Feasibility Study Report
Tamakoshi-V Hydroelectric Project

Salient Features of the Project

Location

Type of Project	Cascade development of Upper Tamakoshi HEP
Village Development Committee	Khare, Orang and Lamabagar VDCs
District	Dolkha
Zone	Janakpur
Headworks site	Between Purano Jagat and Gongor village
Powerhouse site	Jamune and Suri Dovan. Approx. 7.0 Km upstream from the present road head at Singate Bazar.
Name of the River	Tamakoshi River

Hydrology

Design Discharge	66 m^3/sec
Annual average flow	68.03 m^3/sec
Compensation Flow	1.3 m^3/sec
1000 yrs return period flood at powerhouse site	2691 m^3/sec (Elevation 999.64 amsl)
Glof Flood	6500 m3/s (Elevation 1002.64 amsl)

Access Road

Existing Road	Existing Singate- Lamabagar Road constructed by Upper Tamakoshi HEP

Interconnection with UTHEP

Type	Tailrace tunnel of UTHEP is interconnected with the headrace tunnel of Tamakoshi-V
Head Pond	width = 13.60 m, length = 22.75 m, height = 21.97 m
Connecting Tunnel	110.0 m length; invert level of starting point = EL 1153.99 masl

Spillway

Type	Uncontrolled ogee shaped
Design Discharge	66.0 m^3/sec

Length of the crest	15.0 m
Crest Level	El. 1154.52 amsl
Outlet of Spillway Tunnel	El.1147.00 amsl
Headrace Tunnel	
Type	Modified Horse shoe typed,
Length	8.20 Km
Finished Diameter	5.60 m
Surge Tank	
Type	Circular- Restricted Orifice
Effective Size	15.0 m internal diameter; Height = 73.61 m
Orifice	diameter = 5 m; Height = 5 m
Normal Water Level	El. 1149.92 masl
Vertical Shaft	
Total Vertical length	122.38 m
Horizontal Length	41.44 m
Internal Diameter	4.2 m
Thickness of Penstock	10 mm to 32 mm
Powerhouse	
Type	Underground
Dimension	L=50.0 m, W=16.0 m, H=31.0 m. (upto floor)
Generator Setting Level	El. 1003.41 amsl
Turbine Setting Level	El. 993.51 amsl
Type of Turbine	Francis (Vertical Axis)
No. of unit	4
Capacity of each unit	21.75 MW
Tailrace Conduit	
Type	Concrete Conduit
Length	Tunnel = 141.60 m ; Open Canal = 54.55 m
Size and Shape (combined)	Free flow tunnel of B=6.8m and H = 5.2 m and a Trapezoidal canal with Base width 6.80 m and Top width=12.80m
River Tail Water Level	El. 993.11 amsl

Switchyard

Type	Outdoor Type
Area	Two Terrace:- Lower = 80 m x 40 m Higher = 40 m x 40 m

Transmission Line

Voltage of Transmission Line	220 KV double circuit
Length of Transmission line	4 Km upto nearest point of Tamakoshi-Khimti TRL

Power and Energy Generation

Gross Head	160.93 m
Net Head	149.61 m
Installed Capacity	87 MW
Annual Energy	460.50 GWh (Without outages)
Dry Season Energy	61.64 GWh (With outages)
Wet Season Energy	366.63 GWh (With outages)

Cost Estimates

Civil Costs in US $	57.69 million (without contingencies)
Hydraulic Steel Structures in US $	2.30 million
Electromechanical Equipment in US $	30.17 million
Transmission Line in US $	11.67 million
Engineering, Management Cost in US $	8.47 million
Contingencies US $	11.19 million
Resettlement and Environment Mitigation Works in US $	3.18 million
Owner's Cost US $	3.18 million
Total Cost in US $	131.99 million
Cost per KW in US $	1517

Financial Indicators

	Implementation by NEA	Implementation by IPP
Financial cost in US $	13,660.3 M.NRs (with IDC)	14,172.5 M.NRs (with IDC)
Debt/equity ratio	70/30	70/30
Interest Rate on Debt	8.5%	12.0%
Return on Equity	14.0%	18.0%
Return on Investment	8.29%	13.49%
B/C ratio	1.07	1.24

DSCR	1.52	1.58
Energy Rate as of 2011 in Rs/KWh	3.81	7.17

1. Introduction

1.1 General

Nepal's swift rivers flowing south through the Himalayas have been termed by experts as nature's bountiful gift to the country. The perennial nature of country's rivers and the steep gradient of the country's topography provide ideal conditions for development of one of the largest hydroelectricity potential in the world. Current estimates indicate that Nepal has a theoretical potential of 83000 MW of Hydropower out of which around 42000 MW is economically feasible. However, it is a bit disappointing that more than 98% of the potential is still untapped and undeveloped. The total installed capacity of Nepal is only 689 MW including all power generated by Individual Power Producers (IPPs). This capacity is far below the current electricity demand for both base and peak load thus country is facing up-to 16 hours load shedding. Nepal Electricity Authority (NEA) has projected the increase of electricity demand by 10 percent per year so if the generation is not added to the system at the earliest, the situation will be worsening in days to years. Therefore; Nepal Electricity Authority, the only Government Undertaking, responsible for the generation, transmission and distribution of electricity in Nepal and beyond has decided to initiate the feasibility study of a project which could be commissioned at the earliest possible date. In this regards, Tamakoshi-V Hydropower Project has been selected for the initiation of the Feasibility Study.

1.2 Background

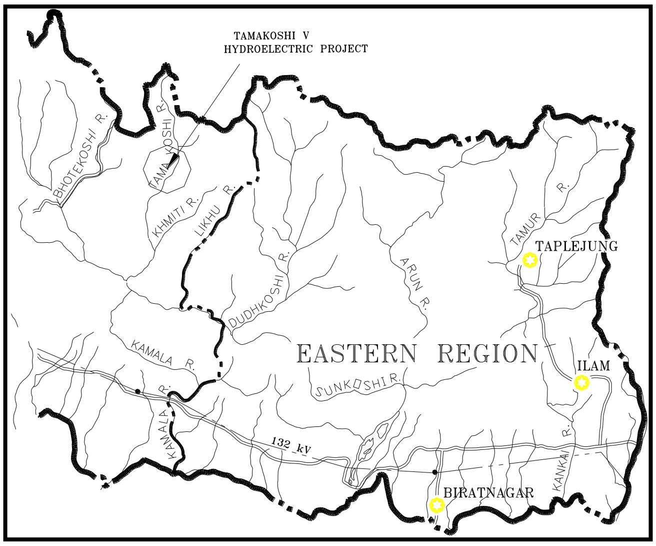
Nepal is blessed with 6000 river networks which are confined to four main river basins namely Koshi River Basin, Gandaki River Basin, Karnali River Basin and Mahakali River Basin. Most of the potential sites for the power projects are being identified during different studies and remaining river stretches are also being identified by the private power developers to get the license right of that particular stretch. The project identification program of Project Development Department (PDD) has identified Tamakoshi –V from the all the previously identified projects based on the availability of infrastructures in the vicinity of the project area and taken it for the feasibility study.

1.3 Scope of Work

Scope of work for this fiscal year 2067/068 is to complete the feasibility study of the project including the necessary field investigations. Field investigation includes the completion of topographical survey, seismic refraction survey, material availability survey, core drilling, upgrading of hydrological data and completion of all necessary survey work. Apart from this, the Environmental Impact Assessment will also be initiated in this fiscal year so that it could be completed by the next fiscal year.

1.4 Location

Tamakoshi-V is located in the Central Development Region of Dolakha District of Janakpur Zone. The project area is situated within Longitude 86°13'11" to 86°13'56" East and Latitude 27°47'30" to 27°50'00" North. The whole project area lies in Khare, Orang and Lamabagar Village Development Committees. This project is conceptualized to develop as a tendon operation project with Upper Tamakoshi HEP. The intake site / underground interconnection system with Upper Tamakoshi tailrace outlet is located in Lamabagar VDC at an elevation of 1156.50 m whereas the underground powerhouse lies at the right bank of Tamakoshi River just downstream of the Suri River confluence with Tamakoshi River.



1.5 Access

The Tamakoshi-V Hydropower Project is located approximately 170 km north east of Kathmandu, the capital of Nepal and approximately 40 km away from the district head-quarter of Dolkha District- Charikot Bazaar. The district head-quarter is connected with the capital by Arniko Highway upto Lamasangu which is approximately 90 km and by Lamasnagu – Jiri road which is approximately 40 km up to Charikot. A gravel road of about 33 km is available from Charikot to Singate Bazaar is recently upgraded for the construction of Upper Tamakoshi Project. The newly constructed road connecting Singate Bazaar and Lamabagar for the construction of Upper Tamakoshi HEP passes from the both powerhouse and the headwork sites of this project. This road is recently built. Apart from the powerhouse and headwork sites of this project location of the adit tunnel for the construction of the headrace tunnel is very close to the newly built road. Thus the access to the construction adit will also be easier. Hence, this project does not need access road. However; few kilometers of project road is to be constructed to reach surge tank site, adit tunnels at surge tank, adit tunnel for the underground powerhouse and some particular locations of the project before the construction of the project.

1.6 Study Execution

The identified site will be verified at site by the team of experts. Different possible locations for the hydraulic structures will be identified. A topographical survey, map preparation, hydrological analysis, complete geological investigation, environmental study, finalization of the layout and the feasibility study will be carried out.

The geology and geo-technical studies and investigation of this project are carried out by the Soil, Rock and Concrete Laboratory of NEA. It has submitted the study and investigation reports. Likewise, the Environmental Impact Assessment (EIA) study of this project is being carried out by Environmental and Social Study Department of NEA. The study is ongoing and will be completed by next fiscal year. The Power Evacuation Study of this project is carried out by System Planning Department of Nepal Electricity Authority. The department has submitted their final report.

As the project shall be developed as a tendon project with Upper Tamakoshi HEP, optimization of the design discharge is not required. The project will be developed based on the design discharge of the Upper Tamakoshi Project. However, selection of alternative based on the location of the powerhouse will be done. The selected layout will then be taken for the full fazed feasibility study.

1.7 Organization of the Report

This report is organized in three volumes comprising three sections, Main Report, Drawing and Annex. Volume One, the Main Report describes the topography survey, geological and geotechnical investigation, hydrological study, alternative study, design, power and energy, cost estimates, construction planning and the results of the economic and financial analysis related to the project. All the drawings related to the major project components are also presented in the second volume. All detailed supporting data have been presented in the Annex- Volume Three.

Brief descriptions of the chapters dealt with in this report are as follows:

Executive Summary	:	This chapter briefly presents the summary of the entire study.
Chapter 1	:	Provides an introduction to the study, background, scope of work and also presents the organization of the report,
Chapter 2	:	Topographic Survey Mapping
Chapter 3	:	Hydrology
Chapter 4	:	Geology and Geotechnical Investigation
Chapter 5	:	Project Capacity and Layout Optimization
Chapter 6	:	Design Parameters, engineering description and the overall dimensions of the major project components/structures proposed for the design discharge.
Chapter 7	:	Power and Energy generation from the project,
Chapter 8	:	Power Evacuation Study
Chapter 9	:	Cost estimation, assumption for the the cost estimate to cover direct to cover direct and indirect costs, and the cost of the project as a whole.
Chapter 10	:	Brief description of the construction schedule of the project, transportation of equipment and materials,

construction power supply, camp facilities and construction methods.

Chapter 11 : Environmental Impact Assessment

Chapter 12 : Financial Analysis

Chapter 13 : Conclusion and recommendations of the project.

The Annex contains the detailed supporting data related to the design and analysis performed during the feasibility study. The Annex is sub divided as follows:

Annex A - Topography

Annex B - Hydrology

Annex C - Geology

Annex D - Design

Annex E - Power and Energy

Annex F - Power Evacuation

Annex G - Cost Estimate

Annex H - Financial Analysis

2. Topographic Survey and Mapping

2.1 Introduction

The survey works for the proposed project were conducted in March, 2009 and additional survey to complete the survey work was carried out in December, 2009. Proper survey and leveling works are necessary to design the components, to prepare drawings and to calculate the quantities of the project components. The survey data greatly influences the quality of design. Therefore, all the survey works were carried out precisely and correctly.

2.2 Scope of Work

The main objective of this survey is to carry out detailed topographical survey of headworks / interconnection system and powerhouse sites with headrace tunnel alignment in appropriate scale.

- All the survey works were under taken using national grid co-ordinates and elevations.
- Close traverse survey was carried out to establish required ground control points at various locations in the project area.
- All the major ground control points were monumented with marks on permanent boulders.
- Topographical maps of headworks and powerhouse sites with proposed headrace tunnel alignment area were prepared in appropriate scales.
- Number of cross-sections of Tamakoshi River was taken at hedworks and both powerhouse options at required interval.
- Survey work for Seismic Refraction Survey
- Cross section survey work of Tamakoshi River at the new Gauging Station

2.3 Available Information and Data

The information available for carrying out the feasibility study of the Tamakoshi-V Hydropower Project is as follows:

i. Topographical Maps prepared during project identification study.
ii. List of coordinates and elevation of permanent benchmarks around the project site established by Upper Tamakoshi HEP.
iii. Project Layout map of the project prepared during project identification study.

2.4 General

The senior surveyor and his group carried out the detailed topographical survey of the selected schemes. All the data necessary to determine the locations, coordinates and levels were obtained by direct measurement in the field. To achieve the required accuracy and standards, Sokkia total station with least count of 5” was used.

2.5 Methodology

The methodology used for the entire survey works was developed as per the scope of works, which includes desk study, reconnaissance survey, monumentation of control points, control traversing, horizontal and vertical control and topographic survey.

2.5.1 Desk Study

Prior to the field survey, desk study was carried out by using existing topographical map of the site (Scale 1:25,000 and 1:10,000) prepared during project identification study. Detailed information about the project area for the survey work was noted. Finally all the available layout plans and location maps prepared during the study were collected.

2.5.2 Reconnaissance Survey

After finalizing the desk study, a team of multi-disciplinary experts were mobilized for field verification. After finalizing the project site and before the detailed survey work, a brief reconnaissance survey was carried out with flagging at necessary points around the entire project area to be mapped. All the flagging points were marked by red enamel paint. The first step of the survey was to fix the control points around the project area with respect to existing control points established by the project during the feasibility study.

2.5.3 Monumentation of Ground Control Points

Before carrying out detailed survey at major structural locations, number of permanent ground control points was established with connection to main traverse line. They were made conspicuous in the field with crosses chiseled on permanent boulders. They were also made noticeable in the field by marking with red enamel paint. Altogether 8 permanent benchmarks BM-1 to BM-8 were established at the project area. Among which BM-1, BM-2 BM-3 and BM-4 were established at powerhouse area (Option –I) and BM-5, BM-6, BM-7 and BM-8 were established at powerhouse site (Option –II). In the headworks area, there were already permanent benchmarks established by Upper Tamakoshi HEP. Description cards of each of the control points are given in Annex A3.

2.5.4 Control Traversing

Upper Tamakoshi HEP had established number of control points around the project area from Singati to Gonger. There are two permanent control points UTP-4 and UTP-5 at Singati. The basic control traverse survey was carried out from UTP-4 and UTP-5 at Singati with the following values of coordinates and elevations.

Traverse Survey at Powerhouse Site from BM-1

Table 2.1 Co-ordinates and Elevation of Basic Control Points and Permanent Benchmarks

S.No.	X-Northing	Y-Easting	Elevation	Remarks
UTP-4	3080987.210	423177.500	1281.936	Benchmark at Singati
UTP-5	3080951.570	423210.200	1277.737	Benchmark at Singati

A closed traverse was carried out from UTP-4 and UTP-5 at Singati to tailrace site of Upper Tamakoshi HEP via Powerhouse sites at Suri Dovan and Tatopani. Traverse survey was carried out along the bank of Tamakoshi River.

All traverses formed by the conventional survey were closed loops or closed on existing traverse points. The traverse legs were made as long as possible and a fixed tripod system was used for all reflecting prisms to achieve better accuracy. After connecting all the project area by different traverse points, numbers of offset points were established by carrying out the traverse survey from two main traverse points wherever necessary.

2.5.5 Horizontal and Vertical Control

Sokkia Station with a least count of 5" was used for measuring horizontal and vertical angles. One complete set of horizontal and vertical angles was observed during the control traversing.

For horizontal control, the following measurements were taken:

- Mean angle and distance computation were checked precisely.
- Angular closure was checked for closed loops.
- Azimuth was checked between traverse points
- Angular misclosures were adjusted, and
- ΔX and ΔY were computed for planimetric closure.

In the traverse survey, the horizontal angles were observed in one complete round within a mean of 15". Distance was measured in the fore and back sights directions and the mean distance adopted. The closing errors were distributed according the common survey standard.

Taking River Cross-section at Headworks Site

Altogether 22 traverse points were established in the main-traverse line, 13.9 km in length. Similarly 21 offset points were established wherever necessary around the project area. While surveying a traverse line, all angles and distances were measured by applying the force centering method.

Distance measurement was performed using Sokkia total stations with standard reflecting prism with an accuracy of 5mm ± 5ppm. Both back sighting and fore sighting of direct distance were measured. A reasonable closing error was achieved.

2.5.6 Accuracy

The closing errors were distributed according to common survey standards. Since, in all the survey works, high accuracy survey instruments with a least count of 5" were employed. The closing error is -0.119 m in Northing and -0.101m Easting and +0.022m in elevation.

2.5.7 Data Processing

All the survey data were computed in the field as well as in the Kathmandu office. Similarly, some field data were evaluated and horizontal distances and elevations were calculated reciprocally. All the coordinates and elevations of each station and survey point were then computed with respect to the given UTM coordinates and elevation of the control point UTP-4 and UTP-5 established by Upper Tamakoshi HEP. After completely checking the data entry, mapping Software was used for map preparation. Finally, the topographic map was prepared in AutoCAD 2007 format.

2.6 Detailed Topographical Survey and Mapping

The features of terrain were surveyed by means of spot surveying. Spot positions were taken by the tachometric method from different traverse points. Inaccessible points like rock faces, top of cliff, landslide edge, etc. were sighted from at least two known points by reading both the horizontal and vertical angles.

Taking Detailed Survey at Powerhouse Site (Option –II) at Suri Dovan

Features such as riverbanks, high flood level, landslides, cliff, house, cultivated, lands, roads, canal, embankment, boulders, etc., were recorded.

The detailed topographical survey of underground Surgetank, penstock and powerhouse structure were carried out in the scale 1:1000 with contour interval of 1m. Altogether there are 14 sheets of maps in A4 size.

Altogether 65.5 ha of land were covered in the ground survey at headworks area, 12.5 ha at powerhouse (Option – I) at Tatopani, and 22.3 ha at powerhouse site (Option-II)at Suri Dovan. All the topographical maps are given in Annex A1 in appropriate scales.

2.7 Preparation of Tunnel Alignment Map

For preparation of map along tunnel alignment, digital data of topo sheet in 1:50,000 scales, 2786-01 (Lamosangu) was collected from NG Survey Department. From Arc View GIS Software, required alignment area was selected from all the digital data. Then a CSV file was created in order to make Digital Terrain (DTM) Model, which consists of relief model and site model having X, Y, Z coordinates of each point. After creating DTM, 10m contours were generated so as to prepare the map with 10m contour intervals. All the features were then transferred to the map and finally topographical map of tunnel alignment area was prepared in 1:10,000 scales with 10m contour intervals.

2.8 River Cross-Sections

Several cross-sections of the Tamakoshi River were taken to plot the river cross sections for computing the rating curves for the headworks and powerhouse sites. Altogether 11 cross-sections of Tamakoshi River were taken at headworks site at every 50m interval. Similarly 9 cross-sections were taken at powerhouse site (Option-I) and 13 sections were taken at Suri Dovan powerhouse site (Option –II). The sections were taken at every 50 m intervals. Apart from this, additional five cross section of the river at the B Suri Dovan Powerhouse site and five river cross sections at newly installed gauging station were taken in March 2011. The newly installed gauging station is about 1 km downstream for the Suri Dovan powerhouse site at Bhorele. All the river cross-section data are given in Annex A2.

Taking river cross-section at headwork site.

2.9 Seismic Refraction Survey

The seismic refraction survey was carried out in proposed powerhouse site (Option I) at Jamune, in (Option II) at Suryatar and in the location of MCT zone at Tatopani. Total length of the seismic line in the project area is 1.875 km. Location of seismic lines and their descriptions are given in the following Table:

Table 2.2 Description of Seismic Profiles at Powerhouse Site (Option I)

S.No.	Seismic Lines	Chainage	X-Northing	Y-Easting	Elevation(m)	Remarks
1	SLP-1	0+000	3072499.544	421453.783	1032.808	
		0+115	3072434.49	421536.18	1007.65	
2	SLP-2	0+000	3072525.14	421478.74	1043.29	
		0+115	3072457.83	421560.19	1008.01	
3	SLP-3	0+000	3072586.69	421507.84	1040.16	
		0+115	3072517.28	421592.583	1009.31	
4	SLP-4	0+000	3072585.015	421547.313	1029.533	
		0+175	3072450.162	421438.246	1027.712	
5	SLP-5	0+000	3072560.16	421576.576	1016.298	
		0+175	3072424.48	421468.05	1019.62	
6	SLP-6	0+000	3072550.8	421583.42	1012.13	
		0+175	3072415.79	421481.72	1015.14	
	Total Length	735m				

Table 2.3 Description of Seismic Profiles at Powerhouse Site (Option II)

S.No.	Seismic Lines	Chainage	X-Northing	Y-Easting	Elevation (m)	Remarks
1	SLP-7	0+000	3071400.49	420736.081	1026.934	
		0+165	3071243.411	420736.585	994.213	
2	SLP-8	0+000	3071373.345	420775.45	1007.39	
		0+095	3071288.559	420776.342	991.32	
3	SLP-9	0+000	3071398.34	420816.17	1000.44	
		0+85	3071326.3	420816.8	992.58	
4	SLP-10	0+000	3071420.36	420855.191	1005.75	
		0+85	3071352.98	420855.191	994.62	
5	SLP-11	0+000	3071345.599	420684.681	1014.53	
		0+165	3071345.14	420845.27	993.59	
6	SLP-12	0+000	3071399.976	420873.869	997.439	
		0+130	3071258.13	420733.157	994.18	
	Total Length	725m				

Table 2.4 Description of Seismic Profiles at Hot Spring MCT Zone

S. No.	Seismic Lines	Chainage	X-Northing	Y-Easting	Elevation (m)	Remarks
1	SLP-13	0+000	3075726.511	423159.654	1067.46	
		0+115	3075660.59	423066.06	1068.47	
		0+230	3075554.53	423021.55	1066	
2	SLP-14	0+000	3075732.712	423103.367	1096.21	
		0+060	3075697.1	423126.8	1067.74	
3	SLP-15	0+000	3075678.85	423027.83	1076.64	
		0+065	3075658.27	423077.74	1067.21	
4	SLP-16	0+000	3075609.11	422999.02	1092.42	
		0+060	3075594.39	423043.89	1064.69	
	Total Length	415m				
	Total Length	725m				

2.10 Annexes

The survey data and maps are given in the following different Annexes:

- Topographical Maps (Annex –A1)
- River Cross-section Data(Annex –A2)
- Description cards of permanent Benchmarks (Annex-A3)

3. Hydrology

3.1 Introduction

Since the Tamakoshi V project is the cascade of upstream Upper Tama Koshi Hydroelectric Project system (456 MW), hydrological data used in this study is based on the Upper Tama Koshi Hydroelectric Project 2008, March and 2001 July, and the Upgrading Feasibility Study conducted by Norconsult in 2005 .

The reference hydrology (monthly flow and daily) flows are basically from Upper Tama Koshi Hydroelectric project. There are no major tributaries to be added in the Tamaoshi V Hydroelectric Project besides the water flow from the tailrace of upstream project Upper Tama Koshi Hydroelectric Project. The major tributary are Rolwaling khola and Bhaise Khola, which will also be tapped by Upper Tamakoshi HEP.

A gauging station was established at the power site about 150 m upstream of Bhrole Bridge to measure the discharge at the powerhouse site of the project. This gauging station was washed out during the 2067 flood. In order to continue the discharge measurement next gauging station is established at about 1 km downstream for the Suri Dovan powerhouse site at Bhorle Bazar. This site is about 200 m downstream from the Bhrole Bridge.

3.2 Available Data

3.2.1 Maps

The maps used in the study are as follows.

1. FINMAP, the map scale is 1:25000 and 1:50,000, topographic maps of the whole catchment area.
2. District maps of Nepal scale is 1:125,000, topographic maps of whole catchment area.
3. Topographic survey map of the project area prepared by NEA

3.2.2 Climate Data

Monthly precipitation and climatological data for most important meteorological Stations in Nepal are presented in "Climatological Records of Nepal, DHM". The total number of climate gauge stations is around 157. The monthly-published data are available from 1971 to 2006. A few climate gauging stations have equipped with precipitation gauge, temperature data, humidity data, wind velocity data and pan evaporation data otherwise the climate gauge station have only rain gauge stations. The precipitation stations that are useful to this project are shown in the **Table 3.1**. These stations are shown in the **Figure 3.1.** Rain gauge stations are not available at the catchment area in the Tibet (China).

Table 3.1: Rain Gauge Stations near and at the Upper Tama Koshi Basin

Code	Name	Catchment	Location				Elevation	Mean Rainfall	Period	# compl. years
			Latitude (N)		Longitude (E)		(m a.s.l.)	(mm/a)		
			Deg.	Min.	Deg.	Min.				
1006	Gunthang	Bhotekoshi	27	52	85	52	1720	4009	1971-2006	30
1027	Bahrabaise	Bhotekoshi	27	47	85	54	1220	2968	1971-2006	31
1028	Pachuarghat	Bhotekoshi	27	34	85	45	633	1027	1971-2006	28
1101	Nagdaha	Tamakoshi	27	41	86	06	870	1434	1977-2006	24
1102	Charikot	Tamakoshi	27	40	86	03	1940	2068	1970-2006	35
1103	Jiri	Tamakoshi	27	38	86	14	2003	2281	1971-2006	25
LAMA	Lamabagar	Tamakoshi	27	53	86	16	1945	4115	2001-2006	3
JAGA	Jagat	Tamakoshi	27	46	86	17	1155	3388	2001-2006	2
BEDD	Bedding	Tamakoshi	27	53	86	22	3690	849	2000-2002	1
TSHO	Tshorolpa	Tamakoshi	27	52	86	28	4580	751	1999-2002	2
1202	Chauri Kharki	Dudhkoshi	27	42	86	43	2619	2135	1971-2006	30
1206	Okhaldunga	Dudhkoshi	27	19	86	30	1720	1772	1971-2006	35
1217	Khugung	Dudhkoshi	27	49	86	43	3750	808	1971-1990	14
1220	Chialsa	Dudhkoshi	27	31	86	37	2770	1824	1971-1998	21
NYAL	Nyalam (Tibet)	Sunkoshi	28	10	86	00	3750	720	1976-1987	11
TING	Tingri (Tibet)	Arun	28	36	87	37	4302	260	1960-1987	23

The evaporation data, temperature data and the wind speed data are available at the rain station 1103 and referred to the project.

3.2.3 Stream Flow Data

DHM has installed more than 99 stream gauging station (hydrometric station) on the rivers of Nepal. The earliest date of records is from 1962 in the major rivers of Nepal. Most of the major rivers of Nepal have permanent gauge house equipped with the cable-way for discharge measurements, automatic water surface record chart and the staff gauge. The published data from DHM has monthly flow data, instantaneous flood and low flow. On request, the DHM provides daily data, rating curves, staff gauge readings and flow charts for national interest project. The **Table 3.2** shows the stream gauging stations that are on the Tama Koshi river and its nearby rivers.

Table 3.2: Stream flow data around the Catchment area

Steam Gauge	River Name	Location	Year of records	Lat./long.	Drainage area(km2)
647	Tama Koshi	Busti	1971-06	$27^0$38'-$86^0$05'	2753
650	Khimti Khola	Rasnaulu	1979-06	$27^0$34'-$86^0$11'	313
610	Bhote Koshi	Bahrabise	1965-06	$27^0$47'-$85^0$53'	2410
620	Balephi Khola	Jalbire	1964-06	$27^0$48'-$85^0$46	629
652	Sun Koshi	Khurkot	1968-06	$27^0$20'-$86^0$00'	10000
GS2	Tama Koshi	Lama Bagar	2001-06	$27^0$53'-$86^0$16'	1759
GS8D.	Rolwaling Khola	Rikhu	2006-07	$27^0$20'-$86^0$14'	290
445	Arughat	Budhi Gandaki	1964-06	$28^0$2'-$84^0$48'	4270
447	Betrawati	Trisuli	1967-06	$27^0$58'-$85^0$11'	4650
600	Uwa Gaun	Arun	1985-06	$27^0$36'-$87^0$20'	26759

Note: Data are from Upper Tama Koshi HEP(456 MW)

3.3 Basin Characteristic

Tama Koshi is one of the major tributaries of Sapta Koshi river system. The river flows almost North-South from Tibet to Nepal. The river basin upstream of the dam axis is shown in **Figure 3.2**. This river basin was roughly digitized from 1:500,000. The main source of Tama Koshi flow is the snow and glacier melt from the higher Himalayas. The peak in the basin are Jobo Guru (EL. 7181), Jobo Rabzang (EL. 6666) and Gauri Shankar Himal (EL.7146). The highest peak in the basin is at elevation 7312 (unknown peak lies in the Tibet). The total area of Tama Koshi River basin up to intake site is 1587 km^2. This area is based on the catchment are of Busti gauging station minus the Tibet catchment area plus the catchment are upstream of dam site to Tibet border. About 80 % (1265 km^2) of the catchment area lies at the Tibet. The precipitation records that are available in Nepal covers only 20 % (322 km^2) of the catchment area. There are 57 glacier lakes identified by the ICIMOD and UNEP inside the Tama Koshi catchment. The Rolwaling valley alone has 13 glacial lakes. The detail break down of catchment area is shown below as measured in 1:50,000 scale topographic map (**Table 3.3**):

Table 3.3: Catchment Characteristic

Area(km^2)	Tama Koshi V Headworks	Power House
Total Area	2153	2453
Area Below 5000 m	775	1075

Up to the intake dam the total catchment area amounts to 2153 km^2 of which some 70% lies in the Tibetan autonomous region of China.

The physical characteristics of the Tibetan area are not known in detail, except for descriptions of the glacial areas as given in the GLOF Risk Assessment carried out during the Feasibility Study. In this region glacial areas and high mountain peaks up to 7000m are located on the northern boundary of Lapche Khola sub-catchment and on the south and eastern boundary of the Rongchar Chu sub-catchment. Both areas contain numerous glacial lakes, the largest of which has a volume of 48.5 Mm^3.

3.4 River System

The geographical regions, which run in a generally parallel west to east direction, are bisected by major river systems. Including a number of internal and bordering river catchments, Nepal can be divided into three major drainage basins

Western Region: Karnali (dominant), Mahakali, Rapti, Banganga
Central Region: Narayani (dominant), Bagmati
Eastern Region: Sapta Koshi (dominant), Arun, Kankai

The project area, and Tama Koshi river, is located in the Eastern Region. Together with neighbouring rivers: Bhotekoshi (to the west) and Dudhkoshi (to the east), Tama Koshi is a tributary of the Sun Koshi which joins Arun and Tamar rivers at around elevation 450 m to form the final Sapta Koshi section.

Beyond the Indian border the Sapta Koshi becomes a major tributary of the Ganges river which is joined by the Brahmaputra river from the north, originating also in Tibet, and flows through Bangladesh to discharge into the Bay of Bengal.

The Tama Koshi river upstream of the proposed dam is comprised of two major rivers followed by other small tributaries (**Figure 3.2**). The main-stem Tama Koshi river drains the water from the Higher Tibetan Himalayan range

Starting at Upper Tama Koshi dam site the Tama Koshi river is about 7.5 km long to the point where it splits into the Lapshe Khola and the Jum Khola (Jum Khola in Nepal, Rongchar Khola in Tibet). The average gradient of up to this point is about 1 in 38.

3.5 Climate

3.5.1 Climate Zones

Corresponding to the elevation difference within a span of only about 200, the extreme spatial climate variation experienced in Nepal can be divided into the following five characteristic climate zones. Hot monsoon climate in the Terai, Inner Terai, and Siwilak lowland regions with a hot and wet summer, and mild and dry winter. Warm temperate monsoon climate in the Middle Mountains up to an elevation of about 2,100 m.Cool temperate monsoon climate in the Middle Mountains and the High Mountains between elevations 2,100 m and 3,300 m. Alpine climate in the High Mountain region up to an elevation of about 4,800 m.

Tundra type of climate above the snow line where there is perpetual frost and cold desert conditions.Precipitation, air temperature, evaporation, and relative humidity are the dominant parameters which condition the climate in a particular location, or region.

Monsoonal circulation defines the prominent seasonal climate of Nepal, which is principally conditioned by easterly winds during the summer months, and westerly winds from October to May. Most of the annual rainfall occurs during the summer monsoon period between June and September. Transitional periods between the winter dry season and summer monsoon season are characterized by convective rainfall.

3.5.2 Ecological Zones

Climate and moisture regions are often liked and classified in terms of ecological zones, which in turn are related to elevation, vegetation, land and forest cover. Ecological zones and vegetation maps for Nepal can be found in the document. From this source the predominant ecological zones, related to elevation, climate, and vegetation, when superimposed on the topography in the project area, can be deduced as:

Subtropical: below 1500m

In the lower valley and tributary valleys extending from the confluence of Rolwaling Khola to Jagat, Singate and downstream.

Temperate: between elevation 1500m and 2500m

In the mid valley and tributary valley sections including dam site and powerhouse site.

Sub Alpine: between elevations 2500m and 3500m

Alpine: between elevations 3500m and 5000m

Nivel: at elevations above 5000m

The latter high altitude zones clearly coincide with the snowbound and glacial areas contained within the upper catchment of Rolwaling Khola and on the western and eastern boundaries upstream of the intake dam site. These zones also extend continuously along and beyond the north-eastern border within the sub-catchment of the Rongchar Chu tributary in Tibet.

In addition to the above ecological classification the same document defines four moisture regions in Nepal, as: Arid, Semi-Arid, Humid and Per-Humid. According to this the project area falls in the Humid region, whereas areas immediately to the south and west (Bhotekoshi) Per-Humid conditions prevail in which actual rainfall is strongly related to monsoon influence.

Within the Tibetan area of the catchment less information is available. With reference to FAO documents, the major ecological-climatic divisions in the northern Himalayan are expressed under Subtropical Mountain and Temperate Mountain Systems.

3.5.3 Climate Study

The catchment lies in the High Himalayas and the High Mountain and the physiographic characteristics of the Tama Koshi River catchment influences climate. Climatic condition varies with altitude. Since the climate is dominated by topographical variations, the catchment area experiences severe cold, subtropical to temperate climate. As in other parts of Nepal the Tama Koshi River catchment also experiences the effects of the southwest monsoon, which on an average lasts from June to the end of September. The region receives rainfall approximately 80 % of the annual rainfall during this period. Rainfall intensities vary throughout the basin with maximum intensity occurring on the south facing slopes. During the monsoon period, relative humidity reaches at their maximum, temperatures are lower compared to the pre-monsoon period.

The climatological parameters are important to know the site condition of the project as well as to derive the hydrological parameters. The basic parameters are precipitation, relative humidity, air temperature and wind speed. It is noticed that one meteorological station (Index No 1103) is located closed to project site of Tama Koshi Project. The meteorological station 1103 is equipped with the wind measurement device.

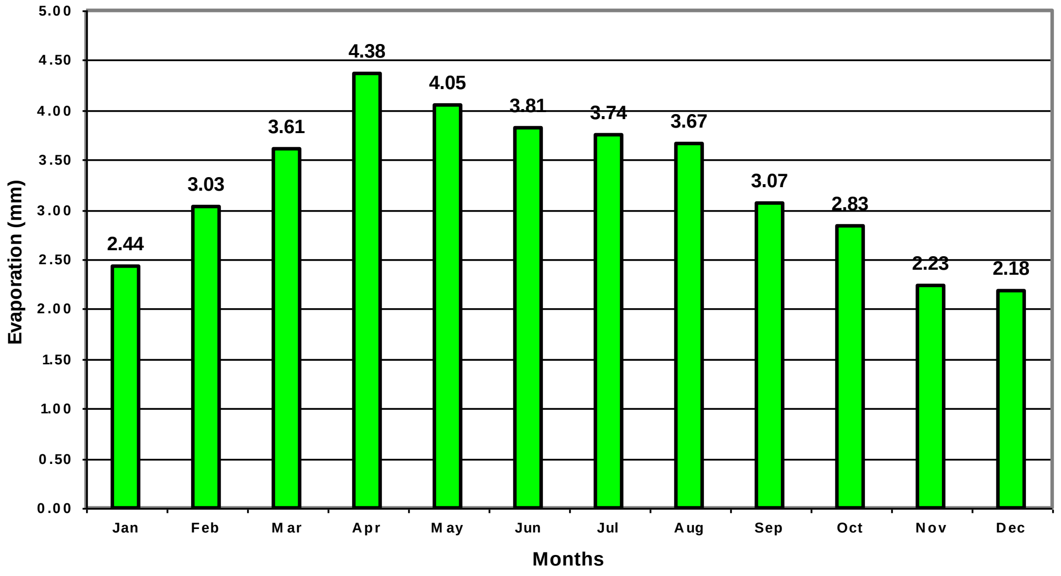
3.5.4 Evaporation

The pan evaporation data are available at station Jiri, closest to the proposed dam site Evaporation data are available from the year 1976 to 1984 and shown in Table 4.4. The reservoir evaporation will be 70 % of that value. **Figure 3.3** depicts the annual pattern of evaporation over the area. As usual the figure indicates that the evaporation occurs at the maximum rate during the dry period of the pre-monsoon season.

Table 3.4: Monthly Evaporation Data at Index No 1103

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976	2.6	3.6	3.3	2.1	1.8	2.3	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
1977	3.1	2.1	3.6	3.4	4.1	2.9	2.2	1.5	2.4	2	1.8	2
1978	2.5	2.6	3.2	3	2.4	2.4	2	2	1.9	2.5	1.8	1.8
1979	1.8	3.9	3.7	4.1	4.4	4.4	3.4	N.A.	3.1	2.6	2.4	2
1980	1.9	2.4	3.2	4.3	4.1	4.2	3.6	4.3	3.3	3.3	2.4	1.8
1981	1.5	2.7	3	4.1	3.7	4	4.2	4.7	3.8	3.3	2.6	3.5
1982	3	3.1	4.9	9	6.9	5.3	5.2	4.8	3.4	3.3	2.1	2
1983	3.1	3.8	4	5	5	5	5.6	4.7	3.6	N.A.	2.5	N.A.
Days	31	28	31	30	31	30	31	31	30	31	30	31
Average	2.44	3.03	3.61	4.38	4.05	3.81	3.74	3.67	3.07	2.83	2.23	2.18
Evaporation mm/month	76	85	112	131	126	114	116	114	92	88	67	68
Reservoir Evaporation mm/month	53	59	78	92	88	80	81	80	65	61	47	47

Figure 4.3:Evaporation Data at Index Station No 1103



3.5.5 Temperature

The worst temperature at the site (referred from the index station 1103 at Jiri) is taken as 28^{o}C (upper limit) and –7^{o}C (lower limit), as shown in the Table 4.5

3.5.6 Humidity

The maximum and minimum monthly relative humidity at the project location are 92% and 51% respectively (Table 4.5)

3.5.7 Wind speed

The average monthly maximum wind speed that can have at the site is 4.0 km/hour (based on station 1103).

Table 3.5: Temperature and Humidity at station 1103

Year	Month	Air Temperature (ºC)		Relative Humidity (%)		
		Absolute Extreme				
		Max & Date	Min & Date	Month	8:45	17:45
1971	Jun	36.0/5		Jan	92	
	Jan/Feb		2/31,1	Feb		54
1972	May	25.6/18		Sept		88
	Jan		NA	Dec	61	
1973	April	26.5/16		Sept		90
			NA	April		51
1974	April	25.3/19		Sept		87
	Jan/feb		(-4)/16,9	March	56	
1975	April	26.9/8		Nov	90	
	Dec		(-7)/22	April		49
1976	Jun	24.5/12		Aug	95	
	Dec		(-2.9)/25	Dec	69	
1977	May	25.8/31		Aug		90
	February		(-4.5)/6	March		64
1978	April/May	25.9/26-22		Sept	89	
	Jan		(-6.0)/10	Mar		51
1979	May	26.6/18		Aug/Jul	85	85
	Dec		(-3.1)/22	April		55
1980	April	25.8/12		Aug		90
	Jan		(-3.5)/7	May	60	
1981	Jun	25.9/13		Jan	95	
	Jan		(-4.6)/10	Mar		57
1982	May	26.2/27		Aug		91
	Jan		(-3.2)/14	Mar		64

1983	Jun	26.8/20		Aug/Sep		88
	February		(-6)/11	March		63
1984	Jun	28.8/3		July/Nov/Aug		88
	Nov		0.0/24	Aprii		68
1985	Jun	28.5/22		Aug		94
	Jan		(-4)/7	April	63	
1986	Jun,Aug	25.6/6,17		July/Aug	91	91
	Jan,Feb		(-3)/28,9	Mar	76	
1987	May	26.5/24		July		92
	Dec		(-1.8)/23	April	62	
1988	May	27.2/11		Dec	94	
	Jan		(-3.8)/28	March		66
1989	May	28/7		Jan	96	
	February		(-5.3)/17	April		53
1990	Jun	27.1/8		Jan	94	
	Jan		(5.2)/3	April	70	70
1991	May	27.5/10		Jan,Dec	92	
	Jan		(-4.1)/4	Feb,March		57
1992	April	28.2/12		Nov	93	
	Jan		(-6.1)/2	April		52
1993	May	26.4/5		Jan	91	
	Jan		(-5.5)/21	Mar		68
1994	Jun	27.7/4		Nov/Aug/Sept	90	90
	Jan		(-7.3)/17	April		58
1995	May	27.5/25		Nov	95	
	Jan		(-5.9)/10	Apr		59
1996	April	27.2/20		Nov	94	
	Jan		(-5)/18	April		61

3.6 Hydro metrological Database

DHM has installed more than 99 stream gauging station (hydrometric station) on the rivers of Nepal. The earliest date of records is from 1962 in the major rivers of Nepal. Most of the major rivers of Nepal have permanent gauge house equipped with the cable-way for discharge measurements, automatic water surface record chart and the staff gauge. The published data from DHM has monthly flow data, instantaneous flood and low flow. On request, the DHM provides daily data, rating curves, staff gauge readings and flow charts for national interest project. The **Table 3.2** shows the stream gauging stations that are on the Tama Koshi river and its nearby rivers.

Data were compiled from field stations located in and near to the project area. In the upper project area hydrometric stations and measuring points belong to the NEA project network, whereas other hydrometric stations in the Tama Koshi catchment and neighbouring catchments, as well as rainfall and meteorological stations, belong to the national DHM networks.

3.6.1 Gauging Station GS2 Tama Koshi at Lamabagar

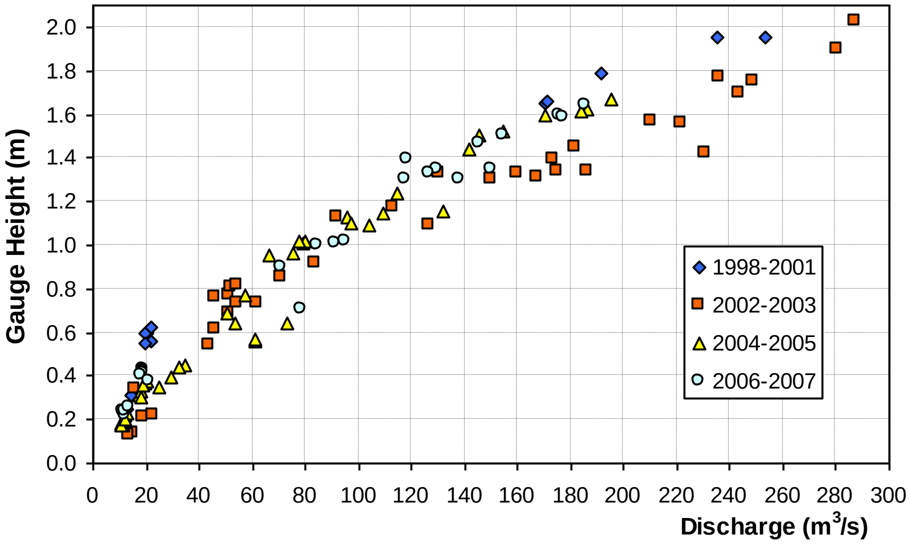
At the gauging station GS2 a gauge was first established in 1998. The current gauge at the suspension bridge in Lamabagar upper village was established by NEA in January 2001. Discharge measurements were taken with current meter from the suspension bridge, until a permanent cableway was erected in June 2003 a short distance downstream.

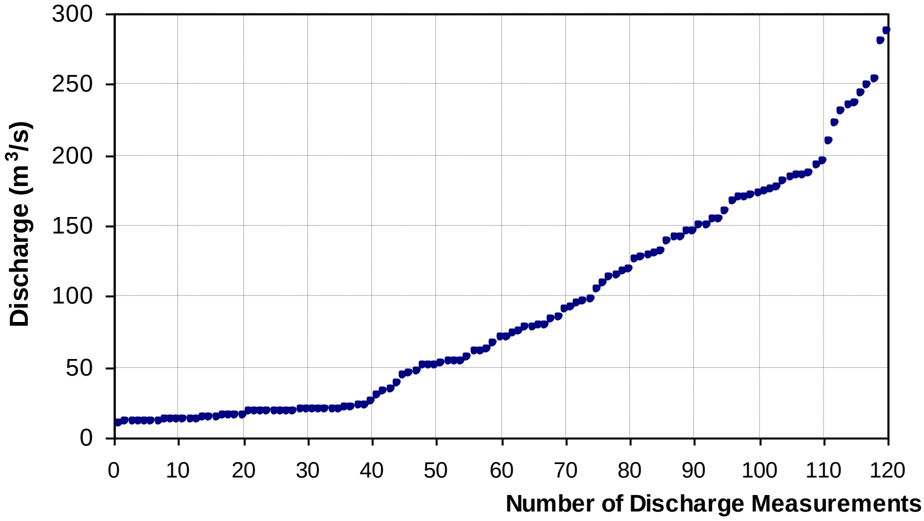
The gauge is read three times per day and a continuous set of daily water levels is available since January 2001 until the present (June 2009), except for some apparently missing values in January and February 2007.

Discharge measurements have been carried out relatively regularly at different times of the year, and so cover a wide range of flow conditions experienced. Between November 1998 and October 2007 a total of 123 measurements have been taken. The range and scatter of these measurements in ascending order, from 10.5 m^3/s in March 2004, to 287 m^3/s in August 2003, is shown in **Figure 3.4**.

From these measurements partial-period rating curves have been derived by the NEA project hydrology team. In the Feasibility Study, using measurements up to August 2004, 13 curves were defined for sequential chronological periods which were valid for a particular wet, dry or all-year season. For the definition of some later curves, sufficient discharge measurements were available in each period to cover the full range of seasonal conditions. The requirement for different-period curves is conditioned by instability of the cross section and seasonal changes in bed level, which is apparent when viewing the scatter of measured points in Figure 3.4.

Figure 3.4: Discharge measurements, GS2 Tama Koshi at Lamabagar





Based on daily gauge height readings, the derived curves (Table 3.6) were applied to generate a continuous daily stream flow series covering the period 2001 to 2006. Due to a degree of sampling variance and scatter in the 2005 measurements, the different types of statistically-fitted regression curves (14 to 18) corresponding to this period were appropriately adjusted in order to maintain continuity.

Table 3.6: Derived rating curves for gauging station GS2 Tama Koshi at Lamabagar

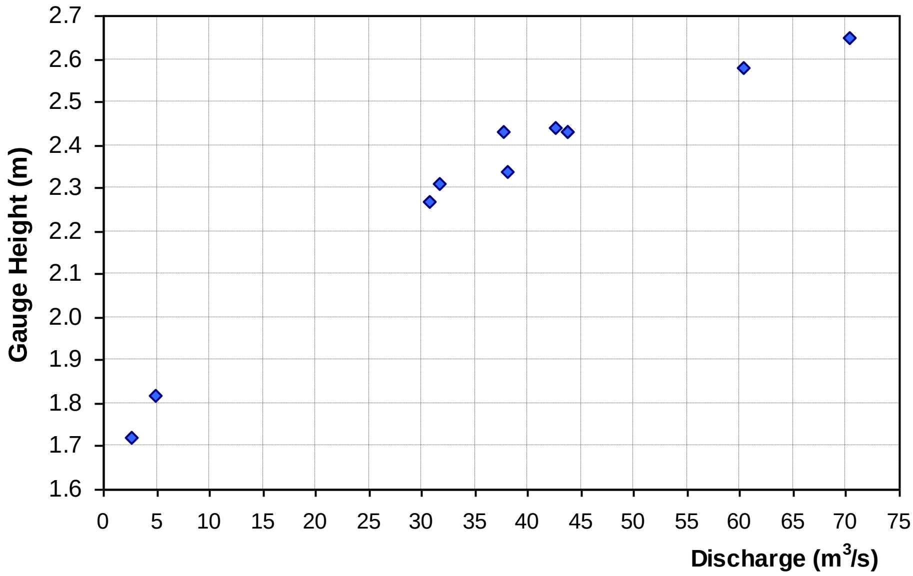
Curve No.	Equation	Season	Valid Period	
			From	To
1	$Q = 26.585\ H^{0.485}$	dry season	December 1998	26. January 2001
2	$Q = 64.983\ H^{2.152}$	wet season	(Old Gauge)	
3	$Q = 28.725\ H^{0.559}$	dry season	27. January 2001	23. May 2001
4	$Q = 58.431\ H^{2.056}$	wet season	24. May 2001	28. August 2001
5	$Q = 68.944\ (H + 0.044)^{1.736}$	wet season	29. August 2001	15. October 2001
6	$Q = 67.300\ (H + 0.044)^{1.4971}$	dry season	16. October 2001	03. June 2002
7	$Q = 146.099\ (H - 0.228)^{1.8936}$	wet season	04. June 2002	31. August 2002
8	$Q = 115.056\ (H - 0.013)^{1.5032}$	wet season	01. September 2002	25. October 2002
9	$Q = 73.529\ (H + 0.063)^{1.000}$	dry season	26. October 2002	31. March 2003
10	$Q = 66.250\ (H + 0.0804)^{1.000}$	dry season	01. April 2003	09. June 2003
11	$Q = 62.171\ (H + 0.2231)^{1.687}$	wet season	10. June 2003	30. June 2003
12	$Q = 58.349\ (H + 0.254)^{2.014}$	all season	01. July 2003	31. December 2003
13	$Q = 29.955\ (H + 0.480)^{2.405}$	all season	01. January 2004	31. December 2004
14	$Q = 50.505\ H + 1.005$	dry season	01. January 2005	March 2005 ($H \leq 0.36$)
15	$Q = 247.272\ H^{2.5406}$	inter season	March 2005	09. June 05 ($0.36 < H \leq 0.64$)
16	$Q = \exp(0.90424\ H + 3.6836)$	wet season	10. June 2005	07. August 2005 ($H > 0.64$)
17	$Q = 78.262\ H^{1.6815}$	wet season	08. August 2005	24. November 2005
18	$Q = 33.444\ H - 4.776$	dry season	25. November 2005	19. March 2006
19	$Q = 56.591\ (H + 0.163)^{1.991}$	all season	20. March 2006	31. August 2006
20	$Q = 35.508\ (H + 0.410)^{2.286}$	all season	01. September 2006	16. March 2007
21	$Q = 55.747\ (H + 0.246)^{2.026}$	all season	17. March 2007	October 2007

3.6.2 Tributary station GS8 Rolwaling Khola near Rikhu

Since June 2006 until the present (June 2009) water level has been observed on a daily basis (twice-daily at the lower gauge), with some apparently missing observations during December 2006 and January 2007 in the gauging station GS8.

At the lower gauge a total of 11 flow measurements have been taken up to September 2007, which cover 2 wet seasons and one dry season. Actual driest measured conditions were experienced in March 2007, at which time the lowest flow measurement of 2.6 m^3/s was made. In contrast the highest measurement was 70.2 m^3/s in July 2007, as shown in the distribution plot in **Figure 3.5**.

Figure 3.5: Discharge measurements, GS8D Rolwaling Khola (2006-2007)



From these measurements, 2 period rating curves were derived by NEA as shown in **Table 3.7**. The derived curves were applied to generate a continuous daily streamflow series at GS8D covering an approximate 13-month period from June 2006 to August 2007. The other data from September 2007 has to be processed. Analysis and comparison of this flow series with that at GS2 Lamabagar is presented in Section 4.

Table 3.7: Derived rating curves for gauging station GS8D Rolwaling Khola near Rikhu

Curve No.	Equation	Season	Valid Period	
			From	To
1	$Q = 32.786 (H - 1.328)^{2.691}$	all season	26. June 2006	17. March 2007
2	$Q = 44.702 (H - 1.435)^{2.282}$	all season	18. March 2007	Sepember 2007

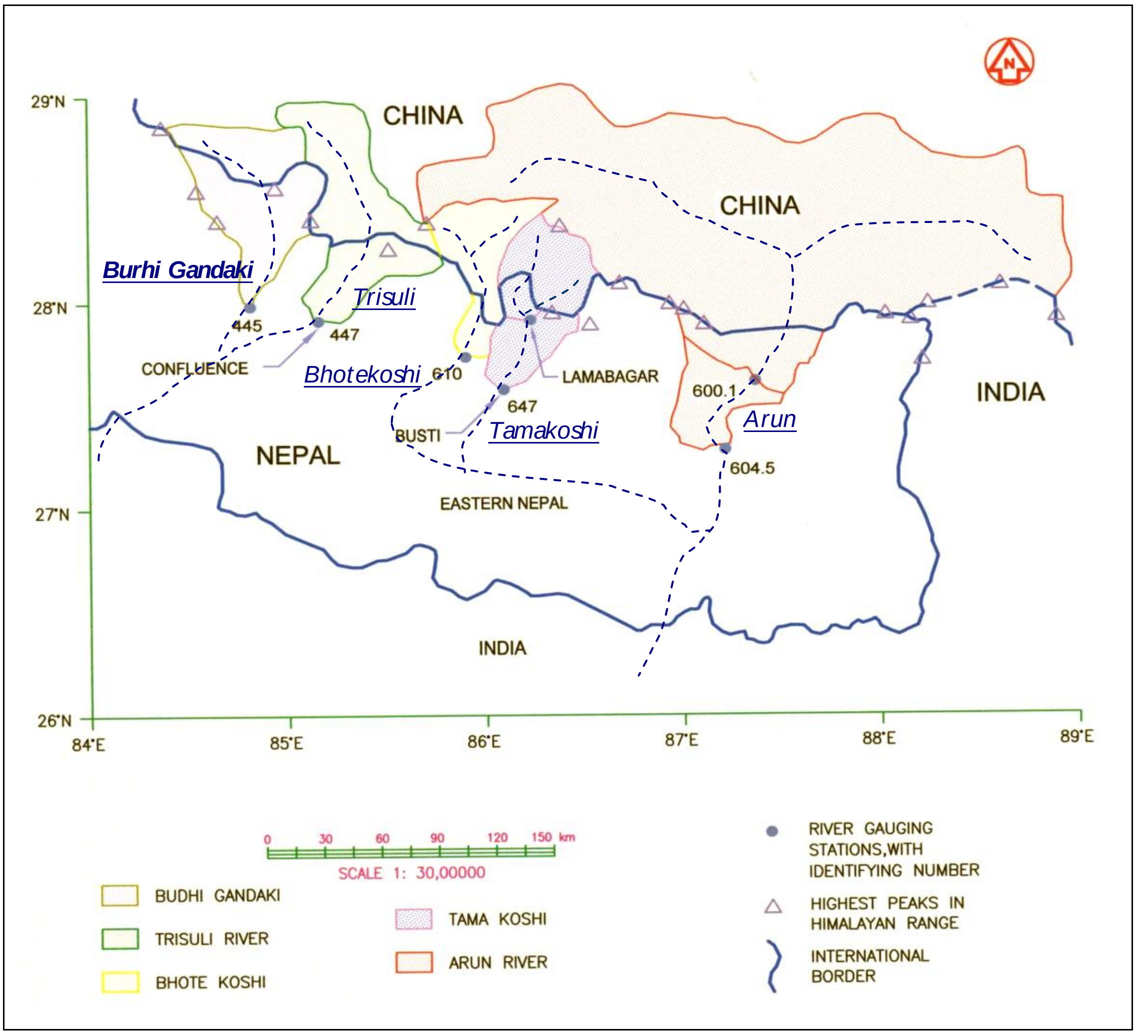
3.6.3 DHM Network

The Department of Hydrology and Meteorology (DHM) is the responsible agency for set up and operation of hydrological and meteorological stations, as well as for carrying out and supporting objective hydrological and meteorological research studies at the national level.

The complete set of key reference stations are those located on Trans-Himalayan rivers, similar to Tama Koshi, with their respective headwaters in Tibet, The location of the reference stations in neighbouring catchments to the west and east of Tama Koshi is shown in **Figure 3.6**. In this map the relative proportion of headwater catchment area for the respective river basins originating in Tibet can be visualised.

In the Tama Koshi river basin immediately downstream of the NEA network and project area near to Lamabagar, the principal DHM station (647) is located at Busti. In the Eastern river-system region other key stations are located on Bhotekoshi, Sunkoshi and Arun rivers. In the Central region, Narayani basin, key stations are located on Trisuli and Burhi Gandaki rivers.

Figure 3.6: Trans-Himalayan catchments



3.7 Reference Hydrology Tamakoshi V

Since the Tama Koshi V is the cascade of Upper Tama Koshi Hydroelectric Project, the discharge from the tailrace of Upper Tama Koshi Hydroelectric Project is considered as the inflow to Tama Koshi V Hydroelectric project. Therefore, all hydrological data base are based on the Upper Tama Koshi HEP Hydrology. For the reference purpose, the daily hydrological data are reproduced from Upper Tama Koshi Hydroelectric Project.

3.7.1 Flow Series of Tama Koshi at Lamabagar

3.7.1.1 Daily Flow Series and Statistics

Given the complete record of daily gauge height (water level) and the established partial period rating curves (Table 4.6) a series of mean daily flow was generated for the 6-year period 2001 to 2006 at the Tama Koshi network station GS2 near to the intake dam site at Lamabagar. Monthly and annual statistics are presented in **Table 3.8** and monthly mean profile in **Figure 3.7**.

Table 3.8 Monthly and annual stream flow statistics, Tama Koshi Lamabagar

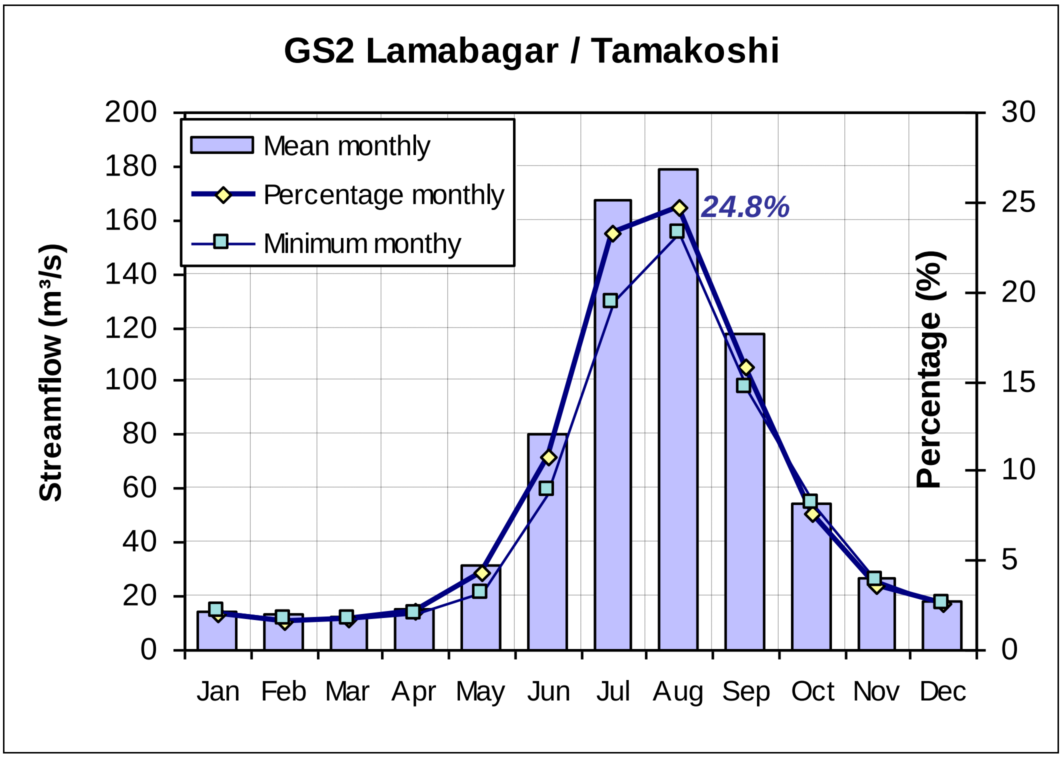
Month	GS2 Tamakoshi at Lamabagar			
	Qm	Qm(%yr)	Qmax	Qmin
Jan	14.7	2.0	17.2	12.8
Feb	13.0	1.6	15.9	11.1
Mar	12.6	1.7	15.8	10.8
Apr	15.7	2.1	19.8	13.1
May	31.3	4.3	44	20.6
Jun	80.3	10.8	102.4	59.2
Jul	167.5	23.2	229.8	129.6
Aug	178.8	24.8	235.9	156.1
Sep	118.1	15.8	148.1	93.1
Oct	54.5	7.5	64.9	48.9
Nov	26.5	3.6	30.9	23.5
Dec	18.2	2.5	20.5	15.8
Mean	61.3	(m^3/s)		
CV	1.003			
Runoff	1099	(mm/a)		
Monsoon	74.5	(%year)		

Year	Mean	Max day	Min day	CV day
2001	60.9	262.5	12.9	1.02
2002	78.6	369.4	15.0	1.07
2003	64.5	291.0	11.2	1.02
2004	50.7	203.8	9.9	0.99
2005	53.4	311.7	9.8	1.03
2006	59.7	258.9	10.4	0.96
Maximum	78.6	369.4	15.0	1.07
Minimum	50.7	203.8	9.8	0.96

Monsoon season flow, with a maximum in August (24.8%) amounts to 74.5% of annual flow, can be compared to the respective figures of (25.8%), 75.3% at Betrawati on Trisuli river and (28.3%), 78.8% at Busti on Tama Koshi downstream. The higher value at Busti confirms earlier analysis, and the apparent greater effect of monsoon rainfall in producing higher runoff in the incremental area downstream of the project intake site at Lamabagar.

