2.4 REVIEW OF GEOLOGICAL STUDY

2.4.1 Geomorphology

Geomorphologically Nepal Himalaya corresponds with the five geotectonic divisions from south to north, distinctly following E-W running belts.

- The Gangetic Plain/ Terai Plain
- The Sub- Himalaya/ Siwaliks,
- The Lesser Himalaya,
- The Higher Himalaya,
- The Tibetan/ Tethyn Zone

2.4.1.1 The Gangetic plain / Terai plain

It is the continuation of Indo-Gangetic plain having elevation form 100 to 200 m above amsl. In Nepal the width varies between 10 to 30 km and extends from east to west for about 870 km except at Koilabas area.

2.4.1.2 The sub- Himalaya

Siwaliks occupy the frontal deep of the mountains, which raises to 1300 m above mean sea level and shows an arcuate face with orthogonal structures having steep escarpment towards the plain of the south. Characteristically, it is rugged with numerous gullies, talus cones and scare, at places it forms dun valleys like Trijuga, Dangdeokhuri, Rapti etc.

2.4.1.3 The Lesser Himalaya

Bordering the Siwalik Sub- Himalayas in the south and running parallel to the Main Boundary Thrust (MBT) is a conspicuous mountain range, which rises to 3000m in elevation above mean sea level. Only the major rivers like Mahakali, Karnali, Gandaki, Kosi etc. cut it through.

Within the Lesser Himalaya there are midland valleys in the form of topographical depression such as Kathmandu and Pokhara. The width of these valleys is approximately 30km extending more or less from east to west in the form of a strip.

2.4.1.4 The Higher Himalaya

North to the Lesser Himalaya, the hills rise suddenly and make the snow-capped peaks of the Higher Himalayan range. Among the 14 mountains over 8000 m high in the world, 9 belong to the Higher Himalaya of Nepal. It forms deep gorges, rugged terrain which is cut by the rivers like Gandaki and Arun flowing from Tibet.

2.4.1.5 The Tethyn Zone

North of Higher Himalaya lies the Tethys Himalaya made up of fossiliferous sedimentary rocks. Inner Himalayan valleys like Mustang and Largu are found within the Tethyan zone. The area reminds the desert condition in the north.

2.4.2 Geology of Nepal Himalayas

The geology of Nepal was studied mainly by Nepalese geologists through Department of Mines and Geology and foreign geologists, especially by French and Japanese and Russian (Bordet P 1961, Hashimoto S., Yosihda O., Akiba O. 1973 and Talalov V. 1972). The following is the generalized geological description of Nepal Himalaya:

2.4.2.1 The Gangetic plain

A narrow strip of terai plain represents the northern part of Gangetic plain. The Terai plain is made up of alluvial and colluvial fans spread out at the toe of Siwalik hills with progressively finer materials being deposited downstream towards the south. The Main Frontal Thrust

(MFT), expressed as a prominent topographic break, marks its northern boundary. This is the product of the last episode of the Himalayan upheaval.

2.4.2.2 The sub-Himalaya/ Siwalik

The Siwaliks consist of Neogene molasses type fluvial sediments represented by sandstone, mudstone, claystone, shale, conglomerate, pebble and boulder beds. The deposited sediments show upward coarsening sequence.

The Siwalik is 1.5 km (Dharan) to 25 km wide. It is folded, faulted and tectonically active zone. The MBT delimit the zone to the south and the north respectively.

2.4.2.3 The Lesser Himalaya

Lesser Himalaya, 60-100 km wide, consists of intensely folded metasedimentary rocks represented by carbonates, quartzite and phyllite of Nawakot Complex and is delimited by the MBT in the south and the Main Central Thrust (MCT) in the north. It is overridden by crystalline thrust sheets (Lesser Himalayan Crystallines) represented by various types of gneisses, granites and migmatites in the form of large klippen rooted in the Higher Himalaya.

2.4.2.4 The Higher Himalaya

The Higher Himalaya consists of thick sequence of Higher Himalayan Crystalline rocks and underlies Tethyan sedimentary rocks. It consists of 5-10 km thick slab of high-grade metamorphic rocks. Owing to intense deformation, the lithology is altered and obliterated.

2.4.2.5 The Tibetan/ Tethyn Himalaya

It consists of a thick folded fossiliferous sedimentary rock succession. The rocks of he area are represented by impure limestone, marl, slate/ shale, sandstone, black shales and sandy dolomite intruded by Tertiary granite bodies.

2.4.3 Structures and Tectonics

The MFT, MBT and MCT are the major structural elements dominating the tectonics of the Himaalya, which have brought the Higher Himalayan Crystallines on to the low grade metasedimentary succession of the Lesser Himalaya which in turn have been thrust over the Siwalik molasse sediments.

The regional geologic structure of the Nepal Himalaya is also characterised by the presence of the major synclines and anticlines. In eastern Nepal, rocks of the Kuncha and Nawakot Groups form Arun and Tamor anticlinal tectonic windows surrounded by high grade crystalline rocks occupying the corresponding top of the anticline. The high grade crystalline rocks have been tectonically transported south along the MCT almost to the vicinity of the MBT and the MCT here (Central, Mid western and Far western Nepal) merges with the Mahabharat Thrust (MT).

The transverse fault system along Arun, Dudhkoshi, Seti valleys etc in NE-SW direction appear to be regionally extensive and apparently transgressing into Tibet. The frontal zone of the Himalaya is most active due to continuing convergence of Indian plate. The Main Boundary Active Faults at Udaypur (West of Saptakosi) in the east and at Dang (Tulsipur to Thuli Bheri river) in the west appeared to be active during sub-recent times.

2.5 REVIEW OF ACCESSIBILITY

2.5.1 Existing Road System

The existing road network has been developed by the Department of Roads through assistance from various donor agencies. The HMG/N has accorded high priority in development of roads in every 5-year plan. Special attentions have been paid on rural road construction during the last decade.

According to the 9th 5-year plan, the target was to construct and maintain a total of 2983 km of roads, which include 1290 km of feeder roads and 1693 km of rural roads. Although all district headquarters were envisaged for connection to road transport network by the end of 9th 5-year plan, according to the progress of the 9th Plan, only about 65% of the target has been achieved. The construction of Sanfebagar-Mangalsen, Rukum-Musikot, Katari-Okhaldhunga, Jajarkot-Chinchu, Sankhuwasabha-Khandbari and Khimti-Ramechap are still underway. The district headquarters of Humla, Mugu, Manang, Dolpa, Solokhumbu, Khotang, Mustang, Rukum, Jumla, Darchula, Jajarkot and Bhojpur have remained unconnected to the road transport network till date. An updated road network map of Nepal is given in Appendix - A.

2.5.2 Distance from the Road Head

Considering the importance of access roads for the planning of small hydropower the distance from road head to the project site is considered as one of the criteria for screening of the project. For this purpose a road map prepared by the Department of Roads, HMG/N called "Strategic Road Network" has been used to determine the distance of project site from the road head.

In costing of the project the transportation of construction materials and minor equipments are considered from the nearest road head by porter, whereas heavy equipments would be transported by using helicopters from nearest airport or road head or district head quarter as convenient and safe means of transport.

Some improvements of existing and approach foot trails are incorporated in the planning of small hydropower projects so that the equipments could be transported safely to the respective sites from the helipads.

2.6 REVIEW OF DISTANCE FROM NATIONAL GRID

2.6.1 Background

The isolated small hydropower projects under the present study are located in remote areas where the extension of national grid will not happen during the next decade. The projects provide power to rural communities for lighting and rural industries, which increase the employment opportunities. The rural isolated schemes will help decrease the strain on a nation's foreign currency spent on importing kerosene and agricultural products. The generated electricity would be distributed to the limited surrounding load centers using 400 V distribution lines and 11 kV or 33 kV transmission lines.

2.6.2 National Grid Development

The integrated Nepal power grid has been expanded across east to west using 132 kV transmission lines. Feasible load centers are connected with national grid through sub-stations at appropriate locations. The NEA has also implemented rural electrification program through extension of national grid in a number of districts. Extension of national grid to rural areas is quite expensive and difficult. NEA has developed isolated small hydropower plants to serve remote and rural areas where grid extension is not viable.

The following transmission lines are presently under construction in the strengthening program of national grid and transmission system.

Table 2.8: Transmission line projects under strengthening program

High Voltage System	Transmission Line	Length (km)
220 kV System (347 km)	Khimti – Dhalkewar	75
	Hetuda – Bardhghat	132
	Hetuda – Dumkibas	140
132 kV System (549 km)	Kusha – Dhalkewar	120
	Dumkibas - Butwal	43
	Khimti - Bhaktapur - Balaju	47
	Modi – Pokhera	40
	Kali Gandaki 'A' Pokher	58
	Pokhera – Marsyandgi	85
	Bhaktpur – Syuchatar	20
	Pathlaiya – Parwanipur	15
	Dhalkewar – Sitamadi (India)	30
	Butwal – Sonuli (India)	30
	Mahendranagar – Tanakpur (India)	11
	Mid-Marsyangdi - Dumre	25
	Bhotekoshi – Sunkoshi	25
66 kV Transmission Line (70 km)	Chilime – Tirshuli - Devighat	39
	Indrawati – Panchkhal	31
33 kV Transmission Line (430 km)	Sindhuwa – Khadbari	45
	Buipa – Okheldhunga	29
	Ilam – Fidim – Taplejung	90
	Sheetalpati – Mushikot	50
	Chinchua – Rakum – Jajarkot	70
	Ghorahi – Halleri – Rolpa	45
	Tatopani – Larjung – Muktinath	----
	Udipur – Beshishahar – Monang	81
	Dadeldhura – Baitadi	8
	Dadeldhura – Baitadi	12

An updated national transmission networks map of Nepal is given in Appendix - A.

2.6.3 Remoteness and Transmission System

The topography does not permit extension of national grid throughout the country. Therefore in such areas isolated power plants are considered suitable option for rural electrification.

During review stage, projects within 30 km range from existing or planned transmission lines are excluded from the study. Only isolated projects with surrounding load centers are included.

In the present study provision is made to supply the power to nearby load centers with 11/33 kV overhead transmission lines and 380/220 V distribution lines. The proposed load centers of each project is shown in Appendix - A.

2.6.4 Transmission and Distribution Lines

All load centers proposed by previous study have been reviewed and confirmed. Topographical maps of the project area have been used during verification and updating of the load centers. The distance for 11 kV transmission lines have been determined from the topographic maps. Similarly 3-phase distribution system is considered in order to provide reliable power that can induce small-scale industrial use. The main criteria during study are considered as follows:

- Minimum power losses on transmission line
- Safety of the people living and working near the line
- Protection from lightning and other damage
- Stability of the structures in temperate areas or in areas of ice and snow
- Use of environmental friendly materials

Based on above criteria the 11 kV transmission lines are proposed incorporating step-up and step-down transformers as required for power supply. The calculated distance of transmission lines have been added together and used for screening of the projects.

2.7 REVIEW OF POWER DEMAND AND SUPPLY SITUATION

2.7.1 General

About 85 percent of the population of Nepal lives in rural areas. The rural population heavily depends on traditional source of energy. Fuel wood occupies 78 percent of the total energy followed by agricultural residue 4 percent and animal waste 6 percent. Only one percent of the total energy requirement is met by electricity and overall 18% of the total population has access to electricity. The use of fossil fuel constitutes nearly 11 percent of the total energy consumption.

Nepal has tremendous water resources and the hydropower is most promising alternative source of energy. Presently, the existing hydropower capacity is only 535 MW, which is only 1.25 percent of the economically feasible potential hydropower.

2.7.2 Present Power Situation

2.7.2.1 Existing generation

The list of major hydropower, diesel power, small hydropower and micro hydropower plants are presented in Appendix A. According to the records so far 15 major hydropower plants are in operation with the total capacity of 516.050 MW. These plants are mainly concentrated in the central and western regions of Nepal. In addition 6 diesel power plants are in operation with total capacity of 56.756 MW. Similarly small and micro hydropower plants are in operation with capacity of 18.617 MW and 0.351 MW respectively. The total existing hydropower is about 535.018 MW. Almost all district headquarters are electrified either by SHP or by national grid.

Both the government and private sectors generate hydropower; whereas the distribution of electricity is solely executed by the NEA. Some of the SHPs are leased to private sector for operation and minor maintenance, whereas MHPs (< 100 kW) are constructed and operated by private entrepreneurs. In order to encourage MHPs, the government provides 50% subsidy on construction cost as an incentive.

2.7.2.2 Projects under construction

The following hydroelectric projects are presently under construction by NEA or private companies. Gamgad and Heldung SHP are isolated systems while the rest are grid connected.

