CHAPTER 6 PROJECT DESIGN

6.1 General

The project optimization study provided in Chapter 5 showed the optimum scheme of the Sapt Gandaki Project to be the fill type dam at the damsite-B. The full supply water level will be at EL.230 with an installed capacity of 225 MW.

The project design has been carried out based on the above determined project scheme.

The project design carried out are as shown in Fig.-6.1 to Fig.-6.6. General basic considerations about the design are described in the previous Section 5.1.3. In this Chapter, further details about the design for the determined scheme are provided.

6.2 River Diversion System

In the case of the fill type dam, the river discharge will not be allowed to overtop the dam during construction. The river diversion system will be designed to have enough capacity to handle any floods throughout a whole year without overtopping the dam.

Then, the recorded maximum flood with a peak discharge of 16,350 m^3/sec is adopted as the diversion design flood. A diversion tunnel at the damsite is considered unsuitable due to insufficient rock covering above the tunnel. It was determined to provide the diversion system with open channels.

Two diversion channels (one with the bottom width of 52 m in right bank and another with the width of 126 m in left bank) are provided by the following reasons;

With due consideration to the occurrence of a big magnitude of the discharge, the handling of such discharge should be made without disrupting the normal situation. Therefore, it is intended that the diversion open channels would be provided with nearly the same width as the existing river width at the damsite. The floods can then be handled as in normal flood condition. The total width of 178 m, nearly same as the existing river width, was provided for the channels. The spillway structures are designed to be installed in the portion of the diversion open channel. This spillway structure will be constructed during the dam embankment work due to the necessary construction procedure. For this construction works, a separate diversion system was considered necessary, i.e. another diversion system is used for handling the river discharge during the construction of the spillway structures in one diversion system. Thus, two diversion open channels will be excavated in both banks as stated. The topography in the right bank is rather steeper resulting in larger excavation volume for the right bank diversion open channel. The width of the right bank diversion open channel is limited to its necessary minimum dimension which makes it possible to discharge the dry season river run-off during the construction of the spillway structure in the left bank channel portion.

In spite of such arrangement, the excavation for the diversion system comes to a big volume of 5.7 million m^3. Aiming to reduce the excavation volume, both the diversion channels are designed to come near to the river channel as close as possible, providing partition walls between the dam and the diversion open channels.

As the foundation rock in the site is not so firm, shotcrete protection will be made on the excavated slopes of the diversion channels to prevent erosion by discharge and collapse of excavated slope. The shotcrete protection will be provided up to EL.196.0 near which the water level will rise at the occurrence of the diversion design flood.

6.3 Dam

The dam is designed as a zoned rockfill dam of the center core type which is the most standard type of the fill type dam. Its upstream and downstream slope will be 1:2.5 (1:1.9 above F.S.L.) and 1:1.9 respectively considering the use of the quarry rock found about 7 km to 10 km north from the damsite, which is the most cheapest way for obtaining the rockfill materials.

The dam crest level was finally determined at EL.238.0 which is 8 m above the reservoir full supply level of EL.230.0 as an allowance of necessary free board.

There is a thick sand and gravel deposit in the river channel, which is 30 to 40 m deep in the middle part. Treatment to cut off underseepage through this thick deposit is hard and costly work, and therefore, the following conceivable treatment methods were carefully examined from both technical and economic viewpoint.

(1) To excavate a core trench down to the foundation rock surface and replace it with the core material.

(2) To carry out foundation cement grouting down to the foundation rock surface in the core portion.

(3) To make a cut-off concrete wall in the sand and gravel deposit by excavating a narrow trench and placing concrete in it.

The method to make the core trench in the deposit is the usual treatment when the deposit is relatively thin. In the case of the Sapt Gandaki Project, however, the deposit is very thick. The required trench excavation of a large quantity in the riverbed is a difficult and time-consuming work due to its muddy condition. As seen in Table-6.1, the necessary cost for this work is higher compared with the other two methods. Then, the method to make a core trench was judged not appropriate in the case of the project.

Investigating the actual work record of the other two methods, i.e. the foundation cement grouting and the cut-off concrete wall, the technical difficulty and necessary time for the work will be generally similar. The necessary cost is also estimated to be generally the same as seen in Table-6.1. Such being the case, the concrete wall in which a higher reliability of the seepage cut-off is expected was adopted.

In the case of application of the concrete wall in the river deposit, attention should be paid for the occurrence of cracks in the core material in the contact portion of the concrete wall and the core material due to a differential settlement. Thus, a plastic material is designed to be provided in the contact portion to allow the settlement of core material on the concrete wall.

Curtain grouting is planned to be done into the foundation rock through pipes to be embedded in the above cut-off concrete wall. Consolidation and blanket grouting will be done in the foundation sand and gravel deposit of the core portion to ensure its firmness and water tighteness.

For the purpose of inspection of seepage water after impounding and of additional grouting is required, an inspection gallery is provided along the bottom line in the core portion.

6.4 Spillway

It is undesirable in the design standard to install a concrete structure in the dam body of a fill type dam, since the dam becomes difficult to act as one body due to the difference of material properties. Then, the spillway is designed to be provided in the diversion channel portions in both banks, separately from the dam.

The spillway consists of a gated concrete dam, a 100 m long stilling basin and a subdam at the end of the stilling basin. Three radial gates (15 m wide and 19 m high) are set in the right bank spillway and 7 radial gates of the same type are set in the left bank spillway. The total width of the spillway is 178 m (52 m in the right bank spillway and 126 m in the left bank spillway) including width of 8 intermediate piers at which the radial gates are anchored.

In compliance with the design criteria in Japan, the spillway has a capacity to pass the spillway design flood of 23,000 m^3/sec (1.2 times of 200 year recurrence flood) at the flood water level set at EL.232.2 without considering any regulation effect of the reservoir. The spillway also has a capacity to handle a 10,000 year recurrence flood which is considered nearly corresponding to the probable maximum flood with a free board of 3.0 m.

As stated above, a sufficient allowance of the free board is provided in consideration of uncertainties involved in the huge catchment area of 31,100 km^2 and possible troubles in the spillway gate operation. Provided with this free board, the malfunction of 4 spillway gates due to troubles can be allowed in discharging the spillway design flood without overtopping the dam.

Further, assuming another possible accident in the spillway gate operation, i.e., the case that the gates are not opened due to lack of any power supply source or operator, it is considered in the design to equip 2 sets of emergency diesel generator which will automatically work at the time of power failure, each having a capacity of 300 kVA, and a device for automatic gate operation which will work at a certain water level.

The energy dissipator is designed as a stilling basin type which is deemed the most suitable type of the energy dissipator in view of the topographic condition and the discharge magnitude to handle. The energy dissipator was designed to effectively dissipate the discharge energy of 100 year recurrence flood (17,800 m^3/sec) which is considered enough in consideration of the degree of importance of the structure.

Two kinds of stilling basin types are considered, i.e. one is the type provided with a subdam at the end of the stilling basin and the other is without the subdam. The economic comparative study of two types indicated a higher cost in the type without the subdam due to necessary excavation to lower the stilling basin floor level by more than 10 m. Thus, the stilling basin was designed as the type provided with subdam at its end.

6.5 Intake and Waterway

The power station is positioned in the left bank adjacent to the left bank spillway, which is deemed the most proper layout from topographic and economical views. Accordingly, the intake and waterway are also located in the left bank adjacent to the left bank spillway. The waterway structures are composed of an intake bay, an intake dam and penstocks.

Taking into consideration sedimentation and suspended load during flood period, the intake bay is essential for protection against sand inflow by the constructing intake wall. The intake wall is provided in parallel to the spillway discharge flow between the diversion channel and the intake dam. Its crest level is set 10 m higher than the spillway overflow crest level so that the sediment will be effectively discharged out together with the spillway discharge without depositing it in front of the intake wall.

Notwithstanding the above arrangement, inflow of some sediment into the intake bay will be inevitable. This unavoidable sediment inflow into the intake bay was designed to be conveyed to the spillway stilling basin by the sand drain conduit embedded in the intake dam.

The axis of the intake dam connected to the spillway is the same as that of the spillway and main dam. Its height is 38 m. Center line of intake conduits is determined at EL.214.5 in consideration of minimum operation water level set at EL.226. Approach velocity at the entrance trash rack is limited to 1.0 m/sec at the maximum discharge to reduce energy loss as much as possible.

The power waterway consists of 3 lines of intake and penstock. In each intake conduit, an intake gate (roller gate of 7.6 m wide and 7.6 m high) is equipped for maintenance purpose of the penstock. Three penstock lines begin just after the intake gates. Length of each penstock line is about 72 m up to the powerhouse. Its diameter was determined at 7.6 m, considering the proper flow velocity in the penstock and the requirement of power generating. The penstocks are all surrounded with concrete encasement in the outside of the intake dam.

The provision for the installation of additional one unit in future is made, i.e. the intake and penstock (only the portion embedded in the dam body) for the additional unit are provided. The penstock is closed with a blindcover at its downstream end.

In relation to the layout of intake and waterway, another conceivable layout, i.e. the layout provided with the desilting basin instead of the proposed intake bay with the intake wall to protect inflow of sediment was also examined. This layout, however, was found to be very costly and not so effective. The proposed provision of the intake bay was judged to be the best way for the reasons explained in detail in Section 5.1.3.

6.6 Power Station

Above-ground type powerhouse is constructed at just downstream of the intake dam (80 m downstream from the dam axis). It houses three units of power generating equipment, each having 75,000 kW capacity. Outdoor switchyard is arranged on the left bank of the tailrace.

6.6.1 Civil Works

The powerhouse is founded on a bedrock of sand stone with enough bearing strength to construct the powerhouse. The powerhouse is provided with dimensions of 104 m in length, 35.1 m in width and maximum height of about 53.9 m to house three units of turbines and generators set at intervals of 26 m (center to center), and other various necessary equipment and facilities. The ground floor level of the powerhouse was determined at EL.198.0, providing a free board of 2.3 m above the tailwater level of EL.195.7 at the time of occurrence of 100 year porbable flood (17,800 m^3/sec). In the determination of the above ground floor level, the hydraulic condition in the adjacent spillway stilling basin (the top level of hydraulic jump is EL.202) is taken into consideration.

The level of the casing center of the turbine is set at EL.179.4 which is 5.2 m lower than the tail-water level at its maximum discharge. Generator floor and erection bay floor have the level of EL.186.9 and EL.198.2 respectively.

The tailrace is an open channel with a width of about 100 m and has a control point at its terminal of EL.180.0. The tailrace joins with the left bank spillway channel at about 60 m downstream from the powerhouse.

A space for the additional one unit in future is provided in the river side, considering a convenience for the operation of the first 3 units. Necessary excavation in the portion, which will be difficult to be done in future, will be made together at the construction stage of the first 3 units. The base concrete and concrete facing on the excavated surface are also provided for protecting the deterioration of the excavated rock surface.

6.6.2 Power Generating Equipment

The turbine is of Kaplan type with the vertical shaft, concreted or steel liner plated spiral casing, and provided with an output of 76,900 kW at full guide vane opening and on-cam. The maximum water discharge is 205.7 m^3/sec at the headrace water level EL.228.0 m, under a net head of 42.32 m. The turbine speed was determined to be 136.3 rpm corresponding to the specific speed of 350.2 m-kW.

The generator is of 3-phase vertical shaft umbrella type synchronous generator with a salient pole revolving field. The cooling system is of self-ventilating re-circulating type with water cooled air coolers. The continuous rating of the generator is 83,300 kVA with the rated voltage of 11,000 volts and current 4,372 amperes and power factor 0.9 lagging. The excitation system is of static thyrister type provided with a manual control at 25-100% rated voltage for live charging operation.

Each generator unit is connected to its respective main transformer bank, located at the transformer yard along the access, with 11 kV cross-linked polyethylene insulated cable of 1,000 mm^2 single core; two pieces for each phase.

The main transformer, adopting unit system with the generator, is of forced-oil circulation air cooled type for outdoor use. The rating of the main transformer is 83,300 kVA with the voltage ratio selected as 10.5 kV for primary to 126-129-132-135 kV for secondary. Impedance voltage is to be about 10%. Each main transformer is connected to the respective circuit breaker located in the outdoor switchyard located 100 m apart from the main transformer yard on EL.198.0.

The outdoor switchyard is provided with a total area of 55 x 80 m. A single bus system with the bus section is of 660 mm^2 single conductor of hard drawn aluminium cable for connecting with 4 units of the main transformer circuit and 4 circuits of 132 kV transmission line. The following 132 kV switchgear equipment is furnished.

(a) Nine (9) 144 kV circuit breakers of SF6 insulated type or vacuum type or minimum oil type

(b) Fifteen (15) 144 kV disconnecting switches

(c) Twenty seven (27) 138 kV current transformers

(d) Six (6) 132 kV capacitive potential devices

(e) Twnety seven (27) 126 kV lightning arresters

Two 160 ton overhead travelling crane will be installed to handle packages, machines in the powerhouse severally and/or jointly for the heaviest components as rotor assembly of about 230 tons.

The control system of the power station is of a one-man remote control from the control room, including that of outdoor switchgear.

6.7 Transmission Lines and Switching Equipment

6.7.1 Transmission Lines

As stated in Para. 3.2.2, the following 132 kV transmission lines will be constructed.

	Section		Route Length	Circuit No.
(1)	Sapt Gandaki	- Hetauda	75 km	Double
(2)	"	- Bharatpur	5 km	Single
(3)	"	- Dumkibas	55 km	Single (double in future)
(4)	Dumkibas	- Butwal	45 km	Single (additional)

Same conductors of aluminium conductor steel reinforced (ACSR) with a nominal aluminum cross section of 264 mm^2 (code name Bear) and ground-wire of galvanized steel wire with a cross section of 70 mm^2 will be used for each line.

The supports will be galvanized lattice steel towers. Towers for the double circuit will be with vertical conductor arrangement of three conductors on each side, and towers for single circuit will be with triangular conductor arrangement.

Same double circuit towers as for Hetauda line will be constructed for the Dumkibas line providing for additional one circuit in future.

On the section between Dumkibas and Butwal, the conductor will be strung on the existing double circuit tower, on which only one circuit conductors are supported at present.

The insulator string will consist of 10 nos. for suspension set and 11 nos. for tension set of cap and pin type suspension insulator discs.

6.7.2 Switching Equipment

The additional switchgear equipment with a control system to connect the above mentioned lines to the 132 kV bus of the following substations will also be provided under this project.

Hetauda SS	;	for two incoming lines
Bharatpur SS	;	for one incoming line
Dumkibas SS	;	for one incoming line and one outgoing line
Butwal SS	;	for one incoming line

6.7.3 PLC Telephone System

For the operation of the power system PLC telephone system will be provided under this project on the Sapt Gandaki-Hetauda section, Sapt Gandaki Bharatpur and Sapt Gandaki-Dumkibas section. This PLC system will be connected to the PLC system on the existing 132 kV system at each substation.

6.8 Fish Passing Facility

As stated in Chapter 11 "ENVIRONMENTAL ASSESSMENT", it is found that the project will have a considerable effect on the riverine fishery to such an extent that it cannot be disregarded. Then, it was decided to provide some fish passing facility for allowing the fish going up and down the stream for spawning.

The fish passing facility consisting of an intake conduit, a gate and 450 m long fish ladder will be provided on the right bank. The intake conduit will be set in the abutment concrete of the right bank spillway and equipped with a roller gate, 2 m wide and 2 m high, for the protection against flood water. The fish ladder is provided on the right bank slope with its slope of 1:10 which is considered proper for fish to go up through it.

A fish passing facility equipped with a movable intake gate and fish ladder to discharge water in any reservoir water levels is too costly. As such a costly facility will not be required, the facility is designed as a fixed type of the intake conduit and fish ladder which makes it possible to discharge water in the full supply water level.

Table-6.1: COST COMPARISON AMONG THREE KINDS OF DAM FOUNDATION TREATMENTS

	Unit	Q'ty ($x10^3$)	Unit Price (U.S.$)	Amount (10^3U.S.$)
(A) Core Trench Method;				
Exca., core	m^3	212.3	3.7	785.5
Embank., core	"	68.6	8.5	583.1
" , rock	"	143.7	12.0	1,724.1
Total:				3,093.0
(B) Grouting Method;				
Drilling	m	14.7	80.0	1,176.0
Grouting	"	14.7	40.0	588.0
Total:				1,764.0
(C) Cut-off Concrete Wall Method;				
Cut-off concrete wall	m^2	4.0	420.0	1,680.0
Total:				1,680.0

CHAPTER 7 CONSTRUCTION PLAN

7.1 General

The implementation schedule of the Sapt Gandaki Project is expected as follows;

- Financing(For tender design)	:	Sept., 1982 to Mar., 1983
- Tender design	:	Apr., 1983 to Jan. 1984
- Tender call and contract	:	Feb., 1984 to Oct., 1984
- Commencement of construction	:	Nov., 1984
- First 75 MW commissioning	:	Nov., 1989
- Second 75 MW commissioning	:	Nov., 1990
- Third 75 MW commissioning	:	Nov., 1992

Construction planning was carried out based on the above implementation schedule and required work quantities of the major items as shown in Table-7.1.

Established construction time schedule is as given in Fig.-7.1 and -7.2. Required construction equipment and plants are as shown in Table-7.2.

Construction planning carried out is outlined for each work item below.

7.2 Construction Plan

7.2.1 Preparatory Works

The contract agreement of the civil works will be finalized at the beginning of October, 1984 at the earliest. Thus, work commencement by the contractor is expected at November, 1984 in consideration of the necessary time for mobilization. Taking into consideration the necessary commencement of diversion concreting in the beginning of 1986 and the required time for plants installation of about one year including the time for transportation, the preparatory works of main access roads on both banks and the power supply system up to the damsite are required to be carried out by HMG beforehand during the dry season of 1983/84. Access roads and power supply system at the damsite, water supply system, plants, offices, quarters and stores, etc. will be completed by the contractor within 7 months, i.e. by June, 1985. All the plants shall be completed by the end of November, 1985, one month before the commencement of the diversion concreting.

Concrete coarse aggregates are planned to be extracted from the gravel deposits in both up and downstream of the damsite by using backhoes, bulldozers, wheel loaders and dump trucks. The aggregates will be classified into each grain size by screening with an aggregate plant installed near the damsite. Concrete fine aggregates will be hauled from the sand bars in the Kageri Khola located at about 8 km from the damsite. Such fine aggregates will be screened at the aggregate plant into an appropriate grain size gradation. The required capacity and quantity of the plants are as listed in Table-7.2.

7.2.2 Diversion Works

The diversion work, which includes excavation of about 6,000,000 m^3 and concreting of about 200,000 m^3 (partition walls between rockfill dam and diversion channels), should start immediately after arrival of construction equipment expected at the end of January, 1985. The river diversion and main dam work will commence at the beginning of 1986/87 dry season.

Excavation on both banks of the river will be done together by using bulldozers, backhoes, dump trucks and crawler drills, and will be finished by the end of September, 1986.

Necessary concreting for the river diversion will involve the partition walls between the rockfill dam and the diversion channel up to EL.196.0, the side wall between the powerhouse and the left bank diversion channel and the protection wall (shotcrete) of the excavated surface. These concretings will be made by using tower cranes, agitator trucks and finished by the end of the 1986 wet season.

A temporary bridge crossing the left bank diversion channel is required for hauling dam embankment materials. This bridge will also be completed by the end of 1986 wet season.

The river diversion is planned to be carried out at the beginning of 1986/87 dry season, i.e. November, 1986. Immediately after the river diversion by the primary cofferdam, the main cofferdam construction will be proceeded. This cofferdam with its crest elevation at EL.196.0 will be completed before the beginning of 1987 wet season so that floods during the 1987 wet season can safely be handled by the diversion channels without any disturbance for the main dam works in the river channel portion.

7.2.3 Main Dam

The main dam work will also be put into execution immediately after the river diversion by the primary coffering, starting from the river bed excavation followed by the dam foundation treatments of the cut-off wall and groutings which will be performed during the 1986/1987 dry season.

The dam embankment work will be commenced from the portion where the necessary foundation treatment is completed. The commencement of the dam embankment will be in January, 1987 and it is planned to be embanked up to EL.196.0 before the beginning of the 1987 wet season, i.e. by the end of May, 1987.

The dam embankment works require two dry seasons for its completion. Thus, its completion is scheduled at the end of next dry season, i.e. the end of May, 1988 by continuing the embankment work throughout the 1987/88 dry season.

Rockfill materials will be hauled from the quarry site located at about 10 km north from the damsite. For its extraction, crawler drills, bulldozers, backhoes, loaders and dump trucks will be mobilized in the quarry site.

Core materials were planned to be brought to a stockpile prior to its embankment, since they will require some mixing of coarse material with clayey earth material on the left bank tableland. As for the coarse material to be mixed, the rock dust materials to be produced in the quarry site or the river bed sand and gravel were considered appropriate. The stockpile will be made by alternate layers of the coarse materials and the clayey earth material so that it will be well mixed by the time of loading to a dump truck by a shovel.

7.2.4 Spillway

The spillway work includes foundation treatment (curtain and consolidation grouts), concreting of spillway weirs, piers and stilling basins amounting to 392,000 m^3, and installation of spillway radial gates.

The spillway work will be executed from the left bank spillway which will be provided in the portion of the left bank diversion channel. During this spillway work, the river flow will have to be handled by only the right bank diversion channel. Therefore, the work will be put into execution in the beginning of 1987/88 dry season when the river flow decreases down to such an extent that it can be handled by the right bank diversion channel (about 2,000 m^3/s can be handled by the right bank diversion channel, provided with a coffer dam with the crest elevation at EL.190 in the left bank diversion channel).

The work will start with the provision of the coffers in the left bank diversion channel, immediately followed by the foundation treatment. The weir concrete is planned to be executed from around mid December, 1987 when the foundation treatment will mostly be completed. The spillway concreting work in the left bank will mostly be completed by the end of the 1987/88 dry season so as to safely handle the floods during the coming 1988 wet season by this spillway and the right bank diversion channel. All the concreting of the left bank spillway except plug concrete, etc. will be finished by the end of the 1988 wet season. The concreting will be made by using tower cranes and agitator trucks.

The right bank spillway work will successively be carried out from the beginning of the 1988/89 dry season after provision of the coffers in the right bank diversion channel and diverting the river discharge into the diversion conduits provided in the left bank spillway constructed. All the works including foundation treatment are planned to be completed during 1988/89 dry season.

The installation of 10 Nos. spillway radial gates will take about one year. This work will be carried out immediately after the completion of the left bank spillway concreting, i.e. from November, 1988. The installation work will be continued one by one also during the 1989 wet season with provision of the spillway stoplog in front of the installation works for the purpose of protection for floods during the wet season. They will be completed by the end of the 1989 wet season.

7.2.5 Intake and Power Station

The intake and power station works are planned to be performed with provision of a partition wall between the diversion channel and the intake and power station work area, and a coffering in the downstream of power station. Thus, the work will be possibly done independently without any special consideration of the river discharge. Therefore, enough time is available for the works, although they include a big excavation of about 3,500,000 m^3.

The excavation work will start with the arrival of the construction equipment together with the excavation work of the left bank diversion channel, and will continuously be performed without any relation with the handling of the river discharge. The intake portion will be finished in October, 1987. The power station portion will finish at the end of 1988.

The concrete of the intake portion amounts to 135,000 m^3. This concrete will be placed including the installation of penstock pipes during the period of November, 1987 to June, 1989 after the completion of the excavation in the intake portion.

The concrete in the power station amounting to about 64,000 m^3 will be placed during the period from July, 1987 to October, 1989 including the installation of generating equipment, tailrace concrete and superstructure.

The concreting will also be made by using a tower crane and agitator trucks, partially assisted by truck cranes.

7.2.6 Electrical Works

One year will be required for the installation of the generating equipment. In order to commission the project at the beginning of 1989/90 dry season, the installation work of the first 75 MW unit is planned to be started from November, 1988 when the substructure concreting started 16 months before will show favourable progress. Manufacturing and transportation of the generating equipment will also take about one year. Thus, the arrangement should be made from 1987.

