Final Report

Review of Karnali (Chisapani) Multipurpose Project (10.800 MW)
Feasibility Studies Carried out in 1989

And

Terms of Reference for Hiring of Consultants to prepare Updated Feasibility Study to Develop Karnali (Chisapani) Project as a Regional Power Project

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LIST OF ABBREVIATIONS

AACE	Association for the Advancement of Cost Engineering
ADB	Asian Development Bank
B/C	Benefit Cost
BoQ	Bill of Quantity
CEA	Central Electricity Authority, (GOI)
CF	Capacity Factor
CFD	Computational Fluid Dynamics
CIA	Cumulative Impact Assessment
CLOF	Cloud Burst Flood
DBA	Dam Break Analysis
DBE	Design Basis Earthquake
DBM	Design Basis Memorandum
DHM	Department of Hydrology and Meteorology, (GON)
EIA	Environmental Impact Analysis
EIRR	Economic Internal Rate of Return
EL	Elevation
EMP	Environmental Management Plan
EOI	Expression of Interest
EPA	Environmental Protection Act, 1997
EPR	Environmental Protection Rules, 1997
ERT	Electrical Resistivity Tomography
FIDIC	International Federation of Consulting Engineers
FSL	Full Supply Level
GIS	Geographical Information System
GLOF	Glacier Lake Outburst Flood
GOI	Government of India
GON	Government of Nepal
GW	Gigawatts
ha	Hectare
HFF	Himalayan Frontal Thrust
HMG	His Majesty's Government (of Nepal)
HPC	Himalayan Power Consultants
IDA	International Development Association
IPDP	Indigenous Peoples Development Plan
KCC	Karnali Coordinating Committee
kV	kilowatts
LDF	Landslide Dam Flood
LIDAR	Light Detection and Ranging
MBT	Main Boundary Thrust
MCE	Maximum Credible Earthquake

MCT	Main Central Thrust
MOL	Minimum Operating Level
MW	Megawatts
MWc	Megawatts continuous
NEA	Nepal Electricity Authority
OBI	Overseas Bechtel Inc.
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
QCBS	Quality and Cost-Based Selection
RAP	Resettlement Action Plan
RBWR	Royal Bardiya Wildlife Reserve
RCC	Roller Compacted Concrete
RFP	Request for Proposal
ROR	Run-of-the-river
SAARC	South Asian Association for Regional Cooperation
SCAEF	Society of Consulting, Architectural, and Engineering Firms (Nepal)
SEC	SAARC Energy Centre
SIA	Social Impact Assessment
SMHA	Snowy Mountains Hydroelectric Authority
SMP	Social Management Plan
TFC	Trillion Cubic Feet
TOR	Terms of Reference
TWL	Tail Water Level
UNDP	United Nations Development Program
VCDP	Vulnerable Community Development Plan
WB	World Bank

EXECUTIVE SUMMARY

0.1 General

SAARC Energy Centre (SEC) proposes development of large regional hydropower plant in south Asia focusing huge hydropower potential of Nepal. The member states Afghanistan, Pakistan, India, Sri Lanka, and Bangladesh would be benefitted from the cheap power generated in Nepal would earn foreign exchange and can overcome trade deficit. In 2016, the Government of Nepal announced that the Karnali Chisapani hydropower project would be developed through a "Multi-stakeholder partnership" approach that comprises investors from across the SAARC region. In this back drop, SEC intended to review the feasibility study of Karnali (Chisapani) Multipurpose project (10,800 MW) carried out in 1989 and update the feasibility study to develop the project as a regional power project.

The general objective of this study is to review the Feasibility Study Report of Karnali (Chisapani) Multipurpose Project (1989) so as to see if there is an opportunity to develop this project for the regional markets and create an opportunity for cooperation for trade in the energy sector and eventually leading to creation of an integrated electricity market in South Asia. The key objective are: (i) review of the existing feasibility studies of Karnali (Chisapani) Hydropower Project (1989). (ii) Appropriately point out the requirements of upgrade/improvement in the data/information contained in the existing studies, where required. (iii) Point out the need to incorporate necessary information which is missing in the existing studies, where required, especially from the point of view that the project is to be undertaken as regional hydro power project. (iv) make available detailed ToR for updating the 1989 Feasibility Study, (v) sensitize the decision makers, professionals, investors and developers of a great opportunity to consider the construction of a regional hydropower project and considerably offsetting the electricity demand and supply gap. And (vi) take another step for advocacy towards promoting regional energy cooperation for materializing the SAARC Energy Ring envisioned by the SAARC leaders.

0.2 Karnali (Chisapani) Multipurpose Project (Feasibility Study 1998)

The Karnali (Chisapani) Multipurpose project (KCMP), located on the Karnali River in western Nepal, will be the largest water resources development on the Indian subcontinent and one of the largest in the world. The Karnali drains the western third of Nepal and flows into India where it is named the Ghagra, ultimately joining the Ganges.Its benefit includes major hydropower production and flow regulation (four fold increase in dry season flow) for increased agriculture in India and Nepal. Other benefits of the project are flood control in Nepal, India and Bangladesh. A detailed feasibility study conducted in 1986-1990 under the loan assistance from IDA has revealed that a 270m high embankment dam with an underground powerhouse of 10,800 MW capacity (18 units of 600 MW each) can be constructed on the Karnali River at Chisapani site, in the far western region of Nepal. In addition, it will provide over 10,000 MW of peaking hydropower predominantly for the northern power region of India and flow regulation for increased irrigation development of 3.2 million hectares in India and 191,000 hectares in Nepal. The project will also provide flood control and navigation facilities. The site is located about 600 km west to Kathmandu and about 500 km east to Delhi. The main features of the project will also include a 84m high reregulating dam 8 km downstream of the main dam required for the two reasons-- first, to provide uniform daily flows downstream to ensure full irrigation benefits both in Nepal and India, and second, to maintain the natural riverine environment.

The damsite at the narrowest, part of the gorge, is an embankment dam containing 45 x 10^6 m^3 of materials obtained from the alluvial fan area, 6 km downstream of the dam site at the location, where the river enters the Terai). The reservoir will extend up to 100 km upstream, and provide sufficient live storage to substantially regulate the river flow. The underground powerhouse sited within the left abutment will house 18 x 600 MW generating units. Power will be delivered into the Northern India grid by 5 x 765 kV transmission lines from the main power plant, while the power from reregulating powerhouse would be transmitted by one 220 kV line. The power plant has been planned as a peaking facility for the Northern India system, capable of operating at about 20% plant factor for firm energy production and at about 25% for average energy production.

Because of the highly variable plant output over a daily cycle, a reregulating facility is provided immediately downstream to ensure near-uniform downstream flows. This facility includes a low embankment dam and reservoir providing 100 x 10^6 m^3 of live storage, and a small 84 MW power plant.

Site Investigation and studies

The assessment made on the feasibility study report, 1989 is based on interpretation of extensive data sets from site investigations including topographic mapping, geologic investigation, seismicity and tectonic measurements and sedimentation and hydrologic data collection, and socioeconomic and environmental field data collection programme, and so on. Aerial photography, ground control surveying and topographic mapping were carried to produce topographical maps covering total area of 4,374 sq. Km. at different scale and contour interval. The geological and geotechnical investigations carried out for the underground works comprises five elements: geological mapping, geophysical survey, core drilling, aditing and rock testing. The investigation includes about 3200 m of core drilling and almost 700 m of exploratory adits. Points of particular interest are angle core drilling under the river and deep holes and adits into the area of the underground powerhouse complex. A total of 12 bed material samples and a total of 403 suspended sediment sample were taken and were analysed in the field laboratory.

Hydrology

The catchment area of the Karnali River at the damsite is 43,679 km^2. It is second largest of the three-major river system of Nepal. There are wide spatial and seasonal variations in temperature and precipitation both throughout the basin. The average long-term flow is estimated at 1389 m^3/s. There is a marked seasonal variation in flows with a distinct seasonal variation. Average monthly flows range from 309 m^3/s in February up to 4359m^3/s in August. The flood hydrology was studied by frequency analysis and a Probable Maximum Flood (PMF) of 63,000 m^3/s was also derived. The peak flood recorded was about 21,000 m^3/s in 1983

Sedimentation

The large reservoir created at Chisapani will tap all the incoming sediments within the reservoir and may lead to channel degradation to the river system downstream. The suspended sediment load measured over the 3 monsoon months in 1987 was estimated at 84 million tonnes. The maximum measured concentration of 45 400 mg/l occurred in July 26 during the peak flood event of the season. Allowing for unmeasured bed load and the unmeasured dry season load, the total load for the year was estimated at 107 million tonnes. HPC study estimated 260 million tonnes as the annual average sediments applying sediment rating curve derived from the 1987 data and taking into consideration sediment loads measured for other basins in the subcontinent. With the sediment load estimated, reservoir sedimentation is not a significant problem for the selected reservoir level (FSL at 415 m) of Chisapani project. The live storage volume would be reduced by only by 17% even after 50 years. The sediments would not encroach on the power intake until approaching 100 years.

Geology

The geology of the main structures of the project is presented in the following paragraphs

i. The Dam site

The Karnali River flowing through the southern part of the Sub-Himalayas has cut through the Churia Hills to form a prominent gorge referred as "the Karnali Gorge". It is about 4 km long. The dam site is located mid-way along the gorge. Geological Conditions at the damsite over a large area are quite uniform but wide variations at places. The rock types are a mix of about 60% sandstones, 20% to 30% mudstones and minor occurrences of breccia, marl and shale. There is no evidence of any significant faulting at the damsite.

ii. Reservoir Area:

The reservoir of Karnali (Chisapani) extends up to 100km upstream along the Karnali river valley. Its area at full supply level is 339 square kilometres. The reservoir lies almost entirely on rocks of Siwalik series, and colluvial, alluvial and residual soils. The upper part of the reservoir lies on limestones of the Lakharpata formation to the north of the MBT. There is no evidence of potential for significant reservoir leakage. Slope instability is present in the reservoir area due to failure on bedding planes in the lower and middle Siwalik formations and non-structural failures in the upper Siwalik rocks. This may result in some landslide activity. However, there is not any significant risk of landslide-induced waves threatening the dam stability.

iii. The Reregulating Facility:

The reregulating facility is located on the Karnali river alluvial fan some 6 km downstream from the mouth of the Gorge. All structure are sited on deep river gravels which have been derived primarily from the resistant rocks of the lesser Himalayas, but with a contribution from the more local sources of the lower Siwalik formation.

Seismology

The continuing convergence of the Indian and Eurasian continental plates has created a series of thrust or fault zones of continental dimensions. MCT lies at a considerable distance (125 km) from the site. It will have limited significance for design purpose. The MBT is considered capable of generating a Magnitude (Richter scale) 8 earthquake and the HFF a Magnitude of 6.5. The significant duration of the acceleration at the site associated with the magnitude of 8 MCE will be over 60 seconds, whereas that due to the relatively small magnitude 6.5 in the HFF will be quite short, about 15 seconds.

Construction Materials

A total of about 60 million m^3 of construction materials consisting of 9 million m^3 of impervious materials, 39 million m^3 of shell fill, 6 million m^3 of filters, 4 million m^3 of aggregates, and 1.5 million m^3 of riprap are required for Karnali project. Ample good quality gravel fill is available in the alluvial fan immediately downstream from the Chisapani gorge.

Project Configuration and General arrangement

The Karnali (Chisapani) Multipurpose Project consists of the following five main features:

- Main civil structures consisting of (i) the Dam and Spillway; (ii) Power Facilities including intake, power tunnels, penstock shafts together with penstock, powerhouse and tailrace
- Hydromechanical equipment including gates, stoplogs, and penstock pipes, and so on.
- Electromechanical equipment including turbines, generators, power transformers, and so on.
- The transmission facilities which deliver the power to Indian power system
- Reregulating facilities

Main Dam

The Main Dam is 270 m high from the lowest foundation level to crest elevation. The gravel fill embankment dam contains over 45 million cubic metres of fill material. The spillway, diversion and outlet facilities are conventional in concept. Flood handling is facilitated by the large degree of flood storage available – peak discharges are reduced to about one third of peak inflow for both the spillway and diversion facilities. The spillway is an ungated chute spillway capable of discharging a maximum flood flow of 19,200 m3/s. It is 860 m long. It terminates at a flip bucket and ultimately into the plunge pool. The large storage reservoir with live storage of 16.2 km3 (equal to 37% of average annual runoff) created almost four-fold the dry season flow in the Karnali River. This in turn increases agricultural production in Nepal and India both. The Karnali will be diverted during construction through two 15 m diameter diversion tunnels, each 2400 m long.

Power Facilities

The power facilities are located on the left bank of the damsite. The power facilities incorporate 18 generating units of 600 MW each producing 20,842 million kWh/yr, housed in an underground cavern of size 705 m x 27.7 m x 50 m and include six power tunnels of 15 m diameter connected to six bell mouthed intake structure with gate shaft. The power tunnels convey water into eighteen steel lined penstocks of 7.2 m dia through six vertical shafts of 14 m diameter. Transformers and valves are housed in a separate underground cavern some 700 m long.

Reregulating Dam

The reregulating dam with maximum height of 24 m is located at about 8 km downstream of the main dam mainly for the following two reasons:

- (i) to provide uniform daily flows downstream to ensure full irrigation benefits both in Nepal and India, and
- (ii) To maintain the natural riverine environment.

Regulated flow from Chisapani would be used to irrigate 191,000 ha in Nepal and 320,000 ha in India. The regulating facilities include a 6km long dam, an 84MW powerhouse and two irrigation off-takes for irrigation development in Nepal.

Power Evacuation

Evacuation of power from the main power plant (10,800 MW capacity) to the Indian system will be achieved by means of five 765 kV transmission lines, while the power from reregulating powerhouse would be transmitted to Indian system by one 220 kV line.

Project Benefits

i. Power Benefits

The Chisapani project has been designed as a peaking hydro plant for power exports to the Northern Indian power system of India comprising the States of Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Rajasthan, Uttar Pradesh and the union territories of Chandigarh and Delhi. The Chisapani project will have comparative advantages as a low cost source of peaking capacity in this system due to its large reservoir storage capacity, high degree of flow regulation, and low incremental generating capacity costs, as well as its relative proximity to major load centres in Northern India. Due to the economic advantages, the recommended size for the Chisapani project in this feasibility study is the maximum practical installed capacity of 10,800 MW, which corresponds to an annual capacity factor (CF) for dry season firm energy generation of about 20%.The power and energy benefit from main power plant at Chisapani and at the power plant at reregulation dam is presented in the table given below.

Table 0.1: Power and Energy Benefits

Description	Main Power plant	Kauriyala Power Plant at Reregulation Dam
Rated generating capacity	10 800 MW	84 MW
Firm Energy	15 266 GWh/yr	585 GWh/yr
Average energy	20 842 Gh/yr	621 GWh/yr

The total discounted benefits of power generation are estimated to be US$ 15,389 million discounted at 10% of the initial project on power date of November 2003.

ii. Irrigation Benefits

The Chisapani reservoir provides sufficient storage regulation to increase minimum dry season flows in the Karnali River by about 300% resulting into a four-fold increase in natural dry season low flows. The Chisapani project will enable large-scale irrigation development in Western Terai on both sides of Karnali River. A total gross command area of 238,709 ha could be irrigated in Nepal Terai between the Rapti River in the east and the Mahana River in the west, of which 191,000 ha is the net area available for irrigation after deducting irrigation infrastructure, roads and villages, etc.

Two large irrigation canals divert water from the Girijapur Barrage on the Karnali River about 8 km south of the Indo-Nepal border. The total cultivable command area totals 3.2 million ha including Saryu (1.2 million ha) and Sarda Sahayak (2.0 million ha). Irrigation service and agricultural production is still being expanded in both areas. There are other large irrigation schemes farther downstream. Irrigation service and agricultural production is still being expanded in both areas. The regulated flow of Chisapani project will enable increased dry season irrigation in India at the existing Karnali (Ghagra) basin irrigation developments in the Sarda Sahayak and Saryu regions, as well as further downstream.

iii. Other Benefits

Other potential benefits that were assessed in the study are flood control and navigation. The flood control benefits in Nepal are estimated to be about US $ 4 million, discounted at 10% to the project in service date. The study has estimated flood benefits farther downstream in India and Bangladesh. The order of magnitude of these additional downstream benefits estimated is about US $ 20 million. Some navigation benefits will also be created in the reservoir area and its vicinity. The discounted navigation benefits estimated at about US$ 1 million.

Socio-Economic and Environmental Issues

The study concludes that the project will cause substantial socioeconomic and environmental impacts, which require further investigations and studies for their effective mitigation. The project requires resettlement of about 60,000 people. It was planned to resettle them, primarily into currently undeveloped areas within the Karnali irrigation command area. Environmental impact includes unavoidable encroachment into the existing Royal Bardiya Wildlife Reserve, which is located in the vicinity of the main dam and reregulating facilities and potential adverse impacts on the Gangetic Dolphin and Garial crocodile. A special consideration of these impacts is clearly an essential element of the decision to proceed with Chisapani.

Project Implementation

It was envisaged an implementation period of 17 years consisting of 5 years for pre-construction activities, followed by nine and half years for project construction including generation from two units and ultimately 4 years for installation of remaining 16 units. A period of five years (1990 to 1994) was allowed for these latter pre-construction activities, ending with the award of the major construction contract. The time required for construction was conservatively estimated at almost nine years i.e. from a January 1995 start to the on-power date for the first two (of eighteen) units, i.e. in November 2003. Installation of the remaining units was tentatively planned at a rate of one every three months, terminating in November 2007. An annual cash flow distribution, beginning with expenditures in 1990, show that about 3% ($ 80 million) would be expended during the five year pre-construction period, and about 85% of the total would be expended before the initial on-power date and the remaining 12% during installation of 16 units.

Capital Cost

The capital cost of the project at 1998 price level was estimated at US$ 4,890 million consisting of US $ 1,667 million for civil works, US $ 1,907 for electromechanical works and transmission lines, and the remaining US $ 1,316 million for access, infrastructures, resettlement and environmental mitigation, engineering and administration, and so on..

Economic Evaluation

The equivalent economic cost of the project for the November 2003 in service date is US $ 6,808 million. The corresponding gross economic benefit is US $ 16,780 million. The net economic benefit is US $ 9,972 million, the benefit /cost ratio is 2.46 and the corresponding internal rate of return is 27%. The net economic benefit will be equivalent to about US$ 1,000 million per year to be shared between the two countries. These economic measures demonstrate that the project is feasible and economically very attractive.

0.3 Gaps and Areas Needing Improvement in the 1998 Feasibility Study

Upon review of the Feasibility Report (1989) of Karnali (Chisapani) Multipurpose Project, the following gaps in the study have been identified. The additional activities to be undertaken to address the gaps have been identified.

a. Site Investigation

Topographic Mapping

The topographic mapping of the project structures areas are adequate, and are in paper form. However, to update the features that may have been added lately, it is essential to update the topographic maps to take into account the recent infrastructure development in the area, using the latest technologies such as LIDAR mapping technologies.

Geological and Geotechnical Investigations

The investigations and tests carried as part of the feasibility study are generally comprehensive except investigation on geological and hydraulic conditions in the fan area of the project. Additional investigation on geological and hydraulic conditions in the fan area affecting design and cost of the reregulating facility needs to be done. Besides, further geological/geotechnical investigations might be necessary for the detailed engineering design of the project. Such additional investigations may also include in situ tests. The consultant (to be hired for the updating of the feasibility study) will determine the scope of additional geological/geotechnical investigations, and carry out investigations subject to the approval of the Employer (i.e. SEC).

Hydrology and Sedimentation

i. Hydrology

Additional data collection during the study period together with the flow information available since the FS study was carried out is required to update the hydrological analysis.

ii. **Sedimentation**

In the past 20 years since the time HPC study was carried out, there are additional hydrological data available. Also, there has been significant change in the land use pattern in the river catchment, impacting the sediments concentration in the river. It is essential to review the hydrological data, and to take sample measurements of suspended sediments in the river and that of the river bed.

Environmental and Socioeconomic Surveys

i. Environmental Survey

Environmental survey need to be updated to reflect the current information on the condition of the forest and agricultural resources and to collect information on resource use by the local population. For this, full-fledged Environmental Impact Assessment (EIA), Cumulative Impact Assessment (CIA), Social Impact Assessment (SIA), Rehabilitation Action Plan (RAP) require to be conducted based on the current requirement of the Nepal environmental laws, and that of the multilateral funding agencies including World Bank(WB), Asian development Bank (ADB, etc. and the bilateral agencies.

ii. Socioeconomic Surveys

The social economic surveys (census and sampling) need to be redone as the population in project area has increased significantly in the past 20 years. Further, the socio economic conditions of the people have undergone significant transformation in that period, as people are moving away from the subsistence farming to other trade, foreign employment and so on.

Geology and Seismology

HPC has made conservative assumptions in the design of all three structures mentioned above and has recommended carrying out detailed geological investigation at the location of the above structures during detailed design stage of the project. It is recommended that as part of the updating of the feasibility study, the consultant will review the geology at the reservoir, dam site and reregulating facility and update as necessary, and identify the additional geological and geotechnical investigations to be carried out.

Construction Materials
The information on construction materials including the core fill materials needs to be updated.

b. Hydrology

The updated feasibility study requires reviewing of the hydrology and updating the data incorporating the additional flow information available in the intervening periods.

c. Sedimentation

The updated feasibility study requires reviewing the hydrology, and update them incorporating additional information from the field investigations/measurements to assess the current status of the sediment load in the river induced by the changed land use pattern in the river catchment. Further, as suggested by the HPC study, the updated feasibility study will also require to carry out an assessment on the potential for river channel degradation downstream of Chisapani especially at the downstream of Girjapur barrage, quantify the likely impacts and identify mitigation measures.

d. Selection of Project Configuration/Dam Type

The consultants to be hired for updating of the project will review the project configuration and the project components to confirm the findings of the HPC study and make recommendations on possible improvement, if any. The Consultant shall also review the location of the main dam and the dam type and make recommendations on the location and the dam type.

e. Project Optimization

The focus of the HPC study was to optimize the project primarily for power generation, with irrigation, flood control and navigational benefits taken as being secondary. Given these other potential benefits, it is recommended to optimize the project as a true multi-purpose of project taking all the benefits i to consideration, if desired by Nepal, and the lower riparian countries. The data availability issue had hindered the HPC to undertake a comprehensive study to optimize the project to capture the other benefits (besides power), particularly irrigation and flood control in India (and Bangladesh). Furthermore, Project optimization (including dam height) is required to be performed to match the regional power market, and in light of the prevailing environmental and social, and safety concerns,

The updated feasibility study will review the optimization of the project given other planned/committed upstream development in the Karnali River basin. For example: Upper Karnali (900 MW) and other projects now in various stages of study including reservoir projects on its tributaries such as West Seti (750 MW), Nausalgad (300 MW) and ROR projects.

As recommend in the study further optimization studies of the project based on additional flow data, opportunities for increased power demand in Nepal, revised estimate of irrigation benefits in Nepal and India in addition to the consideration of financial/economic costs and benefits, are recommended to be carried out.

The updated feasibility study requires carrying out project optimization study in consideration to (i) irrigation, flood control and navigational benefits, (ii) the South Asian power markets, and (iii) financial and institutional concerns from the regional countries' perspective.

f. Reservoir Simulation

The other upstream storage type hydropower development (such as West Seti, Nausalgad) will further firm up the energy generation capacity of Karnali Chisapani. Consequently, it is proposed that as part of the updated feasibility study, the consultant will carry out the system simulation in light of the upstream development in the Karnali river basin (on-going and proposed) using the most current information of the upstream projects, with irrigation, flood control and navigation co-benefits to be optimized along with the power generation. The power system simulation should also be updated considering the increase in the demand, current and planned/under construction generation capacities in Nepal and the electricity demand and current generation capacities in the regional countries.

g. Project Markets

The consultant to be hired for updating of the feasibility study of the Karnali project will review the power market both in Nepal and in the region. For this, the consultant will prepare electricity demand forecasts in the regional countries, and the generation technologies that are likely to be displaced by the project and then determine the power benefits of the Karnali project taking into account the current power market situation in Nepal and in the region.

h. Project Benefits Streams

The project benefits estimation (power, irrigation, flood control) need to be reviewed utilizing the latest data on demand for power, irrigation and possibility of flood control. The HPC report lays more emphasis hydropower generation and water use for irrigation and flood mitigation have not been adequately addressed, despite, the project is a good candidate for multi-purpose development with significant irrigation and flood control benefits and some potential for navigation. The HPC report has noted that the analyses were based on insufficient information on irrigation and flood control, as described below:

Power benefits

Since limited cost data was available from official Indian sources, unofficial sources and reasonable assumptions for comparative generation cost characteristics (capital cost, fuel costs, and unit cost of generation) used in the feasibility study would result in to estimated power benefits less than the actual. The updated feasibility study needs to estimate the power and energy benefit by collecting information from official sources.

Irrigation benefits

As the pertinent data/information on irrigation potential was not available from relevant official sources, the benefit were evaluated both with and without the Chisapani project. These will dependent on the interpretation of the available information from relevant Indian reports and other background documents on water and land use concepts throughout the Ghagra/Ganga plain. Furthermore, as the information on downstream irrigation project is limited, the benefit estimated in this area is also in the conservative side. Owing to this, the updated feasibility study requires to collect relevant information from official sources of GOI to refine the irrigation benefits.

Flood Control benefits in India and Bangladesh

The study has estimated flood benefits farther downstream in India and Bangladesh. It, however states that such benefit in India and Bangladesh are very uncertain due to lack of data. Thus the total flood control benefits appear to be far less than actual irrigation benefits. The updated feasibility study requires collecting relevant data in Nepal, Bangladesh and India and refining the flood control benefits.

In light of the above discussions, it is essential to estimate the power benefits, irrigation benefits, and flood control benefits using updated information. Although the study has stated that downstream navigation benefits are not significant given the river transport is not economically competitive with alternative mode of transport, it may be worthwhile to revisit this conclusion backed up by a detailed analysis.

i. Project General Arrangement and Project Facilities

The consultant to be hired for updating the feasibility study will review the project arrangement and dimensioning of various project structures and recommended improvements backed up by necessary physical and computational (numeric) hydraulic modelling exercises. The numeric modelling is suggested to be carried out for the spillway, plunge pool, energy dissipating structures, weir (for reregulating dam), power intake, irrigation outlets, sediment flushing outlets, low level outlets, and so on. To confirm the results of the numeric modelling, the consultant will carry out physical modelling of key hydraulic structures to be identified in consultation with the Employer (SEC).

Mode of Operation of the Power Plant

It is likely that the current profile of electricity demand may have undergone some changes compared to the one prevailing at the time of the HPC study. For example, currently India experiences two peak periods, one in summer (April- June), and another in winter (December-March). Accordingly, the annual maintenance may be scheduled in the lower demand months outside of the peak periods. The consultant to be hired for updating the feasibility study will collect the information on the latest load profile and suggest maintenance schedule accordingly and also plan the reregulating facility for maximum irrigation benefits.

Switchyard

The updated feasibility shall review the technological options for the switchyard schemes in light of the current level of technology, and recommend the one which is technologically superior and economically feasible. The study should also look into the unit size of the turbine generators, as there is a possibility of having higher capacity Francis turbines.

j. Power Evacuation Study

The updated feasibility study should include carrying out of a comprehensive power system study of the regional countries to identify the system reinforcement needs for the power evacuation for Karnali Chisapani.

0.4 Terms of Reference for Updating the Feasibility Study Report

The Terms of Reference for the updating of the 1989 Feasibility Report have been prepared incorporating, among others, the above gaps presented in Section 02 into the tasks to be performed by the consultant to be hired for updating the 1989 FS. The consulting services have been divided into two phase, Phase I will consists of tasks to be undertaken to update the Feasibility Study report to develop the project as a regional project of multipurpose nature with storage for irrigation, electricity generation, flood mitigations, and so on, and conduct environmental and social studies and Phase II will cover the detailed engineering design and preparation of construction drawings, schedules and tender documents. It is suggested the Request for Proposal should include a provision to retain the Phase I consultant to undertake the tasks in Phase II, if the performance in Phase I is found satisfactory.

The Scope of Work for the Consulting services in Phase I and Phase II study shall comprise the categorized tasks envisaged under this Scope of Work. For the planning of work, organising manpower and material estimates and managing the execution and cost of the Project, the Consultant shall breakdown the Services into Tasks, Subtasks and if necessary in Work Packages and to list them item wise and provide method statement for each activity.

The services carried out by the Consultant shall be reviewed periodically by independent Panel of Experts (POEs) appointed by SEC. The reports submitted by the consultant shall be accepted by SEC after approved by the POEs.

Phase I Study

The feasibility study shall be updated in considerations of the project as a regional project of multipurpose nature with storage for irrigation, electricity generation, flood mitigations, etc. In Phase I. The Consultant shall update/improvement in the data/information contained in the existing studies including feasibility study 1989 covering the contents but not limited to the content provided in Feasibility study 1989. The detailed scope of works under this assignment under Phase I study of the project covers following tasks/activities.

Task 1	Inception report on the assignment
Task 2	Review and update site investigation and studies
Task 3	Review and update hydrological, meteorological and sedimentological studies, etc.
Task 4a	Regional power market and associated studies
Task4b	Willingness and affordability of consumers to pay for the power purchases from the project
Task 5	Review and update power evacuation study
Task 6	Review and update project configuration and project components
Task 7	Review and Update Project optimization Study
Task 8	Review and Update Reservoir simulation

Task 9 Review/update and conduct environmental impacts and social safeguard studies

Task 10 Review and update project benefit streams

Task 11 Review and update of Feasibility Studies

Task 12 Analysis of institutional arrangement for project implementation

Phase II Study

The detailed scope of works under this assignment under Phase II study of the project covers following tasks/activities.

Task 1 Inception Report on the Assignment

Task 2 Review and update site investigation and associated studies including additional field investigations, if any

Task 3 Detail Engineering Design, Specifications and Drawing

Task 4 Model test study (physical and mathematical)

Task 5 Refinement of Project Cost &quantity estimation, Construction Planning and Scheduling, and Economic and financial evaluation

Task 6 Preparation of Complete Tender Documents and Tender Drawings

The project team will consist of international key and non-key experts and national/local experts to accomplish the study. It is envisaged that the international team of experts will be resident in Nepal for the entire duration of the services. Coordination activities only will be carried out in the home office of the Consultant with the possible exception of studies that may require specialist input that cannot be supplied from Nepal. It is estimated that about two hundred and Eighty five (285) person-months of international experts; of which 177 person months for phase-I study and the remaining 108 person months for Phase-II study and five hundred and fifty eight (558) person-months of national experts will be needed to complete the assigned tasks. The estimated time for completion of the assignment under Phase-I study is 30 months and 20 months for Phase-II study. The costs of consulting service are estimated at USD17,598,258 for Phase I, and USD 9,511,243 for Phase II.

0.5 Way Forward

Once the SEC Board determines to carry forward the updated feasibility study of the Karnali (Chisapani) Multipurpose Project, the first step is to look for the funding for the Phase I of the project. Once the funding has been secured, the following are the activities to be undertaken (the estimated duration of each activity has been given in the parenthesis):

1. Preparation of request for proposal (RFP) documents for the hiring of an international consultants, through quality based selection (QBS) or quality and cost based selection (QCBS) procedures with Time-Based Contract. The RFP document will be prepared in accordance with the procurement guideline of the funding agency, and the standard RFP document issued by the funding agency. (3 months including review)
2. Short-listing of the consultant firms. This is normally done by issuing a notice inviting the eligible confirms to submit the expressions of interest (EOIs). (2 months)
3. Issuing the RFP documents to the shortlisted consulting firms, and submission of the proposals (2 months)
4. Evaluation of the technical and financial proposals (4-6 months including decision making and approval)
5. Negotiations and award of the contract (2 months).
6. Setting up of a contract administration office by SEC in Kathmandu.
7. Commencement of consulting assignments
8. Submission of deliverables by the consultants including submission of final report: 30 months from the date of commencement--for Phase I
9. Review of the updated feasibility report by SEC and participating regional countries.
10. If the project is found feasible to extend the contract of the consultants for Phase II of the assignment.
11. Road show to various investors-- multilateral, bilateral and private investors. Since, the Karnali (Chisapani) Multipurpose Project is a large project needing investments unprecedented in any single infrastructure in South Asia, getting necessary finances would be a challenge. For this purpose, a management consultant firm may he hired to determine the modality of the project development (PPP or as a regional project with investment from

the participating countries), and to assess the viable financing structure for the implementation of the project. (2-4 years)

12. Construction of the Project (9 years).

CHAPTER1: INTRODUCTION

The team of Consultant consisting of the following three members lead by Mr. D N Raina submits this Final Report for review of the feasibility study of Karnali Chisapani Multipurpose Project (10,800 MW) carried out in 1989 and preparation of terms of Reference for hiring Consultant to update the feasibility study to develop the project as a regional power project based on the Contract Agreement between the team of the Consultants and SEC. The Final report summarizes the review of feasibility study report of Karnali Chisapani project prepared by Himalayan Power Consultant in 1989, identifies the gaps requiring additional studies and investigation and prepares terms of Reference for hiring the Consultant to upgrade the feasibility study including full flexed environmental Impact Assessment, Social Impact Study and Rehabilitation Action Plan in Phase I of the study and detailed engineering design and preparation of bidding documents in Phase II of the study. The report also estimates the budget required for the planned study and recommends the way forward to materialize the power project in the SAARC regional market.

The Team of Consultant:

Mr. D N Raina,	Team leader
Mr. M P Acharya	Energy Expert
Mr. L N. Bhattarai	Hydropower Expert

1.1 Background

SAARC Energy Center (SEC) proposes development of large regional hydropower plant in south Asia focusing huge hydropower potential of Nepal. The member states Afghanistan, Pakistan, India, Sri Lanka, and Bangladesh would be benefitted from the cheap power generated in Nepal would earn foreign exchange and can overcome trade deficit. In 2016, the Government of Nepal announced that the Karnali Chisapani hydropower project would be developed through a "Multi-stakeholder partnership" approach that comprises investors from across the SAARC region. In this back drop, SEC intended to review the feasibility study of Karnali (Chisapani) Multipurpose project (10,800 MW) carried out in 1989 and update the feasibility study to develop the project as a regional power project.

1.2 Karnali (Chisapani) Multipurpose Project

Karnali (Chisapani) Multipurpose Project is the largest storage project in Nepal. The project has been studied in the past by international consultants with support from multilateral funding agencies. In 1966 under the UNDP assistance the Government of Nepal hired Nippon Koei (Japan) to identify the hydropower potential in the Karnali River. The study recommended, among others, a project of 1,800 MW Capacity for developments at a site upstream of Chisapani. In 1968 the government of Nepal hired Snowy Mountains Hydroelectric Authority (SMHA) to review the study carried by Nippon Koei, and SMHA recommended an alternative site downstream at Chisapani with installed capacity of 3,600 MW. In 1976 the Government of Nepal hired Norconsult (Norway) and Electrowatt (Switzerland) to carry out further study, and both the firms confirmed the recommendation of SMHA for the site at Chisapani with installed capacity of 3,600 MW. In view of the attractiveness of the project, in 1978 the Government of Nepal and the Government of India (GOI) established a high level joint committee, the Committee on Karnali (CK), to promote bilateral discussions on the Karnali (Chisapani) Multipurpose Project. The Committee on Karnali while recognizing the attractiveness of the project recommended carrying out a fresh feasibility study. Accordingly, in 1989, under a loan financing from the International Development Association (IDA), the Government of Nepal prepared the Feasibility Study Report of Karnali (Chisapani) Project for multipurpose development with installed capacity of 10,800 MW, with the estimated cost of USD 4.89 billion at 1988 prices at Chisapani, exploiting the unique location of this site for development of the project.

The IDA funded study was carried out by Himalayan Power Consultants (HPC), a consortium of consultants, which included Acres (Canada, Ebasco (USA), Shawinigan (Canada) and SNC (Canada). The study confirmed that the Karnali (Chisapani) Multipurpose Project scheme of 10,800 MW was technically feasible and economically very attractive. The Karnali (Chisapani) Project is associated with significant benefits in terms of enhanced irrigation (191,000 ha in Nepal, and 3200,000 ha in India), flood control, and navigational benefits, besides power benefits. At the time of completion of the feasibility study, the total demand for power within Nepal was relatively low (at 176 MW). There was limited transmission capacity mostly in the central region of Nepal at 132 kV. Against this backdrop, the project was envisaged for development for power export to India, and for water flow regulation for increased irrigation and flood control. The focus of study was largely hydropower generation, although the project was a good candidate for multi-purpose development with significant irrigation and flood control benefits and some potential for navigation.

b. Project Description

By any international comparison, the Karnali (Chisapani) project is a large-scale development. It includes a 270-m high dam (third highest in the World), a reservoir with 38,000 million m^3 of total storage (largest in the Indian subcontinent), a 700 m long underground powerhouse (longest underground powerhouse in the world, and 10,800 MW of installed capacity (second largest hydro plant in the World). The general layout of project facilities is appended in Annex 2 as shown in Fig. 1 (Fig. 1.1 in the Main report, Feasibility Study 1989) and the project's dominant features are tabulated under Project Highlights in Annex 1.

The Chisapani project site is located in Western Nepal, about 600 km west of Kathmandu and 500 km east of Delhi. It is located in the Karnali River gorge, immediately upstream of the point where the river enters the Terai, part of the Gangetic plain. The damsite at the narrowest part of the gorge, is an embankment dam containing 45 x 10^6 m^3 of materials obtained from the alluvial fan area, 6 km downstream (generally where the river enters the Terai region). The reservoir will extend up to 100 km upstream, and provide sufficient live storage to substantially regulate the river flow. The underground powerhouse, sited within the left abutment, consists of 18 x 600 MW generating units. Power will be delivered into the Northern grid of India by 5 x 765 kV transmission lines. The power plant has been planned as a peaking facility for the North Indian power system, capable of operating at about 20% plant factor for firm energy production and at about 25% for average energy production.

Because of the highly variable plant output over a daily cycle, a reregulating facility is provided immediately downstream to ensure near-uniform downstream flows. This facility includes a low embankment dam and reservoir providing 100 x 10^6 m^3 of live storage, and a small 84 MW power plant.

The reregulating facility also serves as an excellent location for left bank and right bank outlet structures for the potential Karnali Irrigation Command area in Nepal. This 238,700 ha Irrigation development will extend from the foot of the Siwaliks to the Nepal/India boarder, and will span from the West Rapti River in the East to the Mohana River in the West in Nepal.

Besides being a source of supply of irrigation development in Nepal, there will also be substantial additional regulated flows available within India. This will allow increase agricultural production in existing and committed irrigation projects in northern India, particularly in the Sarda Sahayak and Saryu developments.

c. Study Execution

The study was started in June 1986 and was carried out in four stages.

i. **Initial stage:** In this stage (June 1986 to July 1987), the prime emphasis was on identifying the optimum project site and general arrangement of the civil works.
ii. **Optimization** (referred to as Stage A): In this stage (July 1987 to May 1988), the scale of development was optimized. This included selection of the reservoir full supply (FSL) and associated live storage and operating range, as well as installed generating capacity.
iii. **Final design:** (referred to as Stage B): In this stage (May 1988 to June 1989) Feasibility level designs and costs estimates were prepared for the recommended development, and benefits evaluations were further refined. During this period, the result of the entire study were documented and submitted as a Final Draft Report.
iv. **Final Report:** In this stage (June 1989 to December 1989), the Final Draft Report was subject to extensive review by the Governments of Nepal and India, the World Bank, and Overseas Bechtel Inc. These reviews were incorporated as appropriate, and the report was finalized.

The above provides a general description of the study process, especially with respect to the planning and design of the main facilities. Other activates were also carried out alongside. The geological field investigation programme continued generally through the first two dry seasons (November 1986 to June 1987 and November 1987 to June 1988). The aerial photography and ground control programme was executed primarily in the first dry season. A programme of seismic recording was also implemented in the first dry season, as was the socioeconomic and environmental field data collection programme. A special programme of sediment data collection was implemented during the 1987 monsoon season, and has been repeated for the 1989 monsoon season.

Benefit assessments were carried out in the Stage A of the study. Evaluation of power and irrigation benefits were further refined in the Stage B of the study.

The study was carried out predominantly in Nepal. Most of the study effort was executed from HPC's office in Kathmandu, while the field program was managed from a field camp at the Chisapani project site. The programme of the studies and investigations was executed with expatriate personnel from the home office of HPC's partner companies and with counterpart personnel from the office of the Karnali project, the Nepal Electricity Authority (NEA), the department of Hydrology and Meteorology and other ministries and departments of the Government of Nepal.

For this study, HPC engaged various sub-contractors to carry out special duties and investigations. These include:

Salzgitter (Germany)	Irrigation studies
Kenting earth Sciences (Canada)	Aerial Photography and Mapping
Geo-Recon (United States)	Seismic Exploration
WAPCOS (India)	In situ rock stress measurement and specialized soil and rock testing
Himal Hydro Nepal	Adit Excavation
Nepal Electricity authority (Nepal)	Soil and Rock testing
Asian Institute of Technology (Thailand)	Specialized soil and rock testing
Him Consult (Nepal)	Processing of Seismic data
New Era (Nepal)	Socioeconomic and environmental data collection & socioeconomic study

Nepal Consult (Nepal)	Flood damage study
Rites (India)	Transportation study
Faris and Associates (USA)	Specialized study of construction material transportation by conveyors

For a study of this scope and importance, it is essential that leading international experts provide periodic reviews of key areas of technical concern. In this regard, HPC established a Board of Specialist Advisors, which included

Dr H B Seed	Geotechnical design
Dr A J Hendron	Geotechnical design
Dr E Hoek	Rock mechanics
Dr P R Fisher	Engineering Geology
Dr N Pinto	Hydraulics/Spillway design
Mr R A Eider	Hydraulics
Dr M A Kramer	Arch Dams
Dr J F Kennedy	Sedimentation
Dr M S Sevens	Hydrology/meteorology

Because of the size and importance of the feasibility study, Overseas Bechtel Inc. (OBI) was engaged by the Ministry of Water Resources and the office of the Karnali (Chisapani) Multipurpose Project to monitor and guide the overall study effort. As part of its obligation OBI carried out a comprehensive review of the entire Draft report. Additional reviews were also carried out by a panel of experts appointed by the World Bank, and specialists drawn from ministries and departments of the governments of both Nepal and India.

