
113	Commelinaceae	*Cyanotis*	*cristata*	Up to 1700
114	Convolvulaceae	*Ipomoea*	*purpurea*	600-2300
115	Corylaceae	*Carpinus*	*viminea*	1500-2200
116	Cucurbitaceae	*Herpetospermum*	*pedunculosum*	2100-3000
117	Cucurbitaceae	*Edgaria*	*darjeelegensis*	1200-2400
118	Cuscutaceae	*Cuscuta*	*reflexa*	600-2700
119	Cyperaceae	*Carex*	*atrata*	3300-5100
120	Cyperaceae	*Carex*	*baccans*	1200-2400
121	Cyperaceae	*Carex*	*cruciata*	Up to 3300
122	Cyperaceae	*Carex*	*decora*	2700-3600
123	Cyperaceae	*Carex*	*facata*	2700-3600
124	Cyperaceae	*Carex*	*filicina*	1500-3700
125	Cyperaceae	*Carex*	*insignis*	1500-2100
126	Cyperaceae	*Carex*	*sikkimensis*	3600-3900
127	Cyperaceae	*Cyperus*	*compressus*	550-2100
128	Cyperaceae	*Cyperus*	*difformis*	Up to 2400
129	Cyperaceae	*Cyperus*	*niveus*	Up to 1800
130	Cyperaceae	*Cyperus*	*tenuiculmis*	Up to 2150
131	Cyperaceae	*Fimbristylis*	*aestivalis*	Up to 1700
132	Cyperaceae	*Fimbristylis*	*complanata*	1800-2100
133	Cyperaceae	*Kyllinga*	*brevifolia*	Up to 2400
134	Cyperaceae	*Kobresia*	*curticeps*	3000-3700
135	Cyperaceae	*Kobresia*	*duthiei*	3500-4200
136	Cyperaceae	*Kobresia*	*gammiei*	3400-3800
137	Cyperaceae	*Kobresia*	*royleana*	3500-4500
138	Cyperaceae	*Kobresia*	*uncinoides*	3300-4300
139	Daphniphyllaceae	*Daphniphyllum*	*himalense*	2200-3050
140	Dioscoreaceae	*Dioscorea*	*alata*	Up to 2500

141	Dioscoreaceae	*Dioscorea*	*bulbifera*	Up to 2500
142	Dioscoreaceae	*Dioscorea*	*glabra*	Up to 2500
143	Elaeagnaceae	*Hippophae*	*rhamnoides*	3600-4600
144	Elaeagnaceae	*Hippophae*	*salicifolia*	2800-3600
145	Ericaceae	*Agapetes*	*serpens*	1500-2700
146	Ericaceae	*Cassiope*	*fastigata*	2800-4500
147	Ericaceae	*Gaultheria*	*fragrantissima*	1500-2700
148	Ericaceae	*Lyonia*	*ovalifolia*	1500-2800
149	Ericaceae	*Rhododendron*	*arboreum*	1500-3600
150	Ericaceae	*Rhododendron*	*barbatum*	2400-3600
151	Ericaceae	*Rhododendron*	*camelliiflorrum*	2700-3600
152	Ericaceae	*Rhododendron*	*campanulatum*	3000-4400
153	Ericaceae	*Rhododendron*	*thomswonii*	2600-3400
154	Euphorbiaceae	*Emblica*	*officinalis*	2700-3300
155	Euphorbiaceae	*Euphorbia*	*hirta*	Up to 2500
156	Euphorbiaceae	*Euphorbia*	*sikkimensis*	2700-3300
157	Euphorbiaceae	*Ostodes*	*paniculata*	Up to1000
158	Euphorbiaceae	*Macaranga*	*denticulata*	1500-2000
159	Euphorbiaceae	*Malotus*	*philippensis*	Up to 1000
160	Fagaceae	*Castanopsis*	*hystrix*	2000-2300
161	Fagaceae	*Castanopsis*	*indica*	2000-2300
162	Fagaceae	*Castanopsis*	*tribuloides*	1200-2400
163	Fagaceae	*Quercus*	*glauca*	1100-2100
164	Fagaceae	*Quercus*	*lamellosa*	1600-2800
165	Fagaceae	*Quercus*	*leucotrichophora*	1100-2100
166	Fagaceae	*Quercus*	*thomsoniana*	1800-2700
167	Flacourtiaceae	*Gynocardia*	*odorata*	Up to 1000
168	Fumariaceae	*Dicentra*	*scandens*	2000-2700
169	Gentianaceae	*Exacum*	*hamiltonii*	1230-1800
170	Gentianaceae	*Crawfordia*	*speciosa*	2100-3800
171	Gentianaceae	*Swertia*	*angustifolia*	600-1850
172	Geraniaceae	*Geranium*	*donianum*	2400-4000
173	Geraniaceae	*Geranium*	*polyanthes*	2400-4500
174	Gesneriaceae	*Aeschynanthus*	*sikkimensis*	1500-2100
175	Gesneriaceae	*Chirita*	*pumila*	1800-2800
176	Gesneriaceae	*Didymocarpus*	*oblongus*	1000-3000
177	Grossulariaceae	*Ribes*	*acuminata*	2700-3950
178	Hamamelidaceae	*Exbucklandia*	*populnea*	Up to 2000
179	Hydrangeaceae	*Hydrangea*	*anomala*	1800-2150
180	Hydrangeaceae	*Dichroa*	*febrifuga*	1000-2200
181	Hypericaceae	*Hypericum*	*japonicum*	1500-2300
182	Iridaceae	*Belamcanda*	*chinensis*	Up to 2200
183	Iridaceae	*Iris*	*tectorum*	2300-2700
184	Juglandaceae	*Engelhardtia*	*spicata*	Up to 1600
185	Juglandaceae	*Juglans*	*regia*	1500-3000
186	Lamiaceae	*Ajuga*	*macrosperma*	1500-4000
187	Lamiaceae	*Galeopsis*	*bifida*	2700-2900
188	Lamiaceae	*Elscholtzia*	*fruticosa*	1800-3300
189	Lamiaceae	*Elscholtzia*	*strobilifera*	3000-3500