The second and third 75 MW units of the generating equipment are scheduled to be commissioned from the beginning of 1990/91 dry season and 1992/93 dry season, respectively. For the above, the installation of the second unit will successively be started after the installation of the first unit. The manufacturing of the third unit will be commenced successively after the installation of the second unit. The installation works of the second and third units are planned to be carried out without any interruption of the power generation of the preceding installed units by setting tailrace gates.

Transmission line and substation works will be executed during May, 1988 to August, 1989. In consideration of the necessary time for manufacturing and transportation of about one year, the arrangement should be made from the early stage of 1987.

Table-7.1: WORK QUANTITY OF MAJOR WORKS

Work Items	Unit	Work Quantity
Diversion:		
Excavation, common	m^3	2,587,000
" , rock	"	3,160,000
Protection wall (Shotcrete)	"	6,080
Cofferdams:		
Primary coffer	"	22,200
Embankment, core	"	58,700
" , rock	"	211,700
Dam and spillway:		
Excavation, common	"	73,000
Embankment, core	"	346,600
" , rock	"	1,500,000
Cut-off wall	m^2	4,000
Curtain grout	m	24,400
Consoli. & blanket grout	"	13,700
Concrete, weir & side walls	m^3	392,000
" , partition walls	"	218,500
Intake:		
Excavation, common	m^3	325,000
" , rock	"	478,000
Concrete	"	135,000
Curtain grout	m	8,580
Consoli. "	"	2,050
Power station:		
Excavation, common	m^3	539,000
" , rock	"	2,125,000
Concrete	"	64,000

Table-7.2: REQUIRED CONSTRUCTION EQUIPMENT AND PLANTS

Items	Capacity	Quantity
Bulldozer	42 t	8
- do -	32 t	7
- do -	21 t	10
Loader	7.7 m^3	7
- do -	2.5 m^3	2
- do -	1.4 m^3	2
Hyd. backhoe	1.4 m^3	4
- do -	0.7 m^3	2
Dump truck	32 t	55
- do -	20 t	10
- do -	11 t	30
Tractor & trailer	35 t	1
Truck crane	45 t	1
- do -	35 t	2
- do -	20 t	2
- do -	11 t	2
Agitator truck	4.5 m^3	16
- do -	3.0 m^3	5
Water tanker	8 m^3	2
Cargo truck	11 t	5
- do -	8 t	10
Motor grader	3.6 m	2
Road roller	8/10 t	5
Tamping rolling	13.5 t	1
Vibration roller	15 t	2
Crawler drill, hyd.	75 PS	15
- do - , pneum.	10 m^3/min	2
Breaker, hyd.	500 kg	2
Air compressor	10 m^3/min	4
- do -	5 m^3/min	15
Wall drilling machine	(40 m)	1
Boring machine	5.5 kW	24
Grout mixer & pump	11 kW	27

Items	Capacity	Quantity
Submergible pump	200 ϕ 45 kW	8
- do -	100 ϕ 22 kW	10
Concrete pump	50 m^3/h	2
- do -	20 m^3/h	1
Shot concrete equip.		2
Fork lift	3 t	2
Fuel tanker	6 m^3	2
Grease car	6 t	1
Service car	15	2
Aggregate plant A	Port.	1
- do - B	270 t/h	1
Concrete plant A	Port.	1
- do - B	1.5 m^3 x 2	2
Cement silo & access		2
Tower crane	13.5 t x 75 m	2
- do -	4.5 5 x 75 m	1
Water supply system		2
Power supply system		1
Fuel supply system		1
Bar bender yard		1
Sawmill		1
Maintenance shop		1

CHAPTER 8 CONSTRUCTION COST ESTIMATE

8.1 General

The construction cost estimate is made for the determined project scheme, i.e. the fill type dam scheme at damsite-B with F.S.L. at EL.230 and installed capacity of 225 MW.

The total construction cost was estimated at U.S.$354,700 x 10^3 in 1982 July price level as summarized in Table-8.1.

The construction cost estimate was made based on the condition of the expected commissioning date explained in the previous Chapter 7, international competitive contract and considerations or assumptions explained below.

8.2 Preparatory Works

The preparatory works are considered to include the works of the main access roads in both banks, the main power supply system up to the damsite, the office and camps for the government staffs and the testing laboratory which are to be carried out by the government.

The cost for the aggregate and concrete plants, the access roads in the damsite, the power & water supply systems in the damsite and the contractor's camps, etc., which are prepared by the contractor, are included in the unit price of the civil works. The preparatory works to be carried out by the government was estimated to amount to US$2,935 x 10^3 in total.

8.3 Civil Works

Cost of civil works was estimated on the basis of unit prices indicated in Table-8.2.

The unit prices were computed following the construction plan described in the previous Chapter as well as the assumptions stated below.

- Costs were classified into foreign and local currency portions, assuming the costs other than the following will be all foreign currency portion;

  (i) Wages for local workmen employed by the contractor
  (ii) Inland transportation

- Basic prices of materials and labour wages were assumed as listed in Table-8.4 and Table-8.5 based on the field investigation.

- Depreciation, repair and administration cost, assembling and disassembling cost, transportation cost, and freight and insurance cost were included in the plants and equipment cost.

- Equipment operation cost was separately estimated and included in the unit price.

- Freight, insurance and transportation costs were taken into account for all materials, plants and equipment which are to be imported, while no import tax and duty are included in the cost.

After computing the unit prices on the basis of the construction program, current data of unit prices in similar international contract works and in the Kulekhani Project in Nepal were referred, and then, the computed unit prices were adjusted when required.

Work quantity of each civil work item applied for the unit price was measured based on the project design which is provided in Fig.-6.1 to Fig.-6.6.

8.4 Metal and Generating Equipment Works

Metal works of the project include the followings;

Spillway radial gates	10 sets
" stoplog	1 "
Intake trash racks	3 "
" gates	3 "
Gantry crane (on dam crest)	1 "
Penstocks	4 "

Tailrace gates	2 sets
Gantry crane (in tailrace)	1 "

The cost estimate for these metal works was made on the basis of unit price per ton derived from the current contract prices for similar works.

The unit price per ton adopted for each metal work item which includes all costs of material, transportation and erection, etc. is as follows:

Metal Works Items	Adopted Unit Price per Ton (U.S.$)
Spillway radial gate	5,850.0
" stoplog	3,900.0
Intake trash rack	3,000.0
" gate	6,050.0
Gantry crane (dam crest)	6,000.0
Penstock	3,350.0
Tailrace gate	4,400.0
Gantry crane (Tailrace)	6,250.0

The local currency portion was assumed at 10% to cover the necessary local currency for labour wage in erection and inland transportation.

The summary of the metal work cost was shown together with measured work quantity of each work in Table-8.6. The total cost for the metal works was calculated at U.S.$25,190 x 10^3 as stated.

8.5 Electrical Works

The cost for the electrical works was also estimated based on the current international contract prices of similar projects, as shown in Table-8.7 in which the total cost for the electrical works is calculated at U.S.$58,784 x 10^3.

The above cost of the electrical works included the costs for the required transmission lines and substation and switching station equipment in addition to the generating equipment at the power station.

In the electrical work also, the local currency portion was estimated at 10% similar to the metal works in consideration of necessary local currency for labour wage in erection work and inland transportation of equipment.

8.6 Land Acquisition

The land acquisition cost included compensation cost for the agricultural lands, residential houses and facilities that will be submerged by the proposed reservoir, and relocation cost of a portion of the Mugling Road of 8 km in length which will be also submerged by the proposed reservoir.

Although the necessary cost for the above was estimated at U.S.\$8,630 x 10^3, as calculated on the basis of the unit price in Chapter 11, the total cost for the land acquisition was assumed at U.S.\$9,000 x 10^3 to cope with any unforeseen events.

The compensation cost for the lands, houses and facilities was considered to be all in the local currency portion. As for the relocation cost of the Mugling Road, 15% of the total relocation cost amounting to U.S.\$5,000 x 10^3 was assumed as the local currency portion, taking into account the necessary local currency for wage of labour to be employed and inland transportation of construction equipment.

8.7 Engineering Service and Government Administration, and Physical Contingency

The cost for engineering service is assumed to be the fee for detailed design and supervision in the construction stage by an overseas consultant and is considered to belong to the foreign currency portion. The government administration cost is the expense required for the Government's staff and facilities which is in the category of the local currency portion.

The cost for each of engineering service and government administration was taken at 7.5% of the sum of preparatory works, civil works, metal and electrical works and land acquisition, which is considered as the usual percentage in similar projects.

As seen in Table-8.1, the total cost for engineering service and government administration amounted to U.S.$21,869 x 10^3, out of which U.S.$18,486 x 10^3 is in foreign currency portion and U.S.$3,383 x 10^3 in local currency portion.

The cost estimate was made based on the informations available from the feasibility stage investigation up to date. Thus, some allowance should be prepared for such unknown factors as;

- Changes in items and quantities during detailed design stage,
- Change in the assumed geological conditions to be encountered during construction, and
- Degree of accuracy in topographic map on some places, and
- Bidding climate at the time of tendering, etc.

Considering the uncertainties mentioned, the following was taken as the physical contingency, which amounted to U.S.$41,239 x 10^3 in total.

Physical contingency:

(i) 15% of the cost estimated for the preparatory and civil works.

(ii) 10% of the cost estimated for the metal works, electrical works, land acquisition and engineering & government administration.

Table-8.1: SUMMARY OF TOTAL CONSTRUCTION COST

		Amount (10^3 U.S.$)	
	F.C.	L.C.	Total
1. Preparatory Works:	575	2,360	2,935
2. Civil Works:			
(1) Diversion	34,427	6,733	41,160
(2) Dam & spillway	84,466	14,256	96,722
(3) Intake	18,356	3,240	21,596
(4) Power station	30,830	5,375	36,205
Sub-total 2	166,079	29,604	195,683
3. Metal, Generating Equipment, T/L & S/S Works:			
(1) Metal	22,670	2,520	25,190
(2) G/E, T/L & S/S	52,907	5,877	58,784
Sub-total 3	75,577	8,397	83,974
4. Land Acquisition:	4,250	4,750	9,000
5. Engineering Service & Government Administration:/1	18,486	3,383	21,869
6. Physical Contingency:/2	34,833	6,406	41,239
Total	299,800	54,900	354,700

Note: /1; 7.5% of 1 to 4.

/2; 15% of 1 to 2 + 10% of 3 to 5.

Table-8.2: LIST OF UNIT PRICES FOR CIVIL WORKS

Work Items	Unit	Foreign Portion (U.S.$)	Local Portion (U.S.$)	Unit Price (U.S.$)
Excavation:				
Common	m^3	2.96	0.74	3.7
Rock	"	6.80	1.20	8.0
Embankment:				
Primary cofferdam	"	4.00	1.00	5.0
Main dam core	"	7.57	0.93	8.5
" rock	"	10.08	1.92	12.0
Bakcfill	"	3.38	1.12	4.5
Concrete:				
Mass concrete	"	80.80	14.20	95.0
Structural concrete	"	110.50	19.50	130.0
Facing	"	110.50	19.50	130.0
Shotcrete	"	120.00	30.00	150.0
Cut-off wall	m^2	370.00	50.00	420.0
Steel bars	ton	551.00	79.00	630.0
Curtain grout	m	132.00	18.00	150.0
Consolidation grout	"	105.60	14.40	120.0
Blanket grout	"	105.60	14.40	120.0
Gabion	m^3	8.70	1.30	10.0

Table-8.3: SUMMARY OF CIVIL WORK COST

Work Items	Unit	Quantity (x 10^3)	Unit Price Foreign (US$)	Unit Price Local (US$)	Unit Price Total (US$)	Amount Foreign (10^3 US$)	Amount Local (10^3 US$)	Amount Total (10^3 US$)
1. Diversion:								
Exca., common	m^3	2,587.00	2.96	0.74	3.70	7,657.52	1,914.38	9,571.90
" , rock	"	3,117.78	6.80	1.20	8.00	21,200.90	3,741.34	24,942.24
Embank., primary coffer	"	22.20	4.00	1.00	5.00	88.80	22.20	111.00
" , core	"	58.70	7.57	0.93	8.50	444.36	54.59	498.95
" , rock	"	211.70	10.08	1.92	12.00	2,133.94	406.46	2,540.40
Protection wall	"	4.28	110.50	19.50	130.00	472.94	83.46	556.40
Protect. shotcrete	"	6.08	120.00	30.00	150.00	729.60	182.40	912.00
Steel bar	ton	0.104	551.00	79.00	630.00	57.30	8.22	65.52
Minor items	L.S.	-	-	-	5%	1,639.27	320.73	1,960.00
Sub-total						34,427.00	6,733.00	41,160.00
2. Dam & Spillway:								
Exca., common	m^3	72.60	2.96	0.74	3.70	214.90	53.72	268.62
" , rock	"	41.67	6.80	1.20	8.00	283.36	50.00	333.36
Curtain grout	m	24.40	132.00	18.00	150.00	3,220.80	439.20	3,660.00
Blanket & consoli. grout	"	13.70	105.60	14.40	120.00	1,446.72	197.28	1,644.00
Embank., core	m^3	346.60	7.57	0.93	8.50	2,623.76	322.34	2,946.10
" , rock	"	1,498.50	10.08	1.92	12.00	15,104.88	2,877.12	17,982.00
Mass concrete	"	585.50	80.80	14.20	95.00	47,308.40	8,314.10	55,622.50
Structural conc.	"	38.80	110.50	19.50	130.00	4,287.40	756.60	5,044.00
Steel bar	ton	4.66	551.00	79.00	630.00	2,567.66	368.14	2,935.80
Cut-off wall	m^2	4.00	370.00	50.00	420.00	1,480.00	200.00	1,680.00
Minor items	L.S.	-	-	-	5%	3,928.38	677.45	4,605.83
Sub-total						82,466.00	14,256.00	96,722.00

Work Items	Unit	Quantity (x 10^3)	Unit Price Foreign (US$)	Unit Price Local (US$)	Unit Price Total (US$)	Amount Foreign (10^3 US$)	Amount Local (10^3 US$)	Amount Total (10^3 US$)
3. Intake:								
Exca., common	m^3	325.00	2.96	0.74	3.70	962.00	240.50	1,202.50
" , rock	"	478.00	6.80	1.20	8.00	3,250.40	573.60	3,824.00
Curtain grout	m	8.58	132.00	18.00	150.00	1,132.56	154.44	1,287.00
Consoli. grout	"	2.05	105.60	14.40	120.00	216.48	29.52	246.00
Mass concrete	m^3	118.20	80.80	14.20	95.00	9,550.56	1,678.44	11,229.00
Structural conc.	"	19.00	110.50	19.50	130.00	2,099.50	370.50	2,470.00
Steel bar	ton	0.49	551.00	79.00	630.00	269.99	38.71	308.70
Minor items	L.S.	-	-	-	5%	874.07	154.29	1,028.36
Sub-total						18,356.00	3,240.00	21,596.00
4. Power Station & T/L:								
Exca., common	m^3	539.00	2.96	0.74	3.70	1,595.44	398.86	1,994.30
" , rock	"	2,125.00	6.80	1.20	8.00	14,450.00	2,550.00	17,000.00
Backfill	"	24.10	3.38	1.12	4.50	81.46	26.99	108.45
Consoli. grout	m	1.20	105.60	14.40	120.00	126.72	17.28	144.00
Concrete, P/S	m^3	63.90	110.50	19.50	130.00	7,060.95	1,246.05	8,307.00
" , T/L	"	9.63	110.50	19.50	130.00	1,064.12	187.78	1,251.90
Steel bar	ton	3.42	551.00	79.00	630.00	1,884.42	270.18	2,154.60
Superstructure	L.S.	-	-	-	-	3,098.76	422.24	3,521.00
Minor items	"	-	-	-	5%	1,468.09	255.97	1,724.06
Sub-total						30,830.00	5,375.00	36,205.00
Grand Total						166,079.00	29,604.00	195,683.00

Table-8.4: PRICE OF MAJOR CONSTRUCTION MATERIALS

Items	Unit	CIF Material Price in 1982 July Price (U.S.$)
Cement	ton	181
Reinforcment bar	"	528
H-Beam	"	888
Petrol (Regular)	kℓ	915
Light oil	"	640
Explosive (Gelatine)	ton	2,241
" (ANFO)	"	998
Timber:		
Primary hard wood	m^3	283
Second " "	"	129
Plywood:		
1,800 x 900 x 12 m/m	pc.	16.5
1,000 x 1,000 x 12 m/m	"	10.0

Table-8.5: LABOUR WAGE

Labour	Unit	Wage in 1982 July Price Level (U.S.$)
Mechanics	Man. Day	2.76
Electricians	"	2.59
Masons	"	1.55
Brick layers	"	1.55
Carpenters	"	2.16
Plasterers	"	1.55
Drillers	"	1.73
Powdermen	"	1.12
Pipe-fitters	"	2.24
Blacksmiths	"	1.38
Steel benders	"	2.24
Plumbers	"	2.24
Concrete finishers	"	1.73
Greasers	"	1.12
Oilers	"	1.38
Trackmen	"	1.73
Concrete workers	"	1.73
Unskilled labours	"	1.13

Table-8.6: SUMMARY OF METAL WORK COST

Work Items	Unit	Q'ty	Unit Price (U.S.$)			Amount (10^3 U.S.$)		
			F.C.	L.C.	Total	F.C.	L.C.	Total
Spillway radial gates	ton	2,900	5,265.0	585.0	5,850.0	15,269	1,696	16,965
" stoplog	"	405	3,510.0	390.0	3,900.0	1,422	158	1,580
Intake trash racks	"	150	2,700.0	300.0	3,000.0	405	45	450
" gates	"	231	5,445.0	605.0	6,050.0	1,258	140	1,398
Gantry crane (dam crest)	"	90	5,400.0	600.0	6,000.0	486	54	540
Penstocks	"	910	3,015.0	335.0	3,350.0	2,744	305	3,049
Tailrace gates	"	102	3,960.0	440.0	4,400.0	404	45	449
Gantry crane (tailrace)	"	72	5,625.0	625.0	6,250.0	405	45	450
Others	L.S.					278	31	309
Total						22,671	2,519	25,190

Table-8.7: SUMMARY OF ELECTRICL WORK COST

Work Items	Q'ty	Amount (10^3 U.S.$) F.C.	L.C.	Total
Power Station				
Turbine	3 units			19,620
Generator	"			11,600
Main transformer	"			1,650
Outdoor switchgear	1 lot			795
Indoor sw. & control	"			1,165
Ancillary	"			580
Miscella. materials	"			555
F.O.B. total				35,965
C.I.F. (1.1 x F.O.B.)				39,560
Erection	L.S.			9,833
Sub-total		44,454	4,939	49,393
T/L, S/S & SW/S				
F.O.B. total				5,612
C.I.F. (1.1 x F.O.B.)				6,173
Erection	L.S.			3,218
Sub-total		8,452	939	9,391
Grand total		52,906	5,878	58,784

CHAPTER 9 ECONOMIC AND FINANCIAL ANALYSIS

9.1 Economic Analysis

9.1.1 Criteria and Assumptions

The installed capacity of the Sapt Gandaki Project was determined to be 225 MW which gives the highest net benefit (B-C) as stated in Chapter 5. An economic analysis of the Sapt Gandaki Hydroelectric Project was made for the determined optimum project scheme with a criteria of the economic internal rate of return (EIRR). The evaluation period is 50 years, starting in 1982/83 which is the first year of project implementation. The estimate of costs and benefits was made at the price level at the end of 1981/82.

The power benefit attributable to the hydropower project is in general measured by capital, operation and maintenance, and replacement costs of the most competitive alternative. As the alternative, a coal-fired thermal plant with unit capacity of 100 MW is taken up, considering that a coal-fired thermal plant is widely practiced in India and that installation of 100 MW size power station is expected to be prevailing to meet the power demand after 1989/90.

On the other hand, benefits other than power generation such as water supply for irrigation, job opportunity increase, etc. are not incorporated in estimating the project benefit.

9.1.2 Power and Energy Output

The power and energy output is classified to the firm peak power, primary energy and secondary energy. The firm peak power is defined to be the power output which can be guaranteed with 90% firmness in operational duration even under unfavorable hydrologic condition. The estimate of firm peak power was made also assuming that the Sapt Gandaki power plant will share the load of CNPS with a capacity factor of 50%. The firm peak power estimated with these condition is 174 MW.

The primary energy of the Sapt Gandaki power station is utilized to meet the CNPS load. The primary energy will increase in accordance with growth of demand for an initial few years and will reach 757 GWh/ year in 1992/93. In addition to the primary energy, the Sapt Gandaki power station can produce the secondary energy which is not to be utilized in the CNPS, but will be exported to India. The project output for an initial few years is estimated as shown below.

Fiscal Year	Installed Capacity (MW)	Firm Peak Power (MW)	Energy (GWh)		
			Primary	Secondary	Total
1989/90	75	75	322	322	644
1990/91	150	104	456	750	1,206
1991/92	150	142	621	585	1,206
1992/93 onward	225	174	757	852	1,609

9.1.3 Economic Benefit

The cost of the coal-fired thermal plant consists of the installation cost, operation and maintenance cost and replacement cost. The unit installation cost of a 100 MW coal-fired thermal plant which excludes the interest during construction is estimated to be US$1,000/kW as detailed in Table-9.8. The operation and maintenance cost comprises the cost related to the installed capacity (fixed O & M cost) and the fuel for generating energy (variable O & M cost). The annual fixed O & M cost which is considered to be proportional to the installed capacity is estimated to be 30 US$/kW for a 100 MW size. The adjustment factor to compensate the difference on auxiliary use, forced outage, overhaul and transmission loss between the coal-fired thermal and hydropower stations is estimated to be 1.173 /1.

/1: Adjustment factor for capacity benefit

	Hydro	Steam
Transmission loss	5.0%	2.0%
Auxiliary power use	0.3	6.0
Forced outage	0.5	5.0
Overhaul	2.0	10.0

$$\text{Capacity adjustment factor} = \frac{(1-0.05)\ (1-0.03)\ (1-0.005)\ (1-0.02)}{(1-0.02)\ (1-0.06)\ (1-0.05)\ (1-0.100)} = 1.173$$

Therefore, the initial investment cost and annual operation and maintenance cost are derived to be 1,173 US$/kW and 35 US$/kW, respectively, taking into account the adjustment factor.

The economic life of the coal-fired thermal plant is estimated to be 25 years. On expiration of the service life, the plant has to be replaced. The replacement cost is assumed to be 90% of the initial investment cost considering the salvage value of old plants.

The estimate of energy value (kWh value) attributable mainly to the fuel cost of alternative coal-fired thermal plant was made based on the following average coal consumption rate of the coal-fired thermal plant and international coal price at the end of 1981/82.

Coal consumption rate	0.645 kg/kWh
Coal price	63 US$/ton

The energy value is estimated to be 42 US Mill/kWh taking into account the adjustment factor for energy (1.028)/1.

The energy benefit attributable to the primary energy output was estimated based on the above energy value. On the other hand, the secondary energy to be generated by the Sapt Gandaki power station will be consumable in the Greater CNPS in accordance with the demand increase. In this economic analysis, however, it is not considered consumable in the system by the reasons explained in the previous Section 5.1.4.2, but is assumed to be exportable to India, and the revenue from India is considered as the benefit attributable to the project by the secondary energy. In estimating the benefit by the secondary energy, the energy loss of 40% was taken into account. The power exchange rate was taken at U.S. Mill 24/kWh (Rs. 0.3/kWh) which is a prospective value in near future.

/1: Adjustment factor for energy benefit

	Hydro	Steam
Transmission loss	5.0%	2.0%
Auxiliary power use	0.3	6.0

$$\text{Energy adjustment factor} = \frac{(1-0.05)\ (1-0.003)}{(1-0.02)\ (1-0.06)} = 1.028$$

The estimated power benefit is summarized below.

