As the Sapt Gandaki Project is a run-of-river plant having no reservoir to regulate the seasonal flow change, the power output varies with the flow change. If the reservoirs with the capacity to regulate the seasonal flow change are constructed on the upper reaches of Gandaki River basin, the capacity factor of the Sapt Gandaki Project will increase, since the river runoff on the dry season at the Sapt Gandaki Project site will be augmented with the intensive release from the upper reservoirs on the dry season. Thus, the construction of the reservoirs on the upper reaches of the Gandaki River basin has the secondary benefit to firm up the power outputs and to extend the installed capacity of the Sapt Gandaki Project. It is expected that the ultimate installed capacity of the power plant will be not less than 400 MW.

Table 5-1 INSTALLED CAPACITY AND ANNUAL ENERGY OUTPUTS

Installed capacity, MW	Rated discharge, m^3/sec	Rated head, m	Annual primary energy, GWh	Annual secondary energy, GWh	Capacity factor, %
100	308	39	753	107	98
150	462	39	753	418	89
200	616	39	753	663	81
250	770	39	753	1267	74

Table 5-2 ECONOMIC BENEFITS AND COSTS

US$$10^6$

Installed capacity, MW	Benefit		Costs		Net benefit	B/C ratio
	Power	Energy	Capital	O & M		
100	11.93	32.04	35.51	1.89	6.57	1.18
150	15.73	35.95	37.70	2.36	11.62	1.29
200	17.24	39.03	40.03	2.74	13.50	1.32
250	17.24	41.59	41.99	3.03	13.81	1.31

Note: Discount rate is 12%.

The discounting technique is the method of annual cost.

Cost of a thermal power station in Nepal is:

Capital cost per kW US$/kW 903

Fuel cost mill/KWh 42

CHAPTER 6 PRELIMINARY DESIGN AND COST ESTIMATE

6.1 Preliminary Design of the Project

The preliminary design of the Sapt Gandaki Project was made based on the optimal plant scale of 200 MW. The main structures of the Project as depicted in Figure 6-1 and 6-2 consist of a dam, spillway, intake structure and power station. Moreover, the transmission line between Bharatpur and the project site and the switching station at Bharatpur are also included as the components of the Project.

The preliminary design of the structures was made based on the topographical maps of 1:2,000 scale which were produced by enlarging the maps of 1:10,000 scale with 10 m contour.

6.1.1 River Diversion Scheme

Diversion method: If it is required for the construction works to make a dry area at the river bed through the year, the diversion facilities must have the flow capacity of more than 16,000 m^3/sec considering the historical maximum discharge. As it is too costly to construct the diversion scheme with the flow capacity of 16,000 m^3/sec, it is considered reasonable to plan a method in which river flow in the first wet season is allowed to fully overtop the cofferdams and the construction is made only in the dry season. On this basis, there are two ways to construct the diversion facilities: one is the multi-stage diversion method to protect the constructing structures by encircling with sheet piles stage by stage in the river channel and the other is the method to construct a diversion channel on the left bank. For applying the former method, the sheet piles for coffering must be driven into the river bed where much gravels of 10 to 20 cm in diameter scatter and this work is considered very difficult. Thus, the latter method is adopted on the preliminary design of the structures.

Diversion channel and coffer dams: If the design flood for the diversion facilities is selected to be 2,000 m^3/sec, it is possible to perform the construction works at the river bed for 7 months from the beginning of October to the end of May with the probability of more than 0.96 (a 25-year return period) as can be seen in Figure 4-8. If the work time of 8 month a year is required for the construction works, it is necessary for the diversion facilities to have the flow capacity of more than 8,000 m^3/sec. Thus, it is most economical that the diversion facilities have the flow capacity of 2,000 m^3/sec in the construction stage.

Though a tunnel and open channel plans are considered as the diversion facilities, the latter method was employed, because the latter method is cheaper in cost and easier in construction than that of the former method. The diversion channel is 50 m wide and around 700 m long.

The upstream and downstream cofferdams are constructed at a distance of 145 m and 412 m from the axis of the main dam, respectively. Those surface slopes and crests are protected with concrete to prevent from destruction by overtopping of river flow in the wet season. The cut-off wall is constructed beneath the river bed in order to make a construction area dry. The height of the upstream cofferdam is 10 m, with that the diversion channel has the flow capacity of 2,000 m^3/sec.

6.1.2 Reservoir, Dam, Intake and Spillway

Reservoir: The proposed damsite of the Sapt Gandaki Project is located on the Sapt Gandaki River, 1.1 km downstream from the confluence of the Kali Gandaki and Trisulganga Rivers. The Sapt Gandaki reservoir has a gross storage capacity of 346 x $10^6 m^3$ as shown in Figure 6-3.

The annual sediment yield was estimated to be 4,000 m^3/year/km^2 as mentioned in Clause 4.4. It will take less than 3 years to fill up the reservoir with sediment. However, the active storage capacity for the daily operation, 12 x $10^6 m^3$, can be retained by assuming that a channel will be formed with the spillway width and that the slope of sediment deposit is equal to that of the present river bed, 0.0015.

Dam: Considering the large magnitude of floods, the main part of the dam is constructed with a concrete gravity one having a central overflow spillway. A part of the dam on the left bank is constructed with embankment for saving the construction cost. The dam heights of the concrete and embankment portions are 71 m and 48 m, respectively. The total crest length of the dam is 870 m.

The stability of the dam was checked by the overturn, sliding and bearing capacity for the concrete portion. As the shearing strength of the foundation rock can not be expected to be high, the stability for sliding will be critical. A typical cross section and profile of the concrete dam as shown in Figure 6-2 were determined to satisfy the minimum safety factor of 4.0 according to the design standard of a concrete dam in Japan by assuming that the shearing strength of the foundation rock is as much as 7.0 kg/cm^2.

The stability analysis for the embankment portion is made by the slice method applying the seismic coefficient of 0.12. The upstream and downstream slopes are 1:2.4 and 1:2.0, respectively.

The embankment materials for the core, filter and sand and gravel zones will be obtained from excavated materials and river deposits. A cut-off wall is used as the impervious zone for the extreme left wing of the embankment portion to reduce the excavation volume.

Intake: It is expected that the reservoir in front of the spillway will be filled with sediment to the level of the fixed spillway crest, while the sides of the reservoir will be filled upto the maximum operation level with sediment leaving a lower central channel with the spillway width. Thus, the intake structures were designed next to the spillway not so as that the river bed becomes higher than the inlet level of the intake.

The intake structures have the gravity section walls just in front of them to prevent the sediment load from entering into the intake and turbines. The gravity section walls also work as the coffering wall during the construction to make possible the construction of the powerhouse even in the wet season.

Spillway: Flood frequency analysis for the estimate of design floods on the spillway was made in Clause 4.4. It is assumed for the determination of spillway discharge capacity that the reservoir has no retention effect, namely the spillway has the capacity to release the peak inflow discharge of a flood.

The design flood for spillway is determined to be 21,700 m^3/sec which is equivalent to 1.2 times of the 200-year flood (18,100 m^3/sec) in accordance with the design standard of rockfill dam in Japan.

The spillway of which the crest is set at EL.200 m has 9 gates on the crest. The dimension of the gates is 15 m wide and 25 m high. The reservoir water level is at EL.210.80 when the spillway releases the design flood. When the spillway releases the discharge of a 10,000-year flood, the reservoir water level becomes EL.222.9 m. As the dam crest is set at EL.225 m, the dam has the freeboard of 2.1 m.

6.1.3 Powerhouse and Generating Equipments

The above ground type powerhouse is constructed on the right bank immediately downstream of the main dam, and it houses four units of the 50,000 kW generating equipment. Each turbine is to be of the vertical Francis turbine. The rated discharge and head are 154 m^3/sec and 39 m, respectively.

The intake structure which is situated at the upstream side of the concrete dam connects with the penstocks of 6 m in diameter in the dam. The penstocks led to the downstream side of dam are bent downward and led to the toe of the dam.

The elevation of turbine center is determined to be EL.176 m. An open channel tailrace is constructed immediately downstream of the powerhouse.

6.1.4 Transmission Lines and Substation

Four circuits of 132 kV transmission lines of about 5 km between the power station and Bharatpur substation are required as a part of generator circuit. Six sets of 132 kV circuit breakers and associated switchgears, four for the power station and two for Kathmandu substation, are installed at Bharatpur substation.

Two circuits of 132 kV transmission line of about 100 km between Bharatpur substation and Kathmandu substation will be prepared, but one circuit only be installed as first stage. Six sets of 40,000 kVA transformer will be added at the existing substation at Kathmandu. The transmission voltage of 132 kV will be stepped down to 66 kV. Four sets of 35,000 kVA static condenser are required for receiving 200 MW.

However, the cost of these transmission line between Bharatpur and Kathmandu and the substation at Kathmandu is not included in the project cost because such facilities are to be implemented in the expansion program of the 132 kV national main grid of power transmission.

6.2 Construction Plan and Cost Estimate

6.2.1 Construction Plan

The time required for the project implementation, including the finance arrangement, the supplemental investigation and the tender for the contract, was estimated as shown in the bar diagram of Figure 6.4. It takes 8 years for the project implementation; two years for preparation of the project such as loan financing, supplemental investigation, design and tender and 6 years for the construction of dam and appurtenant structures.

The diversion plan was studied elaborately not to be costly and time-consuming. After a comparative study of the alternatives, the scheme of open channel on the left bank was selected against the schemes of multi-stage diversion by sheet pile coffering in the river channel and of diversion tunnels on the right bank. The reasons of the selection are stated in Clause 6.1.

The required construction time period of 6 years can be thought a little longer than the time period required for the construction of a common gravity dam. However, considering that it will take 2 years for the diversion works and the foundation treatment and that 7 months a year are available for the dry works in the river bed even if a large diversion scheme (2,000 m^3 capacity) is constructed, the concrete works for the gravity portion and the earth works for the embankment portion have to be done in 4 years. The construction time schedule conceived for the Project is rather tight.

The critical path of the construction is the sequence of the diversion works, the concrete works and the embankment of the dam as shown in Figure 6.5. In order to proceed in full career, the diversion works shall be completed by the end of the first dry season (May, 1986) and the concrete works for the dam shall start from the beginning of the second dry season. A two-shift work system will be required to progress the project on time.

Electrical works such as the installation of turbines and generators are not a part of the critical path, since the electrical works will be possible to be executed in parallel with the embankment for the dam. When the construction will goes on schedule, the commercial operation of the first units of 100 MW will be commenced at the beginning of 1991, provided that the supplemental investigation and tender design shall start in the middle of 1983.

6.2.2 Construction Cost

The estimate of the work quantity is made based on the plans shown in Figure 6-1 and 6-2. The total project cost (200 MW) is estimated to be US$282.8 million as summarized in Table 6-1. The cost for the first stage of 100 MW is estimated at US$257.5 million. The cost for the first are estimated to be US$154.7 million as summarized in Table 6-2. On the other hand, the costs for metal and electrical works are estimated to be US$59.5 million as depicted in Table 6-3. These estimates are based on the cost survey made in Nepal for the similar project now under construction or nearly to be implemented.

The following conditions are applied for the cost estimate:

(1) the estimate is made at the price level of early 1981,

(2) the exchange rates applied are US$1.00 = Rp.11.6 = ¥210, and

(3) the construction is carried out by the contractors selected through the international competitive bidding.

6.3 Alternative Plan of Project Layout

As mentioned in Clause 6.2, the shearing strength of the bedrock in the river channel is clarified to be relatively less than that on the both banks. Although the shearing strength of bedrock is tentatively assumed to be 7 Kg/cm^2 for cohesion and 40° for internal friction angle for the preliminary design of concrete dam, the successive investigation may indicate the worse condition and lesser strength of the bedrock, which mean a risk of considerable increase in the volume of the concrete dam. The surface zone of the bedrock may be too soft and have to be removed to the depth of several meters to reach the zone sound enough in the worst case.

In view of above-mentioned risk, an alternative plan of the embankment dam instead of the concrete dam was worked out as shown in Figure 6-5. In this plan, the diversion scheme is designed to have a capacity of 16,000 m^3/sec, which corresponds to the recorded maximum flood, in order to avoid submergence of the works in any wet season. A large diversion channel is located in both banks.

The main embankment dam in the river channel is composed of the earth core, filter and shell of sand and gravel fill. The spillway is also divided into two parts located in the both banks. The powerhouse is placed on the left bank.

The project cost and construction time roughly estimated on this plan are almost same as in the plan of concrete dam. However, there is almost no risk involved in this plan in connection with the bedrock strength. Further study will be made on this plan in the following stage of the study. The main feature of this plan is given as follows.

Quantity of major works of alternative plan

Item	Unit	Quantity
Excavation in deversion channel	m^3	6,650,000
Excavation in main dam	"	530,000
Embankment in main dam	"	2,090,000
Concrete in spillway	"	550,000

Table 6-1 SUMMARY OF PRESENT-DAY CONSTRUCTION COST (200 MW)

(Unit: US$x10^3)

Item	Foreign Currency		Local Currency		Total	
1. Preparatory Works	6,500	(6,500)	1,200	(1,200)	7,700	(7,700)
2. Civil Works						
C-1 Diversion Works	8,400	(8,400)	900	(900)	9,300	(9,300)
C-2 Dam and spillway	100,600	(100,600)	18,500	(18,500)	119,100	(119,100)
C-3 Intake	9,300	(9,300)	1,800	(1,800)	11,100	(11,100)
C-4 Powerhouse and tailrace	12,300	(11,600)	2,900	(2,800)	15,200	(14,400)
3. Mechanical Works	19,700	(19,700)	2,200	(2,200)	21,900	(21,900)
4. Electrical Works/1	33,700	(18,300)	3,900	(2,100)	37,600	(20,400)
5. Land Aquisition	0	(0)	6,800	(6,800)	6,800	(6,800)
Sub-total	190,500	(174,400)	38,200	(36,300)	228,700	(210,700)
6. Engineering and Government Administrations/2	14,300	(13,100)	2,900	(2,700)	17,200	(15,800)
7. Physical Contingency/3	30,500	(28,100)	6,200	(2,900)	36,900	(31,000)
Total/4	235,500	(215,600)	47,300	(41,900)	282,800	(257,500)

/1 Exclusive of construction cost of transmission line connecting between Kathmandu and Bharatpur

/2 7.5% of 1 to 5

/3 15 % of 1 to 6

/4 Parentheses show present-day construction cost in 1st stage of 100 MW.

Table 6-2 ESTIMATED COST OF CIVIL WORKS

(Unit: USx10^3$)

Item	Quantity	Unit	Amount
C-1 Diversion works			9,300
1) Excavation	1,180,000	m^3	
2) Embankment in coffer dams	58,000	"	
3) Concrete	6,800	"	
4) Cut-off wall	8,100	m^2	
C-2 Dam and spillway			119,100
1) Excavation	1,294,000	m^3	
2) Grouting	36,500	m	
3) Embankment	562,000	m^3	
4) Concrete	914,000	"	
5) Cut-off wall	5,800	m^2	
C-3 Intake			11,100
1) Wet masonry	700	m^2	
2) Concrete	87,500	m^3	
C-4 Powerhouse and tailrace			15,200
1) Excavation	82,000	m^3	
2) Concrete	58,000	m^3	
3) Building works		L.S.	
Total			154,700

Table 6-3 ESTIMATED COST OF METAL AND ELECTRICAL WORKS

(Unit: $US\$ \times 10^3$)

ITEM	COST
1. Metal Works	
(1) Spillway gates	13,080
(2) Spillway stoplog	1,510
(3) Intake trash racks	1,690
(4) Intake gates	2,170
(5) Intake gantry crane	540
(6) Penstock	2,170
(7) Tailrace gate	340
(8) Gantry crane	400
Sub-total	21,900
2. Electrical Works	
(1) Generating Equipments	36,000
(2) Transmission line and Bharatpur switching station	1,600
Sub-total	37,600
Total	59,500

CHAPTER 7 ECONOMIC ANALYSIS

7.1 Criteria and Assumptions

The optimal plant scale of the Sapt Gandaki Project was determined to be 200 MW on the fixed discount rate of 12 %. The economic evaluation was made based on the method of economic internal rate of return to obtain the discount rate equalizing benefits and costs on the scale of 200 MW.

