exceeding maximum plant discharge	;	22.1 m³/sec
- Overall efficiency of generating equipment	;	0.84

The installed capacity, firm energy, average energy, secondary energy and guaranteed energy assessed based on these conditions and determined dimensions of the project components are as follows;

- Installed capacity	;	16.8 MW
- Firm energy	;	117,048 MWh
- Average energy	;	129,248 MWh
- Secondary energy	;	12,200 MWh
- Guaranteed energy	;	105,343 MWh

6.5. Study on Benedito Novo Hydropower Scheme

6.5.1 Site and type of dam

Comparison study to select the most appropriate dam axis from among three alternative dam axes was performed in the same manner as explained in paragraph 6.3.1. Location of three alternative dam axes is shown in Fig. 6.16.

In this study, a concrete gravity type dam was adopted due to the same reasons as stated in paragraph 6.3.1. The dam axis -A is located at the upmost of the conceivable river stretch. The river width is about 130 m. The dam axis -B is situated at about 250 m downstream of the dam axis -A, at about intermediate portion of about 25 m high rapid. The river width is about 170 m. The dam axis -C is located at about 250 m downstream from the dam axis -B, at just downstream of about 25 m high rapid. The river width is about 130 m. The dam foundation of these three dam axes is composed of gneiss with hard property.

The full supply level (F.S.L.) of reservoir to keep the daily regulation capacity required for power generation was set for the respective dam axes as follows;

Dam axis	F.S.L (EL.m)
A	290
B	287
C	277

The same criteria for dam section as applied for Salto Pilão (1) scheme were adopted for the concrete gravity dam.

The route of the waterway to the powerhouse was decided selecting relatively thick overburden of the mountain ridge. Total length of the headrace tunnel is as follows;

Dam axis	Length of headrace tunnel (m)
A	2,800
B	2,560
C	2,000

The inside diameter of the headrace tunnel was set at 2.8 m which is the same figure as applied in the master plan but concrete lining was decided at 0.3 m considering the rock property. As for a type of surge tank, simple type was assumed and its inside diameter was assumed to be 4 times that of the headrace tunnel. An underground inclined pressure shaft type was adopted for penstock line considering geological condition of the penstock line route. The total length of the penstock line was estimated to be 390 m. The penstock line with one lane and a diameter of 2.2 m was adopted. An open-air type powerhouse of 21 m wide and 38.5 m long was adopted. Considering the extent of the effective head and installed capacity, Francis type power generating equipment was adopted. About 17 km long and 69 kV transmission line to Timbó substation was planned. General plan of the project facilities is shown in Fig. 6.17.

Based on the dimensions of the project components, work quantities for the case of three dam axes were estimated. Using the same unit prices as applied for the master plan, the construction cost was estimated. Result of the estimation is summarized as follows;

Dam axis	Const. Cost (million US$)
A	32.2
B	33.3
C	31.1

The power energy to be generated for the cases of three dam axes was assessed assuming the following tail water level (T.W.L);

Discharge	TWL (EL.m)
Firm discharge;	154.2
Max. plant discharge;	154.3

The assessed firm energy, guaranteed energy and secondary energy are as follows;

(Unit; MWh)

Dam axis	Firm energy	Guaranteed energy	Secondary energy
A	80.6	72.6	12.8
B	78.9	71.0	12.5
C	73.1	65.7	11.7

Based on the estimated construction cost and power energy, unit cost of the guaranteed energy was estimated as shown in Table 6.1. It shows that the unit cost of the guaranteed energy for the case of dam axis-A, US$43/MWh is the smallest value among three cases.

According to the result of environmental impact study, number of household and acreage of land, which will be affected by the scheme, were estimated as follows;

Dam axis	Number of household	Acreage of land (km2)
A	112	0.31
B	28	0.17
C	23	0.03

It shows that large effect exerts to the riparian area if the dam axis-A is adopted, and effect on the dam axis-C is the minimum.

The second smallest unit cost of the guaranteed energy is US$45.6/MWh for the case of dam axis-B. The unit cost of the guaranteed energy for dam axis-C is US$45.9/MWh. Difference of unit cost of guaranteed energy between the cases of dam axes-A and -C is US$2.9/MWh, and decrease in the guaranteed energy in case of dam axis-C against that for the dam axis-A is about 9 %. In consideration of both the economic and environmental aspects, the dam axis-C was selected for further study.

6.5.2 Optimization study and pre-feasibility design of project components

(1) River diversion

Since the proposed damsite is located at an intermediate portion of the river channel bent sharply toward the left side, the diversion tunnel was planned to be located in the left bank connecting the V-shaped river channel directly. The planned length of the diversion tunnel is 155 m. In view of the concrete gravity dam type, design peak flood for river diversion was decided to be 280 m^3/sec with 2-year probability.

In order to lower the height of upstream cofferdam, a free flow type diversion tunnel was adopted in this study. The result of hydraulic calculation showed that diameter of the diversion tunnel is 4.5 m and maximum water level to discharge the design peak flood of 280 m^3/sec is EL 269.7 m. A concrete gravity type cofferdam was planned for upstream cofferdam. Crest elevation of the upstream cofferdam was decided at EL 270.5 m considering a freeboard of 0.8 m. Maximum height of the upstream cofferdam is 10.5 m.

(2) Dam

Both river banks of the damsite form a mountainous area with a relative height of 40 m in the left bank and 160 m in the right bank. The river width is about 130 m. The foundation rock is composed of gneiss associated partly with granite. The left bank is covered with weathered gneiss. In the right bank, talus deposit covers the ground surface. Considering these topographic and geological conditions, a concrete gravity type dam was adopted. The excavated depth of foundation rock was estimated to be about 2 m in the river bed, 5 m in the left bank and 3 to 5 m in the right bank. Full supply level of the reservoir was set at EL 277 m to keep the daily regulation capacity of 158,000 m^3 for power generation. The dam section was determined based on the stability analysis and the following section was adopted;

-	Upstream slope	;	Vertical
-	Downstream slope	;	1 : 0.9
-	Crest width	;	4.5 m
-	Freeboard above full supply level	;	1.5 m

The dam thus planned is 130 m in crest length, EL 278.5 m in crest elevation and 24.5 m in maximum height.

(3) Spillway

In view of the topographic condition, an overflow type spillway with gates was planned to be provided in the dam body. The flood peak discharge of 1,500 m^3/sec with 200-year probability was adopted for design of the overflow weir. Width of the overflow weir was determined considering the flow area of the river channel in upstream and downstream of the damsite and also the size of gates (ratio of the height to the width). The width of the overflow weir was decided at 34 m assuming that 2 units of 17 m wide roller gate are installed. Total width of the overflow weir is 43 m. The crest elevation was calculated in the same manner as mentioned in paragraph 6.3.2 (3). The determined crest elevation of the overflow weir is EL 263.9 m. The crest elevation of hoist deck was decided at EL 296 m. In order to release safely the outflowed flood discharge by changing to a steady flow, a horizontal stilling basin of 50 m in length was planned.

(4) Intake

The intake structure was planned to be provided at right angle against the dam axis in the right river bank. In order to avoid the flowing of sediment into the headrace tunnel, sand trap basin was planned. Bottom elevation and dimension of the sediment sand trap basin were determined based on the flow velocity at full supply level and minimum operation level and referring to the topographic condition at the basin site. Consequently, two units of the basin with sill elevation of 267 m and 40 m long and 24 m wide were planned. Besides, orifice type sediment scouring gate of 8 m high and 4 m wide will be installed at the front of the intake structure. For sake of maintenance of the sand trap basin and headrace tunnel, two roller gates were planned in front of the sand trap basins. General plan and profile of the project facilities at the damsite are shown in Fig. 6.18.

(5) Headrace tunnel

The proposed powerhouse is located at the right bank of the Benedito river, at just upstream of Benedito Novo. The waterway route connecting the damsite and the powerhouse was decided considering the conditions as stated in paragraph 6.3.2 (5), and the route as shown in Fig. 6.19 was decided. Total length of the headrace tunnel is 1,815 m.

The diameter of the headrace tunnel was determined from two aspects, namely, economic comparison and allowable flow velocity in view of operation and maintenance of the tunnel. The headrace tunnel was designed to be of pressure type with circular section. The economical comparison was made in the same manner as stated in paragraph 6.3.2 (5). The result of the economic comparison shows that the case of 2.8 m in inside diameter is the one with least cost.

The allowable flow velocity in the headrace tunnel in view of operation and maintenance has been decided at 2.5 m/sec to 3.5 m/sec. The flow velocity for the case of the maximum plant discharge, 13.9 m^3/sec was estimated at 2.3 m/sec. Thus inside diameter of the headrace tunnel was decided at 2.8 m.

(6) Surge tank

A simple type surge tank was applied in this study. The dimension of the surge tank was determined so as to satisfy dynamic stability conditions by rising of water level for instantaneous full load rejection and lowering of water level for instantaneous load increase from half to full load. As a result, the simple type surge tank with inside diameter of 10 m, 255.1 m in bottom elevation and 286.4 m in top elevation was planned. In view of the connection of the underground inclined pressure shaft type penstock, underground embedded type concrete structure as shown in Fig. 6.20 was designed. The lining of the surge tank was decided at 1 m considering the geological condition that the surge tank structure is provided in gneiss zone which is hard and massive rock.

(7) Penstock line

The proposed penstock is of underground inclined pressure shaft type with one lane. Its route passes through gneiss layer which is hard and massive rock. Total length of the penstock was estimated to be 455 m consisting of 10 m in upper horizontal part, 135 m in inclined part and 310 m in lower horizontal part. Open air steel conduit type penstock line is conceivable as an alternative plan. However, the ground surface along the penstock line is covered with about 10 m thick weathered layer and talus deposit consisting of boulder and they have a tendency of sliding. It is therefore judged that open air steel conduit type penstock line is unsuitable due to huge excavation works and slope protection works.

The diameter of the penstock was determined by economic comparison and allowable flow velocity as stated for the determination of the diameter for the headrace tunnel. The result of the economic comparison shows that the average inside diameter of 2.2 m is the least value. Allowable flow velocity is limited within 7 m/sec. The flow velocity for the maximum plant discharge, 13.9 m^3/sec is 3.7 m/sec. Thus, the penstock line with average diameter of 3.2 m including working clearance of 0.4 m and extra excavation of 0.1 m was planned. It was planned that one lane steel lined circular tunnel is branched into two lanes at immediately upstream of the powerhouse. General plan and profile of the penstock line are shown in Fig. 6.20.

(8) Powerhouse and tailrace

The open air type powerhouse was planned to be provided at the right bank of the Benedito river, at just upstream from Benedito Novo. Result of geological investigation shows that the hard gneiss layer distributes at 5 to 14 m from the ground surface.

The turbine center was set at an elevation of 152.1 m which is 2.1 m lower than the normal tailwater level. The lowest elevation below the draft tube was set at an elevation of 147.9 m. The ground formation height of the power station was set at an elevation 153 m which is 1.85 m higher than the water level in case of 100-year probable flood. The determined dimension of the powerhouse are 21.6 m high, 21.1 m wide and 30.8 m long. About 45 m long open channel type tailrace to the Benedito Novo river was planned. General plan and profile of the powerhouse are shown in Fig. 6.20.

(9) Generating facilities

Two sets of hydro turbine generator and their auxiliary equipment will be installed in the powerhouse. One set of overhead travelling crane of 20 ton capacity will be provided in the powerhouse for hauling heavy power station equipment. 69 kV switchgear will be arranged in the outdoor switchyard.

Considering working head and rated output, the hydraulic turbine will be of vertical shaft Francis type and their particulars are as follows;

(i) Hydraulic conditions

- Reservoir water level		
Full supply level	;	277 m
Minimum operation level	;	270 m
Rated	;	277 m
- Tail water level	;	154.2 m
- Gross head		
Maximum	;	122.8 m
Minimum	;	115.8 m
- Rated head	;	115 m
- Maximum discharge	;	13.9 m^3/sec

(ii) Hydraulic turbines

- Type ; Vertical shaft Francis
- Rated head ; 115 m
- Number of unit ; 2
- Rated output ; 6.8 MW
- Speed ; 720 rpm

The generator will be vertical shaft alternator directly coupled with the hydraulic turbine with particulars as follows;

- Type ; Vertical shaft, suspension type, synchronous generator
- Number of unit ; 2
- Rated output ; 6.6 MW
- Rated capacity ; 7.8 MVA
- Rated voltage ; 6.6 kV

(10) Transmission line

A 69 kV transmission line was planned to be connected with this power plant and existing substation at Timbó. Total length of the transmission line is about 17 km.

6.5.3 Assessment of power output and energy

Based on the determined dimensions of the project components, power output and energy were assessed based on the following conditions;

- Normal operation level ; 277 m
- Tailwater level ; 154.2 m
- Firm discharge ; 8.4 m^3/sec
- Maximum plant discharge ; 13.9 m^3/sec
- Long term average discharge excluding the parts of discharge exceeding maximum plant discharge ; 9.8 m^3/sec
- Overall efficiency of generating equipment ; 0.84

The installed capacity, firm energy, average energy, secondary energy and guaranteed energy assessed based on these conditions and determined dimensions of the project components are as follows;

- Installed capacity ; 13.2 MW
- Firm energy ; 72,689 MWh
- Average energy ; 84,097 MWh
- Secondary energy ; 11,408 MWh
- Guaranteed energy ; 65,420 MWh

7. CONSTRUCTION PLAN AND COST ESTIMATE

7.1 Construction Plan and Cost Estimate for Salto Pilão (1) Hydropower Scheme

7.1.1 Conditions for construction

The following conditions and assumptions were applied to the construction planning;

(i) Considering the extent of scale of the construction works, it is herein assumed to execute the project works by contractor or supplier who will be selected through international competitive bidding.

(ii) Based on the daily rainfall records at Rio do Sul gauge as well as the annual number of Sunday and national holidays in the country, the annual workable days for construction works were set at 250 in which rainfall intensity is less than 10 mm per day. The daily working hour are set at 8 except for the tunnel work for which 2 shifts operation with 15 hours will be applied.

(iii) Conventional method and type of equipment are principally applied.

7.1.2 Construction time schedule

Fig. 7.1 shows a proposed implementation schedule of the project. The construction works of the project are scheduled to be executed during 4 years including 6 months for the preparatory works. Fig. 7.2 shows the proposed construction time schedule including the preparatory works.

7.1.3 Construction plan

(1) River diversion works

The diversion tunnel to be constructed in the left bank of the damsite is 560 m long and horse shoe-shaped concrete lined tunnel of 9.8 m in inside diameter. The diversion tunnel works are planned to be executed in a period of 6 months. The estimated work quantities are 160,600 m^3 of excavation and 26,600 m^3 of concrete. The full face excavation method will be applied for the tunnel excavation using 6-boom drill jumbo, side dump truck shovel and dump truck. H-shaped steel supports with an interval of 1.2 m will be installed over the whole length of the tunnel. The concrete lining work will be executed using a sliding form, concrete pump and agitator truck.

Primary upstream and downstream cofferdams will be constructed by earth embankment immediately after the diversion tunnel is completed. After river diversion, 17 m high upstream cofferdam of concrete gravity type will be constructed. The concrete volume was estimated at 32,300 m^3. The concrete work will be executed by chuteway method using concrete pump and agitator truck.

The diversion tunnel will be closed by a roller gate upon completion of all of the works. After closing the gate, the diversion tunnel will be plugged with concrete. A combination of agitator truck, concrete pump and grout pump will be used for the plugging works.

(2) Main works

(i) Dam and spillway

A concrete gravity type dam having 70,600 m3 in total volume and 20.5 m in maximum height will be constructed at the proposed damsite. Excavation of dam foundation will be commenced at both abutments before river diversion. Excavation of river bed portion will be carried out currently with the construction of the primary cofferdam. The required excavation volume is 110,000 m^3. A combination of 32 ton class bulldozer with ripper, 10 m^3/min class crawler drill, 2.2 m^3 class tractor shovel and 11 ton class dump truck is planned to be used. The excavated materials will be transported to the proposed spoil bank. Foundation treatment for the dam bed rock will be carried out by consolidation and curtain groutings. The estimated grout length is 6,400 m in total. Crawler drill, boring machine, grout pump and concrete mixer will be used for this work. Immediately after completion of foundation treatment and clearing of bed rock, concrete placing will be executed by chuteway method mainly using concrete pump, vibrator and other concreting equipment. A concrete mixing plant of 90 m^3/h in capacity will be installed near the damsite. Concrete placing for the spillway structure will be executed succeeding to the dam concreting works. Installation work of the spillway gates will be carried out after all of the civil works for the dam are completed. The required period for dam construction works is 41 months.

(ii) Intake and headrace tunnel

The intake structure with gates and sand trap basins will be constructed at the right bank of the damsite. The excavation volume of the intake site was estimated at 317,000 m^3.

Excavation of the intake will be carried out by combination of bulldozer, crawler drill, crawler loader and dump truck. The estimated volume of concrete for the intake is 40,800 m^3. Chuteway method using concrete pump will be applied for placing the intake concrete. Since the intake structure is provided toward the reservoir area, rim grouting will be executed along the foot of the intake structure. Installation of the gates will be performed after all of civil works for the intake structure are completed.