Capacity benefit (10^3 US$)

Investment cost	204,102
Replacement cost	183,692
Annual O & M cost	6,090

Energy benefit (10^3 US$)

Fiscal Year	Primary Energy	Secondary Energy	Total
1989/90	13,524	4,632	18,156
1990/91	19,152	10,800	29,952
1991/92	26,082	8,424	34,506
1992/93 onward	31,794	12,264	44,058

9.1.4 Economic Cost

The economic cost comprises the Present-day initial investment cost, operation and maintenance cost and replacement cost excluding duties and taxes which are transfer payments. Since the transfer payments on this project have little effect on the economic evaluation, the economic cost is estimated by deducting only the price contingency and interest during construction from the financial cost. The total economic project cost is estimated at US$354.7 million and its disbursement schedule is presented in Table-9.1.

The economic life of the project facilities is assumed to be 35 years for the metal work, generating equipment, transforming equipment and transmission facilities and 50 years for the civil work. The replacement cost excluding the salvage value is assumed to be 90% of the capital cost. The replacement cost of the metal works and generating equipments is estimated to be US$89.4 million which is to be disbursed in 2 years starting from 2022/23, 2023/24 and 2025/26 for 1st, 2nd and 3rd 75 MW installation, respectively.

The operation and maintenance cost covers salaries and wages of staffs, regular maintenance cost and minor repair cost. The annual O & M cost is estimated to be 2.5% of the direct cost of the power generation and transmission facilities and 0.5% of that of the dam cost. The estimated annual O & M cost for the installed capacity of 225 MW is calculated to be U.S.$4,248 x 10^3.

9.1.5 Economic Internal Rate of Return (EIRR)

The cash-flow of the economic benefit and cost is worked out based on the project implementation schedule as shown in Table-9.2. The present worths of the economic benefit and cost are calculated for various discount rates and those are illustrated in Fig.-9.1. From the Figure, the value of EIRR is derived to be 16.2% under the normally conceivable condition.

The sensitivity test of EIRR was made for the following cases.

		EIRR
A :	Benefit reduction by 10%	14.2%
B :	Cost increase by 20%	13.0%
C :	A + B	11.4%

The value of EIRR under the normal condition shows a high economic viability and the above table shows that the project is not very sensitive to unfavorable change in the benefit and cost. Thus, it is judged that the Sapt Gandaki Project is economically feasible.

9.2 Financial Analysis

9.2.1 General

To assess the project feasibility from the financial viewpoint, the financial internal rate of return (FIRR) and the loan repayability are examined based on the assumed financial conditions. The financial project cost consists of the project economic cost described in the preceeding Section of this Chapter, price escalation and interest during construction.

The revenue is estimated taking into consideration a present power rate of US Mill 44.9/kWh and the said annual escalation rate. On the basis of these cost and revenue, the financial cashflow and statement are derived. The estimation of the cost and benefit are made at the price level of 1992/93 in which the construction works for a 225 MW installation will be completed.

9.2.2 Financial Internal Rate of Return (FIRR)

A financial cashflow is prepared for 30 years starting from 1982/83 as shown in Table-9.5. In preparing this Table, the costs and revenue are estimated under the following conditions.

a) Power revenue is estimated based on the salable energy at the distribution end. The salable energy which can contribute to the revenue is derived to be 80% of the generated energy in consideration of the transmission and distribution losses. In addition, 60% of secondary energy is presumed to be exportable to India at a power rate of US Mill 24 per kWh, estimating the loss of 40%.

b) An escalation rate of 6% is assumed for both the cost and revenue until 1992/93 and beyond that year no escalation is assumed. The tariff rates for primary energy and the secondary energy to be exported to India to be adopted in 1992/93 are estimated at US Mill 85.23 and 45.6 per kWh, respectively.

c) Operation and maintenance cost is estimated at US$8.1 million per annum at the price level of 1992/93.

On the basis of the Table, the value of financial internal rate of return (FIRR) is calculated to be 9.2% for the evaluation period of 30 years. This value shows that the project is financially viable even if the project costs are financed by international financing agencies.

9.2.3 Loan Repayability

In order to prepare the financial statement, the following assumptions are made for the finance of the project.

a) All the foreign portion of the investment cost will be financed by international loans with the following conditions.

Interest rate : 4.0 percent per annum

Repayment period: 30 years including the grace period of 7 years

b) All the local portion of the investment cost and the interest during construction will be financed by the Government.

The total investment cost of the project is estimated at US$544.4 million, which comprises US$467.6 million of foreign currency portion and the equivalent of US$76.8 million of local currency portion as shown below.

(Unit: 10^3 US$)

	Foreign	Local	Total
Construction Cost	299,800	54,900	354,700
Price Escalation	129,902	21,910	151,812
Interest during Construction	37,892	0	37,892
	(75,783)		(75,783)
Total Investment Cost	467,594	76,810	544,404
	(505,485)		(582,295)

Remarks: Figures in parenthesis show the amount in the case of the interest rate of 8%.

With the above finance condition, the financial statement of the project is prepared as shown in Table-9.6.

As shown in Table-9.6, the accumulated surplus in the case of the annual interest rate of 4% is turned into positive figure only one year after the Project reaches its final development stage in 1992/93. Afterwards, the Project yields an annual profit of about US$37 million after deducting the loan repayment from the net revenue. The accumulated surplus at the end of the repayment period, 2011/12, reaches about US$670.0 million, which exceeds the total financial investment cost of U.S.$544 million and makes it possible to reconstruct the same kind of project at the end of project life. Thus, from the viewpoint of loan repayability, the project is justifiable.

The loan repayability in the case of the annual interest rate of 8% was also examined. The accumulated surplus at the end of repayment period in this case amounts to about US$351 million, indicating that the project is still financially viable. It will need 8 years more until the surplus reaches the amount of the total financial investment.

Table-9.1: YEARLY DISBURSEMENT OF CONSTRUCTION COST

(Unit: 10^3 US$)

Items	Summary F/C	Summary L/C	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92	1992/93
1. Preparatory works	575	2,360	587	587	587	587	587	0	0	0	0	0	0
2. Civil works													
(1) Diversion	34,427	6,733	0	0	12,348	16,464	12,348	0	0	0	0	0	0
(2) Dam and spillway	82,466	14,256	0	0	0	9,672	29,017	29,017	19,344	9,672	0	0	0
(3) Intake	18,356	3,240	0	0	0	0	6,479	8,638	6,479	0	0	0	0
(4) Powerhouse	30,830	5,375	0	0	0	0	0	14,048	17,723	3,783	271	272	108
Sub-total 2	166,079	29,604	0	0	12,348	26,136	47,844	51,703	43,546	13,455	271	272	108
3. Metal and generating equipment													
(1) Metal	22,670	2,520	0	0	0	0	5,038	5,038	10,076	5,038	0	0	0
(2) Generating equipment	52,907	5,877	0	0	0	0	5,171	5,171	16,929	11,757	9,878	6,586	3,292
Sub-total 3	75,577	8,397	0	0	0	0	10,209	10,209	27,005	16,795	9,878	6,586	3,292
4. Land acquisition	4,250	4,750	1,260	1,260	1,260	1,260	1,260	1,350	1,350	0	0	0	0
5. Engineering service & Government administration	18,486	3,383	2,898	2,318	2,318	2,318	2,318	2,318	2,701	3,021	766	510	383
6. Physical contingency	34,833	6,406	503	446	2,296	4,362	8,634	9,134	9,627	3,998	1,105	750	384
Total	299,800	54,900	5,248	4,611	18,809	34,663	70,852	74,714	82,229	37,269	12,020	8,118	4,167

Table-9.2: CASH FLOW OF PROJECT COST AND BENEFIT

(Unit: 10^3 US$)

Fiscal Year	Project Cost			Project Cost				
				Power Benefit		Energy Benefit		
	Capital and Replacement Cost	O & M Cost	Total	Capital	Fixed O & M	Primary	Secondary	Total
1982/83	5,248	0	5,248	0	0	0	0	0
1983/84	4,611	0	4,611	0	0	0	0	0
1984/85	18,809	0	18,809	0	0	0	0	0
1985/86	34,663	0	34,663	0	0	0	0	0
1986/87	70,852	0	70,852	0	0	0	0	0
1987/88	74,714	0	74,714	32,991	0	0	0	32,991
1988/89	84,229	0	84,229	56,744	0	0	0	56,744
1989/90	37,269	3,398	40,667	44,721	2,625	13,524	4,632	65,502
1990/91	12,020	3,823	15,844	40,615	3,640	19,152	10,800	74,207
1991/92	8,118	3,823	11,941	24,340	4,970	26,082	8,424	63,816
1992/93	4,168	4,248	8,416	4,692	6,090	31,794	12,264	54,840
1993/94	0	4,248	4,248	0	6,090	31,794	12,264	50,148
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2010/11	0	4,248	4,248	0	6,090	31,794	12,264	50,148
2011/12	0	4,248	4,248	29,692	6,090	31,794	12,264	79,840
2012/13	0	4,248	4,248	51,069	6,090	31,794	12,264	101,217
2013/14	0	4,248	4,248	40,249	6,090	31,794	12,264	90,397
2014/15	0	4,248	4,248	36,554	6,090	31,794	12,264	86,702
2015/16	0	4,248	4,248	21,906	6,090	31,794	12,264	72,054
2016/17	0	4,248	4,248	4,223	6,090	31,794	12,264	54,371
2017/18	0	4,248	4,248	0	6,090	31,794	12,264	50,148
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2021/22	0	4,248	4,248	0	6,090	31,794	12,264	50,148
2022/23	27,163	4,248	31,411	0	6,090	31,794	12,264	50,148
2023/24	35,924	4,248	40,172	0	6,090	31,794	12,264	50,148
2024/25	8,761	4,248	13,009	0	6,090	31,794	12,264	50,148
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2026/27	8,761	4,248	13,009	0	6,090	31,794	12,264	50,148
2027/28	0	4,248	4,248	0	6,090	31,794	12,264	50,148
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
2031/2032	0	4,248	4,248	0	6,090	31,794	12,264	50,148

Table-9.3: NET BENEFIT CALCULATION IN ACCORDANCE WITH DISCOUNT RATE

(Unit: 10^3 US$)

Discount Rate	Benefit in Present Worth (B)	Cost in Present Worth (C)	Net Benefit (B - C)	B/C Ratio
1.0	2,035,663	567,368	1,468,295	3.59
2.0	1,695,322	526,462	1,168,859	3.22
3.0	1,435,677	497,442	938,235	2.89
4.0	1,235,035	476,917	758,118	2.59
5.0	1,078,000	462,526	615,474	2.33
6.0	953,545	452,611	500,934	2.11
7.0	853,693	445,999	407,694	1.91
8.0	772,621	441,857	330,765	1.75
9.0	706,038	439,586	266,452	1.61
10.0	650,750	438,755	211,995	1.48
11.0	604,358	439,049	165,309	1.38
12.0	565,042	440,237	124,805	1.28
13.0	531,412	442,148	89,264	1.20
14.0	502,393	444,656	57,737	1.13
15.0	477,148	447,664	29,483	1.07
16.0	455,018	451,101	3,917	1.01
17.0	435,483	454,911	-19,427	0.96
18.0	418,126	459,051	-40,925	0.91
19.0	402,611	463,489	-60,878	0.87
20.0	388,666	468,200	-79,534	0.83
21.0	376,067	473,162	-97,095	0.79
22.0	364,632	478,362	-113,730	0.76
23.0	354,207	483,786	-129,579	0.73
24.0	344,666	489,424	-144,758	0.70
25.0	335,901	495,269	-159,368	0.68

Table-9.4: CALCULATION OF INTERNAL RATE OF RETURN

(Unit: 10^3 US$)

Discount Rate	Net Benefit in Present Worth (B - C)	B/C Ratio
16.1	1,490	1.00
16.2	-916	1.00
16.3	-3,301	0.99
16.4	-5,664	0.99
16.5	-8,007	0.98
16.6	-10,330	0.98
16.7	-12,633	0.97
16.8	-14,917	0.97
16.9	-17,182	0.96

Economic Internal Rate of Return is 16.2%

Table-9.5: FINANCIAL CASH FLOW

(Unit: 10^3 US$)

Fiscal Year	Capital Cost			O & M	Gross Revenue
	F.C.	L.C.	Total		
1982/83	3,800	1,763	5,563		
1983/84	3,422	1,758	5,180		
1984/85	17,789	4,613	22,402		
1985/86	35,816	7,945	43,761		
1986/87	79,926	14,890	94,816		
1987/88	90,138	15,845	105,983		
1988/89	108,937	17,713	126,650		
1989/90	51,821	7,580	59,401	5,416	25,817
1990/91	18,081	2,227	20,308	6,459	45,920
1991/92	12,935	1,603	14,538	6,846	55,033
1992/93	7,037	873	7,910	8,064	74,897
1993/94	0	0	0	8,064	74,897
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.
2011/12	0	0	0	8,064	74,897

Table-9.6: FINANCIAL STATEMENT (1)

(Unit: 10^3 US$)

Fiscal Year	Capital Cost (1)	Interest during Construction (2)	Operating Expenses (3)	Loan Repayment (4)	Gross Revenue (5)	Total (6)=(1)+(2)+(3)+(4)+(5)	Accumulated Surplus
1982/83	-1,763	-152				-1,915	-1,915
1983/84	-1,758	-289				-2,047	-3,962
1984/85	-4,613	-1,000				-5,613	-9,575
1985/86	-7,945	-2,433				-10,378	-19,953
1986/87	-14,890	-5,630				-20,520	-40,473
1987/88	-15,845	-9,236				-25,081	-65,554
1988/89	-17,713	-13,593				-31,306	-96,860
1989/90	-7,580	-2,073	-5,416	-22,874	25,817	-12,126	-108,986
1990/91	-2,227	-723	-6,459	-26,460	45,920	10,051	-98,935
1991/92	-1,603	-1,241	-6,846	-26,460	55,033	18,883	-80,052
1992/93	-873	-1,522	-8,064	-26,460	74,897	37,978	-42,074
1993/94			-8,064	-29,357	74,897	37,476	-4,598
1994/95			-8,064	-29,357	74,897	37,476	32,878
1995/96			-8,064	-29,357	74,897	37,476	70,354
1996/97			-8,064	-29,357	74,897	37,476	107,830
1997/98			-8,064	-29,357	74,897	37,476	145,306
1998/99			-8,064	-29,357	74,897	37,476	182,782
1999/2000			-8,064	-29,357	74,897	37,476	220,258
2000/01			-8,064	-29,357	74,897	37,476	257,734
2001/02			-8,064	-29,357	74,897	37,476	295,210
2002/03			-8,064	-29,357	74,897	37,476	332,686
2003/04			-8,064	-29,357	74,897	37,476	370,162
2004/05			-8,064	-29,357	74,897	37,476	407,638
2005/06			-8,064	-29,357	74,897	37,476	445,114
2006/07			-8,064	-29,357	74,897	37,476	482,590
2007/08			-8,064	-29,357	74,897	37,476	520,066
2008/09			-8,064	-29,357	74,897	37,476	557,542
2009/10			-8,064	-29,357	74,897	37,476	595,018
2010/11			-8,064	-29,357	74,897	37,476	632,494
2011/12			-8,064	-29,357	74,897	37,476	669,970

Note: 1. Only F/C of initial investment is assumed to be financed by foreign funds.

2. Loan condition; Annual interest rate : 4%
Repayment period : 30 years including 7 years grace period

Table-9.7: FINANCIAL STATEMENT (2)

(Unit: 10^3 US$)

Fiscal Year	Capital Cost (1)	Interest during Construction (2)	Operating Expenses (3)	Loan Repayment (4)	Gross Revenue (5)	Total (6)=(1)+(2)+(3)+(4)+(5)	Accumulated Surplus
1982/83	-1,763	-304				-2,067	-2,067
1983/84	-1,758	-578				-2,336	-4,403
1984/85	-4,613	-2,001				-6,614	-11,017
1985/86	-7,945	-4,866				-12,811	-23,828
1986/87	-14,890	-11,260				-26,150	-49,978
1987/88	-15,845	-18,471				-34,316	-84,294
1988/89	-17,713	-27,186				-44,899	-129,193
1989/90	-7,580	-4,146	-5,416	-32,767	25,817	-24,092	-153,285
1990/91	-2,227	-1,446	-6,459	-37,847	45,920	-2,059	-155,344
1991/92	-1,603	-2,481	-6,846	-37,847	55,033	6,256	-149,088
1992/93	-873	-3,044	-8,064	-37,847	74,897	25,069	-124,019
1993/94			-8,064	-41,809	74,897	25,024	-98,995
1994/95			-8,064	-41,809	74,897	25,024	-73,971
1995/96			-8,064	-41,809	74,897	25,024	-48,947
1996/97			-8,064	-41,809	74,897	25,024	-23,923
1997/98			-8,064	-41,809	74,897	25,024	1,101
1998/99			-8,064	-41,809	74,897	25,024	26,125
1999/2000			-8,064	-41,809	74,897	25,024	51,149
2000/01			-8,064	-41,809	74,897	25,024	76,173
2001/02			-8,064	-41,809	74,897	25,024	101,197
2002/03			-8,064	-41,809	74,897	25,024	126,221
2003/04			-8,064	-41,809	74,897	25,024	151,245
2004/05			-8,064	-41,809	74,897	25,024	176,269
2005/06			-8,064	-41,809	74,897	25,024	201,293
2006/07			-8,064	-41,809	74,897	25,024	226,317
2007/08			-8,064	-41,809	74,897	25,024	251,341
2008/09			-8,064	-41,809	74,897	25,024	276,365
2009/10			-8,064	-41,809	74,897	25,024	301,389
2010/11			-8,064	-41,809	74,897	25,024	326,413
2011/12			-8,064	-41,809	74,897	25,024	351,437

Note: 1. Only F/C of initial investment is assumed to be financed by foreign funds.

2. Loan condition; Annual interest rate : 8%
Repayment period : 30 years including 7 years grace period

Table-9.8: UNIT INSTALLATION COST OF ALTERNATIVE COAL-FIRED THERMAL PLANT

Installed Capacity	100 MW
No. of units and size	2 x 50 MW
Direct Construction Cost	(10^3 US$)
- Land and land rights	1,300
- Civil work	20,000
- Steam generator and auxiliaries	23,000
- Turbine generator and ancillaries (including cooling tower)	22,000
- Electrical instrumentation and control equipment	10,000
- Fuel storage and hauling equipment	2,500
- Ash handling and disposal system	2,000
- Miscellaneous (cranes, shops, stores, etc.)	1,600
- Transmission line	5,000
Sub-total	87,400
Engineering (5%)	4,400
Contingencies (10%)	9,200
Grand-total	101,000
Specific cost per kW	1,010 (≑ 1,000)

CHAPTER 10 ALTERNATIVE PROJECT SCHEME (SECOND CHOICE)

10.1 General

The optimum project scheme is selected to be the fill type dam scheme with the full supply level, EL.230 and an installed power capacity 225 MW. Since this scheme will yield the maximum net benefit, it is most desirable to develop the project with this optimum scheme as recommended in Chapter 5, if there is no financial difficulty.

The necessary investment for the optimum scheme, however, is considerably large. Its construction cost is estimated at U.S.\$355 x 10^6, and with the price escalation and the interest during construction, the required investment will amount to about U.S.\$544 x 10^6. Then, it is considered that difficulty of financing may become major constraint for implementation of the project. In such event, a smaller scheme of the project may have to be selected to reduce the investment cost as the second choice although some economic advantage will be sacrificed.

Considering such possibility, the examination of an alternative project scheme was made mainly from the viewpoint to reduce the investment cost.

10.2 Selection of the Alternative Scheme

The selection of a smaller development scale simply means to choose a full supply level lower than EL.230. However, it is not desirable to lower it down to EL.210, since the economic merit of the project will almost vanish in the case as seen in Fig.-5.1.4 to Fig.-5.1.7. Therefore, the choice of the alternative scheme is limited to the scheme with the full supply level, EL.220, from which both some economic merit and reduction of the investment cost can be expected.

Among the schemes with the full supply level, EL.220, the fill type dam at the damsite-A provided with the installed capacity of 150 MW will yield the maximum net benefit, with the least investment cost. As such, the following scheme has been selected as the most favourable alternative or second choice.

Selected Alternative Scheme

Damsite	Damsite - A
Dam type	Fill type dam
Full supply level	EL.220
Installed capacity	150 MW

10.3 Project Cost in the Alternative Scheme

The preliminary design for the selected alternative project scheme is as given in Fig.-10.1 and Fig.-10.2. The project cost for the alternative scheme is estimated based on this design. It is also based on the same considerations or assumptions as those applied for the optimum project scheme.

The project cost is estimated at U.S.$276.5 x 10^6 (U.S.$234.5 x 10^6 for F.C. and U.S.$42.0 x 10^6 for L.C.) at 1982 July price level as shown in Table-10.1. The annual O & M cost is worked out at U.S.$3,480 x 10^3.

10.4 Project Benefit in the Alternative Scheme

The power and energy output in the alternative scheme is calculated through the reservoir operation as follows.

Firm peak power	134 MW
Annual primary energy	580 GWh
Annual secondary energy	544 GWh

Applying the same criteria for the project benefit explained in Chapter 9 "ECONOMIC AND FINANCIAL ANALYSIS", the benefit in the alternative scheme is derived as summarized below.

Capacity Benefit (10^3 U.S.$)

Investment cost	157,182
Replacement cost	141,464
Annual O & M cost	4,690

Energy Benefit (10^3 US$)

Fiscal Year	Primary Energy	Secondary Energy	Total
1989/90	13,944	7,128	21,072
1990/91	18,018	5,736	23,754
1991/92 onward	24,360	7,824	32,184

10.5 Economic and Financial Analysis for the Alternative Scheme

10.5.1 Economic Analysis

The economic analysis for the alternative scheme is made in Table-10.1 to Table-10.4. Table-10.1 and Table-10.2 show the yearly disbursement of the construction cost and the cash flow of cost & benefit, respectively. The calculation of the economic internal rate of return (EIRR) is made in Table-10.3 and Table-10.4. As seen in Table-10.4, EIRR is calculated at 16.3%. This value indicates that the alternative scheme still has a high economic viability.

10.5.2 Financial Analysis

The financial analysis is made in Table-10.5 to Table-10.7 under the same financial conditions as those applied for the optimum scheme. The financial internal rate of return (FIRR) is calculated to be 8.8% based on the cash flow shown in Table-10.5. Thus, the alternative scheme will be financially viable if the project cost is financed by an interest rate less than 8.8%.

The total financial investment cost of the project including the price escalation (6% per annum) and the interest during construction (4% per annum) will be U.S.$423.5 x 10^6, which comprises U.S.$365.1 x 10^6 of F.C. and U.S.$58.4 x 10^6 of L.C. as shown below.

	F.C.	L.C.	Total
Construction cost	234,500	42,000	276,500
Price escalation	98,129	16,399	114,528
Interest during construction	32,513	–	32,513
	(65,025)		(65,025
Total investment cost	365,142	58,399	423,541
	(397,654)		(456,053)

Remark: ( ) shows the case of the annual interest rate of 8%.

The loan repayability for the above financial investment cost is examined in Table-10.6. As shown in the Table, the accumulated surplus will be turned into positive figure one year after the project reaches its final development stage. The surplus at the end of repayment period, 2011/12, will amount to about U.S.$472 x 10^6 which makes it possible to reconstruct the same kind of the project.

The loan repayability in the case of the annual interest rate of 8% is also examined in Table-10.7. The accumulated surplus at the end of the repayment period of 30 years in this case amounts to about U.S.$206 x 10^6, indicating that the project is still financially viable. The surplus will exceed the total financial investment cost 5 years after the completion of the loan repayment period. This means that the reconstruction of the same kind of project will become possible at the end of the project life of 50 years.