Table 2.9: Hydropower plants under construction

S. No.	Name of the project	Capacity in MW	License holder
1	Chilime Hydroelectric Project	20	Chilime Hydropower Co.
2	Middle Marsyangdi Project	70	NEA
3	Upper Modi Hydroelectric Project	14	GITEC Nepal Pvt. Ltd.
4	Piluwa Khola	3	Arun Valley HDC Pvt. Ltd.
5	Sunkoshi Hydroelectric Project	2.6	Sanima Power Co.
6	Chaku Khola Hydroelectric Project	0.91	Alliance Power Co.
7	Gamgad SHP	0.4	SHPD/NEA
8	Heldung SHP	0.5	SHPD/NEA

2.7.3 Load Demand Forecast

The present load demand forecast is based on 'bottom up' approach based on household, commercial, industrial and public sector demands. The demand forecast is done based on the present energy consumption pattern and future growth due to growth in population, increase in income, creation of new facilities etc. The following parameters have been considered as norm values for load demand forecast based on the NEA's practice:

- Population of the project area
- Growth of population of project area
- Household numbers and sizes in the project area
- Household numbers of low, medium, high income groups
- Agricultural GDP growth
- Existing small-scale industries and growth

The growth in the four sectors have been considered to determine the load demand in rural hills of Nepal such as:

- Domestic sector growth
- Commercial sector growth
- Industrial sector growth
- Public sector growth (public service and street light)

2.7.4 Parameters Applied for Load Demand Forecast

The applications of the parameters in load growth have been determined from socio economic household survey findings. If the parameter is not determined from the survey result then the parameter is considered from reliable secondary sources. National norms are used when the parameter are not available for the project.

The population of VDCs in the project area is obtained from latest national census, 2001. The annual growth of population in the census is generally considered as constant for the project. The household size of the project area is calculated as the average household of VDCs and is considered as constant over the project period.

The income level is categorized is three groups: low, medium and high. The growth pattern of the income group is assumed to be gradual decrease in low-income group into increasing medium and high-income groups. The rate is based on the remoteness of the project area but not greater than two percent per year.

The number of households per commercial center is considered as 13 households as per field study. The growth rate is considered district population growth ant 0.5% per annum and assumed to be constant over the project period. Similarly, the number of households per public service unit considered for the study is 35 (Annex B, Table 1) households with the same growth rate 0.5%.

The electrification coefficients are determined based on the various type of consumer's rate at which the consumers get connected to the service. It depends on household income group, willingness to pay and affordability. It is assumed 60% of low and medium groups households and 70% of higher income groups will connect to the electricity supply in the first year. The coefficient value is assumed to increase by 5.45 in the first decade and by 1.64 in the second decade considering that the coefficient will be 100% in 20 years period in the case of low and medium income groups. The coefficients values is considered as 60% in the cases of commercial, public service light and public services in initial year. The coefficient value for commercial, public service and public light is assumed to increase by 3.54% in the first decade and by 1.64% in the second decade.

The demand for electricity based on the criteria established above is assumed to depend on the type of consumer. Essentially, the consumers are categorized into four groups based on the existing consumption pattern in the hills and mountain regions. The groups are domestic, commercial, non-commercial and industrial.

2.7.5 Electricity Consumption

It is assumed that the people of low income group will consume minimum energy block of 30 kWh per month in the lifeline. Similarly the medium income group will consume 40 kWh per month high income group will consume 40 kWh.

In the case of commercial and public sectors, it is assumed to consume 750 kWh per month throughout the project period. The growth rate of commercial consumer and public service is assumed at 2.68% per annum. The consumption of electricity in industrial sector is assumed to replace existing diesel plant and at least one unit of small-scale industry from each VDC will connect the electricity line energy two years. The growth of energy demand is assumed at 2.68 percent over the design period. It is assumed that an industrial unit at 7 hp electric prime mover will operate for 5 hours a day through 300 days a year consuming 7.8 MWh of electricity per annum. The assumptions are basically based on the normal practice of NEA Norms.

The system loss is not a serious concern in the case of isolated SHPs. It is assumed to be 18% which is an acceptable figure for normal system in the context of Nepal and remains constant over the project period since at present total generation capacity is not fully consumed. It is assumed that the electricity initially used for 1314 hours of utilization.

2.7.6 Summary of Power Demand

The power demand in all the small hydropower projects is less than the generation capacity because the previous study reports are based on the surplus energy to be connected to the INPS. The study analysis shows that the load factor (demand/supply) is reasonable in eight small hydropower projects are greater than 0.5 while that for eleven sub-projects is less than 0.2 [Appendix - A].

2.8 REVIEW OF CIVIL DESIGNS

2.8.1 Design Criteria

This section describes general layout of 32 projects of 100 kW 2000 kW capacity considered in the review and screening phase. Basically run-of the river type projects are considered suitable for further development.

The project layout has been selected considering the following criteria:

- Preference is given to the simplest layout in terms of design and construction.
- The headrace canal/penstock alignment is chosen as short as possible.
- The powerhouse has been located as close as possible to the load centers
- Technical issues such as slope stability, flood risks and other site-specific issues.

For uniformity of results of the reviewed projects, standard design criteria and procedures for general layout of the project components has been adopted. Technically suitable and proven structures are adopted for the schemes to ensure low risk and high value for money.

No storage facility is provided in small hydros at intake stream.

The sizing of the major project components has been performed by DIPEO Module i ¾, which is valid for estimating costs of SHP plants in the range of 100 kW - 12000 kW. The software was also used during small hydropower master plan study.

Plant capacity, gross head, design flow, basic weir dimensions, waterways such as length of the crest, depth of foundation, height of weir, length and type of headrace, length of penstock and number of units of turbines, degree of difficulty, natural slope and geological conditions are the basic input parameters.

Other necessary computations to determine required size of the components are performed by the model itself. The deviation in results from the model against that obtained from a rigorous estimate is found in the order of ± 20 %.

2.8.2 Weir and Intake

Most of the studied hydropower schemes are located in the high mountains, middle mountains and Siwaliks. The characteristics of the river of these regions are quite different. It is essential to consider the characteristics of these rivers for the design and construction of diversion structures. The main characteristics are:

- Steep river gradients and steep slope along both riverbanks.
- High degree of continuous erosion and sediment transport.
- Liable to transport considerable quantities of sediment including big boulders during the monsoon.
- A significant flow and sediment increase in the rivers during the monsoon.

The movement of large boulders and high sediment loads are the challenges for the appropriate design and construction of the diversion structures.

Low height diversion weirs are the most suitable for the small-scale run-of the river plants. Concrete and boulder lined diversion weirs are considered the suitable to divert required discharge and to evacuate excess flood discharge safely. A diversion weir of 1.5 m to 4 m high has been adopted as suitable diversion structure. The height could vary according to the topography at the selected intake site, amount of bed load and discharge. The crest level of the weir was fixed to ensure water depth required for diverting design discharge to the intake.

The location of the weir is selected considering the following items:

- Narrow section in order to make quantity of works as small as possible.
- Good quality of rock mass as bedrock with little deposited sediment.
- The weir is located perpendicular to the river as much as possible.

The bottom rack (Tyrolean) or side intakes are quite popular in small hydros, which allow extraction of discharge excluding gravel and boulders. The type of the intake is selected according to discharge, gradient of river, topography, suspended and bed load etc.

To prevent the intakes from boulder impact and flood water entry, the intakes are located behind a permanent rock outcrop (to prevent boulder) and on the outer bend of the river (to minimize the amount of sediment entry into the intake).

2.8.3 Desilting Facilities

The settling basin is located as close as possible to the intake. The settling basin is designed considering the settling capacity, storage capacity, flushing capacity and topography of the location.

The DIPEO module i ¾ performs necessary hydraulic computations to determine size of the basin required to eliminate 0.2 mm minimum size grains. Some of the results are verified using other methods of computing trap efficiencies such as Vetter method, the results are judged to be acceptable.

2.8.4 Power Canal / Tunnel

Rectangular and/or trapezoidal shaped stone masonry canal or free flow horse shoe shaped tunnel has been adopted to convey the discharge up to forebay or surge-tank. If necessary canal bridges, syphons, embedded slope pipe and supported slope pipes are also provided. The size varies according to the discharge; hence economical size of the canal/ tunnel has been adopted. Necessary free board is provided to the canal so that the design discharge passes without losses.

2.8.5 Surge Chamber/ Forebay

The location of surge chamber/forebay is selected at flat terrace with minimum excavation. The size of the forebay is fixed by the DIPEO, providing storage capacity of one and half to three minutes of design discharge. Side spillway at suitable location is provided to evacuate excess discharge. Similarly surge shaft of sufficient size is provided to resist the water hammer pressure caused by sudden load rejection.

2.8.6 Penstock

Steel penstock is considered suitable for small hydros to transport the design discharge up to the turbines. The optimum size of penstock is calculated by the DIPEO module and usually anchor blocks are provided at each bend. The thickness of steel is determined by the module itself. Computations of penstock size and thickness is verified considering best engineering practice, the results are found to be reliable enough.

2.8.7 Powerhouse

The powerhouse size is considered with empirical relation between kW and size. The space of powerhouse will be adequate for turbine, generator, valves, load control unit operating the powerhouse and space for repair and maintenance. Overhead crane inside the powerhouse is considered for lifting the equipment. Computation of the powerhouse size is performed by the module itself.

2.8.8 Tailrace Canal

Tailrace canal of adequate size has been considered to carry the outflow discharge after power generation. The canal is designed to carry the design discharge to the river without backwater effect.

2.9 REVIEW OF TURBINES

2.9.1 General

Selection of turbine type and number of units is based on inbuilt options of HydrA Nepal software. The outputs are verified using the graphic nomogram given in the various SHP design manuals and manufacturers catalogues. The type basically depends on parameters like head, capacity, discharge and power output.

In the power potential module, the calculation of generating potential uses the data from the flow regime analysis module to identify turbines that operate within the given flow conditions and estimate the energy output of each turbine. Selection is made among a group of 8 turbine types (Francis spiral case, Cross flow, Francis open flume, Pelton, Semi Kaplan, Turgo, Kaplan and Propeller). The operational boundaries and efficiencies of these turbines are presented in the Figure 2.11.

Figure 2.11a Turbine operational boundaries

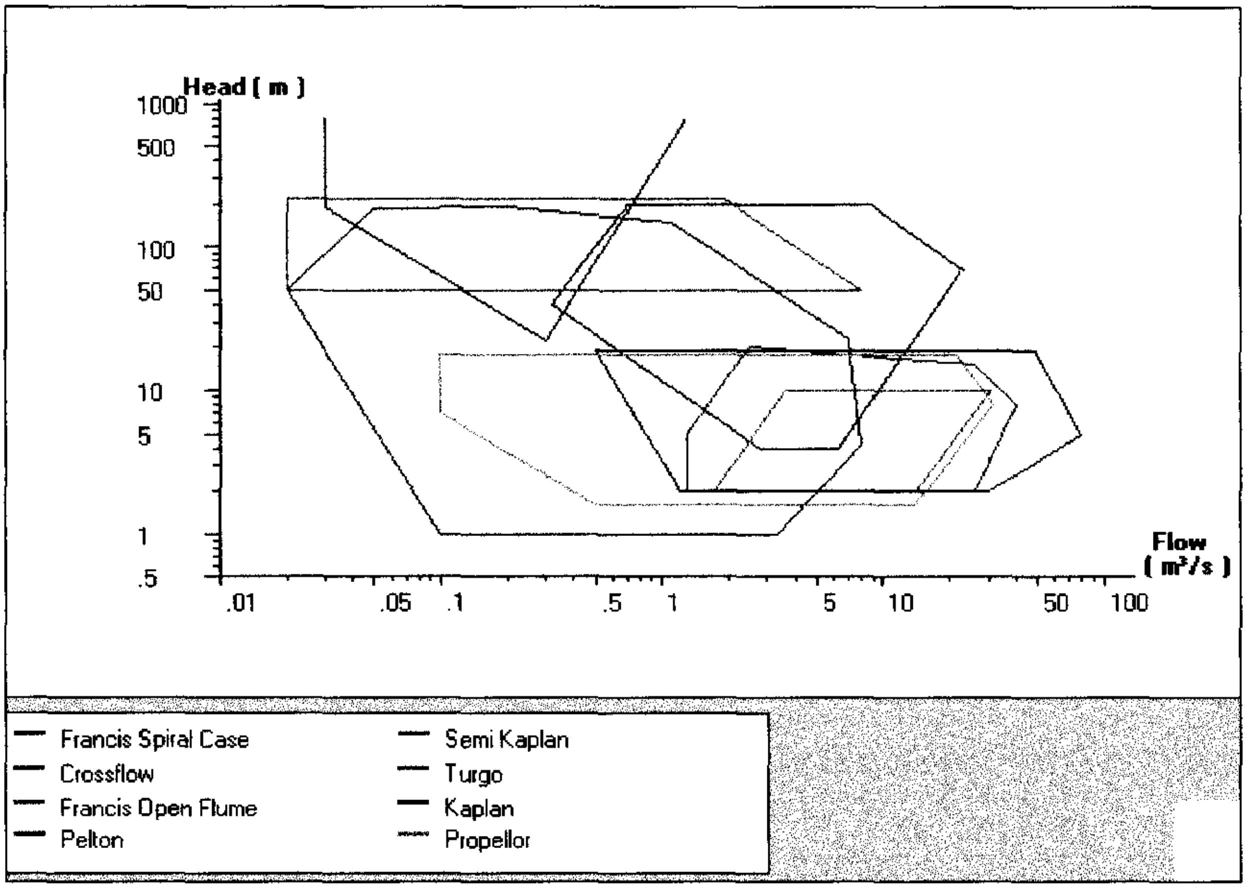
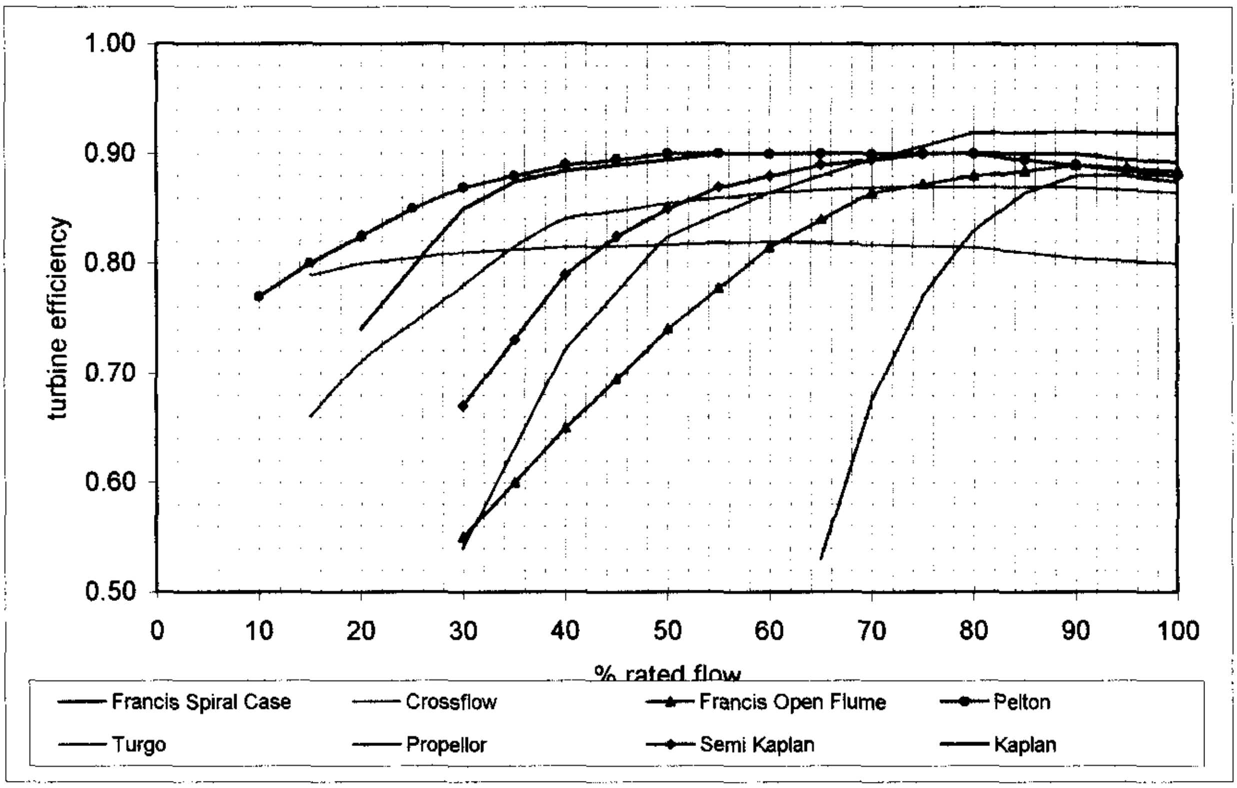