The construction works of the circular type headrace tunnel with 5.2 m in inside diameter and 6,305 m in total length, which are the critical work for this project, will be commenced immediately after completion of a series of the temporary works. The work quantity of the tunnel was estimated to be 217,000 m^3 of excavation and 57,300 m^3 of concrete. In order to reduce the construction period, the construction works will be executed by dividing into two stretches by providing two adit tunnels as shown in Fig. 7.3. The length of the adits is 900 m for No.1 and 150 m for No. 2. It is planned to execute the construction of the headrace tunnel within a period of 41 months. Excavation of the tunnel will be carried out by full face excavation method using 6-boom drill jumbo. About 60 % of the excavated rock will be transported to the stock pile for concrete use and the remaining to the spoil bank. A combination of crawler loader and dump truck is planned to be used for this work. Steel support will be used for about 110 m long fault zone and 500 m long inlet portion where there is no sufficient overburden. Concrete lining work will be executed in two stages; arch lining and inverted lining by combination of concrete pump and agitator truck. Consolidation grouting with 3 m in interval will be executed for the stretch with fault zone and about 500 m long inlet portion using groutings pump and concrete mixer.

(iii) Surge tank

A surge tank, 20 m in inside diameter and 55 m in height will be constructed at the end portion of the headrace tunnel. The estimated work quantity is 183,200 m^3 of excavation and 4,150 m^3 of concrete lining. Excavation of the surge tank will be carried out by pilot heading - enlargement method using a raise climber, leg drill and crawler loader. It will be initiated from the headrace tunnel side and excavated rock will be transported to the spoil bank through No. 2 adit tunnel using dump truck. Concrete lining will be placed by concrete pump and agitator truck from the lower portion upward. Consolidation grouting with 3 m in interval will be executed after completion of the lining work.

(iv) Penstock

The underground type penstock with an average diameter of 3.8 m consists of 20 m long horizontal tunnel in upper part, 233 m long inclined shaft portion and 252 m long horizontal tunnel in lower part. The estimated work quantities are 19,000 m^3 of excavation, 4,100 m^3 of concrete lining and 1,710 tons of penstock pipe. The work execution period is planned to be 19 months. Excavation work of the penstock tunnel will be initiated from upper and lower horizontal parts in the same way as applied for the headrace tunnel through No.2 adit tunnel near the surge tank site and No.3 adit tunnel of 250 m in length near the powerhouse respectively. Excavation of the inclined shaft will be executed by pilot heading - enlargement method. The excavated rock will be transported to the spoil banks by dump truck through No. 2 and No. 3 adit tunnels. After completion of the excavation work, steel liners will installed and concrete will be placed between the steel liner and excavated rock surface by concrete pump and agitator truck. Following this concrete filling work, consolidation grouting with 3 m in interval will be carried out.

(v) Powerhouse and tailrace

An open-air type powerhouse and open channel tailrace will be constructed at the right bank of the Itajai river near Subida. The estimated work quantities are 282,400 m^3 of excavation and 25,000 m^3 of concrete for substructure of powerhouse and tailrace. The work execution period is planned to be 38 months. Excavation for the foundation of substructure will be carried out by combination of crawler drill, bulldozer, loader and dump truck. Concrete work for substructure and superstructure and tailrace will be executed by concrete pump and chuteway method. A concrete plant having 50 m3/h in mixing capacity will be installed close to the powerhouse site. Installation work of the power generating equipment will be carried out during the period of 18 months after completion of the civil works.

7.1.4 Cost estimate

(1) Basic conditions

The construction cost was estimated based on the following basic conditions;

(i) Unit costs for major work items are estimated at price level of May, 1991 referring to similar projects executed recently by CELESC and other agencies.

(ii) Costs of miscellaneous works in each major work item are estimated at around 5 % of the cost of major works.

(iii) Regarding costs for compensation for the submerged and construction areas, the survey results performed by CELESC are referred.

(iv) Cost of engineering service is estimated to cover remuneration for foreign and local consultants, direct expenses etc.

(v) Administration cost is estimated at 5 % of total direct construction cost.

(vi) Physical contingency accounting for 15 % of the total direct construction cost plus engineering service, administration and compensation cost is added.

(2) Total construction cost

The total construction cost including physical contingency was estimated at US$178.2 million as shown in Table 7.1.

(3) Disbursement schedule

Based on the construction time schedule, the construction fund to be disbursed in each construction year was estimated as shown in Table 7.2 assuming that the project works are executed by contractor or supplier who will be selected through an international competitive tendering and 20% of the construction cost is disbursed as an advance payment.

7.2 Construction Plan and Cost Estimate for Dalbergia Hydropower Scheme

7.2.1 Conditions for construction

The conditions and assumptions to be applied for construction planning are the same as those adopted for Salto Pilão (1) hydropower scheme.

7.2.2 Construction time schedule

Fig. 7.4 shows a proposed implementation schedule of the project. The construction works of the project are scheduled to be executed during 3 years and 7 months including 6 months for the preparatory works. Fig. 7.5 shows the proposed construction time schedule.

7.2.3 Construction plan

(1) River diversion works

A 155 m long and horse shoe-shaped concrete lined diversion tunnel with a 6.8 m in inside diameter will be constructed in the left bank of the damsite. The tunnel works are planned to be executed within 5 months. The estimated work quantities are 92,000 m3 of excavation and 6,400 m^3 of concrete. The full face excavation method will be applied for the tunnel excavation using 4-boom drill jumbo and dump truck. Concrete lining work will be executed using sliding form, concrete pump and agitator truck.

Primary upstream and downstream cofferdams will be constructed by earth embankment immediately after the diversion tunnel is completed. After river diversion, 13 m high upstream cofferdam of concrete gravity type will be constructed. The concrete volume was estimated at 18,700 m3. The works will be executed by chuteway method using concrete pump and agitator truck.

The diversion tunnel will be closed by roller gate upon completion of all of the works. After closing the gate, diversion tunnel is plugged with concrete. Concrete pump, grout pump and agitator truck will be used for this work.

(2) Main works

(i) Dam and spillway

A concrete gravity type dam having 22.5 m in maximum height and 113,500 m^3 in total volume will be constructed at the proposed damsite. The required excavation volume is 368,700 m3. The construction works of the dam are planned to be executed in a period of 37 months. Excavation of dam foundation will be commenced at both abutments before river diversion. Excavation of river bed portion will be carried out currently with the construction of the primary cofferdam. A combination of bulldozer with ripper, crawler drill, crawler loader and dump truck is planned to be used. The excavated materials will be transported to the spoil banks. Foundation treatment for dam bed rock will be carried out by consolidation and curtain groutings. The estimated grout length is 8,460 m in total. Crawler drill, boring machine, grout pump and concrete mixer will be used for this work. Immediately after completion of the foundation treatment and clearing of river bed, concrete placing will be executed by chuteway method mainly using concrete pump, vibrator, and other concreting equipment. A concrete mixing plant with a capacity of 90 m^3/h will be installed near the damsite. Concrete placing for spillway structure will be executed succeeding to the dam concrete works. Installation work of the spillway gates will be carried out after all of the civil works for the dam are completed.

(ii) Intake and headrace tunnel

The intake structure with gates and sand trap basins will be constructed at the right bank of the damsite. The estimated work quantities are 90,400 m^3 of excavation and 9,200 m^3 of concrete. Excavation of the intake will be carried out by combination of bulldozer with ripper, crawler drill, crawler loader and dump truck. Concrete placing work will be carried out by chuteway method using concrete pump and agitator truck. Installation work of the gates will be carried out after completion of the civil works.

The construction works of the circular type headrace tunnel with 3.6 m in inside diameter and 8,720 m in total length, which are the critical work for this project, will be commenced immediately after the completion of a series of temporary works. The estimated work quantities are 149,300 m^3 of excavation and 35,800 m^3 of concrete. The construction works of the headrace tunnel are planned to be executed within 37 months. In order to meet the required construction period, the construction works will be executed by dividing into three stretches by providing three adit tunnels as shown in Fig. 7.6. Length of the adit tunnel is 650 m for No. 1, 550 m for No. 2 and 100 m for No. 3. Excavation of the tunnel will be carried out by full face excavation method using 4-boom drill jumbo. About 50 % of the excavated rock will be transported to the stock pile for concrete use and the remaining to the spoil bank. Excavated materials will be transported by battery locomotive and mucking car on rail. A train loader will be provided behind the rocker shovel. Steel support will be used for 110 m long fault zone and 300 m long inlet portion. Concrete lining work will be executed in two stages; arch lining and inverted lining by combination of concrete placer and agitator car. Consolidation grouting with 3 m in interval will be executed for the fault zone and about 300 m long inlet portion.

(iii) Surge tank

A surge tank, 14 m in inside diameter and 61 m in height will be constructed at the end of the headrace tunnel. The estimated work quantities are 54,200 m^3 of excavation and 3,400 m^3 of concrete. Excavation of the surge tank will be carried out by pilot heading-enlargement method using a raise climber, leg drill and rocker shovel. Construction method is the same as that applied for the headrace tunnel of Salto Pilão (1) hydropower scheme. Excavated bed rock will be transported to the spoil bank through No. 3 adit tunnel. Concrete lining will be executed by concrete pump and agitator truck from lower portion upward. Consolidation grouting with 3 m in interval will be executed succeeding the concrete lining work.

(iv) Penstock

The underground type penstock with an average diameter of 2.9 m consists of 23 m long horizontal tunnel in upper part, 71 m long inclined shaft portion and 430 m long horizontal tunnel in lower portion. The estimated work quantities are 41,900 m^3 of excavation, 3,350 m^3 of concrete and 645 tons of penstock pipe. Excavation work of the penstock tunnel will be initiated from upper and lower horizontal parts in the same way as applied to the headrace tunnel. The excavated rock will be transported to the spoil bank through No. 3 adit tunnel near the surge tank and No. 4 adit tunnel with 150 m in length near the powerhouse respectively. Excavation of the inclined shaft will be executed by pilot heading - enlargement method. After completion of the excavation, steel liners will be installed and concrete is placed between the steel liners and excavated rock surface. Consolidation grouting with 3 m in interval will be executed succeeding to the concrete filling work.

(v) Powerhouse and tailrace

An open-air type powerhouse and open channel tailrace will be constructed at the river bank of the Itajai do Norte river near Ibirama. The estimated work quantities are 30,000 m^3 of excavation and 15,300 m^3 of concrete for substructure of powerhouse and tailrace. The work execution period is planned to be 31 months. Excavation of the foundation of the substructure will be carried out by a combination of crawler drills, bulldozer, loader and dump truck. Concrete work for substructure and superstructure and tailrace will be executed by concrete pump and chuteway method. A concrete plant with a capacity of 50 m^3/h will be installed close to the powerhouse site. Installation work of the power generating equipment will be carried out during the period of 17 months after the completion of the civil works.

7.2.4 Cost estimate

The construction cost of the project was estimated based the same conditions as applied for Salto Pilão (1) hydropower scheme. The estimated construction cost is US$102.2 million as shown in Table 7.3. Based on the construction time schedule, the construction fund to be disbursed in each construction year was estimated as shown in Table 7.2.

7.3 Construction Plan and Cost Estimate for Benedito Novo Hydropower Scheme

7.3.1 Conditions for construction

The conditions and assumptions to be applied for construction planning are the same as those adopted for Salto Pilão (1) hydropower scheme.

7.3.2 Construction time schedule

Fig. 7.7 shows a proposed implementation schedule of the project. The construction works of the project are scheduled to be executed during 3 years including 6 months for the preparatory works. Fig. 7.8 shows the proposed construction time schedule.

7.3.3 Construction plan

(1) River diversion works

A diversion tunnel, 155 m long and horse shoe-shaped concrete lined type with 4.5 m in inside diameter will be constructed in the left bank of the damsite. The tunnel works are planned to be executed in a period of 5 months. The estimated work quantities are 15,700 m^3 of excavation and 3,100 m^3 of concrete. The full face excavation method will be applied for the tunnel excavation using 2-boom drill jumbo and dump truck. Concrete lining work will be executed using sliding form and concrete pump and agitator truck.

Primary upstream and downstream cofferdams will be constructed by earth embankment immediately after the diversion tunnel is completed. After river diversion, 10.5 m high upstream cofferdam of concrete gravity type will be constructed. The concrete volume was estimated to be 3,930 m^3. The works will be executed by chuteway method using concrete pump and agitator truck.

The diversion tunnel will be closed by roller gate upon completion of all of the works. After closing the gate, the diversion tunnel will be plugged with concrete. Concrete pump, grout pump and agitator truck will be used for this work.

(2) Main works

(i) Dam and spillway

A concrete gravity type dam having 24.5 m in maximum height and 53,100 m^3 in total volume will be constructed at the proposed damsite. The estimated excavation work quantities are 68,500 m^3. The construction works of the dam are planned to be executed in a period of 24 months. Excavation of dam foundation will be commenced at both abutments before river diversion. Excavation of river bed portion will be carried out currently with the construction of the primary cofferdam. A combination of bulldozer with ripper, crawler drill, crawler loader and dump truck is planned to be used. The excavated materials will be transported to the spoil banks. Foundation treatment for dam bed rock will be carried out by consolidation and curtain groutings. The estimated grout length is 1,900 m in total. Crawler drill, boring machine, grout pump and concrete mixer will be used for this work. Immediately after the completion of foundation treatment and clearing of river bed, concrete placing will be executed by chuteway method mainly using concrete pump, vibrator, and other concreting equipment. A concrete mixing plant with a capacity of 70 m3/h will be installed near the damsite. Concrete placing for spillway structure will be executed succeeding to the dam concrete works. Installation of the spillway gates will be carried out after all of the civil works for the dam are completed.

(ii) Intake and headrace tunnel

The intake structure with gates and sand trap basins will be constructed at the right bank of the damsite. The estimated work quantities are 114,300 m^3 of excavation and 21,300 m^3 of concrete. Excavation of the intake will be carried out by a combination of bulldozer, crawler drill, crawler loader and dump truck. Concrete placing work will be carried out by chuteway method using concrete pump and agitator truck. Installation work of the gates will be carried out after completion of the civil works.

The construction works of a circular type headrace tunnel with 2.8 m in inside diameter and 1,815 m in total length, which are the critical work for this project , will be commenced immediately after completion of the temporary works. The estimated work quantities are 21,500 m^3 of excavation and 6,100 m^3 of concrete. The construction works of the headrace tunnel are planned to be executed in a period of 30 months. In order to meet the required construction period, the construction works will be executed using 130 m long adit tunnel to be constructed near the surge tank site as shown in Fig. 7.9. Excavation of the tunnel will be carried out by full face excavation method using 2-boom drill jumbo. Excavated materials will be transported by battery locomotive and mucking car on rail. A train loader will be provided behind the drill jumbo. Steel support will be used for 110 m long fault zone and 300 m long inlet portion. Concrete lining works will be executed in two stages; arch lining and inverted lining by a combination of concrete pump and agitator car. Consolidation grouting with 3 m in interval will be executed for the fault zone and about 300 m long inlet portion.

(iii) Surge tank

A surge tank, 10 m in inside diameter and 31 m in height will be constructed at the end of the headrace tunnel. The estimated work quantities are 29,600 m^3 of excavation and 1,070 m^3 of concrete. Excavation of the surge tank will be carried out by pilot heading-enlargement method using a raise climber, leg drills and rocker shovel. Construction method is the same as that applied for the headrace tunnel of Salto Pilão (1) hydropower scheme. Excavated bed rock will be transported to the spoil bank through the adit tunnel. Concrete lining will be placed by concrete pump and agitator truck from lower portion upward. Consolidation grouting with 3 m in interval will be executed succeeding the concrete lining work.

(iv) Penstock

The underground type penstock with an average diameter of 2.2 m consists of 10 m long horizontal tunnel in upper part, 135 m long inclined shaft portion and 310 m long horizontal tunnel in lower portion. The estimated work quantities are 16,000 m^3 of excavation, 2,340 m^3 of concrete and 350 tons of penstock pipe. Excavation work of the penstock tunnel will be initiated from upper and lower horizontal parts in the same way as applied to the headrace tunnel. The excavated rock will be transported to the spoil bank through the adit tunnel near the surge tank and another adit tunnel of 200 m in length near the powerhouse. Excavation of the inclined shaft will be executed by pilot heading - enlargement method. After completion of the excavation, steel liners will be installed and concrete will be placed between the steel liners and the excavated rock surface. Consolidation grouting with 3 m in interval will be executed succeeding to the concrete filling work.

(v) Powerhouse and tailrace

An open-air type powerhouse and an open channel tailrace will be constructed at the right bank of the Benedito river in the upstream of Benedito Novo. The estimated work quantities are 13,600 m^3 of excavation and 10,300 m^3 of concrete for substructure of powerhouse and tailrace. The work period is planned to be 30 months. Excavation of the foundation of substructure will be carried out by combination of crawler drill, bulldozer, loader and dump truck. Concrete work for substructure and superstructure and tailrace will be executed by concrete pump and chuteway method. A concrete plant with a capacity of 50 m3/h will be installed close to the powerhouse site. Installation works of the power generating equipment will be carried out during a period of 19 months after completion of the civil works.

7.3.4 Cost estimate

The construction cost of the project was estimated based on the same conditions as applied for Salto Pilão (1) hydropower scheme. The estimated construction cost is US$56.5 million as shown in Table 7.4. Based on the construction time schedule, the construction fund to be disbursed in each construction year was estimated as shown in Table 7.2.