Table-10.1: YEARLY DISBURSEMENT OF CONSTRUCTION COST
(Alternative Scheme)

(Unit: 10^3 U.S.$)

Item	Summary		1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	1990/91	1991/92
	F/C	L/C										
1. Preparatory works	441	1,807	450	450	450	450	450	0	0	0	0	0
2. Civil work												
(1) Diversion	30,947	6,053	0	0	11,100	14,800	11,100	0	0	0	0	0
(2) Dam and spillway	54,717	9,459	0	0	0	6,418	19,253	19,253	12,834	6,418	0	0
(3) Intake	16,371	2,890	0	0	0	0	5,778	7,705	5,778	0	0	0
(4) Powerhouse	25,177	4,389	0	0	0	0	0	11,649	14,562	3,045	222	88
Sub-total 2	127,212	22,791	0	0	11,100	21,218	36,131	38,607	33,174	9,463	222	88
3. Metal and generating equipment												
(1) Metal	21,437	2,383	0	0	0	0	4,764	4,764	9,528	4,764	0	0
(2) Generating equipment	41,264	4,584	0	0	0	0	6,739	6,739	18,340	6,739	4,861	2,430
Sub-total 3	62,701	6,967	0	0	0	0	11,503	11,503	27,868	11,503	4,861	2,430
4. Land acquisition	2,600	2,900	770	770	770	770	770	825	825	0	0	0
5. Engineering service & government administration	14,418	2,639	2,417	1,933	1,933	1,933	1,933	1,933	1,933	2,381	377	284
6. Physical contingency	27,128	4,894	385	338	2,001	3,516	6,900	7,208	2,683	8,148	557	286
Total	234,500	42,000	4,022	3,491	16,254	27,887	57,687	60,076	66,483	31,495	6,017	3,088

Table-10.2: CASH FLOW OF PROJECT COST AND BENEFIT
(Alternative Scheme)

(Unit: 10^3 US$)

Fiscal Year	Project Cost			Project Benefit				
	Capital and Re-placement Cost	O & M Cost	Total	Power Benefit		Energy Benefit		Total
				Capital	Fixed O & M	Primary	Secondary	
1982/83	4,022	0	4,022	0	0	0	0	0
1983/84	3,491	0	3,491	0	0	0	0	0
1984/85	16,254	0	16,254	0	0	0	0	0
1985/86	27,887	0	27,887	0	0	0	0	0
1986/87	57,687	0	57,687	0	0	0	0	0
1987/88	60,076	0	60,076	33,431	0	0	0	33,431
1988/89	66,483	0	66,483	55,131	0	0	0	55,131
1989/90	31,495	3,165	31,495	40,175	2,660	13,944	7,128	63,907
1990/91	6,017	3,165	6,017	23,460	3,500	18,018	5,736	50,714
1991/92	3,087	3,480	3,087	4,985	4,690	24,660	7,824	41,859
1992/93	0	3,480	0	0	4,690	24,360	7,824	36,874
:	:	:	:	:	:	:	:	:
2010/11	0	3,480	3,480	0	4,690	24,360	7,824	36,874
2011/12	0	3,480	3,480	30,087	4,690	24,360	7,824	66,961
2012/13	0	3,480	3,480	49,618	4,690	24,360	7,824	86,492
2013/14	0	3,480	3,480	36,158	4,690	24,360	7,824	73,032
2014/15	0	3,480	3,480	21,114	4,690	24,360	7,824	57,988
2015/16	0	3,480	3,480	4,487	4,690	24,360	7,824	41,361
2016/17	0	3,480	3,480	0	4,690	24,360	7,824	36,874
:	:	:	:	:	:	:	:	:
2021/22	0	3,480	3,480	0	4,690	24,360	24,360	36,874
2022/23	30,606	3,480	34,085	0	4,690	24,360	24,360	36,874
2023/24	30,606	3,480	34,085	0	4,690	24,360	24,360	36,874
2024/25	6,466	3,480	9,946	0	4,690	24,360	24,360	36,874
2025/26	6,466	3,480	9,946	0	4,690	24,360	24,360	36,874
2026/27	0	3,480	3,480	0	4,690	24,360	24,360	36,874
:	:	:	:	:	:	:	:	:
2031/32	0	3,480	3,480	0	4,690	24,360	24,360	36,874

Table-10.3: NET BENEFIT CALCULATION IN ACCORDANCE WITH DISCOUNT RATE

(Alternative Scheme)

(Unit: 10^3 US$)

Discount (%)	Benefit in Present Worth (B)	Cost in Present Worth (C)	Net Benefit (B - C)	B/C Ratio
1.0	1,528,587	452,591	1,075,996	3.38
2.0	1,277,814	419,228	858,586	3.05
3.0	1,086,460	395,573	690,887	2.75
4.0	938,572	378,868	559,704	2.48
5.0	822,825	367,188	455,637	2.24
6.0	731,101	359,178	371,923	2.04
7.0	657,529	353,879	303,649	1.86
8.0	597,817	350,607	247,210	1.71
9.0	548,803	348,870	199,933	1.57
10.0	508,131	348,313	159,818	1.46
11.0	474,031	348,677	125,354	1.36
12.0	445,160	349,771	95,389	1.27
13.0	420,489	351,454	69,035	1.20
14.0	399,226	353,622	45,604	1.13
15.0	380,751	356,196	24,555	1.07
16.0	364,577	359,116	5,461	1.02
17.0	350,319	362,336	-12,017	0.97
18.0	337,668	365,821	-28,153	0.92
19.0	326,377	369,545	-43,167	0.88
20.0	316,243	373,486	-57,242	0.85
21.0	307,102	377,627	-70,526	0.81
22.0	298,817	381,957	-83,140	0.78
23.0	291,276	386,465	-95,189	0.75
24.0	284,385	391,143	-106,758	0.73
25.0	278,065	395,984	-117,920	0.70

Table-10.4: CALCULATION OF INTERNAL RATE OF RETURN
(Alternative Scheme)

(Unit: 10^3 US$)

Discount Rate (%)	Net Benefit (B - C)	B/C
16.1	3,646	1.01
16.2	1,846	1.01
16.3	62	1.00
16.4	-1,707	1.00
16.5	-3,461	0.99
16.6	-5,201	0.99
16.7	-6,926	0.98
16.8	-8,636	0.98
16.9	-10,333	0.97

Economic Internal Rate of Return is 16.3%.

Table-10.5: FINANCIAL CASH FLOW
(Alternative Scheme)

(Unit: 10^3 US$)

Fiscal Year	Capital Cost F.C.	Capital Cost L.C.	Capital Cost Total	O & M Cost	Gross Revenue
1982/83	2,990	1,273	4,263		
1983/84	2,665	1,257	3,922		
1984/85	15,561	3,798	19,359		
1985/86	28,931	6,276	35,207		
1986/87	65,430	11,768	77,198		
1987/88	72,864	12,355	85,219		
1988/89	86,660	13,306	99,966		
1989/90	43,565	6,634	50,199	5,045	30,368
1990/91	9,047	1,118	10,165	5,347	35,726
1991/92	4,916	614	5,530	6,232	51,322
1992/93	0	0	0	6,606	54,401
⋮	⋮	⋮	⋮	⋮	⋮
2011/12	0	0	0	6,606	54,401

Table-10.6: FINANCIAL STATEMENT (1)
(Alternative Scheme)

(Unit: 10^3 US$)

Fiscal Year	Capital Cost (1)	Interest during Construction (2)	Operating Expenses (3)	Loan Repayment (4)	Gross Revenue (5)	Total (6)=(1)+(2) +(3)+(4)+(5)	Accumulated Surplus
1982/83	-1,273	-120				-1,393	-1,393
1983/84	-1,257	-226				-1,483	-2,876
1984/85	-3,798	-848				-4,646	-7,522
1985/86	-6,276	-2,006				-8,282	-15,804
1986/87	-11,768	-4,623				-16,391	-32,195
1987/88	-12,355	-7,538				-19,893	-52,088
1988/89	-13,306	-11,004				-24,310	-76,398
1989/90	-6,634	-1,743	-5,045	-18,517	30,368	-1,571	-77,969
1990/91	-1,118	-2,104	-5,347	-18,517	35,726	8,640	-69,329
1991/92	-614	-2,301	-6,232	-18,517	51,322	23,658	-45,671
1992/93			-6,606	-22,750	54,401	25,045	-20,626
1993/94			-6,606	-22,750	54,401	25,045	5,306
1994/95			-6,606	-22,750	54,401	25,045	31,238
1995/96			-6,606	-22,750	54,401	25,045	57,170
1996/97			-6,606	-22,750	54,401	25,045	83,102
1997/98			-6,606	-22,750	54,401	25,045	109,034
1998/99			-6,606	-22,750	54,401	25,045	134,966
1999/2000			-6,606	-22,750	54,401	25,045	160,898
2000/01			-6,606	-22,750	54,401	25,045	186,830
2001/92			-6,606	-22,750	54,401	25,045	212,762
2002/03			-6,606	-22,750	54,401	25,045	238,694
2003/04			-6,606	-22,750	54,401	25,045	264,626
2004/05			-6,606	-22,750	54,401	25,045	290,558
2005/06			-6,606	-22,750	54,401	25,045	316,490
2006/07			-6,606	-22,750	54,401	25,045	342,422
2007/08			-6,606	-22,750	54,401	25,045	368,354
2008/09			-6,606	-22,750	54,401	25,045	394,286
2009/10			-6,606	-22,750	54,401	25,045	420,218
2010/11			-6,606	-22,750	54,401	25,045	446,150
2011/12			-6,606	-22,750	54,401	25,045	472,082

Note: 1. Only F/C of initial investment is assumed to be financed by foreign funds.

2. Loan condition; Annual interest rate: 4%
Repayment period : 30 years including 7 years grace period.

Table-10.7: FINANCIAL STATEMENT (2)
(Alternative Scheme)

(Unit: 10^3 US$)

Fiscal Year	Capital Cost (1)	Interest during Construction (2)	Operating Expenses (3)	Loan Repayment (4)	Gross Revenue (5)	Total (6)=(1)+(2)+(3)+(4)+(5)	Accumulated Surplus
1982/83	-1,273	-239				-1,512	-1,512
1983/84	-1,257	-452				-1,707	-3,219
1984/85	-3,798	-1,697				-5,495	-8,714
1985/86	-6,276	-4,012				-10,288	-19,002
1986/87	-11,768	-9,246				-21,014	-40,016
1987/88	-12,355	-15,075				-27,430	-67,446
1988/89	-13,306	-22,008				-35,314	-102,760
1989/90	-6,634	-3,485	-5,045	-26,526	30,368	-11,322	-114,082
1990/91	-1,118	-4,209	-5,347	-26,526	35,726	-1,474	-115,556
1991/92	-614	-4,602	-6,232	-26,526	51,322	13,348	-102,208
1992/93			-6,606	-32,385	54,401	15,410	-86,798
1993/94			-6,606	-32,385	54,401	15,410	-71,388
1994/95			-6,606	-32,385	54,401	15,410	-55,978
1995/96			-6,606	-32,385	54,401	15,410	-40,568
1996/97			-6,606	-32,385	54,401	15,410	-25,158
1997/98			-6,606	-32,385	54,401	15,410	-9,748
1998/99			-6,606	-32,385	54,401	15,410	5,662
1999/2000			-6,606	-32,385	54,401	15,410	21,072
2000/01			-6,606	-32,385	54,401	15,410	36,482
2001/02			-6,606	-32,385	54,401	15,410	51,892
2002/03			-6,606	-32,385	54,401	15,410	67,302
2003/04			-6,606	-32,385	54,401	15,410	82,712
2004/05			-6,606	-32,385	54,401	15,410	98,122
2005/06			-6,606	-32,385	54,401	15,410	113,532
2006/07			-6,606	-32,385	54,401	15,410	128,942
2007/08			-6,606	-32,385	54,401	15,410	144,352
2008/09			-6,606	-32,385	54,401	15,410	159,762
2009/10			-6,606	-32,385	54,401	15,410	175,172
2010/11			-6,606	-32,385	54,401	15,410	190,582
2011/12			-6,606	-32,385	54,401	15,410	205,992

Note: 1. Only F/C of initial investment is assumed to be financed by foreign funds.

2. Loan condition; Annual interest rate: 8%
Repayment period : 30 years including 7 years grace period.

CHAPTER 11 ENVIRONMENTAL ASSESSMENT

11.1 General

The followings are considered to be the main items of the environmental problems which should be examined in relation to the project.

- Lands, houses and roads, etc. to be submerged by the proposed reservoir and necessary compensation cost,

- Lands and houses in the area to be used for the project construction works such as borrow areas of construction materials and various construction facilities, and necessary compensation cost,

- Present riverine fisheries in the river basin, adverse effects on fishery due to the project and necessity of fish passing facilities,

- Effect on water use in the upstream and downstream reaches of the project, and

- Any other effects on the environment affecting the living, economy, ecology and culture in the project area.

In the field investigation, data and informations relating to the above environmental problems were collected from the government organizations concerned, inhabitants in the project area and from similar projects such as the Trisuli and the Sunkosi projects. Overall reconnaissance of the project area was also made to collect data to examine the environmental problems.

The environment assessment was made based on the above collected data and informations, and findings through the reconnaissance of the project area.

Conceivable effects on the environment caused by the project and proposed countermeasures are discussed in this Chapter.

11.2 Lands, Houses and Roads, etc. to be Submerged by the Proposed Reservoir

11.2.1 Land Use in the Submerged Area

The present situation of land use in the surrounding area of the project is as presented in Section 4.7 of Chapter 4 SITE CONDITION. The reservoir of the determined project scheme is of the full supply level of EL.230 and the flood water level of EL.232.2. Thus, the proposed reservoir will inundate the upstream area of the damsite as shown in Fig.-11.1 to Fig.-11.3. As seen, the submerged area involves the major tablelands along both banks of the Trisulganga and several minor tablelands along the Kali Gandaki. As stated, these tablelands are mostly cultivated as agricultural land. Some portions are utilized for residential area. Further, the left bank of the Trisulganga where Gorka - Mugling - Narayangar Road (referred to as "Mugling Road") passes along is used as a main national traffic route.

No other particular land use is found in such mountainous areas as they form a steep topography.

11.2.2 Compensation for the Submerged Area

Agricultural lands, residential houses, roads and facilities, etc. to be submerged by the proposed reservoir were measured as indicated in Table-11.2.

Agricultural lands and residential houses to be submerged amounted to 441 ha. and 492 Nos. respectively in the finally determined project scheme. The evacuation of about 2,500 people will be required. Agricultural lands and residential houses in the submerged area are all owned privately, and therefore, their owned should be compensated.

The Mugling Road will be submerged in a section of about 8 km. It will have to be relocated before the completion of the project since it is one of the main national traffic routes.

In addition to the above, three traditional temples and four schools, each accommodating about 50 pupils, are involved in the submerged area. Further, two suspension bridges, one crossing the Trisulganga in Devighat and the other crossing the Kali Gandaki at about 10 km upstream of the damsite, will also be submerged. Three traditional temples and four schools should be replaced to appropriate places above the reservoir water level.

As for the suspension bridges to be submerged, provision of ferry boats for transporting people across the river instead of the suspension bridge is considered as a conceivable and appropriate countermeasure.

The cost required for compensation of the items mentioned above was estimated based on the data and informations collected through the field investigation as mentioned below.

With regard to the compensation cost of the agricultural lands and residential houses, and the replacement cost of the temples and schools, the following informations are obtained from the government organizations concerned and inhabitants in the surrounding area;

Items	Unit Price (in Rs.)
Agricultural Land:	
Paddy field	50,000/ha.
Upland field	40,000/ha.
Residential House:	
First class	50,000/ea.
Second class	20,000/ea.
Third class	10,000/ea.
Fourth class	5,000/ea.
Replacement of Temple:	100,000/ea.
Replacement of School:	50,000/ea.

For the above items, the compensation cost was assessed applying the above unit cost.

For compensation of the suspension bridges, the necessary cost was estimated at Rs. 80,000 assuming the provision of four ferry boats at each site (eight ferry boats in total, each boat having a capacity to accommodate about 20 persons).

The relocation cost of the Mugling Road was estimated based on its unit cost of US$600/m which was derived on the assumption of rock excavation volume of 50 m^3/m in average, the unit price of rock excavation of US$10/$m^3$ and pavement cost of US$100/m.

The total compensation cost was approximately estimated at US$9,000,000 as calculated in Table-11.1.

11.3 Lands and Houses in the Construction Work Area

The project construction works require land acquisition for the borrow areas of dam embankment materials and concrete aggregates, various structures and construction facilities.

The followings are the required land acquisition for the construction work area;

- Gravel deposits in the riverbed upstream and downstream of the damsite for concrete coarse aggregates,
- Sand deposits in the Khageri Khola for concrete fine aggregates,
- Right and left banks near the damsite for various structures of the project and construction facilities,
- Tableland in the left bank of the damsite for the borrow area of the core materials, and
- Rocky mountains at about 7 to 10 km north of the damsite for the quarry site of the rockfill materials.

Fortunately, all the above areas do not include any private land and residential house, so no compensations are needed for the above land use. However, the tableland in the left bank of the damsite for the borrow area of the core material is covered with valuable forest. A large area of the forest will have to be cleared, resulting in an adverse effect on the surrounding environment. The Mugling Road passes adjacent to the rocky mountain recommended for the quarry site of rockfill materials.

The following steps are recommended so as to minimize the adverse effect on the surrounding environment.

Lumbering should be limited to the minimum requirement and after the construction work, the area should be restored by afforestation. Extraction of the quarry rock should be remote from the Mugling Road as much as possible not to obstruct the traffic and to avoid danger by blasting. Special attention should be paid in the quarry site planning.

11.4 Riverine Fishery

The followings were found out through the investigation for the nearby riverine fishery;

Most of the inhabitants in the riverine are engaged in riverine fishery along with agriculture. About 10% of the inhabitants are exclusively engaged in fishery. Though the fishing method is very primitive and of small scale, they are getting cash income by selling the fish in the nearby villages or in Narayangar.

About 10 varieties of fish are caught. They belong to the family of carp or catfish. The detailed mode of life of these fish cannot be known because no data are available and the inhabitants also do not have any knowledge about it. The most popular fish, so-called "Sahar", belongs to the carp family and forms the major part of the catches. It is known to go up and down the stream during spawning time. Therefore, it is presumed that the effect of the project construction on the "Sahar" will be serious.

It has been reported that in similar hydropower schemes, the catch of the "Sahar" fish has diminished in nearby rivers such as around the Trisul and the Sunkosi Projects. As a number of people are making their living from the sales of the fishery products, the problem cannot remain unattended as they will adversely affect the livelihood of the riverine people. To solve the adverse effect of the dam construction on the fish population, it was decided to incorporate some simple fish passing facility in the project design.

A fish passing facility was decided to be provided in the right bank as shown in Fig.-6.3. The fish passing facility with movable gates which make it possible to keep water flowing through the facility under any reservoir water level condition is more favourable in view of the function of the facility. However, provision of the movable gates is very costly. In consideration that such a high functional facility is not necessary, the facility was designed as one of fixed weir in which water flow through the facility and fish passing are possible only when the reservoir is at the full supply level which is the normal water level of the reservoir.

11.5 Water Use around the Project Area

Based on the investigation of the present water use around the project area, it is found that there is no water use from the large rivers of the Kali Gandaki, the Trisulganga or the Sapt Gandaki rivers, etc. to supply the municipalities or the irrigaiton system.

Present municipal water is distributed to the villages or the town from a tank which is installed at a high elevation in the mountainous area and collecting water from several minor streams. Irrigation water is also being collected from the nearby small streams.

Thus, there will not be any adverse effect on the present water use by the realization of the project.

A pumping station by the Chitwan Valley Development Project is now under construction at about 4 km downstream of the damsite. In near future, irrigation water of 20 m^3/sec is planned to be taken from this pumping station. In principle, there is no change from the present condition in the downstream flow even after the completion of the Sapt Gandaki Project, since the Sapt Gandaki Project is designed as the run-of-river type. However, in low river flow season, there is a period when the power plant of the Sapt Gandaki Project will be operated during 12 hours per day and be stopped after that, resulting in no downstream river flow during the remaining 12 hours. In this case, some troubles could occur in lifting irrigation water at the mentioned pumping station, which requires a continuous river flow.

The water supply system and planning in the Chitwan Valley Development Project were investigated to assess this problem. According to the "Report of the Chitwan Valley Development Project, September 1972", the capacities of the pumps and the main canal system were not determined based on continuous flow in view of the adopted irrigation practices.

The main canal system is designed for 12 hours operation. It means that the canal system has a storage capacity to supply 24 hours continuous flow without pumping up during 12 hours.

The pumps have capacity to pump up a discharge of 19 m^3/s. This capacity exceeds the discharge requirement which should be pumped up by 12 hours operation as follows;

	Irrigation Water Requirement in m^3/sec. (24 Hours Continuous Supply)	Converted Discharge for 12 Hours Operation in m^3/sec.
Jan.	4.2	8.4
Feb.	6.9	13.8
Mar.	8.2	16.4
Apr.	8.9	17.8
May	8.3	16.6
Jun.	5.1	10.2
Jul.	2.2	4.4
Aug.	2.7	5.4
Sep.	6.8	13.6
Oct.	4.1	8.2
Nov.	5.1	10.2
Dec.	3.7	7.4

As stated, both the canal system and the pumps have a capacity to withstand the 12 hours operation, i.e. it can manage to supply 24 hours continuous flow by pumping up the required volume of irrigation water during 12 hours operation of the Sapt Gandaki Project. Even if the river flow is stopped during the remaining 12 hours, it was considered that there would not be serious effect on the downstream irrigation project.

11.6 Other Effects

Economy: No adverse effect on the surrounding economy by the project is expected. The project will increase employment opportunity in the area where most of the labour forces are unemployed, leading to the increase in the purchasing power and more active economic activities in the surrounding area.

After the completion of the project, the area may attract tourists and income from tourism is expected to benefit economically the area.

Culture: The main effect on the cultural aspect is considered to be submergence of the famous traditional temples in Devighat where a grand festival is held every year, gathering many people from the whole country. This traditional culture should be preserved. The temples are planned to be moved and reconstructed as orginally as possible. No other particular adverse effect on the culture was found.

Ecology: Due to the lack of any data about ecology, the effect on the ecology by the project is difficult to assess. The following, however, is considered to be a possible adverse effect on the ecology by the project.

Some crocodiles live in the upstream reaches of the Kali Gandaki. They are protected by the Government organization for their survival. The crocodiles seem to live in the shallow river water such as near the sand and gravel deposits. Such places will be filled by the reservoir after the realization of the project and they may become unsuitable for the crocodiles.

In such an event, however, the crocodiles are considered to move to further upstream where they can find many remaining similar places suitable for living. Therefore, no particular countermeasure for the matter is necessary.

Sediment Transport: The Sapt Gandaki is transporting a huge amount of sediment to the downstream area. This sediment transportation may cause troubles in the downstream reach. On the other hand, it may be conveying fertile soil essential for agriculture in the downstream area or it may help keep in balance the delicate ecological environment.

This kind of natural phenomenon will be disturbed by the project. However, it was considered that interruption of the sediment transport would be just tentative until the reservoir will be filled up with sediment, i.e. only several years, and that the effect would be negligibly minor.