Figure 2.11b Turbine efficiencies



Type and number of turbines from the range of operable turbine types have been selected based on the net average annual energy. Number of turbines is selected with consideration of weight of turbine to be transported by the helicopter (MI17 carries up to 4 ton load) to the remote site.

2.9.2 Site Specific Parameters

In order to get consistency in the results of all the reviewed projects a standardized set of site specific parameters are used in the design of electro-mechanical components.

Provisional rated flow defined in HydrA Nepal is the initial estimate of rated flow. This can be entered either as a flow in m^3/s or as a probability of exceedance in percentage. The corresponding probability of exceedance or flow gets updated when a new field is selected. The rated flow is the optimum flow for which all the components of the turbines and pipelines etc have been designed.

The residual flow represents an environmental minimum flow to be retained in the river in order to maintain acceptable conditions for water use downstream of the intake. If there is no downstream water usage, 10% of 90 percentile flow (Q_{90}) has been selected as residual flow. If downstream water usage exists, the residual flow has been adjusted accordingly.

The intake and tailrace ground levels are read from the 1:25,000 and 1:50,000 topographical maps produced by the Survey Department of Nepal or from the previous studies. The net (effective) head is obtained deducting head losses in the system (screens, intake, pipes etc). In the present study, net head is equal to 95% of gross head. The net annual energy is computed taking into account turbine downtime.

HydrA Nepal contains details of eight standard turbines. The following parameters are selected:

Gearbox efficiency :	Where applicable 90% otherwise n/a.
Generator efficiency :	95%
Transformer efficiency:	98%
Turbine efficiency :	As per figure in Figure 2.11 (b) for different types of turbines
Downtime allowance :	240 hours per year

The load factors in the load centers of small hydros are typically low as most power is used during evening peak hours. Promotional activities for load factor development should be considered as an integral component of small hydros to ensure sustainability and optimal utilization of the plant capacity. Typical load factor is 15% - 20%.

2.10 UPDATED PROJECT FEATURES

The general features of the projects are prepared based on review of previous reports and design criteria to ensure that the screening of the projects is done on a consistent basis. The features of the identified project sites include general information such as location, accessibility, hydrology, layout, energy production, transmission etc.

Initially 82 projects were considered for this study. In the course of the study 32 projects are selected based on exclusion criteria for ranking. The summary of project features and cost breakdowns of 10 top ranking projects is presented in Appendix - A.

2.11 REVIEW OF COST ESTIMATES

2.11.1 Costing Method

The total cost of a power plant is one of the important components in the project ranking process. Therefore, it is necessary that the cost calculated for all studied projects under ranking should be consistent. The cost of all studied small hydropower projects are calculated using software DIPEO module i³/₄, which calculates the quantity of major structures and computes the cost using supplied unit rates. The cost calculated using DIPEO module gives the detail cost break down of the following civil structures:

1. Access road
2. Weir and intake
3. Gravel spilling system
4. Sand trap
5. Headrace works (different type of canals and bridges)
6. Surge chamber
7. Penstock
8. Spillway
9. Powerhouse

Besides, the software gives cost of electro-mechanical equipment, costs of studies, initial cost of work, cost for office, store and land acquisition as well as 10% indirect cost on civil works. The cost of electro-mechanical equipment includes items such as turbine, generator, governor, valves and associated electrical and mechanical equipment. However, cost of electro-mechanical equipment and cost for studies have been separately calculated and updated as per prevailing rates applied in similar other projects. The transmission line costs are calculated using the latest rates prevailing in NEA projects.

2.11.2 Rate Analysis

During the screening phase no detailed rate analyses have been carried out. The unit rates derived for the study of small hydropower projects of 5-10 MW capacity are used adding 1% inflation from 2001 to 2002 rates. River basin wise rate analyses were prepared for the referred project, where prevailing district rates for labour, construction materials and equipment and HMG norms were used.

2.11.3 Engineering and Administrative Costs

A summary of engineering cost has been included in Table 2.10, but the administrative costs such as staffing of the Client, operation and maintenance of the offices etc. are not included in the costs.

Table 2.10: Summary of cost estimate

S.N.	Project name	Plant capacity (kW)	Total project cost (US $)	Specific project cost per kW (US $)	Local cost (US $)	Foreign cost (US $)	Operation & maintenance cost per year (US $)	Rehabilitation & replacement cost after 20 years (US $)
1	Kabeli Khola - I	1,110	2,398,185	2,161	1,461,867	936,317	95,927	799,517
2	Kabeli Khola - II	1,860	3,690,250	1,984	2,462,410	1,227,841	147,610	1,091,041
3	Maiwa Khola	1,920	3,181,729	1,989	2,090,831	1,727,898	190,936	1,368,498
4	Leguwa Khola	560	1,165,014	2,080	673,472	491,542	58,251	466,792
5	Sabha Khola	1,260	2,742,515	2,177	1,580,807	1,161,708	109,701	1,091,508
6	Rok Khola	310	851,080	2,745	422,122	428,958	51,065	397,158
7	Yari Khola	160	871,455	5,447	606,235	265,220	52,287	222,620
8	Molung Khola	640	2,579,046	4,030	1,599,237	979,809	154,743	733,509
9	Chaunri Khola	350	1,701,645	4,862	1,125,769	575,876	102,099	490,376
10	Tadi Khola	890	2,185,621	2,456	1,300,388	885,233	109,281	808,433
11	Khani Khola	1,030	2,282,140	2,216	1,378,425	903,715	91,286	715,615
12	Phalankhu - II	500	1,530,576	3,061	886,843	643,733	91,835	560,033
13	Phalankhu – I	660	2,098,330	3,179	1,412,175	686,155	104,917	588,055
14	Darundi Khola	860	3,002,781	3,492	1,945,754	1,057,027	150,139	890,827
15	Chepe Khola	340	2,272,667	6,684	1,628,147	644,520	136,360	572,970

S.N.	Project name	Plant capacity (kW)	Total project cost (US $)	Specific project cost per kW (US $)	Local cost (US $)	Foreign cost (US $)	Operation & maintenance cost per year (US $)	Rehabilitation & replacement cost after 20 years (US $)
16	Charang Khola	400	1,645,911	4,115	1,089,278	556,633	98,755	455,233
17	Jyagdi Khola	340	1,724,961	5,073	1,198,454	526,507	103,498	457,507
18	Ghami Khola	1,080	2,540,496	2,352	1,687,592	852,904	101,620	752,104
19	Bhim Khola	220	1,644,615	7,476	1,124,252	520,364	98,677	402,464
20	Chhal gad	120	1,133,900	9,449	692,721	441,178	68,034	326,878
21	Phoi gad	170	1,088,531	6,403	697,924	390,608	65,312	352,208
22	Chaudhabise	650	1,955,013	3,008	1,202,064	752,949	97,751	660,249
23	Jalijala Khola	100	995,253	9,953	631,924	363,328	59,715	317,428
24	Satya Khola	1,080	3,347,455	3,099	2,467,254	880,202	133,898	725,402
25	Mujkot Khola	950	3,352,629	3,529	2,124,574	1,228,055	167,631	982,355
26	Galwa gad	100	995,313	9,953	618,291	377,022	59,719	331,122
27	Gandi gad	1,280	3,141,367	2,454	2,065,346	1,076,022	125,655	1,005,222
28	Gadsera gad	480	1,689,408	3,520	1,059,517	629,891	101,364	591,491
29	Kala gad	120	888,489	7,404	500,586	387,903	53,309	342,453
30	Jamadi gad	1,300	3,677,157	2,829	2,495,128	1,182,028	147,086	1,121,728
31	Bhartola gad	340	1,730,413	5,089	1,215,610	514,803	103,825	428,403
32	Nilgarh gad	240	1,466,021	6,108	1,079,047	386,974	87,961	359,074

Provision of contingencies is necessary in the calculation of any project cost to compensate unseen expenditure and quantity over run of any construction item. Therefore, 10% of contingency as an indirect cost of the total civil work cost has been made.

2.12 ECONOMIC AND FINANCIAL ANALYSIS

2.12.1 Introduction

Economic analysis of a small hydropower project represents the cost and benefit to the society in terms of opportunity cost. All cost streams and benefit streams are changed to represent economic values. The basic assumptions of conversion factors such as foreign currency, standard conversion factor, opportunity cost of capital and traded or non-traded components at border price etc. is considered as normal standard. Adjusting the estimated cost of all components to reflect the economic value, the economic analysis is performed considering the basic guideline for economic analyses and projects. The economic evaluation is performed to seek the feasibility of the project in national perspective.

The financial analysis is the basic of economic analyses. The financial analysis is conducted on the basis of the consideration of market values. The financial analysis is performed to seek the feasibility of the project in terms of individual investor's perspective. For a project to be economically viable, it must be financially sustainable, as well as economically efficient. If a project is not financially sustainable, economic benefits will not be realized. Financial analysis and economic analysis are therefore complementary.

2.12.2 Evaluation of the Projects

The economic / financial analysis of the sub-project of the small hydropower project is evaluated as per the results of the following terminology.

- Calculation of internal rate of returns EIRR
- Break even tariff
- Calculation of NPV of the capital costs, revenues and net benefit streams
- Benefit cost ratio

For the economic analysis, the costs and benefit streams are considered as follows: capital costs, O&M cost in cost streams and revenue from electricity supply and capacity benefit in benefit streams.

2.12.3 Assumptions

The financial analysis estimates the rate of return in terms of values where as economic analysis measures the effect of project on the social benefit in national perspective. The financial analysis is based on the prevailing market price and inflation rate. However, numerous assumptions are considered in economic analysis so as to bring better allocation of resource to reflect the real economic value. For present analysis the following general assumptions have been adopted.

- All costs and revenues are expressed in 2002 price
- The design period of the project is for 20 years.
- The costs and benefit streams are considered as constant over the design period
- Financial / Economic analysis is evaluated on cash flow stream for 30 years.
- The social opportunity cost of capital is considered at 10%
- The financial opportunity cost of capital is considered at 10% to calculate BET

The following assumptions have been made with regards to costs

- All costs, in particular imported tradable inputs, are included net duties and taxes. This includes VAT which is payable at 10% on all purchases. The VAT is not included in electricity bill.
- Capital costs include physical contingencies but exclude price contingencies.
- Official exchange rate of NRs. 78.0 per US$ has been employed when converting foreign costs to local currency equivalent.
- The shadow exchange rate or standard conversion factor (SCF) of 0.90 has been applied to non-tradable inputs to convert them into economic cost. The conversion factor for local labour and local material is considered as 0.70.