Mean flow for the six-year period (61.3 m^3/s) is now slightly lower than the initial 3 years 2001-2003 (67.7 m^3/s), as established and applied in the FS.

Figure 3.7: Mean monthly flow profile Tama Koshi at Lamabagar



3.7.2 Flow Series of Rolwaling Khola

3.7.2.1 Daily Flow Series and Statistics

Stations on Rolwaling Khola (numbers 8U and 8D) were established in 2006 at a strategic location near to the potential transfer intake site. At both gauges near-continuous daily water levels have been observed since June 2006, and rating curves (Table 4.7) were established from 11 discharge measurements.

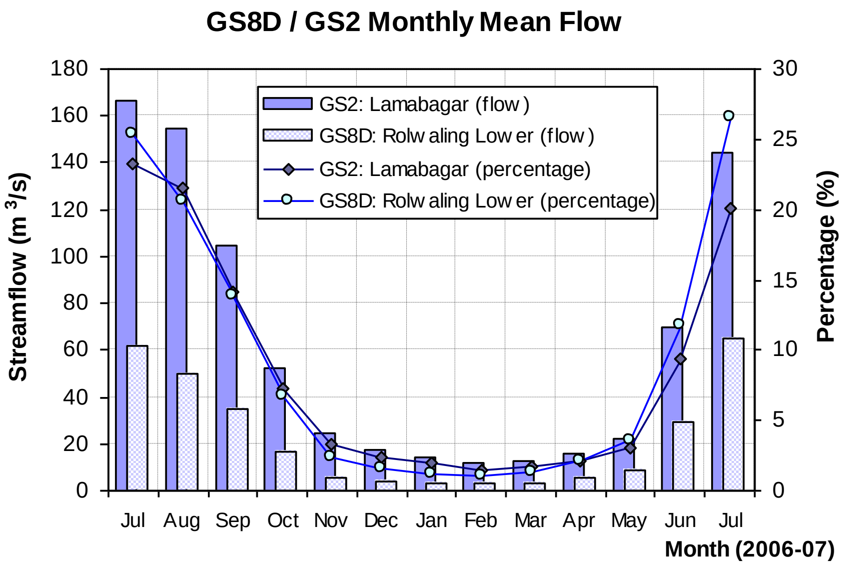
Available daily water level data at the upper and lower stations, as provided by NEA, are examined. In both traces of some unexpected deviations are present and at the lower gauge readings were missing in the data file between December 2006 and January 2007.

Monthly and annual statistics for complete months of the observed period (in which deviant values have been discounted) are presented in **Table 3.9** and monthly mean profile in **Figure 3.8**. For the 12-month period July 2006 to June 2007 mean flow results in 20.7 m^3/s.

Table 3.9: Monthly and annual stream flow statistic, Rolwaling Khola, Tama Koshi Lamabagar July 2006-July 2007.

Month	GS8D Rolwaling Khola		GS2 TK Lamabagar		Ratio Flow
	Qm	Qm (%yr)	Qm	Qm (%yr)	GS8/GS2
Jul	61.9	25.36	166.6	23.20	0.37
Aug	50.3	20.62	154.6	21.53	0.33
Sep	34.9	13.85	104.6	14.10	0.33
Oct	16.3	6.68	52.0	7.24	0.31
Nov	5.9	2.32	24.3	3.27	0.24
Dec	4.0	1.62	17.3	2.41	0.23
Jan	3.1	1.25	14.0	1.95	0.22
Feb	2.9	1.07	12.0	1.51	0.24
Mar	3.3	1.34	12.8	1.78	0.26
Apr	5.3	2.09	15.7	2.12	0.34
May	8.6	3.53	21.9	3.05	0.39
Jun	29.7	11.78	69.4	9.35	0.43
Jul	64.7	26.52	144.5	20.12	0.45
Average July-June	20.72	(m^3/s)	60.99	(m^3/s)	0.34
CV	0.992		0.930		
Runoff	2141	(mm/a)	1093	(mm/a)	1.96
Monsoon	71.6	(%year)	68.2	(%year)	1.05

Figure 3.8: Monthly mean flow at Rolwaling Khola, July 2006-July 2007



3.7.3 Inflow series at intake, dam site

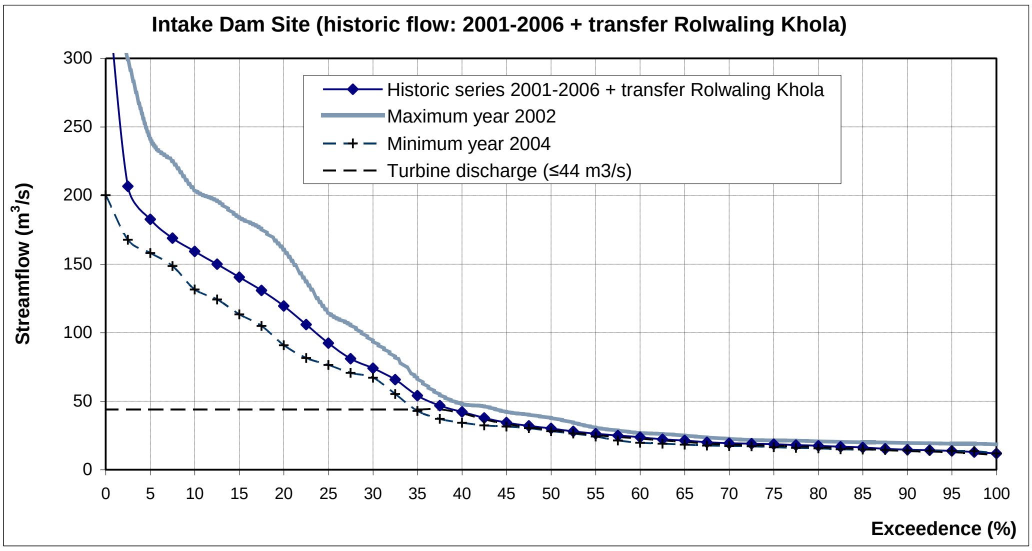
As is usual practice, historical hydrological data form the basis of flow availability assessment and, conventionally for design purposes commensurate with the level of project development it is generally assumed that historical information is representative of future conditions. For this purpose hydrological transfer flow from Rolwaling Khola (near to gauging station GS8) was superimposed on the historical period flow series 2001-2006 at the intake dam site.

Flow transfer was restricted to take place between dry-season months November and May and for a maximum tunnel capacity of $5m^3/s$. Under these conditions mean transferred flow amounts to 2.28 m^3/s giving a total available mean flow of 62.5 m^3/s at the intake dam site.

Daily flow duration curves derived from this third scenario are presented in **Figure 3.9**.

Figure 3.9: Flow Duration Curve data after Rolwaling and Tama Koshi combined

Exced. Prob. (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total Series 2001-06	Max year 2002	Min year 2004
0.0	22.7	20.6	21.4	35.4	91.3	227.6	320.8	363.1	213.5	111.5	42.8	28.6	363.1	363.1	200.3
2.5	21.8	20.2	20.0	31.1	85.3	174.0	299.5	308.9	194.4	98.3	41.5	28.1	206.7	299.2	167.7
5.0	21.7	20.0	19.8	28.5	68.9	145.1	251.5	265.4	182.6	88.6	40.1	27.3	182.6	241.3	158.1
7.5	21.5	19.8	19.4	27.2	62.2	139.2	232.1	252.6	172.1	81.1	38.8	26.4	168.9	224.9	148.5
10.0	21.4	19.5	19.1	25.7	54.4	127.8	225.5	230.7	168.4	76.1	37.9	26.2	159.2	204.0	131.4
12.5	21.1	19.2	19.0	24.7	51.5	122.8	217.3	211.7	160.5	74.1	37.2	25.7	149.9	196.1	124.2
15.0	21.1	19.0	18.7	24.0	49.2	119.3	208.7	206.7	155.1	72.4	36.7	25.6	140.5	183.9	113.3
17.5	20.8	18.9	18.0	23.4	48.0	110.9	201.9	200.6	154.0	70.7	35.1	25.1	130.7	175.7	104.9
20.0	20.4	18.5	17.7	22.8	47.5	106.9	192.2	196.2	149.3	67.9	34.8	24.9	119.4	160.5	90.8
22.5	19.9	17.9	17.5	22.3	46.8	104.7	186.9	192.8	146.6	65.8	34.4	24.6	105.8	137.2	81.4
25.0	19.2	17.7	17.4	21.4	46.1	101.7	184.9	186.6	143.9	64.8	34.0	24.4	92.4	114.6	76.5
27.5	18.9	17.7	16.9	20.3	44.5	96.6	182.1	185.5	135.5	63.9	33.5	24.1	81.1	105.7	70.7
30.0	18.9	17.6	16.9	20.2	42.3	93.8	179.9	184.2	132.2	62.0	33.0	23.7	74.1	93.8	67.1
32.5	18.9	17.6	16.8	20.0	40.2	93.1	176.0	182.2	127.9	59.3	32.4	23.7	65.8	82.2	55.2
35.0	18.9	17.4	16.5	19.4	37.8	89.3	172.4	178.3	123.7	57.6	32.2	23.4	54.1	66.7	42.9
37.5	18.6	16.7	16.4	19.3	35.8	84.1	167.7	174.5	120.7	56.1	32.0	23.0	46.8	54.7	37.2
40.0	18.6	16.1	15.5	19.1	35.4	81.5	165.9	172.9	117.5	54.7	31.6	22.9	42.2	48.0	34.2
42.5	18.6	15.3	15.1	19.0	34.7	80.0	163.1	172.2	113.8	53.0	31.3	22.8	37.8	46.3	32.3
45.0	18.3	15.1	14.8	18.5	33.2	78.3	160.6	168.9	112.0	51.4	30.9	22.5	34.4	42.1	31.6
47.5	18.2	15.1	14.5	18.1	32.0	77.0	158.8	167.1	110.9	50.2	30.8	22.2	32.0	40.1	30.3
50.0	18.1	14.9	14.5	17.9	31.0	75.1	156.1	163.7	109.2	49.2	30.5	22.0	30.1	37.8	28.1
52.5	18.0	14.8	14.2	17.8	29.9	74.0	153.5	161.9	107.3	47.9	30.2	21.9	27.9	34.4	26.4
55.0	17.9	14.7	14.2	17.6	28.7	73.1	150.0	160.8	106.6	47.0	30.2	21.8	26.2	30.6	24.2
57.5	17.5	14.7	14.0	17.5	28.0	70.3	148.8	159.9	105.6	45.8	29.9	21.7	24.9	28.6	21.4
60.0	17.4	14.5	13.9	17.2	27.5	68.1	147.3	159.2	103.2	44.9	29.5	21.4	23.7	26.8	19.6
62.5	17.3	14.2	13.8	17.1	27.2	66.8	143.4	157.0	102.0	43.6	29.2	21.1	22.3	26.2	19.0
65.0	17.3	14.2	13.7	16.7	26.3	58.6	141.9	155.8	97.3	43.0	28.9	20.9	21.4	24.9	18.3
67.5	17.0	14.2	13.6	16.5	25.4	57.0	140.5	154.7	92.4	42.7	28.3	20.5	20.1	23.5	17.7
70.0	16.6	14.0	13.6	16.5	25.2	54.1	138.8	152.1	90.3	42.2	28.0	20.4	19.4	22.5	17.3
72.5	16.6	13.8	13.4	16.2	25.0	50.2	137.0	151.5	88.5	41.2	27.9	20.1	19.0	21.7	17.1
75.0	16.5	13.8	13.2	16.1	24.8	46.5	134.8	149.9	85.7	40.7	27.5	20.0	18.6	21.4	16.5
77.5	16.2	13.8	13.1	15.9	24.5	45.0	133.1	147.4	81.8	40.3	27.5	19.5	17.9	21.2	16.0
80.0	16.0	13.8	13.0	15.6	24.4	42.9	130.7	144.6	81.4	39.1	27.2	19.3	17.4	20.8	15.5
82.5	15.8	13.8	12.9	15.3	23.4	40.5	129.3	142.9	80.3	38.3	26.6	19.3	16.8	20.3	15.0
85.0	15.4	13.8	12.9	14.8	22.2	37.7	125.0	139.0	79.2	36.8	26.2	19.3	16.2	20.0	14.7
87.5	15.4	13.6	12.9	14.5	19.8	35.7	123.9	137.2	77.5	35.4	25.5	19.1	15.3	19.8	14.5
90.0	14.9	13.4	12.9	14.5	19.0	34.2	119.4	136.1	77.1	34.2	25.2	18.9	14.5	19.5	14.0
92.5	14.8	13.2	12.7	14.1	18.3	32.3	112.9	133.6	76.4	33.7	25.1	18.6	14.2	19.2	13.9
95.0	14.5	12.9	12.5	13.4	16.4	31.4	105.8	128.6	74.3	33.0	24.4	18.0	13.8	19.0	13.8
97.5	14.2	12.7	12.3	12.2	15.6	27.9	98.8	123.8	70.7	30.1	23.3	17.3	12.9	18.9	13.6
100.0	14.2	12.3	11.9	11.8	14.2	24.4	81.1	119.6	67.1	23.8	22.8	17.3	11.8	18.4	11.9
Average	18.1	15.9	15.3	19.1	35.8	79.3	165.0	176.0	116.2	53.6	31.0	22.3	62.6	77.0	49.5
			Maximum power generation (Q ≥ 44 m^3/s)					Average turbine flow ≤ 44 m^3/s:					30.1	32.9	28.5



The clear advantage in the third scenario with dry season transfer from Rolwaling Khola is realised by enhanced dry-season power generation to the extent of 25% increase in firm flow and 8% increase in power flow overall for mean, maximum and minimum year conditions.

Regarding dimensions of the potential Rolwaling transfer scheme, optimum capacity of the tunnel is most likely greater than the $5m^3/s$ (applied here as an example only) through which captured flow and total available flow for power generation would increase still further. Furthermore, the actual operation strategy to maximise power generation, which was not simulated objectively in this example, would allow transfer of Rolwaling flow at all times (on a daily basis) in the intermediate season months, as well as in dry months, when available natural flow at Lamabagar is less than the plant discharge capacity of 66 m^3/s.

3.7.4 Flow Series at Bhaise Khola

During the upgrading feasibility study of the UTHEP by Norconsult in 2005, spot discharge measurements were taken in Ghatte Khola, Gongar Khola and Bhaise Khola, and the specific runoff are recorded accordingly. Also, using NEA Regional Flow Estimation Method the specific runoff values are proposed as the standard values for calculating flows in these tributary sab-catchments. This standard specific runoff values for each month have been applied to the Bhaise catchment area to provide estimates of the monthly mean flows.

The flow contribution from the Bhaise Khola catchment was found from the sum of two parts. Bhaise North represents the 17.5 km^2 area of the subcatchment lying above the 2000 m contour, which is the major part of the Bhaise Khola catchment down to its confluence with the Tamakoshi River. A very small second part, Bhaise South, with an area of 1 km^2 was tapped by constructing a short 80 m canal to convey its flow to the weir on the Bhaise North subcatchment.

Table 3.10 : Monthly flow estimation in Bhaise Khola from the consideration of Standard Specific Runoff values

Month	Specific Runoff	Monthly Mean Flows		
		Bhaise North (17.5 km^2)	Bhaise South (1.0 km^2)	Total
	$l/s/km^2$	m^3/s	m^3/s	m^3/s
Jan	24.5	0.429	0.025	0.454
Feb	18.7	0.327	0.019	0.346
Mar	17.3	0.303	0.017	0.320
Apr	15.9	0.278	0.016	0.294
May	18.7	0.327	0.019	0.346
Jun	63.4	1.11	0.063	1.173
Jul	208.0	3.64	0.208	3.848
Aug	255.0	4.46	0.255	4.715
Sep	208.0	3.64	0.208	3.848
Oct	104.0	1.82	0.104	1.924
Nov	49.0	0.858	0.049	0.907
Dec	30.3	0.530	0.030	0.560
Mean	**84.3**	**1.48**	**0.084**	**1.561**

3.7.5 Flow series of Tamakoshi with Bhaise Khola

Flow Series and Statistics of Tamakoshi River at Lamabagar referenced from Upper Tamakoshi HEP feasibility study in 2005. The catchment area in this feasibility report of 2005 was taken as 1,745.50 km^2. There were only few years of observed flow data available from the river gauging station on the Tamakoshi at Lamabager. So the flow at the Intake Dam Site at Lamabagar is obtained by correlating the flow from the Station No 447 of Trishuli River at Betrawati. The average flow values are obtained from the artificially extended 35 years, for years 1967 to 2001, daily flow record at the intake dam site

Table 3.11: Extended flow record (m^3/s) for the Intake dam site of Upper Tamakoshi

Month	Monthly Mean Flows (m^3/s)
Jan	16.1
Feb	14.1
Mar	14.3
Apr	18.0
May	32.8
Jun	84.2
Jul	179.8
Aug	204.7
Sep	133.4
Oct	58.0
Nov	30.4
Dec	20.6
Mean	**67.2**

The flow series of the Tamakoshi River including the flow from the Bhaise Khola could be determined from the above table 3.10 and 3.11

Table 3.12 : Flow series of Tamakoshi River with Bhaise Khola

Month	Monthly Mean Flows (m^3/s)		
	Tamakoshi River	**Bhaise Khola**	**Total flow**
Jan	16.1	0.454	16.554
Feb	14.1	0.346	14.446
Mar	14.3	0.320	14.62
Apr	18.0	0.294	18.294
May	32.8	0.346	33.146
Jun	84.2	1.173	85.373
Jul	179.8	3.848	183.648
Aug	204.7	4.715	209.415
Sep	133.4	3.848	137.248
Oct	58.0	1.924	59.924
Nov	30.4	0.907	31.307
Dec	20.6	0.560	21.16
Mean	**67.2**	**1.561**	**68.761**

The hydrological parameters are being upgraded in different time with the availability of upgraded ground measured river flow. The above given monthly hydrology of Tamakoshi along with Bhaise Khola is calculated during the feasibility study of Upper Tamaksohi in 2003/04.

3.7.6 Monthly Discharge at Upper Tamakoshi Headwork used for Power Purchase Agreement

Presently, Upper Tamakoshi HEP has signed the Power Purchase Agreement with Nepal Electricity Authority based on the following monthly flow data. This monthly flow considered the flow from Bhaise khola and Tamakoshi river at Lamabager.

Table 3.13 : Flow series of Tamakoshi River Based on PPA

Julian Calendar	No. of Days	Discharge River m3/s
Basiak	31	25.00
Jesth	31	56.73
Aswar	31	134.51
Srawan	32	134.51
Bhadra	31	196.95
Aswin	30	94.84
Kartik	30	44.66
Mansir	30	26.06
Poush	29	19.01
Margh	29	15.68
Falgun	30	14.53
Chitra	31	16.21

As the Tamakoshi-V HEP is a cascade development of Upper Tamakoshi Hydropower project, discharge from the tailrace of Upper Tamakoshi will be diverted into the headrace tunnel of Tamakoshi-V for the power generation. Therefore, the discharge used by Upper Tamakoshi HEP (the discharge of Tamakoshi at Lamabagar with Bhaise khola) for the Power Purchase Agreement is considered as the latest hydrological parameter for Tamakoshi –V HEP. Hence, same monthly discharge will be considering to calculate the power generation from Tamakoshi V HEP.

3.8 Flood analysis and design floods

3.8.1 Flood Data Availability

The flood data are not available on the dam site and at the powerhouse site. Flood data are available nearby hydrometric gauging station such as 647. The gauging station 647 is on the Tama Koshi river and about 30 km downstream of the dam site.

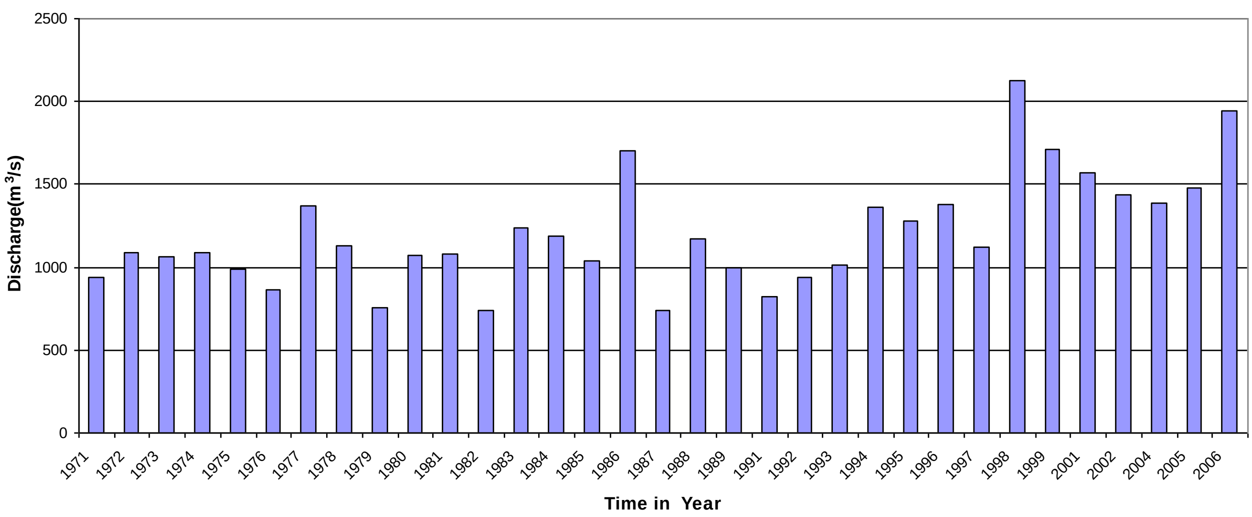
The complete data set of annual maximum daily and peak flood values available up to end of calendar year 2006 is presented in Table 4.10. Mean of the peak flood is 1207 m^3/s. The flood series are graphically represented in the **Figure 3.10**. The maximum peak is 2130 m^3/s in the year 1998 at Busti gauging station.

Table 3.10: Tama Koshi River at DHM Station 647(year 1971-2006), Instantaneous peak flood

Year	Data	Ordered	Rank	Prob.	Ret. Period
1971	942	2130	1	0.017	59.214
1972	1090	1940	2	0.047	21.256
1973	1060	1710	3	0.077	12.953
1974	1090	1700	4	0.107	9.315
1975	990	1570	5	0.138	7.272
1976	863	1480	6	0.168	5.964
1977	1370	1440	7	0.198	5.055
1978	1130	1390	8	0.228	4.386
1979	754	1380	9	0.258	3.874
1980	1070	1370	10	0.288	3.469
1981	1080	1360	11	0.318	3.14
1982	736	1280	12	0.349	2.869
1983	1240	1240	13	0.379	2.64
1984	1190	1190	14	0.409	2.445
1985	1040	1170	15	0.439	2.277
1986	1700	1130	16	0.469	2.131
1987	740	1120	17	0.499	2.002
1988	1170	1090	18	0.53	1.888
1989	1000	1090	19	0.56	1.787
1991	822	1080	20	0.59	1.695
1992	939	1070	21	0.62	1.613
1993	1010	1060	22	0.65	1.538
1994	1360	1040	23	0.68	1.47

Year	Data	Ordered	Rank	Prob.	Ret. Period
1995	1280	1010	24	0.71	1.407
1996	1380	1000	25	0.741	1.35
1997	1120	990	26	0.771	1.297
1998	2130	942	27	0.801	1.248
1999	1710	939	28	0.831	1.203
2001	1570	863	29	0.861	1.161
2002	1440	822	30	0.891	1.122
2004	1390	754	31	0.922	1.085
2005	1480	740	32	0.952	1.051
2006	1940	736	33	0.982	1.018
MEAN	1207				
S.D.	334.2				

Figure 4.10: Flood data series at Busti, G.S. 647



3.8.2 Flood Data Analysis

The instantaneous flood data at the gauging station 647, Busti are used to do the frequency analysis. The flood data from the year 1971 to 2006 are available. They are transferred to dam axis by multiplying catchment area ratio to the flood data at the gauging station at 647. The frequency distributions used are Gumbel I, Lognormal, three parameter Lognormal, and log Pearson type three. The best-fit distribution is "Gumbel-I Distribution" whose Root Mean Square Error is the smallest among all other distribution. The results of frequency analysis at different return period are shown in the **Table 3.12 and Table 3.13**. The flood verses return period are shown in the **Figure 3.11.** The analysis uses the square root of the area ratio to find the flood. The 100 year return period flood recommended is 1814 m^3/s at dam site and 2067 m^3/s at P/H site respectively.

Table 3.11: Intake Site of Tama Koshi V

Return				**Log-Pearson III**	
Period	**Gumbel I**	**Lognormal 3**	**3P-Lgnrml**	**Moments**	**Max.Lklhd**
2	899	915	899	899	899
5	1126	1142	1134	1134	1126
10	1275	1283	1298	1290	1290
20	1423	1408	1455	1439	1439
50	1611	1572	1658	1634	1642
100	1752	1689	**1814**	1783	1807
200	1885	1807	1979	1932	1963
500	2072	1955	2190	2135	2190
1000	2213	2072	**2362**	2299	2370
2000	2354	2182	2534	2463	2550
5000	2534	2331	2768	2690	2808
10000	2675	2448	2948	2870	3011
RMS ERROR:	35.78	41.6	31.46	32.52	32.66

Table 3.12: Powerhouse Site of Tama Koshi V

Return				**Log-person III**	
Period	**Gumbel I**	**Lognormal 3**	**3P-lgnrml**	**Moments**	**Max.Lkhd**
2	1025	1043	1025	1025	1025
5	1283	1301	1292	1292	1283
10	1452	1461	1479	1470	1470
20	1622	1604	1657	1639	1639
50	1836	1791	1889	1862	1871
100	1996	1925	**2067**	2032	2058
200	2147	2058	2254	2201	2236
500	2361	2228	2495	2433	2495
1000	2522	2361	**2691**	2620	2700
2000	2682	2486	2887	2807	2905
5000	2887	2655	3154	3065	3199
10000	3047	2789	3359	3270	3430
RMS ERROR:	35.78	41.6	31.46	32.52	32.66

3.9 Development of Rating Curves

3.9.1 Cross-Section Geometry and Profile

A survey team was sent to the site to measure cross-section geometry and water surface levels at selected points along the river at different sites. The measurements consisted of (un submerged or land surface) cross-section geometry from the water's edge up the banks. The locations of different cross-section are shown in **Figure 3.12 and Figure 3.13** at upstream and downstream powerhouse locations respectively.

Cross-sections were surveyed at number of location at the two alternative powerhouse sites. They are numbered as CX1 to CX-8 of the river in the upstream alternative powerhouse site. The cross section CX-7 and CX-8 are at the tailrace axis of powerhouse. Similarly, the cross section at the downstream powerhouse site numbered as PX-1 to PX-12 from downstream to upstream. The cross section at the tailrace site is numbered as PX-3. All the cross section data and plots are appended in Topographic section of the report.

3.9.2 Manning Roughness Coefficient

The Manning roughness coefficient "n" ranges from 0.030 to 0.035 for the river which is winding, not very weedy and has pools, shoals, pebbles and boulders. Since the riverbed has lot of cobbles and pebbles at the Tama koshi River at powerhouse site, a value of 0.035 was selected to provide a conservative approach to the rating curve determination

3.9.3 Rating Curves

The rating curves are developed using the slope area methods. The rating curves at CX-7, CX-8 and PX-3 are shown in Figure 3.14,3.15 and 3.16 respectively.

Figure 4.14: Rating Curve at CX-7

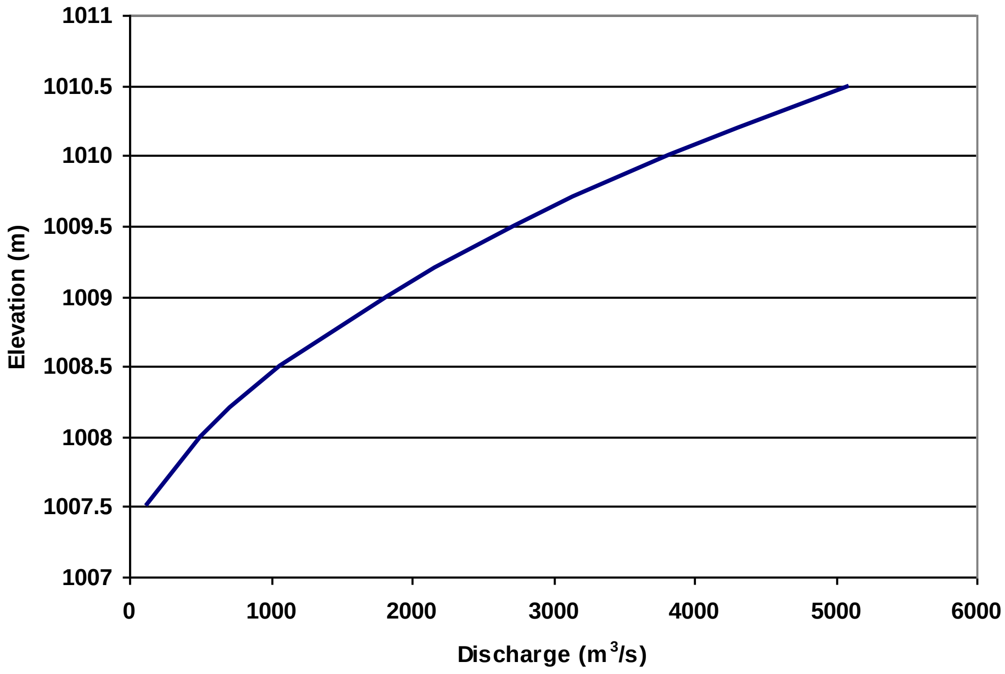
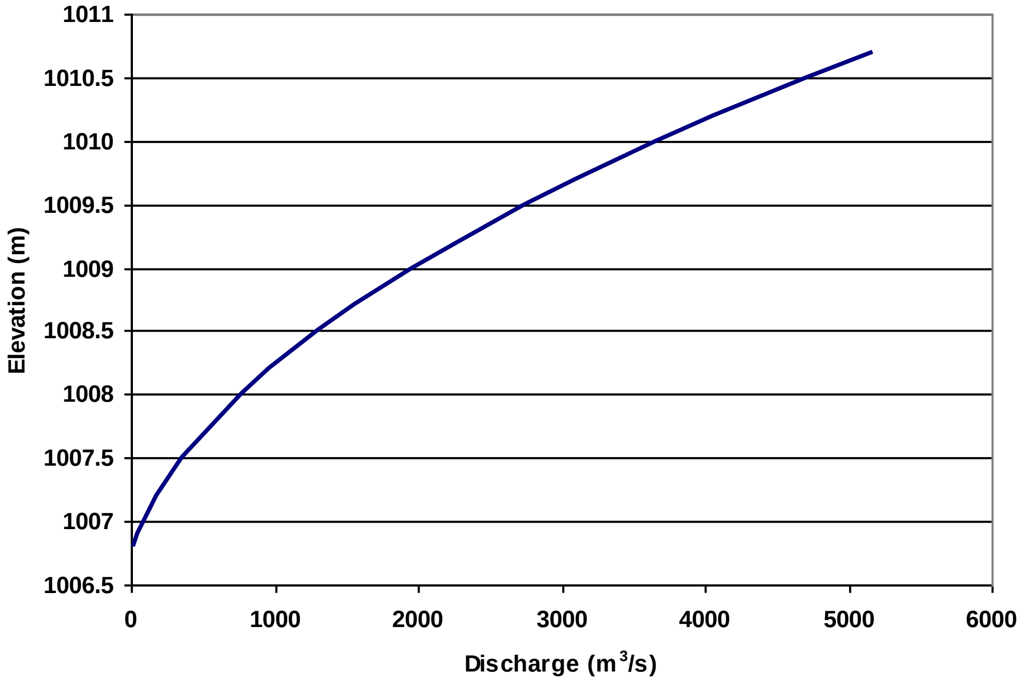
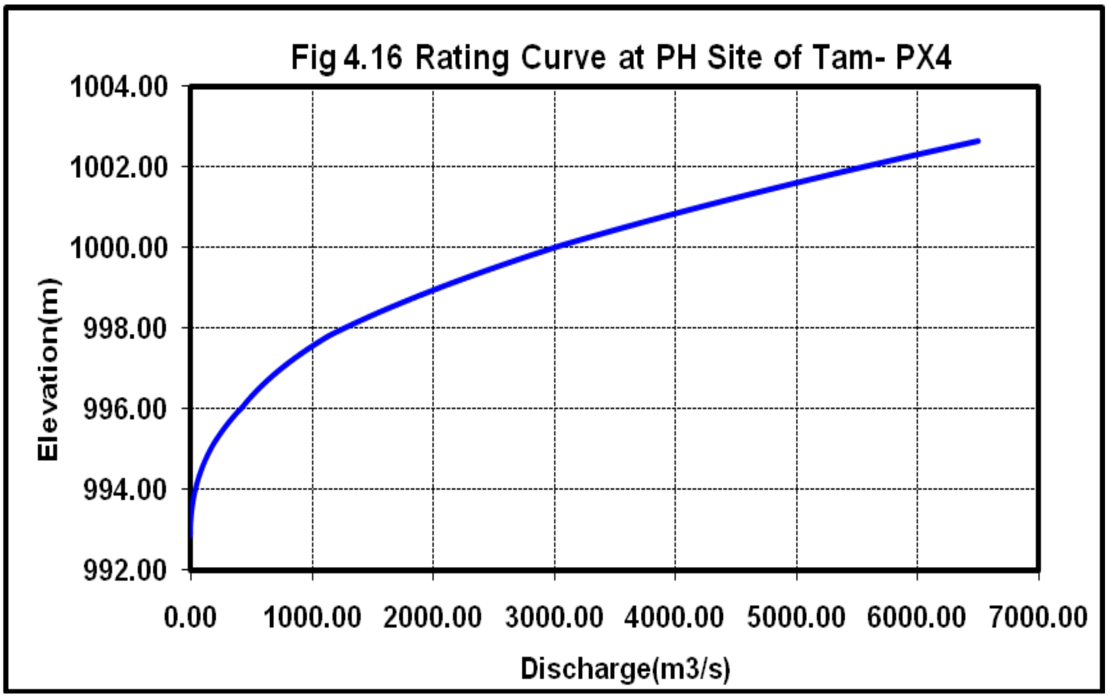


Figure 4.15: Rating Curve at CX-8





3.10 Field Measurement of Tama Koshi/River

The staff gauge has been installed at about 800 m downstream of the powerhouse site and 150 m upstream of the Bhorle suspension Bridge. The number of cross section are also surveyed at the gauge site. The continues measurements of staff gauge and discharge measurements have been carried out by NEA. The summary of discharge measurements are shown below. The details of staff gauge reading and discharge measurements are given in the annex.

Table 3.13: Discharge Measurement summary by NEA (D/S of powerhouse site)

Date	Time	Gauge Height (m)	Discharge (m^3/s)
066/10/22	12:00 PM	28	26.62
066/10/22	4:55 PM	26	26.22
066/10/23	1:15 PM	26	26.34
066/12/06	3:50 PM	0.09	19.245
066/12/07	7:30 AM	0.08	17.939
066/12/07	1:20 PM	0.09	18.167

This data shall be processed to estimate the daily discharge at the gauge site.

3.11 Downstream release

For the purpose of environmental and ecological river system of Tam Koshi, the downstream release from the Upper Tama Koshi HEP (456 MW) are released and to be deducted in the energy estimate in Tama Koshi V HEP.

Approximately 11 km of the river will lose most of its water flow in the dry season from Upper Tama Koshi HEP to the Tama Koshi V HEP. The dewatering effect will be partially mitigated by the inflow from Bhaise Khola and Rolwaling Khola, which join the Tama Koshi at about 2 km and 5 km downstream from the intake respectively. A compensation flow of 1.3 m^3/sec will be released at the dam at all times in accordance with stipulations in the Hydropower Development Policy, 2001.

3.12 Sediment Transport

3.12.1 Introduction

1. The Upper Tama Koshi Hydroelectric Project (456 MW, 2005 May), the upstream development of the Tama Koshi V HEP has full version of Sediment study as given in the chapter 4 and Appendix C. Since the project Tama Koshi HEP V is the cascade development of Upper Tama Koshi HEP, the sediment load as well as the concentration are govern from the upstream project. Therefore, the studies of sediment are reproduced hereunder.

2. A lot of sediment measurements has been carried out by NEA (Upper Tama Koshi HEP) G2 at Lamabagar on Tama Koshi just downstream of the proposed dam site and G3 at Lamabagar at the crest of the natural dam created by huge landslides. A lot of sediment data analysis has been carried out by the Upper Tama Koshi HEP. Sediment sampling at G2 started on 16th July 2001 and was the only gauging station used for sediment sampling prior to the present study.

Sediment gauging at G3 has been initiated during the present study and all the recorded data are published in this report, which covers the period from 28th June 2004 through 30th September 2004. G3 is furnished with time-integrating hand held sampler. Samples are retrieved from the bank of the river at locations with turbulent flow where the sediments are assumed to be well mixed and fairly evenly distributed over the depth and width of the flow.

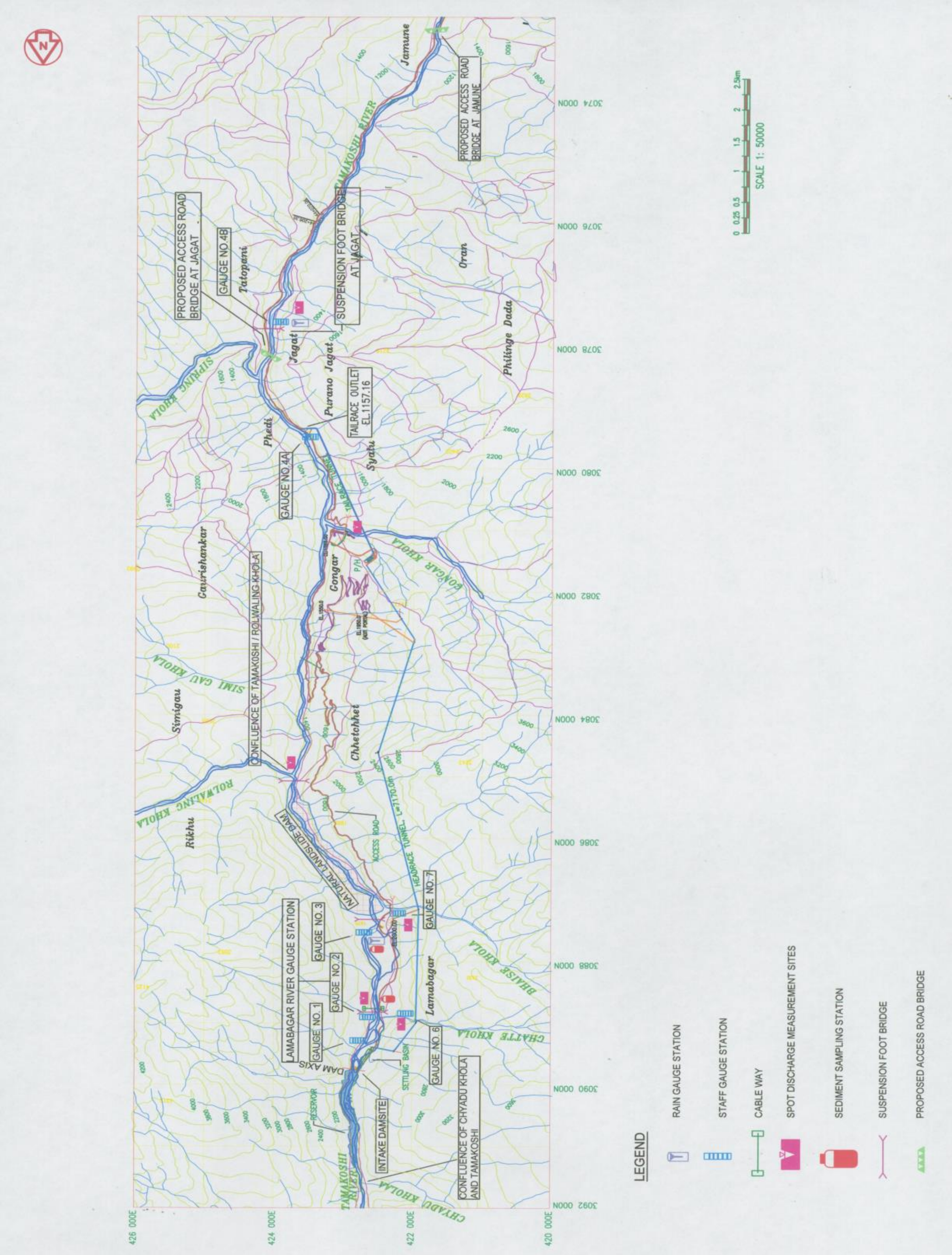


Figure 3.17: Location of major hydrometric stations in Upper Tama Koshi Valley

3.12.2 Particle size distribution

The results of the sampling and laboratory analyses of suspended sediment concentrations carried by the Upper Tama Koshi HEP are given in Appendix C1. Similarly, the results of Particle Size Distribution (PSD) analyses are shown in Appendix C1 and the adopted PSD-curve for the suspended sediments in Tama Koshi is shown in Figure 4.18. The Visual Accumulation Tube (VAT) analysis is considered to be the representative of the particle size distribution of the sand component of the suspended load in Tama Koshi at Lamabagar.

In addition to the results of the PSD-analysis shown in Figure 4.18, sand-break analysis has been performed on all samples handled by Hydro Lab. The sand-break varies between 1% and 89% for the G2 HL data and between 5% and 75% for the G3 HL data. The average observed sand-break of the total sediment load for the three time-series of data was 36% for G2 HL data, 44% for G3 HL data and 42% for the combined data series labelled G2+G3 HL data. A default sand-break of 43% is used in the further analysis of the G2 SRCL data when the 2004 data series shall be compared.

- The VAT analysis of the sand component
- An average sand-break of the suspended load of 50%
- A component of 10% finer than 0.001 mm

3.12.3 Mineralogical Analysis of the Suspended Load

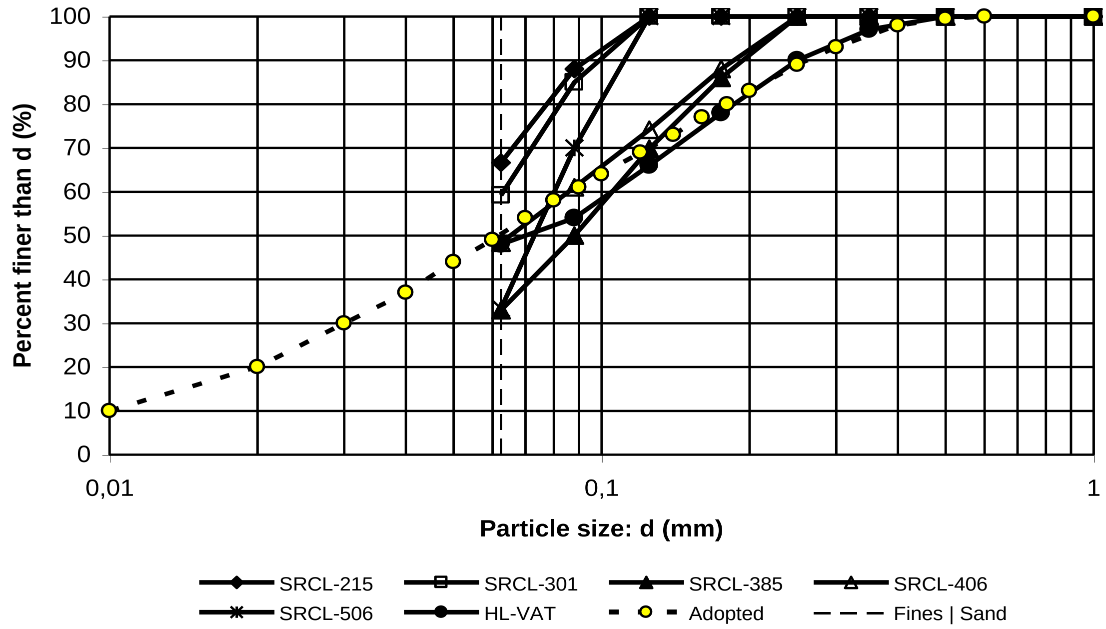
Suspended sediment samples have been subjected to mineralogical analysis by use of microscope. The results of these analyses are shown in Appendix C1 of the Upper Tama Koshi HEP. All of these results show that quartz is the dominating mineral. The content of quartz is a major issue, as quartz is hard and the main cause of wear in turbines in Himalayan hydropower plants. The findings is in line with the expectations based on the general geological features of the higher Himalayas as well as results found at other power plants in Nepal. The quartz content may like the PSD and sand-break vary considerably from sample to sample, but the quartz content of fine sand and silt is expected to be in the range from 60% to 80% of the suspended sediment load in Tama Koshi at Lamabagar.

Particle size distribution analysis of recorded suspended sediment samples

Sampled by		NEA	NEA	NEA	NEA	NEA	NEA	
Location		Gauge 2	Gauge 2	Gauge 2	Gauge 2	Gauge 2	Gauge 2	
Serial number		SRCL 215	SRCL 301	SRCL 385	SRCL 406	SRCL 506	HL 78 - 83	
Date		21.05.2004	19.06.2004	28.07.2004	07.08.2004	26.09.2004	07.08.2004	
Time		16:00	12:00	08:00	16:00	16:00	17:00	
Analysed by		NEA-SRCL	NEA-SRCL	NEA-SRCL	NEA-SRCL	NEA-SRCL	Hydro Lab	
Method		Sieving	Sieving	Sieving	Sieving	Sieving	VA Tube	
Label		SRCL-215	SRCL-301	SRCL-385	SRCL-406	SRCL-506	HL-VAT	
Particle size d (mm)	1	100	100	100	100	100	100	Percent of sample finer than d
	0,5	100	100	100	100	100	100	
	0,35	100	100	100	100	100	97	
	0,25	100	100	100	100	100	90	
	0,175	100	100	***86***	***88***	100	78	
	0,125	100	100	69,83	74,19	100	66	
	0,088	***88***	***85***	***50***	***61***	***70***	54	
	0,0625	66,67	59,18	32,96	48,39	33,33	48	
Concentration		22	16	54	367	317	692	(ppm)
Weigth sample		0,074	0,052	0,173	1,2052	1,0315	3,3442	(grams)
Sandbreak		33	41	67	52	67	52	(%)

Upper Tamakoshi Hydroelectric Project | Norconsult for Nepal Electricity Authority

Observed Particle Size Distribution of Suspended Sediments



Ref. computed TE	Computed trap efficiency of the fines and the sand respectivelly for adopted PSD							
	Discharge	Shear of load trapped in basins			Shear of load passed through basins			
	intake	of all	of fines	of sand	of all	of fines	of sand	Remark
	Q = 72.6	54,7	21,1	90,3	45,34	78,93	9,66	flushing
	Q = 66.0	**56,0**	**22,3**	**91,9**	**43,97**	**77,74**	**8,11**	**no fl.**
	Q = 48.4	60,1	26,4	96,0	39,88	73,63	4,03	flushing
	Q = 44.0	**61,4**	**28,0**	**96,9**	**38,57**	**71,98**	**3,10**	**no fl.**

Figure 3.18: Observed Particle Size Distributions in 2004

3.12.4 Sediment Yield Estimate

The issue of measured and unmeasured sediment load is addressed above. As the data series from July 2001 through June 2004 is found to be vulnerable to error, the available data is not sufficient to make a reliable sediment yield estimate.

Based on the short data records from 2004 the total annual sediment load at Lamabagar in 2004 is estimated to be in the range from 400,000 tonne to 800,000 tonne. The corresponding specific yield in 2004 is in the range from about 230 to 460 tonne/km^2/year. 2004 is, however, considered to be a year with lower sediment load than average. Average annual sediment yield is therefore expected to be considerably higher than the above figures.

Dr. Vick Gally has in cooperation with WECS established a method for preliminary estimation of sediment yield in Nepal based on distribution of catchment area with respect to physio-graphic zones. Main parameters here are elevation distribution of the catchment and an average sediment yield for each of these physiographic zones as shown in Table 4.2.5.

Table 3.14: Sediment yield estimate based on physiographic zones (after V. Gally)

Physiographic zone	Elevation band (masl)	Specific sediment yield (tonne/km2/year)	Catchment within zone (km2)	Computed sediment yield (tonne/year)
Terai	Below 200	NA	0	0
Siwalik	200 – 1,000	5,000 – 15,000	0	0
Middle mountain	1,000 – 2,000	3,000 – 8,000	0.27	810 – 2,160
High mountain	2,000 – 3,000	1,000 – 4,000	6.66	6,660 – 26,640
High Himalaya	Above 3,000	300 – 1,000	1,739.07	869,535 – 2,898,450
Tibetan plateau	-	500 – 1,000	-	-
Total			1,746.00	877,005 - 2,927,250

The Tibetan Plateau is a region located in the rain shadow of the Himalayas. The upper part of the Upper Tama Koshi basin is located in Tibet, but it is all draining to the south and is therefore located south of the mountains, which compose the water divide. Nevertheless, some part of it is located in the rain shadow. It is, however, difficult to determine the actual part of the catchment in the rain shadow, as the monsoon climate is shortcutting into the plateau through valleys like Tama Koshi. As seen in Table 4,2,5, there is no difference between high Himalayas and the Tibetan plateau with respect to estimated specific sediment yield for the upper limit value.

This method gives an average specific sediment yield between 500 and 1,700 tonne/km^2/year. For planning purposes it is recommended to use the somewhat conservative estimate of the specific sediment yield of 1,400 tonne/km^2/year for UTK HEP.

3.13 Glacial Lake Outburst Flood (GLOF) Risk Assessment

3.13.1 Introduction

Apart from the rain generated flood and land slide generated flood, the Glacier Lake Out burst Flood (GLOF) are one of the key issue affecting the structure nearby the Tama Koshi River. Besides Tsho Rolpa in the Rolwaling catchment, most of the glaciers in the catchment of Upper Tama Koshi HEP V are located in Tibet and were not accessible for direct study in the field.

3.13.2 Previous GLOFs in the upper Tama Koshi basin

The satellite imagery has provided the means of reviewing where GLOF type events may likely have occurred previously based on study of various features in the landscape including:

- Breach through a natural moraine dam
- Evidence of a drained glacial lake
- Existence of a possible source of an ice avalanche to trigger the event
- Typical splay deposits immediately downstream of a breach
- Evidence of slope toe erosion especially on outside meanders downstream of a breach

It is thought that at least 14 former GLOF events have occurred within the UTK basin in

China as listed in Table 5.1 with reference to the tributary, location in terms of UTM co-ordinates and type of event. Characteristics of different types of GLOFs and further details of the findings are found in Appendix D of Chapter 5.

Table 3.15: Likely previous GLOF events in Upper Tama Koshi catchment

	Tributary	UTM (E)	UTM (N)	Altitude (m)	km from dam site	Style of event	Comments
A	Lapcha Khola	417700	3118013	4,875	35	GLOF	Breach from former lake with a volume of ~600,000 m³.
B		420819	3124772	5,330	45		Lake 'a4'
C		432377	3119700	5,420	44	Ice avalanche into former lake	Lake 'a14'; lake 'a15' may have had overtopping of moraine dam but no breach.
D	Rongchar Chhu	436570	3118328	5,335	47.5		Evidence of former shoreline.
E		453603	3113523	5,215	52.5	Old GLOF	Lake 'b18'; limited deposition of material.
F		448793	3101369	5,045	44		Lake 'b28'; outlet has evidence of former shoreline; small event.
G*		447782	3100701	4,900	42	En-glacial outburst	Possible repetitive events
H		439888	3096392	4,610	31	Moraine failure	
I*	Manlung Chhu	439690	3097283	4,890	31.5	Failure of moraine dam at glacier snout; no lake	Possible en-glacial outburst
J	Manlung Chhu	442649	3091682	4,965	37.5	Ice avalanche induced failure, virtual total drainage of lake through a breach	
K	Manlung Chhu	443343	3090600	5,035	39	Moraine/debris-covered ice	Lake 'b32'

	Tributary	UTM (E)	UTM (N)	Altitude (m)	km from dam site	Style of event	Comments
						overtopped by 400 m wide displacement wave that formed 2 main drainage outlets that fed into one main breach.	
L	Manlung Chhu	443446	3090138	5,030	39	Drainage of single lake leaving deeper parts as 2 separate lakes; possibly ice avalanche induced.	Lakes 'b34'; perhaps triggered by/related to drainage from lake 'b33'
M*	Manlung Chhu	442794	3090369	4,980	38.5	Outburst from lake by ice cliff – possible repetitive event (?)	Lake 'b35'
N*		431533	3095554	4,560	22	No lake, but possible en-glacial outbursts – repetitive events.	One event occurred between 1996 and 1999.

Events may be en-glacial outbursts rather than GLOFs

3.13.3 Glacier-lake systems in upper Tama Koshi basin

411 lakes, each with an area of more than 1,600 m2, amounting to a total lake area of about 10.66 km2, have been identified by satellite imagery study. Of these lakes, 404 with a total area of 7.92 km2 are located upstream of Lamabagar and 7 with a total area of 1.94 km2 in the Rolwaling catchment.

A major difficulty in GLOF analysis is the lack of knowledge of the volumes of lakes as these are seldom measured directly. By using a state of the art formula for volume estimate based on satellite imagery of the individual area of each lake, the total volume of the 404 lakes upstream of Lamabagar has been estimated to 221.5 million m^3 and the 7

lakes in Rolwaling to 100.9 million m3 with an assumed accuracy of ± 20%.
61 of the larger lakes, each with area above 2 ha and with estimated volumes in the range 0.24 - 92 million m3, have been given closer attention in the GLOF Risk Assessment Study, the largest ones already being possible sources of GLOF events and the smaller ones having a potential for growth to pose a threat in the future.

Of the 61 lakes 6 are located within the catchment of Rolwaling Khola i.e. within Nepal. Among them is Tsho Rolpa, the largest of them all with a current area of about 1.5 km2 and an estimated volume of about 92 million m3. The other 55 are located on the glaciers in Tibet. 37 lie in the eastern and northeastern parts of the catchment draining towards Rongchar Chhu, the main tributary from northeast. Here is the second largest lake with a conglomerate of adjacent smaller lakes located with an estimated total volume of about 48.5 million m3. 18 lakes are located in the northern and northwestern part of the catchment draining towards Lapche Khola, the main tributary from north. The largest lake in this part of the catchment has an estimated current volume of about 8.1 million m^3.

All lakes with an estimated dammed volume at present of more than 4 million m^3, in total 14 lakes, have been studied further as regards current GLOF hazards according to an empirical rating system applied on relevant physical risk parameters. For further explanation of the score system applied and details of the hazard assessment of the selected lakes, see Appendix D, Sub-chapter 4.5 of Upper Tama Koshi HEP.

The conclusion regarding the current risk posed by these 14 lakes is that 5 represent a minimal hazard, 4 represent a moderate hazard, 3 (including Tsho Rolpa) represent a high hazard and two represent a very high hazard. Both lakes with the very high hazard score are located in China in the catchment of Rongchar Chhu. Their estimated volumes are 25 million m3 and 48.5 million m3, respectively.

For lakes with moderate to very high hazard score, it is Dr Reynolds' opinion that an outburst may occur at any time. Experience from earlier events is that the most probable time of the year for GLOFs is the peak of the monsoon season, while GLOFs triggered by earthquake may occur at any time of the year.

An important feature of glacial lakes is the rapid development over time compared to the lifetime of an infrastructure project like UTK HEP. Within ten to twenty years it seems likely that several existing small ponds located on the largest glaciers in the Lapche Khola catchment in Tibet may have coalesced into large supra-glacial lakes, which is a type that can develop high risk for GLOFs.

3.13.4 GLOF Hazards to the Project

As stated earlier, seven identified glacial lakes upstream of project including Tsho Rolpa pose an existing serious GLOF hazard. Further, five glaciers are considered likely to form large supra-glacial lakes of the same order as Tsho Rolpa in Rolwaling, with comparable hazards, within the life span of the project.

The upper Tama Koshi HEP that there is a very real threat of a GLOF occurring from the catchment upstream of the project and that the most likely time of the year is during the peak of the monsoon. Any one of the 7 identified key lakes could generate a GLOF in any year. At present, lake "b32"1 on Manlung Chhu, a tributary to Rongchar Chhu, represents the largest hazard and the largest estimated potential GLOF volume of about 16 million m3.

Lake "b32" is located only some 38 km upstream of Lamabagar and and about 48 km upstream of the project. Tama Koshi flows through a very narrow gorge before opening out onto the flat plains of the village area. Potentially, from the time of a sudden breach at lake "b32", a GLOF may reach the gorge in around 1½ hour. Most of the travelling stretch lies in China. At a discharge rate of 5,000 m3/s, and a speed of 7 m/s (~25 km/h), in a gorge with a width of only 20-25 m, the height of the flood wave could be in the range of 28-36 m. With an initial flow of 5,000 m3/s and a total volume of 16 million m3 the release of most of the volume could take some 2-3 hours with the water flow gradually decreasing although probably coming in several pulses.

3.13.5 Hazards Posed by Tsho Rolpa

For the time being Tsho Rolpa remains Nepal’s largest glacial lake with potential for producing the largest GLOF. The maximum lake depth measured by recent bathymetric survey is 142 m, an increase of 12.5 m since the previous measurement. The increase is probably caused by ice melt at the base of the lake. There is some uncertainty as to the present volume of the lake. The measured area of the lake based on latest satellite imagery is 1.54 km2, with an estimated volume of 94.4 million m3. The volume of a maximum probable GLOF is estimated at around 50 million m3.

Although interim remedial measures were constructed in 1999-2000 in the form of a channel and sluice gates and the lake level was lowered successfully by 3.5 m, ice within the moraine continues to melt, which continues to give considerable cause for concern.

Of greatest concern perhaps is the area associated with the north estern part of the terminal moraine. Here thermo-karstic degradation of the buried ice is occurring and has resulted in periods of extremely rapid lowering of the moraine surface over very short periods of time. As this ice continues to ablate, there will come a point when the lake water may find its way through the moraine by the various crevasse traces that are known from geophysical imaging to be present. There is a real possibility, therefore, that unless the current lake level is reduced significantly, by at least a further 11.5 m, that the lake water could break through the terminal moraine.

As stated in previous sub-chapters it is believed that the catchment upstream of Lamabagar may have potential to release as much as 16 million m^3 in a single event and create an incoming wave with a maximum flow of about 5,000 m^3/s from the gorge upstream of Lamabagar. The worst-case event from Tsho Rolpa is indicated with a total volume of 50 million m^3 and a maximum release flow of 6,500 m^3/s. As the confluence of Rolwaling Khola with Tama Koshi is downstream of the natural dam at Lamabagar a GLOF from Tsho Rolpa will not have direct impact on the project components at Lamabagar. The figures above have been applied as a guideline when using 40 m as minimum difference in elevation from the riverbed to safe locations of project facilities along the river downstream of Chetchet.

4. Geology and Geotechnical Investigation

4.1. General

The Tamakoshi V Hydroelectric Project is a cascade development scheme of Upper Tamakoshi HEP with installed capacity of 87MW, which is located in Dolkha District of Janakpur Zone in the Central Development Region of Nepal. Powerhouse Site is located at Suritar and interconnection system for cascade scheme is located at Mathillo Jagat which is on Charikot-Lamabagar access road of Upper Tamakoshi project.

