SURI KHOLA HYDROPOWER PVT. LTD.

KATHMANDU

UPGRADED FEASIBILITY STUDY REPORT

OF

SURI KHOLA SMALL HYDROPOWER PROJECT

DOLAKHA DISTRICT

Volume I: Main Report

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Acronyms

AC	Alternating current
ACSR	Aluminium conductor steel reinforced
AVR	Automatic voltage regulator
BC Ratio	Benefit cost ratio
BM	Bench mark
BoQ	Bill of quantities
cm	Centimetre
d/s	Downstream
DC	Direct current
DDC	District Development Committee
DHM	Department of Hydrology and Meteorology
DoED	Department of Electricity Development
FIRR	Financial internal rate of return
GoN	Government of Nepal
GWh	Giga Watt hour
HFL	High flood level
Hz	Hertz
EIA	Environmental Impact Assessment
INPS	Integrated National Power System
km	Kilo meter
kN/m^2	Kilo Newton per square meter
kV	Kilo Volt
kVA	Kilo Volt Ampere
kW	Kilo Watt
kWh	Kilo Watt Hour
LT	Low tension
m amsl	Meters above mean sea level
M US$	Million US$
m	Meter
m/s	Meter per second
m^3	Cubic meter
m^3/s	Cubic meter per second
mg/l	Milligram per liter
mm	Milimeter
MoE	Ministry of Energy
MVA	Mega Volt Ampere
MW	Mega Watt
NEA	Nepal Electricity Authority
NPV	Net present value
NRs	Nepalese Rupees
O & M	Operation and maintenance
PCC	Plain cement concrete
SKHP	Suri Khola Hydropower Project
PPA	Power Purchase Agreement
PPM	Parts per million
PVC	Polyvinyl chloride
RCC	Reinforced cement concrete
RoR	Run of the river
rpm	Revolution per minute
RRM	Rock mass rating
T	Ton
ToR	Terms of Reference

u/s	Upstream
US$	United States Dollars
V	Volt
VAT	Value Added Tax
VCB	Vacuum circuit breaker
VDC	Village Development Committee
WECS	Water and Energy Commission Secretariat
Yr	Year

Salient Features of the Project

General	
Development region	Central
Zone	Janakpur
District	Dolakha
District headquarter	Charikot
VDC	Chankhu and Suri
Project location (same as before)	
Longitude	86° 15’ 10” to 86° 12’ 50” East
Latitude	27° 45’ 13.85” to 27° 44’ 10” North
Type of scheme	Run of river (RoR)
Source river	Suri Khola
Hydrology	
Catchment area	36.40 km^2 at intake site
Mean annual precipitation	1650 mm
Design discharge	2.75 m^3/s ($Q_{40\%}$)
Compensation flow	0.066 m^3/s
1 in 100 years return period design flood	167.75 m^3/s
1 in 5 years return period operation flood	61.22 m^3/s
1 in 2 years return period diversion flood	34.55 m^3/s
Power and energy	
Gross head	282.0 m
Rated net head	273.19m
Installed capacity	6400 kW
Dry season energy	5.28 GWh
Wet season energy	27.56 GWh
Annual energy	32.85 GWh
Project components	
Weir	
Type	Concrete lined weir
Crest level	1395 m amsl
Length of weir	20 m including undersluice
Spillway type	Free overflow
Intake	
Type	Gated submerged orifice intake with course

	trash rack
Nos. of opening	2 nos
Opening size	2.5m long X1.0 m

Conneting canal

Type	Box type
Length	18.37 m
Width	1.50 m
Overall depth	1.65 m
L-slope	1:250
Overflow spillway length	7.84 m
Overflow spillway capacity	10 m^3/s

Gravel trap

Type	Continuous flushing hopper type
Overall length	8.17 m
Width	3.75 m
Overall depth	2.60 m
Particle size to be trapped	5 mm
Design flow	3.16 m^3/s
Flushing flow	0.41 m^3/s

Settling basin

Type	Double chamber, gravity flushing type
Settling zone length	43.00 m
Inlet transition length	16.20 m
Single basin width	5.00 m
Overall depth	3.77 m
Particle size to be settled	0.15 mm with 90% settling efficiency
Design flow	2.75 m^3/s

Headpond

Type	RCC tank
Storage period	60 s
Effective length	11.45 m
Width	7.50 m
Effective depth	1.91 m
Effective storage	165 m^3

Normal water level	1394.726 m amsl
Penstock	
Type	Surface, mild steel circular shaped
Length	3277 m
Internal diameter	1.25 m
Thickness	6-25 mm
Design flow	2.75 m^3/s
No. of anchor blocks	56
No. of support piers	412
Powerhouse	
Type	Surface type, RCC structure
Length	27.82 m
Width	16.24 m
Height	12.00 m
Tailrace length	80 m
Turbine	
Type	Pelton (2 units)
Rated capacity	3400 kW one unit
Turbine axis level	1113 m amsl
Design flow	1.375 m^3/s for one unit
Generator	
Type	3 Phase brushless synchronous (2 units)
Rated capacity	4000 kVA each
Rating	50 Hz, 750 rpm
Governor	Electro-Hydraulic
Overhead crane	Lifting capacity 25 T
Step up transformer	
Type	3-Phase, ONAN cooled, Outdoor type
Rating	2 x 4000 kVA, 6.3/33kV, 50 Hz
Transmission line	33 kV Double circuit, 3 phase, 50 Hz, 5.8 km long
Connection with grid	Singati sub-station
Access road	Earthen road, 3.5 km long
Cost and finance	
Project cost (with IDC,)	1084.826 Mill NRs

Cost per kW (with IDC)	1695.04 US$/kW
Debt equity ratio	70/30
FIRR	13.85%
NPV	203.230 Mill NRs
BC ratio	1.23
Return on equity	17.94%

1 INTRODUCTION

1.1 GENERAL

Suri Khola Hydropower Project is located in Dolakha district of Nepal. Dolakha district is one of the rich districts from the perspective of hydropower potential. Khimti Hydropower Project- 60 MW is the largest existing project generating electricity in the district. Upper Tamakoshi Hydroelectric Project-456 MW is under construction in Dolakha district, which is currently the largest under construction project in Nepal. There are numerous other projects at different levels of study. Tamakoshi (3) Hydroelectric Project-880 MW is one of the other mega projects which are under detailed study. Suri Khola, a tributary of Tamakoshi River, has also the potential for development of small sized hydropower project. Suri Khola Hydropower (P) Ltd. got survey license from Department of Electricity Development (DoED) for development of Suri Khola Hydropower Project located at Suri Khola of Dolakha district. The company had conducted feasibility study of the project and plant capacity proposed by the study was 3600 kW. After completion of feasibility study and further river flow measurement by more accurate method of current meter, the company decided to explore possibility of capacity upgrading of the project by increasing head if possible and increasing the design flow which was seen possible as shown by actual measurement of the flow of Suri Khola. Furthermore project's financial soundness could have increased by increasing the power output as marginal increase in energy revenue could be higher than marginal increase in project cost. This could make project more feasible in current situation of construction cost increase and stagnant energy price.

In this connection, a site visit of Suri Khola Hydropower Project was made with representatives of the company, a geologist, a detailed topographical survey team and hydropower professionals from CEPAD Hydro Consultants Pvt. Ltd. The main objectives of the site visit were shifting weir and intake upstream location so that additional head could be gained for more power, project layout identification for new weir and intake location, geological observation of upstream new area and overall geological observation of the project area.

The previously proposed weir and intake location was at an elevation of 1257.00 m amsl. The full supply level (FSL) of intake was at elevation 1260.0 amsl. The tail water level proposed was at 1044m amsl. Thus gross head available was 216 m. A vigorous study was conducted for shifting of the headworks to upstream site within the project survey boundary provided by Department of Electricity Development. An appropriate weir and intake location was identified at about 1500 m upstream and the location is equally suitable as that of previous one. The location of the new headworks is at the confluence of Hulak Khola with Kolun Khola at elevation of 1395m. Likewise the location of the powerhouse site is located at an elevation of 1113m amsl. Now the gross head available due to the change in location of headworks and powerhouse is 282m.

Furthermore, the company has established a gauging station at headworks site and records of daily gauge height was taken for last three/four years. Discharge was measured by using current meters during dry season of the year. At the time of feasibility study, there are very few data are available to analyse the discharge and prepare the long term data series by using these actually measured data. So at that time different indirect methods were used to predict the long term data series like catchment correlation with basin of similar characteristics, Hydest, regional method etc. Out of these, the catchment correlation with discharge data of Khimti khola at Rasnalu station (St. no. 650) gave more or less similar values with few actually measured discharges which were adopted for further study. However, now we have discharge and gauge data of four years period which gives the real flow pattern of the river. So, in this capacity upgrading study of the project, these actually measured data are used and analysed to forecast the long term flow series. The study shows that the discharge at 40% probability of exceedance is 2.75m^3/s whereas flow concluded before was 2.18m^3/s. Thus the project capacity could be upgraded to 6400 kW considering Nepal Electricity Authority's criteria of flow not exceeding 40 percentile probability of exceedence against the installed capacity of 3600 kW proposed earlier. Hence the Upgrading Feasibility Study is carried out and the survey license of upgraded capacity is obtained from Ministry of Energy, Department of Electricity Development. This report addresses the issues attracted due to the change in weir and intake location and increase in plant capacity of the Suri Khola Hydropower Project to 6400 kW.

Difference lies in weir and intake location, headrace alignment, design flow and installed capacity. Thus only relevant information that makes the installed capacity different from the feasibility study is included in this report and following chapters illustrate the issues regarding capacity upgrading of the project.

1.2 OBJECTIVE OF THE STUDY

The main objective of the study was to carry out design and analysis to complement the feasibility study by addressing the issues of capacity upgrading from 3600 kW to 6400 kW of Suri Khola Hydropower Project. Evaluation of technical as well as financial implication to the project was also an objective of upgrading feasibility study. The main objective of the current study is to prepare updated feasibility study report after reviewing all technical aspects, analyzing various options available, with optimization on technical and financial parameters of the project to make it feasible for development. This report will be a basis for the further detailed planning, detailed investigations and detailed engineering designs. This report will also enable the developer to proceed with connection agreement, power purchase agreement (PPA), and financial closure and finally obtain the generation license for the implementation of the project.

1.3 SCOPE OF WORK

This study is guided by the Contract Agreement signed by the Consultant with Client and Terms of Reference (ToR) to prepare upgraded feasibility report for the Suri Khola Hydropower Project in Suri basin for the purpose of facilitating the procedure for PPA, generation license and updated Environmental Impact Assessment (EIA) study of the project. The detailed content and scope is guided by the DoED Guideline of 2003 but the followings are formulated as general objectives of the study:

- Review of the previous works;
- Present the findings of the site visit and investigations by the experts;
- Find the discharge availability at the intake site for power generation;
- Measure discharge at the spot to verify the forecasted trend;
- Evaluate geological and geotechnical conditions of the project site for proposing appropriate project components location and layout;
- Access the site for finding suitable development alternatives and recommend most viable option for development;
- Prepare the general layout, profiles, sections with relevant design of all the project components;

- To analyze the power and energy potentials form the project for capacity and energy declaration for the PPA and connection agreement;
- Prepare feasibility drawings, rate analysis, quantity estimate, BoQ and cost estimate for financial analysis;
- Identify the transmission & interconnection options, recommend most viable option, find transmission line route, T/L cost estimates, interconnection system details;
- Evaluate the project cost as per present market trend assigning appropriate contingencies and provisions for implementation; find potential revenue from the project;
- Prepare Construction planning and management for the project implementation;
- Prepare cost estimation, financial analysis and projection, find financial indicators, and carryout sensitivity analysis;
- Prepare updated detailed feasibility report as per the content of DOED guidelines.

1.4 STUDY METHODOLOGY

Review of feasibility study report and other literatures related to the study of Suri Khola Hydropower Project were completed to outline the statutory compliance of the project as a first step. Previous study reports were made available from Suri Khola Hydropower Pvt. Ltd. and those are referred as basic reference documents. Spot measurements of Suri Khola have been made during the field visits. Other related hydrological and meteorological data are collected and referred from Department of Hydrology and Metrology (DHM) and from other projects studied in the vicinity of Suri basin. Teams comprising of engineers, geologist, hydrologist, electrical engineer, senior surveyor were deputed to the project site for review and investigations of local condition. The consultant has proposed available alternatives and options to the developer.

After rigorous discussion, the developer has decided to upgrade the previous feasibility study of 3.6MW capacity of the project to 7MW capacity. The district rates and prevailing rates related to construction works at the area were collected during the site visit for the purpose of cost estimation. A meeting with the local people was undertaken by the developer to brief the objective of the present study and project to seek cooperation from them. All the calculations, designs, layouts, estimations and report writing were completed in Kathmandu.

Professionals and experts from various fields and from different organizations are involved in the study at different stages with respective responsibility for the investigation, discussions, design and finalization of updated feasibility report preparation of the project.

1.5 ORGANIZATION OF THE REPORT

This report related to the upgraded feasibility study contains two volumes. The first volume contains Main Report including salient features and executive summary, investigation details, layout, design description, construction plan, cost, financial analysis of the project and calculations and investigation annexes. The second volume consists of feasibility drawings. The contents of the respective chapters in the volumes are presented below as an outline:

Volume - 1: Main Report (Upgraded Feasibility Study)

Chapter-1: **Introduction**: Contains the introduction and background of the report

Chapter-2: **Description of Project Area**: includes the description of project location, physical features and accessibility information.

Chapter-3: **Survey & Investigations**: Includes brief outline of the survey and other investigations carried out at site for the project.

Chapter-4: **Hydrological Study**: Presents findings on hydrology and flood studies carried out in order to investigate sufficiency of power potential from the project.

Chapter-5: **Geological Study**: includes description of regional and local geological settings, different engineering geological conditions present at the alignment and proposed project components with further recommendations for next stage of study.

Chapter-6: **Project Design & Description**: describes the features of the proposed project layout, design features and component descriptions.

Chapter-7: **Power, Energy and Benefit Assessment**: contains the assessment of power output from the project and energy available at delivery point form the project for sales and revenue from the sales of energy.

Chapter-8: **Construction Planning**: contains the details of project development schedule, institutional arrangement for the development of the project

Chapter-9: **Operation and Maintenance Plan:** Contains the operation and maintenance plan of the project after commercial operation.

Chapter-10: **Project Cost:** contains the estimate of project cost.

Chapter-11: **Project Evaluation:** contains the assessment of economic indicators of the project and sensitivity analysis

Chapter-12: **Conclusion & Recommendation:** contains the outcomes of the study and further action to be carried for the projects**.**

Annexes

Annex A: Rate Analysis

Annex B: Quantity Calculation

Annex C: Bill of Quantities

Annex D: Cost Estimate of Civil Works

Annex E: Bill of Materials of Hydro-mechanical Works

Vol. - 2: Drawings

2 DESCRIPTION OF PROJECT AREA

2.1 LOCATION

Suri Khola Hydropower Project is located in Chankhu and Suri VDCs of Dolakha district in central development region of Nepal. In the physiographical regions, the project area belongs to middle and higher mountains, as the upper catchments of the suri Khola extends to the elevation of 4040m above mean sea level.

All the project structures lie within the Suri VDC. The project headworks site is located just downstream of confluence of Hulak Khola with Suri Khola and powerhouse site is located at Gurumphi village on left bank of Suri Khola about 300 m upstream from the confluence of Suri Khola with Khare Khola. The settling basin lies on right bank of the river and headrace pipe alignment crosses river at some distance from headworks and passes along left bank of the river. The project encompasses an area between latitude 27°44’10” N to 27°45’13.85”N and longitude 86°12’26” E to 86°15’00” E. The project area location map is shown in Figure 2-1 below.

Figure 2-1: Project Area Location Map

2.2 PHYSICAL FEATURES

Suri Khola is a small tributary of Khare Khola in Sapta Koshi River basin. The river originates from the East-West slope of the Burmuje dada (4040m amsl) of the higher Himlayas range of Nepal. The river drains all these mountains and delivers discharge to Khare Khola at the confluence located near Ghurumphi. Suri Khola comprises of a number of small tributaries. It is a both snow and rain fed river originating from maximum altitude of about 4040 m.

Alignment of Suri Khola Small Hydropower Project passes initially along the right side of Suri Khola and crosses and passes along left bank. There is cultivated land in few places but mostly the alignment passes through forest and barren land. There is vulnerably no unstable area found in the alignment despite the fact that there are some kholsies (rivulets) which need to be crossed in the headrace alignment. It is accessible because of already ready access road along the alignment up to proposed powerhouse site and proposed power evacuation point is very near at Singati Bazzar which is just 6 km from the powerhouse site. In general, the project site is ideal for hydropower development.

2.3 ACCESSIBILITY

Charikot is 133 km away from Kathmandu in the North-East direction. Nearest market is Charikot, (i.e. headquarter of Dolakha district) which is about 42 km away from the power house site. The project is connected by earthen road from Bhorle at Tamakoshi access road. There is RCC Bridge under construction over Tamakoshi River near Bhorle bazzar. The earthen road starts after crossing Tamakoshi River Bridge near Bhorle. This road connects proposed alignment and powerhouse. Access road to the project site from the national market and places of importance are listed below:

Table 2-1: Accessibility to the Suri Khola Hydropower Project Site

S.N.	Distance from	To	Distance(Km)	Description Route
1	Kathmandu (MaitiSuri)	Khadichaur	78	Arniko Highway
2	Khadichour	Charikot	55	Lamosangu-Jiri Highway
3	Charikot	Singati	35	Graveled Road
4	Singati	Bhorle	4.5	Graveled Road
5	Bhorle	Power house	2.5	Earthen road already built
Total Road Length From Kathmandu to PH			175	

Alternatively access from Bardibas can also be used if the road is ready by the time the project construction starts. This road starts from Bardibas following B.P. Highway up to Khurkot and follows Manthali, Khimti power house and finally to Charikot. From Charikot, the same route as indicated above can be followed. For the transportation of materials coming from the south, use of this route will curtail the distance as compares with transportation via Kathmandu. This access route will be used after completion of bridge under construction over Sunkoshi River at Khurkot. This route will not be useful for the transportation of equipments and materials from Kathmandu. The Access route from Kolkata to project site is as shown in the figure below:

Figure 2-2: Access Route & Location of Suri Khola Hydropower Project

2.4 INFRASTRUCTURE FACILITIES

Infrastructure facilities of the project area are satisfactory for the project construction activities. Although the project area is not currently connected with electricity line, a connection is expected soon as a substation is under construction at Singati which is just 6 km apart. The telephone lines are not installed nearby for communication but wireless signal reception of CDMA and SKY phones are also available throughout the project area. The road connection is available upto powerhouse but the project needs to carry out maintenance work and construction of new road upto headworks site.

132/33 kV substation is under construction by NEA in Singati bazzar. Power generated from the Suri Khola Hydropower Project shall be evacuated to INPS through this substation. Construction material and equipments related to transmission line shall be transported from nearby access road.

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3 FIELD INVESTIGATION AND DATA COLLECTION

3.1 TOPOGRAPHICAL SURVEY AND MAPPING

The methodology adopted for topographical survey works of Suri Khola Hydropower Project is described in this section. Details and topographical sheets are presented in - Drawings.

3.1.1 Objectives and scope of works

The main objective of the survey works is to prepare detail topographic maps of the project area for locating major components of the project like weir, intake, settling basin, water conveyance system, penstock alignment, powerhouse and tailrace in appropriate scale, which can be used for detail design purpose.

Scope of work for the field survey includes the following:

- approx 40 ha total project area covering all the project structures such as construction facilities, diversion weir/spillway, settling basin, headrace pipe, penstock and appurtenance, powerhouse, tailrace and outlet facilities, switchyard in scale 1:10,000 and contour interval 1 m.
- the headwork area in scale 1:500 and contour interval of 1 m
- strip survey of the water conveyance route with detailed cross-sections of cross-drainage in 1:1000 scales with 1 m contour interval with adequate coverage on either side from the proposed axis
- the powerhouse, penstock and tailrace area in scale 1:500 and contour interval 1 m
- survey for setting out the boreholes, seismic refraction lines, test pits and trenches if any
- longitudinal profile survey and cross-section of the river from the dam axis 100 m upstream and 50 m downstream
- carryout at least three cross-section survey at the headworks and three at the tailrace sites covering the highest flood marks in order to check magnitude of the flood peaks
- the river cross-section at the powerhouse and tailrace site at upstream and downstream of the river
- walkover survey of the transmission line routes using available 1:50,000 scale topo-maps
- Longitudinal profile survey of the river from the intake to the powerhouse site in 1:2000 scale.

3.1.2 Available Maps

The maps available for carrying out the feasibility study of the project are as follows:

- Topographical map sheet No 2884 05, 2884 06 and 2884 01 (Scale 1:50000 and 1:25000) prepared by the Department of Survey and district map of Dolakha district (Scale 1:125000).
- Project layout plan and general layout plan produced during desk study.
- Digital data of the above topographical sheet.

3.1.3 Surveying

Prior to field survey, a desk study was carried out by using the most recent topographic map of the project area. Detail information about the project area for the survey work was noted. Finally all the available information and location maps prepared during identification study were collected.

After finalization the desk study, a survey team was mobilized for the field survey. To carry out the detail survey, a brief reconnaissance survey was carried out with flagging at necessary points around the entire area to be mapped. The traverse control points for this project were carried from third order trigonometric control points of the national grid established by Survey Department of GON. The ground control points in the project area have, therefore, been connected to the National Grid.

All the major control points were made conspicuous in the field by monumentation of benchmarks by chiselled on permanent boulders. They were also made conspicuous in the field by marking with yellow enamel paint. Altogether 37 permanent points were established around the project area. Among which benchmarks BM-1 and BM-2 were established at powerhouse site. Similarly 2 permanent benchmarks BM3 and BM4 were established at pipe alignment. Finally 2 benchmarks TP-34 and TP-35 were established at powerhouse site.

Control Traversing

Basic control traverse survey was carried out from two-control points BM-1 and BM-2 fixed at the powerhouse site with the following values of coordinates and elevations as shown in Table 3-1below**.**

Table 3-1 Co-ordinate and Elevation of Basic Control Points

Station	Northing	Easting	Elevation	Remarks
BM-1	3071334.14	421474.95	1042.71	
BM-2	3071345.78	421418.41	1035.37	

A closed traverse was carried out from powerhouse site to intake site. Then several other required control points were established by conventional traverse survey covering the entire area to be mapped from intake site to powerhouse site.

All traverse formed by conventional survey were closed loops or closed on existing traverse points. Traverse legs were made as long as possible and fixed tripod system was used for all reflecting prisms to achieve the better accuracy.

The sub-traverses were carried out using the starting and closing bearing of the points established from the main traverse. All the offset points were established from different traverse points, wherever necessary. The coordinates of the established of the established control points are given in Table 3-2

Table 3-2 Co-ordinate and Elevation of Basic Control Points

SN	Nothing	Easting	Elevation	Remarks
1	3071419.57	422169.29	1042.47	TP-1
2	3071230.83	422429.53	1063.96	TP-2
3	3070951.92	423145.56	1105.79	TP-3

4	3070952.05	423216.49	1104.07	TP-4
5	3070935.22	423224.99	1104.65	TP-5
6	3070504.45	423536.09	1136.84	TP-6
7	3070414.65	423602.78	1147.08	TP-7
8	3070262.09	423686.52	1157.80	TP-8
9	3070233.34	423702.30	1162.31	TP-9
10	3070061.18	423833.08	1172.05	TP-10
11	3070045.06	423847.35	1173.58	TP-11
12	3070043.23	423954.71	1195.93	TP-12
13	3069829.76	424143.39	1213.26	TP-13
14	3069742.81	424162.03	1211.61	TP-14
15	3069705.32	424284.53	1219.55	TP-15
16	3069625.37	424335.75	1235.21	TP-16
17	3069605.41	424506.59	1239.93	TP-17
18	3069575.02	424475.38	1250.46	TP-18
19	3069561.09	424637.08	1248.81	TP-19
20	3069504.19	424707.94	1262.32	TP-20
21	3069369.84	424830.58	1277.58	TP-21
22	3069349.80	424886.92	1279.75	TP-22
23	3069387.71	424998.75	1288.41	TP-23
24	3069293.96	425249.87	1316.10	TP-24
25	3069282.95	425216.26	1314.68	TP-25
26	3069248.30	425255.66	1315.95	TP-26
27	3071023.81	422993.69	1093.72	BM-3
28	3071007.51	423026.66	1094.93	BM-4
29	3069225.96	425381.54	1327.57	TP-27
30	3069212.28	425391.64	1334.79	TP-28
31	3069181.90	425463.24	1347.45	TP-29
32	3069163.59	425547.42	1352.57	TP-30
33	3069115.50	425676.03	1369.87	TP-31
34	3069081.74	425726.55	1378.16	TP-32
35	3069092.57	425846.71	1391.76	TP-33
36	3069096.74	425948.67	1392.14	TP-34
37	3069109.28	425939.87	1394.51	TP-35

Horizontal and Vertical Control

Topcon total station with least count of 1" was used for measuring horizontal and vertical angles. One complete set of horizontal and vertical angles were observed during control traversing.

For horizontal control it includes the following:

- Mean angle and distance computation was checked precisely.
- Angular closure checked for closed loops.
- Angular disclosure was adjusted.

In traverse survey the horizontal angles were observed in one complete round within a mean of 1". Distances were measured in fore and back sight directions and the mean distance was adopted. The closing errors were distributed according to common survey standards.

Altogether 37 control points were established in main-traverse line with 8.0 km in length. For vertical control it includes the following:

- Computation for Σ Back sight, Σ Foresight, Σ Difference of height was checked precisely.
- Computation of Δh for each loops were checked, and
- All the loops were adjusted by Dell method so as to provide consistent heights for use in spot surveying.

While surveying a traverse line, all angles and distances were measured by either instrument employing the force cantering method. Both back sighting and fore sighting direct distance were measured. Reasonable closing error was achieved.

Accuracy

The closing errors were distributed according to common survey standards. Closing errors is 0.227 m in Northing and 0.613 m in Easting in 8 km of main traverse line.

Data Processing

All the survey data were computed in the field as well as in the office. Similarly, some field data were evaluated and horizontal distance and elevation were calculated reciprocally. All the coordinates and elevations of each station and survey point were then computed with respect to given UTM.

Detailing

Proper survey and levelling works are necessary to design the components, to prepare drawings and to calculate the quantities of the project components. The survey data greatly affects the quality of design. Therefore, all the survey works were carried out precisely and correctly.

All the required areas from the dam site to powerhouse site were identified by permanently marked control points, which were made conspicuous in the field with yellow paints.

The terrain features were surveyed by means of spot surveying. Spot positions were taken by 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 reading both the horizontal and vertical angles.

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

The topographical survey and levelling works were carried out for the headworks site, pipe alignment, surge tank site, penstock, powerhouse and tailrace sites.

3.1.4 Mapping

Detailed topographical mapping of headworks and powerhouse site were carried out in required scale. A strip survey was carried out for the pipe alignment. During the survey, right of way of at least 40m on either side of the centreline was maintained along the entire pipe alignment. To facilitate the design works both banks of the river were surveyed at headoworks site and powerhouse site.

Finally, after creating a Digital Terrain Model (DTM), a topographical map of the project area was prepared in different scales by AutoCAD Land desktop 07' software. Topographical maps were prepared in 1:1000 scales with 1m contour interval and 40 ha of land were covered in ground survey from headworks to powerhouse site.

Several cross-sections of the Suri Khola were taken to provide river cross-sections for computing rating curves for headworks and powerhouse sites. At the headwork site altogether nine sections were taken and six cross sections were taken in Powerhouse sites.

3.2 HYDROLOGICAL INVESTIGATIONS

3.2.1 Collection of Available Meteorological and Hydrological Data

Precipitation Data

Precipitation data is needed for the analysis of surface runoff and to know the nature of the catchment with respect to the river flow. The DHM is responsible for the collection of all precipitation data throughout Nepal. There are more than 253 DHM precipitation stations throughout Nepal.

There is no rainfall station within the basin. Three rainfall stations in the vicinity of the Suri basin are considered rainfall analysis. All the 3 rainfall stations have been used to homogenize the rainfall data. The long-term mean monthly and annual mean rainfall for the 3 stations is presented table below.