The benefits are capital, operation and maintenance, and replacement costs of the most competitive alternative. A coal-fired thermal plant widely used in India is considered as the most competitive alternative plant in Nepal. The installed capacity of the coal-fired plant is assumed to be same to the one of the Sapt Gandaki Project. Moreover, it is assumed that all the energy produced from the Sapt Gandaki Project can be sold and consumed in Nepal and India without any losses according to the mutual-dependent contract of energy between the both countries.

The estimate of costs was made at the price level of mid-1980/81. In Nepal, a fiscal year starts in the midle of July. The evaluation period of the project was made by 50 years considering that the economic life of the dam is 50 years.

7.2 Economic Cost

The economic cost comprises the base cost, O & M cost and replacement cost excluding duties and taxes which are the transfer payments. However, as the transfer payments on this project have little effect on the economic evaluation, the project cost estimated in the preceding Chapter 6 was used as the economic cost. The base cost is the construction cost such as the dam, powerhouse, and generating equipment, and engineering and administration costs which are 7.5 % of the construction cost. The physical contingency is assumed to be 15 % of the base cost.

The O & M cost covers salaries and wages of staffs, regular maintenance cost and minor repair cost. The replacement cost is assumed to be 90 % of the direct cost on metal works and generating equipments considering the salvage value. The economic life of metal works and generating equipments is assumed to be 30 years.

The economic cost is estimated as shown in Table 6-1. The total capital cost amounts US$282.8 million dollars of which the foreign and local portions are US$235.5 million and US$47.3 million dollars, respectively. The investment timing of the capital cost and the the stream of O & M cost are tabulated in Table 7-1.

7.3 Economic Benefit

The costs of the coal-fired thermal plant consists of the installation cost, O & M cost and replacement cost. The unit price of the installation cost for the 200 MW scale thermal plant is estimated to be US$903/kW.

The O & M costs comprise the costs related to the installed capacity and the generating energy. The annual O & M cost for the installed capacity is estimated to be US$27/kW, while 42 mill/kWh for the generating energy based on the coal consumption rate of 0.645 kg/kWh and the cost of coal of US$65/ton.

As there is difference on auxiliary power use, forced outage, overhaul and energy loss at the primary station between the thermal and hydropower stations, the adjustment is made. The overall adjustment factors assumed are 1.173 for the installed capacity and 1.028 for the generating energy. Those factors are included in the unit price of the installation and O & M costs.

The economic life of the coal-fired thermal plant is estimated to be 25 years. The replacement cost is assumed to be 90 % of the installation cost considering the salvage value.

It is assumed for the estimate of economic benefit that the capacity factor of the plant should be more than 50 % at any time. As the maximum output, which can be generated with the capacity factor of 50 % warranted even in the driest period is 170 MW, the economic benefit of the 200 MW installation is limited to that for 170 MW. Thus, the installation cost for the 200 MW thermal plant is estimated to be US$153.5 million. The construction period for each 100 MW installation is assumed to be 3 years. The value of the secondary energy is assumed to be a half of the primary energy value. The economic benefit stream is shown in Table 7-1.

7.4 Economic Internal Rate of Return

The variation of benefits and costs obtained by applying various discount rates is presented in Figure 7-1. The point where the benefit and cost curves intersect shows the economic internal rate of return. For the installed capacity of 200 MW, the economic internal rate of return was 16.1 %.

The sensitivity tests were made by increasing the cost by 10 % and 20 % and by decreasing the benefit by 10 %. Even in the worst case that the cost is increased by 20 % and the benefit is decreased by 10 %, the economic internal rate of returns was 11.8 % as shown in Figure 7-1. Thus, it is judged that the Sapt Gandaki Project is feasible in the economic viewpoint.

7.5 Associated Benefit

The economic evaluation of the Sapt Gandaki Project was made as a single purpose project of the hydropower. However, this project has the secondary benefit that the irrigation water for the Chitwan Valley irrigation scheme will be directly supplied by gravity flow from the Sapt Gandaki dam which will replace in future the pump-up scheme presently under construction.

The supply of stable energy with a large capacity has the intangible benefits on the economic stimulation and social stability. Moreover, the big dam project gives the job opportunity and transfer of knowledge.

Table 7-1 BENEFITS AND COSTS STREAMS

End of fiscal year	No. of year	Benefits		Costs	
		Power	Energy	Capital	O & M
1983/84	-7			6.22	
84/85	-6			6.70	
85/86	-5			10.09	
86/87	-4			36.68	
87/88	-3			55.58	
88/89	-2	33.87		76.87	
89/90	-1	45.15		58.69	
90/91	1	11.29	16.94	9.71	1.45
91/92	2		33.87		2.90
92/93	3	23.70	33.87	4.32	
93/94	4	31.61	33.87	14.44	
94/95	5	7.90	39.71	3.51	
95/96	6		45.55		
2011/12	22				
12/13	23	30.50			
13/14	24	40.65			
14/15	25	10.15			
15/16	26				
16/17	27	21.33			
17/18	28	28.45		9.41	
18/19	29	7.11		16.48	
19/20	30			18.83	
20/21	31			2.36	
21/22	32				
22/23	33			3.82	
23/24	34			13.40	
24/25	35			1.91	
25/26	36				
32/33	43		45.55		2.90

Note: 200 MW

CHAPTER 8 FIELD SURVEY OF STAGE II AND III

8.1 General

The field survey of the Stage I was carried out during 2 months between February 1 and March 31, 1981. An interim evaluation of the project has been technically and economically presented in the preceeding Chapters based on the information and data obtained from the field survey. With these results, it is judged justifiable to proceed to the Stage II and III Studies.

Following the field survey of the Stage I, the detailed field survey for the feasibility study will be conducted in the Stage II and III. The working items are summarized as follows:

- topographic survey,
- geological investigation including test boring, permeability test, seismic exploration, test grouting, test aditting, rock test in the test adit, and test trenching,
- construction material survey including sampling and laboratory test,
- hydrological survey,
- power demand survey,
- environmental survey,
- socioeconomic survey, and
- construction cost survey.

The time schedule for the field survey of Stage II and III is illustrated in Figure 8-1. The field survey of Stage II and III will have be done by March 1982 and June 1982, respectively.

8.2 Topographic Survey

During the field survey period in the Stage I, the existing aerial photographs and data concerning the topographic survey were collected from the governmental organization concerned. It was found out that both the topographic maps of 1 to 63,360 and 1 to 10,000 in scale are available for planning of the project.

In order to carry out the detailed study, the following survey works are required to be conducted in Stage II:

- levelling on the route between the existing bench marks and that to be newly installed at the damsite and on the routes connecting triangulation points,

° ground control survey by staking points for horizontal and vertical control which are required to prepared an aero-photo maps of 1 to 2,000 in scale covering the proposed reservoir area by using the aero-photographs taken in 1974,

° triangulation survey including installation of triangulation points and plan table survey at both the damsite and the borrow areas of sand and gravel, and

° river cross section survey for the distance of 4 km along the river course downstream from the damsite.

The above site works for topographical survey are quantitatively summarized as shown below.

	Survey item	Quantity	Notes
(1)	Levelling	60 km	10 km for installation of new bench mark at damsite, 50 km for triangulation survey
(2)	Triangulation survey	20 km	
(3)	Plan table survey	80 ha	50 ha for damsite (in scale of 1 to 500), 30 ha for borrow areas of sand and gravel (in scale of 1 to 1,000)
(4)	River cross section survey	16 sections	at a interval of 25 m
(5)	Aero-photo mapping	4 km^2	in scale of 1 to 2,000

8.3 Geological Investigation

8.3.1 General

The following geological investigation works were performed in the Stage I during February and March, 1981:

° geological mapping of the damsite and reservoir area,

° core drilling and water pressure test in three holes with 125.0 m of length in total on the proposed dam axis, and

° seismic exploration in six traverses with 2,500 m of length in total along, parallel with and across the proposed dam axis.

As the result of the above investigation, it was confirmed that the river gravel deposit in the proposed site was within an acceptable thickness and the geological condition might allow to construct high dam by appropriate design of structures and foundation treatment. However, it also picked up several problems to be solved in the future, that is, thick overburden on the left bank and soft or possible fractured rock zones represented by low velocity zones of seismic exploration. The river gravel deposit is sufficiently, though not extraordinarily, thick. Stress should be placed on study and further confirmation of these parts of problem in the investigation in the Stage II.

On the other hand, it is deemed inevitable that the above problems will make the project more costly and the present damsite less attractive. This situation may render it worth while to examine possibility of alternative dam axes within 1 km downstream from the present site. Accordingly, it is desirable that the Stage II investigation will include studies of alternative dam axes.

The other problem is mechanical strength of the foundation rock. In view of flood diversion during the dam construction work, it is strongly preferable to design the dam in concrete gravity type, at least partly, whereas it appears that the shear strength of the rocks of Siwalik formation may be critical for concrete gravity dam of ordinary form. In-situ shear test of the foundation rock is essential for design and cost evaluation of the dam.

8.3.2 Investigation to be Carried Out

With the above conditions in view, the investigation plan of Stage II is proposed as follows:

(1) Core drilling

Hole No.	Direction	Depth (m)	Location
B81-1	Vertical	60	The proposed damsite
B81-2	do	30	- do -
B81-3	do	50	- do -
B81-4	do	60	- do -
B81-5	do	70	- do -
B81-6	do	50	- do -
B81-7	do	50	- do -
B81-8	do	30	- do -
B81-9	do	40	Powerstation site
B81-10	do	70	The proposed damsite
B81-11	do	35	The alternative damsite
B81-12	do	60	- do -
B81-13	do	35	- do -
B81-14	do	60	- do -
Total		700 m	

Water pressure test will be performed for every 5 m section in the part of bore hole through foundation rocks.

(2) Seismic exploration

Traverse No.	Length (m)	Location
SL-7	200	The proposed damsite
SL-8	250	- do -
SL-9	250	- do -
SL-10	1,000	The alternative damsite
SL-11	800	- do -
SL-12	600	- do -
SL-13	800	- do -
(SL-14	1,500	Gravel deposit *)
Total	5,400 m	

* See the clause for Investigation of Quantity of Construction Materials.

In the seismic exploration, the interval of receiving points (geophones) shall be 5 m.

(3) Test adits and in-situ rock tests

Adit No.	Dimensions	Direction	Location
No.1	2 m x 2 m x 50 m	Horizontal on dam axis	The proposed damsite, left bank
No.2	- do -	- do -	The proposed damsite, right bank

Rock shear tests in the adit, 6 spots (3 in each adit)

These tests will be made in the method of block shear test in which rock is sheared under varied vertical load by applying horizontal force to concrete test blocks placed on the surface of the rock. Base of each test block is 60 cm x 60 cm in dimension and its height is 30 cm.

Measurement of deformation moludus of rock, 6 spots (3 in each adit)

The test will be made by the use of loading plate with 30 cm of diameter.

Geological condition inside the adits will be mapped. The spots of the tests will be selected at locations with representative geological condition. Three test blocks will make a groupe for a unit of test, and so shall be placed on rocks of similar condition.

If the situation requires and/or allows, the number of test block for a unit of test may be increased. The required test results are shear strength (cohesion), internal friction angle, deformation modulus and elasticity modulus of the foundation rock.

It is strongly recommended that the adit excavation shall be made under close site guidance of expatriate tunnelling experts, not only because special safety measure should be applied for tunneling works in general but also because this tunnelling work will require particular caution about thin coverture of rocks under very mild slopes. Though a recent major construction work has produced some skilled labours of tunnelling in Nepal, they are yet different from the responsible experts.

8.4 Construction Material Survey

8.4.1 General

As the result of field reconnaissance in the Stage I, the following sources of construction materials were proposed for detailed investigations in the Stage II.

(1) Concrete aggregates

Coarse aggregate:	River beds of the Kali Gandaki, Trisulganga and Sapt Gandaki, within 4 km up and downstream from the damsite.
Fine aggregate:	River sand the Khageri Khole and Rapti Rivers.

(2) Fill materials

Rockfill material:	River gravels of the Kali Gandaki, Trisulganga and Sapt Gandaki, within 6 km upstream and 10 km downstream from the damsite. Hard sandstones and slates in the upstream area of the Trisulganga, more than 7 km north from the damsite.
Filter material:	River sand in the Khageri Khola and Rapti Rivers.
Earthfill material:	Red soil on the hills with ground height around EL.250 m, on the left bank of the damsite.

Sampling will be made in the above locations for laboratory tests.

8.4.2 Investigation on Quality of Construction Materials

(1) Coarse aggregate

Ten pits will be excavated in the gravel bars of the Kali Gandaki, Trisulganga and Sapt Gandaki within 4 km from the damsite. Depth of the pits will be 1 to 2 m.

Sieving test will be made in the site to determine the particle size distribution of the samples from the pits. Sieves to be used will be 8", 6", 3", 1-1/2", 3/4", 3/8" and 3/16", or of nearly similar meshes. Fine grains passing the 3/16" sievel will be analyzed in the laboratory. The samples retained on 3/16" sieve will be sent to the laboratory for the following tests:

- specific gravity and absorption,
- unit weight of aggregate,
- friable particles in aggregate,
- soundness (sodium sulfate method) and
- abrasion of coarse aggregate (the Los Angeles test).

Each sample will be not less than 20 kg in weight. Number of the samples will be ten, that is, similar to that of pits.

(2) Fine aggregate

River sand will be sampled at five spots respectively in the Khageri Khola and Rapti River, and will be sent to the laboratory for the tests as follows:

- sieving analyzes,
- percentage of aggregate passing No.200 screen,
- specific gravity and absorption,
- unit weight of aggregate,
- organic impurities, and
- soundness (sodium sulfate method).

(3) Filter material

Test for filter material is covered by (2).

(4) Earthfill material

Test pits will be excavated to approximately 5 m of depth at 10 spots on the terrace on the left bank of the damsite. Ten samples will be sent to laboratory for the following tests:

- ° specific gravity 10 samples,
- ° natural moisture content 10 samples,
- ° grain size analysis 10 samples,
- ° liquid limit and plastic limit 10 samples,
- ° compaction test 3 samples,
- ° triaxial test (Consolidated-undrained with observation of pore pressure and unconsolidated-undrained) 3 samples, and
- ° permeability test 3 samples.

Number of the samples for compaction test, triaxial test and permeability test depends on the homogeneity of the deposit in the borrow area. If the deposit can be represented by a single sample, the number of the sample to be tested may be decreased.

8.4.3 Investigation on Quantity of Construction Materials

The available quantity of the construction materials will be estimated by confirming the area of deposits and their depths. If the quantity is obviously sufficient in terms of area, check of the depth will not be essential in this stage. Check of the depth of deposits shall be made by test pit and seismic exploration. Seismic exploration for 1.5 km of traverse length will be prepared for gravel deposit and, if necessary, for other materials.

8.5 Hydrological Investigation

Through the field survey of the Stage I, the basic data such as rainfall, temperature or river runoff were collected. Moreover the stream flow measurement and water sampling were performed for the analysis of water quality and sediment load.

As the stream flow measurement and water sampling were only made in the dry season, measurements of the Stage II will be focussed on the high flow season so that measurements of discharge and sediment load can cover the wide range.