8. ECONOMIC EVALUATION

8.1 General

Economic evaluation of the hydropower schemes was made by means of comparison of the unit cost of the guaranteed energy and the marginal cost of the expanded energy of the system, which has been specified by ELECTROBRAS. In addition, Economic Internal Rate of Return (EIRR) was assessed assuming several marginal costs of the expanded energy of the system.

8.2 Unit Cost of Guaranteed Energy

The unit cost of the guaranteed energy was assessed by adopting the estimated power energy and construction cost to the formula specified by ELETROBRAS as shown in paragraph 6.2.2. Result of the assessment is as follows;

Name of scheme	Installed capacity (MW)	Guaranteed energy (GWh)	Secondary energy (GWh)	Construction cost (Mill US$)	Unit cost of guaranteed energy (US$/MWh)
Salto Pilão (1)	113.6	654.2	63.0	178.2	26.5
Dalbergia	16.8	105.3	12.2	102.2	96.7
Benedito Novo	13.2	65.4	11.4	56.5	85.4

It shows that the Salto Pilão (1) hydropower scheme is remarkably superior to the other two schemes from the viewpoints of economic viability and scale of the installed capacity. The marginal cost of the expanded energy in the system for 1991 - 1995 period is set at US$ 45/MWh. It implies from the comparison of this figure and the unit cost of the guaranteed energy of US$ 26.5/MWh that the Salto Pilão (1) scheme is worth developing at the earliest stage as possible.

The unit cost of the guaranteed energy of the Benedito Novo hydropower scheme is US$ 85.4/MWh which is close to US$ 86/MWh of the marginal cost of the expanded energy for 2011 onward. It means that the Benedito Novo hydropower scheme is worth developing but its development will have to be postponed until the stage when the scheme becomes viable as the regional economy is upheaved. While, the Dalbergia hydropower scheme is judged to be infeasible at this stage since the assessed unit cost of the guaranteed energy is beyond the specified marginal cost.

8.3 Economic Evaluation by EIRR

Economic evaluation by means of EIRR was made based on the estimated construction cost and benefit obtained by multiplying the guaranteed energy and the marginal cost. In this study, three cases of the marginal costs, US$ 45/MWh, US$ 48/MWh and US$ 58/MWh were adopted. The estimated power benefit is as follows;

(Unit: Mill US$)

Name of scheme	Guaranteed Energy (MWh)	Marginal cost (US$ / MWh)		
		45	48	58
Salto Pilão (1)	654,211	29.44	31.40	37.94
Dalbergia	105,343	4.74	5.06	6.11
Benedito Novo	65,420	2.94	3.14	3.79

Operation and maintenance cost of the scheme was assessed based on the past record in south/southeast power system and the following figures were obtained;

- For Salto Pilão (1)	;	US$ 0.51 million/year
- For Dalbergia	;	US$ 0.24 million/year
- For Benedito Novo	;	US$ 0.21 million/year

The economic life time of the project was assumed to be 50 years after the completion of the construction works. Based on the construction cost and benefit, EIRR was estimated as follows;

Name of scheme	EIRR (%) Marginal cost (US$ / MWh)		
	45	48	58
Salto Pilão (1)	13.3	14.1	16.5
Dalbergia	3.4	3.7	4.8
Benedito Novo	4.0	4.4	5.6

9. OVERALL EVALUATION

9.1 General

Overall evaluation of the schemes was made based on four aspects, namely, economic feasibility, timing of implementation, degree of contribution to social and economic development in the region and environmental impacts of the three hydropower schemes.

9.2 Economic Feasibility

The result of the economic evaluation of the hydropower schemes is as shown in the previous chapter. The unit cost of the guaranteed energy and EIRR in the case of the marginal cost of US$45/MWh of the expanded energy of the system for the three schemes were estimated as follows;

Name of Scheme	Unit cost of guaranteed energy (US$/MWh)	EIRR (%)
Salto Pilão (1)	26.5	13.3
Dalbergia	96.7	3.4
Benedito Novo	85.4	4.0

9.3 Timing of Implementation

ELETROBRAS specifies the relationship between the marginal cost of the expanded energy of the system and the period to be developed. The timing of implementation of the hydropower schemes was contemplated as follows referring to this relationship;

(1) The unit cost of guaranteed energy for Salto Pilão (1) scheme is only 26.5 US$/MWh. This means that Salto Pilão (1) scheme is worth developing at the earliest stage possible. However it is presumed that about 9 years are needed for a series of works from feasibility study to construction works. Thus, the earliest commissioning time for the power plant of Salto Pilão (1) scheme would be year 2001 even if its feasibility study will be started in 1992.

(2) The unit cost of guaranteed energy for Benedito Novo scheme is 85.4 US$/MWh. This figure is close to the marginal cost of US$86/MWh for 2011 onward. Assuming that the commissioning time of the plant starts in year 2011, commencement of its feasibility study will have to be postponed until 2003.

(3) The unit price of the guaranteed energy for Dalbergia scheme is US$96.7/MWh. It is far beyond the specified marginal cost. It means that this scheme is infeasible at this stage and its development should be postponed to a stage when the scheme becomes feasible as the regional economy is upheaved.

Considering the above results, it is desirable to proceed with the feasibility study for the Salto Pilão (1) hydropower scheme at an earlier stage as possible.

9.4 Degree of Contribution to Social and Economic Development in the Region

The hydropower development in the Itajai river basin will contribute to social and economic development in the region from two aspects, namely, stable power supply to the consumer and creation of job opportunity and activation of regional economy.

The record of power consumption in CELESC power system in past decade shows that the power energy consumption increases at an annual rate of 9.21 % and more than 50% of the power energy was consumed by industrial sector. The annual growth rate of the power consumption in the industrial sector has been 8.5 % and it is predicted to further increase in the future stage. CELESC purchases more than 65 % of the required energy from ELETROSUL at present. ELETROSUL implements large scale hydropower projects but it seems that the progress of these projects is not so easily promoted as scheduled due to difficulty of financing and compensation problems. This may result in restriction of stable power supply to CELESC in the future stage. In this context, the development of hydropower project with larger scale facility in the Itajai river basin will contribute to the region from the viewpoint of stable power supply to the consumer. The degree of contribution to the region by development of hydropower project in the basin will be proportionate to the scale of the schemes. Thus, the degree of contribution by the scheme to the region will be in this order; 1st; Salto Pilão (1), 2nd; Dalbergia and 3rd; Benedito Novo. The Salto Pilão hydropower scheme can generate about 10 % of the power energy required in the state of Santa Catarina or 20 % of that for the industrial sector in 1989.

The construction of the hydropower projects will create job opportunities during the construction period. Workers and some construction materials will be supplied from inside and outside of the basin, and supporting services and other materials for these construction works will be produced in the basin. This supporting business will result in creating job opportunity, and it will contribute to activation of the regional economy. It is clear that construction investment derived from the proposed projects will induce new production from related economic sectors. Incidentally, according to the Japanese inter-industrial relationship, one unit of construction investment induce about 2.36 times of production from related industries. In other words, it creates a value added about 1.36 times as large as the original investment. Since the industrial structure in the study area is different from that in Japan, the coefficient of induced value added would be different from 2.36 in the study area. In any case, however, it is clear that one unit of construction investment can be expected to induce a value added of almost the same amount as the original investment. The extent of creation of job opportunities and activation of regional economy will be proportionate to the amount of construction cost of the hydropower schemes. Thus in this aspect the order of contribution of the schemes will be also 1st; Salto Pilão (1), 2nd; Dalbergia and 3rd; Benedito Novo.

9.5 Environmental Impact

The environmental impact due to implementation of the hydropower schemes is mainly represented by the number of households and acreage of land to be affected by creation of intake dams and construction of project facilities. These were estimated as follows;

Name of Scheme	Number of households	Acreage of land (km2)
Salto Pilão (1)	9	0.33
Dalbergia	17	0.25
Benedito Novo	23	0.03

It shows that the number of household to be affected is almost the same for Dalbergia and Benedito Novo schemes and that for Salto Pilão (1) scheme is the minimum, while the acreage of land to be affected is almost the same for Salto Pilão (1) and Dalbergia schemes and that for Benedito Novo scheme is the minimum. But there are no notable environmental impacts for all the three schemes.

9.6 Overall Evaluation

Judging from the result of the evaluation carried out so far on the above-mentioned four aspects, the Salto Pilão (1) hydropower scheme is the most promising project among the three hydropower schemes. It is therefore recommended that this hydropower scheme be selected for feasibility study in the following stage.

10. PROGRAM FOR FEASIBILITY STUDY IN THE FOLLOWING STAGE

10.1 General

The result of the study carried out so far clarifies that the Salto Pilão (1) hydropower scheme is the most promising project among the three schemes from the technical and economic aspects as well as the environmental aspect. Thus, the program for feasibility study in the following stage was prepared assuming that the Salto Pilão (1) hydropower scheme is selected for this purpose. The work program for the feasibility study comprising field works and feasibility study and design is shown in Fig. 10.1.

10.2 Field Works

The field works comprise topographic survey, environmental and compensation surveys and geological survey. It is scheduled that these works will be carried out and completed prior to the commencement of the feasibility study and design. Details of these surveys are as follows.

10.2.1 Topographic survey

The topographic survey for the Salto Pilão (1) scheme area consists of aerophotogrammetric survey for the project area including reservoir area and project components areas and topographic survey for dam, intake, and powerhouse sites.

The aerophotogrammetric survey will be carried out by the following standard;

Mapping area	;	83 km^2
Mapping scale	;	1 : 5,000
Contour interval	;	2 m

The topographic survey for the dam, intake and powerhouse sites will be made by the following standard;

Survey area		
Dam and intake sites	;	1,200 m x 1,200 m
Powerhouse site	;	500 m x 1,000 m
Scale of maps	;	1:2,000
Contour interval	;	2 m

10.2.2 Environmental and compensation surveys

Environmental impact assessment which is a general requirement for hydropower development project should be conducted as required by the Brazilian government's regulations. Bearing this in mind, the following specific works should be conducted.

(1) Identification of the affected area

The affected area should be classified into directly affected area and indirectly affected area and they should be clearly identified. The directly affected area is further classified in two different sections: one for permanently disturbed and the other for temporarily disturbed. These areas should be precisely plotted on the map, possibly in 1:5,000 or 1:2,000 topographical maps.

(2) Initial environmental examinations

Initial environmental examination of the natural and social environments of both the directly and indirectly affected areas will be performed for the following items;

1) Natural environment

(i) Aesthetic value of landscape; investigation of the aesthetic value of landscape near the dam site.

(ii) Vegetation; conventional survey on forest, open land, bush, and grassland and preparation of the vegetation map.

(iii) Wildlife; distribution survey for fish and birds as well as others categorized as fauna and preparation of the wildlife distribution map.

(iv) Soil; soil survey in the area and surveys on its capability to support vegetation growth and preparation of the soil map.

(v) Mineral resources; preparation of the general mineral resource map.

(vi) Survey for existing national parks and wildlife sanctuaries.

2) Social environment

(i) Population; counting of actual number of people and households in the directly affected area, study of the structure of these people such as age, sex, their occupation, income level and their property for compensation purposes and survey for number and type of houses and their values in the directly affected area.

(ii) Land use; survey for farming area, pasture, open land, bush, and forest and their values, crops grown in the farming area, their yield and prices, harvesting of livestock kept in the directly affected area.

(iii) Economic activities; survey for all the economic activities in the directly and indirectly affected area.

10.2.3 Geological survey

The geological survey comprises core borings at the damsite, surge tank site, penstock route, tailrace site and proposed quarry site, permeability test by means of Lugeon test at damsite, and rock test at the quarry site to examine the availability of rock material for fine aggregate after its crushing. Content of the core boring and Lugeon test are as follows;

(1) At damsite

Borehole no.1	Left abutment	L = 25 m, Lugeon test, 4 nos
Borehole no.2	Right abutment	L = 25 m, Lugeon test, 4 nos
Borehole no. 3	River bed	L = 30 m, Lugeon test, 6 nos
Borehole no. 4	Diversion tunnel	L = 30 m

(2) At waterway site

Borehole no. 5	Surge tank	L = 50 m
Borehole no. 6	Penstock line	L = 50 m

(3) At powerhouse site

Borehole no. 7 Tailrace L = 25 m

(4) At quarry site

Borehole no. 8 L = 30 m

The rock test at the quarry site will be performed by means of Los Angeles test to examine bulk density and water absorption, and unconfined compressive strength. Geological assessment of the project facility sites will be made by interpreting the results of a series of field surveys.

10.3 Feasibility Study and Design

10.3.1 Hydrological study

The following works will be carried out in the hydrological study;

(i) Collection of additional meteorological and hydrological data.

(ii) Review of previous studies.

(iii) Estimation of long term daily river discharge at the proposed damsite and preparation of flow duration curve for the hydrologically critical period.

(iv) Estimation of probable flood necessary for feasibility design of project components.

10.3.2 Socio-economic study

Major works for socio-economic study are as follows;

(i) Collection of data regarding socio-economic index in the basin.

(ii) Study on socio-economic condition in whole Brazil, state of Santa Catarina and Itajai river basin.

(iii) Study on social and economic constraints for implementation of the hydropower project.

10.3.3 Electric power study

The following works will be carried out for electric power study;

(i) Collection of additional data to know the present condition of power sector in whole Brazil, south/southeast power system and CELESC power system.

(ii) Study on the past power supply and operation conditions in the foregoing power supply systems.

(iii) Feasibility design of the power generating and transmission facilities.

10.3.4 Environmental impact assessment

Based on the result of environmental surveys, the environment impact assessment will be made for the following items;

(1) Natural environment

(i) Landscape; examination of loss of aesthetic site for recreation.

(ii) Natural vegetation; study on increase of water plant, if any, due to the impounded water of the reservoir and examination of its importance to the fish and human activities.

(iii) Wildlife; listing of affected species of mammals, birds, fish, and others, and loss of wildlife habitat, study on expected increase or decrease in wildlife species due to the impounded water, and examination of the extent to which wildlife and human activities are adversely affected by the loss of such wildlife.

(iv) Geographical conditions; examination of possible changes in geographical conditions likely to affect the present patterns of land use in agriculture, livestock and forestry in the directly affected area.

(v) Water resources; examination of change in the pattern of water resources for municipal, industrial and irrigation purposes.

(2) Social environment

(i) Human settlement area; identification of the resettlement area of the residents and examination of possible social strife that evacuees might experience.

(ii) Patterns of land use and economic activities; examination of impact of loss of the available land and forest products.

(iii) Public health; examination of increase or decrease in water-born diseases, as a result of the rise of the groundwater level in the area.

(iv) Traffic conditions; examination of changes on the existing roads and construction of new road.

(v) Cultural property; examination of the loss of historic, archaeological, and religious sites.

10.3.5 Plan formulation and feasibility design

Based on the topographic maps prepared in this stage and the result of geological survey, an optimization study will be made for dam axis, full supply level and dam height, and dimension of waterway. Feasibility design of civil works and power and mechanical facilities will be carried out. The power output and energy will be assessed based on the determined dimensions.

10.3.6 Construction planning and cost estimate

Construction plan of the scheme will be studied based on the drawings of structure and estimated work quantities considering meteoro-hydrological and topographical conditions of the project area and labor regulation.

The unit prices for work items of civil, electrical and mechanical works will be analysed based on the construction plan, material and labor costs in the vicinity of the project area and prevailing market price of equipment and referring to the unit prices applied in similar projects. The construction cost will be estimated based on the work quantities and analysed unit prices.

10.3.7 Economic evaluation and financial analysis

Based on the assessed power energy and estimated construction cost, economic evaluation will be made by means of comparison of the unit cost of the guaranteed energy and the marginal cost of power expansion program, which is the evaluation criteria specified by ELETROBRAS. Besides, the economic internal rate of return (EIRR) will be estimated using several marginal costs of the power expansion program. Sensitivity analysis will be made for different conditions such as cost overrun, lower benefit than estimated and their combined cases.

On the basis of the recently revised power tariff, operation revenue will be estimated. Based on these estimated values, the financial internal rate of return (FIRR) will be estimated.

10.4 Staffing

The staff required for carrying out the feasibility study on the Salto Pilão (1) hydropower scheme was estimated as shown in Fig.10.2. The total number of man-months for JICA Study team was estimated at 46.

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11. Brazilian Power Sector Strategies with respect to Environmental and Social Issues

TABLES

Table 3.1 INSTALLED GENERATING CAPACITY IN BRAZIL AS OF DECEMBER 31, 1989 *

(Unit: MW)

	Hydraulic	Diesel	Fuel Oil	Thermal Coal	Uranium	Firewood	Natural Gas	Total
ELETROBRAS System	20,900	570	1,191	554	657	-	120	23,992
FURNAS	6,800	-	666	-	657	-	120	8,123
CHESF	6,894	143	290	-	-	-	-	7,447
ELETROSUL	2,602	-	66	554	-	-	-	3,222
ELETRONORTE	3,623	427	169	-	-	-	-	4,219
ESCELSA	159	-	-	-	-	-	-	159
LIGHT	822	-	-	-	-	-	-	822
Other Companies	17,819	431	653	486	-	2	-	19,391
ITAIPU	10,500	-	-	-	-	-	-	10,500
TOTAL	49,219	1,001	1,844	1,040	657	2	120	53,883

* Private produces not included

Table 3.2 INSTALLED GENERATING CAPACITY IN BRAZIL *

(Unit: MW)

Year	Hydraulic	Diesel	Fuel Oil	Thermal Coal	Uranium	Other (**)	Total
1980	27,081	859	1,876	748	-	1	30,565
1981	30,596	915	1,992	748	-	-	34,251
1982	32,542	947	1,992	748	-	-	36,229
1983	33,556	937	1,972	730	-	2	37,197
1984 (***)	35,001	922	1,966	730	-	8	38,627
1985 (***)	37,503	1,004	1,966	730	657	8	41,868
1986 (***)	39,262	967	1,972	890	657	16	43,764
1987 (***)	42,843	1,019	1,835	1,040	657	16	47,410
1988 (***)	45,783	1,107	1,842	1,040	657	36	50,465
1989 (***)	49,219	1,001	1,844	1,040	657	122	53,883

* Private producers not included.