4.2. Objective

The main objective of the Geology and Geotechnical Investigation is to carry out field investigation work and find out the surface geological condition of the project area; to design the support pattern for the underground structures. The results obtained from the investigation work will be used to assess the technical viability of the project for the Feasibility Study.

4.3. Scope of Work

The main scope of work was to carry out the present investigation comprises manly of geological and engineering geological mapping, core drilling investigations, seismic refraction survey and test pit excavation with laboratory testing.

The scope of work in geological mapping was to produce engineering geological maps of the powerhouse site and the headwork site in the scale of 1:1,000 and engineering geological map of tunnel alignment in the scale of 1:10,000. The scope of work also includes the preliminary geotechnical design including stability analysis and rock support classification and design of underground structures.

The purpose of geotechnical investigation was to collect information on overburden thickness, depth of weathering, rock mass quality, permeability, and ground water table and geotechnical properties of soil. The purpose of test pits was to evaluate the thickness of sediment layers and characteristics of soil materials. Different laboratory tests were performed on samples to assess the quality of the materials. The test samples include the soil samples taken from the pit excavation and the rock samples obtained from the core drilling.

4.4 Geology and Geological Mapping

4.4.1 Regional Geology

Geologically, Nepal Himalaya is divided into five major zones, from north to south. A brief summary of these zones follows in order to provide the background information about regional geological condition of the project site.

- **Tibetan Tethys Himalaya**

It consists of fossiliferous Paleozoic and Mesozoic calc-sedimentary rock sequence. The Tibetan Tethys Unit is exposed in only fewer places within the territory of Nepal, while the other four units are distributed from east to west throughout the country. The Tibetan-Tethys Zone begins at the top of the Higher Himalayan Zone and extends to the north in Tibet. This zone composed of sedimentary rocks such as shale, limestone and sandstone.

- **Higher Himalaya**

Geologically, the Higher Himalayan Zone includes the rocks lying north of the Main Central Thrust (MCT). Two sub-units namely Higher Himalayan Crystallines and Tibetan Sedimentary Zone are identified in Higher Himalayan Zone. This zone consists of an approximately 10 km thick succession of crystalline rocks. The Higher Himalayan Crystalline zone comprises mainly Precambrian high-grade metamorphic rocks such as kyanite-silliminite-bearing gneisses, schists, quartzite and marbles form the basement of this zone. Migmatites and Granites are found in the upper part of this zone. The Higher Himalayan Crystallines are underlain by fossi ferrous Tibetan Sedimentary Zone. This zone is composed of fossiliferous sedimentary rocks, such as shale, limestone, slates and sandstone, ranging in age from Lower Palaeozoic to Mesozoic. Most of the great Himalayan peaks of Nepal, including Mt. Everest, Manaslu, Annapurna, and Dhaulagiri, belong to the Tibetan Sedimentary Zone.

- **Lesser Himalaya**

The Lesser Himalayan Zone is characterized by a broad belt of folded and faulted Precambrian to Pliocene rocks developing a number of thrusts and nappes. It is separated from the Higher Himalayas by the MCT in the north and from the Sub Himalayas by the

MBT in the south. The Lesser Himalayas are mostly comprised of unfossiliferous, sedimentary, and metasedimentary rocks such as slate, phyllite, gneiss, schist, quartzite, limestone, dolomite, etc. There are also some granitic intrusions in this zone.This zone is divided into three sub-units namely Lesser Himalayan Metasediments, Lesser Himalayan Crystallines and Igneous Rocks.

- **Sub-Himalaya (Siwaliks)**

The Himalayan Frontal Thrust (HFT) bound this zone on the south and the Main boundary Thrust (MBT) on the north. The zone comprises generally north dipping sedimentary rocks of the Neogene age. The Lower Siwaliks consists of finely laminated, siltstone, sandstone, and mudstone. The Middle siwaliks are comprised of medium to coarse-grained sandstones. The Upper Siwaliks are comprised of conglomerate and boulder beds.

- **Gangetic Plain**

The Gangetic Plain forms the southern fringe of Nepal Himalaya which consist mainly of alluvial deposits of Pleistocene to Recent age are derived from the erosion of sediments from the Himalayas. This zone is separated from the Sub-Himalayas by the Himalayan Frontal Thrust (HFT) and is the northern edge of the Indo-Gangetic plain to the south.

4.4.2 Seismicity

4.4.2.1 General

The evolution of the Great Himalayan Arc is the result of collision between the Indian and Eruration Tectonic Plates over a distance of 2400 km from Pakistan in the west and Burma in the east. The Himalayas are located near plate boundary. Therefore, the Himalayan region is considered to be seismically active zone. Thus, being a part of Himalayas, Nepal Himalaya is considered to be active seismic zone. However, the existence of tectonic features such as Main Central Thrust (MCT), Main Boundary Thrust (MBT) and Himalayan Frontal Fault (HFF) further accelerates the rate of seismic risk. Therefore, proximity to such structural features is important while assessing the seismicity of the hydroelectric project.

4.4.2.2 Main Central Thrust (MCT)

This is the tectonic contact between the Higher Himalayas and Lesser Himalayas. It is a north dipping thrust fault which at one time was a convergent plate boundary. The MCT was active during the early phases of Himalayan orogeny but is now considered to be less active as compared to Main Boundary Thrust (MBT). Based on historical records (1800's to 1986) the largest earthquake recorded in the MCT zone in the Himalaya was a 7.5 magnitude event in August 28, 1916. The project area is located at the MCT Zone.

4.4.2.3 Main Boundary Thrust (MBT)

This is the active tectonic contact between the Lesser Himalayas and the Siwaliks. The MBT has been the source of very large earthquakes in the past. It is reported that the maximum potential earthquakes in this feature has a magnitude of 8.0. The project site is located at about 75 km north of MBT which is considerably at greater distance. Therefore, less seismic risk associated with this feature is expected for the project.

4.4.2.4 Himalayan Frontal Fault (HFF)

This is a tectonic feature located at the boundary of the Siwalik and the Terai. This fault is also considered to be active. The maximum earthquake potential of this fault is 6.5 in magnitude. The project site is located very far (more than 100 km) from this feature hence less seismic risk caused due to this feature is expected.

4.4.2.5 Seismicity Evaluation

Nepal has experienced a number of large earthquakes in the past which has caused substantial damage of life and property. A micro seismic epicenter map of Nepal Himalaya and adjoining region (1:2000000) prepared by National Seismological Centre, Dept. of Mines and Geology, 1997. The map shows the distribution pattern of the earthquake epicenters in Nepal and adjoining region.

The specific project related seismic studies have not been carried out so far. The records of seismic activities are limited in the Nepal Himalayas and hence correlation of seismic events with adjacent Himalayan region would be a useful source of information for designing the hydraulic structures.

Several seismicity studies have been carried out for the various projects in the country during the engineering design phases and seismic design coefficients are derived for those projects. There is no well established theory about the relationship between the maximum acceleration of the earthquake motion and the value of the design seismic coefficient.

However, there are several methods to convert the maximum acceleration of the earthquake motion into the design seismic coefficient. Generally three methods i.e. simplest method, Empirical method and Dynamic analysis using dynamic model are common to establish the seismic coefficient. The simplest method is represented by $\alpha = A_{max}/980$, where α = Design Seismic Coefficient and A_{max} = Maximum acceleration of the motion (gal). However, this method will evaluate rather large value of seismic coefficient compared with the real value. The empirical method is denoted by $\alpha_{eff} = R\ \alpha = R\ A_{max}/980$. Where the α_{eff} is effective design coefficient and R is Reduction Factor (Empirical value of R is approximately (0.5 – 0.65). The results obtained from this method are found to be similar in the recent studies carried out by using the dynamic analysis and the static analysis. Therefore, this method is considered to be most common method to establish the design seismic coefficient at present. The third method is Dynamic Analysis Method using Dynamic model. This method is considered to be most reasonable method at present. However, to apply this method the parameters like design input motion, the soil structure model, the properties of rock materials etc. are to be known. Therefore a detailed study is required to use this method. Therefore, empirical method is considered to be reliable method to establish the design seismic coefficient for this level of the study.

A project specific seismicity study nearest to Tamakoshi V HEP has been carried out for the Upper Tamakoshi Hydroelectric Project and the recommended Maximum design seismic coefficient is 0.51. Upper Tamakoshi Hydroelectric Project lies in Koshi Basin and the Tamakoshi V HEP is also located in the same river basin. The Tamakoshi V Hydroelectric Project is a cascade project and it will trap the tailrace water of the Upper Tamakoshi HEP.

The design seismic coefficient for the Tamakoshi V Hydroelectric Project is derived based on above empirical method and seismic coefficient recommended for Upper Tamakoshi Hydroelectric Project. The evaluation of seismic coefficient for the Tamakoshi V HEP is made during the present study based on Nepalese standard and Indian standard.

- **Nepalese Standard**

In order to determine the seismic coefficient a seismic design code for Nepal has been prepared. The country is divided into three seismic risk zones based on allowable bearing capacity of three types of soil foundation. Tamakoshi V HEP is located in the third seismic risk zone of Nepal shown in Fig No. 1 and the soil foundation at the headworks site belongs to average soil type. Therefore, the basic horizontal seismic coefficient is considered to be 0.08. By using above empirical method, the effective design coefficient according to seismic design code of Nepal is given by the equation,

$\alpha_{eff} = R * \alpha = R * A_{max}/980$

Where, α_{eff} = effective design seismic coefficient
R = Reduction Factor (Empirical value of R = 0.5 – 0.65)

For the maximum acceleration of 250 - 300 gal, according to Seismic Hazard Map of Nepal (Fig No.4.2), Published by DMG, National seismological Center, September 2002 and reduction factor of 0.5, the calculated effective design seismic coefficient for Tamakoshi V Hydroelectric Project is approximately 0.12 to 0.15.

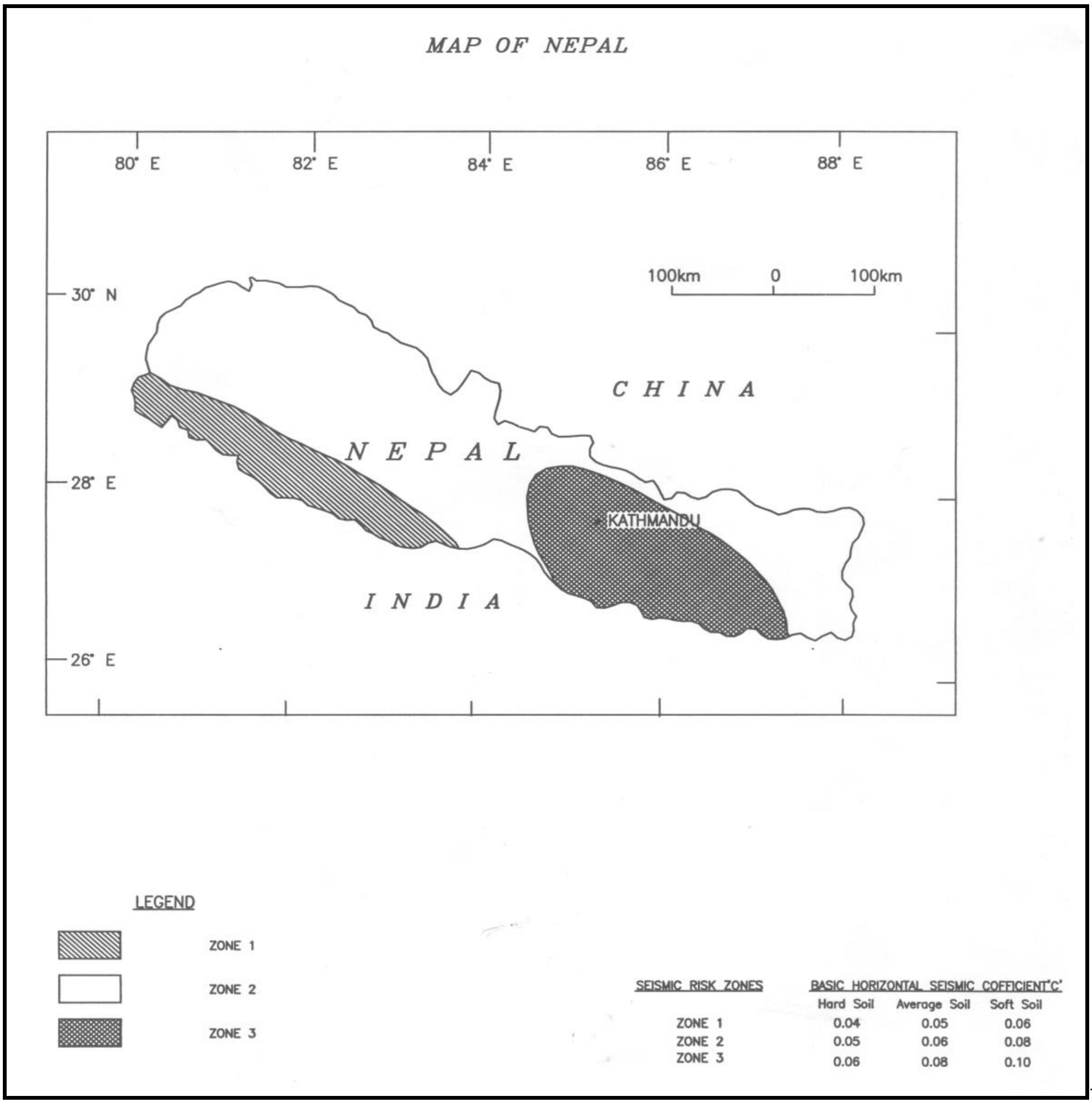


Fig No. 4.1: Seismic Risk Map of Nepal

Fig No. 4.2: Seismic Hazard Map of Nepal

- **Indian Standard**

In order to determine the design horizontal coefficient a seismic risk map for India has been prepared. The map is published in the Indian Criteria for Earthquake Resistant Design of structures. The country is divided into five seismic risk zones in the Indian Standard, Figure No. 4.3. According to seismic risk map of India, Nepal lies in the fourth and fifth seismic risk zone of India. Tamakoshi V HEP is located in the fifth seismic risk zone of India (zone V), and the basic horizontal seismic coefficient (α_o) can be taken as 0.08.

The design horizontal seismic coefficient in the Indian Standard is defined by the equation,

$$\alpha_h = \beta * I * \alpha_o$$

Where, α_h = Design horizontal seismic coefficient

β = Soil foundation factor (1 for dam)

I = Importance factor (2 for dam)

α_o = Basic horizontal seismic coefficient

Therefore, the design horizontal seismic coefficient for Tamakoshi V HEP dam is 0.16 according to the Indian standard.

By comparing all above evaluations and recommended seismic coefficient for Upper Tamakoshi HEP, the design horizontal seismic coefficient for the Tamakoshi V HEP can be taken as 0.51 for the present level of study.

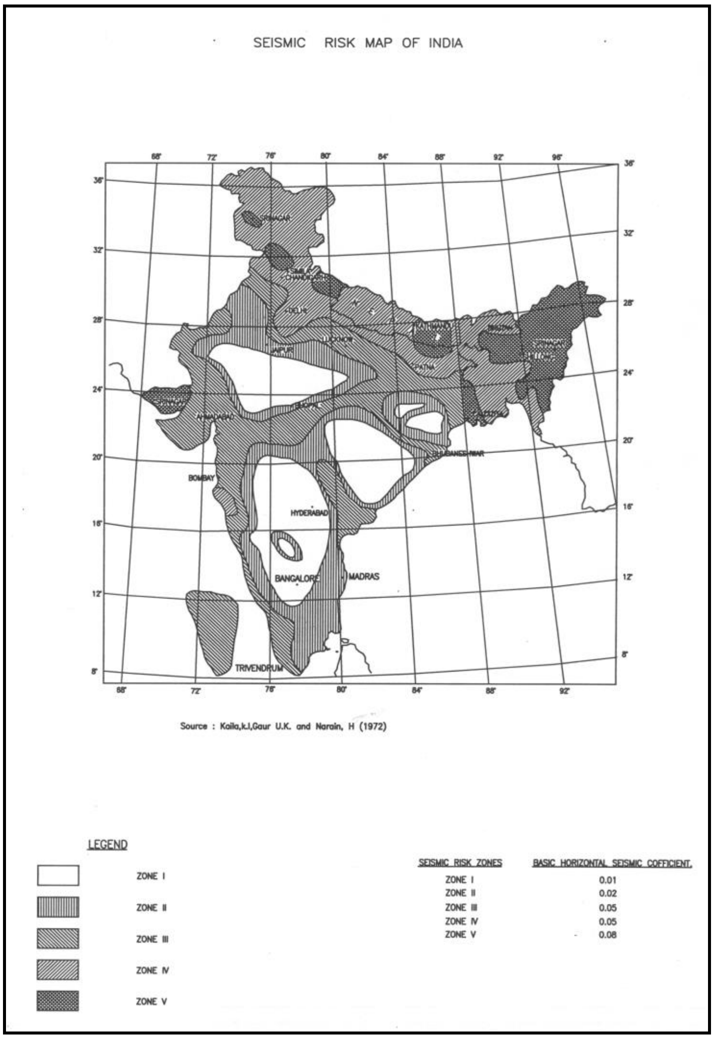


Fig No. 4.3: Seismic Risk Map of India

4.4.3 Geology of Project Area

Tamakoshi-V Hydroelectric Project belongs to Higher Himalayan crystalline Zone which consist mostly Precambrian gneiss, quartzite and marble. This zone is separated from the Tibetan-tethys zone in the north and lesser Himalaya beyond MCT in the south.

The project area lies at the Tamba Kosi Window (Fig No. 4.4). The main lithology of Tamba Kosi Window is gneiss, augen gneiss and crystalline schist. The main soil types in the project area are alluvium and colluvium deposit.

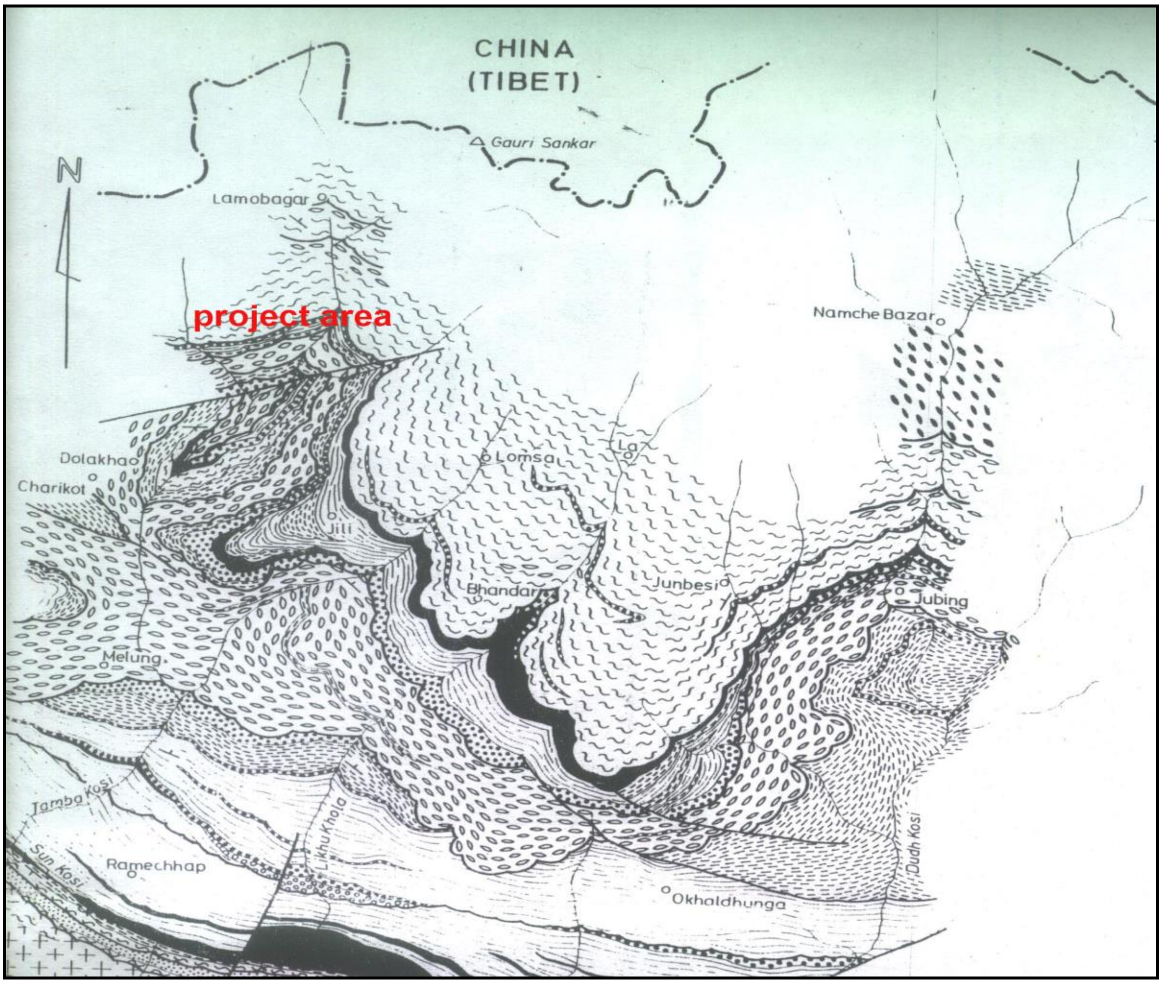


Fig No.4.4: Regional geological map of the project area. (After Ishida and Ohta 1973)

4.4.3.1 Headworks Site

Interconnection Area

The inlet portal is located at the right bank of Tamakoshi River. The intake interconnection will be made to divert the tail water of Upper Tamakoshi HEP towards the headrace tunnel. The slope around the intake area is very steep. The slope is represented by rocky cliff with thin colluvium.

The rock observed at the headworks site consists of medium to thickly foliated, fresh to slightly weathered, grey gneiss with partings of slightly weathered, greenish grey schist. The rock exposure is overlaind by colluvial deposit which is 1-3 m in thickness and comprise of angular to sub-angular gravels to boulders of gneiss in silty sand matrix. The contour density diagram and stereographic projection of major joints is shown in Fig no.4.5 and 4.6 respectively. The attitudes of the discontinuities are as follows.

	Dip/Dip direction	Joint Set
1.	50°/051°	F (Foliation Joint)
2.	55°/308°	J1
3.	55°/234°	J2

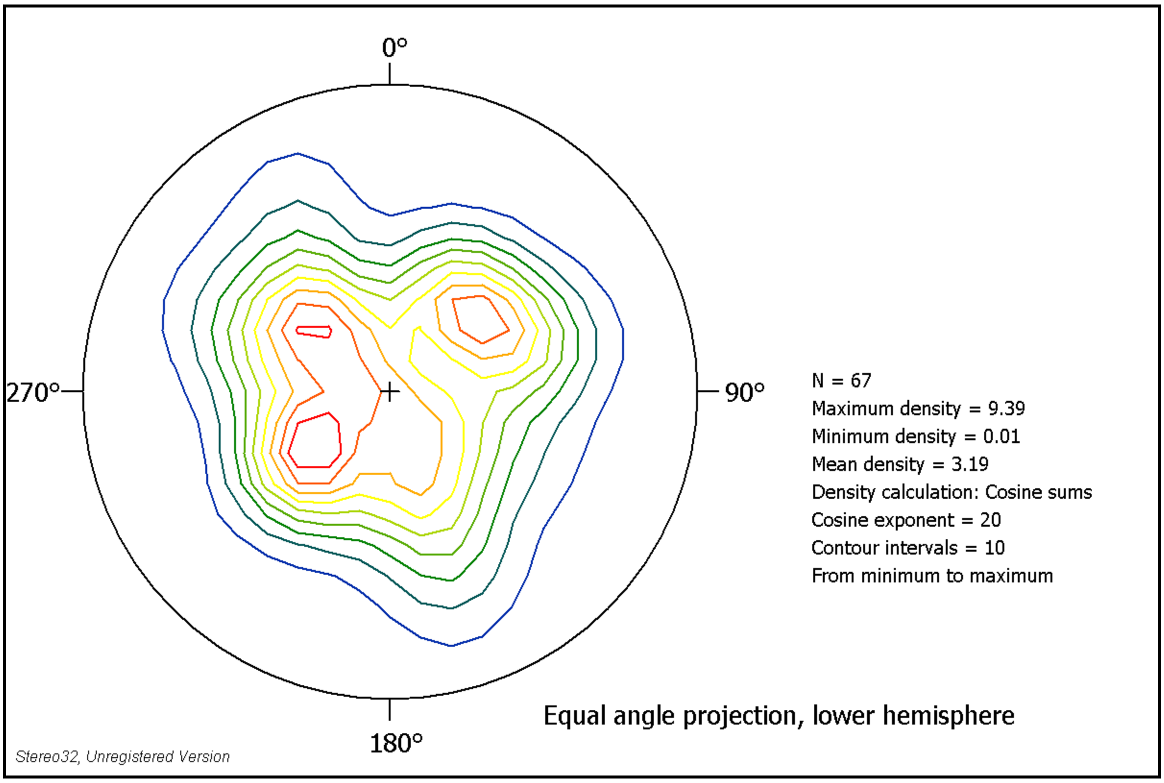


Fig No. 4.5: Contour density diagram of headworks site.

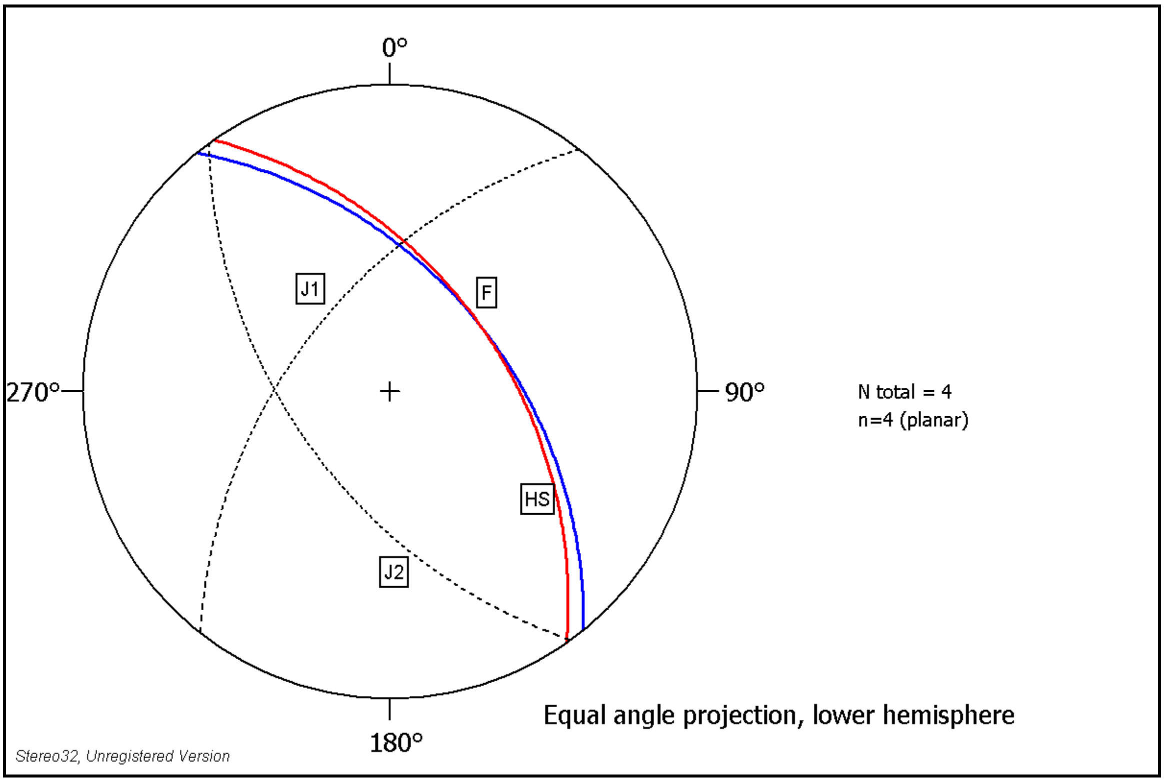


Fig No.4.6: Stereographic Projection of discontinuities of headworks site.

The stereographic projection of discontinuities of headworks site shows the possibility of plane failure of foliation plane with an attitude of 50°/051°. Similarly J2 (55°/234°) has the possibility of toppling failure.

4.4.3.2 Headrace Tunnel

The headrace tunnel is about 8.2 km long and will have a diameter of 5.6 m. The tunnel will pass through the Right Bank of Tamakoshi River. The headrace tunnel passes through gneiss, schist and augen gneiss. A thrust (MCT) also passes through the tunnel alignment. The tunnel passes through mostly on gneiss with partings of schist, crystallized schist, augen gneiss and gneiss intercalated with schist. The percentage of gneiss is about 60%, 30% gneiss and schist intercalation and about 10% of schist with shear zone.

Along the headrace tunnel, the rock encountered from Ch 0+0.00 to 3+450 m and Ch 7+925 to 8+220 m is medium to thickly foliated, fresh to slightly weathered gneiss with partings of greenish grey schist. Two major joint sets with random joints are observed. The stereographic projection of major joints is shown in Fig No. 4.7. The attitudes of the discontinuities are as follows.

	Dip/Dip direction	**Joint Set**
1.	36°/052°	J1 (Foliation Joint)
2.	85°/124°	J2
3.	44°/210°	J3

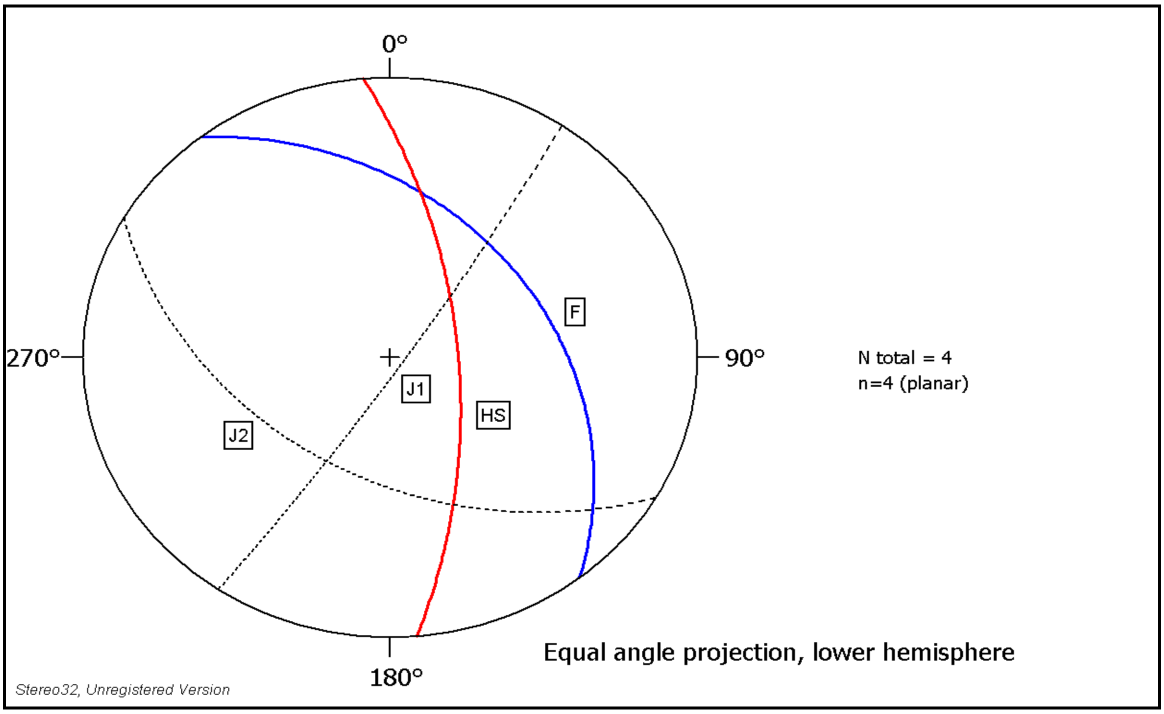


Fig No.4.7: Stereographic Projection of major joints.

From CH 3+450 to 4+150 m, crystalline schist is observed. The crystalline schist is thinly foliated, slight to moderately weathered and dark grey to black grey in color. A thrust (MCT) passes through the tunnel alignment in this section. Shear zones are also observed and the rock mass rating shows poor to very poor rock quality in this section. At present, the MCT is not active. So severe problems may not arise but problems like water seepage and gaseous leakage may arise at the time of tunnel construction. The attitudes of the discontinuities are as follows.

	Dip/Dip direction	Joint Set
1.	35°/070°	J1 (Foliation Joint)
2.	66°/165°	J2
3.	56°/225°	J3

From Ch 4+150 to 5+375 m, medium to thickly foliated, fresh to slightly weathered, grey augen gneiss is observed. The attitudes of the discontinuities are as follows.

Dip/Dip direction	Joint Set

1.	38°/025°	J1 (Foliation Joint)
2.	80°/115°	J2
3.	51°/230°	J3

From 5+375 to 8+220 m, the rock encountered is thin to mediumly foliated, fresh to slightly weathered, grey gneiss intercalated with thinly foliated, fresh to slightly weathered, grey schist. The attitudes of the discontinuities are as follows.

	Dip/Dip direction	**Joint Set**
1.	29°/033°	J1 (Foliation Joint)
2.	42°/135°	J2
3.	48°/188°	J3

Preliminary Rock Support based on surface geological investigation

The rock mass classification has been carried out for the rock mass along the tunnel alignment based on detailed joint mapping on surface rock outcrops along the tunnel alignment. Geomechanical classification using both Rock Mass Rating (RMR) system (Bieniawski, 1989) and Tunneling Quality (Q) (Stillborg, 1994) for the jointed rock mass has been carried out and the rock mass along the tunnel has been classified based on these classifications are shown in Table No. 4-1 and Table No. 4-2 respectively. The summary of the rock mass classification is shown in Table No 4-3.

Table No. 4-1: Rock Mass Classification using RMR System (Bieniawski, 1989)

Rating	**100 - 81**	**80 – 61**	**60 - 41**	**40 - 21**	**<21**
Class Number	I	II	III	IV	V
Description	Very good rock	Good rock	Fair rock	Poor rock	Very poor rock

Table No.4- 2: Rock Mass Classification from Rock Tunneling Quality Index, Q (Stillborg, 1994)

Q – Value	Rock Mass Description	Class number
> 40	Very good rock	I
10 – 40	Good rock	II
4 – 9	Fair rock	III
1 – 3	Poor rock	IV
< 1	Very poor rock	V

Table No. 4-3: Summary of rock mass classification along Headrace Tunnel.

Rock Type	Gneiss with schist partings	Schist	Augen Gneiss	Gneiss & Schist intercalation
RMR Value	62	16	67	37
Q - Value	9.52	0.56	10.18	3.2
Rock Class	III	V	II	IV
Support Class	S3	S5	S2	S4

The following preliminary rock support design for underground structures has been recommended based on rock mass classification.

Table No. 4-4: Preliminary Rock Support Pattern for Tamakoshi V HEP

<table>
<tr><th rowspan="3">S. No .</th><th rowspan="3">Structure</th><th rowspan="3">Location</th><th rowspan="3">Fibrereinforced Shotcrete</th><th rowspan="3">Concretelining</th><th colspan="4">Rock Bolts, ϕ = 25 mm</th></tr>
<tr><th rowspan="2">Type</th><th rowspan="2">Length</th><th colspan="2">Spacing</th></tr>
<tr><th>In-plaine</th><th>Out-of Plane</th></tr>
<tr><td>1</td><td colspan="8">Headrace tunnel (L=8.65 km, Excavated dia. = 6.4 m)</td></tr>
<tr><td rowspan="2">1.1</td><td rowspan="2">Support Type– S2 (Rock Class-II) (Good Rocks)</td><td>Crown</td><td>50 mm</td><td rowspan="2">-</td><td>Grade 60</td><td>3.0 m</td><td>2 m</td><td>2 m</td></tr>
<tr><td>Sidewalls</td><td>50 mm</td><td>Grade 60</td><td>3.0 m</td><td>2 m</td><td>2 m</td></tr>
<tr><td rowspan="2">1.2</td><td rowspan="2">Support Type– S3 (Rock Class - III) (Fair Rocks)</td><td>Crown</td><td>100 mm</td><td rowspan="2">-</td><td>Grade 60</td><td>3.0 m</td><td>1.5 m</td><td>1.5 m</td></tr>
<tr><td>Sidewalls</td><td>100 mm</td><td>Grade 60</td><td>3.0 m</td><td>1.5 m</td><td>1.5 m</td></tr>
<tr><td rowspan="2">1.3</td><td rowspan="2">Support Type– S4 (Rock Class - IV) (Poor Rocks)</td><td>Crown</td><td>100 mm</td><td rowspan="2">300 mm</td><td>Grade 60</td><td>4.0 m</td><td>1.00 m</td><td>1.00 m</td></tr>
<tr><td>Sidewalls</td><td>100 mm</td><td>Grade 60</td><td>4.0 m</td><td>1.00 m</td><td>1.00 m</td></tr>
<tr><td rowspan="2">1.4</td><td rowspan="2">Support Type– S5 (Rock Class - V) (V Poor Rocks)</td><td>Crown</td><td>100 mm</td><td>300 mm with steel ribs of ISMB 200 X 100 at 1.00 m spacing</td><td>Grade 60</td><td>4.0 m</td><td>1.00 m</td><td>1.00 m</td></tr>
<tr><td>Sidewalls</td><td>100 mm</td><td>,,</td><td>Grade 60</td><td>4.0 m</td><td>1.00 m</td><td>1.00 m</td></tr>
</table>

4.4.3.3 Surge Tank

The surge tank is located on the right bank of the Tamakoshi River above Bhorle Village. The rock exposed at the surge tank area consists of medium to thickly foliated, fresh to slightly weathered, grey gneiss with partings of greenish grey schist.

4.4.3.4 Powerhouse Site and Tailrace Tunnel Site

The power house site is located at the right bank of the Tamakoshi River at Bhorle. The rock exposure observed at the power house site consists of medium to thickly foliated, fresh to slightly weathered, grey gneiss with partings of greenish grey schist. The contour density diagram and stereographic projection of major joints is shown in Fig no.4.8 and 4.9 respectively. The attitude of major joint sets at the power house site is:

	Dip/Dip Dir	**Joint Set**
1.	19°/288°	F (Foliation Joint)
2.	67°/085°	J1
3.	40°/220°	J2

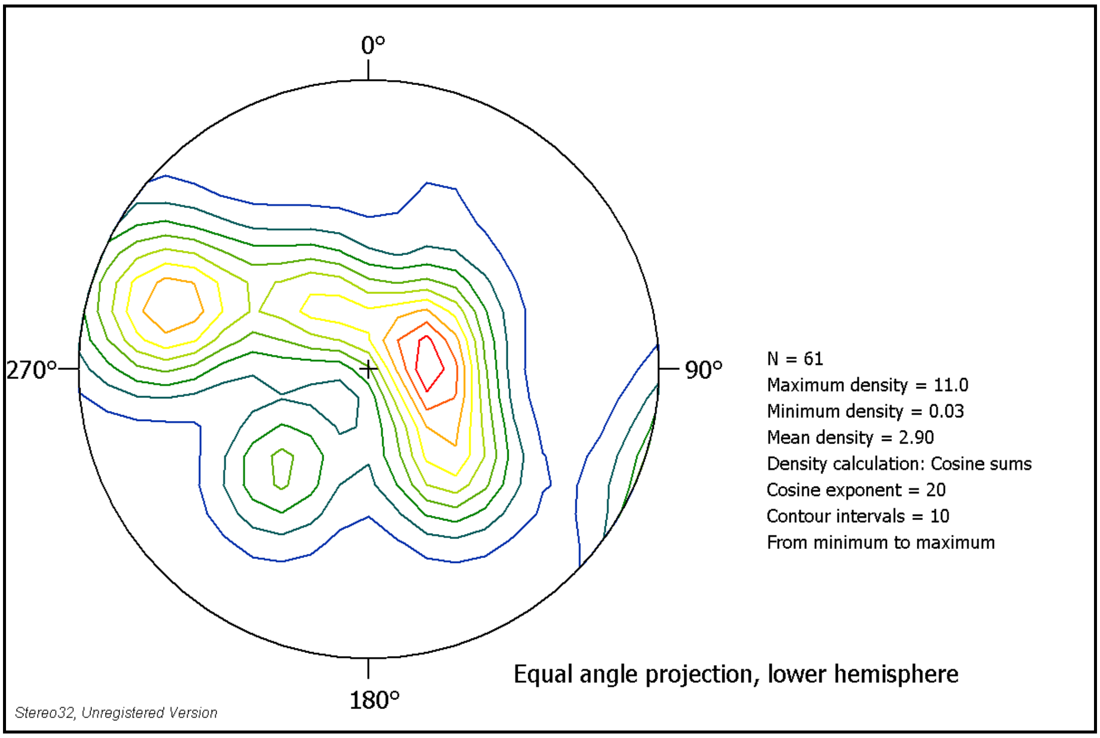


Fig No. 4.8: Contour density diagram of power house site.

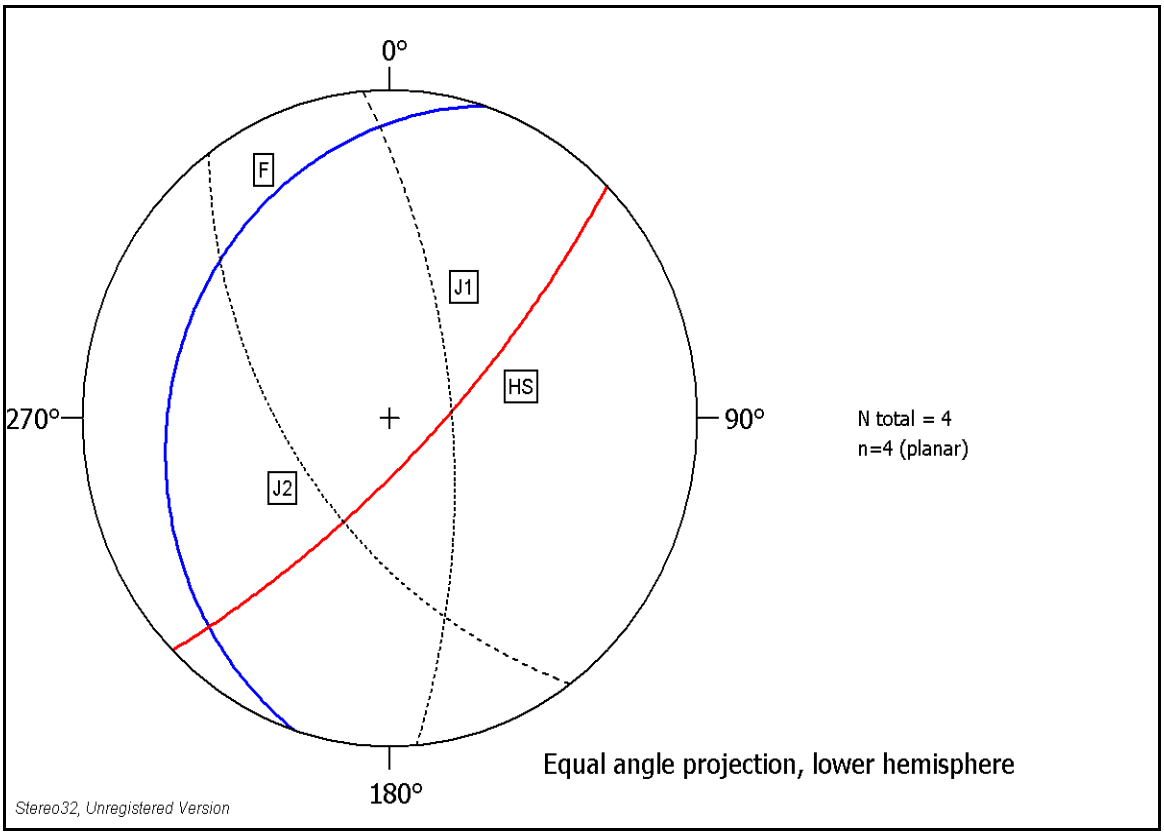


Fig No. 4.9: Stereographic Projection of discontinuities of powerhouse site.

The stereographic projection of discontinuities of power house site (Fig No. 3.11) shows the possibility of wedge failure of the wedge made by J1 (67°/085°) and J2 (40°/220°).

The tailrace tunnel passes through the rock outcrop consisting of medium to thickly foliated, fresh to slightly weathered, grey gneiss with partings of greenish grey schist and alluvial deposit. The alluvial deposit in tailrace tunnel consists mainly of rounded to sub-round boulders and gravel of gneiss in silty sand matrix.

4.5 Test Pit Excavation and Laboratory Test

4.5.1 Introduction

The field exploration has been conducted by pitting method in which test pits of depth up to 3.0 m have been excavated manually with the help of hand shovel. The size of test pits is 1.0 m X 1.0 m. the exploration depth, mainly depends on the site condition. Different samples have been collected for different types of soil encountered in the test pit. In general delineation of the soil in the field is based on soil colour. Field sieve size of 150 mm and 80 mm were used to determine oversize. The fraction passing from 80 mm sieve has been transported to the SRCL, Kathmandu for further laboratory testing such as grain size, specific gravity, shear test and other.

All the laboratory test and analysis have been carried out according to the relevant ASTM, AASHTO and IS standard procedure depending upon their suitability.

4.5.2 Objective

The main objective of the investigation work is to find out engineering and index properties of the construction material collected from the sites.

4.5.3 Scope of Work

The main scope of works to meet the above objectives includes the following activities.

- **Site Investigation**

Following field investigation works have been carried out to collect samples for testing the material in the laboratory.

A total 13 nos. of test pits have been opened up (each of maximum of 3 m at the selected points on the project areas) in the proposed locations. Among them 10 nos. were for granular material and 3 nos. were for the cohesive material. Disturbed samples have been collected from all 13 test pits. Twelve nos. of samples were taken from granular test pits and 3 nos. of samples were from cohesive test pits. Logging of all test pits have been done to study the nature and type of soil strata.

- **Laboratory Testing**

Following tests have been carried out on samples collected from test pits.

- Sieve Analysis
- Unit weight
- Specific gravity
- Direct shear test

- Maximum density
- CBR ,Unsoaked
- Aggregate crushing value
- Aggregate impact value
- Sodium Sulphate Soundness
- Los Angels Abrasion Test
- Alkali Reactivity
- Mica Content
- Natural Moisture Content
- Proctor Test
- Atterberg Limits
- Permeability Test

And the following tests have been carried out for the rock cores and overburden samples.

- Point Load Test
- Specific Gravity
- Uniaxial Compressive Strength
- Unit Weight
- Water Absorption
- Alkali Reactivity

4.5.4 Methodology

The field exploration was conducted by pitting method in which test pits of depth up to 3 were excavated manually with the help of peak and hand shovel. The size of test pits was 1.50 m x 1.50 m. The depth of pits was varying mainly, based on the site condition. Representative samples were collected for different layers of soil strata encountered in the test pit. Test pit logging was done delineating the soil color, grading, physical character and ground water condition. The collected samples were transported to the Soil, Rock and Concrete Laboratory, NEA. Bhagwanpau, Swoyambhu, Kathmandu for basic index and engineering properties tests and analysis.

Relevant laboratory tests were conducted based on material type as grain size, Unit weight, and Specific gravity etc. as mentioned above.

- **Disturbed Samples**

A total of 15 disturbed samples have been collected during field exploration from pitting and collected samples have been well packed and transported to SRC Laboratory, NEA. Bhagwanpau, Swayambhu, Kathmandu for further laboratory testing.

4.5.5 Laboratory Investigation

i) General

In order to determine the relevant engineering and index properties of the construction material the representative samples were subjected to various laboratory tests. All the laboratory tests have been conducted following standards procedure suggested by ASTM, AASHTO, ISRM and IS code standards. The methodology of laboratory tests and analysis is presented in detail in the following paragraphs. The laboratory test results are summarized in Table.

ii) Sieve Analysis

Sieve analysis has been carried out in the laboratory following the standard method suggested by ASTM D 422 – 63. Sieve analysis was carried out on every sample to determine the percentage of each fraction coarser than 80 micron. Altogether 15 sieve analyses have been carried out during the process. Grain size distribution curve have been prepared for each test, they are presented at appendices.

iii) Unit Weight

The unit weight has been carried out at the site according to AASTHO DESIGNATION: T 19-80 and ASTM DESIGNATION C 29-78.

iv) Specific Gravity Test

The specific gravity of soil specimen collected during the field exploration has been determined by pycnometer method according to ASTM D 854 – 83 standard procedures. In this method a calibrated pycnometer and distilled water under known temperatures are used to determine the specific gravity of soil.

v) Direct Shear Test

The direct shear tests have been carried according to AASTHO DESIGNATION: T - 236 -72 and ASTM DESIGNATION: D 3080-72.

vi) Maximum Density

These tests have been carried out according to ASTM standard.

vii) CBR, unsoaked

These tests have been carried out according to AASTHO DESIGNATION: T 193-81 standard.

viii) Aggregate crushing value

The aggregate crushing value tests have been carried out as per IS code testing procedures.

ix) Aggregate impact value

These tests have been carried out according to IS code testing procedures.

x) Sodium Sulphate Soundness

The sodium sulphate soundness tests have been carried out as per AASTHO DESIGNATION: T 104-77(1982).

Xi) Los Angels Abrasion

Los angels Abrasion tests have been carried out as per AASTHO DESIGNATION: T96-77(1982) recommendation on these tests.

xii) Alkali Reactivity

The alkali reactivity tests have been carried out as per ASTM C 97-83 and according to AASTHO DESIGNATION: T85-81.

xiii) Mica Content

These tests have been carried out according to ASTM standard.

xiv) Natural Moisture Content

These tests have been carried out for the cohesive material according to ASTM DESIGNATION: D 2216-71 and AASTHO DESIGNATION: T 265-79.

xv) Proctor Test

These tests have been carried out for the cohesive material according to ASTM DESIGNATION.

xvi) Atterberg Limits

The Atterberge limits tests have been carried out according to AASTHO DESIGNATION: T 89-81 and T 90-81.

xvii) Permeability Test

The permeability tests have been carried out for the cohesive material according to ASTM and AASTHO DESIGNATION.

xviii) Point Load Test

The point load tests have been carried out as per recommendation of the ISRM commission on testing and interpretation of point load test

xviv) Unit Weight

These tests for core samples have been carried out according to AASTHO DESIGNATIONN: T 19-80 and ASTM DESIGNATION: C 29-78.

xx) Water Absorption

These tests have been carried out according to ASTM C 97-83 standard.

xxi) Uni-axial Compressive Strength

These tests have been carried out according to the recommendation of the ISRM commission on testing of rock samples.

4.5.6 Laboratory Test Results

The soil samples collected during the course of field exploration have been subjected to various tests namely; natural moisture content, grain size distribution, specific gravity, Atterberg limits and proctor tests etc. The test results are summaries in Table – 4-5,4-6, 4-7 and all the tests results have been attached here under the annexure.

Table No: 4.5 Tamakoshi-V Hydroelectricity Project

CONSTANT HEAD TEST

Drill Hole No.: TL 1	Location: Powerhouse Site
Depth:10.50 m	Height:0.15 m
Water Table: 5.00 m	Pipe: NW
Date: 22/01/2067	Soil Type: Alluvium

S.N.	Duration (min)	Infiltration volume (litre)	Infiltration rate (Q=l/min)	Average Q (l/min)	Coefficient of permeability (k = cm/sec)
1	5.00	12.00	2.40	1.87	0.00298
2	5.00	8.00	1.60		
3	5.00	8.00	1.60		

CONSTANT HEAD TEST

Drill Hole No.:TL 1	Location: Powerhouse Site
Depth: 19.50 m	Height: 0.15 m
Water Table: 5.00 m	Soil Type: Alluvium
Date: 31/01/2067	

S.N.	Duration (min)	Infiltration volume (litre)	Infiltration rate (Q=l/min)	Average Q (l/min)	Coefficient of permeability (k = cm/sec)
1	5.00	9.00	1.80	1.53	0.00245
2	5.00	6.00	1.20		
3	5.00	8.00	1.60		

CONSTANT HEAD TEST

Drill Hole No.: TL 1	Location: Powerhouse Site
Depth: 28.00 m	Height: 0.15 m
Water Table: 5.00 m	Pipe: NW

Date: 07/02/2067				Soil Type: Alluvium	
S.N.	Duration (min)	Infiltration volume (litre)	Infiltration rate (Q=l/min)	Average Q (l/min)	Coefficient of permeability (k = cm/sec)
1	5.00	11.00	2.20	1.80	0.00287
2	5.00	8.00	1.60		
3	5.00	8.00	1.60		

Table No 4.6: Tamakoshi –V Hydroelectricity Project

DYNAMIC CONE PENETRATION TEST					
Drill Hole No.: TL-1 Total Depth: 10.50 m Casing: NW Date: 22/01/2067			Location: Powerhouse Site Water Table: 5.00 m Soil Type: Alluvium		
Soil description	No. of Blows			N - Value	Remarks
	15 cm	15 cm	15 cm		
	4 cm at 50 blows				couldn't be penetrated further
DYNAMIC CONE PENETRATION TEST					
Drill Hole No.: TL-1 Total Depth: 19.50 m Casing: NW Date: 31/01/2067			Location: Powerhouse Site Water Table: 5.00 m Soil Type: Alluvium		
Soil description	No. of Blows			N - Value	Remarks
	15 cm	15 cm	15 cm		
	7 cm at 50 blows				couldn't be penetrated further
DYNAMIC CONE PENETRATION TEST					
Drill Hole No.: TL-1 Total Depth: 28.00 m Casing: NW Date: 07/02/2067			Location: Powerhouse Site Water Table: 5.00 m Soil Type: Alluvium		
Soil description	No. of Blows			N - Value	Remarks
	15 cm	15 cm	15 cm		
	5 cm at 50 blows				couldn't be penetrated further

Table No 4.7: Tamakoshi-V Hydroelectricity Project

<table>
<tr><td colspan="6">STANDARD PENETRATION TEST
Drill Hole No.: TL-1 Location: Powerhouse Site
Total Depth: 10.50 m Water Table: 5.00 m
Casing: NW Soil Type: Alluvium
Date: 22/01/2067</td></tr>
<tr><td rowspan="2">Soil description</td><td colspan="3">No. of Blows</td><td rowspan="2">N - Value</td><td rowspan="2">Remarks</td></tr>
<tr><td>15 cm</td><td>15 cm</td><td>15 cm</td></tr>
<tr><td></td><td>7 cm at 50 blows</td><td></td><td></td><td></td><td>couldn't be penetrated further</td></tr>
<tr><td colspan="6">STANDARD PENETRATION TEST
Drill Hole No.: TL-1 Location: Powerhouse Site
Total Depth: 19.50 m Water Table: 5.00 m
Casing: NW Soil Type: Alluvium
Date: 31/01/2067</td></tr>
<tr><td rowspan="2">Soil description</td><td colspan="3">No. of Blows</td><td rowspan="2">N - Value</td><td rowspan="2">Remarks</td></tr>
<tr><td>15 cm</td><td>15 cm</td><td>15 cm</td></tr>
<tr><td></td><td>6 cm at 50 blows</td><td></td><td></td><td></td><td>couldn't be penetrated further</td></tr>
<tr><td colspan="6">STANDARD PENETRATION TEST
Drill Hole No.: TL-1 Location: Powerhouse Site
Total Depth: 28.00 m Water Table: 5.00 m
Casing: NW Soil Type: Alluvium
Date: 07/02/2067</td></tr>
<tr><td rowspan="2">Soil description</td><td colspan="3">No. of Blows</td><td rowspan="2">N - Value</td><td rowspan="2">Remarks</td></tr>
<tr><td>15 cm</td><td>15 cm</td><td>15 cm</td></tr>
<tr><td></td><td>5 cm at 50 blows</td><td></td><td></td><td></td><td>couldn't be penetrated further</td></tr>
</table>

4.6 Seismic Refraction Survey

The seismic refraction survey was carried out with ABEM Terraloc MARK-III seismograph manufactured by Atlas Copco in Sweden. It is a 24-channel seismograph with digitized cassette recording and playback system.

4.6.1 General

The seismic refraction survey was carried out in Tamakoshi 5 Hydroelectric Project to assess the sub-surface geological condition at major hydraulic structure. The seismic refraction survey was carried out in the proposed powerhouse site of option number 1 (Jamune), option number 2 (Suri Tar) and in the place of MCT Zone in Tatopani. The total length of seismic lines in the project is 1.875 kilometers. The main purpose of the study was to estimate the thickness and nature of overburden material at the study area. The descriptions of seismic profiles are given below.

Table No. 4.8: Description of Seismic Profiles at powerhouse site in Jamune

S.No	Seismic Line	Length (m)	Remarks
1	SLP-1	115	
2	SLP-2	115	
3	SLP-3	115	
4	SLP-4	175	
5	SLP-5	175	
6	SLP-6	175	
	Total	735	

Table No. 4.9: Description of Seismic Profiles at Powerhouse site in Suritar.

S.No	Seismic Line	Length (m)	Remarks
1	SLP-7	165	
2	SLP-8	95	
3	SLP-9	85	
4	SLP-10	85	
5	SLP-11	165	
6	SLP-12	130	
	Total	**725**	

Table No. 4.10: Description of Seismic Profiles at hot spring MCT Zone

S.No	Seismic Line	Length (m)	Remarks
1	SLP-13	230	
2	SLP-14	60	
3	SLP-15	65	
4	SLP-16	60	
	Total	**415**	

4.6.2 Objectives

The main objectives of the study were to estimate the thickness and nature of overburden material at the study area.

4.6.3 Equipment

The seismic refraction survey was carried out with ABEM Terraloc MARK-III seismograph manufactured by Atlas Copco in Sweden. It is a 24-channel seismograph with digitized cassette recording and playback system. The geophones or the signal receivers have a natural frequency of 10 Hz with 375 ohms coil resistance. The Terraloc printing unit consists of a thermal printer which is used in the site with the power supply of 12 volts which is supplied by the Terraloc itself. The power supply of the Terraloc consist of six 2 volt 25 Amp-hr. sealed nickel cadmium (Ni-Cd) rechargeable batteries which is charged every day in the field with the help of a 450 watt petrol or kerosene generator. The normal charging time per day varies between 10 and 12 hours. The equipment specification of Seismic Refraction is presented in Table No: 4.11.

Table No. 4.11: Equipment Specification for Seismic Refraction

Item	Specification	Made
ABEM TERRALOC MARK-III SEISMIC SYSTEM	No of channels: 24 Sampling Interval: 24, 48, 100, 200, 500 ms Record length: 1000 samples per trace. Amplifier gain: 6 to 126 dB in steps of 6 dB. A\D Converter: 8 bits (256 level) Memory: 2048 bytes for each of the 24 amplifiers. Storage: high-density cassette recording system. CRT display: 9-inch diagonal. Power supply: 12 V with 6 no 2 V, 25 AH batteries.	ABEM SWEDEN
FIELD PRINTER	Printer type: Thermal printer. Line width: 560 dots or 80 ASCII character. Power supply: 12 Volts.	ABEM SWEDEN
GEOPHONE	Natural Frequency: 10 Hz Sensitivity: 290 D sec/cm Coil impedance: 375 Ohms.	ABEM SWEDEN

4.6.4 Work Crew

The geophysical team consisted of a senior geophysicist and two skilled assistants. The team had been assisted by these two assistants for line spreading and blasting work.
The survey team consists of senior surveyor and two surveyors. All the seismic lines in the ground were established by carrying out the points from the Bench Mark which is in the National grid that is been provided by the Survey Department.

4.6.5 Methodology of Field Works

i) General

The seismic survey has been carried out along lines located and surveyed by NEA Surveyors. The setting of the geophones had been made at an even interval of 5 m. Ground profile of the seismic lines including elevations of each geophone location had been made available by the surveyors.

ii) Seismic Spread Layout

The seismic layout for data acquisition in each of the spreads was arranged in the following manner:

Two geophone cables with 12 takeout points each were spread along the line and the takeout points were fixed to the pegged points. Geophones were connected at 5-m interval at the previously fixed points.

- Each of the geophone cables were connected to the seismograph, 1-12 channel in the first drum and 13-24 channel in the second drum using extension cables wherever necessary.

- All of the 24 geophones were planted firmly on the ground. Wherever the ground condition was too dry and/or loose, it was planted at a depth with good ground connection.

- A trigger cable was extended from the seismograph to the shot point and was connected to the trigger geophone located at the vicinity of the blasting point to avoid delay time between trigger time and the blasting moment.

- The Terraloc operator decides whether the acquired record is satisfactory or not by judging the information visible in the CRT equipment. If the record is good he informs the blaster to prepare for the next point.

- All the recordings were made in similar manner for each of the spread to be printed and studied later in the camp.

iii) Data Processing

Before starting the detailed interpretation of the data, necessary routine checking was done and relevant corrections were made as follows:

- The data recorded in the site were played back in the equipment CRT screen for checking. The noise levels were filtered to an appropriate limit.