1.2 Report Format

The feasibility study report consists of a separate Executive Summary, the Main report and twenty separate annexes (some of which comprise two volumes The Main Report is organized and presented to reflect the analytical and chronological development of the study.

Part I – Section 1 to 5	-	covers a brief summary description of the project introduction, general background and the project conclusions and recommendations.
Part II – Section 6 to 11	-	covers site investigations and assessment of site conditions-topography, geology, seismology, construction materials, hydrology and sedimentation.
Part III – Section 12	-	covers the process of initial selection of the project site and dam type.
Part IV – Sections 13 to 17	-	covers the Stage-A optimization study, including selection of the recommended reservoir full supply level, reservoir operating range and installed capacity.
Part V- Section 18 to 25	-	covers the engineering description of project facilities for the recommended development (Stage-B)
Part VI – Section 26 to 27	-	covers the construction plan and capital cost estimate for the recommended development.
Part VII – Section 28 to 29	-	covers impact assessments, including socioeconomic, resettlement and environment.
Part VIII – Section 30	-	covers the economic evaluation of the recommended project.

It should be noted that some of the information used in the optimization study (Stage A) reflects provisional values derived at the intermediate stage of the overall study efforts. Accordingly, there are some variations between these and values ultimately derived for the more detailed design and evaluation of the recommended development (Stage B). Such variations are inevitable in the study of a project of this scale.

In this study, however, the variations are relatively minor, as a substantial amount of the Stage A work was redone using more detailed design, unit costs and benefit evaluations from the Stage B study effort. In view of the very large scale of development, it is required to reconfirm that the optimization process still supported the recommended development.

1.3 OBJECTIVES OF REVIEW

The general objective of this study is to review the Feasibility Study Report of Karnali (Chisapani) Multipurpose Project (1989) so as to see if there is an opportunity to develop this project for the regional markets and create an opportunity for cooperation for trade in the energy sector and eventually leading to creation of an integrated electricity market in South Asia. In particular, following are the key objective of this study

- Review of the existing feasibility studies of Karnali (Chisapani) Hydropower Project (1989).
- Appropriately point out the requirements of upgrade/improvement in the data/information contained in the existing studies, where required.
- Point out the need to incorporate necessary information which is missing in the existing studies, where required, especially from the point of view that the project is to be undertaken as regional hydro power project.
- Make available detailed TORs for updating the 1989 Feasibility Study
- Sensitize the decision makers, professionals, investors and developers of a great opportunity to consider the construction of a regional hydropower project and considerably offsetting the electricity demand and supply gap.
- Take another step for advocacy towards promoting regional energy cooperation for materializing the SAARC Energy Ring envisioned by the SAARC leaders.

1.4 SCOPE OF REVIEW

The scope of this review, include the review of the following aspects of 1989 Feasibility Report:

i. Assessment of demand-supply in Nepal and in the regional countries,
ii. Updating of hydrological studies (using longer years of river flow and meteorological data now available; refining the hydrological modelling using GIS and remote sensing technologies),
iii. Updating of geological, geotechnical and seismic studies/ investigations,
iv. Carrying out dam break/ safety studies

v. Project optimization (including dam height) to match the regional power market, and in light of the prevailing environmental and social, and safety concerns,

vi. Design of the structures (dam--RCC, rock fill, or concrete gravity dam, power house--underground v/s surface),

vii. Project cost and benefit assessment (irrigation, flood control, navigation, and so on)

viii. Assessment of cost of generation,

ix. Studies on environmental and social safeguards,

x. Power evacuation related studies,

xi. Assessment of institutional, regulatory and legal issues of cross border power trade

xii. Study of the regional power market,

xiii. Design of the project governance structure for regional development of the project,

xiv. Implementation and financing modality,

1.5 METHODOLOGY

The review of the 1999 Feasibility Study Report of Karnali Chisapani Multipurpose Project is carried out as a desktop review study. The experience of authors as the experts in the development reservoir and run of the river hydropower projects in Nepal has informed the preparation of the Terms of Reference.

1.6 LIMITATIONS OF THE STUDY

The review is based on the desktop study. No field visits have been made as part of the preparation of this report. As a result, it is suggested to update the parts of the TOR giving the background information on the project site before issuing the Request for Proposal document to the consulting firms.

1.7 ORGANIZATION OF THE REPORT

A summary of the past studies has been presented in Chapter 2. Chapter 3 presents a summary of the key features of the Feasibility Study Report, 1989, and the areas needing additional study/investigation to update the report. A brief introduction on the regional power markets is covered in Chapter 4. The Terms of Reference for the hiring of a consulting firm for updating the feasibility report is given in Chapter 5. Finally, Chapter 7 suggests steps for taking the project forward to update the feasibility study.

CHAPTER 2: THE PROJECT--KARNALI (CHISAPANI) HYDROPOWER PROJECT (18,000 MW)

2.1 PROJECT DESCRIPTION

The Karnali (Chisapani) Multipurpose project is located on the Karnali River in western Nepal. It would be the largest water resources development on the Indian subcontinent and one of the largest in the world, when developed. The project's benefits include hydropower production, irrigation, flood control and navigation. The main function of Karnali (Chisapani), as envisaged in the 1989 Feasibility Study, is generation of 10,800 MW of hydropower and its delivery to the power system in Northern India, with some associated benefits in terms of enhanced irrigation, flood control and navigation. Chisapani exploits one of the few exportable resources available in Nepal and provides a source of low cost power to India. The regulated flow would be used for increased agriculture in both India and Nepal. The site is located about 600 km west to Kathmandu and about 500 km east to Delhi. The site is accessible through East-West Highway running across the length of the country in southern plains. Location of the project is presented in figure 2 (fig. 3.1 in the Main report) and the general arrangement of facilities at the main dam site is shown in figure 3 (fig. 18.1 in the Main report, Feasibility Study, 1989).

The main features of the project include dam and spillway, power facilities, downstream reregulating facilities and high voltage transmission lines to evacuate power to the North India power system.

i. **Main Dam**

The Main Dam is 270 m high from the lowest foundation level to crest elevation. The gravel fill embankment dam contains over 45 million cubic metres of fill material. The Spillway, Diversion and Outlet facilities are conventional in concept. Flood handling is facilitated by the large degree of flood storage available. Peak discharges are reduced to about one third of peak inflow for both the spillway and diversion facilities. The spillway is an ungated chute spillway capable of discharging a maximum flood flow of 19,200 m3/s. It is 860 m long. It terminates at a flip bucket and ultimately into the plunge pool. The large storage reservoir with live storage of 16.2 km2 (equal to 37% of average annual runoff) created increases almost four-fold of the dry season flow in the Karnali River. This in turn increases agricultural production in Nepal and India both. River Karnali will be diverted during construction through two 15 m diameter diversion tunnels, each 2400 m long. The general arrangement at the dam site is presented in figure 4 (fig, 23.1 of the Main Report) appended in Annex 2.

ii. Power Facilities

The Power Facilities are located on the left bank of the damsite. The power facilities incorporate 18 generating units @ 600 MW each producing 20,842 million kWh/yr in-housed in an underground cavern of the size 705 m x 27.7 m x 50 m units and include six power tunnels of 15 m diameter connected to six bell mouthed intake structure with gate shaft. The power tunnels convey water into eighteen steel lined penstocks of 7.2 m diameter through six vertical shafts of 14 m diameter. Transformers and valves are in-housed in a separate underground cavern some 700 m long. The general arrangement of power facilities is appended in Annex 2 in figure 5 (fig. 23.2 of the main Report) and the water conveyance profile is presented in figure 6(figure 23.3 of the Main Report).

iii. Reregulating Dam

The reregulating dam with maximum height of 24 m is located at about 8 km downstream of the main dam mainly for the following two reasons:

a) to provide uniform daily flows downstream to ensure full irrigation benefits both in Nepal and India, and
b) to maintain the natural riverine environment.

Regulated flow from Chisapani Project would be used to irrigate 191,000 ha in Nepal and 320,000 ha in India. The regulating facilities include a 6km long dam, an 84 MW powerhouse and two irrigation off-takes for irrigation development in Nepal.

iv. Power Evacuation

Evacuation of power from the main power plant (10,800 MW capacity) to the Indian system will be achieved by means of five 765 kV transmission lines, while the power from reregulating powerhouse would be transmitted to Indian system by one 220 kV line.

v. Socioeconomic and Environmental Issues

The study concludes that the project will cause substantial socioeconomic and environmental impacts, which require further investigations and studies for their effective mitigation The project requires resettlement of about 60,000 people. It was planned to resettle them, primarily into currently undeveloped areas within the Karnali irrigation command area. Environmental impact includes encroachment into the existing Royal Bardiya Wildlife Reserve, which is located in the vicinity of the main dam and reregulating facilities and potential adverse impacts on the Gangetic Dolphin and Garial crocodile. A special consideration of these impacts is clearly an essential element of the decision to proceed with the Karnali (Chisapani) project.

vi. Project Implementation

The study envisaged an implementation period of 17 years consisting of 5 years for pre-construction activities, followed by nine and half years for project construction including generation from two units and four years for installation of remaining 16 units. A period of five years (1990 to 1994) was proposed for pre-construction activities, ending with the award of the major construction contracts. The time required for construction was conservatively estimated at almost nine years (from January 1995 to November 2003 when the first two of eighteen units are on line. Installation of the remaining units was tentatively planned at a rate of one every three months, terminating in November 2007. An annual cash flow distribution, beginning with expenditures in 1990, show that about 3% ($ 80 million) would be expended during the five year pre-construction period, and about 85% of the total would be expended before the initial on-power date and the remaining 12% during installation of 16 units.

vii. Capital Cost

The capital cost of the project at 1998 price level was estimated at US$ 4,890 million consisting of US $ 1,667 million for civil works, US $ 1,907 for electromechanical works and transmission lines, and the remaining US $ 1,316 million for access, infrastructures, resettlement and environmental mitigation, engineering and administration, etc.

viii. Economic Evaluation

The equivalent economic cost of the project for the November 2003 in service date is US $ 6,808 million. The corresponding gross economic benefit is US $ 16,780 million. The net economic benefit is US $ 9,972 million, the benefit /cost ratio is 2.46 and the corresponding internal rate of return is 27%. The net economic benefit will be equivalent to about US$ 1,000 million per year to be shared between the two countries. These economic measures demonstrate that the project is feasible and economically very attractive.

2.2 KEY FEATURES OF THE PROJECT

Table 2.1: Key Features of Karnali (Chisapani) Project

Location:	At Chisapani on the Karnali River in Western Nepal
Purpose:	Hydropower for export to India plus flow regulation to allow increased irrigation and flood control
Hydrology:	
Drainage area of basin	43,679 km^2 (30% of Nepal)
Long-term average flow	1,389 m^3/s
Average annual precipitation	1247 mm
Average annual runoff	1003 mm
Highest recorded flood	21,700 m^3/s (September 11, 1983)
PMF (Design Flood)	63,000 m^3/s
1 – in – 10,000 yr Flood	32,900 m^3/s
1 – in – 1,000 yr. Flood	26,600 m^3/s
1 – in – 100 yr Flood	20, 600 m^3/s
Sedimentation:	
Sediment average load	260 x 10^6 t/yr
Reservoir Characteristics:	
Full supply level (FSL)	415 m
Minimum operating level (MOL)	355 m
Drawdown	60 m
Surface area at FSL	339 km^2
Length of main arm	100 km
Reservoir volume at FSL	28.2 x 10^9 m^3
Reservoir volume at MOL	12.0 x 10^9 m^3
Live storage	16.2 x 10^9 m^3 (37% of average annual runoff)

Dam Characteristics:	
Type	Gravel-fill embankment with central core
Crest elevation	445 m
Crest length	745 m
Maximum height of dam	270 m
Volume of dam	45 x 10^6 m^3
Spillway:	
Type	Ungated chute with flip bucket and plunge pool
PMF design discharge	19,218 m^3/s
Maximum velocity at flip bucket	57.0 m/s
River Diversion: Facilities:	2 Nos. @ 15 m dia; 2400 m long each; located in the right bank. Its adequate for 1:1000 years flood
Maximum design discharge	9270 m^{3s}
Maximum flow velocity	27 m/s
Power Facilities:	
Location	Left bank
Waterways	6x15 m dia power tunnels and drop shafts; 18 x 7.2 m dia steel lined penstocks to underground power house
Units	18 x 600 MW units (500 MW at MOL)
Rated head	165 m
Normal tail-water level	203 m
Reregulating Facilities:	
Location	8 km downstream from main dam
Reservoir	100 million m3 live storage
Dam	6 km long embankment (max. height =24 m)
Power Plant	6 x 14 MW bulb turbines at 13.5 m head

Transmission Facilities:	5 x 765 kV (From Main power plant to India, 300 km) 1 x 220 kV (From Regulating power plant to India, 160 km)
Capability:	
Capacity	10,800 MW (18x600 MW); 9000 MW (18x 500 MW at MOL)
Firm Energy	15,007 GWh/yr (2077 MWh continuous Dec. to March
Average energy	20,842 GWh/yr
Average energy (from Reregulating)	621 GWh/yr from 84 MW capacity reregulating power plant
Irrigation:	
Potential in Nepal	191,000 ha (Net)
India Sarda-Sahayak	2,000,000 ha (gross)
India Saryu	1,200,000 ha (gross)
Capital Cost (1988 US$):	
Total project cost	US $4,890 million (Excluding Financing)
Capital cost per kilowatt (excluding financing Costs)	US $453 million
Unit cost of generation at Chisapani	3.3 ¢/kWh (Peak power)
Schedule:	
First unit on power	November 2003
Project Completion (eighteenth unit)	November 2007
Economic Evaluation: (at 10% discount rate)	

Net benefits	US$ 9.966 million
B/C ration	2.46
Economic internal rate of return	27%

2.3 OUTLINE OF THE PAST STUDIES

This project received very early attention of the Government of Nepal because of its very promising potential. The earlier studies were carried out by Nippon Koei in 1966, Snowy Mountains Hydroelectric Authority (SMHA) in 1968, Norconsult/Electrowatt in 1977 and Himalayan Power Consultants, a joint venture of four North American Consulting Firms in 1990.

2.3.1 Nippon Koei Study 1966

Nippon Koei of Japan conducted feasibility study in 1966. The study proposed a concrete gravity – arch dam with height of about 200 m at an upstream site (same site as HPC recommended in 1990 study).The reservoir full supply level (FSL) is kept at el 370 m. Its capacity was 1800 MW. A surface power house at the base of the dam, and provision for future underground power plants on both banks of the river was proposed. Its capacity was selected in view of the limited size of the then projected power market in Northern India.

2.3.2 SMHA Review study in 1968

Snowy Mountains Hydropower Authority (SMHA) of Australia reviewed the study conducted by Nippon Koei in 1968. The review study questioned the feasibility of the project configuration and its arrangement and carried out alternative study of this arrangement with an embankment dam of similar height at downstream site. The review study also recommended the alternative development of a peaking project with higher capacity.

2.3.3 Norconsult (Norway) and Electrowatt in 1977

The 1977 Study conducted by Norconsult (Norway) and Electrowatt (Switzerland) carried out a further study, including investigations at the downstream site. This study recommended an embankment dam at the downstream site. The selected FSL was retained at el 370 m, installed capacity was doubled to 3600 MW.

2.3.4 The Need of Final Feasibility Study

None of these studies considered multipurpose aspects of development. Although limited consideration was given to the potential for irrigation development in the Terai region in Nepal, but quantitative evaluation was not carried out. Although it was recognized that there would be significant variations in flow from the power plant, no studies were carried out to reregulate flows released downstream of Chisapani. All the above studies recognized that the power plant capacity was largely controlled by the size of the Indian power market.

The size of the hydropower development was, in all cases constrained by consideration of the relatively limited power market in Northern India. It was recognized that this market would continue to grow and, accordingly, recommendations were made to make provision for increased generating capacity. However, none of the studies considered a development at Chisapani utilizing the full resource potential of this site.

With the continuing interest of the governments of Nepal and India both in the Chisapani project; steps were taken during the late 1970s and early 1980s to proceed with development of the project. A bi-national policy level committee named “Committee on Karnali” was formed in 1978. Subsequently, a technical level committee consisting of technical experts from Nepal and India named “Karnali Coordinating Committee (KCC)” was formed in 1983. In consideration to the following requirements, a Final feasibility study was deemed necessary and hence the Government of Nepal decided to carry out the study to ensure that the overall programme was sufficiently comprehensive to meet all requirements of a study for a major multipurpose development, consistent with the norms of international lending institutions.

- Selection of suitable dam site in consideration to the relative merits of the two alternative dam sites.
- Optimum development as a multipurpose project in consideration of all possible water related benefits.

- In recognition of the role of the project in an integrated basin development context, it was desirable to ensure that the selected development was reasonably compatible with the most likely overall development of the water resources potential of the entire Karnali basin.
- To address the need of comprehensive study of the project compatible with international norms for feasibility studies; more work was required on field investigations, engineering designs, cost estimates, benefit evaluations, socioeconomic resettlement and environmental studies.
- To address the technological changes in construction of major dams and hydro projects over the past 20 years.

2.3.5 Final feasibility study by HPC in 1989

A detailed feasibility study was conducted during1986-1989, under the loan assistance from the International Development Agency (IDA) part of the World Bank, and the local costs provide by GoN. The study was executed by Himalayan Power Consultants (HPC), a joint venture of three Canadian consulting companies (Acres, SNC and Shawinigan/Lavalin) and Ebasco of the United States. General advice and direction for the study was provided by a bi-national Karnali Coordinating Committee (KCC), consisting of technical officials from both Nepal and India. Overseas Bechtel Inc. (OBI) provided advisory services to the Government of Nepal on all aspects of the study.

The study was carried out over a three-year period, starting in June 1986; the final draft report was submitted in June 1989. A further six months was then required to carry out a comprehensive review of the draft report and for report finalization. This included independent and comprehensive reviews by technical specialists of the government of Nepal and India, by OBI, by World Bank and by an independent panel of experts appointed by the World Bank. The Final Report was submitted in January 1990. The study is found to be comprehensive and detailed incorporating extensive field investigations, designs, cost estimates, and benefit evaluations, economic analysis, socioeconomic and environmental assessments.

The main features of the project in the final feasibility study include 270 m high, gravel fill embankment dam, a reservoir with live storage of 16.2 km2 (equal to 37% of average annual runoff), an underground powerhouse with eighteen 600 MW generating units totalling to 10,800 MW installed capacity producing 20,842 million kWh/yr, an ungated chute spillway capable of discharging a maximum flood flow of 19,200 m3/s, and downstream regulating facilities.

2.4 SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS OF THE PAST STUDIES

The conclusions derived from the feasibility studies and the recommendations made therein are summarized in the following paragraphs.

2.4.1 Conclusion

The final feasibility study of 1990 concludes that the project configuration defined in this study is technically feasible and economically viable and very attractive. However, the study is unable to confirm environmental feasibility of the project; mainly, because of deficiencies in baseline data and field inventories. Three aspects of feasibility namely technical, economic and socio-environmental are summarized below.

a. Technical Feasibility:

A multipurpose water resources project on the Karnali River at Chisapani (upstream dam site) is technically feasible. The project include a 270-m high gravel-fill dam, an underground powerhouse on the left bank with 18 x 600 MW generating units, a chute spillway on the right bank capable of discharging 19,200 m^3 /s, a downstream reregulating facility (which includes an 84-MW power plant and two irrigation outlets), Five 765 kV transmission lines from the Chisapani project power plant, and a 220 kV transmission line from the Reregulating facility power plant into Northern India. However, more needs to be known on the geological and hydraulic conditions in the fan area affecting design and cost of the reregulating facility. The study also concludes that the upstream dam site (approximately in the middle of the gorge) is superior due to the more favourable topography and better geological conditions, and overall economy.

b. Economic Viability:

The Chisapani project is economically viable and very attractive - without qualification. The Consultant was aware of no comparable project offering such low generation costs. Based on normally accepted economic evaluation methodology, the gross benefits of the project were estimated at US $16,780 million, compared with the associated economic cost estimated at US $6,808 million. The resulting net economic benefit and B/C ratio was estimated at US $9,972 and 2.46 respectively. For the entire range of sensitivity analyses, and even when examining a worst case scenario, the net economic benefits and the B/C ratio both remain high, thereby confirming the economic viability of the project. Furthermore, early implementation is desirable, as estimated economic opportunities foregone are US $700 million (about US $2 million/d) for each year of delay in implementation.

c. Socio-environmental Feasibility:

The study is not able to confirm environmental feasibility of the project through the study programme because of deficiencies in baseline data and field inventories. Additional field studies are required to define an adequate programme of mitigation, compensation, enhancement and management measures.

Furthermore, The Consultant concludes that the time of completion of the study (early 1990) was a good time to proceed with the project from the view point of the above technical and economic aspects covered in the study. The magnitude of the project net benefits are such that a reasonable proportion assigned to the Kingdom of Nepal would provide a major boost to the national economy.

2.4.2 Recommendations

In view of the very favourable economic merits of the project, the Consultant recommended that Government of Nepal takes immediate steps to ensure implementation of the project at the earliest practical date. The Consultant recommended the followings most urgent task to be accomplished:

- Substantive discussion at appropriate government levels between the two countries, to at least initiate the process towards a Treaty of Implementation.
- Continuing, and in some cases expanding the program of data gathering e.g. sedimentation, environmental and related studies including resettlement, to ensure that final design and definition of the project is made with full knowledge on conditions.
- Full 'technical' involvement of the relevant Indian authorities to ensure that the definition of the project and its designed operating characteristics are fully appropriate for the 'market' conditions.

CHAPTER 3: REVIEW OF FEASIBILITY STUDY PREPARED BY HIMALAYAN POWER CONSULTANTS, DEC. 1989

3.1 BASIS OF REVIEW

The following review of Feasibility Study Report of Karnali (Chisapani) Hydropower Project is based on the study of the following project documents prepared by Himalayan Power Consultants as part of the Feasibility Study.

- Karnali (Chisapani) Multipurpose Project; Feasibility Study, Main Report, December 1989
- Karnali (Chisapani) Multipurpose Project; Feasibility Study, Executive Summary, January 1990
- Annex A: Geology and Site Investigation
- Annex B: Construction Materials
- Annex C: Seismology
  Annex D: Hydrology
- Annex E: Sedimentation
- Annex F : Reservoir Simulation
- Annex G: Power System Studies
- Annex H: Project Optimization
- Annex I : Main Dam
- Annex J: Power Facilities
- Annex K1: Spillway
- Annex K2: Diversion and Outlet Facilities
- Annex L: Reregulating Facilities
- Annex M1: Irrigation Development within Nepal
- Annex M2: Irrigation in India
- Annex N: Environmental Impact and Mitigation
- Annex O: Socioeconomic and Resettlement

- Annex P: Construction Planning
- Annex Q: Capital Cost Estimate
- Annex R: Project Evaluation

3.2 SITE INVESTIGATIONS

A comprehensive programme of field investigations, including topographic mapping, geologic investigation, seismicity and tectonic measurements and sedimentation and hydrologic data collection, and socioeconomic and environmental field data collection programme, and other related activities were executed by HPC as part of the site investigation, and a summary of the activities have been presented in the following paragraphs. Any gaps in the study that need to be carried out to update the study have been presented (in italics) at the end of each section. The assessment made on the feasibility study report 1989 is based on interpretation of extensive data sets from site investigations during the study period by HPC and those investigations carried out as part of previous studies carried out in 1966 and 1977.

3.2.1 Topographic Mapping

Aerial photography, ground control surveying and topographic mapping were carried out in 1986 and 1987 by Kenting Earth Sciences Ltd. under subcontract to Himalayan Power Consultants (HPC) and the following topographic maps have been produced.

- 12.5 km^2 at the damsite at a scale of 1:10,000 with 1m contours
- 460 km^2 of the reservoir area at a scale of 1:10,000 with 5m contours
- 3901 km^2 of the western Terai at a scale of 1:10,000 with 1m contours

All surveys for both vertical and horizontal ground control were tied into the Nepal national grid which is based on the Everest UTM geodetic system.

This information is generally sufficient given the nature of the project site. However, it is essential to update the topographic maps to take into account the recent infrastructure development in the area, using the latest technologies such as LIDAR mapping technologies.

3.2.2 Geological and Geotechnical Investigations

Geological and geotechnical investigations were carried out in two stages—Stag eA, and Stage B. The Stage-A investigations were performed for the selection of a damsite location within the Karnali gorge and for the selection of the optimum type of dam. The Stage B investigation were concentrated at the selected upstream of the damsite, the area of the reregulation facility and the borrow areas to provide data for feasibility design. The investigations carried out for the underground works comprised five elements: geological mapping, geophysical survey, core drilling, aditing and rock testing. The investigation includes about 3200 m of core drilling and almost 700 m of exploratory adits. Points of particular interest are angle core drilling under the river and deep holes and adits into the area of the underground powerhouse complex.

The investigation at Stage A consisted geological mapping at a scale of 1:1000 over an area of 310 ha at the gorge and at a scale of 1:50,000 over an area of 5400 ha at Churia hills, core drilling totalling to 989 m (11 holes) upstream and downstream dam sites, geophysical surveys totalling 625 m, aditing totalling to 125 m (two adits from the 1986 investigation}, in situ rock testing (293 tests), test pitting and trenching (35 test pits and 21 trenches). A total of 154 soil classification tests were performed.

The Stage B investigation consisted of the geological mapping in the reservoir area at a scale of 1:20,000 over an area of 27,500 ha, core drilling at upstream dam site totalling to 2229 m at 20 holes, drilling at reregulating facility totalling to 82 m at 5 holes, seismic refraction totalling to 14,300 m, resistivity soundings – 60, side scan sonar – 69000 m, bathymetry – 16,900 m, in situ rock testing totalling to 1058 tests (point load tests – 848, water pressure tests – 185, dilatometer tests – 17, over-coring tests – 3 and plate-bearing tests – 5Nos, test pitting and trenching (98 test pits and 34 trenches), and soil testing totalling to 479 tests (classification tests – 411, compaction tests – 32, consolidation tests -4 and Strength tests – 32).

The above tests are generally comprehensive except investigation on geological and hydraulic conditions in the fan area of the project. Additional investigation on geological and hydraulic conditions in the fan area affecting design and cost of the reregulating facility needs to be done.

Besides, further geological/geotechnical investigations might be necessary for the detailed engineering design of the project. Such additional investigations may also include in situ tests. The consultant (to be hired for the updating of the feasibility study) will determine the scope of additional geological/geotechnical investigations, and carry out investigations subject to the approval of the Employer (i.e. SEC).

3.2.3 Hydrology and Sedimentation

iii. Hydrology

The Station 280 located immediately downstream from the damsite was used for flow measurement, between July and September 1987. A shore-based system from the existing wire rope cableway was used for this purpose. Flow velocities were measured on 20 verticals spaced 6 m apart within the gauge sections, and was made at 20% and 80% of the water depth at each vertical. Twenty flow measurements were taken at flows between 1600 and 5000 m^3/s. The flows beyond the limit of measurement was determined utilizing the slope area method establishing seven staff gauges and conducting river cross sections survey over a 2.5 km reach of the river extending approximately 1.0 km upstream and 1.5 km downstream from the cableway. By simultaneous reading of all the staff gauges, five river surface profiles were established for flows ranging for 575 to 5000 m^3/s over this reach. Profiles at higher flows were not obtained because the flows during the 1987 monsoon were well below average.

iv. **Sedimentation**

Channel hydraulic characteristic and bed material sizes were determined in April and September 1987 along an 8 km stretch of the Karnali River upstream of the damsite and along the river Bheri (a tributary of Karnali River with confluence just upstream of the damsite). Three cross sections were surveyed on the Karnali River upstream of the damsite and four on the river Bheri. Water surface profiles were measured along both reaches. A total of 12 bed material samples were taken and their gradation determined. During the 1987 monsoon, suspended sediment samples were taken at the damsite utilizing a 135kg, P50 point integrating sediment sampler. A total of 403 suspended sediment sample were taken and were analysed in the field laboratory for sediment concentration. This represents an average sampling frequency of better than once every 6 hours. Four of the suspended sediment samples were analyzed and graded.

In the past 20 years since the time HPC study was carried out, there are additional hydrological data available. Also, there has been significant change in the land use pattern in the river catchment, impacting the sediments concentration in the river. It is essential to review the hydrological data, and to take sample measurements of suspended sediments in the river and that of the river bed.

3.2.4 Environmental and Socioeconomic Surveys

iii. Environmental Survey

The baseline information on a variety of resources in the reservoir and downstream areas within Nepal was collected by a survey team travelling on foot and by boat through these areas. Besides, several helicopter and fixed-wing reconnaissance flights were made over the reservoir area and along the lower Karnali, to gain an overall impression of the geomorphology, and the extent and condition of the forest and agricultural resources. The detailed socioeconomic household surveys were used to collect information on resource use by the local population. However, quantitative information on the dynamics of the various terrestrial and aquatic systems was not obtained through field surveys.

Environmental survey need to be updated to reflect the current information on the condition of the forest and agricultural resources and to collect information on resource use by the local population. For this, full-fledged Environmental Impact Assessment (EIA), Cumulative Impact Assessment (CIA), Social Impact Assessment (SIA), Rehabilitation Action Plan (RAP) require to be conducted based on the current requirement of the Nepal environmental laws, and that of the multilateral funding agencies including World Bank(WB), Asian development Bank (ADB, etc. and the bilateral agencies.

iv. Socioeconomic Surveys

Extensive surveys were carried out to obtain a data base for socioeconomic studies and resettlement planning of the population living in three impact areas: (i) the Chisapani reservoir area, (ii) the area immediately surrounding the reservoir generally within the watershed, and (iii) the downstream alluvial fan area. A total of 7448 interviews were conducted using two types of questionnaire--first, a census questionnaire and the next a questionnaire soliciting detailed information on socioeconomic conditions. The first questionnaire, basically a census form, was administered to all households in the reservoir area. The second questionnaire was administered to almost 10% of these households to solicit detailed information on socioeconomic conditions.

The social economic surveys (census and sampling) need to be redone as the population in project area has increased significantly in the past 20 years. Further, the socio-economic conditions of the people have undergone significant transformation in that period, as people are moving away from the subsistence farming to other trade, foreign employment and so on.

In summary, the updated feasibility study requires reviewing the site investigation performed in the previous studies, identify data gaps and conduct supplementary field investigation. Special attention should be given on the following investigations point out by the 1989 HPC study.

- Investigation on geological and hydraulic conditions in the fan area affecting design and cost of the reregulating facility,
- Any other geological geotechnical investigations deemed necessary by the Consultant to update the feasibility study; probably, test adits at powerhouse cavern for conducting rock mechanical tests
- Supplementary data collection on hydrology and sedimentation during the study period to refine them,
- Collection of additional data on environmental conditions to allow an authoritative assessment of impacts and mitigation.

  Census survey needs to be done to collect local socio-economic conditions, land parcels to be acquired, which will reflect, into resettlement costs.

3.3 GEOLOGY AND SEISMOLOGY

3.3.1 Geology

The geology of the main structures of the project is presented in the following paragraphs.

i. **The Dam site**: The Karnali River flowing through the southern part of the Sub-Himalayas has cut through the Churia Hills to form a prominent gorge referred as “the Karnali Gorge”. It is about 4 km long. The dam site is located mid-way along the gorge. The dam is confined by two tributary valleys within the gorge; namely Bangar Khola which enters the gorge from east side at the upstream of the dam, and Kelari Khola which enters from the west at the downstream of the dam. Geological Conditions at the damsite over a large area are quite uniform but wide variations found at places. An almost complete sequence of Siwalik series rocks is exposed along the gorge as the beds dip generally in an upstream direction. The bedrock at the dam site is an inter-bedded sequence of sandstone and mudstone with subsidiary siltstones and sedimentary breccia. The rock types are a mix of about 60% sandstones, 20% to 30% mudstones and minor occurrences of breccia, marl and shale. The rocks dip at a relatively uniform slope of about 45^0 upstream and slightly oblique across the gorge. The sandstones are of medium strength and inter-layered with the generally weak mudstones. The thickness of overburden ranges up to 14 m, averaging 5 m, and there is up to 12 m alluvium in the river bed area. There is no evidence of any significant faulting at the damsite.

   The study concludes that the geological conditions at the damsite are acceptable for the proposed 270mhigh dam; the only significant weakness is the rock strength and structure (joint sets) with respect to the large underground excavations, this weakness can be readily overcome by careful detailed design and provision of rock support systems.

ii. **Reservoir Area**: The reservoir of Karnali (Chisapani) extends up to 100km upstream along the Karnali river valley. Its area at full supply level is 339 square kilometres. The reservoir lies almost entirely on rocks of Siwalik series, and colluvial, alluvial and residual soils. The upper part of the reservoir lies on limestone of the Lakharpata formation to the north of the

MBT. There is no evidence of potential for significant reservoir leakage. Slope instability is present in the reservoir area due to failure on bedding planes in the lower and middle Siwalik formations and non-structural failures in the upper Siwalik rocks. This may result in some landslide activity. However, there is not any significant risk of landslide - induced waves threatening the dam stability.

iii. **The Reregulating Facility**: The reregulating facility is located on the Karnali river alluvial fan some 6 km downstream from the mouth of the Gorge. All structures are sited on deep river gravels which have been derived primarily from the resistant rocks of the lesser Himalayas, but with a contribution from the more local sources of the lower Siwalik formation. The study concludes that the fan is composed of sandy gravels with cobbles and possibly boulders. However, the conditions of this area are less understood; mainly, because of the difficulties of investigating at depth below the water table due to the presence of boulder material encountered very often. Owing to this, the depth to bed rock and hence the possibility of sealing the dam foundations down to rock is uncertain. Furthermore, the permeability of the alluvium and the characteristics of the alluvium below the top 3 to 4 m are also uncertain.

HPC has made conservative assumptions in the design of all three structures mentioned above and has recommended carrying out detailed geological investigation at the location of the above structures during detailed design stage of the project. It is recommended that as part of the updating of the feasibility study, the consultant will review the geology at the reservoir, dam site and reregulating facility and update as necessary, and identify the additional geological and geotechnical investigations to be carried out.

3.3.2 Seismology

The continuing convergence of the Indian and Eurasian continental plates has created a series of thrust or fault zones of continental dimensions. The main boundary thrust (MBT) passes at about 25 km north of the damsite and the Himalayan Frontal Fault (HFF) which crosses the area approximately midway between the main damsite and reregulating damsite. These tectonic structures control seismic design conditions. As MCT lies at a considerable distance (125 km) from the site, it will have limited significance for design purpose. The MBT is considered capable of generating a magnitude (Richter scale) 8 earthquake and the HFF a magnitude of 6.5. The significant duration of the acceleration at the site associated with the magnitude of 8 MCE will be over 60 seconds, whereas that due to the relatively small magnitude of 6.5 due to HFF will be quite short, about 15 seconds. The preliminary design acceleration selected for the main dam studies reflect the above characteristics with a peak acceleration of 0.60g and duration of over 60 seconds. The probabilistic studies derived an acceleration value of 0.5g for the design of concrete structures, such as spillways and the powerhouses.

3.4 CONSTRUCTION MATERIALS

A total of about 60 million m^3 of construction materials, consisting of 9 million m^3 of impervious materials, 39 million m^3 of shell fill, 6 million m^3 of filters, 4 million m^3 of aggregates, and 1.5 million m^3 of riprap are required for Chisapani project. A limited quantity of usable rock fill is expected to be available from foundation excavation. The construction materials should be obtained from terrace deposits extending downstream along the banks of the alluvial fan. Ample good quality gravel fill is available in the alluvial fan immediately downstream from the Chisapani gorge. This fill is considered much superior to any rock fill which can be quarried locally because of high strength and low compressibility in comparison with the much weaker rock material. After removal by screening of oversized cobbles, core material will consist of approximately equal proportions of gravel, sand and low plastic clayey silt. The shell materials obtained as pit-run excavation from the alluvial fan borrow areas is predominantly sandy gravel with cobbles, and are mainly composed of quartzitic material derived from the metamorphic formations high in the catchment. These materials are sub-rounded and of high strength. The fan alluvium can be readily processed to yield filter and transition materials of the required gradation. Besides, there are a number of potential sources for riprap including the boulders from alluvial fans and valley floors of the transverse *kholas* (streams) downstream from the damsite and the sandstone blocks from excavations at the dam site.

The information on construction materials including the core fill materials needs to be updated.

3.5 HYDROLOGY

The catchment area of the Karnali River at the damsite is 43,679 km^2. It is second largest of the three major river system of Nepal. There are wide spatial and seasonal variations in temperature and precipitation throughout the basin. The existing 36 meteorological stations located within the Karnali basin, together with 21 stations selected from the adjacent basins form the basis of data network that was used for hydrometeorology studies. There are five principal gauging stations located within the Karnali basin, which are operated by Department of Hydrology and Meteorology (DHM). Almost all stations were set up during the early 1960s.

A flow gauge was set up near the mouth of the gorge at the Chisapani damsite in 1961 and the flow records are available since then. As this gauge is located essentially at the damsite, the flows derived at this gauge are directly applicable. HPC used 25 years of flow data from 1962 to1986; and has opined that the 25 year flow sequence is quite adequate for feasibility study purposes. The gauge record was carefully analysed and minor adjustments were made. A long-term flow sequence and flood hydrology are found to be developed to a detailed feasibility standard. The flow sequence defines the water resource available at Chisapani and has been used in reservoir simulation as a key input. The flood hydrology has established the magnitude and frequency of flood events and has been used for the design of spillway and other hydraulic structures including the diversion system during construction.

The average long-term flow is estimated at 1389 m^3/s. There is a marked seasonal variation in flows with some distinct seasonal variations. Average monthly flows range from 309 m^3/s in February up to 4359m^3/s in August. The flood hydrology was studied by frequency analysis and a Probable Maximum Flood (PMF) was also derived. The peak flood recorded was about 21,000 m^3/s in 1983. Although more data would be useful, the database is adequate for flood design; the PMF used for design of the spillway has a peak inflow of 63,000 m^3/s. Major hydrological features of the project are summarized in the following table (Table 3.1).

Table 3:1: Hydrological Features of the Chisapani Project

Hydrologic Characteristics:	
Drainage area of basin	43,679 km^2 (30% of Nepal)
No. of Meteorological stations in Karnali basin	36
No. of gauging stations in Karnali basin	5
Long-term average annual flow	1389 m^3/s
Average dry season flow (November-May)	451 m^2/s
Average wet season flow (June-October)	2690 m^3/s
Average annual basin precipitation	1247 mm
Average annual runoff	1003 mm
Mean annual snowfall for Karnali basin	4400 million m^3 of water equivalent
Runoff ratio	0.80
Runoff volume	43.8 km3/yr
Highest recorded flood	21,700 m^3/s (September 11, 1983)
Design Floods:	
Probable maximum flood (PMF)	63,000 m^3/s
Probable maximum Precipitation (PMP)	499 mm (3-day PMP)
Flood (1 – in – 10,000 yr)	32,900 m^3/s
Flood (1 – in – 1,000 yr.)	26,600 m^3/s
Flood (1 – in – 100 yr.)	20, 600 m^3/s
Sediment average load	260 x 10^6 t/yr
Equivalent specific yield	6000 t/km^2
Climate:	
Average annual rainfall	2200 mm over 80% falling during the monsoon
Temperature	Varies; 15^{o}c in January to 30^{o}c in May

The updated feasibility study requires reviewing of the hydrology and updating the data incorporating the additional flow information available in the intervening periods.

3.6 SEDIMENTATION

The large reservoir created at Chisapani will tap all the incoming sediments within the reservoir and lead to channel degradation to the river system downstream. Suspended sediment data on the Karnali River at Chisapani were first collected during 1963 and 1964 by Nippon Koei as part of 1966 study. The mean annual sediments load estimated by Nippon Koei (1966), Snowy Mountains hydroelectric Authority (SMHA, 1968), and Norconsult-Electrowatt (1976) ranged from 93.5 million to 150 million m3 were based on the Nippon Koei data (1963 and 1964). The Department of Hydrology and Meteorology (DHM) resumed sediment sampling at Chisapani in 1973. Although there are some sampling data available from 1963/64 and 1973 to 1986, most of the DHM data were not considered reliable considering the sampling equipment and techniques used.

An intensive field programme and a comprehensive sampling and measurement programs were undertaken during the 1987 monsoon season by HPC. A total of 403 samples of suspended sediment on 318 occasions, were collected on average every 6 hours from July through September 1987. The suspended sediment measured load over the 3 months was estimated at 84 million tonnes. The maximum measured concentration of 45,400 mg/l occurred in July 26 during the peak flood event of the season. Allowing for unmeasured bed load @ 15% and the unmeasured dry season load (9 months) @ 10%, the total load for the year was estimated at 107 million tonnes. Grain size analysis of the suspended sediments showed that the sediments consist of nearly equal proportion of silt and sand.

The year 1987 was a low flow and low flood year for Karnali River, thereby requiring some adjustment. HPC study estimated 260 million tonnes as the annual average, applying sediment rating curve derived from the 1987 data and consideration of sediment loads measured for other basins in the subcontinent. The estimated sediment load is subject to change as more data become available.

With the sediment load estimated, reservoir sedimentation is not a significant problem for the selected reservoir level (FSL at 415 m) Chisapani project. The live storage volume would be reduced by only by 17% even after 50 years. The sediments would not encroach on the power intake until approaching 100 years. The potential for river channel degradation downstream of Chisapani was studied. However, the database is inadequate to draw firm conclusion. HPC study suggests conducting investigations, especially at the downstream of Girjapur barrage to quantify the potential and identify mitigation measures.

The updated feasibility study requires reviewing the hydrology, and updates them incorporating additional information from the field investigations/measurements to assess the current status of the sediment load in the river induced by the changed land use pattern in the river catchment. Further, as suggested by the HPC study, the updated feasibility study will also require to carry out an assessment on the potential for river channel degradation downstream of Chisapani especially at the downstream of Girjapur barrage, quantify the likely impacts and identify mitigation measures.

3.7 Selection of Project Configuration/Dam Type

3.7.1 Background

The studies conducted by different Consultant conclude differently on the appropriate damsite and type of dam as mentioned in the following paragraphs:

- Nippon Koei Study in 1966 recommended concrete gravity dam at the upstream damsite in preference to an embankment on grounds of lower cost. The downstream site was not considered in any detail.
- SMHA review study (1968) showed considerable reservation as to feasibility and substantial cost increase to accommodate high flood flows at the concrete gravity dam at the upstream. Further pinioned that embankment dam at the upstream is not feasible or extremely doubtful, due mainly to concern as to the cost and difficulty of underground construction for the power facilities and tunnel spillway. However, the study was not conclusive of the feasibility of embankment dam at the down steam site and recommended further investigation and study to confirm feasibility.
- Norconsult-Electrowatt Study in 1977 recommended embankment dam at the downstream site.