** Includes firewood, coal and natural gas.

*** Includes Itaipu's total operating capacity.

Table 3.3 TOTAL ELECTRIC ENERGY PRODUCTION IN BRAZIL *

	Hydro		Thermal		Total
	(GWh)	(%)	(GWh)	(%)	(GWh)
1980	126,151	(96.5)	4,960	(3.8)	131,111
1981	128,119	(95.6)	5,943	(4.4)	134,062
1982	138,463	(96.4)	5,138	(3.6)	143,601
1983	148,567	(97.1)	4,512	(2.9)	153,079
1984 (**)	163,525	(96.3)	6,261	(3.7)	169,786
1985 (**)	178,136	(95.2)	9,028	(4.9)	187,164
1986 (**)	189,321	(93.8)	12,489	(6.2)	201,810
1987 (**)	198,829	(95.1)	10,171	(4.9)	209,000
1988 (**)	213,414	(96.3)	8,274	(3.7)	221,688
1989 (**)	223,865	(96.2)	8,840	(3.8)	232,705

Note; *: Private producers not included
**: Includes ITAIPU supply

Table 3.4 TRANSMISSION LINES IN BRAZIL

(Unit: km)

Year	230 kV	345 kV	440 kV	500 kV	600 kV *	750 kV
1980	18,298	6,486	5,778	6,546	-	-
1981	20,527	6,547	5,778	7,037	-	-
1982	21,110	6,853	5,788	8,149	-	568
1983	21,942	7,056	5,788	8,372	-	568
1984	22,615	7,177	5,763	9,548	-	568
1985	23,210	7,300	5,763	9,560	792	568
1986	24,014	7,304	5,763	9,569	792	890
1987	24,888	7,323	5,763	10,470	1,612	890
1988	25,415	7,174	5,649	13,303	1,612	890
1989	26,554	7,203	5,652	14,753	1,612	1,782

Note; *: Direct current

Table 3.5 ANNUAL BALANCE OF ELECTRIC ENERGY IN CELESC (1979 - 1989)

(Unit: kWh)

Specifications	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1. Own Generation	367,561,796	446,635,955	407,319,367	413,534,210	482,337,357	404,018,324	332,552,353	281,293,962	411,467,634	375,335,322	385,758,503
1.1 Hydro	367,267,816	446,510,755	407,286,767	413,502,860	482,312,487	404,007,224	332,551,913	281,293,962	411,467,634	375,335,322	385,758,503
1.2 Thermal	293,980	125,200	32,600	31,350	24,870	11,100	440	0	0	0	0
2. Energy Received	2,692,794,105	3,071,754,933	3,350,406,634	3,626,847,459	3,877,355,402	4,489,566,318	5,079,090,790	5,340,419,090	5,766,990,767	6,208,555,667	6,674,854,706
2.1 Electrosul	2,660,581,383	3,048,002,453	3,329,473,906	3,615,488,199	3,868,328,202	4,489,566,318	4,827,021,795	4,687,024,806	4,535,966,870	4,708,000,863	4,651,851,594
2.2 Itaipu	0	0	0	0	0	0	252,068,995	653,394,284	1,231,023,897	1,496,514,504	2,002,628,312
2.3 Hidreletrica Xanxere	23,348,448	20,454,880	20,932,728	11,359,260	9,027,200	0	0	0	0	0	0
2.4 Cia de Papel Chapeco	4,097,000	0	0	0	0	0	0	0	0	0	0
2.5 Copel (PR) - Porto Uniao	4,535,914	3,297,600	0	0	0	0	0	0	0	2,501,100	3,943,200
2.6 Copel (PR) - Itapoa	0	0	0	0	0	0	0	0	0	0	3,788,400
2.7 Ceee (RS)	231,360	0	0	0	0	0	0	0	0	0	0
2.8 Fabrica de Papel Primo Tedesco	0	0	0	0	0	0	0	0	0	1,539,200	12,643,200
3. Energy Required	3,060,355,901	3,518,390,888	3,757,726,001	4,040,381,669	4,359,692,759	4,893,584,642	5,411,643,143	5,621,713,052	6,178,458,401	6,583,890,989	7,060,613,209
4. Energy supply	156,402,998	183,857,744	188,426,726	162,751,951	41,684,703	70,531,831	85,204,356	90,616,666	98,627,350	99,223,674	102,981,432
4.1 Cia Docas de Imbituba	17,058,496	18,893,476	19,263,713	6,586,774	0	0	0	0	0	0	0
4.2 Empresa Forca e Luz Joao Cesa	1,489,548	1,731,948	2,256,551	2,057,376	2,098,320	2,148,600	2,532,072	2,510,496	2,621,856	3,201,312	3,398,496
4.3 Empresa Forca e Luz Ararangua	17,151,080	20,493,750	13,622,568	0	0	0	0	0	0	0	0
4.4 Forca e Luz Criciuma	113,182,632	132,804,828	142,312,556	142,573,450	0	0	0	0	0	0	0
4.5 Forca e Luz Guardense	313,908	0	0	0	0	0	0	0	0	0	0
4.6 Forca e Luz Nova Veneza	654,884	1,018,484	1,107,364	1,156,248	1,342,664	1,394,000	1,583,200	1,688,400	1,943,600	2,185,200	2,385,600
4.7 Forca e Luz Sao Bento	0	0	0	0	0	0	0	0	0	0	0
4.8 Forca e Luz Urussanga	6,552,450	8,915,258	9,863,974	10,378,103	12,261,600	16,313,440	21,451,104	22,960,416	24,110,064	22,497,696	25,192,344
4.9 Hidreletrica Xanxere	0	0	0	0	25,982,119	50,675,791	59,637,980	63,457,354	69,951,830	71,339,466	72,004,992
5. Consumption Total	2,676,177,969	3,149,874,274	3,380,061,559	3,579,526,149	3,993,766,172	4,472,742,119	4,979,502,421	5,181,642,907	5,685,205,225	6,008,591,491	6,456,704,745
5.1 Residential	450,987,677	515,189,978	600,596,205	642,423,998	763,322,924	817,736,973	883,842,455	952,642,306	1,104,761,931	1,188,218,844	1,326,651,373
5.2 Industrial	1,551,169,144	1,827,352,839	1,895,016,379	1,995,513,189	2,155,807,371	2,496,113,014	2,840,939,152	2,947,883,116	3,113,514,044	3,281,996,744	3,506,689,574
5.3 Commercial	320,005,627	364,900,153	378,974,287	386,785,497	441,787,213	463,363,780	472,902,392	466,123,733	537,254,354	555,211,189	593,415,110
5.4 Rural	55,216,742	75,279,404	102,135,761	118,037,486	150,707,100	175,960,052	206,667,634	227,020,792	259,776,249	272,985,549	293,534,735
5.5 Rural Cooperation	106,252,511	135,312,172	152,612,319	168,871,584	170,197,731	187,091,440	213,765,688	239,702,041	266,455,170	273,643,649	291,489,190
5.6 Public Power	59,298,299	73,214,206	78,301,995	70,800,593	75,196,075	79,435,386	89,117,816	84,162,817	99,659,808	115,441,201	116,778,687
5.7 Public Illumination	105,898,954	123,800,496	131,092,533	140,983,679	167,100,603	173,661,382	187,295,976	173,697,543	205,022,568	214,256,009	216,328,040
5.8 Public Service	22,121,204	28,483,152	33,373,194	48,566,014	61,047,024	71,201,265	76,896,278	83,268,865	89,698,387	98,131,414	103,456,385
5.9 Own Use	5,227,811	6,341,874	7,958,886	7,544,109	8,600,131	8,178,827	8,075,030	7,141,694	9,062,714	8,706,892	8,361,651
6. Losses, Diff.	227,774,934	184,658,870	189,237,716	298,103,569	324,241,884	350,310,692	346,936,366	349,453,479	394,625,826	476,075,824	500,927,032
7. Max.Demand (kWh/h)	564,700	643,200	700,800	758,100	824,200	894,800	967,600	1,003,500	1,081,300	1,135,400	1,228,400
8. No. of Clients	477,930	527,656	589,448	670,029	735,064	777,720	819,911	868,834	910,792	960,092	1,013,717
8.1 Residential	375,096	413,154	456,841	504,549	557,091	589,215	620,115	654,448	687,857	727,937	772,528
8.2 Industrial	6,989	7,312	7,764	8,076	8,899	11,319	13,414	17,038	18,490	19,430	20,837
8.3 Commercial	49,348	53,040	57,020	60,578	65,103	65,682	66,307	70,499	73,321	75,837	78,623
8.4 Rural	41,266	48,437	61,434	89,562	96,226	103,043	110,798	116,751	120,372	125,268	129,749
8.5 Public Power	4,857	5,303	5,936	6,368	6,746	7,350	8,095	8,844	9,455	10,205	10,567
8.6 Public Illumination	176	180	185	190	213	221	215	212	247	270	216
8.7 Public Service	198	230	268	412	467	511	541	590	592	644	672
8.8 Own Consumer	0	0	0	294	319	379	426	452	458	501	525
9. No. of Supply Points	19	22	15	15	5	6	6	6	5	5	5
Annual Load Factor (%)	61.87	62.44	61.21	60.84	60.38	62.43	63.85	63.95	65.23	66.20	65.61

Table 5.1 POPULATION NEAR PROJECT AREA

(1) a. Salto Pilão: Lontras

	1970	%	1980	%	1989	%	Rate of Annual Increase (%)	
							1970-80	1980-89
Urban	1,678	23.95	3,789	51.73	4,884	63.54	8.48	2.76
Rural	5,328	76.05	3,535	48.27	2,779	36.46	-4.01	-2.63
Total	7,006	100.00	7,324	100.00	7,663	100.00	0.44	0.44

b. Rio do Sul

	1970	%	1980	%	1989	%	Rate of Annual Increase (%)	
							1970-80	1980-89
Urban	21,528	78.18	33,362	92.06	41,881	94.95	4.47	2.55
Rural	6,010	21.82	2,878	7.94	2,227	5.05	-7.09	-2.80
Total	27,538	100.00	36,240	100.00	44,108	100.00	2.78	2.20

(2) Dalbergia

	1970	%	1980	%	1989	%	Rate of Annual Increase (%)	
							1970-80	1980-89
Urban	4,180	19.90	8,230	34.99	11,472	44.44	7.01	3.76
Rural	16,828	80.10	15,292	65.01	14,342	55.56	-0.95	-0.71
Total	21,008	100.00	23,522	100.00	25,814	100.00	1.13	1.04

Note: the above figure includes population of Dalbergia and Ibirama

(3) Benedito Novo

	1970	%	1980	%	1989	%	Rate of Annual Increase (%)	
							1970-80	1980-89
Urban	1,638	14.08	3,767	35.17	4,667	47.03	8.68	2.41
Rural	9,999	85.92	6,945	64.83	5,257	52.97	-3.58	-3.05
Total	11,637	100.00	10,712	100.00	9,924	100.00	-0.82	-0.84

Source: (1) "IBGE" Foundation,
Demographic Census of Santa Catarina - 1970 - 1980
(2) "SEPLAN"/SC estimatives - 1989

Table 5.2 COMPOSITION OF WATER DEMAND IN THE UPSTREAM AREA

Sub-basin	Irrigated Area (1)	Irrigation (2)		Urban Supply (3)	Rural (4)	Industrial (5)	Totals		
		Dec to Mar	Oct/Nov Apr/May				Jul/Sep	Oct/Nov Apr/May	Dec/Mar
Salto Pilão	(ha)	(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m3/s)	(m3/s)
Itajai do Sul	1,034	1.675	0.186	0.024	0.083	0.028	0.135	0.321	1.810
Itajai do Oeste	8,238	13.345	1.483	0.041	0.111	0.072	0.224	1.707	13.568
Itajai-Acu	435	0.705	0.078	0.103	0.007	0.051	0.161	0.239	0.866
Total	9,707	15.725	1.747	0.168	0.201	0.151	0.520	2.267	16.244
Dalbergia									
Itajai do Norte	680	1.102	0.122	0.028	0.099	0.026	0.153	0.275	1.255
Total	680	1.102	0.122	0.028	0.099	0.026	0.153	0.275	1.255
Benedito Novo									
Benedito Novo	1,165	1.887	0.210	0.003	0.019	-	0.022	0.232	1.909
Total	1,165	1.887	0.210	0.003	0.019	-	0.022	0.232	1.909

Source:
(1) Municipal Agricultural Production (IBGE) - 1989
(2) "CASAN" report, September/1990
(3) "FATMA" - Program of environmental recovery of "Itajai" basin, 1990

Table 5.3 AGRICULTURAL CHEMICALS AND SOURCES OF POLLUTION

a. General Use of Agricultural Chemicals in the Upper Itajai River Basin

	Nitrogen (Kg/ha-year)	Phosphorus (Kg/ha-year)	Potassium (Kg/ha-year)
Rice	90	60	20
Tabacco	45	150	60
Onion	37.5	70	35

b. Agricultural Chemicals used in the Project Area

(Unit: ton/year)

	Salto Pilao	Dalbergia	Benedito Novo
Nitrogen	2.179	354	113
Phosphorus	4.050	1.011	97
Potassium	1.691	400	34

c. Sources of Pollution

(Unit: kg DBO/day)

	Salto Pilao	Dalbergia	Benedito Novo
Industry	2,780	11,406	-
Rural	107,100	20,790	6,026
Urban	4,500	1,035	322
Total	114,380	33,231	6,348

DBO: Dissolved Biological Oxygen

Table 5.4 REGULATION OF RIVER FLOW

(1) Monthly minimum discharge (MMD)

Scheme	MMD (m3/s)	Recorded period
Salto Pilão	10.2	1941~1987
Dalbergia	2.4	1935~1987
Benedito Novo	2.1	1934~1987

(2) Available river flow

(Unit: m3/s)

Scheme	MMD	RMF	MED	FD	Available river flow
Salto Pilão	10.2	8.2	109.9	50.3	59.6
Dalbergia	2.4	1.9	52.7	19.3	33.4
Benedito Novo	2.1	1.7	14.5	8.4	6.1

Note;
MED; Monthly mean discharge
FD ; Firm discharge
RMF: MMD x 0.8 = Required maintenance flow
Available river flow: MED - FD

Table 5.5 COMPARISON OF SUBMERGED AREAS AND COMPENSATION AREAS

Scheme	Water Level (m)	Submerged Area (km2)	Compensation Area * (km2)	Relocation of Houses (Units)			Road Construction in the Reservoir Area			
				Reservoir Area	Construction Areas	Realignment (m)	New Bridge (s) (m)	New Road (m)	Culvert(s) (unit)	Submerged Road (m)
Salto Pilão										
Axis A	330	4.43	2.590	87	0	590	40	1900	2	630
Axis B	330	4.59	2.880	87	0	590	40	1900	2	630
Axis C	319	0.40	0.334	9	0	-	-	-	-	-
Dalbergia										
Axis A	232	0.28	0.193	5	12	-	-	-	-	950
Axis B	227	0.37	0.248	5	12	-	-	-	-	1250
Axis C	215	0.29	0.156	8	12	-	-	-	-	-
Benedito Novo										
Axis A	290	0.229	0.307	93	19	440	50	980	3	490
Axis B	287	0.092	0.166	15	13	440	50	980	3	490
Axis C	277	0.029	0.028	13	10	200	50	-	0	250

* See Table 5.6 for details

Table 5.6 DETAILED AFFECTED AREAS

SCHEME	COMPENSATION AREA (km2)				DAM, ROAD & POWER HOUSE (km2)			DISTRIBUTION OR TRANSMISSION LINE (m)		
	Agriculture	Forest	Others	Total	Agriculture	Forest	Others	Agriculture	Forest	Others
Salto Pilão										
Axis A	1.450	0.090	1.050	2.590				5,200	1,800	-
Axis B	1.450	0.270	1.160	2.880				5,200	1,800	-
Axis C	0.150	0.100	0.084	0.334				5,200	1,800	-
Dalbergia										
Axis A	0.005	0.056	0.132	0.193				1,800	-	-
Axis B	-	0.065	0.183	0.248				1,800	-	-
Axis C	0.007	0.040	0.109	0.156				1,800	-	-
Benedito Novo										
Axis A	0.016	0.005	0.286	0.307				-	-	18,000
Axis B	0.011	0.003	0.152	0.166				-	-	18,000
Axis C	0.005	0.011	0.012	0.028				-	-	18,000