- Corrections were made for the delay time and the depth of the blast holes was considered.
- The first arrivals were picked up by the auto time pick function of the Terraloc, which were checked manually for the errors.
- Wherever the odd arrival times appeared or wherever the result were masked by the background noise, the arrivals were picked up using spacing of waveforms of same polarity.
- All the arrival times were plotted in a graph paper against distance of the receiver spacing (TD-Graph).
- The arrival graphics and the listed marker times were printed with a Terraloc printer.

iv) Calculation of Refractor Velocity

All the TD-graphs were studied properly and approximate layering was identified. The velocity lines were drawn pairing appropriate points on the TD- graph for all the curves.

The velocity of each layer was studied for every shot in the forward and the reverse directions. Relevant corrections were made where the velocity at certain curves seemed unrealistic. In case of some difference in velocity in the same layer showed at different places along the seismic profile the harmonic mean of those velocities were calculated in depth calculation.

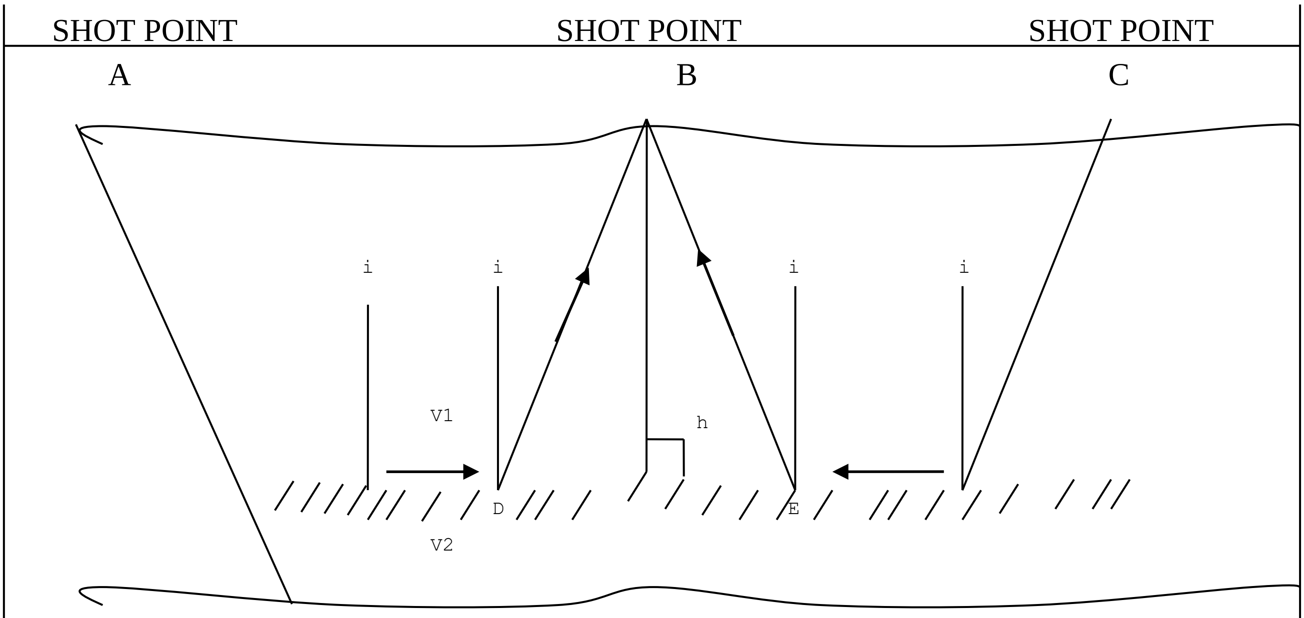
The velocity of the bottom refractor was determined by the far end shot curves by using Mean Minus T method. If the TD-curves of the lower velocity layers showed scattered nature ABEM correction method was applied using the corrected bedrock curve. Thus, the velocity curves for each layer along the spread were determined and noted for each of the seismic spreads for depth calculation.

v) Depth Calculations

The Hagiwara graphical ray path method is used for depth calculation and for the calculation of the overburden materials, and two exterior or the off the end shots (Direct Refractor Curve and Reverse Refractor Curve) for determining the bottom refractor. This method also uses mean minus T and ABEM correction, use-corrected time or original times for depth computation. The bottom refractor is computed using the ABC method of depth calculation, which is as follows:

In ABC method, the arrival time of critically refracted waves (from shot points A and C) as well as from the surface point B are summed up and used together with Figure No.4.10 to calculate the depth under each geophone in the layout. The ABC method uses only the direct refractor curve data and reverses refractor data.

Fig No.4.10: ABC Method (depth calculation)



According to Figure No.---------

$T_{AB} + T_{CB} - T_{AC} = T_{DB} + T_{EB} - T_{ED,}$ where T = Time

But, $T_{DE} = T_{EB} = h/ (V_1 \text{ Cos } i)$

And $T_{ED} = (2 \text{ h Tan } i)/V_2 = (2 \text{ h Sin } i)/ (V_2 \text{ Cos } i)$

According to Snell's Law:

$\text{Sin } i = V_1/V_2$ which gives $T_{ED} = (2 \text{ h Sin}^2 i)/ (V_1 \text{ Cos } i)$ substituting V_2

Therefore,

$$
\begin{aligned}
T_{AB} + T_{BC} - T_{AC} &= 2 h/ (V_1 \text{ Cos } i) - (2 \text{ h Sin}^2 i)/ (V_1 \text{ Cos } i) \\
&= 2 h (1 - \text{Sin}^2 i)/ (V_1 \text{ Cos } i) = (2 \text{ h Cos}^2 i)/ (V_1 \text{ Cos } i) \\
&= (2 \text{ h Cos } i)/V_1
\end{aligned}
$$

Thus, $h = V_1 (T_{AB} + T_{CB} - T_{AC})/2 \cos i$

This equation is solved and used to compute the depth of the bottom refractor of each geophone location throughout the seismic spread.

The computed depths were also calculated manually using the critical distance method and the time intercepts method to confirm the computed depth.

vi) Limitations and Pitfalls

The calculated depths of each geophone along a seismic profile have their limitations and some pitfalls which cannot be overruled which are outlined as follows:

Any seismic velocity section presents a continuous velocity profile which presents rock as a differential function of weathering and fracturing and not a typical kind of rock itself. Hence, weak highly weathered and fractured bedrock characterized by a certain lower velocity band may appear to be an overburden material in a seismic velocity section.

The section which shows low velocity between a high velocity bottom refractor may represent any form of geologically weak zones as shear zone, faults, and filling materials in narrow deep seated channels.

The accuracy of the individual depth profiles is limited by inverse velocity relations (Blind Zone) where the waves refracted are never returned to the surface. In the case of thin layers where the velocity difference is low, the first arrivals are masked by the latter arrivals from the overlying high velocity layer (Hidden Layer). In such cases the calculated depth has an error up to 10 percent at depth of 10 meters and 7 percent at depth of 30 meters.

4.6.6 Exploration Results

4.6.6.1 General

The results of the seismic refraction are presented as individual Seismic Profiles, which show the depths and thickness of individual layers. The bottom layer represents the bedrock or a bottom refractor for that particular seismic velocity section. The dashed and shaded zones that have much lower velocity than the next ones show a geologically weak zone which may represent shear zone, local fault or a highly weathered and/or fractured rock. The boundaries of different velocity layers and velocities in the same layer form a zone with a gradual variation in the material quality and not in a sense of abrupt change of that particular material.

In case of weak zones characterized by lower velocities, the depth to which it is distributed is not known since the seismic waves may have never reached that depth for being recorded by the seismograph. Even the thickness of the disturbed zone is not known. It is expected that the rock quality improve with depth.

The following Table No. 4.12 shows the condition of the bottom refractor in relation to the seismic velocity. Please note that this table has been prepared by our past experience in seismic refraction exploration in at least 100 different locations and cross checked by the geological conditions, test adit study, drilling results and study of geology in adjacent valley sections. The terms used indicate are following:

Table No. 4.12: Bedrock Refractor Nomenclature

Seismic Velocity m/s	Nomenclature	Remarks
2000 or less	Completely Weathered/Fractured rock or compacted gravel and boulder deposit	Bedrock that break downs to particles with a simple hand blow. Fragments to particles with flowing water.
2000 – 3000	Highly to moderately weathered/fractured rock or Highly Compacted gravel and Boulder deposit	Bedrock that breaks down to many pieces with a hammer blow. This condition is not very suitable for good foundation.
3000-4000	Slightly to Moderately weathered/ fractured/jointed	Bedrock that breaks only with two or more blows of a geological hammer. The rock condition is suitable for every engineering foundation with little treatment.
4000 and more	Slightly weathered/fresh rock	Takes several blows to break with a hammer. Rock is nearly fresh with little or no weathering. Fracture and joints are absent or tight. Best condition for foundation.

4.6.6.2 Seismic Profile

All together 16 seismic profiles were executed in power house site 1, 2 and hot spring MCT zone. In general all profiles show 3 layers of sand, boulders and bedrock.

A. Powerhouse Site option number -1 (Jamune)

SLP-1 to SLP-6

The profile SLP-1to SLP-6 is in the right bank of Tamakoshi River. The interpretation of seismic profile SLP-1to SLP-6 shows three velocity layers having velocities of 500-900m/s, 1000-1600m/s and 2500-3000m/s respectively. The thickness of the individual layers is 2-5 m and 2-12 m respectively for the first and the second layers. The total depth from surface to bed rock varies from 3-20 m.
The summary of seismic line SLP-1 to SLP-6 is given below.

Table No. 4.13:Summary of Results of SLP-1

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	500-600	800-900	1	4	Dry sand and gravel	Overburden Deposit
2	1000-1200	1400-1600	2	11	Compacted Sand, boulde and gravel	Overburden Deposit
3	2500	2600	3	15	Slightly to Moderately weathered and fractured rock	

Table No. 4.14: Summary of Results of SLP-2

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	500-600	800-900	2	4.5	Dry sand and gravel	Overburden Deposit
2	1200	1400	10	12	Compacted Sand, boulde and gravel	Overburden Deposit
3	2500-2600	2800-3000	12	16.5	Slightly to Moderately weathered and fractured rock	

Table No.4.15: Summary of Results of SLP – 3

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	500-600	800-900	2	5.5	Dry sand & gravel	Overburden deposit
2	1000	1200	10	13	Compacted sand, boulder & gravel	Overburden deposit
3	1400-1600	2500-2600	12	18.5	Slightly to Moderately weathered and fractured rock	

Table No.4.16: Summary of Results of SLP – 4

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	500	6000	3	5	Dry sand & gravel	Overburden deposit
2	1000-1200	1200-1400	9	14	Compacted sand, boulder & gravel	Overburden deposit
3	1400-1600	2800-3000	12	19	Slightly to Moderately weathered and fractured rock	

Table No. 1.17: Summary of Results of SLP – 5

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	500-600	800-900	2	5	Dry sand & gravel	Overburden deposit
2	1200	1400	8	14	Compacted sand, boulder & gravel	Overburden deposit
3	2500-2600	3800-4000	10	19	Slightly to Moderately weathered and fractured rock	

Table No.4.18: Summary of Results of SLP – 6

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	600-700	800-900	2.5	4	Dry soil, sand & gravel	Overburden deposit
2	1200	1400	9	11	Highly compacted sand, boulder & gravel	Overburden deposit
3	2500-2600	3400-3500	11.5	15	Highly to moderately weathered/fractured rock or Highly Compacted gravel and Boulder deposit	

B. Powerhouse Site option number -2(Surya tar)

SLP-7 to SLP-12

The profile SLP-7to SLP-12 is in the right bank of Tamakoshi River. The interpretation of seismic profile SLP-7to SLP-12 shows three velocity layers having velocities of 500-1000m/s, 1000-1600m/s and 1600-2800m/s respectively. The thickness of the individual layers is 2-5 m and 2-12 m respectively for the first and the second layers. The total depth from surface to bed rock varies from 3-20 m.

The summary of seismic line SLP-7 to SLP-12 is given below.

Table No. 4.18: Summary of Results of SLP – 7

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	500-700	900-1000	1	4	Dry soil, sand & gravel	Overburden deposit
2	1200	1400-1600	1	11	Highly compacted sand, boulder & gravel	Overburden deposit
3	1600	2600-2800	2	15	Highly to moderately weathered/fractured rock or Highly Compacted gravel and Boulder deposit	

Table No. 4.19: Summary of Results of SLP – 8

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	600-700	800-900	3	4	Dry soil, sand & gravel	Overburden deposit
2	1200	1400	9	12	Highly compacted sand, boulder & gravel	Overburden deposit
3	2500	2600	12	16	Highly to moderately weathered/fractured rock or Highly Compacted gravel and Boulder deposit	

Table No.4.20: Summary of Results of SLP – 9

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	900	1000	1	15	Dry soil, sand & gravel	Overburden deposit
2	1400	1600	9	12	Highly compacted sand, boulder & gravel	Overburden deposit
3	2500	2600	10	13.5	Highly to moderately weathered/fractured rock or Highly Compacted gravel and Boulder deposit	

Table No.4.21: Summary of Results of SLP – 10

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	900	1000	1	2	Dry soil & rock fragment	Overburden deposit
2	1400	1600	11	13	Slightly compacted soil, sand, boulder & gravel	Overburden deposit
3	2500	2600	12	15	Highly to moderately weathered/fractured rock or Highly Compacted gravel and Boulder deposit	

Table No.4.22: Summary of Results of SLP – 11

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	700	900-1000	2	4	Dry soil &rock fragment	Overburden deposit
2	1200	1400-1600	8	14	Slightly compacted sand, boulder & gravel	Overburden deposit
3	1600	2500-2600	10	18	Highly to moderately weathered/fractured rock or Highly Compacted gravel and Boulder deposit	

Table No.4.23: Summary of Results of SLP – 12

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	800-900	900-1000	1.5	2.5	Dry sand & gravel	Overburden deposit
2	1200-1400	1400-1600	11.5	14	Slightly compacted sand, boulder & gravel	Overburden deposit
3	1600	2500-2600	13	16.5	Highly to moderately weathered/fractured rock or Highly Compacted gravel and Boulder deposit	

C. Seismic Profile of hot spring MCT zone

SLP-13 to SLP-16

The profile SLP-13to SLP-16 is in the right bank of Tamakoshi River. The interpretation of seismic profile SLP-13 to SLP-16 shows three velocity layers having velocities of 700-1000m/s, 1400-1600m/s and 1600-4000m/s respectively. The thickness of the individual layers is 1-4 m and 8-14 m respectively for the first and the second layers. The total depth from surface to bed rock varies from 12-16 m.

The summary of SLP-13 to SLP-16 is given below.

Table No.4.24: Summary of Results of SLP – 13

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	900	1000	1	1.5	Dry soil &rock fragment	Overburden deposit
2	1200	1400-1600	8	12	Slightly compacted sand, boulder & gravel	Overburden deposit
3	1600	3800-4000	9	13.5	Highly to moderately weathered/fractured rock or Highly Compacted gravel and Boulder deposit	

Table No.4.25: Summary of Results of SLP – 14

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	700-800	900-1000	1	2	Dry soil, sand & gravel	Overburden deposit
2	1400	1600	7	11	Highly compacted sand, boulder & gravel	Overburden deposit
3	2500	2600	8	13	Highly to moderately weathered/fractured rock or Highly Compacted gravel and Boulder deposit	

Table No.4.26: Summary of Results of SLP – 15

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	900	1000	1	2	Dry soil, sand & gravel	Overburden deposit
2	1400	1600	1	11	Highly compacted sand, boulder & gravel	Overburden deposit
3	2500	2600	2	13	Slightly to Moderately weathered/ fractured/jointed rock	

Table No.4.27: Summary of Results of SLP – 16

Layer	Min Velocity (m/s)	Max Velocity (m/s)	Min Thickness (m)	Max Thickness (m)	Layer Properties	Remarks
1	900	1000	1	2	Dry soil, sand & gravel	Overburden deposit
2	1400	1600	8	13	Highly compacted sand, boulder & gravel	Overburden deposit
3	2500	2600	9	13	Slightly to Moderately weathered/ fractured/jointed rock	

4.6.6.3 Discussions

A seismic refraction study was carried out along and across the Tamakoshi River at Jamune, Suritar and Tatopani for Tamakoshi V Hydroelectric Project. The details of each profile have been presented in the profile sections in the attachments. The brief summary and recommendations of the present work is given below.

A total of sixteen seismic refraction profiles measuring 1875 m were executed at the Tamakoshi River. All the profile SLP-1 to SLP-16 shows three velocity layers having velocities of 500-1000 m/s, 1000-1600 m/s and 1600-4000 m/s respectively. The first layer with velocity of 500-1000 m/s represents dry soil, sand and gravel. The second layer with velocity of 1000-1600 m/s represents compacted sand, gravel and boulder. The third layer with velocity of 1600-4000 m/s represents highly compacted gravels and boulders.

The Seismic refraction interpretation in the area show in general that velocity of overburden is 2500-3000 m/s which shows that overburden lies between 10 to 20 meters from the ground level. The layer which has velocity of 2500-3000 m/s shows that it may be bed rock from seismic interpretation but it might be highly compacted zones or boulders. The actual rock type may be defined only after core drilling. Based on geology of the project area of Tamakoshi V having seismic refraction survey, it can be concluded that the geology of Powerhouse site at water level is composed of very thick alluvium and colluviums deposited by damming of the river in ancient time. The deposit consist mainly of boulders and gravels with sand. The thickness of this deposit is assumed to be more than 30-60 meters. The seismic wave is not able to penetrate up to the bed rock due to blind zone and the seismic waves are refracted back from the surface of thickness of compacted overburden. Therefore, deep core drilling is recommended to find out the actual depth of such thick deposit.

The limitation of Seismic Refraction: If there is increase in velocity with depth is inversed and lower layer has the velocity less than that of upper layer than such layer can not be detected. The seismic waves reflect back from the upper layer and such layer or zone which is undetected is called blind zone. Along the Tamakoshi belt there is a highly compacted Alluvium and Colluviums deposit in the second layer, which shows that the seismic waves can not penetrate and reach the bed rock. It means that there is low velocity zone in between second and bed rock, so the seismic waves returns back from the second layer and can not detect bed rock layer.

4.7 Core Drilling

The proposed total depth of drilling depth was 150 m however only 100.50 m of drilling was carried out. Out of 50 m length of drilling work, 30 m length was drilled at tailrace site, 40.0 m at power house site and remaining 30.50 m at the outcrop near penstock alignment. The proposed 50 m deep hole at penstock alignment has to terminate at 30.50 m depth due to encounter of highly fractured zone. The depth of each borehole, their orientation and bedrock is tabulated in Table No. 4.28. The permeability tests / water pressure tests were carried out in boreholes in favorable ground condition. All the photographs and log sheets are shown in Annex-C

Table No. 4.28: Summary of Boreholes

S.N.	Description	Bore Hole No.	Drill Depth (m)	Location	Orientation	Bed Rock Depth (m)
1	Tailrace	TL 1	30.00 m	Right Bank	Vertical	-
2	Power house	PH 1	40.00 m	River Terrace	Vertical	33.55
3	Penstock Alignment	PH 2	30.50 m	Near the road	Vertical	4.30

4.7.1 Core Logging

Core logging was carried out at site by geologist observing the core boxes and driller's daily drilling report. The standard log sheet has been used for the logging purpose. The logging has been carried out for 3 holes drilled at three different sites.

Photographs of 21 core boxes were taken completing the core logging of 100.50 m drilling length. Those boxes were stacked properly and transported to Soil, Rock and Concrete Laboratory, Swoyambhu and stored in container. The core logging record and core photographs are given in Annex -C.

4.7.2 Results and Analyses

The detail reports of boreholes prepared by geologist making observation of core boxes and driller's daily report sheets are given in Annex-C. The summary of each borehole drilling result and analysis are as follows:

Powerhouse Site

a) TL-1

The bore hole, TL-1 was drilled near river bed at right bank side of Tamakoshi River at Bhorle. The 30.00 m deep bore hole drilled at right bank of Tamakoshi River was coring over river bed / alluvial deposit. The deposit is characterized by gravel, cobble and boulders of schist, gneiss in sandy matrix. The maximum size of boulder found was upto

0.85 m. The bed rock is not encountered at this borehole. The water table was recorded at a depth of 5.50 m and 100% brown color water was return from the hole during drilling.

b) PH-1

The bore hole, PH-1 was vertically drilled at the terrace of Tamakoshi River at Bhorle. The 40.00 m deep bore hole drilled at right bank of Tamakoshi River was coring over river bed / alluvial deposit. The deposit is characterized by sub-rounded to rounded gravel, cobble and boulders of schist, gneiss and augen gneiss in sandy matrix. The bedrock is encountered at the depth of 33.35 m and is characterized by fresh to slightly weathered, light gray augen gneiss with gray schist. The core recovery ranges from 50% to 100%. Minimum core recovery of 50% is observed between 36.00 m – 38.00 m and 100% of core recovery is observed between 33.55 m-36.00 m and 39.00m - 40.00 m. The RQD of 14.7% is observed between 34.50 m-36.00 m and others have 0% RQD. The average recovery is 86% and average RQD is 2.94%. Based on the overall RQD of this borehole, the rock can be classified as very poor to poor rock quality. The water table was recorded at a depth of 10.50 m and 100% brown color water was return from the hole during drilling.

c) PH-2

The bore hole, PH-2 was drilled vertically to depth of 30.50 m. The hole passes at the foot hill side at righ bank of Tamakoshi River at Bhorle. The deposit is characterized by gravel, cobble and boulders of schist, gneiss and augen gneiss in sandy matrix. The bedrock is encountered at the depth of 4.30 m and is characterized by slight to moderately weathered, light gray, fractured augen gneiss. The core recovery ranges from 0 to 100%. The core recovery between 21.40–23.00 m is 0%, 7.00–8.50 m, 8.50-9.50 m, 17.05-18.55 m, 18.55-21.40 m, 23.00-24.50 m, 24.50-26.00 m and 27.50-30.50 m have 46.7%, 70%, 16.7%, 15.8%, 83.3%, 37% and 26.7% respectively while the others have 100% core recovery. The RQD varies between 0 to 46.2%. The minimum RQD of 0% is observed between 7.00-8.50 m, 17.05-18.55 m, 18.55-21.40 m, 21.40-23.00 m, 23.00-24.50 m, 24.50-26.00 m and 27.50-30.50 m. The average recovery is 68.51% and the average RQD is 15.17%. Based on the overall RQD of this borehole, the rock can be classified as very poor to fair quality rock (Deer's Classification). The water table was not recorded and 100% water loss during drilling.

4.7.3. In-Situ Test in the Borehole

In-situ tests such as constant head pressure test, standard penetration test (SPT) and dynamic cone penetration test (DCPT) were carried out in the borehole TL-1. Different laboratory test in core samples of borehole DH-3 were carried out. The summary is given in Table No. 4.29.

Table No. 4.29: Summary of Laboratory Test results, Core Sample

S.No.	Drill Hole No.	Depth m	Unit weight gm/cm^3	Specific gravity	Water Absorption %	Uniaxial Compressive Strength kg/cm^2	Alkali Reactivity	
							S_C mmole/l	R_C mmole/l
1	DH - 3	5.23 - 5.37	2.60	2.62	1.01	505.10	4347.97	40.00
2		10.88 - 11.00	2.78	2.70	0.62	100.02	4909.97	25.00
3		12.00 - 12.25	2.90	2.66	0.67	465.37	4861.02	16.67
4		14.04 - 14.13	2.56	2.68	0.79	212.85	4248.08	25.83
5		16.08 - 16.30	2.58	2.65	0.56	776.31	5509.15	30.00
6		26.10 - 26.24	2.61	2.68	0.74	662.26	5434.89	22.50

The results of In-Situ tests in borehole are given in Annex-2.

- Permeability Test Results

Altogether 3 (three) constant head pressure test were done. The test results have shown the permeability values in the range of 2.45 X 10-3 to 2.98 X 10-3 cm/sec. These values showed the overburden deposit is moderately permeable.

- SPT/DCPT Test Result

Altogether three (3) SPT and three (3) DCPT test were carried out at borehole TL-1. Both the tests were terminated as the required depth couldn't be penetrated at 50 blows.

4.8 Conclusion

Tamakoshi V Hydroelectric Project is a cascade development scheme of Upper Tamakoshi HEP with installed capacity of 87MW located in Dolokha district. The geology of the area consists mostly of gneiss and schist. The main soil types in the project area are alluvium and colluvium deposit. The MCT passes through the tunnel alignment. At present MCT is not active and hence there won't be severe problem but problems like water seepage and gaseous leakage may arise at the construction of the tunnel. The rock type at headworks area is gneiss with schist partings. Gneiss with schist partings, crystallized schist, augen gneiss and gneiss intercalated with schist are the main rock types encountered in the headrace tunnel alignment. A thrust (MCT) also passes through the tunnel alignment. The power house site is located at the right bank of Tamakoshi River. The rock mass rating shows the rock quality as very weak to good.

For the construction material survey, a field exploration has been conducted by pitting method in which test pits of depth up to 3.0 m have been excavated manually with the help of hand shovel. The size of test pits is 1.0 m X 1.0 m. the exploration depth, mainly depends on the site condition. The fraction passing from 80 mm sieve has been transported to the SRCL, Kathmandu for further laboratory testing such as grain size, specific gravity, shear test and other.

The soil samples collected during the course of field exploration have been subjected to various tests namely; natural moisture content, grain size distribution, specific gravity, Atterberg limits and proctor tests etc. The test results are presented above

A total of sixteen seismic refraction profiles measuring 1875 m were executed at the Tamakoshi River. All the profile shows three velocity layers having velocities of 500-1000 m/s, 1000-1600 m/s and 1600-4000 m/s respectively. The first layer with velocity of 500-1000 m/s represents dry soil, sand and gravel. The second layer with velocity of 1000-1600 m/s represents compacted sand, gravel and boulder. The third layer with velocity of 1600-4000 m/s represents highly compacted gravels and boulders. In general all profiles show 3 layers of sand, boulders and bedrock. To confirm the actual sub surface condition, a core drilling at different hydraulic structures is carried out.

Altogether three drill holes with total depth of 100.50 m were drilled at the powerhouse site. The bed rock was encountered in two drill holes (PH-1 and PH-2). The rock consists of grey colored, fractured gneiss. Alluvial deposit is the predominant overburden deposit. The permeability test results show the overburden materials as moderately permeable.

4.9 Recommendation

In order to carry out the detail engineering design earliest possible following investigation works have been recommended to carry out geological and geotechnical studies prior to the detail engineering design of the project.

A. Geological Mapping

- Detailed geological mapping in MCT area, powerhouse area & headworks area (1:500 scale).
- Additional Geological Mapping in headrace tunnel area (1:10000) covering all the tributaries crossing the alignment.
- Review of rock support design
- Detailed engineering geological mapping in adit tunnel with detailed Rock Mass Classification.

B. Core Drilling & In-situ tests

- One vertical drill hole at surge tank (L= 150 m)
- One vertical drill hole at underground powerhouse (L= 175m)
- One vertical drill hole at MCT zone (L= 50 m)
- One vertical drill hole at tunnel alignment area near adit-2 location (L= 125 m).
- Lugeon tests in bedrock and permeability tests in overburden.

C. Test adits

i) Excavation

- One test adit (2m x 2m) in tunnel alignment, Adit -2 (L= 210 m).
- One test adit (2m x 2m) in underground powerhouse area, Adit-3 (L= 120 m).

ii) Rock Mechanics Tests

- Block shear test/Plate bearing tests in all adit tunnels
- Hydrofracturing / Dilotometers tests in Adit-2 and Adit -3.
- In-situ stress measurements in Adit-2 and Adit-3.

D. Laboratory tests

- Uniaxial Compressive Stress test , Point Load Tests , modulus of elasticity, friction angle 'ø' and cohesion on drilled core samples.
- Sulphate soundness, abrasion test, specific gravity, bulk density, alkali reactivity test, water absorption, aggregate impact values, aggregate crushing and abrasion values flakeness index, elongation index on samples collected from exploratory adit.
- Petrographic study on drilled core samples.

5. Project Capacity and Layout Optimization

5.1 Background

This project area is located on the right bank of Tamakoshi River and is conceptualized as cascade to the Upper Tamakoshi HEP with tandem operation. Therefore, the project capacity is tied up with the tailrace discharge of the Upper Tamakoshi Project.

This project does need separate headwork. It takes the discharge from the tailrace of the proposed Upper Tamakoshi Project through the inter connection system and conveyed to the headrace tunnel of the Project. Therefore, the capacity of the project depends directly with the tailrace discharge from the Upper Tamakoshi. Two possible powerhouse locations are observed during the site verification study. Both powerhouse locations are on the right bank of the Tamakoshi River. Powerhouse for the Option I is located approximately 1.2 km upstream from the confluence of Tamakoshi River and Khare Khola. The second powerhouse option is located just downstream from the confluence of Tamakoshi River and Khare Khola in Suri Dovan village. This option is named as Option-II.

5.2 Location

This project is located in the Central Development Region of Doklha District of Janakpur Zone. The whole project area lies in Orang, Khare and Lamabager Village Development Committees. The headwork/interconnection system for the tandem operation for the both option is located nearly in between Purano Jagat and Gongor village and the powerhouse options are located at Jamune village and Suri Dovan Village respectively.

The water level at interconnection point with UTKHEP tailrace tunnel for the both options is 1157.49 amsl and the tail water levels are 1008.5 amsl and 995.5 amsl for Option I and Option II, respectively.

5.3 Access to the Project

Tamakoshi-V Hydropower Project is located approximately 170 km north east of Kathmandu, the capital of Nepal and approximately 42 km away from Charikot Bazaar the district head-quarter of Dolkha District-. Charikot Bazaar, the district headquarter is connected by Lamasangu Giri road. Lamasangu is about 90 Km from the Kathmandu. A gravel road of about 38 km is available from Charikot to Jamune which passes through the powerhouse area and very close to the headwork area. The under construction road connecting Singati Bazaar and Lamabagar for the construction of Upper Tamakoshi passes from both powerhouses and headwork sites of the Tamakoshi-V Project. Hence, this Project dose not need to built an additional access road. However; few kilometers of project road might be required during the project construction and for the smooth operation and maintenance.

5.4 Reconnaissance Site Visit

A technical team comprising Senior civil/hydropower engineers, Surveyor and a Geologist visited the project area on January 2009. The team members walked from Singati Bazaar to Gongar village along the banks of Tamakoshi River to explore the possible locations for the powerhouse. The team has identified two different locations of powerhouse.

The powerhouse option-I is located at the Jamune village at an elevation of 1008.5 masl with 149.01m of natural head and power generating capacity of 80.0 MW. Powerhouse for the option-II is identified just downstream from the confluence of Khare Khola and Tamakoshi River at Suri Dovan village. This arrangement will have the natural head of 162 m with total power generation of 87.0 MW. The power generation for both the option are calculated assuming that this scheme will be developed only after the completion of Upper Tamakoshi Hydropower Project with the installed capacity of 456 MW. Therefore, the design discharge taken for the power and energy calculation for both schemes are 66.0 m^3/s, equivalent to the design discharge of Upper Tamakoshi HEP.

Geologically, rock exposure are visible in the headwork area and the along the tunnel alignment but the powerhouse seems to have some deposition materials on top of the bed rock. Tunnel alignment for the both options crosses the less active Main Central Thrust (MCT) at the Tatopani.

Table 5.1: Comparison of Options

Proposed Options	Inter-connection water Level	Tail-water Level Level, m	Approx. Head, m	Discharge, m3/s	Tunnel Length, km	Power Generation, MW	Total Energy in GWh	Remarks
I	1157.49	1008.5	148.99	66	7.373	80	431.60	MCT Zone
II	1157.49	995.4	162.09	66	8.651	87	470.00	MCT Zone

Note: Power production in MW and energy generation in GWh is based on the assumption that this scheme will be constructed only after the full construction of Upper Tamakoshi HEP.

5. 5 Project Features

5.5.1 General

Major structures of this project comprise of interconnection structure between the free flow tailrace tunnel of Upper Tamakoshi HEP and the pressurized headrace tunnel of Tamakoshi-V Hydropower Project, headrace tunnel, surge tank, drop shaft, pressure tunnel, powerhouse and tailrace. Proposed arrangement for the both Options is shown in the Drawing No: TV-AL-101 toTV-AL-104.

Pressurized tunnel is proposed as the water conveyance system for the both layout alternatives- Options-I and Option II. The length of the headrace tunnel is 7.373 km and 8.651 km for Option –I and Option-II, respectively. Four number of electricity generating equipments are proposed for the both alternatives but the total installed capacity and energy generation is different. A free flow tailrace canal discharges the design discharge from the powerhouse to the Tamakoshi River itself after the energy generation.

5.5.2 Interconnection with Upper Tamakoshi Hydroelectric Project Tailrace

Interconnection between the free flow tailrace tunnel of Upper Tamakoshi and pressurized head race tunnel of Tamakoshi V project is arranged using 64.89m long transition tunnel. Tunnel with 5.5 m finish diameter diverts water from Upper Tamakoshi tailrace tunnel to the headrace tunnel of Tamakoshi –V project. A smooth curve is maintained between the headrace tunnel of Tamakoshi-V and the tailrace tunnel of proposed Upper Tamakoshi. Elevation at the end horizontal portion of connection tunnel is 1154.91amsl. In order to maintain the required suction head in the headrace tunnel of Tamakoshi-V HEP, an inclined drop is proposed just after the horizontal portion of connecting tunnel. The bottom elevation of the inclined portion is 1142.90 amsl. An ogee shaped spillway with 20 m long crest length and 3.0 m high is designed in the interconnection arrangement. The capacity of this spillway is designed for the discharge of 66 m^3/s. The main purpose of this spillway is to safely discharge 66 m^3/s of water to the Tamakoshi River in case the Tamakoshi-V is suddenly shut down and the tailrace gate of Upper Tamakoshi is not opened during the Tandom operation of Upper Tamakoshi Hydropower Project. The interconnection system is shown in the Drawing No.:TV-AL-102

5.5.3 Headrace Tunnel

Design discharge for the both options being same, a circular shaped headrace tunnel with its finish diameter 5.5 m has been adopted as the water conveyance system for both layout options. The headrace tunnel starts at the end of the interconnection arrangements as mentioned above.

Option-I

Total length of the pressurized headrace tunnel for this option is 7.373 km long with its internal diameter 5.5 m. The tunnel passes through fair to the good rock zone of Gneiss rock. The tunnel also passes through the MCT zone in Tatopani village. Sacrificially the MCT seems very passive therefore; it has been assumed that the headrace tunnel could be constructed along its alignment with adequate supports. The exact requirements of tunnel support will be finalized after the detailed geological investigation of the project area. However; on the basis of preliminary geological information, 10 cm sortcrete, 30 cm concrete lining and 3 m long 25mm diameter rock bolt at the 3 m c/c is proposed as the tunnel support.

Tunnel profile and section is presented in Drawing No: TV-AL-105

Option-II

Total length of the pressurized headrace tunnel for this option is 8.651 km long with its internal diameter 5.5 m. The tunnel passes through fair to the good rock zone of Gneiss rock. The tunnel also passes through the MCT zone in Tatopani village. Sacrificially the

MCT seems very passive therefore; it has been assumed that the headrace tunnel could be constructed along its alignment with adequate supports. The exact requirements of tunnel support will be finalized after the detailed geological investigation of the project area. However; on the basis of preliminary geological information, 10 cm sortcrete, 40 cm concrete lining and 3 m long 25mm diameter rock bolt at the 3 m c/c is proposed as the tunnel support.

Tunnel profile and section is presented in Drawing No:TV-AL-105 and106

5.5.4 Surge Tank

Surge tank is located in between the inclined shaft and the pressurized headrace tunnel to stabilize the pressure created during load rejection and to fulfil necessary water during load acceptance. For the both options, an orifice typed surge tank is proposed.

Option-I

The surge chamber of the option –I is located inside the rock with its top opening in atmosphere. Internal diameter of the surge tank is 14.0 m and the diameter of restricted orifice is 3.0m. The surge tank is located at the distance of 7.326 km from the beginning of headrace tunnel and 30.83 m before the start of the inclined shaft. Suction head of 8.21 m is provided at the junction of headrace tunnel and surge shaft. The maximum and the minimum water level at the surge tank are 1125.30 and 1183.47m, respectively. The top elevation of the surge tank is 10 m above the maximum water level, which is 1193.47m. The top elevation of the surge tank is exposed to the atmosphere.

Option-II

The surge tank for the option –II is located inside the rock with top opening. The surge tank is located at the distance of 8.651 km from the beginning of headrace tunnel and 30.83 m before the start of the inclined shaft. Internal diameter of the surge tank is 14.0 m and the diameter of orifice is 8.12 m. The suction head of 8.21 m is provided at the start of the surge shaft. The maximum and the minimum water level are 1185.50 m and 1122.01 m respectively. The top opening elevation of the surge shaft is 1195.50 m.

5.5.5 Inclined Drop Shaft

For the both options of this project a 5.5 m diameter inclined shaft is proposed between the headrace tunnel and horizontal high pressured tunnel. The length of the inclined shaft for option-I and option-II are 133.81 m and 146.5m, respectively. Inclined shafts are supported using partly steel lining and partly steel. The void between the steel and the rock will be filled with concrete. The horizontal portion of the shaft- connecting powerhouse and the inclined shaft- penstock will be fully steel lined.

5.5.6 Steel lined tunnel

Steel lined pressure tunnel is adopted at the bottom horizontal portion of the conveyance system in between the end of the inclined shaft and bifurcation due to the high pressure in these areas. The length of the horizontal portion for option –I and option-II are 140.0m and 28.55m respectively. The internal diameter for the steel lined tunnel for the both option are 40 m. The plan of the drawings is shown in Drawing TV-AL-101.

5.5.7 Powerhouse & Switchyard

For the both layout options, surface powerhouses are proposed on the right bank of Tamakoshi River. Design discharge for the both options is adopted at 66m^3/s. Due to the difference in powerhouse location, available natural head the corresponding power and energy generation are different in both options. In both options, four sets of vertical axis Francis Turbines is adopted with adequate suction head below the tailrace water level. Generator floor elevation for both option are at the safe height from the possible Glassier Lake Outburst Flood (GLOF) in Tamakoshi River. Four number of electricity generating equipments are adopted considering the operation of at least one turbine at 60% water availability if Upper Tamakoshi HEP operates only one turbine out of its 6 turbines.

Option-I

Powerhouse is located at the right Bank of Tamakoshi River on the deposited terrace, presently used by the villagers for cultivations, close to the Jamune village. However, the foundation of the powerhouse is expected to be based on the bed rock. This location is approximately 1.w km upstream from the confluence of Khare Khola and Tamakoshi River. Power house is equipped with four sets of generating equipments capable of generating 80.00 MW of electricity equivalent to 431.6 GWh of energy. Four vertical axis Francis Turbine with 20 MW generating capacity is designed considering the operation of at least one turbine at 60% water availability if Upper Tamakoshi is operating only one turbine.

The powerhouse is 44 m long, 13 m wide and 28.7 m high from the foundation to the roof top. The erection bay and the generator floor of the powerhouse are located at an elevation of 1013 amsl. This elevation is considered safe from the possible GLOF event in Tamakoshi River. The centre to centre distance between the equipments are 8 m and the clear area available for the erection bay is 10 m x 13 m. Turbine centre line are at an elevation of 1004.16 amsl which is 4.35 m below the tail water level of 1008.50. The bottom of the draft tube is located at an elevation of 1000.33 amsl.

The switchyard is located just outside the powerhouse on the open terrace and its size is 50m x 30 m. It is equipped with necessary number of step up transformers. The switchyard is connected to the transmission system for the power evacuation to the Integrated Nepal Power System (INPS).

Powerhouse plan and section is presented in Drawing No:TV-AL-103

Option-II

The powerhouse in this option-II is design for the generation of 87.0 MW power and it is equipped with four number of vertical axis Francis turbines with its powerhouse size of 44.0 m X 13.0 m X 28.7 m. The powerhouse is located on the open terrace at the right bank of Tamakoshi River just downstream from the confluence of Upper Tamakoshi and Khare Khola at Suri Dovan Village. The erection bay and the generator floor is at EL1000.00 while the turbine centre line is located at an EL991.15 and the tail water level is 995.4 asml. The Erection bay and the generator floor is kept at the safe elevation from the possible GLOF event in the Tamakoshi River. The distance between the equipments are 8m c/c and the available area at the erection bay is 13 m x 10 m. The powerhouse is equipped with four vertical axis Francis Turbine generators with an installed capacity of 87.00 MW and 470 GWh of energy. All the necessary ancillary control and protection equipments will be installed inside the powerhouse. Transformers bay will also be constructed outside the open terrace just close to the powerhouse location. The switchyard has a size of 50 m X 30 m and it is equipped with necessary number of step up transformers. The switchyard is connected to the transmission system for the power evacuation to the Integrated Nepal Power System (INPS).

Powerhouse plan is presented in Drawing no:TV-AL-104

5.5.8 Tailrace and outlet

For the both option there will be free flow tailrace canal discharging water back to the Tamakoshi River. The outlet structure will have a length of 61 and 84 m length respectively for option –I and option-II. Four individual draft tube outlets are connected to the outlet structure built just outside the powerhouse for the creation of necessary suction head to francis turbines. From this point onwards, there will be free flow canal structures which flows the design discharge back to the Tamakoshi River itself after the power generation. The outlet structure is provided with an automatic gate to prevent backwater flow inside the powerhouse during the high floods and in the event of GLOF.

5.5.9 Transmission Line

For the both options, power evacuation from these schemes will be made through single circuit 132 KV Transmission line connected to the substation at proposed Upper Tamakoshi HEP powerhouse site at Gangor. The length of this Transmission Line is estimated 10 km for the option-I and 12 km for the option –II.

5.5.10 Cost Estimate

The cost estimate was prepared on the basis of the sequential execution of the following steps:

- Subdivision of the total project into a number of distinct structures (Interconnection facilities, headrace tunnel, surge tank, inclined shaft, powerhouse, tailrace etc.).

- Breaking down of structures into a number of distinct construction tasks. These are overburden excavations, rock excavation, underground excavation, backfill work, concrete works, etc.

- Calculation of the quantities of each item according to the above-mentioned tasks – interconnection structure, spillway, water conveyance system etc. Concrete quantities of the powerhouse were estimated on the basis drawings, however, the excavation quantities were based on the layouts prepared.

- Summation of all the products of the quantities and the unit costs yields the total cost of construction.

- The summation with allowances for, contingency and allowances for engineering and management and provision for camp facilities gives the total project cost.

Option –I

Estimated cost of the project is US$ 136.89 Million based on preliminary design. The cost includes 15% physical contingency for civil and 8.0% for Electro-Mechanical works. The breakdown of cost estimate is shown in Table 5.2.

Table 5.2: Cost Calculate for Option-I

S. No	Description of Items between interconnection and tailrace	Amount US $
1	Connecting Tunnel	2,82,461
2	Headworks Arrangement	4,77,691
3	Flushing Tunnel (L=136m)	1,055,978
4	Headrace Tunnel (L =7373.09m, Dia = 5.5m)	65,236,501
5	Surge Tank (Total H =76.3m Dia = 14m)	3,394,135
6	Inclined Shaft (L =129.0m, Dia = 5.5 m)	1,314,312
7	Adit Tunnels (L =300m, Dia =3.6m)- 2 numbers	1,952,068
8	Steel Lined Tunnel (L =-207.5m, Dia = 3.5 m)	2,334,336
9	Powerhouse	2,484,771
10	Electromechanical Equipment and Transmission line	29,840,000
11	Access Road and Project Road	1,153,846
12	Total Civil Cost	77,333,366
13	Total EM and HM Cost	3,7824,336
14	Total Project Cost (14+15)	1,15,157,702
15	Civil Contingencies	11,600,004
16	EM and HM Contingencies	3,025,946
17	Preconstruction Work	5,757,885
18	Environmental cost -1% of total project cost with Contingencies	1,355,415
19	Total Project cost	1,36,919,255
20	Cost per Kilowatt	1,711

Option –II

Estimated cost of the project is US$ 152.69 Million based on preliminary design. The cost includes 15% physical contingency for civil and 8.05% for Electro-Mechanical works. The breakdown of cost estimate is shown in Table 5.3

Table 5.3: Cost Calculate for Option-II

S. No	Description of Items	Amount US $
1	Connecting Tunnel	2,82,461
2	Headworks Arrangement	4,77,691
3	Flushing Tunnel (L=136m)	1,055,977
4	Headrace Tunnel (L =8651.91m, Dia = 5.5m)	76,638,730
5	Surge Tank (Total H =80.91m Dia = 14m)	3,618,716
6	Inclined Shaft (L =142.0m, Dia = 5.5 m)	1,427,959
7	Adit Tunnel (L =300m, Dia =3.6m)	1,952,068
8	Steel Lined Tunnel (L =89.56-m, Dia = 4.0m)	1,127,554
9	Powerhouse	2,484,771
10	Electromechanical Equipment	32,451,000
11	Access Road/project road	1,153,846
12	Total Civil Cost	89,086,187
13	Total EM and HM Cost	40,991,107
14	Total Project Cost (14+15)	130,077,295
15	Civil Contingencies	13,362,928
16	EM and HM Contingencies	3,279,288
17	Preconstruction Work	4,454,309
18	Environmental coat -1% of total project cost with Contingencies	1,511,738
19	Total Project cost	152,692873
20	Cost per Kilowatt in US $	1,755

5.5.11 Project Schedule

For the both options, the feasibility study and detailed engineering of this project will require two to three years while actual construction of the project will require three years. The detailed project schedule will be produced at the end of the feasibility study.

5.5.12 Power & Energy

Installed capacity of the power plant and corresponding energy output is depended on the available head, diverted discharge and the over all efficiency of power generating equipments. Although, the power generation in Run off the River plants are different in different months, an installed capacity of the power plant is fixed for the discharge corresponding to certain exceedance flow. In the case of Tamakoshi-V HEP, the design discharge of proposed Upper Tamakoshi HEP equivalent to 66.0 m3/s has been adopted as the discharge for the installed capacity of the power plants in both option-I and option-II. Upper Tamakoshi has an arrangement of taking discharge of Rolwaing khola during dry seasons (Jan, Feb, March, April, May Nov and December), the power generation and the corresponding energy is calculated using water from Rolwaling in dry periods.

Option-I

Total installed capacity of the Tamakoshi-V HEP Option -I is calculated as 80.0 MW based on the 87% overall efficiency, 142.105 m net head and 66.0 m^3/s design discharge. Considering 5% outage and 10% downstream release, the annual energy generation is estimated to be 409.70 GWh out of which 61.38 GWh is dry season energy. The peak power generation of 80.00 MW will be available for 4 months while the minimum power generation will be about 19.30 MW in the month of March.

Since, Upper Tamakoshi has an arrangement of taking discharge of Rolwaing khola during dry seasons (Jan, Feb, March, April, May Nov and December) and Tamakoshi-V is taking its design discharge directly from the tailrace tunnel of Upper Tamakoshi HEP, the power generation and the corresponding energy is calculated using water from Rolwaling in dry periods. Estimated power and energy are shown in Table 3.5.

Table 5.4: Monthly Power and Energy Generation from Tamakoshi-V- Option-I

Energy Calculation			**Tamakoshi-V Option-I**				
Net Head	142.105	M	Qdesign	66	M3/s	Downstream release	
Efficiency	0.87		Power	80	MW	Outage	
Gravity	9.81	m/s2	min Q (Tama)	15.30	M3/s	Dry Season Price	
Irrigation			0		M3/s	Wet Season Price	
Discharge	**m3/s-Tama**	**m3/s Rolwaling**	**Days**	**Available in Rolwaling**	**Available Discharge in Tama**	**Power in KW**	**Energy in GWh-outage**
January	18.10	2.67	31	2.436	16.57	23051	16.29
February	15.90	2.34	28	2.106	14.37	19982	12.76
March	15.30	2.37	31	2.136	13.77	19291	13.63
April	19.10	2.99	30	2.756	17.57	24652	16.86
May	35.80	5.44	31	5.206	34.27	47877	33.84
June	79.30		30		77.77	80046	54.75
July	165.00		31		163.47	80046	56.58
August	176.00		31		174.47	80046	56.58
September	116.20		30		114.67	80046	54.75
October	53.60		31		52.07	63152	44.64
November	31.00	5.05	30	4.816	29.47	41583	28.44
December	22.30	3.42	31	3.186	20.77	29054	20.54
						Total	409.7
			Dry Energy in GWh		61.38		
			Wet Energy GWh		348.27		

Option-II

Total installed capacity of the Tamakoshi-V HEP Option -I is calculated as 87.0 MW based on the 87% overall efficiency, 154.7 m net head and 66.0 m^3/s design discharge. Considering 5% outage and 10% downstream release, the annual energy generation is estimated to be 446.00 GWh out of which 66.83 GWh is dry season energy. The peak power generation of 87.15 MW will be available for 4 months while the minimum power generation will be about 21.00 MW in the month of March.

Since, Upper Tamakoshi has an arrangement of taking discharge of Rolwaing khola during dry seasons (Jan, Feb, March, April, May Nov and December) and Tamakoshi-V is taking its design discharge directly from the tailrace tunnel of Upper Tamakoshi HEP, the power generation and the corresponding energy is calculated using water from Rolwaling in dry periods. Estimated power and energy are shown in Table 3.6

Table 5.5: Monthly Power and Energy Generation from Tamakoshi-V Option-II

Energy Calculation			**Tamakoshi-V Option-II**				
Net Head	154.715	m	Qdesign	66	m3/s	Downstream release	
Efficiency	0.87		Power	87	MW	Outage	
Gravity	9.81	m/s2	min Q (Tama)	15.30	m3/s	Dry Season Price	
Irrigation			0		m3/s	Wet Season Price	
Discharge	**m3/s-Tama**	**m3/s Rolwaling**	**Days**	**Available in Rolwaling**	**Available Discharge in Tama**	**Power in KW**	**Energy in GWh-outage**
January	18.10	2.67	31	2.436	16.57	25096	17.74
February	15.90	2.34	28	2.106	14.37	21756	13.89
March	15.30	2.37	31	2.136	13.77	21003	14.84
April	19.10	2.99	30	2.756	17.57	26839	18.36
May	35.80	5.44	31	5.206	34.27	52126	36.84
June	79.30		30		77.77	87149	59.61
July	165.00		31		163.47	87149	61.60
August	176.00		31		174.47	87149	61.60
September	116.20		30		114.67	87149	59.61
October	53.60		31		52.07	68756	48.60
November	31.00	5.05	30	4.816	29.47	45273	30.97
December	22.30	3.42	31	3.186	20.77	31633	22.36
						Total	446.0
			Dry Energy in GWh		66.83		
			Wet Energy GWh		379.18		

5.5.13 Environmental Impact

The project will not have any environmental impacts in the headwork area since it is diverting water from the tailrace tunnel of Upper Tamakoshi HEP. However, the powerhouse being located on the cultivated land, around 5 to 10 hectares of land will have to be acquired for the powerhouse structures. Therefore the project impact area will be mainly at the powerhouse site area. The environmental study team have already taken over the task of Environmental Impact Assessment work thus the detailed environmental impact will be presented in the separate Environmental Report.

5.5.14 Project Economics

Project economic evaluation has been carried out based on discounted cash flow method. The assumptions for project evaluation are:

(a) The construction period is four years. Project life is fifty years for civil works and twenty-five years of elector-mechanical equipments.

(b) The cash disbursement of capital cost is 20%, 50% and 30% in first, second and third year respectively.

(c) Operation & Maintenance cost of 1.5% of capital cost per annum is assumed.

(d) Discount rate of 10% per annum is assumed.

(e) Project benefit is estimated at 9 cents/KWh for dry season and 5 cents /KWh for wet season, based on Power Purchase Arrangements rate of NEA (7 Nrs for Dry season and 4 NRs for wet season with 3% escalation for 10 years).

(f) Five per cent outage is considered in the annual energy generation estimate.

Economic evaluation of both projects is shown 5.6 and 5.7.The results of the project evaluation are as follows:

Option-I	B/C	1.71
	EIRR	18.50%
Option-II	B/C	1.67
	EIRR	18.0%

Table 5.6: Economical Analysis

Option-I

Installed Capacity		80	MW	Construction Period	3	
Total Energy		409.70	GWh	Total Investment	136.90	136896954
Dry Season Energy		61.38	GWh	Running Cost	1%	
Wet Season Energy		348.32	GWh	Discount Factor	10%	136896954
Dry Season Energy Rate		0.09	NRs	Analysis Period	50	
Wet Season Energy Rate		0.05	NRs	Anuity Factor		
Dispersion				NPV-Benefit	281.08	
1	20%	Outage	2%	NPV-Cost	164.57	
2	50%	Escalation	3%	B/C Ratio	1.71	
3	30%			EIRR	18.5%	
				Revenue Rates		

Year	Capital Expenditure	Running Cost	Total Cost	Dry	Wet	Gross Benefit	Total Benefit
1	27.38						
2	68.45						
3	41.07						
4		1.37	165.95	0.09	0.05	23.82	-142.13
5		1.37	1.37	0.10	0.05	24.53	23.17
6		1.37	1.37	0.10	0.06	25.27	23.90
7		1.37	1.37	0.10	0.06	26.03	24.66
8		1.37	1.37	0.11	0.06	26.81	25.44
9		1.37	1.37	0.11	0.06	27.61	26.24
10		1.37	1.37	0.11	0.06	28.44	27.07
11		1.37	1.37	0.11	0.07	29.30	27.93
12		1.37	1.37	0.12	0.07	30.17	28.81
13		1.37	1.37	0.12	0.07	31.08	29.71
14		1.37	1.37	0.12	0.07	31.08	29.71
15		1.37	1.37	0.12	0.07	31.08	29.71
16		1.37	1.37	0.12	0.07	31.08	29.71
17		1.37	1.37	0.12	0.07	31.08	29.71
18		1.37	1.37	0.12	0.07	31.08	29.71
19		1.37	1.37	0.12	0.07	31.08	29.71
20		1.37	1.37	0.12	0.07	31.08	29.71
21		1.37	1.37	0.12	0.07	31.08	29.71
22		1.37	1.37	0.12	0.07	31.08	29.71
23		1.37	1.37	0.12	0.07	31.08	29.71
24		1.37	1.37	0.12	0.07	31.08	29.71
25		1.37	1.37	0.12	0.07	31.08	29.71
26		1.37	1.37	0.12	0.07	31.08	29.71
27		1.37	1.37	0.12	0.07	31.08	29.71
28	14.92	1.37	16.29	0.12	0.07	31.08	14.79
52		1.37	1.37	0.12	0.07	31.08	29.71
53		1.37	1.37		0.07	23.75	22.39
			247.95				**1260.97**

Table 5.7: Economical Analysis

Option-II

Installed Capacity		87.15	MW	Construction Period	3	
Total Energy		446.00	GWh	Total Investment	152.69	152685560
Dry Season Energy		66.83			1%	
Wet Season Energy		379.17	GWh	Discount Factor	10%	152685560
Dry Season Energy Rate		0.09	NRs	Analysis Period	50	
Wet Season Energy Rate		0.05	NRs	Anuity Factor		
Dispersion				NPV-Benefit	305.99	
1	20%	Outage	2%	NPV-Cost	183.51	
2	50%	Escalation	3%	B/C Ratio	1.67	
3	30%			EIRR	18.0%	

Year	Capital Expenditure	Running Cost	Total Cost	Revenue Rates Dry	Wet	Gross Benefit	Total Benefit
1	30.54						
2	76.34						
3	45.81						
4		1.53	185.09	0.09	0.05	25.93	-159.15
5		1.53	1.53	0.10	0.05	26.71	25.18
6		1.53	1.53	0.10	0.06	27.51	25.98
7		1.53	1.53	0.10	0.06	28.34	26.81
8		1.53	1.53	0.11	0.06	29.19	27.66
9		1.53	1.53	0.11	0.06	30.06	28.53
10		1.53	1.53	0.11	0.06	30.96	29.44
11		1.53	1.53	0.11	0.07	31.89	30.36
12		1.53	1.53	0.12	0.07	32.85	31.32
13		1.53	1.53	0.12	0.07	33.83	32.31
14		1.53	1.53	0.12	0.07	33.83	32.31
15		1.53	1.53	0.12	0.07	33.83	32.31
16		1.53	1.53	0.12	0.07	33.83	32.31
17		1.53	1.53	0.12	0.07	33.83	32.31
18		1.53	1.53	0.12	0.07	33.83	32.31
19		1.53	1.53	0.12	0.07	33.83	32.31
20		1.53	1.53	0.12	0.07	33.83	32.31
21		1.53	1.53	0.12	0.07	33.83	32.31
22		1.53	1.53	0.12	0.07	33.83	32.31
23		1.53	1.53	0.12	0.07	33.83	32.31
24		1.53	1.53	0.12	0.07	33.83	32.31
25		1.53	1.53	0.12	0.07	33.83	32.31
26		1.53	1.53	0.12	0.07	33.83	32.31
27		1.53	1.53	0.12	0.07	33.83	32.31
28	16.2255	1.53	17.75	0.12	0.07	33.83	16.08
52		1.53	1.53	0.12	0.07	33.83	32.31
53		1.53	1.53		0.07	25.86	24.33
			276.13				**1366.51**

5.5.15 Financial Analysis

Apart from the Economic Analysis the Project has to be assessed from the operating company's point of view as this project is being prepared for attracting private investment. The financial analysis is carried out by the usual discounted cash flow technique. Three tools namely the Internal Rate of Return on Equity Investment, Net Present Value and Benefit Cost Ratio have been applied.

The analysis is carried out in US $ as the price for the energy that will be sold from this project to Nepal Electricity Authority (NEA) upon conclusion of the Power Purchase Agreement (PPA) between NEA and the developer of this project in US$

The relevant specific parameters applied for the financial analysis in this study are as follows:

- **Analysis Period:** will be assumed to be 3 years – project construction period
- **Investment Cost**: The total investment required for the project including 1% custom, 1.5% local tax and VAT @ 13%. The investment cost determined is financial cost as it is based on unit costs prevailing currently in the market and therefore adopted for the financial analysis. The estimated investment cost is escalated by 5% to make up for inflation.The project is assumed to require three years to complete. The percentage project cost disbursement is assumed to be 70% and 30% of the total project cost in the first and second year respectively. The interest during construction (IDC) has been estimated at an interest rate of 10%.
- **Operation & Maintenance Costs**: Annual operation and maintenance costs of the plant in the first year of commercial operation following completion of the project have been assumed to be 1.5 percent of the total project cost. Thereafter it is assumed to increase at the annual escalation rate of 3 percent
- **Insurance Premium**: Annual insurance premium of the plant is assumed to be 1.0 percent of the total financial cost plus additional 13% VAT.

- **Discount Rate**: The discount rate has been taken to be 10% and used to calculate the Net Present Value and Benefit Cost Ratio of the project as well as to compare with the calculated IRR on Equity Investment

- **Royalty:** According to the Electricity Act, 2049, for hydropower plants ranging between 1 and 10 MW, the Government imposes, for the first 15 years from the date of commercial operation, NRs. 100 per year for each installed kW as capacity royalty and 2.0 percent of energy revenue as energy royalty. From the 16th year onwards, the capacity royalty increases to NRs. 1,000 per year for each installed kW and the energy royalty increases to 10 percent of energy revenue

- **Tax Rate**: As stipulated in the Income Tax Act 2058, the applicable corporate tax rate for enterprises undertaking electricity generation is 20 percent and an income tax of 1.5%.

The result from the financial analysis carried out based on the above mentioned parameters is as follows:

Option –I

Case	**Construction Period =3 years**
Project Name	**Tamakoshi-V : Option-I**
Project Location	**Central Development Region**
Type of Scheme	**RoR Scheme**

Installed Capacity				80.05	MW
Total Energy				409.66	GWh
Total Project Cost				139.91	M.NRs
Project cost without contengencies, environment cost, project construction manatement cost				120.92	M. NRs
Total Civil Cost				77.33	M.NRs
Total E/M Cost				29.84	M.NRs
Total H/M Cost				4.81	M.NRs
Total Transmission and Substation Cost				3.17	M.NRs
Pre-Construction Cost				5.76	M.NRs
Total Financial Cost				171.20	M. NRs
Specific Energy Cost				0.06	US$/Kw
Exchange Rate				1.00	75

Equity				30%	%
Debt				70%	%
Interest Rate				10%	%
Interest Duration				10	Years
Equal Repayment to Bank				21.33	MUS$/ann

B/C Ratio	**1.08**	
FIRR	**11.8%**	
NPV	**14,559**	**K US$**

Option-II

Case				**Construction Period = 3 years**	
Project Name				**Tamakoshi-V: option –II**	
Project Location				**Central Development Region**	
Type of Scheme				**RoR Scheme**	
Installed Capacity				87.15	MW
Total Energy				446.01	GWh
Total Project Cost				154.75	M.NRs
Project cost without contengencies, environment cost, project construction manatement cost				133.40	MNRs
Total Civil Cost				89.09	M.NRs
Total E/M Cost				32.45	M.NRs
Total H/M Cost				3.82	M.NRs
Total Transmission and Substation Cost				3.59	M.NRs
Pre-Construction Cost				4.45	M.NRs
Total Financial Cost				189.91	M. NRs
Specific Energy Cost				0.06	NRs/Kw
Exchange Rate				1.00	75
Equity				20%	%
Debt				80%	%
Interest Rate				10%	%
Interest Duration				10	Years
Equal Repayment to Bank				26.75	MNRs/ann

B/C Ratio	**1.08**	
FIRR	**11.8%**	
NPV	**13,957**	**K NRs**

5.5.16 Conclusion and Recommendation

As this project is conceptualized to operate in tandem operation with Upper Tamakoshi HEP (456 MW), the construction of this project is supposed to be commissioned only after the full operation of Upper Tamakoshi HEP. Therefore, the energy calculation of this project is based on the design discharge of 66 m^3/s.