Table-11.1: COMPENSATION COST FOR AREA SUBMERGED BY RESERVOIR

Items	Q'ty	Unit Price (Rs)	Amount (Rs)
- Agricultural Lands:			
Paddy field	48 ha	50,000/ha	2,400,000
Upland field	393 "	40,000/ha	15,700,000
- Residential Houses:			
First class	11 ea.	50,000/ea.	550,000
Second class	39 "	20,000/ea.	780,000
Third class	152 "	10,000/ea.	1,520,000
Fourth class	290 "	5,000/ea.	1,450,000
- Replacement of Temple	3 ea.	100,000/ea.	300,000
- Replacement of School	4 ea.	50,000/ea.	200,000
- Compensation for Suspension Bridge			80,000
- Relocation of Mugling Road			65,000,000
- Miscellaneous (20%)			22,000,000
Total:			Rs. 110,000,000 (U.S.$ 8,630,000)

Table-11.2: LANDS, HOUSES AND FACILITIES TO BE SUBMERGED BY THE PROPOSED RESERVOIR

Area	Agricultural Lands(ha)			Residential Houses (ea.)					Others			
	Paddy Field	Upland Field	Total	1st Class	2nd "	3rd "	4th "	Total	Temple (ea)	School (ea)	Suspension Bridge(ea)	Road (km)
Devight Area	0	80	80	1	7	25	40	73	3	1	1	0
Quidi "	0	50	50	0	2	35	15	52	0	0	0	0
Thimura "	15	35	50	0	0	25	45	70	0	1	0	0
Guhetar "	10	80	90	0	0	10	60	70	0	0	0	0
Bhathadi "	8	7	15	0	0	5	20	25	0	0	0	0
Kalimati "	10	50	60	0	0	25	35	60	0	0	0	0
Jugedi "	5	20	25	10	30	15	5	60	0	1	0	0
Sandaybagar "	0	13	13	0	0	5	15	20	0	0	0	0
Hardi "	0	13	13	0	0	7	15	22	0	0	0	0
Kalikatar "	0	15	15	0	0	0	20	20	0	1	1	0
Others "	0	30	30	0	0	0	20	20	0	0	0	8
Total:	48	393	441	11	39	152	290	492	3	4	2	8

CHAPTER 12 CONSIDERATION OF IRRIGATION WATER SUPPLY BY GRAVITY FLOW

12.1 General

In the downstream area of the Sapt Gandaki Project site, there is an irrigation project named as the Chitwan Valley Development Project. It consists of three irrigation projects of Narayani Project, Lothar Project and Khageri Project and is now under construction.

In the Narayani Project, required irrigation water is planned to be pumped up by the pumping station now under construction at about 4 km downstream from the Sapt Gandaki Project site. However, with the Sapt Gandaki Project, this irrigation water supply will be possible by gravity flow from the Sapt Gandaki reservoir without pumping up at the downstream of the Sapt Gandaki Project. The gravity flow from the Sapt Gandaki reservoir will make the operation, maintenance and replacement cost of the pumping station unnecessary. It, however, will be accompanied with a loss of energy of the Sapt Gandaki Project due to the supply of irrigation water and the necessary construction cost of the intake facilities and canal, etc.

It was considered that an economic evaluation is required to judge whether the facilities for the irrigation water supply from the Sapt Gandaki Project reservoir should be provided or not. The study for the matter was made in this Chapter.

12.2 Cost Comparative Study

12.2.1 General

For this purpose, a cost comparative study was made between the pumping-up plan and the gravity-flow plan, taking into account the cost required throughout the whole project life.

The cost comparative study was made based on the following basic assumptions;

(i) The pumping station and canals of the Chitwan Valley Development Project which are now under construction will become serviceable from the beginning of 1985.

(ii) The Sapt Gandaki Project will be completed in 1989 and the irrigation water supply from the Sapt Gandaki Project reservoir by gravity flow will become possible from November, 1989.

(iii) Thus, up to November, 1989, irrigation water will be supplied by means of pumping up in the both cases of the pumping-up plan and the gravity-flow plan.

(iv) The pumping station and the canals, etc. in the Chitwan Valley Development Project are already under construction. Those were considered as the existing facilities, i.e. the installation cost of the pumping station and the canals, etc. under construction was not considered as the cost required in the pumping-up plan.

The followings are the cost comparative study carried out based on the above basic assumptions.

12.2.2 Cost for Pumping-up Plan

As explained in the above Section 12.2.1, the installation cost of the pumping station and the canals, etc. under construction in the Chitwan Valley Development Project is not considered as the cost required for this pumping-up plan. The followings were considered the necessary cost for the pumping-up plan;

(i) Replacement cost of pumping facilities

(ii) Power cost for pumping operation

The maintenance cost of the pumping facilities is neglected in consideration of its minor effect on the comparative study.

Each of the above costs was assessed based on "the Report of Chitwan Valley Development Project, September 1972" as follows;

(1) Replacement Cost of Pumping Facilities

Two pumping stations (A and B) are installed for supplying irrigation water to the irrigation are (12,730 ha) of the Narayani Project. The pumping station A works to pump up river water to a tank at upper elevation from which water is distributed to the irrigation area through the canals. The pumping station B works to pump up water from the above tank to further upper elevation and to distribute water to the higher altitude of the irrigation area.

The pumps to be installed at each pumping station are as follows;

Pumping Station	Pump: Design Head (m)	Pump: Capacity (m^3/s)	Pump: Number of Unit
A	18.6	5.0	3
	11.6	2.0	2
B	16.0	5.0	1
	16.0	2.0	1

The installation cost for the above pumping equipment is estimated in "the Report of Chitwan Valley Development Project" as shown in Table-12.1 in 1972 price level. The installation cost of the pumping equipment classified by life time of each component and converted into 1982 price level on the assumption of annual price escalation rate of 6%, is as given below; (See Table-12.1)

Life Time (Year)	Cost in 1972 Price Level (U.S.$)			Total Cost in 1982 Price Level (U.S.$)
	Pump Station A	Pump Station B	Total	
15	614,000	216,200	830,200	1,486,800
30	851,200	0	851,200	1,524,400
Total	1,465,200	216,200	1,681,400	3,011,200

All of the above installation cost was assumed to become necessary for replacing the equipments after their life time by disregarding some amount of salvage value which is actually expected but deemed negligibly small.

(2) Power Cost for Pumping Operation

The power cost required for pumping operation was estimated based on the monthly power requirements given in the said Report and the current power rate of 0.572 Rs./kWh (equivalent to U.S.$0.04486/kWh).

The annual power cost for the pumping operation was calculated at U.S.$771,420/Year as follows;

Month	Power Requirement (kWh)	Power Cost (U.S.$)
Jan.	1,087,000	48,766
Feb.	1,714,000	76,895
Mar.	2,306,000	103,454
Apr.	2,404,000	107,850
May	2,230,000	100,044
Jun.	1,235,000	55,406
Jul.	523,000	23,464
Aug.	662,000	29,700
Sept.	1,662,000	74,562
Oct.	1,112,000	49,888
Nov.	1,267,000	56,842
Dec.	993,000	44,549
	Annual Power Cost	U.S.$771,420/Year

12.2.3 Cost for Gravity-Flow Plan

In the gravity-flow plan, it is required to provide an intake facility at the Sapt Gandaki Project reservoir and a canal from the reservoir to the tank installed by the Chitwan Valley Development Project. Furthermore, this plan causes a loss of power benefit of the Sapt Gandaki Project due to the supply of irrigation water without power generation. This loss of energy benefit at the Sapt Gandaki Project was regarded as the cost required in the gravity-flow plan. Thus, the followings were considered as the necessary cost for the case of the gravity-flow plan.

(i) Construction cost of intake facilities and a canal in the gravity-flow plan

(ii) Loss of energy benefit at the Sapt Gandaki Project

Each of the above costs required in the case of the gravity-flow plan is assessed below.

(1) Construction Cost of Intake Facilities and a Canal in the Gravity-Flow Plan

In order to assess the construction cost of the intake facilities at the reservoir side and the canal from the reservoir to the irrigation area, the design of the simplest and cheapest structures to supply the required water of 19.0 m^3/s at maximum was preliminarily examined. The cheapest design resulted in the provision of the intake facilities (intake gate, stoplog, trash rack and conduit) in the dam body of the left abutment, 2.5 m dia. steel conduit, 250 m long, installed on the excavated surface of the access road of the power station and a canal with trapezoidal section of 3,750 m in length. The design of the structures determined through hydraulic and structural examination are as seen in Fig.-12.1.

The total construction cost was estimated at U.S.$1,154,710 based on the above design as calculated in Table-12.2.

(2) Loss of Energy Benefit at the Sapt Gandaki Project

The loss of energy at the Sapt Gandaki Project is calculated by the following formula;

$$E = 9.8 \cdot \alpha \cdot Q \cdot H \cdot T$$

where, E : Energy loss in kWh

α : Combined efficiency of turbine and generator (0.85)

Q : Discharge of irrigation water in m^3/s

H : Head in m (45.44 m)

In the case that peak power operation of 225,000 kW is made at the full supply water level of EL.230, the tailwater will be at the level of EL.184.56. Therefore, the head (H) was assumed at 45.44 m (230 - 184.56 = 45.44)

T : Operation hours (12 hrs./day)

The loss of energy and benefit due to the irrigation water supply are calculated based on the monthly irrigation water requirement and the current power rate of U.S.$0.04486/kWh, as shown in Table-12.3, resulting in an amount of 18,219,608 kWh and U.S.$817,387 respectively.

12.2.4 Cost Comparison and Judgement

The costs required in each plan of the pumping-up plan and the gravity flow plan are shown together for comparison as follows;

Plan	Cost Items	Cost (U.S.$)	Remarks
Pumping-up Plan	Replacement Cost of Pumping Facilities	1,486,800	Replacement after 15 years
	- do -	1,524,400	Replacement after 30 years
	Power Cost for Pumping Operation	771,420	Annual Cost
Gravity-Flow Plan	Construction Cost of Irrigation Water Supply Facilities	1,154,710	
	Benefit Loss of the Sapt Gandaki Project due to Irrigation Water Supply	817,387	Annual Cost

The cumulative cost in each plan throughout the life time is as seen in Fig.-12.2. As seen in the Figure, the gravity-flow plan resulted in a more expensive one during the earlier half of the life time, i.e. 25 years up to the end of 2014. After that, the pumping-up plan will become more costly due to necessary replacement cost of the pumping facilities.

Thus, it was judged that the full utilization of the existing pumping facilities, for the time being, would be more profitable from the overall viewpoint and that the gravity-flow plan should be considered at the time when the replacement of the pumping facilities after 25 years will become necessary.

Table-12.1: INSTALLATION COST OF PUMPING EQUIPMENT IN CHITWAN VALLEY DEVELOPMENT PROJECT

i) Installation Cost for Pumping Station A

(Base year of Cost Estimate: 1972)

Item	Life Time (Year)	Cost (US$)		Total Cost (US$)
		Area I, II, III	Area I-Ext.	
Pump Set	15	233,400	22,100	255,500
High Tension Motors	15	265,100	34,700	299,800
Fittings	15	46,900	6,800	53,700
Transformers, Switch Gears, Overhead Line	30	851,200	0	851,200
Switch Gear	15	0	5,000	5,000
Total Cost (US$)	-	1,396,600	68,600	1,465,200

ii) Instalaltion Cost for Pumping Station B

(Base year of Cost Estimate: 1972)

Item	Life Time (Year)	Cost (US$)		Total Cost (US$)
		Area I, II, III	Area I-Ext.	
Pump Set	15	63,200	22,100	85,300
High Tension Motors	15	69,800	34,700	104,500
Fittings	15	14,600	6,800	21,400
Switch Gears	15	-	5,000	5,000
Total Cost (US$)	-	147,600	68,600	216,200

Table-12.2: CONSTRUCTION COST OF INTAKE FACILITIES AND A CANAL IN GRAVITY-FLOW PLAN

	Work Items	Unit	Q'ty	Unit Price (U.S.$)	Amount (U.S.$)
(A)	Civil Work				
	- Excavation, common	m^3	90,000	3.70	333,000
	- Stone pitching (20 cm thick)	m^2	45,200	5.00	226,000
	- Structural concrete for anchor block	m^3	210	130	27,300
	- Steel bar	ton	7	630	4,410
	Sub-total				590,710
(B)	Metal Work				
	- Intake gate (2.5 m x 2.5 m)	ton	4.5	5,000	22,500
	- Intake stoplog	ton	6.0	4,000	24,000
	- Intake trash rack (2.5 m x 5.0 m)	ton	2.5	3,000	7,500
	- Steel pipe (t = 9 m/m)	ton	150	3,400	510,000
	Sub-total				564,000
	Grand Total				1,154,710

Table-12.3: CALCULATION OF LOSS OF ENERGY AND BENEFIT AT SAPT GANDAKI PROJECT DUE TO IRRIGATION WATER SUPPLY

Month	Irrigation Water Requirement in 24 hrs. Supply (m^3/s)	Converted Discharge Available for Power Generation in 12 hrs. Operation (m^3/s)	Energy Loss (kWh)	Benefit Loss (U.S.$)
Jan.	4.2	8.4	1,182,785	53,063
Feb.	6.9	13.8	1,755,100	78,739
Mar.	8.2	16.4	2,309,246	103,600
Apr.	8.9	17.8	2,425,526	108,816
May	8.3	16.6	2,337,408	104,863
Jun.	5.1	10.2	1,389,908	62,356
Jul.	2.2	4.4	619,554	27,795
Aug.	2.7	5.4	760,362	34,112
Sept.	6.8	13.6	1,853,211	83,141
Oct.	4.1	8.2	1,154,623	51,800
Nov.	5.1	10.2	1,389,908	62,356
Dec.	3.7	7.4	1,041,977	46,746
Total			18,219,608	817,387

CHAPTER 13 EXTENSION SCHEME OF SAPT GANDAKI PROJECT

13.1 General

The installed capacity of 225 MW was decided to be the optimum power capacity of the Sapt Gandaki Project. The determination of this installed capacity depends upon the firm discharge of 290 m^3/sec warranted with 90% firmness of duration. The firm discharge drops remarkably in spite of a large annual average river run-off of about 1,500 m^3/sec due to the large seasonal variation of the river run-off.

However, with some storage to regulate the seasonal variation of the river run-off provided in the upstream reaches of the Sapt Gandaki Project, the firm inflow discharge into the Sapt Gandaki Project can be increased accordingly, resulting in the possibility of expanding the installed capacity of the Sapt Gandaki Project. The possibility of the extension and the possible extension scheme are examined in this Chapter.

13.2 Possibility of Upstream Regulation Storage

Various storage type projects were taken up in the upstream reaches of the Sapt Gandaki project site in the basin master plan. Those projects are as tabulated below.

No.	Name of Project	Catchment Area (km^2)	Average Runoff (m^3/sec)	Installed Capacity (MW)	Active Storage Capacity (10^6 m^3)
1.	Andhi Khola No.1	420	29	190	800
2.	" No.2	450	30	90	280
3.	Utlar Ganga to Bari Gad	220	16	270	190
4.	Kali Gandaki No.1	9,150	410	1,600	5,200
5.	" No.2	11,340	500	480	3,000
6.	Seti No.1	2,740	190	320	1,850
7.	" No.2	2,960	200	160	0 /1
8.	Marsyangdi	4,500	220	740	3,600
9.	Burhi Gandaki	5,370	215	500	1,850
10.	Trisulganga	16,260	710	1,500	6,700
11.	Langtang Khola	250	9.0	175	100

/1: Storage depends on Seti No.1.

Some difficulties in implementing the above storage type schemes might be encountered such as social constraints, insufficient economic feasibility or difficult accessibility to the sites and so on. However, assuming that the realization of the Kali Gandaki No.2 (effective storage volume of 3,000 x 10^6 m^3), Seti No.1 (effective storage of 1,850 x 10^6 m^3) and Burhi Gandaki (effective storage of 1,850 x 10^6 m^3) will be realized at a comparatively earlier stage than the others, an effective storage of 6,700 x 10^6 m^3 is expected to be secured in the upstream reaches of the Sapt Gandaki project site.

13.3 Relation Among Upstream Storage Volume, Increase of Firm Discharge and Dependable Power at Sapt Gandaki Project

With a storage reservoir upstream of the Sapt Gandaki project site, it will be used to store to some extent the large river discharge in the wet season. In the dry season water will be released while the river discharge becomes less. Thus, the firm inflow discharge into the Sapt Gandaki reservoir will increase, leading to a power capacity increase of the Sapt Gandaki Project. The extent of the increase of the firm inflow discharge depends upon the volume of the upstream storage, i.e. capacity for regulation. The relationship between the storage volume and the firm discharge was examined by using a mass curve prepared from the stream flow data at the Sapt Gandaki project site. Various storage volumes were assumed on the prepared mass curve. Possible release discharge by utilizing each assumed storage volume was obtained on the mass curve.

The relationship between the assumed storage volumes and firm discharge with 90% firmness thus obtained is shown in Fig.-13.3.1.

The possible extension of the power capacity in the Sapt Gandaki Project is not directly related with the firm discharge, but depends on how will the firm discharge be regulated daily in the immediate upstream power plant (Kali Gandaki No.2) of storage scheme. The reservoir capacity of the Sapt Gandaki Project (8.5 x 10^6 m^3) is only enough to daily regulate the firm discharge of 290 m^3/sec at the plant factor of nearly 50%. Then, the final dependable peak power of the Sapt Gandaki Project will depend on the daily peak discharge released from the upstream plant after daily regulation of the firm discharge. Table-13.3.1 shows the relation between the firm discharge and the dependable peak power of the Sapt Gandaki Project for the following cases.

(i) No daily regulation of the firm discharge is made in the upstream storage plant.

(ii) Daily regulation of the firm discharge is made at 50% plant factor in the upstream storage plant.

13.4 Possible Extension of Sapt Gandaki Project

As referred to Fig.-13.3.1, the firm discharge can be increased up to around 750 m^3/sec by the realization of three storage type projects in the upstream reaches (storage volume of about 6,700 x 10^6 m^3 in total by Kali Gandaki No.2, Seti No.2 and Burhi Gandaki Projects which are considered to be realized at a comparatively earlier stage than the others). With this increase of firm discharge, the dependable peak power at the Sapt Gandaki Project is derived to be in a range of about 330 MW to 570 MW, depending on the mode of daily regulation in the upstream storage plant. Then, the possible extension of the installed capacity in the Sapt Gandaki Project is considered to be from 400 MW to 600 MW.

The facilities for the extension can be constructed on the right bank in addition to an additional 75 MW unit in the power station on the left bank. The scheme in the case of the additional installation of 200 MW on the right bank is provided in Fig.-13.4.1. The approximate estimate of the necessary construction cost in this case is U.S.$185,000 x 10^3 at the July 1982 price level as shown in Table-13.4.1.

Table-13.3.1: DEPENDABLE POWER FOR ASSUMED FIRM DISCHARGE

Firm Discharge (m^3/s)	Daily Dependable Energy (10^3 kWh)		Dependable Peak Power at 50% Plant Factor (MW)	
	(i)	(ii)	(i)	(ii)
325	2,190	2,981	182	248
375	2,401	3,440	200	287
425	2,611	3,898	218	325
475	2,822	4,357	235	363
525	3,033	4,815	253	401
575	3,244	5,274	270	439
625	3,455	5,733	288	478
675	3,667	6,191	306	516
725	3,878	6,650	323	554
775	4,090	7,108	341	592

Note: The above figures show the daily dependable energy and dependable peak power in case (i) no daily regulation of the firm discharge is made in the upstream storage plant, and case (ii) daily regulation of the firm discharge is made at 50% plant factor in the upstream storage plant.

Table-13.4.1: CONSTRUCTION COST FOR EXTENSION SCHEME OF SAPT GANDAKI PROJECT

Work Items	Amount (10^3 US$)
1. Preparatory works:	3,600
2. Civil works:	72,004
(1) Intake	6,286
(2) Headrace tunnel	25,116
(3) Surge tank	6,958
(4) Penstock tunnel	6,530
(5) Powerhouse and tailrace	27,114
3. Mechanical works:	23,400
4. Electrical works:	50,333
Sub-total	149,337
5. Engineering & government administration:	11,200
6. Physical contingency:	24,081
Total	184,618

CHAPTER 14 DEVELOPMENT PLAN OF HYDROPOWER PROJECTS

14.1 General

There are several hydroelectric power projects for which feasibility study has been carried out. Those are the Kali Gandaki Project (Scheme A), Kankai Multipurpose Project, Mulghat Project and Sapt Gandaki Project. Their principal features are provided in Table-14.1.

The feasibility studies for these hydropower projects revealed that all the projects would be technically sound and economically feasible.

All these hydropower projects can be realized stagewise to meet the increasing power demand in the most advantageous development order. The most advantageous development plan of the hydropower projects is examined in this Chapter. The development order of Sapt Gandaki - Kankai - Kali Gandaki - Mulghat is recommended as the most advantageous one from a practical viewpoint.

Detailed discussions to determine the above are provided hereunder.

14.2 Comparative Study

14.2.1 Definition

The most advantageous development order of the hydropower projects is defined as the most profitable one out of development orders which can meet the power demand throughout a year. Several development orders and the commissioning time of each project which satisfy the power demand throughout a year are selected. A scheme showing the maximum combined net benefit has to be found out, taking into consideration all costs and benefits involved.

14.2.2 Selected Development Orders and Commissioning Time for Comparison

The seasonal power outputs of each hydropower project are as given in Table-14.2. As seen in the Table, in the three hydropower projects of Sapt Gandaki, Mulghat and Kali Gandaki, the power output shows a steep decrease during the dry season due to its run-of-river type with no capacity to regulate the abundant run-off in the rainy season. On the other hand, the Kankai project has the capacity to regulate the seasonal variation of the run-off and to effectively increase the power supply capacity during the dry season. Therefore, it was considered that such a storage type hydropower project as the Kankai Project should be jointly operated together with the run-of-river type hydropower project. The drop of the output of the run-of-river type power station during the dry season can be filled up, leading to an effective substantial increased supply capacity.

The following three cases of development orders in which the Kankai Project follows a run-of-river type of hydropower project and one case of development order in which the Kankai Project comes first were taken up for comparative study.

CASE 1 : Sapt Gandaki - Kankai - Kali Gandaki - Mulghat

CASE 2 : Kali Gandaki - Kankai - Mulghat - Sapt Gandaki

CASE 3 : Mulghat - Kankai - Kali Gandaki - Sapt Gandaki

CASE 4 : Kankai - Sapt Gandaki - Mulghat - Kali Gandaki

Necessary commissioning time of each project to satisfy the power demand without any deficit is as follow as illustrated in Fig.-14.1.

CASE 1 : Sapt Gandaki (Nov., 1989) - Kankai (Oct., 1993) - Kali Gandaki (Feb., 1996) - Mulghat (Feb., 1997)

CASE 2 : Kali Gandaki (Nov., 1989) - Kankai (Nov., 1989) - Mulghat (Feb., 1993) - Sapt Gandaki (Feb., 1994)

CASE 3 : Mulghat (Nov., 1989) - Kankai (Nov., 1989) - Kali Gandaki (Jan., 1993) - Sapt Gandaki (Feb., 1994)

CASE 4 : Kankai (Nov., 1989) - Sapt Gandaki (Jan., 1992) - Mulghat (Feb., 1996) - Kali Gandaki (Feb., 1997)

14.2.3 Cost

The cost of each project consists of the construction cost, and the operation and maintenance cost (O & M cost).

The construction cost of each project was referred to the feasibility report prepared for each project. The construction cost of each project which was converted into 1981/82 price level by assuming an annual escalation rate of 6% are given below together with its necessary construction period.

Construction Cost and Construction Period

Project	Construction Period (years)	Construction Cost at 1982 Price Level (10^6 U.S.$) Dam and Auxiliary Facilities	Power Station, etc.	Total
Sapt Gandaki	6	208.5	146.2	354.7
Kali Gandaki	5	33.0	121.3	154.3
Kankai	5	52.5	17.5	70.0
Mulghat	4	110.6	44.4	155.0

The disbursement rate of the construction cost was assumed as follows referring to the standard rate.

	Disbursement Rate (in %)					
Project	1	2	3	4	5	6
Sapt Gandaki	8	8	20	25	25	14
Kali Gandaki	10	15	30	30	15	
Kankai	10	15	30	30	15	
Mulghat	15	35	35	15		

The annual O & M cost was taken at the sum of 0.5% of the cost for the dam and auxiliary facilities and 2.5% of the cost for the power staiton, etc.

The cash flow and the present worth calculations as of 1981/82 for the cost are provided in Table-14.3 for all the assumed cases of the development plan. As calculated in the Tables, the combined cost for each assumed case of the development plan in terms of the present worth as of 1981/82 came to the followings;

Cost Items	CASE 1	CASE 2	CASE 3	CASE 4
- Construction cost	278,300	281,300	280,700	253,600
- O & M cost	12,800	16,800	13,300	9,900
Total	291,100	298,100	294,000	263,500

14.2.4 Benefit

The benefit is considered to be the power benefit and to consist of the capacity benefit, primary energy benefit and secondary energy benefit, all of which are difined in CHAPTER 9.