Table 3-3: Rainfall Station near Suri Basin

Index	Station	Elevation(m)	Distance From Suri(Km)
1101	Nagdaha	850	18
1102	Charikot	1940	25
1103	Jiri	2003	18

Table 3-4: Precipitation of 3- station near Suri Basin, mm

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
NAGDAHA	8.2	14.9	30	72.8	149.7	239.5	371.5	288.3	182.4	39.1	11.2	7.4	1440.7

CHARIKOT	16.1	23	40.9	77.2	158.2	313.4	558.8	529.8	263.9	65.7	11.3	16.4	2104.4
JIRI	16.9	22.6	44	86.8	172.8	369	578.2	535.3	283.9	76.1	17.3	15.5	2224.8
MEAN	13.7	20.1	38.3	78.9	160.2	307.3	502.8	451.1	243.4	60.3	13.2	13.1	1923.3
												Monsoon	1504.60

Temperature

The mean temperature at the Intake and at power house site based on regional analysis based on temperature data (DHM) at different elevation is given in table and figure below. Temperature varies with topography and with elevation.

Table 3-5: The mean temperature at the Intake and at power house (Data Source: DHM)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Intake (°C)	11.3	13.4	17.5	21.3	23.2	24.3	24.1	24.1	23.2	20.3	16.5	12.8	19.4
Power House(°C)	11.9	14.1	18.3	22.1	24.1	25.2	24.8	24.8	24.0	21.1	17.3	13.4	20.1

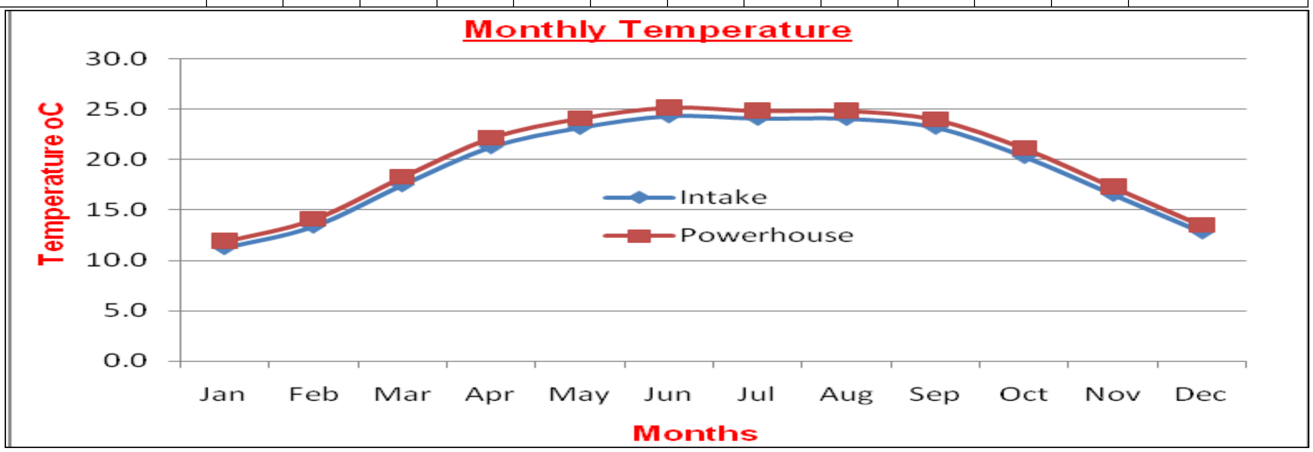


Figure 3-1: The mean temperature at the Intake and power house

Stream Flow Data

There is no gauging station established by DHM at Suri Khola. DHM data of nearby rivers were collected for reference purpose. Also discharge measurements by current meter at Suri Khola intake was carried out and it have been planned to continue further at least for 8 dry months of a year.

The field discharge measurements and the DHM discharge data gathered for hydrological analysis have been presented below:

Table 3-6: Spot Measurements of Flow in Suri Khola at Different Time

Date of Measurement	Discharge (m^3/s)	Gauge Height (m)
2064/1/25	0.773	
2064/2/18	2.16	

064/12/2	1.006	
065/9/2	1.473	
066/1/9	0.876	
066/2/21	1.021	
066/6/22	5.01	
066/8/18	1.719	
066/12/6	0.954	
067/7/6	5.221	
067/10/25	1.138	
067/11/3	1.068	
067/12/20	0.913	
068/1/26	0.913	
068/6/25	8.068	
068/1/10	1.051	0.39
068/8/23	1.94	0.47
068/11/5	1.09	0.4
069/10/3	1.422	0.38

For hydrological analysis of the Suri Khola Hydropower Project, related flow data of various rivers were collected from DHM. The reference data are listed below in table 3.4.

Table 3-7: DHM Gauge Stations Data Collected for Reference Regression

River & Station No.	*Data Available Years	Area, km^2
Likhu-Sagutar (660)	1964-2006	823
Balephi-Jalbire (620)	1964-2006	629
Khimti- Rasnalu (650)	1964-2006	313
Melamchi-Helambu	1964-2006	130
Tamakoshi-Busti (647)	1971-2006	2753
Bagmati-Sundarijal (505)	1963-1995	505
Roshi- Panauti (640)	1964-1988	570
Kulekhani-Lamichaur (570)	1963-1977	640

Installation of Gauge Station

One gauge has been established in Suri Khola u/s of Gurumphi village near the suspended bridge. A local person was deputed by the client for regular monitoring and gauge reading. Necessary instruction and methodology for gauge reading was given to the reader. Gauge station has been regularly monitored and daily stages have been recorded. The established gauge site has been surveyed and planned to be calibrated after every monsoon season. The gauge data obtained will be used to develop rating curve at the section in order to predict the discharge and flood level in different days.

3.3 GEOLOGICAL AND GEOTECHNICAL INVESTIGATIONS

3.3.1 Collection of Available Data and Map

Before proceeding to the field to carry out the geological and geotechnical investigations the consultant has collected the maps as follows:

- Generalized geological map of the Nepal Himalaya
- Seismic hazard map of Nepal
- Topographical map of the project area
- Earthquake epicentres map of Nepal Himalaya (DMG, 2006)

3.3.2 Geotechnical Investigations

Geotechnical investigation was carried out to study geotechnical characteristics of the soil of the different locations such as head works, settling basin, headrace canal alignment and power house area. It also identifies the potential source of construction materials near the existing site. 1.5m x 1.5m x 1.5m size test pits were excavated. About 20 to 30 kg of sample were collected in each area for classification, compaction and other geotechnical testing. The visual classification and the thickness of all the soil layers were also noted. The soil samples collected were carried out the lab test.

3.4 CONSTRUCTION MATERIAL SURVEY AND TESTING

During the site visits, preliminary survey was also carried out for finding the potential availability of the construction materials around the project area. The local available construction materials are stone, boulders, coarse & fine aggregates and sand.

Good quality stone can be available in abundant quantity from stone quarry at the headworks area. River boulders can also be used as source of stone. From the bank of river the stone can be extracted and transported to use for retaining wall and other structures in headworks, desander and alignment. River boulders in the banks are of different quality, so only selected ones are to be used for construction.

Coarse aggregate and filter material required behind the retaining structures may also be prepared from the river bed material available in the river. The aggregate can be crushed with crusher plant with selected boulder only as there are different qualities of stone available around the river bank. The screening of the riverbed materials may also be a source of construction material but that should be carefully used and limited to the low quality concrete only.

Sand deposits could be found in powerhouse site and along the alignment in river bank. Sand can be extracted from the Tamakoshi River valley as well. Sand quantity is limited in the site and found only in pockets but the lower reaches of Suri Khola have potential sand quarry site. There is higher quality of sand in the bank of Tamakoshi river downstream of powerhouse area and further d/s. Depending upon the economical condition and quality of sand requirement, it can be borrowed from Tamakoshi River for construction works. The material from the crusher plant may also be partly used for the fine material as binding agent and can be mixed in limited percentage.

3.5 TRANSMISSION LINE ROUTE SURVEY

The route for transmission line has been identified during the site visit by walkover survey with the help of topographic maps of the project area to the proposed interconnection point at 132/33 kV substation under construction at Singati Bazzar. The transmission line route was followed as per the guidelines and field conditions so that minimum disturbance and problem should appear during construction. From the walk over and GPS survey, total length for transmission line found is about 6 Km.

The T/L route survey was carried out from the left bank of Tamakoshi River. As there are number of transmission lines under construction and planned from the right side along the access road of Upper Tamakoshi Hydroelectric Project, the left bank option was selected for survey. The power evacuation line from Sipring SHP, 33kV construction power line to Upper Tamakoshi project as well as distribution feeders are planned from that side. There is also 220kV power evacuation line from Upper Tamakoshi as well on this side. All these considerations have been noted during the choice of the final T/L route.

3.6 FINDINGS & REMARKS

The survey work was carried out and completed with required detail points covering all project area including the alternative sites. Following are some of the remarks found on site while conducting survey and investigation work.

- Most of the areas along the alignment near headworks, desander falls in private land. Most of the parts in headrace alignment also fall in private land and few only in public land.
- The powerhouse house area lies in cultivated terrace about 300m u/s from the confluence of Suri with Khare Khola at Gurumphi village.
- Further layout survey should be carried out before detail design phase based on the control points established during feasibility study for accuracy and necessary field adjustment before detailed design.
- Company should purchase/lease the private and Government land required as soon as possible after finalization of connection agreement and PPA for project implementation.
- The transmission line route and length estimation has been prepared based on walk over site visits of the area and available topographic map. There is need to carry out the detail route survey once the Connection Agreement with the NEA will be finalized.
- Regular monitoring of established gauge station and gauge reading is necessary.
- There is requirement of further geotechnical investigations and tests completed before detailed design.

4 HYDROLOGICAL STUDIES

4.1 GENERAL

Hydrological study is the major part of the feasibility study in hydropower projects. Energy that is generated in hydropower projects is mainly the function of head and discharge available. Suri Khola Hydropower Project is relatively high head and medium discharge project. Hence, discharge variation plays major role in parameter sensitivity. Also, in designing of hydropower structure, we have to identify the flood, sediment pattern in the basin. Owing to this specific requirement of the project, and to perform the hydrological study effectively its scope has been identified as follows:

- Collection of hydrological and meteorological data,
- Establishment of a gauging station to collect water level and discharges at different time.
- Development of rating curves at intake and powerhouse,
- Assessment of water availability(Mean Monthly Flow, Flow duration curve & Design Discharge, Low Flow and High Flood),
- Sediment Analysis,

Findings from this study will be accommodated in design and energy estimates for the project.

4.2 HYDRO-METEOROLOGICAL CHARACTERISTICS OF NEPAL

Nepalese Rivers are families of Ganga-Brahmaputra Basin. Rivers of Nepal are broadly classified into ten major river basins system. The study on Nationwide Hydro-Meteorological Data Management Project (DHM/JICA, 1993) has re-categorized Nepalese river basins into 17 drainage systems.

The Kosi, Gandaki and Karnali River basins originate from the Himalayas thus having snow melt component. Medium Size Rivers that originate from the southern slopes of the Mahabharat range are non snow fed perennial. Rivers originating from Siwalik-Churia range are categorized into one basin termed as Southern River basin. Hundreds of streams on the southern Indo-Nepal border grouped into eight river basins. Unlike other river basins, these eight Tarai river basins do not contain a single outlet.

The Hydrology of Nepalese Rivers is dominated by the south west Monsoon from the Bay of Bengal and entering Nepal around mid June and lasting until the mid of September. About 75 to 80 percent of total annual rainfall occurs during these four monsoon months of June to September. Similar pattern prevails as the temporal variability of runoff as well.

The steep gradient, young geology, sharp physiographic changes within short distances and the orographic influence due to high mountain barriers influence the spatial variability of precipitation. On the other hand, depleting forest cover, population pressure and increasing urbanizations, cultivation on steep slopes have a combined effect on the dynamics of hydrologic cycle and water induced environmental degradation such as landslides and debris flow contributing to ever increasing uncertainty in the estimation of peak floods and sediment concentrations.

4.3 BASIN PHYSIOGRAPHY AND DRAINAGE

Suri Khola originates from the Burmuje Danda of the Higher Himlayas Range of Nepal. Suri Khola is a small tributaty of Khare khola which finally joins with Tamakoshi River. It is a perennial river. Suri Khola lies in Dolakha district of Janakpur zone in Central Development Region.

The highest elevation of Suri catchment area is 4040m amsl at Burmuje Danda. The forest coverage in the upper parts of the area is quite dense. In upper part the river runs through a deep valley. The cultivated land lies upto higher ridges, on left bank of Suri Khola. The settling basin and powerhouse site lies on the cultivagtes land.

The catchment basin of Suri Khola is shown in Figure 4.1. At the intake, the catchment area of the project is 36.4 km^2. The powerhouse is located at left bank of Suri Khola and the catchment area at powerhouse is about 236 km^2.

Table 4-1: Catchment Area at Intake Site (km^2)

Total Area	36.4
Area below 5000m	36.4
Area below 3000m	26.73

4.4 CLIMATOLOGICAL DATA

4.4.1 Long Term Mean Monthly and Annual Rainfall

There is no rainfall station within the basin. Three rainfall stations in the vicinity of the Suri basin are considered rainfall analysis. All the 3 rainfall stations have been used to homogenize the rainfall data. The long-term mean monthly and annual mean rainfall for the 3 stations is presented table below.

Table 4-2: Rainfall Station near Suri Basin

Index	Station	Elevation(m)	Distance From Suri Khola(Km)
1101	Nagdaha	850	18
1102	Charikot	1940	25
1103	Jiri	2003	18

Table 4-3: Precipitation of 3- station near Suri Basin, mm

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
NAGDAHA	8.2	14.9	30	72.8	149.7	239.5	371.5	288.3	182.4	39.1	11.2	7.4	1440.7
CHARIKOT	16.1	23	40.9	77.2	158.2	313.4	558.8	529.8	263.9	65.7	11.3	16.4	2104.4
JIRI	16.9	22.6	44	86.8	172.8	369	578.2	535.3	283.9	76.1	17.3	15.5	2224.8
MEAN	13.7	20.1	38.3	78.9	160.2	307.3	502.8	451.1	243.4	60.3	13.2	13.1	1923.3
												Monsoon	1504.60

For Suri Khola the average of the above three rainfall station has been considered i.e the annual rainfall in the Suri basin will be 1876 mm.

4.4.2 Temperature

The mean temperature at the Intake and at power house site based on regional analysis based on temperature data (DHM) at different elevation is given in table and figure below. Temperature varies with topography and with elevation.

Table 4-4: The mean temperature at the Intake and at power house (Data Source: DHM)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Intake (°C)	11.3	13.4	17.5	21.3	23.2	24.3	24.1	24.1	23.2	20.3	16.5	12.8	19.4
Power House(°C)	11.9	14.1	18.3	22.1	24.1	25.2	24.8	24.8	24.0	21.1	17.3	13.4	20.1

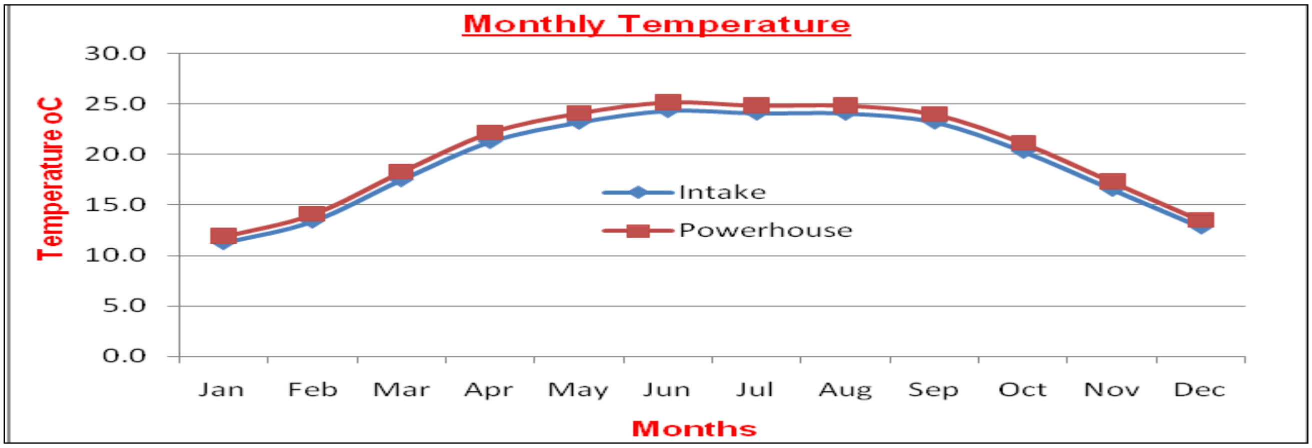


Figure 4-1: The mean temperature at the Intake and power house

4.5 HYDROLOGICAL DATA COLLECTION

4.5.1 Measured Flow Data

A gauging station was established at project location just upstream of powerhouse site on February 10, 2010. After that continuous gauge readings are recorded three times a day. Some spot measurements were carried out on Suri Khola by the developer since 2007. The discharge is measured by using current meter using velocity area method. The discharge measurements are shown in the Table below;

Table 4-5: Discharge Measurement by the Project

Date of Measurement	Discharge (m^3/s)	Gauge Height (m)
2064/1/25	0.773	
2064/2/18	2.16	
064/12/2	1.006	
065/9/2	1.473	
066/1/9	0.876	
066/2/21	1.021	
066/6/22	5.01	
066/8/18	1.719	
066/12/6	0.954	
067/7/6	5.221	
067/10/25	1.138	

067/11/3	1.068	
067/12/20	0.913	
068/1/26	0.913	
068/6/25	8.068	
068/1/10	1.051	0.39
068/8/23	1.94	0.47
068/11/5	1.09	0.4
069/10/3	1.422	0.38

4.5.2 Long Term Flow Series

Suri Khola has no permanent gauging station established by Department of Hydrology and Meteorology. However a gauging station was established at project location just upstream of powerhouse site on February 10, 2010 by the developer of the project. Continuous gauge readings are recorded three times a day. Some spot measurements were carried out on Suri Khola by the developer since 2007. The consultant has collected all the available hydrological data around the Suri basin measured by DHM and has performed the statistical analysis. The selection of the river near the vicinity has been made based on the similar catchment characteristics. Data were screened and used for mean monthly flow analysis and for FDC generation. Selected rivers and gauge locations are and given in table and also shown in figure below.

Table 4-6: Stream Gauging Stations nearby the Project Area

River & Station No.	*Data Available Years	Area, km2
Likhu-Sagutar (660)	1964-2006	823
Balephi-Jalbire (620)	1964-2006	629
Khimti- Rasnalu (650)	1964-2006	313
Melamchi-Helambu	1964-2006	130
Tamakoshi-Busti (647)	1971-2006	2753
Bagmati-Sundarijal (505)	1963-1995	17
Roshi- Panauti (640)	1964-1988	87
Kulekhani-Lamichaur (570)	1963-1977	126

<u>*Note:*</u>

**Values in this column indicate the years for which flow data are available. Some years may be missing for some of the stations*

4.6 LONG TERM FLOW ANALYSIS

Since long term flow data of any hydropower project plays crucial role in revenue generation, it is very important to predict the mean monthly discharge data at intake with great care. There are various approach used in Nepalese context. For Suri Khola Hydopower Project, following methods are found to be justifiable for analysis;

- Regional Regression Method

- Similar Catchment Area (SCA) Method
- Medium Irrigation Project(MIP) method
- WECS-DHM/Hydest Method

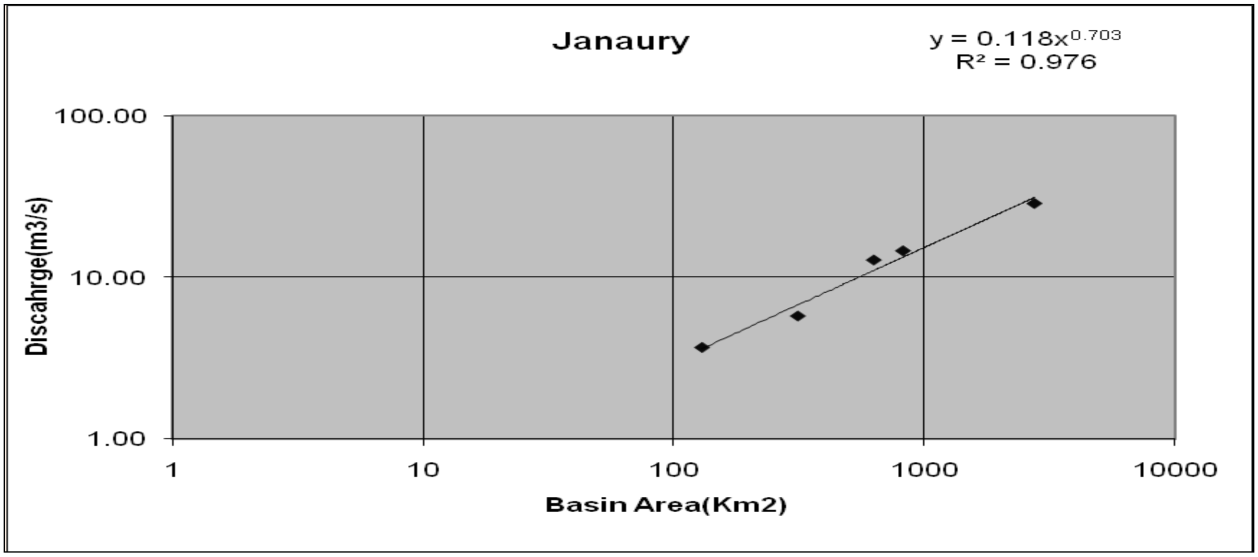
Analyses by all these methods are presented separately below in respective headings;

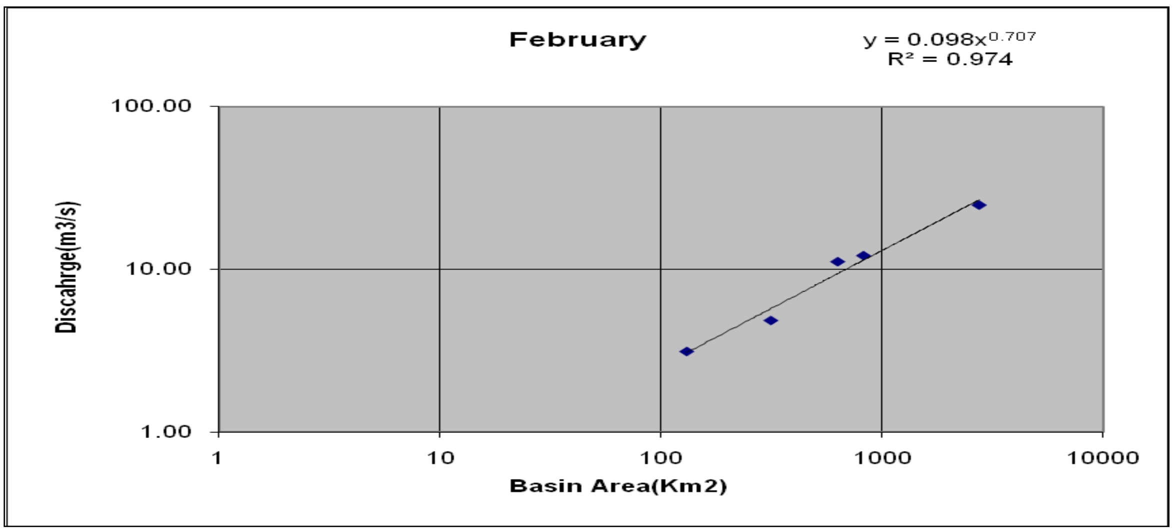
4.6.1 Regional Regression Method

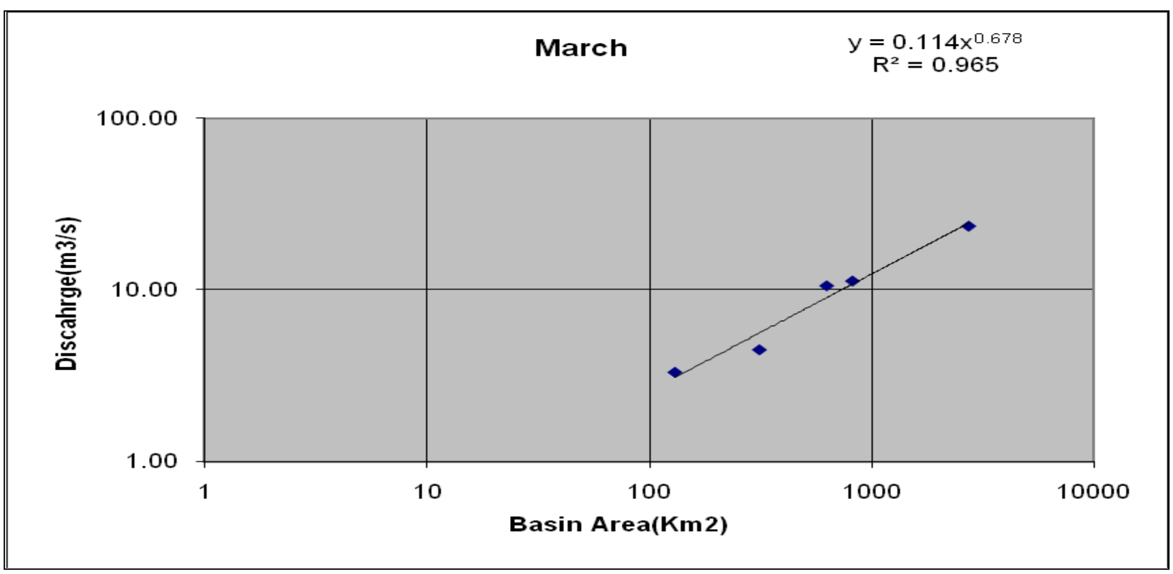
There are some rivers near the Suri Khola vicinity such as Tamakoshi, Khimti, Balephi, Melamchi, Likhu etc. Rivers selected above fall in similar meteorological and ecological zone. But sizes of catchment differ. Khimti, Balephi, Melamchi have been also considered for regression analysis. With the mean monthly flow data of each river mentioned above and the respective basin area, the regression equations for each month have been generated. The R^2 value obtained for each month is above 0.95 so it may be assumed that the equations obtained will give the reliable flow data. The regression equation obtained has been used to forecast the mean monthly flow at Suri intake. Finally, the mean monthly flow obtained from the regression equation has been considered to be given the reliable trend of flow in Suri Khola. The values obtained by this method have been compared with the measured flows and some factor for each month has been used to finalize the best & reliable values.