The survey items of the Stage II are summarized as follows:

- ° data collection on runoff, rainfall, sediment and other meteorology in addition to those collected in Stage I,
- ° runoff measurement at the Gaging Station 450 by using floats (Around 20 times),
- ° sediment measurement by water sampling (30 samples), weight measurement of sediment contained in each sample and preparation of accumulated particle size distribution curves for the specified samples (5 samples), and
- ° chemical analysis of the river water regarding Ca^{+}, Mg^{+}, Na^{+}, K^{+}, CO_3^{-}, SO_4^{-} and pH (5 samples).

8.6 Power Demand Survey

The power demand survey of Stage I consists of data collection concerning the existing power facilities, those under construction and planning and the historical power supply condition. Based on those data, the power demand is projected as discussed in Chapter 3.

On Stage III, the followings on power demand survey are scheduled to be done:

- ° continuation of relevant data collection in addition to the data collected on the Stage I,
- ° survey on construction cost, operation and maintenance cost, fuel cost, forced outage, etc. of the possible alternative thermal power stations, and
- ° survey of the power tariff system.

8.7 Environmental Survey

The data and information on the irrigation schemes around the project area collected in Stage I were reported in the Clause 4.5. In addition to the above, the environmental survey on the following items will be carried out in Stage II.

8.7.1 Land Aquisition

The area and houses which will be submerged in the proposed reservoir are estimated to be around 19 km^2 and 240 nos., respectively. In addition to the above, various construction areas such as borrow areas for construction materials, sites for laboratory and construction equipments, etc. will be needed in the construction stage. Data collection to estimate the compensation cost and the assets to be compensated will be conducted in close contact with the government organizations concerned.

8.7.2 Fishery

The present situation of riverine fisheries in the river basin will be investigated. As the Sapt Gandaki Project will have some adverse effects on the riverine fisheries, the necessity of fish passing facilities will be studied in Stage III.

8.7.3 Miscellaneous

In addition to the above items for environmental survey, collection of data, reconnaissance and studies will be made in examining the impact on the environment of living, economy, ecology and culture in the Project area which will be caused by the project implementation.

8.8 Socioeconomic Survey

Data collection of the various economic indicators in Nepal will be made in Stage III. The collected data will be mainly used in estimating economic costs such as opportunity cost of capital and labour, etc. as well as in making the power demand forecast.

The survey will also be made on various markets, transfer costs such as taxes and subsidies, boader prices of trade-goods, shadow rate of foreign exchange, etc. The financial status of NEC and its power tariff system will be look into based on the data collected on the power survey. Collection of the data in the socioeconomic survey will be made on the items such as; GDP; population; industry; infrastructure; employment; commodity prices; national budget; and long term development plan.

8.9 Construction Cost Survey

The following data will be collected in the construction cost survey of the Stage III.

8.9.1 Cost Data

Data related to price of basic construction materials such as cement, reinforcement bar, fuel, explosives, etc. and tender or contract prices of the latest construction works will be collected.

8.9.2 Transportation

Data on the transportation facilities to convey the construction materials and equipments to the project site will be obtained from the organizations concerned or through route inspection. The transportation by sea, air line, road and railway will be examined regarding hauling capacity, traffic limits, etc. and the informations collected will be reflected in the design of heavy equipment, estimate of transportation cost and construction planning.

8.9.3 Construction Plan

The construction planning engineer will thoroughly inspect the project site and will examine the cost data in Stage III. With the result of the inspection and studies, construction plan for the project will be prepared carefully taking into account such a large stream flow of the Sapt Gandaki River.