190	Lamiaceae	*Colquhounia*	*coccinea*	1600-2800
191	Lamiaceae	*Lamium*	*amplexicaule*	2700-4200
192	Lamiaceae	*Leucosceptrum*	*canum*	1500-2500
193	Lamiaceae	*Origanum*	*vulgare*	600-3800
194	Lamiaceae	*Prunella*	*vulgaris*	1500-3600
195	Lamiaceae	*Colebrookea*	*oppositifolia*	600-1000
196	Lamiaceae	*Ocimum*	*tenuiflorum*	600-2300
197	Lamiaceae	*Salvia*	*sikkimensis*	2700-4000
198	Lardizabalaceae	*Holboellia*	*latifolia*	1800-2900
199	Lauraceae	*Cinnamomum*	*tamala*	450-2100
200	Lauraceae	*Persea*	*duthiei*	1500-2700
201	Lauraceae	*Litsea*	*doshia*	1500-2100
202	Lauraceae	*Litsea*	*sericea*	1600-2800
203	Liliaceae	*Allium*	*prattii*	2400-4500
204	Liliaceae	*Allium*	*sativum*	Up to 1400
205	Liliaceae	*Allium*	*wallichii*	2400-4600
206	Liliaceae	*Aletris*	*pauciflora*	2500-4900
207	Liliaceae	*Asparagus*	*filicinus*	Up to 2100
208	Liliaceae	*Camplandra*	*aurantiaca*	1200-2400
209	Liliaceae	*Cardiocrinum*	*giganteum*	1800-3300
210	Liliaceae	*Chlorophytum*	*khasianum*	1200-3200
211	Liliaceae	*Chlorophytum*	*nepalense*	1400-2500
212	Liliaceae	*Clintonia*	*undensis*	2200-3600
213	Liliaceae	*Disporum*	*cantoniense*	2700-4700
214	Liliaceae	*Fritillaria*	*cirrhosa*	1500-4800
215	Liliaceae	*Ophiopogon*	*intermedius*	1200-3000
216	Liliaceae	*Ophiopogon*	*wallichianus*	2000-2800
217	Liliaceae	*Lloydia*	*delavayi*	4000-4500
218	Liliaceae	*Paris*	*polyphylla*	1800-3300
219	Liliaceae	*Polygonatum*	*brevistylum*	2100-3000
220	Liliaceae	*Polygonatum*	*cirrhifolium*	1700-3400
221	Liliaceae	*Streptopus*	*simplex*	2400-4200
222	Liliaceae	*Trillidium*	*govanianum*	2700-4000
223	Loganiaceaes	*Buddleja*	*macrostachya*	1500-2500
224	Loranthaceae	*Loranthus*	*odoratus*	2000-2500
225	Loranthaceae	*Scurrula*	*elata*	2100-32s00
226	Magnoliaceae	*Magnolia*	*campbellii*	2000-3100
227	Magnoliaceae	*Michelia*	*velutina*	1500-2100
228	Malvaceae	*Sida*	*rhombifolia*	1200-2400
229	Malvaceae	*Urena*	*lobata*	1500-1750
230	Melastomaceae	*Oxyspora*	*paniculata*	680-2150
231	Meliaceae	*Melia*	*azedarach*	Up to 1200
232	Meliaceae	*Toona*	*ciliata*	700-2100
233	Menispermaceae	*Cissampelos*	*pareira*	Up to 1000
234	Menispermaceae	*Stephania*	*elegans*	1500-2100
235	Menispermaceae	*Stephania*	*glabra*	600-1600
236	Mimosaceae	*Albizia*	*chinensis*	450-1500
237	Mimosaceae	*Mimosa*	*himalayana*	750m

238	Moraceae	*Ficus*	*auriculata*	900-2000
239	Moraceae	*Ficus*	*bengalensis*	Up to 1000
240	Moraceae	*Ficus*	*oligodon*	Up to 1600
241	Moraceae	*Ficus*	*semicordata*	600-1500
242	Moraceae	*Ficus*	*subincisa*	Up to 1000
243	Musaceae	*Musa*	*balbisiana*	Up to 1750
244	Myrsinaceae	*Maesa*	*rugosa*	1500-2400
245	Oleaceae	*Jasminum*	*dispermum*	1500-3000
246	Onagraceae	*Circaea*	*repens*	2000-4000
247	Onagraceae	*Epilobium*	*cylindricum*	1500-3000
Orchidaceae				
248	**Orchidaceae**	*Arundina*	*graminifolia*	ca 1750
249	**Orchidaceae**	*Bulbophyllum*	*affine*	600-1000
250	**Orchidaceae**	*Bulbophyllum*	*hymenanthum*	1800-2100
251	**Orchidaceae**	*Coelogyne*	*nitida*	1800-2100
252	**Orchidaceae**	*Cymbidium*	*elegans*	ca 1500
253	**Orchidaceae**	*Dendrobium*	*amoenum*	Up to 1750
254	**Orchidaceae**	*Dendrobium*	*chrysanthum*	1800-2100
255	**Orchidaceae**	*Habenaria*	*albomarginata*	ca 3900
256	**Orchidaceae**	*Liparis*	*dentata*	ca 1800
257	**Orchidaceae**	*Liparis*	*paradoxa*	Up to 1800
258	**Orchidaceae**	*Malaxis*	*acuminata*	900-2100
259	**Orchidaceae**	*Malaxis*	*muscifera*	2200-3000
260	**Orchidaceae**	*Oberonia*	*pyrulifera*	Up to 2000
261	**Orchidaceae**	*Platanthera*	*excelliana*	3000-3600
262	**Orchidaceae**	*Resleya*	*atropurpurea*	ca 3900
263	Oxalidaceae	*Oxalis*	*corniculata*	250-2450
264	Oxalidaceae	*Oxalis*	*latifolia*	250-2450
265	Pandanceae	*Pandanus*	*nepalensis*	Up to 1700
266	Papaveraceae	*Meconopsis*	*paniculata*	3300-4200
267	Papilionaceae	*Millettia*	*glaucescens*	Up to s600
268	Papilionaceae	*Desmodium*	*confertum*	800-1500
269	Papilionaceae	*Desmodium*	*elegans*	750-2450
270	Papilionaceae	*Desmodium*	*heterocarpon*	1800-1950
271	Papilionaceae	*Desmodium*	*motorium*	300-1650
272	Papilionaceae	*Desmodium*	*triflorum*	300-1600
273	Papilionaceae	*Indigofera*	*hebepetala*	2100-2500
274	Papilionaceae	*Indigofera*	*heterantha*	1500-2500
275	Papilionaceae	*Lespedeza*	*gerardiana*	2400-3600
276	Papilionaceae	*Erythrina*	*arborescens*	1500-2400
277	Papilionaceae	*Shuteria*	*hirsuta*	1200-2000
278	Papilionaceae	*Phaseolus*	*vulgaris*	1500- 2300
279	Papilionaceae	*Moghania*	*macrophylla*	1500-2200
280	Papilionaceae	*Parochetus*	*communis*	1800-2800
281	Papilionaceae	*Trigonella*	*corniculata*	2500-3800
282	Philadelphaceae	*Deutzia*	*compacta*	2100-3350
283	Piperaceae	*Piper*	*pedicellatum*	Up to 1800
284	Piperaceae	*Peprommia*	*tetraphylla*	1250-2100