Owing to this, the Terms of Reference to the Consultant HPC stressed the need for a thorough comparative study supported by data from additional investigations at both sites with the goal of selecting the most optimal location, and dam type before the optimization and final feasibility design study stages (A & B).Thus, the objective of the study was to select the best dam site and type of dam by means of a comprehensive analysis incorporating additional investigations and comparative design and cost studies. The resulting recommended project configuration has been used as the basis for the second stage optimization studies to establish reservoir-operating levels and the installed capacity.

The consultants to be hired for updating of the project will review the project configuration and the project components to confirm the findings of the HPC study and make recommendations on possible improvement, if any.

3.7.2 The Gorge and the Dam Type

The Karnali gorge is 4 km long. The George has been recognized as a potential location for construction of a large hydroelectric development featuring a high dam and consequent large storage reservoir. Two dam sites identified at this gorge are:

i. Upstream Damsite

The site is situated 2 km upstream of the mouth of the gorge at its narrowest and deepest section. The topography provides the specific site advantage, in that it allows the minimum volume and hence potentially minimum cost for a high dam of any appropriate type. Both the embankment type and concrete gravity type dam are considered at the upstream site.

ii. Downstream Damsite

The downstream site with relatively wide gorge offers two other minor advantages relative to the upstream site. Firstly, it is close to the existing access facilities and sources of construction materials. Secondly, the river level is about 1 to 2 m lower, giving a small increase in developed head at the same reservoir level. Only embankment type dam is considered at this site because of relatively wide gorge.

3.7.3 Damsite Selection

The feasibility study carried out by HPC in 1990 considered comparing dam type alternatives at both the dam sites in terms of five different aspects--cost comparison, technical acceptability, impact of possible optimization changes to reservoir levels and installed capacity, comparison with previous studies--and concluded that the embankment dam at the upstream site is clearly the best choice, mainly on cost grounds. Besides, it is also technically superior compared to the other site for the given geological conditions. An embankment dam at the upstream site was confidently selected in consideration to this analysis.

The consultants to be hired for updating of the feasibility study would review the location of the dam and the dam type and make recommendations on the location and the dam types.

3.8 Project Optimization

3.8.1 Objective

The objective of the Stage A optimization studies was to determine the optimum size of the project taking into account all the multipurpose benefits and the long-term potential for development in the Karnali River basin. The major project size-related variables that have been optimized are the reservoir operating levels and the power plant installed capacity.

3.8.2 Approach

The optimization was carried out comparing costs and benefits for the project, primarily as an economic analysis expressed in net benefits (B-C) and benefit/cost (B/C) ratios. The project was optimized considering only power benefits in consideration to uncertainty in the value of additional irrigation benefits due to increased reservoir storage. However, the study has confirmed that almost the entire reservoir size considered is capable of providing the maximum identifiable downstream irrigation flow demands. The range of alternatives considered in the optimization study are: (i) the FSL varying from el 370 masl to 430 masl, (ii) drawdown varying from 40 m to 70m, and (iii) the installed capacity corresponding to 20% to 30% capacity factor (CF).

The HPC study has considered the range of project capacity factors from 20% to 30% as suggested by the Indian delegation to the Karnali Coordinating Committee (KCC) as a suitable plant capacity factor for a hydro peaking plant operating to serve the Northern Region of India. Accordingly, alternative rated generating capacities to 7200 MW, 9000 MW and 10,800 MW were evaluated for the Chisapani project with FSL, 415 m and MOL 355 m. These capacities correspond to firm CF of approximately 30%, 24% and 20%. The evaluation of these three alternative generating capacities were studied and found that the most economic capacity is 10 800 MW at 20% CF. Incremental B/C ratio for additional generating capacity is about 1.8. Lower CF for the Chisapani project will also become feasible with continuing growth of the Northern India power system, and Chisapani could then be a source of additional low-cost peaking capacity. Thus, the project size is not only dictated by cost/benefit and economic considerations but by the ability of the Indian power system to absorb the amount of power available.

Additional generating capacity can be installed in the future if upper Karnali hydro storage projects are developed and flow regulation at Chisapani is improved. A second underground powerhouse can be developed on the right bank to install additional generating capacity, if this becomes necessary. This right bank power plant could be sized for up to 9 x 600-MW units. Initial provision for a right bank powerhouse intake structure, at a cost of about US $80 million, has been included in the project design.

After the initial optimization of Chisapani project as an independent hydro project for power exports, the HPC study has also evaluated the impact of upstream Karnali hydro project development on Chisapani project. Finally, the influence of other project benefits, such as irrigation and flood control on the optimum project size was also considered.

The focus of the HPC study was to optimize the project primarily for power generation, with irrigation, flood control and navigational benefits taken as being secondary. Given that irrigation and flood control benefits will also be significant, it is recommended to optimize the project as a true multi-purpose of project taking all the benefits in to consideration, if desired by Nepal, and the lower riparian countries. The data availability issue had hindered the HPC to undertake a comprehensive study to optimize the project to capture the other benefits (besides power), *particularly irrigation and flood control in India (and Bangladesh). For this purpose, as part of the updated feasibility study, necessary data related to irrigation and flood control need to be collected.*

The updated feasibility study will review the optimization of the project as a multipurpose development, given other planned/committed upstream development in the Karnali River basin. For example: Upper Karnali (900 MW) and other projects now in various stages of study including reservoir projects on its tributaries such as West Seti (750 MW), Nausalgad (300 MW) and ROR projects.

3.8.3 Outcome of Project Optimization Study

The main parameters established in the project optimization studies are summarized in the table given below (Table 3.2):

Table 3.2: Main Parameters Established by the Project Optimization Study

Reservoir FSL	El 415
Reservoir MOL	El 355
Installed Capacity (18x600 MW)	10 800 MW
Firm plant capacity at MOL	9 000 MW
Extreme reservoir level at PMF	El 443.6 m, although levels higher than 420 m are extremely rare
Tail water level	195 m ; 3 units running
	209 m; PMF conditions
Full plant discharge at MOL	5880 m3/s @ 327 m3/s/unit
Full Plant discharge at FSL	7110 m3/s @ 395 m3/s/unit

The principle recommendations of the optimization studies are summarized below.

- The Chisapani project should be designed for a reservoir FSL of el 415 m.
- The Chisapani project should be designed for a reservoir drawdown of 60 m corresponding to a MOL of el 355 m.
- The Chisapani project power plant should be designed for a firm capacity of 9000 MW at MOL. The rated capacity should be 20% higher than firm or 10,000 MW total. For this case, 18 generating units is the appropriate number with 500 MW/unit Capacity at MOL, and 600 MW/unit rated capacity.
- In future studies for the final engineering of the Chisapani project, the optimum size of the major project dimensions should be re-evaluated, based on updated and more detailed estimates of power and irrigation benefits, and consideration financial as well as economic benefits and costs.
- Further studies are required at upstream hydro project sites in the Karnali basin to develop a basin master plan, and to evaluate more carefully interaction between the Chisapani project and prospective upstream projects.

As recommend in the study further optimization studies of the project based on additional flow data, opportunities for increased power demand in Nepal, revised estimate of irrigation benefits in Nepal and India in addition to the consideration of financial/economic costs and benefits, are recommended to be carried out.

The Chisapani project size was not only dictated by cost/benefit and economic considerations but also by: (i) the ability of the Indian power system to absorb the amount of power available, (ii) physical or practical limits stemming from concern as to size precedents and operational constraints, and (iii) financial and institutional concerns.

The updated feasibility study requires carrying out project optimization study in consideration to (i) irrigation, flood control and navigational benefits, (ii) the South Asian power markets, and (iii) financial and institutional concerns from the regional countries' perspective.

3.9 Reservoir Simulation

3.9.1 Introduction

Reservoir simulations were used to define the power and energy capability for the numerous project combinations used in the Stage A optimization studies and also, for the selected project arrangement at Stage B. The majority of the simulations considered the Chisapani project reservoir alone. A series of multi-reservoir simulations also analysed the impact of the potential future development of the upstream the hydro projects and ultimate full development of the Karnali basin.

Operation of Chisapani project would be influenced by the operation of other hydro projects connected in the system and vice versa. In such cases, the capability of the system as a whole will be greater than the sum of the individual project capabilities. Unfortunately, a system simulation of the Northern India hydro system including Chisapani could not be performed in the absence of large amount of consistent data (notably a flow sequence for irrigation). As a consequence, the power and energy capabilities added to the system by Chisapani are probably somewhat understated by the isolated Chisapani simulations. A modest system simulation with Chisapani was carried out for the Nepal hydro system to analyse the potential gain in system capability by using the Chisapani storage regulation to firm-up Nepal's wet season hydro energy without reducing the energy available to India. The reservoir simulations were also used to examine the flow available for irrigation downstream from Chisapani.

3.9.2 Methodology

The Acres Reservoir Simulation Program (ARSP) was used for reservoir simulation. The monthly flow sequence at Chisapani for the 25 year period 1962-1986 with an average flow of 1389 m3/s was used for stage B simulation. An average flow of 1408 m^3/s based on the earlier stage discharge curve was considered during the Stage A simulation. Reservoir evaporation, based on pan evaporation data at the Chisapani meteorological station for 1976–1984, is assessed at an annual average of 1307 mm. Head losses and tail-water levels were developed based on assumed plant operating patterns.

i. Simulation Run for Chisapani Alone

The result of the simulation runs for Chisapani alone at base case of FSL 415 m with 60 m of drawdown are summarized in the table given below.

Table 3.3: Summary of simulation Runs for Chisapani Alone

Target CF (%)	Plant capacity Firm/Installed (MW)	Energy Firm(MWc)/Average (MWc)/Average Annual (GWh/yr)
30	6000/7200	1769/2395/20991
24	7500/9000	1756/2434/21337
20	9000/10,800	1746/2450/21475

These simulation results were used in the optimization studies, which established the optimum project at FSL 415 m, 60 m drawdown, MOL at el 355 m, and the installed capacity with18 units @ 600 MW totalling to 10,800 MW.

ii. *Karnali Basin Simulation*

A reconnaissance study of the Karnali River was performed to identity potential large-scale hydropower projects in the basin. The objective was to ensure that the optimization of Chisapani considers the longer-term development potential and that future developments will not negatively impact Chisapani project. Six projects were identified--KR1B and KR07 on the main stream of the Karnali, BR04, BR05 on the Bheri River, and SR1A and SR06 on the Seti River. The projects denoted by KR07 and BR03 are run-off-river plants, the others are storage projects.

Full basin development was simulated with two alternatives at Chisapani--FSL415 and FSL 370 m. Order-of-magnitude capital costs together with benefits were estimated for the upstream projects. These results were used to assess the optimum sequences of development after Chisapani. With the sequence known, successive multi reservoir simulations were carried out to define the system capability as each project is added. At full development, the system firm energy (with

Chisapani FSL, 415 m) was estimated 5132 MWc with an annual average energy of 6255 MWc. These values are almost three times those of Chisapani alone. About 12% additional firm energy is available at Chisapani due to the development of the storage projects at the upstream of Chisapani.

iii. Nepal System Simulation

The impact of joint operation of Chisapani and the Nepal hydro system was studied using simulation. The Nepal Power System is dominated by run-of-river hydro plants and hence firm energy is controlled by dry season natural flows and there is always an energy surplus during the monsoon season. Chisapani can be operated to produce additional firm energy during the dry season so that the extra energy is sent to the Nepal system with the target demand in India still being met. In the monsoon season, Chisapani generation is then necessarily reduced and the Nepal system surplus is sent to Chisapani and on to India to compensate. Actual power transfers do not necessarily have to flow to and from Chisapani, but there must be a transfer capability between the Nepal and Indian power systems. The system was simulated twice, i.e., with and without Chisapani. The increase in firm energy due to combined operation is 130 MWc, as follows (total for combined system: 2280MWc, less Nepal system alone: 352MWc, Less Chisapani alone: 1798MWc, gain due to combined operation: 130 MWc).

3.9.3 Stage B Results

More precise simulations were undertaken in Stage B, once the project characteristics were defined by the optimization studies. As noted earlier these featured more accurate modelling of head loss, turbine efficiency, tail water level (TWL) and a small change (about 1% reduction) in the flow sequence. Two basic cases were simulated, one with constant firm energy demand, and the other seasonal variation in firm energy. The results of these two simulations are summarized below.

Table 3.4: Results of Stage B Simulation

	Constant Firm	Seasonal variation
Firm Energy (MWc)	1 759	2 077 and 1 532
Average Energy (MWc)	2 393	2 379
Average Energy (Gh/yr)	20 960	20 840

Comparison shows that the 18% increase in firm energy during the critical 4 months requires a 13% reduction in firm energy during the remaining 8 months and a 0.6% reduction in average energy. The lower average energy is simply attributable to the somewhat greater reservoir drawdowns required for the seasonal variation case. This case was judged to be more realistic, and hence was used for power system simulation and benefit determination.

3.9.4 Multipurpose Operation for Irrigation

Without Chisapani regulation, even current planned irrigation demands cannot be reliability satisfied from November to February. This shortfall will become much more severe if any large-scale irrigation development is introduced in Nepal using flow from the Karnali. The maximum irrigation demand scenario is based on full development of 190,000 ha in the Nepal Terai, supplied with water from the reregulating reservoir just downstream from Chisapani, plus significant increases in irrigation intensity in the Saryu and Sarda (Sahara) areas in India. This entails an approximate doubling of the net irrigation flow demand from the Karnali. A water balance check of these irrigation demands and the regulated flow released from Chisapani (Stage B simulation, power only, seasonal variation) revealed that all irrigation flow demands are satisfied and there is a surplus regulation flow available. Thus, it was confirmed that the large degree of flow regulation provided at Chisapani would allow substantial downstream irrigation benefits and that any identifiable irrigation flow demands could probably be satisfied without compromising operation for power generation

The other upstream storage type hydropower development (such as West Seti, Nausalgad) will further firm up the energy generation capacity of Karnali Chisapani. Consequently, it is proposed *that as part of the updated feasibility study, the consultant will carry out the system simulation in light of the upstream development in the Karnali river basin (on-going and proposed) using the most current in formation of the upstream projects, with irrigation, flood control and navigation co-benefits to be optimized along with the power generation. The power system simulation should also be updated considering the increase in the demand, current and planned/under construction generation capacities in Nepal and the electricity demand and current generation capacities in the regional countries*.

3.10 Project Benefit Streams

3.10.1 Power Benefits

a. Power Market in Northern India

The Chisapani project has been designed as a peaking hydro plant for power exports to the Northern Indian power region of India comprising the States of Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Rajasthan, Uttar Pradesh and the union territories of Chandigarh and Delhi. The region suffered from severe power shortages for a number of years and thus potential demand was significantly greater than the actual "demand" supplied (supply constraint). The official load forecast, 13^{th} Electric Power Survey by The Central Electricity Authority dated December 1987, predicted a peak demand of about 53,000 MW in 2003, compared to less than 500 MW demand in Nepal on the earliest practical Chisapani on-power date. It is evident from the relative sizes of the two systems that the viability of the project and the scale of development was, therefore, be dictated by the characteristics of the power system in India. On the possibility of using power from Chisapani in the Nepal, it was concluded that the Nepal system has no significant need for Chisapani power until after 2010, and that supply to Nepal have no significant impact on the total project power benefits.

The growing power demand in the Northern Region of India was then expected to be met largely by additional thermal generation using indigenous coal supplemented by a considerable contribution from new hydro plants -- generally for peaking operation. The official data showed that in 1994/95, the last date for which system expansion is documented, the total installed capacity would be about 32,000 MW, of which 15000 MW (47%) from Coal-fired, 14,000 MW (43%) from Hydro, and the remaining 3,000 MW (10%) from other sources.

The Chisapani project will have comparative advantages as a low cost source of peaking capacity due to its large reservoir storage capacity, high degree of flow regulation, and low incremental generating capacity costs, as well as its relative proximity to major load centres in Northern India. Due to the economic advantages, the recommended size for the Chisapani project in this feasibility study is the maximum practical installed capacity of 10,800 MW, which corresponds to an annual capacity factor (CF) for dry season firm energy generation of about 20%.The power and energy benefit from Main power plant at Chisapani and at the power plant at reregulation dam is presented in the table given below.

Table 3.5: Summary of Power and Energy Generation

Description	Main Power plant	Kauriyala Power Plant at Reregulation Dam
Rated generating capacity	10 800 MW	84 MW
Firm Energy	15 266 GWh/yr	585 GWh/yr
Average energy	20 842 Gh/yr	621h/yr

b. **Potential Generation Sources and Computation of Benefits**

A conventional technique for assessing the viability of large hydro projects was used to assess the power benefits from Chisapani. The power benefits were obtained by developing and comparing "with" and "without" project scenarios for expansion of the Northern India generations system through to 2012, an adequate time after installation of all Chisapani generating units. A power system simulation computer model was used to develop, simulate and "cost" the various expansion plans. A reference generation expansion scenario without the project was developed to determine the cost of serving the power. An alternative expansion scenario with Chisapani was then developed and its cost factored in. The power benefits are then the difference in costs between the reference scenario and with the project scenario. Thus the system cost without Chisapani minus system cost with Chisapani are the benefits. Thus the benefits are thus synonymous with cost savings (or avoided cost) at the total system level.

Only a few cost data was available from official Indian sources. Hence, unofficial sources and reasonable assumptions were used in the feasibility study. A comparative generation cost characteristics (capital cost, fuel costs, and unit cost of generation) used in the study at 1988 price level is summarized in the table given below:

Table 3.6: Generation Costs in India Assumed in the Study

Generation Type	Capital $/kW	Fuel cost	Unit Cost ¢/kWh (At typical capacity factor, CF)
Coal fired (500 MW)	850	$35/tone	4.5 (minimum at 65% CF)
Gas Turbine, Oil (100 MW)	400	$42/barrel	13.5 (at 20% CF)
Indian Hydro	1000	-	4.8 (at 25% CF)
Chisapani (Reference)	450	-	3.3 (at 25% CF)

These costs allow a very simplified perspective on the magnitude of the Chisapani power benefits in terms of the reduction in thermal generation costs.

The power benefits from the main power plant were determined from detailed generation planning studies of the optimum power system expansion plans for the Northern India Power System with and without Chisapani project. The Chisapani project will displace a mix of coal fired thermal generation and gas turbine generation in India. The benefits from the Kauriyala power plant (reregulating dam) are estimated in section 25 at US $ 269 million. The total discounted financial benefits of power generation were estimated to be US$ 15,389 million (or economic benefits of US$ 13,586 million with a standard conversion factor of 0.8 on local costs), discounted at 10% of the initial project on power date of November 2003.

On the power market for the Karnali project, the HPC had begun with a premise that opportunities for using Chisapani power generation in Nepal are very limited due to the relatively small size of the Nepal power system (forecast peak load of 500 MW in 2007/2008), due to low rates of future load growth, and due to an expected adequacy of power supply from other planned hydropower developments in Nepal until the year 2011. Consequently, this economic evaluation has assumed that all generation from Chisapani project will be exported to India.

The consultant to be hired for updating of the feasibility study of the Karnali project will review the power market both in Nepal and in the region. For this, the consultant will prepare electricity demand forecasts in the regional countries, and the generation technologies that are likely to be displaced by the project and then determine the power benefits of the Karnali project taking into account the current power market situation in Nepal and in the region.

3.10.2 Irrigation Benefits

The Chisapani reservoir provides sufficient storage regulation to increase minimum dry season flows in the Karnali River by about 300% resulting into a four-fold increase in natural dry season low flows. At present, the river is a source of small scale irrigation in Nepal and large scale irrigation in India and can meet all foreseeable water demands due to expansion in Nepal and at Sarda, Sahayak and Saryu in India and farther downstream of Karnali River.

In Nepal: The Chisapani project will also enable large-scale irrigation development in Western Terai on both sides of Karnali River. A total gross command are of 238,709 ha could be irrigated in Nepal Terai between the Rapti river in the east and the Mahana river in the west, of which 191,000 ha is the net area available for irrigation after deducting irrigation infrastructure, roads and villages, etc. The irrigation scheme consisting of two main gravity canals totalling to about 134 km, one in the east and the other in the west of the river, are supplied water from Reregulating reservoir. The economic capital cost of implementation of the irrigation facilities is estimated at US$ 627 million and annual net benefits are about US $ 157 million. The economic rate of return (EIRR) of this development is estimated to be approximately equal to 9.8% --slightly less than the 10% social opportunity cost of capital in Nepal. Although no net benefits are included in the analysis for irrigation development in Nepal, the water requirements for the full ultimate irrigation in Nepal are allowed for in the project operating requirements, as this area may be developed for irrigation in the future. In the long term, agricultural input and output relationships will likely change in Nepal as population growth, food shortages increase, and higher production rates are attained in Nepal agriculture sector.

In India: Two large irrigation canals divert water from the Girijapur Barrage on the Karnali River (Ghagra in India) about 8 km south of the indo-Nepal border. The total cultivable command area totals to 3.2 million m3 including Saryu (1.2 million ha) and Sarda-Sahayak (2.0 million ha). Irrigation service and agricultural production is still being expanded in both areas. There are other large irrigation schemes farther downstream. Irrigation service and agricultural production is still being expanded in both areas. The regulated flow of Chisapani project will enable increased dry season irrigation in India at the existing Karnali (Ghagra) basin irrigation developments in the Sarda Sahayak and Saryu regions, as well as further downstream.

As the pertinent data/information on irrigation potential was not available from relevant official sources, the benefits were evaluated both with and without the Chisapani project, which are dependent on the interpretation of the available information from relevant Indian reports and other background documents on water and land use concepts throughout the Ghagra/ Ganga plain. Besides, a number of assumptions are made in the study. Irrigation benefits were evaluated, taking into account constraints imposed by existing canal capabilities, and maximum practical irrigation intensities. Benefits for use of excess water farther downstream were also evaluated for regulated dry season water supply in excess of water requirements in Nepal and at the Girjapur barrage for Sarda Sahayak and Saryu. It is very likely that the water will be used farther downstream on the Ghagra-Ganga river system, although information on downstream irrigation project is limited.

It is evident that the additional dry season flow made available by the Chisapani reservoir can be used to increase additional production at Sarda and Saryu both. Irrigation intensities can be increased, in general, by maintaining the present Kharif and Rabi crops and introducing Zaid (dry season) crops. Total discounted irrigation benefits in India estimated are summarized in the table given below.

Table 3.7: Irrigation Benefits in India (Discounted)

Description	Net Irrigation Benefits in India in million US$ at 10% Discount rate
Sarda Sahayak Area	705
Saryu Area	1,428
Subtotal	2,133
Increase Sarda canal capacity	586
Use of excess water d/s	450
Total Net Benefits	3,169

3.10.3 Other Benefits

Other potential benefits that were assessed in the study are flood control and navigation.

a. Flood Control Benefits

The Chisapani project has a substantial storage volume above the normal FSL for the purpose of storing and reducing incoming flood peaks. The stored flood will be discharged over the ungated spillway kept at a crest elevation at the normal FSL of 415 m. The routing of floods at the reservoir will reduce the peak outflow of large flood peaks on the Karnali at Chisapani to about 25% of the peak flow. This will eliminate virtually all flood damages on the Karnali below the project site in Nepal, and flood damages will also be reduced farther downstream in India and even in Bangladesh. The flood control benefits in Nepal are estimated to be about US $ 4 million, discounted at 10% to the project in service date. The study has estimated flood benefits farther downstream in India and Bangladesh. However the report states that such benefit in India and Bangladesh are very uncertain due to lack of data. The order of magnitude of these additional downstream benefits estimated is about US $ 20 million. Thus, total flood control benefits are consequently very small relative to power and irrigation benefits. The updated feasibility study requires collecting relevant data in Nepal, Bangladesh and India and refining the flood control benefits.

b. ***Navigation Benefits***

Some navigation benefits will also be created in the reservoir area and its vicinity. Ferry boats can be operated to carry local passengers and supplies that will otherwise have to use local trails. The discounted benefits estimated at about US$ 1 million are very low due to the low opportunity cost of local labour, low traffic volumes and short distances involved. Navigation benefits on the Karnali downstream of the dam are judged to be insignificant, since river transport is not economically competitive with alternative mode of transport.

The project benefits estimation (power, irrigation, flood control) need to be reviewed utilizing the latest data on demand for power, irrigation and possibility of flood control. The HPC report has noted that the analyses were based on insufficient information, as described below:

Power benefits

As only a few cost data was available from official Indian sources; unofficial sources and reasonable assumptions for comparative generation cost characteristics (capital cost, fuel costs, and Unit cost of generation) used in the feasibility study would result in to estimated power benefits less than the actual. The updated feasibility study needs to estimate the power and energy benefit by collecting information from official sources.

Irrigation benefits

As the pertinent data/information on irrigation potential was not available from relevant official sources, the benefit were evaluated both with and without the Chisapani project. These will dependent on the interpretation of the available information from relevant Indian reports and other background documents on water and land use concepts throughout the Ghagra/Ganga plain. Furthermore, as the information on downstream irrigation project is limited, the benefit estimated in this area is also in the conservative side. Owing to this, the updated feasibility study requires to collect relevant information from official sources of GOI to refine the irrigation benefits.

Flood Control benefits in India and Bangladesh

The study has estimated flood benefits farther downstream in India and Bangladesh. It, however states that such benefit in India and Bangladesh are very uncertain due to lack of data. Thus the *total flood control benefits appear to be far less than actual irrigation benefits. The updated feasibility study requires collecting relevant data in Nepal, Bangladesh and India and refining the flood control benefits.*

In light of the above discussions, it is essential to estimate the power benefits, irrigation benefits, and flood control benefits using updated information. Although the study has stated that downstream navigation benefits are not significant given the river transport is not economically competitive with alternative mode of transport, it may be worthwhile to revisit this conclusion backed up by a detailed analysis.

3.11 Project General Arrangement

3.11.1 General Arrangement

The general arrangement of Karnali (Chisapani) Multipurpose Project consisting of the following five main features presented in figure 3 (fig. 18.1 in the Main report) is appended in Annex 2:

- Main civil structures consisting of (i) the Dam and Spillway; (ii) Power Facilities including intake, power tunnels, penstock shafts together with penstock, powerhouse and tailrace
- Hydromechanical equipment including gates, stoplogs, and penstock pipes, etc.
- Electromechanical equipment including turbines, generators, power transformers, etc.
- The transmission facilities which deliver the power to Indian power system
- Reregulating facilities

3.12 Project Structures

3.12.1 Main Dam

The optimization studies lead to selection of FSL at 415 m combined with the provision of 30 m for flood surcharge and free board, result in a maximum height of the dam of 270 m. An embankment with an impervious core was used as the basis for these selection and optimization studies. The gravel fill embankment dam contains over 45 million cubic metres of fill material. An earth core rockfill dam is the most satisfactory type of dam for accommodating seismically induced foundation displacement. Besides, ample good quality gravel fill is available in the alluvial fan immediately downstream from the Chisapani gorge. This fill is considered much superior to any rock fill which can be quarried locally because of high strength and low compressibility in comparison with the much weaker rock material. A gravel-fill earth core embankment dam was therefore selected as the most suitable type for Chisapani.

The dam axis is contained within narrow limits by the two Kholas: Bangar, upstream on the left and, to a lesser extent, Kelari, downstream on the right. An axis roughly midway between these Kholas also takes advantage of the valley's topography to minimize embankment volume.

Detailed design studies of embankment dam conducted by HPC include: (i) Finite element stability analyses for stresses covering both static and dynamic conditions (for several dam heights and sections), and (ii) Limit equilibrium stability analysis. These analyses are fully documented in two appendices to Annex I of the feasibility study report 1990. The embankment section consists of seven zones of different materials. The width of central impervious core, Zone 1, is marginally greater than 40% of water height and reaches a maximum of about 110 m at the lowest point of embankment. The core is protected both upstream and downstream, by two filter zones –Zone 2 is a fine filter varying from 4 to 8 m wide, and Zone 3 is a coarse filter varying from 6 to 12 m wide. The filter zones extend over the foundation area beneath the downstream shell. Horizontal layers of Zone 3 filter material provide additional drainage within the upstream shell and enhance the seismic stability. The bulk of shell material (about 70%) consists of Zone 4 pit-run alluvium. Two additional zones are provided within the shells to optimize material use – Zone 6 is a cobble sized material; it is used mainly in a 50 m wide zone at the u/s slope of the embankment, and significantly improves the seismic stability of the dam. A layer of Zone 6 material is also used to provide surface protection to and improve the appearance of the downstream slope. The remaining shell material is Zone 5, comprising about 10% of the shell. There is provision for use of the abundant rock available from required excavations at the dam site. The final material is Zone 7, a layer of riprap protection on the upstream slope covering the full d/s range in the reservoir. A typical section of the Chisapani Dam presented in figure 4 (fig. 19.1 of the main Report) is appended in Annex 2.

The material investigations and testing have established the availability of ample quantities of suitable embankment fill materials. For the impervious core, a relatively granular material of low compressibility was selected. After removal by screening of oversized (> 80 mm) cobbles, core material will consist of approximately equal proportions of gravel, sand and low plastic clayey silt. The shell materials obtained as pit-run excavation from the alluvial fan borrow areas is predominantly sandy gravel with cobbles, and is mainly composed of quartzite material derived from the metamorphic formations high in the catchment. These materials are sub rounded and of high strength. The fan alluvium can be readily processed to yield filter and transition materials of the required gradation.

3.12.2 Diversion Facilities

The diversion tunnels are located on the right bank in consideration to the topographic conditions at the site, and the location of power facilities on the left bank. Two diversion tunnels each 2400m long need to clear the spillway plunge pool area and terminate further downstream. These consist of the two diversion tunnels and related inlet/outlet structures plus the coffer dams and protective measures incorporated into the main dam embankment. Geological conditions and consequent tunnel support requirements suggest that 15 m diameter is prudent and economical for construction, so two 15–m dia tunnels were selected in preference to the larger size. These diversion facilities have been designed for subsequent use as low level and sediment outlets. Peak flood flows are large, ranging from about 10,000 m3/s (annual average)- to over 20,000 m3/s (1 in 100 yr return period). However, all major recorded flood peaks have occurred in the 4-month period, i.e. mid-June to mid-October.

The tunnel invert levels are 188.5 m at the inlet, dropping to 182 m at the outlet over an average length of almost 2400 m. Under normal and dry season flows, the tunnel will flow part-full, but will generally flow full during the wet season. Flow velocities are high but not unprecedented – exceeding 20m/s for a wet season flood of 1:10-yr return period and 30 m/s for 1:1000-YR. The tunnels will carry the river flow during construction of the main dam, for 4-1/2 years. To allow construction of the inlet structures and tunnel during high flood flows in the Karnali, a rollcrete cofferdam is founded on rock adjacent to the river.

3.12.3 Spillway

The Spillway, Diversion and Outlet facilities are conventional in concept. Flood handling is facilitated by the large degree of flood storage available. The peak discharges are reduced to about one third of peak inflow for both the spillway and diversion facilities. The spillway is an ungated chute spillway capable of discharging a maximum flood flow of 19,200 m3/s.

Flood energy to be dissipated in Chisapani is extremely high, because of the size and height of its dam. However, the high flood flows are of relatively short duration, e.g. the average flow over the 5d flood period is little more than half the peak. In addition Chisapani reservoir is so large that the extreme peak discharge and energy can be sharply reduced by flood storage, e.g. the volume available with 30 m of flood surcharge above the 415 m FSL is 7.3 km3, slightly more than the 1:10,000-yr, 5-d flood inflow volume. Therefore, all previous studies and the preliminary design layouts provided a large degree of flood surcharge, and typically reduce the peak discharge to less than 50% of peak inflow.

Chute together with flip bucket/plunge pool for energy dissipation was selected comparing the construction cost and operating performance of the potential spillway types presented above. The structural width of the crest is 70 m and the chute extends for some 860 m and is flared from 70 m to 100 m at the flip bucket. The hydraulic width of the crest is taken as 60 m. Under PMF conditions, peak discharge is 19,218 m3/s, maximum head on the crest is 28.7 m and maximum velocity is 56.9 m/s at the bucket. The invert level of flip bucket is EL 220 m. A conventional simple bucket is provided with a shallow bucket angle to promote better plunge pool flow conditions. Under higher discharges, the jet impact area will be approximately 100 m from the bucket, increasing to just over 200 m for the PMF. The pool bottom elevation is kept at el 140 m. The pool is fully concrete lined, to prevent progressive erosion of the weaker rock strata.

3.12.4 Outlet Facilities

There are three separate outlet facilities; namely: low level outlets, emergency irrigation outlet and sediment flushing outlet, in addition to the spillway and power facilities. Description of each outlet is briefly presented in the following paragraphs.

i. **Low level outlets:**

Meet downstream riparian flow requirements during initial reservoir impoundment. The outlets are located within the left diversion tunnel, and during their construction the diverted flow is restricted to the right tunnel only, hence work is done during the dry season low flow period.

ii. **Emergency Irrigation outlet:**

To ensures release of adequate flow to meet downstream irrigation demands in the event of a prolonged and complete shutdown of the power facilities. A conservative discharge capacity of 1000 m3/s was selected based on the assessment of maximum irrigation flow demands in May for full development in Nepal's Terai and at the Sarda and Saryu development in India. The outlet is located on the left bank adjacent to the power intake. The flow is passed through a 9-m dia, concrete lined tunnel about 800 m long, which terminates at a flip bucket located between and above the two upstream tailrace tunnel portals. The control gate is operated via a gate shaft.

iii. **Sediment Flushing outlet:**

Allow sediment flushing in the future, if and when sediments deposited in the reservoir encroach on the power intake.

It is predicted that, over a period of 75 years, the sediment accumulation in the reservoir forebay will reach el 305 m, that is, only 17 m below the invert of power intakes. It is therefore desirable to incorporate a flushing facility to draw the sediments away from the intake area. The flushing facilities are designed for a discharge of 5000 m3/s at EL 310 m with the capability of passing 800m3/s at EL355 m. These facilities make use of the diversion tunnels. The two 15-m dia, concrete lined intake tunnels at EL 270 m are located in the right bank and connected to the diversion tunnels via inclined sections. Flow is controlled by two radial gates per tunnel located in a shaft some 500 m d/s from the intakes.

3.12.5 Reregulating Facilities

The Chisapani power plant is designed to operate primarily as a peaking power facility to suit the needs of the Northern India power system, for 9 months of the year from mid-October to mid-July. This will require the power plant to discharge full plant flow of up to about 7000 m^3/s for 4 to 5 hours per day and be shut down during the remaining time. Owing to this, reregulation of flow is required to full fill (I) Irrigation water supply needs at the downstream, and (ii) social and natural environmental needs. The reregulating facilities comprise: (i) a 6 km long dam, (ii) a 425-m long spillway discharging to the Geruwa, incorporating an outlet structure for controlled dry season release, (iii) the Kauriyala power plant with 6 x 14 MW (84-MW) capacity and an adjacent outlet structure, and (iv) two irrigation outlets on the east and west banks.

a. Reregulating Dam

The Reregulation dam is low embankment dam and reservoir located at 8 km d/s from the main dam. It comprises a 6-km long, zoned fill embankment with an impervious core constructed directly on the materials of alluvial fan. The maximum height of the dam is 24 m. The total dam volume is about 9 million m3 including blanket volume. The full supply level is kept at el 200 m. The live storage volume is 100 million m3. The concrete gravity ogee spillway is located on the right side of the Geruwa channel towards the eastern extremity of the dam. It is gated consisting of 21 bays @ 15 m wide with stilling basin. The spillway is designed to pass the PMF discharge (19,218 m3/s) from Chisapani dam. A summary of the reregulating facilities is presented in the table given below.

Table 3.8: Key Features of the Reregulating Facilities

Reregulating Facilities	
Type	Low embankment dam and reservoir
Location	8 km downstream from main dam
Length	6 km
Maximum dam height	24 m
Dam volume	6×10^6 m^3 + 3×10^6 m^3 for blanket
Reservoir level	200 m FSL
Drawdown	7 m
Live storage	100×10^6 m^3
Spillway	Gated 21 bays x 15 m wide with stilling basin, 19 218 m^3/s design discharge

Power Plant	6 x 14 MW bulb turbines at 13.5 m headand rated discharge @ 118 m3/s
Irrigation Outlets	2 Nos
Design discharge in irrigation outlets	160 m3/s

The consultant to be hired for updating the feasibility study will review the project arrangement and dimensioning of various project structures and recommended improvements backed up by necessary physical and computational (numeric) hydraulic modelling exercises. The numeric modelling is suggested to be carried out for the spillway, plunge pool, energy dissipating structures, weir (for reregulating dam), power intake, irrigation outlets, sediment flushing outlets, low level outlets, and so on. To confirm the results of the numeric modelling, the consultant will carry out physical modelling of key hydraulic structures to be identified in consultation with the Employer (SEC).

3.13 Power Facilities: Design Arrangement (Civil Works)

The term power facilities include the power intake, power waterways, powerhouse and associated structures, generating equipment, switchyard at Chisapani, and transmission lines to India. This section is confined to the civil and related geotechnical and hydraulic design and layout of the structures. The general arrangement of power facilities and water conveyance profiles are presented in figure 5 (figure 23.2 in the Main report) and figure 6(fig. 23, 3 in the Main Report) respectively in Annex 2.

The civil structures of the Power Facilities are located on the left bank of the dam site. The main components are:

- The power intake located high on the south bank of the Bangar Khola
- Six horizontal power tunnels, vertical penstock shafts and penstock manifolds with 18 steel lined penstocks

- The underground powerhouse complex—the powerhouse cavern housing 18 units and an upstream transformer gallery, downstream draft tube gallery, associated cable and ventilation shafts and access tunnels
- Six tailrace tunnels exiting through portals immediately downstream from the Chisapani dam

Provision has also been made to accommodate a future expansion with nine 600 MW additional units. These facilities are located on the right bank, and only the initial stage of the intake is included for construction at this time.

3.13.1 Power Intake

The intake approach channel is kept at EL 322. Six intake tunnels @ 15 m dia convey water into the powerhouse through the headrace tunnel of varying length. Each intake includes a vertical gate shaft of 15 m internal diameter excavated in rock. The total height of the concrete lined gate shaft from the invert level of the connecting tunnel to the intake gate is 118 m. The intake deck level is kept at el 445 m compared to PMF level at el 443.80 m. The trash racks are slopping, maximum flow velocity through the rack is 1.8 m/s, and racking equipment is operated from the intake deck via a sloping beam and deck arrangement. The maintenance gate and the main intake gate are operated using intake gantry crane.

3.13.2 Waterways

All waterways are fully concrete lined. Analysis of hydraulic transients and regulation characteristics confirmed that no surge chambers are required. With the selected governor and generator inertia, the most downstream (southern) unit with a total u/s waterway 1500 m long is, however, close to the margin of acceptability. Waterway dimensions, and thus head losses were conventionally optimized by minimizing the combined cost of construction and the value of energy associated with head losses. Friction loss was determined using manning's n value of 0.013. The dimensions and maximum flow velocities are summarized in the following table (Table 3.9).

Table 3.9: Maximum Flow Velocities in Waterways

Description	Diameter (m)	Maximum Velocity (m/s)
Power Tunnels	15.0	7.1
Penstock shafts	14.0	8.2
Steel lined Penstocks	7.2	10.3
Tailrace tunnels (Width x Height)	15x18 (horseshoe)	5.5

3.13.3 Powerhouse Complex

The complex includes three parallel caverns; one for transformers and switching equipment, the other for powerhouse and the next for draft tube gates. The central powerhouse cavern is the largest of the three, and contains the generating equipment. It is 27.7 m wide. The u/s cavern houses the transformers and switching equipment is 17.0 m wide. The smaller d/s gallery (draft tube gallery) provides access to the draft tube gates and houses the gantry crane for handling the gates. It is 8m wide.

i. Powerhouse

The powerhouse consists of 18 generating unit bays, two double size service bays –one at each end of the powerhouse –and a main control at the extreme north end. The powerhouse is arranged in two floors; the main floor contains the main electrical cabinets and the station service transformers, and the service distribution panels and buses and are located on the u/s side of the units. The lower turbine floor has two longitudinal galleries and generally houses all the auxiliary mechanical and electrical equipment. The space above the main floor is reserved for the passage of the main powerhouse cranes which run on crane rails supported by RCC beams and columns.

ii. Transformer Gallery

The transformer gallery is also arranged in three floors. The middle floor contains the bank 18/400 kV single-phase transformers with generator switchgear and bus duct galleries below. The upper floor contains the SF6 switching equipment.

iii. **Drainage Facilities**

The powerhouse complex is completely shielded by a drainage curtain at the u/s end of the transformer gallery. The curtain consists of a network of galleries which are interconnected with the drainage galleries in the dam abutment. The pre-support adits above the caverns provide further protection. A drainage gallery is also located transverse to the penstocks near the upstream limit of the steel lining.

iv. Access

A link to a road over the tailrace portals and the north access tunnel, and a ring tunnel passing at the back of the penstock manifolds, combine to provide full access to both ends of the complex. Access tunnels are 10 m wide.

A review of the power facilities (civil) is suggested to incorporate the most current design practices.

3.14 Power Facilities: Electromechanical and Mechanical Equipment

Although, Chisapani ranks as one of the largest hydroelectric developments in the world, the equipment proposed is typical for such a project and well within the limits of current experience. The operating conditions for the facilities and brief description of the major power plant equipment are presented in the following paragraphs.

3.14.1 Operating Requirements

3.14.1.1 Mode of Operation

Reservoir simulation studies were used to assess the overall power and energy capability of Karnali Chisapani Project. The firm energy is about 1750 MWc, and the average annual energy production is about 20,830 GWh. The probable mode of operation of the power plant as suggested in the HPC study is summarized below.

- Peak system demands in the Northern Region of India occur from December to March and April through June each year, the plant operates at about 20% capacity factor (CF) to produce 2074 MWc during the 4-month period (Dec.-Mar.); no units would be scheduled for maintenance.

- During the remaining 8 months the target firm energy is reduced to 1602 MWc.
- In later stage of the monsoon season, usually during August to October, with the reservoir full, continuous generation at up to full plant capability is possible when river flows are high.
- Annual maintenance is scheduled for the lower demand months of April and July (note- April-June end is the summer peak in India) to November inclusive, to allow for maintenance interval 1 month/unit, three units would be out of service during these 6 moths.
- With average peaking operation of 4 to 5 h/d, the large short duration plant discharges from Chisapani are regulated at the d/s regulating facility to maximize irrigation benefits in India and mitigate disturbance in the natural riverine environment.