2.12.4 Methodology

The investment cost and annual cost are divided into two components foreign cost and local cost to derive at the economic cost. The foreign component includes transfer of payment of 1% hence the conversion factor to change from financial cost to economic cost is 99%. The financial costs of local components which generally include local labour and local material are adjusted to reflect the economic value by a standard conversion factor of 70%. Similarly, other local components and locally produced items are adjusted to reflect economic costs by conversion factor 90%.

The tariff structure is applied based on the present NEA tariff rate. The tariffs are varied with level of income and different categories. The analysis of the project has been prepared for cash flow streams projection for 30 years. The economic benefits are classified into direct - the revenue generated from the electricity tariff and indirect – as capacity benefit normally considered by NEA (US$ 104/kW/annum) for the analysis in the present study.

The internal rate of return (IRR) is the major tool to measure the viability of the project. IRR is the rate of benefit incurred during the project period. FIRR is benefit incurred on a project where all costs and benefit schemes are measured in financial price. The FIRR represents the financial benefit during the project period. Economic internal rate of return (EIRR) is determined on the basis of all costs and benefits streams in economic price. For a project to be acceptable the EIRR should be greater than the economic opportunity cost of capital.

2.12.5 Summary of Economic/Financial result

The economic analysis results are found as expected since the value of surplus energy is not considered. The analysis results depicts positive economic internal rate of return (EIRR) only in seven small hydropower projects namely Maiwa Khola, Leguwa Khola, Molung Khola, Phalanku I&II, Bhim Khola and Mujkot Khola. These seven projects may be considered as feasible considering the small hydropower projects as service oriented. The internal rate of return is higher than 10% only in three small hydropower projects viz: Phalanku I, Phlanku II and Mujkot Khola. Similarly the benefit cost ratio is greater than one only in these three small hydropower projects. The break-even tariff is unusually higher than the prevailing tariff rate except in the case of Mujkot Khola SHP with US$ 0.11. The generation cost of all the projects except in few projects are considered as normal (Appendix - A).

2.13 SOCIAL ANALYSIS

2.13.1 Affordability

The affordability of the rural household for electricity bill is based on the sample household survey. The affordability of household for electricity bill, therefore, is assessed on the basis of parameters such as income level, land holding size, time acquired for fuel wood, household size, number of cooking stoves, type of house etc. In general affordability for electricity bill by the consumer household may be considered less than five percent of the household income. However for the present study affordability value is considered from the previous study reports.

2.13.2 Willingness to Pay

The willingness to pay for electricity bill is based on the interest of the household to connect the electricity line. So, the result information on willingness to pay must be based on the survey data. The affordability value of the household for electricity may be also considered as the willingness to pay if the information is not available. However for the present study the value of the willingness to pay of the previous project report is considered for the criteria of screening of the project.

2.13.3 Sustainability

Sustainability of the projects is most important factor for small hydropower project in rural hill areas. The economic and financial considerations must be worked out considering operation and maintenance cost for long-term sustainability. The project may be considered as sustainable when the project runs for long term maintaining the cost of operations, maintenance and rehabilitation costs. At least the revenue generation per annum from the project should cover the operation, maintenance and rehabilitation costs. Sustainability of the project also depends on the other factors such as management of the project, availability of spare parts for maintenance, distance from project site to major market.

Sustainable development of environment resources-based energies is a key requirement of the hill areas of the country. One of the basic requirements for sustainability is to make available of the information of different aspects of energy and income status level, affordability and willingness to pay. The project will also be sustainable through income generating options such as agro-processing, flour and rice mill and other possible options in the project area with integration approach with community development. For sustainable rural energy system small hydropower can be developed in order to maintain following rural development (a) improved quality of life especially for women and children (b) promotion of efficient end use technologies and promotion of non farm activities. (c) conservation and restoration of natural environment.

2.13.4 Summary of Social Aspects

The study of the affordability based on the secondary data shows that the households of ten small hydropower projects may be considered as affordable for the electricity bill since the ratio of affordable rupees per month with the present tariff rate per month is higher than 90%. These small hydropower projects are namely Maiwa Khola, Leguwa Khola, Sabha

Khola, Rok Khola, Yari Khola, Molung Khola, Kabeli Khola I and II, Ghami Khola and Bhartola Gad.

In the case of willingness to pay, the ratio of willingness to pay amount with the present tariff rate is less than one percent. This indicates that the rural household are not willing to pay present tariff rate. The study is based on the previous study reports however the results could be encouraging when the detail feasibility study is to be conducted.

2.14 REVIEW OF ENVIRONMENTAL ASPECTS

2.14.1 General

The overall objective of the environmental screening of 32 small hydropower projects is to assess the physical, biological and social environmental impacts based on the previous studies. This report provides elements for decision-making on whether or not to implement the projects and on possible consideration for further environmental investigations. The evaluation is designed for small-scale hydropower projects, which do not require full scale EIA. For this reason, the review criteria have been limited to important issues only.

The positive environmental impacts are significant in all the projects, hitherto, they are not mentioned in the environmental examinations.

The evaluation takes into account the overall existing physical environmental conditions. Based on the existing situation, the impacts are evaluated and scores are allocated. Some of the projects do not exclusively discuss the environmental impacts. However, the impacts are predictable and are common in all the projects such as impacts during construction phases. Emphasis has been given to protect areas (see map of protected areas), heritage sites, land acquisition and relocation etc. which are technically more important compared to loss of few trees and vegetation which can be justified through plantations.

2.14.2 Physical Environmental Impacts Component

The evaluation is based on existing environmental conditions such as accessibility, topography, vegetation etc. The major components of physical environment, in most of the cases are derived on the basis of project description. Results of evaluation, in some cases are based on socio-economic conditions, infrastructure and other economic activities as well. These information, which are reflected through database and project's economic and technical analysis represent a good base and have been used as a valuable tool to come to reliable assessment and endorse the weightage allocated.

The project evaluation is designed to benefit from the existing river sources. Some of the projects are very small in size and most of them are located in good hydrological regimes. The approach, throughout the evaluation process has been to support the electrification process in rural areas, which can have numerous positive environmental impacts.

The physical environmental impacts are assessed with the help of six major indicators and they are:

Change in topography during construction;
Activation of erosion and landslides;
Sedimentation of rivers and contamination of river by construction wastes;
Change in existing land use;
Construction waste production and its disposal; and
Noise level and air quality.

2.14.3 Biological Environmental Impact Component

The biological environmental impacts are assessed with the help of three major indicators where the impacts are significant and they are:

- Vegetation clearance;
- Affects to the habitat of wild animals, endangered birds and aquatic life;
- Affects to the community forests, leasehold, and religions forests.

Since the projects are small in nature, detailed and exhaustive indicators were not used. Comparing the various indicators and the extent of impact, the final score has been allocated.

2.14.4 Socio-economic Impact Component

Almost all the reports have given adequate attention to socio-economic impacts. Most importantly, much of the information was derived from the economic benefits and their co-relation with enhancement of social status. Seven indicators have been used to assess the socio-economic impacts and they are:

- Any violation of water rights of locals;
- Any acquisition of the land/or property;
- Any effects to local economy - market, crop production, labor force availability;
- Local employment opportunities;
- Possibility of impact to the disadvantaged group (dag); and
- Acquisition and/or pressure on heritage sites.

The impacts are indirectly evaluated and are assessed accordingly by the directly concerned impacts. A final score was allocated after evaluation of each component.

2.14.5 Conclusion

Finally, it must be noted that IEE was made a requirement only after the promulgation of Environment Protection Act (EPA, 1996) and Environment Protection Rules (EPR, 1997). Much of the studies evaluated were carried out before this requirement. Hence, a systematic IEE is not carried out in the projects that were studied before 1996.

Also, this assessment takes into account the fact that a sound regulatory and supervisory mechanism can minimize the physical, biological and socio-economic impacts. For example, providing fish passes can maintain the wild fauna of the river system even during dry season. These are the issues, which might not have been mentioned in the report, but in the present context, it is considered that such precautions will be automatically taken care of. If careful environmental mitigation measures are to be implemented, small-scale projects are mostly considered to be environmentally sustainable.

2.15 SCREENING AND RANKING PROCESS

2.15.1 Introduction

The criteria of screening and ranking of SHPs are developed by the study team after consultation with the client and NEA. The screening criteria developed for 5-10 MW capacity hydropower study project and medium hydropower project have been used as reference source.

The main objective of screening and ranking is to select top ranking ten SHPs out of 32 projects suitable for further detail study. According to the TOR 10 projects are required to be recommended for advancement to the JICA for review and necessary actions.

2.15.2 Preliminary Screening

In this process a list of total 82 projects including previously identified sites were prepared for review. During review the project capacity, gross head, design discharge, level of the studies, distance of projects from national grid and fulfillment of requirements of the ToR had been reviewed. Finally, 32 projects were selected for the reconnaissance level of studies and desk type of detailed studies.

2.15.3 Ranking Process

With objective to select and recommend 10 top ranking projects out of 32 projects following considerations are included in the criteria for ranking:

- Length of waterway, based on length/kW ratio
- Distance of project from road head
- Length of the transmission and distribution line required for the project
- Available head of the project
- Hydrological risks
- Geological condition of the site
- Availability of construction materials at site
- *Water rights problem*
- Energy contribution and power demand
- Construction cost per kW of installed capacity
- Operation and maintenance cost
- Socio-economic value of the project
- Regional balance concept for power development
- Environmental aspect of the project

Based on above considerations and parameters the study team developed following scoring system for the screening and ranking of the projects (Table 2.11). For accuracy, uniformity and engineering judgment, mathematical linear relations have been developed and used for calculating scores. The developed mathematical formula is presented in table below.

Table 2.11: Criteria and weights for ranking process

Criteria	Scoring system	Weightage
Technical	Length and type of waterway.	4
	Length from road head	5
	Length of T&D line	5
	Available head	4
	Hydrological risk	4
	Geological consideration	4
	Availability of construction materials	3
	Water right problem	3
	Various risks	2
Economic consideration	Energy contribution & power demand	17
	Project cost	8
	O & M consideration	5
	Socio-economic values	20
Regional balance	Development on regional basis	8
Environmental consideration	Physical impacts	3
	Biological impacts	2
	Social impacts	3

2.15.4 Findings

Based on the criteria and engineering judgment the ranking of projects was done on scoring basis. The detailed result of screening is presented in Table 2.12. Similarly the top ten projects scoring highest weightage are recommended for further detail studies. The findings are based on desk study and study reports. The projects parameters require confirmation by field visits and field investigation. The recommended projects list is presented in Table 2.13.