285	Plantaginaceae	*Plantago*	*depressa*	1500-2500
286	Plantaginaceae	*Wulfenia*	*nepalensis*	1500-2500
287	Poaceae	***Bambusa***	***tulda***	Up to 1500
288	Poaceae	***Chimonobambusa***	***hookeriana***	1800-2200
289	Poaceae	***Dendrocalamus***	***hamiltonii***	1000-2000
290	Poaceae	***Dendrocalamus***	***hookeri***	1000-2000
291	Poaceae	***Thamnocalamus***	***aristata***	2200-3300
292	Poaceae	*Yushania*	*racemosa*	3000-3600
293	Poaceae	*Arthraxon*	*hispidus*	Up to 1900
294	Poaceae	*Arthraxon*	*lancifolius*	900-1800
295	Poaceae	*Brachiaria*	*ramosa*	Up to 1800
296	Poaceae	*Brachiaria*	*villosa*	Up to 2400
297	Poaceae	*Capillipedium*	*assimile*	600-2100
298	Poaceae	*Chrysopogon*	*aciculatus*	Up to 1700
299	Poaceae	*Chrysopogon*	*gryllus*	800-2900
300	Poaceae	*Digitaria*	*ciliaris*	Up to 1500
301	Poaceae	*Digitaria*	*setigera*	Up to 1600
302	Poaceae	*Eulalia*	*hirtifolia*	Up to 2400
303	Poaceae	*Eulalia*	*quadrinervis*	Up to 1500
304	Poaceae	*Imperata*	*cylindrica*	Up to 2700
305	Poaceae	*Microstegium*	*vimineum*	1500-2000
306	Poaceae	*Miscanthus*	*nudipes*	2100-2700
307	Poaceae	*Oplismenus*	*compositus*	Up to 2400
308	Poaceae	*Pennisetum*	*flaccidum*	Up to 2500
309	Poaceae	*Pogonatherum*	*paniceum*	Up to1800
310	Poaceae	*Saccharum*	*longisetosum*	1500-2700
311	Poaceae	*Saccharum*	*rufipilum*	1500-2500
312	Poaceae	*Saccharum*	*sikkimensis*	2700-2900
313	Poaceae	*Setaria*	*glauca*	600-2400
314	Poaceae	*Setaria*	*palmifolia*	700-2100
315	Poaceae	*Setaria*	*verticellata*	1500-1800
316	Poaceae	*Themeda*	*hookeri*	Up to 2500
317	Poaceae	*Zea*	*mays*	Up to 1900
318	Poaceae	*Agrostis*	*hookeriana*	3000-4000
319	Poaceae	*Agrostis*	*myriantha*	Up to 1800
320	Poaceae	*Agrostis*	*stolonifera*	1500-4000
321	Poaceae	*Arundinella*	*hookeri*	2500-3000
322	Poaceae	*Arundinella*	*nepalensis*	Up to 1600
323	Poaceae	*Calamogrostis*	*emodensis*	2200-4000
324	Poaceae	*Cynodon*	*dactylon*	Up to 2000
325	Poaceae	*Eleusine*	*coracana*	Up to 2800
326	Poaceae	*Eleusine*	*indica*	600-2000
327	Poaceae	*Eragrostis*	*japonica*	600-2400
328	Poaceae	*Eragrostis*	*nigra*	1500-3000
329	Poaceae	*Eragrostis*	*tenella*	600-1000
330	Poaceae	*Poa*	*annua*	1500-4000
331	Poaceae	*Thysanolaena*	*latifolia*	Up to 1600
332	Poaceae	*Trisetum*	*spicatum*	3600-4800

333	Polygalaceae	*Polygala*	*furcata*	1800-2600
334	Polygonaceae	*Aconogonum*	*campanulatum*	2900-4100
335	Polygonaceae	*Aconogonum*	*molle*	2900-4100
336	Polygonaceae	*Fagopyrum*	*esculenta*	1200-2400
337	Polygonaceae	*Fagopyrum*	*tataricum*	1800-3500
338	Polygonaceae	*Persicaria*	*amplexicaulis*	1500-2800
339	Polygonaceae	*Persicaria*	*barbata*	1500-2800
340	Polygonaceae	*Persicaria*	*capitata*	1500-2800
341	Polygonaceae	*Persicaria*	*runcinata*	1500-2800
342	Polygonaceae	*Oxyria*	*digyna*	3600-4600
343	Polygonaceae	*Rheum*	*acuminatum*	3400-4100
344	Polygonaceae	*Rumex*	*nepalensis*	1500-4500
345	Primulaceae	*Androsace*	*hookerianum*	2400-3000
346	Primulaceae	*Primula*	*denticulata*	1500-4500
347	Primulaceae	*Primula*	*gracilipes*	2700-4100
348	Primulaceae	*Primula*	*obliqua*	3200-4500
349	Primulaceae	*Primula*	*scapigera*	2300-3000
350	Primulaceae	*Primula*	*sikkimensis*	2700-4700
351	Punicaceae	*Punica*	*granatum*	1200-2400
352	Ranunculaceae	*Anemone*	*obtusiloba*	3000-4000
353	Ranunculaceae	*Anemone*	*rivularis*	1900-3900
354	Ranunculaceae	*Anemone*	*vitifolia*	1550-2750
355	Ranunculaceae	*Caltha*	*acuminata*	600-2400
356	Ranunculaceae	*Caltha*	*palustris*	3050-5000
357	Ranunculaceae	*Clematis*	*gouriana*	600-2400
358	Ranunculaceae	*Clematis*	*montana*	2100-4100
359	Ranunculaceae	*Ranunculus*	*diffusus*	1500-2700
360	Ranunculaceae	*Ranunculus*	*sceleratus*	1300-2700
361	Ranunculaceae	*Thalictrum*	*alpinum*	3600-4500
362	Ranunculaceae	*Thalictrum*	*foliolosum*	1500-2100
363	Rhamnaceae	*Rhamnus*	*nepalensis*	Up to 2000
364	Rosaceae	*Cotoneaster*	*bacillaris*	2100-4500
365	Rosaceae	*Cotoneaster*	*microphyllus*	2100-4500
366	Rosaceae	*Fragaria*	*nubicola*	1800-3600
367	Rosaceae	*Geum*	*elatum*	3900-4300
368	Rosaceae	*Neillia*	*thrysiflora*	1200-2500
369	Rosaceae	*Prunus*	*armeniaca*	1500-2800
370	Rosaceae	*Prunus*	*cerasoides*	1200-2000
371	Rosaceae	*Prunus*	*cornuta*	2300-3300
372	Rosaceae	*Prunus*	*undulata*	900-1900
373	Rosaceae	*Potentilla*	*atrosanguinea*	2500-3600
374	Rosaceae	*Potentilla*	*fulgens*	2400-3000
375	Rosaceae	*Pyrus*	*communis*	1200-2000
376	Rosaceae	*Rosa*	*brunoniana*	1500-2500
377	Rosaceae	*Rosa*	*indica*	600-2900
378	Rosaceae	*Rosa*	*macrophylla*	2100-3800
379	Rosaceae	*Rosa*	*moschata*	2800-3600
380	Rosaceae	*Rosa*	*sericea*	3000-4000
381	Rosaceae	*Rubus*	*acuminatus*	1700-2200