Two possible powerhouse locations are observed for Tamakoshi-V Hydroelectric Project along the right bank of Tamakoshi River. Preliminary technical study of both the possible alternatives is carried out based on the surface geological information and project cost.

Based on the calculated project cost and estimated energy generation, economical and financial analysis is carried out.

Following are the condition and recommendation of this interim report:

1. Tamakoshi –V is conceptualized to operate in tandem operation with Upper Tamakoshi Hydropower project.

2. This project will be constructed only after the completion of Upper Tamaksohi HEP in its full capacity – 456 MW, 66 m^3/s design discharge and additional water from Rolwaling Khola or Bhaise Khola. Thus the energy calculation of Tamakoshi-V is based on the design discharge of $66m^3/s$.

3. An interconnection arrangement is conceptualized to divert design discharge required for the Tamakoshi- V from the tailrace to Upper Tamakoshi near to the Gongor village- therefore no additional headwork is constructed for this project

4. Two possible powerhouse locations are found on the right bank of the Tamakoshi River. Techno-economical analysis shows that both the options are equally attractive with very close financial indicators. The geological investigation also shows the similar nature of the rock formation in the both locations of the powerhouse. Hence, the selection is based on the increment of power/energy and the utilization of the available resources. The Option II with more power generation utilizing all possible available resources is chosen for the further study.

5. All the further studies will be based on the second layout alternative.

6. Project Description

6.1 Project Conceptual Layout

The Tamakoshi -V HEP is conceptualized as cascade project of Upper Tamakoshi HEP with tandem operation. The project area is located on the right bank of Tamakoshi River. This project does not need separate headwork. It takes the discharge from the tailrace of the Upper Tamakoshi Project through an inter connection arrangement and conveyed to headrace tunnel of this Project. An underground powerhouse is proposed at Suri Dovan.

The general arrangement of the project comprises of underground inter connection arrangement of headrace tunnel with the tailrace tunnel of Upper Tamakoshi HEP. The interconnection system consists of connecting tunnel, a head pond required to maintain suction head at the pressurized head race tunnel entrance, spillway and spillway tunnel. The water from tailrace of Upper Tamakoshi HEP is diverted to this interconnection system and conveyed to the 8.20 Km long concrete lined headrace tunnel, a 122.38 m high drop shaft, 41.44 m long pressure tunnel, 141.61 m long tailrace tunnel, 54.55 m long tailrace canal and underground powerhouse containing four vertical axis Francis turbines, from where it is released into the Tamakoshi river at about 0.2 km downstream from the confluence of Tamakoshi River and Khari Khola at Suri Dovan.

Optimization of the design discharge and installed capacity of the project are not necessary as this project shall be developed as cascade project of Upper Tamakoshi HEP for the tandem operation. There is no major tributary contributing significant dry season flow in the river stretch from the headwork of Upper Tamakoshi to the tailrace of the same project.

As per the latest development concept of Upper Tamakoshi HEP, instead of flow from the Rolwaling Khola flow from Bhasi River will be diverted to the headwork of Upper Tamakoshi Project at the first stage and flow from Rolwaling will be diverted only after the operation of Upper Tamakoshi to increase the dry season discharge in the project in the second stage. Hence, the design discharge of this project shall be taken same as the design discharge of Upper Tamakoshi Project, which is 66.0 m^3/sec. The interconnection system, headrace tunnel, surge tank and the other structures of the project are designed for the discharge of 66.0 m^3/sec.

The field investigation of this project is completed. Based on the outcome from the field investigations layout and design of the structures of this project has been carried out.

The main features of the Project are as follows:

- Interconnection system comprising a connecting tunnel, headpond, spillway, and spillway outlet tunnel;

- Water conveyance system consisting of a 8200.00 m long concrete lined, 5.6 m finish diameter headrace tunnel, a 98.0 m high (from the Crown of the Surge Tank), 15.0 m diameter surge tank, 122.38 m high drop shaft, 41.44 m long pressure tunnel, 141.61 m long tailrace tunnel, 54.55 m long tailrace canal

- During the selection of the alternative layout, a surface powerhouse was assumed. Based on the outcome of the geotechnical investigation that suggests unavailability of the bedrock for 30 m or more from the surface, suitability of the surface powerhouse is questionable. Hence, based on the rock condition an underground powerhouse is proposed. A underground powerhouse is equipped with 4 number of turbines with an installed capacity of 87 MW (4 X 21. 75 MW); and

- For power evacuation from Tamakoshi-V HEP, Pie connection of Tamakoshi V to Upper Tamakoshi-Khimti 220 kV transmission line at Tamakoshi-V switchyard is proposed.

The general arrangement of the project is shown on Drawing No. TV-GL-200

6.2 Description of the Project

6.2.1 General Arrangement of Inter Connection System

The general arrangement of the Tamakoshi V inter connection system, as outlined above, comprises of a connecting tunnel from tailrace tunnel of Upper Tamakoshi HEP, headpond, spillway and spillway tunnel. An inter connection system is constructed to divert the design discharge of Upper Tamakoshi HEP into underground headpond of Tamakoshi –V through a connecting tunnel. Depth of the headpond is designed to satisfy the suction head required for the pressurized headrace tunnel of Tamakoshi –V. The headpond width, length and height are 13.60m, 22.75m and 21.97 m respectively. The height is measured from the crown to the bottom.

Length of the pond is governed by the length of the spillway required to drain out the discharge safely into the river itself in case, the Tamakoshi V is not operating and the

Upper Tamakoshi is in operation, and tailrace gate of the Upper Tamakoshi is closed. The width of the pond is designed for the smooth transition of water from connecting tunnel to the head pond.

The general arrangement of the Inter Connection System is shown on Drawing TV-HW-400

6.2.1.1 Connecting Tunnel

Design Criteria

The free flow connecting tunnel is designed to withdraw all the water coming into the tailrace to Upper Tamakoshi without effecting its power generation i.e. without raising the water level in the tailrace of Upper Tamakoshi HEP. The size of the connecting tunnel is same as the tailrace tunnel of Upper Tamakoshi and it is connected to the headpond of the Tamakoshi-V. The tunnel size is designed using Manning formula as a free flow tunnel with the minimum head loss principle. A tailrace gate at the Upper Tamakoshi will be closed for the diversion of tailrace discharge into the connecting tunnel through the smooth entrance way and to the headpond of Tamakoshi-V.

Description of Structures

The connecting tunnel starts approximately 75.0 m upstream of Upper Tamakoshi HEP tailrace tunnel outlet. The total length of this structure is about 110.0 m. The invert level of starting point is at EL 1153.99 masl.

The shape, size and support system of the connecting tunnel is similar to the Upper Tamakoshi HEP tailrace tunnel. A concrete support of 0.2 m thick concrete lining is proposed on the side walls and invert of connecting tunnel with necessary rock bolts. The invert level of end point is at EL 1153.97 masl. A wider section of the connecting tunnel is proposed at the end stretch before the pressurized headrace tunnel of Tamakoshi-V HEP. A vertical lift gate is provided approximately 20.0 m away from the interconnection point. The gate will be operated through a gate chamber above the connecting tunnel for the repair and maintenance of headpond. The part of the connecting tunnel from start to about 20 m downstream from the gate chamber needs to be constructed during the construction of Upper Tamakoshi Tailrace.

6.2.1.2 Headpond

Design Criteria

Headpond is design for the smooth flow of design discharge into the pressurized headrace tunnel of Tamakoshi –V. Headpond functions as transition section between the pressurized headrace tunnel and free flow connecting tunnel. The dimension of the headpond is designed to fulfill necessary suction head required for the pressurized headrace tunnel of Tamakoshi-V and to accommodate a free flow spillway on its right wall. Hence, the depth of the headpond is governed by the required suction head and the length is decided by the crest length of spillway.

The spillway at the right wall of headpond will be functioned during in case the Tamakoshi-V is stopped while the Upper Tamakoshi is still running. In this situation, the spillway will channel out all the water coming from tailrace toward Tamakoshi River without interrupting the power generation of Upper Tamakoshi.

Water required for the initial start up of the turbines in Tamakoshi- V will be fulfilled from the tailrace tunnel of Upper Tamakoshi Project.

Description of Structures

A headpond is proposed for the smooth flow of design discharge into the headrace tunnel of Tamakoshi V fulfilling the suction head requirement criteria. To maintain the required suction head of the headrace tunnel of Tamakoshi V, the headpond depth is maintained at 16.94 m. The invert level at starting point of headpond is at EL 1153.99 masl which slopes up to 14.0 m up to invert level of EL 1137.480 masl. The 0.4 m thick concrete lining has been proposed in headpond. The slope is maintained at 1:1 ratio. Bell mouth structure is proposed at the beginning of the headrace tunnel. The invert level of the headrace tunnel is 1141.98 amsl which is 4.5 m above the bottom elevation of head pond. The intake sill of 4.50 m is maintained to avoid intrusion of unnecessary particles into the headrace tunnel. A vertical trashrack is provided at the bell mouth entrance to prevent floating materials from entering into the headrace tunnel. The suction head provision of 7.20 m provided from the tunnel crown level.

The length of the Upper Tamakoshi HEP is 2.87 km long and flow area is 19.74 m^2 which is capable of storing 54679 m^3 of water. In case of sudden shutdown of Upper Tamakoshi Powerhouse, water stored in the tailrace tunnel will be utilized to run the Tamakoshi-V powerhouse for 13 minutes.

6.2.1.3 Spillway and Spillway tunnel

Design Criteria

Spillway is designed to spill out maximum discharge of 66m^3/s in case of partial or total shut down of Tamakoshi V HEP while Upper Tamakoshi HEP is still in operation. Spillway crest level and its width is designed in such a way that water level at head pond and connecting tunnel does not affect the water level of Upper Tamakoshi HEP tailrace tunnel during spilling and surge due to load rejection. Spillway is designed as an ogee shape.
Shape and size of the spillway tunnel has been kept similar as that of Upper Tamakoshi HEP tailrace tunnel. The elevation of spillway outlet tunnel is proposed to keep the structures safer from 1000 yr return period flood in Tamakoshi River.

Description of Structures

The crest level of spillway is kept at EL 1152.52 masl and 15m crest length of spillway is proposed. Ogee shaped spillway is connected to spillway tunnel with contraction transition. The 0.4m concrete lining has been provided around spillway. The spillway tunnel has same support system as that of Upper Tamakoshi HEP tailrace tunnel. The outlet of spillway tunnel is kept at EL 1147.00. The spillway tunnel outlet is provided with an automatic vertical lift gate, which will be in operation only during extreme flood conditions such as PMF, GLOF etc. During the extreme conditions, the sensor provided in the gate will automatically close the gates to safeguard powerhouse and other structures.

6.2.2 Water Conveyance System

Water conveyance system of the project consists of headrace tunnel, surge tank, steel lined tunnel inclined shafts with horizontal component at intermediate level and high pressure steel lined tunnel. Water from Upper Tamakoshi HEP tailrace will be diverted in to the head pond through connecting tunnel and then conveyed to the headrace tunnel. A Surge Tank is provided at the end of the headrace tunnel. An inclined shaft will convey water to the high pressure steel lined tunnel and thereafter to the turbines through manifold. A steel lined tunnel will connect the main headrace tunnel with the inclined shaft. The steel lined tunnel will be bifurcated to feed the four turbines installed in the powerhouse. Following are the basic assumptions made in the optimization of headrace tunnel/ inclined shaft and high pressure steel line tunnel:

- Economic life of the civil structures is 50 years.

- Discount rate is 10%.
- The powerhouse will be operated six hours per day during dry season and round the clock during wet season.
- All tunnels are fully concrete lined with 30 cm thickness.
- Minimum thickness of shotcrete is 10 cm.

Value for the average energy is assumed to be 6.0 US cent per kWh. These correspond to the posted rate of Nepal Electricity Authority. Details of the conveyance system are dealt in the following sections.

6.2.2.1 Headrace Tunnel

Headrace tunnel starts from the gate shaft of the slopping intake and ends at the surge tank. Total length of the headrace tunnel is 8200.00 meters. The size of the headrace tunnel is optimized along with the size of the surge tank. Apart from the basic assumptions, following assumptions are made for the optimization of headrace tunnel

- All tunnels are concrete lined.
- Maximum value of Manning’s coefficient for concrete lining is 0.014 where as the minimum value is 0.01.
- Minimum thickness of lining is 30 cm.

Description of the Structure

Total length of the headrace tunnel up to proposed surge tank area is estimated to be 8200.0 meter. There are two horizontal bends in the tunnel. First bend is about 170 degree with the flow direction at a distance of about 296.0 meter from the intake. Second bend is about 133 degree and is located at a distance of about 8200.0 meter from the intake. Based on the above assumptions, the optimum diameter of the headrace tunnel is estimated to be 5.6 meter. As no in-depth study of the geotechnical conditions has been carried out, the headrace tunnel is assumed to be fully concrete lined. The thickness of the lining is estimated to be 30 cm. The design velocity in the tunnel is 2.20 m/s. The excavated diameter of the tunnel is 6.20 meter. The longitudinal profile of the headrace tunnel is presented in the Dwg. No. TV-HT-500. The optimization of the headrace tunnel is presented in Figure No. 6.1. The invert level of headrace tunnel at the starting point is 1144.40 masl and that below the surge tank orifice is estimated to be 1112.40 masl.

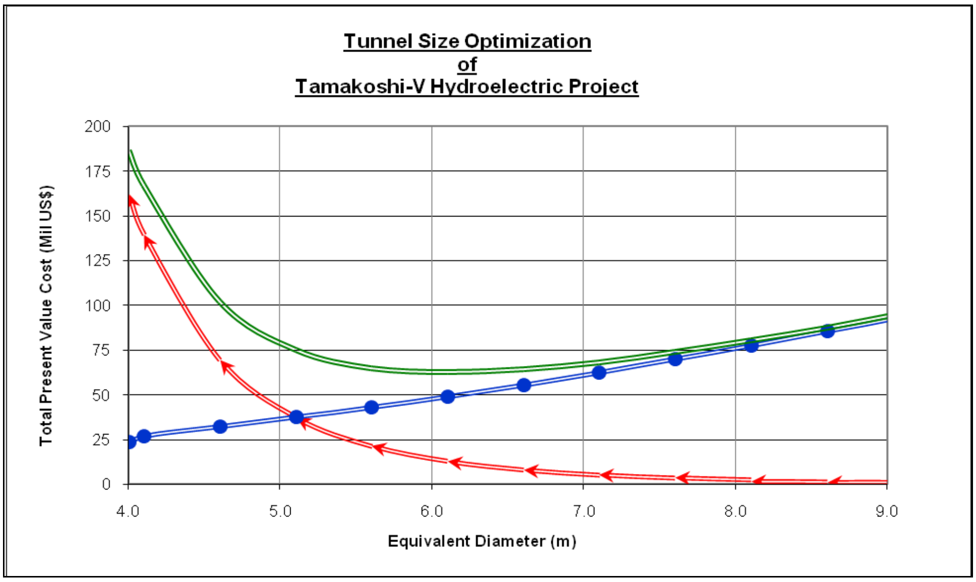


Figure No 6.1: Optimization of Headrace Tunel

The headrace tunnel is extended to the starting point of inclined shaft downstream of surge tank. This portion of headrace tunnel is 40.00 meter long with 5.60 meter diameter and is concrete lined. A valve chamber is provided in between surge tank and starting point of inclined shaft. The main function of this gate is to allow the maintenance of the inclined shaft and penstock pipe without dewatering the whole tunnel.

Three construction adits are provided for the construction of headrace tunnel. Adit No. 1 will be provided downstream of the headpond. This will facilitate the independent access to headrace tunnel during construction period. This adit will be used for the construction of the upstream part of the headrace tunnel. Similarly, Adit No. 2 will be provided approximately at the central part of the headrace tunnel. This will facilitate the construction of the tunnel from two faces. Adit No.3 is proposed just upstream of the surge tank. This adit will be used for the construction of downstream part of the headrace tunnel, surge tank, valve chamber and up to the starting point of inclined drop shaft. This adit will also serve as the access tunnel to valve chamber. All these adits will be plugged near the headrace tunnel by the concrete after the construction. An access tunnel to the powerhouse will be constructed during the construction of the powerhouse and initially it will be used as a construction adit and after that it will be used as access tunnel.

6.2.2.2 Surge Tank

The sizing of the Surge Tank was done during the optimization of the headrace tunnel using the Thoma relationship which considered the pressure parameters of the power tunnels. The Surge Tank is located as far downstream as possible to maximize the effectiveness of controlling in the high pressure section of tunnel. . The size of the Surge Tank has been determined to satisfy the following conditions:

- Cross section of the Surge Tank is not less than the Thoma Cross Section area but must be a practical diameter to facilitate construction.
- Adequate freeboard should be provided above and below the maximum upsurge and minimum down surge and also to suit the topography.
- The height of the surge tank should be enough to accommodate the water level during the sudden closure of the power house
- The minimum operation level of the surge tank should have sufficient suction water level during the sudden demand of the water.

Minimum head loss in the headrace tunnel is assumed to estimate the maximum upsurge whereas maximum head loss in the headrace tunnel is assumed to estimate the down surge. The diameter of the surge tank is fixed in such a way that the ratio of friction loss to maximum surge, neglecting friction, is less than 0.8 for the upsurge and down surge calculations. Jaeger's equation is used to estimate the maximum upsurge and Calame and Gaden's relationship is used to estimate the maximum down surge.

Apart from the assumptions made for the optimization of headrace tunnel following assumptions are made to fix the size of the Surge Tank:

- Minimum free board on surge tank is 3 meter.
- Minimum cover for surge tank orifice is 5 meter.

Description of the Structure

Based on the results of the design criteria, restricted orifice Surge Tank with 15.0 meter internal diameter have been provided at the end of the headrace tunnel, at a distance of 8200.00 meter from the beginning of headrace tunnel at headpond. The orifice diameter is calculated to be 5.0 m and the height of orifice is 5.0 m. The maximum water level in the surge tank is estimated to be El. 1178.88 masl and the minimum water level estimated during maximum down surge is El. 1138.10 masl. In the normal condition the water level at the surge tank will be 1149.92 masl.

The Surge Tank inlet shall be reduced by a steel throttle to reduce the up surge and down surge to acceptable limits. This should be flexible and easy to replace and shall be fixed in such a way, that it can withstand differential pressure and high velocities. The throttle will have 5.0 m diameter. Between the headrace tunnel and the pressure shaft, downstream of the surge tank, valve chamber with a butterfly valve will be provided. This valve will be used to isolate the high pressure tunnel and vertical shaft from the headrace tunnel. This gate will be closed in the event of maintenance in the high pressure section of the power conduit which require isolation and dewatering of the power plant. This will avoid dewatering of the whole stretch of the headrace tunnel and surge tank.

The top level of the Surge Tank is fixed at El. 1191.16 masl. The invert level of the Surge Tank is El. 1118.0 masl. Hence, the total height of the Surge Tank is 73.61 meter. The invert level of the headrace just below the surge tank is estimated to be 1112.40 masl. The Surge Tank will have 0.85 meter thick reinforced concrete lining. The excavated diameter of the surge tank is estimated to be 16.70 m.

Construction of the Surge Tank will be carried out through Adit No 3 which is located just upstream of the Surge Tank. Details of Surge Tank are presented in the Dwg. No. TV-ST600 and 601.

6.2.3 High Pressure Tunnel

The high pressure tunnel consists of following two parts:

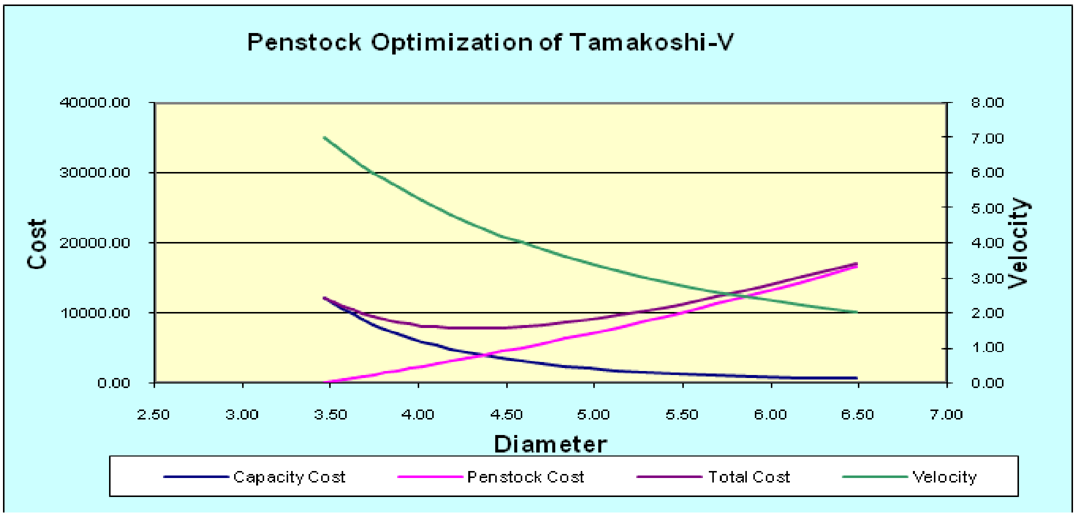
- Vertical shaft, and
- Lower horizontal portion

Entire high pressure tunnel is circular in shape. The inclined shaft starts at the distance of 40 meter downstream from the Surge Tank. The total length of vertical shaft is estimated to be 122.38 meter. The lower horizontal portion of the high pressure starts from the lower portion of inclined shaft. The lower horizontal portion is 41.44 meter long.

The vertical shaft is assumed to be steel lined. Diameter of the steel lined section of vertical and horizontal portion are 4.30 m. The 40.0 m long horizontal portion just after the surge tank and before the start of vertical shaft is also steel lined. The excavated diameter at these sections will be 5.0 m.

Optimization was carried out to estimate the size of the steel lined portion. Apart from the basic assumptions made in the optimization of headrace tunnel, following assumptions are made for the optimization of high pressure steel lined tunnel.

- Maximum value of Manning's coefficient for steel line is 0.014 where as the minimum value is 0.010.
- Allowance for the water hammer is 50% of the total gross head.
- Pressure transferred to the rock mass is 50% of the total stress developed during water hammer.
- Allowable hoop stress is 1500 kg per sq. meter.
- Provision for erosion is 1.5 mm



The optimum finished diameter of the steel lined section is 4.30 m.

The thickness of the steel lining varies from 10mm at the beginning to 32 mm at the bottom. The average velocity of flow in this portion is estimated to be 4.60 m/s. Concrete lining thickness of 300 mm and shotcrete thickness of 10mm is provided in the entire high pressure steel lined tunnel.

6.2.4 Manifolds/ Bifurcation

Manifolds are provided at the end of the high pressure steel lined tunnel. This will feed the discharge to each units of turbine. The main steel lined tunnel is branched out into four smaller manifolds. These smaller manifolds feed the water to turbine. The diameter of these small manifolds is 2.75 meter.

6.3 Powerhouse

6.3.1 General

The powerhouse is designed for the generation of 87.0 MW power and it is equipped with four number of vertical axis Francis turbines. The proposed underground powerhouse is located on the right bank of Tamakoshi river inside the vertical rock cliff just downstream from the confluence of Tamakoshi and Khare Khola at Suri Dovan village. The rock mass comprises quartzite with medium foliated, moderately weathered schist rock is present in the powerhouse area. The powerhouse accommodates four turbine generators each with a capacity of 21.75 MW and ancillary facilities for control and protection.

The tailrace has been arranged within the allocated licensed area very close to powerhouse. Due to the boundary restriction it is aligned in this way, otherwise it would have been aligned in the way to minimize the cutting and the layout pattern.

The overall layout plan of the powerhouse complex including penstock and tailrace is presented in Drawing No. TV-PH-700.

6.3.2 Design Criteria

The powerhouse design is governed by the following principle criteria:

The powerhouse should be easily accessible. The powerhouse shall be located in a stable location that entails minimum slope protection works, safe from the geological and hydrological hazards and should have sufficient space for the switchyard. A surface switchyard close to the powerhouse is selected which is above high flood level. This will shorten the length of the power cable and ancillary equipment .

Number of unit is actually governed by transportation criteria, system size and available hydrological parameters. The four numbers of units for the project is based on the hydrological criteria i.e. smooth running of at least one unit in case only one unit of Upper Tamakoshi is in operation.

The spacing of the turbine/generator units is governed by the size of the generator including, the exciter space required between the generator and turbine enclosures. The unit spacing between units are thus 8 m c/c. A vertical turbine-generator alignment has been adopted, as it provides easy access to the equipment and the powerhouse layout is simple thereby economizing the costs. The turbine centre line setting has been maintained at an elevation of 992.61 m and the generator (machine) floor at El. 1001.41. An erection bay is also provided on the same floor level at that of machine floor at El 1001.41 m and the generator floor level is 1000.00, which is at the higher elevation from possible 1000 years return period flood in Tamakoshi River which is 999.64 amsl.. In case of GLOF event, the sensor provided in the project will automatically close the tailrace gate to safeguard the powerhouse.

The overall length of the powerhouse is governed by the unit spacing of turbine/generator and the space required for the erection bay. The overall length is thus calculated as 50.00m m. The control room and workshops are located at the El 1001.41m.

The width of the powerhouse hall is governed by the diameter of the Francis turbine plus the space requirements for ancillaries like butterfly valves, generator control panel etc. The width of the machine hall is 16.00 m. The spaces for lift and the staircase have also been accommodated in this part.

The height of the powerhouse generator hall is governed by the vertical distance required for the transportation of the generator stator, the height of gantry crane and the height required for the roof. The overall height of the powerhouse is thus estimated at 30.21 m. from the roof top to the foundation.

6.3.3 Powerhouse Layout

The powerhouse accommodates four number of vertical Francis turbine of 21.75 MW each and generator units. The space between the units are kept at 8m centre to centre. A maintenance bays is proposed on the left side of the powerhouse.

The erection bays lie at the same El.1001.41 at the generator floor and connected with an access road. The powerhouse accommodates a control room at El. 1001.41 m and a workshop on the El. 997.41m just below the erection bay. The turbine floor is at El. 993.51m. All the said floors are easily accessible by the proposed stairs. Three number of sump pits are arranged at an elevation 988.36 amsl which will collect the leakage water in the powerhouse. The pumps connected to the sump pit will drain out the collected water into the tailrace automatically.

An arrangement of inspection gallery is provided from the El. 997.41m at the back (u/s) gallery to draft tube. For maintenance and erection facility hatches for each turbine just above the butter fly valve is provided from the machine floor across the u/s and d/s gallery and it accesses up to the sump pit and turbine floor. The penstock feed the discharge into the turbines via butterfly valves from the U/P side of the spiral casing. The four draft-tubes discharge into four separate tailrace conduit. These four tailrace conduit discharges through an outlet structure to the tailrace canal which convey the tail water into the

Tamakoshi River. The powerhouse has a size of 50.00m x 16 m x 31.00 m (L x B x H). The main levels of the powerhouse are as follows:

Generator Floor	1001.41 masl
Erection Floor cum monitoring Room	1001.41 masl
Turbine floor	993.51 msl
Control room floor	1001.41msl
Gantry Crane level	1011.41msl

The layouts and cross section of different floor levels are illustrated in the Drawing No.TV-PH-700, to 706.

Erection Bay

The service bay is provided on the left sides of the machine hall which accommodate the turbine and generator components during initial, consecutive erection of the units and during future maintenance periods. Enough space is provided for vehicular access, assembly of the draft tube liner, turbine stay ring, and head cover main shaft, guide bearing and rotor as well. This area serves as a lay down area for the runner. The workshop is proposed adjacent to the turbine floor, below the erection bay slab at El. 997.41m level.

Turbine Generator Floor

The generator is 7.5m dia., 7.10 m high, covering the combined area of turbine and generator floors. The powerhouse crane spans 11.40 m high and is supported on reinforced concrete columns. The gantry Crane has a capacity of 350 T maximum.

The generator floor is at an elevation of 1001.41 amsl. The unit control panels are located at the top floor El1001.41m of the service area part of the same power house building. The governor for the unit is provided adjacent to the machines at turbine floor.

Four numbers of draft tube gates each with a dimension of 3.6 m x 2.25 m will be provided along with hoists just outside of the powerhouse cantilever beam supporting the hoisting mono rail beam equipped with a hoisting device along the d/s wall of the powerhouse at the elevation 1011.41m.

Control Room and Accessories

A control room with electrical utilities and office facilities are provided at the service area part at an El. 1001.41m floor. This floor is facilitated with a glass room to ease the movement and for the inspection of the machine floor. The control room at an elevation of 1001.41 m looks over the generator hall and contains all the necessary equipment for the control and protection of the powerhouse. It will also accommodate operation and monitoring equipment of the intake, water conveyance system, under sluice and gate operation system. The 6.6 kV switchgear is at the same level as that of the control room. The DC supply and battery chargers are provided at the workshop floor level (El 997.41 amsl).

6.4 Tailrace Conduit and Outlet Structure

6.4.1 Tailrace Conduit

The dimension of the tailrace is designed to carry the design discharge of 21.75 m^3/s with a velocity of 1.25 m/s in the single conduit. From the construction point of view, the tailrace conduit has been designed as a tunnel of 141.6 m and partly an open canal of 54.55m long. The total length of the tailrace conduct is 196.15m. The details of tailrace conduit and outlet structure are shown in TV-PH-707.

6.4.2 Outlet Structure

The outlet structure will be located 196.15 m downstream from the powerhouse on the right bank of the Tamakoshi River. The major components of the structure will be the tailrace openings and the gate-operating platform. The outlet structure has been designed as a tunnel and open channel. The invert level of the outlet structure will be at 990.60 masl based on minimum flow of 16.50 m^3/s. The normal tail water level is at 993.11 amsl.

The deck elevation of the outlet structure is taken as 1003.00 masl, which is higher than the high flood level (HFL) at an elevation of 995.60 masl corresponding to 1:100 year flood. This protects equipment placed on the deck of the outlet structure from the high flood. Road access is provided to the outlet structure from the powerhouse area.

The outlet structure will have four fixed wheeled gates installed at the outlet gate shaft. These gates will be fully opened to allow the design discharge to pass from the tailrace conduit into the river. The size of the gates will be 4.0 m x 2.50 m and will be operated with the help of a hoisting device installed at the mono rail in the cantilever beams at elevation 1001.41 from control room floor levels.

6.5 Switchyard

An outdoor switchyard has two terraces with a size of 80 m x 40 m at lower level and 40 m x 40 m at the higher level and is provided about 144 m away from the underground powerhouse on the built-up terrace. The switchyard at El 1005.00m will be provided with an access road and graveled base.

6.6 Power Facilities - Electrical Equipment

6.6.1 Generator

Design Criteria

The unit rating of the turbine-generator has been selected based on the criterion that the minimum two units and capacity of each unit does not exceed 10% of the total NEA's forecasted load of the system. This assumption is based on the following consideration:

a. to limit the transportation sizes and weights;
b. to minimize the power shortage during maintenance or forced outage of a unit;
c. to provide sufficient flexibility during operation;
d. to be able to maintain the system stability during the tripping of a unit.

Based on optimum capacity of 87 MW and above mentioned criteria the generating unit rated output has been selected at 21.75 MW.

Each of the four generators in the underground powerhouse will be synchronous vertical shaft unit coupled to their associated Francis turbines. The rating of generator will be 24.17 MVA (21.75 MW at 0.9 power factor), which will slightly exceed the turbine output under mean reservoir level and head conditions. For the purpose of this study, the generator rated voltage is selected to be 11 kV, 50 Hz and at 0.9 power factor. The speed will match the turbine synchronous speed, which is 428.57 RPM. It has been assumed. For the purpose of these studies, that synchronous condenser operation will not be required.

The rotor and stator windings will be insulated at class F, however the temperature rise will be limited to 80 degree Celsius over a maximum cooling air temperature of 40 degree Celsius.

The generator will be totally enclosed, air and water cooled with air to water heat exchangers located in the generator pit. The generator fire protection will be provided by a

CO_2 delude system. The activation of the CO_2 fire protection system will be conditional to the operation of the flame or smoke detectors in the generator pit combined with the operation of the generator differential protection.

The generator will be equipped with a set of combined pneumatic or hydraulic operated brakes and jacks.

For the fast response to assist with the stability of 220 kV systems during disturbances, it is proposed to have the generator equipped with static excitation system and power system stabilizer. For the field flashing, a rectified AC supply will be used.

Due to transportation limitations, both the generator stator and rotor will need to be delivered to site in sections and assembled within the powerhouse. For assembly during construction and to enable disassembly for maintenance, the station crane capacity will have to be suitable for lifting the complete rotor.

Table No. 6.1:The preliminary main parameters of the generators are summarized in the following table:

Parameters	Value
Number of units	4
Rating	21.75 MW vertical shaft
Power factor	0.9 over exited
Normal capability	24.17 MVA at 1.0 to 0.9 power factor over exited
Cooling	Totally enclosed Water /Air Cooling
Synchronous speed	428.57 r/min
Number of poles	14
Frequency	50 Hz
Rated voltage	11 kV
Efficiency	0.96
Neutral grounding	Resistive grounding via grounding transformer

6.6.2 Excitation System

The selected excitation for the generator is a Static Excitation system. The required d.c. excitation is provided through a bridge rectifier and filtering arrangement. Automatic Voltage Regulator (AVR) will be used for the generator.

6.6.3 Switchgear, Cable, PT, Neutral cubicles and Associated Equipment

The nominal current rating of the connection of the each generator terminals to the switchgear at 11 kV is 1268.46 A. To meet this current rating, it is possible and the suitable solution to use parallel 12 kV XLPE insulated cables without affecting the reliability of the installation. The bus will connect the generator terminals to12 kV generator switchgear, which will be located in the generator floor. The taps connection from main bus to the Exciter will be through Marshalling cubicle (MC) adjacent to the Excitation Transformer of each unit. The excitation transformer and the cubicle will be installed at the generator floor next to the MC.

The neutral side of the generator will connect the generator neutral terminals to generator neutral grounding cubicle through a high voltage power cable.

The connections between 12 kV switchgears for power transformers located in the generator floor and the main step-up transformer located at outdoor switchyard is also selected by 12 kV XLPE insulated cables. In order to meet this current requirement, single core multi parallel copper conductor cables are enough for each power transformer, which is commercially available. Taps from the main bus will connect to the potential transformer (PT) and Surge protection cubicle, to the excitation transformer cubicle, and to the unit auxiliary service transformer.

The Auxiliary Service Transformer, 12 kV main Switchgears and will be located on the generator floor and 220 kV control panels will be located in the control room. Similarly, auxiliary transformers, LV switchgears and the motor control centres (MCC) will be located at the turbine floor.

The phase to ground short-circuit current is limited by the generator neutral resistor and a three phase short circuit current of the 11 kV generator bus is in the range of 15 kA. The appropriate rating of the generator circuit breaker on the 11 kV bus will be 1600 A, 40 kA, 12 kV and appropriate rating of the transformer circuit breaker on the 11 kV bus will be 3200 A, 40 kA, 12 kV. This scheme is widely used for medium size of hydroelectric project in other countries.

The outgoing feeders of the 12 kV switchgears will be aligned with main switchgear located at generator floor.

The powerhouse scheme is as shown on the single line diagram in Dwg. no. TH-15

6.6.4 Main Power Transformers

Two generating units will be connected to individual 12 kV switchgear bus. Each power transformers for two generators will be three phase, oil immersed, forced oil cooling system. The outgoing 12 kV switchgear bus of two units will be connected to three-phase step-up power transformers, which will be located at outdoor switchyard. On the low voltage side, the transformer will be equipped with flange for cable connections and on the high voltage side 220 kV bushings will be provided.

Connections of high voltage terminals of the transformers, switchgear and protection equipment, located at the switchyard will be made by ACSR bear conductors. The neutral of the HV side of the transformer will be solidly grounded.
In view of the size and weight limitations associated with the transport of transformers from Indian port to site, the possibility of using three phase-transformers instead of one-three phase transformer for two generators, it has been considered to use three phase transformers.

The three phase 63 MVA 50 Hz power transformers will step-up the 11 kV of generator voltage to 220 kV. This transformer rating is standard size and consistent to the rating of the two generators. Although, the variation in voltage can be accomplished by the voltage adjustment of the generator, it is recommended that an off-load tap-changer will be provided to compensate for changes in the system operating characteristics throughout the life of the plant. The proposed tap range is +/- 2 x 2.5%. The cooling shall be ONAN. This cooling method will not require fans, which eliminate fans controls and meets the operating conditions.

Table No. 6.2: The Transformer Parameters are summarized as follows

Rating	63 MVA, Three phase (standard)
Cooling	ONAN
Primary voltage	11 kV
Secondary voltage	220 kV
Vector group	DYn-11 (Solidly grounded neutral)
Frequency	50 Hz
Taps	-5%; -2.5%; 0; +2.5%; +5% on the 220 kV windings
Impedance	less than 12 %
Efficiency	99 %

6.6.5 Powerhouse Electrical Auxiliaries

6.6.5.1 AC Powerhouse Auxiliaries

AC powerhouse auxiliaries fall into two main groups, essential services auxiliaries and common services auxiliaries. These are discussed separately below.

a. Essential AC Auxiliaries.

Essential unit auxiliaries are those without which the unit cannot be kept in operation, namely governor and transformer oil pumps, the cooling water pumps, the lubrication oil pumps and the Excitation systems. For the power house the essential services double ended switchgear supply the power house essential services. The Essential services switchgear is fed from two alternate sources, namely, from auxiliary service or as descried below in section (b), or from the emergency diesel generator as described in following section. The two incoming circuit breakers are interlocked to prevent inadvertent paralleling of two alternate sources.

b. Common Services AC Auxiliaries.

The common services auxiliaries can be divided into three sub-groups as follows:

- **Non-essential common service auxiliaries** are those which are less affected by the loss of supply over a short period of time. These auxiliaries include communication equipment and lighting. These loads will be fed via the Motor Control Centres (MCC) which in turn fed from the Common Auxiliary Services Switchgear.

- **Operational common services auxiliaries** are those without which over a longer period of time the powerhouse will cease to be operational, such as dewatering pumps, switchgear and governor air compressors (if required) and battery chargers. These loads will be normally fed through the 400/230V Motor Control Centres (MCC).

- **Maintenance common services auxiliaries** can be dispensed with occasionally. Typical ones are station cranes, the majority of air conditioning, compressed air for tools and oil filtering equipment. These loads will be fed via the Common Auxiliary Services Switchgear.

The selected scheme for the auxiliary services is shown in the Single Line Diagram of Auxiliary Services (Dwg no. TH-16) is based on the following criteria:

1. failure of single Auxiliary Services transformer or LV main feeder bus or circuit breaker should not cause the failure of the unit auxiliary system;

2. maintenance on Unit Auxiliary Services Switchgear will be possible without interruption to essential auxiliary services;

3. physical layout of the powerhouse should be taken into account, so that the suggested scheme is both practical and cost effective

Based on the above criteria, several alternative sources of supply are provided. The sources and their interconnections to the various level of supply are discussed below:

- The primary of the dry type auxiliary transformers is connected to the 12 kV switchgear and the secondary to the 400/230 V auxiliary services switchgear. The incoming circuit breakers of the Auxiliary Services Switchgear are interlocked, thus preventing the inadvertent paralleling of two units on the low voltage side. The outgoing circuit breaker for the LV switchgear feeds the MCCs of unit and powerhouse common auxiliaries.
- The emergency services switchgear is normally fed from the 400/230V Low Voltage Common Auxiliary Service Switchgear. The automatic transfer is made to the emergency diesel generator upon loss of the main supply voltage.

- In case of the main supply failure, the diesel emergency generator will automatically start and feed the Essential Services Switchgear. In such an eventuality, the circuit breaker to the Auxiliary Services Switchgear will open to prevent overloading of diesel generating unit.

- A diesel generator, sized to feed the essential loads, will provide station emergency power supply in the event of unavailability of the generating units and an overall system outage.

- One of the feeders of the common auxiliary services switchgear will feed the outside switchyard, the tailrace and headworks auxiliaries, the lighting around the powerhouse entrance.

6.6.5.2 DC Powerhouse Auxiliaries

For the utmost reliability, the Control, Protection, Alarm, and Telemetering equipment will be fed from a DC supply. The DC supply is provided by main and redundant battery sets and each set supplied by double battery chargers. The basic concept being that, the failure of a single DC supply system should not put into jeopardy the operation of the control and protection relay system and consequently the powerhouse. The emergency lighting can be DC, autonomous individual units or with UPS (uninterruptable power supply). For the purpose of this study, a DC battery supplied emergency lighting has been selected. The 110 V DC panels will be located in the battery charger next to the battery room. Battery and charger sizes will be determined during subsequent design phase. The batteries for the control, protection and emergency lighting will be 110 V DC, and those for communication systems will be at 24 V or 48 V DC.

An uninterruptible power supply (UPS) will also provide the AC supply, derived from 110 V dc supplied static inverters, for the SCADA system.

6.6.5.3 Emergency Diesel Generator

It is proposed that one emergency generator set be installed in the diesel generator building to provide an emergency source of power in the event of a system and power outage. The diesel generator will be located at the switchyard. The diesel generating set alternative was adopted as the preferred standby power supply on the basis of cost taking into consideration its anticipated limited usage and guaranteed availability. Since there is only one headrace tunnel, if this is drained no water would be available for generation purpose.

The diesel generator would be of adequate rating to supply sufficient power to enable the black starting of one unit, and the operation of drainage pumps, a governor oil pump, a bearing oil pump, an air compressor for governor system, and feed the battery chargers. The standby generator capacity is estimated to be about 200 kW at 0.8 power factor. The terminal voltage of the generator will be 400/230V.

The proposed scheme shown in Dwg no. NH-16 is designed to provide maximum flexibility in maintaining a secure and reliable auxiliary supply system.

The main distribution system for auxiliary electrical supplies will be as follows:

- 400/230 V ac, 3 phase, 4 wire, 50 Hz, with earthed neutral for station lighting and power auxiliaries;
- 110 V dc, unearthed, for unit control, protection, metering and for emergency lighting;
- 110 V ac, 50 Hz (derived from 110 V dc supplied static inverters) for equipment which requires a reliable ac supply;
- 24 V or 48 V dc for communications.

6.6.5.4 Distribution to outlaying works

The outlaying works for Tamakoshi-V HEP includes:

- lighting around the powerhouse entrance and the switchyard
- power for the tail race;

Local loads at the powerhouse and housing accommodation can be supplied at 400/230 V from the LV switchgears from auxiliary service switchgears.

6.6.5.5 Distribution to Housing Complex

It is anticipated that the staff housing complex will be located near the switchyard. The power for this complex will be supplied from the 11 kV switchgear located at the emergency diesel generator building. A distribution transformer 11/0.4 kV located near the complex will be provide the distribution voltage for the staff housing.

6.6.6 Control and Protection

A control room for the powerhouse, the medium voltage switchgear and the associated works will be located within the powerhouse. It will be possible to control the units and the auxiliary system from this control room.

6.6.6.1 Powerhouse Group and Unit Control

The powerhouse will normally be attended. Full automatic control of the units will be possible from the powerhouse control room.

The unit electronic governors and the unit control panels will be arranged on the generator floor. Both manual and automatic control will be provided. For the testing of the unit during commissioning and maintenance, it will be possible to control a unit in either automatic or manual mode from the panel. However, unit synchronization will not be

permitted from the unit control panel. When the unit is ready for synchronizing, the automatic or manual synchronization will be possible only from the Control Room.
The powerhouse and switching equipment will be controlled from the control desk located in the Control Room. The station control console with its own control and monitoring instruments, the synchronizer, the station annunciators, the metering panels, the protective relay panels and the temperature recorders will be located in the powerhouse Control Room. The unit protection will includes the following relay functions: generator earth fault, over voltage, under voltage, voltage restrained over current, reverse power, under/over-frequency, loss of excitation, negative sequence, stator over-temperature, Volt/Hz protection, bearing failure, governor accumulator tank pressure**,** over-speed, over-current transformer differential, 11 kV earth fault, transformer winding temperature, unit auxiliary service transformer/switchgear over current and earth fault protections.

6.6.6.2 HV Switchgear and Transmission Line Protection

The basic concept of protective relay schemes on a high voltage system is to minimize damage to system equipment, to minimize the effects of the system disturbances, and to ensure that no single contingency will disable the protection on any element of the system. Thus protective relays must be capable of reliable operation to sense and isolate all faults rapidly. They must also possess a high degree of security against unwanted operations. For maximum reliability, all circuits of the system should be protected by protective schemes, which is capable of independent detection and isolation of all faults without undue disturbance to the system.

Breaker failure protection should be provided to trip all necessary local and remote circuit breakers or the unit in the event of a particular breakers failure to clear the fault.

A basic concept of full local back-up protection, comprising duplicate high speed line protection using distance relays, over current and earth fault relays plus sequential tripping schemes for breaker failure is recommended for the 220 kV transmission lines The associated relay and control panels will be located in the powerhouse control room.

6.6.6.3 Control and Indication at the Headworks

Only equipment failure alarms at essential gates, gate position indication will be transmitted to the powerhouse Control Room.

6.6.6.4 Communication System

NEA presently has a communication system between powerhouses, the load dispatch centre (LDC), and substations which is accomplished by three basic means, namely power line carrier (PLCC), fibber optical networks and Trunk Dialing telephone system.

Two communication systems centred in the power station Control Room can be envisaged:

- Optical fibre circuits for communications from the powerhouse to Lamosangu substation and to the Load Dispatch Centre (LDC). Both systems can carry speech and data.

- a Trunk Dialing telephone service in the Control Room for communication with the LDC and other substations.

Provision for transmission of data and system status to the SCADA system at the NEAs LDC in Kathmandu should also be considered.

An internal telephone system is foreseen for the powerhouse, its offices and workshops, the emergency generator building, the residence of operational personnel, guard houses and the headworks i.e Upper Tamakoshi control room. A telephone system with two external lines will also be provided.

6.6.7 Grounding (Earthing)

The basic objective of the powerhouse, transformer gallery, switchyard, Emergency Generator building and of the remote installations grounding is

- to provide low resistance grounding;
- to limit the step and touch potentials within the acceptable limits as indicated in IEEE 80;
- to limit the ground potential rise during ground fault occurrence and to limit over voltages;
- to assure the proper operation of the protective relay system.

To be able to obtain the low grounding resistance value, it might be necessary to interconnect the powerhouse ground system to switchyard ground system and to tailrace pond. During detailed design phase ground resistivity measurements will have to be done for the design of the grounding grid.

Special attention should be paid for the grounding of the large metal objects within 50 metres of the transmission line. The fences surrounding the substation will be grounded at approximate intervals of 30 metres.

6.6.8 HV Switchyard/Substation

The proposed powerhouse is considered that the supply for system as well as for local needs. Only the excess power can be used for export from the existing interconnected power system points to Indian grid.

For the installation of the HV switching equipment and transformer, a conventional outdoor switchyard with two levels is considered. The switchyard will be located on the south-west side of the powerhouse access tunnel. The switchyard has been positioned such a way to minimise the amount of excavation necessary for the installation of equipment. The generated power will be evacuated through 220 kV transmission line of Upper Tamakoshi with loop-in loop-out arrangement at the switchyard of Tamakoshi-V.

The proposed layout of switchyard equipment is shown in Dwg no. TH-17.

6.6.9 Transmission Line

A detail power evacuation study is carried out for Tamakoshi-V hydropower project in consideration of various alternative schemes. The schemes were formulated for evacuation in the 220 kV switchyard of Upper Tmakoshi HEP and 132 kV substations at Singati.

All the alternative schemes were compared on results of technical and economical analysis, available space in under construction 220 kV substation of Upper Tamakoshi and 132 kV Singati substation for the extensions.

Based on above analysis, view of construction, operation, space constrains and maintenance of substation, facility in connection point and power losses on line and equipment, the construction of 4 km double circuit 220 kV transmission line from nearest point of under construction Tamakoshi-Khimti line to switchyard of Tamakoshi-V with loop in loop out arrangement is recommended for the power evacuation.

The detail of transmission line is described in power evacuation study report.

6.6.10 Construction Power

Alternatives for supply of construction power during construction of the Tamakoshi-V HEP project are:

- Pre-building of 220 kV transmission lines from Upper Tamakoshi–Khimti line to the project. This will require installation of 220/11 kV line bays and transformer at switchyard and 11/0.4 kV 3 phase step-down distribution transformers at the construction sites.
- Construction of 33 kV line from nearest 132/33 kV substation at Singati to the project site. This will require installation of 33/11 kV line bays at switchyard and 11/0.4 kV 3 phase step-down distribution transformers at the construction sites.
- Diesel generator on site. Depending on the load it will be necessary to install diesel generator unit and LV distribution board for power distribution to the different load centres around the construction site. Although the unit installation time is shorter, the overall cost for operation and maintenance are high. Due to problems related to fuel supply, transport, handling, this solution is not considered to be the best option.

For the construction site essential loads, a back-up emergency diesel generator unit is recommended. This emergency diesel set would be provided by the general contractor.

6.7 Powerhouse Mechanical Equipment

6.7.1 Plant Capacity

For a design discharge of 66 m^3 /s and the rated net head of 149.6 meter, the installed capacity of the project is calculated to be 87 MW at the Generator terminal. The installed capacities are based on the results of the optimization studies and are approximate values. Depending on the efficiency of the supplied machinery, the calculated output capacity could show minor differences.

6.7.2 Number Of Units and Unit Capacity

Several elements affect on the number of units chosen for hydraulic power plant, such as the characteristic of the interconnecting system, available discharge throughout the seasons, type of operation, the maintenance methods and the total cost invested in the project. Sufficient numbers of generating units are essential to ensure operation of turbines with higher efficiencies and flexibility of unit maintenance without generation loss. The normal decision for unit number is by economic analysis. The project is conceptualized as cascade to the Upper Tamakoshi HEP with tandem operation. So number of units should be selected considering the number of units selected in Upper Tamakoshi HEP. So for the project four units of generating units are selected.

Based on the optimum capacity of 87 MW and the number of units of four, the rated output of each unit of the project has been selected at 21.75 MW with 149.6 m rated net head and the rated flow of 16.5 m^3/sec.

In calculating the required turbine and generator power outputs for this study, the following values of efficiency are assumed, based on the experience data available.

Turbine	92.5%
Generator	97%

6.7.3 Selection of Turbine Type

In practice, various procedures are used for selection of type of turbines. From USBR turbine selection graph and the selection graph of various manufacturers of head verses discharge, the selection of a vertical axis Francis turbine constitutes the best option with a rated head of 149.6 m and discharge of 16.5 m^3/sec for the project.

6.7.4 Specific Speed and Synchronous Speed

The calculated specific speed limit for the given rated head is 147.92 kW-m. The corresponding turbine speed limit is 517.1 rpm. The synchronous speed must be selected based on the number of the generator poles and the network frequency. A lower speed of 428.57 rpm as compared to 500 rpm was selected for suitable turbine setting with minimum excavation work. With selection of lower speed wear and tear of the equipment will be less compared to high speed equipment. So the corresponding actual specific speed of the turbine at rated head is 122.6 kW-m.

6.7.5 Description Of Turbines

The turbines will be of the vertical shaft, single runner Francis type with spiral case and elbow type draft tube. The turbine will be equipped with wicket gates for regulation of power output and control of speed for starting, synchronizing and shut down.

6.7.6 The principle characteristics of the Francis turbines are follows:

- Number of turbine	:	Four (4)
- Type of turbine	:	Francis
- Shaft arrangement	:	Vertical
- Shaft rotation	:	Clockwise (viewed from above)
- Installed capacity of each turbine	:	22399 kW
- Installed capacity of each unit	:	21750 kW
- Rated discharge for each unit	:	16.5 m3/ sec
- Rated net head	:	149.6 m
- Gross head	:	160.92 m
- Rated speed	:	428.57 rpm
- Specific Speed	:	122.6 kW-m
- Runway speed	:	732 rpm
- Runner outlet diameter	:	1.490 m
- Spiral case inlet diameter	:	1.55 m
- Draft tube exit height	:	2.4 m
- Draft tube exit width	:	4.6 m
- Turbine center line to invert of draft tube	:	4.76 m
- Runner center line	:	el 933 masl
- Full supply level	:	el 1154.42 masl
- Tailrace water level (Normal)	:	el 993.5 masl

6.7.7 Runner

The runners must possess mechanical strength to transmit power from vanes to turbine shaft, and associated hydraulic and centrifugal forces. It must also be able to withstand forces due to runway speed and continuous light load operation. To avoid cavitation and erosion, the runners will be made of integrally cast or welded stainless steel with appropriate blend of chromium and nickel, 13/4 CrNi well suited for site repair welding. All runners are designed to be interchangeable, including spare runners.

6.7.8 Spiral Casing and Stay Ring

The spiral case will be made of high quality steel plate with welded radial joint divided into sufficient number of sections. The spiral case shall safely carry the maximum internal pressure resulting from maximum head and pressure rise due to surge and water hammer. A manhole, 600 mm in diameter will provide access to the spiral casing from the turbine floor. The stay ring shall be made of heavy welded steel plate and welded into integral part with spiral case. The turbine distributor will also equipped with the turbine head cover and bottom cover.

6.7.9 Guide Vanes

The guide vane will be made of chromium stainless cast steel, and thus highly resistant to cavitation sand erosion and shall be rigid enough to withstand deflection. The guide vane will be provided with oil less self-lubricating bearings, for turbine side cover and for draft tube side cover.

6.7.10 Turbine Shaft and Intermediate Shaft

The shaft connecting the runner with the generator shaft will consist of the turbine shaft and the intermediate shaft. The intermediate shaft connects the turbine with the generator shaft. The turbine shaft will be rigid and made of forged carbon steel or alloy steel properly heat treated. It will be designed to withstand a critical speed of 130% of runway speed of the turbine and all other stress during the operation of the turbine.

Intermediate shaft will make convenience for turbine maintenance work, and the runner and regulating parts will be removed through an access provided in the machine barrel at the turbine floor level, without dismantling the generator parts.
A shaft seal assembly will be provided to control leakage along the shaft from the runner chamber.

6.7.11 Draft Tube

Draft tube will be cone and elbow type made of welded steel plate and made of steel liner. The draft tube cone shall be dismantable to enable an easy replace of the runner from downward of the spiral case of the turbine. Interior of the draft tube shall be smooth and exterior shall be ribbed for reinforcement and sufficient number of welded anchors to establish firm grip to surrounding concrete. A draft tube cone will be equipped with two hinge door manholes and accessible all around.

6.7.12 Guide Bearing

The turbine guide bearing will be located above the shaft seal and self-oil lubricated type complete with oil reservoir and water cooling coil. It will be designed to withstand without damage the natural retardation of the turbine and generator from maximum runaway speed to rest without the use of the brakes. The lining material of the bearing shell will be suitable high grade anti-friction metal securely anchored to the shell, grooved for lubrication circulation and accurately bored for a proper fit on the shaft.

6.7.13 Turbine Shaft Seal

A contact-free or direct contact system will be used for sealing propose. The direct contact system requires the supply of clean lubricating water. In case a contact-free type (labyrinth type) seal, the hydraulic design of the turbine will be of a type, preventing water from entering into the shaft seal during the normal operation.

A separate standstill inflatable shaft seal will be provided to prevent the entrance of operational water from the tail water side into the sealing during unit standstill. The seal will be provided with a dry contact to be used in the interlocking control scheme.

The shaft seal casing will have a split construction and flanged connections for draining and aeration.

The leak water will be led directly to the drainage sump through the stainless steel piping. The system will be complete with pipes, valves, pumps, strainers, etc., as required.

The shaft seal will be mounted on the head cover and will be designed so that sealing elements can be inspected, adjusted or replaced without dismantling the guide bearing.

6.7.14 Turbine Pit Liner

The pit liner will be made of steel plate in segments, which will be welded together at site. It will be equipped with necessary stiffening ribs, pathways, platforms, etc. for access to the turbine parts.

6.7.15 Turbine Inlet Pipe Assembly

The turbine inlet pipe assemblies will include the flange on the spiral casing inlets, the flanged expansion/dismantling pipes, the turbine inlet valves, and the flanged reducing cones between the inlet valves and the penstock manifold branches.

6.7.16 Expansion/Dismantling Pipe

As part of the turbine inlet pipe, a combination of expansion and dismantling pipe will be furnished between the spiral casing inlet and the inlet valve.

The pipe will be flanged directly to the turbine spiral casing on the downstream side and to the Butterfly valve on the upstream side.

6.7.17 Governor

Each generating unit will be equipped with an efficient governing system of the digital micro-processing controlled solid state electro-hydraulic, PID control, for fast response and stable load control, permitting independent unit operation.

The governors will ensure stable governing in parallel operation. In combined operation they can regulate the required power even during fluctuation of the water level. In case of frequency fluctuation in the system an automatic switch over to speed control will be initiated to stabilize the power system frequency. The governor is selected to have sufficient capacity to supply the oil required for the guide vane servomotors to completely open or close the guide vanes.

The governor is provided with the electronic speed signal device for speed detection and reference. It must often be capable of control by frequency and output, water level, and power flow in the interconnections. In addition a simplified opening controlled i.e manual control will enable a continuation of the turbine operation, if the speed and power controller with the electronic feed-back device fail. This function shall be independent of the other governor functions.

The governor control equipments will include;

- Speed Measuring Device
- Servomotor feed-back system
- Speed monitoring system
- Gate Position Switches
- Oil pressure accumulator system
- Hydraulic actuator control unit
- Instrumentation, alarm and safety devices
- Mechanical hydraulic over-speed device

governor regulation data will be as follows:

Speed rise during full load rejection	:	≤ 50%
Pressure rise during full load rejection	:	≤ 30%
Turbine closing time Main Inlet Valve(MIV)	:	≤ 60 seconds
Guide vane closing time	:	≤ 8 seconds

oil pressure unit for the governor system will be suitably selected so that the unit has sufficient capacity to drive the governor and actuate the oil-pressure system. The governor will be located on the turbine floor near to the turbine.

6.7.18 Pressure Oil Supply System

The pressure oil supply system of each unit consists of an oil sump tank, pressure accumulator for governor oil servomotor mechanism, two motor driven oil pumps, control valves, piping, monitoring system and other accessories.

The pressure used depends upon the amount of energy required to move the turbine wicket gates. Oil pressure system is arranged as a single system for the governor, and inlet valve and by-pass valve actuators of the unit. The oil pressure system will have sufficient capacity for operating the turbine servomotors, inlet valve, and other necessary system. The rated pressure of the oil pressure system will be suitably selected.

6.1.19 Main Inlet Valve And Bypass Valve

inlet valve will be provided for each generating unit. The inlet valve will be of butterfly type with counter weight closing system. The inlet valve body shall be made of cast steel. The valve body shall be ruggedly built and adequately ribbed to minimize distortion under full load. For safety reason and to reduce the required capacity of the drainage and dewatering system, each valve will be equipped with smaller by-pass valve for the filling procedure for the spiral casing.

The butterfly valve will be connected by rigid flanges to the spiral casing and through expansion/ dismantling joint to the penstock bifurcation pipes.

The oil pressure unit of the turbine governor will be used to operate the inlet valve and by-pass valve.

valve will be open in balanced condition by oil pressure and will be closed by counter weight for safety reason. The Inlet valve will operate under the following conditions:

- **Normal Operating Conditions:** Valve opening will be initiated after 50% pressure balancing between the upstream and downstream side is reached, whereas valve closing will take place under no-flow conditions (turbine guide vanes closed)

- **Emergency Operating Conditions:** In case failure of guide vanes to work, the valve will close under the maximum turbine flow and head at the turbine inlet in the shortest time without causing the pressure in the penstock to rise above its design value.

6.7.20 Station Water System

The station water systems include the cooling water system and service and domestic water supply.

A. Cooling water supply system

Provision of cooling water supply system will be provided for generator air cooler, bearing oil coolers, etc. The CW supply system will consist of tailrace water pumped to the CW supply headers by based mounted pumps installed in the powerhouse interior. From the headers, separate risers will convey Cooling Water to the air coolers and oil heat exchangers of the generating units through coarse and fine filters and will be discharged to the tailrace. The drainage of the backwash water from the automatic self cleaning strainers will discharge into the tailrace.

Cooling water supply system for each unit will consist of:

- (two) cooling water supply pumps, base mounted, complete with electric motors.
- Complete piping systems for the CW supply circuit.
- (two) automatic self cleaning strainers each complete with electrical control panel with the provision of manual cleaning also.
- (two) duplex coarse strainers, complete with acessories.

The cooling water for shaft seal is further passed through micro filters before passing through shaft seal coolers.