However, it is likely that the current profile of electricity demand may have undergone some change as compared to the one prevailing at the time of the HPC study. For example, currently India experiences two peak periods, one in summer (April- June), and another in winter (December-March). Accordingly, the annual maintenance may be scheduled in the lower demand months outside of the peak periods. The consultant to be hired for updating the feasibility study will collect the information on the latest load profile and suggest maintenance schedule accordingly and also plan the reregulating facility for maximum irrigation benefits.

3.14.1.2 Reservoir Water Levels

The reservoir simulation indicates that the reservoir will be at or near the 415 m FSL about 25% of the time. Because of the large installed capacity, spill will be infrequent (apart from the first year when less than the full complement of units in service). The mean reservoir level is about 395 m. At the other extreme, the reservoir will approach within 5 m of the MOL (which is EL 355 m) only rarely –less than 5% of the time. Dry season drawdown under average flow conditions is about 40 m and approaches the maximum drawdown of 60 m only about once every 5 years. The variation in the operating head was large (max 214 m and min 145 m), making the selection of turbine a challenge. The range of operating heads of the turbines is within the precedent experience.

3.14.2 Equipment Selection

3.14.2.1 Turbines

The selection of turbines is based on the (i) operating heads and the unit capacity, (ii) specific speed and synchronous speed; (iii) turbine setting and cavitations coefficient; and (iv) speed and pressured rise on the penstock.

The design head of 185 m has been selected slightly below the average head of 189 m. The turbines unit capacity of 620 MW corresponding to the design head has been established accounting for the losses for the generator and transformer and for the station service for a rated unit capacity of 600 MW. The total number of units is 18.

3.14.2.2 Generators

The selection of generators did not pose any serious problems, since they are within the range of design parameters for recent machines of the type and size proposed for Chisapani. For the specific speed of 154.4m the synchronous speed of 120 rpm was selected, requiring a 50-pole generator at 50 Hz. The unit capacity of the generators is 642 MW and the generation voltage is 18 kV.

3.14.2.3 Electrical Main Single-Line Scheme

Three options namely Scheme-A, Scheme-B and Scheme-C of single line generation and switchyard schemes were analysed.

Scheme-A: Stepping up the voltage to 400 kV in the first stage using a bank of: three single-phase 18/400 kV transformers (underground) connected to each generator. Subsequently, the voltage is stepped up to 765 kV using 400/765 kV auto transformers to supply five 765 kV single- circuit transmission lines to deliver power to the terminating switching stations in India.

Scheme B: The second scheme consists of a single stage transformation from 18 kV to 765 kV with a bank of three single-phase transformers, and utilization of GIS switchgears and bus ducts to supply five 765 kV single-circuit transmission lines to deliver power to India.

Scheme C: The Scheme C is similar to Scheme B but involves transformation to 400 kV only, with power being transmitted to India at 400 kV.

Of these three, the first option was recommended for being a proven technology at that time. However, this study recommends studying the Scheme-B in greater depth during the detailed engineering design because of some potential advantages.

The report has also described major power plant equipment such as turbine and governors, turbine inlet valves, power house cranes, generators, 18/400 kV unit transformers, exciters, autotransformers, switchgears, electrical auxiliary services, and so on.

The updated feasibility shall review the technological options for the switchyard schemes in light of the current level of technology, and recommend the one which is technologically superior and economically feasible. The study should also look into the unit size of the turbine generators, as there is a possibility of having higher capacity Francis turbines.

3.15 Power Evacuation Study

The power system study for the power evacuation to India was not carried out for lack of information, and was expected to be carried by Central Electricity Authority (CEA) in India. The system study for Nepal was however carried out.

The updated feasibility study should include carrying out of a comprehensive power system study of the regional countries to identify the system reinforcement needs for the power evacuation for Karnali Chisapani.

3.16 Construction Schedule and Construction Methods

3.16.1 Major Work Items and Access Condition

The major item of works of the construction of Chisapani project are: (i) 40 million m3 of Excavation for surface structures, (II) 6 million m3 of underground excavation, (iii) 56 million m3 of Embankment fill, and (iv) 3 million m3 of Concrete including rollcrete & shotcrete. The HPC study carried out a comprehensive study to analyse the construction task to develop an accurate and reliable construction schedules and cost estimates of the project.

Kolkata in India is the probable port of entry for imported goods supplied from the third countries outside of India. The project site is at a total of 1200 km by road/rail from Kolkata and it is approximately 215 km by road from the nearest major railhead at Gonad in India. The site is 605 km from Kathmandu via the east west highway. A major concern is the transportation of the larger and heavier equipment components for the 600 MW units. A comprehensive transportation study confirmed that the most critical items (400/765 –kV auto transformers) can be handled on the Indian railways using special rail wagons. To provide an efficient transportation service, significant improvements in the existing transportation infrastructure are necessary, and their estimated cost has been included in the project cost estimate.

3.16.2 Implementation Schedule

a. Critical Construction Sequence

In consideration to the physical configuration of the project, the total construction duration is controlled by the time required to construct either the main dam or the powerhouse complex including unit installation. Both sequences are preceded by periods for mobilization and provision of initial access and infrastructures, and both are followed by testing and commissioning of the first unit. Thus, either of Main dam or Powerhouse or both can fall in the critical path.

b. **Project Implementation Schedule**:

It was assumed that a decision to initiate project preconstruction activities would be taken at the beginning of 1990. A period of 5 year was considered for preconstruction activities including treaty formulation for project implementation between Nepal and India, financial arrangements, bridging study and Stage 2 engineering and preliminary activities. The milestone was the award of civil contract on January 1, 1995.

The main construction period was envisaged 106 months (8 yrs 10 months), period from contract ward to the first date on power, November 1 2003. It was expected to award the main contract by January 1, 1995. It was considered as the schedule start date. During the first two years after contract award, construction activity is essentially preparatory and at a low level. Large-scale construction was planned after 4 years of contract ward. It was planned to commission two units on the first on power date. The remaining 16 units were planned to be commissioned by 2007 at 3-month intervals after the first 2 units. The project implementation was planned to be concluded with commissioning of Unit 18 on November1, 2007.

3.16.3 Construction Methods and the Contract Packages

The study envisaged the following four specific aspects of construction works.

i. Excavation and disposal
ii. Embankment construction
iii. Powerhouse area access
iv. Underground construction

The Contract packages are basically envisaged in three Lots; one for access and Infrastructures construction/improvement/upgrading, the other for the main civil works and the third for equipment. The Civil works Lot is planned through a single consortium in consideration to minimize the management/coordination burden on the client and executing authority. However, separation of the civil work in to two large contracts –1) dam, spillway, reregulating facilities, and 2) power facilities including the intake structures was considered during the study. The HPC study concludes that the approach is feasible, but introduces significant interfacing problems, and a large construction management staff to ensure that problems due to interfacing do not develop into claims. The third lot for equipment is planned to be split in to two packages or contract streams in view of the magnitude of generating equipment purchase, and to avoid dependence on any single supplier.

The consultant to be hired for the updating the feasibility study will suggest the construction methods in light of the current construction practices. The slicing of the contract packages shall also be reviewed and changes suggested if there is a possibility of reducing the project costs, implementation time and construction risks.

3.17 Environmental and Social Impact Study

The most significant environmental impacts expected to result from the construction and implementation of the project and the proposed mitigation measures to mitigate the negative impacts is presented in Chapter 28of the Feasibility study Report. No assessment of Environmental impacts within India (e.g. along the Ghaghara, the Indian name for the Karnali) has been made.

The project includes the following major elements of environmental significance:

- The **Chisapani reservoir,** with a normal maximum surface area of about 350 km^2 and extending up to 100 km upstream
- The **reregulating reservoir,** with a surface area of about 15 km^2, located at the head of the alluvial fan at the mouth of the Karnali gorge.
- **A transmission line** corridor extending about 80 km south and west to the Indian boarder (total distance to the connection point is about 300 km)
- **Access Improvement** for road and rail.
- A potential large-scale **irrigation development** in the Nepal's Terai supplied by water from the reregulating reservoir which would extend over as much as 238,700 ha in a broad strip about 55 km on each side of the lower Karnali River.
- **Resettlement** of some 60,000 people displaced by the project (mostly from the main reservoir area). Resettlement areas totalling 12,650 ha have been identified, and are at present forestland that can be developed for irrigated agriculture.

The feasibility study has covered the environmental impact due to the reservoir and change in flow regime, impact on water quality, on agriculture forest resources, and wildlife. The information source for the environmental impact assessment was the published information on land use, supplemented by field reconnaissance. The HPC report has noted that there are major deficiencies in the data relating to several resources including fisheries, aquatic ecosystem, wildlife, forest and water chemistry, as it was not possible to obtain this information during the study.

The report has proposed a number of mitigation, compensation and enhancement measures, has proposed to reduce the environmental impacts of the project. The recommended actions are:

a) Establishment of an environmental department within the project implementing authority.
b) Establishment of an agency to coordinate and manage all activeness relative to the operation of the reservoirs and surrounding areas.
c) Incorporation of provision to add oxygen to releases from the reregulating reservoir to compensate for oxygen deficiency in the discharges from the Chisapani power plant.
d) Propounding clearing of all harvestable timber from the reservoir and all other vegetation
e) Establishment of a long term systematic water quality monitoring programme.
f) Construction and operation of fisheries research station to provide a basis for management and harvesting of fishery resources.
g) Establishment of a reservoir forest management unit to harvest timber and fuel wood from the watershed on a sustained basis.
h) Financial support to the Department of National Parks and Wildlife Conservation to enforce protection within and adjacent to the RBWR.
i) Inclusion of a portion of the area adjoining the reservoir into the RBWR.
j) Ecological studies of Gangetic dolphin and Garial populations within the lower Karnali to design conservation and enhancement programme.
k) Establishment of programme to conserve and manage the wildlife and other resources of the area surrounding the reservoir to maximize their recreational and tourist potential.

On the environmental impact assessment, a fresh study need to be done as part of the updated feasibility study to align the study in line with the requirements of the Environmental Protection Act (EPA) 1997 and Environmental Protection Rules (EPR), 1997, which were enacted subsequent *to the HPC study. Among others, socio economic survey and census survey have been carried out to establish the baseline. The assets inventory survey has to be carried out to establish the likely private land to be acquired for the purpose of the project.*

Further, the information to address the deficiencies in the data relating to several resources including fisheries, aquatic ecosystem, wildlife, forest and water chemistry, need to be obtained.

The environmental and social assessment (ESIA) shall comply with IFC Performance Standards on Environmental and Social Sustainability.

3.18 Project Cost Estimate

3.18.1 General

The construction cost estimate was carried out in parallel with the construction planning and scheduling of the project. The estimate is based on:

- 1988 prices, customs duties have been excluded and no significant taxes or subsidies are included in the estimate
- the US dollar as the cost unit; for currency conversions the following rates are used US $ 1 = NRs 22 = IRs 12.8
- the assumption that the procurement process will emphasize competition and cost effectiveness i.e. open competitive bidding with judicious selection of international and local (Nepal and/or India) tenders. Therefore, no allowances are included to cover cost premiums—either to favour local supply, or to obtain supplier financing.

3.18.2 Cost Estimation Methodology

Major component and the central estimating approach adopted are:

- Main civil works: contractor type estimate

- Permanent equipment: mix of budget prices from potential suppliers plus internal information on international prices
- Transmission facilities: budget prices for the conductors, design quantities for lower structures; total cost are compatible with those used for transmission planning by Indian authorities.
- Off-site costs (a combination of items including resettlement, environmental provisions, access facilities, etc.)
- Project indirect costs, i.e., contingencies and engineering, management percentage allowances.
- The largest and most complex cost component is for civil works construction.

The capital cost of the project is presented in the table given below.

Table 3.10: Capital Costs of the Project

Description	**Capital Cost (1988)**
Civil works cost	US $1,667 million
Electromechanical equipment	US $1,575 million
Transmission Cost	US $332 million
Access and infrastructure	US $280 million
Engineering and management	US $385 million
Resettlement and environment	US $232 million
Contingencies	US $419 million
Total project cost	US $4,890 million
Capital cost per kilowatt (excluding financing Costs)	US $453 million

The consultant to be hired for updating the feasibility study shall review the project cost to reflect the current cost of materials, labor and equipment, cost of services, and the costs of land acquisition and rehabilitation of the project affected people.

3.19 Socioeconomic Impact and Resettlement

The HPC report has identified the displacement the population of 38,000 persons within the area to be flooded by the Chisapani reservoir as a major socioeconomic impact. The project impacted areas identified for impact assessment are:

- Reservoir area (350 km^2)
- Area surrounding the reservoir (1230 km^2)
- Lower Karnali (the fan, extending to the Indian boarder, 300 km^2)
- Resettlement area (126 km^2)
- Potential irrigation area (2390 km,^{2})
- Construction zone (50 km^2)

The data for the socioeconomic impact assessment were collected by HPC through field survey of 10% of the affected population and a census survey of all households in the reservoir area. Based on the socioeconomic study a resettlement criteria and policy were prepared by the consultants.

The socioeconomic conditions of the population in the project-impacted areas have undergone a significant transformation in recent years, due to improved road, communication and other infrastructure, providing opportunities for alternative employment. The number of people living in the area has also gone up significantly. Besides agriculture, local commerce and trade has flourished and people are seeking employment in foreign countries. Thus the HPC study on socioeconomic impact is now outdated. Resettlement of the people directly affected by the project will be a major issue to be looked at carefully and resettlement plans to be prepared in detail.

As a result, the part of the updated feasibility study (the socioeconomic impact assessment) has to be redone to reflect the current situation and meet the requirements of EPA and EPR. To enhance the acceptability of the social impact assessment to funding agencies, it is suggested that the social safeguard studies should be carried out in line with the environmental and social safeguard policies of the multilateral funding agencies such as the Asian Development Bank and the World Bank, particularly IFC Performance Standards on Environmental and Social Sustainability.

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3.20 Economic and Financial Analysis

3.20.1 Economic Evaluation

The project will produce benefits for hydroelectric power generation, irrigation, flood control and navigation. The sharing of the benefits arising from the development of the project among the participating countries will largely be dependent on cost and benefit sharing agreement. In addition, the institutional arrangements for implementing the project, and the terms and conditions of financing made available from international, commercial and foreign aid community, will have a significant impact on the net financial benefits ultimately derived from the project by Nepal, India and other participating countries in the project.

The HPC study has evaluated and quantified the benefits under the following categories:

(i) power benefits,
(ii) irrigation benefits;
(iii) flood control benefits, and
(iv) Navigation benefits.

The power benefits have been estimated largely assuming that project will displace a mix of coal fired thermal generation and gas turbine generation in India. The irrigating benefits will accrue due to the flow regulation provided by Chisapani project that will enable increased dry season irrigation in India at the existing Karnali (Ghagra) basin irrigation developments in the Sarda Sahayak and Saryu regions, as well as further downstream.

The flood benefits will result as a result of the Chisapani project having a substantial storage volume above the normal FSL for the purpose of storing and reducing incoming flood peaks. These will be discharged over the ungated spillways. The resulting routing of floods will reduce the peak outflow of large flood peaks on the Karnali at Chisapani to about 20 – 25% of the peak flow. This will eliminate virtually all flood damages on the Karnali below the project site in Nepal, and flood damages will also be reduced farther downstream in India and even in Bangladesh.

The navigation benefits due to the project have been estimated to be small in the upstream and downstream of the dam. In the upstream, due to short distances involved the scope for navigation benefit is very small. Similar, navigation benefits below the project are also assessed to be insignificant, in view of the fact that the river transport is not economically competitive with alternative road transport.

In the updated feasibility study, the consultants will carry out benefits calculations of electricity taking into account the current opportunity cost of electricity in the regional countries from this project developed as a regional project. The current generation mix will determine the type of electricity generation, which will potentially be displaced by the Karnali Chisapani project, and hence the power benefits.

Further the irrigation and flood control benefits should also be re-evaluated taking into account the current opportunities for the same. In respect of navigation benefits, the consultants may review if there are new opportunities for enhanced navigation upstream and downstream of the project.

3.20.2 Benefit/Cost Analysis

With a 10% discount rate, the total discounted project benefit is US $16,755 million and total discounted cost is US $6,808 million. Total discounted net benefit for the project is US $9,947 million, and the B/C ratio is 2.46 (discount rate 10%). The EIRR on additional investment requirements compared with the base case alternative is about 27%. The project economics are very attractive by all of these economic measures.

A number of sensitivity studies were also conducted to evaluate the project economic under various conditions of load growth, increased coal costs, reduced irrigation benefits, reduced flood control and navigation benefits, increased project costs and project delay. In all the sensitivity cases the benefits were in excess of 2.2. Hence the project is found attractive economically.

To reassess the cost/benefit analysis at current level, it is necessary to have updated information on the project costs and benefits. The consultants engaged for the updated feasibility analysis shall carry out the economic analysis with updated cost and benefits calculation.

3.21 Discussions on Generation Price

The Karnali (Chisapani) Multipurpose Project Feasibility Study (1989) report has worked out the total capital cost of the project to be USD 4,890 million and the capital cost per kW of USD 453 excluding the financing costs. The unit cost of generation has been worked out to be US¢ 3.3 per kWh, which compared favourably with the base load cost of coal generation of US¢ 4.5 per kWh at that time.

The cost of generation at the current prices may be higher than the one given in the 1989 Feasibility Study and the updated cost of generation can only be ascertained after updating the investment cost and energy generation data. Given the other planned or committed upstream storage hydropower development in the Karnali River basin, the energy generation can be higher than the estimated average annual generation of 20,842 GWh. At the same time, the policy to move towards cleaner energy may put the energy generation from this project at a premium. Better load following characteristics of a hydropower project make it an attractive generation option compared to fossil fuel generation from technologically comparable option such as gas turbine power plant.

As noted in the foregoing sections, the project is not only associated with power benefit, but also with significant irrigation and flood control benefits. When these additional benefits are factored into the total benefits, the economic benefit at the current prices is expected to be significantly higher.

The updated feasibility study should attempt to quantify all of these benefits to assess the economic feasibility of this project for the region development at the current prices.

The consultant to be hired for the preparation of the updated feasibility study shall also prepare a financial model of the project and work out the financial indicators to establish the financial viability of the project from a lenders perspective. Such indicators shall include, among others, internal rate of return, debt service coverage ratio, payback period and cost of generation.

CHAPTER 4: DEVELOPING KARNALI CHISAPANI AS REGIONAL HYDROPOWER PROJECT

4.1 Rationale

4.1.1 Electricity Sector Scenario in SAARC Region

SAARC Member States have a large energy resource base comprising of hydro, Solar, wind power potential and coal. However South Asia region has very limited oil and natural gas reserves. Energy resource endowment of SAARC countries is given below in **Table 4.1:**

Table 4.1: Energy Resource Endowments of SAARC Countries

Country	Coal (mill. tons)	Oil (mill. .barrels)	Natural Gas (TCF)	Biomass (mill. tons)	Hydro (GW)	Solar Power (kWh/sqmts./ day	Wind (MW)
Afghanistan	440	NA	15	18–27	25	NA	NA
Bangladesh	884	12	8	0.08	0.33	3.8-6.5	V. Ltd.
Bhutan	2	0	0	26.6	30	2.5-5	4,825
India	90,085	5,700	39	139	150	4-7	151,918
Maldives	0	0	0	0.06	0	NA	NA
Nepal*	NA	0	0	27.04	83	3.6-6.2	3,000
Pakistan	17,550	324	33	NA	59	5.3	24,000
Sri Lanka	NA	150	0	12	2	NA	25,000
Total	**108,961**	**5,906**	**95**	**223**	**349.33**		

Source: SARI/Energy presentation at the HAPUA- UNESCAP Workshop on 17-19th April'2017, Jakarta, Indonesia

Despite large resources, the region is facing acute electricity shortages hampering economic and social development of the region. The country wise installed capacity of the SAARC Member States is given below in **Table: 4.2:**

Table 4.2: Electricity Generation Installed Capacity of SAARC Countries

S. No	Country	Installed Capacity (MW)
1	**Afghanistan**	1,341
2	**Bhutan**	1,614
3	**Bangladesh**	12,578
4	**India**	315,426
5	**Nepal**	898
6	**Sri Lanka**	4,050
7	**Pakistan**	24,829
8	**Total**	360,689

Source: SARI/E, Task Force 1 Report -IRADe Report on CBET in South Asia: Challenges and investment opportunities, etc.

*DOED, MOE, GON

In spite of significant installed capacity of about 361 GW, South Asia is one of the least served regions in the world, once it comes to having access to electricity. Percentage of population having access to electricity in the region is given below in **Table 4.3:**

Table 4.3: Access to Electricity in South Asia

S. No	Country	Percentage of Population with Access to Electricity
1	Afghanistan	15.6%
2	Bangladesh	41%
3	Bhutan	60%
4	India	66.3%
5	Maldives	100%
6	Nepal	43.6%
7	Pakistan	62.4%
8.	Sri Lanka	88%

Source: http://apod.nasa.gov/apod/image/0011/earthlights2_dmsp_big.jpg

South Asia, with a population of is 1,649.28 million is host to 20% of world population. From the data given in **Table 4.3**, one can observe that nearly 1/3rd (37.5%) or 618.81 million people in

South Asia do not have access to electricity. Making electricity available to such a large population is a daunting task.

Even those people who have access to electricity are unable to fully reap the benefits of electrification due to long power outages (planned and unplanned) leading to the region having one of the lowest per capita electricity consumptions in the world, as can be seen from the figures given in **Table 4.4** below:

Table 4.4: Per Capita electricity Consumption of SAARC Countries

S. No	Country	Per Capita Electricity Consumption Per Year (kWh/year)
1	Afghanistan	49
2	Bangladesh	259
3	Bhutan	977
4	India	684
5	Maldives	521
6	Nepal	106
7	Pakistan	449
8	Sri Lanka	490
9	World Average	2,782

Source: SEC; Development of a Potential Regional Hydropower Plant in South Asia: A Pre-feasibility Study

The average per capita electricity consumption of South Asia is 517 kWh per person/year; as against the world average of 2,782 kWh per person/year. That means South Asia's average annual per capita electricity consumption is just 18.58% of the world average.

Non availability of supply, poor power quality (even where electricity is available), long power cuts and irregular supply are taking their toll on the social and economic development of SAARC region. These factors have been one of the primary reasons of South Asia remaining one of the least developed regions of the world, and being host to the largest segment of world's poor. Enhancing availability of electricity supply can facilitate social transformation through better health care, quality education, and higher standards of living. On the economic front, availability of quality electricity supply at affordable rates will help the existing industries to tide over their difficulties, facilitate fresh investments and enhanced economic activity in the region. Empirical studies have shown that positive impacts of electrification are more pronounced in far flung and rural areas, where the poorest segments of society live; than in the developed areas. The biggest challenge before the SAARC Member States is to meet the electricity demand at an accelerated pace, through the development of indigenous energy resources for the benefit of the people living in the region. Given that the energy resources are not evenly spread across the region, development of energy resources in one or more countries in the region and sharing the electricity generated with neighboring countries will be a win-win situation for the entire region. A case in instance is the Bhutan-India and India-Bangladesh power trade.

4.1.2 Enhancing Electricity Supply though the Development of Regional Power Plants

South Asia needs massive capacity additions to meet its electricity demand. Keeping in view the need for controlling the adverse impacts of Climate change, development of clean energy resources is the best option. One of the environmentally benign and time tested resources for electricity generation is hydropower. The potential of which is quite significant in relation to the electricity demand in the region. Hydropower development in addition to electricity generation, help in flood control, irrigation, providing drinking water and has other attendant benefits, such as, extension of roads, power transmission, schools, hospitals and other basic infrastructure facilities to remote areas, right up to the project sites. Development of large power plants, including hydropower plants as regional projects was therefore, included as one of the main recommendations[1] of the *"SAARC Regional Energy Trade Study (SRETS)".* Regional hydropower projects in addition to meeting the demand of the host country will supply electricity to neighboring countries. The concept was approved by the SAARC Member States as part of SRETS report.

Para 2 of the Preamble to the *"SAARC Framework Agreement on Energy Cooperation (Electricity)*[2]*"* aimed at promoting energy cooperation and free flow of electricity across the region

[1] SRETS Chapter-7: Inter Regional Energy Trade and Related Options; Para 7.6.4- Proposed Trade Options: Regional/Sub-regional Power Plants

[2] SAARC Framework Agreement on Energy Cooperation (Electricity) too states that "Realizing the common benefits of cross border electricity exchanges and trade among the SAARC Member States leading to optimal utilization of regional electricity

too recognized the need for enhancing electricity supply to meet the demand across the region. Therefore, the best option to augment electricity supply within the region in an environment friendly manner is to harness the hydropower resources to meet the regional electricity demand.

Country wise hydropower potential, techno-economically exploitable potential, present installed hydro Capacity and percentage of the techno-economically exploitable potential harnessed by the Member States in given below in **Tab 4.5:**

Table 4.5: Country Wise Hydropower Potential of SAARC Member States

S. No	Country	Potential (MW)	Techno-economically Feasible (MW)	Present Generation (MW)	Generation Capacity %
1	Afghanistan	23,000	18,400	298	1.625
2	Bangladesh	1,897	775	220	28.39
3	Bhutan	30,000	23760	1,484	6.25
4	India	150,000	84,400	40,195	47.62
5	Maldives	0	0	0	0
6	Nepal	83,000	42,130	743	1.76
7	Pakistan	100,000	60,000	6,928	11.54
8	Sri Lanka	4,000	2,423	1,628	67.19
9	**Total**	**391,897**	**231,888**	**51,496**	**22.21**

Source: SEC; Development of a Potential Regional Hydropower Plant in South Asia: A Pre-feasibility Study

Hydropower potential in South Asia is primarily spread in countries located in foothills of Himalayas, with smaller quantities in other places as well. SAARC countries that have the lion's share of region's hydropower potential are Afghanistan, Bhutan, India, Nepal and Pakistan. Sri Lanka and Bangladesh have a small potential, while Maldives has none. India and Pakistan despite having large hydropower potential have the largest demand for electricity in the region. SAARC Member States with significant hydropower potential that far exceeds their electricity demand in foreseeable future are Nepal, Bhutan and Afghanistan. As per International Hydropower

generating resources, enhanced grid security, and electricity trade arising from diversity in peak demand and seasonal variations"

Association, Nepal's theoretical hydropower potential is estimated at around 83,000 MW[3], of which 42,000 MW has been identified as techno-economically viable. Only an insignificant part thereof (1.76%) has been developed so far. According to the Department of Electricity Development, Ministry of Energy, Government of Nepal, the total generation capacity of the country as on July 21, 2017 from **61 projects was 898.109** MW[4], as against a potential of 42,000 MW, leaving a large scope for harnessing the potential. Bhutan is already exploiting a significant part of its hydropower potential and has plans to harness about 20,000 MW in near future, leaving little scope for simultaneous development of other large projects. The security situation in Afghanistan may not permit expeditious development of large hydropower project for regional purpose at the moment.

As such, Nepal with a large unexploited hydropower potential can help the region, by offering one or more of its large hydropower project sites for regional development. Nepal, otherwise as well, needs to expedite the harnessing of its hydropower potential not only to meet its own electricity demand, but to export the surplus energy. This fact has been recognized by the country while formulating its energy policy. Nepal has made necessary provisions in its electricity laws and regulations too, to export electricity to neighboring countries. Hydropower Development Policy 2001 that governs the development of the sector in Nepal, provides for import and export of electricity as one of the options of meeting the electricity demand within the country and also provides for exporting the surplus electricity[5]. Necessary provisions thereto have also been made in the Nepal Electricity Act 2049 (1992) as published in the Official Gazette by Government of Nepal on 17 December, 19992 (2049/9/2)[6]. Nepal is exchanging electricity with India under bilateral agreements and is presently strengthening cross border power transmission networks to facilitate wheeling of larger volumes of energy flows to and from India.

Karnali Chisapani Hydropower project with an estimated potential of 10,800 MW, provides an excellent opportunity for developing it as a regional power project. The main reasons being:

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[3] https://www.hydropower.org/country-profiles/nepal

[4] Ministry of Energy Government of Nepal, DOED: http://www.doed.gov.np/operating_projects_hydro.php

[5] Harmonizing Electricity Laws and Regulations of SAARC Member States authored by D. N. Raina for the SAARC Law and the ADB

[6] Review of Electricity laws and Regulations of the SAARC Member States, authored by D. N. Raina for the SEC, Islamabad

i. This project of 10,800 MW Capacity, in addition to fully meeting Nepal's own demand for electricity in foreseeable future, can meet significant part of the energy demand in other SAARC Member States, as well.
ii. Joint development of the project by SAARC countries will facilitate early and easy financing of the project.
iii. Participating countries will Offtake 100% energy generated by the power plant, thereby assuring a steady stream of revenues and timely debt servicing.
iv. Spreading of risk through multiple stockholding will help reduce the financing costs, and give comfort to lenders to finance the project.
v. Development Financial Institutions promoting regional energy cooperation in South Asia will be willing to provide financing, technical assistance and support in other forms.
vi. All SAARC Member States are signatory to the "*SAARC Framework Agreement on Energy Cooperation (Electricity)"* and are committed to facilitating electricity flows across South Asia through their territory. This obviates the risks involved in obtaining the right of way for transmission corridors for energy flows from the Karnali Chisapani hydropower project.
vii. Energy cooperation will lead to confidence building amongst the member states, with potential to encourage cooperation in other sectors as well; leading to long-lasting peace in South Asia[7].

4.2 Need to carry out Power Market and Other Associated Studies

The last Feasibility Study of Karnali Chisapani hydropower project, with estimated potential of 10,800 MW was carried out by Himalayan Power Consultants in December, 1989. The entire universe in the context of which the project was visualized in 1989 has undergone a sea change. None of the external factors related to the project are same today, as they were in 1989. The South Asian power market in 1989 was a little less than 80,000 MW which today has grown to a level of 361GW. The only cross border power transmission connections in South Asia that time were between India and Nepal. None of the present day interconnections between, India-Bhutan, India-

[7] Energy Security for South Asia, SARI/Energy–USAID, co-authored by D. N. Raina, T. L. Sankar, Hilal A Raza, Prof. Dr. Mahinder Lama, Dr. Priyantha Wijayatunga et. al.

Bangladesh, Iran-Pakistan, Afghanistan-Central Asian Republics and Iran existed then. Even the Indian power system, the largest in South Asia was a fragmented system with five regional power grids with no connectivity between them. Moreover, the size of economies of SAARC countries has grown many folds, as the region has been one of the fastest growing regions in the world economically for over a decade now. The geopolitical and security situation have changed dramatically.

Technology, machinery and equipment used for project implementation have undergone a metamorphosis. Analytical tools used for surveys, investigations, seismology, hydrology, assessment of power generation potential; name a thing, it has changed dramatically. Environmental concerns, rules and regulations that hinder project development today were less stringent then. New sources of electricity generation and technologies related thereto, such as, wind, solar and geothermal have added new dimensions to the power scenario of each country. Evolution of power market, especially in India with the introduction of information technology based trading platforms and power exchanges have to be taken cognizance of now. Other factors, such as, connectivity of Indian power system with those of Bhutan, Bangladesh and Nepal, Pakistan's proposal to import larger volumes of electricity from Iran, Afghanistan's interconnections with its neighbors and implementation of proposed CASA-1000 project will be other important factors to be evaluated for their eventual impact on development of any large regional power plant in South Asia.

Therefore, most of the assumptions on the basis of which the implementation of the Karnali Chisapani project was recommended in the Feasibility study in 1989 need to be revisited, re-examines and re-assessed as part of the proposed Feasibility Study for undertaking the project in the prevailing circumstances. Moreover in 1989, the project was conceived as a bilateral multipurpose project between India and Nepal, with both countries sharing the costs and benefits. In the present context it is intended to be taken up as a regional project. So the very premise of a bilateral-multipurpose project to a multilateral stake holding pattern in the project will have its impacts on assessing cost and benefits to promoter member states.

Given that the project is now contemplated to be developed as a regional project, it is essential to assess the prevailing power market conditions, the development plans and other related factors in each of the SAARC Member States participating in Karnali Chisapani project. It shall have to be examined whether execution of Karnali Chisapani Project brings in superior benefits, than other options available to Member States in the present day context. In essence, all major factors that may have a direct bearing on the execution of the project shall have to be examined before implementing the project. The major areas that should be examined and assessed are listed in paragraphs given below.

4.2.1 Power Market Study

There is need to carry out the Power markets study of Nepal, Afghanistan, Bangladesh, India, Pakistan and Sri Lanka, the six beneficiary states from the project. All requisite activities, but not limited to the following should form part of the Power Market Study:

i. Review power market in Afghanistan, Bangladesh, India, Nepal, Pakistan and Sri Lanka,
ii. Review the present and projected electricity demand-supply scenario of each of the above countries,
iii. Review their load growth forecast at low, medium and high economic growth rate scenarios,
iv. Review their existing and planned generation capacity additions to meet the demand;
v. Evaluate the potential of each of these countries meeting its own demand with and without commissioning of Karnali Chisapani project.
vi. Evaluate whether implementation of Karnali Chisapani project would be a superior option for the participating member states to meet their demand, over their existing development plans and other options, such as the inter-regional power trade with Central Asia and South East Asia.
vii. Review the seasonal variation of energy and capacity demand, and ability of the power systems to meet the energy and capacity demand of the relevant Member States;

viii. Examine the existing and planned additions and alternative supply options in the six countries

4.2.2 Review of willingness and affordability of consumers (in Afghanistan, Bangladesh, India, Nepal, Pakistan and Sri Lanka)

Willingness and affordability of consumers to pay for energy from Karnali Chisapani project, in participating Member States will be an important factor in determining the cost at which they will be willing to purchase power from the project. In case the cost of supply from Karnali is equal to or lower than the marginal cost of supply, participating Member States may be more than willing to buy electricity from the project. Bangladesh, Bhutan, India and Pakistan have independent Electricity Regulatory Commissions in place to determine electricity tariffs. In Nepal, electricity tariffs are fixed by the government of Nepal on the recommendations of Electricity Tariff Fixation Commission. Government regulates electricity tariffs in Afghanistan. It is, therefore, assumed that the prevailing electricity tariffs are rational and based on the willingness and affordability of consumers to pay. As such, only a broader review of prevailing tariffs and the potential of participating countries to absorb additional supplies from Karnali Chisapani project at comparable costs, without un-duly raising the tariffs may encourage these countries to buy electricity from project. The following aspects need to be assessed and factored in to evaluating the feasibility of the Karnali Chisapani project:

i. Energy Price Study covering evaluation of the average cost of generation within each of the participating countries;
ii. Comparison of the pricing of electricity from Karnali (Chisapani) hydro power project, vis-à-vis the generation cost from planned generation projects by the Member States;
iii. Study the comparative cost of generation in each Member State from alternative options, such as; hydro, thermal, solar, wind resources;
iv. Market and energy price trends in the six member states; and
v. Evaluate the benefits to each Member State from purchasing power imported from the proposed Karnali Chisapani project.

4.3 Power System Studies for power evacuation from Karnali, Chisapani project

Once implemented, the surplus energy from the Karnali Chisapani after meeting the demand in Nepal shall have to be wheeled to India and through it to Bangladesh, Sri Lanka, and Pakistan and through Pakistan to Afghanistan. Nepal is currently augmenting its cross border transmission infrastructure to handle addition energy flows to India and vice-versa. Bangladesh-India interconnection on western border of Bangladesh presented loaded at 500 MW. It has a capacity to wheel additional 500 MW with augmentation of sub-station capacity and addition of conductors. Feasibility studies for interconnecting India power grid with that of Sri Lanka and Pakistan have been completed. The construction of these interconnections can start immediately. The Afghanistan-Pakistan power transmission interconnection has also been studied under the CASA 1000 project by SNC Lavalin. Though studied for flow of 1000 MW from Central Asia to Pakistan via Afghanistan, this segment of the CASA 1000 can be redesigned to carry additional energy flows from Karnali Chisapani Project with appropriate strengthening of the system design.

Each SAARC Member State has its Power System Master Plans in place. A review of these plans will inter-alia help identify the volume of cross border energy flows from Karnali Chisapani project that can be facilitated through the existing and proposed transmission systems in and between each of these countries and also identify the additional cross border interconnections required to facilitate energy flows from Karnali project. Associated transmission systems to wheel the energy from the Bus-Bars of Karnali Chisapani hydropower project to load centers in participating countries should form an integral part of a feasibility study of the project. Therefore, the power evacuation study for the Karnali Chisapani project should take cognizance of the findings of the above review. The review should include:

i. Assessment of the locations of the load centers.
ii. Transmission Line Studies (Load flow and transient studies)
iii. Delivery point for the power transmission requirement, such as voltage and number of circuits, reactive power requirements, etc.
iv. Interface with the existing system and preferred substation arrangement at the receiving end.

v. Transmission voltage and alternatives

vi. Substation requirements at interconnection points to the regional electricity network.

vii. Review of system load curves and load forecast in the six countries.

CHAPTER 5: TERMS OF REFERENCE FOR HIRING CONSULTANTS FORKARNALI (CHISAPANI) MULTIPURPOSE PROJECT

5.1 Background

The catchment area of the river Ganges spans over into China, India, Nepal and Bangladesh. Nepal is located in the Ganges basin. Three major tributaries of Ganges originating in China and flowing down to India to join the Ganges river-- the Karnali, the Sapta Gandaki and the Sapta Koshi Rivers contribute about 41% of the total annual flow of the Ganges.

The Karnali (Chisapani) Multipurpose project (KCMP), located on the Karnali River in western Nepal, will be the largest water resources development on the Indian subcontinent and one of the largest in the world. Its benefit includes major hydropower production and flow regulation (four fold increase in dry season flow) for increased agriculture in India and Nepal. Other benefits of the project are flood control in Nepal, India and Bangladesh. A detailed feasibility study conducted in 1986-1990 under the loan assistance from IDA has revealed that a 270m high embankment dam with an underground powerhouse of 10,800 MW capacity (18 units of 600 MW each) can be constructed on the Karnali River at Chisapani site, in the far western region of Nepal. In addition, it will provide peaking hydropower predominantly for the northern power region of India and flow regulation for increased irrigation development of 3.2 million hectares in India and 191,000 hectares in Nepal. The project will also provide flood control and navigation facilities. The site is located about 600 km west to Kathmandu and about 500 km east to Delhi. The main features of the project will also include a 84m high reregulating dam 8 km downstream of the main dam required for the two reasons-- first, to provide uniform daily flows downstream to ensure full irrigation benefits both in Nepal and India, and second, to maintain the natural riverine environment.

A brief background of the prevailing power market in South Asia is given in Chapter 4 of this report. One can observe that the size of the power market, generation profile, fuel mix, generation sources due to introduction of new technologies, demand-supply scenarios, socio-economic conditions have undergone a sea change since the FSR of the Karnali project was prepared in 1989. It is, therefore, essential to reassess several factors while revising and updating this feasibility study to reflect the context of the present situation. The activities to be undertaken from the resulting changes have been highlighted in Chapter 3 and should form an integral part of the revision/updating of the FSR of the Karnali project.

In this backdrop, SEC desires to procure the services of internationally recognized consulting firm ("Consultant") having competent team of specialists to review and update the Feasibility Study and conduct environmental and social studies of Karnali (Chisapani) Multipurpose Project in Phase I and perform Detail Engineering Design and prepare Bidding Documents for the project in Phase II. All services of the Consultant described in the following section shall be performed in close co-operation with SEC, the Project Executing Agency. This Terms of Reference (TOR) attempts to outline the Consultant's tasks during execution of the services as detailed as possible. However, the Consultant shall note that the list of tasks and activities can by no means be considered as the complete and comprehensive description of the Consultant's duties. It is rather the Consultant's responsibility to critically verify the scope of services indicated and to include additional activities wherever deemed necessary, according to professional judgment and the knowledge of the Consultant. Accordingly, Consultant shall perform all works as necessary to fulfil the objectives of the Project.

The Client hereby invites proposals from the shortlisted Consultants, either solely or in association with non-short-listed competent Consulting firms to provide Engineering services for updating the Feasibility study and for conducting environmental and social studies of Karnali (Chisapani) Multipurpose Project.

The Client intends that Consultant appointed for Phase I study may continue in that role to carry out the Detail Engineering Design and prepare Bidding Documents for the project in Phase II, subject to the satisfactory performance of the consultant in the Phase I study. All the studies shall comply with the standard requirements practiced in this industry for the project of this size and magnitude. Final review and approval of the Consultant's work shall be done by the Client or any other review consultant or a panel of experts.

5.2 Project Information and Previous Studies

Following Project Information are based on the Feasibility Study carried out in 1989.

5.2.1 The Project

The Karnali (Chisapani) project, located on the Karnali River in western Nepal, would be the largest water resources development on the Indian subcontinent and one of the largest in the world. It includes a 270-m high dam (third highest in the World), a reservoir with 38,000 million m^3 of total storage (largest in the Indian subcontinent), a 700-m long underground powerhouse (longest underground powerhouse in the world, and 10,800 MW of installed capacity (second largest hydro plant in the World). Flood handling is facilitated by the large degree of flood storage available. The peak discharges are reduced to about one third of peak inflow for both the spillway and diversion facilities. The spillway is an ungated chute spillway capable of discharging a maximum flood flow of 19,200m3/s. Its benefit includes major hydropower production, dominantly for export into Northern India power grid and flow regulation (four fold increase in dry season flow) for increased agriculture in both India and Nepal.

The damsite at the narrowest, part of the gorge, is an embankment dam containing 45 x 10^6 m^3 of materials obtained from the alluvial fan area, 6 km downstream of the dam site at the location, where the river enters the Terai). The reservoir will extend up to 100 km upstream, and provide sufficient live storage to substantially regulate the river flow. The underground powerhouse sited within the left abutment will house 18 x 600 MW generating units. Power will be delivered into the Northern India grid by 5 x 765 kV transmission lines from the main power plant, while the power from reregulating powerhouse would be transmitted by one 220 kV line. The power plant has been planned as a peaking facility for the Northern India system, capable of operating at about 20% plant factor for firm energy production and at about 25% for average energy production.

Because of the highly variable plant output over a daily cycle, a reregulating facility is provided immediately downstream to ensure near-uniform downstream flows. This facility includes a low embankment dam and reservoir providing 100 x 10^6 m^3 of live storage, and a small 84 MW power plant.