Table 2.12: Screening of small hydropower projects

S.No	Name of Projects	District	Head	Disch.	Capacity	Waterway Length (4)			Distance to road (5)			Transmission Length (5)			Available Head (4)			Hydrological Risk (4)		Geological Risk (4)		Construction Material (3)		Water Right (3)		Other Risks (2)		Energy Contribution & Power Demand (17)		Construction Cost per kW (8)		Operation & Maintenance Cost (5)		Affordability (7)		Willingness to Pay (6)		Sustainability (7)		Regional Balance (8)		Environmental Status (8)			Total Score (100)	Ranking of Project
			Head (m)	Q (m3/s)	MW	Length	km / MW	Score	Length	km / MW	Score	Length	km / MW	Score	Head	m/kW	Score*	Risk	Score	Risk	Score	Status	Score	Status	Score	Risks	Score	Ratio	Score	US $	Score	%	Score	Ratio	Score	Ratio	Score	Ratio	Score	Region	Score	Phy.	Bio.	Soci	Score	
	Eastern Development Region																																														
1	Kabeli Khola I	Taplejung	74	2.18	1.11	2.0	1.802	3.89	32.0	28.8	4.53	42.0	37.838	4.67	74.0	0.07	0.74	N	1	Medium	2.5	Near by	2	N	3	N	2	0.10	1.75	2161	7.678	4	4	0.93	3.01	0.61	0.66	0.28	1.31	EDR	3.0	1.5	1.5	2.5	51.23	
2	Kabeli Khola II	Taplejung	80	3.03	1.86	2.3	1.253	3.94	22.0	11.8	4.81	42.0	22.581	4.82	80.0	0.04	0.80	N	1	Medium	2.5	Not Avl	1	N	3	N	2	0.06	1.05	2000	8	4	4	0.93	3.01	0.61	0.66	0.18	0.84	EDR	3.0	1.5	1.5	2.5	49.93	
3	Maiwa Khola	Taplejung	260	0.95	1.92	5.4	2.786	3.82	15.0	7.8	4.88	109.0	56.771	4.48	260.0	0.14	2.60	N	1	Low	3	Avl.at Site	3	Y	1	N	2	0.40	6.72	2000	8	4	4	1.21	4.97	0.61	0.66	0.82	3.83	EDR	3.0	2	1.5	2.5	62.95	2
4	Loguwa Khola	Dhankuta	400	0.09	0.28	1.8	6.429	3.52	15.0	53.6	4.11	7.5	26.786	4.78	400.0	1.43	4.00	N	1	Medium	2.5	Not Avl	1	Y	1	N	2	0.30	5.16	2060	7.84	5	3	1.11	4.27	0.61	0.66	0.58	2.71	EDR	3.0	2.5	1	1.5	55.57	4
5	Sabha Khola	Sankhuwa	130	1.39	1.26	3.8	3.016	3.80	35.0	27.8	4.54	21.4	16.984	4.88	130.0	0.10	1.30	N	1	Low	3	Avl.at Site	3	N	3	N	2	0.10	1.75	2177	7.646	4	4	1.11	4.27	0.61	0.66	0.26	1.21	EDR	3.0	2	1.5	2.5	55.07	5
6	Rok Khola	Solukhumbu	340	0.12	0.31	1.5	4.839	3.65	160.0	516.1	0.00	9.7	31.290	4.73	340.0	1.10	3.40	N	1	Medium	2.5	Avl.at Site	3	N	3	N	2	0.24	4.05	2745	6.51	6	2	1.11	4.27	0.61	0.66	0.31	1.45	EDR	3.0	2	1	1.5	49.72	
7	Yari Khola	Udaypur	100	0.21	0.16	1.2	7.500	3.43	30.0	187.5	1.88	13.0	81.250	4.23	100.0	0.63	1.00	N	1	Medium	2.5	Near by	2	P	2	N	2	0.84	14.22	5447	1.106	6	2	1.11	4.27	0.61	0.66	0.54	2.52	EDR	3.0	2	1	1	51.82	
8	Molung Khola	Okhaldhunga	83	1.1	0.64	1.8	2.750	3.82	55.0	85.9	3.57	75.0	117.188	3.87	83.0	0.13	0.83	N	1	Low	3	Near by	2	P	2	D.F	1	0.91	15.45	4030	3.94	5	3	1.34	5.88	0.61	0.66	0.76	3.55	EDR	3.0	2	1.5	2	62.06	3
	Central Development Region																																													
9	Chaunri Khola	Ramechap	50	0.86	0.35	2.5	7.143	3.46	15.0	42.9	4.29	26.0	74.286	4.30	50.0	0.14	0.50	N	1	Low	3	Near by	2	N	3	N	2	0.26	4.48	4862	2.276	6	2	0.88	2.66	0.66	0.96	0.22	1.03	CDR	1.0	1.5	1.5	2	42.96	
10	Tadi Khola	Nuwakot	121	1.05	0.89	2.1	2.360	3.85	10.0	11.2	4.82	23.4	26.292	4.78	121.0	0.14	1.21	G	4	Low	3	Near by	2	P	2	D.F.	1	0.15	2.51	2456	7.088	5	3	0.70	1.40	0.81	1.86	0.22	1.03	CDR	1.0	2.5	1.8	2.5	51.35	
11	Khani Khola	Lalitpur	135	0.98	1.03	3.3	3.204	3.78	10.0	9.7	4.85	57.0	55.340	4.49	135.0	0.13	1.35	N	1	Medium	2.5	Not Avl	1	Y	1	D.F.	1	0.10	1.68	2216	7.568	4	4	0.39	0.00	0.52	0.12	0.22	1.03	CDR	1.0	2	1	2	41.36	
12	Phalankhu Khola II	Rasuwa	60	1.04	0.5	2.2	4.400	3.68	1.5	3.0	4.96	26.0	52.000	4.53	60.0	0.12	0.60	G	4	Medium	2.5	Avl.at Site	3	N	3	N	2	0.22	3.81	3061	5.878	5	3	0.66	1.12	0.66	0.96	0.24	1.12	CDR	1.0	1.5	1	1	48.66	
13	Phalankhu Khola I	Rasuwa	105	0.81	0.66	1.9	2.879	3.81	12.0	18.2	4.70	30.0	45.455	4.59	105.0	0.16	1.05	G	4	Medium	2.5	Avl.at Site	3	N	3	N	2	0.29	4.98	3179	5.642	6	2	0.66	1.12	0.66	0.96	0.27	1.26	CDR	1.0	1.5	1	1	49.12	
	Western Development Region																																													
14	Daraudi Khola	Gorkha	52	2.39	0.86	2.0	2.326	3.85	18.0	20.9	4.66	50.5	58.721	4.46	52.3	0.06	0.52	C	2	V. Low	4	Not Avl	1	Y	1	D.F.	1	0.31	5.33	3492	5.016	5	3	0.64	0.98	0.74	1.44	0.30	1.40	WDR	3.0	2.5	1.5	3	49.65	
15	Chepe Khola	Lamjung	20	2.35	0.34	0.7	1.912	3.89	10.0	29.4	4.52	21.8	64.118	4.40	20.0	0.06	0.20	G	4	Low	3	Not Avl	1	N	3	N	2	0.54	9.14	6684	0	6	2	0.77	1.89	0.69	1.14	0.23	1.07	WDR	3.0	1.5	1	1.5	48.25	
16	Charang Khola	Mustang	60	0.86	0.4	1.0	2.500	3.84	150.0	375.0	0.00	30.8	77.000	4.27	60.0	0.15	0.60	N	1	Medium	2.5	Avl.at Site	3	N	3	N	2	0.07	1.22	4115	3.77	6	2	0.80	2.10	0.73	1.38	0.44	2.05	WDR	4.0	1.5	1	1.5	40.73	
17	Jyagdi Khola	Syangja	80	0.55	0.34	3.6	10.588	3.18	10.0	29.4	4.52	21.0	61.765	4.43	80.0	0.24	0.80	N	1	High	1.5	Near by	2	N	3	N	2	0.37	6.32	5063	1.874	6	2	0.80	2.10	0.73	1.38	0.19	0.89	WDR	3.0	1.5	1	1.5	43.99	
18	Ghami Khola	Mustang	147	1.05	1.06	1.8	1.620	3.91	150.0	138.9	2.69	30.6	28.333	4.76	147.0	0.14	1.47	N	1	Low	3	Avl.at Site	3	P	2	N	2	0.14	2.44	2352	7.296	4	4	1.05	3.85	0.73	1.38	0.27	1.26	WDR	4.0	2.5	1.5	2.5	54.56	6
19	Bhim Khola	Baglung	75	0.42	0.22	2.5	11.364	3.12	20.0	90.9	3.49	35.7	162.273	3.41	75.0	0.34	0.75	N	1	Low	3	Near by	2	P	2	N	2	0.83	14.11	7476	0	6	2	0.75	1.75	0.75	1.50	0.31	1.45	WDR	3.0	1.5	1	1.5	48.58	
	Mid Western Development Region																																													
20	Chhai Gad	Dolpa	155	0.12	0.12	1.3	10.833	3.16	140.0	1166.7	0.00	34.8	290.000	2.12	155.0	1.29	1.55	N	1	Low	3	Near by	2	N	3	D.F.	1	0.83	14.06	9449	0	6	2	0.52	0.14	0.70	1.20	0.25	1.17	MWDR	6.0	2.5	1.5	2.5	47.91	
21	Phoi Gad	Dolpa	135	0.16	0.17	1.1	6.353	3.53	170.0	1000.0	0.00	24.4	143.529	3.60	135.0	0.79	1.35	N	1	V. Low	4	Near by	2	Y	1	N	2	0.29	4.89	6403	0	6	2	0.88	2.66	0.88	2.28	0.14	0.65	MWDR	6.0	1.5	1	2	41.46	
22	Chaudabise Khola	Jumla	64	1.48	0.65	1.8	2.769	3.82	250.0	384.6	0.00	28.2	43.385	4.61	64.0	0.10	0.64	N	1	Medium	2.5	Avl.at Site	3	N	3	N	2	0.15	2.55	3008	5.984	5	3	0.36	0.00	0.70	1.20	0.17	0.79	MWDR	8.0	2.5	1	2.5	48.10	
23	Jaljala Khola	Jumla	140	0.09	0.1	3.4	34.000	1.29	215.0	2150.0	0.00	14.0	140.000	3.64	140.0	1.40	1.40	N	1	Medium	2.5	Near by	2	Y	1	D.F.	1	0.51	8.64	9953	0	6	2	0.36	0.00	0.61	0.66	0.13	0.61	MWDR	8.0	2	1.5	2.5	39.74	
24	Satya Khola	Jajarkot	152	1.02	1.08	3.6	3.333	3.77	85.0	78.7	3.69	47.1	43.611	4.61	152.0	0.14	1.52	N	1	V. Low	4	Not Avl	1	N	3	D.F.	1	0.22	3.80	3099	5.802	4	4	0.22	0.00	0.70	1.20	0.30	1.40	MWDR	6.0	1.5	1	1.5	49.80	
25	Mulkot Khola	Jajarkot	52	2.62	0.95	3.0	3.158	3.79	70.0	80.0	3.67	14.7	78.632	4.26	52.0	0.05	0.52	N	1	V. Low	4	Near by	2	N	3	N	2	0.49	8.26	3529	4.942	5	3	0.54	0.28	0.52	0.12	0.33	1.54	MWDR	6.0	2	1	1	52.37	9
26	Gahira Gad	Humla	77	0.18	0.10	1.46	14.600	2.86	350	3500.0	0.00	14.0	140.000	3.64	77.0	0.77	0.77	N	1	Low	3	Not Avl	1	Y	1	N	2	1.81	17.00	9953	0	6	2	0.77	1.89	0.81	1.86	0.42	1.96	MWDR	8.0	1.5	1	1.5	51.98	10
	Far Western Development Region																																													
27	Gandi Gad	Doti	135	1.38	1.28	4.4	3.438	3.76	18.0	14.1	4.77	41.5	32.422	4.72	135.0	0.11	1.35	N	1	Low	3	Avl.at Site	3	N	3	N	2	0.18	2.99	2454	7.092	4	4	0.85	1.05	0.52	0.12	1.20	5.60	FWDR	8.0	3	2	3	63.46	1
28	Gadsera Gad	Doti	50	1.48	0.48	2.0	4.167	3.70	18.0	37.5	4.38	11.7	24.375	4.80	50.0	0.10	0.50	N	1	Medium	2.5	Near by	2	N	3	D.F.	1	0.14	2.41	3520	4.96	6	2	0.6	0.70	0.52	0.12	0.08	0.37	FWDR	8.0	2.5	1	2.5	47.45	
29	Kala Gad	Darchula	95	0.18	0.12	1.0	8.333	3.37	60.0	500.0	0.00	13.8	115.000	3.89	95.0	0.79	0.95	N	1	Low	3	Near by	2	N	3	N	2	0.54	9.25	7404	0	6	2	0.64	0.98	0.52	0.12	0.21	0.98	FWDR	8.0	1.5	1	2	45.04	
30	Jamadi Gad	Baitadi	80	2.42	1.30	4.6	3.538	3.75	3.0	2.3	4.97	18.3	14.077	4.91	80.0	0.06	0.80	N	1	Low	3	Avl.at Site	3	N	3	N	2	0.14	2.38	2829	6.342	4	4	0.36	0.00	0.52	0.12	0.21	0.98	FWDR	8.0	2	1	3	54.26	8
31	Bhartola Gad	Darchula	180	0.27	0.34	4.5	13.235	2.97	40.0	117.6	3.04	26.3	77.353	4.27	180.0	0.53	1.80	N	1	Low	3	Near by	2	P	2	N	2	0.25	4.29	5089	1.822	6	2	0.97	3.29	0.52	0.12	0.14	0.65	FWDR	8.0	2	1.5	2.5	48.26	
32	Nilgarh Gad	Baitadi	400	0.068	0.24	3.7	15.417	2.79	15.0	62.5	3.96	8.5	35.417	4.69	400.0	1.67	4.00	N	1	Medium	2.5	Near by	2	P	2	N	2	0.75	12.68	6168	0	6	2	0.36	0.00	0.52	0.12	0.33	1.54	FWDR	8.0	1.5	1	2.5	54.29	7

Table 2.13: Recommended small hydropower projects

S. No.	Name of projects	District	Head (m)	Discharge (m^3/s)	Capacity MW	Rank
27	Gandi Gad	Doti	135	1.36	1.28	**1**
3	Maiwa Khola	Taplejung	260	0.95	1.92	**2**
8	Molung Khola	Okhaldhunga	83	1.1	0.64	**3**
4	Leguwa Khola	Dhankuta	400	0.09	0.28	**4**
5	Sabha Khola	Sankhuwasabha	130	1.39	1.26	**5**
18	Ghami Khola	Mustang	147	1.05	1.08	**6**
32	Nilgarh Gad	Baitadi	400	0.088	0.24	**7**
30	Jamadi Gad	Baitadi	80	2.42	1.30	**8**
25	Mujkot Khola	Jajarkot	52	2.62	0.95	**9**
26	Galwa Gad	Humla	77	0.16	0.10	**10**

2.16 CONCLUSIONS AND RECOMMENDATIONS

2.16.1 Conclusions

The main objective of the study is to formulate a basic plan for the rural electrification through small hydropower development in rural hilly areas of Nepal. The study required identification of primary load centers small hydropower potential sites for power generation from 100 kW to 2000 kW in rural hilly areas, which will not be served by the national power grid within the next decade. In the process of identification of potential load centers and SHP sites, previously studied and newly identified projects were selected and reviewed. Potential load centers at hilly areas away from national grid were identified and prioritized in district-wise-basis. Out of 82 potential small hydropower projects, 32 projects were found least cost alternative to electrify the priority load centers. The study team conducted detailed desk study of the 32 projects. Considering technical, economical, social and environmental parameters in the screening and ranking process, top ranking ten projects were selected.