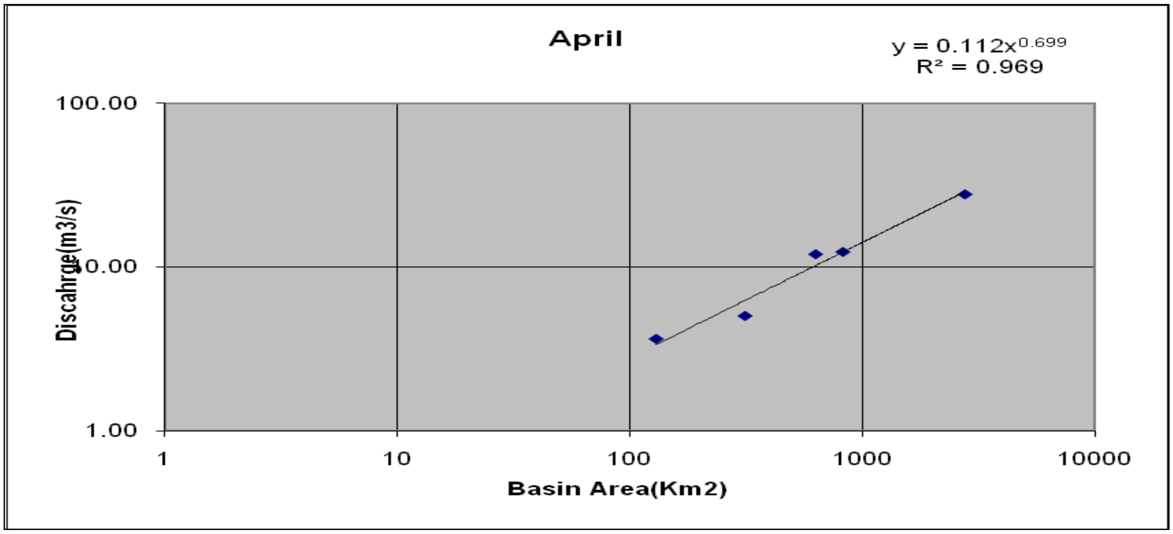
Table 4-7: Mean Monthly Flow at Suri Khola Intake by Regional Regression Method

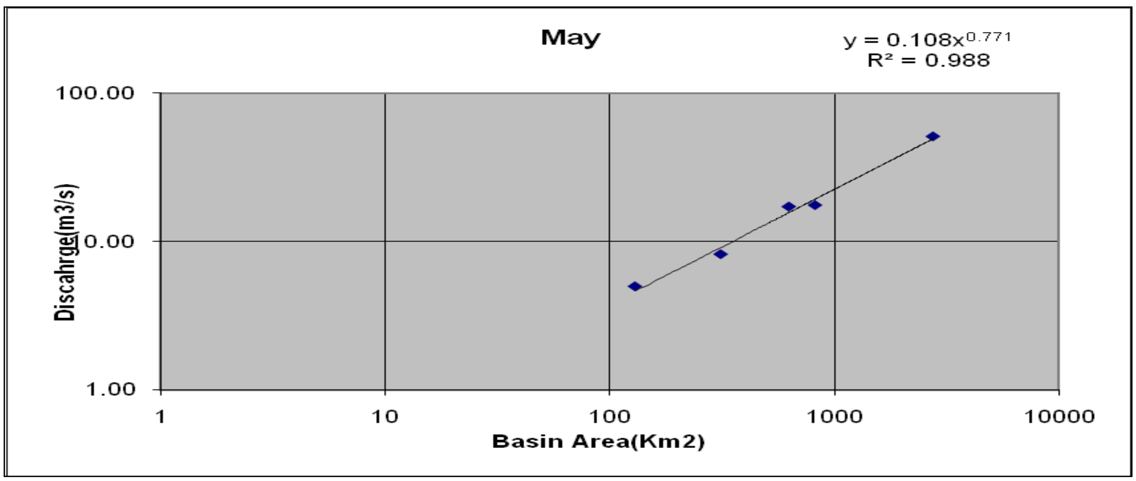
SN	Month	Likhu	Balephi	Khimti	Tamakoshi	Melamchi	Regression Equation	Suri (m^3/s)
1	Jan	14.60	12.8	5.75	28.7	3.67	$y = 0.118x^{0.703}$	**1.48**
2	Feb	12.10	11.1	4.84	24.7	3.12	$y = 0.098x^{0.707}$	**1.24**
3	Mar	11.30	10.6	4.49	23.6	3.32	$y = 0.114x^{0.678}$	**1.30**
4	Apr	12.40	12.0	5.03	27.9	3.64	$y = 0.112x^{0.699}$	**1.38**
5	May	17.60	17.2	8.22	51.1	4.99	$y = 0.108x^{0.771}$	**1.73**
6	Jun	50.50	50.9	34.2	164	10.62	$y = 0.199x^{0.849}$	**4.21**
7	July	145.00	132	85.5	414	24.36	$y = 0.399x^{0.887}$	**9.68**
8	Aug	167.00	164	88.9	483	28.45	$y = 0.422x^{0.900}$	**10.72**
9	Sep	121.00	113	52.4	305	22.31	$y = 0.375x^{0.858}$	**8.19**
10	Oct	59.90	50.8	23.8	120	12.72	$y = 0.337x^{0.755}$	**5.69**
11	Nov	30.70	25.1	11.5	59.3	7.46	$y = 0.227x^{0.712}$	**2.93**
12	Dec	20.00	17	7.57	38.8	4.46	$y = 0.125x^{0.738}$	**1.77**
	Area	823	629	313	2753	130		**4.19**

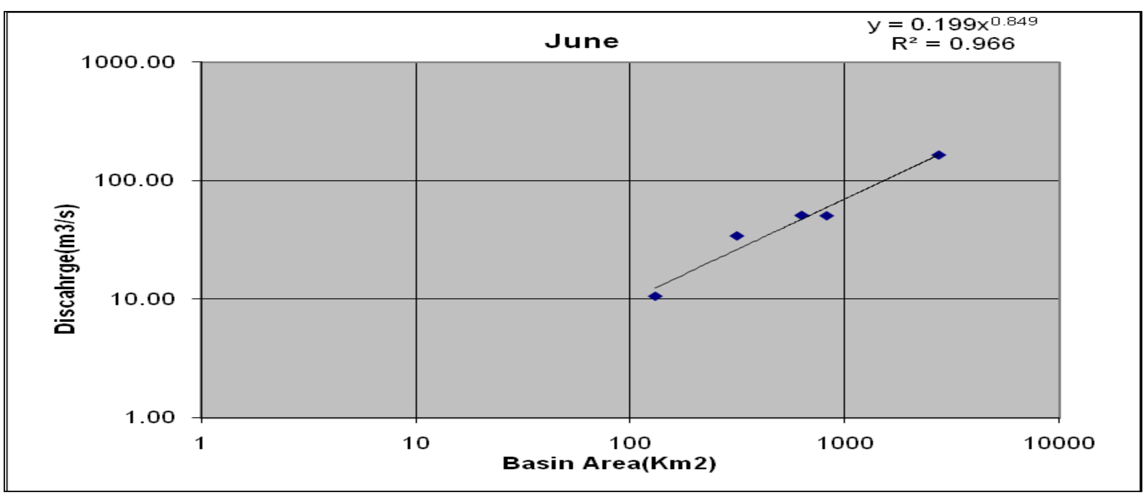

Janaury
y = 0.118x^0.703
R² = 0.976
100.00
10.00
1.00
Discahrge(m3/s)
1
10
100
1000
10000
Basin Area(Km2)

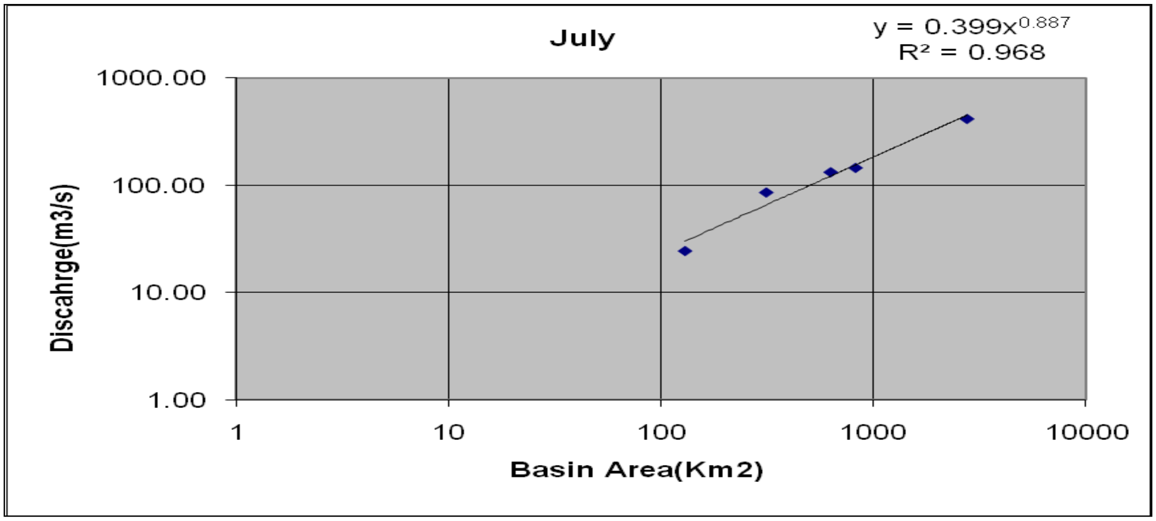

February
y = 0.098x^0.707
R² = 0.974
100.00
10.00
1.00
Discahrge(m3/s)
1
10
100
1000
10000
Basin Area(Km2)

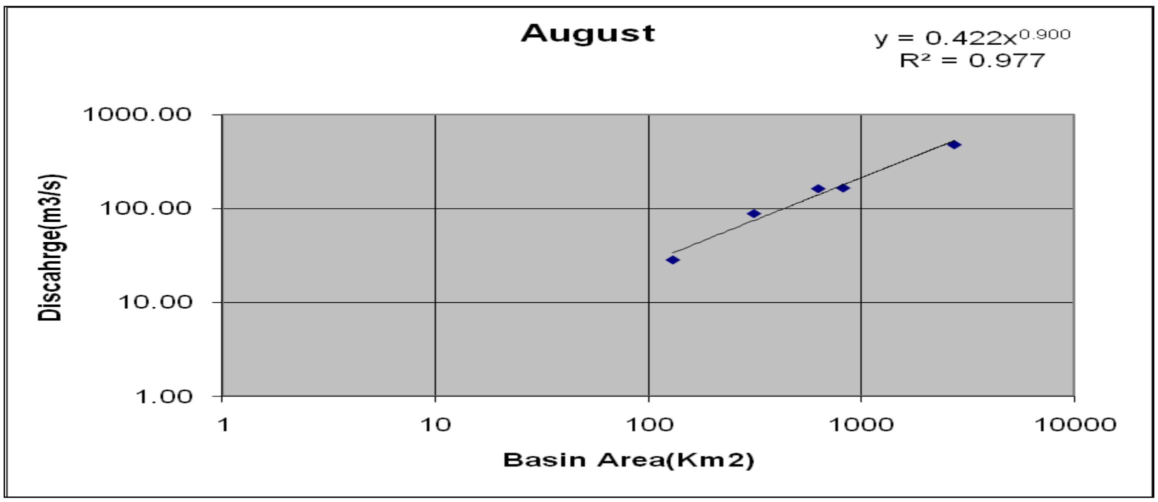

March
y = 0.114x^0.678
R² = 0.965
100.00
10.00
1.00
Discahrge(m3/s)
1
10
100
1000
10000
Basin Area(Km2)

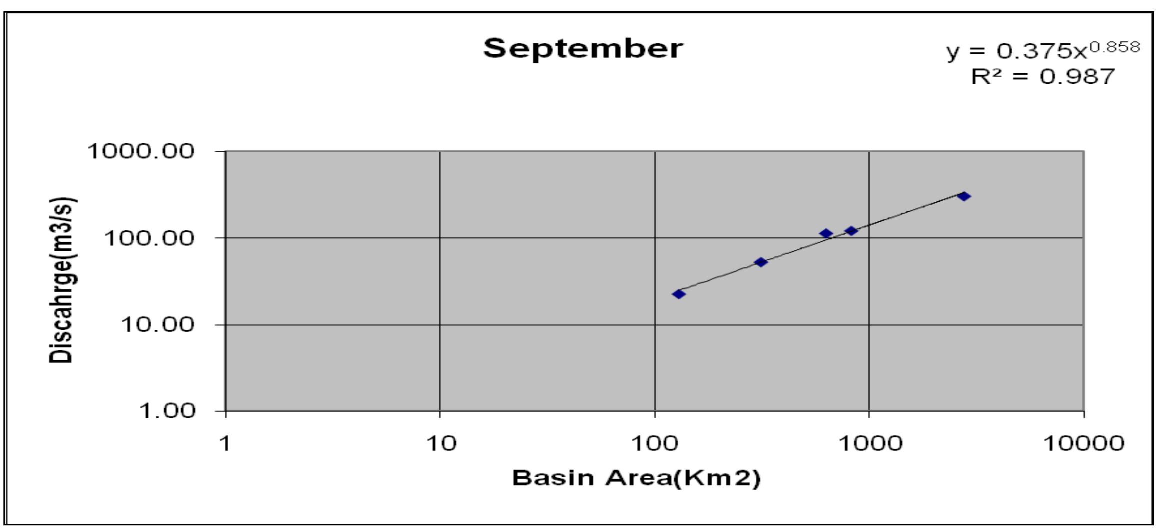

April
y = 0.112x0.699
R² = 0.969
100.00
10.00
1.00
Discahrge(m3/s)
1
10
100
1000
10000
Basin Area(Km2)

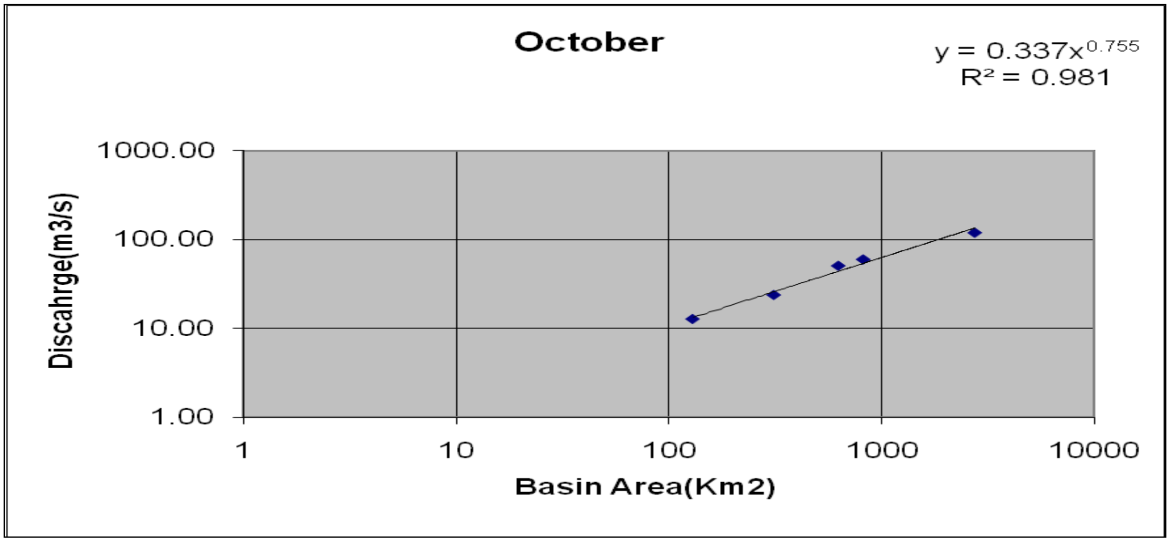

May
y = 0.108x0.771
R² = 0.988
100.00
10.00
1.00
Discahrge(m3/s)
1
10
100
1000
10000
Basin Area(Km2)

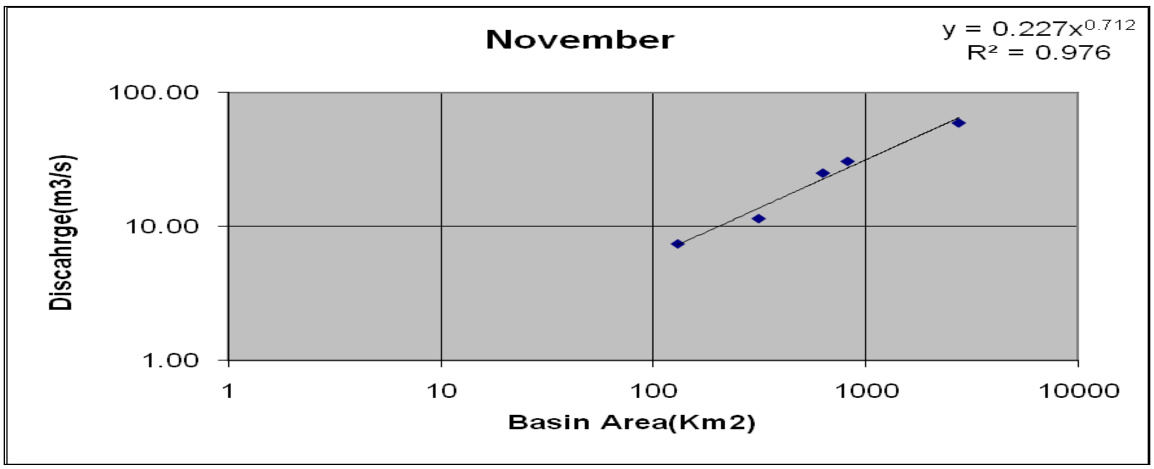

June
y = 0.199x0.849
R² = 0.966
1000.00
100.00
10.00
1.00
Discahrge(m3/s)
1
10
100
1000
10000
Basin Area(Km2)


July
y = 0.399x0.887
R² = 0.968
1000.00
100.00
10.00
1.00
Discahrge(m3/s)
1
10
100
1000
10000
Basin Area(Km2)


August
y = 0.422x0.900
R² = 0.977
1000.00
100.00
10.00
1.00
Discahrge(m3/s)
1
10
100
1000
10000
Basin Area(Km2)


September
y = 0.375x0.858
R² = 0.987
1000.00
100.00
10.00
1.00
Discahrge(m3/s)
1
10
100
1000
10000
Basin Area(Km2)





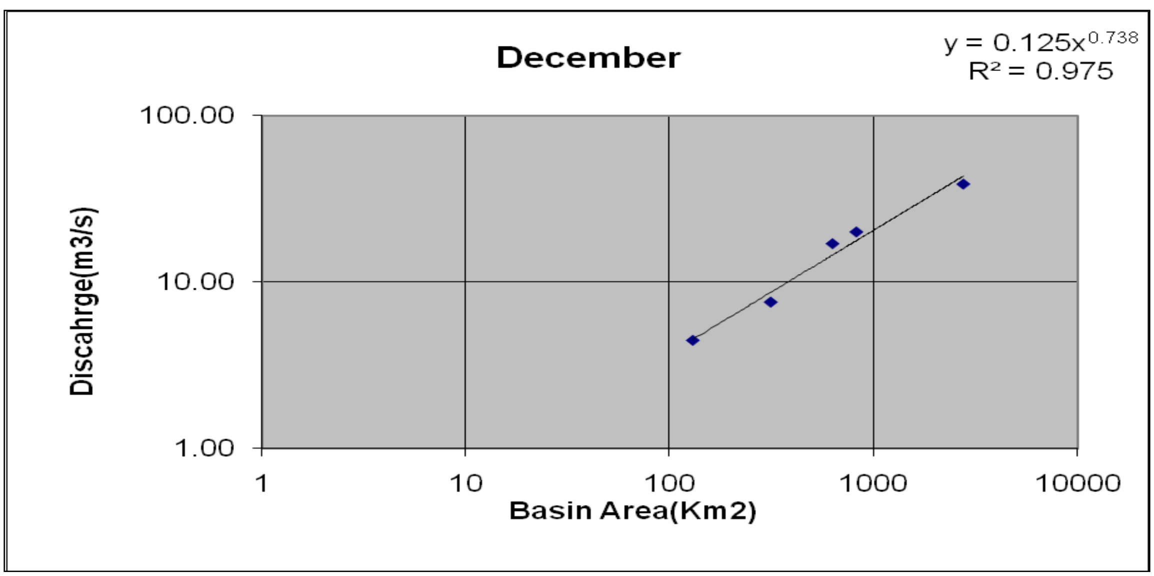


Figure 4-2: Regional Regression Best fit Curve for Suri intake monthly flow

4.6.2 Similar Catchment Area Method

The direct catchment area ratio of Suri Khola Intake (Area=36.4 Km^2) and other river near the Suri Khola area has been used to forecast the mean monthly flow in Suri Khola intake. Mainly the flows have been generated from Likhu, Balephi, Khimti, Melamchi. The mean monthly flow of used river flow by DHM and data obtained at Suri intake from different river have been listed below in the comparative tabular as well as graphical form below.

Table 4-8: Mean Monthly Flow of different River of DHM Stations (m^3/s)

DHM Station Location	Sagutar	Jalbire	Rasnalu	Helambu
Station No	660	620	650	627.5
Months/River	**Likhu**	**Balephi**	**Khimti**	**Melamchi**
Jan	14.60	12.80	5.75	3.67
Feb	12.10	11.10	4.84	3.12
Mar	11.30	10.60	4.49	3.32
Apr	12.40	12.00	5.03	3.64
May	17.60	17.20	8.22	4.99
Jun	50.50	50.90	34.20	10.62
Jul	145.00	132.00	85.50	24.36
Aug	167.00	164.00	88.90	28.45
Sep	121.00	113.00	52.40	22.31
Oct	59.90	50.80	23.80	12.72
Nov	30.70	25.10	11.50	7.46
Dec	20.00	17.00	7.57	4.46
Drainage Area	**823**	**629**	**313**	**130**

Table 4-9: Mean Monthly Flow at Suri Intake from Different River (m^3/s)

Months	Likhu	Balephi	Khimti	Melamchi	Average
Jan	0.646	0.741	0.669	1.028	**0.77**
Feb	0.535	0.642	0.563	0.874	**0.65**
Mar	0.500	0.613	0.522	0.930	**0.64**
Apr	0.548	0.694	0.585	1.019	**0.71**
May	0.778	0.995	0.956	1.397	**1.03**
Jun	2.234	2.946	3.977	2.974	**3.03**
Jul	6.413	7.639	9.943	6.821	**7.70**
Aug	7.386	9.491	10.339	7.966	**8.80**
Sep	5.352	6.539	6.094	6.247	**6.06**
Oct	2.649	2.940	2.768	3.562	**2.98**
Nov	1.358	1.453	1.337	2.089	**1.56**
Dec	0.885	0.984	0.880	1.249	**1.00**

Among all of the above data obtained, average of all rivers has been considered as the mean monthly flow at Suri intake by SCA method. To counteract the some differences in catchments Characteristics, averaging of all values have been done.

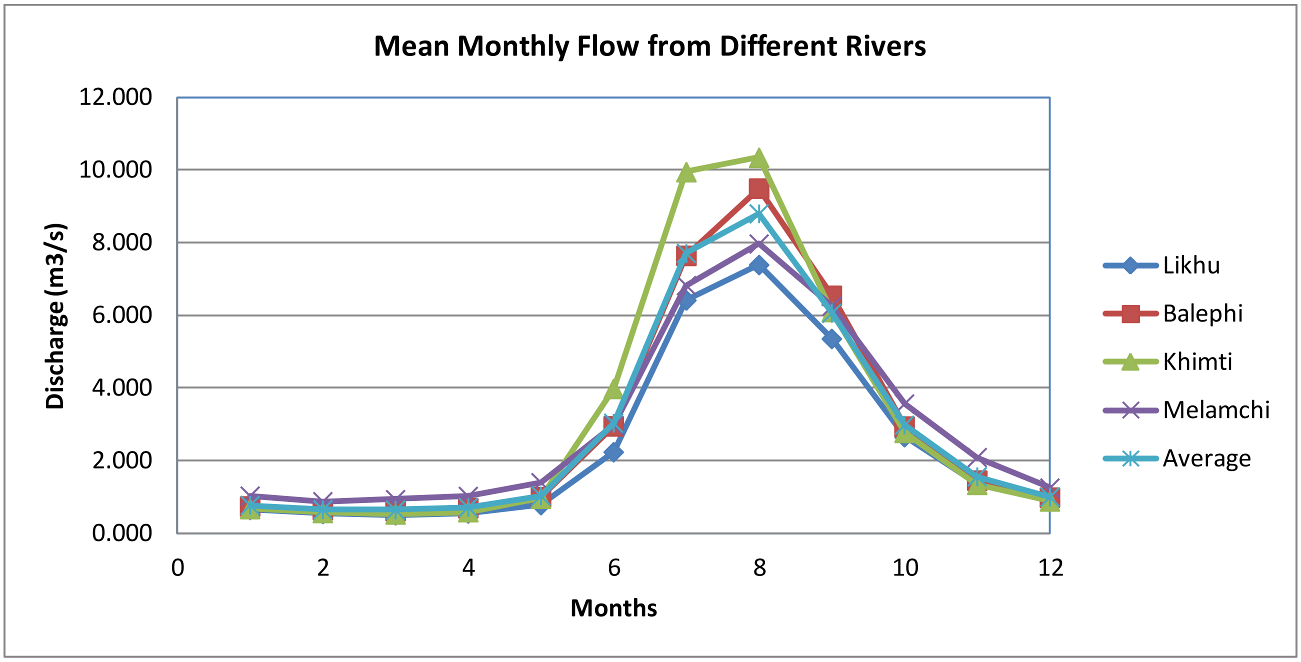


Figure 4-3: Comparative Mean Monthly Flow at Suri Intake by SCA method

4.6.3 MIP Method

The Medium Irrigation Project (MIP) method presents non-dimensional hydrographs of mean monthly flows for seven different physiographic regions of Nepal. This method is applicable to the ungauged sites. The measured flow is used with regional non-dimensional hydrograph to synthesize an annual hydrograph for the intake site. April flows are recommended to be as unit flow. However flows other than April are also used to generate annual flows by interpolation. Hence using the non dimensional hydrograph of Region-1 and the actual flow measured at Suri Khola intake, mean monthly flow at Suri intake have been calculated and listed below in the tabular form.

Table 4-10: Mean Monthly Flow at Suri Intake by MIP Method (m^3/s)

Months	19-Feb	23-Mar	16-Jan	9-Dec	17-Feb	23-Oct	11-Mar	15-Feb	8-Feb	22-Oct	Average
Jan	1.19	1.51	1.14	1.12	1.18	1.43	1.17	1.13	1.22	1.32	**1.24**
Feb	0.89	1.13	0.85	0.84	0.88	1.07	0.88	0.85	0.91	0.99	**0.93**
Mar	0.65	0.82	0.62	0.61	0.64	0.78	0.64	0.61	0.66	0.72	**0.68**
Apr	0.5	0.63	0.47	0.47	0.49	0.6	0.49	0.47	0.51	0.55	**0.52**
May	1.29	1.64	1.23	1.21	1.27	1.55	1.27	1.23	1.32	1.43	**1.34**
Jun	2.98	3.78	2.85	2.8	2.94	3.58	2.93	2.83	3.04	3.3	**3.10**

Jul	7.19	9.14	6.88	6.77	7.11	8.65	7.09	6.84	7.35	7.98	**7.50**
Aug	12.4	15.76	11.87	11.67	12.25	14.91	12.22	11.79	12.68	13.76	**12.93**
Sep	8.19	10.4	7.83	7.7	8.09	9.84	8.06	7.78	8.37	9.08	**8.53**
Oct	3.97	5.04	3.8	3.73	3.92	4.77	3.91	3.77	4.08	4.4	**4.14**
Nov	2.03	2.58	1.95	1.91	2.01	2.44	2	1.93	2.06	2.26	**2.12**
Dec	1.54	1.95	1.47	1.45	1.52	1.85	1.52	1.46	1.57	1.71	**1.60**

The graphical representation of the mean monthly flow obtained from different month measured flow by MIP method has been presented below in graphical form as well.

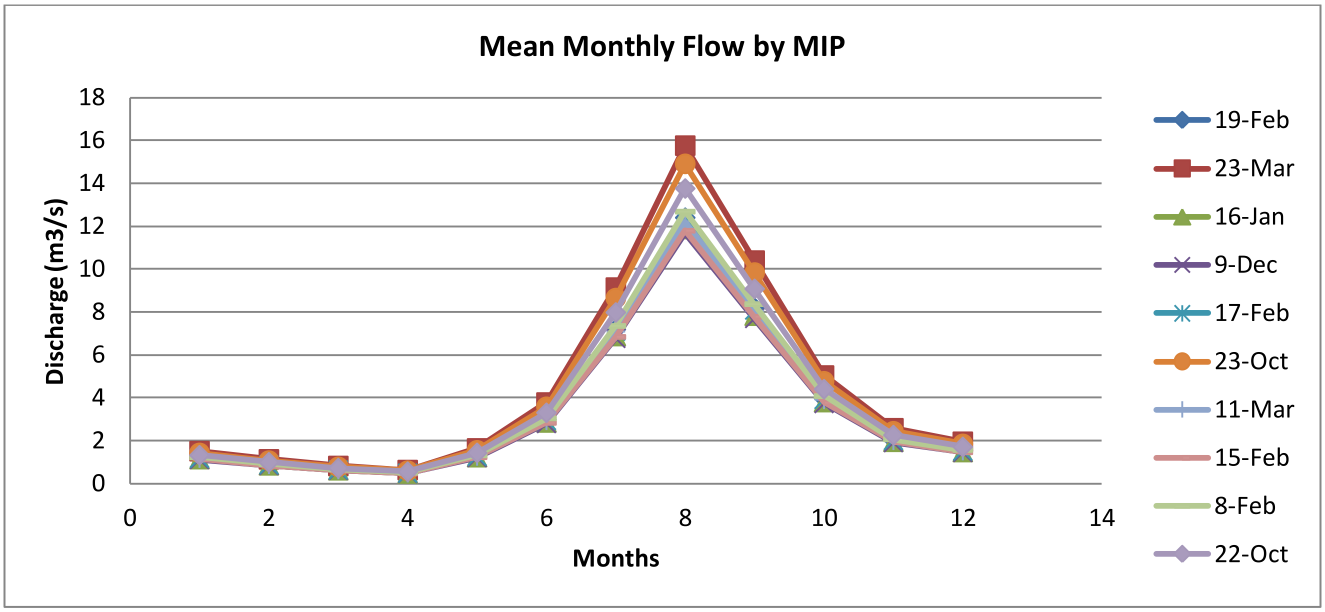


Figure 4-4: Mean monthly Flow by MIP Method from different measured flow

Finally average value from all the measured flow data has been considered as the mean monthly flow at Suri SHP intake by MIP Method.