5.2.2 Location & Access

The Chisapani project site is located on the Karnali River in Western Nepal. The Karnali drains the western third of Nepal and flows into India where it is named the Ghagra, ultimately joining the Ganges. The damsite is about 600 km west of Kathmandu and 500 km east of Delhi. At this point the river flows in a deep gorge about 4 km long through the Churia hills - the first foothills of the Himalayas. At the downstream end of the gorge, the topography and river channel change abruptly, the river having created large alluvial fan or delta composed largely of sand and gravel. The fan extends about 30km to the South of Indian border and is over 10 km wide in places. The two largest structural features of the project are thus sited in quite different conditions:

- The main dam ,at about the mid-point of the gorge, with very steep topography, abundant rock-out crops and a deep, fast flowing river channel.
- The reregulating dam, across the fan, about 6km downstream of the gorge mouth, crossing the flat area of the fan with no rock as a foundation and one main and several subsidiary river channels – up to a third of the fan area at this point is below water during the monsoon season.

The Royal Bardia Wild life Reserve adjoins the project area on the left bank of the river. Its proximity to the project is of considerable environmental significance.

Chisapani is accessible through East-West highway running across the length of the country in southern plains. Principal access into India extends south from Kohalpur and there is an existing railhead in India just across from the border town of Nepalganj some 100 km from Chisapani. With a population of about 40,000, Nepalganj is the nearest urban center and has an airport with daily flights from Kathmandu.

5.2.3 Site Investigation and studies

The assessment made on the feasibility study report, 1989 is based on interpretation of extensive data sets from site investigations including topographic mapping, geologic investigation, seismicity and tectonic measurements and sedimentation and hydrologic data collection, and socioeconomic and environmental field data collection programme, and so on. The geological and geotechnical investigations carried out for the underground works comprises five elements: geological mapping, geophysical survey, core drilling, aditing and rock testing. The investigation includes about 3200 m of core drilling, seismic refraction totalling to about 15,000 m, and almost 700 m of exploratory adits. Points of particular interest are angled drilling under the river and deep holes and adits into the area of the underground powerhouse complex.

5.2.4 Hydrology & Sedimentation

5.2.4.1 Hydrology

The catchment area of the Karnali River at the damsite is 43,679 km^2. It is second largest of the three major river system of Nepal. There are wide spatial and seasonal variations in temperature and precipitation both throughout the basin. The average long-term flow is estimated at 1389 m^3/s. There is a marked seasonal variation in flows with a distinct seasonal variation. Average monthly flows range from 309 m^3/s in February up to 4359m^3/s in August. The flood hydrology was studied by frequency analysis and a Probable Maximum Flood (PMF) was also derived. The peak flood recorded was about 21,000 m^3/s in 1983. Although more data would be useful, the data base is adequate for flood design. The PMF used for design of the spillway has a peak inflow of 63,000 m^3/s. Major hydrological features of the project are summarized in the following table.

Table 5.1: Hydrological Features of the Project

Hydrologic Characteristics	
Drainage area of basin	43,679 km^2 (30% of Nepal)
No. of Meteorological stations in Karnali basin	36
No. of gauging stations in Karnali basin	5
Long-term average annual flow	1389 m^3/s
Average dry season flow (November-May)	451 m^2/s
Average wet season flow (June-October)	2690 m^3/s
Average annual basin precipitation	1247 mm
Average annual runoff	1003 mm
Mean annual snowfall for Karnali basin	4400 million m^3 of water equivalent
Runoff ratio	0.80
Runoff volume	43.8 km3/yr
Highest recorded flood	21,700 m^3/s (September 11, 1983)
Design Floods	
Probable maximum flood (PMF)	63,000 m^3/s
Probable maximum Precipitation (PMP)	499 mm (3-day PMP)
Flood (1 – in – 10,000 yr)	32,900 m^3/s
Flood (1 – in – 1,000 yr.)	26,600 m^3/s
Flood (1 – in – 100 yr.)	20, 600 m^3/s
Sediment average load	260 x 10^6 t/yr
Equivalent specific yield	6000 t/km^2
Climate	
Average annual rainfall	2200 mm over 80% falling during the monsoon
Temperature	Varies; 15^{o}c in January to 30^{o}c in May

5.2.4.2 Sedimentation

The large reservoir created at Chisapani will tap all the incoming sediments within the reservoir and may lead to channel degradation to the river system downstream. The suspended sediment load measured over the 3 monsoon months in 1987 was estimated at 84 million tonnes. The maximum measured concentration of 45 400 mg/l occurred in July 26 during the peak flood event of the season. Allowing for unmeasured bed load and the unmeasured dry season load, the total load for the year was estimated at 107 million tonnes. Grain size analysis of the suspended sediments showed that the sediments consisted of nearly equal proportion of silt and sand. Year 1987 was a low flow and low flood year for Karnali River, thereby requiring some adjustment. HPC study estimated 260 million tonnes as the annual average sediments applying sediment rating curve derived from the 1987 data and taking into consideration sediment loads measured for other basins in the subcontinent. The estimated sediment load is subject to change as more data become available. With the sediment load estimated, reservoir sedimentation is not a significant problem for the selected reservoir level (FSL at 415 m) of Chisapani project. The live storage volume would be reduced by only by 17% even after 50 years. The sediments would not encroach on the power intake until approaching 100 years. The potential for river channel degradation downstream of Chisapani was studied. However, the database was inadequate to draw a firm conclusion. HPC study suggests conducting investigations, especially at the downstream of Girjapur barrage to quantify the potential river channel degradation and identify mitigation measures.

5.2.5 Geology, Seismology and Construction Materials

5.2.5.1 Geology

iv. The Dam site

The Karnali River flowing through the southern part of the Sub-Himalayas has cut through the Churia Hills to form a prominent gorge referred as “the Karnali Gorge”. It is about 4 km long. The dam site is located mid-way along the gorge. Geological Conditions at the damsite over a large area are quite uniform but wide variations at places. An almost complete sequence of Siwalik series rocks is exposed along the gorge due the fact that the beds dip generally in an upstream direction. The bedrock at the dam site is an inter-bedded sequence of sandstone and mudstone with subsidiary siltstones and sedimentary breccia. The rock types are a mix of about 60% sandstones, 20% to 30% mudstones and minor occurrences of breccia, marl and shale. The rocks dip at a relatively uniform slope of about 45^0 upstream and slightly oblique across the gorge. The sandstones are of medium strength and inter-layered with the generally weak mudstones. The thickness of overburden ranges up to 14 m, averaging 5 m, and there is up to 12 m alluvium in the riverbed area. There is no evidence of any significant faulting at the damsite.

5.2.5.2 Reservoir Area:

The reservoir of Karnali (Chisapani) extends up to 100km upstream along the Karnali river valley. Its area at full supply level is 339 square kilometres. The reservoir lies almost entirely on rocks of Siwalik series, and colluvial, alluvial and residual soils. The upper part of the reservoir lies on limestones of the Lakharpata formation to the north of the MBT. There is no evidence of potential for significant reservoir leakage. Slope instability is present in the reservoir area due to failure on bedding planes in the lower and middle Siwalik formations and non-structural failures in the upper Siwalik rocks. This may result in some landslide activity. However there is not any significant risk of landslide-induced waves threatening the dam stability.

5.2.5.3 The Reregulating Facility:

The reregulating facility is located on the Karnali river alluvial fan some 6 km downstream from the mouth of the Gorge. All structure are sited on deep river gravels which have been derived primarily from the resistant rocks of the lesser Himalayas, but with a contribution from the more local sources of the lower Siwalik formation. The study concludes that the fan is composed of sandy gravels with cobbles and possibly boulders. However, the Condition of this area is less understood, mainly, because of the difficulties of investigating at depth below the water table due to the presence of boulder material encountered very often. Owing to this, the depth to bed rock and hence the possibility of sealing the dam foundations down to rock is uncertain. Furthermore, the permeability of the alluvium and the characteristics of the alluvium below the top 3 to 4 m are also uncertain.

5.2.5.4 Seismology

The continuing convergence of the Indian and Eurasian continental plates has created a series of thrust or fault zones of continental dimensions. MCT lies at a considerable distance (125 km) from the site. It will have limited significance for design purpose. The MBT is considered capable of generating a Magnitude (Richter scale) 8 earthquake and the HFF a Magnitude of 6.5. The significant duration of the acceleration at the site associated with the magnitude of 8 MCE will be over 60 seconds, whereas that due to the relatively small magnitude 6.5 in the HFF will be quite short, about 15 seconds. The preliminary design acceleration selected for the main dam studies reflect the above characteristics with a peak acceleration of 0.60g and duration of over 60 seconds. The probabilistic studies derived an acceleration value of 0.5g for the design of concrete structures, such as spillways and the powerhouses.

5.2.5.5 Construction Materials

A total of about 60 million m^3 of construction materials consisting of 9 million m^3 of impervious materials, 39 million m^3 of shell fill, 6 million m^3 of filters, 4 million m^3 of aggregates, and 1.5 million m^3 of riprap are required for Karnali project. Ample good quality gravel fill is available in the alluvial fan immediately downstream from the Chisapani gorge. This fill is considered much superior to any rock fill which can be quarried locally because of high strength and low compressibility in comparison with the much weaker rock material. The fan alluvium can be readily processed to yield filter and transition materials of the required gradation. Besides, there are a number of potential sources for riprap including the boulders from alluvial fans and valley floors of the transverse *kholas* (streams) downstream from the dam site.

5.2.6 Project Configuration and General arrangement

The Karnali (Chisapani) Multipurpose Project consists of the following five main features:

- Main civil structures consisting of (i) the Dam and Spillway; (ii) Power Facilities including intake, power tunnels, penstock shafts together with penstock, powerhouse and tailrace
- Hydromechanical equipment including gates, stoplogs, and penstock pipes, so on.

- Electromechanical equipment including turbines, generators, power transformers, and so on.
- The transmission facilities which deliver the power to Indian power system
- Reregulating facilities

5.2.6.1 Main Dam

The Main Dam is 270 m high from the lowest foundation level to crest elevation. The gravel fill embankment dam contains over 45 million cubic metres of fill material. The spillway, diversion and outlet facilities are conventional in concept. Flood handling is facilitated by the large degree of flood storage available – peak discharges are reduced to about one third of peak inflow for both the spillway and diversion facilities. The spillway is an ungated chute spillway capable of discharging a maximum flood flow of 19,200 m3/s. It is 860 m long. It terminates at a flip bucket and ultimately into the plunge pool. The large storage reservoir with live storage of 16.2 km3 (equal to 37% of average annual runoff) created almost four-fold the dry season flow in the Karnali River. This in turn increases agricultural production in Nepal and India both. The Karnali will be diverted during construction through two 15 m diameter diversion tunnels, each 2400 m long.

5.2.6.2 Power Facilities

The power facilities are located on the left bank of the damsite. The power facilities incorporate 18 generating units of 600 MW each producing 20,842 million kWh/yr, housed in an underground cavern of size 705 m x 27.7 m x 50 m and include six power tunnels of 15 m diameter connected to six bell mouthed intake structure with gate shaft. The power tunnels convey water into eighteen steel lined penstocks of 7.2 m dia through six vertical shafts of 14 m diameter. Transformers and valves are housed in a separate underground cavern some 700 m long.

5.2.6.3 Reregulating Dam

The reregulating dam with maximum height of 24 m is located at about 8 km downstream of the main dam mainly for the following two reasons:

(iii) to provide uniform daily flows downstream to ensure full irrigation benefits both in Nepal and India, and

(iv) to maintain the natural riverine environment.

Regulated flow from Chisapani would be used to irrigate 191,000 ha in Nepal and 320,000 ha in India. The regulating facilities include a 6km long dam, an 84MW powerhouse and two irrigation off-takes for irrigation development in Nepal.

5.2.6.4 Power Evacuation Facilities

Evacuation of power from the main power plant (10,800 MW capacity) to the Indian system will be achieved by means of five 765 kV transmission lines, while the power from reregulating powerhouse would be transmitted to Indian system by one 220 kV line.

5.2.7 Project Benefits

5.2.7.1 Power Benefits

The Chisapani project has been designed as a peaking hydro plant for power exports to the Northern Indian power system of India comprising the States of Haryana, Himachal Pradesh, Jammu and Kashmir, Punjab, Rajasthan, Uttar Pradesh and the union territories of Chandigarh and Delhi. The Chisapani project will have comparative advantages as a low cost source of peaking capacity in this system due to its large reservoir storage capacity, high degree of flow regulation, and low incremental generating capacity costs, as well as its relative proximity to major load centres in Northern India. Due to the economic advantages, the recommended size for the Chisapani project in this feasibility study is the maximum practical installed capacity of 10,800 MW, which corresponds to an annual capacity factor (CF) for dry season firm energy generation of about 20%.The power and energy benefit from main power plant at Chisapani and at the power plant at reregulation dam is presented in the table given below.

Table 5.1: Power and Energy Benefits

Description	Main Power plant	Kauriyala Power Plant at Reregulation Dam
Rated generating capacity	10 800 MW	84 MW
Firm Energy	15 266 GWh/yr	585 GWh/yr
Average energy	20 842 Gh/yr	621 GWh/yr

The total discounted benefits of power generation are estimated to be US$ 15,389 million discounted at 10% of the initial project on power date of November 2003.

5.2.7.2 Irrigation Benefits

The Chisapani reservoir provides sufficient storage regulation to increase minimum dry season flows in the Karnali River by about 300% resulting into a four-fold increase in natural dry season low flows. The Chisapani project will enable large-scale irrigation development in Western Terai on both sides of Karnali River. A total gross command area of 238,709 ha could be irrigated in Nepal Terai between the Rapti River in the east and the Mahana River in the west, of which 191,000 ha is the net area available for irrigation after deducting irrigation infrastructure, roads and villages.

Two large irrigation canals divert water from the Girijapur Barrage on the Karnali River about 8 km south of the Indo-Nepal border. The total cultivable command area totals 3.2 million ha including Saryu (1.2 million ha) and Sarda Sahayak (2.0 million ha). Irrigation service and agricultural production is still being expanded in both areas. There are other large irrigation schemes farther downstream. Irrigation service and agricultural production is still being expanded in both areas. The regulated flow of Chisapani project will enable increased dry season irrigation in India at the existing Karnali (Ghagra) basin irrigation developments in the Sarda Sahayak and Saryu regions, as well as further downstream.

5.2.7.3 Other Benefits

Other potential benefits that were assessed in the study are flood control and navigation. The flood control benefits in Nepal are estimated to be about US $ 4 million, discounted at 10% to the project in service date. The study has estimated flood benefits farther downstream in India and Bangladesh. The order of magnitude of these additional downstream benefits estimated is about US $ 20 million. Some navigation benefits will also be created in the reservoir area and its vicinity. The discounted navigation benefits estimated at about US$ 1 million.

5.2.7 Socio-Economic and Environmental Issues

The study concludes that the project will cause substantial socioeconomic and environmental impacts, which require further investigations and studies for their effective mitigation. The project requires resettlement of about 60,000 people. It was planned to resettle them, primarily into currently undeveloped areas within the Karnali irrigation command area. Environmental impact includes unavoidable encroachment into the existing Royal Bardiya Wildlife Reserve, which is located in the vicinity of the main dam and reregulating facilities and potential adverse impacts on the Gangetic Dolphin and Garial crocodile. A special consideration of these impacts is clearly an essential element of the decision to proceed with Chisapani.

- **Project Implementation**

It was envisaged an implementation period of 17 years consisting of 5 years for pre-construction activities, followed by nine and half years for project construction including generation from two units and ultimately 4 years for installation of remaining 16 units. A period of five years (1990 to 1994) was allowed for these latter pre-construction activities, ending with the award of the major construction contract. The time required for construction was conservatively estimated at almost nine years i.e. from a January 1995 start to the on-power date for the first two (of eighteen) units, i.e. in November 2003. Installation of the remaining units was tentatively planned at a rate of one every three months, terminating in November 2007. An annual cash flow distribution, beginning with expenditures in 1990, show that about 3% ($ 80 million) would be expended during the five year pre-construction period, and about 85% of the total would be expended before the initial on-power date and the remaining 12% during installation of 16 units.

- **Capital Cost**

The capital cost of the project at 1998 price level was estimated at US$ 4,890 million consisting of US $ 1,667 million for civil works, US $ 1,907 for electromechanical works and transmission lines, and the remaining US $ 1,316 million for access, infrastructures, resettlement and environmental mitigation, engineering and administration, and so on..

- **Economic Evaluation**

The equivalent economic cost of the project for the November 2003 in service date is US $ 6,808 million. The corresponding gross economic benefit is US $ 16,780 million. The net economic benefit is US $ 9,972 million, the benefit /cost ratio is 2.46 and the corresponding internal rate of return is 27%. The net economic benefit will be equivalent to about US$ 1,000 million per year to be shared between the two countries. These economic measures demonstrate that the project is feasible and economically very attractive.

5.3 Objectives of Carrying the Study

The main objective of the study is to prepare the Project for implementation from the current level of Feasibility Study. The overall objective of the consulting service is to update the Feasibility Study to develop the project as a regional project of multipurpose nature with storage for irrigation, electricity generation, flood mitigations, and so on, and conduct environmental and social studies of KCMP in Phase I, and continue to carry out Detail Engineering Design along with detailed structural design of the project and preparation of construction drawings and schedules and to prepare tender documents including tender drawings and construction plan, in Phase II, subject to the satisfactory performance in Phase I. It is also intended to prepare the documents to meet leading multilateral agencies' requirements for implementation of the project so that SEC shall be in a position to facilitate construction of the project immediately after completion of the study.

The specific objectives of the consulting services at different phases of the study are outlined as follows:

PHASE I STUDY

- Review of Feasibility Study and other available relevant reports/data and update/improvement in the data/information contained in the existing studies including feasibility study 1989 covering the contents but not limited to the content provided in Feasibility study 1989.
- Review and update topographic maps for dam site, powerhouse site and other project areas as necessary;
- Review and update geological and geotechnical studies/ investigations.
- Review and update seismological investigation and studies;
- Review and update hydrological and sedimentological studies,
- Review and update project configuration and project components and conduct optimization study to determine the optimum size of the project taking into account all the multipurpose benefits and the long-term potential for development in the Karnali River basin.
- Review and update reservoir simulation study
- Conduct regional power market study including assessment of electricity demand projections in South Asian countries. Carry out the studies to fill the gaps in the feasibility study report , comprising of:
  - (i) Power Market study,
  - (ii) Assessment of willingness and affordability of consumers in Afghanistan, Bangladesh, India, Nepal, Pakistan and Sri Lanka; to pay for the power from the Karnali (Chisapani) project, and
  - (iii) Power system studies for evacuation of power from the proposed project to the power systems of the above countries; and carry out the studies and all activities listed in therein.
- Study different financial modality for implementation of the project of this magnitude and size and propose a suitable modality for implementation of the project as regional multipurpose project.
- Carry out power evacuation study and prepare potential power evacuation schemes
- Review and update project benefit streams including electricity generation, irrigation, flood control, navigation, etc.
- Review and update project cost, schedule, economic and financial analysis

- Review project environmental and social studies and conduct environmental and social impact analysis, cumulative impact assessment, resettlement action pan and so on, for the Project.
- Conduct necessary study to develop the project as multipurpose project covering all necessary aspects to strengthen the existing studies including feasibility study 1989.
- Update the Feasibility Study of the project as a regional project of multipurpose nature with storage for irrigation, electricity generation, flood mitigations, and so on and update different activities mentioned above.
- Prepare an updated cost estimate of the Project.
- Assess the pricing of electricity produced from the Project, and analyse it in relation to the prices of alternative generation options from renewable energy sources such as solar PV, wind, and others in the regional countries.
- Evaluate the project benefit streams including the downstream benefits in terms of irrigation, flood control and navigation. Evaluate the project costs including cash flow, and economic and financial analysis;
- Analyse financial structure and plan including potential source of financing (including investment by stakeholder member states, international financial institutions, etc.} along with the associated modalities for implementation of the project as a regional hydropower project
- Analyse and recommend appropriate institutional arrangement for project implementation.
- Carryout risk analysis on quantities as well as qualitative basis with respect to the implementation of the project as a regional hydropower project,

PHASE II STUDY

- Carry out mathematical modelling and conduct physical modelling of dam, spillway and intake structures;
- Conduct Detail Engineering Design of the project components including detailed structural design and prepare detailed design drawings (construction drawings) and construction schedules.
- Prepare prequalification documents and tender documents for the construction of the project and associated infrastructure.

The consulting firm hired for the Phase I of the study will be retailed for the Phase II subject to the satisfactory performance in Phase I of the study.

5.4 Scope of Services

The scope of consulting services in preparation of the project for implementation shall be implemented in the following two phases namely Phase-I, and Phase-II. Phase-I, basically is to update the feasibility study of the project as a regional project of multipurpose nature with storage for irrigation, electricity generation, flood mitigations, etc., conduct environmental and social studies, and studies relating to pricing, power market and power systems. Financial structure and plan including potential sources of financing (including investment by stakeholder member states, international financial institutions, etc.), along with the associated modalities for implementation of the project as a regional hydropower project.

Phase-II, will cover the carrying out detailed engineering design and preparation pre-qualification and bidding documents including tender drawings for construction and suggest the contracting modality (design-built or EPC). In the initial phase of study the client intends to procure consulting services only for Phase I study. The Phase II study will be carried out as follow on activities subject to the outcome of Phase I of the study. It is suggested the Request for Proposal should include a provision to retain the Phase I consultant to undertake the tasks in Phase II, if the performance in Phase I is found satisfactory.

Phase-I:

- Review and update the Feasibility Study in considerations of the project as a regional project of multipurpose nature with storage for irrigation, electricity generation, flood mitigations, etc.:
- Review and carry out the EIA/SIA/CIA studies and Resettlement Action Plan
- Carry out the Power Market Study of Afghanistan, Bangladesh, India, Nepal, Pakistan and Sri Lanka; Asses willingness and affordability of consumers to pay for the power purchases from the Karnali Chisapani project within these countries, and Power System Studies for evacuation of Karnali energy to the power systems of the above countries.

- Carryout economic and financial analysis of the project and prepare a financing structure and plan including potential source of financing (including investment by stakeholder member states, international financial institutions, private sector, or a consortium of the financers) along with the associated modalities for implementation of the project as a regional hydropower project will also has to be studied. Besides, risk analysis on quantitative as well as qualitative basis with respect to the implementation of the project as a regional hydropower project will have to be performed.

Phase-II

- Mathematical and physical modelling of hydraulic structures,
- Detailed engineering design and construction drawing preparation,
- Preparation of prequalification documents for contractors,
- Preparation of bidding document.

The services carried out by the Consultant shall be reviewed periodically by independent Panel of Experts (POEs) appointed by SEC. The reports submitted by the consultant shall be accepted by SEC after approval by the POEs.

5.4.1 Phase I Study

The feasibility study shall be updated in considerations of the project as a regional project of multipurpose nature with storage for irrigation, electricity generation, flood mitigations, etc. In Phase I. The Consultant shall update/improvement in the data/information contained in the existing studies including feasibility study 1989 covering the contents but not limited to the content provided in Feasibility study 1989. The detailed scope of works under this assignment under Phase I study of the project covers following tasks/activities.

Task 1 Inception report on the assignment
Task 2 Review and update site investigation and studies
Task 3 Review and update hydrological, meteorological and sedimentological studies, etc.
Task 4a Regional power market and associated studies

Task4b Willingness and affordability of consumers to pay for the power purchases from the project

Task 5 Review and update power evacuation study

Task 6 Review and update project configuration and project components

Task 7 Review and Update Project optimization Study

Task 8 Review and Update Reservoir simulation

Task 9 Review/update and conduct environmental impacts and social safeguard studies

Task 10 Review and update project benefit streams

Task 11 Review and update of Feasibility Study Including Economic and Financial Analysis

Task 12 Analysis of institutional arrangement for project implementation

Phase-I Study

The detailed scope of works under this assignment under Phase I study of the project is presented in the following paragraphs.

Task 1: Inception Report on the Assignment

Main activities under this task shall include review of existing reports, applicable guidelines/norms, available data, project review, planning and initiation of the field work and up-dating of the work plan submitted with the proposal on the basis of the findings of the review.

The Consultant shall, immediately upon initiation of the inception assignment, begin collection of all relevant reports, data and maps from different secondary sources and carry out the review study. In the project review, all information/data of the project should be subjected to critical analysis and scrutiny in order to establish a realistic understanding of the type and scope of additional information/data required for subsequent analysis/design. As part of the project review, the Consultant shall:

a. Identify key areas, which will require additional field work or demand major efforts in data collection/ investigation;

b. Review the Feasibility Study Report and other documents;
c. Establish methods and procedures for further studies

The Consultant shall undertake an Inception visit to the project site covering all project components and carry out engineering studies with respect to the topographical and geographical features, geological, hydrological, meteorological and sedimentological aspects of the project area. Besides, environmental and social aspects will also be studied during the inception site visit.

In parallel with data collection and field reconnaissance, the Consultant shall prepare a time schedule with milestones and specific key dates. This schedule shall be submitted by the Consultant as part of the proposal, suitably updated to reflect the additional information/ data needs.

The Inception Report shall summarize the results of the review of existing data/ reports, summarize the results of the field reconnaissance, discuss the key data/information gaps requiring additional field work/investigation, data collection, data verification, and describe the approaches and methodology that the Consultant intends to follow in carrying out various activities to complete the assignment. The Inception Report shall also include the updated methodology and work plan for the studies, detailed schedule for each task, detailed field investigation plan, manning schedule of each personnel for effective mobilization. All collected data/information, reports; documents should be subject to critical scrutiny in order to establish a realistic understanding of the field situation, data gap, additional investigation and studies to be included in the study. The Consultant shall make a presentation of the Inception findings to SEC with the use of appropriate visual aids.

Task 2: Review and Update Site Investigations and Studies

The objective of this task is to collect all reports of previous field studies and investigations of the project, then review and update them. The review shall be focused on identifying the necessary data gaps to update the study based on refinements to the Project arrangement required by engineering tasks being performed in parallel. The consultant shall then carry out required supplementary field investigation after getting approval from the client. Finally after obtaining the report of those supplementary investigations, the consultant shall update and validate the respective field investigation. The results of this activity together with the details of the field investigation shall be presented in the Updated Field Investigation Report and shall be summarized in the Updated Feasibility Study Report and finally shall be used in the engineering design of the project. The review and updating of site investigation shall include but not limited to the followings.

a) Topographical Survey

The Consultant shall review the topographical maps prepared in the previous studies including feasibility study 1989 and conduct site verification works to identify any data gaps in topographic maps, established datum and field survey works conducted earlier. The data gaps shall also be identified with respect to the planned engineering design changes under the scope of current study. If some of the earlier investigations or the topographical survey needs to be verified through fresh investigations or additional topographical survey is required to be performed for the planned engineering studies to produce final report acceptable for the proposed detail design work; the consultant shall list all the required additional topographical survey works and propose the required additional investigations to the client. The Consultant shall carry out additional topographical survey after getting approval from the Client. After obtaining the survey data and topographical maps of any supplementary field investigations, the consultant shall update the topographical maps in standard scale and incorporate them in the engineering studies under the current study. LIDAR mapping with ground verification shall be carried out to update the topographical maps.

b) Hydrological, Meteorological and Sedimentological Investigation

The Consultant shall review the hydrological, meteorological and sedimentological investigation carried out in the previous studies including feasibility study 1989 identify data gaps, if any, and acquire all relevant data from different secondary sources to update the feasibility study. The Consultant shall perform, *inter alia*, the following activities:

- Acquire all the data related to stream flow and other hydro-meteorological data (Precipitation, temperature, relative humidity, evaporation, solar radiation, wind speed etc.) from the gauging and climatic stations in the catchment area of Karnali Chisapani Project.
- Supplementary data collection on hydrology and sedimentation during the study period to refine them,
- As a part of sediment investigation, study and monitoring, the consultant shall:

    - Acquire the historical suspended and bed load sediment data/information on Karnali river
    - Study catchment characteristics from sediment point of view
    - Establish and conduct sediment sampling and analysis program of suspended and bed load sediments. At least 2 sets of samples per day shall be collected at dam site for rainy seasons (4 months) and one set of samples per week shall be collected for the remaining period in a year for concentration analysis. For the purpose of this clause, a "set of samples" shall be defined as a number of individual samples collected by depth-integrating sampler at not less than three verticals (mid channel and at two quarter points) across the river so as to have a good representation of the mean sediment concentration of the river at the time of sampling;
    - Collect one set of samples per week for rainy season and one set of samples per month for the remaining period in a year for particle size distribution and mineralogical (petrography) analysis;
    - Develop a rating curve of suspended sediment load of the river;
    - Estimate the bed load contribution to the total sediment load by means of site measurements or other means appropriate;
    - Carry out reservoir sedimentation studies
    - Estimate the possible ranges of sediment load to the power stations and recommend suitable value for design;
    - Carryout the water quality analysis to determine the corrosive effectiveness (hardness).

- Collect secondary data on climate change to examine its potential impact on the project;
- Investigation on possibility of aggravated erosion in the catchment area due to change in land use pattern, road and other infrastructure construction in the catchment' which may result in rapid sedimentation. The consultant shall make a comprehensive investigation of the problems with a view to propose measures to reduce the long term sedimentation.

c) Geological, Geotechnical, and Construction Material Investigation

The consultant shall review the geotechnical; geological and geophysical investigation carried out in the previous studies including feasibility study 1989; identify data gaps, if any and conduct necessary investigations to update the feasibility study and relevant investigations required for detailed engineering study in Phase II study. The consultant will check and verify the locations of boreholes, ERT and relate them with project requirement. The Consultant shall perform, *inter alia*, the following activities:

i. The consultant shall review and check the engineering geological mapping prepared based on the topographic maps at 1:500 scale at the dam site, spillways, intake, power facilities including power tunnel, powerhouse, transformer cavern, tailrace, etc. in order to obtain more data in respect to rock mass confirmation.
ii. The consultant shall review and check the engineering geological mapping prepared based on topographic maps at 1: 5,000 scale of the reservoir for assessment of slope stability, and leakage.
iii. The consultant shall review the geology at the reservoir, dam site and reregulating facility and update as necessary, and identify the additional geological and geotechnical investigations to be carried out and carry out the investigations. The consultant shall review and check the core drilling and geotechnical investigation in rock/overburden at dam site, tunnel, powerhouse sites, and other areas carried out in the previous study.

iv. The consultant shall review and check the Electrical Resistivity Tomography (ERT) carried out in the previous study for assessment of depth of overburden and rock quality in the project area.

v. The Consultant shall review and check the test adits and its geological loggings and related investigations.

vi. The consultant shall review and check geological and geotechnical investigations performed at the borrow areas and quarry areas for construction materials such as sand, aggregates, filter materials, etc. The Consultant shall assess and make fair estimate of volume of each material from each of the borrow areas available for use during construction.

vii. The Consultant shall examine the need of further geological/geotechnical investigations for the detailed engineering design of the project including in-situ tests --rock mechanical testing for initial ground stress measurement including "hydro fracturing" for an investigation for underground powerhouse, block shear, plate bearing, and so on at the locations deemed necessary by the Consultant.

viii. The Consultant shall carry out investigation on geological and hydraulic conditions in the fan area affecting design and cost of the reregulating facility.

ix. The consultant shall update the information on construction materials including the core fill materials. The Consultant shall carry out supplementary field investigation required for updated feasibility study in Phase I and detailed engineering design in Phase II. For this, the Consultant shall identify required field investigations and perform it after getting approval from the Client. The cost of which will be covered from the Provisional sum.

d) Seismological Investigation

The reservoir created by the high dam of the Karnali Chisapani Multipurpose project will be a major structure located in an environment with a potential for extreme event of earthquakes. The security of all aspects of the design under such conditions is of paramount importance and must be fully investigated. The consultant shall review the seismological investigation carried out in the previous studies including feasibility study 1989; identify data gaps and conduct necessary investigations to update the feasibility study and relevant investigations required for detailed engineering study in Phase II study. The Consultant shall perform, among others, the assessment of magnitudes and locations of past earthquake events. The program should include determination of fault plane and focal depth for some of the larger events near the dam site, headrace tunnel alignment, powerhouse site, within and in the vicinity of project area. Information available from Department of Mines, Government of Nepal and any other reliable sources may be used for this purpose. Information and the data of recent earthquake that occur in April 25, 2015 need to be used for this purpose. Determination of dynamic response profiles for accelerations and velocities applicable at different elevations shall be carried out for the Design Basis Earthquake (DBE) and Maximum Credible Earthquake (MCE) including likely damage to structures for each case.

e) Investigation Related to Glacier Lake Outburst Flood (GLOF)

Detail investigation on existence and possibility on development of glacial lakes which may prove to be a considerable risk for the project and recommendation on the measures to minimize the risks of potential GLOF. The activities to be carried out by the consultant shall include but not limited to the followings:

- Detail investigation and monitoring by remote sensing with satellite imagery on existence and possibility of development of glacier lakes, which may prove hazardous for the project structures;
- Collect the historical GLOF data;
- Review the assessment of occurrence of floods, GLOFs, Cloud Outburst Floods (CLOFs) and Landslide Dam Floods (LDFs);
- Analyse & estimate potential GLOF hazard for the project; and
- Study carry out impact assessment of flood risks due to floods of different return periods including GLOF with possible mitigation measures.
- Perform a study of the hydraulic behaviour on the Arun river plain of incoming GLOFs by applying a hydraulic mathematical model;
- Perform a feasibility study of technical systems and operation of a comprehensive early warning of GLOFs to the communities along the Arun valley and propose a solution.

f) Environmental and Socioeconomic Survey

The Consultant shall review the environmental and socioeconomic survey and collect additional required to update the study in line with the requirements of Nepal legal requirements and .to meet the requirements of IFC Performance Standards on the Environmental and Social Sustainability. Environmental and social study shall be updated to reflect the current information on the condition of the forest and agricultural resources and to collect information on resource use by the local population. For this, full-fledged Environmental Impact Assessment (EIA), Cumulative Impact Assessment (CIA), Social Impact Assessment (SIA), Rehabilitation Action Plan (RAP) require to be conducted based on the current requirement of the Nepal environmental laws, and that of the multilateral funding agencies including World Bank(WB), Asian development Bank (ADB, etc. and the bilateral agencies.

The Consultant shall conduct social economic surveys (census and sampling) to collect the socio economic information on the project impacted people for the preparation of environmental and social mitigation plans.

Task 3: Review and Update Hydrological & Sedimentological Study

The consultant shall review the hydrological, meteorological and sedimentological studies carried out in the previous studies including feasibility study 1989; assess the adequacy of available data and identify the gaps, if any and undertake the respective studies with the use of additional data series collected after the 1989 study to refine the long-term stream flow, flood frequency analysis including PMP and PMF, reservoir simulation, power potential, sediment flow assessment and climate change impacts which will be used for update of the Feasibility Study Report and subsequently in the Detailed Engineering Design in Phase II study. Dam Break analysis shall be performed for the GLOF and PMF studies as necessary. The Consultant shall perform and update, inter alia, the following activities including the following activities which will be performed under these studies:

- **Hydrological Study**
  - Long-term stream flow at Project site.
  - Flood frequency analysis and re-assessment of appropriate design flood.
- **Meteorological Study**
- **Sedimentological Study**
  - Sediment Yield Study
  - Sediment Management Study
  - Qualitative analysis of Sediment
- **Climate Change Impact Study.**

The Consultant shall analyse the effect of climate change such as erratic rainfall pattern on the river discharge. The activities to be carried out by the Consultant under this task include but not limited to the followings:

a) Assessment and estimation of long term mean flow of the Karnali River by using appropriate methods at the locations where appropriate.

b) Flood frequency analysis for determination of floods at different return periods and refinement of probable maximum flood (PMF) in appropriate locations particularly at the dam and powerhouse sites in consideration of meteorological data and determination of the design flood for spillway and diversion during construction considering, among others, the economic aspects.

c) Dam Break Analysis (DBA) for the planned Karnali Chisapani dam to determine the possible peak flood and associated water stages in the downstream reaches in the event of dam failure. The analysis shall generate, among others, necessary data leading to recommendation of a framework for early warning system and evacuation plan.

d) Assessment and estimation of sediment inflow into the planned Karnali Chisapani reservoir. The assessment shall estimate the sediment yield by using appropriate methods to determine the dead storage capacity and identify the needs of sediment management measures.

e) Assessment and estimation of flood flow due to Glacier Lake Outburst Floods (GLOFs), Cloud Outburst Floods (CLOFs) and Landslide Dam Floods (LDFs) for dam spillway design & safety.

f) Investigation of alternative sediment management options. The Consultant shall investigate the possibility of application of flushing, sluicing, density current venting, etc., through mathematical calculations or numerical modelling to determine the most appropriate method to be applied. Assessment of effect of dam construction on the river flow regime, particularly of downstream degradation and upstream aggradations, and recommendation for appropriate measures to minimize the adverse effects shall be presented.

g) Assessment of possible impact of climate change on hydrological characteristics by using different scenarios (without climate change, low climate change and high climate change) drawing from existing literature and data.

h) Assessment of meteorological aspects relevant to construction phase, such as duration of the rainy season, rainfall characteristics, number and duration of rainfall events, dry interval between rainfall events, temperature etc.

i) Reservoir operation simulation studies using appropriate computer model(s) in view of the regional power market and future demand.

j) Determination of reservoir storage in consideration to load pattern and its growth potential, technical and economic aspects.

k) Assessment of possible impact of upstream hydropower projects on the planned Karnali Chisapani Storage project

Task 4 (A) Regional Power Market study

In order to ensure that the upcoming project meets the expectations of the countries participating in the project, there is need to carry out the Power markets study of Nepal, Afghanistan, Bangladesh, India, Pakistan and Sri Lanka, the six beneficiary states of the project. All requisite activities, but not limited to the following should form part of the Power Market Study:

a) Review power market in Afghanistan, Bangladesh, India, Nepal, Pakistan and Sri Lanka,

b) Review the present and projected electricity demand-supply scenario of each of the above countries,

c) Review their load growth forecast at low, medium and high economic growth rate scenarios,

d) Review their existing and planned generation capacity additions to meet the demand;

e) Evaluate the potential of each of these countries meeting its own demand with and without commissioning of Karnali Chisapani project.

f) Evaluate whether implementation of Karnali Chisapani project would be a superior option for the participating member states to meet their demand, over their existing development plans and other options, such as the inter-regional power trade with Central Asia and South East Asia.

g) Review the seasonal variation of energy and capacity demand, and ability of the power systems to meet the energy and capacity demand of the relevant Member States;

h) Examine the existing and planned additions and alternative supply options in the six countries.

Task 4 (B) Review of willingness and affordability of consumers (in Afghanistan, Bangladesh, India, Nepal, Pakistan and Sri Lanka)

Willingness and affordability of consumers to pay for energy from Karnali Chisapani project, in participating Member States will be an important factor in determining the cost at which they will be willing to purchase power from the project. In case the cost of supply from Karnali is equal to or lower than the marginal cost of supply, participating Member States may be more than willing to buy electricity from the project. Bangladesh, Bhutan, India and Pakistan have independent Electricity Regulatory Commissions in place to determine electricity tariffs. In Nepal, electricity tariffs are fixed by the government of Nepal on the recommendations of Electricity Tariff Fixation Commission. Government regulates electricity tariffs in Afghanistan. It is, therefore, assumed that the prevailing electricity tariffs are rational and based on the willingness and affordability of consumers to pay. As such, only a broader review of prevailing tariffs and the potential of participating countries to absorb additional supplies from Karnali Chisapani project at comparable costs, without un-duly raising the tariffs may encourage these countries to buy electricity from project. The following aspects need to be assessed and factored in to evaluating the feasibility of the Karnali Chisapani project:

a) Energy Price Study covering evaluation of the average cost of generation within each of the participating countries;
b) Comparison of the pricing of electricity from Karnali (Chisapani) hydro power project, vis-à-vis the generation cost from planned generation projects by the Member States;
c) Study the comparative cost of generation in each Member State from alternative options, such as; hydro, thermal, solar, wind resources;
d) Market and energy price trends in the seven-member states; and
e) Evaluate the benefits to each Member State from purchasing power imported from the proposed Karnali Chisapani project.

Task 5: Review and Update Power Evacuation Study

Each SAARC Member State has its Power System Master Plans in place. A review of these plans will inter-alia help identify the volume of cross border energy flows from Karnali Chisapani project that can be facilitated through the existing and proposed transmission systems in and between each of these countries and also identify the additional cross border interconnections required to facilitate energy flows from Karnali project. Associated transmission systems to wheel the energy from the Bus-Bars of Karnali Chisapani hydropower project to load centers in participating countries should form an integral part of a feasibility study of the project. Therefore, the power evacuation study for the Karnali Chisapani project should take cognizance of the findings of the above review. The review should include:

a) Assessment of the locations of the load centers.
b) Transmission Line Studies (Load flow and transient studies)
c) Delivery point for the power transmission requirement, such as voltage and number of circuits, reactive power requirements, etc.
d) Interface with the existing system and preferred substation arrangement at the receiving end.
e) Transmission voltage and alternatives (asynchronous or synchronous interconnection),

f) Substation requirements at interconnection points to the regional electricity network.

g) Review of system load curves and load forecast in the six countries.

Task-6: Review and update project configuration and project components

The objective of this Task is to confirm the optimum overall project configuration and the project components. The Consultant shall review the general arrangement of Karnali (Chisapani) Project consisting of the following five main features and refine the design based on the field studies and investigations:

- Main civil structures consisting of (i) the Dam and spillway; (ii) Power facilities including intake, power tunnels, penstock shafts together with penstock, powerhouse and tailrace
- Hydromechanical equipment including gates, stoplogs, and penstock pipes, etc.
- Electromechanical equipment including turbines, generators, power transformers, etc.
- The transmission facilities which deliver the power to Indian power system
- Reregulating facilities

The consultant shall review the project arrangement and dimensioning of various project structures and refine them by necessary physical and computational (numeric) hydraulic modelling exercises. The numeric modelling is suggested to be carried out for the spillway, plunge pool, energy dissipating structures, weir (for reregulating dam), power intake, irrigation outlets, sediment flushing outlets, low level outlets, and so on. To confirm the results of the numeric modelling, the consultant will carry out physical modelling of key hydraulic structures to be identified in consultation with the Employer.