382	Rosaceae	*Rubus*	*biflorus*	2300-3500
383	Rosaceae	*Rubus*	*ellipticus*	1200-2000
384	Rosaceae	*Rubus*	*niveus*	1000-2500
385	Rosaceae	*Rubus*	*paniculatus*	600-2800
386	Rosaceae	*Rubus*	*sikkimensis*	3500-3900
387	Rosaceae	*Spiraea*	*canescens*	2700-3300
388	Rubiaceae	*Galium*	*aparine*	2700-3000
389	Rubiaceae	*Galium*	*elegans*	2700-3000
390	Rubiaceae	*Galium*	*paradoxum*	1550-2500
391	Rubiaceae	*Rubia*	*manjith*	1200-2700
392	Rubiaceae	*Mussaenda*	*roxburghii*	1100-2300
393	Rutaceae	*Tetradium*	*fraxinifolium*	1000-1550
394	Rutaceae	*Zanthoxylum*	*armatum*	700-2100
395	Rutaceae	*Zanthoxylum*	*oxyphyllum*	2100-3000
396	Salicaceae	*Populus*	*ciliata*	2100-3000
397	Salicaceae	*Salix*	*denticulata*	1800-3700
398	Salicaceae	*Salix*	*disperma*	1500-3600
399	Sambucaceae	*Sambucus*	*adnata*	2700-3400
400	Saxifragaceae	*Bergenia*	*ciliata*	1600-3300
401	Saxifragaceae	*Saxifraga*	*elliptica*	2000-3000
402	Saxifragaceae	*Saxifraga*	*strigosa*	2500-3200
403	Scrophlariaceae	*Scrophularia*	*urticifolia*	1600-3000
404	Scrophlariaceae	*Majus*	*surculosus*	1500-3000
405	Scrophlariaceae	*Hemiphragma*	*heterophyllum*	1500-2400
406	Scrophlariaceae	*Veronica*	*anagalis-aquatica*	1800-2400
407	Scrophlariaceae	*Lindernia*	*viscosa*	1800-2800
408	Scrophlariaceae	*Pedicularis*	*mollis*	2700-4300
409	Smilacaceae	*Smilax*	*aspericaulis*	1200-2600
410	Smilacaceae	*Smilax*	*menispermoidea*	1800-3500
411	Smilacaceae	*Smilax*	*perfoliata*	600-2000
412	Solanaceae	*Solanum*	*erianthum*	1000-2000
413	Solanaceae	*Datura*	*stramomium*	Up to 2000
414	Sonnaratiaceae	*Duabanga*	*grandiflora*	600-1000
415	Symplocaceae	*Symplocos*	*glomerata*	1800-2700
416	Symplocaceae	*Symplocos*	*lucida*	1500-3000
417	Tamaricaceae	*Tamarix*	*ericoides*	600-1200
418	Tetracentraceae	*Tetracentron*	*sineme*	1600-2600
419	Theaceae	*Eurya*	*acuminata*	1500-2300
420	Theaceae	*Eurya*	*cerasifolia*	
421	Theaceae	*Schima*	*wallichii*	300-2000
422	Thymelaeaceae	*Daphne*	*bholua*	1800-3100
423	Thymelaeaceae	*Edgeworthia*	*gardneri*	1500-3000
424	Ulmaceae	*Celtis*	*tetrandra*	1500-3000
425	Urticaceae	*Boehmeria*	*glomeruliflora*	700-1600
426	Urticaceae	*Boehmeria*	*macrophylla*	300-2000
427	Urticaceae	*Debregeasia*	*salicifolia*	1500-2400
428	Urticaceae	*Lecanthus*	*peduncularis*	1200-2500
429	Urticaceae	*Pilea*	*scripta*	1000-2500

430	Urticaceae	*Pilea*	*umbrosa*	1000-2000
431	Urticaceae	*Urtica*	*dioica*	1000-2000
432	Valerianaceae	*Valeriana*	*jatamansii*	1500-3600
433	Verbenaceae	*Lantana*	*camara*	600-1200
434	Verbenaceae	*Premna*	*interrupta*	2000-4000
435	Verbenaceae	*Vitex*	*negundo*	300-1700
436	Verbenaceae	*Caryopteris*	*bicolor*	200-1500
437	Violaceae	*Viola*	*betonicifolia*	1500-2800
438	Violaceae	*Viola*	*biflora*	2500-4000
439	Vitaceae	*Parthenocissus*	*semicordata*	1370-2600
440	Vitaceae	*Vitis*	*heyneana*	Up to 2400
441	Vitaceae	*Cissus*	*repens*	300-1600
442	Zingiberaceae	*Amomum*	*aromaticum*	Up to 1800
443	Zingiberaceae	*Amomum*	*subulatum*	Up to 1800
444	Zingiberaceae	*Hedychium*	*cocciineum*	Up to 1550
445	Zingiberaceae	*Hedychium*	*spicatum*	Up to 3000
446	Zingiberaceae	*Hedychium*	*thyrsiforme*	Up to 1200
447	Zingiberaceae	*Costus*	*speciosus*	600-1000
448	Zingiberaceae	*Zingiber*	*officinale*	Up to 2000
449	Zingiberaceae	*Roscoea*	*auriculata*	2800-3500
450	Zingiberaceae	*Roscoea*	*purpurea*	1800-2900