B. Station Service Water System

A water storage tank installed at the suitable location of the powerhouse will serve as the source for the turbine shaft seal water and the service water. The source of service water is untreated, de-sanded water from the tail race or penstock tapping or near by river tapping. The station service water appurtenances consist of hose bibbs and water hoses.

Service water will be used for wash down of floor areas and for general cleaning, fire fighting. For drinking purpose, the necessary treatment of water will be required.
Treatment Plant will comprise of Dosing kits for Alum & Chlorine, Dual Media Filters, Activated Carbon Filter, UV Filters, Raw Water Suction Pumps, Discharge Pumps, treated water HDPE Storage Tanks etc.

6.7.21 Water Drainage System

The leakage water from the turbine shaft seal and gate control mechanism, and walls of powerhouse building will be collected in the drainage sump through drainage header. The submersible type drainage pumps are use to pumped it through embedded piping to the tail water downstream from the draft tube gate. The water shall be discharged above flood level of tail-race from there the water will flow by gravity into the tailrace.

Three (3) numbers Submersible type Pumps (two for normal operation & one for emergency operation) of equal capacity driven by suitable rating AC motors will be installed.

The drainage sumps will be provided with level sensors to facilitate auto starting and auto stopping of the pumps. The sump level very high will be sensed by a separate level sensor and alarm provided.

6.7.22 Water Discharge System

The water from all the coolers, bearing etc., will be discharged to tail race through embedded piping by gravity to the extent possible. The water below tailrace level or water in the draft tube will be collected in the sump pit by opening drain valve connected to the lowest point of the draft tube through the embedded stainless steel piping, located in the de-watering sump. Collected water will be then discharged to tailrace by pumping.

The water in the headrace tunnel is normally discharged through drain piping by opening drain valve installed near the surge tank. If, no provision of drain valve is available, then it is discharged by careful operation of turbine by manually under no load condition and then by opening penstock drain valve located at the penstock pipe upstream of inlet valve. The water below tailrace level will be discharged to tailrace exterior by pumping.

Two (2) numbers Submersible type Pumps (one for normal operation & one for stand by operation) of equal capacity driven by suitable rating AC motors will be installed and the system will be complete with all the accessories.

It will be better to have a common sump for both drainage and dewatering system as well as pump sets working for both purposes to reduce space as well as pump numbers and hence cost.

6.7.23 Compressed Air System

In the powerhouse compressed air will be used for generator air brakes, governor system, service air connections for air-driven tools, pneumatically controlled valves. This system is common to both units and comprises two air cooled compressors, one on duty and other stand by which feed the main air receiver tank. The system also consists, air filter, air receiver, moisture traps, pressure reducing valve, control system, piping, etc.
Two types of compressed air system are used:

A. High pressure air system

High pressure compressed air is used for governor oil pressure system. A high pressure compressed air supply system comprising two independent compressors serving all hydraulic units will be installed. An automatic change over switch will select the main and stand-by compressor. The compressed air supply will be complete in all respects containing all control and protective devices like air safety valves, after coolers, moisture separators, shut-off valve, automatic moisture drain traps, air dryers etc.

B. Low pressure air system

Low pressure compressed air is used for station service purposes, and generator air brake system. Low-pressure system is tapped from high pressure system by pressure reducing valve into other low pressure tank. As alternative, separate low pressure compressor unit system can be installed.

6.7.24 Brakes and Jacking System

Generating unit will be equipped with a set of combined pneumatic or hydraulic operated brakes and jacks. The brakes and jacking system is required for bringing large machines to rest in a reasonably short time and for minimizing wear on the bearing by protracted slow running when shutting down. Air brake or hydraulic oil pressure brake can be use. If air being used, it will be supplied by the compressed air system. If air compressor unit is not used, then hydraulic oil pressure brake will be used. The brake linings shall be of non-asbestos type.

The brake cylinder shall also serve hydraulic jacks for lifting the turbine and generator rotating parts as required for inspection and removal of the thrust bearing. For this purpose, high pressure is required and generally provided by an external oil pump unit.

6.7.25 Centralized Grease Supply System

In recent practice an oil-less bearing system are used so centralized grease supply system could be skipped. If grease has to be use in certain parts a manual hand grease pump will be recommended. This results in a cost reduction as well as saving in spaces.

6.7.26 Power House Overhead Travelling Crane

The powerhouse crane will be used for unloading, assembly, erection and future maintenance of the turbines, generators, inlet valves and other mechanical and electrical equipment. The crane will be electrically driven, cabin operated, indoor, single trolley, double girder overhead traveling type. The controllers will be so located that one person can easily operate them and permit an unrestricted view of the load. The crane will be furnished with a single travelling trolley for the main hoist and auxiliary hoist. The operational range of the crane will ensure erection of all major equipment parts, including the turbine inlet valves. The capacity of the main hoist is determined by the weight of the heaviest part of the generators which is usually generator rotor. **The approximate capacity of the crane will be 60 ton.**

All the motions of the crane will be through Variable Voltage Variable Frequency (VVVF) control. Two brakes working on different principles will be provided for all hoists. All hoist controls and brakes will provide for limiting the vertical movement of the hooks, with rated load and when starting from standstill, within increments of 1.5 mm. The controls and brakes will limit the movement of the bridge and trolley, under the above operating conditions, within increments of 3.5 mm and 5 mm respectively.

principal characteristics of the overhead traveling crane are as follows:

Overhead traveling crane	:	Bridge type welded construction
Span	:	14 m

Main hoist capacity	:	60 t
Auxiliary hoist capacity	:	8 t
Length of runway	:	50 m

6.7.27 Air-Conditioning And Ventilation System

The powerhouse air-conditioning system is used to provide fresh, filtered and cooled air to the Control room, office rooms and other important areas. Packaged type air conditioner will be used for such rooms. It will consist of packaged type indoor air-conditioners unit on the rooms, unit of the air cooled condensing units on the exterior or roof and refrigerant pipe.

Fresh air supply ventilation system is installed in the power house to dispose contaminated air and to excess heat produced from the operation of generating units. The ventilation system will mainly consist of necessary numbers of axial ventilation fans, air supply ducts with air diffusers. The various powerhouse rooms and areas whose ambient are not air conditioned are continuously supplied with fresh filtered outside air like, switch-gear room, office floor, machine hall, generator floor, turbine floor, draft tube floor.

Air from the toilets, kitchen room, first aid room, storage room , relay room, workshops, battery room, diesel generator room, oil room is continuously exhausted out of the plant by separate wall mounted exhaust fans. Number of air exhaust fans of appropriate capacity will be installed.

6.7.28 Oil Handling System

The oil handling system is utilized for storing contaminated lubricating oil from the bearing pots of the generating units, clean and purified lubricating oil, and for filling the bearing pots with purified oil, and local treatment of oil at the governor oil sumps and at bearing oil.

One oil treatment plant is permanently installed inside the oil room, and a separate portable oil treatment plant is furnished, installed on a platform truck. The oil stored in the dirty-oil tank is filtered through the permanent oil treatment plant and stored in the clean oil tank.

The portable oil treatment plant is used for local reconditioning and filtering of oil at the location of governor oil sumps, and at each generating unit. The portable unit includes flexible oil hoses with hose to pipe fittings.

A separate oil handling system of appropriate type for purification of transformer oil will be provided with necessary accessories.

6.7.29 Fire Protection System

A complete fire detection system will be installed in the powerhouse. The system will comprise of smoke detectors and heat sensors installed in appropriate location along with alarm system.

The fire fighting system will consist of water deluge and sprinkle system, CO2 deluge system and portable dry chemicals and CO2 cylinders. The water for fire-fighting system will be drawn from the service water supply system tank installed at the suitable location of the powerhouse.

Generator fire protection will be provided by a CO2 deluge system. The activation of CO2 fire protection system will be conditional to the operation of the flame or smoke detectors in the generator pit combined with the operation of the generator differential protection.

A water hose system will be provided at various location of the powerhouse. The system will consist of fire hose of appropriate size with adjustable spray nozzle.
The transformer deluge system includes piping, valves and nozzles, fire detectors and local control units for deluge water release and for giving audible and visible alarms.

Sufficient number of portable dry chemicals and CO2 cylinder will be provided at various locations. The dry chemicals should be designed for fighting fires in solids, oil and electrical equipment. The CO_2 units should be designed for fighting fires in oil and electrical installations.

6.7.30 Emergency Diesel Generator

One emergency diesel generator set sufficient capacity, complete with the necessary switch-gear and accessories will be provided in the diesel generator room. This will provide an emergency source of power in the event of a system and power outage to supply emergency electric power to permit black starting of unit and for operation of cooling water pump system, governor oil system, battery charger, communication facilities and emergency lighting of powerhouse and control house.

One set geared trolley type, hand operated chain hoist, mono-rail crane with mono-rail to maintain the diesel engine will be provided in the diesel engine room.

6.7.31 Mechanical workshop

Mechanical workshop will be equipped with machine tools and devices appropriate for the maintenance and repair of all mechanical components and machining of the smaller components of the mechanical, electrical equipment and hydraulic steel structure. The work shop will service the power plant for minor repair and maintenance work at the site, and this could reduce the outage time.

Mechanical workshop will be equipped with following major machine tools and devices:

- Universal lathe
- Pillar-mounted drilling machine
- Table drilling machine
- Double-wheel rough-grinding machine
- Tool-grinding machine
- Metal power hacksaw machine
- Manual bench-type shears
- Mobile compressor
- Electric welding machine
- Gas-welding equipment
- Work benches
- Hand-drilling machines

One complete set of basic tools including hammer, chisels, pliers, screwdrivers, wrench, spanners, jacks, chain blocks, etc. will be provided.

Equipment with smaller power consumption and portable electric hand tools are to be designed for single phase, 230 volt, 50 Hz power supply.

6.7.32 Elevator

The Elevator will be provided for 10 to12 persons with 700 kg to 1000 kg capacity complete with all accessories necessary for meeting all applicable performance and safety requirements. The elevator will be designed according to IS 14665. The speed of the car will be 1 m/sec with leveling accuracy of ± 5 mm.

Its operational mode will be with VVVF drive control and it will be designed for normal and emergency power conditions. It will also be provided with Automatic Rescue Devise (ARD).

6.8 Hydraulic Steel Structures

6.8.1 General

The project is conceptualized as cascade to the Upper Tamakoshi HEP with tandem operation. This project does need separate headwork. It takes the discharge from the tailrace of the proposed Upper Tamakoshi Project through the inter connection system and conveyed to the headrace tunnel of the Project. Major structures of this project comprise of interconnection structure between the free flow tailrace tunnel of Upper Tamakoshi HEP and the pressurized headrace tunnel of Tamakoshi-V Hydropower Project.

Hydraulic steel structures of the Project mainly consist of the following:

- Connecting tunnel Inlet Gate and Stoplog.
- Headrace tunnel inlet trashracks.
- Emergency Closing Valve
- Draft tube gates
- Tailrace stoplog
- Steel linerl

6.8.2 Design Criteria

gates shall be designed to function properly at all water levels, under normal, unusual and extreme conditions and shall be easy to operate and maintain. The design and studies for the hydraulic steel structures of the hydropower schemes were carried out in conjunction with the design of the civil works, the electrical and mechanical equipment. The basis for design was a set of design criteria, which will ensure that each structure will meet stringent safety standards and confirm to the associated civil structures, electrical and mechanical equipment.

hydraulic steel structures were designed in accordance with the prevailing standards and codes of practice such as ISI, DIN etc. In the following the principal dimensions and details of each of the hydraulic steel structures are presented.

- **Connecting Tunnel Inlet gate**

The main purpose of the gate is to regulate the flow in headrace tunnel and to close the flow during the maintenance of the same.

The gate will be of welded construction type vertical lift wheel gate. The gate consist of upstream skin plate, main beams, wheel assemblies, sealing arrangements, guide shoes, rollers and other necessary components. All the steel materials, components, bolts, guide frames will be of corrosion resistant steel. The gate will be operated by electrically operated screw spindle type with provision of manual operation.
The principle characteristics of the tunnel inlet gate are as follows:

Type of gate	Vertical lift wheel gate
Number of gate	One (1)
Clear span	5.6 m
Clear height	3.0 m
Design water level	1156.49 masl
Sill level	1153.99 masl
Design head	2.5 m
Water tightness	3 Edges seal at upstream
Hoist type	Electrical screw spindle hoist with provision of manual operation

- **Connecting Tunnel Inlet Stoplog**

One set of stoplog will be provided at connecting tunnel to stop flow of water during repairing and maintenance of connecting tunnel inlet gate.

The stoplog will be of welded construction. The skin plate and seal arrangement will be provided on upstream side. Stoplog will have music note seals against the embedded vertical metal guides and horizontal compression rubber seals between the stoplog panels and at the bottom. The stoplog will be stored partly in the upper section of the stoplog in dogging device. The embedded parts will include the guide and seal frames as well as dogging device for storage in the slots and in the respective storage.

It is expected that the height of each stoplog panel will be between 1.0 and 1.5 m, the actual height will be dependent upon the hoisting arrangement and capacity, on site storage facilities and transportation limitations. In view of the high head to which the lower stoplog panel will be subjected, it is anticipated that the various panels will be designed to be installed in a particular order, In that way the upper panels can be designed for a lower loading.

A permanent monorail electric hoist with provision of manual operation with a supporting structure anchored to the deck and spanning across the piers will be provided for the stoplog panels.

The principle characteristics of the connecting tunnel stoplog are as follows:

Type of stoplog	Vertical lift slide type
Number of stoplog	One (1) set
Number of stoplog panels	Two to three
Clear span	5.6 m
Clear height	3.0 m
Design water level	1156.49 masl
Sill level	1153.99 masl
Design head	2.5 m
Water tightness	3 Edges seal at upstream
Hoist type	Electric motor operated monorail hoist

- **Headrace Tunnel Inlet Trashrack**

To check the floating debris and suspended materials from entering into the waterways, the inlet of headrace tunnel is covered with one set of trashrack with clear width 5.6 m and height of 12.3 m.

The trashrack will also protect the human or animal life, if they accidentally fall in the waterway. The clear opening of the bars will be sufficient to pass the flow into the culvert and will prevent the flow of unwanted matter such as logs, trees branch, etc. The screen will be of the non-withdraw type, consisting of fixed installed screen panels supported by a streamlined transverse beam. The complete trashrack and embedded parts will be made of normal steel, provided with a suitable protection coat.

The trash rack will be designed to withstand the static load and vibration phenomenon which are likely to occur due to the flow of water through the trash rack.

The main characteristics of the trashracks will be as follows:

Type	Fixed trash rack
Number of trashracks	One set
Bar pitch	70 mm
Clear span	5.6 m
Clear height	12.3 m
Inclination angle	***Vertical***
Sill level	1144.4 masl
Water load on bar element	1.5 kg/cm
Corrosion allowance	2 mm for all exposed surfaces in water
Material	JIS - SS41 or other equivalent

- **Emergency Closing Valve**

The emergency closing valve will be provided for emergency closure of water flow in case of turbine main inlet valve failure, the valve will be used as well to empty the penstock pipe without de-watering the headrace tunnel. The valves shall be of the Lattice blade butterfly valve with diameter of 4200 mm.

Valve control is normally by over-speed detection with provision for local control or by remote control by push button located in the powerhouse control room. Valve closure will be by counterweight. Opening will be by a hydraulic cylinder. Normal valve closure will be controlled by the over-speed detector and will occur against the flow. The valve will be opened under balanced conditions only.

The connection pipe will be provided with a manhole 600 mm in diameter, the cover of which shall be securely bolted to the manhole flange with a watertight joint and provided with appropriate facilities for opening.

A by-pass valve will be provided to fill the penstock pipe.

Air inlet/relief valve will be provided with an isolating valve. The air valve will be of a diameter allowing high pressure pipe de-watering within the guaranteed time.

The principle characteristics of the valve are as follows:

Internal diameter	: 4.2 m
Design discharge	: 66 m^3/sec
FSL level	: 1154.42 m
Valve center level	: El. 1092.94 masl
Highest upsurge level in the surge tank	: El. 1179.61 masl
Static head	: 61.48 m
- Design Head	: 86.67

- **Draft-tube Gates**

Draft tube gates will be provided to each unit to permit dewatering of the units for turbine and draft tube inspection and maintenance purposes. This gate is required to operate under balanced upstream and downstream water pressure conditions and therefore, vertical lift gates of the sliding type or sectional bulkhead gate will be use. The balanced condition must be restored before the draft tube gate is opened, by refilling the draft tube and turbine casing. A by-pass between the tailrace and the draft tube will be provided to facilitate this refilling.

The gates will have downstream seal system which is toward the draft tube side.

A permanent monorail electric hoist with provision of manual operation with a supporting structure anchored to the deck and spanning across the piers will be provided for the stoplogs.

The principle characteristics of the draft tube gates are as follows:

Type of gate	Slide type with filling valve
Number of gate	Four (4)
Clear span	4.6 m
Clear height	2.4 m
Design water level	995.3 m
Sill level	988.3 m
Design head	7 m
Water tightness	4 Edges seal at down stream
Hoist type	Electric mono-rail hoist with provision of manual operation system

- **Tailrace Outlet Stoplog**

One set of stoplog will be provided at tailrace outlet in order to prevent the high flood of the river entering into the powerhouse and for maintenance purposes.

The stoplog will be of welded construction. The skin plate and seal arrangment will be provided on upstream side The stoplogs will have music note seals against the embedded vertical metal guides and horizontal compression rubber seals between the stoplog panels and at the bottom. The stoplog will be stored partly in the upper section of the stoplog in dogging device. The embedded parts will include the guide and seal frames as well as dogging device for storage in the slots and in the respective storage.

expected that the number of stoplog panel will be between 3 and 5, the actual height will be dependent upon the hoisting arrangement and capacity, on site storage facilities and transportation limitations. In view of the high head to which the lower stoplog panel will be subjected, it is anticipated that the various panels will be designed to be installed in a particular order, In that way the upper panels can be designed for a lower loading.

A permanent monorail electric hoist complete with a supporting structure anchored to the power house wall and spanning across will be provided for the gates.

The principle characteristics of the tailrace stoplog are as follows:

Type of stoplog	:	Vertical lift slide
Number of stoplog	:	One set
Number of stoplog panels	:	Three to five
Clear span	:	6.8 m
Clear height	:	5.2 m
Design water level	:	995.3 masl
Sill level	:	991.51 masl
Design head	:	3.71 m
Water tightness	:	4 Edges seal at upstream
Hoist type	:	Electrical motor operated mono rail hoist with provision of manual operation
Material	:	JIS - SS41, SM41 or equivalent

- **Steel Liner**

From the tailrace tunnel of Upper Tamakoshi the water is conveyed to the powerhouse through the headrace tunnel, surge tank and steel lined tunnel. Steel lined pressure tunnel is adopted from horizontal portion down-stream of surge tank up to manifold branch pipes due to the high pressure in these areas. The plan and section of the drawings is shown in Drawing No:TV-ST-600 to 602.

The steel liner consists of straight pipes, bend pipes, manifold, reducing pipes, stiffener rings, thrust rings, drain pipes, manholes and all other necessary accessories. The inside diameter of steel liner is 4.2 m up to the manifold and thickness of steel pipe varies from 16 mm to 26 mm. The thickness of the pipe shell shall be designed to resist both the internal and external pressure and other loads. The thickness was calculated taking into account the water hammer effects. The steel materials used will be JIS SM41B or equivalent. The share ratio by rock is considered as 40%. The total length of main steel liner is about 166 m and length of the four end branch pipes with diameter 1.45 meter is about 87 m.

The thrust rings are welded to the steel liner and have the strength sufficient for transferring axial thrust to surrounding concrete.

The principle characteristics of the steel lined Tunnel:

Type	: Steel liner
Quantity	: One lane
Length	: 166 m
Material	: Steel, JIS SM41B or equivalent
Allowable stress	: 1250 kg/cm2
Internal diameter	: 4.2 m
Design discharge	: 66 m^3/sec
Full supply level	: 1154.42 masl
Maximum Surge Level	: 1179.61 masl
Penstock Center line at bottom	: 993 masl
Pressure rise head	: 40.355 m
Static head	: 161.42 m
Maximum design head	: 201.775 m (including water hammer)
Material of steel	: SM41B or equivalent
Thickness of liner	: 16 mm to 26 mm
Manifold Branch pipe	

Diameter : 1.45 m, four lanes
Length : 87 m
Thickness of end pipe : 14 mm

TableNo.6.3: Summary of Gates, Stoplogs and Trash Rack

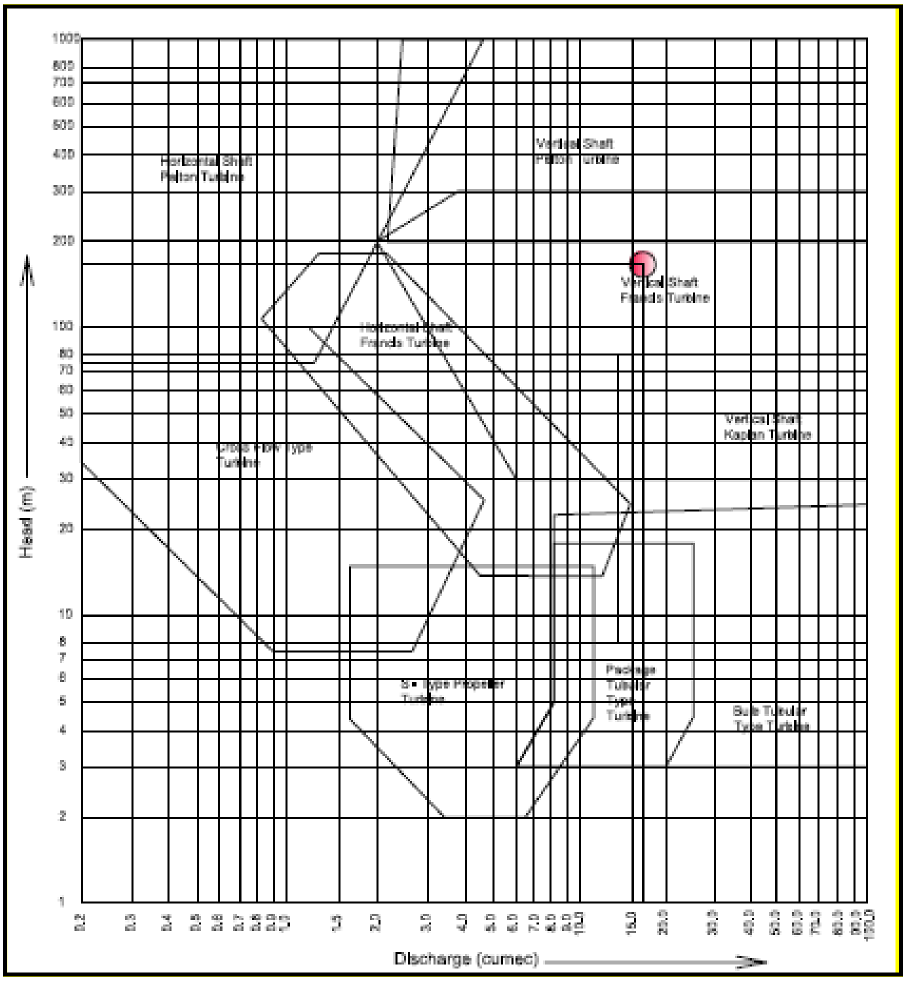
	Design head	Height	Wide	Number	Design water level	Sill level
HFL					1156.49	
FSL					1154.42	
Connecting Tunnel Inlet Gate	2.5	3	5.6	1	1156.49	1153.99
Connecting Tunnel Inlet Stoplog	2.5	3	5.6	1	1156.49	1153.99
Headrace Tunnel Inlet Trashrack (vertical), pitch - 70 mm		12.3	5.6	1	1154.42	1144.4
Emergency Closing Valve (Diameter 4.2 m)	86.67	-	-	1	1179.61	1092.94(Valve Center line)
Draft tube Gates	7	2.4	4.6	4	995.3	988.3
Tail race Stoplog	3.79	5.2	6.8	1	995.3	991.51

7. Power and Energy Generation

7.1 Selection of Type of Turbine

The project will be operated under the gross head of 160.93 m and design discharge of 66 m^3/sec. The type of turbine suitable for this range of gross head and discharge is reactive type of turbine. So the selection of turbine is straightforward and chosen a Vertical Francis Turbine.

Francis turbine operates in relatively moderate design discharge and head with very high efficiency. The efficiency decreased with the decrease and increase of design discharge. The turbine needs to be halted if the discharge decreases below 50% of the design discharge.



7.2 Head loss, Power and Energy

The net head and the available discharge is the principal component in calculating the power and energy from a power plant. In addition to these, the other factors responsible for the output power are the efficiency of turbine, generator and transformer.

The gross head between the full supply level at head pond and the turbine centerline at powerhouse is in the range of 160.93 m. The major head loss component in the conveyance system is the head loss due to friction, which is a function of available discharge. Similarly other head loss components such as bend loss and entrance loss, valve loss also contribute a little in total head loss in the system. The maximum head loss occurring in the Head Race Tunnel (HRT) system due to friction is 6.97 m. The total maximum head loss is 11.32 m. The monthly head loss is presented in the table below:

Month	**Turbine Discharge (m3/s)**	**Total Monthly Head loss (m)**	**Gross Head (m)**	**Net Head in (m)**
Basiak	23.55	2.94	160.93	157.99
Jesth	55.28	8.41	160.93	152.52
Aswar	133.06	11.32	160.93	149.61
Srawan	133.06	11.32	160.93	149.61
Bhadra	195.50	11.32	160.93	149.61
Aswin	93.39	11.32	160.93	149.61
Kartik	43.21	5.29	160.93	155.64
Mansir	24.61	3.17	160.93	157.76
Poush	17.56	1.78	160.93	159.15
Margh	14.23	1.28	160.93	159.65
Falgun	13.08	1.12	160.93	159.81
Chitra	14.76	1.35	160.93	159.58

The efficiency of generator, transformer and turbine has been considered 0.97, 0.99 and 0.92 respectively. So the maximum overall plant efficiency is 0.8835.

A minimum of 10 % of the flow of the driest month is left in the river as the minimum downstream release. The driest month in this river is March, having mean monthly flow 14.53 m^3/s. So a minimum of 1.453 m^3/s is released in the river itself throughout the year. Power will be generated with the remaining flow only.

The summary of energy calculation from two units of turbine installation is shown in the table below. The calculation does not take into account of the scheduled and unscheduled outages. Period from Jesth to Poush is considered as wet season and Margh to Baisak is considered as dry season.

Month	No of days	Available Flow (m3/s)	Head loss (m)	Net head (m)	Net Power (MW)	Net Energy (GWh)
Basiak	31	23.55	2.94	157.99	32.42	24.12
Jesth	31	55.28	8.41	152.52	73.46	54.66
Aswar	31	133.06	11.32	149.61	86.05	64.02
Srawan	32	133.06	11.32	149.61	86.05	66.08
Bhadra	31	195.50	11.32	149.61	86.05	64.02
Aswin	30	93.39	11.32	149.61	86.05	61.95
Kartik	30	43.21	5.29	155.64	58.60	42.19
Mansir	30	24.61	3.17	157.76	33.83	24.36
Poush	29	17.56	1.78	159.15	24.35	16.95
Margh	29	14.23	1.28	159.65	19.79	13.78
Falgun	30	13.08	1.12	159.81	18.21	13.11
Chitra	31	14.76	1.35	159.58	20.52	15.27

From the table,

Maximum Power Output = 87.0 MW

Total Annual Energy = 460.50 GWh (Without outages)

Dry season Energy = 61.64 GWh (With outages)

Wet Season Energy = 366.63 GWh (With outages)

Annually the total scheduled and unscheduled outage that is considered in such power project is 7% of total time. So the saleable total annual energy generated from this plant will also be the same percentage of total energy and that will be 428.26 GWh. Generally the plant outage is taken during wet season.

8. Power Evacuation Study

8.1 Scope and Objective

Tamaksohi-V Hydroelectric Project (HEP) is proposed to be developed by Nepal Electricity Authority (NEA), Nepal. Tamaksohi-V HEP is situated in Bulung V.D.C. of Dolakha district in central Nepal. Tamaksohi-V HEP is of 87 MW capacity and is expected to be commissioned by FY 2018/19. It is expected to generate 446.01 GWh of energy annually.

The overall objective of this report is to develop the most optimum power evacuation proposal for the Project on techno-economic basis, as well as to examine the impact on Integrated Nepal Power System (INPS) upon its integration. In order to do this, it is necessary to review the existing Integrated Nepal Power System (INPS), its future generation & transmission plans as well as its future load forecast. The study and analysis has been performed as per standard practices and criteria outlined later. All available power evacuation options have been explored in the study and the most optimum scheme(s) identified among the possibilities on technical and economic basis. Spreadsheet calculation method is employed for determining the optimum conductor size and voltage level. Load flow studies are performed using the PSS/E software. The main guideline for the study is NEA's Transmission Master Plan-1998.

8.2 Existing Integrated Nepal Power System (INPS)

8.2.1 The Generation System

For the past few years the Integrated Nepal Power System (INPS) has had a deficit of energy as well as power during the dry season. This year it suffered from lack of energy and power even during the wet season and this is expected to continue for the next half decade.

The average annual demand growth rate in INPS is 9% for power and 8% for energy. The annual peak demand in FY 200/10 was 885.28 MW. The total 693.2 MW generation system in FY 2008/09 comprises of hydropower plants with installed capacity of 639.8 MW and thermal plants with installed capacity of 53.41 MW, they too can not deliver their full capacity. About 50 MW was imported from India and about 100 MW was resorted to load shedding.

The main power plants in the present system as of FY 2009/10 are:

Plant Name	Type	Operation	Installed Capacity
• Kulekhani I	Hydro	Storage	60 MW
• Kulekhani II	Hydro	Storage	32 MW
• Marshyangdi	Hydro	Run-of river	69 MW
• Trishuli	Hydro	Run-of-river	24 MW
• Gandak	Hydro	Run-of-river	15 MW
• Devighat	Hydro	Run-of-river	14 MW
• Jhimruk	Hydro	Run-of-river	12 MW
• Sunkoshi	Hydro	Run-of-river	10 MW
• Khimti-I	Hydro	Run-of-river	60 MW
• Bhotekoshi	Hydro	Run-of-river	36 MW
• Modi Khola	Hydro	Run-of-river	14 MW
• Kaligandaki-A	Hydro	Run-of-river	144 MW
• Chilime	Hydro	Run-of-river	20 MW
• Puwa Khola	Hydro	Run-of-river	6 MW
• Indrawoti	Hydro	Run-of-river	5 MW
• Middle Marsyangdi	Hydro	Run-of-river	70 MW
• Duhabi Multi Fuel	Thermal		39 MW
• Hetauda Diesel	Thermal		14 MW

INPS has an installed capacity of 689.35 MW of which 635.94 MW (92.3 %) is hydro and 53.41 MW (7.7 %) is Diesel. The hydro power plants are mainly run-of-river (ROR) schemes with limited or no storage provision. The two cascaded Kulekhani power plants are the only storage plants, with a total peaking capacity of 92 MW.

The energy generated by the existing plants in 2009/10 is 3,689.27 GWh and 612.58 GWh was imported from India. INPS has system losses in the order of 26.58%. Internal sales in 2009/10 was 2,603.35 GWh while 74.48 GWh was exported in bulk to India. The unfavourable seasonal profile of generation to that of loads makes Nepal dependent on import during dry season peak hours and exports mainly during off-peak hours in the wet season.

8.2.2 The Transmission System

The backbone of transmission system in Nepal is the east-west 132 kV tie-line running from Anarmani substation in the east to Lalpur (Mahendranagar) substation in the west. Except for the sections Bardghat S/S - Bharatpur S/S - Hetauda S/S and Duhabi S/S - Anarmani S/S, the entire east-west tie is constructed with double circuit (d/c) towers. The Duhabi-Hetauda section is strung d/c ACSR Bear, while Butwal-Mahendranagar section is strung ACSR Bear conductor on one circuit only. The 132 kV sections Bardghat S/S - Bharatpur S/S - Hetauda S/S are single circuit (s/c) line with ACSR Panther conductor.

From Bharatpur substation a s/c 132 kV line is running to Pokhara via Damauli. One each s/c ACSR Duck 132 kV lines are connecting Marshyangdi P/S to Bharatpur and Suichatar substations. 132 kV d/c ACSR Duck line is connecting Kaligandaki P/S to Butwal substation where as Kaligandaki is also connected to Pokhara substation by 132 kV s/c ACSR Duck line. Modi P/S is also connected to Pokhara substation by 132 kV s/c ACSR Bear line. Kulekhani-II is connected to Kathmandu and Hetauda by 132 kV d/c ACSR Bear lines (only one circuit strung each). Kulekhani-I is connected to Kathmandu and Hetauda by 132 kV d/c ACSR Wolf lines. Hetauda connects Birgunj by 66 kV d/c ACSR Wolf line. 132 kV s/c ACSR Bear lines connect Khimti-I and Bhotekoshi to Lamosanghu which is further connected to Kathmandu by 132 kV d/c ACSR Bear line.

Chilime is connected to Trishuli by 66 kV s/c ACSR Wolf line. Trishuli is connected to Kathmandu by 66 kV d/c ACSR Wolf line whereas Devighat is connected to Kathmandu by 66 kV d/c ACSR Dog line.

The Kathmandu valley absorbs a considerable fraction of the INPS load and the supply to Kathmandu area is mainly through,

a. Siuchatar 132/66 kV substation which is fed from one 132 kV single circuit ACSR Duck line from Marshyangdi P/S, one 132 kV single circuit ACSR Bear line from Hetauda via Kulekhani II P/S and one 66 kV d/c ACSR Wolf line from Kulekhani-I.

b Balaju 132/66 kV substation which is fed from a single circuit 132 kV ACSR Duck line from Siuchatar S/S and one double circuit 66 kV ACSR Wolf line from Trishuli P/S.

c. Chabil 66/11 kV substation fed from a double circuit 66 kV ACSR Dog line from Devighat P/S.
d. Bhaktapur 132/66 kV substation fed from one 132 kV double circuit ACSR Bear line via Lamosanghu substation from Khimti, Bhotekoshi and one 66 kV s/c ACSR 120 sq.mm line from Sunkoshi P/S.

The transmission system of INPS is even at present; congested in various sections of which the most serious ones are Bardghat-Bharatpur-Hetauda 132 kV single circuit, Marsyangdi-Kathmandu 132 kV single circuit and Hetauda-Birgunj 66 kV double circuit links. Many other links are also expected to be congested as more generation plants get integrated into the system.

8.2.3 Status of Transmission Network in the Vicinity of Tamakohsi-V HEP

8.2.3.1 Lamosanghu Sub-station

The 60 MW Khimti Hydro Power Project and 36 MW Upper Bhotekoshi Hydro Power Project are connected to INPS grid by 132kV single circuit transmission lines with ACSR Bear and Eagle conductor respectively at 132/33 kV Lamosanghu substation. Lamosanghu substation is connected to 132 kV Bhaktapur substation by double circuit 132 kV transmission line with ACSR Bear conductor. Lamosanghu substation has 132 kV main and transfer bus with bus coupler facilities. The substation is located in the premises of Sunkoshi power house. However, there is no electrical connection between 66 kV Sunkoshi switchyard and 132 kV Lamosanghu switchyard. A 132/33kV 15MVA transformer is installed in Lamosanghu s/s.

8.2.3.2 Sunkoshi Sub-station

The Sunkoshi hydropower Station (10.05 MW) generates at 6.3 kV and the power is stepped up to 66 kV level at Sunkoshi switchyard. A 60 km long 66 kV single circuit transmission line with ACSR 120 mm2 size conductor evacuates the power generated by Sunkoshi power house to INPS via Paanchkhaal, -Banepa- Bhaktapur-Baneshwar and Patan Sub- stations.

Sunkoshi power station has a 6.3/11 kV 5 MVA transformer and 6.3/33 kV 3 MVA transformer. Both 6.3/11 kV and 6.3/33 kV transformers are fed from generator bus at 6.3 kV. In the Sunkoshi 11 kV S/S, there are indoor type switchgears with two numbers of 11 kV incoming circuit breakers (VCB) and four numbers of outgoing feeders. The 2.5 MW Sunkoshi Small Hydro Power Station is connected to the 11 kV bus through a dedicated IPP owned transmission line. The 1.5 MW Chaku small Hydorpower project is connected to 11 kV Barabise feeder emanating from 11 kV Sunkoshi substation.

The 6.3/33 kV transformer in Sunkoshi Power House supplies 33/11 kV Makaibari s/s (1.5 MVA) and Jiri s/s (1.5 MVA) in Dolakha district through a 33kV transmission line.

8.2.4 Operation

The operation of the existing system is controlled from the Load Dispatch Center (LDC), which also has the facility of remote control. SCADA facility exists in the entire INPS. On-line active and reactive power, voltage, frequency, etc. data can be observed in the day to day operation in the LDC. The operation of the power system is conducted / controlled by the LDC. As far as possible load is supplied and when there is no more generation/import left, load shedding is applied. The system is suffering from power and energy deficit in the generation system; hence normally there is no power reserve.

The limited reactive compensation available in the system is a constraining factor in the dispatch. Lack of voltage compensating devices in the system has caused poor power factors and no flexibility whatsoever in the operation of the system. In order to operate satisfactorily when the system grows, reactive as well as active power reserves should be allocated in power plants so that a certain automatic control capability during contingencies exist. That can easily be done by adding sufficient static compensation and establishing an operational constraint on the use of the reactive power in the generators. A normal approach would be to limit the power factor in plants during normal operation to, say, 0.90.

One example of the problems facing the existing system is the smooth control of reactive power required during peak hours. The active loading on transmission lines south of the Katmandu valley causes a suppressed voltage, but the control possibilities are none. If additional reactive power is fed from the generators, the additional straining of the transmission lines caused by the reactive power triggers a voltage collapse and a complete black-out of the Nepali system.

8.2.5 Export & Import

Nepal has system peak during the winter while the more tropical India has system peak during summer. The two countries therefore have mutual interests in power exchange, and accordingly a number of smaller interconnections have been constructed. The relatively poor voltage and frequency control in the larger Indian system is one of the reasons prohibiting synchronous connection of the two systems. The power exchange is carried out by connecting loads along the border towards the system that is in a state of surplus at the time. Likewise, on some interconnections generation in Nepal can be connected directly towards loads in India, and vice versa.

Nepal imports power from India at 132 kV voltage level from Tanakpur (India) to Mahendranagar (Nepal) in the far west and from Purnia via Kataya (India) to Duhabi (Nepal) in Far East. Nepal exports power to India at 132 kV voltage level from Gandak (Nepal) to Ramnagar (India). All three 132 kV interconnections are single circuit. Other than that there are about 10 number of 33 kV and 6 number of 11 kV cross-border interconnections along the Nepal-India border.

It was principally agreed with India in 2001 to raise the power exchange capability from 50 MW to 150 MW, but due to transmission constraints it has not yet been materialized.

8.3 Generation and Transmission Plans

8..3.1 Generation

At present, 2 main hydropower plants are under construction and expected to be competed by end of FY 2011/12:

Plant Name	Voltage	Type	Dispatch Type	Size
• Chameliya	132 kV	Hydro	Run-of-river	30 MW
• Kulekhani-III	132 kV	Hydro	Cascade of KL-I&II	14 MW

Many more hydropower plants are planned for construction in near future. The generation plants coming in future are as follows,

Table No. 8.1: Hydro Power Projects on the Pipelines

Projects	Sum of MW	Projects	Sum of MW
1. FY 2010/11	**25.7**	Khani Khola	2
Baramchi Upgraded	3.22	Khani Khola	30
Belkhu	0.32	Lower Balephi	18.514
Bhairabhkunda	3	Lower Modi	20
Chake	0.99	Mai Sanima	15.6
Chaku Khola(Upgraded)	1.5	Middle Modi	14.6
Golmagad	0.58	Nyadi	20
Hewa	4.455	Radhi	4.4
Jiri	0.99	Sardi Khola	3.5
Lower Chaku	1.765	Tadi	5
Lower Indrawati	4.5	Tadi (Thaprek)	0.97
Lower Piluwa	0.99	Tungun Thosne	4.3
Middle Chaku	1.8	Upper Ingwa	9.7
Narayani Shankar, Biomass	0.6	Upper Mai	9.247
Tinau	0.99	Upper Trishuli-3A	60
2. FY 2011/12	**94.152**	Pakhar Khola	0.98
Ankhu-1	6.93	Lower Khare Khola	8.26
Chameliya	30	**5. FY 2014/15**	**222.4**
Charnawati	0.98	Lower Sunkoshi-III	9.9
Dapcha Rosi	4.9	Madi-1	10
KL-III	14	Upper Mailung -A	5
Ladku Khola	0.7	Upper Trishuli-3B	40
Mailung	5	Dordi	27
Naugarh Gad	8.5	Likhu-IV	52.4
Phawa	4.95	Balephi	24
Sipring	9.658	Sanjen	42.5
Siuri	4.95	Khorunga Khola SHEP	4.8
Upper Hugdi	2.599	Upper Khorunga	6.8
Upper Puwa-1	0.985	**6. FY 2015/16**	**657.1**
3. FY 2012/13	**138.328**	Kabeli-A	30
Andhi Khola (Incremental)	4.3	Upper Dordi-A	22
Bijaypur-I	4.5	Upper Mailung	14.3

Lower Modi I	9.9	Super Madi	44
Madkyu Khola	10	Down Piluwa	9.5
Midim Khola	3	Trishuli-III	20
Namarjun Madi	11.88	Upper Tadi	11
Rahughat	30	Lower Tadi	5
Rudi Khola	3	U. Tamakoshi	456
Rudi Khola - A	6.8	Ghar Khola	8.3
Seti Khola	0.465	Upper Khimti	12
Upper Chaku A	22	Khani khola-1	25
Upper Madi	19.008	**7. 2016/17**	**321.4**
Upper Sanjen	11	Mristi	42
Pikhuwa	2.475	Upper Modi-A	42
4 FY 2013/14	**250.671**	Upper Seti (ST)	127
Devighat Cascaded	9.6	Upper Marsyangdi	50
Handi Khola	2	Chhahare Khola	17.5
Hewa-A	12	Ankhu Khola HPP	42.9
1709.7 MW			

Transmission & Substation

Transmission

The transmission lines that are under construction are as follows:

- Khimti - Dhalkebar (220 kV) SC DC-Tower ACSR Bison Duplex
- Hetauda - Bharatpur (220 kV) SC DC-Tower ACSR Bison Duplex
- Matatirtha-Harisiddhi-Bhaktapur (132 kV) SC DC-Tower ACSR Bear Simplex

Substation

The transmission system reinforcements that have been taking place are mainly driven by load growth and partly by generation additions. The following substations of 66 kV and above voltage level are under construction:

132 kV: Matatirtha s/s, Harisiddhi s/s

Capacity up-gradation of Balaju, Bhaktapur, Duhabi and Butwal 132 kV substations is also underway. The power transformers taken out from there will again be used to upgrade other substations.

In order to meet the increasing load demand and for power evacuation from plants as per the Generation Expansion Plan, NEA has developed transmission expansion plan. The transmission planning as per NEA's Transmission Plan is as follows,

Table No. 8.2: Transmission line projects

S. N.	Transmission System	Expected Commissioning Year
1	Khimti-Dhalkebar D/C, 220 kV T/L strung S/C & charged at 132 kV	2010/11 Under Construction
2	Syangja 132/33 kV, 30 MVA Substation	2011/12 Under Construction
3	Kamane (Hetauda) 132/33 kV, 30 MVA Substation	2011/12 Under Construction
4	Pathalaiya Switching Station	2011/12
5	Matatirtha (Thankot) – Harisiddhi - Bhaktapur 132 kV D/C T/L strung S/C	2012/13 Under Construction
6	New Hetauda-New Bharatpur 220 kV, DC Transmission line charged at 132 kV	2012/13 Under Construction
7	132 kV, D/C Middle Marsyangdi-Damauli- Abu Khirani, transmission line loop	2012/13 Under Construction
8	132 kV Second circuit stringing, Butwal–Shivapur-Lamahi - Kohalpur	2012/13 Under Construction
9	Chapali substation	2012/13
10	New Bharatpur - Bardaghat 220 kV, DC Transmission line charged at 132 kV	2012/13
11	Hetauda - Kulekhani-II - Siuchatar 132 kV Second Circuit stringing.	2012/13
12	Singati- Lamosanghu 132 kV D/C	2012/13
13	New Marsyangdi – Matatritha (Thankot) 220 kV D/C Transmission line charged at 132 kV.	2013/14
14	Duhabi-Dhalkebar-Hetauda 400 kV D/C charged at 220 kV.	2013/14

15	Second circuit stringing of Khimti-Dhalkebar D/C, 220 kV T/L & charged at 220 kV.	2013/14
16	Dhalkebar-Muxxaffarpur 400 kV D/C Cross Border Transmission Line	2013/14
17	Gorjang-Khimti Transmission Line	2013/14
18	Baneswor –Bhaktapur UG cable 132kV	2013/14
19	Kabeli Corricor 132kv Transmission line	2013/14
20	Modi Lekhnath 132kV Transmission line	2014-15
21	Trishuli-Chilime 220kV Transmission line	2014-15
22	Trishuli 3B Hub station	2014-15
23	Samundratar-Naubise 132 kV S/C transmission line	2014/15
24	Kaligandaki Corridor (220 kV double circuit Kusma-Butwal-Bardaghat line).	2014/15
25	The 132 kV single circuit transmission line connecting Manang S/S –Udipur Hub S/S – Middle Marsyangdi P/S.	2015/16
26	Tamaskoshi (Khimti)- Kathmandu 220kV Transmission line	2015/16

NEA's has been constructing the Khimti-Dhalkebar 220 kV double circuit transmission line and has plan to build Upper Tamakoshi- Khimti 220 kV double circuit transmission line and 220/132 kV Khimti substation to evacuate power of Upper Tamakoshi HEP (456 MW) and to facilitate power evacuation from Tamakoshi and Khimti area. Similarly NEA has plan to build 132 kV substation at Singati and 132 kV double circuit transmission line from Singati to Lamosanghu to facilitate power evacuation from Singati area. This may make Tamakoshi-V's power evacuation more comfortable and also reduce its transmission investment, but materialization of such plan and their expected commissioning date is uncertain (expected commissioning date FY 2014/15, before commissioning of Tamakoshi-V HEP) at this point of time.

Reactive Compensation

In order to maintain voltage control in the system, although insufficient, NEA has been installing capacitor banks at various voltage levels to meet reactive compensation needs for the system.

8.4 Load Forecast

8.4.1 Load Forecast 2010/11 – 2027/28

NEA's total load forecast has been segregated into substation-wise load forecast for the purpose of transmission planning. This is still based on methodology adopted in NEA's Transmission System Master Plan (TSMP) of 1998. Some adjustments have been incorporated considering the prevailing trend in load growth in and around various substation areas. In the FY 2018/19, internal Nepal substation load is expected to reach 1792.5 MW. The transmission losses will account for about 114.4 MW requiring a generation of 1906.9 MW. The transmission loss is expected to reach 6 % in 2017, which is considered realistic given the geography and load distribution in the country. NEA's latest load forecast is attached as Annex- F.

8.5 Transmission Line and Substation Design

8.5.1 General

Presently NEA has only 132 kV and 66 kV transmission lines and substations in service. NEA is constructing its 1st 220 kV transmission line from Khimti to Dhalkebar and another 220 kV transmission line from Hetauda to Bharatpur is also on the pipeline for construction. NEA's planned next higher transmission voltage is 400 kV.

8.5.2 Standard System Voltages

The exiting transmission voltages in Nepal are 132 kV and 66 kV. Construction of 220 kV transmission lines is underway. To meet future requirements higher voltages are being adapted.

In the long term, supply of equipment for non-preferred voltage levels could become sparse and possibly increase the cost of projects through limited competition or even monopoly markets. The dominating neighbour for Nepal in terms of the transmission system is India. A large share of the transmission and substation equipment used in Nepal is manufactured in India, and India is also the only likely importer of electric power from Nepal. In a long-term perspective, both countries could benefit from similar standards for transmission equipment, especially with respect to voltage levels. Nepal should therefore give due importance to the voltage levels in India when selecting domestic standards. India is currently using 132 kV, 220 kV and 400 kV for transmission, which are also being adapted in Nepal.

The nearest substation in the Tamakoshi-V Hydroelectric Project area are the proposed 132 kV Singati substation and 220 kV switchyard of Upper Tamakoshi HEP. The Upper Tamakoshi HPP has under ground power house and switchyard. So there is a low possibility for space to be available for additional line bay required for Tamakoshi-V HPP. For this scenario we require to construct a switching s/s on the transmission line evacuating power from Upper Tamakoshi HPP to Khimti s/s in the vicinity of Tamakoshi V HEP power house. We will refer such a proposed substation as New Upper Tamakoshi substation. Hence for evacuation of 87 MW power from Tamakoshi-V HEP has three options they are, connecting to the 132 kV Singati substation, connecting to the 220 kV Upper Tamakoshi switchyard and connecting to New Upper Tamakoshi s/s are considered for study.

8.5.3 Conductor Size

The conductor types currently used in Nepal on 33 kV and 132 kV transmission voltage levels are ACSR Wolf (195 mm^2 total), Panther (262 mm^2 total), Bear (326 mm^2 total) and Duck (347 mm^2 total). They match with those found in India.

As stated above transmission voltage under consideration for present study are 33 kV and 132 kV. For 33 kV voltage level ACSR Wolf conductor shall be considered and for 132 kV voltage level ACSR Wolf & Bear conductors shall be considered.

8.5.4 Insulation Co-ordination

8.5.4.1 Creepage

The existing 132 kV lines are built with 10 insulator units per suspension string. Thus the creepage distance is:

132 kV: 10x292 mm = 2920 mm, i.e. 22.1 mm/kV

20 mm/kV is equivalent to the value recommended by IEC 815, Guide for the Selection of Insulators in Respect of Polluted Conditions, for pollution class 2. (16 mm for Class 1). In case of 132 kV, tension strings have one additional insulator unit per string.

Tower design should therefore allow for tower top clearances to cater for string lengths with creepage distances required for various pollution class (together with string lengths and clearances as described below in this chapter).

It is recommended that new lines are built to IEC pollution class 2 (20 mm/kV) in urban areas, and to pollution class 1 (16 mm/kV) in mountain regions, farm lands, areas with low population and non-industrial areas.

The existing 33 kV lines are built with 3 insulator units per tension string and 33 kV pin-insulators are used for straight-line supports.

8.5.4.2 Withstand Voltages

	Withstand Voltages (kV)		
No. of insulator units	Power Frequency, wet	Impulse	IEC-requirements IEC 71-1
132 kV, 9 units	325	695	Low: 185/450
10 units	360	765	High: 275/650

The values in the table show that the insulation levels obtained with the number of insulator units required to fulfil the creepage distance requirements for both pollution class 1 and 2 are better than insulation levels recommended in IEC 71-1.

8.5.4.3 Insulator Types

It must be noted that the above conclusions are based on the use of standard disc porcelain or glass insulators of the following types:

Combined electromechanical strength	:	45 kN	70 kN	120 kN
Disc diameter	:	254 mm	254 mm	254 mm
Disc spacing	:	146 mm	146 mm	146 mm
Creepage pr. unit	:	292 mm	292 mm	292 mm
Withstand voltages, one unit:				
- Power frequency, wet	:	40 kV	40 kV	40 kV
- Impulse	:	100 kV	100 kV	100 kV

For 132 kV suspension insulator string, length including fittings and the number of insulator units needed to obtain recommended creepage will be as follows:

132 kV, 10 units + fittings : 1700-1900 mm

For 33 kV, pin insulators are used in case of suspension-support and disc-insulators are used only in tension strings and the number of tension insulator units needed to obtain recommended creepage will be as follows:

33 kV, 3 units + fittings : 650-800 mm

Should it be necessary to use other insulator types with higher mechanical strength, the string lengths will be different. Stronger insulators may be needed in extra long spans, where ice loads occur, for very large conductors or for heavy conductor bundles. This must be evaluated on a case to case basis and towers must be designed accordingly taking into account the prescribed creepage and clearances.

Other insulator type will also result in different withstand voltages, which in any case should be higher than values recommended by IEC if recommended creepage is maintained.

8.5.5 Clearances

8.5.5.1 Ground Clearance

Present practice in Nepal is:

33 kV : 6.5 m at + 65°C conductor temperature

132 kV : 7.0 m at + 65°C conductor temperature

For all new lines it is recommended that these ground clearance requirements are maintained at +80°C conductor temperature, for all voltages.

8.5.6 Tower Types

8.5.6.1 Present Practice

A typical NEA tower family consists of 6 towers. For 132 kV single circuit they are:

Application	Designation	Angle (degrees)	Wind Span (m)	Weight Span (m)
Suspension	A	2	350	700
Suspension	SA	2	700	1000
Suspension & Tension	F	10	350	700
Tension	B	15	350	700
Tension	C	30	350	700
Tension	D	60 (or terminal)	350	700

Type SA is sometimes needed for river crossings in the Terai area, and otherwise for long spans in hilly terrain.

Type F can be equipped with tension strings (light angle) or suspension strings (heavy vertical load, i.e. tower is located on a site considerably higher than the adjacent towers) Similar tower families are used for double circuit lines. Towers are self-supporting, of the lattice steel type with four tower legs embedded in pad and chimney type concrete foundations. Steel grillage foundations have been used in some cases. Single circuit towers have conductors in triangular formation. Double circuit towers have conductors in vertical formation, one circuit on each side of the tower.

Single circuit 33 kV lines are built on single-pole structure whereas double circuit 33 kV lines are built on double-pole structures. Employing 9 to 11m steel or PSC poles, the spans range from 40m to 60m.

8.5.6.2 Proposal and Comments

Almost without exception, tension towers are made in fairly small series for any one project. This is normally not economic in modern manufacturing processes. It is recommended that the number of tower types be kept to a minimum. The following is proposed for 132kV:

Application	Designation	Angle (degrees)	Wind Span (m)	Weight Span (m)
Suspension	S1	2	350	700
Suspension	S2	2	700	1000
Tension	T1	30	350	700
Tension	T2	60	350	700
Tension/Terminal	T3	90 45^{o} as terminal	350	700

The design span, determining standard tower height assuming level ground should be 330 m for 66 and 132 kV lines and 40-60m for 33 kV lines (depending upon the pole height, 9-11m).

Suspension S1 will be applied as the normal, standard suspension tower suitable for Terai and elsewhere where normal span lengths are natural. Suspension S2 will be suitable for long spans often necessary in hilly terrain. The tension towers cover all angles up to 90 degrees as well as terminal positions and uplift situations. Where the angle capacity is not fully utilised the towers may be used for longer wind spans than indicated provided the span profile so permits.

For conductors in triangular formation (single circuit) and vertical formation (double circuit) the phase spacing should not be less than:

- Vertical spacing : 3.75m for 132kV lines (phases on the same side of tower).

- Horizontal spacing: 6.0m for 132kV (phases on opposite sides of tower).

This is a result of the recommended tower top clearances but also to ensure that phases will not come into contact with each other under wind conditions causing uneven swing out of conductors. The issue of phase spacing is of particular importance in mountainous terrain where long spans are needed.

For extra long spans it may be necessary to use special towers providing extra phase spacing or alternatively single phase towers to achieve the same. The horizontal phase spacing in long spans should not be less than 1 % of span length in order to minimise the risk of phases coming into contact with each other during swing out caused by wind.

8.5.6.3 Tower Height Increments

All towers should have height increments by deducting/adding tower body sections and/or individual leg extensions as per present practice.

The number of variations should be kept as low as possible in order to simplify manufacture, logistics and erection.

8.5.7 Tower Loads

8.5.7.1 General

Tower loads are determined by wind span, weight span, wind on structures, insulator strings and conductors and weight of the same.

Tower loads act in three planes, vertical, horizontal and longitudinal. Vertical loads are weight of conductors and structures as well as down pull caused by level differences between towers, which is taken into account when determining the weight span. Horizontal (or transverse) loads are caused by wind and by horizontal pull from deviation angles in the line.

Longitudinal loads are caused by conductor tension on one side only of tension towers and by an abnormal (broken wire) load on suspension towers, subject to definition by standards or national codes of practice.

According to prevailing practices there is generally no certain basis for determination of climatic loads in the form meteorological records from various parts of the country, other than the average wind measurements referred to below. Therefore, changes to the climatic loads used presently can hardly be justified since no new or additional information is available for analysis.

8.5.7.2 Wind Load

(a) Present practice:

- Wind speed 34.4 m/s, determined as gust, based on measuring of averages.
- Wind pressure on conductors: $P = 0.0634 \times v^2$ -75 kg/m^2(736 N/m^2)
- Wind pressure on structures: $P = 0.10252 \times v^2$ -121 kg/m^2(1190 N/m^2)
- Air resistance factor of 1.71 for total wind pressure, front and back of structure, thus P = 207 kg/m^2 (2030 N/m^2) on projected area of tower.

This is based on ASCE No. 52, Guide for Design of Steel Transmission Towers.

(b) EdF recommendation:

The EdF recommendation is based on IEC 826, Loading and Strength of Overhead Transmission Lines.

For 50 years return period, average annual maximum x 1.3.

Extreme wind:	Kathmandu, Terai	:	130 km/h (36 m/s)
	Other areas	:	160 km/h (44.4 m/s)
EdF uses:	Kathmandu, Terai	:	100 km/h (27.8 m/s)
	Other areas	:	120 km/h (33.3 m/s)

(c) Comments

There is no other measurements or readings available than those forming the basis for present practice. The wind speeds applied are slightly higher than those used in sample calculations in the Indian Standard Code of Practice for Design, Installation and Maintenance of Overhead Power Lines, which probably is justifiable in view of the topographical conditions in Nepal.

(d) Recommendation

NEA has not experienced damages caused by wind. So until better measurements are available, and a review based on these can be carried out, it is not recommended to alter present practice with regard to wind loads and the use of ASCE No. 52.

8.5.7.3 Ice Loads

For the Khimti - Lamosanghu 132 kV transmission line project, ice loads were considered at altitudes above 2500 m (a section of 2 km). The specified ice load is 35 N/m for conductors and 20 N/m for earth wire, in combination with a conductor temperature of 0^oC. The exposed line section is located at the Mure Ridge area, and is secured by tension towers at each end.

It is recommended that this practice is applied also elsewhere at altitudes above 2500 m. Whenever possible, efforts should be made to avoid selecting line routes at such altitudes, mainly because there are no measurements of icing available. This represents a serious uncertainty as to what kind of conditions may actually be encountered at such altitudes, which in turn may result in reduced reliability of lines in these areas.

During planning of new lines it must be borne in mind that ice loads for mechanical reasons may necessitate the use of larger conductors than those required for reasons of economic power transfer. The resulting impact on dimensions of insulator strings, towers and foundations must be taken into account to arrive at realistic prices for such areas.

8.5.7.4 Broken Wire Condition

This load case is selected to cater for situations where longitudinal forces on one side of tower occurs.

Present practice is:

- For terminal towers: 100 % of maximum working tension of all conductors and earthwires acting simultaneously on one side of tower.
- For suspension towers: 60% of maximum working tension of any one conductor or 100 % of one earthwire acting on one side of tower.

- For tension towers: 100 % of maximum working tension for any one conductor plus one earthwire acting simultaneously on one side of tower.

This practice is in line with, or do not differ much from, practices in a number of other countries. It is recommended that no changes are made.

8.5.7.5 Earthquake

An earthquake factor of 0.15 g is presently being applied in tower design. This practice need not be altered.

8.5.8 Design Standards

NEA specifies that lattice steel towers shall be designed as set out in ASCE 52, Guide for Design of Steel Transmission Towers.

This is an internationally accepted standard, which is also recommended for future use.

8.5.9 Steel Quality

All steel for the presently under construction transmission lines is high tensile steel. This may be caused by a need to keep weights low for manual hauling. Domestic high tensile steel was not available to the Indian tower manufactures and had to be purchased in Europe and South Africa. It should be looked into, if the potential savings by using mild steel would be substantial or if they would be off-set by increased weights and transport costs.

8.5.10 Stringing

8.5.10.1 Stringing Tension

The specified stringing tension, which is designed to allow for everyday stress (EDS) at 60 N/mm^2 at +32ºC is in line with practice also in India. EDS of 60 N/mm^2 at +32ºC for ACSR-30/7 conductors (Wolf, Bear) is acceptable.

Vibration dampers and armour rods to protect the conductors from damage in or near the suspension clamps should be applied throughout, as per present practice. The type and location of vibration dampers should be calculated and documented to approval.

In cases where extra long spans are necessary, the breaking strength of conductors may be the limiting factor. In some cases it may be necessary to use a stronger conductor for such spans, normally one with larger steel core to provide the needed extra mechanical strength while the power transfer capability is maintained. In such cases higher than normal stringing tensions may be applied, provided adequate vibration damping is installed in accordance with qualified design calculations.

8.5.10.2 Stringing Method

The stringing method for 220 kV and above lines is somewhat more demanding than the ordinary method for 132 kV & below lines. From voltages at 220 kV and above, it is imperative that the conductors are not subjected to handling resulting in scratches, cuts and other damage to the surface. Such damage will result in corona losses and noise.