Table 6.1 UNIT COST OF GUARANTEED ENERGY FOR COMPARATIVE STUDY

1. Salto Pilão (1) Hydropower Scheme

Dam axis	Construction cost (x1000 US$)	Secondary energy (MWh)	Guaranteed energy (MWh)	CUEG (US$/MWh)
Axis-A	143,809	65,425	686,366	20.2
Axis-B	126,072	66,350	689,467	17.5
Axis-C	128,278	63,078	654,863	18.8

Note:CUEG; Unit Cost of Guaranteed Energy

2. Dalbergia Hydropower Scheme

Dam axis	Construction cost (x1000 US$)	Secondary energy (MWh)	Guaranteed energy (MWh)	CUEG (US$/MWh)
Axis-A	85,309	13,399	111,793	75.8
Axis-B	68,995	12,850	106,407	64.2
Axis-C	67,794	10,626	91,627	73.5

3. Benedito Novo Hydropower Scheme

Dam axis	Construction cost (x1000 US$)	Secondary energy (MWh)	Guaranteed energy (MWh)	CUEG (US$/MWh)
Axis-A	32,196	12,802	72,562	43.0
Axis-B	33,343	12,549	71,008	45.6
Axis-C	31,071	11,681	65,747	45.9

Table 7.1 Construction Cost of Salto Pilão (1) Hydropower Scheme (1/3)

Work Item	Unit	Unit Price (US$)	Quantity	Amount (thousand US$)
I. Direct Cost				
1. River Diversion Works				
(1) Diversion tunnel				
(a) Portal excavation, common	cu.m	5	55,300	277
(b) Portal excavation, rock	cu.m	20	37,000	740
(c) Tunnel excavation	cu.m	90	68,300	6,147
(d) Backfill	cu.m	4	2,800	11
(e) Portal concrete	cu.m	170	2,920	496
(f) Lining concrete	cu.m	170	23,700	4,029
(g) Reinforcing bar	ton	1,300	414	538
(h) Steel support	ton	2,500	224	560
(i) Diversion closure gate	ton	6,000	9	54
(j) Plug concrete	cu.m	100	1,140	114
(2) Primary cofferdam	cu.m	6	21,300	128
(3) Secondary cofferdam				
(a) Excavation, common	cu.m	5	50,500	253
(b) Excavation, rock	cu.m	20	6,540	131
(c) Concrete	cu.m	100	32,300	3,230
(4) Downstream cofferdam	cu.m	6	36,100	217
(5) Miscellaneous works	L.S			844
Sub-total of Item 1				17,768
2. Dam and Spillway				
(1) Excavation, common	cu.m	5	86,100	431
(2) Excavation, rock	cu.m	20	24,300	486
(3) Backfill	cu.m	4	7,600	30
(4) Mass concrete	cu.m	100	66,500	6,650
(5) Structural concrete	cu.m	170	4,050	689
(6) Reinforcing bar	ton	1,300	125	163
(7) Spillway bridge	L.S			35
(8) Bridge for maintenance	L.S			7
(9) Curtain grouting	L.S			337
(10) Consolidation grouting	L.S			45
(11) Spillway gate	ton	6,000	1,095	6,570
(12) Sand scouring gate	ton	6,000	140	840
(13) Miscellaneous works	L.S			444
Sub-total of Item 2				16,725
3. Intake and Sand Trap Basin				
(1) Excavation, common	cu.m	5	126,300	632
(2) Excavation, rock	cu.m	20	190,600	3,812
(3) Backfill	cu.m	4	18,200	73
(4) Mass concrete	cu.m	100	11,400	1,140
(5) Structural concrete	cu.m	170	29,400	4,998
(6) Reinforcing bar	ton	1,300	380	494
(7) Intake gate	ton	6,000	196	1,176
(8) Trashrack	ton	3,500	133	466
(9) Sand flush gate	ton	6,000	4	24
(10) Rim grouting	L.S			205
(11) Miscellaneous works	L.S			568
Sub-total of Item 3				13,586

(to be continued)

Table 7.1 Construction Cost of Salto Pilão (1) Hydropower Scheme (2/3)

Work Item	Unit	Unit Price (US$)	Quantity	Amount (thousand US$)
4. Headrace Tunnel				
(1) Tunnel excavation	cu.m	90	216,870	19,518
(2) Lining concrete	cu.m	170	57,260	9,734
(3) Reinforcing bar	ton	1,300	2,020	2,626
(4) Steel support	ton	2,500	315	788
(5) Consolidation grouting	L.S			154
(6) Work adit	L.S			1,586
(7) Miscellaneous works	L.S			1,641
Sub-total of Item 4				36,047
5. Surge Tank				
(1) Open excavation, common	cu.m	5	99,600	498
(2) Open excavation, rock	cu.m	20	64,600	1,292
(3) Shaft excavation	cu.m	130	19,000	2,470
(4) Lining concrete	cu.m	190	3,300	627
(5) Structural concrete	cu.m	170	850	145
(6) Reinforcing bar	ton	1,300	195	254
(7) Consolidation grouting	L.S			22
(8) Surge tank gate	ton	6,000	65	390
(9) Miscellaneous works	L.S			265
Sub-total of Item 5				5,962
6. Penstock				
(1) Open excavation, rock	cu.m	20	10,400	208
(2) Shaft excavation	cu.m	130	8,650	1,125
(3) Backfill	cu.m	4	8,600	34
(4) Open concrete	cu.m	170	1,450	247
(5) Backfill concrete	cu.m	200	2,640	528
(6) Reinforcing bar	ton	1,300	15	20
(7) Consolidation grouting	L.S			106
(8) Steel liner	ton	3,800	1,710	6,498
(9) Work adit	L.S			446
(10) Miscellaneous works	L.S			438
Sub-total of Item 6				9,649
7. Power Station & Tailrace				
(1) Excavation, common	cu.m	5	216,700	1,084
(2) Excavation, rock	cu.m	20	65,700	1,314
(3) Backfill	cu.m	4	6,000	24
(4) Concrete	cu.m	190	24,300	4,617
(5) Backfill concrete	cu.m	100	700	70
(6) Reinforcing bar	ton	1,300	830	1,079
(7) Superstructure	cu.m	190	15,600	2,964
(8) Draft tube gate	ton	6,000	20	120
(9) Generating equipment	L.S			26,990
(10) T/L & S/S	L.S			3,417
(11) Tailrace bridge	L.S			13
(12) Miscellaneous works	L.S			410
Sub-total of Item 7				42,102

(to be continued)

Table 7.1 Construction Cost of Salto Pilão (1) Hydropower Scheme (3/3)

Work Item	Unit	Unit Price (US$)	Quantity	Amount (thousand US$)
8. Access Road				
(1) New construction road	Km	360,000	3.5	1,260
(2) Improvement of existing road	Km	180,000	1.5	270
(3) Bridge	m	5,700	10	57
(4) Miscellaneous works	L.S			79
Sub-total of Item 8				1,666
Total of Item I				143,506
II. Compensation Cost				
1. Land				
(1) Agricultural land	sq.Km	220,000	0.15	33
(2) Forest	sq.Km	80,000	0.10	8
(3) Grass land	sq.Km	195,328	0.067	13
(4) Reforestation	sq.Km	150,000	0.017	3
Sub-total of Item 1				57
2. House				
(1) Wooden house	Nos.	9	12,672	114
Total of Item II				171
III. Administration Cost				7,175
IV. Engineering Service Cost				4,100
V. Physical Contingency (15 %)				23,243
Grand Total				178,195

Table 7.2 DISBURSEMENT SCHEDULE

(Unit: x thousand US$)

Year/Scheme	Salto Pilão (1)	Dalbergia	Benedito Novo
1st	55,398	30,202	17,392
2nd	19,900	23,036	16,076
3rd	54,231	35,807	23,061
4th	48,666	13,152	-
Total	178,195	102,197	56,529

Table 7.3 Construction Cost of Dalbergia Hydropower Scheme (1/3)

Work Item	Unit	Unit Price (US$)	Quantity	Amount (thousand US$)
I. Direct Cost				
1. River Diversion Works				
(1) Diversion tunnel				
(a) Portal excavation, common	cu.m	5	41,500	208
(b) Portal excavation, rock	cu.m	20	41,300	826
(c) Tunnel excavation	cu.m	90	9,330	840
(d) Backfill	cu.m	4	2,100	8
(e) Portal concrete	cu.m	170	3,000	510
(f) Lining concrete	cu.m	170	3,390	576
(g) Reinforcing bar	ton	1,300	110	143
(h) Steel support	ton	2,500	45	113
(i) Diversion closure gate	ton	6,000	7.5	45
(j) Plug concrete	cu.m	100	550	55
(2) Primary cofferdam	cu.m	6	2,000	12
(3) Secondary cofferdam				
(a) Excavation, common	cu.m	5	20,900	105
(b) Excavation, rock	cu.m	20	2,540	51
(c) Concrete	cu.m	100	18,700	1,870
(4) Downstream cofferdam	cu.m	6	11,700	70
(5) Miscellaneous works	L.S			269
Sub-total of Item 1				5,700
2. Dam and Spillway				
(1) Excavation, common	cu.m	5	250,700	1,254
(2) Excavation, rock	cu.m	20	118,000	2,360
(3) Backfill	cu.m	4	16,200	65
(4) Mass concrete	cu.m	100	109,700	10,970
(5) Structural concrete	cu.m	170	3,750	638
(6) Reinforcing bar	ton	1,300	390	507
(7) Riverbed protection	cu.m	70	1,650	116
(8) Spillway bridge	L.S			35
(9) Bridge for maintenance	L.S			7
(10) Curtain grouting	L.S			473
(11) Consolidation grouting	L.S			141
(12) Spillway gate	ton	6,000	680	4,080
(13) Sand scouring gate	ton	6,000	120	720
(14) Miscellaneous works	L.S			828
Sub-total of Item 2				22,193
3. Intake and Sand Trap Basin				
(1) Excavation, common	cu.m	5	51,300	257
(2) Excavation, rock	cu.m	20	39,100	782
(3) Backfill	cu.m	4	4,440	18
(4) Structural concrete	cu.m	170	9,210	1,566
(5) Reinforcing bar	ton	1,300	120	156
(6) Intake gate	ton	6,000	60	360
(7) Trashrack	ton	3,500	50	175
(8) Sand flush gate	ton	6,000	4	24
(9) Miscellaneous works	L.S			139
Sub-total of Item 3				3,476

(to be continued)

Table 7.3 Construction Cost of Dalbergia Hydropower Scheme (2/3)

Work Item	Unit	Unit Price (US$)	Quantity	Amount (thousand US$)
4. Headrace Tunnel				
(1) Tunnel excavation	cu.m	110	149,340	16,427
(2) Lining concrete	cu.m	180	35,820	6,448
(3) Reinforcing bar	ton	1,300	1,060	1,378
(4) Steel support	ton	2,500	110	275
(5) Consolidation grouting	L.S			106
(6) Work adit	L.S			1,982
(7) Miscellaneous works	L.S			1,232
Sub-total of Item 4				27,848
5. Surge Tank				
(1) Open excavation, common	cu.m	5	39,700	199
(2) Open excavation, rock	cu.m	20	2,900	58
(3) Shaft excavation	cu.m	130	11,600	1,508
(4) Lining concrete	cu.m	190	2,700	513
(5) Structural concrete	cu.m	170	670	114
(6) Reinforcing bar	ton	1,300	160	208
(7) Consolidation grouting	L.S			24
(8) Surge tank gate	ton	6,000	45	270
(9) Miscellaneous works	L.S			131
Sub-total of Item 5				3,025
6. Penstock				
(1) Open excavation, common	cu.m	5	27,300	137
(2) Open excavation, rock	cu.m	20	9,500	190
(3) Shaft excavation	cu.m	130	5,100	663
(4) Backfill	cu.m	4	34,900	140
(5) Open concrete	cu.m	170	1,540	262
(6) Backfill concrete	cu.m	200	1,810	362
(7) Reinforcing bar	ton	1,300	16	21
(8) Consolidation grouting	L.S			95
(9) Steel liner	ton	3,800	645	2,451
(10) Work adit	L.S			280
(11) Miscellaneous works	L.S			216
Sub-total of Item 6				4,816
7. Power Station & Tailrace				
(1) Excavation, common	cu.m	5	24,500	123
(2) Excavation, rock	cu.m	20	5,500	110
(3) Backfill	cu.m	4	5,000	20
(4) Embankment	cu.m	6	22,000	132
(5) Concrete	cu.m	190	14,600	2,774
(6) Backfill concrete	cu.m	100	620	62
(7) Reinforcing bar	ton	1,300	350	455
(8) Superstructure	cu.m	190	5,600	1,064
(9) Draft tube gate	ton	6,000	6	36
(10) Generating equipment	L.S			7,363
(11) T/L & S/S	L.S			654
(12) Miscellaneous works	L.S			184
Sub-total of Item 7				12,976

(to be continued)

Table 7.3 Construction Cost of Dalbergia Hydropower Scheme (3/3)

Work Item	Unit	Unit Price (US$)	Quantity	Amount (thousand US$)
8. Access Road				
(1) New construction road	Km	360,000	1.85	666
(2) Improvement of existing road	Km	180,000	0.15	27
(3) Bridge	m	5,700	20	114
(4) Miscellaneous works	L.S			40
Sub-total of Item 8				847
Total of Item I				80,880
II. Compensation Cost				
1. Land				
(1) Forest	sq.Km	120,000	0.065	8
(2) Grass land	sq.Km	601,625	0.183	110
Sub-total of Item 1				118
2. House				
(1) Wooden house	Nos.	12,946	5	65
Total of Item II				183
III. Administration Cost				4,044
IV. Engineering Service Cost				3,760
V. Physical Contingency (15 %)				13,330
Grand Total				102,197

Table 7.4 Construction Cost of Benedito Novo Hydropower Scheme (1/3)

Work Item	Unit	Unit Price (US$)	Quantity	Amount (thousand US$)
I. Direct Cost				
1. River Diversion Works				
(1) Diversion tunnel				
(a) Portal excavation, common	cu.m	5	5,500	28
(b) Portal excavation, rock	cu.m	20	6,000	120
(c) Tunnel excavation	cu.m	100	4,200	420
(d) Backfill	cu.m	4	1,700	7
(e) Portal concrete	cu.m	170	1,500	255
(f) Lining concrete	cu.m	180	1,600	288
(g) Reinforcing bar	ton	1,300	55	72
(h) Steel support	ton	2,500	30	75
(i) Diversion closure gate	ton	6,000	5.5	33
(j) Plug concrete	cu.m	100	320	32
(2) Primary cofferdam	cu.m	6	3,000	18
(3) Secondary cofferdam				
(a) Excavation, common	cu.m	5	6,400	32
(b) Excavation, rock	cu.m	20	900	18
(c) Concrete	cu.m	100	3,930	393
(4) Miscellaneous works	L.S			88
Sub-total of Item 1				1,878
2. Dam and Spillway				
(1) Excavation, common	cu.m	5	43,000	215
(2) Excavation, rock	cu.m	20	25,500	510
(3) Mass concrete	cu.m	100	50,300	5,030
(4) Structural concrete	cu.m	170	2,800	476
(5) Reinforcing bar	ton	1,300	85	111
(6) Riverbed protection	cu.m	70	2,050	144
(7) Spillway bridge	L.S			14
(8) Bridge for maintenance	L.S			3
(9) Curtain grouting	L.S			87
(10) Consolidation grouting	L.S			27
(11) Spillway gate	ton	6,000	650	3,900
(12) Sand scouring gate	ton	6,000	70	420
(13) Miscellaneous works	L.S			331
Sub-total of Item 2				11,267
3. Intake and Sand Trap Basin				
(1) Excavation, common	cu.m	5	83,200	416
(2) Excavation, rock	cu.m	20	31,100	622
(3) Backfill	cu.m	4	20,640	83
(4) Mass concrete	cu.m	100	2,540	254
(5) Structural concrete	cu.m	170	18,800	3,196
(6) Reinforcing bar	ton	1,300	235	306
(7) Intake gate	ton	6,000	120	720
(8) Trashrack	ton	3,500	72	252
(9) Sand flush gate	ton	6,000	4	24
(10) Miscellaneous works	L.S			244
Sub-total of Item 3				6,116

(to be continued)

Table 7.4 Construction Cost of Benedito Novo Hydropower Scheme (2/3)