*** Species of Bamboos**

Annexure-VI

Importance Value Index of species at different sampling locations in the study area

TREES	SITE-I	SITE-II	SITE-III	SITE-IV	SITE-V	SITE-VI	SITE-VII	SITE-VIII
Alangium chinense	7		51	7	10	6		
Albizia chinensis	6	13	20	7	111	6	37	31
Alnus nepalensis	158	216	203	18	0	8	36	26
Altingia excelsa							10	
Artocarpous chaplasa					16			
Bauhinia purpurea			71	27	37	13	30	
Bombax ceiba	6			7		13		
Castanea sativa	7							
Castanopsis hystrix	6		83	52	27	69		20
Duabanga grandiflora				15		13		
Emblica officinalis				7		6		
Engelhardia spicata	19	13	166	7	0	15		
Erythrina indica					10		15	
Eurya acuminata								10
Ficus auriculata								40
Ficus oligodon							17	
Ficus semicordata	8		40					
Grewia tiliaefolia	19			7	21	6		
Juglans regia							103	20
Lithocarpus elegans	8		20	17	14	15		
Macaranga denticulata	23	15	30					
Mallotus philippensis				9	21	8		
Mangifera indica			55					
Oroxylum indicum							9	

Persea robusta							19	10
Rhus chinensis			20	7	10			
Schima wallichii	29	44	93	107	10	118		
Terminalia myriocarpa	6		20	8		6		
Toona ciliata			20		13			
SHRUBS								
Anisomeles indica	5							
Artemisia indica	14	30	8	6	40	9		
Bambusa sp.	0	0	0	0	65	112		
Boehmeria macrophylla	20		14	64		10		
Brassiopsis mitis							80	101
Buddleja asiatica					10			
Callicarpa vestita			3	7	4			
Cannabis sativa					5			
Cassia occidentalis					7			
Celastrus monospermus							16	
Datura stramomium				2		7		
Debregeasia longifolia	15		9	10	7	10		
Debregeasia salicifolia						4		
Dendrocalamus hamiltonii	81	113	139	54	65	0	99	67
Edgeworthia gardeneri								17
Emblica officinalis						5		
Erythrina arborescens			3					
Eupatorium cannabinum	57	6	38	6		28		
Eupatorium odoratum	11	53	5	57	12	35		
Flemingia strobilifera			4	3		4		
Girardinia diversifolia			3					
Grewia vestita		12				10		
Indigofera heterantha		9	4	5		11		
Inula cappa			15	9		5		

Canarium strictum	18			4	4			
Musa sp.	9	26	20	3	13	17		
Mussaenda roxburghii							48	22
Neillia thyrsiflora								41
Oxyspora paniculata							25	38
Oxytropis paniculata	32	31	17	39	21	10		
Pandanus nepalensis			3					
Rhamnus purpureus							32	
Psidium guajava						4		
Rubia manjith						5		
Rubus ellipticus	19	13	3	10	7	4		15
Saurauia roxburghii	4							
Sida cordifolia					4			
Smilax aspera				5		6		
Solanum indicum		6	4					
Trevesia palmata			3					
Triumfetta rhomboidea	15		4	8	7	4		
Urtica dioica			3	3	12			
Woodfordia fruticosa			3					
HERBS								
Achyranthes aspera	11	8		6		15	4	
Aconogonum molle	25	95					61	
Ageratina adenophora								
Ageratum conyzoides	101	7	12	10	16	29	95	26
Amaranthus hybridus					12			
Amomum subulatum		31	77	26		74		
Apluda mutica							5	
Artemisia indica								19
Arthraxon hispidus								9
Aster molliusculus								21

Begonia picta		3						
Bidens bipinnatus	11	10	10	11	17	11	13	20
Carex baccans							5	
Centella asiatica								37
Cissampelos pariera			3	3		3		
Clinopodium umbrosum				11		4		
Colocasia esculenta					9			19
Commelina benghalensis			4					14
Conyza canadensis			6					
Crassocephalum crepidiodes	7	3	3	3	11			
Cyanotis vaga	7	4	8		5			
Cynodon dactylon								14
Cynoglosum glochiadiatus								5
Cyperus rotundus	4				7	9		
Datura stramomium								
Dichrocephala chrysanthemifolia							10	
Digitaria ciliaris			18		9	10		9
Dioscorea bulbifera						4		
Elatostema platyphyllum							5	
Elsholtzia densa		3						
Euphorbia hirta	7		3		12			
Fagopyrum esculentum							7	
Flemingia strobilifera			36					
Galinsoga parviflora		7	7	11	29	9		
Galium aparine								12
Gnaphalium affine							5	4
Hedychium spicatum			4			5		
Hydrocotyle nepalensis				8		8		17
Impatiens exilis	4	7	9	4		4	8	

Inula cappa	8							
Ipomoea nil	3	3				5		
Kylinga sp.	8		3	3	5			
Lecanthes peduncularis	7		5	51	5	13	5	
Ocimum indicum					83			
Oxalis corniculata								14
Paspalum paspaloides	4	9	3					
Peristrophe bicalyculata	18	39	5	28		9		
Persicaria capitata			5	9		3	6	16
Pilea scripta	17		6				23	
Pilea umbrosa							35	
Plantago major				8		14		
Polygonum dumetorum	11		5		8			
Polygonum recumbens					13			
Pouzolzia sanguinea	11	20	5	45	9	11		
Pteris sp.	4	10		25		11		
Rubia manjith		3		9	5			
Rubia sikkimensis		5						
Rumex nepalensis								27
Scutellaria linearis		6						
Setaria palmifolia								10
Solanum nigrum								7
Stellaria media	26	27	27	29	33	40	8	
Swertia sp.			5					
Tridax procumbens					12			
Vigna sp.						9		
Viola betonicifolia							5	
Wulfenia nepalensis	6		31					