Therefore, at 220 kV level it is necessary to apply a stringing method termed “tension stringing”, which means that the conductors at all times are kept clear of the ground to avoid damage. This is normally achieved by interaction between a brake at one end of the stringing section and a winch at the other end. In the mountainous areas this may complicate the stringing works, particularly with regard to logistics. In order to minimise such problems the stringing equipment should wherever possible be rigged at points with reasonably easy access, such as at road crossings.

For 132 kV & lower voltage level lines, stringing method shall be as specified above but employment of tension-stringing method may not be mandatory.

8.5.11 Foundations

In flat areas in river valleys and on the Terai plains the ground water level is normally high and the areas are subjected to seasonal floods.

In such areas the foundations must often be designed for submerged conditions, and should always be of the reinforced concrete pad and chimney type.

In hilly terrain, or even mountainous terrain, solid rock suitable for bolt anchor foundations is seldom encountered. Mostly the rock is decomposed and can very often be excavated manually with pick and shovel. Thus, in most cases blasting or heavy machinery is not needed, and conventional soil foundations are installed.

On the Khimti-Lamosanghu line, steel grillage foundations were installed at tower sites with difficult access. This is mainly due to easier handling and lighter transport weights compared to concrete foundations.

These practices are generally accepted and widely used. However, the following should be taken into account:

- Steel grillage foundations should not be used where foundations are, or can be, submerged.
- Steel grillage foundations normally have a shorter life span than concrete foundations and the steel structure above ground, depending on soil corrosiveness, quality of galvanising and application of bituminous paint.
- The area most sensitive to corrosion damage is normally a zone from ground level to about 0.4 m below the surface. It may delay corrosion if tower legs are properly encased in concrete in this zone and to 0.3 - 0.4 m above the ground line. Such encasing may also be necessary for distribution of shear forces in the region of the ground line.
- Generally, concrete foundations should be used wherever possible for all voltage levels.

With the topography and geology in northern Nepal it is of utmost importance to execute foundation and earthing works in a way that minimise the risk of erosion damage. Specifications should describe erosion protection measures and the Bill of Quantities should include prices for the same.

8.5.12 Substation

8.5.12.1 Substation Types

Substation design in Nepal is left with the different developers to decide. However, based on technical and economic considerations, EdF had recommended that a single breaker scheme with transfer bar should be adopted for all voltage levels.

There is no reason to revert the recommendation given by EdF as none of the key parameters used in the analysis have changed. The recommended overall layout of the substations is thus shown in Figure 8.5.1. This design is adequate for 132 kV and 220 kV.

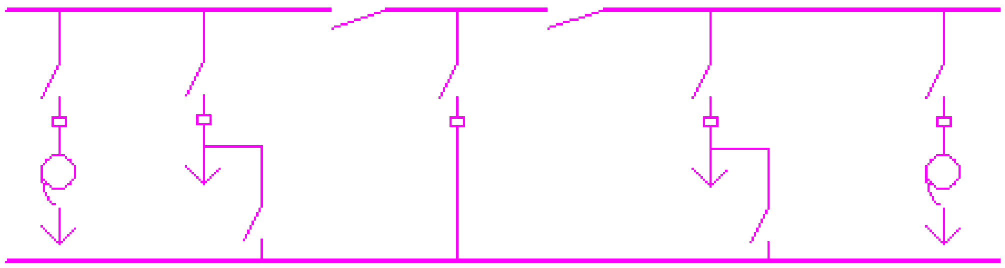


Figure 8.5.1: Substation Layout, 1 Circuit Breaker and Transfer Bar

But the line bays at the receiving end of existing substations must be constructed in symmetry with the existing system.

8.5.12.2 Climatic Parameters

The substation equipment shall be designed to the same climatic parameters as the transmission lines:

- Ambient Temperature : 40 °C
- Maximum operating temperatur : 80 °C
- Wind Speed : 0.6 m/s
- Sun Factor : 1000 W/m

The sun factor value can be modified when more accurate calculation methods based on latitude, height above sea level are used.

8.5.12.3 Degree of Pollution

The pollution level to be applied in substation design is the same as for transmission line design. Pollution class 2 (from IEC-815) shall be used in the urban areas, and pollution class 1 in mountain regions, farm lands, non-industrial areas and areas with low population.

8.5.12.4 Rating of Equipment

The design rating of equipment should be selected so as to avoid re-investment during the life time of the component. The calculated maximum symmetric short circuit currents at stage FY 2017 are:

- 132 kV: 10 kA

The design ratings should be chosen from standard values well above these values. The dynamic or momentary short circuit current on which the equipment design shall be based shall be computed by multiplying the r.m.s. value of the symmetrical short circuit current by the factor 2.0 x √2, according to IEC-909.

The short-circuit ratings for 132 kV equipment adapted by NEA is 25 kA, which is also recommended for Tamakoshi-V HEP.

8.5.12.5 Insulation Co-ordination

The highest voltage for equipment shall be selected according to IEC-71.1:

- 36 kV for 33 kV nominal voltage
- 145 kV for 132 kV nominal voltage

Corresponding lightning impulse withstand voltage shall be selected in accordance with IEC-71-1. As a general rule, the impulse withstand voltage shall be equal to or higher than the withstand voltage selected for the transmission line.

IEC-71.1 specifies several withstand voltages for each voltage level. As a general rule, the higher levels shall be selected for systems not protected by lightning arresters.

8.5.12.5 Mechanical Design

The mechanical design of substation components shall comply with wind, earth quake factor etc. as specified for the transmission lines.

8.5.13 Cost, Losses and Power Flow

Transmission lines act as power conveyors and are necessary to bridge the distance between the generating plants and the distribution substations. The major costs involved in such process of conveying power are initial capital investment, operating costs and the cost of loss in the line. As annual operating costs are considered to be a small fixed percentage of initial capital investment, the major cost involved are the initial capital investment and losses. Increasing capital investment means building larger lines resulting in decrease of losses. Decreasing capital investment means building smaller lines resulting in increasing losses. Hence, transmission lines should be built so that the total life cycle cost (present value sum of, investment, O&M cost and losses over the project life period) is least. Techno-economic optimization methods are employed for the purpose.

The losses in a line are directly proportional to the square of the current flow in the line. As power flow increases in the line, increase in loss does not take place in a linear manner but rises parabolically. Hence, high line loading results in excessive line losses and at a certain level investing in construction of additional new line becomes more economical than further loading the same line. In order to access such threshold load levels, techno-economic analysis must be performed case wise.

The reactive power transferred over a line is directly proportional to the voltage drop along the line ($|Vs| - |Vr|$) and is independent of the power angle (phase angle between Vs & Vr). Thus the major cause of voltage drop on the line is the transfer of reactive power over the line. And real power transfer is directly proportional to Sin δ. When a line is long, X is high resulting in a high power angle. The power angle at which most lines operate is about 40^0. In order to maintain a good voltage profile and to maintain voltage stability, the control of reactive power is necessary.

Series reactance of a line consumes lagging-vars, whereas shunt capacitance of a line consumes leading-vars which are proportional to V^2. Decrease in voltage thus causes reduction in these leading-vars which causes a greater difference between the lagging and leading vars. This chain effect results in a further decrease in voltage and may finally lead to a voltage collapse.

Real line losses represent a waste of energy while reactive losses necessitate increase in investment for shunt compensation equipment, etc. Real and reactive losses are given by,

$$\text{Re}\,al \quad line \quad losses \;=\; 3I^2R \;=\; 3\frac{P^2+Q^2}{V^2}R$$

$$\text{Re}\,active \quad line \quad losses \;=\; 3I^2X \;=\; 3\frac{P^2+Q^2}{V^2}X$$

Hence, real line losses also increase with increase in Q. In order to reduce real and reactive line losses, the reactive power transfer over the line should be kept to a minimum.

8.6 Transmission Route, Cost Estimate and Value Of Money Transmission route

The Transmission route from Tamakoshi-V to either Singati s/s or switchyard of Upper Tamakoshi HEP lies in difficult mountainous terrain. The route won't accessible by road and this shall form the basis for transmission cost estimates.

Cost Estimate

Transmission Lines

Cost estimate for 132 kV and 220 kV is based on NEA's Transmission System Master Plan 1998 (TSMP-1998). The estimated cost for lines with conductor sizes and voltages of our concern are as shown in the table below.

Table No. 8.4: Transmission Line Costs [kUSD/km, excl. of taxes and duties]

Conductors per phase	132 kV		220 kV	
	s/c	d/c	s/c	d/c
1 x Wolf	59.3	94.8	-	-
1 x Bear	77.0	123.2	-	-
1 x Bison	-	-	102.2	163.5
2 x Bison	-	-	148.1	236.5
1 x Moose	-	-	118.8	190.0
2 x Moose	-	-	172.2	275.0

Substation Components

132 kV and 220 kV cost estimate is based on NEA's TSMP-1998. The estimated substation costs for various voltages of our concern are as shown in the table below. The following maximum transport weights are assumed to apply for Nepal.

- Terai plains : 80 tons
- Kathmandu Valley : 30 tons
- Other areas : 30 tons

Table No. 8.5: Transformer Costs

	Transformer Costs [MUSD excl. taxes and duties]	
	Size [MVA]	**1 x 3 ph**
11/132 with OLTC	50	1.5
11/220 with OLTC	50	1.7
132/220 with OLTC	50	1.9

OLTC: On load tap changer

Table No. 8.6: Bay Costs

	Bay Costs [kUSD]	
	132 kV	220 kV
Line Bay	550	910
Transformer Bay	410	750
GIS Line Bay*		1630

* Rate applicable for GIS with XLPE cable terminals. GIS cost will increase approximately 20% for SF6 cable termination.

Table No. 8.7: Control Building Costs

	Cost	Size [m^2]	Size [m^2]
Buildings	[USD/m^2]	132 kV	220 kV
Control Building	600	200	500
Store/Workshop	400	- -	200
Total Cost [kUSD]		120	380

The 1998 estimates being at European standard are more or less valid till date in the Nepali contest hence are adopted in the study. The cost of energy for loss-capitalization purpose is taken as USc 6.02 per kWh, which is again a 1998 value. In the optimization process, optimization is compromised between the capital investment and resulting losses. As cost of both is based on 1998 values, the result of optimization is unaffected regardless of any cost escalation since the 1998 estimates.

Value of Money

Money has no value of its own. Its value is proportional only to the goods and services it can procure. The amount of goods and services money can provide in a given year relates directly to the relative value of money at that point of time. In absence of inflation a specified amount of money could buy the same amount of goods and services in one time as in another. But due to inflation the value of any specified amount of money decreases over time. The same amount of money can procure less goods and services in a later period of time.

"Real value" and "Nominal value" can be used to express the effect of time on the value of money. Nominal value refers to the amount received or spent in a given year. But due to inflation a dollar received in year-X will be worth more or less than a dollar received in year-Y. In order to compare the two, the real purchasing power of year-X dollar must be compared with the real purchasing power of year-Y dollar, or if convenient both could be referred to a 3rd year-Z value.

For inflation of 10 % per year, the relative value of $ 100 in hand in 2009 will be $ 110 in 2010 or $ 121 in 2011 and so on. Similarly, future values must also be discounted to obtain their value today. The real value of $ 121 to be received in 2011 is only $ 100 in 2009 value. The following table illustrates the real value (in constant 2009 value) of future money at 10 % discount rate.

Year	2009	2010	2011	2012	2013	Total
Nominal Value (actual $)	100.00	100.00	100.00	100.00	100.00	500.00
Real Value (2009 buying power)	100.00	90.91	82.64	75.13	68.30	416.98
Nominal Value (actual $)	100.00	110.00	121.00	133.10	146.41	610.51
Real Value (2009 buying power)	100.00	100.00	100.00	100.00	100.00	500.00

The first two rows demonstrate the decline in real value of a stream of \$ 100 to be received annually in future. The second two rows demonstrate the increase in annual dollar required to be received in future to maintain the same real income of \$ 100 (on 2009 buying power).

A discount rate of 10 % has been considered in all economic analysis of present study.

8.7 Transmission System Study

Planning Method

General

This chapter explains the planning criteria applied during study and other planning related assumptions.

For the Supply-quality the allowable voltage and frequency variations adopted are as follows:

- Maximum allowable voltage variation in normal operation: ± 5%
- Maximum allowable voltage variation during emergencies: ± 10%
- Maximum allowable frequency variation during emergencies:± 5%

Spread-Sheet Calculation Method

Basic Formula

The selection of transmission lines for the planned power plants in Nepal are based on economic evaluation of different line/tower solutions over the lifetime of the project. The optimisation takes into account investment cost, cost of transmission losses and operation & maintenance costs.

The calculation is primarily performed on a per km transmission line basis, and is as such not dependent on the length of the transmission line. Further optimization is performed on transmission-system basis, including transmission line cost as well as substation costs. The following formulas apply to the calculation:

$$K_{Total} = K_{Investment} + K_{Losses} + K_{O\&M}$$

$$K_{Losses} = \left(\frac{P_{Peak}}{U_{Rated} . pf} \right)^2 \cdot R \cdot T_{Loss} \cdot k_E \cdot D$$

$$K_{O\&M} = K_{Investment} \cdot \frac{c_{O\&M}}{100} \cdot D$$

where

P_{Peak} = Maximum Transmitted Power
U_{Rated} = Rated AC line Voltage
R = AC line resistance
T_{Loss} = Loss Duration
k_E = Energy Cost D = Discount Factor
$c_{O\&M}$ = Annual Operation & Maintenance cost [% of initial investment]

Costs

Transmission line and substation costs are stated in Chapter 6. The spread-sheet optimisation is carried out based on transmission line costs alone, but substation costs are also considered after preliminary screening and before a final recommendation is made.

AC resistance values

The AC resistance in a line is dependent on temperature and thus on loading. With high power transfer, the conductor temperature will be high. To be on the safe side, the ambient temperature is considered as 40°C. For economic optimisation it is preferred to use conservative resistance values, i.e. resistance at maximum or close to maximum operating temperature. In this optimisation it has been selected an operating temperature of 75°C. For the conductors used in this study, the following AC resistance shall apply:

- ACSR Wolf : 0.2187 Ω/km at 75°C

- ACSR Bear : 0.1310 Ω/km at 75°C
- ACSR Bison : 0.0927 Ω/km at 75°C
- ACSR Moose : 0.0673 Ω/km at 75°C

Plant Loss Duration

The equivalent plant loss duration is a function of plant factor. The equivalent loss duration is the time the plant will have to be operated on rated capacity in order to produce the annual losses, and is calculated from:

$$T_{Loss} = \frac{T_{Utilisation}^2}{8760} \cdot \left(1 + \frac{1}{2}\left(1 - \frac{T_{Utilisation}^2}{8760^2}\right)^2\right) \quad \text{[hours]}$$

The technical characteristics of the plants are shown in the following table.

Table No.8.7: Plant Characteristics

Plant Name	Plant Capacity [MW]	Annual Energy [GWh]	Plant Factor	Generation Duration [hrs]	Plant Loss Duration [hrs]
Tamakoshi-V HEP	87	446.01	0.5852	5126.55	3648.70

Energy Cost

The energy cost normally to be used for optimisation of transmission lines is the long run marginal cost of generation. The average incremental cost of generation better reflects the real value and is therefore used. The average incremental cost of generation as per TSMP-1998 is 6.02 USc/kWh.

Operation & Maintenance

The operation and maintenance cost of transmission lines range from 0.5% to 1.5%, and Nepal is considered to be in the upper range due to the recurring monsoon and frequent landslides. An annual operation and maintenance cost of 1.5% is therefore used in the optimisation.

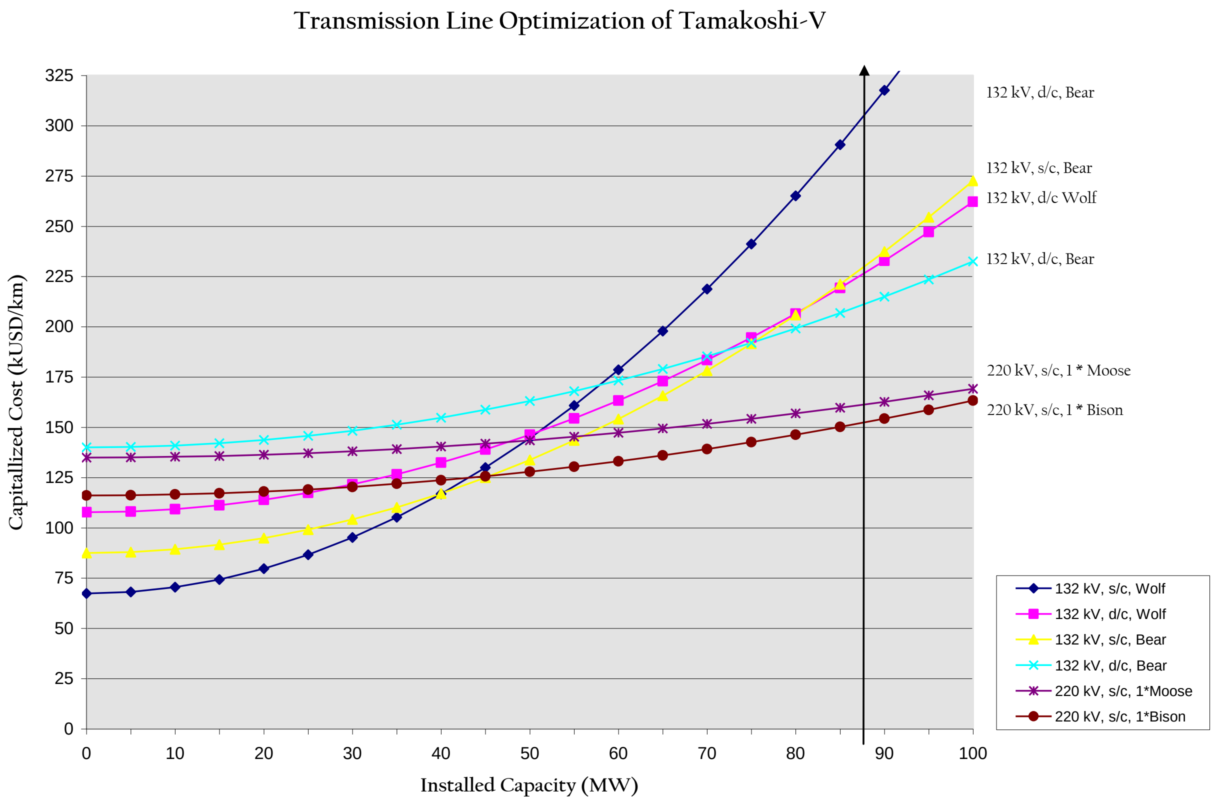
Discount Factor

The discount factor represents the discounted value of fixed annual payments of one unit each year of the lifetime.

For Tamakoshi-V HEP, with 25 years of project lifetime and 10% discount rate, the discount factor is 9.077.

Transmission line scheme based on the Spread-Sheet Method

The result of the spreadsheet economic optimization of transmission lines from Tamakoshi-V HEP is shown schematically in figure below. With the plant capacity of 87 MW and the annual energy of 446.01 GWh the plant factor for Tamakoshi-V HEP is 0.5852. With this plant factor the Plant Loss Duration [hrs] amounts to 3648.70 (hours). Applying this loss duration hours in the spreadsheet method the optimum conductor and voltage for Tamakoshi-V HEP is a 220 kV s/c ACSR 1*Bison. The total capitalised cost for all schemes is also present in table below:



S. No.	Transmission Line	Capitalized Cost (kUSD/km) [for Evacuation of 87 MW power at 0.5852 Plant Factor]
1	132 kV single circuit Wolf	301.2
2	132 kV single circuit Bear	227.6
3	132 kV double circuit Wolf	224.6
4	132 kV double circuit Bear	210.0
5	220 kV s/c ACSR 1*Bison	151.8
6	220 kV s/c ACSR 1*Moose	160.9

Transmission System Optimization

The transmission-line-optimization conducted earlier only considers the transmission line cost on per km basis. Detailed optimization must be performed comparing each complete transmission system (transmission line + substation) to achieve real system optimization.

Following transmission system schemes for system optimization have been evaluated

1. 132 kV single circuit Bear from Tamakoshi-V to Singati s/s.
2. 132 kV double circuit Bear from Tamakoshi-V to Singati s/s.
3. 132 kV single circuit Bear from Tamakoshi-V to New Upper Tamakoshi s/s.
4. 132 kV double circuit Bear from Tamakoshi-V to New Upper Tamakoshi s/s.
5. 220 kV s/c ACSR 1*Bison from Tamakoshi-V to Upper Tamakoshi HPP.
6. 220 kV s/c ACSR 1*Bison from Tamakoshi-V to New Upper Tamakoshi s/s.
7. 220 kV s/c ACSR 1*Moose from Tamakoshi-V to Upper Tamakoshi HPP.
8. 220 kV s/c ACSR 1*Moose from Tamakoshi-V to New Upper Tamakoshi s/s.
9. 220 kV d/c ACSR 1*Bison from Tamakoshi-V to New Upper Tamakoshi s/s.

Optimization was performed on transmission package (total capital cost + O&M cost + cost of losses) capitalized cost basis, employing the values of plant factor, energy cost, power factor, discount rate and project life provided or agreed by the Project. The results are show in the table below.

S. No.	Transmission System	Capitalized Cost (MUSD)
1	132 kV single circuit Bear from Tamakoshi-V to Singati s/s	6.95
2	132 kV double circuit Bear from Tamakoshi-V to Singati s/s	8.1
3	132 kV single circuit Bear from Tamakoshi-V to New Upper Tamakoshi s/s	18.79
4	132 kV double circuit Bear from Tamakoshi-V to New Upper Tamakoshi s/s	19.97
5	220 kV s/c ACSR 1*Bison from Tamakoshi-V to Upper Tamakoshi HPP	9.97
6	220 kV s/c ACSR 1*Bison from Tamakoshi-V to New Upper Tamakoshi s/s	12.81
7	220 kV s/c ACSR 1*Moose from Tamakoshi-V to Upper Tamakoshi HPP	10.06
8	220 kV s/c ACSR 1*Moose from Tamakoshi-V to New Upper Tamakoshi s/s	12.85
9	220 kV d/c ACSR 1*Bison from Tamakoshi-V to New Upper Tamakoshi s/s	15.16

The results show that, *132 kV s/c Bear* 6 km long transmission line to Singati s/s exhibits the least capitalized cost for evacuation of 87 MW power at 0.5852 plant factor, hence *"132 kV s/c Bear transmission line to Singati s/s"* is the most economical option.

In all three cases in FY 2018/19 the N-1 contingency of d/c Khimti – Dhalkebar transmission line leads to this line loading beyond 120%. This problem will be solved by the necessary reinforcement of INPS.

In the case of connection of Tamakoshi-V to Singati s/s through "132 kV s/c Bear" transmission line in FY 2018/19 Wet Peak season the N-1 contingency of d/c Singati - Lamosanghu transmission line leads to this line loading of 114.1%. There is a huge possibility that in near future a number of IPP projects could be commissioned to connect to Singati s/s leading to the N-1 contingency of d/c Singati - Lamosanghu transmission line with loading of more than 120% which is beyond the NEA's transmission criteria.

If such a condition arises then for evacuation of Tamakoshi V HEP the next best power evacuation scheme of a 220 kV s/c ACSR 1*Bison 10 km long from Tamakoshi-V to Upper Tamakoshi HPP should be considered. For this power evacuation scheme there is an uncertainty relating to the availability of space for construction of GIS line bay to connect the transmission line coming from Tamakoshi V to the switchyard of Upper Tamakoshi HPP. As Upper Tamakoshi HPP switchyard is under ground type provisioning of space for future GIS line bay construction is required. Hence considering this fact the option to connect Tamakoshi-V to Upper Tamakoshi s/s underground switchyard may not be envisaged.

The next best option is a 220 kV s/c ACSR 1*Bison 4 km long transmission line(including construction of New Upper Tamakoshi s/s) from Tamakoshi-V to New Upper Tamakoshi s/s. This scheme requires construction of New Upper Tamakoshi s/s which is a switching s/s on the transmission line route evacuating power from Upper Tamakoshi HPP to Khimti s/s in the vicinity of Tamakoshi V HEP power house. The technical viability of construction of New Upper Tamakoshi s/s requires further study and permission from Upper Tamakoshi HEP and NEA.

The existing down-time i.e. average annual outage in Nepal is 0.28 hours per km and the ENS cost due to such forced outage is 29.2 USc/kWh. Hence, the reliability cost of not constructing a d/c transmission line instead of a s/c line is, Cost of ENS = 292 USD/MWh * 0.28 Hr/km/year * 87 MW * 0.5852

= 4.1627 kUSD/km/year

Discount factor = 9.077

Capitalized cost of ENS = 4.1627 kUSD/km/year * 9.077 * 6 km = 226.71 kUSD

The capitalized ENS cost (reliability cost) of not constructing a d/c transmission line instead of a s/c line is 226.71 kUSD, whereas the extra capitalized cost involved in transmitting 87 MW power through a 220 kV d/c 1*Bison line instead of a 220 kV s/c 1*Bison line is 2.34 MUSD.

Hence, 220 kV s/c ACSR 1*Bison transmission line 220 kV s/c ACSR 1*Bison 4 km long transmission line (including construction of New Upper Tamakoshi s/s) from Tamakoshi-V to New Upper Tamakoshi s/s is economical even after consideration of reliability compared to "220 kV d/c ACSR 1*Bison to New Upper Tamakoshi s/s".

Hence, Tamakoshi-V (87 MW) shall be connected to New Upper Tamakoshi s/s (4 km away) through "220 kV s/c 1*Bison" 4 km long transmission line with construction of New Upper Tamakoshi s/s which is a switching s/s on the transmission line route evacuating power from Upper Tamakoshi HPP to Khimti s/s in the vicinity of Tamakoshi V HEP power house.

Economic-analysis for transmission-system optimization by spread-sheet method and their estimate is attached as Annex-2.

Assumptions for Load Flow

The following assumptions for the load flow studies of INPS:

1. **Winter Peak Load:** Winter Peak Load of different substations (s/s) would be based on the NEA load forecast prepared by the System Planning Department of NEA. Winter Peak Load is coincident with the System Peak Load.

2. **Summer Peak Load:** Based on the historical load data of different s/s and the nature of load supplied by the s/s, Summer Peak Load of the following s/s would be taken as the same as the Winter Peak Load, as these s/s mainly supply the industrial load:

Dang Cement, Dynasty Cement, Butwal, Bharatpur, Hetauda, Hetauda Cement, Amlekhgunj, Hulas Steel, Jagadamba Steel, Simra, Ashok Steel, Triveni Spinning Mill, Himal Iron, Jyoti Spinning, Parwanipur, Chadranigahapur, Birgunj, Dhalkebar, Lahan, Duhabi, Damak and Anarmani.

However, for the remaining s/s, the Summer Peak Load is assumed to be 10% less than the Winter Peak Load.

3. **Summer Off-Peak Load**: To examine the nature of load flows during the off-peak hours, it is assumed that Summer Off-Peak Load would be 50% less than Summer Peak Load for the s/s mentioned above in Section 2; due to high load factor of the load supplied by these s/s. For the remaining s/s Off-Peak load would be 60% less than that in the peak time during the summer season.

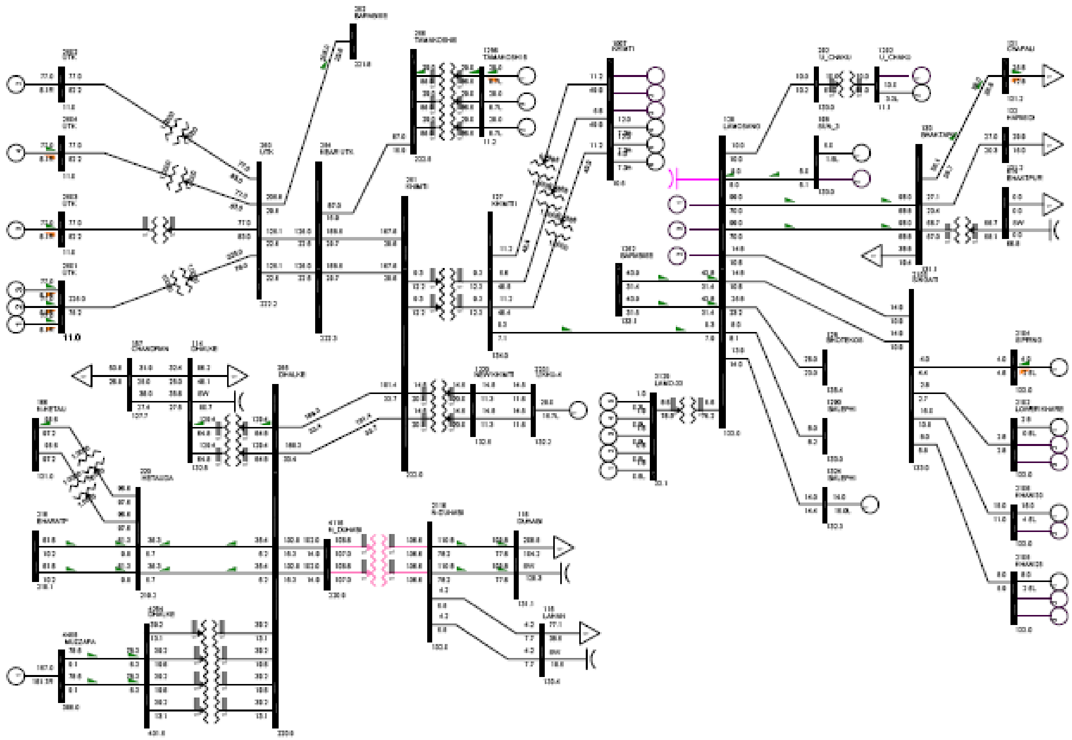
4. **Generation Data:** Generation data for storage, peaking and run-of-the-river (ROR) would be based on actual availability of the power plants during summer and winter season. For candidate power plants (NEA as well as IPPs) estimated availability would be used. Summer season generation represents the maximum generation potential of the power plant and is represented by the installed capacity of the power plants; while the winter season generation would be the generation capacity of the power plants during the month of December, which is not the typical dry season availability of the hydropower plants. Generation in the month of December is used to coincide with Winter Peak Load of s/s. Further it would be assumed that storage power plants are not operated during the summer season, while fully operated in winter season and peaking ROR would operate at full capacity (installed capacity) only during winter season peak load. In case of the ROR plants where winter season generation data is not available, it would be assumed to be one third (1/3) of the installed capacity of the ROR plant.

Load Flow study:

On the basis of above mentioned transmission system optimisation and assumption load flow study is performed by connecting the Tamakoshi-V HEP (87 MW) to New Upper Tamakoshi s/s (4 km away) through "220 kV s/c 1*Bison" 4 km long transmission line with construction of New Upper Tamakoshi s/s which is a switching s/s on the transmission line route evacuating power from Upper Tamakoshi HPP to Khimti s/s in the vicinity of Tamakoshi V HEP power house.

The load flow study is performed for Dry season peak period, Wet season peak period and Wet season off peak period. The schematic diagram of Tamakoshi-V HEP (87 MW) connected to Singati s/s 132 kV switchyard is shown below. The details of Load Flow study are shown in Annex 3.

Tamakoshi V (87MW): Load Flow Diagram: FY 2018-19: Dry Peak Period



Conclusion

- For power evacuation of Tamakoshi-V HEP (87 MW) a 220 kV s/c ACSR 1*Bison transmission line 220 kV s/c ACSR 1*Bison 4 km long transmission line from Tamakoshi-V to New Upper Tamakoshi s/s shall be constructed with construction of New Upper Tamakoshi s/s which is a switching s/s on the transmission line route evacuating power from Upper Tamakoshi HPP to Khimti s/s in the vicinity of Tamakoshi V HEP power house.

- Timely completion of the all the transmission and reinforcement plans as mentioned in chapter 3.

9. Cost Estimate

9.1 General

This cost report describes the methodology used in estimating the project cost of the 87 MW Tamakoshi V Hydroelectric Projects located in Dolakha districts, Janakpur Zone of Central Development Region of Nepal. The estimated project cost is based on the quantity estimated on feasibility study of the project and its drawing. The unit rates of item are based on existing labour and material cost at present with current prices 2011.

9.2 Criteria, Assumptions and cost components

The following criteria and assumptions are the basis of the cost estimate:
All costs are in June 2011 dollars.

- For currency conversion, rate of exchange rate is as follows:
- US $1 = NRs 75

A key assumption is that the project management and procurement policy will stress open competitive bidding and that government policies will not hinder cost-effective construction. Contractors will be free to employ labour from Nepal and other neighbouring countries as deemed cost effective.

9.3 Estimating methodology

The major component breakdown for the estimating process is:

- support facilities, access roads and other general items
- electromechanical equipment
- main civil construction works, including on-site access
- camp and housing accommodation facilities
- engineering, management, administration and other owner’s costs
- contingencies

9.4 Civil Works

The cost estimate was prepared with the following approaches. A quantities estimate requires the sequential execution of the following steps:

- Subdivision of the total project into a number of distinct structures (headworks, Spillway tunnel and Headpond, Headrace Tunnel, Surge tank, dropshaft and high pressure steel lined tunnel, powerhouse, tailrace tunnel and tailrace canal etc.).

- Breaking down of structures into a number of distinct construction tasks or measurable pay items. These are overburden excavation, rock excavation, fill work, concrete works, etc.).

- Calculation of the appropriate quantity of each item estimated from designed drawings as presented in the study.

- Selection of the labour, material and construction equipment resources required for all construction work.

- Estimating the unit costs for the project by using the cost of the combined resources used and their expected production.

- Summation of all the product of the quantities and the unit costs yields the total cost of construction.

- The summation with allowances for contractor's profit, contingency and allowances for engineering and management and provision for camp facilities gives the total project cost.

In application of this approach, contractor's overhead and profits mark-up is applied during the unit rate development.

9.4 Resource Costs

9.4.1 Labour Rates

For estimating purpose, the labour force was subdivided into four categories of workers: unskilled, semiskilled, skilled and highly skilled. These categories were used to develop the unit rates as per crew requirements.

Considering the overall construction requirements for the project, hourly rates of labour were developed based on prevailing labour rates of the project site. Since the project site will be accessible, availability of labour in local area is considered. The calculated rates of workers on an hourly basis are as follows:

- Unskilled labour NRs 45.38 / hr
- Semiskilled labour NRs 52.94 / hr
- Skilled labour NRs 60.50 / hr
- Highly skilled labour NRs 90.75 / hr

9.4.2 Construction Equipment Rate

It is proposed that major components of civil works will be constructed by using standard construction methods employing various construction machines and equipment as far as possible. Equipment operating and owing cost per hour is referred from the similar number of projects which are under studies by Nepal Electricity Authority. The representative operating and owning cost of heavy equipment and tools are as follows.

- Tipper Truck NRs 1383.78 / hr
- Wheel Loader HP 160 NRs 2877.86 / hr
- Concrete Mixer 0.5 m^3/hr NRs 390.66 / hr
- Bulldozer HP 165 NRs 3256.93 / hr
- Air Compressor 150 CFM NRs 601.60 / hr

9.4.3 Construction Material

Most of the construction material including Reinforcement bar will probably be supplied and processed from Nepal. Required amount of Cements will be supplied from nearest commercial market. Construction material cost is adopted of the city price.

- TOR Steel Reinforcement NPR 78000 /ton
- Cement NPR 15000/ton
- Gelatine NPR 200/kg

9.5 Unit Costs

After combining the required resources mix and applying the expected crew production, the total cost of an activity is calculated and hence the unit rate. Representative Unit rate for project construction is presented in Table 9.1.

Table 9.1 Unit Rates

S.No.	Item	Unit	Rate US$
1	Rock Excavation	**m^3**	14.31
2	Open Cut Excavation	**m^3**	3.05
3	Tunnel Excavation	**m^3**	51.99
4	Concrete Lining in Tunnel (M25)	**m^3**	159.13
5	Concrete Lining (M25)	**m^3**	151.82
6	Lean concrete	**m^3**	108.77
7	Reinforcement (Underground)	**t**	1579.42

9.6 Indirect Costs

Each unit cost for the civil works for both the projects includes the contractor's overhead and profit which are assumed to be 20% of direct cost. In which, 10 % is considered as overhead and 10 % as profit in direct cost.

9.7 Preliminary Works

A sum of US $ 4.108 million is provided for the preliminary works for Tamakoshi V HEP for Tamakoshi V HEP. This work includes mobilization, demobilization cost for construction periods. It includes necessary vehicle for the project. Provision for construction power during project is also made in this heading.

9.8 Access Road

As the access road to the Upper Tamakoshi HEP passes through the headworks and powerhouse sites of this project, this project needs no access road. However, the project needs total of 6 km of project road to reach several adits , surge tank and undern ground powerhouse. A total sum of US $ 1.3 million provision is made for Access

9.9 Civil Work cost

The total estimated cost for the civil works for Tamakoshi V HEP including access road is US$ 57.69 million. This amount is 54.50% of the total Construction Base Cost. Headrace Tunnel is major cost component in project cost.

9.10 Hydromechanical works Cost

Total amount of hydraulic steel structures as stoplogs, gates, valves, including steel penstock and accessories of Tamakoshi V Hydroelectric Projects are US $ 2.309 million.

9.11 Electromechanical Equipment

The cost of the electromechanical equipment were estimated by a combination of methods including:

- interpretation of budget prices supplied by potential suppliers, mainly for the larger and more expensive equipment such as turbines, generators, power transformers and main inlet valves;
- in-house estimates using established international prices and/or relationships for more routine items, the in-house information being based on years of collection of price data, and often eliminates the errors of variations of prices occurring due to abrupt changes in supply and demand;
- percentage of lump sum provisions on a ratio basis, based on experience for lesser miscellaneous items;
- in mechanical services, the empirical relation developed for estimation includes: heating ventilation, air conditioning, drainage, dewatering, oil storage, cooling water, compressed air, embedded/exposed piping ducts, elevator, diesel generator, maintenance equipment and water level measurements; and
- in electrical services, the empirical relation developed for estimation includes: low voltage switching, control equipment, DC system equipment, system transformers, communication equipment and station service equipment.

The total cost for four units of electromechanical equipments of turbine-generators and all ancillary equipments required in the powerhouses of Tamakoshi V is estimated to US $ 30.175 million.

9.12 Transmission Line, Substations and Switchyard

The power generated from the Tamakoshi V HEP project will be evacuated in switchyard of substation through a 220 kV double circuit transmission line from power house to LILO point. Length of the transmission line between Tamakoshi V HEP to the point is about 8 km. The total estimated cost for the selected transmission line for Tamakoshi V HEP is about US $ 11.67 million. The cost includes all necessary accessories and line bays.

9.13 Engineering, Management Cost

A provision of US $ 8.476 million which is 8 % of the total construction base cost has been made for engineering and management including the detailed engineering and supervision cost.

9.14 Contingencies

Contingencies will be applied to various areas of work to cover changes in physical scope, which cannot be identified at this stage. The following allowances will be applied:

10% on preliminary works, access road and surface works.
15% on all underground works
5% on electro-mechanical equipment, and Transmission works.

The following contingencies have been assumed for Tamakoshi V Hydroelectric Project.

Contingencies for Preliminary and access road	US $ 0.56 million
Contingencies for Underground works civil	US $ 8.43 million
Hydromechanical, electromechanical and transmission line	US $ 2.207 million
Total provision made for contingencies	US $ 11.198 million

9.15 Resettlement and Environmental Mitigation Work

Appropriate sum has been allocated for environmental, compensation and mitigation purposes. A provision for the resettlement, environmental mitigation and management equivalent to US $ 3.178 million have been made for Tamakoshi V HEP.

9.16 Owners cost

A provision of 3% of base cost equal to US $ 3.178 million has been provided as the owners cost for Tamakoshi V Hydroelectric Project.

9.17 Project Cost

The total estimated project costs for Tamakoshi V HEP is US $ 131.99 million. The summary of the estimated total project costs for the project are tabulated below:

Table No. 9.2: Summary of the Project Cost

Serial No	Installed Capacity (MW)	87
	Description	Amount in US $
1	Preliminary Expenses	4,108,500
2	Access Roads and Bridge	1,300,000
3	Headworks	487,099
4	Spillway tunnel and Headpond	1,368,860
5	Access Tunnel	715,120
6	HeadraceTunnel	42,987,365
7	Adit Tunnel	2,651,432
8	Surge Tank	2,507,653
9	Dropshaft and Penstock	945,198
10	Powerhouse	3,366,312
11	Tailrace	1,171,736
12	Switch yard	194,869
13	Gates ,Valves & Steel liner	2,309,715
14	Turbines, Generators & Accessories	30,175,200
15	Transmission Line, Substations and Switchyard	11,670,720
	TOTAL CONSTRUCTION BASE COST	105,959,779
	Engineering, Management (8% of base)	8,476,782
	Resettlement and Environment 3%	3,178,793
	Owners cost 3%	3,178,793
	TOTAL PROJECT BASE COST	**120,794,148**
	Contingencies:	
	10% of Civil works & Preliminary Works(1 -2) and Switchyard(12)	560,337
	15% of underground work (3- 11)	8,430,116
	5% of Electromechanical and Transmission (15 - 17)	2,207,782
	Total Contingencies	11,198,235
	GRAND TOTAL	131,992,383
	ROUNDED GRAND TOTAL	**131,992,000**
	Installed Capacity (kW)	87,000
	Cost / kW	1,517

Detailed Bill of Quantities (BoQ) is presented in the Annex G.

10. Construction Planning

10.1 General

Construction planning is a major component of project studies that transpires into successful development of the project within time and estimated budget. The project is located in the Dolkha District, Janakpur Zone of Central Development Region of Nepal in Tamakoshi River. The project is approximately 42.0 Km north of Charikot Bazar, the district headquarter of Dolakha District. This project is a cascade development of the Upper Tamakoshi Hydroelectric Project (UTHEP) utilizing tailwater of the UTHEP as its design discharge. This project will be utilizing all the infrastructures (Road, Bridge, transmission line etc) constructed by the UTHEP. The project comprises of an interconnection with the tailrace of UTHEP, 110 m long intake tunnel, Head Pond, 8.20 km long pressure headrace tunnel, 15.0 m dia and 73.61 m high Surge Tank, 122.38 m vertical drop shaft, underground powerhouse with an installed capacity of 87 MW from four electromechanical units and ancillary facilities.

10.2 Site Condition

Topography and Land Use

The project site is located in the mid hill region of Central Development Region of Nepal. The intake site / underground interconnection system with Upper Tamakoshi tailrace outlet is located in Lamabagar VDC at an elevation of 1156.49 m. The underground powerhouse lies at the right bank of Tamakoshi River just downstream of the Suri River confluence with Tamakoshi River.

Climatic Conditions

The project area has hot summer season with maximum temperature ranging from 30^oC to 36^oC. The minimum temperature during winter ranges from 3^oC to 5^oC. The average annual rainfall is approximately 2333 mm which occurs during the month July-September.

Telecommunication Facilities

Currently, CDMA and GSM telephone network exists at the Project Site. Satellite telephone link may also be made. Mobile communication equipment will be used to communicate with the various project sites. Once the project is commissioned, power line cable communication (PLCC) will be used for information exchange between the powerhouse and load dispatch center.

10.3 Access to the Site

Calcutta is the most appropriate sea port for the transportation of construction materials and equipment from the third world countries. Similarly, Birgunj would be considered as the appropriate rail way station for this project as it has a broad gauge railway connection. Total railway distance between Calcutta & Birgunj dry port is 763 km.
The Project is located approximately 170 km north east of Kathmandu and 40 km away from Charikot, the district head-quarter of Dolkha District. The district head-quarter is connected with the capital by Arniko Highway upto Lamasangu which is approximately 90 km and by Lamasnagu – Jiri road which is approximately 40 km up to Charikot. At present, the nearest road head from the Project site is about 33 km gravel road of from Charikot to Singate Bazaar. However, the newly constructed road by UTHEP connecting Singate Bazaar and Lamabagar passes from the both powerhouse and the headwork site of this project. The under construction road for UTHEP and the tunnel alignment for Tamaksohi V Project both are at the right bank of the Tamakoshi river thus making the access to the construction adit easier. Few kilometers of project road will have to be constructed to reach surge tank site, adit tunnels and some particular location by the project before the construction of the project.

The following modes of transportation are recommended:

- Transport all light offshore general cargo by road.
- Transport the heavier offshore by Indian railway directly to Birgunj
- Transport from Birgunj to the project site by road.

10.4 Construction Power and Camp

Construction power requirement is estimated at about 2850 kW, which is shown below.

Batching Plant		=	500 kW
Construction camp		=	1000 kW
Air Compressor	100 x 6	=	600 kW
Workshop		=	100 kW
Welding		=	50 kW
De-watering Pump		=	100 kW
Office		=	50 kW
Vent fan	50 x 6	=	300 kW
Tunnel Lighting		=	100 kW
Power Winch		=	50 kW

Sub Total	=	2850 kW
Diversity Factor	=	0.6
Peak Power Requirement	~	1750 kW

Construction power will be arranged through 132 kV line either from Singati substation of the Upper Tamakoshi Sub-station. This constructed line will further be used for power evacuation of the generated energy from Tamakoshi-V. Backup power will be needed for critical works like tunnel lighting, water pumping and ventilation, batching plant etc. The backup power will be provided through diesel generators of suitable size.
Construction camp will be required to house both the employer's staff and contractor's staff. The campsite will be located near the midpoint between headwork & near powerhouse site. The camp will comprise of office, living quarters, store, workshop, medical post etc. It is envisaged that permanent structures of the camp will be used for accommodation of the operation and maintenance staff once the construction is completed. Much of the construction camp will be built from pre-fabricated units, which will be dismantled once the project is completed. The camps are proposed to be completed prior to the award of main contract. About 4 months time will be required to complete the construction camp.

10.5 Project Construction Work and Construction Planning

All construction activities will be mainly concentrated in Headrace Tunnel and powerhouse site. Following are the main activities during construction.

- Access road
- Connection with Upper Tamakoshi HEP Tailrace
- Intake Tunnel
- Head Pond
- Spillway Structure and Tunnel
- Power (Pressure) Tunnel
- Surge Tank
- Vertical Drop Shaft
- Powerhouse and switchyard.
- Tailrace Tunnel and Outlet Structure.
- Transmission line

The layout of the project is shown in Drawing No. TV GL -200 and the construction schedule is summarized in Figure 10.1. The work involved at each of these areas is outlined below:

In order to provide the necessary access to the work areas, camp sites, borrow areas and disposal area, an access road to the disposal areas and proposed campsite will be constructed. The basic assumptions, principal project components and their sequence of activities and construction works to be executed in the project area are presented in the following sections.

10.5.1 Basic Assumptions

Following are the basic assumptions used for the construction planning:

- Eight hours per shift, three shift work per day and six days work per week is assumed.
- Mobilization period of 30 days is assumed immediately after the award of the contract.

Progress rates assumed for different major work items of construction works are as follows:

Tunnel Excavation	:	3.5 meter per day per face
Concreting	:	Two Batching Plant of 40 cu.m per hour capacity and some allowances for formworks
Vertical Shaft excavation	:	1 meter per day

10.5.2 Connection with Upper Tamakoshi HEP Tailrace

It is expected that the Upper Tamakoshi HEP (UTHEP) will construct a connecting tunnel, about 50 m tunnel to connect the intake tunnel of the Tamakoshi V HEP during the construction of its tailrace tunnel. The connecting tunnel will be closed by a regulating gate to control the flow from the tailrace of the UTHEP so that while constructing the connection between UTHEP and Tamakoshi V HEP, the shutdown of the UTHEP be avoided. It is anticipated that the connection works including the breakthrough of the connecting part and subsequent concreting work will take 7 days.

10.5.3 Intake Tunnel

The Intake tunnel links the regulating gate near the tailrace of UTHEP and the headpond of the Tamakoshi V HEP. Inverted D shaped tunnel carries 66 cumecs from the tailrace of

UTHEP. The intake tunnel excavation is envisaged to be completed in 35 days where as the concreting work is expected to be completed in 35 days.

10.5.4. Head Pond

Major works comprises of earth and rock excavation, concreting, erection of gates etc. The excavation is expected to be completed in 60 days and the concreting work is expected to be completed in 15 days.

10.5.5 Spillway Structure and Tunnel

Major works comprises of earth and rock excavation and concreting of the overflow Ogee shaped spillway and the gravity flow tunnel. The excavation is expected to be completed in 70 days and the concreting work is expected to be completed in 55 days.

10.5.6 Power (Pressure) Tunnel

The standard horseshoe shaped excavation with circular finished Power (Pressure) Tunnel has an excavation diameter of 6.4 m, finished diameter of 5.6 m . The total length of the tunnel up to Surge Tank is 8.2 km. The tunnel will be driven from six work faces including two from adit 1 located at 50 m downstream of Head Pond. Drill and blast method will be used for the tunnel excavation. Tunnel excavation will be carried out using leg drill and rocker shovel while dump trucks or battery operated rail cars will be used for mucking. The tunnel will have pipelines for ventilation, dewatering, and compressed air supply in addition to the low voltage power supply for lighting, vent fan, pumping. As tunnelling is critical component of project construction, it will be carried out in three shifts per day. The anticipated progress rate of tunnelling is 3.5 m per day from each face. All power tunnel excavation will be completed over a period of 23.33 months which includes provision of support also like ribs, rockbolts and shotcreting as well. Concrete lining will be placed using sliding steel formwork once full excavation has been made.

All the power tunnel length is envisaged to be fully lined with concrete and the lining will be done from two sides simultaneously. Assuming that the progress of the tunnel lining be 18 m per day from each side, the power tunnel lining will require a period of 6.67 months.

10.5.7 Surge Tank

The underground surge tank has a finished diameter of 15 m and length of 73.61 m. An access cum ventilation tunnel of 100 m length has been provided on the top portion. Around Six months for excavation and 1.5 months for lining is envisaged. Preceding activity for Surge Tank construction is construction of the 104 m long ventilation tunnel and 20 m long tunnel from valve chamber to surge tank, after the excavation of the valve chamber.

Excavation proceeds with the excavation of a pilot shaft and the Surge tank excavation from top to bottom, using the pilot shaft for mucking, with provision of rock bolt and shotcrete support. Once the full excavation has been made, it will be provided with concrete lining from bottom to top.

10.5.8 Drop Shaft and horizontal part

The vertical drop shaft is 122.38 and horizontal part is 41.44m. The combined length is 163.88 m. and an excavated diameter of 4.2 m. Major works comprises of pilot shaft excavation and the shaft excavation from top to bottom, using the pilot shaft for mucking, with provision of rock bolt and shotcrete support. Once the full excavation has been made, it will be provided with concrete lining from bottom to top. It is anticipated to be excavated in period of 115 days while concrete lining will require another 15 days.

10.5.9 Powerhouse and switchyard

The underground powerhouse has a dimension of 50.0 m x 16 m x 31.0 m and the elevation of generator floor and erection floor is 1001.41 m. Preceding activity for powerhouse construction is construction of the 141.61 m long tailrace tunnel and 136 m long Powerhouse access tunnel. The excavation of powerhouse area will be carried out by heading and benching operation to the foundation level. Thereafter, subsurface and superstructure concreting will proceed. Powerhouse excavation is estimated to be completed over a period of five months while concreting will require about three months. Erection of the equipment will be made after civil works have been completed.

The works at switchyard comprises of earthwork, erection of equipment and will be carried over a period of around seven month.

Tailrace Tunnel and Outlet Structure

The tailrace has been designed as a 141.61 m. long tailrace tunnel and 54.55 m. long tailrace canal. It will be excavated over a period of two months. The outlet structure works comprises of excavation and slope stabilisation, concrete works and erection of gates. A period of one month has been estimated for this activity. So, for the tailrace conduit total time estimated will be three months.

Transmission Line

For power evacuation of Tamakoshi-V HEP (87 MW) Pie connection of Tamakoshi V to Upper Tamakoshi-Khimti 220 kV transmission line at Tamakoshi-V switchyard is proposed. This will be built over the period of one year.

Construction Schedule

The project construction will be preceded by detailed engineering study which will require a period of one year. It is envisaged that financial arrangement will be made during the same period. Preparatory works like access road, camp, construction power will be undertake through a separate contract ahead of the main construction. Major construction at the site will be carried out over a period of 4 years.

Contract Packaging

As this is a medium size hydropower project, the contract can be made in four package namely access road & camp, civil works, elector-mechanical works and transmission line. The small number of contract package is made in order to make its management simple & avoid interference. Alternatively, the project can also be built through Engineering, procurement & construction (EPC) which could reduce the costs & shorten construction period.

Critical path

Longest sequence of activities in a project plan which must be completed on time for the project to complete on due date. An activity on the critical path cannot be started until its predecessor activity is complete; if it is delayed for a day, the entire project will be delayed for a day unless the activity following the delayed activity is completed a day earlier.

In this project, the critical path is the construction of the headrace tunnel which is 8200.0 m long. Therefore, careful attention should be given for the construction of the same.

11. Environmental Impact Assessment

11.1 Background

Nepal has been able to harness only a small fraction of its enormous water resource potential to generate Hydroelectric which has resulted in an acute shortage of energy at present. The present total installed capacity of INPS is nearly 697 MW and the peak power demand is 897 MW which gradually increasing at the rate of approximately 10 % per year. This has resulted in a severe loss to productive sectors like industries and inconvenience to the domestic consumers. Considering the present power scenario Tamakoshi –"V" Hydroelectric Project was identified as one of the potential project for feasibility level study during the fiscal year 2065/066 for immediate generation expansion.

This project which is a Run-of-River type is located in Dolakha District in the Central Development Region of Nepal. Geologically the project lies between Latitude 27^o 47' 30"N and 27^o 050' 00" N and Longitude 86^o 13' 11" E and 86^o 13' 56" E. The project with an installed capacity of 53 MW is situated approximately 170 km north east of Kathmandu and approximately 40 km from Charikot, the district head quarter of Dolakha District. The headworks site is located in Lamabagar VDC and the powerhouse site in Laduk VDC.The project encompasses Khare, Orang, Bulung, Laduk, Suri, Lamabagar, and Gaurishankhar VDCs of Dolakha District. This headworks and power house of the project site lies in Lamabagar and Laduk VDC respectively. Both of these VDCs are under Gaurishankhar Conservation Area which was declared as conservation area on January 11, 2010.

As per Environment Protection Rules (EPR), 1997 (first amendment 1999), Schedule -1, E an Environmental Impact Assessment (EIA) study of the hydropower project with capacity more than 5 MW project is mandatory. Therefore, the EIA study of the project is being carried out by the Environmental and Social Studies Department of Nepal Electricity Authority. The scoping document and terms of reference for the project has been already prepared and submitted to Ministry of Environment for approval. Once the approval is stamped, the full phased EIA study will be started.

11.2 General Description of the Project

11.2.1 Project Accessibility

Presently, road access is available up to the headworks and powerhouse site. The newly constructed road connecting Singati Bazaar and Lamabagar for the construction of Upper

Tamakoshi HEP (456 MW) passes adjacent to the proposed powerhouse and headworks area.

11.2.2 Project Features

The Tamakoshi " V " HEP has been conceptualized as cascade project and operates in tandem with Upper Tamakoshi HEP. The project area is located on the right bank of Tamakoshi River. This project does not need separate headwork. The Tamakoshi " V " HEP has been conceptualized as cascade project and operates in tandem with Upper Tamakoshi HEP. The proposed project does not need separate headwork. The discharge from the tailrace of the Upper Tamakoshi Project is taken through the inter connection system and conveys to the headrace tunnel of this Project in order to generate power from the surface powerhouse proposed at Suri Dobhan.

11.2.3 Salient Features

Project Name	:	Tamakoshi "V" Hydroelectric Project	
Development Region	:	Central	
Location	:	Dolakha District	
Type	:	Cascade Development with Upper Tamakoshi	
Installed capacity	:	87 MW	
Design Discharge	:	66 m^3/s	
Powerhouse	:	Underground	
No. of Turbine	:	4 in number	
Turbine Type	:	4, Vertical Axis Francis Turbine	
Headrace Tunnel Length	:	8.20 km.	
Annual energy	:	460.50 GWh	
Project Road length	;	6 km	
Transmission length	:8 Km 132 kV d/c Pie connection of Tamakoshi V to Upper Tamakoshi-Khimti 220 kV transmission line at Tamakoshi-V switchyard		
		<u>NEA Secnario</u>	**<u>Private Secnario</u>**
B/C ratio	:	1.07	1.25
Energy cost in 2017 Rs/kWh	:	3.65	6.77
EIRR%	:	8.69	13.51
Estimated Project Cost	:		147 Million US$

11.3 Methodology for Scoping Exercises

The methodology for Scoping Exercise follows the National EIA guidelines (1993) and EPR, 1997 and its amendment). Literature review followed by extensive field investigations were the methods adopted for scoping exercises. A short preliminary field visit by a multidisciplinary team was conducted to identify the major impacts and collect the baseline data. A simple checklist was prepared in order to identify the impacts and ensure that no vital components of the physical, biological, socio-economic and cultural impacts in terms of magnitude, extent and duration were omitted. Group discussions were also held with concerned groups, government officials and with people in the project-affected villages to obtain their views and suggestions concerning the project and its probable impacts.

11.3.1 Project Area Delineation

The study area for EIA study has been divided into three parts on the basis of the proximity and magnitude of impacts.

Core Project Area

The core project area implies the area fenced off for safeguarding of various structures as well as the area permanently acquired by the project.

Surrounding Area

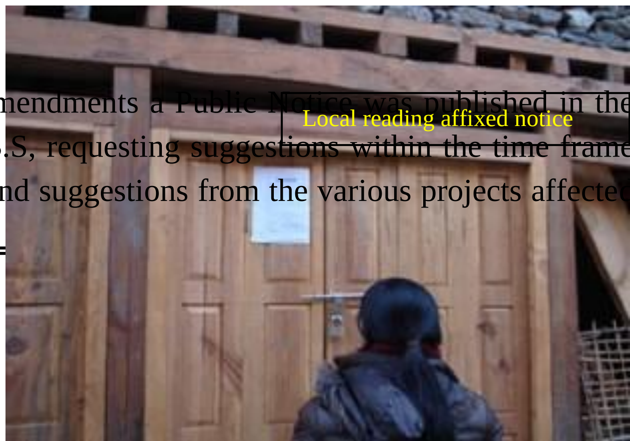
The surrounding area includes the villages and areas of the affected VDCs. Purano Jagat village (Lamabagar VDC), Phedi village (Gaurishankhar VDC) and Suri Dobhan of Khare and Suri VDC are the affected villages.

Outlying Area

The outlying area lies far from the project but will be affected by implementation of the project. The Lamabagar VDC, Gaurishankhar VDC, Orang VDC, Khare VDC, Laduk VDC, Bulung VDC, and Suri VDC of Dolakha District can be considered as the outlying area.

11.3.2 Public Notice

As required by the EPR, 1997 and its amendments a Public Notice was published in the Gorkhapatra daily on 13th Poush 2067 B.S, requesting suggestions within the time frame of 15 days. The notice sought opinions and suggestions from the various projects affected



VDCs and also from all the concerned parties and stakeholders to identify the potential environmental impacts related to the proposed Tamakoshi "V" Hydroelectric Project. The notice listed the affected VDCs. Beside this, a request letter was sent to all the affected VDCs for their comments and suggestions. A copy of Public Notice was also attached with the letter. The copies of public notices were pasted in VDC offices, schools and other public place of importance.

The suggestions received from local people during the field survey have been incorporated in relevant sections of Scoping Document.

11.3.3 Public Consultation

Altogether 7 meetings have been conducted in Purano Jagat, Gongor, Bhorle, Suri Dobhan and Jamune etc of the project affected VDCs. About 54 participants attended the meetings.. The local people, teachers, businessmen, farmers and students attended the meetings and took part in discussion on various issues. The discussions with local people revealed that they were positive to the proposed project.

The main issues raised during the meeting were focused on project share allocation and its assurance, use of local resources, local employment opportunity, financial support for the local level proposed plan and local infrastructures, construction of village road, skill training programs in local levels, coordination and consultation with the local people, etc. The issues raised by the local people and stakeholders are summarized in the Table 11.1 .