Although the benefit consists of three kinds of benefits, two kinds of the capacity benefit and the primary energy benefit are not counted in this study for the following reason;

The capacity benefit is considered to be the installation cost of the alternative thermal plant with capacity just corresponding to the power demand curve. The capacity benefit will have a same value in all the cases of the development plan. The primary energy benefit will also be the fuel cost of the alternative thermal plant to produce the energy as required in the demand forecast. Then, the primary energy benefit will also come to a same value in all the cases. The above two kinds of the benefit are not taken into consideraton in the comparative study of the combined net benefit.

Above all, the secondary energy benefit is only taken into account in the comparative study. The cash flow and present worth calculations as of 1982 for the secondary energy are given in Table-14.3 for all the assumed cases of the development plan. The combined secondary energy benefit in terms of the present worth as of 1981/82 is estimated below;

Unit: 10^6 U.S.$

	CASE 1	CASE 2	CASE 3	CASE 4
Secondary energy benefit	44.50	38.40	36.10	30.20

14.3 Result and Recommendation

The result of the comparative study carried out is summarized in Table-14.4.

As seen in the Table, the study indicated that the development plan in which the Kankai project is firstly developed would have the most economic merit. However, examining the implementation of this case, it is found that the construction works of the Kankai and Sapt Gandaki projects will mostly overlap, since the Sapt Gandaki has to be completed two years after the completion of the Kankai Project. Considering that the difficulty of financial arrangement for the above overlapped construction work may be a major constraint for the implementation, the following development plan denoted as CASE 1 in the comparative study which resulted in the second advantageous development plan is considered as the most recommendable one from the practical viewpoint.

Sapt Gandaki (Nov., 1989) - Kankai (Oct., 1993) -
Kali Gandaki (Feb., 1996) - Mulghat (Feb., 1997)

Table-14.1: PRINCIPAL FEATURES OF HYDROPOWER PROJECT

Items	Hydropower Projects				
	Marsyangdi	Kali Gandaki	Kankai	Mulghat	Sapt Gandaki F.S.L.230 & 225 MW Scheme
- Location	Central	Central	Eastern	Eastern	Central
- Catchment area (km^2)	3,850	7,100	1,190	5,640	31,000
- Mean annual discharge (m^3/s)	385	310	45.3	324	1,436
- 90% dependable discharge (m^3/s)	44	41	-	46.1	290
- Rated discharge (m^3/s)	93	108	80.8	160	617
- Rated net head (m)	87.5	95	59	49	42 (32)
- Installed capacity (MW)	66	90	38	68.4	200(150)
- Type of project	Run-of-river	Run-of-river	Storage	Run-of-river	Run-of-river
- Effective storage (m^3)	1.7×10^6	1.0×10^6	730×10^6	4×10^6	8.5×10^6
- Construction period	5	5	5	4	
- Construction cost at 1982 price (10^6 US$)	200*	154	70**	155	354.7 (276.5)
- Dependable peak power (MW)	61	51	38	38	174 (134)
- Annual prim. energy (GWh)	267	223	166	166	757 (580)
- Annual seco. energy (GWh)	187	356	8	268	852 (544)
- Benefit (10^6 US$):					
Capacity benefit	71.5	59.8	44.6	44.6	204 (157)
Annual prim. energy benefit	11.2	9.4	7.0	7.0	31.8 (24.4)
Annual seco. energy benefit	2.7	5.1	0.1	3.9	12.3 (7.8)
- I.R.R.	8.4	12.3	21.6	9.0	16.2 (16.3)

Note: (i) ( ) shows the features for F.S.L. 220.0 & 150 MW scheme.

(ii) * : The recent inforamtion of the necessary construction cost is taken into consideration.

(iii) ** : The cost allocated to the power is adopted.

Table-14.2: MONTHLY ENERGY SUPPLY CAPACITY OF EACH HYDROPOWER PROJECT

(Unit: GWh)

	Supply Capacity up to Marsyangdi	Kali Gandaki	Kankai	Mulghat	Sapt Gandaki
Jan.	94.9	24.9	36.2	19.4	82.9
Feb.	81.4	15.7	30.7	14.7	64.3
Mar.	81.1	18.4	31.4	13.4	58.1
Apr.	78.6	19.6	25.8	19.8	74.8
May	97.3	42.2	0	42.3	118.0
Jun.	101.1	61.3	1.9	48.8	148.6
Jul.	100.5	62.1	2.2	48.2	145.3
Aug.	97.0	61.8	7.2	48.3	142.2
Sep.	95.6	59.9	8.3	47.3	143.3
Oct.	100.8	63.1	6.6	50.5	152.1
Nov.	103.0	61.8	10.3	32.9	149.4
Dec.	99.2	42.1	13.2	24.9	108.4
Total	1,130.5	532.9	173.8	410.5	1,387.4

Note: The energy supply capacity is calculated based on the discharge in the second driest year.

Table-14.3: COMPUTATION OF PRESENT WORTH FOR COSTS AND BENEFITS

Case 1	Present Day Cost and Benefit as of 1981/82 (10^6 US$)											Present Worth as of 1981/82 (10^6 US$)		
	Construction Cost				O/M Cost				Benefit of Secondary Energy					
Year	Sapt Gandaki	Kankai	Kali Gandaki	Mulghat	Sapt Gandaki	Kankai	Kali Gandaki	Mulghat	Energy Demand (GWh)	Energy Supply (GWh)	Bene-fit	Constr. Cost	O/M Cost	Benefit of 2ndary Energy
1984/85	28.4											20.2		
1985/86	28.4											18.0		
1986/87	70.9											40.2		
1987/88	88.7											44.9		
1988/89	88.7											40.1		
1989/90	49.6	7.0			4.7				1,077.5	2,691.7	23.2	22.9	1.9	9.4
1990/91		10.5			4.7				1,212.6	2,691.7	21.3	3.8	1.7	7.7
1991/92		21.0	15.5		4.7				1,357.5	2,691.7	19.2	11.8	1.5	6.2
1992/93		21.0	23.1		4.7				1,511.4	2,691.7	17.0	12.7	1.4	4.9
1993/94		10.5	46.3	23.3	4.7	0.7			1,674.7	2,865.5	17.1	20.6	1.4	4.4
1994/95			46.3	54.2	4.7	0.7			1,847.3	2,865.5	14.7	23.0	1.2	3.4
1995/96			23.1	54.2	4.7	0.7	3.2		2,034.3	3,444.3	20.3	15.8	1.8	4.2
1996/97				23.3	4.7	0.7	3.2	1.7	2,236.5	3,878.4	23.6	4.3	1.9	4.3
Total	354.7	70.0	154.3	155.0	37.6	2.8	6.4	1.7	-	-	156.4	278.3	12.8	44.5

- to be continued -

Case 2	Present Day Cost and Benefit as of 1981/82 (10^6 US$)											Present Worth as of 1981/82 (10^6 US$)		
	Construction Cost				O/M Cost				Benefit of Secondary Energy					
Year	Kali Gandaki	Kankai	Mulghat	Sapt Gandaki	Kali Gandaki	Kankai	Mulghat	Sapt Gandaki	Energy Demand (GWh)	Energy Supply (GWh)	Bene-fit	Constr. Cost	O/M Cost	Benefit of 2ndary Energy
1985/86	15.5	7.0										14.3		
1986/87	23.1	10.5										19.1		
1987/88	46.3	21.0										34.1		
1988/89	46.3	21.0		28.4								43.3		
1989/90	23.1	10.5	23.3	28.4	3.2	0.7			1,077.5	1,883.1	11.6	34.5	3.5	4.7
1990/91			54.2	70.9	3.2	0.7			1,212.6	1,883.1	9.7	45.1	1.4	3.5
1991/92			54.2	88.7	3.2	0.7			1,357.5	1,883.1	7.6	46.0	1.3	2.4
1992/93			23.3	88.7	3.2	0.7	1.7		1,511.4	2,317.2	11.6	32.2	1.6	3.3
1993/94				49.6	3.2	0.7	1.7	4.7	1,674.7	3,878.4	31.7	12.7	2.6	8.1
1994/95					3.2	0.7	1.7	4.7	1,847.3	3,878.4	29.2		2.4	6.7
1995/96					3.2	0.7	1.7	4.7	2,034.3	3,878.4	26.6		2.1	5.4
1996/97					3.2	0.7	1.7	4.7	2,236.5	3,878.4	23.6		1.9	4.3
Total	154.3	70.0	155.0	254.7	25.6	5.6	8.5	18.8	-	-	151.6	281.3	16.8	38.4

- to be continued -

Case 3	Present Day Cost and Benefit as of 1981/82 (10^6 US$)											Present Worth as of 1981/82 (10^6 US$)		
	Construction Cost				O/M Cost				Benefit of Secondary Energy					
Year	Mulghat	Kankai	Kali Gandaki	Sapt Gandaki	Mulghat	Kankai	Kali Gandaki	Sapt Gandaki	Energy Demand (GWh)	Energy Supply (GWh)	Bene-fit	Constr. Cost	O/M Cost	Benefit of 2ndary Energy
1984/85														
1985/86		7.0										4.4		
1986/87	23.3	10.5										19.2		
1987/88	54.2	21.0										38.1		
1988/89	54.2	21.0	15.5	28.4								53.9		
1989/90	23.3	10.5	23.1	28.4	1.7	0.7			1,077.5	1,738.4	9.5	34.5	1.0	3.8
1990/91			46.3	70.9	1.7	0.7			1,212.6	1,738.4	7.6	42.3	0.9	2.7
1991/92			46.3	88.7	1.7	0.7			1,357.5	1,738.4	5.5	43.5	0.8	1.8
1992/93			23.1	88.7	1.7	0.7	3.2		1,511.4	2,317.2	11.6	32.1	1.6	3.3
1993/94				49.6	1.7	0.7	3.2	4.7	1,674.7	3,878.4	31.7	12.7	2.6	8.1
1994/95					1.7	0.7	3.2	4.7	1,847.3	3,878.4	29.2		2.4	6.7
1995/96					1.7	0.7	3.2	4.7	2,034.3	3,878.4	26.6		2.1	5.4
1996/97					1.7	0.7	3.2	4.7	2,236.5	3,878.4	23.6		1.9	4.3
Total	155.0	70.0	154.3	354.7	13.6	5.6	16.0	18.8	-	-	145.3	280.7	13.3	36.1

- to be continued -

Case 4	Present Day Cost and Benefit as of 1981/82 (10^6 US$)											Present Worth as of 1981/82 (10^6 US$)		
	Construction Cost				O/M Cost				Benefit of Secondary Energy					
Year	Kankai	Sapt Gandaki	Mulghat	Kali Gandaki	Kankai	Sapt Gandaki	Mulghat	Kali Gandaki	Energy Demand (GWh)	Energy Supply (GWh)	Energy Bene-	Constr. Cost	O/M Cost	Benefit of 2ndary Energy
1985/86	7.0											4.4		
1986/87	10.5	28.4										22.1		
1987/88	21.0	28.4										25.0		
1988/89	21.0	70.9										41.6		
1989/90	10.5	88.7			0.7				1,077.5	1,304.3	3.3	40.1	0.3	1.3
1990/91		88.7			0.7				1,212.6	1,304.3	1.3	32.0	0.3	0.5
1991/92		49.6			0.7	4.7			1,357.5	2,865.5	21.7	16.0	1.7	7.0
1992/93			23.3	15.5	0.7	4.7			1,511.4	2,865.5	19.5	11.2	1.6	5.6
1993/94			54.2	23.1	0.7	4.7			1,674.7	2,865.5	17.1	19.8	1.4	4.4
1994/95			54.2	46.3	0.7	4.7			1,847.3	2,865.5	14.7	23.0	1.2	3.4
1995/96			23.3	46.3	0.7	4.7	1.7		2,034.3	3,299.6	18.2	14.2	1.5	3.7
1996/97				23.1	0.7	4.7	1.7	3.2	2,236.5	3,878.4	23.6	4.2	1.9	4.3
Total	70.0	354.7	155.0	154.3	5.6	28.2	3.4	3.2	-	-	119.4	253.6	9.9	30.2

Table-14.4: RESULT OF COMPARATIVE STUDY FOR DETERMINATION OF HYDROPOWER PROJECTS DEVELOPMENT PLAN

(Unit: 10^6 US$)

	CASE 1		CASE 2		CASE 3		CASE 4	
	Commission-ing Time	Project	Commission-ing Time	Project	Commission-ing Time	Project	Commission-ing Time	Project
Project and its commissioning time	Nov., 1989	Sapt Gandaki	Nov., 1989	Kali Gandaki	Nov., 1989	Mulghat	Nov., 1989	Kankai
	Oct., 1993	Kankai	Nov., 1989	Kankai	Nov., 1989	Kankai	Jan., 1992	Sapt Gandaki
	Feb., 1996	Kali Gandaki	Feb., 1993	Mulghat	Jan., 1993	Kali Gandaki	Feb., 1996	Mulghat
	Feb., 1997	Mulghat	Feb., 1994	Sapt Gandaki	Feb., 1994	Sapt Gandaki	Feb., 1997	Kali Gandaki
Construction cost	278.300		281.300		280.700		253.600	
O & M cost	12.800		16.800		13.300		9.900	
Cost Total	291.100		298.100		294.000		263.500	
Capacity & primary energy benefit	B		B		B		B	
Secondary energy	44.500		38.400		36.100		30.200	
Benefit Total	B + 44.500		B + 38.400		B + 36.100		B + 30.200	
Net Benefit	B - 246.600		B - 259.700		B - 257.900		B - 233.000	

Note: Each value is indicated by the present worth as of 1981/82.

FIGURES

FIG- 2.1

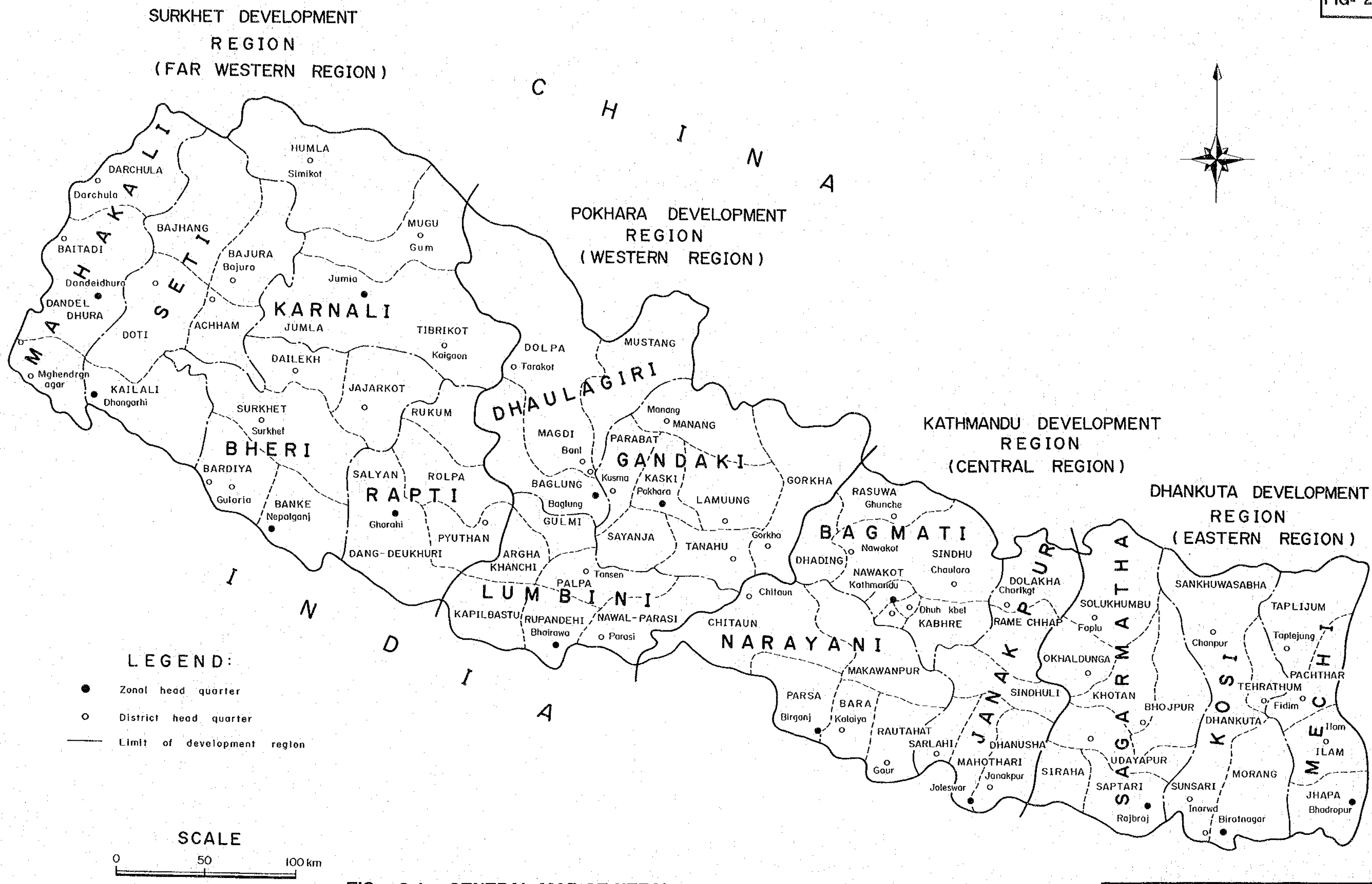

FIG- 2.1 : GENERAL MAP OF NEPAL

HIS MAJESTY'S GOVERNMENT OF NEPAL
SAPT GANDAKI HYDROELECTRIC
POWER DEVELOPMENT PROJECT
FEASIBILITY REPORT

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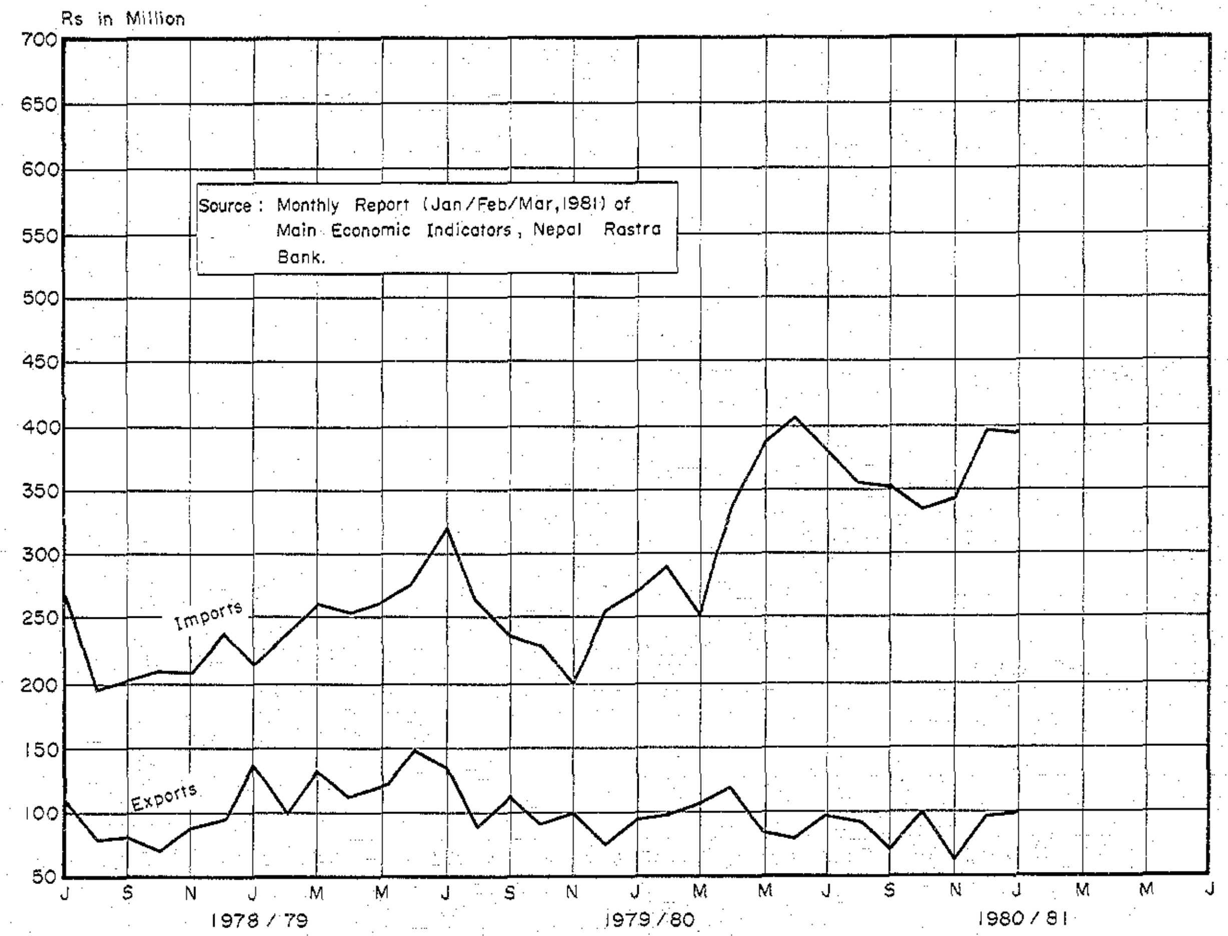

FIG- 2.2 : CHANGE OF FOREIGN TRADE

HIS MAJESTY'S GOVERNMENT OF NEPAL
SAPT GANDAKI HYDROELECTRIC
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FIG- 2.2

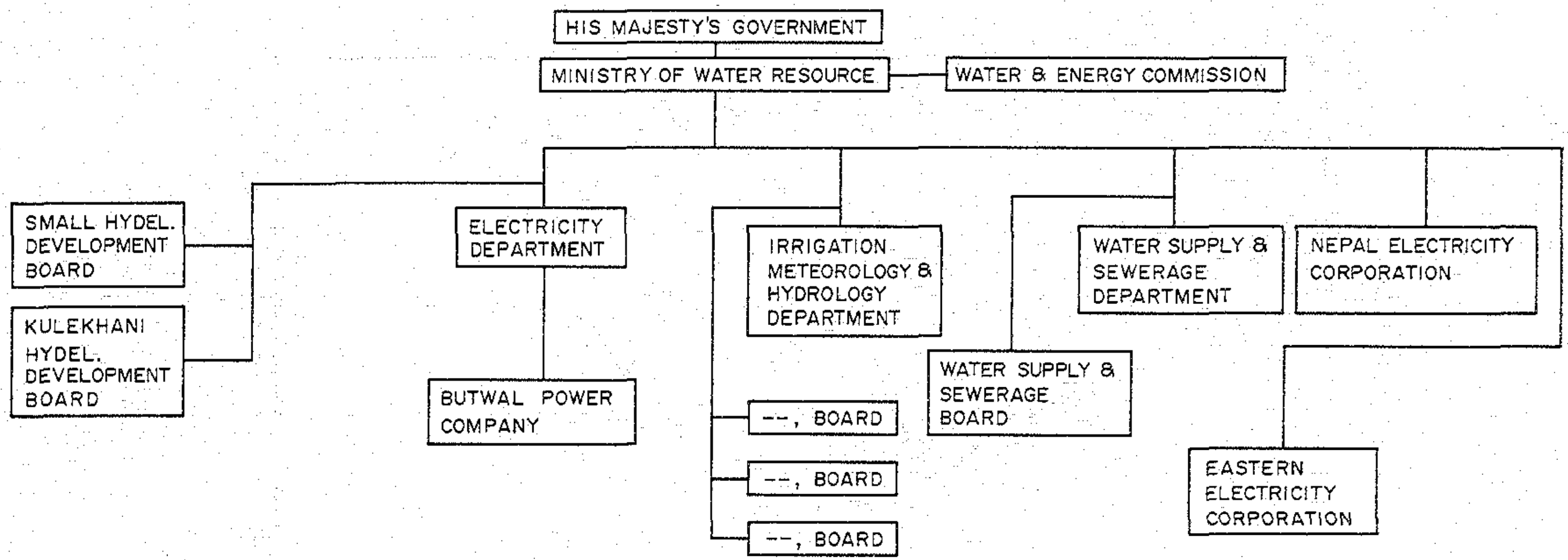

FIG- 3.1.1 : ORGANIZATION OF MINISTRY OF WATER RESOURCES

HIS MAJESTY'S GOVERNMENT OF NEPAL SAPT GANDAKI HYDROELECTRIC POWER DEVELOPMENT PROJECT FEASIBILITY REPORT	FIG-3.1.1
JAPAN INTERNATIONAL COOPERATION AGENCY	