Annexure-VII

List of Butterflies reported from the project area

S. No.	Common Name	Scientific Name	Distibution	Conservation Status
Family : Papilionidae				
1	**Common blue bottle**	*Graphium sorpedon sorpedon*	Legship up to 2,000m	Common
2	**Glassy blue bottle**	*Graphium cloanthus*	Rangit valley at 1,500-2800 m	Common
3	**Veined jay**	*Graphium bathycles chiron*	Rangit valley	Very common
4	**Common rose**	*Pachiopta aristolochiae*	Up to 1,800 m	Rare
5	**Spangle**	*Princeps protentor protentor*	Legship, 900 - 2,800 m	Not rare
6	**Redbreast**	*Princeps alcimenor*	Up to 1,800 m, Legship	Not rare
7	**Common mormon**	*Princeps polytes ramulus*	Up to 1,800 m, Rangit valley	Common
8	**Paris peacock**	*Princeps paris paris*	Up to 2,800 m, Rangit valley	Common
9	**Krishna peacock**	*Princeps krishna*	From 900 - 2,800 m at Gyalzing	Not rare
Family : Pieridae				
10	**Chocolate albatross**	*Appias lycida lyncida*	Up to 1,800 m	Not rare
11	**Spot puffin**	*Appias lalage durnasa*	From 1,800 - 2,000 m, Tholong valley	
12	**Lesser gull**	*Cepora nadina nadina*	Up to 1,800 m	Not rare
13	**Redspot jezebel**	*Delias descombi descombi*	From 900 - 2,800 m, Legship	Not rare
14	**Hill jezebel**	*Delias bellanona ithiela*	Up to 1,800 m, Legship, Tashiding	Not rare
15	**Yellow**	*Delias agostina agostina*	Up to 2,800 m, Legship	Not rare
16	**Redbase jezebel**	*Delias aglaia*	Up to 2,000 m, Rangit valley	Not rare
17	**Plain sulphur**	*Dercas lycoris*	Up to 1,800 m	Not rare
18	**Common brimstone**	*Goneptrix rhami nepalensis*	From 1,800 - 4,500 m	Not rare
Family : Lycaenidae				
19	**Metallic cerulean**	*Jamides alecto eurysaces*	Up to 1,800 m, Tashiding, Legship	Not rare
20	**Pea blue**	*Lampides boeticus*	Up to 1,800 m, Lower valleys of Rangit	Not rare
21	**Tailed punch**	*Dodena eugenes venox*	Up to 2,800 m, Yoksum and Bakhim	Not rare
22	**Dark judy**	*Abisara fylla*	Up to 1,800 m, Yoksum, Gyalzing, Tashiding	Not rare

23	**Jungle glory**	*Thaumantis diores diora*	Up to 900 m, Rangit valley	Rare
24	**Common evening brown**	*Melanitis leda isimene*	Found up to 2,000 m, in the Rangit valley, Legship, Tashiding	Rare
25	**Common red forester**	*Lethe mekara mekara*	From 1,800 m, Tashiding and Yuksom	Rare
26	**Treble silverstripe**	*Zoophoessa baladena baladena*	1,800 - 2,800 m, Bakhim	Not rare
27	**Niger**	*Orsotricoena medus medus*	Up to 1,800 m, Rangit valley, Legship	Common
28	**Common fivering**	*Yipthima baldus baldus*	Up to 1,800 m, Rangit valley	Common
29	**Pallied nawab**	*Polyura arja*	Up to 1,800 m, Legship	Common
30	**Circe**	*Hestena nama*	Up to 1,800 m, Rangit valley	Common
31	**Tabby**	*Psuedergolis wedah*	Up to 1,800 m, Rangit valley	Not rare
32	**Angled castor**	*Ariadne ariadne pallidior*	Up to 2,800 m, Lower valleys of Rangit	Not rare
33	**Common leopard**	*Phalanta phalanta*	Up to 1,800 m, in Rangit valley	Very common
34	**Yellow pansy**	*Precis hierta magna*	Not rare, up to 2,800 m, Rangit valley	
35	**Blue Pansy**	*Precis orithya ocyale*	Up to 2,800 m, Legship	Not rare
36	**Indian red admiral**	*Vanessa indica indica*	From 1,800 - 3,800 m, Yuksom	Not rare
37	**Himalayan jester**	*Symbrenthia hypestis cotanda*	From1,800 - 3,800 m, Tashiding	Not rare
38	**Blue oakleaf**	*Kalima hordefieldi*	Up to 1,800 m	Not rare
39	**Black vein sergeant**	*Parathyma ranga ranga*	Up to 1,800 m	Not rare
40	**Common sergeant**	*Parathyma prius*	Up to 1,800 m, Tashiding	Not rare
41	**Commodore**	*Moduza procris procris*	Up to 1,800 m	Not rare
42	**Common baron**	*Euthalia aconthea suddhodana*	Lower valleys of Rangit	Common
Family : Hesperiidae				
43	**Red lacewing**	*Cethosia biblis tisamena*	Up to 1,800 m	Common
44	**Magpie crow**	*Euploea radamaanthus*	Up to 1,800 m, Tashiding	Not rare
45	**Common spotted flat**	*Celaenorrhinus leucocera*	Up to 2,000 m, Rangit valley	Common

Annexure VIII Daily average Discharge at Ting Ting Dam Site 1975-76 to 2005-06

Catchment Area : 372 sq.km.