FIGURES

Fig 2-1

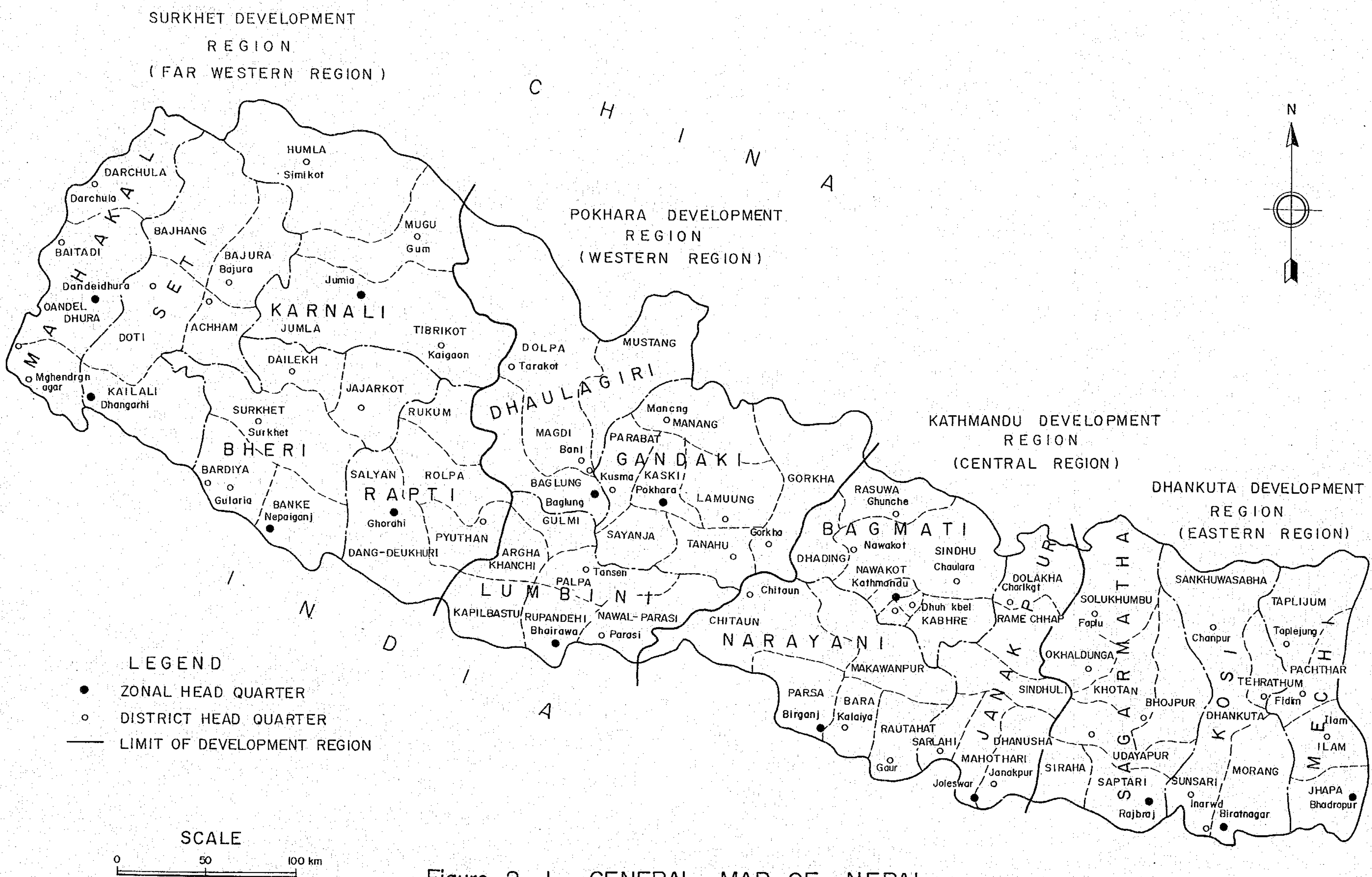


Figure 2-1 GENERAL MAP OF NEPAL

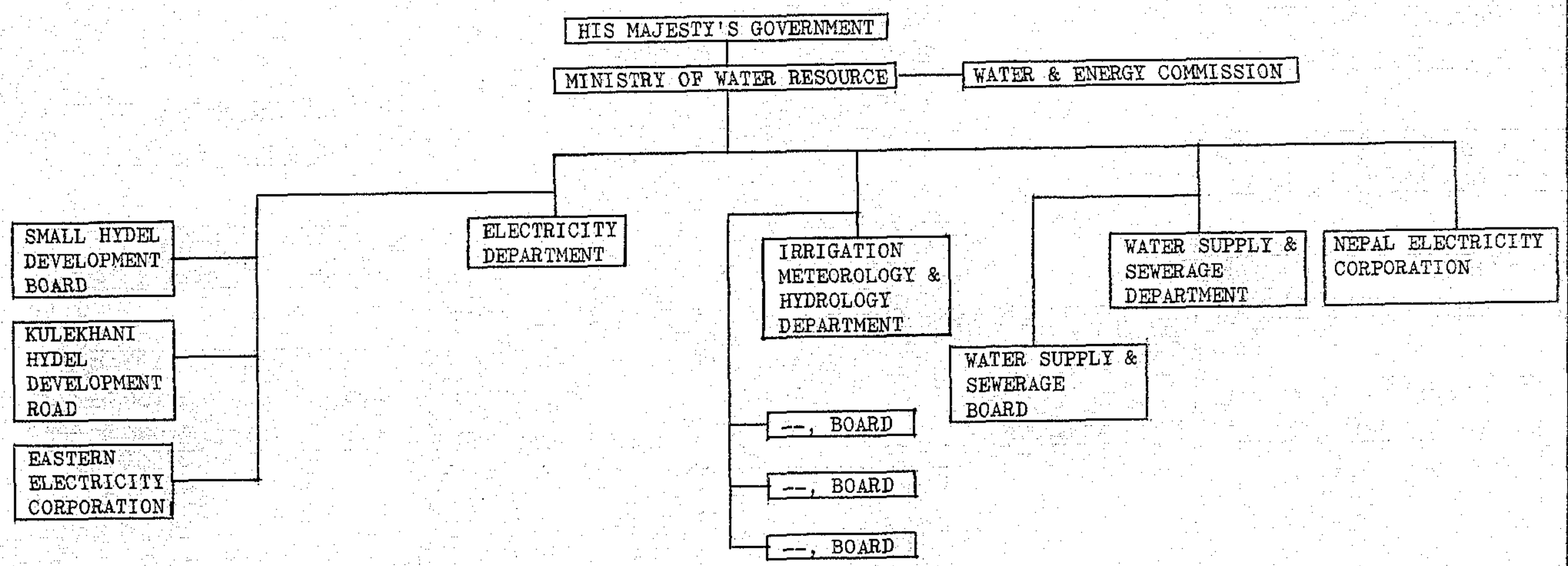


Figure 3-1 ORGANIZATION OF MINISTRY OF WATER RESOURCES

Fig. 3-1

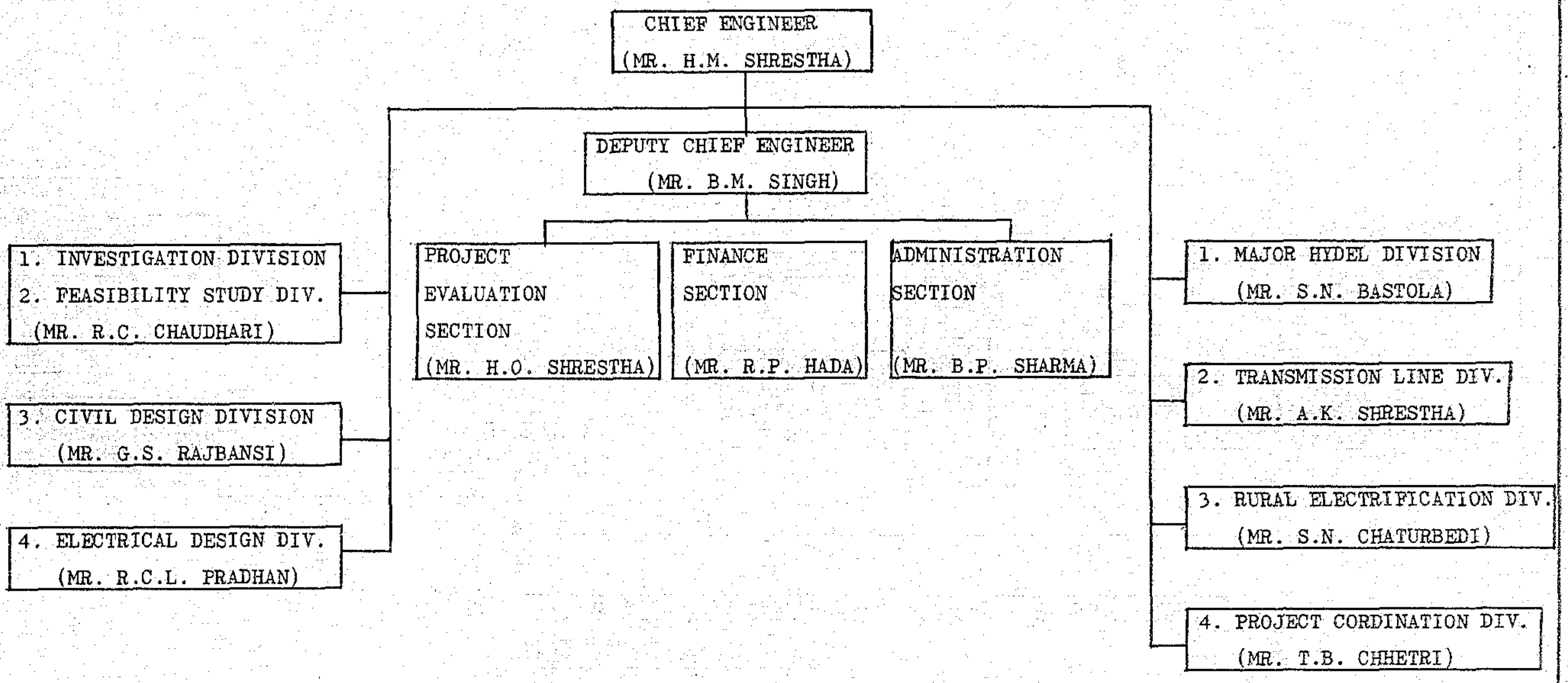


Figure 3-2 ORGANIZATION OF ELECTRICITY DEPARTMENT

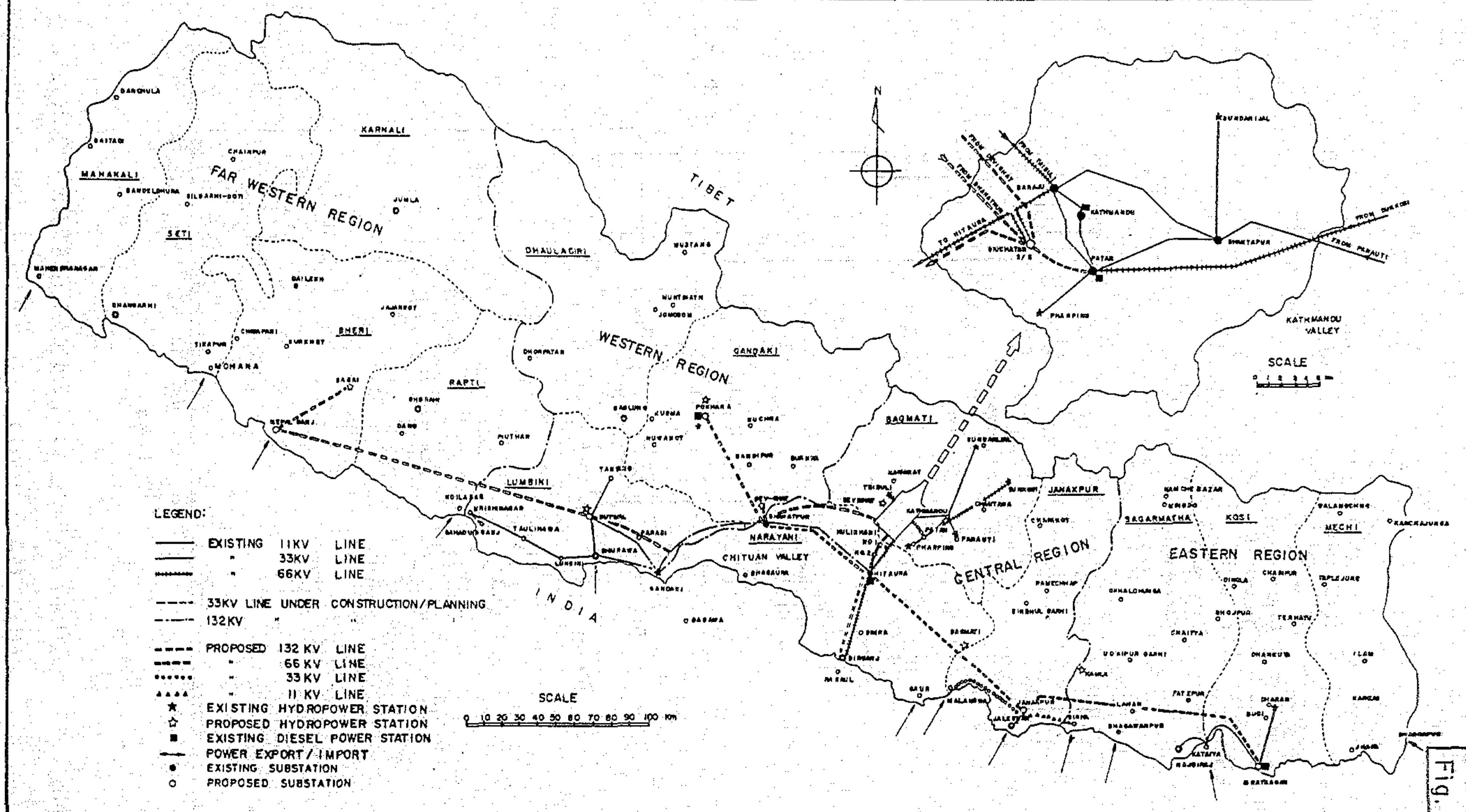


Figure 3-3 POWER SUPPLY NETWORK IN NEPAL

Fig. 3-3

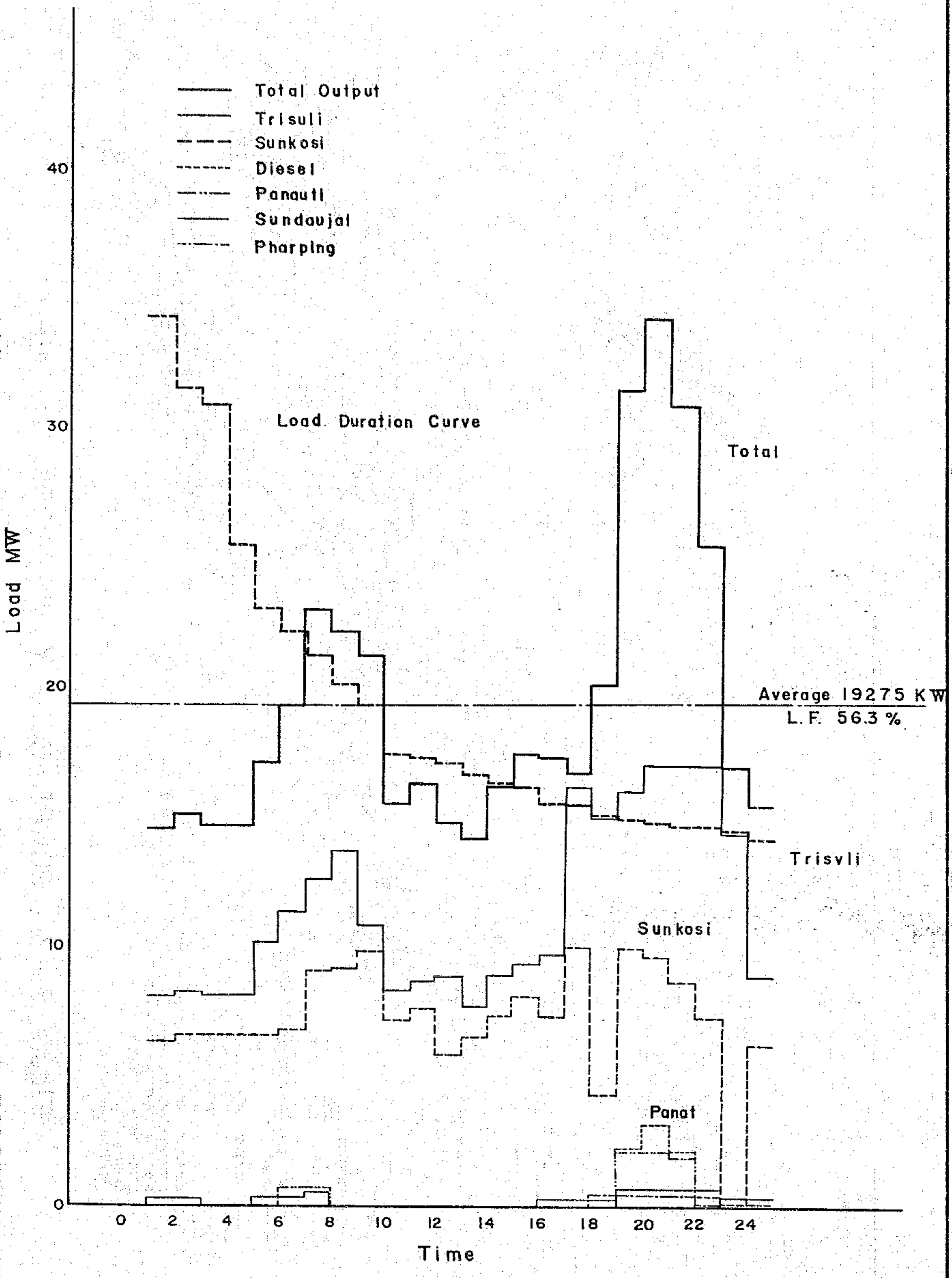


Figure 3-4 LOAD CURVE & LOAD DURATION CURVE (8th MAY 1980)

Fig. 3-5

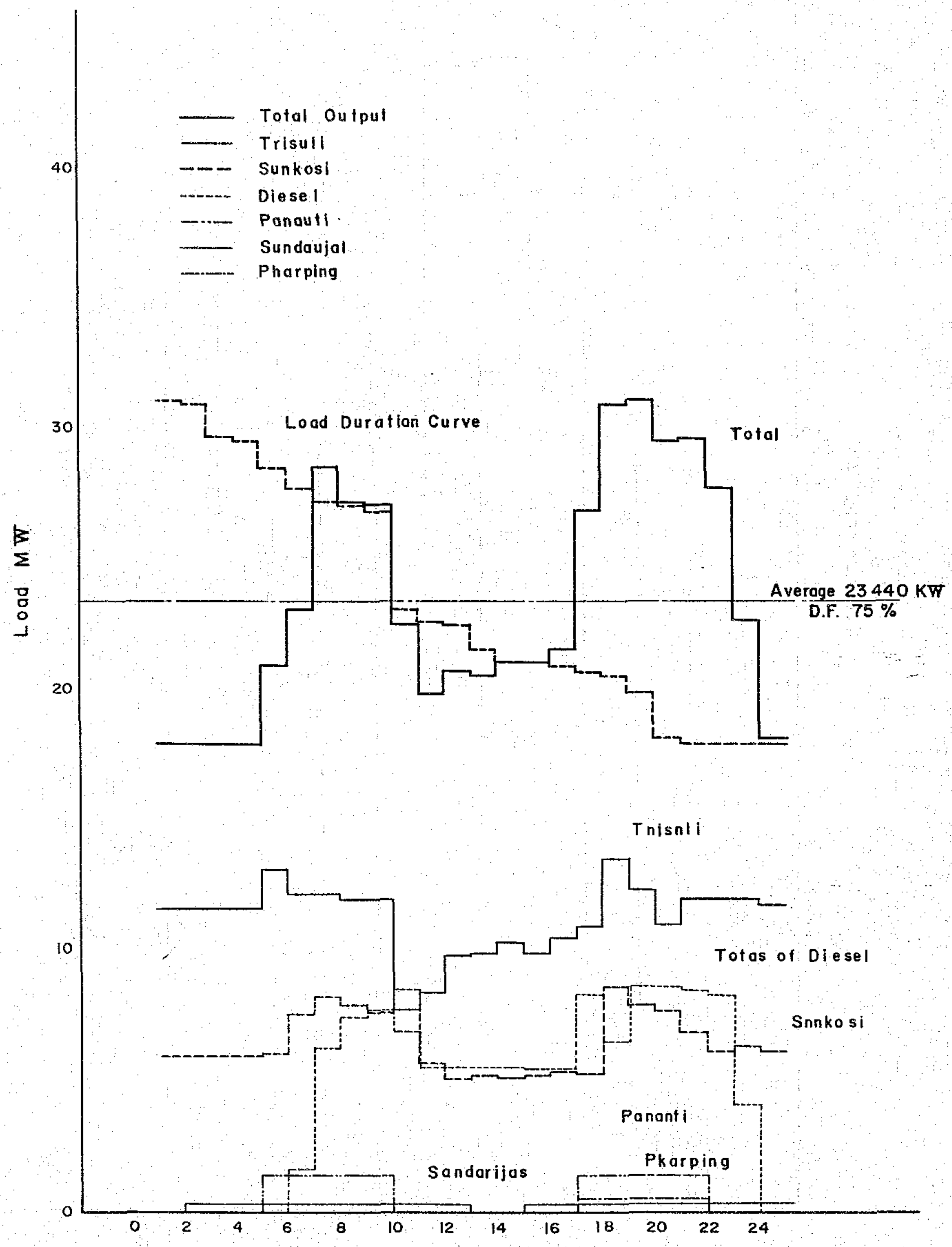


Figure 3-5 LOAD CURVE & LOAD DURATION CURVE

(6th January 1981)