4.6.4 WECS/DHM Method

A study on 'Methodologies for Estimating Hydrologic Characteristics of Ungauged Locations in Nepal' was published by WECS and DHM in July 1990. This study uses the approach of multiple regression equations relating the physiographic and climatologic characteristics of the selected basins to the average monthly flow values. All together twelve individual monthly regression equations were developed. For the complete hydrological analysis by this approach, the catchments area and its distribution in altitude are essential along with monsoon wetness index of catchments. The monsoon wetness index from the isoheytal map for Suri Khola catchment is about 1505 mm in present study, the monsoon wetness index is taken with respect to the average of nearest meteorological station which is at Naghdaha, Charikot, Jiri, Melung.

The total catchment area of the headwork site is 36.4 km^2 and the area below 5000 m is 36.4Km^2 and below 3000 is 26.73 Km^2. The monsoon wetness index for this analysis has been considered as 1505 mm. The following are the results from WECS/DHM method:

Table 4-11: Mean Monthly at Suri Intake by WECS/DHM Method (m^3/s)

Month	Mean Monthly Flow(m^3/s)
January	0.491
February	0.419
March	0.367
April	0.349
May	0.437
June	1.687
July	5.202
August	6.394
September	4.957
October	2.182
November	0.971
December	0.641

4.6.5 Actually Gauged and Measured Data

The company has established gauge station and daily gauge heights are recorded and discharge measurements are taken frequent basis. The mean monthly discharge is presented in Table.

Month	Mean Monthly Flow(m^3/s)
January	1.04
February	0.80
March	0.69
April	0.77
May	0.88
June	1.71
July	7.85
August	12.61
September	9.54
October	5.38
November	2.61
December	1.36

4.6.6 Summary, Comparison and Adoption of Mean Monthly Flow

Mean monthly flows of Suri Khola at intake site for Suri Khola Hydropower Project derived from various methods as mentioned above have been presented in tabular and graphical form.

Table 4-12: Summary of Mean Monthly Flows by Different Methods

Methods	MIP	Hydest	Actual	Modified Hydest	Regression	Catchment Area
Jan	1.24	0.49	1.04	0.96	1.48	0.77
Feb	0.93	0.42	0.80	0.82	1.24	0.65
Mar	0.68	0.37	0.69	0.87	1.30	0.64
Apr	0.52	0.35	0.77	0.65	1.38	0.71
May	1.34	0.44	0.88	0.67	1.73	1.03
Jun	3.10	1.69	1.71	2.76	4.21	3.03
Jul	7.50	5.20	7.85	6.76	9.68	7.70
Aug	12.93	6.39	12.61	10.09	10.72	8.80
Sep	8.53	4.96	9.54	7.02	8.19	6.06
Oct	4.14	2.18	5.38	3.44	5.69	2.98
Nov	2.12	0.97	2.61	1.67	2.93	1.56
Dec	1.60	0.64	1.36	1.16	1.77	1.00

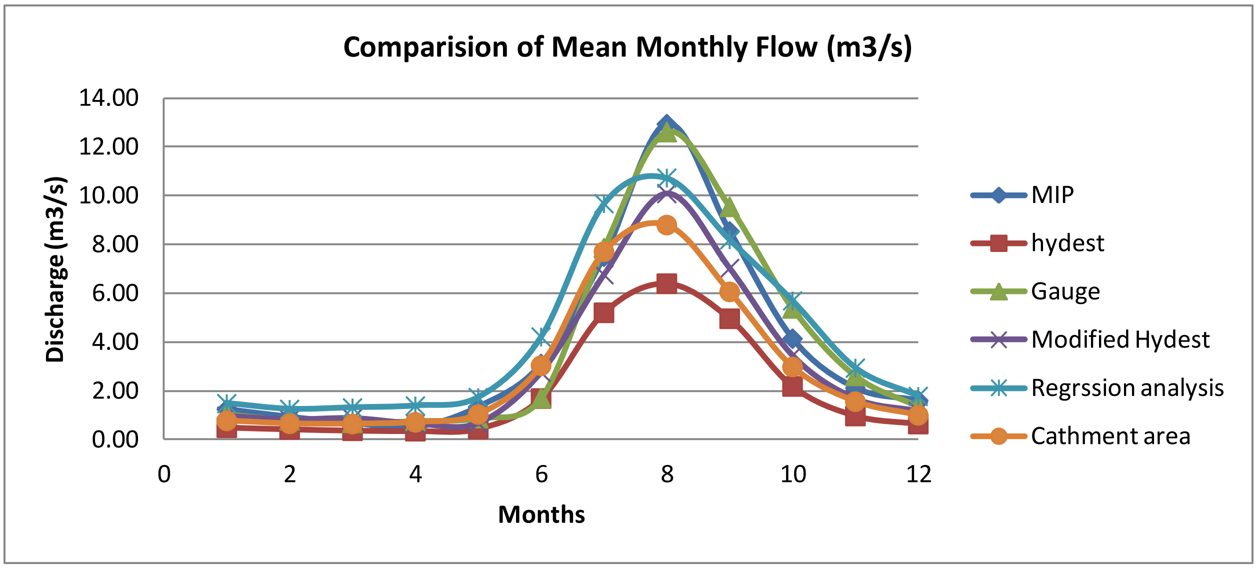


Figure 4-5: Comparative Summary of mean monthly flows (Suri Intake)

4.6.7 Adopted Mean Monthly Flow for Suri Intake

The long term mean monthly flows of Suri Khola for the power generation is adopted from actual measured discharge data. The recommended mean monthly flow at Suri intake is as follow.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Flow(m^3/s)	1.04	0.80	0.69	0.77	0.88	1.71	7.85	12.61	9.54	5.38	2.61	1.36

The mean annual discharge is 3.77 m^3/s. The recommendation criteria for mean monthly flow at Suri intake are;

- The company has established a gauging station at headworks site and records of daily gauge height was taken for last three/four years. Discharge was measured by using current meters during dry season of the year. At the time of feasibility study, there are very few data are available to analyse the discharge and prepare the long term data series by using these actually measured data. So at that time different indirect methods were used to predict the long term data series like catchment correlation with basin of similar characteristics, Hydest, Regional method etc. However, now we have discharge and gauge data of four years period which gives the real flow pattern of the river. The reliability of actually measured data would be definitely higher as compared to other indirect methods. So this method is adopted.
- Mean monthly flow calculated by MIP (Medium Irrigation Project) is the value obtained from the hydrograph representing the whole area in region. For such a small basin area and basin having snow contribution also, it may not give the reliable value and trend than other method.
- WECS/DHM method is also approximation method before measuring the real data in the site. Since we have measured data in intake site, adoption of discharge data by this method in this stage will be illogical.

4.7 FLOW DURATION CURVE

A flow duration curve (FDC) is a probability discharge curve that shows percentage of time a particular flow is equalled or exceeded. A FDC was developed in order to determine the dependable flow at proposed headworks site. Based on the long term data adopted at Suri intake, FDC at Suri intake has been determined by various methods such as;

The % exceedence discharge obtained by different methods have been presented below in tabular form as we as in graphical form.

Table 4-13: Percentage Exceedence Discharge by Different Method at Suri Intake

Percentile	MIP	Hydest	Actual	Regression	Catchment area
5%	12.22	13.53	16.86	10.15	8.96
10%	9.21	7.46	13.05	9.53	7.46
20%	7.22	3.85	7.38	7.69	6.19
40%	2.84	1.03	2.75	3.70	2.32
50%	1.92	0.77	1.53	2.35	1.35
60%	1.46	0.51	1.00	1.75	0.99
65%	1.28	0.47	0.93	1.69	0.94
80%	0.88	0.34	0.75	1.40	0.68
95%	0.51	0.21	0.68	1.28	0.54
100%	0.47	0.16	0.64	1.24	0.50

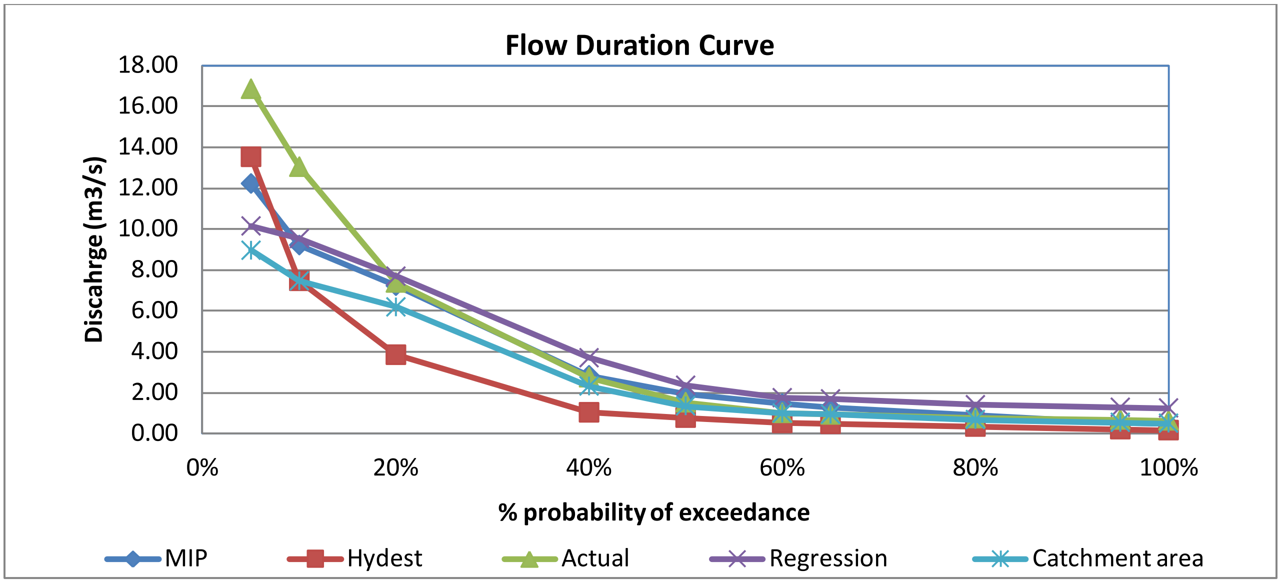


Figure 4-6: Flow duration curves from different method

The discharge at different probability of exceedance for Suri Khola at the proposed intake site obtained by different methods has slight variation with each other. However, FDC from actual measured data is adopted as final FDC for design. Since it has the average value in between largest by Regression and Lowest in MIP method, it is most reliable for design discharge of the project from Suri intake. As per the prudent practice for design discharge determination at 40% probability of exceedence, the design discharge of the project is 2.75 m^3/s.

4.8 RIPARIAN RELEASE

The long term mean monthly flow for the driest month, at Suri intake site is $0.69m^3/sec$. As a general practice, a flow equivalent to 10% of driest month that will be about $0.069m^3/sec$ which will be released downstream as the riparian release for fish and aquatic life.

4.9 DESIGN FLOODS

In hydropower projects, high floods are required for the design of the headwork as well as the power house structures. It has been a common practice to analyze the dry flow that occurs during the dry periods for the construction of headwork structures. Flood hydrology is analyzed in two parts- design floods for the design of headwork and other hydraulic structures and construction floods for diversion of flood during construction period.

High floods of different magnitudes are regular phenomena every year during summer monsoons. In Nepal, the flood season generally starts in first week of June and continues till mid of September. Recurring floods are the most often computed using the following approaches,

- Correlation method (flood analysis using Khimti Khola, G.S. 650)
- Regional flood frequency analysis
- Hydest (WECS/DHM) Method

4.9.1 Correlation method (flood analysis using Khimti Khola, G.S. 650)

The instantaneous flood data at the gauging station 650, Khimti Khola are used to carry out the frequency analuysis. Drainage area below 3000m gave the highest correlation for rain generated floods. The flood data from the year 1964 to 2006 are available ans transposed to the Suri Basin multiplying by 0.116 (taking catchment area ratio) to the flood data at the gauging station at 650. The available flood data at Khimti khola is shown in Table 4-14.

Table 4-14: Instantaneous Flood at Gauging Station 650 (CA 313 km^2)

Year	Data	Year	Data
1964	134	1986	920
1965	201	1987	1330
1966	236	1988	1120
1968	356	1989	511
1969	99.1	1990	665
1970	323	1991	654
1971	323	1992	2420
1972	189	1993	2620
1973	580	1994	2420
1974	556	1995	164
1975	428	1996	102
1976	1180	1997	102
1977	201	1998	198
1978	835	1999	81.8
1979	166	2000	239
1980	363	2001	255
1981	950	2002	102
1982	1890	2003	255
1983	2060	2004	118
1984	1090	2005	115
1985	1200	2006	97.5

The frequency distributions used are Gumbel I, Lognormal and 3P lognormal. The best fit distribution is “3P- lognormal” distribution. The 100-year flood with this distribution is 627m^3/s. The results of frequency analysis and the instantaneous data are shown in the Table 4-15.

Table 4-15: Results of Frequency Analysis

Period	Distribution		
	Gumbel I	Lognormal	3p-lognormal
5	141	133	136
10	186	211	259
20	228	308	446
50	283	472	829
100	**323**	**627**	**1258**
200	364	815	1842
500	418	1116	2938
1000	458	1393	4077
Rms error	37	36	114

4.9.2 Regional Flood Frequency Analysis

Most often for ungauged site, regional flood frequency analysis is used to estimate the floods. For the regional flood frequency analysis, the Koshi Bains is considered as a region. The total number of DHM hydrological stations in this basin is 13. They are shown in

Table 4-16: Major Hydrometric Gauging Station at Koshi Basin Region

Stationn No	Years of Record	River Name	Station Name
640	22	Roshi Khola	Panauti
650	15	Khimti Khola	Rasnaula village
610	24	Bhote Koshi	Barabise
620	29	Sabhya Khola	Jalbire
647	15	Tamakoshi	Busti
660	26	Likhu Khola	Sangutar
795	20	Kankai Mai	Mainachuli
670	26	Dudhkoshi	Rabuwa Bazar
604.5	15	Arun River	Turkeghat
630	27	Sun Koshi	Pachuwar Ghat
690	26	Tamur River	Mulghat
652	20	Sunkoshi	Khurkot
80	20	Sunkoshi	Kampughat

The logarithmic Multiple Linear Regression was carried out with respect to annual flood, drainage area and monsoon wetness index. Duration of instantaneous peak discharge recorded in these stations varies from 16 years to 24 years. To perform the regression analysis, at first, the flood frequency analyses at each individual station were carried out. The results of each flood frequency analysis at different return period were combined to do the regression analysis. The summary results of regression analysis are shown in Table 4-17 . The regional equation to estimate the flood at different return period has been developed as given below:

$Q= kA^b$

Where, A= area below 300 m in km^2

Q= flood at different return period m^3/s

K=regression constant at different return period

Table 4-17: Results of Regression Analysis

Return Period (Years)	Floods (m^3/s)	Eastern Region (Koshi Basin)	
5	113	7.4008	0.7862
20	178	13.0848	0.7535
50	227	17.6058	0.7380
100	268	21.5181	0.7281
1000	447	39.9035	0.6969
10000	710	69.7807	0.6695

Since the catchment area below 3000 m is about 26.73 km^2, the flood adopted in the design is 268 m^3/s. Similarly, the flood adopted at the powerhouse is about 565 m^3/s.

4.9.3 Flood Frequency Analysis Using WECS-DHM Method

Water and Energy Commission Secretariat in collaboration with DHM has developed a method for estimating Hydrology Characteristics of ungauged location in Nepal. This used the multiple regression method to estimate the flood at the ungauged location of Nepal. The distribution used in this method is two parameter log normal distribution. The output of WECS-DHM method is shown below in Table 4-18.

Table 4-18: Flood from Hydest (WECS-DHM) Method

Return Period (m^3/s)	Daily Flood (m^3/s)	Instantaneous Flood (m^3/s)
2	31	53
5	48	92
10	60	122
20	72	154
50	90	201
100	103	239
200	118	281
500	138	342
1000	154	392

4.10 DIVERSION FLOOD

Construction of a hydropower project requires the diversion of the river through a man-made channel to pass the dry season flood. This is a staged diversion that will be effected during the dry season from November to May. Thus a flood frequency analysis is required to determine the magnitude of floods for different return periods during that period. For this, the extreme daily peak floods during the period from November to May generated form Likhu for four years have been used for Gumbel distribution to obtain the floods in different return period. The values obtained have been listed below in table.

Table 4-19: Max flow (Among Nov- May) for four years, generated from Likhu (m^3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Aug	Sep	Oct	Nov	Dec
1996	5.0	4.1	3.6	2.7	6.1	28.5	83.8	84.7	69.2	21.0	8.4
2005	7.9	6.4	7.9	4.3	8.6	15.7	36.2	59.3	46.0	28.9	24.1
2003	4.6	3.4	2.2	9.4	22.6	30.1	46.5	46.2	55.5	34.4	5.4
1997	3.5	3.9	2.2	2.7	5.4	25.2	87.7	84.4	41.8	43.1	13.6

Table 4-20: Diversion Flood for Suri Khola at the Proposed Intake & Powerhouse Site

Return Period	Gumbel(m^3/s) Intake	Gumbel (m^3/s) PH
2.33	2	14
5	4	26
10	6	35
20	7	44
50	9	56

4.11 LOW FLOW ANALYSIS

For Low Flow analysis, WECS/DHM-Hydest method was used. Taking the Monsoon wetness index as 1504.6mm and Basin area at intake, the Low flow statistics obtained in Suri intake are in the following table.

Table 4-21: Low Flow Analysis (m^3/s)

Return Period (yrs)	Duration	Discharge(m^3/s)
2	1	0.26
	7	0.28
	30	0.38
	Monthly	0.44
10	1	0.09
	7	0.12
	30	0.21
	Monthly	0.26

20	1	0.05
	7	0.09
	30	0.18
	Monthly	0.23

4.12 SEDIMENT INVESTIGATION AND ANALYSIS

Sediment concentration and particle size distribution data used are required to design the settling basin. The cost of settling basin is based on the sediment load, which has to be flushed out at the time of power plant operation. Otherwise, sediment heavily damages the turbine blades, spiral casing, and other mechanical parts. For the preliminary design purpose, the analysis of sediment load is carried out using prevailing empirical methods – Himalayan Sediment Yield Technique, and Regional Analysis.

4.12.1 Sediment yield studies in Nepal

Middle Mountain zone experiences a wide range and different types of erosions. Pasture land is increasing and forests are being depleted for the use of fuel wood and fodder thus increasing surface erosion. The valley slopes are forested; however, landslides are quite frequent yielding considerable amounts of debris flowing into the river.

Sediment data and soil erosion rates which are reported in various literatures are listed below.

- Binnie, 1988 has estimated 177 tons per square kilometer per year for Kulekhani watershed.
- Bathymetric survey report of Phewa Lake at Pokhara, western Nepal, carried out by Bruijnzeel and Bremer during 1976 to 1979 has indicated the annual sediment yield could be 3700 tons per square kilometer per year.
- Sedimentation monitoring of Kulekhani reservoir (K.M. Sthapit, 1996) has indicated the sediment contribution rate as below:
- 1982 to 1993 :6.6 t/km^2/yr.
- 1993 Monsoon:51.84 t/km^2/yr
- 1994 Monsoon:9.12 t/km^2/yr.
- 1995 Monsoon:10.2 t/km^2/yr
- Reservoir survey of 45 reservoirs in India by CWC, 1991 has indicated that the annual sediment yield could range 20 to 4000 tons per square kilometer per year.
- The measured suspended sediment loads at the diversion structure for the Marsyangdi Hydro Project indicated a suspended sediment yield of 5185 t/km2/yr.
- The Koshi River, or the Sapta Koshi has a catchment area of 59,280 Km2 Sun Koshi, Tama Koshi, the Dudh Koshi, Arun and Tamur River lie within this river system.

Suspended sediment measurements data had been collected by the Indian Central Water Commission (CWC 1981) from 1948 to 1977.

- Galay, 1987 has quoted 8200 tons per square kilometer per year for Tamur river.
- The average annual soil losses from the main land uses were 0.48 ton/ha for irrigated terraces, 3.65 ton/ha for rain fed terraces, 1.86 ton/ha for grassland, 0.80 ton/ha for forested land, and 23.95 ton/ha for forest scrub and abandoned land. The combined average erosion rate was 5.55 ton/ha
- In Khimti I Hydropower Plant the maximum recorded sediment concentration is 8536 ppm. But 20000 ppm concentration was used for design of the sediment settling and flushing capacity.
- The average annual suspended sediment load of the Kali Gandaki Hydro Electrical Project was taken as 65 million tons for the design of civil and electromechanical components. The total load entering the sedimentation basin was considered as 5.9 million tons/year. However, due to the difference between the hydro-meteorological conditions of the Kali Gandaki River and the Solu River, this information was treated only as reference information and was not utilized for the further analysis.

Some Assumptions of the Suri Basin

- Watershed area mainly consists of forests, farms, grassland and terraced cultivation. Rainfall intensity is medium. Upper reach of the Suri Khola lies in high Himalayan region. River is fed by snow melt also and so the lean period flows are expected in appreciable quantities.
- The river bed near powerhouse and Intake site consists of boulders and cobbles. And there are rapids and falls. Sand and silt deposits in the river banks were seen in negligible amount at during field visit. River water seemed clear probably with low concentration of suspended sediments.
- Unless exceptional events occur, suspended sediment load in the river water would be low. However bed load transport that might be in sizes ranging from coarse gravels to small cobbles.
- Appropriate factors either of catchment area ratio (CAR) or of flow ratio which ever suitable is used to assess sediment yield from other rivers and areas.

4.12.2 Sediment Yield of Nepalese Rivers

Sediment yield of some of the Nepalese river basins are presented in Table below. These values should be taken as indicative of average basin yields, and little or no inference can be drawn on the spatial and temporal variation of sediment concentrations. However, the values can be taken for comparison in light of measurement taken during Feasibility Study in 1997-98 and the more recent measurements of 2008.

Table 4-22: Sediment Yield of Nepalese Rivers

River	Location	Watershed Area (km^2	Runoff (mm/y)	Sediment Yield ($t/km^2/y$)
Arun	Tribeni	36533		1430
Baghmati	Kathmandu	585		4552
Kali Gangaki	Setibeni	7130	1062	4173
Kankai Mai	Mainachuli (Site	1148	1593	4840
Karnali	Chisopani	42890		5130
Lothar Khola	Lothar (Site 470)	169	1866	3640
Narayani	Narayan Ghat (Site 450)	31100	1622	5684
Phewa	Chankapur	85		985
Rapti	Jalkundi (Site 360)	5150	845	2800
Seti	Banga near Belgaon (Site 260)	7460	1230	2802
Small streams	Kathmandu Valley	177		2199
Sun Kosi	Tribeni	19230		3950
Tamur	Tribeni	5900		8210
Tamur	Mulghat (Site 690)	5640	1756	10205
Trisuli	Betrawati	4110		1852
			max	10205
			min	985
			average	4163
			STD	2501

Source: FAO Website- http://www.fao.org/AG/AGL/aglw/sediment

**** Regional equations were tried to established from whole data series and from data of snow fed rivers only (Non snow fed river – Bagmati, Kankai, Lother, Phewa, Rapti,and small treams were taken out) and a. But the correlation coefficients are relatively poor on both cases and so an estimate from this approach is not considered.*

4.12.3 Estimate of Sediment Yield

Regional Studies

A regression equation determined by Sharma K.P. and Kansakar S.R. based on the sediment data of 12 river catchments that is recommended to the Middle Mountains and Siwaliks region is also used to assess the sediment transport. This equation is:

$$A_{sy}^{0.5} = -2.20092 + 0.05439(A_{rock})^{0.5} + 0.0748(A_{2000})^{0.5} + 0.05097(MWI)^{0.5}$$

Where,

A_{rock}= Area of rocky catchment above 2000m = 24.4 km^2

A_{2000}= Catchment area below 2000 m = 12 km^2

MWI= Monsoon Wetness Index =1505 mm

The calculation gives annual suspended sediment yield of 551,000 tons per year. With mean annual flow of 3.77m^3/s, the sediment concentration at headworks site is estimated maximum of 4634 parts per million (ppm).

Himalayan Sediment Yield Technique (HSYT)

Estimate of sediment yield of the Suri River was conducted by the Himalayan Sediment Yield Technique developed jointly by Medium Hydro-electric Study Project/ Canadian International Water Engineering Consultants (MHSP/CIWEC) in 1997. The Himalayan Sediment Yield Technique is used to estimate the sediment yield for a specific location on the main stream of a catchment. Briefly, this involves using an estimate of sediment yield from each physiographic region and multiplying the sediment yield by the appropriate area. An allowance is also made for landslides and the glacier lake outburst flood to obtain a total estimate of the basin sediment yield. Zone Specific Yield for elevations above 3000 m has been assumed as 1500 t/km^2/yr while that for elevations below 3000 m has been taken as 2000 t/km^2/yr

Table 4-23: Suspended Sediment Load of SKSHP by the Himalayan Technique

(km^2)	Area above 3000m (km^2)	Specific Yield (t/ km^2/yr)	Annual (tons/yr)	Area below 3000m (km^2)	Specific Yield (t/ km^2/yr)	Annual (tons/yr)	(t/ km^2)/yr)
177.8	9.67	1,500	14505	26.73	2,000	53460	1867

Estimation of Bed Load

The estimation of bed transport rates is complicated because of the difficulty in obtaining accurate measurements of bed load quantities from either theoretical or laboratory analyses. Instruments designed to measure the bed movement disturb the natural movements of the bed material thus introducing a bias into the measurements, and it is almost impossible to determine the magnitude of this bias. Simultaneous measurements often provide estimates that differ by several hundred percent. The difficulty arises because of an array of factors associated with variations in flow patterns, bed surface characteristics, and particle shape. While these difficulties are recognized, a number of estimation methods have been developed from the theoretical and laboratory analyses.

Bed load measurement data are almost nonexistent in Nepal. The bed load is the function of the sediment carrying capacity, which in turn depends on the flow velocity. Therefore, for steeply sloping mountainous rivers, the bed load component in percentage of the total load may be quite high.

The bed load is estimated as a percentage of the suspended sediment. In the upper Lesser Himalayas with steep slopes, the bed load is taken as 40 to 60 percentage of the suspended sediment load. Similarly, at the lower Lesser Himalayas, the bed load is taken as 5 to 15 percentage of the suspended sediment load (Schumm 1977, Galay et al 1995).

4.13 CONCLUSION AND RECOMMENDATION

- The average precipitation for the Suri Khola Basin is found 1923mm per year taking the average value of three stations eg Jiri, Charikot, and Nagdaha.
- Long-term mean monthly flow estimate from analysis carried out from actual measured data is recommended for power generation flow from Suri Khola.
- The Flow Duration curve generated from the daily flow series of actually measured data for Suri intake is recommended.
- The Q40% discharge at Suri intake will be 2.75m^3/s.
- The high flood has been estimated with reference to gauging station 650. The recommended design flood at 100 year return period is 268 m^3/s from.
- Construction flood at Suri intake and powerhouse will be 7.0m^3/s and 44.0m^3/s at respectively. For design of diversion, planning during construction, these discharges have to be used.
- The suspended sediment concentration during rainy season will be about 4634 PPM. However for design purpose, 5000ppm is recommended for safer side. It is strongly recommended that more suspended sediment and bed load sampling be carried out during rainy season and shall be updated this report.
- In Suri Khola basin, mica has the dominancy over quartz and other minerals. Since quartz content is significantly seen, design of settling should be done carefully so that quartz particle will be settled and washed out as far as possible.
- There should be regular monitoring and measurement of gauge data at the gauge station established.
- It is strongly recommended to measure the flow at Suri for least dry months so that the adopted mean monthly can be verified for confidence.