	Year	75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88	88-89	89-90	90-91
		cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec
June	I	38.43	32.28	33.23	29.44	15.43	26.40	25.81	26.10	9.80	37.32	42.41	26.15	18.01	18.01	47.29	46.66
	II	54.29	54.88	36.11	73.60	26.52	45.74	41.41	47.16	12.34	58.51	51.00	41.91	29.36	29.36	95.74	45.62
	III	59.51	47.50	33.69	50.25	24.73	41.57	40.32	63.22	34.61	71.56	48.54	40.87	61.92	61.92	75.94	57.55
July	I	57.13	64.26	41.41	48.75	71.39	39.62	111.96	65.34	52.04	62.38	54.79	56.34	71.89	65.18	82.48	81.77
	II	72.60	57.13	55.71	75.06	64.89	75.48	50.21	70.39	78.69	68.35	58.17	55.71	57.17	58.80	83.53	113.47
	III	76.69	43.49	54.50	67.26	147.62	107.59	80.77	91.24	53.08	128.27	72.06	50.58	53.54	68.35	73.18	75.73
August	I	53.96	49.50	66.47	75.19	86.61	72.47	89.20	55.84	42.53	45.66	53.54	46.25	78.73	78.94	51.87	71.06
	II	48.87	71.47	78.85	57.25	49.08	87.95	111.63	50.04	44.66	38.03	53.54	34.86	81.86	78.44	52.13	91.78
	III	49.62	62.17	89.03	37.36	70.68	66.59	75.98	56.88	55.54	41.32	39.70	44.37	47.08	62.42	51.46	61.13
Sept	I	73.56	49.50	69.01	45.95	110.92	76.52	76.85	57.17	71.85	83.94	51.75	39.03	76.27	69.51	46.83	65.80
	II	70.22	35.49	59.46	63.63	63.59	58.09	71.10	56.67	154.12	65.93	49.50	43.83	47.20	50.42	45.54	55.50
	III	50.00	62.17	89.03	43.66	34.57	41.99	40.41	49.91	133.98	44.08	45.83	41.91	53.58	42.41	45.20	57.25
Oct	I	56.13	29.98	59.01	37.49	42.45	56.63	32.61	39.78	70.76	34.36	33.49	38.57	34.99	27.19	56.30	47.96
	II	44.29	24.60	31.23	26.23	38.74	30.11	27.86	35.95	31.36	31.02	84.94	32.53	20.47	25.31	41.95	40.45
	III	27.77	19.02	26.23	21.56	25.06	24.27	26.27	36.36	21.73	29.23	27.02	22.64	15.89	21.89	31.82	31.78
Nov	I	21.85	14.72	24.77	18.97	20.60	18.64	24.56	33.44	17.76	27.36	12.43	14.93	14.26	20.18	27.36	27.94
	II	18.64	13.84	17.10	18.39	16.97	11.88	21.93	31.36	15.68	25.40	11.38	11.93	11.26	17.64	23.89	24.52
	III	15.85	11.55	13.84	17.10	17.06	14.09	20.10	30.11	13.80	24.52	10.01	11.80	11.13	17.72	21.73	21.98
Dec	I	13.84	9.01	12.59	14.97	41.91	12.68	17.72	26.60	11.88	22.02	7.67	17.68	10.93	17.64	19.06	19.85
	II	12.68	7.92	10.80	13.51	31.69	11.22	15.47	19.72	10.88	17.81	6.13	17.18	10.80	16.47	16.55	18.89
	III	11.72	7.05	10.26	12.34	29.98	10.43	15.18	17.39	10.22	16.30	6.17	16.01	9.51	16.26	15.43	18.43
Jan	I	10.22	7.05	9.92	10.17	14.05	9.47	14.60	16.39	12.64	15.55	6.17	13.64	9.09	11.51	15.30	18.01
	II	9.09	7.21	8.55	9.42	13.47	8.92	13.34	15.18	8.88	14.34	6.05	11.30	9.17	14.89	13.51	16.89
	III	8.47	7.13	8.55	8.84	13.14	8.55	13.43	14.76	8.51	13.14	6.05	10.13	9.13	14.34	11.76	17.26
Feb	I	8.97	7.05	8.30	7.92	12.89	8.55	14.18	14.05	8.30	12.68	6.00	9.80	8.42	14.43	12.72	16.51
	II	7.88	6.96	9.09	7.63	12.93	8.17	13.72	13.76	8.30	12.13	6.34	9.34	8.17	13.51	12.97	16.81
	III	7.63	6.88	8.59	7.21	14.05	8.38	13.97	13.51	8.01	11.47	6.21	9.09	8.09	13.93	14.34	16.60
Mar	I	8.09	6.59	8.80	6.84	7.84	7.71	14.34	7.96	8.51	11.13	6.21	9.09	5.92	14.60	14.97	16.51
	II	7.21	7.96	8.63	7.42	7.13	8.17	14.64	4.25	8.88	10.72	6.21	9.09	13.68	16.22	15.43	16.68
	III	7.34	7.17	8.80	6.80	9.80	9.34	15.39	3.79	8.67	10.47	6.21	9.67	14.09	16.30	15.22	17.10
Apr	I	7.34	12.64	8.92	8.26	15.30	10.88	19.77	4.17	8.88	11.51	6.17	14.76	14.09	15.60	15.01	20.02
	II	7.84	12.97	12.64	9.17	17.39	10.09	18.39	3.71	9.01	12.34	6.13	14.47	13.80	15.89	20.27	17.39
	III	11.51	11.93	13.84	9.88	19.02	10.51	18.47	6.46	9.47	12.89	7.01	14.85	14.76	16.30	20.52	17.81
May	I	20.35	11.18	13.59	11.05	18.47	13.09	19.85	10.97	13.05	12.55	13.30	17.10	16.43	17.51	21.81	23.98
	II	13.22	13.84	19.35	12.59	18.14	13.68	18.26	9.13	18.14	12.97	13.84	18.81	18.14	15.64	26.73	19.68
	III	15.01	25.85	21.64	10.34	22.52	18.26	18.56	9.67	26.35	28.23	18.51	19.77	19.10	55.84	23.19	28.86