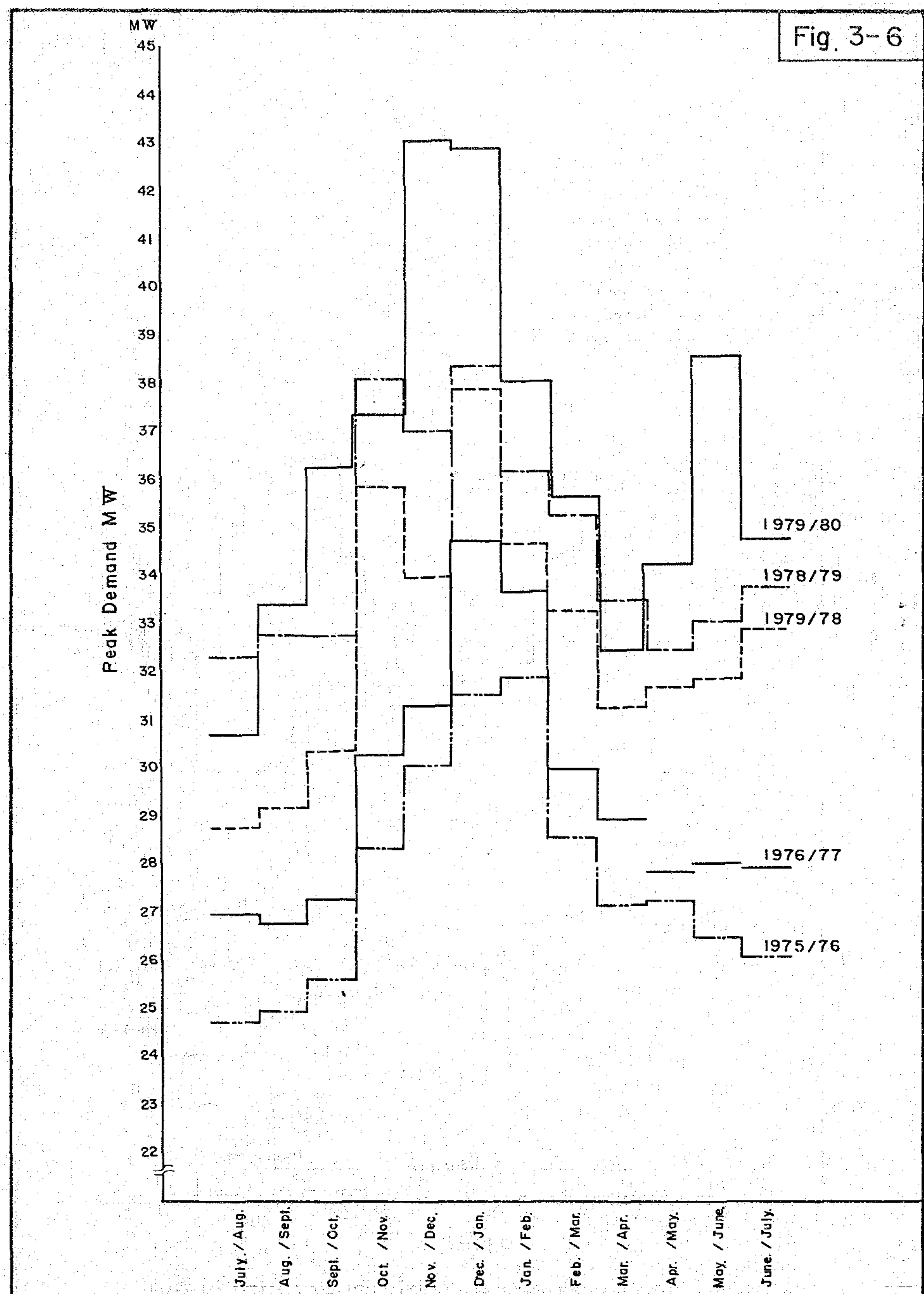


Figure 3-6 MONTHLY PEAK DEMAND IN CNPS

Fig. 3-7

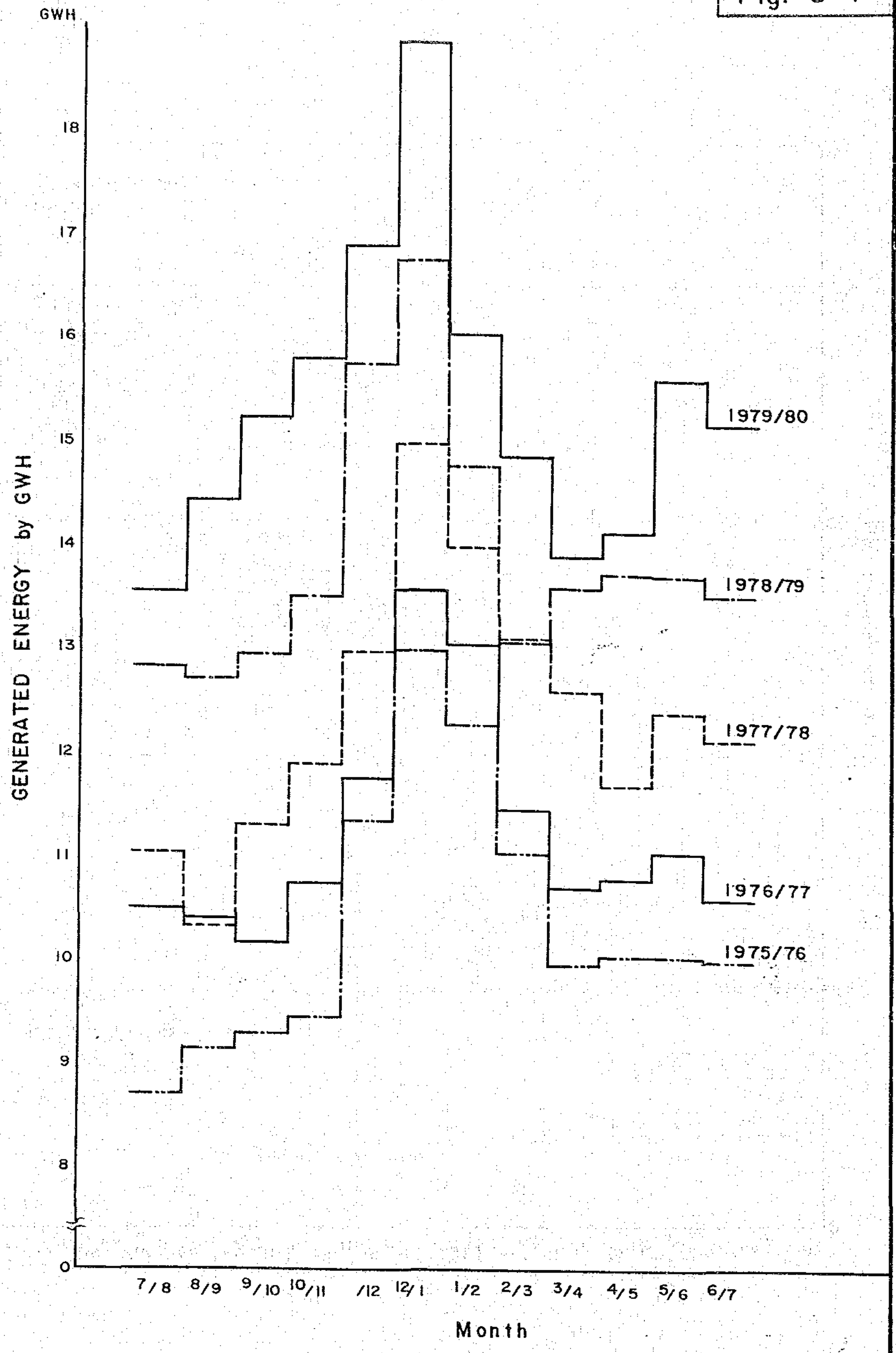


Figure 3-7 MONTHLY GENERATED ENERGY IN CNPS

Fig. 3-8

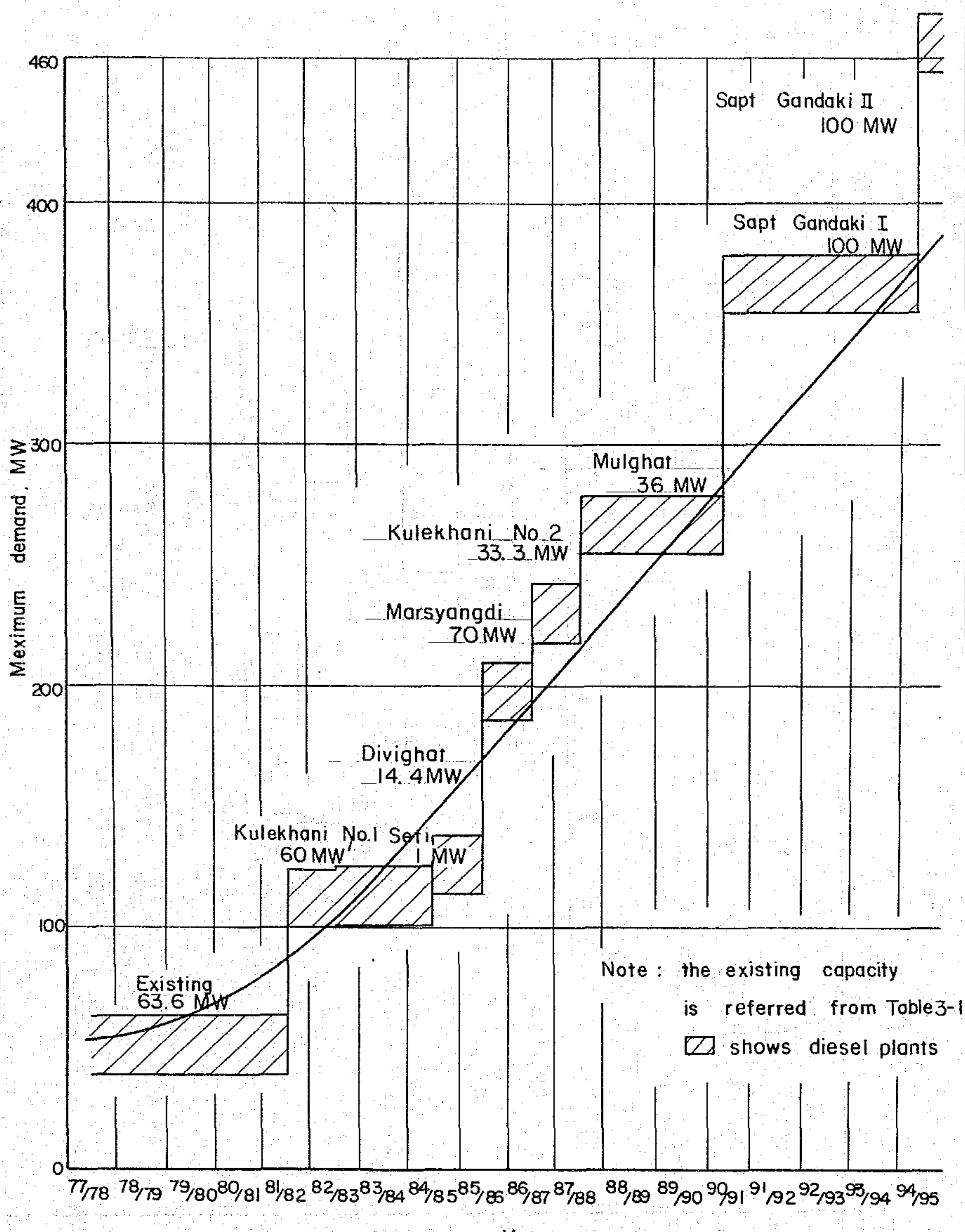


Figure 3-8 PREDICTION OF POWER DEMAND

Fig. 3-9

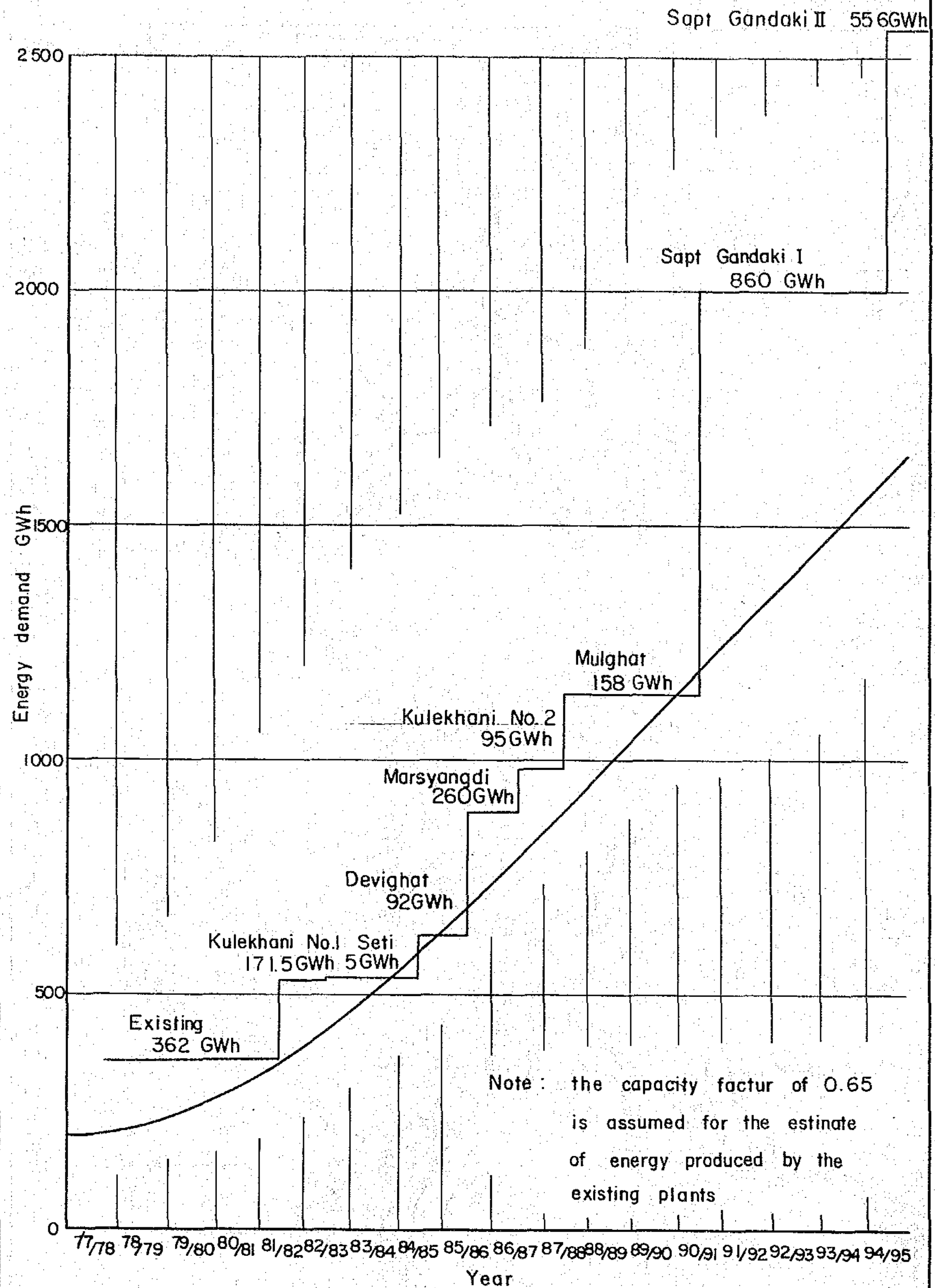


Figure 3-9 PREDICTION OF ENERGY DEMAND

Fig. 3-10

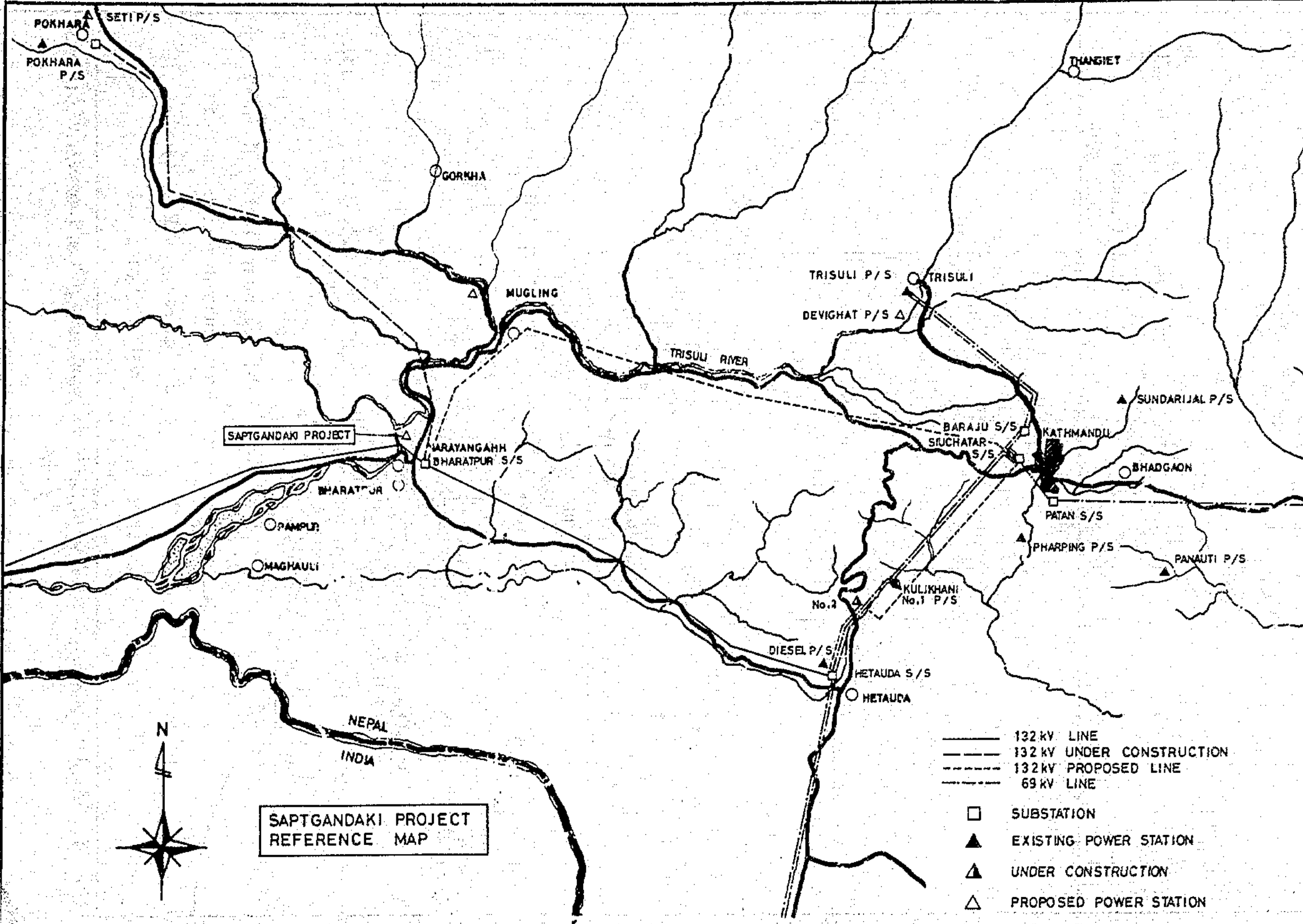


Figure 3-10 PROPOSED ROUTE OF TRANSMISSION LINE

Fig. 3-11

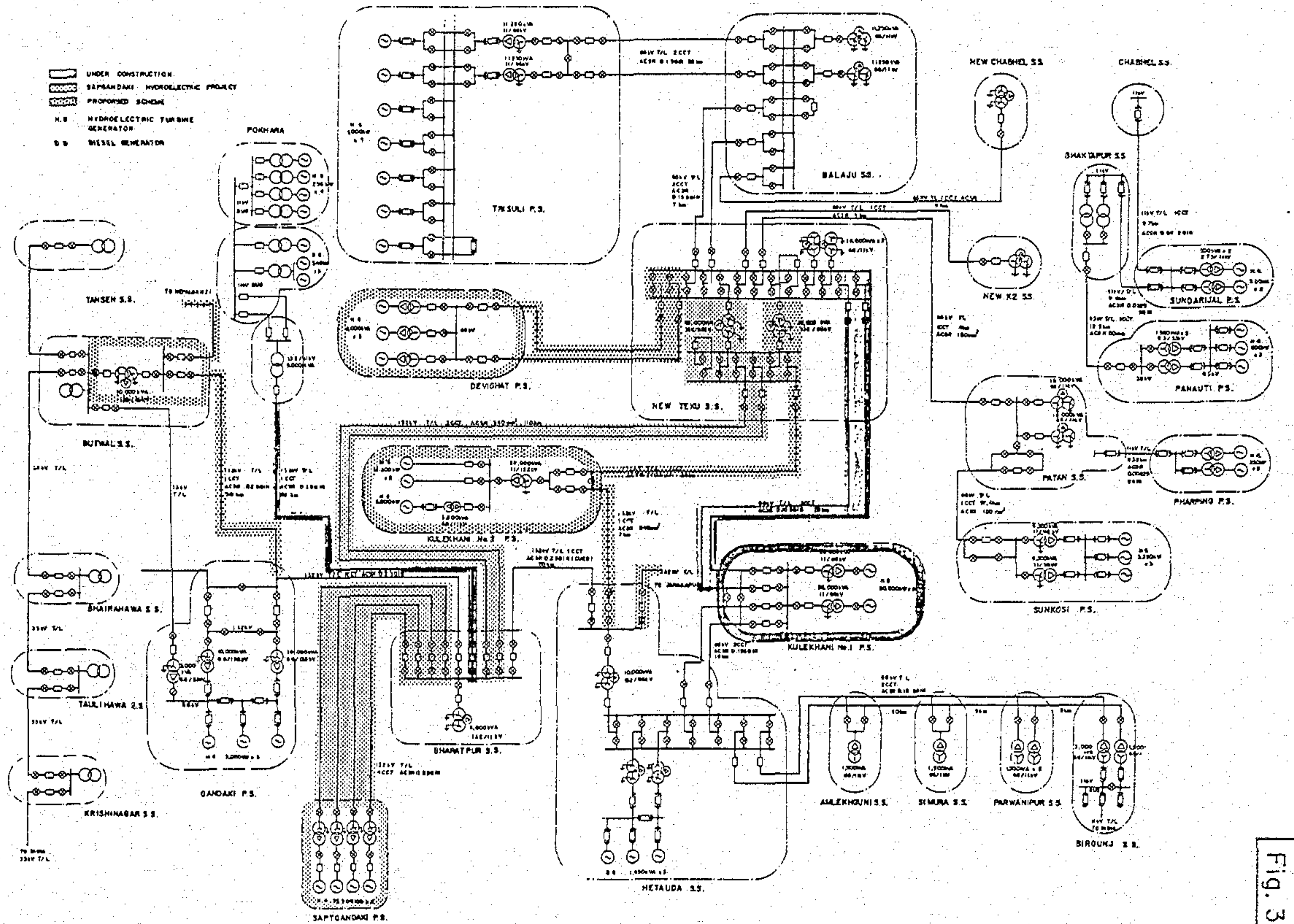


Figure 3-11 PROPOSED TRANSMISSION SYSTEM

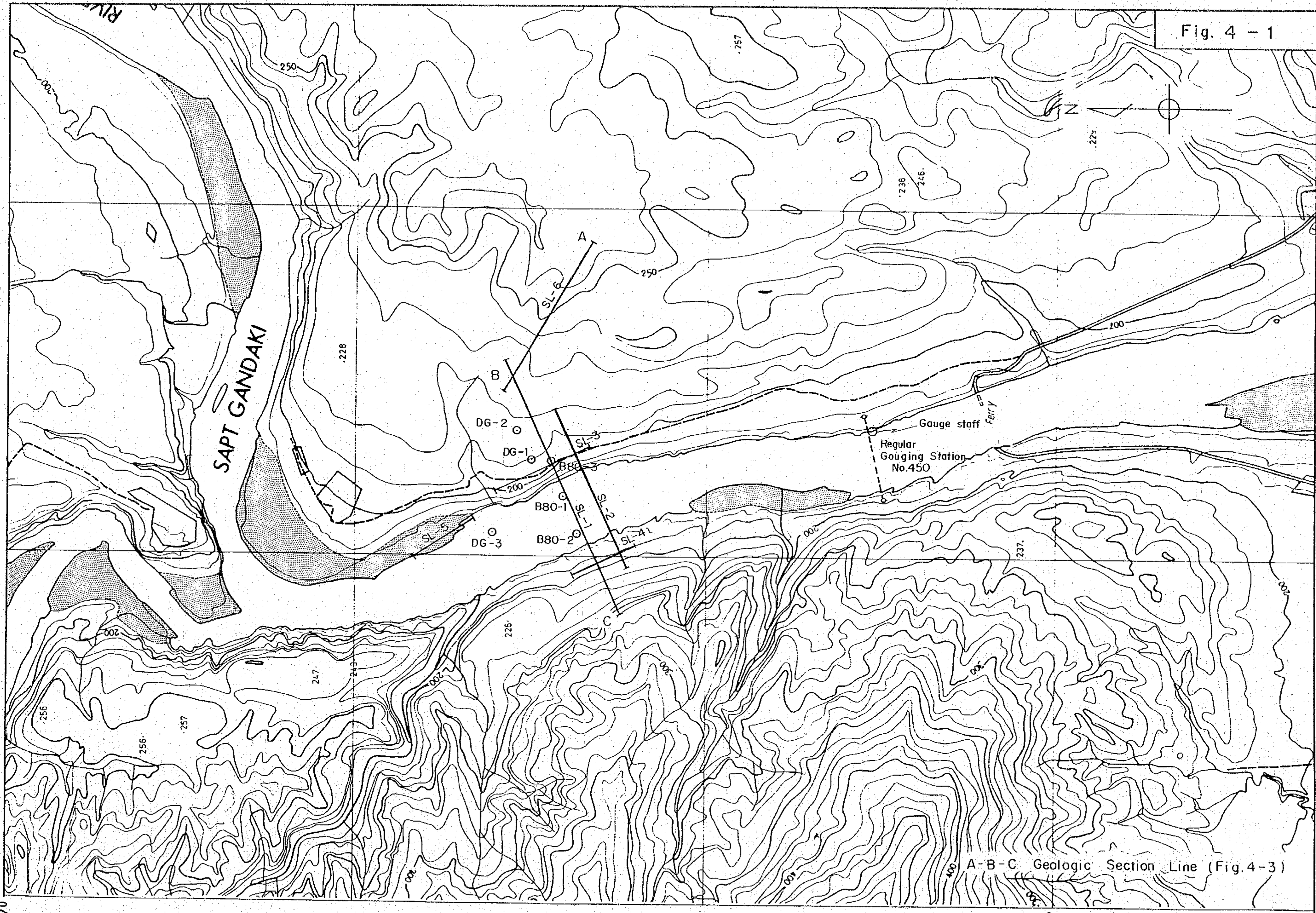
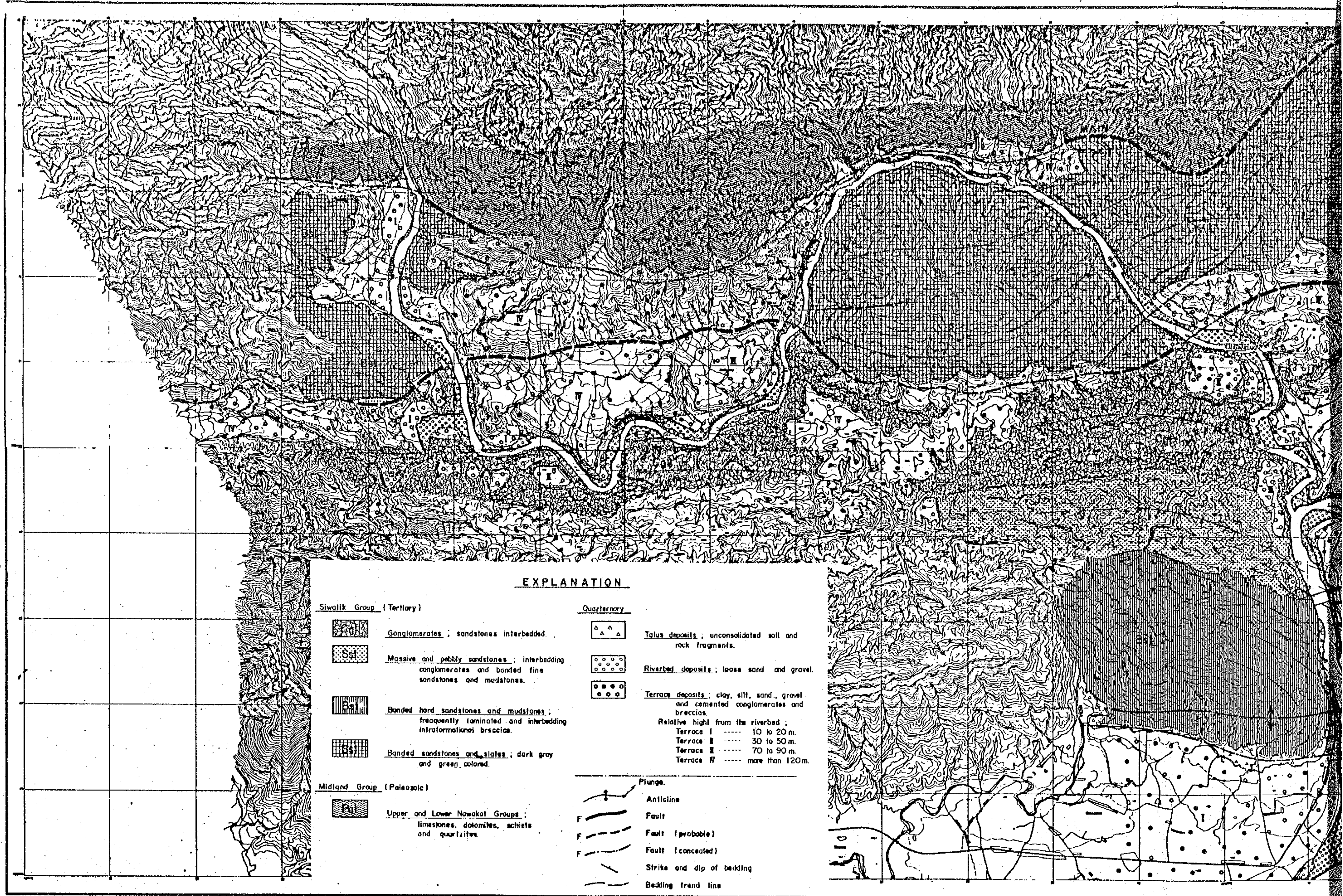


Figure 4-1 LOCATION MAP OF GEOLOGIC INVESTIGATION

(Scale 1 : 10 000)

⊙ Test Boring

Seismic Traverse



EXPLANATION
Siwalik Group (Tertiary)
Cgl
Conglomerates ; sandstones interbedded.
Sst