In course of the study the study team consulted with the NEA to finalize the screening and ranking criteria. Incorporating their feedbacks, the screening criteria had been finalized and used to select and recommend top ten ranking projects. The recommended projects are located in various development regions, four projects in eastern region, one project in western, two in mid western and three in far western region. While selecting projects, regional balance in small hydropower development has been considered. The regions with high density of small hydropower projects, are provided low weightage, whereas Karnali zone, Mustang, Manang and far-western region are given higher weightage.

The results of economic analysis of some of the small hydropower projects are not very encouraging. The poor economic resource bases of certain districts make small hydropower less attractive in economic terms. Therefore small hydropower schemes should be considered as essential infrastructure from social perspective for the development of the country. It has several intangible benefits, such as health of the people, education for children, provision of opportunity for jobs and changes in life style.

2.16.2 Recommendations

Top ranking ten small hydropower projects that serve as least cost alternative to electrify priority load centers are recommended for further study and investigations based on screening and ranking process. The recommended projects are identified based on desk studies and secondary information. They are not verified by field visits. Therefore it is advised and recommended to confirm the load centers and sites and data by conducting field surveys and investigations.

Implementation of small hydropower projects in remote areas is a challenging task. Adequate studies of sites are essential with geological and hydrological investigation before finalizing the projects. Transportation of electro-mechanical equipment is also considered difficult problem for small hydropower implementation. Therefore, large number of smaller units is preferred so that weight of individual parts could be reduced to lifting load of available helicopters (i.e., MI-17).

The economic indicators of small hydropower in certain districts are not so encouraging because of poor local conditions and less opportunities for load factor development. The economic indicators can be improved and viability of project may be enhanced if some productive end use program of electricity, like agro-processing industries, repairing and workshop centers and other employment generating industries are introduced under small hydropower implementation package.

2.17 PROJECT SELECTED FOR PHASE 2 STUDY

Out of the top ten ranking projects, the study team was requested to suggest three project sites for Phase II study. Finally, the Client selected only one project, Ghami Khola Small Hydropower Project, considering the security condition of the project sites.

The rest of the present report elaborates on field investigation, preliminary design and implementation planning of the Ghami Khola small hydropower project.

3 THE SELECTED PROJECT

3.1 GENERAL INFORMATION

3.1.1 Project Location

Ghami Khola Small Hydropower Project lies in upper Mustang area of Mustang district in the western development region. Very limited development activities are planned and implemented in upper Mustang area by HMG/N because of its remoteness.

The proposed project is located on the right bank of Ghami Khola in Ward no. 6 of Ghami VDC. The project intake site is located at 1.5 km west of Ghami village whereas powerhouse site is at 800 m distance from the village. The confluence of Ghami Khola with Kali Gandaki is about 5 km downstream from the proposed powerhouse site.

A Location map of Ghami Khola SHP is depicted in Figure 3.1.

The geographical locations of the main structures are as follows:

Project structures	Latitude	Longitude	Elevation
Intake	29° 04' 17"	83° 50' 56"	3732 m
Powerhouse	29° 04' 04"	83° 52' 13"	3642 m

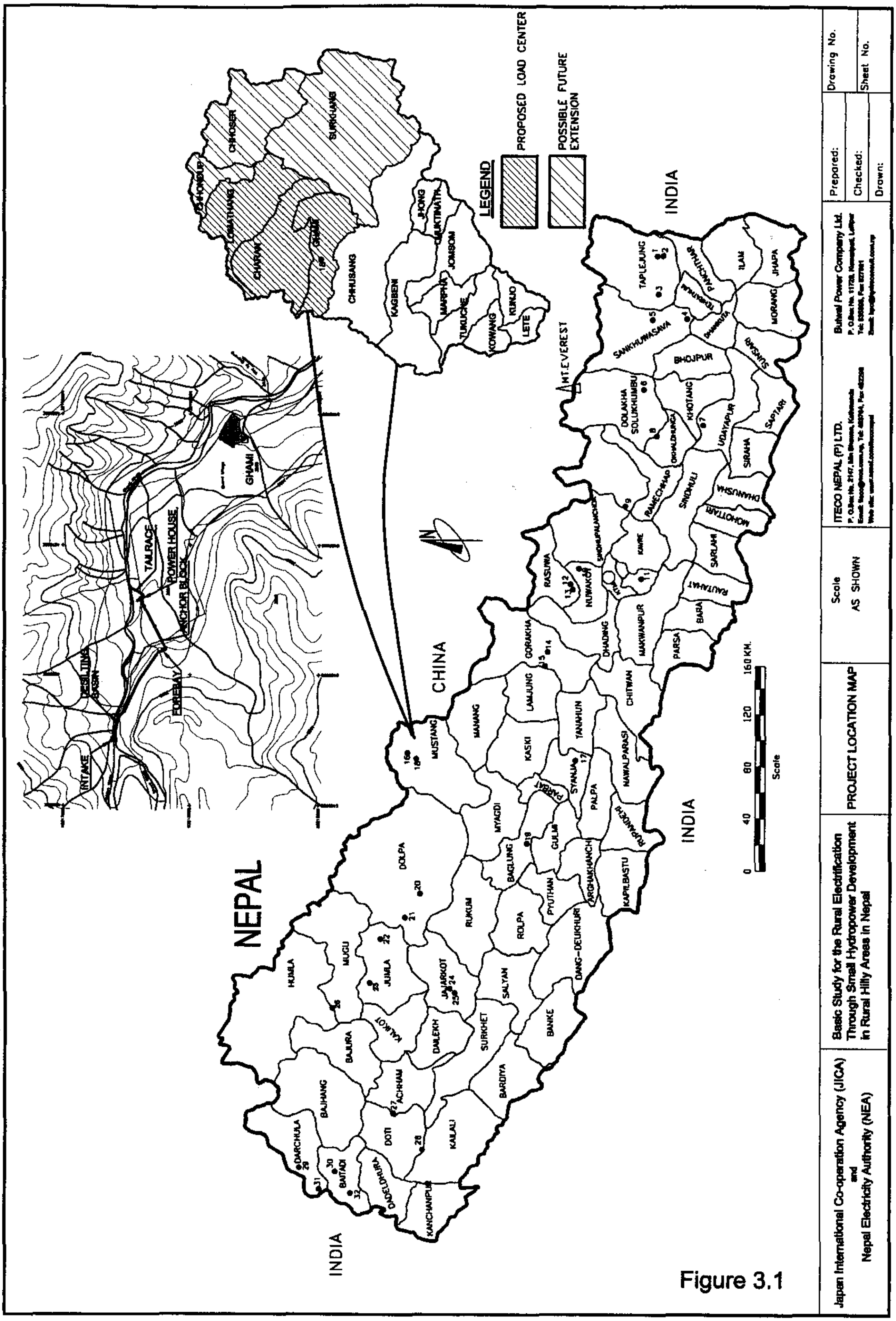
3.1.2 Access

The project area is not accessible by road due to its remoteness. The nearest road head is Beni, headquarter of Myagdi district, 150 km away from the project site. It takes about eight days of trek from Beni to project site Ghami via Jomsom, district headquarter of Mustang district. The foot trail up to Kagbeni is all weathered, whereas from Kagbeni to Ghami is rough trail and passes through rugged terrain. However a motorable road has reached to Lomangthan, one day walking distance from Ghami, from the Tibetan territory of China. Food stuffs and consumer goods are transported by truck from Kodari to Lomangthan 450 km away via Tibet in two days. The motorable road is being extended from Lomangthan to Charang, which is at 10 km distance from Ghami using VDC funds recently.

The nearest airport is at Jomsom, which is 65 km far from the project site. It takes about four days of normal trek to reach Ghami site from Jomsom airport. Regular daily flights are operated in the morning hours by various airline companies from Pokhara. Helicopter services may also be chartered from Pokhara to Jomsom.

3.1.3 Geography and Climate

Ghami Khola is a tributary of Kali Gandaki, which meets near Chilling Gaun. The catchment area of Ghami Khola is about 232 sq. km ranging from 6000 m above the mean sea level to 3734 m at the intake and the river is predominantly snow fed. The climate of the project area is of alpine type. Most of the area is covered by snow and very little precipitation occurs during rainy season. Common vegetation observed in the area include bushes and coniferous plants up to 4000 m elevation. The extreme maximum temperature reaches to 25^{O} C in the summer and -15^{O} C in the winter. The relative humidity varies from 50% to 90%.


NEPAL
CHINA
INDIA
INDIA
INDIA
INDIA
LEGEND
PROPOSED LOAD CENTER
POSSIBLE FUTURE EXTENSION
MT.EVEREST
INTAKE
DESILTING BASIN
FOREBAY
ANCHOR BLOCK
POWER HOUSE
TAILRACE
GHAMI
CHHUSANG
KAGBENI
JHONG
MUKTINATH
JOMSOM
MARPHA
TUKUCHE
KOWANG
KUNJO
LETE
SURKHANG
CHHOSER
CHARANG
GHAMI
MUSTANG
DOLPA
MANANG
MYAGDI
KASKI
LAMJUNG
GORAKHA
TANAHUN
CHITWAN
DHADING
NUWAKOT
RASUWA
MAKWANPUR
PARSA
BARA
RAUTAHAT
SARLAHI
MAHOTTARI
DHANUSHA
SIRAHA
SAPTARI
UDAYAPUR
KHOTANG
BHOJPUR
SUNSARI
MORANG
JHAPA
ILAM
PANCHTHAR
TAPLEJUNG
SANKHUWASAVA
DOLAKHA
SOLUKHUMBU
OKHALDHUNGA
RAMECHHAP
SINDHULI
KAVRE
NAWALPARASI
RUPANDEHI
KAPILBASTU
PALPA
SYANJA
PARBAT
BAGLUNG
GULMI
ARGHAKHANCHI
PYUTHAN
ROLPA
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DANG-DEUKHURI
SALYAN
BANKE
BARDIYA
SURKHET
DAILEKH
JAJARKOT
JUMLA
MUGU
HUMLA
KALIKOT
BAJURA
BAJHANG
ACHHAM
DOTI
KAILALI
DARCHULA
BAITADI
DADELDHURA
KANCHANPUR
0 40 80 120 160 KM.
Scale
Japan International Co-operation Agency (JICA) and Nepal Electricity Authority (NEA)
Basic Study for the Rural Electrification Through Small Hydropower Development in Rural Hilly Areas in Nepal
PROJECT LOCATION MAP
Scale AS SHOWN
ITECO NEPAL (P) LTD.
Butwal Power Company Ltd.
Prepared:
Checked:
Drawn:
Drawing No.
Sheet No.

Figure 3.1

Agriculture and livestock are the major economic activities in the project area. The economic activities are highly affected by the alpine climate. People use to work in the field from April to October for agriculture production whereas in rest of the year no agricultural farming is possible due to snow cover.

There is no meteorological station in the Ghami Khola basin. Nearest meteorological station exists in Lomangthan with index no. 0612 which is established by the DHM and operated by the ACAP. Similarly there is a meteorological station in Jomsom airport with index no. 0601.

3.1.4 Topography and Geology

The elevation of the Ghami Khola valley ranges from 3500 m to 6000 m. The topography of the valley area is having gentle rolling slope while that above is generally steep to very steep. Permanent snow line starts at an elevation of 5000 m. As the valley receives low rainfall, the topography and morphology is generally controlled by snow and past glacial events.

Geologically, the project area lies in the Tethys Himalayas to the north of Higher Himalaya bounded by South Tibetan Detachment System and Indus Tsanspo Suture zone. The area reminds the desert condition in the north. The project area lies in Upper Chelegaon Formation which is covered by quaternary glacial and fluvio-glacial sedimentary deposit over massive Tethys basin. The unit is composed of alternation of various facies-sandstones, conglomerate, laustrine limestone and clay beds.

3.2 TOPOGRAPHIC SURVEY

3.2.1 Topographic Survey

The study team conducted field investigations and topographic survey as required by the ToR within a period of 15 days. The survey team consisting hydropower engineer, geo-technical engineer, hydrologist, survey engineer, socio-economist and environmentalist visited the site and conducted the respective surveys and investigations.

The topographic survey was conducted in the project area with objectives of locating hydropower components like intake, desanding basin, headrace canal, forebay, penstock, powerhouse and tailrace to obtain topographic data necessary for preliminary design of the structures as required by the ToR.

The study team visited all the potential component sites and assessed their suitability from technical, geological, hydrological and geotechnical considerations. The team verified the site and fixed the locations for structures.

Survey control points were fixed at intake, forebay, and powerhouse sites using GPS instrument to control the geographical co-ordinates and finding the elevation difference between the points. Longitudinal survey of the river at intake site was conducted about 50 m upstream to 200 m downstream of the weir axis using theodolite. Similarly longitudinal survey of the river at powerhouse site was carried out covering 100 m distance. Necessary cross sections were surveyed at intake and powerhouse sites.