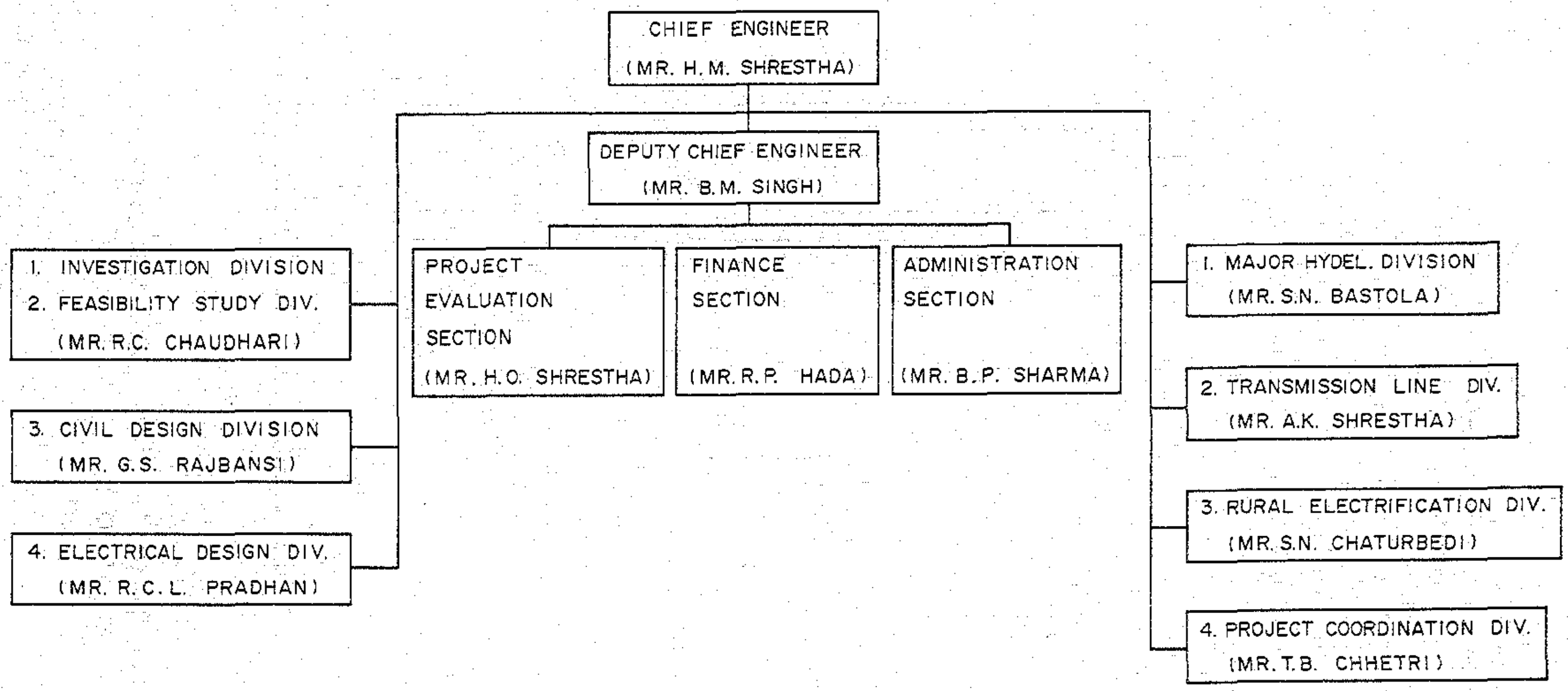

FIG- 3.1.2 : ORGANIZATION OF ELECTRICITY DEPARTMENT

HIS MAJESTY'S GOVERNMENT OF NEPAL
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FIG-3.1.2

FIG-3.2.1

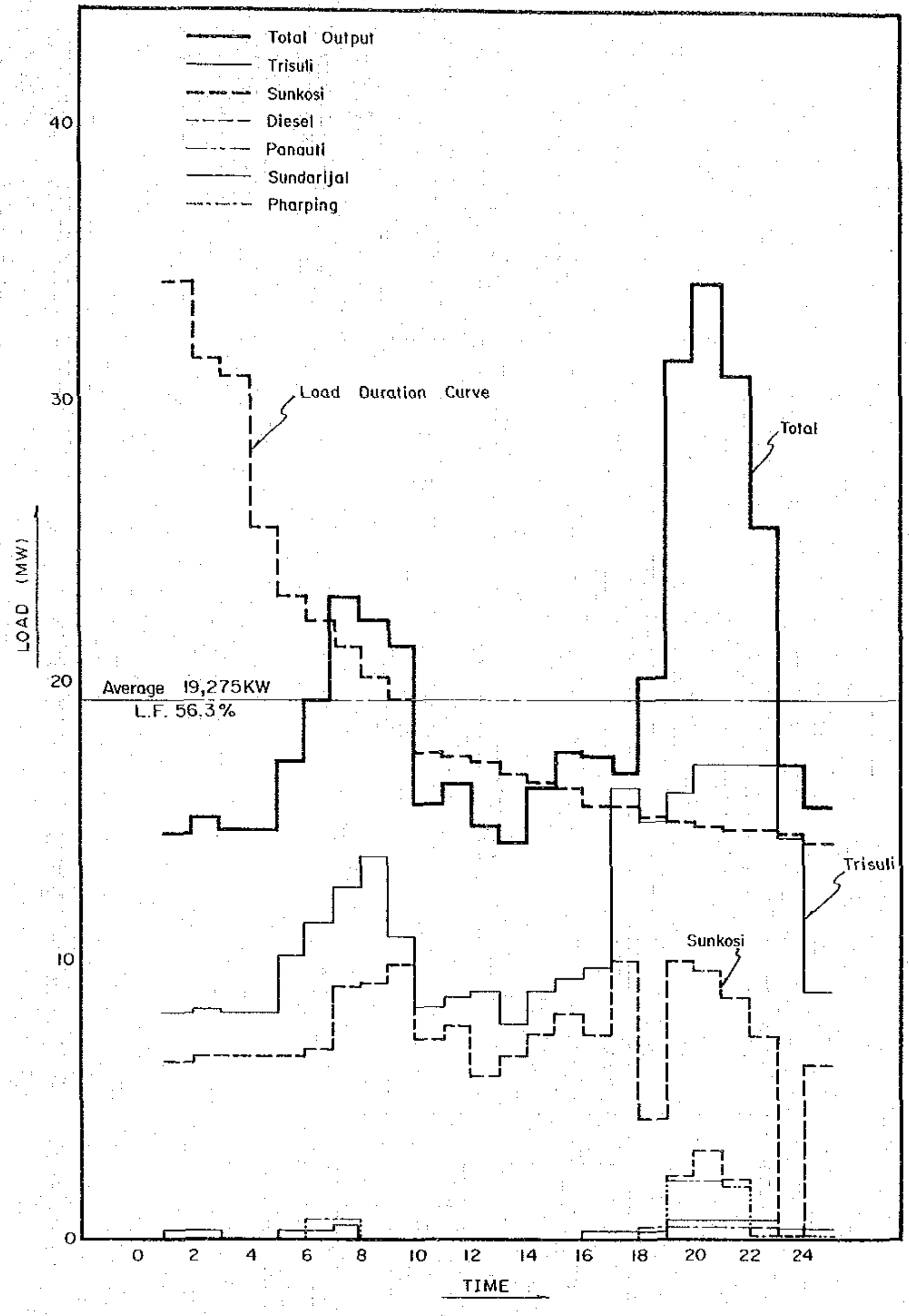

FIG- 3.2.1 : LOAD CURVE & LOAD DURATION CURVE (8th MAY 1980)

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FIG-3.2.2

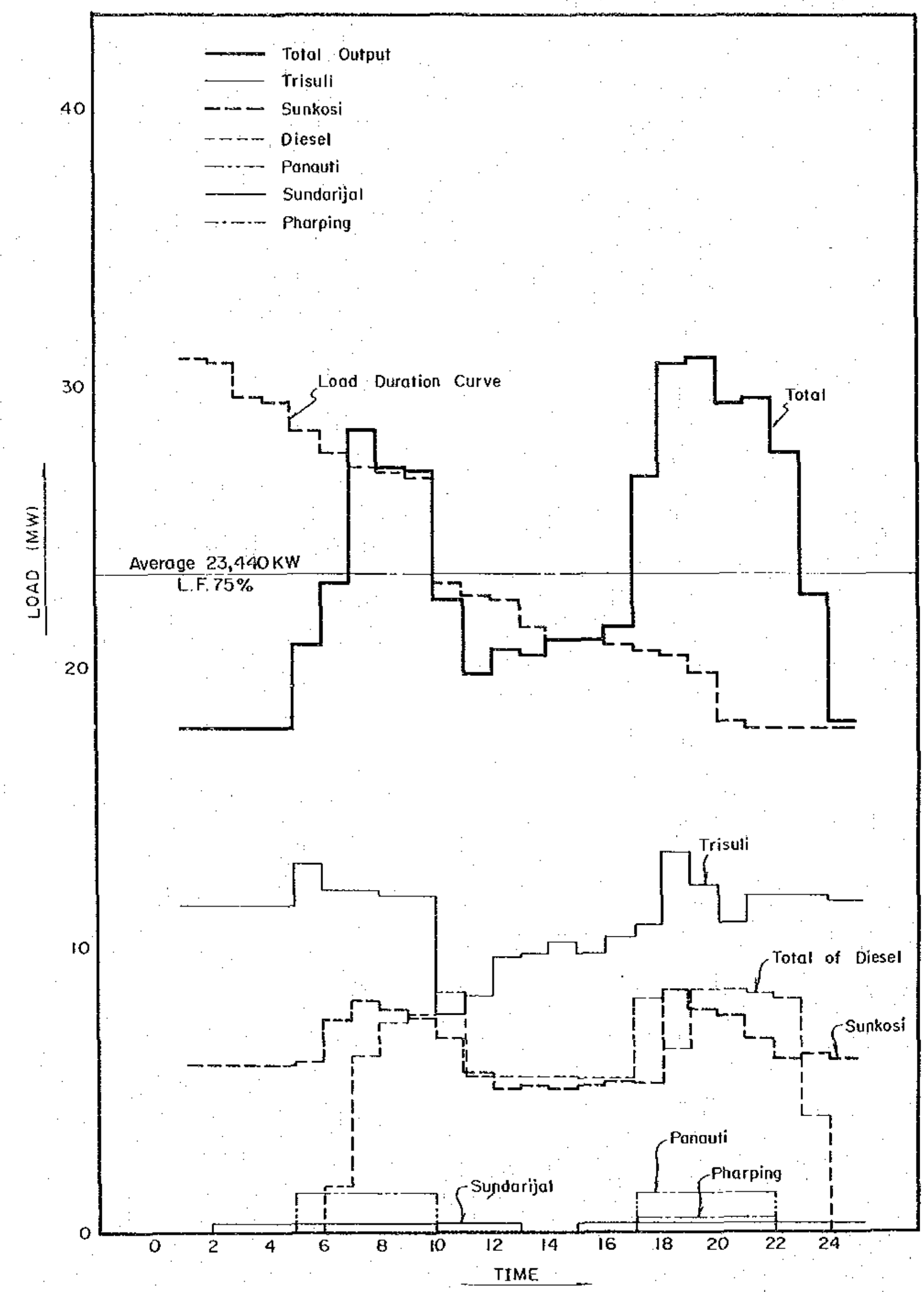

FIG- 3.2.2 : LOAD CURVE & LOAD DURATION CURVE (6th JANUARY 1981)

HIS MAJESTY'S GOVERNMENT OF NEPAL
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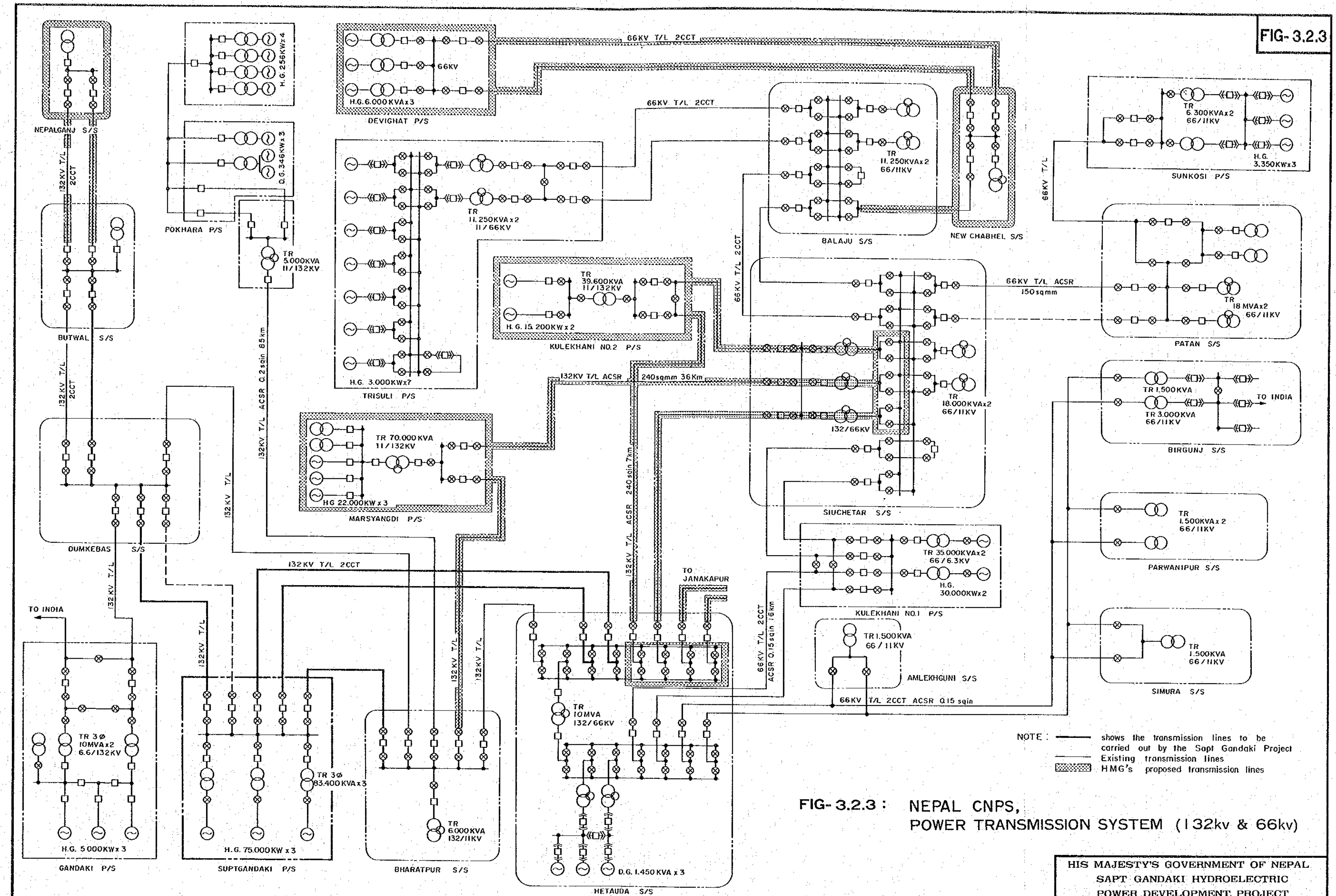

FIG-3.2.3 : NEPAL CNPS, POWER TRANSMISSION SYSTEM (132kv & 66kv)

HIS MAJESTY'S GOVERNMENT OF NEPAL
SAPT GANDAKI HYDROELECTRIC POWER DEVELOPMENT PROJECT
FEASIBILITY REPORT
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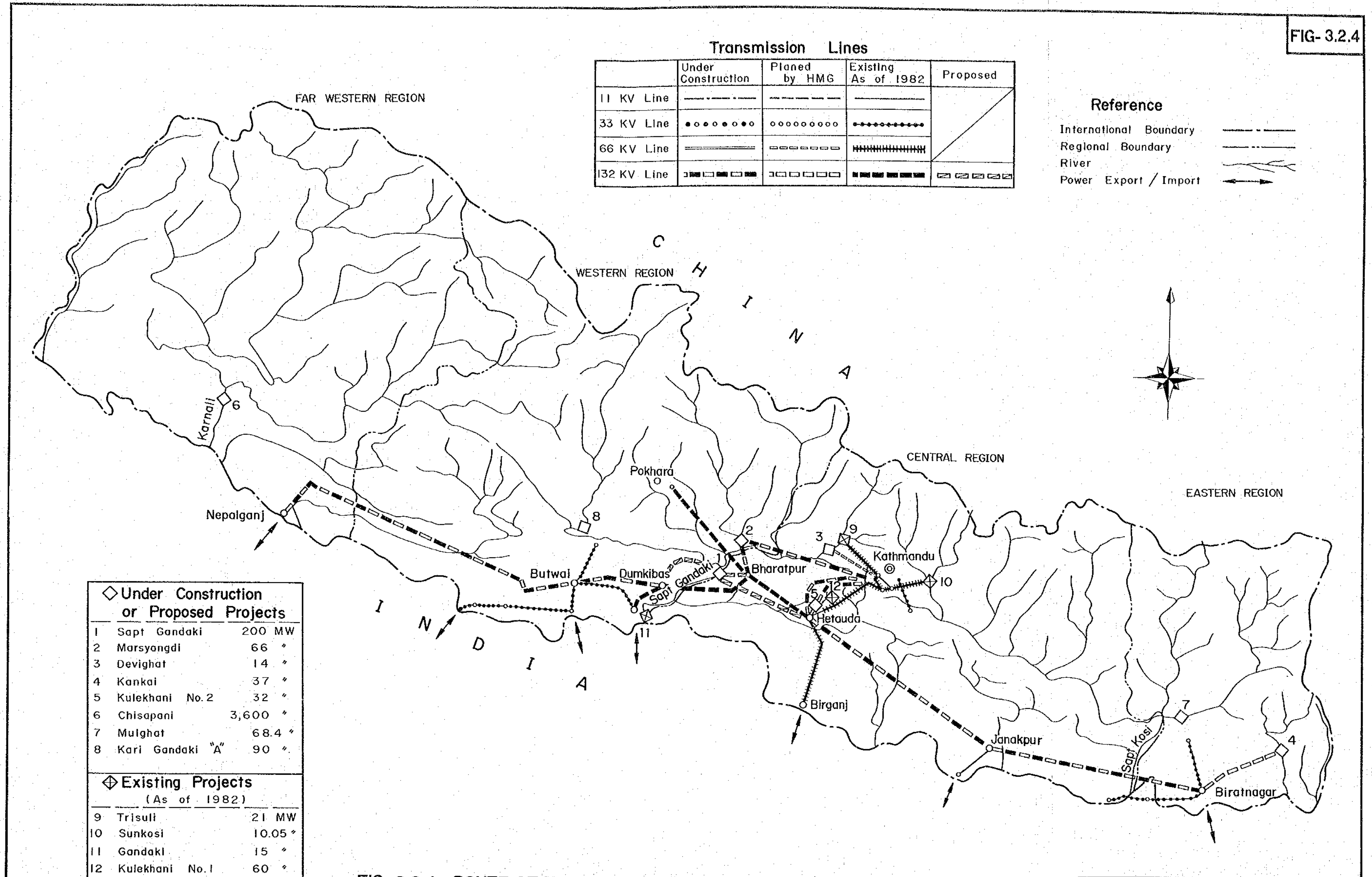

FIG- 3.2.4 : ROUTE OF TRANSMISSION LINES

HIS MAJESTY'S GOVERNMENT OF NEPAL
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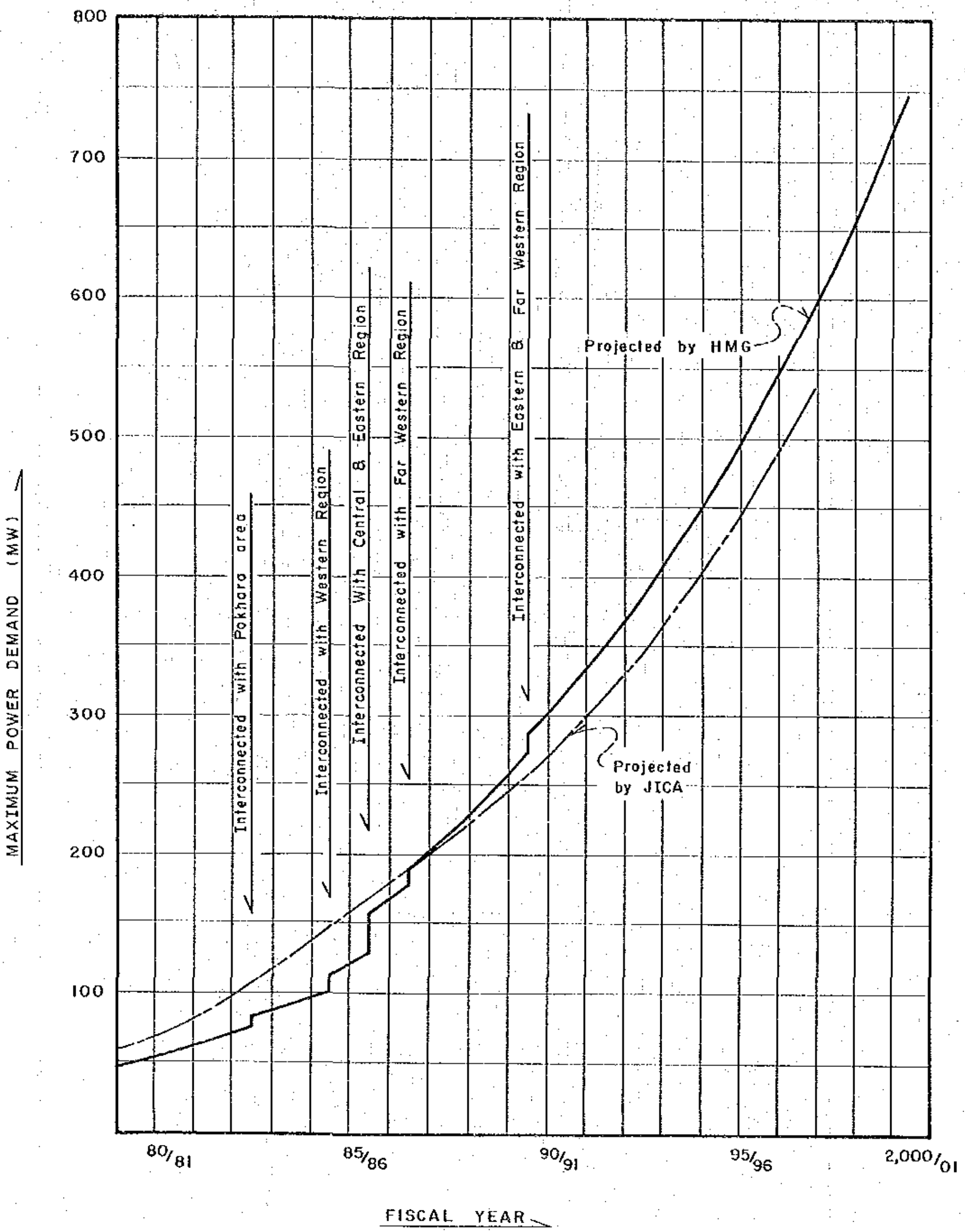