5 GEOLOGICAL AND GEOTECHNICAL STUDIES

5.1 INTRODUCTION

The proposed Suri Khola Hydropower Project is located in Dolakha district of central Nepal. The proposed project utilizes water from the Suri Khola that flows in the northeast to south west direction. Intake site for the proposed project is located about 1395m amsl at just downstream of the confluence of Hulak Khola with Kolun Khola. The powerhouse site for the proposed project is located at left bank of Suri Khola at Gurumphi village about 300m upstream from the confluence of Suri Khola and Khare Khola.

5.2 OBJECTIVES OF PRESENT STUDY

The main Objectives of the work are

- Preparation of detail geological and engineering geological map of the project area.
- Identification of hazardous zone in the project area

For this purpose, the following are the scope of the work:

- Conduct the detailed geological mapping on 1:25,000 scale of the project area with suitable cross section.
- Conduct the detail engineering geological map of the headworks, canal alignment and powerhouse and tailrace area.
- Identification of the soil type and estimation of thickness of the soil in the headworks, headrace canal alignment, penstock, powerhouse and tailrace area.
- Distribution of soil/rock on the topographical (survey) map.
- Locate the existing landslide at uphill and downhill side of the canal alignment and headworks and powerhouse area.
- Recommend the protection measure wherever applicable.
- Preparation of the report.

5.3 METHODOLOGY

The methodology adopted consisted of desk study and field investigation works. The initial desk study consisted of collection and interpretation of available geological reports, geological maps, aerial photographs, and topographical maps of the project area.

In field investigation works, a field reconnaissance survey was carried out to get information regarding the general layout of the project components. Geological route traverse in the project area and adjoining regions was conducted to assess the soil & rock types and orientation of discontinuities.

The engineering geological mapping was carried out in 1:1000 scale topographical maps. Finally, this geological report was prepared after the analysis and compilation of existing and field data.

5.4 REGIONAL GEOLOGY

The proposed project area of the Suri Khola Hydropower Project is located in the zone of Lesser Himalaya. The Lesser Himalaya is separated to the north by Main Central Thrust (MCT) from Higher Himalaya and to the south by Main Boundary Thrust (MBT) from Siwalik Group. The Siwalik Group is separated from the Terai Plain by Main Frontal Thrust (MFT). The Lesser Himalayan rock in the project area comprise of metamporphic rocks such as schist and gneiss are predominant in the project area. These rocks have been correlated with the Seti and Ulleri Formation in the Midland Zone of the Central Nepal.

Broadly, Nepal has been divided into five lithologic units, from north to south. They are Tibetan Tethys unit, Higher Himalayan unit, Lesser Himalayan unit, Siwalik unit and Terai plain. The Tibetan Tethys unit exposes only occasionally 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 is composed of sedimentary rocks such as shale, limestone and sandstone ranging in age from Lower Paleozoic to Paleogene.

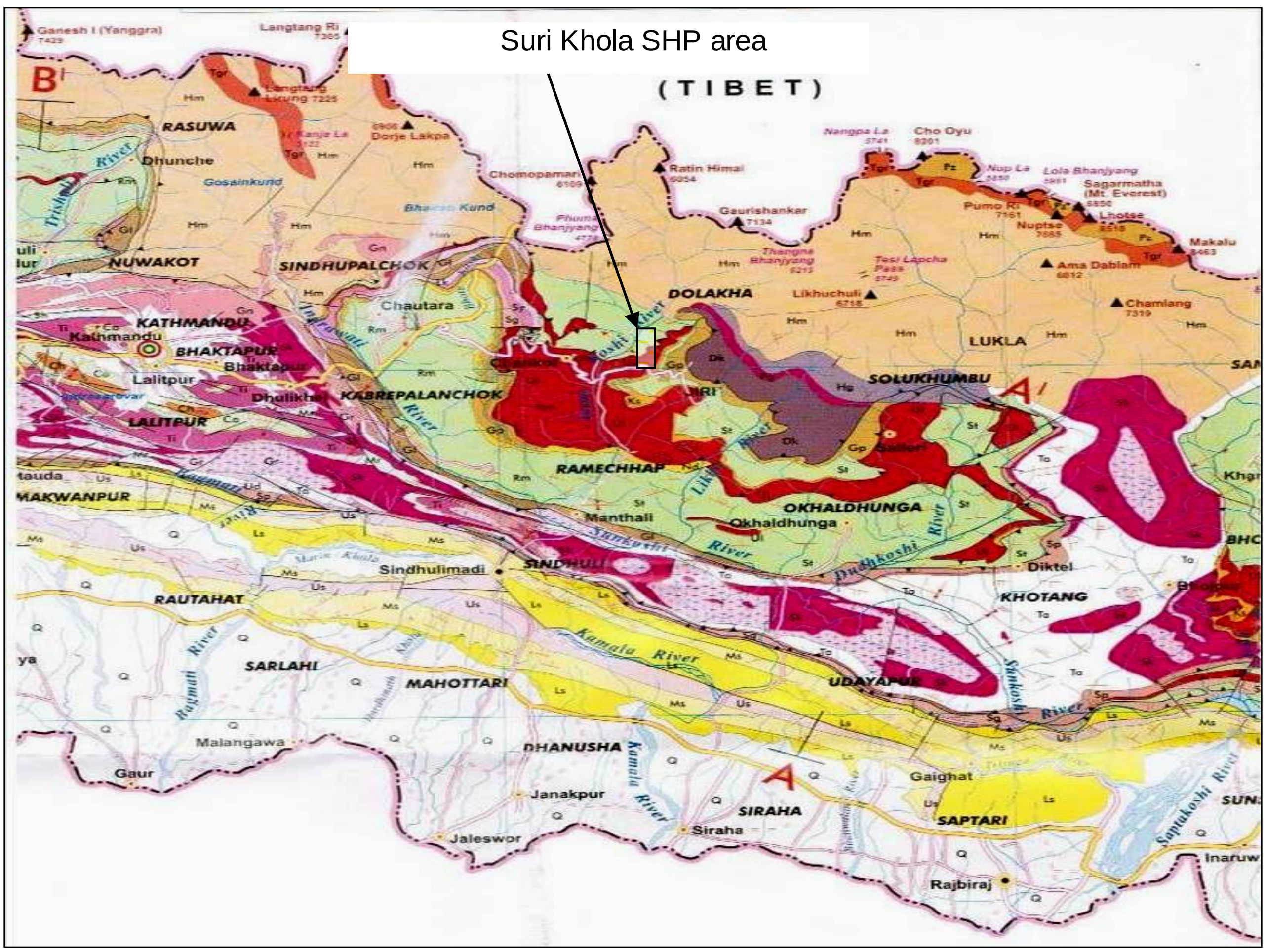


Figure 5-1: Location of project area in regional geological map

The Higher Himalayan Unit include the rocks lying north of the MCT and below the fossiliferous Tibetan-Tethys Zone. This zone consists of an approximately 10km thick succession of crystalline rocks also known as the Tibetan Slab. The crystalline unit of the higher Himalaya extends continuously along the entire length of the country and its width varies from place to place. The high-grade kyanite-sillimanite bearing gneisses, schists and marbles of the zone form the basement of the Tibetan Tethys zone. Granites are found in the upper part of the unit.

The Lesser Himalayan Zone is bordered in the south by the MBT and in the north by the Main Central Thrust (MCT). The Lesser Himalayan rocks throughout the Himalayas consist of two sequences: allochthonus and autochthonus. The MBT itself is a fault zone that has brought older Lesser Himalayan rocks over the Siwalik. The Lesser Himalayas are mostly comprised of unfossiliferous, sedimentary and meta-sedimentary rocks such as slate, phyllite, schist, quartzite, limestone, dolomite etc. ranging in age from Precambrian to Eocene. There are also some granitic intrusions in this zone.

The Suri Khola Hydropower project area lies in the Lesser Himalayan Unit of the Central Nepal. The gneiss and schists are the main rock types present in the project area. Detail geology of the project area has been presented in respective chapter – geology of the project area.

The Siwalik is bounded in the north by the Main Boundary Thrust (MBT) and in the south by the Main Frontal Thrust (MFT). It consists basically of fluvial deposits of the Neogene age. The Lower Siwalik consists of finely laminated sandstone, siltstone and mudstone. The middle Siwalik are comprised of medium to coarse grained salt and pepper type sandstones. The Upper Siwalik is comprised of conglomerates and boulder beds. The dun valleys within the Siwalik consist of Quaternary fluvial sediments.

The Terai zone represents the northern edge of the Indo-Gangetic alluvial plain and is the southernmost tectonic division of Nepal. Though physiographically this zone does not belong to the main part of the Himalayas, it is a foreland basin and owes its origin to the rise of the Himalayas, it is thus genetically related. To the north, this zone is often delineated by an active fault, the main Frontal Thrust (MFT). The Siwalik rocks are found to rest over the sediments of the Terai in many places along this thrust. The Terai is covered by Pleistocene to recent alluvium. The average thickness of the alluvium is about 1500m. The basement topography of the Terai is not uniform. The Terai region contributes significant quantity of good quality construction material and groundwater in Nepal.

5.5 GENERAL GEOLOGY OF PROJECT AREA

5.5.1 Geomorphology

The project area comprises of river terraces of Suri Khola and rock outcrops. The slopes at areas of rock outcrops are moderate to steep .The river terraces are confined to the banks of the Suri Khola. The main landforms observed in the project area are following:

5.5.2 River Terraces

Two levels of terraces can be well distinguished in the project area. The height of lower level terrace is 7 m in average from the river bed in the project area whereas the upper level terrace is more than 10 m high. The lower terrace is varying in width from almost few meters to more than 50 m in the project area. At some reaches, only the lower terrace is present.

5.5.3 Recent Riverbeds

Recent riverbeds are seen in the Suri Khola. Some tributaries are reworking the gravels of the older terrace deposits and smaller fan deposits can be clearly seen at the mouth of tributaries. Some meandering belts of Suri Khola and Khare Khola consist of sand deposits.

5.5.4 Geological Formation

The project area consists of interbedding sequence of foliated gneiss, phyllites and schists. In most of the areas, schists are undulated, thin to medium bedded, wavy continuous, fractured and jointed, slightly to moderately weathered grey, light grey to greenish grey in colour. Quartz veins are present in most of the exposure which are randomly folded and discontinuous. The rocks are dipping, in general, with dip angles varying from 20^0 to 40^0 towards NE

5.6 SEISMICITY

The seismic activity in the Himalaya is experienced because of northward movement of Indian Plate along the sub-horizontal decollement, which is known as Main Himalaya Thrust (MHT). The MCT coincide with the Mean Frontal Thrust (MFT) in the south, MBT below Lesser Himalaya roots along MCT beneath the High Himalaya and southern Tibet. Convergence rate of the Indian Plate in the Himalaya region is estimated about 20 mm/yr. The magnitude and recurrence of Himalayan earthquakes depend upon the geometry and velocity of the Indian plate with respect to the Tibetan Plate.

Historical data shows that four great and large earthquakes have occurred in the last century due to the sudden release of accumulated stresses in the active geological fault of the Himalaya. The 1934 Bihar-Nepal earthquake was one among the four great earthquakes of the whole Himalaya with the magnitude of 8.3. National Seismological Centre (Department of Mines and geology, 2006) have been recording small to medium sized earthquakes that frequently occurring in the territory of the Nepal. Now a day's seismicity and the Historical records indicate that the Himalaya has experienced recurrence of the large earthquake. Earthquake epicentre map Nepal shows that medium sized earthquakes (6 to7 magnitude) are mostly confined to the MHT between the foot hills and the Higher Himalaya in Figure 5.2. The data of the recorded earthquakes during the period between1994 and 2000 indicate that the average frequency of the earthquakes of $5<M<6$ in the mid-west Nepal is two per year, however, the recurrence rate of earthquake $6<M<7$ is lower i.e. one in six year.

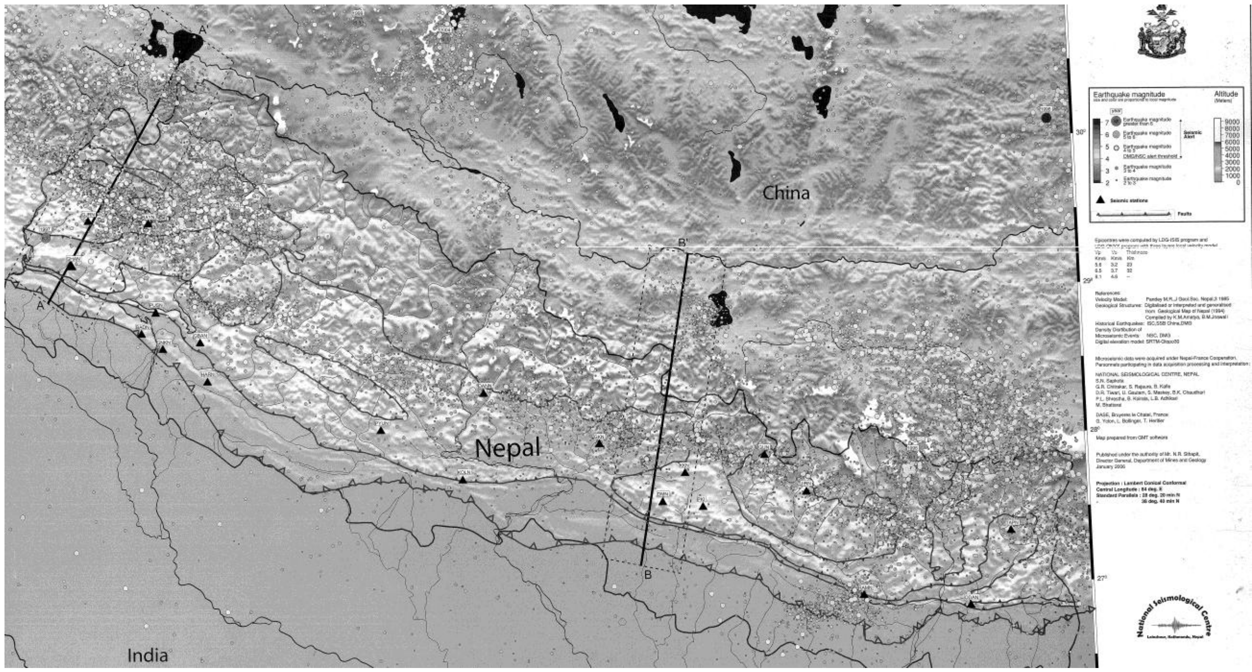


Figure 5.2: Earthquake epicentres map of Nepal Himalaya (DMG, 2006)

The evaluation of seismic coefficient for the Suri Khola Hydropower Project is made during the present study of based on Nepalese standard. In order to determine the seismic coefficient a seismic design code for prepared. The project area located on the third seismic zone, Therefore, the basic horizontal seismic coefficient is considered to be 0.08. By using the above empirical method, the effective design coefficient according to the seismic design code of Nepal is given by the equation,

α_{eff} = R* α =R* A_{max}/980

Where, α_{eff} =effective design seismic coefficient

R =Reduction factors (empirical value of R = 0.5 – 0.65)

For the maximum acceleration of 250 – 300 gal according to seismic hazard map of Nepal in Fig 5.3, published by DMG, National seismological centre and reduce factors 0.55 the effective design seismic coefficient of Suri Khola is 0.14 to 0.16

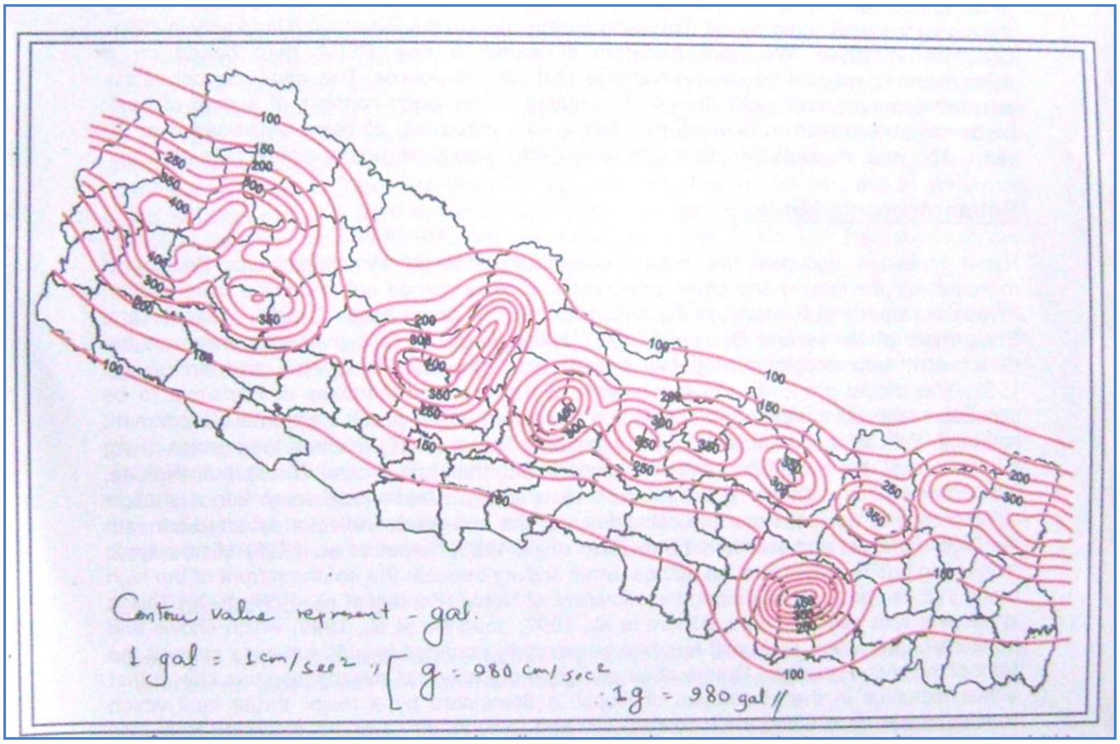


Figure 5.3: Location of project area in seismic hazard map of Nepal (Department of mines and Geology, GoN - 2002)

5.7 GEOLOGY OF PROJECT AREA

The project area lies in the Lesser Himalayan zone represented by Jiri Metasediment Zone consisting of Phyllite, schist and quartzite. Structurally, Tama Koshi window exposes mainly lithological units in this region. Most of the area is covered by colluvial deposits with thickness varying from 2m to about 20 m. There are many wetland zones along the project alignment. Outcrop of rock is very less exposed at this site. Discontinuities associated with the rock mass show possibility of wedge failure. There are many vulnerable massive rock blocks in the hill slope. Geo-mechanical classification for the rock mass of the project site was carried out using CSIR classification Based on detailed surface joint mapping on exposed rock outcrops. The classification showed the rock quality vary from fair to poor rock belonging to class III to IV type. Morpho-structural analysis has been done on the basis of data on rock discountinuities and the direction of slope. Systematic measurement of planar structures such as foliations, joints and other discontinuities were done at different locations along the project site. Using the dips software, discontinuities were analysed in lower hemisphere projection of equal are net.

5.7.1 Headworks site

The proposed diversion weir site lies at the confluence of Hulak Khola with Kolun Khola. At the proposed weir site river valley is about 40m wide across. The proposed weir/intake lies at narrow valley at an elevation of 1395m amsl. Gradient of the stream is very high. The left abutment of weir will be founded on alluvial deposit. The thickness of alluvial deposit on the left abutment is expected about 20m. The right abutment of the weir will be founded on fresh to shightly weathered. Medium grained, thinly to moderately foliated, strong to moderately strong, quartizite schist.

Photo: 3.1: Weir Location

The foundation condition of the headworks site was investigated mainly by the geological mapping. Bedrock outcrop is exposed on the right bank at uphill slope only. The river is smoothly covered by big boulders of quartzitic schist and quartzite across the weir axis. The local topography and geology indicates the slightly deep bedrock profile at the river channel. The river channel consists mainly of the river alluvium, which is estimated to be about 10m thick at river bed. The boulder, cobbles gravel and sand represent the alluvium deposit. The river alluvium is considered to be highly permeable.

5.7.2 Settling Basin

The proposed site of settling basin is covered by colluvial deposit. The foundation for the proposed location of settling basin is expected to be covered by mixed alluvial and colluvial deposit underlying the schist. The deposit comprises sub rounded boulders of schist and quartzite imbedded in medium cohesive brownish grey coloured silty clay. The flushing duct and gate are also located in the same terrain. Bedrock at settling basin can be expected to be found at about 12m depth. Slope of the terrain is about 20^o to 30^o. This relatively gentle section is about 80 m wide across and about 300 m length.

In general, the river alluvium is considered to be medium dense to loose in nature. The material is considered to be moderately permeable. The bearing capacity of such material for the design purpose can be taken as moderate. This zone needs to be protected by proper river training works, retaining structures and bioengineering works.

Photo 3-2: Settling Basin Area

5.7.3 Water Conveyance System

The steel headrace sum penstock steel pipe is proposed as water conveyance system of this project. The 1.3 m diameter steel pipe is of 3384m long and it is located on the right bank initially and crosses Suri khola and follows the left bank. Geological mapping was carried out throughout the alignment and geological information was plotted in the 1:1000 scale topographical maps. The pipe alignment passes through forests, rock cliffs, in and out of streams. The geological condition of the pipe alignment changes at different places. Pipe alignment is mostly covered by colluvium deposits with exposures of silverly grey to dark greenish grey coloured quartzitic schist generally exposed along the river crossings and steep rock cloffs. It is estimated from the mapping that the maximum thickness of the colluvial deposit is about 40m. The colluvial deposit mainly consists of angular to sub-angular boulders of schist, quartzite and phyllite.

Photo 3-3: Pipe Alignment

The change wise description along the pipe alignment is described below.

Chainage 0+00 m to 1+300 m

This portion of the pipe alignment will be excavated mostly in colluviual deposit with alluvial deposit in the initial portion of the alignment. The alluvial deposit comprises rounded to sub rounded boulders to pebbles of schist, gneiss, phyllite ad quartzitic phyllite in sandy-silty matrix. The colluvial seposit mainly consists of angular to subangular fragments and blocks of schist and physsite embedded in brownish grey coloured cohesive silty clay. The slope of the terrain in this segment is less than 40o. Besides, the occurrence of some big rock boulders along the alignment, no major geological instabilities were observed in this section. There are many small streams flowing out at this section. Rock boulders in this stream and hill slope can be used as the construction materials. At some locations the pipe alignment passes through the swamp zone. So, due consideration should be given in controlling the hydro-geological conditions at these zones and soil need to be treated. A stream crossing is proposed to change the initial alignment along right bank to left bank. The geological condition of the crossing is similar to weir axis. The pipe should be embedded to sufficient depth below the scoring depth of the river. The river training and bank protection works should be done to protect during high flood condition. The rock type found in this section is dark silvery grey to light greenish grey schist having quartz veins inter foliated with quartzite. The thinly to moderately foliated rock is strong with tight to moderately open joints in filled by soft infillings. Rock Mass rating (RMR) value of the rock at this section has shown the rating value about 33-59. This value indicates that the rock mass at this section can be categorized as Class III to Class IV type with description of fair to poor rock.

The major discontinuities at this zone are given as:

Foliation: $30^o/150^o$ (Dip Amount/Dip Direction)
Joint: $75^o/25^o$
Joint: $60^o/110^o$

<u>Chainage 1+300 m to 2+400 m</u>

This portion of the pipe alignment will be excavated in colluvial deposit. The colluvial deposit mainly consists of angular to sub angular fragments and blocks of schist and phyllite embedded in brownish grey coloured cohesive silty clay. The slope of the terrain in this segment is less than 40^o. The rock outcrop found in this section is steep. Rock type is dark to light greenish grey quartzitic schist having very long quartz veins. The thinly to moderately foliated rock is strong with tight to moderately open joints in filled by soft infillings. Rock Mass rating (RMR) value of the rock at this section has shown the rating value about 42. This value indicates that the rock mass at this section can be categorized as Class III type with description of fair rock.

The major discontinuities at this zone are given as:

Foliation: $30^o/115^o$ (Dip Amount/Dip Direction)
Joint: $80^o/25^o$
Joint: $75^o/250^o$

<u>Chainage 2+400 m to 3+200 m</u>

This portion of the pipe alignment will be excavated partly on colluvial deposit and partly in the bedrock. The colluvial deposit mainly consists of angular to sub-angular fragments and blocks of schist and phyllite embedded in brownish grey coloured cohesive silty soil. No major geological instabilities were observed. There are many small streams flowing out at this section. The slope of the terrain in this segment is less than 30^o. The rock outcrop found in this section is moderate. Rock type is dark to light greenish grey quartzitic schist having very long quartz veins. The thinly to moderately foliated rock is strong with tight to moderately open joints in filled by soft infillings. Rock Mass rating (RMR) value of the rock at this section has shown the rating value about 50. This value indicates that the rock mass at this section can be categorized as Class III type with description of fair rock.

The major discontinuities at this zone are given as:

Foliation: $15\text{-}20^o/155^o$ (Dip Amount/Dip Direction)
Joint: $80^o/25^o$
Joint: $75^o/250^o$

<u>Chainage 3+200 m to 3+384 m</u>

This portion of the pipe alignment will be excavated partly on colluvial deposit and partly in the alluvial deposit. The colluvial deposit mainly consists of angular to sub-angular fragments and blocks of schist and phyllite embedded in brownish grey coloured cohesive silty soil. The slope of the terrain in this segment is less than 20°. No major geological instabilities were observed.

The major discontinuities at this zone are given as:

Foliation: 15-20°/155° (Dip Amount/Dip Direction)
Joint: 49°/178°
Joint: 77°/74°

The joints are generally tight to open with slightly rough to smooth joint surface in filled by clay. The go-mechanical classification for the bedrock exposed on the hill slope of the powerhouse site was carried out based on detailed surface joint mapping using CSIR classification. Rock Mass Rating (RMR) value of the rock at this location varies from 34 to 52. This values indicates that the rock mass can be categorized as a Class III type fair rock to Class IV poor rock.

5.7.4 Powerhouse

The surface powerhouse has been proposed on left bank of Suri Khola at about 300 m upstream from the confluence of Suri Khola with Khare Khola. The proposed site is flat agricultural land which comprises of old alluvial deposit of big boulders of gneiss, schist and quartzite embedded in clayey silty sand. The upper part of the terrain is covered by colluvial deposit which comprises of schist and quartzitic schist embedded in silty clay. The area is about 35 m wide across and about 100 m long. Proper river training works need to be done to protect the river bank slope.

Foundations

The foundation condition of the powerhouse site was investigated mainly by the geological mapping. Bedrock outcrop is exposed on the left bank of Suri Khola at the opposite hill slope. The river bank is mostly covered by alluvial deposit. The local topography and geology indicates the deep bedrock profile at the river channel. The bank is mostly covered by alluvial deposit. The river channel consists mainly of the river alluvium, which is estimated to be about 15 to 30 m thick at river bed. The river alluvium is considered to be highly permeable. But the bearing capacity for the foundation of the powerhouse seems to be allowable. Depth to bed rock is expected to be about 10m below the power house foundation.

5.8 CONSTRUCTION MATERIAL SURVEY

Various naturally available materials such as impervious core material for cofferdam, coarse and fine aggregates, riprap materials are required for the construction of the project structures. Construction material sites are observed mostly along the both banks of Khare Khola within the stretch of project area. From the field observation three major potential sites are investigated along with some probable quarry site for construction materials. The right old fluvial deposit of Khare Khola just opposite site of powerhouse area and left bank fluvial deposit about 200 m upstream from the confluence of Suri Khola with Khare would be major site for coarse aggregate and as well as for significant volume of sand. The river boulders can be collected from Suri Khola but sand aggregates are not available in this stream. So the major source for the construction material is from Khare Khola in upstream and downstream area from proposed powerhouse location.

Figure 5-4: Potential site for construction material in old and recent river deposit D/S of power house area

Figure 5-5: Construction material in recent river deposit at Tamakoshi River

5.8.1 Tests of Construction Materials

Akara Materials Testing Laboratory Pvt. Ltd. has conducted the test on the construction materials collected from different location of Suri Khola Hydropower Project. Different test performed are described below in separate heading.