Task 7: **Review and Update Project optimization Study**

The objective of this task is to determine the optimum size of the project taking into account all the multipurpose benefits and the long-term potential for development in the Karnali River basin. The consultant shall review the optimization study performed in 1989 Feasibility study and update them adopting standard approach practiced in this industry, however the same shall not be inferior to the approach adopted In 1989 feasibility study. The Consultant shall carry out the optimization study in consideration of: (i) the South Asian power market, (ii) financial and institutional concerns from the regional perspective, in addition to accounting for all the multipurpose benefits and the long-term potential for development in the Karnali River basin.

Task-8: Review and Update Reservoir Simulation

The objective of this task is to assess the overall power and energy capability of Karnali Chisapani Project. The consultant shall review the reservoir simulation study performed in 1989 Feasibility study and update them adopting standard approach practiced in this industry, which however, shall not be inferior to the approach adopted In 1989 feasibility study. The consultant shall carry out the system simulation in light of the upstream development in the Karnali river basin (on-going and proposed), and current generation capacities (in the regional countries and the demand for electricity). The other upstream storage type hydropower development (such as West Seti, Nausalgad) will further firm up the energy generation capacity of Karnali Chisapani. The Consultant shall also consider the influence of these developments on project benefits such as irrigation and flood control.

Task-9: Review/Update and Conduct Environmental Impact and Safeguard Studies

The consultant shall review the environmental and social studies undertaken in 1989 Feasibility study and prepare a full-fledged Environmental Impact Assessment of the Karnali (Chisapani) Multipurpose Project and conduct the Environmental and Socio-economic Impact Assessment of the Projects in accordance with the requirements of the Government of Nepal Environmental Protection Act, 1997 and Environmental Protection Rules, 1997 (with amendments), as well as latest World Bank (WB) and Asian Development Bank (ADB) guidelines with regard to environmental protection and resettlement.

The scope of work of the Environmental Impact Assessment of the Project includes detailed field surveys, analyses and preparation of Scoping Report, TOR for EIA, and EIA Report as per the Environmental Protection Act, 1996 and Environmental Protection Rules, 1997 (with amendment).

The major activities regarding the environmental impact and safeguard studies as per the relevant Nepalese laws and regulations, latest ADB and WB Guidelines for Environmental and Social Considerations shall include but not limited to the followings:

a) Prepare the Terms of Reference (ToR) and Scoping documents as per the Environment Protection Act 1996, Environment Protection Rules 1997 and above mentioned guidelines. Before proceeding with the EIA, the ToR and Scoping documents need to be approved by the Ministry of Environment, Government of Nepal (GoN).

b) Carry out the base line survey in the entire project area. This shall include, among others, collecting and updating information on flora, fauna, residents, houses, infrastructures, culture and tradition, ethnic communities, water quality, pattern of agriculture, economic activities, pattern of settlements etc.

c) Conduct a detailed qualitative and quantitative analysis of the anticipated changes to the baseline to determine the direct, indirect, induced and cumulative impacts of the project in construction, operation and maintenance phases. These impacts may include, but not limited to, loss of habitat and ecosystems, hydrological changes, loss of flora and fauna, impacts on wildlife, food supply chain and migration patterns of wild life, water quality, emission of greenhouse gases, erosion and sedimentation, loss of physical and cultural resources, impacts associated with construction etc. The Consultant shall present the analysis and the results in appropriate form.

d) Conduct Social Impact Assessment (SIA) of the project with reference to the following: Identify permanent and temporary socioeconomic impacts arising from land acquisition, changes in land use, and restrictions of access as a result of construction of the project facilities, including measures to minimize the number of affected land users within the river catchments including upstream and downstream areas. The consultant shall identify and evaluate social and economic impacts resulting from project implementation, including but not limited to, the types of social impacts, the extent and severity of these impacts (construction areas; quarry areas, spoil disposal areas, construction camps, community resettlement areas, access roads, power transmission line/corridors).

e) Prepare the following Environmental and Social Management Plans:

i) Prepare Environmental Management Plan (EMP) covering, but not limited to, the following:

- Erosion and sedimentation control, spoil disposal and management, quarry management, water quality, reservoir clearance, chemical and used oils and lubricant waste management, hazardous materials, emission and dust control, noise control, physical cultural resources, vegetation clearing, landscaping and re-vegetation, solid waste management, use of explosive materials, and any other construction related issue.
- The measures for management of social impacts shall include, but not limited to, management required to mitigate the impact due to change in land use patterns, employments, compensations, water quality, seasonal flooding, soil degradation, and bank soil stability/erosion and land use changes, fire hazards, river transportation, inundated forests, impediments to movements of animals, cattle, people, and disruption of communication between communities, loss of land, land disputes, increased flooding, water borne diseases, loss of social fabrics, negative impacts on fishing activities, inability to afford new technologies and impact on ritual sites.
- Management of operation related impacts which shall include reservoir inundation, water quality, riparian release and management of other identified impacts relevant to the operation and maintenance stages.

ii) Prepare a Resettlement Action Plan (RAP), and an Indigenous/Vulnerable People's/Community Development Plan (IPDP/VCDP) as part of Social Management Plan (SMP), with full participation of stakeholders. The plans shall, among others, include the following:

- full census and inventory of lost assets/households (permanent or temporary), indicating the scope and magnitude of likely resettlement effects, and list likely losses of households, agricultural lands, business and income opportunities, as well as affected communal assets and public buildings.
- an entitlement matrix, listing all likely effects, such as permanent and or temporary land acquisition, and a study to determine the replacement costs of all categories of losses based on the asset valuation process, with particular attention to vulnerable

groups including indigenous peoples, women, children and the poor and socially excluded.

- Cost estimates and clear budgets for land acquisition and resettlement costs with a specific sourcing and approval process.
- Project specific social and gender action plan including rehabilitation of rural infrastructure, livelihood-related activities, and any specific training or awareness programs for local communities and vulnerable people such as women and the socially excluded. The action plan shall include the cost and the checklist for monitoring the baseline data in the plan.
- An implementation schedule consistent with all the resettlement plan requirements, making sure that major components are carried out before the civil works.
- social action programs; and
- Implementation plans for land purchase and acquisition, payment of compensation, livelihood restoration programs, and community development plans.

iii) Prepare Detailed Monitoring Framework to effectively monitor the implementation of various plans during construction and operation phase

f) Assess the capacity of the executing and implementing agencies to plan, manage, implement, finance, and monitor, and prepare capacity-building measures and training workshops for stakeholders.

g) Organize public hearings in project affected area to discuss all the assessments done and mitigation measures suggested.

h) Finalization of these safeguards documents (resettlement action plan, indigenous people plan, environmental management plan, addendum of EIA, appropriate monitoring plan) in line with WB and ADB Guidelines.

Task 10 Review and update project benefit streams

The objective of this task is to review the project benefits identified in the 1989 feasibility study and to estimate the power benefits, irrigation benefits, and flood control benefits using updated information.

Power Benefits: The consultant shall review the power benefits computed in the feasibility study 1989 and revise it based on the current the power market both in Nepal and in the region. For this, the consultant shall prepare electricity demand forecasts in the regional countries, and the generation technologies that are likely to be displaced by the project and then determine the power benefits of the Karnali project.

Irrigation Benefits: The Consultant shall review the irrigation benefit computed in 1989 feasibility study. As the official data/information on irrigation potential particularly in India was not available from relevant official sources in the Feasibility study 1989, the benefit were evaluated both with and without the Chisapani project using the unofficial/secondary sources. The data was derived from the interpretation of the available information from relevant Indian reports and other background documents on water and land use in the Ghagra/Ganga plain. Furthermore, as the information on downstream irrigation project was limited, the benefits estimated in this area is also in the conservative side. Owing to this, the Consultant shall collect relevant information on irrigation within the reach of the project both in India and Nepal from official sources to refine the irrigation benefits.

Flood Control Benefits: Feasibility study has estimated flood benefits farther downstream in India and Bangladesh. Such benefit in India and Bangladesh are very uncertain due to lack of data. Thus the total flood control benefits appear to be far less than actual irrigation benefits. The Consultant shall review the flood control benefits computed in 1989 feasibility study and refine them collecting relevant data in Nepal, Bangladesh and India.

Navigation Benefits: The feasibility study 1989 has observed that downstream navigation benefits are not significant given the river transport is not economically competitive with alternative mode of transport. The Consultant shall review the potential for downstream navigation and carry out detailed analysis to compute navigation benefits.

Task-11: Review and Update of Feasibility Study Including Economic and Financial Analysis.

The Consultant shall review the feasibility study report and other available relevant reports/data and update the data/information covering the contents but not limited to the content provided in Feasibility study 1989. The Consultant shall review and update project configuration and project components and conduct optimization study to determine the optimum size of the project taking into account all the multipurpose benefits. The Consultant shall conduct necessary study and update the Feasibility Study as a regional project of multipurpose nature with storage for irrigation, electricity generation, flood mitigations, etc.

The review and update shall include; among others; project optimisation study, reservoir simulation study, design of different project components including optimization of individual components, regional market and pricing studies, estimation of updated cost, construction planning and economical and financial analysis of the project. The final outcome of this task shall be the updated feasibility study. The major activities to be performed by the Consultant shall include but not limited to the followings:

i. Review and Perform Design Studies;

- Finalize the project configuration based on updates field investigations and studies under (Task 2), updated hydrological and sedimentological studies under (Task 3), Regional Power market study (Task 4A), willingness and affordability of consumers to pay for the power purchases from the project (Task 4B), update power evacuation studies (Task 5), updated project optimization study (Task 6) and reservoir simulation study (Task 7), review update and conduct EIA and Safeguard studies.
- Carryout optimization studies including optimization of project capacity, dam height, tunnel, penstock diameter, etc. and quantify the number and size of the turbine units, based on updated database.
- Review and update the hydraulic &structural design of each component including but not limited to main dam, spillway facilities, intake, headrace tunnel, surge tank(s), powerhouse, tailrace, and other associated structures in consideration to the updated activities under task 2 to Task 8 mentioned above. The Consultant shall carry out Hydraulic design for all hydraulic structures/water conveyance system including hydraulic transient analysis with water hammer effect for surge tank shall be performed as necessary to verify the principal dimensions, design parameter and proper hydraulic performance of the project. The

consultant shall carryout hydro-mechanical and electro-mechanical studies to determine the type of trash racks, gates, turbine, generator, substation, and transmission line etc.

- Review and perform engineering study of each component of the project adopting standard practice adopted in this industry, but not inferior to the approach adopted in the feasibility study 1989. The Consultant shall carry out hydraulic, geotechnical and structural design of main dam, spillway facilities, intake, headrace tunnel, surge tank(s), powerhouse, tailrace, and other associated structures. The study shall also include access roads and bridges, cofferdams, diversion tunnels, electrical and mechanical equipment, substations. The engineering study design shall be based on stability analysis, confirmatory stress analysis and the information collected during the investigation. The design shall include, but not limited to, the complete design of hydraulic structures, foundation treatment and grouting, instrumentation, seepage analyses, stability, deformation and stress analysis and architectural work and finishing of powerhouse. Structures shall be designed for steady state and transient conditions. The designs shall conform to and be suitable for the site conditions and shall aim at achieving minimum overall cost and a minimum consumption of land, without adversely affecting safety, security, efficiency or longevity of the works or the environment The consultant shall provide detailed calculation regarding design of each component.

- Carryout Hydro-Mechanical and electro-Mechanical design of gates, valves, turbine, generator, substation, and transmission line etc.
- Prepare engineering drawings of all the components of the project including Hydro and electro-Mechanical works, transmission lines and substations.
- Review previous reports and finalize / reconfirm the location of camp for client and contractors, spoil disposal and establish the need for construction of additional access road and bridge including finalization of road alignment and site for bridge. The quantum of construction power required shall be reviewed and updated and recommend appropriate option along with cost estimates and other necessary details.
- Carry out comprehensive power system study of the regional countries to identify the system reinforcement needs for the power evacuation for Karnali Chisapani.

- Collect information on the latest load profile and suggest powerplant maintenance schedule accordingly and also plan the reregulating facility for maximum irrigation benefits.
- The Consultant shall review the technological options for the switchyard schemes in light of the current level of technology, and recommend the one which is technologically superior and economically feasible. The study should also look into the unit size of the turbine generators, as there is a possibility of having higher capacity Francis turbines.

ii. Review and Update Construction Planning and Scheduling

The Consultant shall review the Construction Plan and Scheduling performed in the Feasibility study and update them from a contractor's point of view of operation, a realistic and practical construction and equipment procurement plan along with construction power supply. The consultant shall suggest the construction methods in light of the current construction practices. The slicing of the contract packages shall also be reviewed and changes suggested if there is a possibility of reducing the project costs, implementation time and construction risks.

The plan shall serve to establish construction schedules, with start and finish and interim critical milestone dates as well as key dates for interfaces between civil, hydro-mechanical and electro-mechanical works. The Consultant shall carryout material handling studies which will aid the contractor to efficiently quarry, store, haul, use and dispose huge amount of construction material required for construction of the physical project. The result of material handling studies shall be incorporated in the construction plan which shall be supported by network and logic diagram showing the sequence in which construction activities are to be performed, their interdependencies, constraints and the critical path of the execution of the work, and so on.

(iii) Review and Update Transportation Planning for Powerhouse Equipment and Machineries

The Consultant shall identify the nearest seaport for the import of powerhouse equipment and machineries, and the most direct mode of inland transportation (railways or road or both) taking into consideration the condition of the existing roads and bridges on the transportation route from the nearest seaport to the project site. In light of the capacity of the bridges along the transportation route, the Consultant shall recommend the maximum weight of a single consignment that can be safely transported along the identified route for the identified transportation mode, and suggest a need for improving load-bearing capacity of specific bridges especially within Nepal. The consultant shall collect the load bearing information of the bridges and the road /railway track along the identified route.

iv. Review and Update Project Cost and Quantity Estimation

The Consultant shall review the project cost and quantity estimation established in the feasibility study 1989 and update them in a standard practiced in this industry, however, it shall not be inferior to the approach adopted in the previous feasibility study. The consultant shall review the project costs to reflect the current cost of materials, labor and equipment, and the costs of land acquisition and rehabilitation of the project affected people. The Consultant shall prepare detail quantity estimate based on engineering design and drawings for the purpose of cost estimate. Preparation of the BoQ shall be in accordance with recognized standard method of measurement of civil engineering works and shall be appropriate to the level of information required.

For civil works, the unit cost for each individual item shall be composed of labour and staff costs, construction materials, plant and equipment costs, fuel and lubrication, transport, electrical power etc. The cost estimate needs to be based on construction methodology and planning as determined. The cost for turbines, generators, substation equipment, switchgear, gates, and so on shall be based on the budgetary quotation received from the manufacturers and within the frame work of prevailing market prices. The cost estimates shall be prepared from a contractor's point of view using resource based costing and shall follow international standard practice (Cost and Performance Calculations of the Construction Industry).

v. Review and Update Economic and Financial Analysis of the Project

The consultant shall review and update the economic and financial analysis of the project adopting standard approach. However, it shall not be inferior to the one that was adopted in the feasibility study 1989. In the updated feasibility study, the consultants shall carry out benefits calculations of electricity taking into account the current opportunity cost of electricity in the regional countries from this project developed as a regional project. The current (projected) generation mix and the electricity prices from competing generation technologies, will determine the type of electricity generation, which will potentially be displaced by the Karnali Chisapani project, and hence the power benefits. Further the irrigation and flood control benefits should also be re-evaluated taking into account the current opportunities for the same. In respect of navigation benefits, the consultants shall review if there are new opportunities for enhanced navigation upstream and downstream of the project.

The Consultant shall analyse demand, supply, and economic viability, and assess tariff pricing. The Consultant shall also analyse the financial viability and suggest the financial structuring of the project. The Consultants shall perform all necessary activities. The following being the major activities:

- Analyse the economic viability of the project. Identify all economic costs and benefits with sensitivity analyses and evaluate economic internal rates of return;
- Review the forecasted load growth and revenues and costs in relation to tariffs, cost recovery and the cost of generation from renewable sources of energy that came in to play after the 1989 feasibility study. Determine future sustainable tariffs to support the project;
- Asses and analyse the financial viability of the project. Identify all risks for revenues and costs with sensitivity analyses, and evaluate financial internal rates of return. Include risk mitigation and risk transfer plans as necessary;
- Analyse the alternative possibilities of promoting the project, ranging from the public sector development to the public and private development approach. Simulate and evaluate optimal financial structuring and modelling in terms of profits, costs, and risks through all measures such as equity, loans, or an insurance (guarantee) mechanism from private investors and lenders, export credit agencies, multilateral development banks, and bilateral donors;
- Calculate the cost of electricity and royalty or water value of irrigation and flood control benefits.

- Develop financial projection models comprising financial statements and financial ratios for the next 25 years to assess the project and its institutional financial viability and impacts using key performance indicators.

vi. Preparation of Updated Feasibility Study

The consultant shall update the Feasibility Study of the Project based on the above-mentioned activities. The updated feasibility study report shall include the outcome of all tasks 1 to 12. The structure and format of the updated Feasibility Study Report shall be as per the standard followed in this industry for the size and scale of the project and shall be responsive to the international financing agencies requirement.

Task-12: Analysis of Institutional Arrangement for Project Implementation

The Consultant shall make an assessment of the institutional arrangement required for implementation of physical project of this size and complexity. The Consultant shall first recommend the institutional set up for the implementation of the Project and its governance structure. The consultant shall analyse the alternative institutional setups for the implementation of the project and recommend appropriate institutional arrangement for project implementation backed by analysis. For the recommended institutional setup, the Consultant shall propose organizational structure clearly defining the role of each position and responsibility. The consultant shall also clearly identify the requirement of resources including but not limited to capacity building measures (trainings, workshops etc.), physical infrastructures, requirement of software, equipment etc. The Consultant's recommendations shall also include the aspects of coordination among the stakeholder governments in the region.

The Consultant shall also analyse financing structure and plan including potential sources of financing (including investment by stakeholder member states, international financial institutions, etc.) for implementation of the project as a regional hydropower project. Besides risk analysis with respect to the implementation of the project as a regional hydropower project shall be carried out.

5.4.2 Phase II Study

The detailed scope of works under this assignment under Phase II study of the project covers following tasks/activities.

Task 1 Inception Report on the Assignment

Task 2 Review and update site investigation and associated studies including additional field investigations, if any

Task 3 Detail Engineering Design, Specifications and Drawing

Task 4 Model test study (physical and mathematical)

Task 5 Refinement of Project Cost &quantity estimation, Construction Planning and Scheduling, and Economic and financial evaluation

Task 6 Preparation of Complete Tender Documents and Tender Drawings

Phase II Study: The detailed scope of works under this assignment under Phase II study of the project is presented in the following paragraphs.

Task-1: Inception of Assignment

Main activities under this task of Phase II study shall include review of the updated Feasibility study Report, applicable guidelines/norms, available data, planning and initiation of the field work and up-dating of the work plan submitted with the proposal on the basis of the findings of the review.

The Consultant shall, immediately upon initiation of the assignment, begin collection of all relevant reports, data and maps from different secondary sources and carry out the review study. In the project review, all information/data of the project should be subjected to critical analysis and scrutiny in order to establish a realistic understanding of the type and scope of additional information/data required for subsequent analysis/design. As part of the project review, the Consultant shall:

a. Identify key areas, which will require additional field work or demand major efforts in data collection/ investigation;

b. Review the updated Feasibility Study Report and other documents;
c. Establish methods and procedures for further studies

The Consultant shall undertake an Inception visit to the project site covering all project components and carry out engineering studies with respect to the topographical and geographical features, geological, hydrological, meteorological and sedimentological aspects of the project area. Besides, environmental and social aspects will also be studied during the inception site visit.

In parallel with data collection and field reconnaissance, the Consultant shall prepare a time schedule with milestones and specific key dates. This schedule shall be submitted by the Consultant as part of the proposal, suitably updated to reflect the additional information/ data needs.

The Inception Report shall summarize the results of the review of existing data/ reports, summarize the results of the field reconnaissance, discuss the key data/information gaps requiring additional field work/investigation, data collection, data verification, and describe the approaches and methodology that the Consultant intends to follow in carrying out various activities to complete the assignment. The Inception Report shall also include the updated methodology and work plan for the studies, detailed schedule for each task, detailed field investigation plan, manning schedule of each personnel for effective mobilization. All collected data/information, reports; documents should be subject to critical scrutiny in order to establish a realistic understanding of the field situation, data gap, additional investigation and studies to be included in the study. The Consultant shall make a presentation of the Inception findings to SEC with the use of appropriate visual aids.

Task-2: Review and update site investigation and studies including additional field investigations, if any

The objective of this task is to collect all reports of previous field studies and investigations of the project, then review and update them. The review shall be focused on identifying the necessary data gaps to update the study based on refinements to the Project arrangement required by engineering tasks being performed in parallel. The consultant shall then carry out required supplementary field investigation after getting approval from the client. Finally after obtaining the report of those supplementary investigations, the consultant shall update and validate the respective field investigation. The results of this activity together with the details of the field investigation shall be presented in the Updated Field Investigation Report (Phase II) and shall be used in the engineering design of the project. The review and updating of site investigation shall include but not limited to the followings.

a) Topographical Survey

The Consultant shall review the topographical maps prepared in Phase I (Updated Feasibility Study and update them, if needed; and incorporate them in engineering studies under the current study.

b) Hydrological, Meteorological and Sedimentological Investigation

The Consultant shall review the hydrological, meteorological and sedimentological investigation carried out in the previous studies including the Updated feasibility study (Phase I) and identify data gaps, if any, and acquire all relevant data from different secondary sources and update the hydrological, meteorological and sediment analysis.

c) Geological, Geotechnical, and Construction Material Investigation

The consultant shall review the geotechnical; geological and geophysical investigation carried out in the previous studies including updated feasibility study 1989; identify data gaps, if any and conduct necessary investigations for detailed engineering study in Phase II study. The Consultant shall carry out supplementary field investigation required for detailed engineering design in Phase II. For this, the Consultant shall identify required field investigations and perform it after getting approval from the Client. The cost of which will be covered from the Provisional sum.

d) Seismological Investigation

The consultant shall review the seismological investigation performed in Phase I study and refine them for detailed engineering study (Phase II).

e) Investigation Related to Glacier Lake Outburst Flood (GLOF)

The consultant shall review the GLOF study performed in Phase I study and refine them for detailed engineering study (Phase II).

Task-3: Detail Engineering Design, Specifications and Drawing

The primary objective of this task is to refine, update and supplement and prepare detailed design and drawings of the project configuration option finalized in the updated feasibility study. The detailed design including reinforcement details where applicable shall cover each component of major structures e.g. dam and reservoir including spillway and other outlets, intake, water ways, surge tank, powerhouse, tailrace, Hydro-Mechanical structures, electro-Mechanical works and transmission line and substations for power evacuation, roads, bridge, employer's camp, landscaping in necessary areas, and so on. The drawings shall be prepared on the basis of detailed design and shall be adequate in coverage for use in construction

For every component of the project, the consultant shall formulate prior to detail engineering design, a Design Basis Memorandum (DBM) to record the basis on which a design will be developed. It shall establish the design and functional criteria, and prepare the layout and design concepts of all project facilities/ components; state the assumptions, parameters, and standards applied, loading conditions, factors of safety, allowable stresses, stability criteria, and all other factors which are necessary to fully carry out the detailed design. The design criteria shall describe in sufficient detail methodologies and analysis methods, database and international standards or codes and prudent practices employed.

The consultant shall prepare confirmatory stability, stress analysis and reinforcement design and details for the various features including main dam, spillway facilities, intake, headrace tunnel, pressure shaft and steel lined tunnel, powerhouse, tailrace, and other associated structures using the state of the art techniques in consistent manner by matching the methods to needs.

Electro-Mechanical, Hydro-Mechanical, transmission line and substation design work shall be based on internationally accepted practices and shall include drawings and supporting calculations. The Electro-Mechanical design shall involve, among others, selection of proper electrical and mechanical systems and equipment, dimensioning/sizing of the equipment, etc. Electro-Mechanical works including transmission line and sub-station station design work shall be based on the approved design criteria and internationally accepted practices and shall include drawings and supporting calculations.

The consultant shall have full discretion on the method, procedure, tools and approaches for the performance of the design work. The performance of the designs ultimately accepted, shall be demonstrated by a “Confirmatory Analyses” with the state-of-art structural and hydraulic methods.

The Consultant shall prepare Engineering Drawings and Specifications of all the components of the project including hydro and electro-mechanical works, transmission lines and substations; describing work in terms of measurements, tolerance, and material and as necessary in process tests. Engineering drawings shall be prepared in accordance with the Design Base Memorandum and show the general outline and enough detail regarding the structures, material and equipment to enable the contractors and suppliers to prepare and submit competitive bids.

Detail Design and Technical Performance Specifications shall be prepared to the international standards. They shall be carried out to a level of detail so as to enable contractors and suppliers to clearly interpret type and scope of works involved and to submit competitive tenders.

Task-4: Model test study (Hydraulic and Numeric)

The consultant shall carry out numeric modelling for the spillway, plunge pool, energy dissipating structures, weir (for reregulating dam), power intake, irrigation outlets, sediment flushing outlets, low level outlets, and so on. To confirm the results of the numeric modelling, the consultant shall carry out physical modelling of key hydraulic structures to be identified in consultation with the Employer.

I. Numeric Model: The consultant shall carryout 2D and 3D computational hydraulic model studies of dam, intake, overflow spillway and the plunge pool or stilling basin, energy dissipating structure, intake, sediment flushing outlet, irrigation outlets, and other structures if necessary to finalize the design, using Computational Fluid Dynamics (CFD) analysis method.

II. Hydraulic Model: Following the computational CFD analysis, as confirmatory tests, the consultant shall carryout hydraulic model studies of dam, intake, overflow spillway and the plunge pool or stilling basin, sediment flushing outlet, irrigation outlets, and other structures as necessary to finalize the design. Model test shall be carried under two arrangements and second arrangement may be made on the result of first arrangement.

Arrangement 1 (Base case):

Under this, a fixed bed river model shall be constructed to reproduce the Karnali river at the location of the dam site. The river model shall include suitable length of the river to represent the major structures of the project. The model scale shall be 1:60. The river topography will be build based on the topographic map and the cross-section profiles. The flow, bed load, floating debris transport patterns and reservoir sustainability are the major phenomenon that shall be studied during physical modelling. The structures such as dam, intake, spillway and stilling basins shall be reproduced in the model for testing. The study will focus on intake hydraulics, passage of bed load, passage of floating debris, passage of floods through the spillway provided in the dam and the flow patterns in the settling basins.

A**rrangement 2 (Modification on base case):**

Based on the hydraulic performance of the base case, some modifications on base case arrangement might be required. Required modifications shall be made based on the analysis and judgment of the study team. Tests shall then be performed on the modified project arrangements modelled to study its performance. Necessary modifications in the model shall be made till the best result is obtained. The modifications shall not be limited to the following changes:

- Change of width of bed load flushing structure
- Change of river bed level at upstream (within modelled river stretch), this depends upon the change of dam crest elevation
- Resizing of intake
- Changing alignment of intake tunnel
- Changing the orientation of the dam, intake, spillway gates, change in type of intake etc.

Task-5: Refinement of Project Cost & quantity estimation, Construction Planning and Scheduling, and Economic and financial evaluation

Refinement of the Project Cost

The objective of the refinement of the project cost involves the preparation of Project cost estimate from the detail engineering designs and Bill of Quantities (BoQ) for use in preparation of tender documents. The project estimates shall be suitable for presenting to international financing agencies for funding.

Using the information obtained from the detailed engineering drawings, the Consultant shall prepare detailed BoQ consistent with the construction plan and schedule, and in accordance with recognised standard methods of measurement of civil engineering works. Thus, after finalizing the detailed engineering design of each project components, the consultant shall refine the project cost estimate based on Bill of Quantity, unit rates in the way to be consistent with proposed construction planning and schedule. The cost estimates shall be refined from a contractor's point of view using resource based costing and will follow Class 3 level of accuracy as described by AACE (Association for the Advancement of Cost Engineering) International Standards.

The cost estimation shall comprise of a basic cost along with the required contingencies. Cost for infrastructures and access shall be properly addressed. Cost for hydro-mechanical and electro-mechanical equipment (turbines, generators, substation, switchgear, gates, BoP and their auxiliaries) shall be based on previous similar projects, extrapolations of international references, and similar offers. Estimates of major equipment costs shall also be derived from manufacturers' quotations, recent comparable bid prices and other relevant empirical data.

Refinement of the Construction Planning

The objective of refining the Construction planning is to prepare a realistic and practical construction and equipment procurement plan (Master Schedule) and schedule with milestones which aligns with detailed engineering design and cost estimate. The Consultant shall prepare a construction plan and schedule, aligned with the construction sequencing and methods identified in layout and cost studies. It shall update the Phase I study with inclusion and integration of missing activities. The plan will be supported by network and logic diagrams showing the sequence of construction activities, their interdependencies, constraints, and resulting critical path. The schedule shall include start and finish dates, and interim critical milestone dates. The approach to construction planning shall be based on latest industry practices for construction method and techniques and construction equipment planning, considering regional aspects and limitations.

Refinement of Economical and Financial Evaluation

The Consultant shall refine the Economic and Financial evaluation based on refined detailed cost estimates and refined project schedule resulting. The Consultant shall also analyse financial structure to recommend the most appropriate financing structure. The consultant shall analyse economic and financial viability of the project by considering all pertinent information such as cost and revenue, construction planning and risk assessment. Prior to the evaluation, the consultant shall determine the basis and assumption for economic and financial evaluation and their criteria. The consultant shall analyse the financial viability and suggest the financing structuring of the project. The consultant shall also perform sensitivity analyses in terms of varied discounted rates, capital cost decreased/increased, delay in commissioning and cumulative effect of cost and time over run etc.

Task-6: Preparation of Complete Tender Documents and Tender Drawings

The Consultant shall prepare complete Tender/Bidding Documents complete with Tender Drawings for all works with appropriate details and specifications, BoQ and other necessary documents e.g., FIDIC Yellow book and Red book for bidding purpose. The Tender Documents shall describe the works, including temporary works as necessary in sufficient detail to allow bidders to confidently determine the cost of construction and ensure competitive and comparable tenders. The Consultant shall make his recommendations and discuss in detail with SEC, the extent to which bidders should be permitted to suggest alternative designs, construction methods or temporary works.

5.5 Duration of Services

The estimated time for completion of the assignment under Phase-I study is 30 months and 18 months for Phase-II study.

5.6 Reporting Requirements and Time Schedule for Deliverables

5.6.1 Reporting Requirements

The reports to be prepared and submitted by the Consultant in compliance with this Terms of Reference fall under the categories of management reports, technical reports, environmental reports and combined reports. Each report shall be complete with an Executive Summary and shall include maps, drawings, data collected and/or used in the analysis. The consultant shall submit 2 copies of the electronic versions in addition to the hard copies of the reports in number as mentioned in the following section. The electronic versions of these reports shall include the complete documents including all data, analysis, design calculations etc. The environmental data shall include complete set of environmental documents approved by the Ministry of Environment (MoEnv), and shall include all the data in appropriate formats. The consultant shall discuss their interim findings at review meetings to be held with SEC project management team on regular basis.

(I) Management Reports

The Management Reports shall comprise quarterly progress reports and monthly progress reports concerning physical progress/status of works, expenditures, etc. in formats acceptable to SEC covering all the activities of the consultant during the period and shall be submitted within two weeks after completion of each quarter and within one week after completion of each month. The Management Reports shall contain summary of the progress of the different activities achieved in the particular period and shall also include the plan and program for the subsequent period. All communications from the SEC to the consultant and by the Consultant to SEC shall be in writing. Each party will designate a representative to interact and interface with each other, who will be the sole authority to exchange communications between the parties. Minutes of all meetings will be recorded and signed by both the parties, in token of having arrived at decisions taken in each meeting.

(II) Technical Reports

These shall comprise a series of Reports covering the main technical studies, investigation, issues, etc., related to the project. Each report shall be complete with an Executive Summary and shall include maps, drawings figures and diagrams as necessary. The reports shall include Annexes providing the basic data used in the analysis.

iii. **Inception Report**

The Inception Report shall present details of the assignment and reporting requirement stated in Task-1. Separate report shall be provided for Updated feasibility study stage (Phase I) and for detailed engineering stage of the study (Phase II).

iv. **Topographical Survey and Mapping Report**

The Consultant shall prepare, among others, a Topographic Survey and Mapping Report stated in Task-2.

v. **Geotechnical Studies and Investigations Report**

The Consultant shall provide separate report(s) or a comprehensive report on geological investigations, geological mapping, refraction survey and ERT, etc. The results of geotechnical studies and investigations shall cover in situ and lab tests, tests on construction materials, soil tests specified in the TOR and all findings, test reports, calculations, and conclusions organized in the form of a Geotechnical Report. Separate report shall be provided for Updated feasibility study stage (Phase I) and for detailed engineering stage of the study (Phase II).

vi. **Geotechnical Baseline Report**

The results of geotechnical studies and investigations and all findings, test reports, calculations, and conclusions shall be organized in the form of a Geotechnical Report and summarised in the various project reports. The results, data and interpretations uncovered from the geotechnical studies and site investigations and the corresponding interpretations and recommendations shall be presented in such a manner that it can be used as a stand-alone document for further development of the projects. The baseline statements shall be in quantitative terms that can be measured and verified during construction. The principal aim of the Geotechnical Baseline Report is to establish an understanding of the subsurface site conditions, referred to as a baseline, which can form the basis of contractual conditions in construction contracts.

vii. **Hydrology and Sedimentation Report**

The Hydrology and Sedimentation Report shall describe the hydrological activities required in the TOR. The report shall also present the analysis of the hydrological data and present results and conclusions regarding magnitude and variability of flows and flood estimates. The report shall also provide a detailed description of estimates of sediment load, extent of sediment deposition anticipated in reservoirs and potential for mitigating measures by reservoir flushing. Separate report shall be provided for Updated feasibility study stage (Phase I) and for detailed engineering stage of the study (Phase II).

viii. **Water Resources Management Report**

The Water Resources Management Report shall present analysis/synthesis/interpretation of the data to be used in construction of dam and regulation of the flow at the downstream water resources projects including irrigation use in India and Nepal. Besides, details of the estimated energy output for the various options considered shall also be presented in the report.

ix. **Power System Analysis Report**

The power Market, Power System and Power Evacuation Study Report shall describe the power market in the SARC countries, shall present the results of the power system studies and power evacuation studies. The report shall cover, among others, preparation of long-term electricity demand forecast for the regional countries ,a review of the existing and planned transmission and generation plans in the study countries, electricity prices studies, contribution of power generated from Karnali (Chisapani) to meet the electricity demands, and in the provision of ancillary services. The consultant then shall prepare the scope of transmission network requirements (both green-field and reinforcement) to evacuate the power from the Karnali (Chisapani) project backed up by a detailed analysis (technical and financial) of alternative options such as asynchronous links, or HVDC.

The study shall also summarise the findings of the study on willingness and affordability of consumers to pay for the power from the project and any challenges that might be posed to the project viability due to the deployment of the latest renewable energy technologies for power generation as an alternative source for electric energy within the region. The focus of the findings shall be the evaluation of alternatives emerging from the solar and wind energy, the prices of which are coming down at an accelerated pace, thereby having the potential to challenge the viability of the project.

x. **Interim Design report**

The Interim Design Report shall include the findings of project layout and optimization, hydraulic design, hydro-mechanical design, electro-mechanical design and electrical design. It shall include the design works completed within the reporting period.

xi. **Draft Final Updated Feasibility Report**

Draft Final Updated Feasibility Report shall include the complete feasibility study reports of the projects including design, optimization, drawings, quantity and cost estimates, construction planning, power evacuation plan, economic and financial analyses and other details as mentioned in the scope of work. The Updated Feasibility report shall be in detail covering investigation, alternative analysis, conceptual design, economic and financial analysis and so on. The draft report shall include as separate volume(s) the drawings, Updated Feasibility level design calculations, geotechnical and geological analysis and design, hydrologic and sedimentological analysis and design, seismic analysis and design, construction material survey, power system analysis, electro-mechanical design, hydro-mechanical design, transmission line and substation design, effect of flow regulation and dam construction in upstream and downstream reaches, and so on.

The consultant has to present the findings contained in the Draft Final Updated Feasibility Report to SEC, Panel of Experts appointed by SEC, other concerned agencies and stakeholders. The venue and date of presentation will be fixed based on mutual understanding. The names and list of participants will be provided by SEC, which will include the representative from the concerned ministries of SARC countries, SAARC Secretariat, SEC, professionals, experts and concerned stakeholders. The suggestions and comments provided at the presentation will also be duly incorporated by the consultants in the final reports.

Updated Feasibility Report (Final)

The Updated Feasibility Report (Final) shall be prepared incorporating comments, suggestions from SEC, Panel of Experts, any other concerned agencies and the stakeholders. It shall also incorporate the recommendations made in the approved EIA Report. This Final Report will, therefore, be the consolidated report based on both the Feasibility Study and EIA. The consultant shall submit ten copies of electronic version of the complete report on compact disk in addition to the hard copies of the reports in requisite number as mentioned above. The electronic version of the report shall include the complete report and drawings including the complete data in appropriate formats compatible with mainstream software.

xii. **Design Criteria Report**

The Design Criteria report shall be prepared incorporating design philosophy and design criteria in designing different project components including civil structures, hydraulic steel structures, electromechanical and hydro mechanical equipment, etc.

xiii. **Updated Financial Report**

The Updated financial report shall be prepared based on the detailed design studies of the project and will have to be submitted in twelve (12) copies.

xiv. **Draft Final Detailed Design Report**

Draft Final Detailed Design Report (12 copies) shall include, among others, the following:

- Design Criteria Report
- Detail Design Calculation
- Detailed Quantity Estimate
- Detailed Cost Estimate
- Construction Planning and Scheduling
- Design Drawings

(III) Environmental Reports

Draft Final EIA Report

The Environmental Impact Assessment report should be for the whole project including transmission line (A separate environmental study may be required for transmission line and in that case separate report should be submitted for both Hydroelectric and transmission line component). The EIA report shall consist of the following reports in six (6) copies in addition to the main report.

- Resettlement Action Plan
- Indigenous Community Development Plan
- Environmental Management Plan

Besides, the Consultant shall also produce and submit the following reports:

- At SEC's request, all necessary reports concerning special matters related to the project including activity report for example optimization report, reservoir simulation, etc.
- Minutes of meetings attended by the consultants.

5.6.2 Time Schedule for Deliverables

The reports to be prepared and submitted in compliance with this Terms of Reference fall under three categories: (1) Management Reports, (2) Technical Reports, (3) Environmental reports and (4) Combined Reports (Technical and Environmental both). The time schedule for deliverables after the commencement the commencement of services is presented in the following table.

Table 5.2: schedule for deliverables

Phase I Study

S. N.	Report	Report Type	No. of Copies
1	Inception Report (task 1)	Technical & Environmental Combined	10
2	Topographical Survey and Mapping Report	Technical	6
3	Geological and Geotechnical Report	Technical	6
4	Hydrology and Sedimentation Study Report	Technical	6
5	Interim design report including Project optimization report	Technical	12
6	Draft Scoping Report and ToR	Environmental	6
7	Approved Scoping Report and ToR	Environmental	6
8	Environmental baseline Report	Environmental	6
9	Upgraded Feasibility Study Report (Draft)	Technical	12
10	Water Resources Management Report	Technical	6
11	Power System Analysis Report	Technical	6
12	Geotechnical Baseline Report	Technical	12
13	Cost Estimation Report	Technical	6
14	Economic and Financial Analysis Report	Technical	6
15	Upgraded Feasibility Study Report (Draft Final)	Technical	12
16	Resettlement action Plan	Environmental	6
17	Indigenous Community Plan	Environmental	6

18	Environmental Management Plan	Environmental	6
19	Draft Final EIA Report	Environmental	12
20	Upgraded Feasibility Study Report (Final)	Technical	25
21	Approved EIA Report	Environmental	25
22	Draft Consolidated Report(Upgraded Feasibility Study and EIA)	Combined	12
23	Final Report - Consolidated Report (Upgraded Feasibility Study and EIA)	Combined	25
24	Monthly Progress Reports	Management	6
25	Quarterly Progress Reports	Management	6

Phase II Study

S. N.	Report	Report Type	No. of Copies
1	Inception Report (task 1)	Technical & Environmental Combined	10
2	Geological and Geotechnical Report	Technical	6
3	Hydrology and Sedimentation Study Report	Technical	6
4	Geotechnical Baseline Report	Technical	12
5	Cost Estimation Report	Technical	6
6	Physical Model Test Report	Technical	12
7	Approved EIA Report	Environmental	25
8	Design Criteria Report	Technical	12
9	Draft Final Detailed Design report	Technical	12
10	Final Detailed Design report	Technical	25
11	Draft Final Tender Document	Technical	12
12	Final Tender Documents	Technical	25
13	Updated Financial Report	Technical	12
14	Monthly Progress Reports	Management	6

15	Quarterly Progress Reports	Management	6

5.7 Project Team Composition and Qualification Requirements for the Key Experts

5.7.1 Project Team Composition

The project team will consist of international key and non-key experts and national/local experts to accomplish the study. It is envisaged that the international team of experts will be resident in Nepal for the entire duration of the services. Coordination activities only will be carried out in the home office of the Consultant with the possible exception of studies that may require specialist input that cannot be supplied from Nepal.

It is estimated that about two hundred and Eighty five (285) person-months of international experts; of which 177 person months for phase-I study and the remaining 108 person months for Phase-II study and five hundred and fifty eight (558) person-months of national experts will be needed to complete the assigned tasks. The breakdown of the estimated inputs (person months) of international experts is given in the following table.