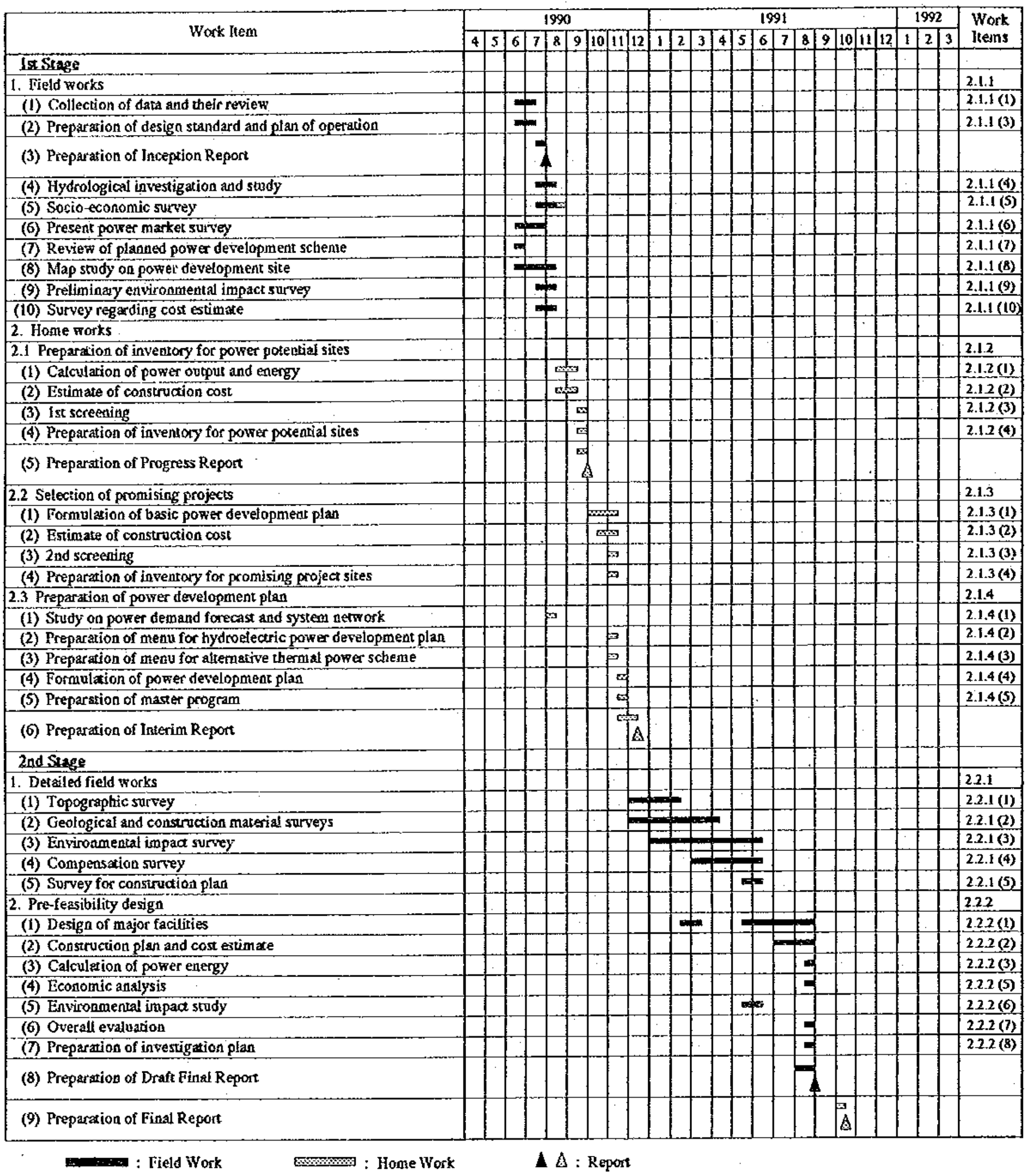
Work Item	Unit	Unit Price (US$)	Quantity	Amount (thousand US$)
4. Headrace Tunnel				
(1) Tunnel excavation	cu.m	140	21,520	3,013
(2) Lining concrete	cu.m	192	6,100	1,171
(3) Reinforcing bar	ton	1,300	155	202
(4) Steel support	ton	2,500	51	128
(5) Consolidation grouting	L.S			66
(6) Work adit	L.S			118
(7) Miscellaneous works	L.S			229
Sub-total of Item 4				4,926
5. Surge Tank				
(1) Open excavation, common	cu.m	5	20,000	100
(2) Open excavation, rock	cu.m	20	6,300	126
(3) Shaft excavation	cu.m	130	3,300	429
(4) Lining concrete	cu.m	190	990	188
(5) Structural concrete	cu.m	170	80	14
(6) Reinforcing bar	ton	1,300	55	72
(7) Consolidation grouting	L.S			18
(8) Miscellaneous works	L.S			47
Sub-total of Item 5				994
6. Penstock				
(1) Open excavation, common	cu.m	5	7,150	36
(2) Open excavation, rock	cu.m	20	5,860	117
(3) Shaft excavation	cu.m	130	3,000	390
(4) Backfill	cu.m	4	10,600	42
(5) Open concrete	cu.m	170	1,050	179
(6) Backfill concrete	cu.m	200	1,290	258
(7) Reinforcing bar	ton	1,300	10	13
(8) Consolidation grouting	L.S			84
(9) Steel liner	ton	3,800	350	1,330
(10) Work adit	L.S			201
(11) Miscellaneous works	L.S			122
Sub-total of Item 6				2,772
7. Power Station & Tailrace				
(1) Excavation, common	cu.m	5	9,600	48
(2) Excavation, rock	cu.m	20	4,000	80
(3) Backfill	cu.m	4	700	3
(4) Embankment	cu.m	6	5,100	31
(5) Concrete	cu.m	190	9,000	1,710
(6) Backfill concrete	cu.m	100	1,300	130
(7) Reinforcing bar	ton	1,300	220	286
(8) Superstructure	cu.m	190	4,600	874
(9) Draft tube gate	ton	6,000	4	24
(10) Generating equipment	L.S			5,650
(11) T/L & S/S	L.S			2,657
(12) Miscellaneous works	L.S			114
Sub-total of Item 7				11,607

(to be continued)

Table 7.4 Construction Cost of Benedito Novo Hydropower Scheme (3/3)

Work Item	Unit	Unit Price (US$)	Quantity	Amount (thousand US$)
8. Relocation Road				
(1) Excavation, common	cu.m	5	71,600	358
(2) Excavation, rock	cu.m	20	46,200	924
(3) Slope Protection	sq.m	3.3	11,400	38
(4) Bridge	m	5,700	20	114
(5) Miscellaneous works	L.S			72
Sub-total of Item 8				1,505
9. Access Road				
(1) New construction road	Km	360,000	1.4	504
(2) Improvement of existing road	Km	180,000	0	0
(3) Bridge	m	5,700	0	0
(4) Miscellaneous works	L.S			25
Sub-total of Item 9				529
Total of Item I				41,593
II. Compensation Cost				
1. Land				
(1) Agricultural land	sq.Km	675,000	0.005	3
(2) Forest	sq.Km	400,000	0.011	4
(3) Urban area	sq.Km	7,700,000	0.012	92
Sub-total of Item 1				100
2. House				
(1) Brick house	Nos.	37,586	7	263
(2) Wooden house	Nos.	13,300	6	80
Sub-total of Item 2				343
3. Existing Power Station	KW	500	3,120	1,560
Total of Item II				2,003
III. Administration Cost				2,080
IV. Engineering Service Cost				3,480
V. Physical Contingency (15 %)				7,373
Grand Total				56,529

FIGURES



Work Item	Work Items
1st Stage	
1. Field works	2.1.1
(1) Collection of data and their review	2.1.1 (1)
(2) Preparation of design standard and plan of operation	2.1.1 (3)
(3) Preparation of Inception Report	
(4) Hydrological investigation and study	2.1.1 (4)
(5) Socio-economic survey	2.1.1 (5)
(6) Present power market survey	2.1.1 (6)
(7) Review of planned power development scheme	2.1.1 (7)
(8) Map study on power development site	2.1.1 (8)
(9) Preliminary environmental impact survey	2.1.1 (9)
(10) Survey regarding cost estimate	2.1.1 (10)
2. Home works	
2.1 Preparation of inventory for power potential sites	2.1.2
(1) Calculation of power output and energy	2.1.2 (1)
(2) Estimate of construction cost	2.1.2 (2)
(3) 1st screening	2.1.2 (3)
(4) Preparation of inventory for power potential sites	2.1.2 (4)
(5) Preparation of Progress Report	
2.2 Selection of promising projects	2.1.3
(1) Formulation of basic power development plan	2.1.3 (1)
(2) Estimate of construction cost	2.1.3 (2)
(3) 2nd screening	2.1.3 (3)
(4) Preparation of inventory for promising project sites	2.1.3 (4)
2.3 Preparation of power development plan	2.1.4
(1) Study on power demand forecast and system network	2.1.4 (1)
(2) Preparation of menu for hydroelectric power development plan	2.1.4 (2)
(3) Preparation of menu for alternative thermal power scheme	2.1.4 (3)
(4) Formulation of power development plan	2.1.4 (4)
(5) Preparation of master program	2.1.4 (5)
(6) Preparation of Interim Report	
2nd Stage	
1. Detailed field works	2.2.1
(1) Topographic survey	2.2.1 (1)
(2) Geological and construction material surveys	2.2.1 (2)
(3) Environmental impact survey	2.2.1 (3)
(4) Compensation survey	2.2.1 (4)
(5) Survey for construction plan	2.2.1 (5)
2. Pre-feasibility design	2.2.2
(1) Design of major facilities	2.2.2 (1)
(2) Construction plan and cost estimate	2.2.2 (2)
(3) Calculation of power energy	2.2.2 (3)
(4) Economic analysis	2.2.2 (5)
(5) Environmental impact study	2.2.2 (6)
(6) Overall evaluation	2.2.2 (7)
(7) Preparation of investigation plan	2.2.2 (8)
(8) Preparation of Draft Final Report	
(9) Preparation of Final Report	