FIG- 3.3.1 : POWER DEMAND FORECAST FOR INTERCONNECTED SYSTEM

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POWER DEVELOPMENT PROJECT
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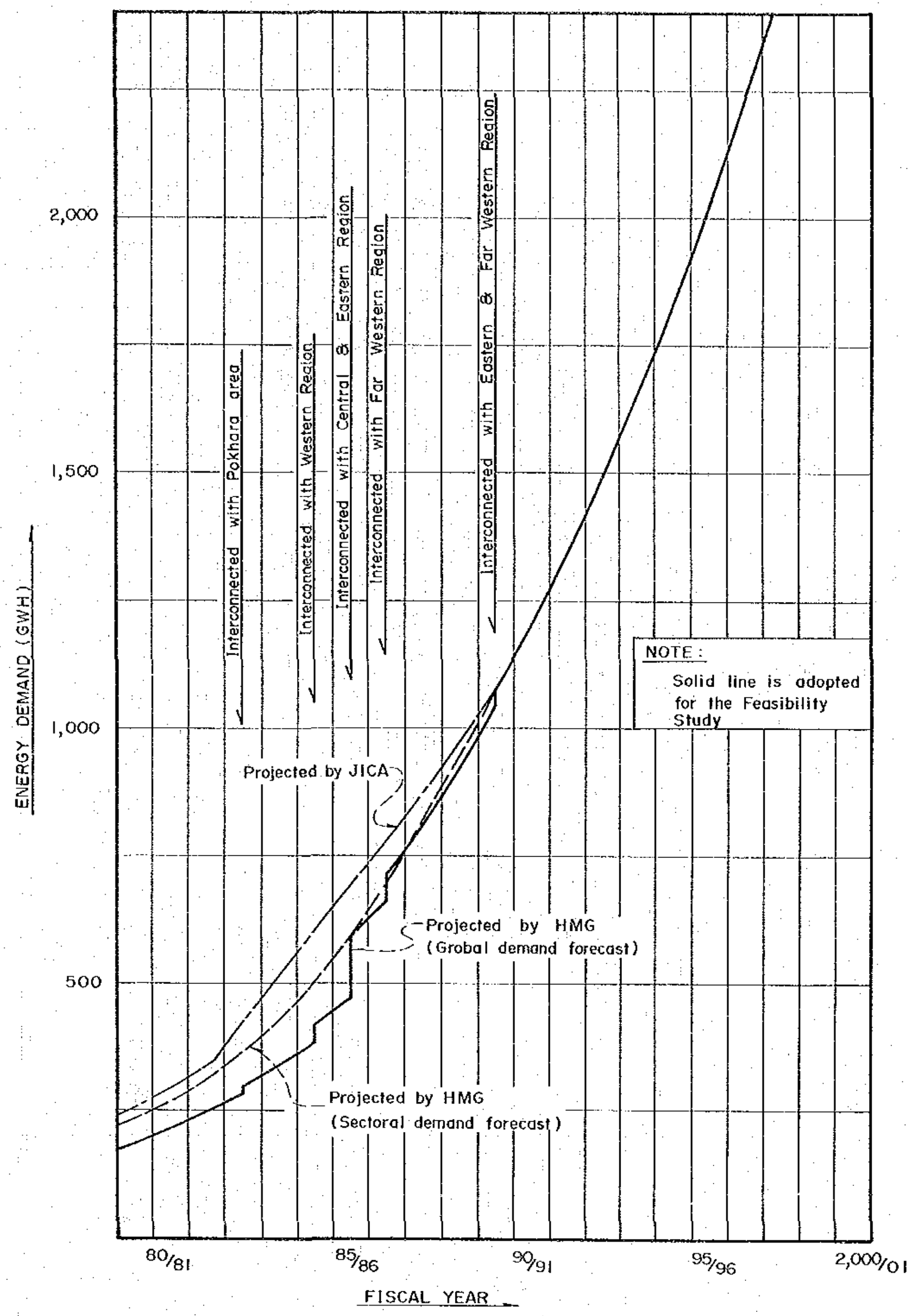

FIG- 3.3.2 : ENERGY DEMAND FORECAST FOR INTERCONNECTED SYSTEM

HIS MAJESTY'S GOVERNMENT OF NEPAL
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FIG- 3.4.1

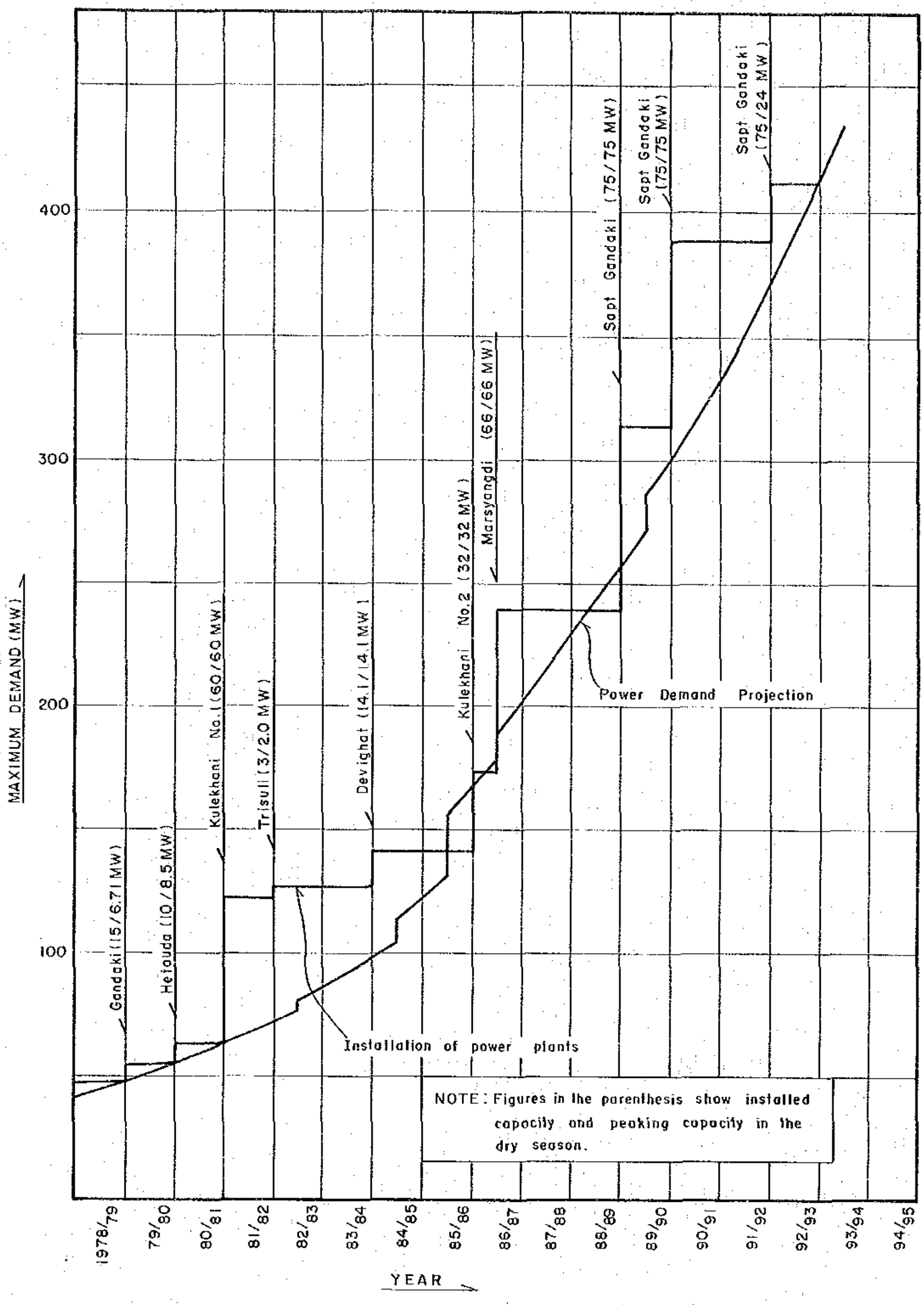

FIG- 3.4.1 : INSTALLATION SCHEDULE OF POWER PLANTS

HIS MAJESTY'S GOVERNMENT OF NEPAL
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FIG-4.1.1

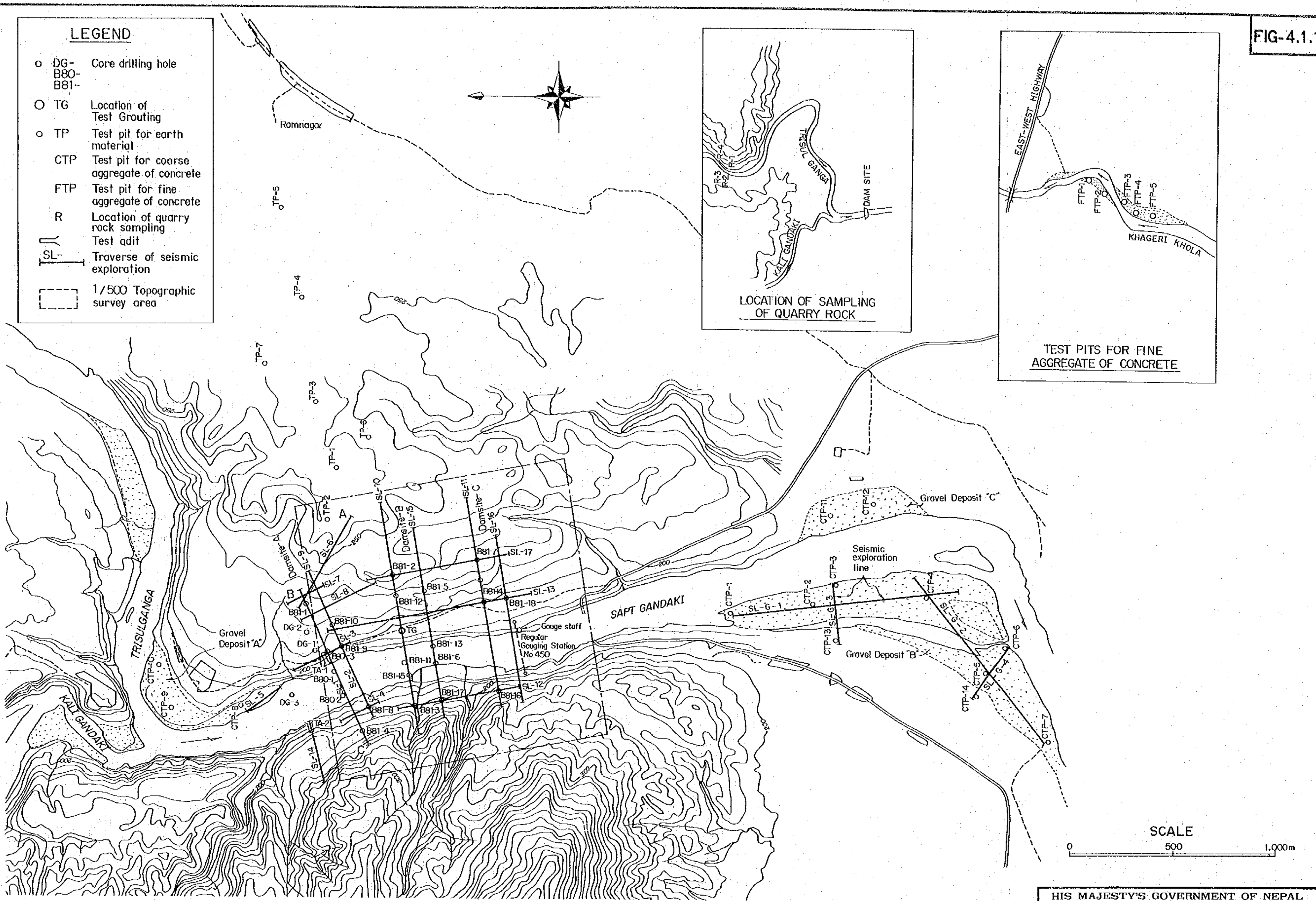

FIG- 4.1.1 : LOCATION MAP OF INVESTIGATION

HIS MAJESTY'S GOVERNMENT OF NEPAL
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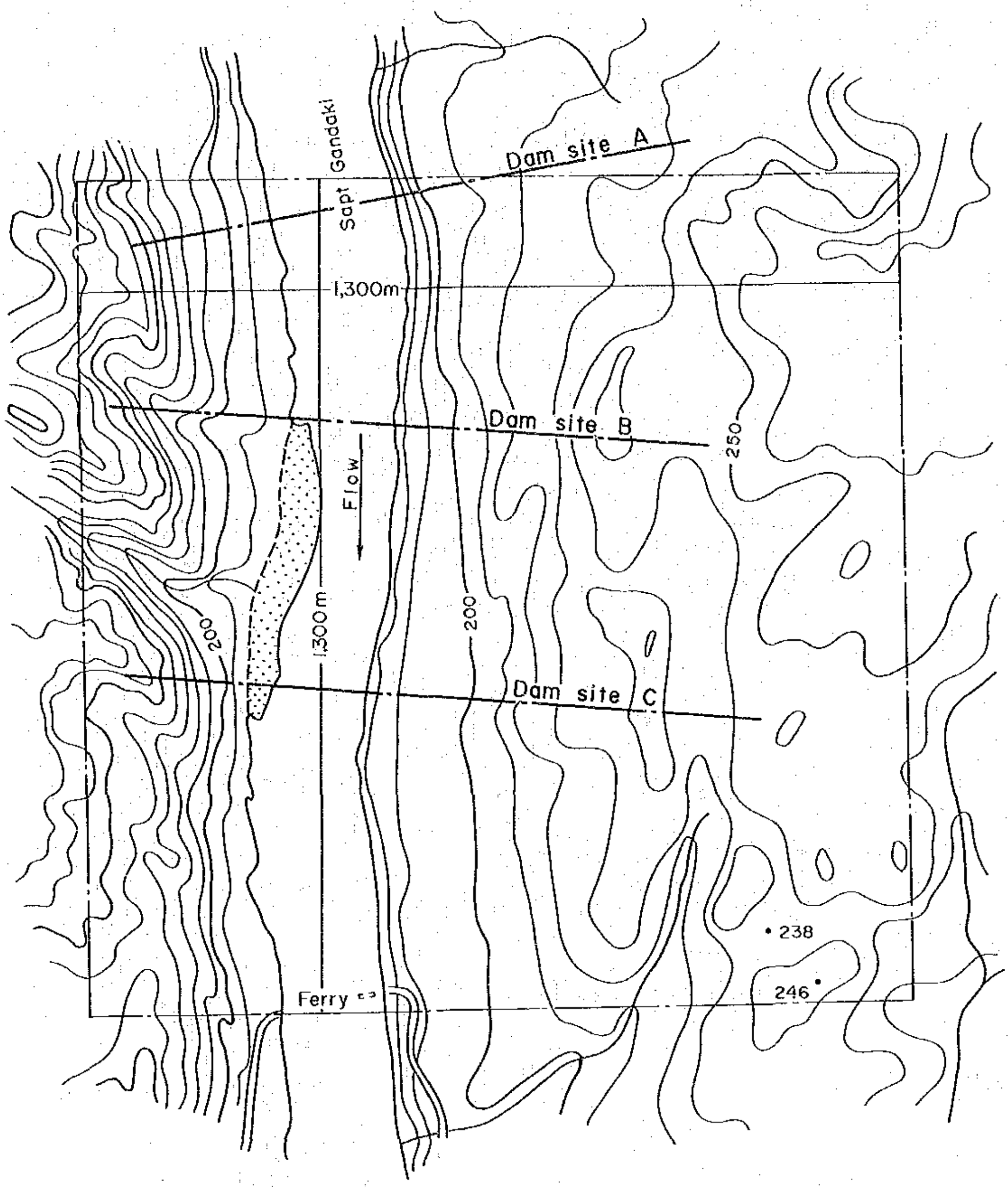
FIG-4.2.1



NOTE:

Total area = 169 ha

FIG-4.2.1 : AREA OF PREPARATION OF 1/500 TOPOGRAPHIC MAP AROUND DAMSITE

SCALE 0 500m

HIS MAJESTY'S GOVERNMENT OF NEPAL
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POWER DEVELOPMENT PROJECT
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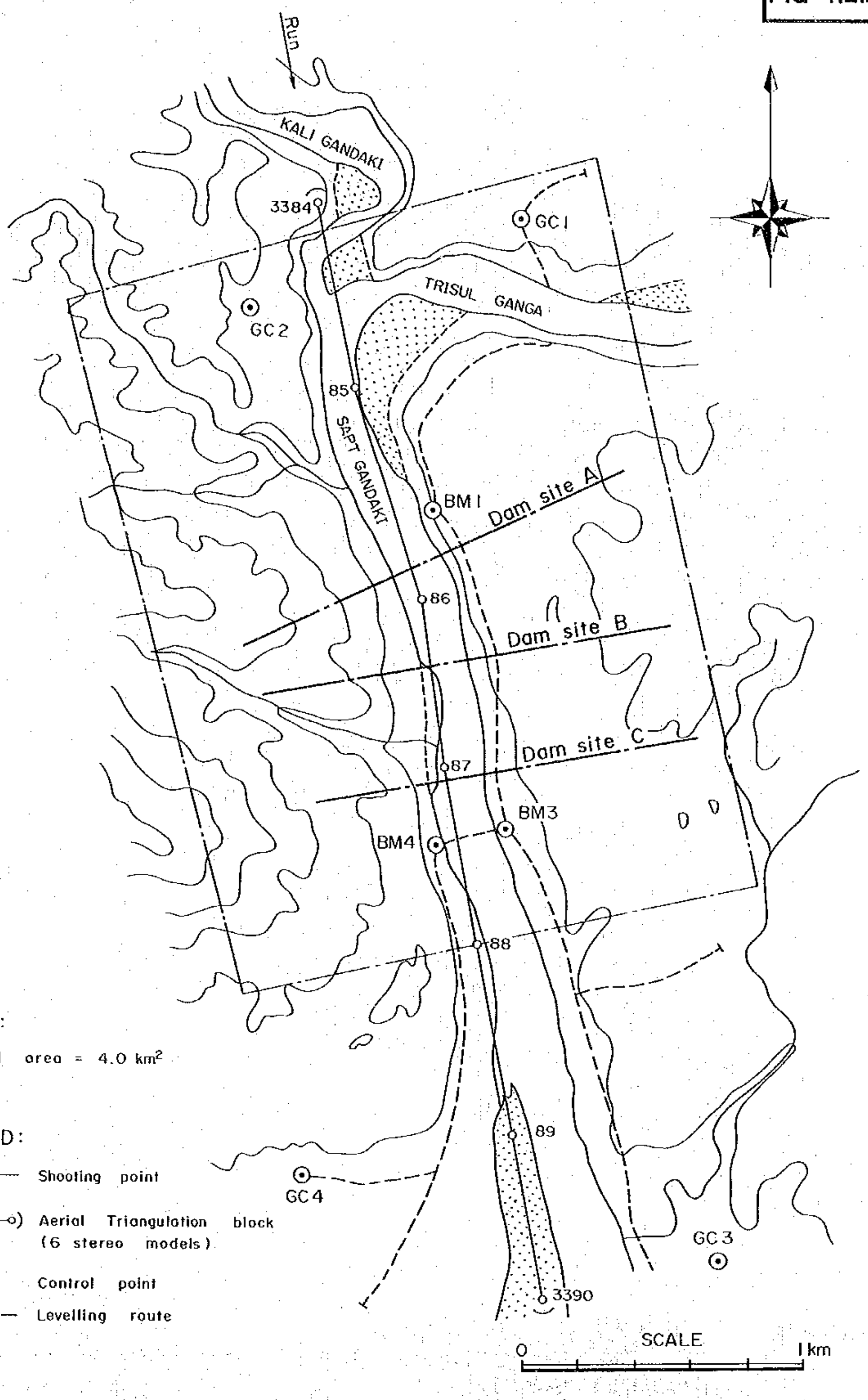
FIG-4.2.2



NOTE:

Total area = 4.0 km^2

LEGEND:

—o— Shooting point

(o—o—o) Aerial Triangulation block (6 stereo models)

⊙ Control point

– – – – Levelling route

FIG- 4.2.2 : AREA OF 1/2000 AERO-PHOTO MAPPING

HIS MAJESTY'S GOVERNMENT OF NEPAL
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FIG-4.2.3

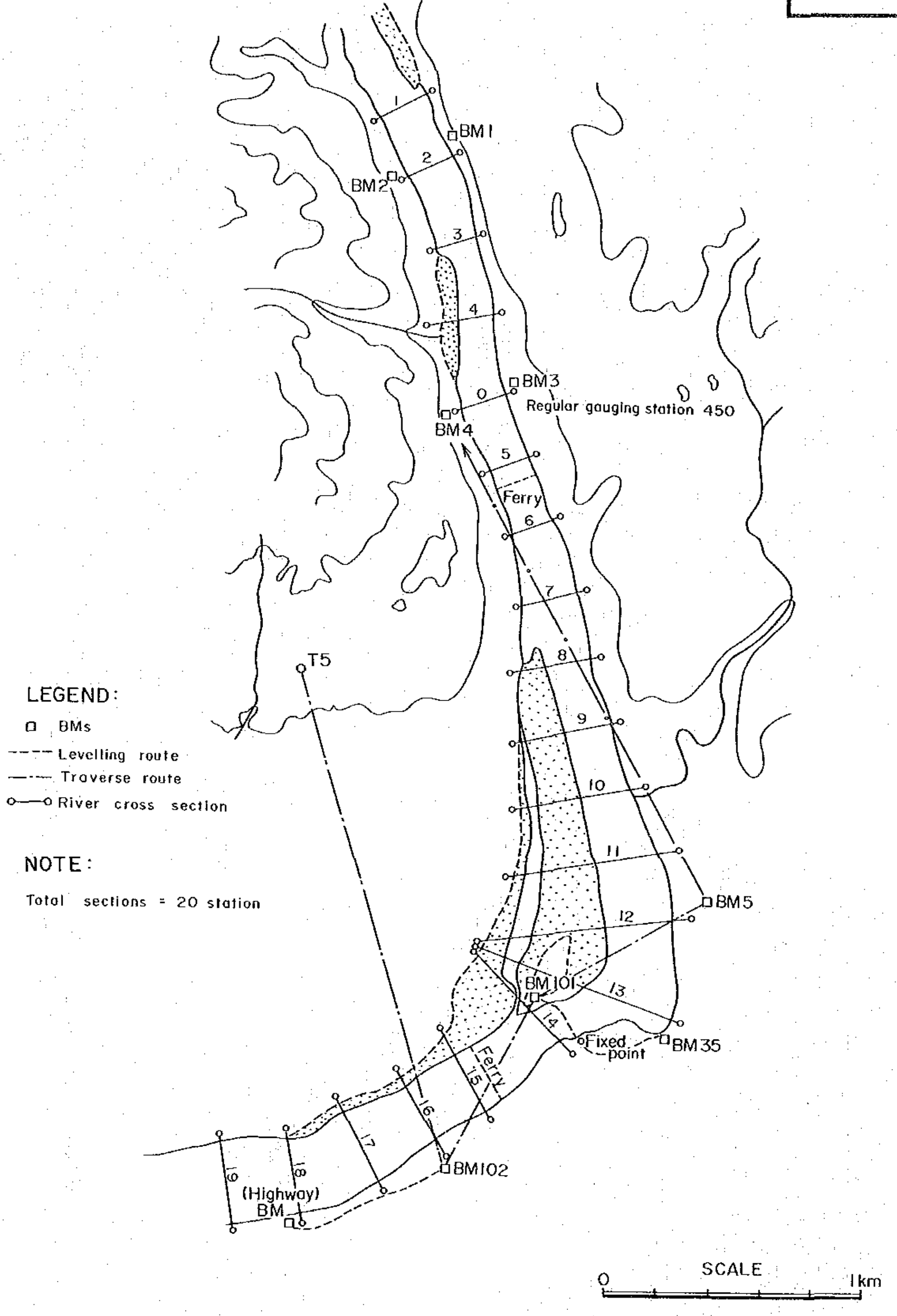

FIG- 4.2.3 : LOCATION MAP OF RIVER CROSS SECTIONS

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