The control points at intake, desanding basin, headrace canal, forebay, penstock and powerhouse were marked on permanent boulders which were labelled with red enamel paint. The longitudinal profile of headrace canal and penstock alignment were surveyed by using theodolite, whereas leveling instrument was used for taking intake and powerhouse cross sections. All field data were checked and confirmed immediately at the field.

3.2.2 River Situation Survey

During field survey work necessary information was collected to determine the river flow, river gradient and condition of river bed, bank and bends etc. The intake location was selected considering the hydraulic parameters for safety of intake weir, ease of diverting the discharge and ease of construction and operation. Exact location of intake over the river was determined by using GPS and survey of longitudinal section was conducted along the river profile to determine the river slope and direction of flow using theodelite. As two streams (Dhuya Khola and Naktan Khola) confluence at 100 m upstream of proposed intake about 300 m upstream stretch of both streams were studied. Transport of bed materials and flood marks of the river were investigated. Since no heavy rains occur in this area, because of shadow effect of the Higher Himalayas major portion of discharge is fed by snow melts. The structure heights and location were fixed considering river condition, peak flows and high flood levels.

Similarly the powerhouse location was selected considering the requirement of head and safety from high floods and GLOFs. The river profile survey of powerhouse site was conducted as per requirement of the ToR to fix the tailrace level and to determine the river flow.

3.2.3 Map Preparation

All necessary maps required by the TOR for preliminary design and quantity estimates have been prepared to the following scales:

Intake site cross section	:	1:200
Desanding basin longitudinal section	:	1:200
Power canal	:	1: 2000
Forebay plan and section	:	1:200
Penstock longitudinal profile	:	1: 2000
Powerhouse and tailrace plan and section	:	1:200

3.3 HYDROLOGY

3.3.1 River Basin Characteristics

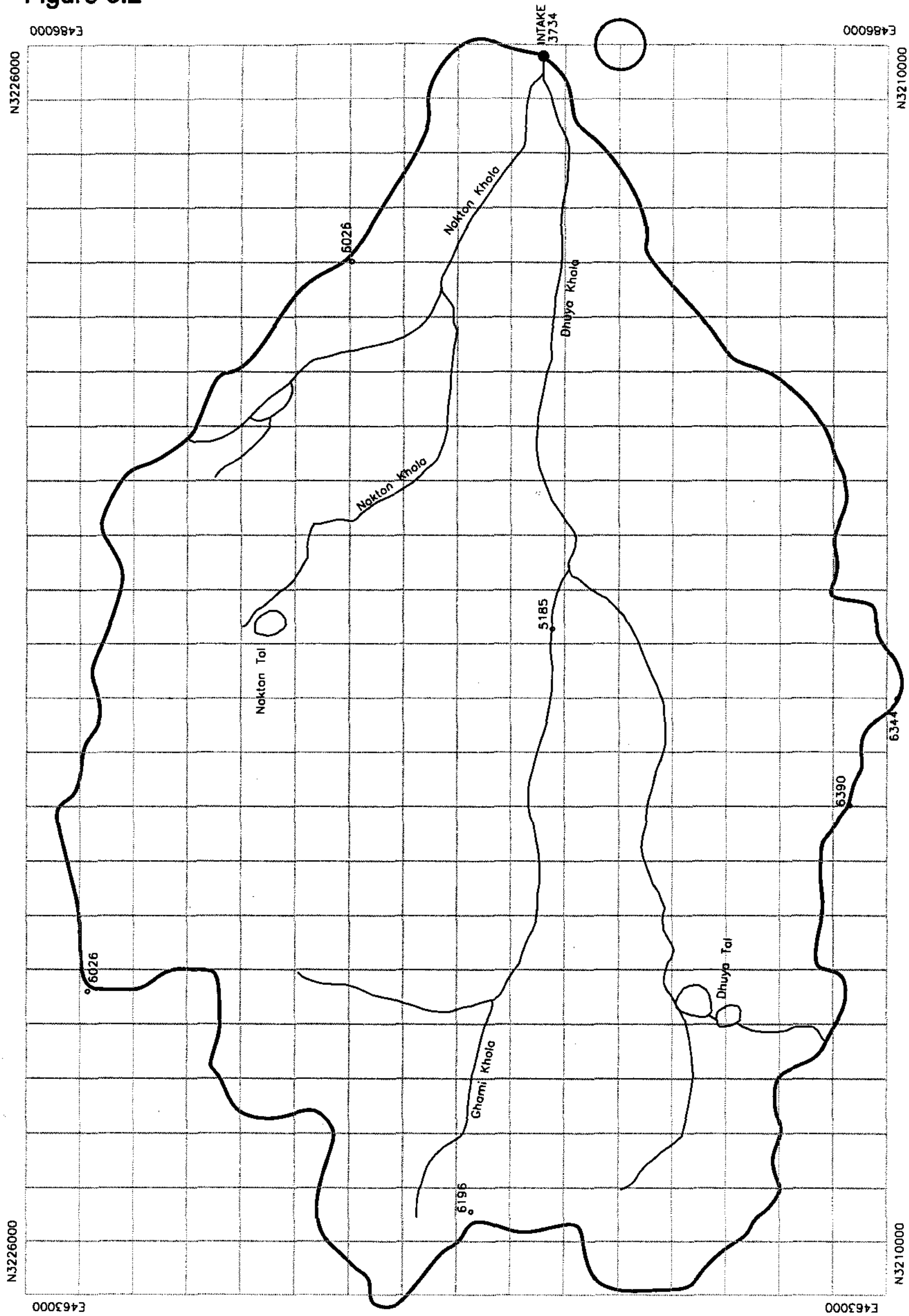
The Ghami Khola is one of the tributaries of Kali Gandaki river. It lies in Mustang district of western development region of Nepal. The Ghami Khola originates from the Ghami Bhanjyang at an elevation of 6000 m and flows towards southeast before joining with Kali Gandaki. Dhuya Khola and Naktan Khola are major tributaries of Ghami Khola upstream of the intake site. The catchment of Ghami Khola lies between the latitude of 29° 00' 12" and 29° 09' 13" N and Longitude 83° 37' 15" and 83° 51' 47" E. The whole catchment area lies below an elevation of 6400 m. The catchment area is shown in Figure 3.2.

The upper part of Ghami Khola basin has several lakes. The entire catchment lies within the upper Himalaya. The oval shaped catchment area is mainly covered with small glaciers and barren rocky terrain having very little cultivated terrace along the riverbank. The total length of Ghami Khola is 33.5 km, whereas the average slope is about 7.6 percent . The river basin acquires a lot of snow and so it is perennial in nature.

The proposed intake site is located at an elevation of 3734 m and is about 24 km downstream from the origin of Ghami Khola. The total catchment area at the proposed intake site as measured on the 1:50,000 scale map prepared by the, Survey Department is 232.32 km^2. The river gradient from the intake to the powerhouse site is about 8.5 %. In general, the width of the river at the intake site is about 41.5 m, where as it is 30 m wide at the tailrace site.

The cross section of the Ghami Khola at the intake axis is shown in Figure 3.3.

Figure 3.2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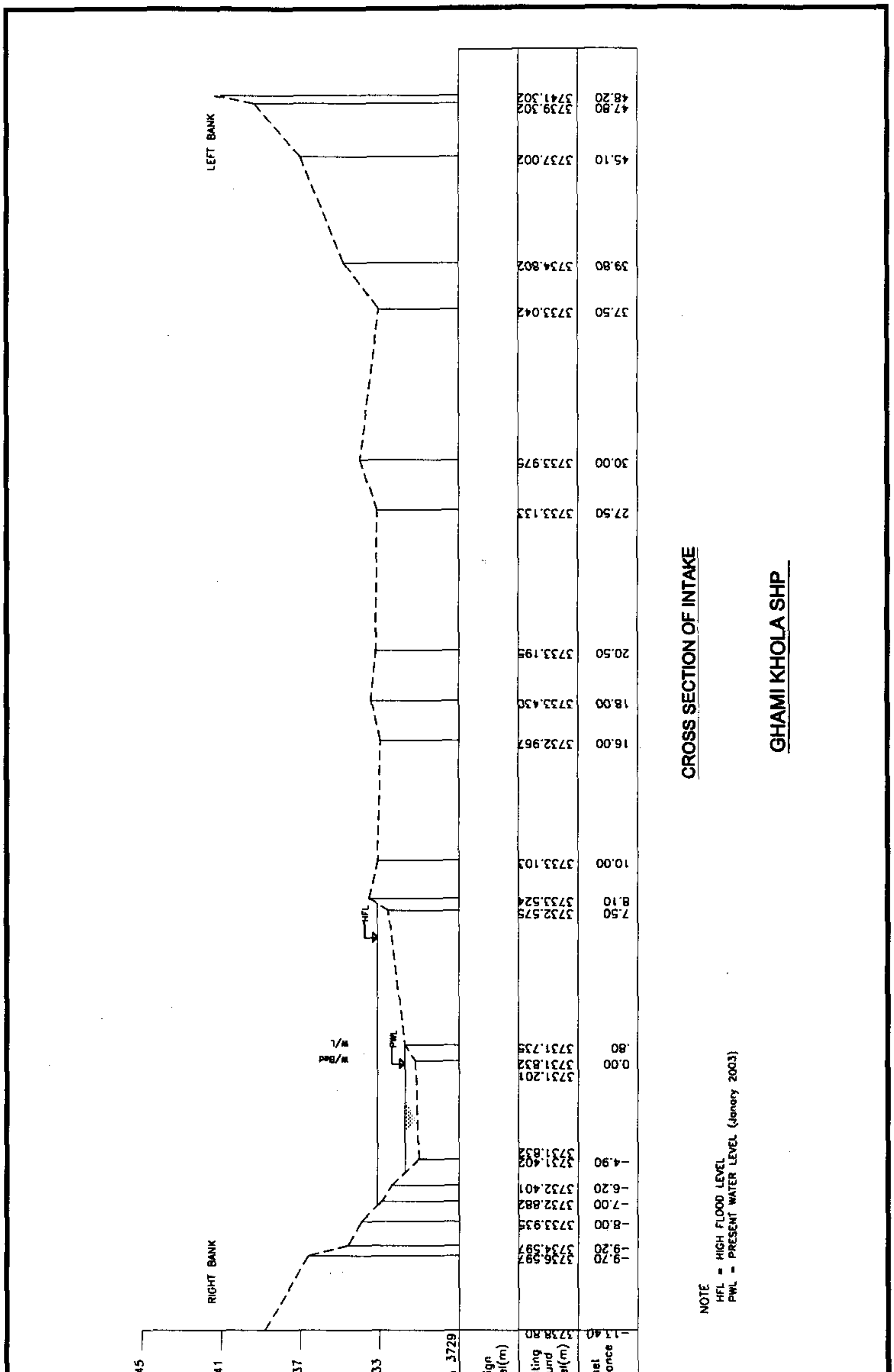
CROSS SECTION OF INTAKE
GHAMI KHOLA SHP
LEFT BANK
RIGHT BANK
HFL
PWL
W/L
W/Bed
Datum 3729
3733
3737
3741
3745
Design Level(m)
Existing Ground Level(m)
Offset Distance (m)
-11.40 3738.80
-9.70 3736.597
-9.20 3734.597
-8.00 3733.935
-7.00 3732.882
-6.20 3732.401
-4.90 3731.402 3731.832
0.00 3731.832 3731.201
.80 3731.735
7.50 3732.575
8.10 3733.524
10.00 3733.103
16.00 3732.967
18.00 3733.430
20.50 3733.195
27.50 3733.133
30.00 3733.975
37.50 3733.042
39.80 3734.802
45.10 3737.002
47.80 3739.302
48.20 3741.302
NOTE
HFL = HIGH FLOOD LEVEL
PWL = PRESENT WATER LEVEL (Janary 2003)

Figure 3.3

Table 3.1 depicts the characteristics of the catchment area at the proposed intake site.

Table 3. 1: Characteristics of the Ghami catchment at intake site

Elevation, m	Between 3000 to 5000	Above 5000	Total
Total area, km^2	16.74	215.57	232.32
Percentage of total area	7%	93%	100%

3.3.2 Precipitation Data

As there are no sufficient precipitation stations around the Ghami Khola basin, Theissen polygon and isohyetal method could not be used to calculate the average precipitation for the basin. The average long-term annual precipitation of the study area has been estimated to be 250 mm on the basis of the isohyetal map (1971-1984). The 24 hours maximum precipitation is 155 mm in 1981. There is a DHM rainfall station no. 0612 at Lomangthan established in 1973. The average annual precipitation for the station no. 0612 at Lamangtan has been calculated as 125 mm. This station is located approximately 20 km north of the proposed intake site at an elevation of 3705 m. Rainfall data is available since 1974.

To further understand the effects of elevation and location the rainfall around the vicinity of the project area were also studied. Monthly precipitation were collected from the publications of DHM for the period up to 1994. The stations that have been reviewed for this study are presented in Table 3.2.

Table 3.2: Rain gauge stations near the Ghami Khola catchment

Station	Name of station	Location		Elevation m	Annual precipitation mm
		Latitude	Longitude		
0601	Jomsom	28^0 87'	83^0 43'	2744	311
0612	Lomangthang	29^0 11'	83^0 58'	3705	276

Source: Precipitation records of Nepal, DHM, Nepal

Table 3.3 presents the annual and 24-hour precipitation at Lomangthan.