<u>Los Angles Abrasion Test (LAA)</u>

The Los Angeles abrasion test (LAA) is a test used to indicate aggregate toughness and abrasion characteristics. Aggregate abrasion characteristics are important because the constituent aggregate in concrete must resist crushing, degradation and disintegration in order to produce a high quality. The standard test subjects a coarse aggregate sample to abrasion, impact, and grinding in a rotating steel drum containing a specified number of steel spheres.

$$Loss = \left(\frac{M_{original} - M_{final}}{M_{original}} \right) \times 100$$

The test result shows that the LAA value as 41.9%. This is the marginal value. For road and bride construction, LAA value less than 45% is accepted. Considering the same standard in hydropower project, the material tested has the marginal value of LAA.

This shows marginal use possible form random sample. For special use the processing like selecting, cleaning, sieving, and grading is necessary. The crusher plant feed needs to be selected for the water retaining structures. For mass concreting and lean concrete such material shall be limited in common. Great care should be taken during collection of boulders for crushing to get aggregate to gain high strength.

<u>Specific Gravity and Water Absorption</u>

Specific gravity is a measure of density (mass per unit volume) of material as compared to the density of water. Water absorption, which is also determined by the same test procedure, is a measure of the amount of water that an aggregate can absorb into its pore structure. 4 samples tests of coarse as well as fine aggregate (As per IS 2386 part III) were performed in lab. The average specific gravity of coarse aggregate for all samples is found around 2.7 and average water absorption for the sample is found varying from 0.757% to 1.215%.

For fine aggregate more near about same specific gravity and little more water absorption are found. As per standard of road and bridge the water absorption should be less than 2%. Hence the test result is satisfactory however great care in selection crushing of material should be taken during construction stage. Also the specific gravity of both coarse and fine aggregate is also good. Brief detail of result has been summarized in w table 5.1 below.

Table 5-1: Summary of the tests on Specific Gravity and Absorption

SN	Particulars	D/s of power house Area	PH Area	Tamakoshi River
Coarse Aggregates				
1	Average Specific Gravity (oven dried)	2.691	2.674	2.682

2	Average Specific Gravity (Saturated Surface Dried)	2.747	2.700	2.707
3	Average Apparent Specific Gravity	2.747	2.744	2.752
4	Average Water Absorption	0.757%	0.95%	0.958%
Fine Aggregates				
1	Average Specific Gravity (oven dried)	2.601	2.622	2.582
2	Average Specific Gravity (Saturated Surface Dried)	2.747	2.660	2.618
3	Average Apparent Specific Gravity	2.747	2.724	2.677
4	Average Water Absorption	1.302%	1.42%	1.368%

<u>Grain Size Distribution: Sieve Analysis</u>

A sieve analysis is a procedure used to assess the particle size distribution of a granular material. Grain size distribution is often of critical importance in construction material choice and its use. The test result shows that all samples taken as fine and coarse aggregate are suitable to use in construction of the project. The brief summary of result has been presented below in Table 5.2 below.

Table 5-2: Summary of the tests on sieve analysis

SN	Particulars	D/s of power house	Power house area	Tamakoshi River
1	% finer than 4.75 mm in total sample	70.45%	65.56%	49.27%
2	% of particles larger than 4.75 mm in total sample	29.55%	34.44%	50.73%
3	Fineness modulus	2.19	2.95	2.85

5.9 CONCLUSIONS AND RECOMMENDATIONS

Based on present geological study following conclusions and recommendations have been made.

<u>Conclusions</u>

- Headworks constitute a diversion weir and intake. The diversion weir will be founded on alluvial deposit. Other structures will be founded partly on alluvial and colluvial soil.
- The settling basin will also be excavated on alluvial deposit. The soil in the proposed settling basin area is medium dense, boulder mixed soil.
- Two types of rock mass have been mapped along the alignment – schist and phyllite. Mostly pipe alignment passes through colluvial deposits.
- The powerhouse will be founded on alluvial deposit on left bank – Suri Khola. Depth to bed rock is expected to be about 10m below the power house foundation.
- Sufficient amount of fine and coarse aggregates are available at the bank of Khare Khola and Tamakoshi River but they need to be selected and processed.
- The sample test result shows that the coarse and fine aggregate found are to be limited for the use on high strength concrete and hence selected stone to be used either during

collection or from quarry for the use in crusher plant. The random river bed material is only useful for lean concrete.

Recommendations

Although DoED guideline indicates, Geotechnical Investigations like Drilling and ERT to be done for projects >10MW capacity, this project has mainly surface components with pipe option and none of the location is found having very doubtful geology so that really prevents planning the project within prescribed boundary or imparts project in risk without having a drill hole information. The capacity of the project is also below 10 MW. Hence the drilling is not carried out. However, if possible 2D ERT on headworks and powerhouse site would be beneficial for the project to improve the confidence level from geological point of view.

6 PROJECT DESIGN AND DESCRIPTION

6.1 GENERAL

The proposed Suri Khola Hydropower Project is a run-of-the-river type project with major components comprising of diversion weir, undersluice, intake cum gravel trap, connecting canal, settling basin, headpond, penstock pipe, powerhouse and tailrace. Detail description on these components is discussed in below sub-headings.

This layout has been confirmed based on the field visits and study findings. The layout of project is shown in DWG No. SKHP–10-F01 in volume II: Drawings.

The Weir crest level is fixed at an elev ation of 1395.0 m amsl and turbine axis level is fixed at an elevation of 1113 m amsl. Thus gross head for this new project layout is computed as 282.0m.

Headworks components lie in right bank of Suri Khola. Construction road to be constructed by the company starts from Suri Dovan to Headworks.

6.2 CIVIL WORKS

6.2.1 Headworks

The diversion weir, side intake, gravel trap with flushing culvert, approach canal with spillway, settling basin and head pond are the major components of the headworks. The headworks has been designed based on the following design criteria and assumptions. It is importantly necessary for all the components to be hydraulically, structurally and geo-technically stable.

Design criteria

Bed control at the intake. No build of bed load at intake opening site

Safe passage of hazard floods, i. e. free overflow weir is required

Safe passage of floating debris without blockage at the intake openings

Gates are to be avoided as far as possible

Assumptions

100 years return period flood considered for designing intake and floodwall

Design discharge of 2.75 m^3/s is considered for design of hydraulic structures of the project.

It is assumed that 90% sediment exclusion (0.15 mm size particles) from the settling basin will be achieved. All suspended sediment larger than 0.15 mm shall be flushed back to the river.

Conventional hydraulic flushing

- **River Diversion**

Temporary diversion of Suri Khola is required to facilitate the construction of the headwork structures of the project. As the headworks structures are planned to be constructed in dry seasons of the year, the river diversion scheme during construction is designed for a return period of 1 in 20 years dry season flood. The diversion of the river at the proposed headworks site will be carried out in single stage.

During the dry season of the first year of the construction, the river flow will be diverted to the left part of the river by construction of a cofferdam along and across the river. During this period, concrete weir, cutoff walls, boulder riprap in between cutoff walls, side protection wall and intake will be constructed. After construction of all structures, cofferdams will be demolished and levelled up to the designed shape and size. The channel made for river diversion will then be filled by riverbed material and guide wall will be constructed accordingly. River flow will be diverted to original water course where construction of weir and intake has already been completed. It is assumed that the construction of weir and intake can be completed within one working season of a year.

The cofferdams are gravity type with impervious core inside and excavated shell materials in outside with boulder aprons in upstream and downstream faces. Main features of the cofferdams are as follows:

Height of dam: 2.0 m above river bed

Top Width: 1.0 m

Side Slopes: 1V:1.5 H

Length of cofferdam: 119.58 m

- **Diversion weir**

Function of weir is to divert the desired flow to the intake with minimal sediment. Thus as diversion obstruction across the river is designed to divert the flow to the intake and an under sluice is embodied in the weir to scour the sediment in front of the intake. The design criteria and outputs are described in the following paragraphs.

Concrete weir with 30 cm thick hard stone lining (in 1:2 cement sand mortar) at top is designed for this project. The weir is divided into two parts by 20.734 m long divide wall of 0.75 m width. One is 2.5 m wide under sluice and another is 16.75 long spillway. The divide wall of 20.73 m long and 0.75 m width is made up of C25 RCC. The rounded portion of divide wall is lined with mild steel at u/s and d/s. The top elevation of divide wall at u/s side is 1398.40 m amsl whereas 1394.30 at d/s side.

The weir is designed to pass 100 years return period flood of 167 m3/s safely and the flood wall is designed to pass 100 years return period flood. The top elevation of flood wall at u/s of weir is taken as 1398.40 m amsl including 50 cm free board. The Spillway part of weir is 16.75 m long and consists of 40% plum concrete encased by 50 cm thick C25 RCC slab. The elevation of crest of weir is at 1395 m amsl. The elevation of upstream platform of under sluice is 1392 m amsl.

The weir consists of 11.0 m long and 20.0 m wide stilling basin. The top elevation of stilling basin is 1390 m amsl. The stilling basin of weir consists of boulder lined and infilled with C25 concrete into voids and Boulders are laid on 50 cm thick RCC slab and protected by a end toe wall.

The under sluice consists of 1 nos. of gate of size 2.50 m X 2.5 m (widthXdepth) each. The crest elevation of under sluice is 1392 m amsl and operation level of under sluice gate is 1398.65 m amsl. The width of divide wall is taken 0.75 m and 0.75 wide wall is placed to support under sluice gate.

The abutment coefficient is taken as 0.10 and pier coefficient is taken 0.01 for the calculation of effective length of weir. The discharge coefficient is taken as 1.70. According to Lane's weighted creep theory, the exit gradient is found to be 0.179 which is safe for the soil which consists of gravel and sand.

Details of weir and under sluice are shown in Drawing no SKHP-20-F03 and SKHP-20-F04 in volume II: Drawings.

- **Flood Protection Wall**

RCC flood walls C25 concrete is designed at right and left bank of the weir. Top level of flood wall is 1398.40 m amsl at upstream side while at downstream side it is taken as 1394.30 m amsl which correspond to 1 in 100 years return period flood magnitude of 167.75 m3/s. The width of base of flood wall is 3.5 m and 50 cm thick.

The flood wall is presented in Drawing no.SKHP-20-F05 in volume II: Drawings.

- **Intake cum Gravel trap**

A side intake with gated orifice will be constructed at the left bank of the river. The intake is side intake and submerged weir type. A course trash rack of 20 mm thick and 50 mm wide flat mild steel bars with 100 mm clear spacing flushed with river side face of the intake orifices will be placed to control entry of large trashes and boulders inside intake. The trash rack should be removable so that it could be replaced in case of damage. Coefficient of discharge is taken 0.60. The water level at intake canal is maintained at 1394.80 m amsl. The orifice of intake is designed as submerged type having 2 nos. of each 2.5 m long and 1.0 m deep. The intake orifices are designed to abstract design flow of 3.16 m^3/s flows which consists 2.75 design flow and 15% of design flow for gravel flushing discharge. Allowances of 0.15 m is made to address the head decrease due to weir crest erosion. Intake chamber is designed to trap the gravel also and the slope of the bed of the intake chamber is fixed as 1:4 (V: h). Also the transverse slope is also designed in intake to avoid the gravel deposition at corner. The total length of intake cum gravel trap is 8.05 m long and 3.75 m average width. A flushing orifice, of diameter 0.50 m is kept to flush out the gravel at the end of gravel trap. The flushing channel is 0.50 diameter pipe and 16.40 m long. One flushing gate 0.5 x 0.5 m is kept at flushing orifice to control the flushing flow. The maximum discharge capacity through the flushing orifice is 0.84 m^3/sec.

- **Spillway**

A 7.84 m long spillway will be constructed near the end of concrete intake chamber. This spillway will be capable of discharging 10 m^3/s additional water entered through the intake. The spillway is only designed for the flood entered in 1:20 yrs return period flood through intake. The intake gate will also control the flow through the intake in wet season. The intake gate shall be lowered to make the opening small in flood season. The spillway is sharp crested type and the head over the crest is set to 1.0 m. The discharge coefficient for sharp crested type spillway is taken as 1.90. The spillway canal 1.5 m X 1.45 m is designed to convey water from spillway to river. The spillway canal is 17 m long.

- **Connecting Canal**

A rectangular Approach canal having size 1.5 m X 1.65 m (Width X Depth) is proposed to convey water from intake to gravel trap. The bed slope of approach canal is 1:250 (V:H) and is designed to convey designed flow 2.75 m^3/s.

- **Settling basin**

Settling basin has double chamber. It will settle 0.15 mm size sediment particle with 90% trap efficiency and it will be capable of flushing 5 mm particle size efficiently. Flushing system will be gravity flushing system and flushing of each chamber will be carried out one at a time emptying one for flushing while another is in operation for power generation. Design flow for the settling basin is 2.75 m^3/s. Inlet and outlet gates will be provided for both the chambers for flushing operation. Settling zone length is 43.00 m and inlet transition length is 16.20 m. basin with of a chamber is 5.0 m and the overall depth is 3.77 m.

Storage volume of the settling basin is worked out considering sediment concentration of 3000 ppm and flushing interval 12 hours. Flushing operation for a single chamber is required 60 minutes. A fine trash rack will be installed at the inlet of Penstock pipe to check the entry of trashes.

6.2.2 Head Pond

A reinforced concrete head pond will be constructed at the end of settling basin to dissipate the surge pressure created in to penstock pipe due to load fluctuation or rejection. This structure will also serve as water storage for additional flow for short period and provide sufficient submergence to penstock inlet to avoid vortex. The plant could be operated in isolated mode as head pond is constructed as surge intercepting structure.

The head pond is capable of supplying full design flow for 60 seconds from its effective storage which is 165.00 m^3. Its effective length is 11.45 m and width is 7.50 m. Effective depth is taken as 1.91 m. The full supply level at headpond is 1394.726m amsl. A fine trash rack will be installed at head pond. Further a 6” diameter washout valve will be installed at the head pond.

6.2.3 Water Conveyance System

The water conveyance system from head pond to powerhouse is steel penstock pipe in continuous dropping option. This option is selected on the basis of the topography of the site. Mild steel penstock pipe will convey design flow of 2.75 m^3/s from head pond to turbine. The length of penstock is 3384 m and its internal diameter is 1.30 m. Thickness of the penstock pipe varies from 6 mm to 22 mm. Anchor blocks will be provided at bends to restrain against movement. These blocks have been designed for vertical bends, horizontal bends and combined vertical and horizontal bends. The horizontal bend is necessary to align the pipe along a more stable geological slope whereas vertical bend to avoid excessive cutting and reduce height of saddle support. Based on this topography and landmarks, total number of anchor blocks required are 52 and whereas support piers are 370 nos. Expansion joint will be provided at each section of penstock between two anchor blocks to allow sliding of pipe during expansion and contraction. A bifurcation will be installed at the end portion of the penstock to distribute water to both turbines equally.

6.2.4 Powerhouse and Tailrace

Surface powerhouse will be located at Gurumphi village on left bank of Suri Khola, just 300m upstream of the confluence of Suri khola with Khare River as shown in Drawing no. SKHP-50-F01 of Volume II: Drawings. The powerhouse will house two sets of electromechanical equipments such as pelton-generator set, governor and control systems etc. There will be store room, control room, office room and machine hall. The powerhouse structure will be an RCC framed structure and its roof will be of CGI sheet in truss structure. The overall dimension of powerhouse is 27.82 m, 16.24 m and 12.00 m in length, width and height respectively. The turbine axis is located at 1113 m amsl.

Outdoor switchyard will be constructed nearby the powerhouse. Cut and cover type of rectangular concrete canal will be constructed as tailrace. The length of which is 80 m. The tailrace discharges water to Suri river.

Power house complex basically consists of 3 parts Viz.

- Machine Hall including unloading yard
- Control and switchgear room
- Outdoor switchyard and Transformers

The superstructure of powerhouse is made of RCC column structure and stone masonry will be used for partition and Sal wood door and windows will be provided. A series of windows and ventilation openings will be provided for the necessary natural lighting and maintaining the ventilation. A 3.6m wide main rolling gate will be provided. The roofing of the powerhouse is made of truss structure and CGI roofing.

The powerhouse will be made of reinforced cement concrete (RCC) in various grade concretes. The machine foundation, like generator foundation, Turbine foundation, flywheel foundation is made of C25. The foundation of transformer and switchgears will be of C20 grade concrete. The control and switchgear room consist of control panel, switchgears, battery backup and office arrangements for plant in-charge. There will be sufficient area for loading and unloading right after the main entrance which can be used as service area.

Rainwater from the roof will be collected in a peripheral gutter, which empties into the drainage arrangement on the outside of the powerhouse.

6.3 HYDRO-MECHANICAL WORKS

Hydro-mechanical works consists of steel penstock pipe used to convey water to powerhouse to hit the turbine from head pond, steel gates used in different structures to control the flow, steel trashracks used to control the entry of gavels, debris towards the structures, stoplogs used to control the flow during the maintenance of gates. The detail of metal works is described in following headings.

6.3.1 Steel Penstock Pipe

One of the main conveyances of this project is steel penstock pipe. The length of penstock is 3277 m. The water from head pond is conveyed to powerhouse in steel penstock pipe having different thickness and same diameter. Mild steel plates of grade IS 2062-B will be used for the fabrication of pipe at factory and transported to the site. There will be 56 anchor blocks and 412 saddle supports provided in the pipe alignment. The pipe will be restrained longitudinally by Anchor blocks and supported in 7 m interval in support piers. The pipe will need the following components:

- Pipes
- Bends
- Expansion joints
- Base plate
- Wash hole
- Stiffener Plates

- Anchor ring
- Strainer Pipe

The diameter of the pipe is determined by optimization of cost. The minimum cost obtained to be at 1250mm diameter and chosen as optimum diameter for water conveyance. The thickness is calculated based on to be operated in isolated mode and transients travelling all the way to Headpond. The opening and closing time of turbine is considered as 30s and 10s respectively. Anchor ring, strainer pipe and stiffeners are provided inside anchor block and these details have to be prepared during detail engineering. The detail of the penstock pipe is presented in Table 6-1 below.

Table 6-1: Details of penstock pipe

S.N.	Length (m)	Thickness (mm)	Width (mm)	Mean Dia. (mm)	Q'ty (2.5m/Pc)	Unit Wt. (Kg)	Total Wt. (Ton)	Expansion Joints	Remarks
1	551.00	8	3,953	1,258	221	620.62	137.16	28	Thick. 8 mm
2	208.00	10	3,959	1,260	84	776.95	65.26		Thick. 10 mm
3	275.00	12	3,965	1,262	110	933.76	102.71		Thick. 12 mm
4	346.00	14	3,971	1,264	139	1,091.03	151.65		Thick. 14 mm
5	271.00	16	3,978	1,266	109	1,249.09	136.15	11	Thick. 16 mm
6	241.00	18	3,984	1,268	97	1,407.35	136.51		Thick. 18 mm
7	408.00	20	3,990	1,270	164	1,566.08	256.84		Thick. 20 mm
8	176.00	22	3,997	1,272	71	1,725.70	122.53	13	Thick. 22 mm
9	779.00	25	4,006	1,275	312	1,965.44	613.22		Thick. 25 mm
10	22.00	20	3,990	1,270	9	1,566.08	14.09	NR	Thick. 20 mm
Total	**3,277.00**				**1,316**		**1,736.13**	**52**	

6.3.2 Base Plates & HDPE sheet

The caps of saddles are provided with 5mm thick mild steel base plates to facilitate the uniform distribution of load on the bearing area. The base plate will hold pipe at least in 120 degrees at the lower part. The base plate will be anchored in cap concrete with the help of mild steel bar welded in base plate at the time of laying and fixing. The plate width on saddle is 0.60m and has curved length of 1.33 m in 1300mm dia. pipe. There is need of 494 base plates. The total weight of base-plates will be 12.06MT

6.3.3 Expansion Joints

There are 26 expansion joints needed in Suri Khola Hydropower Project penstock pipe. Some sections are buried where expansion joint is not needed. They vary in length according to the length of pipe from IP to IP. Expansion joint will be located just below the anchor block. Sleeve type expansion joint with greased jute packing is purposed for Expansion Joint at Penstock Pipe.

6.3.4 Gates and stoplogs

For controlling of discharge, 12 gates are provided at headworks in different locations. The intake gates can be used to control the discharge to the inlet channel. The sealing arrangement consists of seal in gate, skin plate, back support rib and roller from back. The minimum skin plate thickness including a corrosion allowance should be 16 mm. The operating platform is made with 25cm slab and the side channel is extended up facilitating the lifting arrangement. In front of each gate, provision of stoplogs is made available to facilitate the repair and maintenance of gates. The details of gates and stop logs are described in Table 6-2 and Table 6-3 below.

Table 6-2: Details of gates

SN	Description	Unit	Qty.	Size (W x H) m	Type
1	Undersluice gate	Set	1	2.5 x 2.50	Vertical wheel type with guide frame hoists and accessories
2	Intake Gate	Set	2	2.5.x 1.0	Vertical wheel type with guide frame hoists and accessories
3	Gravel Trap Flushing Gate	Set	1	0.5 x 0.5	Vertical lift slide with guide frame hoists and accessories
4	Settling Basin Inlet Gate	set	2	1.5x 1.68	Vertical wheel type with guide frame hoists and accessories
5	Settling Basin Outlet Gate	set	4	1.0 x 1.91	Vertical wheel type with guide frame hoists and accessories
6	Settling Basin Flushing Gate	set	2	0.6 x 0.6	Vertical lift slide type with guide frame hoists and accessories

Table 6-3: Details of Stop logs

SN	Description	Unit	Qty.	Size (W x H) m	Type
1	Undersluice stop logs	Set	1	2.50 x 2.50	Stop logs with guide frames hoists and accessories

The side channels in gates are extended up to the top of wall where operating platform is provided with handle and gear arrangement. The gate is operated by a hoisting mechanism. Main parts of the gate are side channels, skin plate, front seal, stiffener angles, lifting device with handle.

Sand-flushing gate is provided at the exit of sand purging cannel. The size of opening of sand purging canal is 0.6mx0.6m and gate is provided with front seal arrangement. The flushing operation is continuous type so the particles are flushed regularly through the canal.

There are inlet and outlet gates provided in settling basin to use the basin alternatively in rainy seasons. The sluice gate and operation of settling gates shall be coordinated during the operation.

6.3.5 Trash Racks

There is provision of Trash racks in order to prevent the entry of floating stuffs, small rock and debris through the channel. Intake Trash rack will have clear opening of 100mm and the racks are rectangular shaped with round head welded at the top. The Rack will be inclined in 90 degrees so that the cleaning operation of rack can be easy. The detail of the trash racks used in the project is described in Table 6-4 below.

Table 6-4: Details of Trash racks

SN	Description	Unit	Qty.	Size (W x H) m	Type
1	Intake Trash Rack	set	2	2.5x 1.015	Trash rack with supporting beam and accessories
2	Penstock Inlet Trash Rack	Set	1	6.0 x 3.07	Trash rack with supporting beam and accessories

A trash rack with 25mm clear spacing is provided at Penstock inlet to prevent the entry of floating debris to the turbine. The trash rack has to be cleaned manually with the help of scraper periodically from the operating platform.

6.4 ELECTRO-MECHANICAL EQUIPMENT

The electro-mechanical system shall be capable of operating plant in off grid mode as well as grid connected modes (on-grid and off-grid modes). Two units each of 3400 kW, 600 rpm Pelton turbine with horizontal shaft is proposed for the given net head of 270.30m and rated flow of 2.75m^3/s. The turbine set shall be provided with a complete set of inlet valve, deflector, auxiliary equipment and other accessories. The shaft of the turbine is connected to the shaft of the generator with a flexible direct coupling. The proposed generator is each of 4000 kVA, three-phase brushless synchronous type. The generation voltage of 6.3kV is stepped up to 33kV with the help of 4400 kVA two transformers. The power generated from the project shall be evacuated to INPS through 33 kV transmission line connecting at Singati substation, at Dolakha. The project shall construct 6 km 33 kV transmission line from the Project switchyard to 132/33 kV substation at Singati Bazaar, Dolakha.

The energy meter shall be placed at Singati substation for power trading purposes. There will be static bi-directional energy meter, one way for measuring the energy sold to NEA, while the other for energy import required from the National grid at the time of maintenance and break down of the system.

With the help of integrated control and protection system, the complete control and supervision of the power equipment will be possible from the control room inside the powerhouse. The control room shall consist of control panel and control desk. The control panel shall have indications and alarms for any type of mechanical and electrical failures and trips. It also consists of automatic recorders for generator kW, kWh, voltage, operation hours, temperature measurements, etc. The control desk shall consists of indicating lamps & alarm for sequence control operation and displaying single line diagram up to 33kV feeder line with push buttons/handles for "*emergency stop*".

Since the generation voltage of 6.3kV can also be used for lighting powerhouse, switchyard, charging DC batteries for start up and emergency lighting, and in addition one station transformer is also proposed for station use.

A single line diagram showing all the electromechanical equipment and control system is presented in Drawing.

6.4.1 Turbine

Until the details are acquired from the prospectus manufacturers and the type and characteristics of the turbine are known, two sets of horizontal shaft Impulse turbine is proposed for the rated net head of 270.30 m with a rated shaft output of 3400 kW. The turbine shall have an additional 10% overload capacity for continuous operation if the water flow is available. Marginal cost benefit analyses are recommended for finalizing the type of the turbine. The specifications of the turbine recommended are presented in Table 6-5.

Table 6-5: Turbine Specifications

Particular	Specifications
Type	Pelton
Layout	Horizontal shaft
No of units	Two
Rated net head	270.30 m
Design discharge	1.375 m^3/sec
Rated speed	600 rpm
Rated output	3400 kW
Rated efficiency at 100%load	90 %

6.4.2 Control System

The control system shall implement the following main functions:

- Automatic start-up, synchronizing and shutdown.
- Automatic governing of the unit.
- Automatic or semi automatic black start.
- Manual step-by-step operation.
- Mechanical and thermal protection.
- Electrical protection.
- Alarm handling.
- Emergency shutdown, etc.

The control system shall allow the programming of automatic daily or weekly production schedules, based on the power output (but limited by the minimum allowable water level) and on the water level set point. When running on a schedule, dispatching among the units shall be automatic but it shall be possible to set the preferred unit. The control system shall record relevant production data of the plant.

6.4.3 Governor

Under different load conditions, water flow is regulated and controlled with the help of a governor. The system shall allow speed and/or frequency control with a droop setting, water level control and external power control, and it shall also be possible to set the opening manually. The turbine shall be provided with an electronic controller acting on the hydraulic actuator. The performance characteristics should be confirmed regarding operation of the governor. The rated specifications of the prescribed governor are presented in Table 6-6.

Table 6-6: Governor Specifications

Particular	**Specifications**
Type	Electronic, PI(D)
Actuator System	Oil-hydraulic, self closing without electric power
Adjustment and Calibration	Mechanical adjustment: self-closing speed and limit switches. Electronic adjustment: All governor parameters shall be adjustable from the unit's control panel but critical parameters shall be locked (password, seal or similar).

Adjustment for Speed or Frequency Droop	Between 0 and 10% with accuracy not above 0.5 %
Monitoring	Digital output of speed, temperature and vibration

6.4.4 Remote alarm system

The station control system shall provide an interface for connecting a remote alarm system. The interface shall include 8 binary outputs for signaling the current operating status and alarms (by group).

6.4.5 Inlet Valve

Inlet valve will be installed at the incoming mains of the turbine. It is provided for the opening and safe closure of the flow under maximum static as well as dynamic heads including operations on some critical stages like sudden rejection of load and speed overrun beyond certain limit.

Mechanical operation of the Inlet valve shall be carried out hydraulically with pressurized oil system through servomotor, which will ultimately be controlled by the governor. The material of the valve & casing should be strong enough to withstand the internal pressures.

6.4.6 Generator

Two sets of 3-phase, 50 Hz AC, each of 4000 kVA horizontal shaft synchronous generator is proposed for the power generation. The generator shall have an additional 10% overload capacity for the continuous operation. The system shall be capable to run and generate electrical power in an isolated and grid modes (off-grid and grid modes). The brushless excitation system is preferred for the exciter unit, which has to be directly coupled to the main turbine shaft. Regarding operation in low flow, generator shall ensure a good range of efficiency throughout a wide variation of load. All the structural details, material, cooling system and insulation will be confirmed to IEC 60034 standards. The specifications related to the selected generator for the project are presented in Table 6-7.