5.7.1.1 International Experts

The following table (Table 5.3) presents the international experts for the updated feasibility study:

Table 5.3: International Experts

Expertise	Phase I Study	Phase II Study
(A) Key		
Project Manager/Team Leader	20	14
Lead Engineer - Reservoirs, Dams, Waterways and Power facilities (Hydropower Engineer)	10	8
Lead Engineer - Water resources, Planning and Impact studies (Water Resources/Hydrologist/Hydraulic Engineer)	7	6

Lead Engineer – Field Investigation and Geotechnical (Geotechnical Engineer)	8	3
Lead Expert-- Power System Planning, Power Market Studies, Electricity Pricing Study (Power System Planning Expert and/or Power System Economist)	10	3
Engineering Geologist	8	2
Dam Engineer	5	6
Hydrologist/Sedimentologist	5	2
Dam Break and Flood Plain Analysis Expert	6	2
Hydraulic Engineer	6	2
Hydraulic Modeling Expert		3
Tunnel Engineer - Geotechnical Engineer	2	5
Structural Engineer	3	8
Seismologist	2	1
Irrigation Engineer	10	2
Agriculture Economist	10	2
Natural Resources Management Expert	6	
Multi Criteria Decision Analysis Expert	3	
Construction Planning and Scheduling Engineer	3	2
Cost Engineer/ Quantity Surveyor	4	2
Project economist – Economic & financial Analysis	5	1
Power System Engineer	3	2
Electricity/Energy Economist	4	1
Hydro- mechanical Engineer	2	4
Electro-mechanical Engineer	2	4
Transmission Line & Sub-station Engineer	3	3
Contract Specialist		9
Environmental Specialist	10	1
Sociologist	8	1
Community Development/ Resettlement Expert	6	1
Sub-total (key Int'l)	**161**	**98**
(B) **Non Key**		
Electrical Engineer	3	2
GLOF Expert	2	
Climate change Expert	2	
Road/Bridge Expert	3	

Transportation Engineer	4	
Other non-key Experts	6	8
Sub-total (Non key Int'l)	**16**	**10**
Total International Experts	**177**	**108**

5.7.1.2 National/Local Professionals

The expertise of the national experts is given in the following table (Table 5.4):

Table 5.4: National Experts

Expertise	Phase I Study	Phase II Study
A: Senior National Professionals		
Counterpart Lead Engineer - Reservoirs, Dams, Waterways and Power facilities (Hydropower Engineer)	24	16
Counterpart Lead Engineer - Water resources, Planning and Impact studies (Hydrologist/Hydraulic Engineer)	16	12
Counterpart Lead Engineer – Field Investigation and Geotechnical (Geotechnical Engineer)	14	10
Counterpart Lead Expert--Power System Planning, Power Market Studies, Electricity Pricing Study (Power System Planning Expert and/or Power System Economist)	16	5
Geologist	12	3
Water Resources Engineer	20	12
Natural Resources specialist	20	5
Multi Criteria Decision Analyst	12	3
Hydrologist	12	3
Hydraulic Engineer	12	4
Structural Engineer	6	12
Irrigation Engineer	20	4
Construction Planning and Scheduling Engineer	6	4
Cost Engineer/ Quantity Surveyor	12	6
Project economist – Economic & financial Analysis	8	4
Power System Engineer	5	3
Hydro- mechanical Engineer	6	8
Electro-mechanical Engineer	6	8
Transmission Line & Sub-station Engineer	6	3
Contract Specialist		12
Environmental Specialist	14	
Sociologist	12	
Community Development/ Resettlement Expert	10	
Agricultural-Engineer	8	
Botanist	7	
Zoologist	5	
Fisheries	6	

Civil Engineers	30	50
Electrical Engineers	21	25
Sub-Total Non-key National	**346**	**212**

5.7.2 Qualification Requirements

5.7.2.1 International Expert Key

(i) Project Manager/Team Leader:

The Team Leader shall preferably have a Master's degree or equivalent civil/hydropower/water resources/hydraulic/structure engineering discipline and must have preferably twenty five (25)years of professional experience, fifteen (15)years of which in planning, design, specification, tender document preparation, construction supervision of hydropower projects.

The expert shall have previous team leader experience in feasibility studies and detailed engineering design of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity of not less than 4000 MW. Experience shall also cover planning, design, specification, tender document preparation, construction, testing and commissioning of reservoir projects of similar magnitude to the Karnali Chisapani Project. It is expected that the expert will be resident in Kathmandu for approximately 34 months, of which 20 person- months in Phase I study and 14 person-months in Phase II study with frequent visits to the project site.

(ii) Lead Engineer - Reservoirs, Dams, Waterways and Power facilities (Hydropower Engineer):

The Lead Engineer – Reservoirs, dams, waterways and Power facilities (Hydropower Engineer) who will work as the Deputy Team Leader shall have preferably Master's degree or equivalent in civil/hydropower/water resources engineering and must have preferably twenty-five (25) years of professional experience in planning, design and construction supervision of hydropower projects of similar nature and magnitude to the Karnali Chisapani Project.

The expert shall have previous experience of working as hydropower engineer in conducting feasibility studies and detailed engineering design of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW involving dam with height of at least 150m. Experience shall also cover planning, design, specification, tender document preparation, construction supervision of reservoir projects of similar size to the Karnali (Chisapani) Project. Experience in feasibility, detailed design, construction supervision of hydropower project in South Asia as hydropower engineer will be an added advantage of the expert. It is expected that the expert will be resident in Kathmandu for approximately 18 months, of which 10 months in Phase I study and 8 months in Phase II study, with frequent visits to the project site.

(iii) Lead Engineer - Water Resources; Planning and Impact studies (Water Resources/Hydrologist/Hydraulic Engineer):

The Lead Engineer – Water Resources, Planning and Impact studies shall have preferably Master's degree or equivalent in water resources engineering/Hydraulics/ Hydrology/civil/hydropower and must have preferably twenty-five (25) years of professional experience in planning, design and construction supervision of hydropower projects of similar nature and scale to the Karnali (Chisapani) Project.

The expert shall have previous experience of working in multiple projects as water resources engineer, hydrologist, hydraulic engineer for carrying out in feasibility studies and detailed engineering design of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW involving dam with height of at least 150m. Experience shall also cover planning, design, specification, tender document preparation, construction supervision of reservoir projects of similar size to the Karnali (Chisapani) Project. Experience in the coordination and planning of environmental and social studies will have added advantages. Experience in feasibility, detailed design, construction supervision of hydropower project in South Asia as hydrologist or hydraulic engineer or water resources or hydropower engineer will be an added advantage of the expert. It is expected that the expert will be resident in Kathmandu for approximately 13 months, of which 7 months in Phase I study and 6 person-months in Phase II study, with frequent visits to the project site.

(iv) Lead Engineer - Field Investigation and Geotechnical (Geotechnical Engineer):

The Lead Engineer – Field investigation and geotechnical studies shall have preferably Master's degree or equivalent in geotechnical or civil engineering or engineering geology and must have preferably twenty five (25) years of professional experience in planning, design and construction supervision of hydropower projects of similar nature and scale as the Karnali (Chisapani) project.

The expert shall have experience in geotechnical investigation, testing, and design of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW involving dam with height of at least 150m as geotechnical engineer/ expert and shall have proven skills including training experience. Experience shall also cover planning, design, specification, tender document preparation, construction supervision of reservoir projects of similar size to the Karnali (Chisapani) Project. Experience in the coordination and planning of field investigation of reservoir project of size similar to Karnali (Chisapani) project will have added advantages. Experience in feasibility, detailed design, construction supervision of hydropower project in Himalayan geology as geotechnical engineer will be an added advantage of the expert. It is expected that the expert will be resident in Kathmandu for approximately 11 months, of which 8 months in Phase I study and 3 months in Phase II study, with frequent visit and stay at the project site.

(v) **Lead Expert--Power System Planning, Power Market Studies, Electricity Pricing Study (Power System Planning Expert and/or Power System Economics)**

The expert shall preferably have a Master's degree or equivalent in electrical power engineering, with an additional Master's degree or equivalent in electricity economics or related discipline and must have preferably twenty (20) years of professional experience in power system planning with some experience in power system planning in cross border power and trade, and technical and regulatory issues related to regional power trade.

The expert shall have experience of power system studies including evacuation studies, load forecasting, electricity pricing, and various aspects of regional power trade, such as technical issues related to systems interconnection, system control, electricity pricing, and regulations (including the areas needing harmonization), and must have successfully worked in at least one regional power interconnection project. The Lead Expert should have experience in using the transmission system planning software package such as PSSE to supervise the Power System Engineer. Experience in power system analysis assignments in Asia will be an added advantage of the expert. Most of the above studies will be carried out in Phase I. Phase II of the project will largely be limited to revisiting the system planning, system operation and regulatory issues based on the updated information. It is expected that approximately thirteen (13) person-months, of which 10 person- months of input will be utilized in Phase I study and 3man months in Phase II study. The Expert will also coordinate with the national agencies of the regional countries for power system data, and for their inputs.

(vi) Engineering Geologist

The Geologist shall preferably have a Master's degree or equivalent in engineering geology discipline and must have preferably twenty (20) years of professional experience.

The expert shall have experience of geological investigation, studies and design in feasibility study and detailed engineering design of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW as a geologist. Experience shall also cover planning, design, specification, tender document preparation, construction supervision of reservoir projects of similar size to the Karnali (Chisapani) Project. Experience of geological investigation studies and design of hydropower project in Himalayan geology as geologist will be an added advantage of the expert. It is expected that the expert will be resident in Kathmandu for approximately 10 months, of which 8 months in Phase I study and 2 months in Phase II study, with frequent visit and stay at the project site.

(vii) Dam Engineer

The Dam Engineer shall preferably have a Master's degree or equivalent in geotechnical /civil/dam/hydropower /hydraulic engineering discipline and must have preferably twenty (20) years of professional experience.

The expert shall have previous working experience as Dam Engineer in feasibility study and detailed engineering design of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW involving dam with height of at least 150m. Experience shall also cover planning, design, specification, tender document preparation, construction supervision of reservoir projects of similar size to the Karnali (Chisapani) Project. It is expected that the expert will be resident in Kathmandu for approximately 11 months, of which 5 person-months in Phase I study and 6 person- months in Phase II study, with frequent visit and stay at the project site.

(viii) Hydrologist/Sediment engineer

The Hydrologist shall preferably have a Master's degree or equivalent in hydrology or water resources engineering or civil engineering or sediment discipline and must have preferably twenty (20) years of professional experience.

The expert shall have experience in hydrological investigation, analysis and study of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW as hydrologist. The expert shall also have experience in sediment study including investigation, analysis and interpretation and design of reservoir sedimentation and its management in reservoir type hydropower projects with storage capacity not less than 10 billion m^3 as a sediment engineer and shall have proven skills including training experience. Experience shall also cover planning, design, specification, tender document preparation, construction supervision of reservoir projects of similar size to the Karnali (Chisapani) Project. Experience of hydrological investigation, analysis and design of hydropower projects in South Asia as hydrologist/sediment engineer will be an added advantage of the expert. It is expected that the expert will be resident in Kathmandu for approximately seven (7) months, of which 5 person-months in Phase I study and 2 person-months in Phase II study, with frequent visit to the project site.

(ix) Dam Break and Flood Plain Analysis Expert

Dam breach analysis expert shall estimate the potential hazards associated with a failure of the dam including inundations analyses covering the following elements: estimation of the dam breach parameters, estimation of the dam breach outflow hydrograph; routing of the dam breach hydrograph downstream; and estimation of downstream inundation extent and severity using one-dimensional (1-D), two-dimensional (2-D), and three dimensional (3-D) modeling.

The dam break and flood plain analysis expert shall preferably have a Master's degree or equivalent in hydrology or water resources engineering or civil engineering and must have preferably twenty (20) years of professional experience in the relevant field. The expert shall have experience in dam break analysis of project of similar scale. It is expected that the expert's input will be 8 person-months of which 6 person months in Phase I and 2 person- months in Phase II study.

(x) Hydraulic Engineer

The Hydraulic Engineer shall preferably have a Master's degree or equivalent in civil/hydraulic engineering discipline and must have preferably twenty (20) years of professional experience.

The expert shall have previous working experience in the design of hydraulic structures in feasibility study and detailed engineering design of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW and involving dam of at least 150 m height as a hydraulic engineer. Experience shall also cover planning, design, specification, tender document preparation, construction supervision of reservoir projects of similar size to the Karnali (Chisapani) Project. It is expected that the expert will be resident in Kathmandu for approximately eight (8) months, of which 6 person-months in Phase I study and 2 person-months in Phase II study, with frequent visit to the project site.

(xi) Hydraulic Modeling Expert

The Hydraulic Modeling Expert shall preferably have a Master's degree or equivalent in hydraulic engineering discipline and must have preferably twenty (20) years of professional experience.

The expert shall have previous working experience in the physical and computational (numeric) modeling (computational fluid dynamics) of hydraulic structures as an input to feasibility study and detailed engineering design of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW and involving dam of at least 150 m height as a hydraulic engineer. Experience shall in physical and computational modeling of hydraulic structures of a project similar size to the Karnali (Chisapani) Project is desirable. It is expected that the expert will be resident in Kathmandu for approximately 3 person-months in Phase II study, with frequent visit to the project site.

(xii) Tunnel Engineer – Geotechnical Engineer

The Tunnel Engineer shall preferably have a Master's degree or equivalent in civil/geotechnical/geology/hydropower engineering or other relevant and must have preferably fifteen (15) years of professional experience

The expert shall have experience in field investigation, tests, design and construction supervision of successfully completed (Constructed and Commissioned) hydropower projects with power tunnel length totaling 5 km having its diameter not less than 12 m and powerhouse cavern of width not less than 25 m as tunnel engineer/expert or geotechnical engineer. The expert shall also have experience in geotechnical investigation, testing, and design of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW as geotechnical engineer/ expert and shall have proven skills including training experience. Experience of having carried out feasibility studies and detailed design or construction supervision of hydropower projects in Himalayan geology as tunnel engineer will be an added advantage of the expert. It is expected that the expert will be resident in Kathmandu for approximately seven (7) months, of which 2 person-months in Phase I study and 5 man months in Phase II study, with frequent visit to the project site.

(xiii) Structural Engineer

The Structural Engineer shall preferably have a Master's degree or equivalent in civil/structural engineering discipline and must have preferably twenty (20) years of professional experience.

The expert shall have previous working experience in feasibility study and detailed engineering design of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW and involving dam of at least 150 m height as a structural engineer and shall have proven skills including training experience. Experience shall also cover planning, design, specification, tender document preparation, construction supervision of reservoir projects of similar size to the Karnali (Chisapani) Project. It is expected that the expert will be resident in Kathmandu for approximately ten (10) months, of which 2 person-months in Phase I study and 8 person-months in Phase II study, with frequent visit to the project site.

(xiv) Seismic Engineer/Expert or Seismologist

The Seismic Engineer/Expert or Seismologist or Seismic engineer shall preferably have a Master's degree or equivalent in seismic engineering//Earthquake Engineering or other relevant discipline and must have preferably twenty (20) years of professional experience.

The expert shall have experience of seismological investigation, studies and design in as part of detailed engineering design of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW or 10 billion m3 reservoir capacity and involving dam of at least 150 m height as a seismic engineer/expert and shall have proven skills including training experience. Experience shall also cover planning, design, specification, tender document preparation, construction supervision of reservoir projects of similar size to the Karnali (Chisapani) Project. It is expected that the expert will be resident in Kathmandu for approximately three (3) months, of which 2 person-months in Phase I study and 1 person-month in Phase II study, with frequent visit to the project site.

(xv) Irrigation Engineer

The irrigation engineer shall preferably have a Master's degree or equivalent in Irrigation Engineering or Water resources engineering and must have preferably twenty (20) years of professional experience.

The expert shall have previous working experience in feasibility study and detailed engineering design of irrigation project with command are not less than 100,000 ha of successfully completed (Constructed and Commissioned) irrigation projects as a irrigation engineer and shall have proven skills including training experience. Experience shall also cover planning, design, specification, tender document preparation, construction supervision of irrigation projects of similar size to the Karnali (Chisapani) Project. Experience of having carried out feasibility or detailed design/construction supervision or a combination thereof for hydropower projects in South Asia as irrigation engineer will be an added advantage of the expert. It is expected that the expert will be resident in Kathmandu for approximately 12 months, of which 10 person-months in Phase I study and 2 person-months in Phase II study, with frequent visit to the project command areas in the South Asia region for data collection to assess the irrigation benefit. The irrigation engineer will work closely with the Agriculture Economist

(xvi) Agriculture Economist

The agriculture economist shall preferably have a Bachelor degree in Agriculture Science and Master's degree or equivalent in Agriculture Economics or related field and must have at least twenty (20) years of professional experience in the related area.

The expert shall have previous working experience in assessing the benefits of irrigation projects in terms of improved agriculture yields with command area not less than 100,000 ha irrigation projects as a agriculture economics. Experience in a feasibility study of a multipurpose hydropower projects as an agriculture economist in South Asia will be an added advantage. It is expected that the expert will be resident in Kathmandu for approximately 12 months, of which 10 person-months in Phase I study and 2 person-months in Phase II study, with frequent visits to the project command areas in the South Asia region for data collection to assess the irrigation benefit. The Agriculture Economist will work closely with the Irrigation Engineer to assess the irrigation benefits.

(xvii) Construction Planning and Scheduling Expert

The Construction Planner shall preferably have a Master's degree or equivalent in civil engineering or construction management or other engineering discipline and must have preferably twenty (20) years of professional experience.

The expert shall have experience in preparation of construction plan and schedule of successfully completed (Constructed and Commissioned) hydropower projects having capacity not less than 4000 MW as construction planner. It is expected that the expert will be resident in Kathmandu for approximately five (5) months, of which 3 person-months in Phase I study and 2 person-months in Phase II study, with frequent visit to the project site.

(xviii) Natural Resources Management (NRM)/ Natural Assets Management (NAM) Expert

Natural Resources Management Expert shall preferably have Master’s degree or equivalent in natural resources management with bachelor’s degree in civil engineering or most related combination and must have preferably twenty (20) years of professional experience.
Resources management for creating highest value in terms of benefit generation out of the multipurpose water resources infrastructure project is the to be made by the NRM/NAM expert. The NRM/NAM aspect is expected to consider / contribute best natural resources utilization and evaluation of the resources permanently submerged due to creation of the reservoir. The professional is expected to consider / contribute best natural resources utilization covering foreseeable upstream and downstream stretch of the watershed covered under the development. The professional shall be well experienced with professional and academic exercise in evaluation

of resources and computation of resource rent for complex water resources project similar to Karnali Chisapani. It is expected that the expert will be resident in Kathmandu for approximately six (6) months, in Phase I study, with frequent visit and stay at the project site.

(xix) Criteria Decision Analysis (MCDA) Expert

The MCDA Expert shall preferably have Master's degree or equivalent in planning and management for infrastructure development with bachelor's degree in civil engineering or most related combination and must have preferably twenty (20) years of professional experience. The professional shall be well experienced with professional and academic exercise in application of at least Analytic Hierarchy Process (AHP) based MCDA.

The expert is expected to gather key decision indicators covering Technical, Social / Safeguard / Gender, Environmental / Climate, Economic / Financial for a holistic option analysis. The options are expected to emerge in the process of development of the multipurpose project and need to utilize scientific MCDA tool. The utilization of MCDA tool may be for ranking, priority setting and decision basis for recommendation. The adopted MCDA tool is expected to have capability to cover subjective and objective information in a single framework for holistic analysis, generation of weights of various criteria, sub-criterions and indicators. It is also expected to conduct sensitivity analysis in the process of option analysis. The MCDA expert is expected to work independently but in close coordination with other domain experts as well as key stakeholders of the project. It is expected that the expert will be resident in Kathmandu for approximately three (3) months in Phase I study

(xx) Cost Engineer/Quantity Surveyor

The Cost Engineer/Quantity Surveyor shall preferably have a Master's degree or equivalent in civil/mechanical engineering or other relevant discipline and must have preferably twenty (20) years of professional experience.

The expert shall have previous experience as cost engineer/estimator of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than

4000 MW as cost engineer/estimator and shall have proven skills including training experience. Experience shall also cover quantity/cost estimation and tender document preparation of reservoir projects of similar size to the Karnali (Chisapani) Project. It is expected that the expert will be resident in Kathmandu for approximately six (6) months, of which 4 person-months in Phase I study and 2 person-months in Phase II study, with frequent visit to the project site.

(xxi) Project Economist

The Project Economist shall preferably have a Master's degree or equivalent in economics or finance or Engineering economics or Business Administration or other relevant discipline and must have preferably twenty (20) years of professional experience.

The expert shall have experience in economic analysis of hydropower projects, economic study of the displaced people and project area in reservoir type hydropower project involving permanent resettlement of Project Affected Families as economist. The expert shall also have experience in financial analysis of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW as financial specialist. It is expected that the expert will be resident in Kathmandu for approximately six (6) months, of which 5 person-months in Phase I study and 1 person-month in Phase II study, with frequent visit to the project site.

(xxii) Power System Engineer

The Power System Engineer shall preferably have a Master's degree or equivalent in power system or electrical engineering discipline and must have preferably twenty (20) years of professional experience in electrical system modeling and analysis, and be familiar with system analysis software such as PSS/E. He/she should be well-versed in load flow, stability and short-circuit analysis as well as international best practices in power system planning.

The expert shall have experience in planning, expansion, reinforcement and analysis of integrated power system and power evacuation of capacity 4000 MW or above as Power System Engineer.

Experience in the planning, expansion and reinforcement analysis of integrated power system in South Asia as power system expert will be an added advantage of the expert. It is expected that the expert will be resident in Kathmandu for approximately five (5) months, of which 3 person-months in Phase I study and 2 man-months in Phase II study, with frequent visit to

(xxiii) Electricity/Energy Economist

The Project Economist shall preferably have a Master's degree or equivalent in economics, energy economics or finance or business administration or other relevant discipline and must have preferably twenty (20) years of professional experience.

The expert shall have experience in demand analysis, electricity pricing, regional electricity trade, and willingness and ability to pay analyses for electricity. The expert shall have experience in having carried out similar assignments in a regional setting preferably in developing regions of the world. The estimated total input of this expert will be six (6) months, of which 5 person-months in Phase I study and 1 person-month in Phase II study, with frequent visit to the project site.

(xxiv) Hydro-mechanical Engineer

The Hydro-mechanical Engineer shall preferably have a Master's degree or equivalent in mechanical engineering or other related discipline and must have preferably twenty (20) years of professional experience.

The expert shall have experience in the preparation of hydro-mechanical design specifications of hydro-mechanical components of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW as mechanical/hydro-mechanical engineer and shall have proven skills including training experience. It is expected that the expert will be resident in Kathmandu for approximately six (6) months, of which 2 person-months in Phase I study and 4 person-months in Phase II study, with frequent visit to the project site.

(xxv) Electro-mechanical Engineer

The Electro-mechanical Engineer shall preferably have a Master's degree or equivalent in electrical/power system engineering discipline and must have preferably fifteen (15) years of professional experience.

The expert shall have experience in the preparation of powerhouse electrical equipment design specifications, conditions of contract at the detailed engineering study of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW as an electro-mechanical engineer. It is expected that the expert will be resident in Kathmandu for approximately six (6) months, of which 2 person-months in Phase I study and 4 person-months in Phase II study, with frequent visit to the project site.

(xxvi) Transmission Line & Sub-station Engineer

The Transmission Line & Sub-station Engineer shall preferably have a Master's degree or equivalent in high voltage/electrical engineering discipline and must have preferably twenty (20) years of professional experience.

The expert shall have experience in design of transmission lines and substations of 765 kV or above voltage class as transmission line & substation engineer. It is expected that the expert will be resident in Kathmandu for approximately six (6) months, of which 3 person-months in Phase I study and 4 person-months in Phase II study, with frequent visit to the project site.

(xxvii) Contract Specialist

The Contract Specialist shall preferably have a Master's degree or equivalent in Construction management or law or engineering or other relevant discipline and must have preferably twenty (20) years of professional experience.

The expert shall have experience in the preparation of conditions of contract of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW as contract specialist and shall have proven skills including training experience. Experience shall also cover tender document preparation, negotiation, and arbitration of reservoir projects of similar size and scale to Karnali (Chisapani) Project. It is expected that the expert will be resident in Kathmandu for approximately seven (7) months in Phase II study, with some necessary visits to the project site.

(xxviii) Environmental Specialist

The Environmental Specialist shall preferably have a Master's degree or equivalent in environmental science/ engineering/natural resources or other relevant discipline and must have preferably twenty (20) years of professional experience.

The expert shall have experience in the preparation of EIA of reservoir type hydropower projects involving permanent resettlement of project affected families as environmental specialist and shall have proven skills including training experience. He should have lead team of experts in carrying out EIA studies for similar size hydropower projects meeting EIA standards of International Financial Institutions, such as, the ADB and the World Bank and similar other organizations. It is expected that the expert will be resident in Kathmandu for approximately ten (10) months in Phase I study, with necessary visits to the project site.

(xxix) Sociologist

The sociologist shall preferably have a Master's degree or equivalent in sociology or anthropology or social sciences or other relevant discipline and must have preferably twenty (20) years of professional experience.

The expert shall have experience in sociological study as part of EIA and/or SIA in reservoir type hydropower projects involving permanent resettlement of Project Affected Families as sociologist.

It is expected that the expert will be resident in Kathmandu for approximately eight (8) months in Phase I study, with necessary visits to the project site.

xxx) Community Development /Resettlement Expert

The Community Development/Resettlement expert shall preferably have a Master's degree or equivalent in rural development/social/anthropological science and must have preferably twenty (20) years of professional experience.

The expert shall have experience in preparation of resettlement plan in reservoir type hydropower projects involving permanent resettlement of persons as community development/resettlement expert. It is expected that the expert will be resident in Kathmandu for approximately six (6) months in Phase I study, with some necessary visits to the project site.

(B) International Expert Non key

(i) Electrical engineer

The Electrical Engineer shall preferably have a Master's degree or equivalent in electrical engineering discipline and must have preferably fifteen (15) years of professional experience.

The expert shall have experience in the design and preparation of specifications of powerhouse electrical equipment at the detailed engineering study of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW as an electrical engineer. It is expected that the expert will be resident in Kathmandu for approximately six (6) months, of which 2 person-months in Phase I study and 4 person-months in Phase II study, with frequent visit to the project site.

(ii) GLOF Expert

The GLOF Expert shall preferably have a Master's degree or equivalent in engineering /natural science/hydrology or other relevant discipline and must have preferably fifteen (15) years of professional experience.

The expert shall have experience in the study and analysis of GLOF and in the study of climate change of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW as GLOF/Climate change expert. Experience in hydrological and meteorological studies including GLOF and climate change for hydropower projects in the Hindu Kush region as hydrologist or GLOF expert or Climate change expert will be an added advantage of the expert. It is expected that the expert will be resident in Kathmandu for approximately two (2) months in Phase I study, with frequent visits to the project site.

(iii) Climate Change Expert

The Climate Change Expert shall preferably have a Master's degree or equivalent in engineering /natural science/hydrology or other relevant discipline and must have preferably fifteen (15) years of professional experience. The expert shall have experience in the study and analysis of impact of climate change of successfully completed (Constructed and Commissioned) reservoir type hydropower projects with capacity not less than 4000 MW as Climate change expert, preferably in the Hindu Kush region.

The Climate Change Expert should cover climate change impacts, including the quantification of direct and embedded CO2e emissions using a standard methodology such as the IFC Carbon Emissions Estimator Tool (CEET) or similar method.

The Consultant shall include any proposed measures to increase the resilience of project infrastructure to climate-related impacts, particularly landslides. The Consultant shall include these criteria and parameters in the technical design criteria.

It is expected that the expert will be resident in Kathmandu for approximately two (2) months in Phase I study, with frequent visits to the project site.

(iv) Road/Bridge Expert

The road/bridge expert shall preferably have a Master's degree or equivalent in civil/road/bridge engineering discipline and must have preferably fifteen (15) years of professional experience in related areas.

The expert shall have working experience in planning and design of roads and bridges and shall have experience in examining the upgrading needs of the existing roads and bridges on the transportation route from the nearest seaport to the project site, to improve load bearing capacity for transportation of powerhouse electrical and mechanical equipment for hydropower projects with unit capacity of not less than 400MW. It is expected that the expert will be resident in Kathmandu for approximately four (4) months, of which 3 person-months in Phase I study and 1 person-months in Phase II study, with visits to the project site and the potential transportation route. The road/bridge expert shall in close coordination with the transportation engineer.

(v) Transportation Engineer

The transportation expert shall preferably have a Master's degree or equivalent in /transportation engineering discipline and must have preferably fifteen (15) years of professional experience.

The expert shall have working experience in identifying the most effective mode of inland transportation of the powerhouse electrical and mechanical equipment for hydropower projects with unit capacity of not less than 400MW. The expert shall also have the experience in assessing the nearest seaport to the project site for the transportation of equipment, and identify the most direct inland transportation route in coordination with the road/bridge expert. It is expected that the expert will be resident in Kathmandu for approximately four (4) months, in Phase I study, with visits to the project site and the potential transportation route.

(vi) Other International Experts, if required

The Consultant shall propose experts in different fields deemed necessary to complete the assignments. These experts shall preferably have a Master's degree or equivalent in relevant field and must have preferably twenty (20) years of professional experience. It is expected that the expert will be resident at the home office of the Consultant for approximately fourteen (14) months, of which 4 man months in Phase I study and 10 man months in Phase II study, with frequent necessary visit to the project site.

(C) National Experts (Non Key)

It is recognized that local expertise will be needed in several areas of the study. Hence budgetary provision with breakdown of man months has been made to take advantage of the experience of the most senior professionals in Nepal in field, such as, water resources, hydrology, hydropower, agriculture, environmental and social issues, and rural socioeconomic conditions. Involvement of such individual consultants or firms with specialization in respective fields will help in sharing of knowledge and transfer of technology and expertise to local engineers and scientists during the study. However, the prime responsibility for quality advice will remain with the international Consultant. It is really difficult to define precisely the number of man months needed. However, a tentative input of local professionals required for the study is estimated and presented in the following table. Besides, some budgetary provisions for additional input through local consulting firm to conduct studies on agriculture, environment and socioeconomic data collection have been made separately.

I. Senior National Professionals

(i) Counterpart Lead Engineer - Reservoirs, Dams, Waterways and Power facilities (Hydropower Engineer):

The counterpart Lead Engineer – Reservoirs, dams, waterways and Power facilities who will assist the Lead Engineer (key International) in performing his duties and supervise staff assigned to support the lead engineer in the design of reservoir, dams, water ways and power facilities and participate in the review/update/design of these structures shall have preferably Master's degree or equivalent in hydropower/water resources engineering and must have preferably twenty five (25) years of professional experience in planning, design and construction supervision of hydropower projects.

The senior professional shall have previous experience of working as project manager/team leader of planning, design, (feasibility study and detailed engineering) and construction supervision and management of hydropower projects involving underground tunnels and underground powerhouse caverns. He also must have experience in planning and design (feasibility studies and detailed engineering design) of storage type hydropower projects. Experience shall also cover planning, design, specification, tender document preparation, and construction supervision hydropower projects. Experience of working with multinational and multicultural teams and involvement in storage project similar to Karnali (Chisapani) will be an added advantage of the professional. It is expected that the senior professional will be resident in Kathmandu for approximately forty (40) months, of which 24 person-months in Phase I study and 16 man months in Phase II study, with frequent visits to the project site.

(ii) Counterpart Lead Engineer - Water resources, Planning and Impact studies:

The counterpart Lead Engineer – Water Resources, Planning and Impact studies who will assist the lead Engineer (Key Int'l) in performing his duties and supervise staff assigned to support the lead engineer to perform hydrology and participate in reservoir simulation study, participate in and provide local knowledge and experience in all hydrological sediment study activities and assist in the hydraulic design of the project. He shall have preferably Master's degree or equivalent in water resources engineering/Hydraulics/Hydrology/ and must have preferably twenty-five (25) years of professional experience in planning, design and construction supervision of hydropower projects.

The senior professional shall have previous experience of working as project manager/team leader of planning, design, (feasibility study and detailed engineering) and construction supervision and management of hydropower projects. He also must have experience in planning and design (feasibility study and detailed engineering design) of storage type hydropower projects. Experience of working with multinational and multicultural teams and involvement in storage project similar to Karnali (Chisapani) and experience in the coordination and planning of environmental and social studies will be an added advantage of the professional. It is expected that the senior professional will be resident in Kathmandu for approximately Twenty-Eight (28) months, of which 16 person-months in Phase I study and 12 person-months in Phase II study, with frequent visits to the project site.

(iii) Counterpart Lead Engineer - Field Investigation and Geotechnical (Geotechnical Engineer):

The counterpart Lead Engineer – Field investigation and geotechnical studies will assist the lead Engineer (Key Int'l) in performing his duties including assist in evaluating the results of all field explorations and provide local knowledge and experience in all aspects of the study and assist in obtaining all background data. She/he shall have preferably Master's degree or equivalent in geotechnical or civil engineering or engineering geology and must have preferably twenty-five (25) years of professional experience in planning, design and construction supervision of hydropower projects.

The expert shall have experience in geotechnical investigation, testing, and design of ROR and reservoir type hydropower projects as geotechnical engineer/ engineering geologist and shall have proven skills including training experience. Experience shall also cover planning, design, specification, tender document preparation, and construction supervision of hydropower projects. Experience in the coordination and planning of field investigation of reservoir project of size similar to Karnali (Chisapani) project will have added advantages. It is expected that the senior professional will be resident in Kathmandu for approximately Twenty-four (24) months, of which 14 person-months in Phase I study and 10 person-months in Phase II study, with frequent visits to the project site.

(iv) Counterpart Lead Expert--Power System Planning, Power Market Studies, Electricity Pricing Study (Power System Planning Expert and/or Power System Economist)

The Counterpart Lead Expert will assist the Lead Expert--Power System Planning, Power Market Studies, Electricity Pricing Study (Key Int'l) in performing his duties including power system planning, power evacuation studies, power market studies, and study on electricity pricing including assessment of the willingness and ability to pay for electricity in in the regional countries. In particular, the Counterpart Lead Expert shall be responsible for carrying out the power system studies including load flow, short circuit analysis, and transient stability. Based on the analyses, the Expert shall identify the backbone and tie lines—synchronous, asynchronous or back to back HVDC grid solutions-- and grid substations including their capacity, that need to be constructed to evacuate the power from the project to the identified regional markets. The Expert shall have preferably Master's degree or equivalent in power system engineering and must have preferably twenty-five (25) years of professional experience in planning and design transmission systems using preferably PSS®E - Power Transmission System Planning Software, version 33 or later.

Experience shall also cover planning, design, specification, tender document preparation, construction supervision transmission and substations. It is expected that the senior professional will be resident in Kathmandu for approximately Twenty-four (24) months, of which 14 person-months in Phase I study and 10 person-months in Phase II study, with frequent visits to the project site.

(II) Other National Professionals:

Other national professionals, except civil engineers and electrical engineers shall have preferably Master's degree or equivalent in relevant field and must have preferably fifteen (15) years of professional experience. Civil Engineers and electrical engineers shall preferably have a Master's degree or equivalent in relevant field and must have preferably three (3) years of professional experience.

5.8 Employer's Input

5.8.1 Data and Reports

SEC will provide the following inputs, project data and reports to facilitate preparation of the Proposals to the short-listed Consultants.

(i) The following reports and data will be made available to the consultants:
   - Feasibility Study Report of Karnali (Chisapani) Multipurpose Project – 1989 along with annexes,

(ii) Assistance to facilitate site visit if required by shortlisted consultant with prior notice to SEC

5.8.2 Administrative support for Consultant Team

If required by local regulations, SEC will provide Consultant with necessary support letters for obtaining visas for consultant staff and other personnel permits. The cost and timing of obtaining the above is entirely consultant responsibility.

5.9 Other Facilities and Support Services

All other facilities such as vehicles, computers photocopy machines, fax machines, furniture, fixtures, office space, office equipment, accommodation for its staffs shall be managed by the Consultant and the cost of all the facilities required by the consultant to carry out the assignment shall be included in the consultant's proposal.

5.10 Project Schedule

Two schedules one Project Study Schedule and the other Implementation Schedule comprising of different activities including is 30 months for Phase I study 18 months and 9 years for project construction are presented below.

Table 5.6: Work Schedule

WORK SCHEDUL FOR THE STUDY (Project Preparation for Implementation)

S. No	Activities of Works		Year 1												Year 2												Year 3												Year 4												Year 5												Year 6			
			1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
1	Decision to carry forward the updated feasibility study	★																																																																	
2	Funding arrangement for the Phase I Study	★																																																																	
3	Preparation of EOI, RFP and Bidding Documents including review		■	■	■																																																														
4	Shortlisting of Consultants					■	■																																																												
5	Issue of RFP Documents & Submission of Proposals							■	■																																																										
6	Evaluation of the technical and financial proposals including Decision									■	■	■	■	■																																																				
7	Negotiations and award of the contract														■	■																																																		
	Commence of Services																★																																																	
8	Setting up of a contract administration office by SEC in Kathmandu													★																																																				
9	Phase I Study and Submission of deliverables including Draft Final Report																	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■																										
10	Review & Comments by POE/SEC/Participating Regional countries																																										■	■	■	■																						
11	Submission of Final Report (Phase I)																																														■	■																				
12	Decision to carry forward Phase II study																																															★																				
13	Funding arrangement for the Phase II Study																																															★																				
14	Letter to Procced to the Consultant for Phase II Study																																																★																			
15	deliverables including Draft Final Report																																																	■	■	■	■	■	■	■	■	■	■	■	■	■	■				
16	Review & Comments by POE/SEC/Participating Regional countries																																																															■	■		
17	Submission of Final Report (Phase II)																																																																	■	■

Table 5.7: Implementation Schedule

IMPLEMENTATION SCHEDUL

S. No	Activities of Works		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16
1	Decision to carry forward the updated feasibility study																	
2	Funding arrangement for the Phase I Study																	
3	Preparation of EOI, RFP and Bidding Documents including review																	
4	Shortlisting of Consultants																	
5	Issue of RFP Documents & Submission of Proposals																	
6	Evaluation of the technical and financial proposals including Decision																	
7	Negotiations and award of the contract																	
	Commence of Services																	
8	Setting up of a contract administration office by SEC in Kathmandu																	
9	Phase I Study and Submission of deliverables including Draft Final Report																	
10	Review & Comments by POE/SEC/Participating Regional countries																	
11	Submission of Final Report																	
12	Decision to carry forward Phase II study																	
13	Funding arrangement for the Phase I Study																	
14	Letter to Procced to the Consultant for Phase II Study																	
15	deliverables including Draft Final Report																	
16	Review & Comments by POE/SEC/Participating Regional countries																	
17	Submission of Final Report																	
18	Financial Arrangment																	
19	Tendering anf Award of Contract (Mid of Year 6 to Year 7)																	
20	Construction & Completion including generation from first 2 units (7.5 Years)																	
21	Commissionong of all 18 Units (1.5 years)																	

CHAPTER 6: COST ESTIMAES FOR HIRING OF THE CONSULTANTS

6.1 Basis for Cost Estimate

The cost estimate of the consulting assignment is based on the estimate of the person-months of each identified experts for the assignment and the estimated monthly rates, and the related direct cost components. The information such as the personnel input (person-months), and the monthly rates are based on the experience of the experts from recent procurement of consulting services for the two storage projects in Nepal--1200 MW Budhi Gandaki Hydropower Project, and 300 MW Dudh Koshi Hydropower Project both procured under the international competitive selection under the Quality and Cost Based Selection procedure. While estimating the person-month inputs, the available information from the contract signed with the Himalayan Power Consultant for the Feasibility Study of the Karnali (Chisapani) Multipurpose project has also been utilized. The monthly rates of the national consultants have been based on the suggested billing rates of Society of Consulting, Architectural & Engineering Firms (SCAEF, Nepal) (please see SCAEF website, http://scaef.org.np

The Consultant (of this review study) believe that the Feasibility Study (1989) carried out by the HPC is comprehensive in terms of site investigation, site selection of project structures/components, hydrological studies, project optimization and sizing. Therefore, only analysis by way of review and updating of the recommendations of the HPC study report is proposed in this study. Carrying out fresh topographical survey is suggested, as there has been significant change in the land use in the project areas, as new settlements have come up and a number of new physical infrastructure shave been put in place in the period since the HPC study. Regarding the hydrological studies, updating of the hydrology and flow analysis in light of the availability of additional flow data since the HPC study was completed, is suggested. Similarly, further analysis with respect to the sedimentation for the confirmation of the results and to carrying out further studies if necessary have been envisaged. Regarding, seismological investigations, in light of the recent earthquake in Nepal further analysis is warranted to confirm the seismic design parameters. After a review of the available information from the HPC study, the consultant may propose for additional geological or geotechnical investigations. The amount provided in the provisional sum may be utilized for such additional geotechnical/geological investigations.

Areas needing significant data collection, analysis and update are the social and environmental assessment, resettlement, and power market analysis and transmission planning and the irrigation benefits assessment.

The cost estimates prepared on the above basis are summarized in Table 6.1, and the detailed cost estimates in presented in **Annex 3**. The cost estimates have been divided in to the following categories:

A. Remuneration of the personnel

B. Miscellaneous Expenses

C. Environmental and Social Assessment

D. Hydrological Investigation and Physical Modeling

E. Topographical Survey and Mapping

F. Power System and Power Market Studies

G. Provisional Sum

H. Contingencies

Table 6.1: Summary of Budget Estimate for Phase I and Phase II of the Study

S.No.	Description	Amount in US$	
		Phase I	**Phase II**
A	Remuneration	**8,594,006**	**4,958,501**
B	Out of Pocket Expenses		
	i) Miscellaneous Expenses	1,834,770	1,224,480
	ii) Lump Sum Competetive Items		
	Environmental Study (EIA, SIA, EMAP, etc.)	905,000	
	Hydrological Investigation including Physical Model Testing	375,000	550,000
	Topographical survey including LIDAR Mapping	705,000	
	Other survey including natural resources, irrigated area and agriculture	185,000	
	Power System and Power Market Studies	570,000	
	Sub-total ii	2,740,000	550,000
	Sub-total B	**4,574,770**	**1,774,480**
C	Provisional Sum	**2,500,000**	**1,500,000**
D	Contingencies	**581,040**	**340,830**
	Sub-total (A+B+C+D)	**16,249,816**	**8,573,811**
	VAT@13%	**2,112,476**	**1,114,595**
	TOTAL AMOUNT IN US$	**18,362,292**	**9,688,406**

CHAPTER 7: The Way Forward

7.1 General

Once the SEC Board determines to carry forward the updated feasibility study of the Karnali (Chisapani) Multipurpose Project, the first step is to look for the funding for the Phase I of the project. Once the funding has been secured, the following are the activities to be undertaken (the estimated duration of each activity has been given in the parenthesis):

1. Preparation of request for proposal (RFP) documents for the hiring of an international consultants, through quality based selection (QBS) or quality and cost based selection (QCBS) procedures with Time-Based Contract. The RFP document will be prepared in accordance with the procurement guideline of the funding agency, and the standard RFP document issued by the funding agency. (3 months including review)
2. Short-listing of the consultant firms. This is normally done by issuing a notice inviting the eligible confirms to submit the expressions of interest (EOIs). (2 months)
3. Issuing the RFP documents to the shortlisted consulting firms, and submission of the proposals (2 months)
4. Evaluation of the technical and financial proposals (4-6 months including decision making and approval)
5. Negotiations and award of the contract (2 months).
6. Setting up of a contract administration office by SEC in Kathmandu.
7. Commencement of consulting assignments
8. Submission of deliverables by the consultants including Final Report: 30 months from the date of commencement--for Phase I. Review of the updated feasibility report by SEC and participating regional countries.
10. If the project is found feasible to extend the contract of the consultants for Phase II of the assignment.
11. Road show to various investors-- multilateral, bilateral and private investors. Since, the Karnali (Chisapani) Multipurpose Project is a large project needing investments unprecedented in any single infrastructure in South Asia, getting necessary finances would be a challenge. For this purpose, a management consultant firm may he hired to determine

the modality of the project development (PPP or as a regional projects with investment from the participating countries), and to assess the viable financing structure for the implementation of the project. (2-4 years)

12. Construction of the Project (9 years).

7.2 Threshold Criteria of International Consultants (Minimum Qualification of the Consultant to submit EOI Proposal)

The Consultant must have extensive consulting experience in general and must have experience in carrying out feasibility study, environmental impact assessment and detailed design or construction supervision of large hydropower projects; and one of them should be a reservoir (storage capacity type hydropower plant of capacity 4200 MW (about 40% of the Karnali Chisapani capacity) preferably, with dam height of 160 m or higher (About 60% height of planned Karnali Chisapani). The Consultant may have the above-mentioned experience from different projects.