Fig. 1.1 PERFORMED OVERALL WORKS

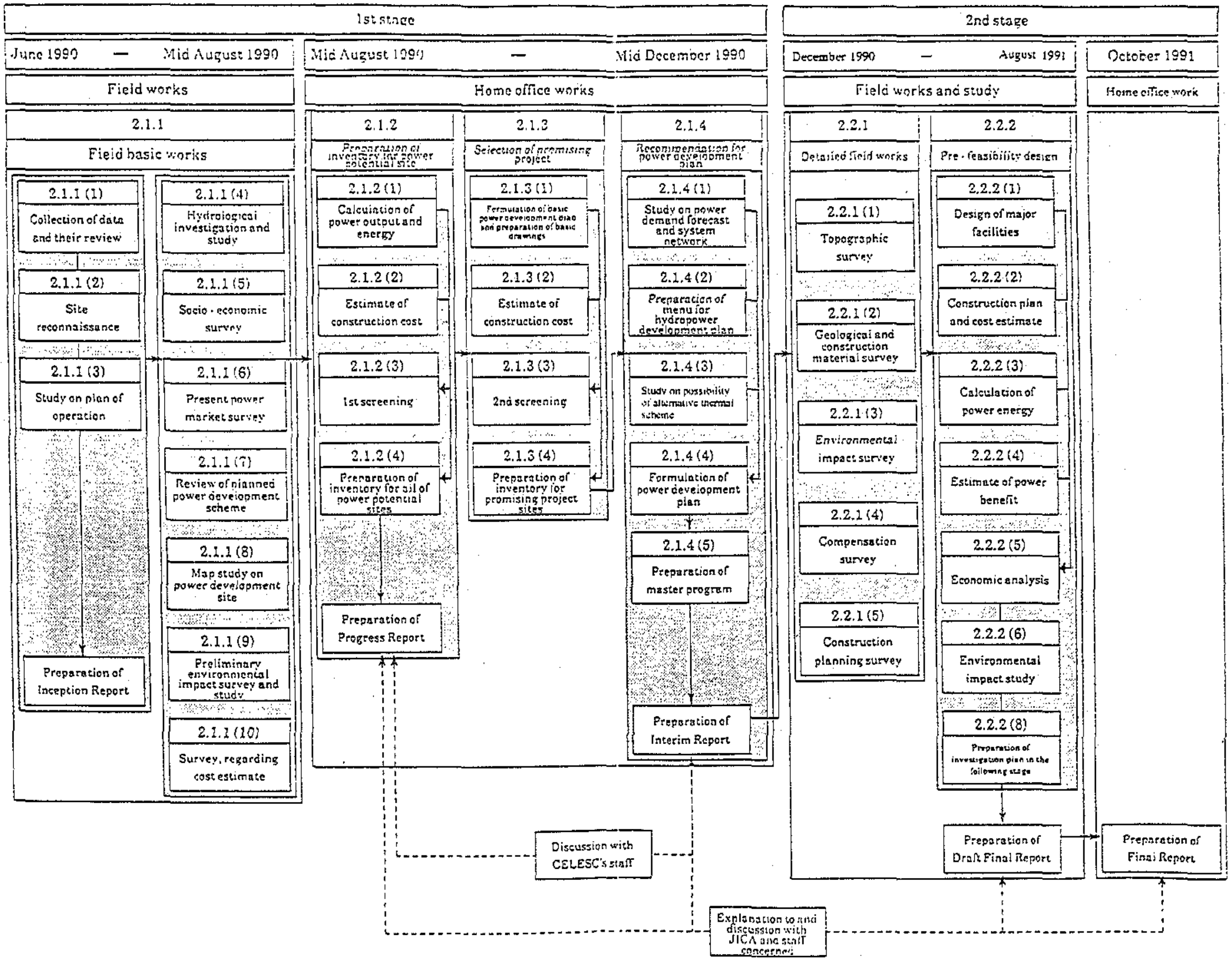


Fig. 1.2 OVERALL WORK FLOW

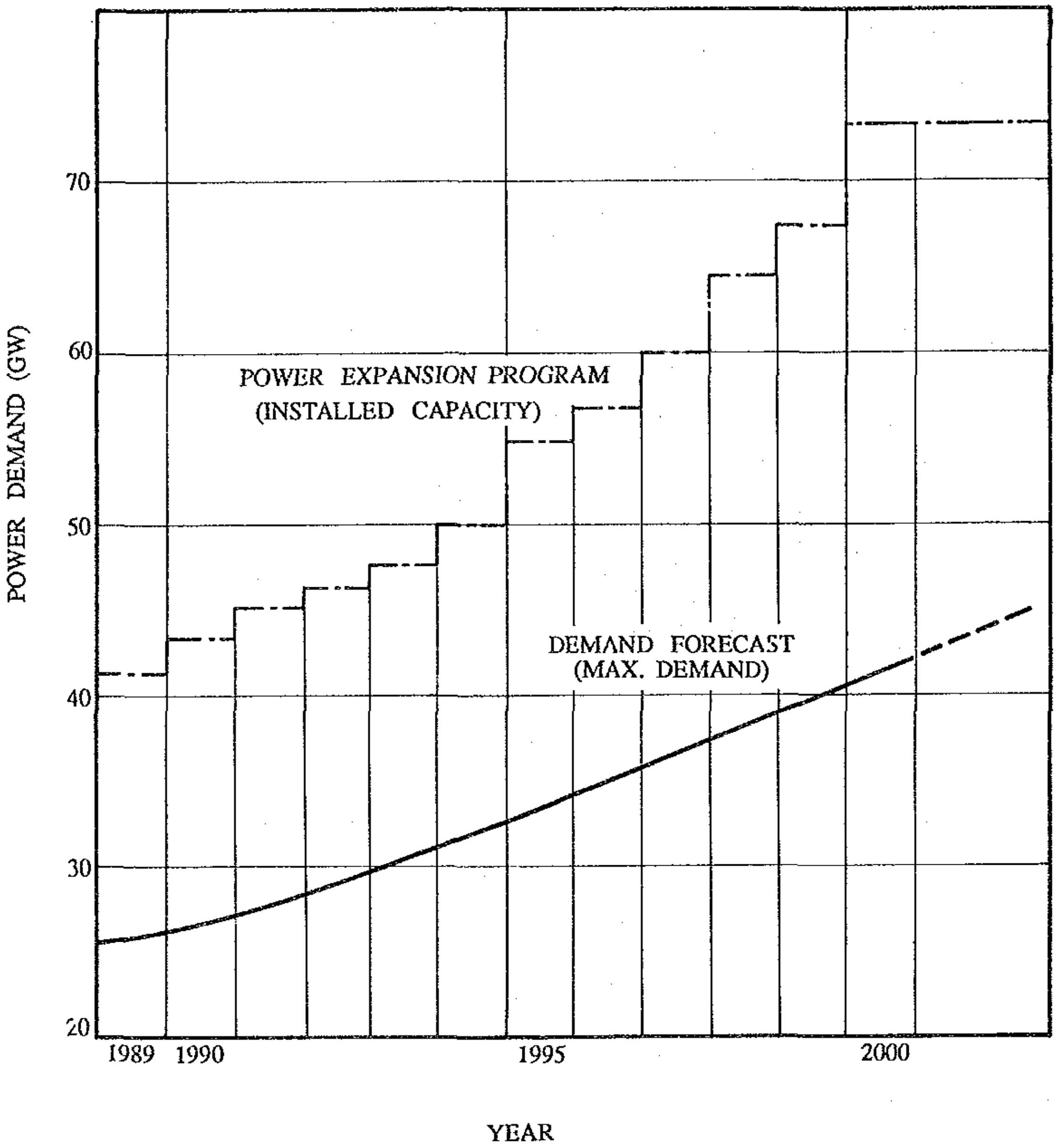


Fig. 3.1 POWER DEMAND FORECAST AND POWER SUPPLY CURVE

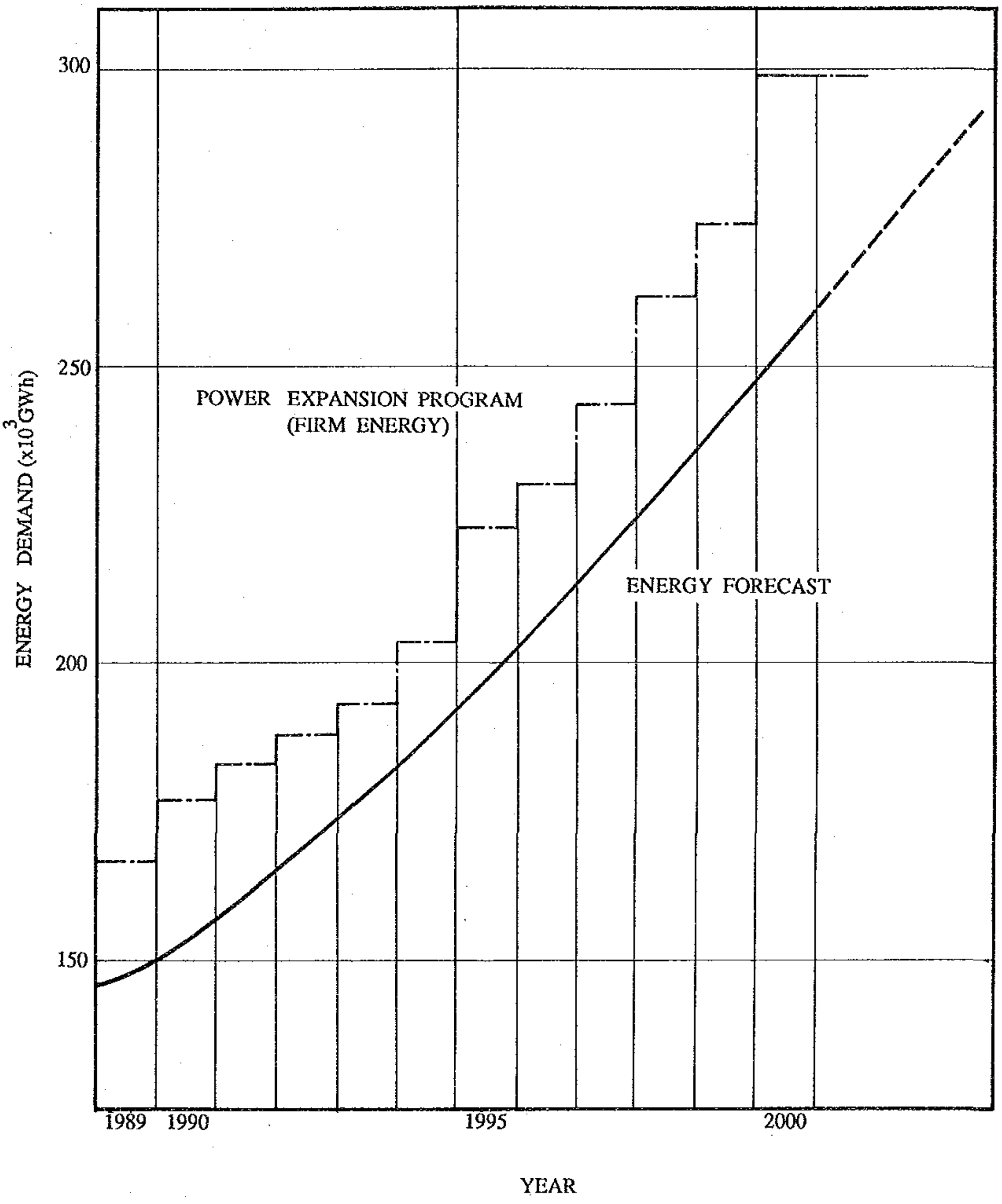
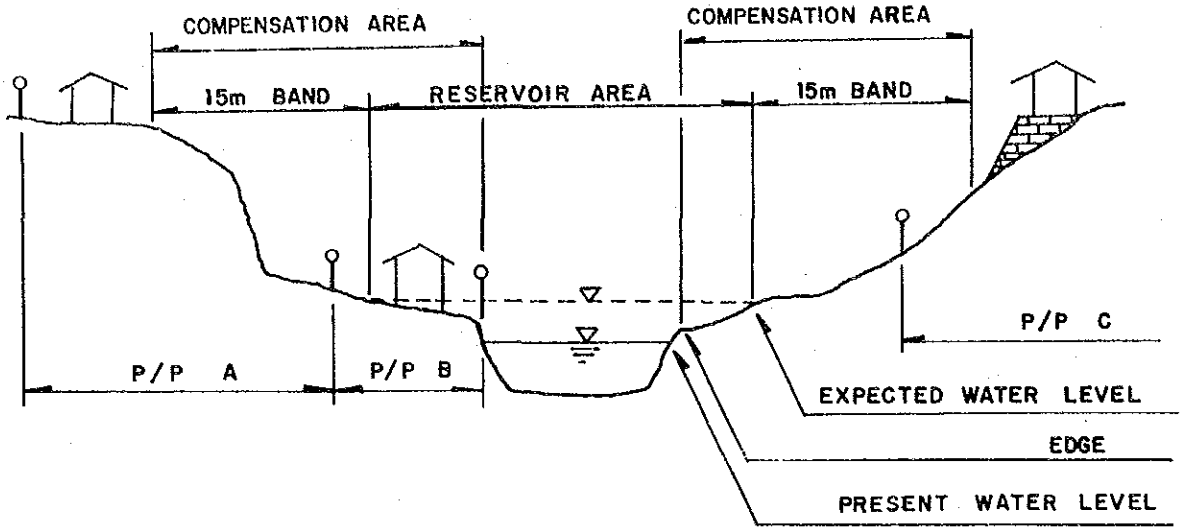


Fig. 3.2 ENERGY DEMAND FORECAST AND ENERGY SUPPLY CURVE

A . COMPENSATED



P/P : PRIVATE PROPERTY

B. NOT COMPENSATED

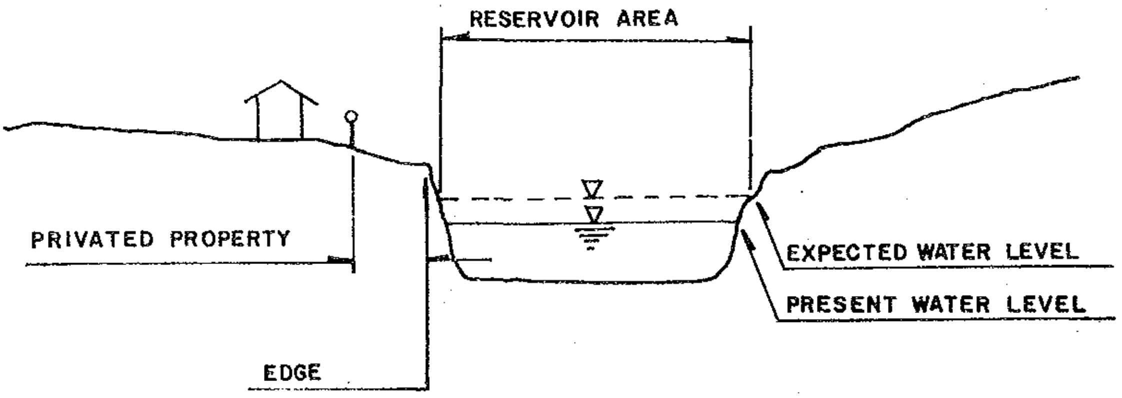


Fig.5.1 DEFINITION OF COMPENSATION AREA

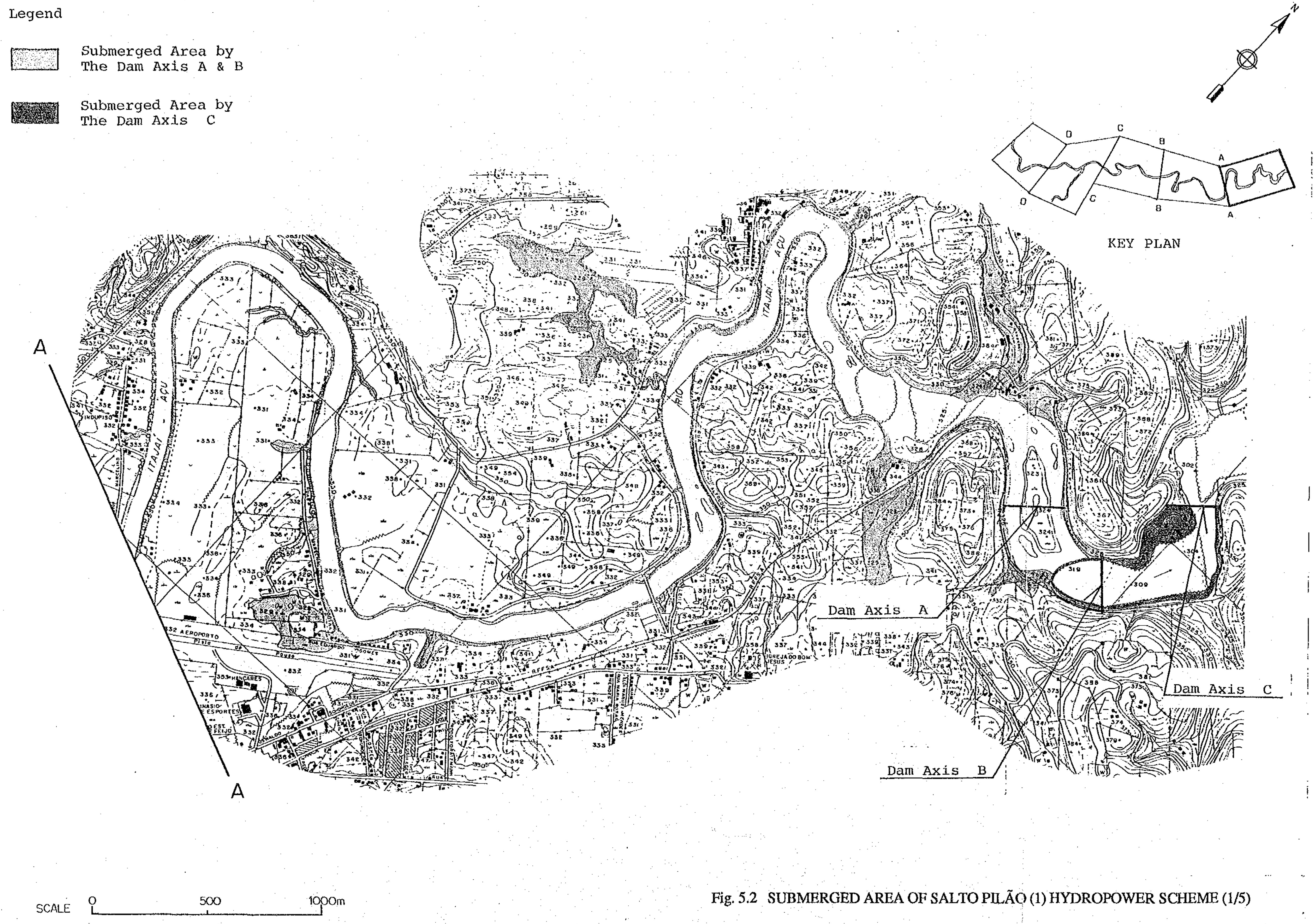


Fig. 5.2 SUBMERGED AREA OF SALTO PILÃO (1) HYDROPOWER SCHEME (1/5)

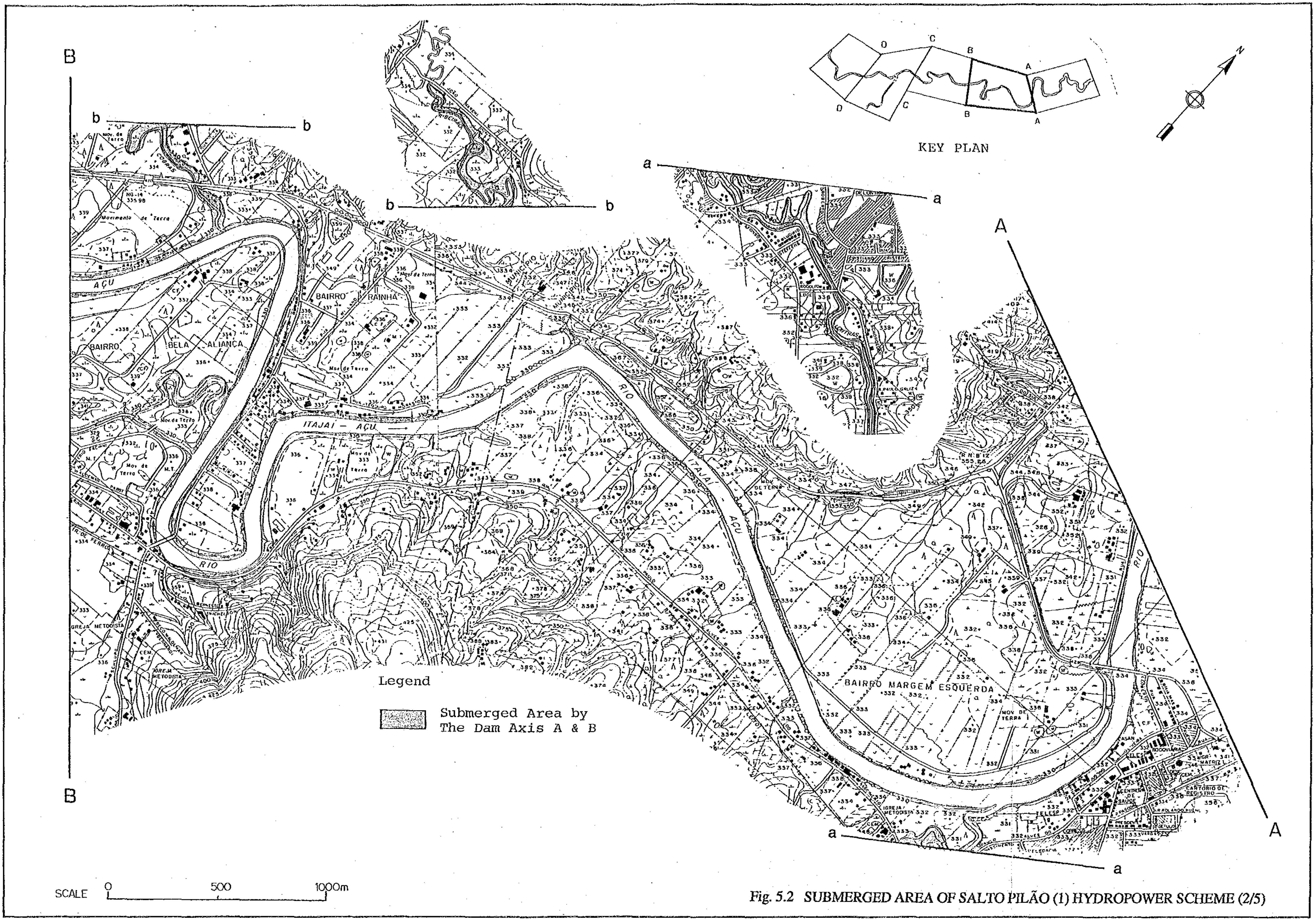
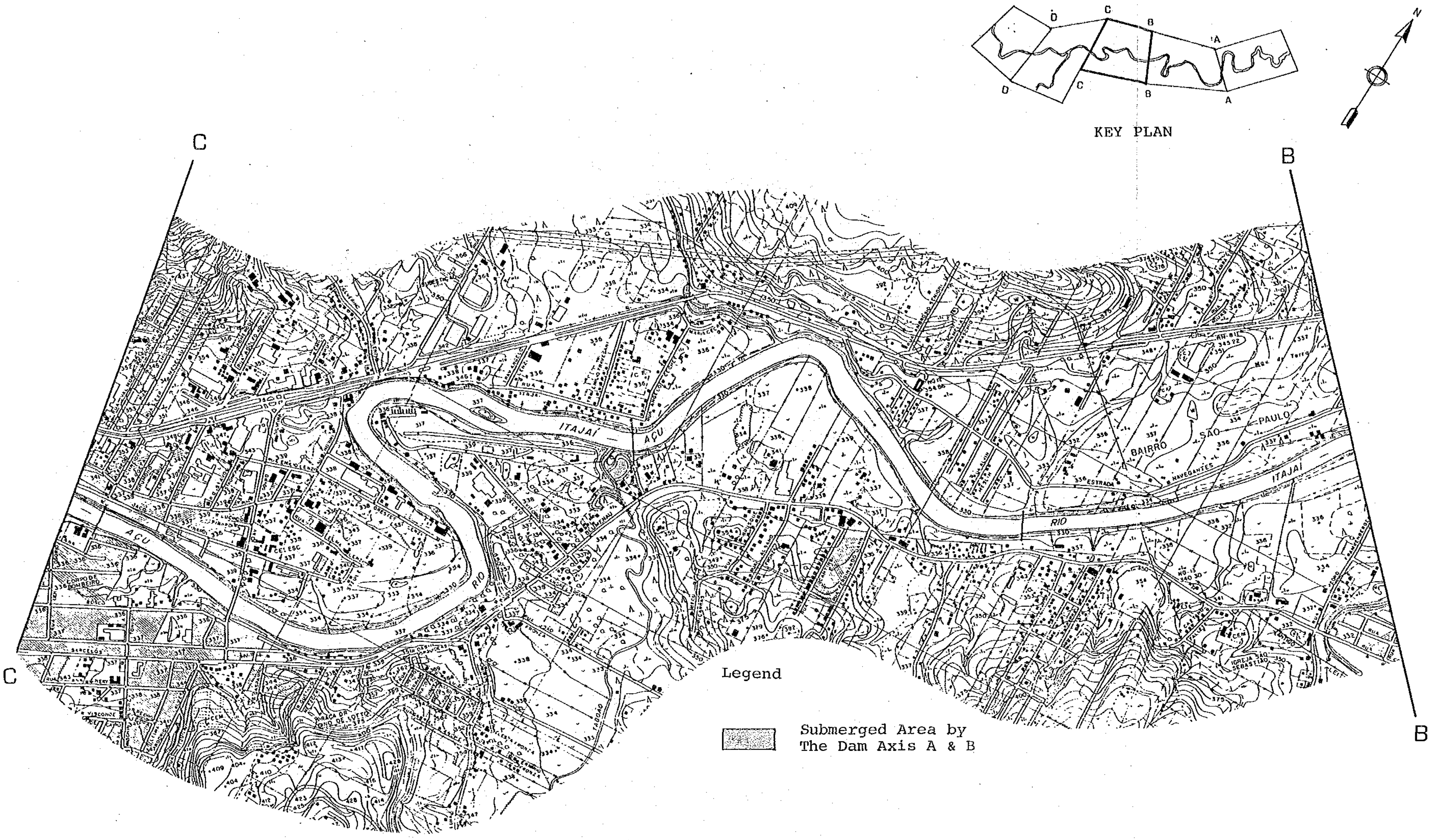