Table 6-7: Generator Specifications

Particular	**Specifications**
No of Units	Two
Generator type	Synchronous brushless, 3Ø AC
Layout	Horizontal; directly coupled to the turbine
Rated capacity	4000 kVA
Rated efficiency	96%

Power factor	0.8
Voltage regulation	± 10%
Rated Speed	600 rpm
Frequency	50Hz
Generation Voltage	6.3kV
Insulation grade	Class F
Phase Connection	Star connected

6.4.7 Excitation

Automatic Voltage Regulator (AVR), all the protection schemes, control logic, etc., should be integrated in the excitation system.

6.4.8 Step-up Transformer

The power generated at 6.3kV level shall be delivered to 33 kV National grid with the help of step up two sets of power transformers. The transformers shall be of 4375 kVA capacity, manufactured according to IEC 76 and outdoor type. The step-up transformer specifications are presented inTable6-8.

Table6-8: Step up Transformer Specifications

Particular	**Specifications**
No of Unit.	Two
Type	Step up power transformer
Rated Capacity	4000 kVA
Rated efficiency	99%
Type of cooling	ONAN (Oil Natural Air Natural)
Vector group	YnD11
Voltage levels	33/6.3 kV
Connection (HV/LV)	Star/Delta
Phase	3Ø
Frequency	50Hz
Tap changing facility	± 2*2.5% with 5 steps

The core lamination of the transformer should be perfectly thin and insulated to ensure minimum no load losses. Windings should be of high conductivity copper and firmly clamped to withstand all of the stresses during faults in the line. All provision shall be made for the following protection/schemes (i) Buchholz relay protection (ii) Pressure relief device (iii) Winding temperature alarm.

The series of standard tests shall be conducted to ensure the efficiency, quality of material and workmanship as well. All bushings should be made of porcelain, homogenous, non-porous and uniformly glazed. The 132kV line bushings are directly connected to outdoor bus bar through disconnecting switch. LV side bushings shall be mounted on the side wall of transformer enclosed in cable box.

6.4.9 Circuit Breaker

Air Circuit Breaker (ACB) shall be used in low voltage side. The ACB shall be located inside the powerhouse. Draw out type ACB shall be used in powerhouse, which operates both as breaker as well as disconnecting switch (Isolator). ACB shall be of 3 phase with single throw in operation. The details of the recommended circuit breaker are presented in Table 6-9 and Table 6-10.

Table 6-9: Air Circuit Breaker Specifications

Particular	**Specifications**
No of Unit.	Two
Type	3Ø, Single throw withdrawal type.
Location	On each generator side
System Voltage	6.3kV
Rated Voltage	1000V
Rated Current	3000 A

Regarding operation and function of circuit breaker, they will be capable of breaking maximum fault current in system at minimum response time.

Vacuum Circuit breaker shall be used in 33kV side and shall be indoor type located inside the powerhouse. The VCB shall be of 3 phase with single throw in operation. The followings are the general details of the CB required:

Table 6-10: Vacuum Circuit Breaker Specifications

Particular	**Specifications**
No of Unit.	One
Type	3Ø, Single throw.
Location	After Power Transformer
System Voltage	33000V
Rated Voltage	36000V
Rated Current	800 A
Rated interrupting current	25 kA

Regarding operation and function of circuit breaker, they will be capable of breaking maximum fault current in system at minimum response time. Manual, automatic and remote control system of the CB shall be provided as well.

6.4.10 Isolator

The disconnecting switch is used as an isolator for disconnecting the system from grid during maintenance periods. The switch shall be installed in outdoor pole mounted type near 33 kV line operated on no load condition only. Each part of the Isolators shall be provided with subtropical finish to prevent fungus growth. Table 6-11 presents the details of the recommended isolator.

Table 6-11: Isolator Specifications

Particular	Specifications
No of Unit.	One
Type	Outdoor type, Single throw, hand operated with grounding facility.
Current Capacity	800 A
Rated Voltage	33 kV
Phases	3Ø

6.4.11 Lightning Arrester

The Lightning Arresters shall be provided in the first pole for protection of substation equipment including transformer from the possible lightning strike. They shall also be installed at the transmission line to prevent the entry of possible harmful surges towards the substation from the grid. The LA shall be provided with surge monitor. The rating of LA shall be 10 kA, 30 kV.

6.4.12 Switchyard and its Components

The transformer and circuit breaker of the power plant shall be of outdoor type covering approximate area of 30 sq. metres in the side of powerhouse building. This area shall mainly comprise of one set of vacuum circuit breaker. The power cable of sufficient capacity laid inside the cable ducts shall make the connection between generator and the primary side of the transformer.

The power transformer shall be connected to the 33kV line. The 33 kV bus bar systems shall be supported by pole with ball and socket type suspension insulators and pin insulator.

The outgoing feeder line shall have disconnecting switch, drop out fuse, lighting arrestor and all protection system as required. The single line diagram is shown in drawing. The suitable clearances and fencing around the equipment shall be provided for safety consideration.

6.4.13 Station Power Supply System

Power needed for powerhouse lighting, battery charging, governor oil pumps etc shall be tapped directly from 400V main bus bar. For the protection, 75 A MCCB shall be used with all necessary arrangements. For back up supply one 50 kVA, 6.3/0.4 kV station transformer which shall also be used for station lightning and AC supply. The sufficient protection shall be provided in HV and LV side.

6.4.14 Protection System

The protection schemes for the turbine & generator include the over and under voltage, over speed, over current, earth fault, over and under frequency, islanding and reverse power protection. In addition, suitable alarm/trip circuits are provided for abnormal conditions such as increase in bearing temperature, low pressure etc.

A protection scheme with an automatic control circuit will be provided to stop the turbine in event of power supply failure or any other faults. The generator should also be isolated from main line in event of any fault or abnormal operation. For the power transformer, Buchholz protection and temperature trip circuits are provided. To protect the 33 kV transmission line and transformer from high voltage surges, lighting arrestor shall be provided.

In order to protect the personnel from the electric shock and equipment from damage due to short circuit, all the electrical equipment in the powerhouse and switchyard area will be properly grounded.

6.4.15 Control Systems

- **Battery and Battery charger**

A bank of battery capable of supplying 24 VDC, 200 Ampere-hour (Ah) and a 24VDC floating charge static battery charger should be provided to supply DC power for control and protection system. The battery shall be located inside the powerhouse and connected to the distribution board and battery charger.

- **Automatic Synchronizing Equipment**

Automatic synchronization shall be performed by the control equipment. The equipment shall permit either manual or automatic control of turbine speed and generator voltage; and automatic control of breaker closing for connecting the generator to running system with minimum disturbance. The equipment shall include an automatic synchronizer, a voltage balancing relay and a speed matcher.

- **Lighting system, cabling**

The electrical equipment shall also cover lighting, cabling and earthing system design. The powerhouse shall be provided with emergency lamps automatically switched 'on' in case of the failure of the AC supply and switched 'off' when the AC supply is resumed. Suitable low voltage AC and DC power cables shall be used from the low voltage switchboards to various equipment, power socket outlets, pull box, distribution boards, fixtures and switches accordingly. All the necessary power cables shall be laid for feeder lines between low-tension panels and low voltage terminals of step up transformer located outside at the switchyard.

An effective earthing station and network shall be provided in the vicinity of the power house by forming an underground mesh to facilitate equipment grounding for electrical safety and establishment of a reference zero potential point. Grounding rods shall be used to reduce the grounding resistance of the mesh. The earth grounding resistance shall not exceed one ohm.

6.4.16 Interconnection Point and Transmission Line

Total of 6 kilometer 33 kV transmission line from project powerhouse to Singati substation of Nepal Electricity Authority shall be constructed by project to evacuate the generated power and same shall also be used during the construction and maintenance phase and even during the normal operational phase. The power will be evacuated to the national grid through substation at Singati where metering arrangement for power trading facility shall be installed. The transmission line shall be in steel towers of standard height and placed at an average span of 60m. Necessary materials and accessories like insulators, cross arms, stays, jointing sleeves shall be in accordance with the IEC standard for use on 33 kV transmission line.

6.4.17 Metering Equipment

The metering equipment shall be placed for each generator to measure the power generated. Similarly an energy meter shall also be installed after the power transformer in 33 kV side to monitor the transmitted power and energy. The static bi-directional energy meter shall be installed by the project on 33 kV side in Singati substation by constructing one line bay. The energy meter shall be used for the purpose of power trading i.e. to measure energy export by the power house and also to measure energy import by the powerhouse during breakdown and maintenance periods. The energy meter and metering equipment shall be indoor and outdoor type respectively. A provision of a separate set of check energy meter shall also be provided by the company. The company shall install 33 kV VCB, 33 kV DS, DS with ES, LA, CT and PT in the line bay to connect with the under construction substation bus bar.

Each metering units shall consist of an energy meter, current transformer, potential transformer and other accessories required as per the specification provided by the NEA.

7 POWER, ENERGY AND BENEFIT ASSESSMENT

7.1 POWER & INSTALLED CAPACITY

The installed capacity is determined with net head, design discharge and efficiency of the machines. The outage and losses are considered for finding the energy output from the project. The parameter for deciding the plant capacity is listed below:

7.2 MEAN MONTHLY DISCHARGE

From the hydrological analysis it is found that the Q_{40} or discharge having 40% probability of exceedance is found to be 2.75 cumecs. The discharge obtained from actually measured discharges is used for power and energy calculation as long term mean monthly river discharge. The results are shown in Table 7-1.

Table 7-1: Mean monthly plant discharge for energy calculation

Month	Mean monthly river discharge	Minimum Riparian Release	Plant discharge for power generation
Baishakh (Apr/May)	0.834	0.069	0.765
Jestha (May/June)	0.881	0.069	0.812
Ashad (June/July)	4.710	0.069	2.750
Shrawan (July/Aug)	10.560	0.069	2.750
Bhadra (Aug/Sept)	11.190	0.069	2.750
Ashwin (Sept/Oct)	7.402	0.069	2.750
Kartik (Oct/Nov)	2.572	0.069	2.503
Mangsir (Nov/Dec)	1.963	0.069	1.894
Poush (Dec/Jan)	1.172	0.069	1.103
Magh (Jan/Feb)	0.913	0.069	0.844
Falgun (Feb/Mar)	0.769	0.069	0.700
Chaitra (Mar/Apr)	0.712	0.069	0.643

7.3 NET HEAD

The plant will have different net heads for different discharges. The net head will also vary from month to month because of the discharge variation and corresponding change in friction loss. The water conveyance system consists of combination of headrace pipe, headrace canal and headrace tunnel. The losses in the water conveyance system are also calculated. The water level at crest of proposed weir site is at El 1395.0m and turbine centre level is at El 1113.00 m. The available gross head of the project is 282.0 m. The rated net head which is calculated with design discharge is found to be 273.19m. The following are the important level for finding head:

Table 7-2: Mean monthly plant discharge for energy calculation

Month	Baishakh (Apr/May)	Jestha (May/June)	Ashad (June/July)	Shrawan (July/Aug)	Bhadra (Aug/Sept)	Ashwin (Sept/Oct)	Kartik (Oct/Nov)	Mangsir (Nov/Dec)	Poush (Dec/Jan)	Magh (Jan/Feb)	Falgun (Feb/Mar)	Chaitra (Mar/Apr)
Net Head, m	281.00	280.92	273.19	273.19	273.19	273.19	274.64	277.64	280.30	280.86	281.11	281.19

7.4 RATED EFFICIENCIES

The efficiency of turbine, generator and transformer is considered for finding out the installed capacity of the plant. There are following efficiencies are considered for calculation of power generated from the plant.

Turbine Efficiency: Turbine efficiency differs on design discharge and also depends upon turbine manufacturers. Rated Efficiency of Turbine at design discharge is taken as 90%

Generator Efficiency: Generator has Iron and copper losses which makes power output lower than available from mechanical output. The Rated Efficiency of generator is taken as 96.5% for the Project.

Transformer Efficiency: Transformers also has Iron and copper losses which makes power output lower than available from generator. The Rated Efficiency of transformer is taken as 99% for the Project.

The variation of on efficiency over the load is considered while calculating the power and energy from the project to find out more accurate scenario of deemed generation.

7.5 POWER POTENTIAL

Power from the plant is estimated as follows:

Power from the Plant = 9.81* H * Q * Efficiency = 9.81*273.19*2.75*(0.90*0.965*0.99) = 6336 kW

The plant installed capacity however is taken little bit in higher side which will be 6400kW having two units of Pelton Turbines (Each capacity 3400 kW) connected with self excited synchronous generators.

Paying additional Capacity royalty, it is advisable to have 10% higher capacity machine.

7.6 LOSSES AND OUTAGE

Transmission Line losses: Transmission line has loss due to line resistance mainly which has to be considered for calculation of total losses. A study is conducted for Power loss for the evacuation of 6.643 MW power from 33kV, about 6km long transmission line which shall not exceed by 2%:

Losses at Switchgears and connections: There shall be loss due to line resistance in the contacts, terminals and seals. This shall come less than transmission line loss at any cases, hence recommended loss for such class shall not exceed 1%

Outages: The outages are of two types Viz, Planned outage and Forced outage. The shutdown for scheduled maintenance of plant and transmission line is included in planned outage and breakdown from unseen factors, like line breakage, flood, machine breakdown etc are forced outage. The outage in 33kV line is generally 144 hrs which is 1% based on general practice in Nepal.

Total outage figure for deduction while finding energy at delivery point shall be taken as summation of losses at switchgears, transmission line and outages. Total of 4% outage is calculated as foreseen outage for energy at delivery point. However, considering long transmission line, breakdown for repair & maintenance and other factors additional 1% outage can be taken. Only one unit will be in operation for 4-5 months, so the repair & maintenance of the units can be planned accordingly. Hence, total of 5% outage is reasonable to consider for the calculation of energy and corresponding revenue for the project.

7.7 POWER AND ENERGY COMPUTATION

The power generated from the proposed project mainly depends upon available head and efficiencies of turbine, generator and transformer. For the given project, the combined efficiency of generator and transformer has been considered as 0.859.

The installed capacity of the project will be fixed as 6.4 MW. The total annual energy generation from the project is computed as 34.579 GWh. Considering the outage of 5%, the deemed energy generation supplied to the national grid is computed as 32.850GWh out of which the dry season energy (Poush to Chaitra) is 5.28 GWh and the wet season energy (Baisakh to Mansir) is 27.566 GWh. The plant factor of the project is computed as 61.7%.

The computation of power and energy generation from Suri Khola Small Hydropower Project is given in Table 7.3.

Table 7-3: Computation of Power and Energy Generation

Design Discharge, Q_d	2.75 m^3/s	Outage	5.00 %
Gross Head, H_g	282.00 m	Turbine Efficiency	0.90 %
Rated Net Head, H_{net}	273.19 m	Generator Efficiency	0.965 %
Riparian Flow, $Q_{d/s}$	0.069 m^3/s	Transformer Efficiency	0.99 %
		Combined Efficiency	0.859 %

Month	Available River Discharge (m^3/s)	Available Plant Discharge (m^3/s)	Days	Net Head (m)	Plant Output (kW)	Total Energy Generation (kWh)	Outage and Losses (kWh)	Net Wet Season Energy (kWh)	Net Dry Season Energy (kWh)
Baishakh (Apr/May)	0.834	0.765	31	281.00	1,813	1,348,578	67,429	1,281,149	
Jestha (May/June)	0.881	0.812	31	280.92	1,924	1,431,140	71,557	1,359,583	
Ashad (June/July)	4.710	2.750	32	273.19	6,336	4,713,984	235,699	4,478,285	
Shrawan (July/Aug)	10.560	2.750	31	273.19	6,336	4,866,048	243,302	4,622,746	
Bhadra (Aug/Sept)	11.190	2.750	31	273.19	6,336	4,713,984	235,699	4,478,285	
Ashwin (Sept/Oct)	7.402	2.750	31	273.19	6,336	4,713,984	235,699	4,478,285	
Kartik (Oct/Nov)	2.572	2.503	30	274.64	5,799	4,036,312	201,816	3,834,496	
Mangsir (Nov/Dec)	1.963	1.894	29	277.64	4,436	3,193,633	159,682	3,033,952	
Poush (Dec/Jan)	1.172	1.103	30	280.30	2,607	1,876,918	93,846		1,783,072
Magh (Jan/Feb)	0.913	0.844	29	280.86	2,000	1,391,891	69,595		1,322,297
Falgun (Feb/Mar)	0.769	0.700	30	281.11	1,659	1,194,609	59,730		1,134,879
Chaitra (Mar/Apr)	0.712	0.643	30	281.19	1,525	1,098,141	54,907		1,043,234
Total						**34,579,223**	**1,728,961**	**27,566,780**	**5,283,482**

Summary

Net Dry Season Energy (GWh)	5.28
Net Wet Season Energy (GWh)	27.56
Energy to National Grid (GWh)	32.85
Plant Factor	61.7%

8 CONSTRUCTION PLANNING

8.1 GENERAL

This chapter of the report describes the approach used to develop the construction schedule. The schedule was prepared using timeline gantt charts presenting all the major activities.

The main objectives of this study are:

- To make reasonable assumptions concerning the construction methodology achievable at the site conditions prevailing at the area considering remoteness and accessibility,
- To develop a construction schedule for the project implementation estimating probable job completion targets and identify the critical activities to be taken care.

The construction activities will comprise river diversion for headworks construction, construction of diversion weir and intake, intake canal & gravel trap, desander, head tank, headrace/penstock pipe, surface powerhouse, tailrace canal and switchyard. The construction will also include the electro-mechanical installations comprising of turbines, generators, governors and auxiliary equipment. In addition, hydro-mechanical parts like gates, valves, hoisting devices will also be provided.

8.2 ACCESSIBILITY

Charikot is 133 km away from Kathmandu in the North-East direction. Nearest market is Charikot, (i.e. headquarter of Dolakha district) which is about 42 km away from the power house site. The project is connected by earthen road from Bhorle at Tamakoshi access road. There is RCC Bridge under construction over Tamakoshi River near Bhorle bazzar. The earthen road starts after crossing Tamakoshi River Bridge near Bhorle. This road connects proposed alignment and powerhouse. Access road to the project site from the national market and places of importance are listed below:

Table 8-1: Accessibility to the Suri Khola Hydropower Project Site

S.N.	Distance from	To	Distance(Km)	Description Route
1	Kathmandu (MaitiSuri)	Khadichaur	78	Arniko Highway
2	Khadichour	Charikot	55	Lamosangu-Jiri Highway
3	Charikot	Singati	35	Graveled Road
4	Singati	Bhorle	4.5	Graveled Road
5	Bhorle	Power house	2.5	Earthen road already built
Total Road Length From Kathmandu to PH			175	

Alternatively access from Bardibas can also be used if the road is ready by the time the project construction starts. This road starts from Bardibas following B.P. Highway up to Khurkot and follows Manthali, Khimti power house and finally to Charikot. From Charikot, the same route as indicated above can be followed. For the transportation of materials coming from the south, use of this route will curtail the distance as compares with transportation via Kathmandu. This access route will be used after completion of bridge under construction over Sunkoshi River at Khurkot. This route will not be useful for the transportation of equipments and materials from Kathmandu.

8.3 MODE OF PROJECT IMPLEMENTATION

Construction of hydropower projects is a complex task as it involves numerous fields of expertise e.g. construction of civil works, metal fabrication, construction of transmission lines and procurement and erection of electro mechanical equipments for generation and distribution. Hydropower projects can be implemented by one of the following procedures:

a. EPC (Engineering, procurement and construction)/ Turnkey Contract

b. Contracts with Engineer for design and supervision

c. Contracts with supervision by the Client

EPC Turnkey mode of contract is the most convenient for a Client as the Contractor is responsible for all activities related to project implementation i.e. design, construction, equipment supply, erection and commissioning. This mode of contract execution is devoid of the need of coordination among contractors. However EPC turnkey contracts require contractors with such multidisciplinary capabilities, which is virtually very difficult to get such contractors in Nepal. Hence such EPC turnkey contract implementation would require involvement of foreign contractors, which would make the project cost high.

The second mode of contract execution would be by hiring a Consultant to act as the Engineer with one or more contractors deployed for project execution. This mode of contract execution would require an experienced consulting organization with capabilities in design and project management.

For a small Hydropower project such as that of Suri Khola Project the third mode of project execution is recommended whereby the consultant undertakes the design activities and client undertakes the project management on its own.

8.4 CONTRACT PACKAGING

While deciding on contract packaging it is essential to use local resources and expertise to the maximum so that the cost of the project is minimized. There is currently no manufacturer in Nepal which can manufacture turbines and generation equipment of the size required by the Suri Khola Hydropower project. Hence the package for electro-mechanical equipment supply would have to be made with foreign manufacturers in mind by the ICB (international competitive bidding) method. The other works involved in the project could be undertaken by local contractors. Hence the civil works, transmission lines and hydro-mechanical works should be packaged with LCB (local competitive bidding) method in mind.

For the Suri Project the contract packaging for recommended would be as follows:

a. Package 1: Access road and Camping facilities

b. Package 2: Civil Works

c. Package 3: Hydro-Mechanical Works

d. Package 4: Transmission Line Works

e. Package 5: Electro-Mechanical Equipment Works

For reducing costs international equipment suppliers should be advised to link up with local agencies for local services required during the ICB contract execution.

8.5 PREPARATORY WORKS:

Preparatory works of the project for the main construction works will consist of permanent land acquisition followed by the construction of access road to the major construction sites, access tracks, extension of 11 kV transmission line for construction power up to headworks and powerhouse. Temporary land acquisition for the construction purpose shall be the made by the respective contractors.

The Contractor will construct a camp for their work force comprising skilled and unskilled laborers. As the project is small in nature, the extent of camp requirement will be lesser. However, to avoid haphazard camps and to maintain environmental integrity, the Contractor will be required to construct well-managed camps. It is envisaged that two such camps will be required one each for the headworks site and the powerhouse site. The Employer will also be required to construct camps and colonies, which could be later converted to permanent facilities for operation and maintenance.

Preparatory works like connection of construction power line to the actual works area, drinking water supply and sanitation facilities, fixing of quarry sites, fixing of sites for construction equipment & batching plant etc will be proposed and managed by the contractor. Construction of access tracks from powerhouse to headworks shall be made ready before the commencement of the major civil and hydro-mechanical works.

It is planned that electricity can be availed from NEA from 11 kV line at Gurumphi, which can be utilized for construction power for the project. This line is required to extend along the penstock pipe alignment up to headworks site.

8.6 BASIC ASSUMPTION

The average length of day-light in the project area is roughly 8-10 hours, so that surface construction activities have been assumed to extend over the same period. A margin for time lost due to adverse weather or other unforeseen delaying conditions has been allowed in the adopted production rates.

Following factors have been used to estimate the efficiency of work:

- working efficiency of personnel - 0.83
- availability of machine- 0.80
- experience of operator or time of delay - 0.85
- Total efficiency of manpower - 0.71
- Total efficiency of machine - 0.56

8.7 CONSTRUCTION SCHEDULE

The construction of the project involves works at three sites, i.e., at headworks of Suri Khola at confluence of Kolung Khola and Hulak Khola of Suri VDC and the powerhouse site is located at Gurumphi of Suri VDC and along the pipe alignment between headworks and powerhouse site. For the earliest completion, the construction works has to be carried out at all sites simultaneously.

The construction works involved at each of these areas are described in the following paragraphs:

Headworks Area

The works in the headworks area comprise construction of:

- the cofferdam for river diversion
- the diversion weir, undersluice and guide wall
- intake and intake chamber
- gravel trap, settling basin and flushing channel

Water conveyance system

The works in this area comprise construction of:

- the headrace/penstock pipe
- the saddle supports
- the anchor blocks
- the river crossing and cross drainage structures

Powerhouse Area

The works in this area comprise construction of:

- the powerhouse building
- the tailrace canal
- the switchyard

Figure 8.1 shows the graphical presentation of major construction activities on a gantt chart.

8.7.1 River Diversion During Construction

Construction of the diversion weir with side intake on the river will require keeping the working area dry during the construction period. To keep the area dry, the flow in the river will be required to be diverted and the working area will be protected by means of cofferdams. In the first stage, during the dry season of first year of the construction, the river flow will be diverted to the left part of the river by construction of a cofferdam along and across the under sluice portion. During this period, the under sluice, divide wall and weir will be constructed. In the second stage, during the dry season of the second year of the construction, the river flow will be diverted to the right part of the river through the under sluice by construction of cofferdams across the river at upstream and downstream of the weir and stilling basin structures. The remaining part of diversion weir, intake stilling basin and wing walls will be constructed during this period. After construction of all structures, cofferdams will be demolished and levelled up to the designed shape and size.

8.7.2 Diversion Weir and Intake

The side intake will be constructed together with diversion weir up to the required depth. Trash rack and gates will be installed to control the flow into the intake channel. Excavation of the headworks site will be completed in 30 days after which the concreting work will commence. Similarly, reinforced concrete weir and cutoff walls will be constructed in the downstream of the weir and subsequent filling of big stones. Concrete guide walls will be constructed after the completion of the diversion weir. Gabion protections, Riprap for bank protections on both banks of the Suri Khola just upstream and downstream of the permanent diversion weir will be constructed. The whole construction work is envisaged to be completed in 240 days.

8.7.3 Intake Canal and Gravel Trap

The construction of Intake canal and gravel trap will be commenced immediately after the mobilization period. The construction is planned to be completed in 150 days.

8.7.4 Settling Basin

In order to reduce the suspended particles from the water to be utilized for power generation settling basin will be constructed. It is planned to construct and complete with in 150 days.

8.7.5 Water Conveyance System

The penstock pipe will be constructed simultaneously from the date of start of river diversion works. It commences from outlet of settling basin and reaches up to powerhouse building. The erection of pipe together with excavation works and construction of saddle supports and anchor blocks will be commenced simultaneously at different stretches in order to complete the job in time. The site conditions show that at some stretches there will be heavy excavation. As far as possible, the water conveyance from settling basin to powerhouse is aligned based on the terrain conditions. The penstock pipe route is crossing small streams below the ground level providing enough protections with gabions, stone masonry and riprap. Excavation in some stretches of the alignment together with foundation excavation for saddle supports and anchor blocks will be done first. Subsequently, saddle supports and anchor blocks will be constructed according to the design and penstock pipe will be installed and welded simultaneously. The pipe will be transported by means of tractor/trucks on the alignment from the temporary fabrication house and be aligned into the proper location by means of chain pulleys.

A different team will be involved to excavate and concreting of civil works so that the construction of which shall be completed with other parts of water conveyance system.

8.7.6 Powerhouse

The main civil works in the powerhouse consist of excavation and concrete works for the machine foundation and construction of building structure. The excavation work will be carried out using excavators for common materials. The excavation works for rock will be carried out by blasting method. The excavation work for the powerhouse will take about 30 days and the slope stabilizing measures will have to be carried out in parallel with the excavation work. The substructure concrete will be placed first to provide space for jet injectors and runners. The columns, beams, and roof will be constructed to allow installation of the powerhouse crane. The construction of powerhouse including machine foundation is planned to be completed in 240 days. The installation of electro-mechanical equipment will be commenced once major civil works of the powerhouse is completed.

8.7.7 Tailrace

The RCC box culvert type tailrace canal will be constructed to discharge the water coming out from the turbine. The excavation of the tailrace can be carried out independently from other structures. The excavation of the tailrace canal will take two weeks and concreting/stone masonry will take two month.

Protection works like riprap and gabion crates will be placed at the end of the tailrace canal as per the requirement.

8.7.8 Switchyard

The bus ducts connecting the generator to the step up transformers in the switchyard, will be accommodated in a cable and exhaust shaft emanating from the service bay.

Site preparation for the switchyard by levelling can be carried out independently with the other works. The civil works of the switchyard will be completed in 3 months.

8.7.9 Electro-mechanical Equipment

After the completion of civil works, the works for electro-mechanical equipment like turbine, generators, governors, transformers and auxiliaries will commence. The contract for the electro-mechanical equipment will be initiated after the civil works contract finalized. Design and specifications will be prepared in a month and tendering will be made. The successful tenderer will be allowed twelve months time to design, fabricate and deliver the equipment at the project site. The installation of the Electro-mechanical equipment will be completed in three months. It is envisaged that the testing and commissioning work will be done in month. After successful testing and commissioning of all structures and equipment, commercial generation will be started.

8.7.10 Transmission Line

For transmission line also, separate tender will be called. Five months have been planned following contract award to the supplier for design, fabrication and delivery of the transmission line materials. Four months have been scheduled for the installation of the 33 kV line from Powerhouse to Singati Substation, the 33 kV bus bar of national grid of NEA.