Table 3.3: Annual and 24 hour rainfall at Lomangthan, station no. 0612

Year	Annual rainfall (mm)	Maximum in 24 hrs. (mm)
1974	202	29
1975	185	18
1976	-	-
1977	155	17
1978	296	24
1979	-	-
1980	170	26
1981	155	35
1982	-	-
1983	-	-
1984	122	17
1985	276	26

Source: Precipitation records of Nepal, DHM, Nepal

3.3.3 Stream Flow Measurement

Ghami Khola is an ungauged river, therefore direct measurements are not available for the river. Ghami Khola is totally snow fed river so catchments of similar size and characteristic are not available to correlate the flow characteristics of the river. Therefore in order to estimate hydrological parameters of the river, HydrA Nepal, HYDEST, MIP and MHSP methods are used.

Table 3.4: River gauging stations near the Ghami Khola catchment

Station Number	River name	Location	Elevation (m)
404.7	Myagdi Khola	Mangal Ghat	914
410	Kali Gandaki	Seti Beni	546
415	Aandhi Khola	Dumrichaur	543
417	Barigad Khola	Rudrabeni	731

3.3.4 Mean Flow

The mean monthly flows at Ghami Khola are generated with the following methods.

3.3.4.1 WECS/DHM 1990 methodology (HYDEST program)

The HYDEST method has been used to estimate mean flows at the proposed intake site. The monsoon wetness index from the isoheytal map for Ghami Khola catchment is 250 mm. The average monthly flow of Ghami Khola computed by using the HYDEST program is presented in the Table 3.5.

Table 3.5: Average monthly flow of Ghami Khola at intake using HYDEST

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow (m^3/s)	0.24	0.20	0.18	0.16	0.20	6.70	1.57	1.91	1.42	0.67	2.86	1.96

3.3.4.2 MIP method

Medium irrigation project has divided Nepal into seven hydrological regions. Ghami watershed falls on region 1. This approach needs at least one actual measurement during the period of November to April. This flow has been used to modify the non-dimensional hydrograph to compute mean monthly flows.

Table 3.6: Average monthly flow of Ghami Khola at intake using MIP

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow (m^3/s)	2.8	2.1	1.5	1.17	3.04	7.02	16.96	29.25	19.3	9.36	4.79	3.63

3.3.4.3 MHSP method (NEA 1997)

In order to complement the low flow analysis, recently developed MHSP method was also used to determine low flows. The results from the method are given in the Table 3.7.

Table 3.7: Average monthly flow of Ghami Khola intake using MHSP

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Flow (m^3/s)	3.46	2.84	2.62	3.26	3.72	7.43	17.5	22.03	17.21	8.62	4.82	2.84

The results of MHSP and MIP methods are closer, however the result of MHSP gave more realistic figures comparative to other methods.

3.3.5 Flood Discharges

There are no flood data for the Ghami Khola. The lack of flood data prevents the use of the traditional flood frequency analysis for estimation of the design floods at the proposed intake site. To obtain the flood estimates at the intake site MHSP and HYDEST methods are used.

3.3.5.1 MHSP method

Table 3.8: Flood flows of Ghami Khola at intake using MHSP method

Return period years	Flood discharge (m^3/s)
5	225
20	339
50	424
100	494

3.3.5.2 HYDEST method

Table 3.9: Flood flows of Ghami Khola at intake using HYDEST method

Return period years	Flood discharge(m^3/s)	
	Daily	Instantaneous
2	1	2
10	2	6
20	3	8
50	3	12
100	4	15

The comparative results from the above methods are much higher then the expected values. To be more realistic and taking into account of high flood marks, the 100 year flood of 200 m^3/s has been taken as design flood values for the present study.

3.3.6 Low Flow Events

The low flow information is generally used to assess the reliability and the economics of the proposed project. If the occurrence of inadequate flow is much too frequent, a particular project might prove to be uneconomic and unreliable.

For RoR plant 1 day low flow event will be the parameter of concern for the planners compared to the higher duration (30 days/Monthly) events, so only 1-day low flow events are summarized below.

Table 3.10: Low flow events of Ghami Khola using HYDEST method

Return period	Low flow discharge (m^3/s)
2	0.12
10	0.02

3.3.6.1 Flow measurements

Field verification of the analyzed hydrological data was carried out by actual flow measurement at intake site of Ghami Khola on 14 January 2003. The measurement at site gave the mean flow of 2.8 m^3/s.

3.3.7 Flow Duration Curve

A flow duration curve is an exceedance probability-discharge curve that shows the percentage of time a particular flow is equaled or exceeded. For the development of the flow duration curves for the proposed intake site HydrA Nepal, MHSP, HYDEST methods are adopted.

Based on the flow duration curve the firm flow (90 percentile) at the proposed intake is 1.9 m^3/s. The numerical flow duration values are presented in the Tables 3.11, 3.12 and 3.13.

3.3.7.1 HydrA method

Flow duration curve based on HydrA results is presented in Table 3.11.

Table 3.11: Flow duration values for Ghami Khola at intake site (HydrA Nepal)

% Exceedance	5	10	20	40	60	90	95
Flow (m^3/s)	12.36	9.58	6.9	3.2	2.06	1.33	1.12

3.3.7.2 HYDEST method

Flow duration curve based on HYDEST results is presented in Table 3.12.

Table 3.12: Flow duration values for Ghami Khola at intake site (HYDEST)

% Exceedance	0	5	20	40	60	80	90	95	100
Flow (m^3/s)	3.45	2.24	10.49	3.73	1.88	0.16	0.11	0.09	0.06

3.3.7.3 MHSP method

Flow duration curve based on MHSP method is presented in Table 3.13.

Table 3.13: Flow duration values for Ghami Khola at intake site (MHSP)

% Exceedance	Maximum flow	25	45	65	85	90	95	Minimum flow
Flow (m^3/s)	97.56	10.14	4.17	3.43	2.24	1.9	1.56	0.43

The results obtained from the flow duration values (Table 3.11, 3.12 and 3.13) at the 90 percentile are found to be 1.33, 1.9 and 0.11 m^3/s from HydrA, MHSP and HYDEST respectively. Where as, the actual discharge measurement at site in January was 2.8 m^3/s. Calculated discharge from MHSP methods seems nearest to the actual discharge. Therefore MHSP method is adopted.

3.3.8 Sediment Study

The sediment transport pattern in the Ghami river is complex. Very little information is known about the sediment transport pattern in the Ghami Khola. However, it is expected to follow certain characteristics common to many Himalayan rivers.

Sediment load in the river may vary from year to year. For design purposes a long-term database is therefore required. Most of the sediment transport takes place during the monsoon season (usually assumed to be 80% to 90%). But in the case of Ghami river, it is totally snow fed river, besides there is very low rainfall. Sediment concentration of the river at the site is expected to be low.

3.3.9 Summary and Conclusions

As there are no sufficient precipitation stations around the Ghami Khola, precipitation record of several months has not been recorded even from the existing stations. Since the river does not have discharge records, HydrA, HYDEST, MIP and MHSP methods are used for hydrological analysis. Long-term average flows from MHSP and MIP method seem nearer than HYDEST method. However Ghami is predominantly snow fed river and 93% of its catchment lies above 5000 amsl, therefore results of HYDEST are not considered to be reliable. Results of MHSP seem more reliable than MIP. There is no flood data of Ghami Khola. The results obtained from the applied methods are much higher than the expected values. To be more realistic and taking into account of high flood marks, the 100-year flood of 200 m^3/s has been taken as design flood values. The actual discharge measurement at site in January was 2.8 m^3/s. The numerical flow duration values for 90 percentile is 1.9 m^3/s based on MHSP and it seems more reliable than HydrA and HYDEST results. For irrigation 0.5 m^3/s is taken from total design discharge of 1.9 m^3/s while another 10% of low flow has been reserved for riparian discharge for environmental purposes. Thus the available discharge for hydropower generation is 1.2 m^3/s.

Based on the site visit report, topographical maps and the methods used to estimate hydrological parameters, the design discharge is sufficient to be reliable enough. Because of very poor database for high altitude catchments, the statistical methods are not very reliable. It is therefore recommended to install a river gauging station and a precipitation station within the Ghami basin. Sediment sampling should be carried out at least for one rainy season to estimate the sediment concentration of Ghami Khola.

3.4 GEOLOGY AND GEOTECHNICS

3.4.1 Regional Geology

The proposed area is situated within the Thethys Himalayas, bounded by South Tibetan Detachment System (STDS) in the south and Indus Tsangpo Suture Zone (ITS) in the north. Regional geological mapping of the area in 1" = 1 mile scale is carried out by DMG (A. N. Bhandary and L.D Tshering, K. R. Poudyal and J. N Shrestha). The area is included within the Upper Chelegaon Formation and Ghami Khola Formation. The Upper Chelegaon Formation is the youngest formation lying unconformably over the Mesozoic basement. Distinct outcrops of the formation have been observed along the wide range of Kali Gandaki river banks. The unit is composed of an alternation of various facies – sandstones, conglomerate (especially pebbly and cobbly), lacustrine limestone and clay beds.

Although the project area lies within the Upper Chelegaon Formation, the area is covered by quaternary glacial and glacio-fluvial sedimentary deposit filled up the massive Tethys' basin. The glacio-fluvial deposit is formed after the river action, which consists of mainly sub-rounded to rounded gravel and pebble. No rock outcrops and slide zones were observed during field visit in the vicinity of the project area. Similarly no major streams, screes, and rivulates crossing the water conveyance system were observed along the headrace canal.

As such no major geological instabilities have been observed at and around surface civil structures such as weir and intake, desilting basin, power canal, forebay, penstock alignment, powerhouse complex and tailrace.

3.4.2 Geology of the Project Area

The project area is studied geologically and geotechnically in semi-detailed scale. Previous geological study of the project area and project structures, slightly at different locations from the presently proposed structures, include pit excavation at desanding basin (depth 2.6 m), forebay (depth 2.10 m) and powerhouse (depth 1.60 m) sites with few laboratory tests. The project structures are located along the right bank of the river.

The left bank at the intake site is comparatively steeper (55^0) than the right bank (35^0). The left bank is composed of gravelly to bouldery compacted clayey sand to silty sand and the right bank consists of gravelly to bouldery silty sand. The desilting basin consists of loose alluvial deposit. The headrace canal alignment passes mainly through almost gentle to flat terrace composed of gravelly to bouldery silty sand. The forebay is located at the spur top consisting of hard, compact cemented conglomerate. The penstock alignment passes through cultivated terrace composed of gravelly, bouldery sand, silty and clayey sand. The powerhouse is located on upper alluvial terrace consisting of clayey silt at the top (0.30 m) followed by gravelly sand (1.30 m) and sandy gravel (1.60 m), whereas the tailrace is made up of river bed alluvial deposit.

The field study report of Ghami Khola SHP is of the feasibility study standard. Therefore additional detailed geological/ engineering geological and geotechnical studies should be carried out prior to detailed design stage.

3.4.2.1 Weir and intake site

The weir axis is located 100 m downstream of the confluence of Ghami and Naktan Kholas which is just upstream of the intake of the existing irrigation canal at an elevation of 3725 m. River width at the weir axis is 44 m. The area is characterized mostly by the presence of big boulders of granite, gneiss, quartzite, sandstone and shale. The boulders are sub-rounded to sub-angular (max. dia. 5 m) with size of 4.5 m x 3.0 m x 2.5 m.

No bedrock outcrops have been expected above the depth of 30 m at the weir foundation and intake. But there is a small bedrock outcrop on the river bed level at its left bank about 30 m upstream of the weir axis.

Lower part of the left bank slope of intake site is made up of yellowish dark grey to black, medium compact gravely to boulderly clayey sand and sandy gravel with slope angle of about 34^0 and the upper part black grey silty sand of glacio-fluvial origin with slope angle of about 55^0.

On the other hand the right bank slope is composed of alluvial terrace below the slope elevation of the glacio-fluvial deposit consisting of gravely to boulderly silty sand (slope 35^0).

3.4.2.2 Desilting basin

A 46 x 10 m size desilting basin will be constructed on the alluvial terrace composed of big boulders of gneiss, granite and quartzite. The area is composed of river boulders. The stretch from the intake to the desilting basin is composed of rounded to sub-rounded boulders. The desilting basin and the spillway lie on the alluvial deposit consisting of brownish grey, loose silty sand at the top and brownish grey gravely sand below the depth of 2.0 m as observed on the section of small soil slide on the river bank.

3.4.2.3 Headrace canal alignment

About 807 m long headrace canal is proposed from intake to the forebay passing through major three types of lithologic variations in the same unit of Upper Chelegaon Formation. The proposed headrace canal passes through the alluvial and glacio-fluvial deposits. The canal passes through alluvium (including intake and desilting basin) from chainage 0+000 to 0+100 m). This section (about 100 m) is composed of river boulders. The section is expected to be stable but bank cutting by the river may cause considerable problems on the stability of the civil structures of intake and desilting basin.

The canal alignment from chainage 0+100 to 0+430 m is composed of gravely to boulderly silty sand of glacio-fluvial origin with a natural slope of about 55^0. The material is loose and many erosional scars with few minor soil slides are observed along the alignment. Thus this section of about 330 m length may have some instability problems. Along the hill slope, large