Table 11.1 Issues raised during public meeting at different places of project affected VDCs

S.NO.	Meeting data	Meeting conducting place	No, of participants	Issues raised
1	2067/09/20	Lamabagar VDC-7, Chitre	10	• Assurance about the distribution of the project share for the local community

				• Maximum use of local resources • Employment opportunity for the locals based on their qualification • Minimize the environment pollution and focus on environment conservation in local level • Financial support for the ongoing and proposed programs in local level • Appropriate compensation should be provided for the loss of land and other properties • Rural electrification
2	2067/09/20	Bulung VDC-3, Sharada Lower Secondary School premise	8	• Financial support for the proposed rural road (Singati Bazaar- Laduk-Bulung-Orang-Lamabagar VDC) • Rural electrification Financial support for the construction of an additional building
3	2067/09/21	Suri VDC-9, Bhorley	6	• Protection of Bhorle Bazaar (The access road for Tamakoshi HEP construction caused the Tamakoshi river course towards Bhorle bazaar) • Impact on fish business • Employment opportunity for the locals of project affected families
4	2067/09/21	Khare VDC-3, Jamune	10	• Employment opportunity for the locals of project affected families • The available irrigation facility should not be disturbed • Rural electrification • The local income generating resources should not be affected • Priority should be given to education, health and road sectors in the project affected area
5	2067/09/22	Gaurishankar VDC-9, Phedi	6	• Local Employment opportunity based on skills

				• Community awareness program in local area • Skill training program for local youths • Education support program for the poor and deprived local people • No politics in employment sector
6	2067/09/22	Lamabagar VDC-6, Gongar	7	• Large scale interaction program in presence of local community
7	2067/09/22	Lamabagar VDC-9, Jagat	7	• Objection about the activities of Upper Tamakoshi HEP particularly in compensation issue • Plantation work has not been carried out as recommended by EIA report of Upper Tamakoshi HEP • Effective coordination with the local community forest users' groups prior to the project implementation • Coordination and consultation with the local people while conducting any activities of the project work • Employment opportunity based on qualification and skill
	Total		**54**	

11.4 Existing Environmental Conditions

11.4.1 Physical Environment

11.4.1.1 Topography and Landuse

The core project area lies relatively in steep topography. The head works which consists of transition tunnel is located in narrow stretch of the Tamakoshi River near to the tailrace outlet of Upper Tamakoshi Project which is presently under construction. Steep rock outcrop is seen at the right bank with more than 75^{o} slope while small patches of agriculture land exist at the left bank and forest at the upper slopes. The river width is approximately less than 50 m at the proposed headworks site.

The surface powerhouse is located on open terraced agricultural land at the right bank of Tamakoshi River just downstream from the confluence of Upper Tamakoshi and Khare Khola at Suri Dobhan at right bank. Steep topography with more than 75o slope exist on the upper slopes of the proposed powerhouse area. Construction scars of road construction were observed on the left bank of Tamakoshi river opposite of powerhouse.

11.4.1.2 Land use Pattern

The landuse in the project area mainly consists of forest and patches of agricultural land. The right bank of the head works area consists of rock outcrop with forest on the upper slope while the left bank consists of patches of agricultural land with forest on the upper slope. The proposed surface powerhouse is located on cultivated terrace land with forest on the upper slope.

Land use at powerhouse site

11.4.1.3 Watershed Conditions

The watershed of the proposed project is relatively good. Surfacially, the watershed appears intact except at some places where disturbances is evident from the construction of road and hydropower project. Watershed of the immediate area comprises of forest, agricultural land, barren cliffs and rock outcrops.

Watershed in and around at the core project

Forest is observed along the river banks which have been disturbed by construction of road and hydropower projects like Upper Tamakoshi and Siprin Khola Project.

11.4.1.4 Climate, Air Quality and Noise Quality

The project area experiences sub-tropical and temperate of climate The maximum and minimum temperatures at the nearest site (referred from the index station 1103 at Jiri) are taken as 28^{o} C (upper limit) and –7 ^{o} C (lower limit). The average precipitation recorded is 2625 mm from the Jiri station (District Development Profile Of Nepal, 2000). The maximum and minimum monthly relative humidity at the project location is 92 % and 51% respectively.

The project area is influenced by monsoon rain which normally starts in the middle of June. The region receives approximately 80% of the annual rainfall during this period.

As the project area lies in the interior part of the country air and noise pollution is less however, spurt of dust pollution was observed at intervals in the vicinity of the project area due to construction activities of Upper Tamakoshi HEP and Siprin Khola HEP. Air and noise pollution was mainly from activities like blasting, grading and excavation works.

Spurt of dust due to blasting near the proposed headwork site

11.4.1.5 Hydrology

Tamakoshi river one of the major tributaries river of Sapta Koshi river system. The main source of Tamakoshi discharge is the snow and glacier melt from the higher Himalayas. The peaks in the basin are Jobo Guru, Jobo, Rabzang and Gauri Shankhar Himal. The total area of Tamakoshi basin up to intake site is 1587 km^2. About 80% (1265 km2) of the catchment lies in Tibet.

The main tributaries of Tamakoshi River are Lapche, Bhaise, Rolwaling, and Gongar Khola at the upstream of headworks area and Siprin Khola, Oran Khola, Khare khola at the downstream of headworks area.

This river is characterized by high firm flow as much of the discharge is derived from the snow melt. In addition, the river has good river gradient at the proposed project site. The river flows along relatively narrow stretch. Since the Tamakoshi is the cascade of Upper Tamakoshi Hydroelectric Project the entire hydrological data is based on the Upper Tamakoshi HEP Hydrology. The minimum and maximum monthly flow has been estimated as 176 cumecs and 18.1 cumecs respectively from the flow duration curve data plotted with recorded data between the years 2001-2006. The mean monthly flow at the proposed headworks site has been estimated as 62.5 cumecs. The 100 year return period flood recommended is 1814 cumecs at headworks area and 2067 cumecs at powerhouse site respectively.

There are 57 glaciers lakes identified by ICIMOD and UNEP inside the Tamakoshi catchment. The Rolwaling valley alone has 13 glacial lakes. The Tamakoshi watershed has highly active glacial fields that have triggered several GLOF events in recent history; all recorded events originating in Rolwaling Valley. Furthermore, interpretation of satellite images identifies 14 GLOF events within Upper Tamakoshi basin. A specific "Glacial

Lake Outburst Flood (GLOF) Risk Assessment Study" was carried out as part of the during the feasibility study of Upper Tamakoshi HEP. It has provided an updated inventory of glacial lakes and GLOF events explains the general mechanisms of hazardous glacier-related processes in the high mountain environment and identifies potential GLOF threats within the Tamakoshi Basin.

11.4.1.6 Geology

The project area lies in the lesser Himalayan metasediments in Central Nepal. The main rock types present in the project area are gneiss, schist and quartzite. The rock observed at the headworks site consists of medium to thickly foliated, fresh to slightly weathered, grey gneiss with partings of slightly weathered, greenish grey schist.

The headrace tunnel is about 8.65 km long and will have a diameter of 5.5 m is proposed. The tunnel will pass through the right bank of Tamakoshi River. The headrace tunnel passes through gneiss, schist and augen gneiss. MCT passes through the tunnel alignment.

The surge tank is located on the right bank of the Tamakoshi River above Bhorle Village. Thin cover of colluvial soil is present in the proposed location. Medium strong, moderately weathered, fractured, schist rock is present in the proposed surge tank location.

The power house site lies on terraced alluvial deposit. The alluvial deposit comprises of sub-rounded to rounded, gravel to boulder of gneiss, schist in silty sand matrix. The rock exposure is observed at the uphill side of the power house site. The rock consists of medium to thickly foliated, fresh to slightly weathered, grey gneiss with partings of greenish grey schist.

The tailrace tunnel passes through the alluvial deposit. The alluvial deposit along the tailrace tunnel consists mainly of rounded to sub-round boulders and gravel of gneiss in silty sand matrix.

11.4.2 Biological Environment

The Tamakoshi "V" Hydroelectric Project lies in Dolakha District of Janakpur zone. According to the Dolakha District Forest Office's Yearly Progress Report of 2066/067, 101,500 hectares of land is covered with forest in Dolakha district comprising of 47.37% of the total land area of the district.

The project lies in the Gaurishankhar Conservation Area which was declared as conservation area on January 11, 2010 by Government of Nepal. Major forest types found in the district are hill Sal forest, Pine forest, Schima-Castanopsis forest, Rhododendron forest, Alder forest, Lower temperate mixed broad leaf forest, Upper temperate mixed forest etc.
Chilaune (*Schima wallichi*) and Utis (*Alnus nepalensis) are the* dominated forest found in the core project area.

11.4.2.1 Gaurishankhar Conservation Area

The Gaurishankhar conservation area covers an area of 2179 sq.km and covers 3, 2, 14 VDCs of Ramechap, Dolakha and Sindhupalchowk respectively. The Sagarmatha National Park and buffer zone area lies in the east of the conservation area and Langtang National Park and buffer zone area lies in the west. At present, the headquarter of the conservation area is in Charikote and its Unit offices are located in Chaku, Shivalaya and Thandanda. Sub unit office is located at Gongor, about 3 km upstream of proposed transition tunnel of Tamakoshi “V” HEP.

All the seven affected VDCs lie inside the Gaurishankhar conservation area.

11.4.2.2 Vegetation and Community Forests in the Project Area

The total numbers of forests handed over to the community for its management in Dolakha District till the end of FY 2066/067 is 344 covering total area of 40195 ha. The number of beneficiary households is approximately 38,662 (DFO Dolakha, 2067).

A total of 7 Community Forest has been identified during field visit which will be affected by project construction. The list of forests has been tabulated below:

Table 11.1 Community Forest in the Project Area

S. N.	Name of the Community Forest	VDC & Wards	Area (ha)	Household	Remarks
1.	Giddhe Salleri CFUG	Laduk-9	161.7	140	
2.	Jukepani CFUG	Bulung-1	63.87	65	
3.	Aine Dhunga CFUG	Bulung-3	125.25	133	
4.	Bimira Tatopani CFUG	Bulung			NA
5.	Dumji Tatopani CFUG	Orang- 1 to 9	128.75	261	
6.	Sindurpa Sisneri CFUG	Lamabagar-8, 9	68.15	76	
7.	Chakrabati Jamdupatal CFUG	Lamabagar – 6	563.75	365	

Note: NA- Not Available in the record of DFO Dolakha

Source: District Forest Office, Dolakha, 2067

During field survey it was observed that the forest has been more or less disturbed throughout the project area along the Tamakoshi valley as a result of human activities, road construction and hydroelectric projects. Felling of trees for firewood and timber, uncontrolled grazing of domestic animals and occasional forest fires are the factors which has resulted in decrease of forest cover.

Vegetation in and around the core project area

Mixed broad leaf forest is dominant in the project area comprising of Chilaune (*Schima wallichii)*, Utis (*Alnus nepalensis*), Simal

(*Bombax ceiba*), Maledo (*Macaranga indica*), Paiyu (*Prunus cerasoides*) etc. The stocking size of the trees ranges from pole size to small timber size. Similarly, in area near the power house site (option II) the trees species available are Utis (*Alnus nepalensis*), Salla (*Pinus roxburghii*), Khirro (*Sapium insigne*), Chilaune (*Schima wallichii)* etc.

Dense forest was not seen in and around the project affected areas. Also due to steep and rocky topography the density of vegetation in the existing community forest seems to be low.

Angeri (*Osbeckia nepalensis*), Dhanero (*Woodfordia fruticosa*), Chutro (*Berberis asiatica*), ghangaru (*Pyracantha crenulata*), banmara (*Eupatorium odratum*) etc. are the major shrubaceious species in the project area.

Some of the plant species having timber, medicinal and food values in and around the project areas are as follows:

a. Timber, Firewood and Fodder use

Plants like Salla (Pinus spp.), Chilaune (Schima wallichi) are extensively being used for timber.

Fire wood: Almost all the plant species are used for firewood.
Fodder: Leaves of Kutmero (Listea monopelata), Khanayo (Ficus semicordata), Koiralo (Bauhinia spp.), Siris (Albizia spp.), Bans (Bambusa sp.), is being used as fodder.

b. Medicinal use

Kurilo (*Asparagus spp.*), Hadchur (*Viscum album*), Harro (*Terminalia chebula*), Barro (*Terminalia bellirica*), Amala (*Emblica officinalis*), Chutro (*Berberis asiatica*), Titepati (*Artemisia indica*) etc are commonly collected from the project area for medicinal use by locals. But the exploitation of medicinal plants has not been in commercial basis.

c. Edible plants

Fruits of Kaphal (*Myrica esculenta*), Ainselu (*Rubus ellipticus*), Kera (*Musa paradisiacal)*, Amba (*Psidium guajava*), and Amala (*Phyllanthus emblica*) are edible fruits reported in the project area. Similarly, Citrus species (*Suntala*, *Mausam*, *Nibuwa*, *Bhogate* etc.) are the common fruits of the project area.

d. Protected Species of Flora

Simal (*Bombax ceiba*) is the single species available in the project area which is banned for felling, transportation and export as per the Forest Rules, 1995.

11.4.2.3 Wildlife

11.4.2.3.1 Mammals

The local residents informed that the movement of the wildlife in the project area is low because of the degradation of the available forest and unavailability of dense forest. Most of the wildlife reported in the proposed project area is migratory and not confined only to the project area. The proposed project site is not a specific habitat for any wildlife and avifaunal species. The reported mammals of the project area are Bandar (*Macaca mulata*), Chituwa (*Panthera paradus*), Ratuwa Mriga (*Muntiacus muntjak*), Ghoral (*Nemorrhaedus goral*), Dhendu (*Macaca assamensis*), Syal (*Canis aureus*), Dumsi (*Hystrix indica*), Lokharke (*Funanbulus spp*.), Salak (*Manis pentadactyla*), Bat (*Pteropus giganteus*) etc

11.4.2.3.2 Birds

Forests, bamboo grooves, agricultural fields, villages, river and streams in the project vicinity provide a variety of habitats for different species of birds. However, like the mammals, most birds of the project area are migratory and are not confined to the project area only. The locals informed that the Cuckoo (*Plantative cuckoo*), Crow (*Corvus splendens*), House Sparrow (*Passer domesticus*), Kalij (*Lephura leucomelana*), Baj (*Buteo spp*.), Fisto (*Phylloscopus spp*.), Koili (*Cuculus spp*.), Lampuchchhre (*Cissa erythrorhyncha*), Jureli (*Pycnonotus cafer*), Dhukur (*Streptopelia chinensis*), Nyauli (*Megalaima virens*), Kalchauda (*Myophonus caeruleus*) are the common bird species found in the project area.

11.4.2.3.3 Rare, Endangered, Threatened and Protected Species of Fauna

Leopard (CITES I), Rhesus Monkey (CITES II), Jackal (CITES III), are the protected mammal species. No protected bird species are available in the project area.

11.4.2.3.3 Fish

Asala (*Schizothorax sp*), Katle (*Neolissocheilus hexagonolepis*), Buduna (*Garra gotyla*), Chuchche (*Xenentodon cancila*) are the major fresh water species reported in the *Tamakoshi River*.

11.4.3 Socio-economic and Cultural Environment

11.4.3.1 Project Affected District

The Tamakoshi ”V” Hydroelectric Project is located in Dolakha district of Central Development Region, Nepal. Charikot, the district headquarter is located at about 133 km north east of the Kathmandu. There are 51 village development committees and one municipality in the district. The total area of the project affected district is 2,191 sq. km with average population density 160.5 persons/sq km. Out of total area, cultivated land occupies about 56,683 ha. According to the population census the total population of the district is 175,912 with male 86,110 (48.95%) and female 89,802 (51.05%). The overall literacy rate is 49.0%.

11.4.3.2 Profile of the Project Affected VDCs

11.4.3.2.1 Population and Households

The project affected area consists of 7 VDCs namely Lamabagar, Gaurishankar, Khare, Bulung, Laduk, Orang and Suri. According to the National Population Census, 2001, there area 3,592 households with average households size 4.63. Similarly, the total population of the project affected VDC is 16,623 with male 8,227 (49.49%) and female 8,396 (50.51%). The figure indicates that the female population in the project affected VDCs are higher as compared to the male population. Among the project affected VDCs, the highest population is in Laduk VDC and the least population is in Gaurishankar VDC. The population distribution of the project affected VDCs is shown in Table 4.2.

Table 11.2: Population distribution of the project affected VDC

VDC	HHs No.	Population Total	Male	Female	HHs size
Lamabagar	394	1808	930	878	4.59
Gaurishankar	303	1397	708	689	4.61
Khare	421	2079	1005	1074	4.94
Bulung	503	2242	1078	1164	4.46
Laduk	812	3793	1849	1944	4.67
Orang	440	2010	1014	996	4.57
Suri	719	3294	1643	1651	4.58
Total	3592	16623	8227	8396	4.63
Percent		**100.00**	**49.49**	**50.51**	-

Source: Population of Nepal, Population Census, 2001

11.4.3.1.2 Ethnicity

The project affected VDC is a heterogeneous composition of people of different origins, cultures, languages and ethnicities. The project area is composed of many ethnic groups making up distinct communities according to altitude and climatic condition. The project area is dominated by Tamang (39.9%) followed by Chhetri (19.38%) and Sherpa (8.93%). According to the classification of Nepal Government, there are indigenous, dalit and Janajati ethnic groups in the project affected area. Among them the majority groups are: Sherpa, Gurung, Newar, Thami and occupational caste groups like Kami, Damain and Sarki.

11.4.3.1.3 Religion

The distribution of religion varies widely in the project affected VDCs. The dominant religious population in the project affected VDC is Hindu (58.93%) followed by Buddhist (41.02%)

11.4.3.1.4 Education

The national census 2001 reported that the literacy rate in the project affected district is 54.6% for the population of six years of age and above. The male and female literacy rates are 63.8% and 36.3% respectively. However, the overall literacy rate in the project affected area is 25.57% (with male literacy rate 48.97% and female literacy rate 24.06%).

Figures in Table-4.3 Indicates that there are still about 69% women are illiterate in the project affected VDCs. The project area is supported by primary schools, lower secondary schools, high schools, and some privately managed schools. Similarly, higher secondary level is available only in Gaurishankar Higher Secondary School (Lamabagar VDC), Haleshwor Higher Secondary School (Suri VDC), and Laduk Higher Secondary School (Laduk VDC). There is a higher secondary school in the Khare VDC. Students mostly go either in Charikot or in Kathmandu for higher level education in different streams.

Table 11.3 Population 6 years of age and over by literacy status and sex for VDC

VDC	Total			Can't read and write			Can read only			Read and write			Not stated		
	Total	M	F	Total	M	F	Total	M	F	Total	M	F	Total	M	F
Lamabagar	1449	760	689	1113	483	630	41	33	7	286	243	43	9	0	9
Gaurishankar	1244	613	631	810	322	489	99	76	23	311	215	95	24	0	24
Khare	1803	889	914	920	333	587	210	133	78	615	409	206	58	15	43
Bulung	1972	962	1010	868	340	527	198	67	131	878	547	331	29	8	21
Laduk	9297	1575	1722	1957	774	1183	111	50	60	1222	743	479	8	8	0
Orang	1705	874	830	1257	510	747	79	64	15	369	300	69	0	0	0
Suri	2752	1348	1404	1132	334	798	79	33	46	1490	981	509	50	0	50
Total	20222	7021	7200	8057	3096	4961	817	456	360	5171	3438	1732	178	31	147
Percent	100	34.72	35.60	39.84	44.10	68.90	4.04	6.49	5.00	25.57	48.97	24.06	0.88	0.44	2.04

Source: Population of Nepal, Population Census, 2001

11.4.3.1.5 Major Settlement

Settlement patterns in the project area appear to be generally influenced by the availability of productive land and other public facilities. Dense settlements are situated in market areas and agriculturally productive areas along the riverside. However, settlements in the form of scattered households are also found at the upper slopes that have relatively less productive narrow terraces. More than 10 settlements have spread over the gently hilly slopes and valleys.

A typical settlement pattern near the project area

The major settlements in the project affected area are Singati, Suridobhan, Jamune, Bhorle, Phedi, Jagat, Gongar, and Lamabagar.

11.4.3.1.6 Language

Nepali (51.03%) is widely spoken language by the people for communication. Besides Nepali, the second most spoken language in the project affected VDCs is Tamang (39.0%) followed by Sherpa (8.43%), Sunuwar (0.80%), Thami (0.22%), Newar (0.22%), and other (0.27%).

11.4.3.1.7 Festivals, Culture and Activities

The major festivals celebrated by the Hindu communities in the project area are Vijaya Dashami, Tihar, Maghe Sankranti, Holi, Ram Nawami, Buddha Jayanti and Teej. Lhosar is the major festival of the Sherpa, Tamang, Gurung, and Magar communities. Popular cultural activities in the project area are Teej Mela (fair), Bhailo and Deusi, (singing and dancing activities) in Tihar, Holi (colour festival), Bhajan-Kirtan in Ram Nawami, (praying by singing), cultural programmes in Shree Panchami and Dhami and Jhankri Naach (dance performed during various religious activities and festivals).

11.4.3.1.8 Historical, Archeological and Religious Sites

In the project affected district and VDCs there are many historical, archeological and religious sites. There are many significant historical, religious and tourists attraction centers. Dolakha (Bhimeshwor), Kalinchowk (Bhagawati), Shailungeshwor danda (Mahadev), Bigu and Lamabagar (Tashi Gumba), Lapche Gaun, etc. are religious sites for pilgrimages. Tscho Rolpa and Gausishankar Himal are the major tourist attractions in Dolakha district.

11.4.3.1.9 Migration

From the field survey, it was found that more than 95% of the households have lived in the same vicinity for three or more generations. The population is therefore generally stable, growing with a low birth rate, and the area has not been subjected to significant migration. However, factors leading to migration of the population form the project affected area are construction of Dolakha-Singati Road, Singati-Lamabagar Road, and the lack of social services and other facilities in the project area. Outward migration is generally seasonal for the search of jobs in nearby towns like Kathmandu with the aim of supplementing household's income. In general male members of Brahmin and Chhetry families go to nearby town or Kathmandu to work as government employees, and the young men of Sherpa, among, Gurung, Magar and Chetry families go abroad to join military and other services.

11.4.3.1.10 Land use, average holding size and land transaction

Agriculture, forest, water bodies, barren, pasture and the snow lands are the predominant form of land use in the project area. Other types of land use in the project area consist of grazing, residential/ villages, public lands and other such and wetlands. The review of available data of the district (CBS, 2001) shows that there is 2.78% households are landless in the project affected VDCs. Similarly, households having land less than 0.5 ha is 61.64%. This figure implies that the majority of households in the project affected VDCs occupy land within this range. Only 4.48% of the households have land greater than 1.5ha.

Land transaction in the area was rare earlier. However, due to the construction of the access road (Upper Tamakoshi HEP) the land transaction in the project area has been reported to in increasing trend. Land transaction along the access road and proposed powerhouse site is seems to be high. Field study revealed that the average price of land is estimated to be 980,000/ha.

11.4.3.1.11 Crop Production, Pattern and Yield

The major crops grown in the project area are paddy, maize, millet, wheat, barely, potato, oilseed, etc. Similarly, green vegetables, guava, banana, etc are also produced in the area. The cropping pattern varies from site to site depending upon the altitude, land quality and availability of irrigation. More fertile and year round irrigated lands are cultivated three times a year where as non-irrigated lands are cultivated once a year. The selection of crops is based on the land quality and irrigation facilities available. The cash crops of the project site constitute of potatoes, lemon and seasonal vegetables.

11.4.3.1.12 Livestock

Livestock and agriculture are integral parts of the agrarian society. Households in the project area raise livestock both for cash income and farming purpose. Livestock raising activities area carried out by all households in the project affected area irrespective of their caste, culture, climate or topography. However, the number and type of livestock vary across the village and ethnic groups. The major types of livestock raised in the area are goat (15%), cow (35%), buffalo (25%), sheep (10%), chauri (10%) and Yak (5%). In addition, most of the households are involved in poultry farming

11.4.3.1.13 Business, Trade activities and Tourism

About 1.5% of the households in the project affected area depend on business and trade activities. Trade and business activities in the project area basically include small grocery and tea shops. Such business activities are mainly found in major settlements along the major foot trails. Charikot, and Singati are the main trade centers of the project affected district. Other small trade centers are Bhorle, Lamabagar and Jagat.

The project area has some special tourist attraction and is regularly visited by trekkers. There exists no official statistics on trekking activities, but local information suggests that the yearly tourist traffic is in the order of 1000. The trekking route to Mt. Gaurishankar and Tscho Rolpa follow the Tamakoshi to Chetchet, where the trail to Simigaun and Beding turns east and up the steep valley side. The project area also consists of Dolakha Bhimsen, Sundrawati Bhagwati, Deulangeshwor Mahadev, Rolwaling valley, Bedding village, Barasay Paltan, etc which have high religious value.

11.4.3.1.14 Occupation

The scoping study revealed that agriculture is the main source of livelihood for the people. Other activities are service, trade/ business, manufactures (18.62%), transport (0.62%) and others (18.41%). However, in recent years, many young people go to foreign countries such as Hong Kong, Singapore, Japan, Korea, America, Arab countries, etc to work as labors.

11.4.3.1.15 Health and Sanitation

Due to poor transportation facilities, lack of proper drainage system, etc people of the project area face sever health problems. Despite the existence of health posts and sub-health posts in the project affected area, there is lack of health workers. The population in the project area mostly depends upon the facilities available in the district headquarter.

The present sanitation facilities in most of the project affected VDCs appear to be satisfactory. There is a pipe water system in most of the houses. Most of the pipe water facilities are provided from small kholsis and springs. Out of the total population, 91.6% use pipe water, 6.9% and 1.5% use dug-well and river/kholsi water respectively.

Open defection along the river or in the open fields is also common practice in the project affected area. Less than 25% of the households in the project area are equipped with toilet facilities.

According to the District Public Health Office, falls/injuries/fractures, gastritis, skin disease, mouth complains/toothaches, sore eye, and eye complaints, abdominal pains and ear complaints are the main health problems in the project area. Most of the project affected VDCs have either health post or sub-health post.

There are very limited recorded cases of sexually transmitted diseases such as HIV/AIDS. As many people from this area go outside (Kathmandu, India and abroad) for seasonal jobs, the potential in bringing HIV/AIDS exist.

11.4.3.1.16 Communication

Communication facilities are satisfactory in the project area. Mobile network and CDMA phones are available in most of the project area. Email, internet facilities are available in the Charikot, Singati and Lamabagar areas. The district post office is located in Charikot Bazaar, and there is a post office in each of the project affected VDCs.

11.4.3.1.17 Transportation

Public transportation facility is available only in Laduk, Bulung and Suri VDCs. However, road network is connected with most of the project affected VDCs. An earthen road exists from Dolakha Bazaar to Lamabagar which passes through Singati, Bhorle, Jamune, Jagat and Lamabagar. Recently, vehicle has started to operate unto headworks of proposed project on the earthen road constructed by Upper Tamakoshi HEP.

11.4.3.1.18 Water supply

Piped water facilities have been provided to most of the inhabitants of the project affected area. Water from Andheri khola, Phokate Khola, Sipring Khola, Ghatte Khola, Khare Khola, Gogane Khola, Worang Khola, Khambu Khola, etc are used for drinking water. The settlements especially on the lower slopes have access to piped water supply. In some villages of the project area, an INGO known as Eco Himal has provided piped water systems. It was also observed that local NGOs like “Tuki Sangh” provided clean water to the local people. Singati bazaar, Jagat, Suri Dobhan, Jamune, and other settlements along the access road have piped water facilities.

11.4.3.1.19 Energy

Most of the VDCs in the project area are partially electrified through national grid. Gaurishankar VDC (ward no-2, 3 Simigaun), Lamabagar (ward no. 2, 3), Orang (ward no 6, 7) are partially electrified through micro hydro schemes utilizing small local Khola. These schemes are supported by Rural Energy Development Project and funded jointly by VDCs and private parties.

There is a Sipring Khola Hydroelectric Project of 9.6 MW capacity developed by private sector in Sipring Khola of Khare and Gaurishankar VDCs which is presently under construction. Orang Khola Micro hydro, Ghatte Khola Peltric Set, Gogane Khola Peltric Set, Khumbu Khola Peltric Set, Manthali Khola Peltric Set, etc are generating electricity and distributing power locally. The list of peltric set, micro-hydro and hydroelectric projects in the project affected VDCs are shown in Table-4.13. Besides, solar panels are also used in project area in project affected VDCs.

On average, a household spends 5 hours daily for the collection of firewood. The local people are dependent on near by Community Forest for fuel wood. Kerosene is used for lighting purpose in most of the VDCs.

Table 11.4 : List of Peltric set, Micro-hydro and Hydroelectric Projects in project affected VDCs

S.No.	Name of Scheme	Capacity	Location	Benefited households	Remarks
1	Sipring Khola HEP	9.6 MW	Khare and Gaurishankar VDCs	Data not available	Under construction
2	Ghatte Khola Peltric Set	5 kW	Khare VDC	300	Currently not in operation
3	Khumbu Khola Peltric Set	5 kW	Khare VDC-9	150	Operation condition
4	Manthali Peltric Set	5 kW	Khare VDC-1	200	Operation condition
5	Kalangkhola Micro hydro project		Suri VDC	Data not available	Proposed
6	Kapti Khola Small Hydroelectric Project		Suri VDC	Data not available	Proposed
6	Jalbiretar Peltric Set		Laduk VDC	Data not available	Proposed
7	Gogare Khola Peltric Set		Khare VDC	Data not available	Proposed

11.4.3.1.20 Law and order situation

Police post is available in Singati bazaar and Lamabagar. Other project affected VDCs have no such facilities. During the field visit, the security condition of the project area was found to be satisfactory.

11.4.3.1.21 Cremation Site

Suri Dobhan (Khare VDC), Sipring Khola Dobhan (Gaurishankar VDC), and Orang Khola Dobhan (Bulung VDC) and Singati Khola Dobhan (Laduk VDC) are some of the cremation site of the project area. Brahmin and Chhetri are the users' of these cremation sites.

11.4.3.1.22 Proposed program in Project affected VDCs

There are different development programs like irrigation scheme, road construction, suspension bridge, rural electrification and agriculture development which have been proposed in the project affected VDCs. Some of the proposed programs that will be implemented in near future has been tabulated below:

Table 11.5: List of development programs proposed by VDCs

S.No	Name of program	VDC	Remarks
1	Pewa Khola Irrigation Project	Suri VDC-6,7,8,9	-
2	Thingsang-Bigu-Chilankha-Laduku Road Project	Ladkuk	-
3	Singati-Laduk-Orang—Gongar Road Project	Laduk, Orang, Gongar VDCs	-
4	Sursingtar Khola Suspension Bridge	Khare and Chankhu VDCs	-
5	Jyadawa Irrigation Project	Laduk VDC-2,5	Proposed by Central Subdivision Irrigation Office, Dolakha
6	Masane Irrigation System	Laduk VDC-4	Proposed by Central Subdivision Irrigation Office, Dolakha
7	Okhreni Pokhari Irrigation Project	Suri VDC-8	Proposed by Central Subdivision Irrigation Office, Dolakha
8	Rural Electrification and Transformer installation	Different wards of Laduk and Suri VDCs	Nepal Electricity Authority (Branch Office, Dolakha)
9	Rural Environment Conservation Society	Laduk and Bulung VDC	Sustainable Soil Management Program, Dolakha
10	Ecological Agriculture and Rural Development Society, Dolakha	Suri VDC	Sustainable Soil Management Program, Dolakha

11.5 Key Environmental Issues

The main environmental issues identified during the scoping field visits are given below:

11.5.1 Physical Environment

Construction Phase

- Impact due to landtake for project facilities and access road,
- Potential for local air quality deterioration and noise pollution due to construction activities,
- Impact on landuse pattern, topography, geology, slope stability,
- Impact due to stockpiling of construction materials and muck disposal,
- Impact on water quality,
- Impact on drainage pattern,
- Sediment and waste releases providing adverse water quality effects,
- Land disturbances related to vegetation clearance,
- Impact due to quarry site and borrow areas,
- Impact due to vibration of structures

Operation Phase

- Impact due to dewatering
- Downstream impacts due to the powerhouse releases and due to the diversion of the flow,
- Downstream water use conflicts,
- Impact on microclimate,
- Impact of change in natural drainage system,
- Degradation of river bed downstream of tailrace,
- Change in water quality especially in the dewatered stretch.

11.5.2 Biological Environment

Construction Phase

- Impacts on vegetation and forest resources,
- Impact on rare, endangered, threatened and protected species of flora and fauna,
- Impact on the ethno-botanical species
- Impact on biodiversity
- Loss of forest area as a part of site clearance,
- Encroachment of Community Forest,

- Impacts on Government listed species,
- Impacts on fish migration, and
- Disturbance to wild animals and possibility poaching
- Impact on GauriShankhar Conservation area.

Operation Phase

- Loss of forest land,
- Impact on vegetation /forest due to easy access,
- Impact on Community Forest,
- Impact on wildlife due to habitat fragmentation,
- Disturbance to wild animals,
- Impacts on fish migration due to long dewatered length,
- Change in habitat of wild animals,
- Impact on wildlife during operation phase due to destruction of habitats
- Impact on GauriShankhar Conservation area.

11.5.3 Socio-economic and Cultural Environment

Construction Phase

- Impact due to land Acquisition,
- Change in land use,
- Loss in agricultural production,
- Occupational and Safety hazards,
- Impact on law and order,
- Impact on health and sanitation,
- Impact on socio-cultural practices,
- Impact on historical, archeological, cultural and religious sites,
- Impact on infrastructures, communal resources and practices,
- Impact on local economy/people due to sudden cash flow due to increased economic activities,
- Land value changes,
- Influx of workers,
- Impact on vulnerable group and gender issues.

Operation Phase

- Loss of agricultural production,
- Impact on people's behaviour and local economy,
- Impact on vulnerable group and gender issues
- Impact on community due to loss of community forest,

The construction of the Tamakoshi "V" project will have cumulative impacts on the physical, biological and socio-economic and cultural environment due to the presence of Upper Tamakoshi HEP. The cumulative impact will be especially from the long dewatered length of approximately 20 km. Quantitative, Qualitative analysis of the available data and expert judgments are some of the methods which will be used to assess the cumulative impacts.

11.5.4 Beneficial Impacts

The beneficial impacts from the project implementation are as follows

Construction Phase

- Local employment and increased economic opportunities;
- Impact due to increase in local skills in construction activities;
- Impact due to increase in economic opportunities.

Operation Phase

- Positive impact on rural economy due to electricity royalty.
- Decrease in load shedding due to implementation of the project
- Opportunities for Hydroelectric development;
- Changes in local economic activities; and
- Change in micro and macro economy.
- Development of new infrastructures;
- Rural electrification.

11.6 Summary and Conclusions

The main impacts associated with the project will be the dewatering of the river between the transition tunnel and the powerhouse and permanent acquisition of agricultural land for the construction of powerhouse.

11.7 Terms of Reference

Based on the scoping exercise a Terms of Reference (ToR) has been prepared and submitted to Ministry of Environment for approval. The ToR after approval will be a working guideline for the EIA in determining the factors to be assessed. After the approval of the Scoping Document and ToR a detail field study will be conducted to collect the baseline data for assessment and prediction of the impacts. The EIA will be done in accordance to the Environment Protection Rules, 1997.

12. Financial Analysis

12.1 General

The ultimate aim of a power project is to produce power and energy at a financially viable cost. Financial analysis takes the view of the individual project participants. The financial costs associated with the project are based on normal accounting conventions. Thus, assets are valued based on engineering estimate and are depreciated over their normal lives, which may be determined by law rather than technical or financial criteria.

The main purpose of the project evaluation is to provide financial information facilitating pricing as well as investment and financing decision. It is necessary to examine the project thoroughly prior to its implementation to ensure the developer that the risk is worth taking. Evaluation of project in terms of financial risk and return is important consideration for investment and financial commitment to the project.

12.2 Methodology

Financial analysis takes the view of the individual project participants. The financial costs associated with project are based on normal accounting conventions. Thus, assets are valued in terms of their financing costs and are depreciated over their leased period.

Financial planning is concerned with the estimation of the financial implications of a proposed development. It is based on the use of market prices and, therefore, includes any taxes or royalties which will be levied on the factors of production and any subsidies, capital or operating, which may be received as part of the development. All costs are charged and all revenues credited to the analysis in the actual amounts expended or received and in the case of foreign costs converted at the anticipated official exchange rate at the time of expenditure. For this analysis the financial rate of return and cash flow is assessed from the perspective of a utility owner/operator.

The evaluation methodology follows the traditional practice in project analysis where benefits and cost streams are first estimated. For a project to be acceptable, project benefits should outweigh costs.

There are different modes of financing for the project. In this study the project is analyzed for the following two different types of development.

- Development by NEA.

In case the project is developed by NEA, the entire finance will be arranged through subsidiary loan agreement with Government of Nepal (GoN) using development loan or foreign grant. Local component of the project will be borne by NEA as equity. However, the taxes and duties portion will be converted into equity participation of GoN. Exchange risk in this case will be borne by GoN.

- Development through Private Developer.

Incase the project is developed through private developer, the developer will arrange the require finance through commercial bank and equity. The project will be developed according to the prevailing hydropower policy. The entire energy will be sold to NEA through mutually agreed Power Purchase Agreement (PPA).

In general terms, financial evaluations involve the following tasks:

12.2.1 Estimation of Project Costs

Financial analysis is concerned with the estimation of the financial implications of a proposed development. It is based on the use of market prices and, therefore, includes any taxes or royalties which will be levied on the factors of production and any subsidies, capital or operating, which may be received as part of the development. All costs are charged and all revenues credited to the analysis in the actual amounts expended or received at the time of expenditure. For this analysis the financial rate of return and cash flow is assessed from the perspective of a utility owner/operator. Annual cash flow must be sufficient to provide dividend to the equity investor and retain some income to cover emergency expenses.

Cost components include headwork and powerhouse construction costs, water conveyance costs, diversions and other civil works, electro mechanical, hydro mechanical, transmission and sub-station costs, project environmental impact mitigation, management and monitoring costs. Apart from the above, pre-operating cost is also considered to estimate the capital cost of the project. Annual operating and maintenance expenditures and replacement cost for electro-mechanical equipment are also included. The costs are allocated to the year of expenditure and expressed at constant prices. The financial analysis extends the costing to include taxes and duties, insurances, escalation, loan processing fees, interest during construction, capital repayment and interest on debt. The major portions of the project cost are disbursed within the construction period. However, annual cost including operation and maintenance cost is spread over the analysis duration.

12.2.2 Estimation of Project Benefits

Revenue generated from the sale of energy is the only direct benefit from the project. For the estimation of saleable energy generated from the project, transmission loss, self consumption and outages (scheduled and unscheduled) are deducted from the annual generation. Tamakosi-V is the cascade development of Upper Tamakosi. Hence, any interruption in the generation of Upper Tamakosi will have direct effect on the generation of Tamakosi-V. Because of this fact, higher percentage of scheduled and unscheduled outage which is 7.5% is assumed to estimate the saleable energy.

For the financial analysis, the principle project benefits are revenues, which can be derived from the operation of the project. Average energy rate is estimated ensuring required return on equity (RoE). Return on equity sought by the investor is generally 6% higher than the prevailing interest rate on debt. The project benefits are received during the operation period only. It is assumed that the commercial operation of the project is from January, 2017.

12.2.3 Decision Making Tools

In the analysis, project costs and benefits are compared using discounted measure of project worth. Discounting is the technique used to convert a stream of benefits or costs to its Present Value to account for the time value of money. Internal rate of return and the benefit cost ratios are the popular financial parameters used in discounting method. Apart from the discounting techniques, other parameters are like debt service ratio and payback period are use to ensure the financial soundness of the project. Following are the parameters used for decision making:

- **Average Energy Rate** is the key parameter used for making decision. This rate is estimated assuming that the **Return on Equity (RoE)** of the project is at the acceptable level of the developer so that the investor are encouraged to invest in the project. Further, the average energy rate should be compatible with the prevailing energy tariff.

- The **Financial Internal Rate of Return (FIRR)** is the discount rate corresponds to the zero Net Present Value. That is the discounted rate at which the present value of the benefits equals the present value of costs. The FIRR indicates the financial profitability of the investment project. The FIRR is used to assess whether a project meets a minimum threshold or not. If the FIRR is less than the discount rate, which has been used, the project is thought to be uneconomical, as the discounted benefits do not outweigh the discounted costs. Projects are attractive if the calculated FIRR exceeds the cut-off-rate or opportunity cost of capital.

- The **Benefit- Cost Ratio (B/C)** is the ratio of the present value of the benefit stream to the present value of the cost stream. The B/C Ratio indicates the extent to which the discounted stream of benefits exceeds the discounted stream of costs. A ratio greater than one indicates that benefits exceed costs while a ratio that is less than one indicates that costs exceed benefits.
- **Debt Service Ratio** is the parameter which demonstrates the repayment capability of the project. Financial soundness of a project could be evaluated from this parameter. Generally, debt service ratio of 1.5 is desired. However, for the hydropower projects, where the market is guaranteed for its entire economic life through power purchase agreement, debt service ratio of 1.3 should be acceptable.

- **Payback Period** is the duration in year within which entire investment on the project is recovered. Shorter the payback period better is the project. This parameter is very important in the country where the long term government policy is not stable.

Based on the above financial parameters, investment decision is made by the developer as well as by the financing institutions.

In the financial analysis, the main tool for the evaluation of the project is the return on equity. The project with acceptable return on equity is termed as financially viable project. Apart from this, the debt service ratio should be acceptable to the bankers. The net cash flow of the project must be sufficient enough to ensure steady and acceptable dividend to the equity investor.

12.3 Assumptions for Financial Analysis

Following are the basic assumptions made for financial analysis:

- Base year for the cost and benefit is January, 2011.
- Local component is assumed to be 25% of the total cost where as remaining 75% is assumed to be foreign component.
- Entire cost is estimated in foreign currency (US$) and is converted into local currency during at the time of disbursement using estimated exchange rate of that time.

- Exchange rate for 1 US $ is 75.00 for the base year.
- Construction period is 4 years.
- Commercial operation date is assumed to be January 1, 2017.
- Escalation rate on the local component of the cost is assumed to be 5% whereas that for foreign component is assumed to be 3%.
- Estimation of exchange rate is base on the long term inflation of 5% on local currency and 3% on foreign currency.
- Custom of 1% and local tax of 1.5% are assumed to be applicable on hydro mechanical, electrical and generating equipments as these will be imported from third country using foreign currency. Custom and local taxes are not considered on remaining items of the project.
- Value added tax (VAT) of 13% is considered on entire project cost except on the hydro mechanical, electrical, transmission line, generating equipments, resettlement & environment and owner's cost.
- Average energy cost is based on January 2011 price level and is escalated annually at the rate of 3% per annum for first 9 years of operation.
- Interest on debt for NEA arranged through subsidiary loan agreement with the GoN is assumed to be 8.5% per annum where as that for the private developer arranged from the commercial banks is assumed to be 12% per annum.
- Entire loan will be in local currency.
- The interest during construction is capitalized.
- Interest as well as capital will be repaid in equal installments and biannually after commercial operation.
- Expected return on equity is assumed to be 14% for NEA scenario where as it is assumed to be 18% for private developer.
- For NEA scenario, entire local component is assumed to be equity investment where as debt equity ratio for private developer is assumed to be 70:30.
- Guarantee fee, establishment fee and commitment fee are waived in case of NEA scenario. In case of private developer, the guarantee fee and commitment fee are waved whereas establishment fee payable to commercial bank is 0.5% on total debt.
- Loan duration is 25 years after the year of commercial operation for NEA scenario whereas that for the private developer is 10 years.
- Financial analysis duration is assumed to be 30 years after the commercial operation.
- Straight line depreciation method with annual depreciation at the rate of 4% per annum is adopted.
- Annual operation and maintenance cost is assumed to be 1% of the total construction cost and is escalated at the rate of 5%.

- Annual insurance cost is 0.5% of the construction cost and is escalated at the rate of 5% per annum.
- Runner replacement cost is assumed to be 30% of the electromechanical cost and is assumed to be replaced once in ten years. As of January, 2011 price level this cost would be 9.744 million US $.
- Bonus and welfare fund of 2% of net profit annually.
- Royalty on installed capacity is Rs. 100 per kW per annum for first 15 years and Rs. 1000 per kW per annum then after.
- Royalty on revenue is 2.0% on total revenue for first 15 years and 10% on total revenue then after.
- Corporate tax is 20% throughout the operation period.
- Entire energy is assumed to be sold.
- Scheduled and unscheduled outage is assumed to be 7.5% for the estimation of the salable energy.

12.4 Result of the Financial Analysis

Following are the different cases analyzed in the financial analysis.

NEA Scenario : Project developed by NEA with subsidiary loan agreement with GoN.
Private Scenario : Project developed by private developer with debt equity ratio of 70:30.

Based on the above assumptions, total escalated cost of the project by the end of the construction is estimated to be 12,090.9 million NRs. Out of this total amount, local component is 2,653.3 million NRs. and foreign component is 9,437.6 million NRs. Out of this cost, the physical contingency is estimated to be Rs. 839.9 million. Total taxes and duties including VAT is Rs. 280.7 million whereas price contingency during construction period is Rs. 1,910.8 million. These costs do not include loan processing fees and interest during construction.

Table No: 12.1Summary of Total Financial Cost
(NEA Scenario)

S. No.	Items	Cost in (Million Rs.)		
		LC	FC	Total Cost
1.	Base Cost as of Year 2011	1,768.1	7,291.4	9,059.5
2.	Physical Contingency	185.1	654.8	839.9
3.	**Total Cost as of Year 2011**	**1,953.2**	**7,946.2**	**9,899.4**
4.	Taxes and Duties	280.7	-	280.7
5.	**Total Financial Cost as of Year 2011**	**2,233.9**	**7,946.2**	**10,180.1**
6.	Price Contingency	419.3	1,491.5	1,91.08
7.	***Total Cost at the End of Construction***	**2,653.2**	**9,437.7**	**12,090.9**
8.	Interest During Construction	-	1,569.4	1,569.4
9.	**Total Financial Cost at the end of Construction**	**2,653.2**	**11,007.1**	**13,660.3**

Total financial cost of the project includes loan processing fees and interest during construction on debt portion of the cost. Based on the assumed disbursement of the cash flow, the total financial cost of the project for the NEA Scenario is estimated to be 13,660.3 million NRs. Out of this total amount, local component is 2,653.2 million NRs. and foreign component is 11,007.1 million NRs. Entire local component is an equity where as the foreign component is debt. As the project is proposed to be financed through subsidiary loan agreement with the GoN, the loan processing fee is assumed to be zero. However, the interest during construction is estimated to be NRs. 1,569.4 million.

Similarly for Private Scenario, the total financial cost is 14,172.5 million NRs. Out of this total amount, local component is 2,702.9 million NRs. and foreign component is 11,469.7 million NRs. Loan processing fee is estimated to be Rs. 49.6 million where as the interest during construction is estimated to be Rs. 2,032.1 million. The summary of the total financial cost for NEA Scenario & Private Scenario are shown in Table No. 12.1 and 12.2 respectively. Detail disbursement of equity and debt during construction period is shown in Table 12.3.

Table No: 12.2 Summary of Total Financial Cost (Private Scenario)

S. No.	Items	Cost in (Million Rs.)		
		LC	**FC**	**Total Cost**
1.	Base Cost as of Year 2011	1,768.2	7,291.4	9,059.6
2.	Physical Contingency	185.1	654.8	839.9
3.	**Total Cost as of Year 2011**	**1,953.3**	**7,946.2**	**9,899.5**
4.	Taxes and Duties	280.7	-	280.7
5.	**Total Financial Cost as of Year 2011**	**2,234.0**	**7,946.2**	**10,180.2**
6.	Price Contingency	419.3	1,491.5	1,910.8
7.	**Total Cost at the End of Construction**	**2,653.3**	**9,437.6**	**12,090.9**
8.	Loan Processing Fee	49.6		49.6
9.	Interest During Construction		2,032.1	2,032.1
10.	**Total Financial Cost at the end of Construction**	**2,702.9**	**11,469.7**	**14,172.5**

Table No: 12.3Disbursement of Equity and Debt

Year	Project Cost in Million Rs. (NEA Scenario)			Project Cost in Million Rs. (Private Scenario)		
	Equity	**Debt**	**Total**	**Equity**	**Debt**	**Total**
2013	492.6	1,822.2	2,314.8	829.8	1,552.4	2,382.2
2014	775.8	3,015.8	3,791.6	1,228.7	2,631.4	3,860.1
2015	814.6	3,400.5	4,215.1	1,290.2	3,069.4	4,359.6
2016	570.2	2,768.5	3,338.7	903.1	2,667.5	3,570.6
Total	**2,653.2**	**11,007.0**	**13,660.2**	**4,251.8**	**9,920.7**	**14,172.5**

Table No: 12.4 Financial Analysis with respect to Equity Investment (NEA Scenario)

Table No: 12.5 Financial Analysis with respect to Equity Investment (Private Scenario)

According to the analysis, the average energy rate for NEA Scenario for base case is estimated to be NRs. 3.19 per kWh. For Private Scenario, average energy rate is estimated to be NRs. 6.08 per kWh. These rates correspond to the year 2011. The average energy rates for NEA Scenario and Private Scenario correspond to the year 2017 is NRs. 3.81 and NRs. 7.17 per kWh respectively. For NEA scenario the expected return on equity is assumed to be 14.0% where as it is assumed to be 18% for private scenario. Details of the analysis are shown in Tables 12.4 and 12.5.

Sensitivity analysis is carried out for above scenarios assuming the following:

Case - A : Base Case
Case - B : Project Cost is increased by 10%
Case - C : Entire Construction is delayed by One Year

Summary of the result of the sensitivity analysis is shown in the Table 12.6 and 12.7. The benefit cost ratio is based on the discount rate of 10%.

Table No: 12.6 Summary of the Result
(NEA Scenario)

S. No.	**Items**	Case-A Base Case	Case-B Project Cost is increased by 10%.	Case-C Construction is delayed by One Year
1.	Financial Cost (Million Rs.)	13,660.3	15,026.3	14,343.3
2.	Required Tariff as of 2017 (Rs./kWh)	3.81	4.19	4.08
3.	Debt Service Ratio (1^{st} Year) as of 2017	1.52	1.52	1.55
4.	Benefit Cost Ratio	1.07	1.07	1.07
5.	Financial Internal Rate of Return (%)	8.29	8.31	8.28
6.	Payback Period (Year)	17.54	17.51	17.59

Table No: 12.7 Summary of the Result
(Private Scenario)

S. No.	Items	Case-A Base Case	Case-B Project Cost is increased by 10%.	Case-C Construction is delayed by One Year
1.	Financial Cost (Million Rs.)	14,172.5	15,589.8	14,881.2
2.	Required Tariff as of 2017 (Rs./kWh)	7.17	7.88	7.65
3.	Debt Service Ratio (1st Year) as of 2017	1.58	1.58	1.60
4.	Benefit Cost Ratio	1.24	1.24	1.24
5.	Financial Internal Rate of Return (%)	13.49	13.48	13.46
6.	Payback Period (Year)	8.28	8.29	8.29

The details of the analysis are presented in Annex F of this report.

12.5 Discussion of the Result

Financial analysis was carried out assuming an average tariff for annual energy and escalated at the rate of 3% per annum for nine years. **For NEA Scenario**, as the interest on debt is only 8.0% per annum, the expected return on equity is assumed to be 14% only. To ensure this return, the average tariff is estimated to be Rs. 3.19 per kWh. This rate corresponds to the year 2011. However, the average rate will be Rs. 3.81 per kWh in the year 2017 which is the year of commencement of the project. Cut off tariff would be Rs. 4.16 per kWh form the year 2020 onward. This would result in the net cash flow of Rs. 500.98 million in the first year of operation. Case A which is a Base Case correspond to the normal situation where all the cost and benefit including construction process are assumed to follow exactly as it is perceived during design phase. Further, the debt service ratio in this case is 1.52 in the first year. Hence, the financial institutions should be comfortable to finance the project. The benefit cost ratio at the discount rate of 10% is estimated to be 1.07. Benefit cost ratio of this range for the project financed with low interest rate of 8% seem to be marginal. The analysis shows that the financial internal rate of return (FIRR) of the project is 8.29%. The lower value of benefit cost ratio and the FIRR is socially justifiable. Entire investment will be recovered by 17.54 years.

If the project cost is increased by 10% (Case B), the financial cost will increased to Rs. 15,026.3 million. This will result in the increase of required tariff to Rs. 3.51 per kWh (Year 2011) to maintain the RoE of 14%. Similarly, if the entire project is assumed to be delayed by one year (Case C), the financial cost will increased to Rs. 14,343.3 million and the tariff should be increased to Rs. 3.32 per kWh (Year 2011) to maintain the RoE of 14%.

For Private Scenario, interest on debt is 12% per annum. Hence, the expected RoE is 18%. To ensure this return, the average tariff is estimated to be Rs. 6.08 per kWh. This rate corresponds to the year 2011. However, the average rate will be Rs. 7.17 per kWh in the year 2017. Cut off tariff would be Rs. 7.72 per kWh form the year 2020 onward. This would result in the net cash flow of Rs. 787.27 million in the first year of operation. Case A which is a Base Case correspond to the normal situation where all the cost and benefit including construction process are assumed to follow exactly as it is perceived during design phase. Further, the debt service ratio in this case is 1.58 in the first year. Hence, the financial institutions should be comfortable to finance the project. The benefit cost ratio at the discount rate of 10% is estimated to be 1.24. Benefit cost ratio of this range for the project may be considered comfortable. The analysis shows that the financial internal rate of return (FIRR) of the project is 13.49%. Entire investment will be recovered by 8.28 years.

If the project cost is increased by 10% (Case B), the financial cost will increased to Rs. 15,589.8 million. This will result in the increase of required tariff to Rs. 6.68 per kWh (Year 2011) to maintain the RoE of 18%. Similarly, if the entire project is assumed to be delayed by one year (Case C), the financial cost will increased to Rs. 14,881.2 million and the tariff should be increased to Rs. 6.32 per kWh (Year 2011) to maintain the RoE of 18%.

12.6 Conclusion

It is evident from the above analysis that the project is financially feasible and attractive if it is developed through NEA. The estimated tariff rate of Rs. 3.19 per kWh as of today is far below the prevailing rate offered in power purchase agreement (PPA). The cut off tariff for this scenario is Rs. 4.16 per kWh from the year 2020 on ward. Further it should be noted that total intake by the government from the project in the form of royalties and corporate tax is Rs. 17,034.6 million during its 30 years of operation. Further, some additional revenue will be generated in the form of dividend tax. Apart from this, considerable contribution will be made by the project in the national economy by circulating huge amount of cash in the market in the form of operation & maintenance cost, insurance premium, bonus to the staff and dividend to the stock holders.

The project is very marginal if it developed through private sector. Because of the high interest rate of the commercial bank, expected return on equity is higher for private investor. Estimated tariff rate to realize the required RoE is Rs. 6.08 per kWh as of the year 2011. This rate is higher than the prevailing rate offered in PPA. At present, this tariff rate could be justified only in terms of the cost of alternative energy source which is much higher than the required tariff rate of this project.

Hence, it is recommended that the project be developed by NEA through subsidiary loan agreement with GoN using development loan or foreign grant.

13. Conclusion and Recommendation

13.1 Conclusion

Tamakoshi-V Hydropower Project is conceptualized to develop as a cascade project with Upper Tamakoshi Hydropower Project. An interconnection between the tailrace of Upper Tamakoshi HEP and a head pond area of Tamakoshi V will withdraw design discharge required for the power production in Tamakoshi _V HEP. The project being a cascade project with Upper Tamakoshi HEP, no diversion weir and related structures are required to construct on the river. However, the interconnection system consists of a connecting tunnel, overflow spillway and headpond at the start of headrace tunnel are required to divert flow of Upper Tamakoshi to the Tamakoshi V HEP. A headrace tunnel of 5.60 m diameter and 8200 m long connects the headpond with the restricted orifice surge tank. Surge tank is 73.61 m high and 15.0 m in diameter. A butter fly valve located just after the surge tank will isolate the headrace tunnel and the 122 m high vertical steel lined drop shaft and 41 m long horizontal steel lined high pressure tunnel. This will give the flexibility to repair the penstock pipe without dewatering headrace tunnel and surge tank.

An underground powerhouse and a surface switchyard are proposed on the right bank of Tamakoshi River just downstream from the confluence of Tamakoshi and Khare khola at Suridovan. The powerhouse accommodates 4 number of vertical axis Francis Turbines enable to generate 21.75 MW each.

Total power generation from this project will be 87.0 MW equivalent to 419.3 GWh of energy per annum. For power evacuation of Tamakoshi-V HEP, in total 8 km long 220 kV s/c transmission line from Tamakoshi-V to New Upper Tamakoshi s/s shall be constructed with construction of New Upper Tamakoshi s/s which is a switching s/s on the transmission line route evacuating power from Upper Tamakoshi HPP to Khimti s/s in the vicinity of Tamakoshi V HEP power house.

The geology of the area consists mostly of gneiss and schist. The main soil types in the project area are alluvium and colluvium deposit. The MCT passes through the tunnel alignment. At present MCT is not active and hence there won’t be severe problem but problems like water seepage and gaseous leakage may arise at the construction of the tunnel. For this adequate support system is proposed in the headrace tunnel. The rock mass condition of the project is very poor to good.

Both the headwork site and the powerhouse area of the project lies along the access road of Upper Tamakoshi HEP. Therefore, no access road is required for the construction of this project. However, a few kilometers of project road connecting the main road with the surge tank, construction adits and camp area need to be constructed. Beside that approximately 500 m of access tunnel will be required to construct to reach at the different structures like powerhouse, headpond etc.

Optimization of the design discharge and installed capacity of the project are not necessary as this project shall be developed as cascade project of Upper Tamakoshi HEP for the tandem operation. There is no major tributary contributing significant dry season flow in the river stretch from the headwork of Upper Tamakoshi to the tailrace of the same project. Therefore, the capacity of the project depends directly with the tailrace discharge from the Upper Tamakoshi.

However, two possible powerhouse locations are found on the right bank of the Tamakoshi River. Powerhouse for the Option I is located approximately 1.2 km upstream from the confluence of Tamakoshi River and Khare Khola. The second powerhouse option is located just downstream from the confluence of Tamakoshi River and Khare Khola in Suri Dovan village.Techno-economical analysis shows that both the options are equally attractive with very close financial indicators. The geological investigation also shows the similar nature of the rock formation in the both locations of the powerhouse. Hence, the selection is based on the increment of power/energy and the utilization of the available resources. The Option II with more power generation utilizing all possible available resources is chosen for the further study.

The construction duration of this project is about four year. Being a cascade project of Upper Tamakoshi HEP, some interface work is to be done at the tailrace tunnel of Upper Tamakoshi HEP. For this the Upper Tamakoshi HEP need to construct a 50 m long connecting tunnel and the gate chamber to connect the intake tunnel of the Tamakoshi V HEP during the construction of its tailrace tunnel. The total project base cost is estimated to be 131.99 M. US$ without IDC, but including physical contingencies.

Environmental Impact Assessment (EIA) study of the hydropower project is ongoing. The scoping document and terms of reference for the project has been already prepared and submitted to Ministry of Environment for approval. Once the approval is stamped, the full phased EIA study will be started. The EIA study will be completed by next fiscal year

The project evaluation study of this project shows that the project is more attractive if constructed by Nepal Electricity Authority with the loan taken from Nepal Government rather than if the project develop by the private developer. The financial indicators with consideration of developing the project by NEA and Private Investors are as follows:

Description	Interest Rate	Loan Period Year	Return on total Investment		Energy Cost KWh/NRs at 2011/2017	Debt Service Ratio (DSR)
			IRR on total project cost	Pay back Period in Years		
NEA	8.0%	25	8.29%	17.54	3.19/3.81	1.52
Private	12%	10	13.49%	8.28	6.08/7.17	1.58

This project is financially feasible and attractive if it is developed through NEA. The estimated tariff rate of Rs. 3.19per kWh as of today is far below the prevailing rate offered in power purchase agreement (PPA). The cut off tariff for this scenario is Rs. 4.16 per kWh from the year 2020 on ward. Further it should be noted that total intake by the government from the project in the form of royalties and corporate tax is Rs. 7,884.9 million during its 30 years of operation. Further, some additional revenue will be generated in the form of dividend tax. Apart from this, considerable contribution will be made by the project in the national economy by circulating huge amount of cash in the market in the form of operation & maintenance cost, insurance premium, bonus to the staff and dividend to the stock holders.

The project is marginal if it developed through private sector. Because of the high interest rate of the commercial bank, expected return on equity is higher for private investor. Estimated tariff rate to realize the required RoE is Rs. 6.08 per kWh as of the year 2011. This rate is higher than the prevailing rate offered in PPA. At present, this tariff rate could be justified only in terms of the cost of alternative energy source which is much higher than the required tariff rate of this project.

13.2 Recommendation

Following are the recommendation of the feasibility study of this project:

- Detailed topographical survey of powerhouse site is required to be carried out.

- The project is conceptualized to construct with an interconnection with Upper Tamakoshi Tailrace tunnel. Therefore; an agreement between the Upper Tamakoshi Company and the NEA should be carried out before further development of the project.

- An access road to the project site is constructed to transport the equipments of Upper Tamakoshi. Therefore there will be no road constrains for the transportation in Tamakoshi-V HEP.

- Four units of electro mechanical equipments are proposed for Tamakoshi V HEP so that at least one unit could be operated if only one turbine out of six is in operation in Upper Tamakoshi HEP. However, the minimum flow in the Upper Tamakoshi tailrace need to be verified to finalize the number of turbines in the Tamakoshi V HEp..

- An additional geological investigation/s in major structures needs to be carried out during the detailed engineering design.

- Transmission line alignment has to be surveyed.

- Based on the financial analysis, it is recommended that the project be developed by NEA through subsidiary loan agreement with GoN using development loan or foreign grant.

As the project is technically and financially viable the project is recommend for the implementation. For this detailed engineering design of the project need to be carried out earliest possible.