Massive and pebbly sandstones ; interbedding conglomerates and banded fine sandstones and mudstones.
Bst
Banded hard sandstones and mudstones ; freaquently laminated and interbedding intraformational breccias.
Bsl
Banded sandstones and slates ; dark gray and green colored.
Midland Group (Paleozoic)
Pgl
Upper and Lower Nawakot Groups ; limestones, dolomites, schists and quartzites.
Quarternary
Talus deposits ; unconsolidated soil and rock fragments.
Riverbed deposits ; loose sand and gravel.
Terrace deposits ; clay, silt, sand, gravel and cemented conglomerates and breccias.
Relative hight from the riverbed ;
Terrace I ----- 10 to 20 m.
Terrace II ----- 30 to 50 m.
Terrace III ----- 70 to 90 m.
Terrace IV ----- more than 120 m.
Plunge.
Anticline
F
Fault
F
Fault (probable)
F
Fault (concealed)
Strike and dip of bedding
Bedding trend line

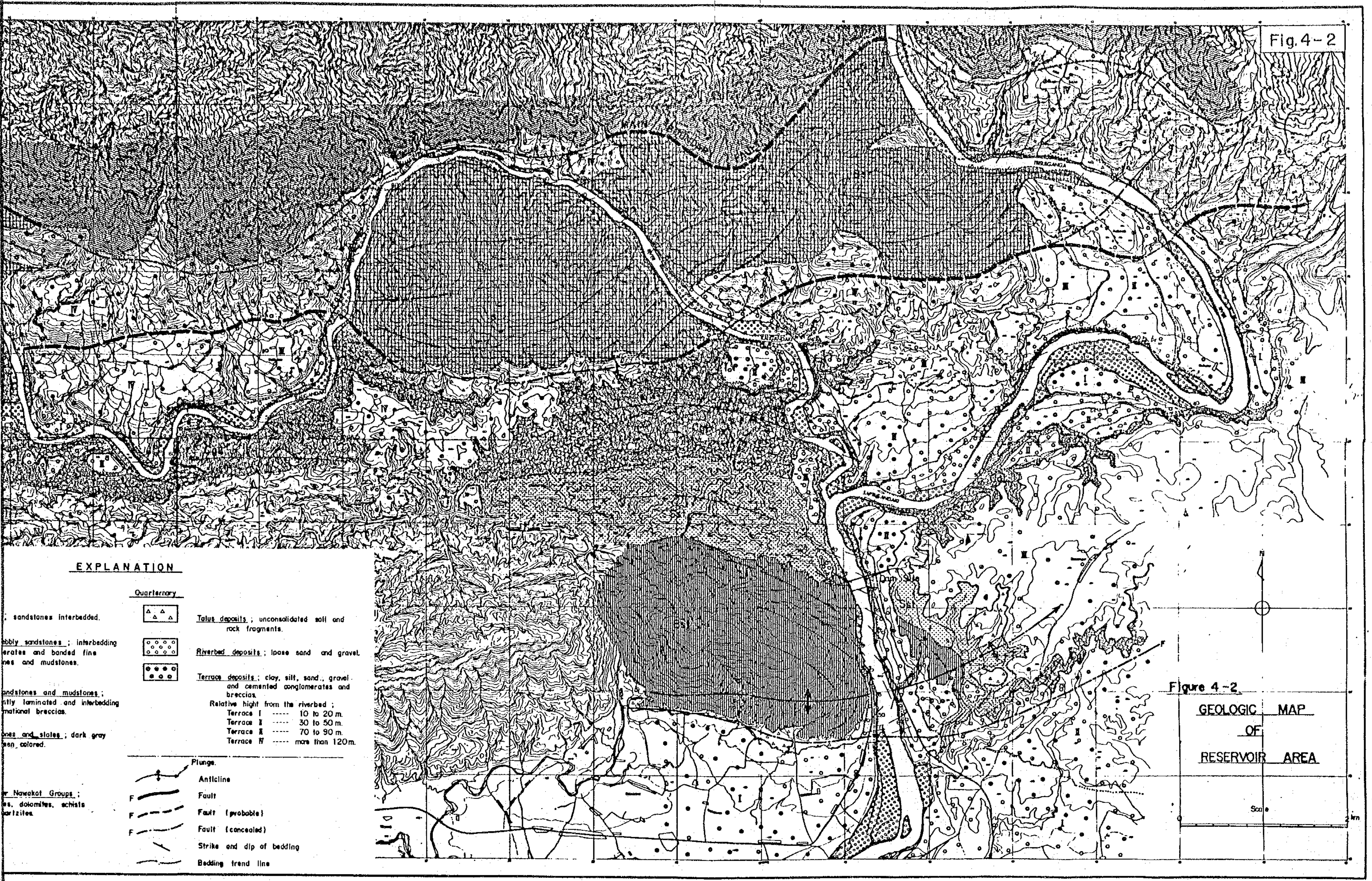
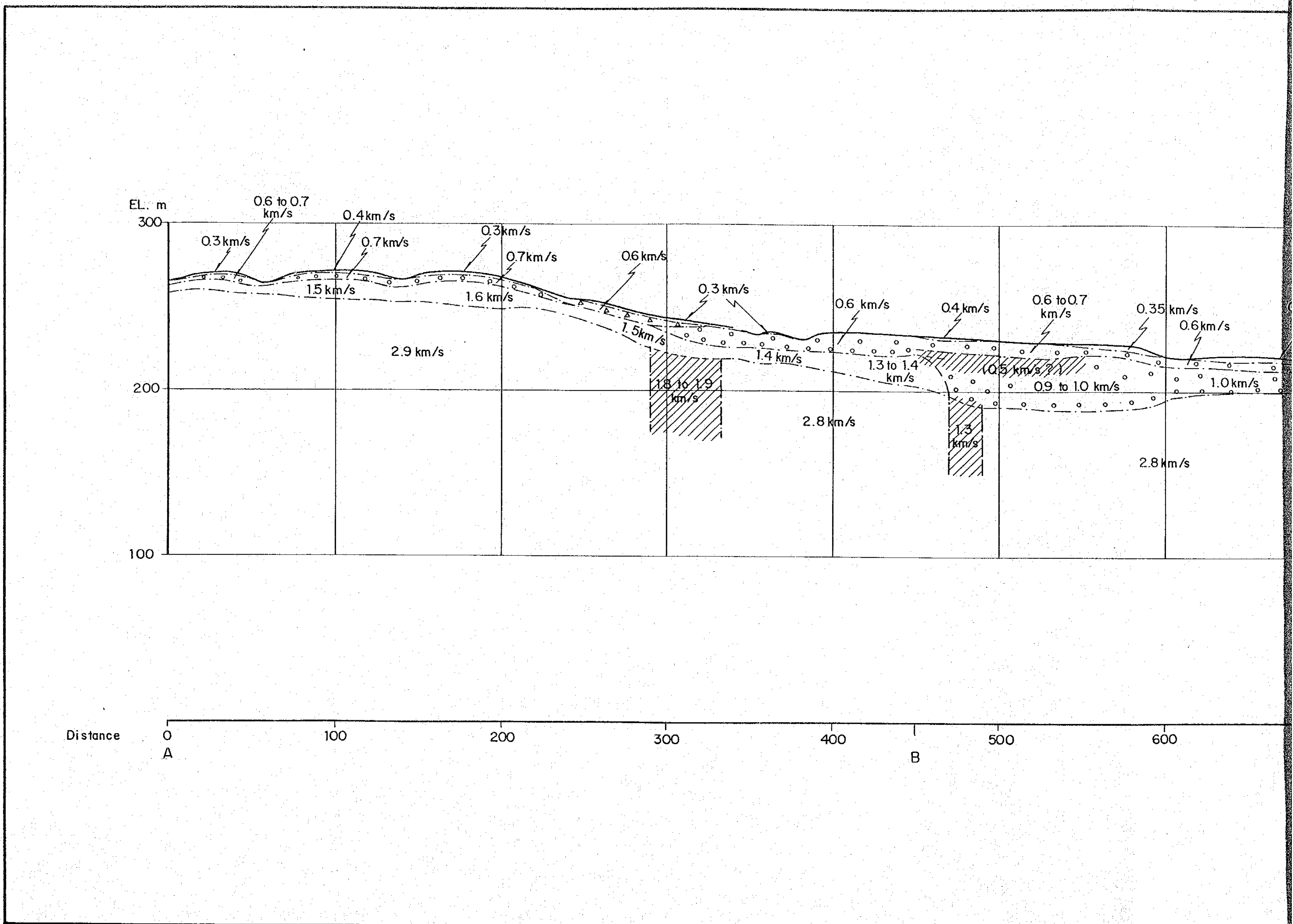