	Year	91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	2001-02	2002-03	2003-04	2004-05	2005-06
		cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec	cumec
June	I	60.30	30.82	31.28	26.88	36.09	27.40	31.32	28.63	41.58	42.93	61.03	22.38	23.12	34.40	16.50
	II	100.33	30.07	26.15	34.75	60.94	26.38	51.97	47.45	74.03	53.45	58.24	35.38	41.18	36.65	27.71
	III	72.81	52.63	44.99	50.09	59.99	62.42	63.59	76.90	116.40	74.76	63.58	65.94	106.67	57.21	58.89
July	I	84.69	73.10	55.63	49.47	88.07	59.45	62.15	119.16	126.01	100.98	37.89	96.84	184.36	73.28	90.53
	II	97.08	93.37	54.38	37.98	69.85	88.30	62.39	88.70	91.75	80.67	45.17	132.53	119.50	89.04	97.21
	III	61.76	105.04	89.28	55.00	60.32	81.51	48.46	138.29	97.61	100.90	88.66	155.98	92.97	82.78	70.82
August	I	110.63	86.32	89.49	47.20	60.91	56.13	67.06	102.40	72.56	109.73	59.74	107.84	92.50	59.56	53.54
	II	128.14	75.48	69.06	60.79	56.92	61.34	70.92	144.24	101.02	105.08	60.72	114.20	70.25	56.73	92.09
	III	85.11	93.62	82.15	57.96	57.51	60.91	51.13	152.26	124.12	108.30	80.89	103.10	80.95	72.33	67.90
Sept	I	86.65	72.02	62.26	49.78	55.33	75.43	55.38	114.81	88.57	85.68	79.43	52.83	60.35	92.64	54.15
	II	58.09	92.20	50.29	40.70	47.77	47.35	70.46	43.92	65.08	62.96	68.48	48.61	82.66	53.84	38.41
	III	47.91	58.80	52.67	42.40	61.03	48.43	65.83	48.29	69.33	47.14	46.36	41.71	57.22	63.77	59.06
Oct	I	41.99	52.00	44.37	33.47	36.28	51.58	42.12	33.21	63.35	32.47	78.81	29.42	44.09	60.08	40.39
	II	33.11	55.17	45.08	26.31	28.91	35.20	30.74	56.92	56.35	23.39	50.19	22.86	29.30	34.92	25.43
	III	25.98	45.95	30.11	22.12	20.89	26.16	18.47	28.31	34.41	21.38	32.23	25.39	25.87	24.78	23.72
Nov	I	21.85	37.07	23.98	18.98	20.73	22.77	14.27	17.57	25.35	16.38	20.57	15.69	26.65	19.44	17.74
	II	18.35	32.69	20.56	16.69	19.55	20.99	14.30	15.95	21.24	15.45	16.49	13.67	16.08	13.53	14.37
	III	15.39	29.61	16.51	14.47	15.29	14.43	12.35	13.28	17.70	12.46	13.95	12.08	13.79	14.02	13.52
Dec	I	15.85	28.15	13.97	12.91	13.52	11.64	11.41	11.73	15.91	11.12	12.35	10.33	12.35	11.48	11.71
	II	16.10	24.85	12.13	11.09	11.53	10.00	11.07	11.43	12.17	9.71	10.89	9.64	10.79	10.46	10.37
	III	15.72	22.94	10.59	9.64	11.04	8.89	8.87	9.56	11.27	8.27	9.58	8.88	10.17	10.47	9.45
Jan	I	23.31	14.76	16.55	9.12	8.67	8.86	6.81	9.17	7.43	8.31	8.58	8.44	8.87	10.01	8.81
	II	20.31	14.47	15.51	9.01	8.65	7.85	6.28	8.08	6.89	7.32	8.00	7.63	7.85	8.41	7.84
	III	20.56	12.93	14.55	8.20	7.73	7.85	6.05	6.81	6.57	6.92	8.18	6.90	7.54	8.25	7.64
Feb	I	20.72	13.26	14.43	7.92	9.41	7.13	6.61	9.43	6.74	6.82	7.30	7.90	7.66	7.16	7.65
	II	20.68	14.01	14.01	8.27	8.91	7.11	5.74	8.91	6.50	6.43	6.42	7.62	7.78	8.08	7.61
	III	20.10	12.18	13.68	10.35	9.01	7.28	6.08	8.52	6.56	7.31	6.43	8.66	7.90	7.84	7.38
Mar	I	22.35	12.80	23.39	8.56	9.50	7.17	7.38	8.54	6.54	6.67	7.02	8.09	8.02	8.47	6.85
	II	24.44	12.64	23.60	8.15	11.94	12.07	8.14	7.82	7.01	5.83	7.48	8.54	7.70	8.50	7.66
	III	25.31	12.72	23.52	12.03	11.75	10.32	9.05	8.34	7.42	5.09	8.41	9.16	9.76	9.36	7.81
Apr	I	23.35	12.89	24.23	9.31	11.09	13.04	8.40	8.98	6.75	4.34	8.82	14.59	8.63	9.16	11.90
	II	20.77	15.64	18.35	9.81	11.20	12.01	9.14	10.96	6.20	4.50	9.20	12.16	11.78	9.20	11.04
	III	20.72	18.14	21.56	12.86	12.24	12.87	14.09	14.78	8.62	16.20	11.23	15.36	12.52	10.91	15.20
May	I	27.56	26.35	14.06	13.54	20.19	13.86	14.70	8.54	13.05	20.62	11.86	11.85	9.08	15.56	15.84
	II	29.27	26.44	13.28	22.43	24.25	14.89	12.39	7.82	19.79	17.37	16.64	13.94	17.46	14.67	17.09
	III	27.73	18.68	22.36	31.60	27.56	16.17	17.61	8.35	70.19	35.06	16.65	18.73	29.18	17.88	23.98

		75-76	76-77	77-78	78-79	79-80	80-81	81-82	82-83	83-84	84-85	85-86	86-87	87-88	88-89	89-90	90-91
Average	mm	2545	2173	2559	2315	2963	2570	2973	2622	2624	2787	2222	2117	2353	2679	2969	3198
Annual	cumec	30	26	30	27	35	30	35	31	31	33	26	25	28	32	35	38
Inflow	MCM	947	808	952	861	1102	956	1106	975	976	1037	827	788	875	996	1104	1190
Monsoon	mm	1666	1487	1674	1574	1830	1759	1931	1637	1752	1771	1468	1234	1595	1618	1774	1944
Inflow	cumec	59	52	59	56	65	62	68	58	62	62	52	44	56	57	63	69
	MCM	620	553	623	586	681	654	718	609	652	659	546	459	593	602	660	723
Non	mm	879	686	885	740	1133	811	1042	985	872	1016	754	883	758	1060	1195	1254
Monsoon	cumec	16	12	16	13	20	14	18	17	15	18	13	16	13	19	21	22
Inflow	MCM	327	255	329	275	421	302	388	366	325	378	281	328	282	394	445	466

		91-92	92-93	93-94	94-95	95-96	96-97	97-98	98-99	99-00	00-01	2001-02	2002-03	2003-04	2004-05	2005-06
Average	mm	3640	3388	2839	2131	2561	2497	2363	3418	3591	3041	2696	3056	3221	2661	2502
Annual	cumec	43	40	33	25	30	29	28	40	42	36	32	36	38	31	30
Inflow	MCM	1354	1260	1056	793	953	929	879	1271	1336	1131	1003	1137	1198	990	931
Monsoon	mm	2342	2052	1683	1311	1687	1647	1650	2634	2532	2308	1782	2330	2390	1830	1720
Inflow	cumec	83	72	59	46	60	58	58	93	89	81	63	82	84	65	61
	MCM	871	763	626	488	628	613	614	980	942	858	663	867	889	681	640
Non	mm	1298	1336	1156	820	873	849	713	784	1058	733	914	726	830	832	782
Monsoon	cumec	23	24	20	15	15	15	13	14	19	13	16	13	15	15	14
Inflow	MCM	483	497	430	305	325	316	265	292	394	273	340	270	309	309	291