8.7.11 Construction Materials

The construction materials required for the project will be procured from the domestic produces/suppliers. The main construction materials required are as follows:

- Cement
- Reinforcement bars and timber

- Fuels
- Coarse and fine aggregates and cohesive materials will be produced from the rocks obtained from the quarries. Some coarse aggregates will also be processed from the excavated materials.
- Steel plates for headrace/penstock pipe

8.7.12 Disposal of Excavated Materials

Sites as identified during field visit for environmental survey will be used for the disposal of surplus soil and rock excavation materials. The excavated foundation materials and muck from the headrace tunnel, canal and pipe will be disposed in these landfills. The excavated materials will be transported to the landfills. For enhancing the environment of project area the landfill will be planted with grass, shrubs, and trees

9 OPERATION AND MAINTENANCE PLAN

An organizational structure of operation crew of the plant is shown in Figure 9.1 and manpower required for operation is presented in Table 9-1. A plant manager will lead operation of the plant. He should be from electrical back ground. External support may be required during maintenance of the plant in case of emergency maintenance and scheduled maintenance. Operation team consist combination of electrical and mechanical technicians. At least a technician level operator will be standby at powerhouse during power plant operation. Other operation assistants could be deployed as their requirement. Detailed operation and maintenance plan and manual will be prepared during construction of the project for smooth and uninterrupted operation of the plant. An account and administration team at plant look after account, administration, public relation and other logistics at plant.

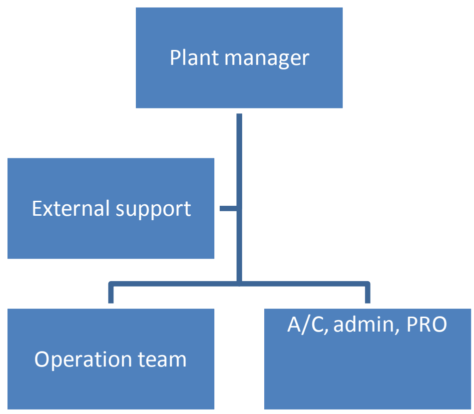


Figure 9.1: Structure of operation crews

Table 9-1: Manpower required for plant operation

SN	Manpower	Category	Nos.	Duration (Months)	Remarks
1.	Plant manager	Officer	1	12	
2.	Operators	Jr. officer	3	12	
3.	Operation assistants	Helper	6	12	
4.	A/C and admin officer	Jr. officer	1	12	
5.	Office assistant	Jr. officer	1	12	
6.	Support staffs	Helper	3	12	

Maintenance of power plant will be done in regular basis and as emergency maintenance. Regular inspection of civil works, hydro-mechanical works, electromechanical works and transmission line will be carried out for assurance of their service level. Standard operation and maintenance manual containing inspection plan and schedule and regular maintenance works will be prepared before completion of the power plant. Emergency maintenance may require in case of unexpected cause like floods, structural break down of project components etc. Out side support may be required in some cases of emergency maintenance. Replacement of turbine runner may require in between plant operation period. To address such events well ahead plan and schedule will be put in the operation and maintenance manual.

10 COST ESTIMATE

This chapter of the report deals with methodology used and presents the project cost estimate. Detailed bill of quantities of each items of works of all project structures were carried out and unit rate of the items of works were worked out from rate analysis and similar projects under construction and already constructed. The cost estimates of items which has to be imported from abroad and cost does not depends upon item rates were worked out from quotations, previous quotations and contract agreement made in earlier projects. Details of assumptions made, criteria set, methodology and cost estimate are described in sections below.

10.1 CRITERIA AND ASSUMPTIONS

The following criteria and assumptions were made in cost estimate preparation.

The cost estimate and financial analysis has been based on the NPR.

The exchange rate US $ 1 = NPR 100.50 used

All costs has been first estimated on a per unit basis for each of the components and then added to obtain the entire project cost.

Lump sum costs adopted where breakdown cost is not available.

Material costs reflect real costs incurred at other projects of similar size or having similar scope of works.

Construction material obtainable from the local market whereas some of the steel items and all of the electromechanical equipment need to be imported.

Some skilled and all of the semi-skilled and unskilled manpower can be obtained locally.

The unit costs include profit, and overhead, which the contractor would charge.

13% Value Added Tax (VAT) applicable to all construction material procured.

As per the facilities provided by the Electricity Act 1993, VAT has been excluded from electromechanical equipment, and all plant and machinery, which the contractor would import for the completion of works.

1% of custom duty, 1. 5% of local taxes added.

Contingency sum added on civil, hydro-mechanical, electromechanical and transmission line.

It is expected that an open competitive bidding will be supposed to be for awarding the contracts and the project will not be forced to use higher rates for any reason.

10.2 METHODOLOGY

The project is divided into a number of major components for the estimating process as follows:

- Project development cost
- Land procurement and lease and lease
- Infrastructure and camping facilities
- Main civil construction works
- Weir, intake, gravel trap, approach channel , settling basin and head pond

- Civil works in penstock pipe
- Powerhouse and tailrace
- Electro-mechanical equipment
  - Turbines
  - Generators
  - Transformers
  - Auxiliary equipment
- Construction power
- Hydro-mechanical equipments (Metal works)
- Transmission line
- Interconnection facilities
- Engineering, management and administration costs
- Environmental mitigation and monitoring
- Physical and price contingencies
- Interest during construction.

Some parts of the project especially civil and electrical structures were designed internally. But electromechanical equipment and design were left to contractors and suppliers. Hence actual bill of quantity could not be prepared for those components which were not designed internally. However size and required standard and specifications were specified during design works. In this way cost of some of the items of works were worked out on item rate basis whereas others were on lump sum basis. Furthermore items like engineering and management, camps and facilities, diversion works, operation and maintenance etc. were also worked out on lump sum basis. As mentioned earlier unit rate and lump sum values were taken from references of previous projects. The basic rates of major items considered for rate analysis is shown in Table 10-1. These rates correspond to the rate at project site.

Table 10-1: Basic rates used to calculate the project cost

S. N.	Type	Unit	Rate (NRs)	Remarks
A	**Labour**			
1	Skilled Labour	man-day	700.00	8 Hrs/Day
2	Unskilled Labour	man-day	350.00	8 Hrs/Day
B	**Material**			
1	Cement	Bag	925.00	including transportation, loading, unloading, store charge etc.
2	Sand	m^3	4295.76	Including collection, screening, transportation etc
3	Graded filter material	m^3	2652.66	Including collection, screening, transportation etc
4	Aggregates	m^3	4922.98	Including collection, screening, transportation etc
5	Stone	m^3	1927.97	Including collection, screening,

				transportation etc
6	Saal Wood	m^3	250000.00	
7	Low Quality Wood	m^3	52950.00	
8	Plywood 12mm	m^2	1345.00	commercial
9	C.G.I. Sheet (24 gauge)	m^2	1000.00	medium
10	Glass for Window (4mm)	m^2	1200.00	
11	Ready made paints	Lit.	700.00	exterior paint
12	Lime for Paintings(primer)	Lit.	230.00	
13	Reinforcement bars	Kg	80.20	including transportation, loading, unloading, store charge etc.
14	Reinforcement-Binding Wire	Kg	110.00	including transportation, loading, unloading, store charge etc.
15	Gabion wire(10SWG)	Kg	99.0	including transportation, loading, unloading, store charge etc.
16	Salvage Wire(7SWG)	Kg	99.00	including transportation, loading, unloading, store charge etc.
17	Gabion Binding wire(12SWG)	Kg	99.00	including transportation, loading, unloading, store charge etc.
18	Nail	Kg	120.00	
19	Holdfast 7 nos/kg (different sizes)	No.	20.00	
20	75 mm hinge	No.	20.00	
21	100 mmTowerbolt	No.	90.00	
22	Handle (special)	No.	60.00	
23	Screw	No.	8.00	
24	Iron Pipe 2.5" Diameter	M	375.00	
25	Iron Pipe 4" Diameter	M	550.00	
26	Ready made Enamel	Ltr	500.00	
27	Wood Primer	Ltr	400.00	
28	Red oxide	Ltr	250.00	
29	Gum (Mobical)	Kg	250.00	
30	Welding Rod	No.	12.00	
31	Welding Machine	Day	600.00	8 Hrs/Day
32	Impervious Material	m^3	2000.00	
33	Gravel	m^3	2500.00	
34	PVC water stop 300 mm wide	M	1000.00	

35	Thermocol filler 12 mm thick (Hydrocell)	m^2	1100.00	
36	Geotextile	m^2	1200.00	
37	Seleant	Kg	250.00	
38	22x24 SWG Nut bolt	No.	20.00	
39	8 mm J hooks	No.	20.00	
40	Bitumen washers	No.	5.00	

The rate analysis of item of work based on these basic is presented in the Annex-A of this report.

10.3 COMPONENTS OF PROJECT COST

Cost implication is obvious with different project activities. Project cost is a main project parameter which also determines project's suitability for implementation. Project cost also shows potential area of cost minimization during construction. The components of Suri Khola Hydropower Project costs were divided into following heads and described in sections below.

- Pre-construction cost
- Construction cost
- Land and environmental mitigation cost
- Engineering and management cost, and
- Contingency cost.

Interest during construction is also a cost but it is not directly used for construction of any structure. Hence it is not included in cost estimate. However it will be incorporated in financial analysis as it will be capitalised at the time of project completion. Similarly operation and maintenance cost is also cost but will be expended during operation phase. Thus this will also be incorporated in financial analysis not in cost estimate.

10.3.1 Pre-construction cost

Pre-construction cost is development cost of project before start of its construction. It generally includes all detailed feasibility study cost, overhead cost during project development phase, expenses on tax, duties and royalties and other logistics costs. The project development phase could be considered up to detailed feasibility study phase. Project cost beyond that event could be considered at construction phase cost. The total pre-construction cost expended before start of construction activities is NRs 39,850,000.00 as pre-construction cost.

10.3.2 Construction cost

The cost of the project that is directly expended in project construction is called construction cost. The cost expended after detailed feasibility study and actual completion of project construction could be regarded as construction cost. The construction cost includes infrastructures, facilities and cost for civil works and electromechanical cost. Similarly the construction cost also includes hydro-mechanical cost and transmission line and interconnection facilities.

Access road, construction road, river diversion, construction power and camps costs are infrastructure costs. Similarly water supply, quarters and communication are also infrastructure cost. But transportation, offices and workshops are facilities costs whereas landslide stabilization, fencing and safety and health are other costs.

Civil works cost includes cost of headworks, headrace, forebay, penstock and powerhouse.

Similarly construction cost includes electro-mechanical costs from water to wire and hydro-mechanical costs. Cost of metal works at headworks, headrace, forebay and penstock are considered as cost of hydro-mechanical works.

Power evacuation transmission line cost and interconnection substation cost also fall under the head of construction cost. The breakdown and estimate of all cost are presented in Annex A-D

10.3.3 Engineering and management cost

Lump sum cost of engineering and management cost is estimated as NRs 24,235,639.00 which includes cost of project management, salaries, office overhead fees and other expenditures of project management and construction supervision.

10.3.4 Contingency cost

Contingency is also not a project cost however project cost may rise in future due to increase in market price and quantity variation. Hence sum of 10% of civil works, 5% of hydro mechanical works, electromechanical and transmission line works is provided as contingency cost to cover unexpected increase in project cost. The amount of contingency cost is estimated in separately for each individual works. The summary of total project cost is presented in Table 10-2: Cost breakdown as follows.

Table 10-2: Cost Breakdown of Suri Khola Hydropower Project

S.N.	Description	Calculation	Base Cost in NRs	Contingency (%)	Contingency Amount	VAT / Custom %	Amount	Total Cost in NRs
1	**Pre Operating Expenses (Pre Implementation Cost)**							
	Particulars	**Amount in NRs**						-
	Feasibility study and EIA		6,000,000					6,000,000
	Licensure, PPA etc		3,000,000					3,000,000
	Salary (Direct and indirect)		10,000,000					10,000,000
	Administration expenses		6,000,000					6,000,000
	Others		500,000					500,000
	Total 1		**39,850,000**	**0%**	**-**	**0%**	**-**	**39,850,000**
2	**Civil Works**							
	Headworks						-	-
	River Diversion		3,171,450	10%	317,145	13%	453,517	3,942,112
	Weir and Undersluice		62,569,244	10%	6,256,924	13%	8,947,402	77,773,570
	Intake cum Gravel Trap		14,271,392	10%	1,427,139	13%	2,040,809	17,739,340
	Spillway and Spillway canal		5,768,412	10%	576,841	13%	824,883	7,170,136
	Settling basin and Headpond		43,481,861	10%	4,348,186	13%	6,217,906	54,047,953
	Civil Works in Penstock Pipe		83,927,385	10%	8,392,738	13%	12,001,616	104,321,739
	Powerhouse and Tailrace		67,267,044	10%	6,726,704	13%	9,619,187	83,612,936
	Switchyard		4,939,282	10%	493,928	13%	706,317	6,139,528
	Total 2		**285,396,069**		**28,539,607**		**40,811,638**	**354,747,314**

3	**Access Road Construction**							
	Access road and pipe alignment		53,022,921	10%	5,302,292	13%	7,582,278	65,907,491
	Total 3		**53,022,921**		**5,302,292**		**7,582,278**	**65,907,491**
4	**HYDROMECHANICAL WORKS**							
4.1	**Steel pipe**							
	Penstock Pipe and Bends(1776.024Ton)							
	Procurement of Plate	1776.024 Ton@495$	88,352,754	5%	4,417,638	0%	-	92,770,392
	Transportation from Factory to Birgunj (1736127kg)	1776.024 Ton @NRs 6400	11,366,554	5%	568,328	0%	-	11,934,881
	Loading and Unloading Charge at Birgunj	1776.024 Ton @NRs 400	710,410	5%	35,520	0%	-	745,930
	Transportation from Birgunj to Factory	1776.024 Ton @NRs 2250	3,996,054	5%	199,803	13%	545,461	4,741,318
	Service Charge for Custom Clearance and Forwarding	1776.024 Ton @NRs500	888,012	5%	44,401	13%	121,214	1,053,626
	Custom Charges	1% f purchase price	883,528	5%	44,176	0%	-	927,704
	Fabrication, Transportation and Erection, Testing and Commissioning	1776024kg@ NRs 50	88,801,200	5%	4,440,060	13%	12,121,364	105,362,624
	Total 4.1		194,998,511		-		-	217,536,475
4.2	**Gates, Trashracks, Stoplogs and Penstock Accessories**				-		-	
	Undersluice Gate	4757 Kg @NRs 135	642,195	5%	32,110	13%	87,660	761,964
	Undersluice Stoplog	4158 Kg @NRs 135	561,330	5%	28,067	13%	76,622	666,018
	Intake Gate	6593 Kg @NRs 135	890,055	5%	44,503	13%	121,493	1,056,050
	Gravel Flushing Gate	2151 Kg @NRs 135	290,385	5%	14,519	13%	39,638	344,542
	Desander Inlet Gate	2104 Kg @NRs 135	284,040	5%	14,202	13%	38,771	337,013
	Desander Outlet Gate	3229 Kg @NRs 135	435,915	5%	21,796	13%	59,502	517,213
	Sand Flushing Gate	3199 Kg @NRs 135		5%	21,593	13%		512,408

			431,865				58,950	
	Course Trashrack	970 Kg @NRs 135	130,950	5%	6,548	13%	17,875	155,372
	Fine Trashrack	3710 Kg @NRs 135	500,850	5%	25,043	13%	68,366	594,259
	Expansion Joints	67318 Kg @NRs 165	11,107,470	5%	555,374	13%	1,516,170	13,179,013
	Saddle and Wear Plate	12061 Kg @NRs 110	1,326,710	5%	66,336	13%	181,096	1,574,141
	Bifurcation	5503 Kg @NRs 160	880,480	5%	44,024	13%	120,186	1,044,690
	Bellmouth	1907 Kg @NRs 160	305,120	5%	15,256	13%	41,649	362,025
	Steel Lining	1696 Kg @NRs 110	186,560	5%	9,328	13%	25,465	221,353
	Total 4.2							21,326,062
	Total 4							**238,862,537**
5	**ELECTROMECHCANICAL (Plant & Machinery)**							
	Complete Cost of E/M Including Manufacture, Supply, Transportation and Customs Charges		142,790,400	5%	7,139,520	1.0%	1,499,299	151,429,219
	Installation, Testing and Commissioning,		3,500,000	5%	175,000	13.0%	455,000	4,130,000
	Inspection Visit to Factory,		1,500,000	5%	75,000	0.0%	-	1,575,000
	CT/ PT, Energy Meter		4,000,000	5%	200,000	1.0%	40,000	4,240,000
	Gantry Structure		2,000,000	5%	100,000	13.0%	260,000	2,360,000
	L/C Opening Charges of Banks	0.15%* 6 Quarter	1,285,114	5%	64,256	0.0%	-	1,349,369
	Earthing and Other Miscellaneous Cost		2,500,000	5%	125,000	13.0%	325,000	2,950,000
	Total 5		**157,575,514**		**7,878,776**		**2,579,299**	**168,033,588**
6	**TRANSMISSION & INTERCONNECTION COST**							
	Transmission Line & Fittings		18,000,000	5%	900,000		-	18,900,000

	Switching station equipment and installation		6,000,000	5%	300,000		-	6,300,000
	Other		1,500,000	5%	75,000		-	1,575,000
	Total 6		**25,500,000**	**0**	**1,275,000**		**-**	**26,775,000**
7	**Project Developmet**							-
	Staff Quarter and Camp		10,500,000	0%	-	0.00%	-	10,500,000
	Office Equipment and Logistic		2,000,000	0%	-	0.00%	-	2,000,000
	Vehicle		8,000,000	0%	-	0.00%	-	8,000,000
	Insurance /Misc and Contingency and Con Power		15,500,000	0%	-	0.00%	-	15,500,000
	Total 7		**36,000,000**	**-**	**-**	**-**	**-**	**36,000,000**
8	**Land Purchased & Dev**							
	Land Lease and Purchased		33,750,000		-			33,750,000
	Total 8		**33,750,000**	**0%**	**-**	**0%**	**-**	**33,750,000**
9	**Environmental Mitigation and Social Contribution**							
	Community Contribution		6,000,000	0%	-	0.00%	-	6,000,000
	Plantation of trees and other environmental protection activities			0%	-	0.00%	-	-
	Total 9		**6,000,000**	**0%**	**-**	**0%**	**-**	**6,000,000**
10	**Project Management and Supervision**							
10.1	**Project Management**							
	Office Running Cost		24,235,639	0%	-	0%	-	24,235,639
	Site Office Running Cost			0%	-	0%	-	-
	Other Cost							-
	Management Cost		***24,235,639***	**-**	**-**	**-**	**-**	***24,235,639***
10.2	**Consultancy Fees and Charges**							-

	Detail Engineering and preparation of tender documents		4,500,000		-	13%	585,000	5,085,000
	Supervision and Engineering Cost		4,500,000		-	13%	585,000	5,085,000
	Other Consultant		2,000,000		-	13%	260,000	2,260,000
	Consultancy		***11,000,000***	***-***	***-***	***0***	***1,430,000***	***12,430,000***
	Total 10		**35,235,639**		**-**		**1,430,000**	**36,665,639**
	Total Cost without IDC		**672,330,143**	**0**	**42,995,675**	**-**	**52,403,215**	**1,006,591,570**
11	**Interest During Construction and Loan Arrangement fee**							
	Interest During Construction		70,682,302					70,682,302
	Loan Arrangement fee		7,552,852					7,552,852
	Total 11		**78,235,154**	**-**	**-**	**-**	**-**	**78,235,154**
	Total Cost with IDC		**750,565,297**	**0**	**42,995,675**	**-**	**52,403,215**	**1,084,826,724**

In this way total project cost with financing came out to be NRs 1,084,826,724.00. In summary which is 10.78 M US$ in exchange rate of 100.5 NRs/US$ and per kW cost came out to be US$ 1686.60.

11 PROJECT EVALUATION

The ultimate aim of a power project is to produce power and energy at financially viable cost. 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 engineering costs and are depreciated over their normal lives which may be determined by law rather than technical or financial criteria.

Financial analysis is connected 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 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.

11.1 COST ESTIMATION

Cost components include headwork and powerhouse construction costs, water conveyance costs, diversions and other civil works, electromechanical, hydro-mechanical, transmission costs etc. Annual operating and maintenance expenditures are also included. Engineering and management cost are also considered in financial analysis. The costs are allocated to the year of expenditure and expressed at constant prices.

The financial analysis extends the costing to include royalties, taxes and duties, insurance, depreciation, interest during construction, capital repayment and interest on debt. Detailed cost analysis is presented in cost estimate chapter.

11.2 BENEFIT ESTIMATION

For the financial analysis, the principal project benefits are revenues, which can be derived from the operation of the project. Seasonal energy value is considered for financial analysis as according to PPA rate. Outage and internal consumptions are also considered while calculating energy benefit. Energy rate is assumed as NRs 4.80 for wet months and NRs 8.40 for dry months as declared by Nepal Electricity Authority with 3% escalation for 5 years from date of commercial operation.

11.3 FINANCIAL ANALYSIS

Financial analysis of the Project is carried out to assess the financial viability of the Project. There are different modes of financing. In this study, the project is analyzed assuming that the project will be developed through private developer using local currency. The developer will arrange the required finance through commercial bank and equity. The project will be developed according to the prevailing hydropower policy of Nepal. The entire energy will be sold to NEA through mutually agreed Power Purchase Agreement (PPA). Financial parameters like FIRR, NPV, BC ratio and RoE are computed from the net cash flow of project as shown in Figure 11.1 and Figure 11.2.

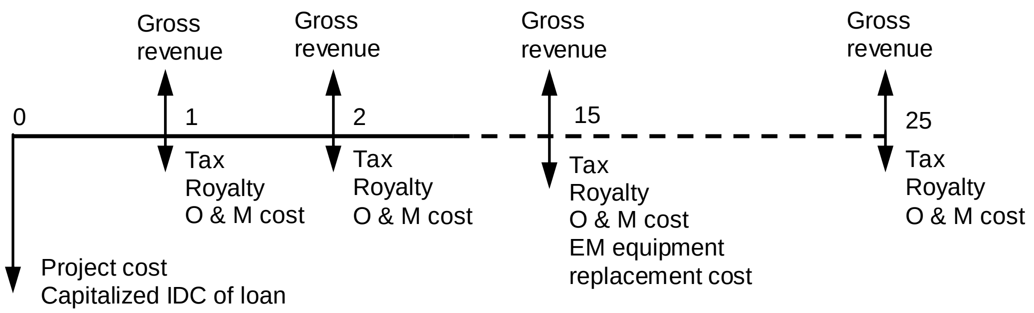


Figure 11.1: Project FIRR

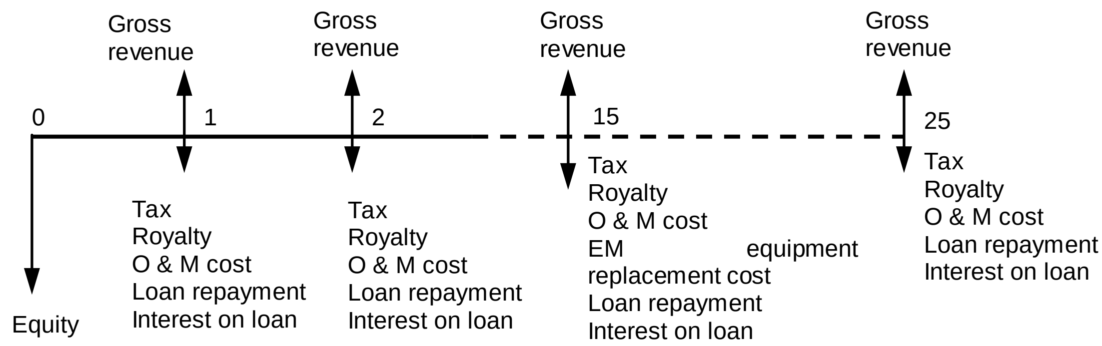


Figure 11.2: Return on Equity of project

11.3.1 Criteria and Assumptions

The ultimate aim of a feasibility study is to ascertain the economic and financial viability of the project under consideration. Economic evaluation of a project investigates its viability from the perspective of society, as a whole, while its financial evaluation examines its attractiveness from the investor's view point. For a project to be considered feasible, a project's economic and financial benefits should outweigh its corresponding costs.

In the present study, an economic analysis as well as a financial analysis has been performed for the proposed Project. These analyses are based on the following assumptions:

- Base benefit obtained from the sales of energy generated by the Project as per signed energy table and posted rate. The unit rate of electricity fixed by NEA for the Power Purchase Agreement (PPA) of this type of project is NRs. 4.80 for the wet months and Rs. 8.40 for the dry months (Poush to Chaitra).
- Base cost of the Project is taken from the findings of the costing at Updated Feasibility Report.
- Annual maintenance expenditure is taken as about 5% of the annual Revenue for every year. Annual increase of 3% of maintenance cost is considered in this analysis.
- 2 % of Revenue and Rs 100 per kW has to be paid to the government as royalty for 15 years. then, 10% of Revenue and Rs1000 per kW has to be paid.

- The Project will obtain 70 percent of the total cost on loan from domestic banks. Remaining 30 percent cost shall be borne by the Project itself.
- The annual discount rate (interest rate) on bank loan is taken as 11 percent.
- Economic life of the Project is taken to be 30 years for this study.

11.3.2 Findings and Discussion

- Project is found to be attractive provided for selling price and 3% escalation in the base rate at least for 5 years as per prudent PPA framework for installed capacity based on Q40%.
- Specific Cost comes around US $ 1686/kW (1$=100.5Rs) which is fair for such size of projects with such terms and conditions.
- The IRR of 13.85 %, B/C Ratio of 1.23, 6.44 years payback period are positive indicators from financial analysis. The other indicators are also found to be attractive for implementation of the project.
- Cash Flow indicates that there will be sufficient money to pay the debt from the first year of operation
- Insurance of the project for risk coverage and sincere care on construction supervision and operation shall be necessary and worth investing.
- Project implementation on time and CoD on scheduled date is very important for this project.

The detail financial analysis of the project is presented separately in financial analysis report.

12 CONCLUSION AND RECOMMENDATION

The feasibility study of Suri Khola Hydropower Project has shown that the project will have installed capacity of 6400 kW and it is feasible to construct as a beneficial project for investment. It will also found to be attractive to supply of energy to rural area of Dolakha district for fulfilling shortcoming supply over demand. The following conclusions and recommendations are drawn from the study of this project.

12.1 CONCLUSIONS

- With the rated net head of 270.30 m and design discharge of 2.75 cumecs (Q40), The project will have installed capacity of 6400kW and generate 31.86 GWh net electricity annually.
- The discharge projection is reliable as the series have high correlation even obtained from different methods including spot measurements. The Plant factor is found to be 61.73% based on deemed energy deliberation by the project.
- The Cost of the project is found to be 1084.826 millions NRs. and the specific project cost is found to be 1688 US$/kW based on 2015/16 price level.
- There is no conflict on water use and there are no any resettlement issues, only little private land is required for headworks some length of water conveyance and Powerhouse area.
- The geology of the project area is favourable for hydropower construction and no any severe situation found for the project stability.
- Project is accessible from the existing road which passes nearby distance from the proposed powerhouse site.
- It is necessary to make the plant able to run in full isolated mode of operation considering long 132kV transmission line beyond Singati Sub-station.
- The financial analysis shows that FIRR of the project is 13.85% and B/C ratio 1.23 which is very attractive indicators from financial point of view. Whereas RoE is 17.95% at 11% interest rate. Hence the project is worth to invest.

12.2 RECOMMENDATIONS

Following recommendations were made after drawing conclusion of the feasibility study.

- Cost reduction strategy should be applied during construction of project which could be possible by optimizing the project components and efficient management of the construction activities. This will make the project more feasible and reduce the risk from project cost increment.

- Suri Khola Hydropower Project is recommended for implementation as it is found feasible from the technical, financial and environmental aspects.

- There is need of participating local peoples in construction of project and make them feel the ownership of the project. They can even invest collectively and share the benefit. Local peoples can get employment and get benefit from the reliable power supply.

- It is recommended for the further detailed design of the project and construction of the project.