Figure 4-2
GEOLOGIC MAP
OF
RESERVOIR AREA



EL. m
300
200
100
0.3 km/s
0.6 to 0.7 km/s
0.4 km/s
0.7 km/s
0.3 km/s
0.7 km/s
0.6 km/s
0.3 km/s
0.6 km/s
0.4 km/s
0.6 to 0.7 km/s
0.35 km/s
0.6 km/s
1.5 km/s
1.6 km/s
1.5 km/s
1.4 km/s
1.3 to 1.4 km/s
(0.5 km/s ?)
0.9 to 1.0 km/s
1.0 km/s
2.9 km/s
1.8 to 1.9 km/s
2.8 km/s
1.3 km/s
2.8 km/s
Distance
0
A
100
200
300
400
B
500
600

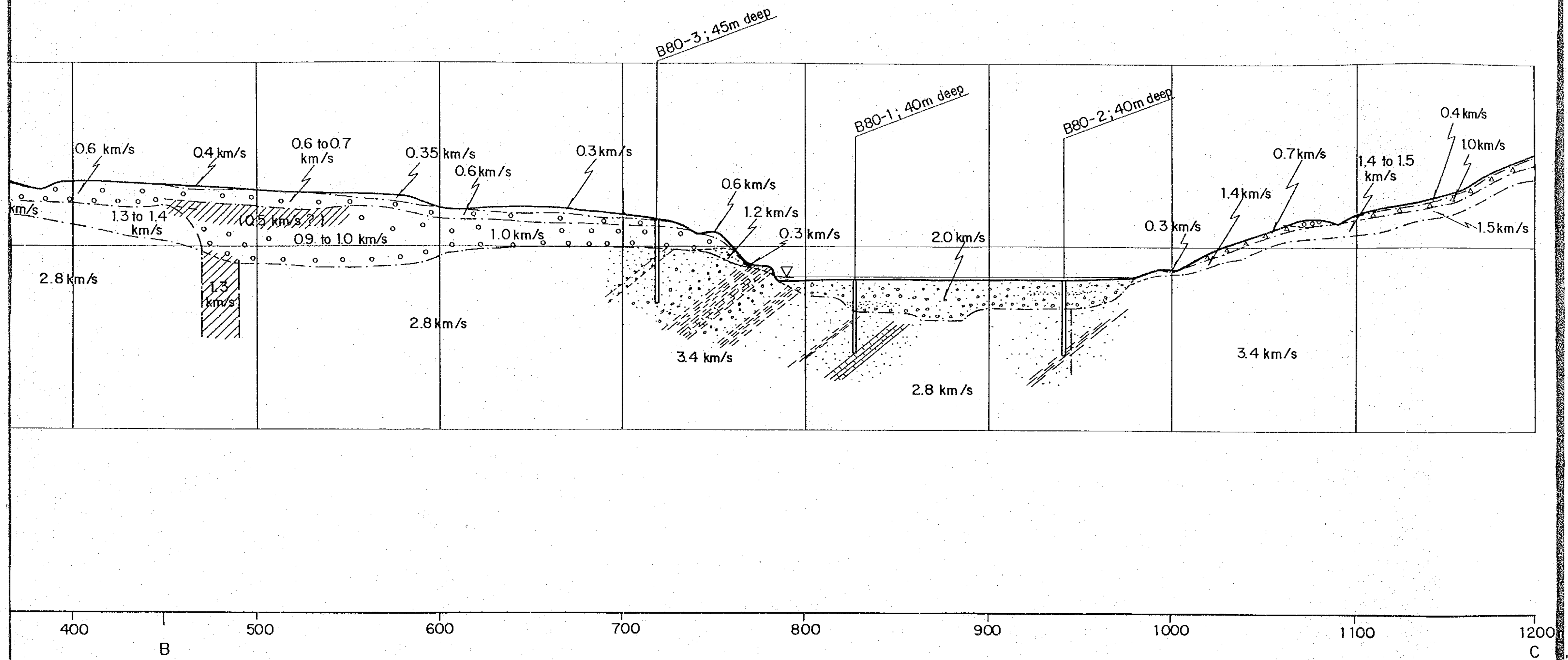


Figure 4 - 3 GEOLOGIC SECTION OF DAMAXIS

Fig. 4 - 3

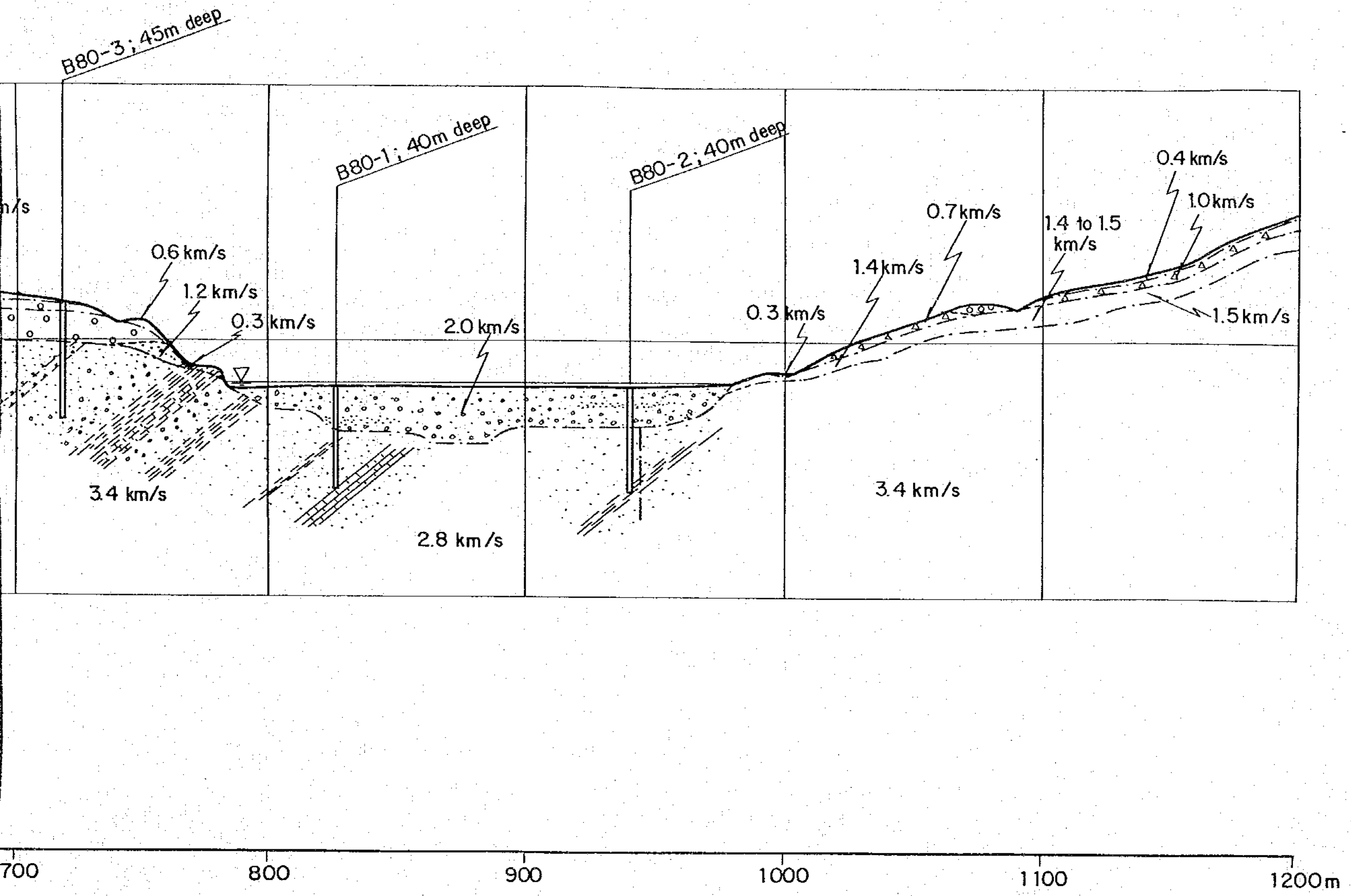
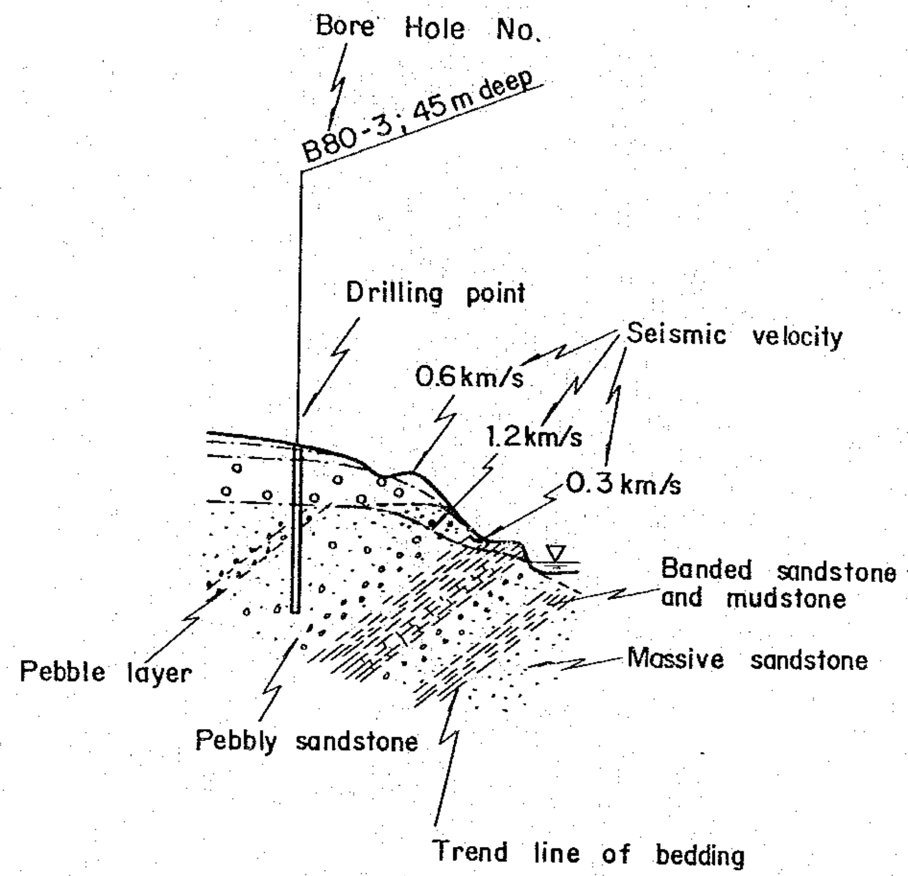