The interested Consultants must provide information in the form of brochures, description of completed similar assignments, work experience in the specified areas, availability of appropriate skills among staff, etc. to show their technical, managerial and financial competence to perform the services. Such information must also include a brief description of the firm together with the organization structure and staffing. In particular, the information must include, among others, the following:

- General and specific experience of the firm,
- Experience of the firm in feasibility study, detailed design and construction supervision of reservoir type projects of this scale. The Consultant must provide information on jobs undertaken in the past giving a brief description of each job undertaken, the funding source(s), and amount of contract and information on the Client/Employer,
- Corporate profile of the firm,
- Information on organizational strength.

ANNEXES

ANNEX 1: PROJECT HIGHLIGHTS

KARNALI (CHISAPANI) MULTIPURPOSE PROJECT

Location:	Karnali River at Chisapani, Bardiya and Kailali Districts 600 km form Kathmandu, 500 km from Delhi and 100 km from Nepalgunj
Hydrologic Characteristics	
Drainage area of basin	43,679 km^2 (30% of Nepal)
Long-term average flow	1889 m^3/s
Average dry season flow (November-May)	451 m^2/s
Average wet season flow (June-October)	2690 m^3/s
Average annual basin precipitation	1247 mm
Average annual runoff	1003 mm
Runoff ratio	0.80
Highest recorded flood	21,700 m^3/s (September 11, 1983)
Design Floods	
Probable maximum flood (PMF)	63,000 m^3/s
1 – in – 10,000 yr	32,900 m^3/s
1 – in – 1,000 yr.	26,600 m^3/s
1 – in – 100 yr.	20, 600 m^3/s
Sediment average load	260 x 10^6 t/yr
Equivalent specific yield	6000 t/km^2
Reservoir Characteristics	
Full supply level (FSL)	415 m
Minimum operating level (MOL)	355 m

Drawdown	60 m
Surface area at FSL	339 km^2
Length of main arm	100 km
Reservoir volume at FSL	28.2 x 10^9 m^3
Reservoir volume at MOL	12.0 x 10^9 m^3
Live storage	16.2 x 10^9 m^3
Equivalent to	37% of average annual runoff
Loss of live storage due to sedimentation, after 75 years	30%
Dam Characteristics	
Type	Gravel-fill embankment with central core
Crest elevation	445 m
Crest width	15 m
Dam width at FSL	140 m
Crest length	745 m
Lowest foundation elevation	175 m
Maximum height of dam	270 m
Embankment slopes	2.25:1)(upstream), 1.9:1 (downstream)
Volume of dam	45 x 10^6 m^3
Spillway	
Type	Ungated chute with flip bucket and plunge pool
Crest width	60 m
Chute length	860 m
Width of Flip bucket	100 m
Invert elevation of flip bucket	220 m
Bottom elevation of plunge pool	140 m
PMF design discharge	19,218 m^3/s
Maximum velocity at flip bucket	57.0 m/s

River Diversion Facilities	
Location	Right bank
Upstream cofferdam crest elevation	205 m
Dam crest elevation (Stage 2)	287 m
Number of tunnels	2
Diameter of tunnels	15 m
Length of tunnels	2400 m each
Maximum design discharge	9270 m^{3s}
Equivalent flood (Stage 2)	1:1000 yrs
Upstream water elevation	286 m
Maximum flow velocity	27 m/s
Diversion tunnels also provided for Bangar and Kelari Kholas	
Outlet Facilities	
Low level for riparian release during reservoir filling	In one diversion tunnel, up to 1000 m^3/s at 160 m head
Emergency irrigation	Left bank tunnel, 1000 m^3/s
Sediment flushing (initial provision only)	Into diversion tunnels, 5000 m^3/s total
Intake Structure	
Location	South wall of Bangar Khola valley
Type	Bell mouthed intake with gate shaft
Number of intakes	6
Invert level	322 m
Power Tunnels	
Type	Circular Concrete-line tunnel

Number of tunnels	6
Diameter	15 m
Length	390 – 880 m (4100 m total)
Vertical Drop Shafts	
Number of Shafts	6
Diameter	14 m
Length	140 m each
Penstocks	
Type	Steel-lined
Number of penstocks	18
Diameter	7.2 m
Length	16 – 230 m (3300 m total)
Valve type	Butterfly valve, 7.2 m diameter
Powerhouse and Equipment	
Type	Underground cavern
Dimensions	Length 705 m, width 27.7 m, height 50 m(height from drainage gallery to crown)
Number of units	18
Turbine type	Vertical shaft, Francis turbine (620 MW)
Generator type	Totally enclosed vertical shaft, synchronous umbrella type (642 MVA)
Transformers	54 x 214 MVA 18/400 kV, single phase 27 x 428 MVA 400/765 kV, single phase (autotransformers)
Powerhouse cranes	Two 720-t heavy duty cranes
Power Plant Head and Flow	
Minimum net head at MOL	145 m

Maximum net head FSL	208 m
Rated net head	165 m
Design net head	185 m with reservoir at el 393.3 m
Maximum power discharge at MOL	7110m^3/s, 18 units running
Maximum power discharge at FSL	4900 m^3/s, 15 units running
Normal tail-water level	203 m
Tailrace Tunnels	
Type	Horseshoe-shaped tunnel with gates
Number of tunnels	6
Dimensions	15 m wide, 18 m high
Length	165 -270 m (1215 m total)
Reregulating Facilities	
Type	Low embankment dam and reservoir
Location	8 km downstream from main dam
Length	6 km
Maximum dam height	24 m
Dam volume	6 x 10^6 m^3 + 3 x 10^6 m^3 for blanket
Reservoir level	200 m FSL
Drawdown	7 m
Live storage	100 x 10^6 m^3
Spillway	Gated 21 bays x 15 m wide with stilling basin, 19 218 m^3/s design discharge
Power Plant	6 x 14 MW bulb turbines at 13.5 m head
Transmission	
Type	5 circuits of 765 kV (Main power plant to India, 300 km)

	1 Circuit of 220 kV (Regulating power plant to India, 160 km)
Main Power Plant Capacity	
Target firm capacity factor	20%
Firm capacity	9000 MW (18 x 500 MW at MOL)
Installed capacity	10,800 MW (18 x 600 MW)
Firm Energy	15,007 GWh/yr
Average energy	20,842 GWh/yr
Reregulating Power Plant	
Average energy (typical)	621 GWh/yr
Irrigation in Nepal	
Gross command area	238,700 ha
Net command area	191,000 ha
Capital cost (irrigation infrastructure)	US $ 627 million
Annual benefit (al full development)	US $157 million
Internal rate of return	9.8%
Irrigation in India	
Increase in dry season flow due to Chisapani	300%
Increase in annual production	18 x 10^6 t (Sarda and Saryu only)
Saryu Sahayak gross command area	2,000,000 ha
Saryu gross command area	1,200,000 ha
Total gross command area	3, 200, 000 ha
Annual benefits	US $416 million
Socio-environmental Impact	
Total submerged land	339 km^2 at FSL (+15 km^2 for reregulating)

Inundated cultivated land	7200 h
Inundated Forest land	20,500 ha
Total affected population	43,000 (1987)
Population to resettle	60,000 (allowing for growth)
Land area required	12,650 ha
Total resettlement cost	US $108 million
Total environmental mitigation cost	US $75 million
Construction Quantities	
Surface excavation for structure	$40 \times 10^6 m^3$
Underground excavation	$6 \times 10^6 m^3$
Embankment fill	$56 \times 10^6 m^3$
Concrete	$3 \times 10^6 m^3$
Capital Cost (1988)	
Civil works cost	US $1,667 million
Electromechanical equipment	US $1,575 million
Transmission Cost	US $332 million
Access and infrastructure	US $280 million
Engineering and management	US $385 million
Resettlement and environment	US $232 million
Contingencies	US $419 million
Total project cost	US $4,890 million
Capital cost per kilowatt (excluding financing Costs)	US $453 million
Implementation Schedule	
Preconstruction	5 years
Construction	9 years
Installation and commissioning	4 years
Main construction start	January 1995

First unit on power	November 2003
Project Completion (eighteenth unit)	November 2007
Economic Evaluation (Values discounted at 10% November 2003)	
Capital cost	US$ 6,396 million
Q&M cost	US$ 412 million
Total cost	US$ 6,808 million
Power benefits	US$ 13,586 million
Irrigation benefits	US$ 3,169 million
Other benefits	US$ 25 million
Total benefits	**US$ 16,780 million**
Net benefits	US$ 6,396 million
B/C ration	2.46
Economic internal rate of return	27%
Power benefits (in India)	
Forecast peak demand in Northern India (in 2007, Chisapani completion date)	78,000 MW
At full absorption Chisapani power will displace	4000 MW of coal-fired and 8000 MW of Gas turbine plant
Consequent cost saving are over US$8,000 million investment in thermal plant, over US $500 million/yr in fuel, (10 x10^6 t of coal plus substantial oil)	
Unit cost of generation at Chisapani	3.3 ¢/kWh (Peak power)
Comparative cost of base load coal generation	4.5¢ /kWh

Annex 2: Drawings

Figure 1(Figure 1.1 in the Main Report; Feasibility Study, 1989): General Arrangement of Karnali (Chisapani) Multipurpose Project

Figure 2(Figure 3.1 in the Main Report; Feasibility Study, 1989): Project Location map of Karnali (Chisapani) Multipurpose Project.

Figure 3(Figure 18.1 in the Main Report; Feasibility Study, 1989): General arrangement of Karnali (Chisapani) Multipurpose Project.

Figure 4(Figure 19.1 in the Main Report; Feasibility Study, 1989): Chisapani Dam Typical Sections of Karnali (Chisapani) Multipurpose Project

Figure 5(Figure 23.2 in the Main Report; Feasibility Study, 1989): General arrangement Power Facilities of Karnali (Chisapani) Multipurpose Project

Figure 6(Figure 23.3 in the Main Report; Feasibility Study, 1989): Water conveyance system profile of Karnali Chisapani Multipurpose Project

(All these Drawings are place at the end of this report)

Annex 3: Cost Estimate

A. REMUNERATION

		Phase I			24	months
		Phase I			16	months

	Expertise	No of PM		Rate US$/mm	Amount (US$)	
		Phase I	Phase II		Phase I	Phase II
	International Consultant - Key					
1	Project Manager/Team Leader	20	14	45,000	900,000	630,000
2	Lead Engineer - Reservoirs, Dams, Waterways and Power facilities (Hydropower Engineer)	10	8	40,000	400,000	320,000
3	Lead Engineer - Water resources, Planning and Impact studies (Hydrologist/Hydraulic Engineer)	7	6	40,000	280,000	240,000
4	Lead Engineer – Field Investigation and Geotechnical (Geotechnical Engineer)	8	3	40,000	320,000	120,000
5	Lead Engineer – Power System Planning, Power Market Studies, Electricity Pricing Study	10	3	40,000	400,000	120,000
6	Engineering Geologist	8	2	35,000	280,000	70,000
7	Dam Engineer	5	6	35,000	175,000	210,000
8	Hydrologist/Sedimentologist	5	2	35,000	175,000	70,000
9	Dam Break and Flood Plain Analysis Expert	6	2	35,000	210,000	70,000
10	Hydraulic Engineer	6	2	35,000	210,000	70,000
11	Hydraulic Modeling Expert		3	35,000	-	105,000
12	Tunnel Engineer - Geotechnical Engineer	2	5	35,000	70,000	175,000
13	Structural Engineer	3	8	35,000	105,000	280,000
14	Seismic Expert/Seismologist	2	1	35,000	70,000	35,000
15	Irrigation Engineer	10	2	35,000	350,000	70,000
16	Agriculture Economist	10	2	35,000	350,000	70,000
16	Construction Planning and Scheduling Engineer	3	2	35,000	105,000	70,000
17	Natural Resources Management Expert	6		35,000	210,000	-
18	Multicriteria Decision Analysis Expert	3		35,000	105,000	-
19	Cost Engineer/ Quantity Surveyor	4	2	35,000	140,000	70,000
20	Project economist – Economic & financial Analysis	5	1	35,000	175,000	35,000
21	Power System Engineer	3	2	35,000	105,000	70,000
22	Electricity/Energy Economist	4	1	35,001	140,004	35,001
23	Hydro- mechanical Engineer	2	4	35,000	70,000	140,000
24	Electro-mechanical Engineer	2	4	35,000	70,000	140,000
25	Transmission Line & Sub-station Engineer	3	3	35,000	105,000	105,000
26	Contract Specialist		9	35,000	-	315,000
27	Environmental Specialist	10	1	35,000	350,000	35,000
28	Sociologist	8	1	35,000	280,000	35,000
29	Community Development/ Resettlement Expert	6	1	35,000	210,000	35,000
	Sub total Key Int'l	**171**	**100**		**6,360,004**	**3,740,001**
	International Consultant - Non Key					
29	Electrical Engineer	3	2	35,000	105,000	70,000
30	GLOF Expert	2		35,000	70,000	
31	Climate Change Expert	2		35,001	70,002	
32	Road/Bridge Expert	3		35,000	105,000	-
33	Transportation Engineer	4		35,000	140,000	
34	Various Other Experts	6	8	35,000	210,000	280,000
	Sub total Non Key Int'l	**20**	**10**	**35,000**	**700,002**	**350,000**
	Total International Experts	**191**	**110**		**7,060,006**	**4,090,001**

Annex 3: Cost Estimate (cont...)

National Professionals (Non Key)

	Expertise	Person-Months		Rate	Amount (US$)	
		Phase I	Phase II	US$/mm	Phase I	Phase II
	A: Senior National Professionals					
1	Counter part Lead Engineer - Reservoirs, Dams, Waterways and Power facilities (Hydropower Engineer)	24	16	6,000	144,000	96,000
2	Counter part Lead Engineer - Water resources, Planning and Impact studies (Hydrologist/Hydraulic Engineer)	16	12	6,000	96,000	72,000
3	Counterpart Lead Engineer – Field Investigation and Geotechnical (Geotechnical Engineer)	14	10	6,000	84,000	60,000
4	Counterpart Lead Expert – Power System Planning, Power Market Studies, Electricity Pricing Study)	16	5	6,000	96,000	30,000
	B: Other National Professionals					
5	Geologist	12	3	4,500	54,000	13,500
6	Water Resources Engineer	20	12	4,500	90,000	54,000
7	Natural Resources specialist	20	5	4,500	90,000	22,500
8	Multi Criteria Decision Analyst	12	3	4,500	54,000	13,500
9	Hydrologist	12	3	4,500	54,000	13,500
10	Hydraulic Engineer	12	4	4,500	54,000	18,000
11	Structural Engineer	6	12	4,500	27,000	54,000
12	Irrigation Engineer	20	4	4,500	90,000	18,000
13	Construction Planning and Scheduling Engineer	6	4	4,500	27,000	18,000
14	Cost Engineer/ Quantity Surveyor	12	6	4,500	54,000	27,000
15	Project economist – Economic & financial Analysis	8	4	4,500	36,000	18,000
16	Power System Engineer	5	3	4,500	22,500	13,500
17	Hydro- mechanical Engineer	6	8	4,500	27,000	36,000
18	Electro-mechanical Engineer	6	8	4,500	27,000	36,000
19	Transmission Line & Sub-station Engineer	6	3	4,500	27,000	13,500
20	Contract Specialist		12	4,500		54,000
21	Environmental Specialist	14		4,500	63,000	
22	Sociologist	12		4,500	54,000	
23	Community Development/ Resettlement Expert	10		4,500	45,000	
24	Agriculture Engineer	8		3,500	28,000	
25	Botanist	7		3,500	24,500	
26	Zoologist	5		3,500	17,500	
27	Fisheries	6		3,500	21,000	
28	Civil Engineers	30	50	2,500	75,000	125,000
29	Electrical Engineers	21	25	2,500	52,500	62,500
	Sub total Non Key Nat'l	**346**	**212**		**1,534,000**	**868,500**
	Total of A: Remuneration				**8,594,006**	**4,958,501**

Annex 3: Cost Estimate (cont...)

B Out of Pocket Expenses

I Miscellaneous Expenses

	Description		Quantity		Rate in US$	Amount in US$	
			Phase I	Phase II		Phase I	Phase II
1	International Travel	RT	44	35	2,500	110,000	87,500
2	In transit Travel Expenses	RT	44	35	50	2,200	1,750
3	Regional travel	RT	16	4	600	9,600	2,400
4	Local Travel (Kathmandu-Nepalgunj) Expatriate	RT	105	93	350	36,750	32,550
5	Per Diem –Int'l. Kathmandu	days	5,730	3,300	100	573,000	330,000
6	**Home office Backup support**						
7	Office Operations	month	24	16	7,000	168,000	112,000
8	Communications	month	24	16	1,500	36,000	24,000
9	Report Preparation, including stationery	month	24	16	1,000	24,000	16,000
10	**Office Expenses**						
11	Office Rent (Kathmandu and Site)	Months	24	16	5,000	120,000	80,000
12	Office Furniture	LS	1	1	50,000	50,000	50,000
13	Office Equipment (Computer, Printer, UPS, Fax, Networking including all accessories)	LS	1	1	60,000	60,000	60,000
14	Vehicle rental -Kathmandu (5 Nos.)	Months	24	16	4,500	108,000	72,000
15	Vehicle Rental-At Site (3 Nos.)	Months	12	8	3,900	46,800	31,200
16	Office Operation (KTM + Site)	Months	12	8	5,000	60,000	40,000
17	Company/branch setup including other related costs	LS	1	1	2,500	2,500	2,500
18	Legal and accounting advisory services	year	2	1	10,000	20,000	12,500
19	Communications	month	24	16	500	12,000	8,000
20	Report Preparation, including stationery	month	24	16	1,000	24,000	16,000
21	Operation & maintenance of Vehicles	month	24	16	3,000	72,000	48,000
22	Insurance	Months	24	16	400	9,600	6,400
23	**Office Administrative & Support Staff**						
24	Office Manager	Month	24	16	1,500	36,000	24,000
25	Account Officer	Month	24	16	1,000	24,000	16,000
26	Draft person	Month	24	16	1,500	36,000	24,000
27	Office Assistant	Month	48	32	400	19,200	12,800
28	Drivers	P month	156	104	500	78,000	52,000
29	Office Security	Months	24	16	600	14,400	9,600
30	**Consultant's Local Professionals Expenses**						
31	Travel by Air (Kathmandu-Nepalgunj)	RT	16	4	220	3,520	880
32	Per Diem Field Allowance for Local Staff	Days	3,460	2,120	20	69,200	42,400
33	Software	LS	1	1	10,000	10,000	10,000
34	**Total of Miscellaneous expenses**					**1,834,770**	**1,224,480**

Annex 3: Cost Estimate (cont...)

	II. Other Lump sum Competitive						
A	**Environmental Study (EIA, SIA, EMAP, etc.)**						
	Description		Quantity		Rate in US$	Amount in US$	
			Phase I	Phase II		Phase I	Phase II
1	Preliminary Site Visit and study	LS	1	NA	20,000	20,000	
2	Baseline Survey	LS	1	NA	225,000	225,000	
3	Census Survey	LS	1	NA	250,000	250,000	
4	Public Hearing	LS	1	NA	50,000	50,000	
5	Impact Study	LS	1	NA	75,000	75,000	
6	Preparation of EMAP	LS	1	NA	65,000	65,000	
7	EIA report	LS	1	NA	30,000	30,000	
8	Social Impact Assessment	LS	1	NA	75,000	75,000	
9	Rehabilitation and Resettlement Action Plan (ACRP- Acquisition Compensation Resettlement Action Plan)	LS	1	NA	50,000	50,000	
10	Buffer zone and affected area development planning	LS	1	NA	65,000	65,000	
	Sub-total					**905,000**	
B	**Hydrological Investigation including Physical Model Testing**						
	Description		Quantity		Rate in US$	Amount in US$	
			Phase I	Phase II		Phase I	Phase II
1	Bathymetric Survey (supplementary)	LS	1	NA	250,000	250,000	
2	Physical Modeling of Spillway and other hydraulic structures	LS	NA	1.00	550,000		550,000
3	Hydrological and sedimentological investigation as required in the TOR	LS	1	NA	125,000	125,000	
	Sub total					**375,000**	**550,000**
C	**Topographical survey including LIDAR Mapping**						
	Description		Quantity		Rate in US$	Amount in US$	
			Phase I	Phase II		Phase I	Phase II
1	Establishment of survey control network with connection from national grid & ground verification	LS	1	NA	250,000	250,000	
2	Preparation of topographical maps	LS	1	NA	30,000	30,000	
3	LIDAR mapping of reservoir area and its periphery including possible resettlement area	LS	1	NA	425,000	425,000	
	Sub-total LiDAR Mapping & Topographical Survey					**705,000**	
D	**Other survey including natural resources, irrigated area and agriculture**	**LS**				**185,000**	
E	**Power System and Power Market Studies**						
	Power System Analysis	LS	1	NA	200,000	200,000	
	Power Market Study	LS	1	NA	180,000	180,000	
	Willingness and ability to pay study	LS	1	NA	190,000	190,000	
	Subtotal E					**570,000**	
	Sub-total of Lump Sum Competitive Items					**2,740,000**	**550,000**
	Sub-total of B					**4,574,770**	**1,774,480**

Annex 3: Cost Estimate (cont...)

C Provisional Sum

	Description		Quantity		Rate in US$	Amount in US$	
			Phase I	Phase II		Phase I	Phase II
	I. Geological, Geotechnical Investigation and Hydrological Investigations						
	Supplementary Investigation as a part of updated feasibility study	LS	1		2,500,000	2,500,000	
	Addition Investigation as part of detailed engineering study	LS		1	1,500,000		1,500,000
	Sub-total Geological/geotechnical and Hydrological Investigation					2,500,000	1,500,000
	Sub-total of C					**2,500,000**	**1,500,000**
D	**Contingencies**						
	Description		Quantity		Rate in US$	Amount in US$	
			Phase I	Phase II		Phase I	Phase II
	Physical Contingency @ 10 % of A, B & C					323,219	192,075
	Price Contingency @ 3% in Remuneration					257,820	148,755
	Sub-total of D					581,040	340,830

Annexure 3: Summary of Cost Estimate

S.No.	Description	Amount in US$	
		Phase I	**Phase II**
A	Remuneration	**8,594,006**	**4,958,501**
B	Out of Pocket Expenses		
	i) Miscellaneous Expenses	1,834,770	1,224,480
	ii) Lump Sum Competetive Items		
	Environmental Study (EIA, SIA, EMAP, etc.)	905,000	
	Hydrological Investigation including Physical Model Testing	375,000	550,000
	Topographical survey including LIDAR Mapping	705,000	
	Other survey including natural resources, irrigated area and agriculture	185,000	
	Power System and Power Market Studies	570,000	
	Sub-total ii	2,740,000	550,000
	Sub-total B	**4,574,770**	**1,774,480**
C	Provisional Sum	**2,500,000**	**1,500,000**
D	Contingencies	**581,040**	**340,830**
	Sub-total (A+B+C+D)	**16,249,816**	**8,573,811**
	VAT@13%	**2,112,476**	**1,114,595**
	TOTAL AMOUNT IN US$	**18,362,292**	**9,688,406**

Figure-1: General Arrangement

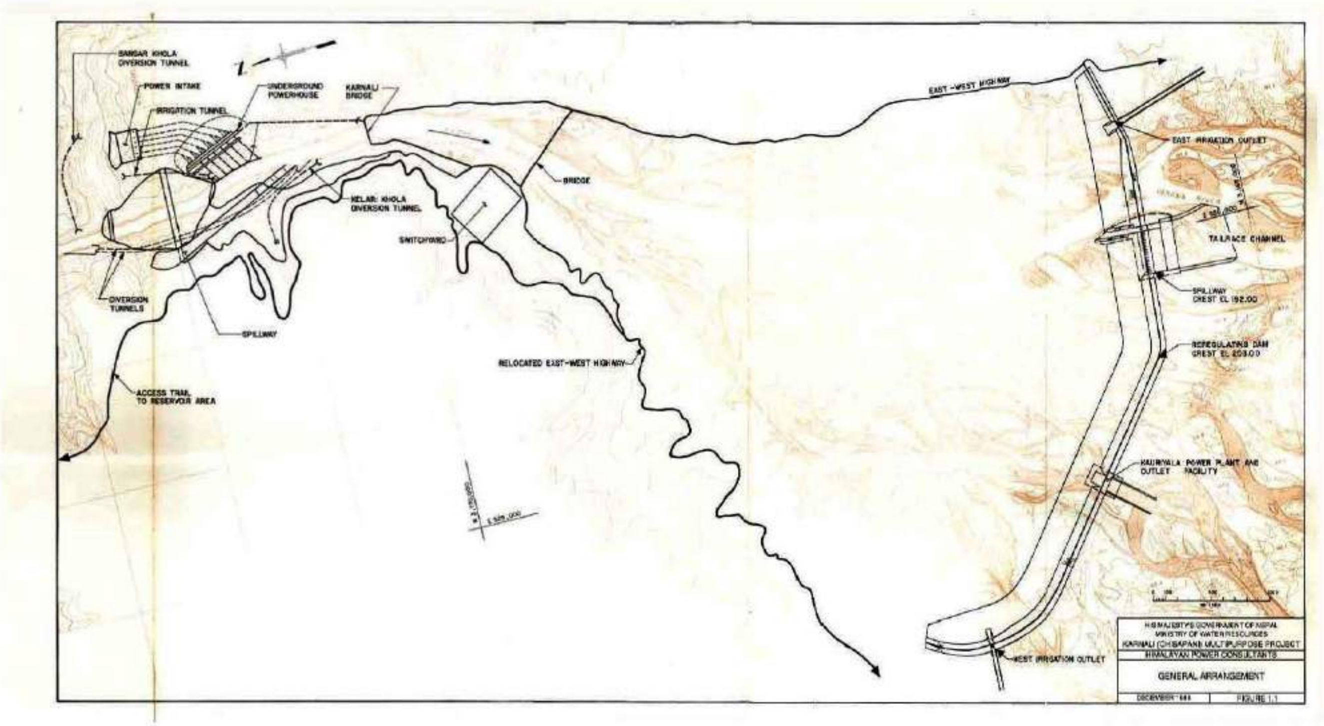
BANGAR KHOLA DIVERSION TUNNEL
POWER INTAKE
IRRIGATION TUNNEL
UNDERGROUND POWERHOUSE
KARNALI BRIDGE
BRIDGE
KELARI KHOLA DIVERSION TUNNEL
SWITCHYARD
DIVERSION TUNNELS
SPILLWAY
RELOCATED EAST-WEST HIGHWAY
ACCESS TRAIL TO RESERVOIR AREA
EAST-WEST HIGHWAY
EAST IRRIGATION OUTLET
TAILRACE CHANNEL
SPILLWAY CREST EL 192.00
REREGULATING DAM CREST EL 203.00
KAURIYALA POWER PLANT AND OUTLET FACILITY
WEST IRRIGATION OUTLET
HIS MAJESTY'S GOVERNMENT OF NEPAL
MINISTRY OF WATER RESOURCES
KARNALI (CHISAPANI) MULTIPURPOSE PROJECT
HIMALAYAN POWER CONSULTANTS
GENERAL ARRANGEMENT
FIGURE 1.1

Figure-2: Project Location Plan

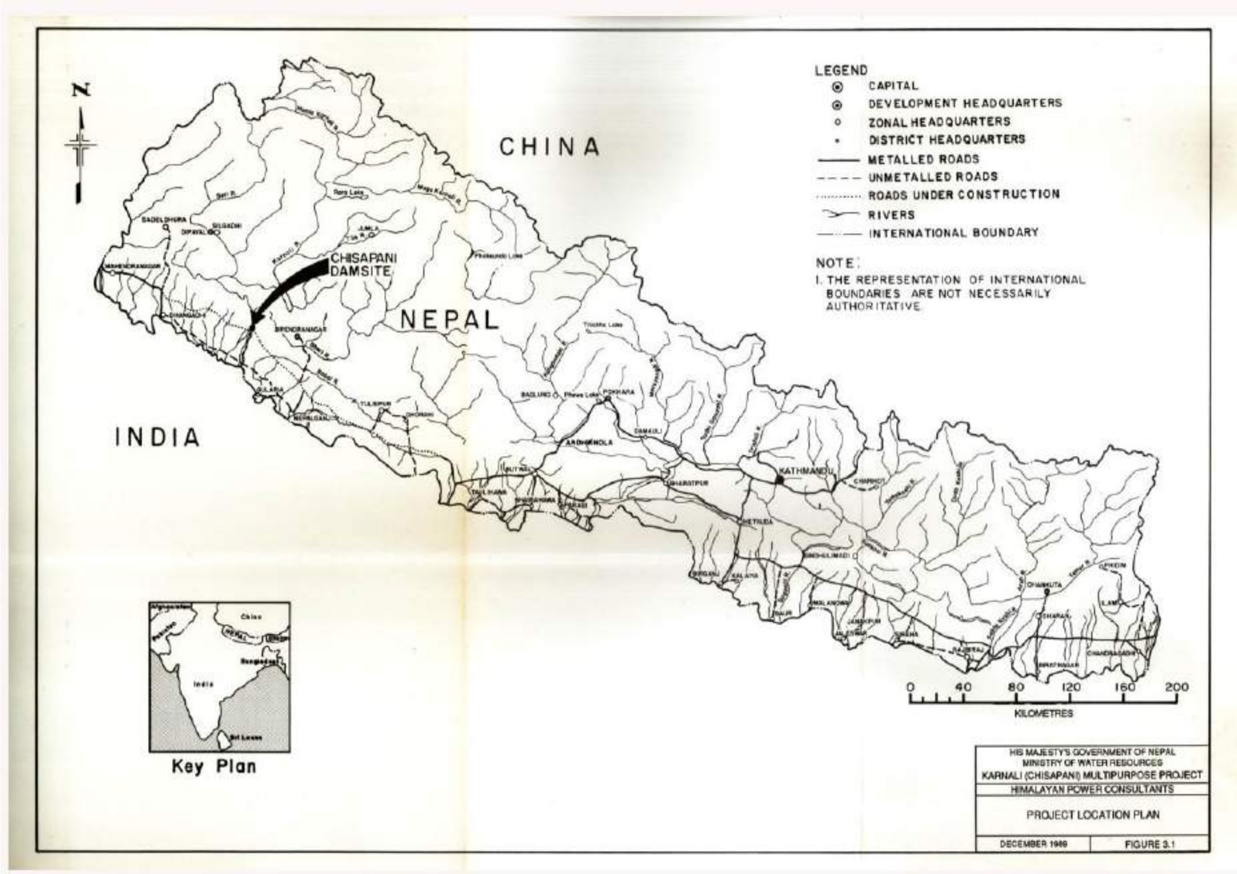

Figure-3: General Arrangement Damsite

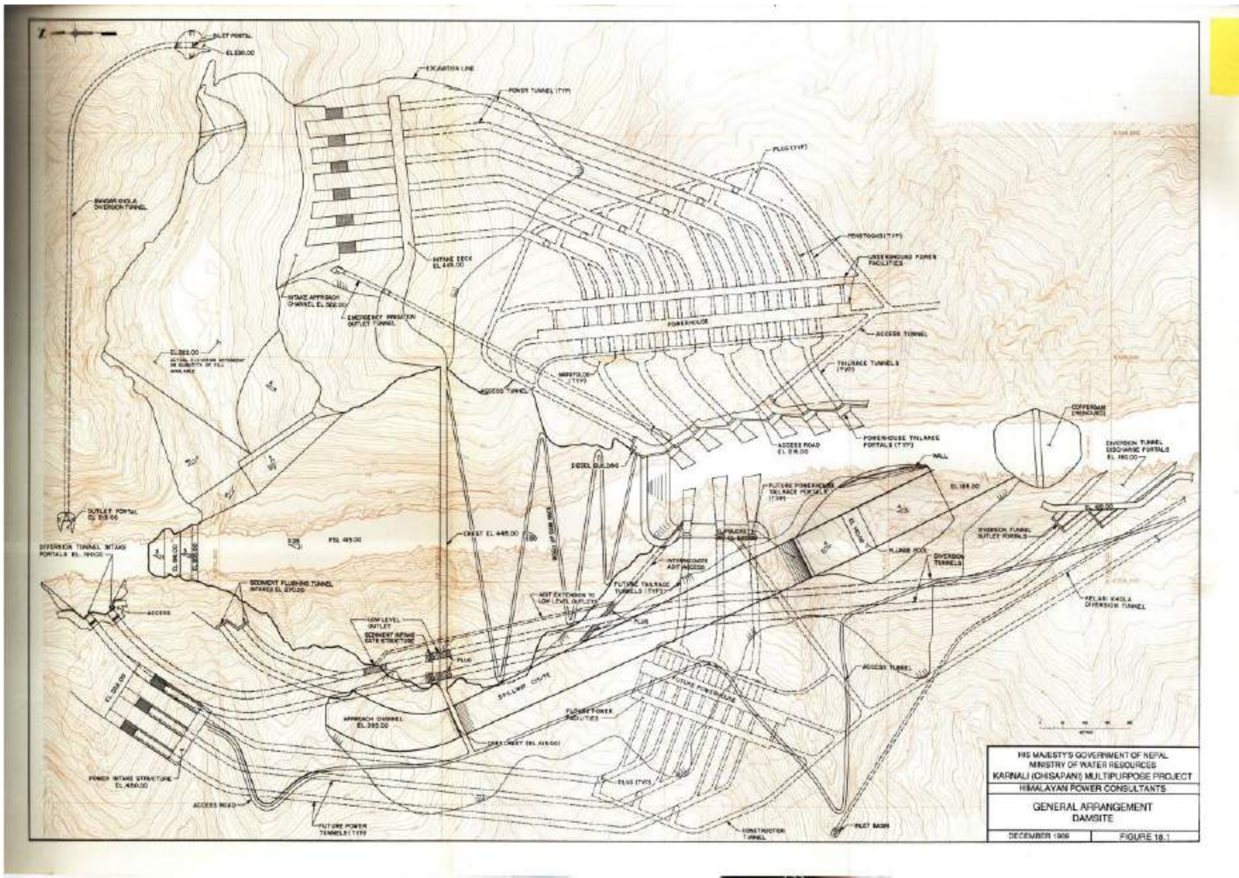

Figure-4: Chisapani Typical Section

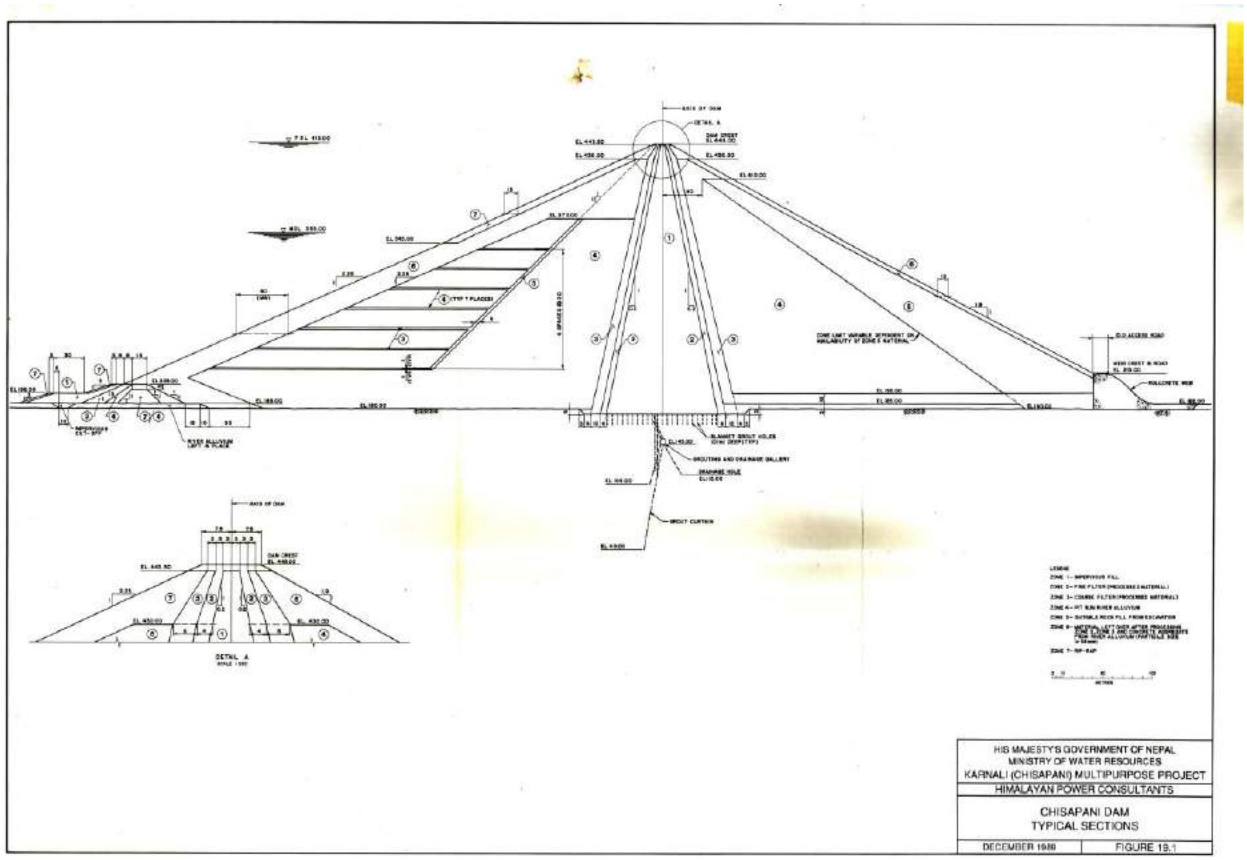

Figure-5: General Arrangement Power Facilities

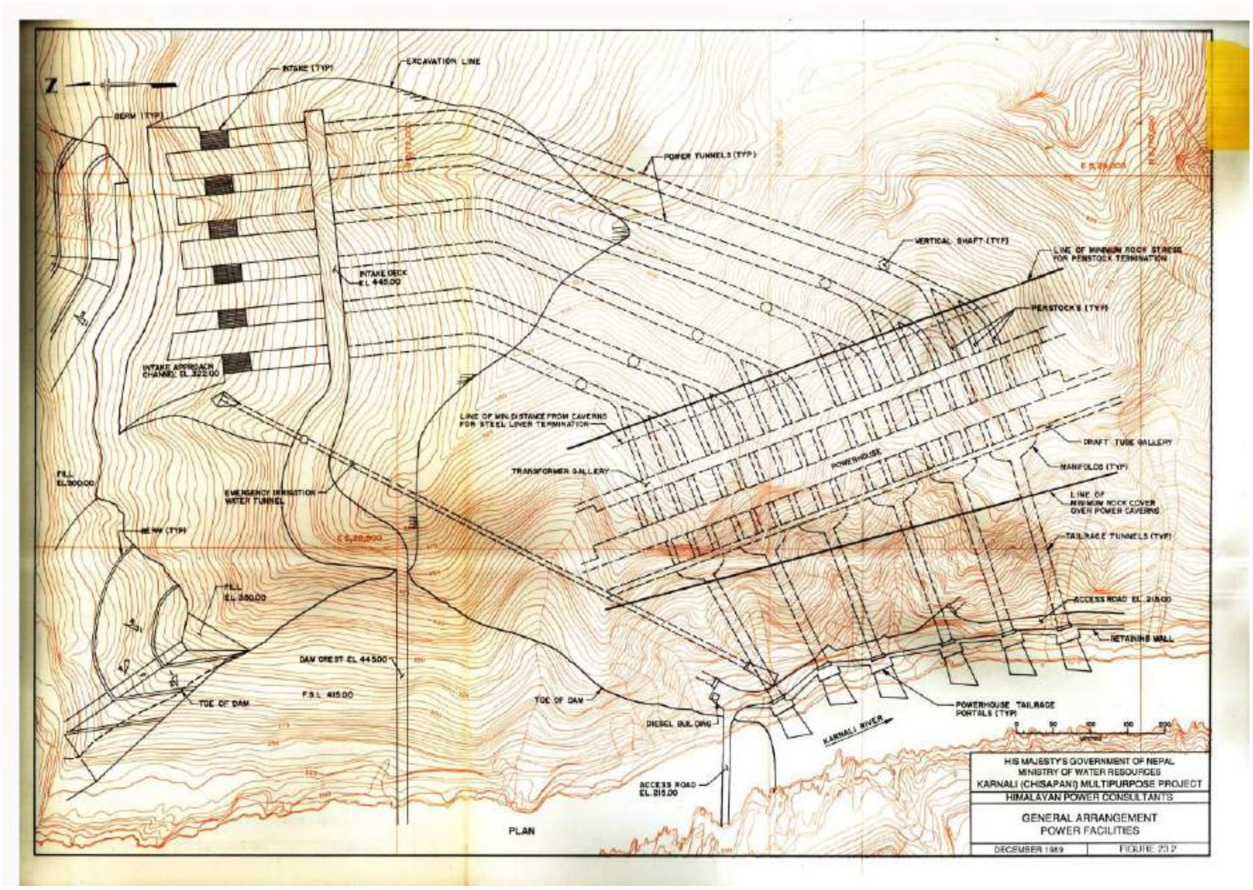

Figure-6: Water Conveyance System Profile