Figure 4 - 3 GEOLOGIC SECTION OF DAMAXIS

Explanation

Talus deposits

Terrace deposits

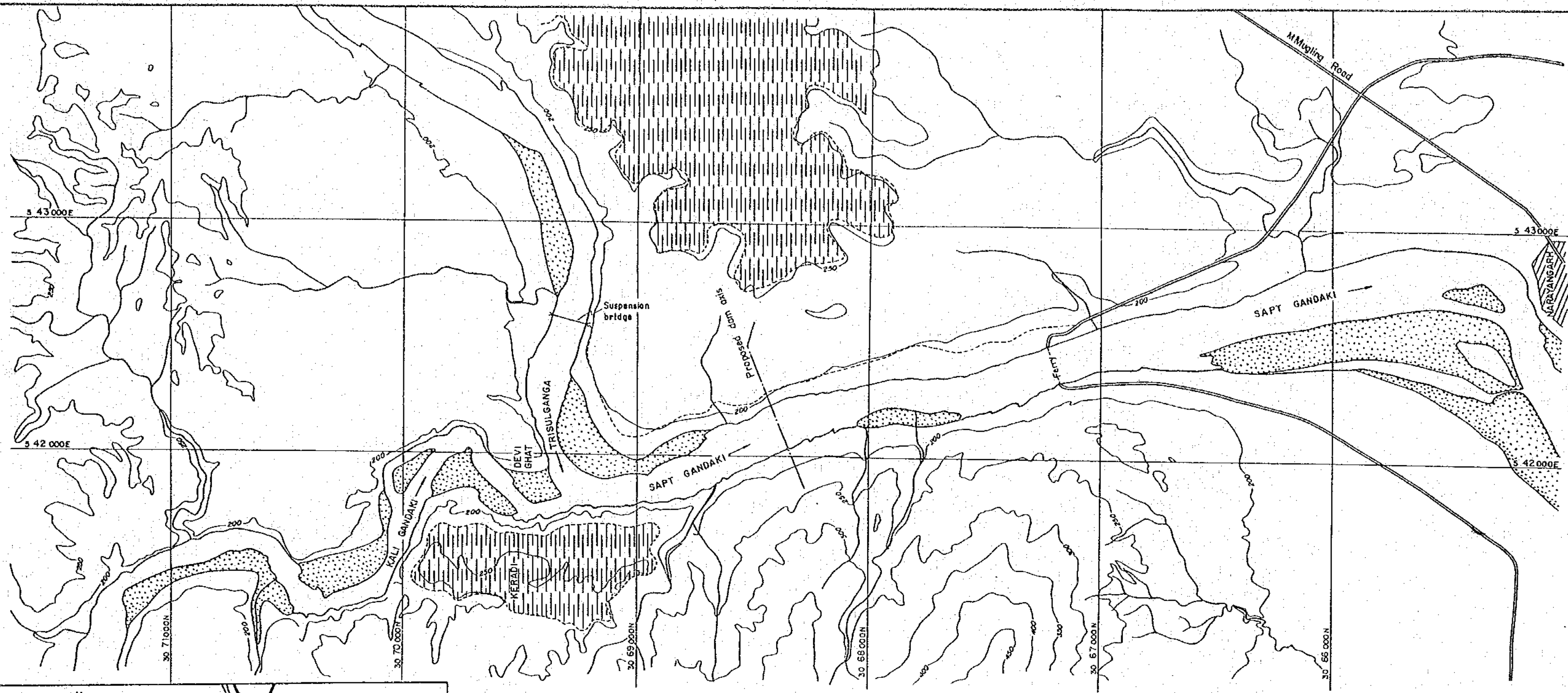


Boundary of seismic velocity

Boundary of rock facies

※ The location of this section is shown in the Fig 4 - 1

Fig. 4-4

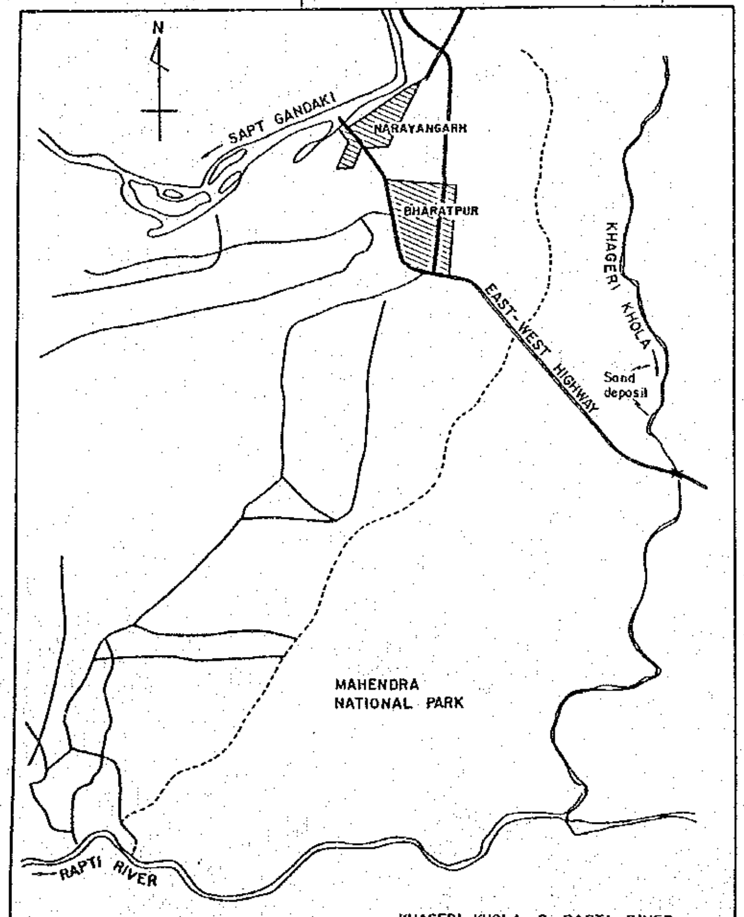


CONCRETE AGGREGATE ROCKFILL AND EARTH CORE

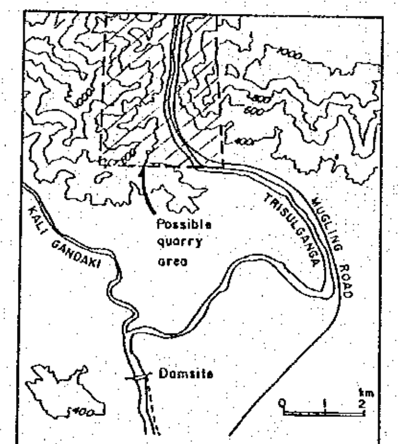
Scale
0 500 1000 m

River gravel for coarse concrete aggregate or gravel fill material

Red soil for impervious earth core



KHAGERI KHOLA & RAPTI RIVER, BORROW PIT FOR FINE AGGREGATE OF CONCRETE



QUARRY ROCK

Figure 4-4 LOCATION MAP OF CONSTRUCTION MATERIAL

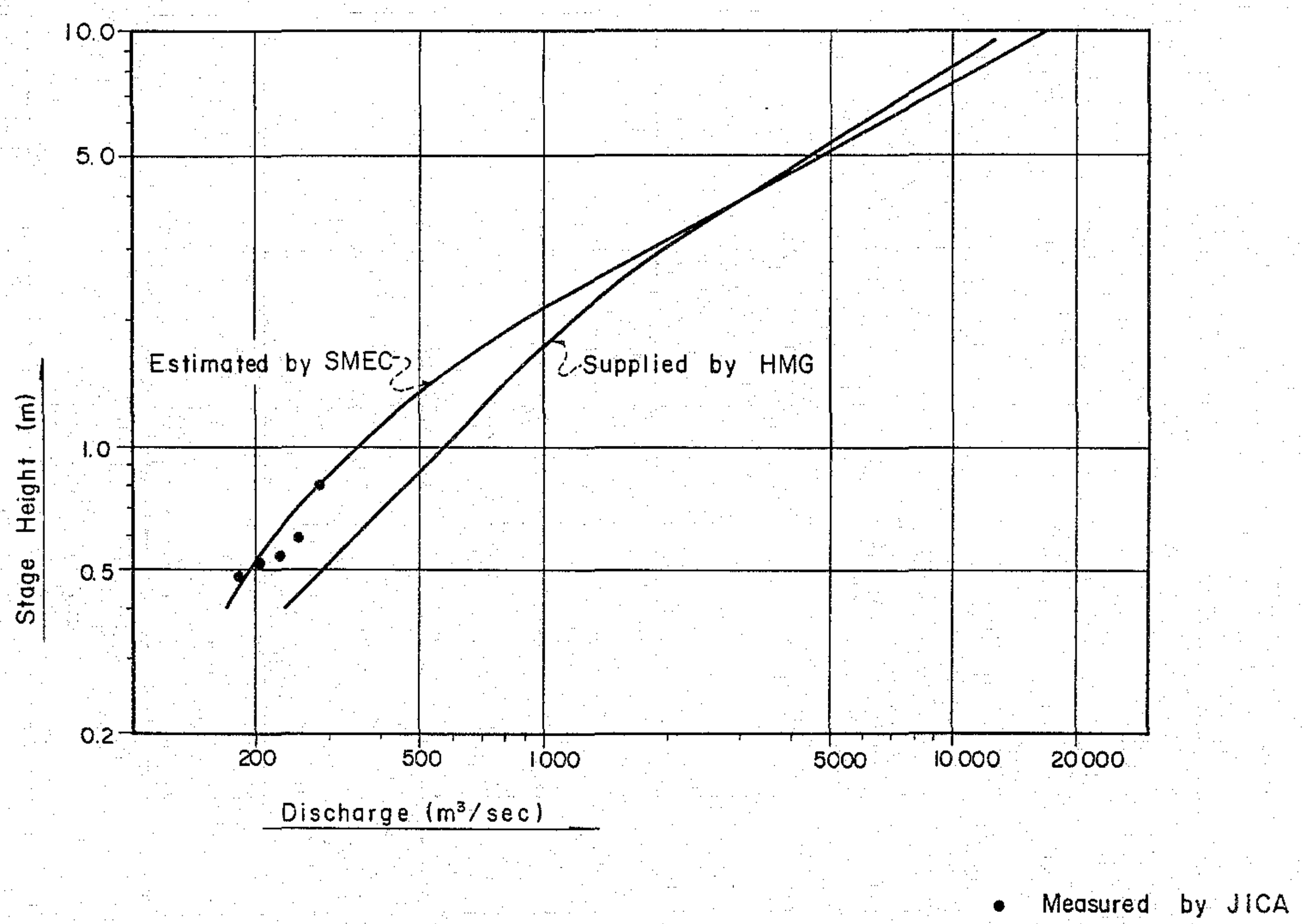


Figure 4-5 DISCHARGE RATING CURVES AT GAGING STATION 450

Fig. 4-5

Fig. 4-6

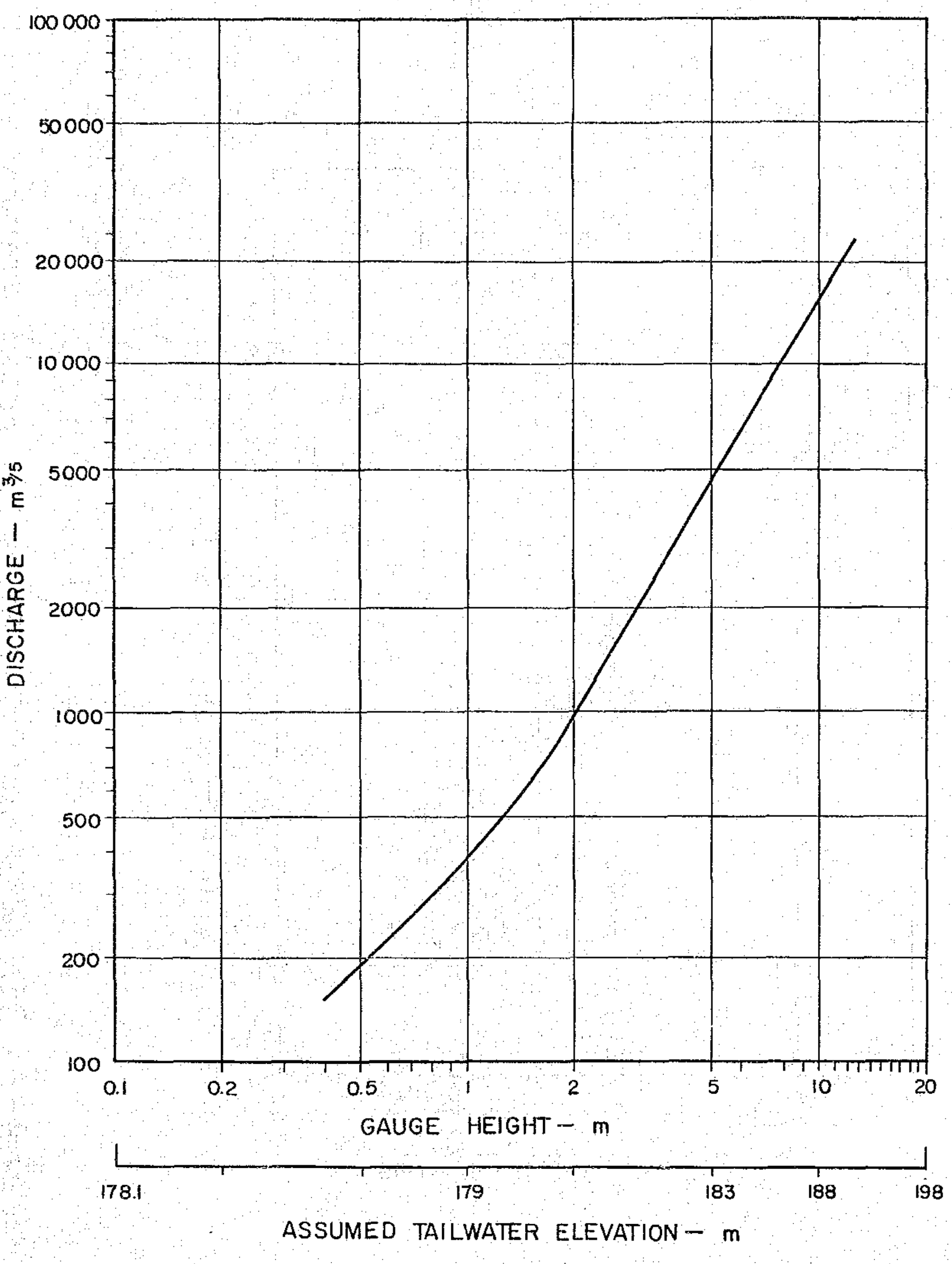


Figure 4-6 DISCHARGE RATING CURVE AT THE DAMSITE

Fig. 4-7

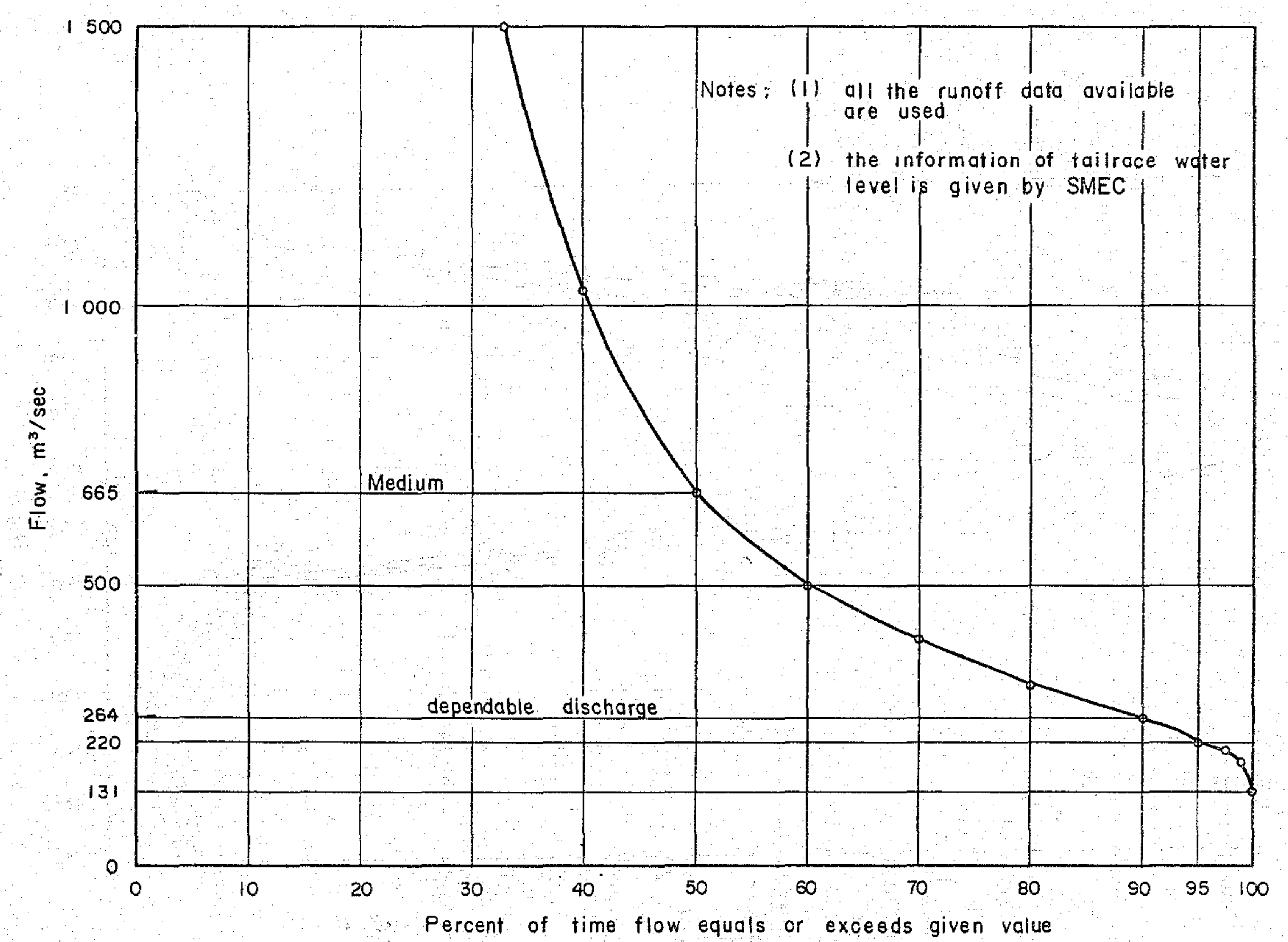


Figure 4-7 FLOW DURATION CURVE