Fig. 5.2 SUBMERGED AREA OF SALTO PILÃO (1) HYDROPOWER SCHEME (2/5)



▨ Submerged Area by The Dam Axis A & B

Fig. 5.2 SUBMERGED AREA OF SALTO PILÃO (1) HYDROPOWER SCHEME (3/5)

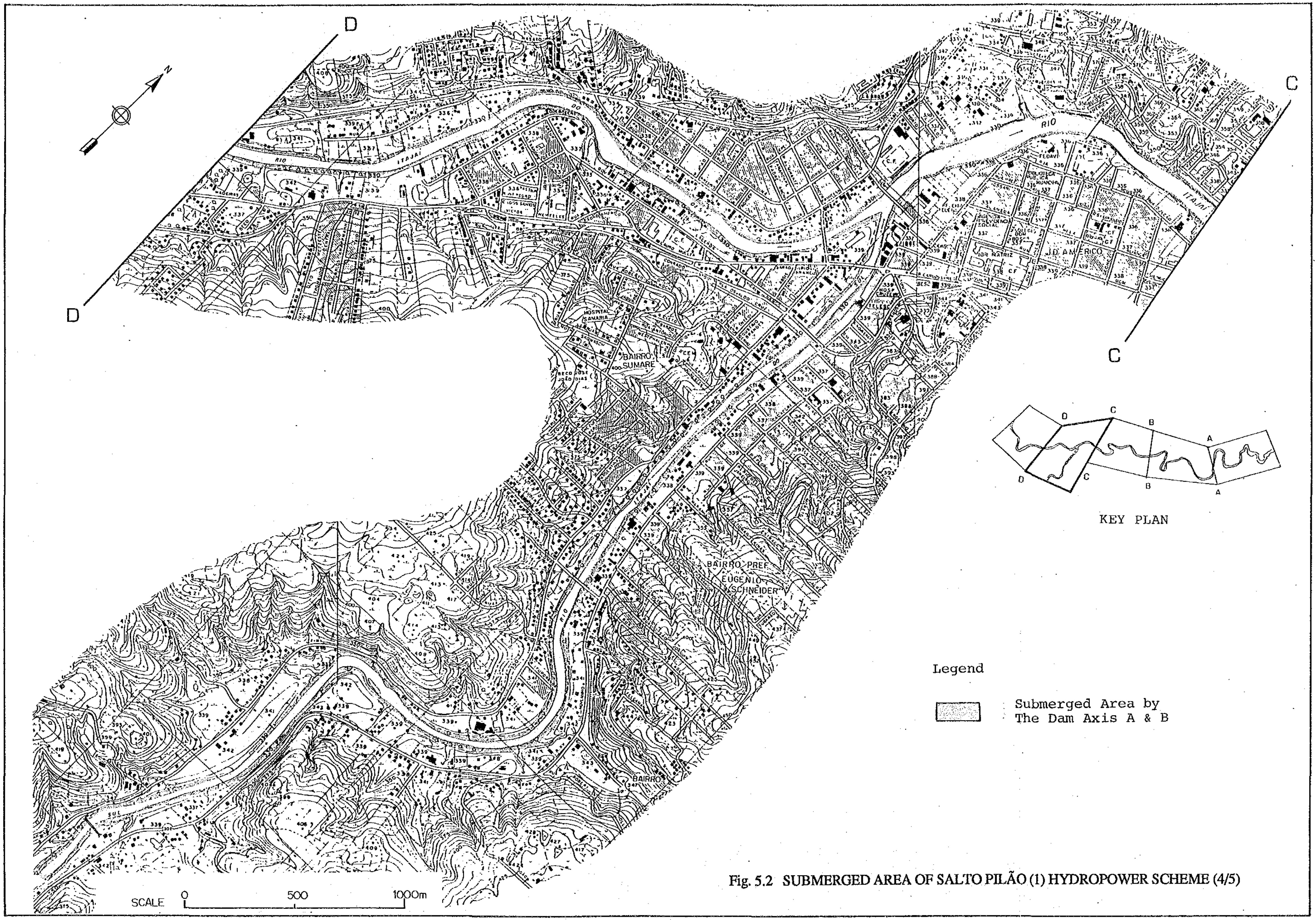


Fig. 5.2 SUBMERGED AREA OF SALTO PILÃO (1) HYDROPOWER SCHEME (4/5)

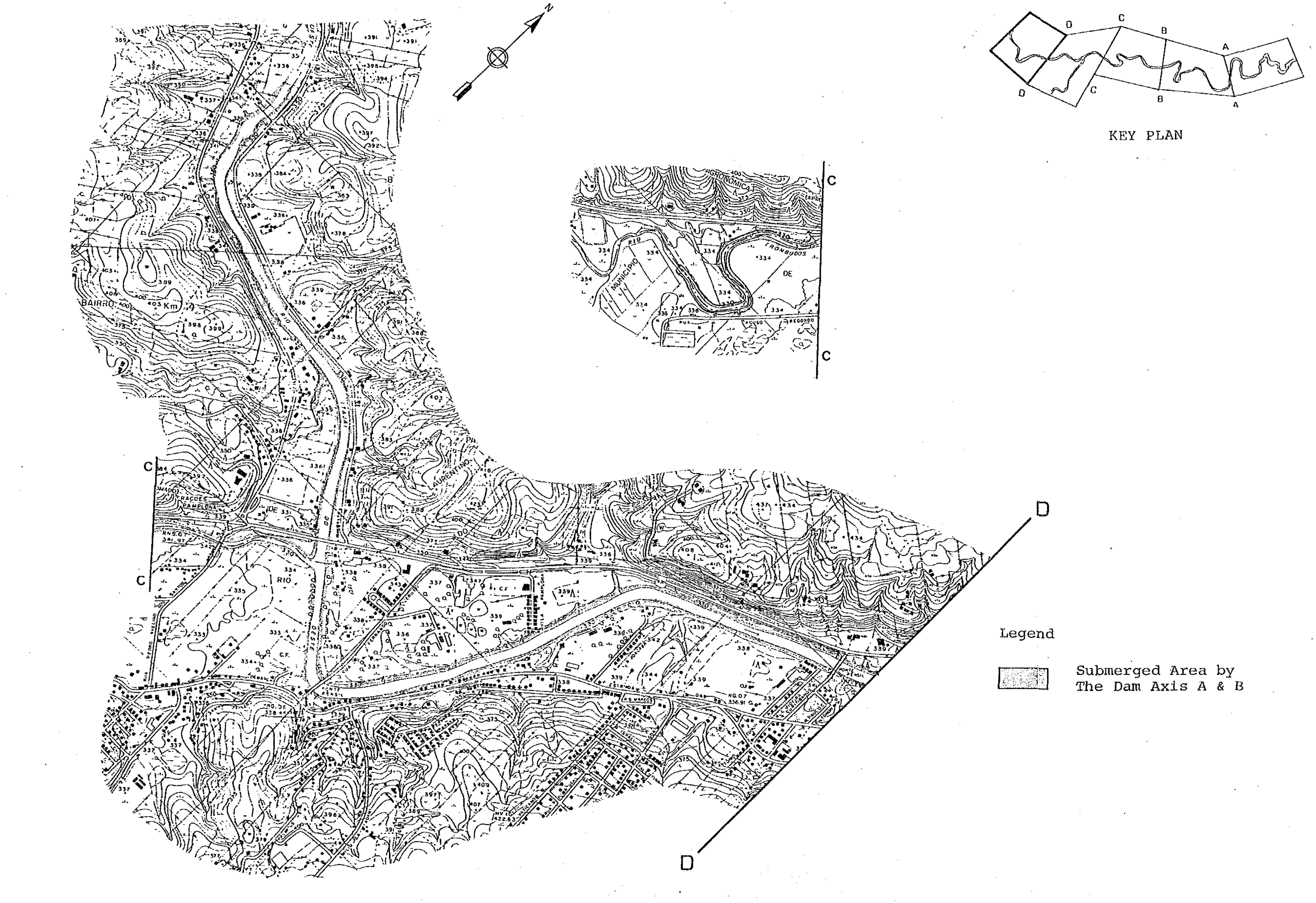


Fig. 5.2 SUBMERGED AREA OF SALTO PILÃO (1) HYDROPOWER SCHEME (5/5)

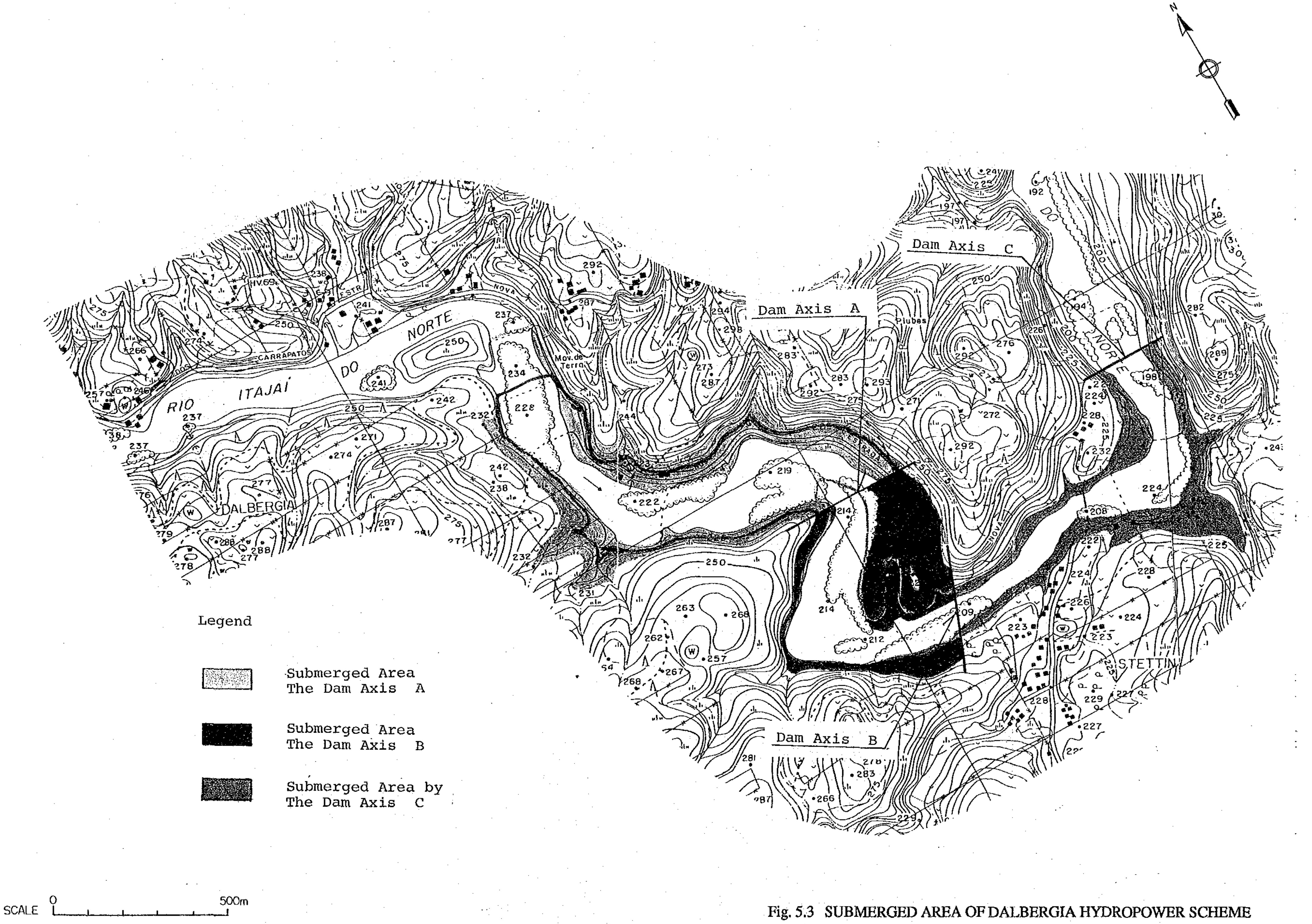


Fig. 5.3 SUBMERGED AREA OF DALBERGIA HYDROPOWER SCHEME

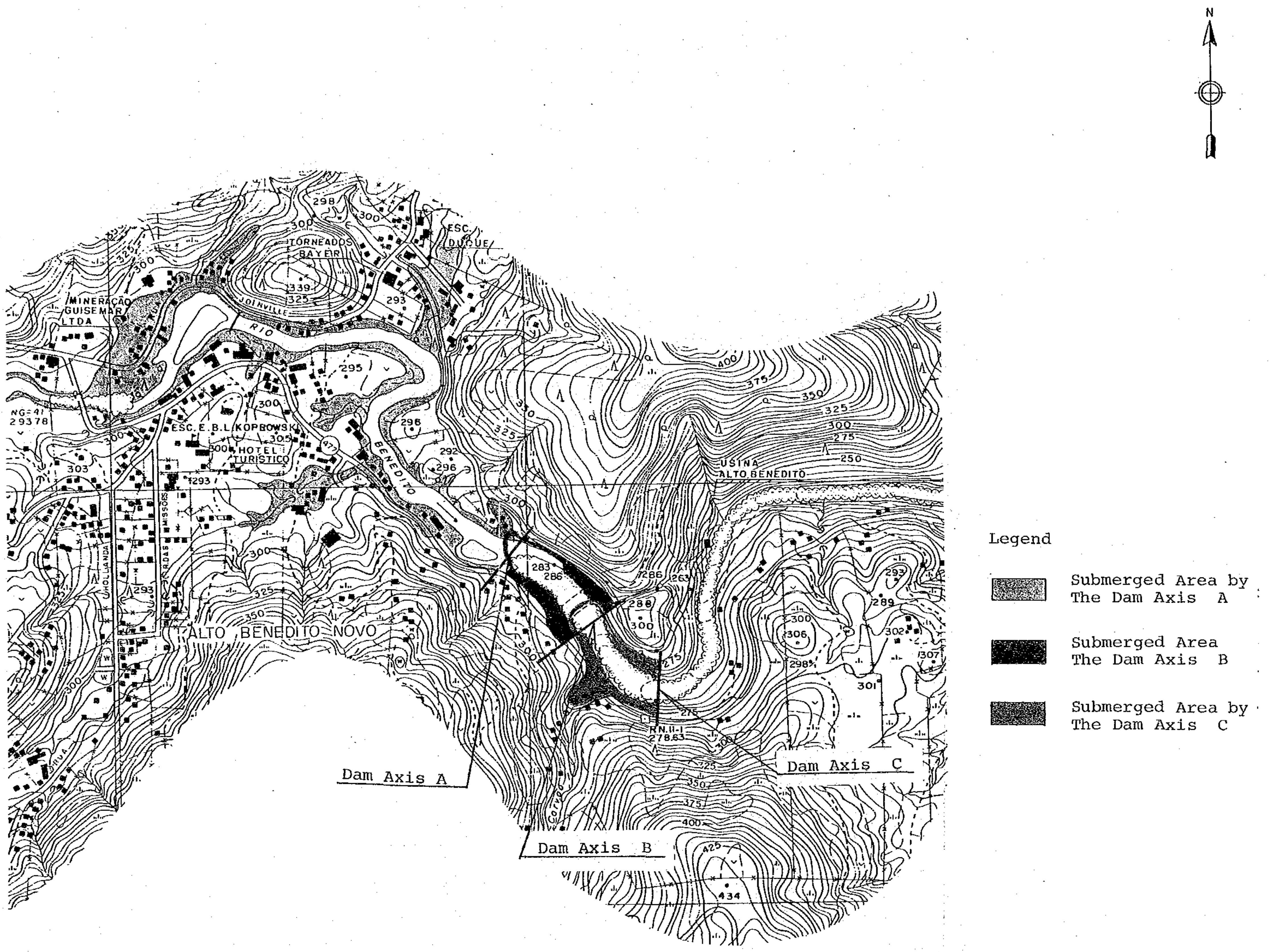


Fig. 5.4 SUBMERGED AREA OF BENEDITO NOVO HYDROPOWER SCHEME

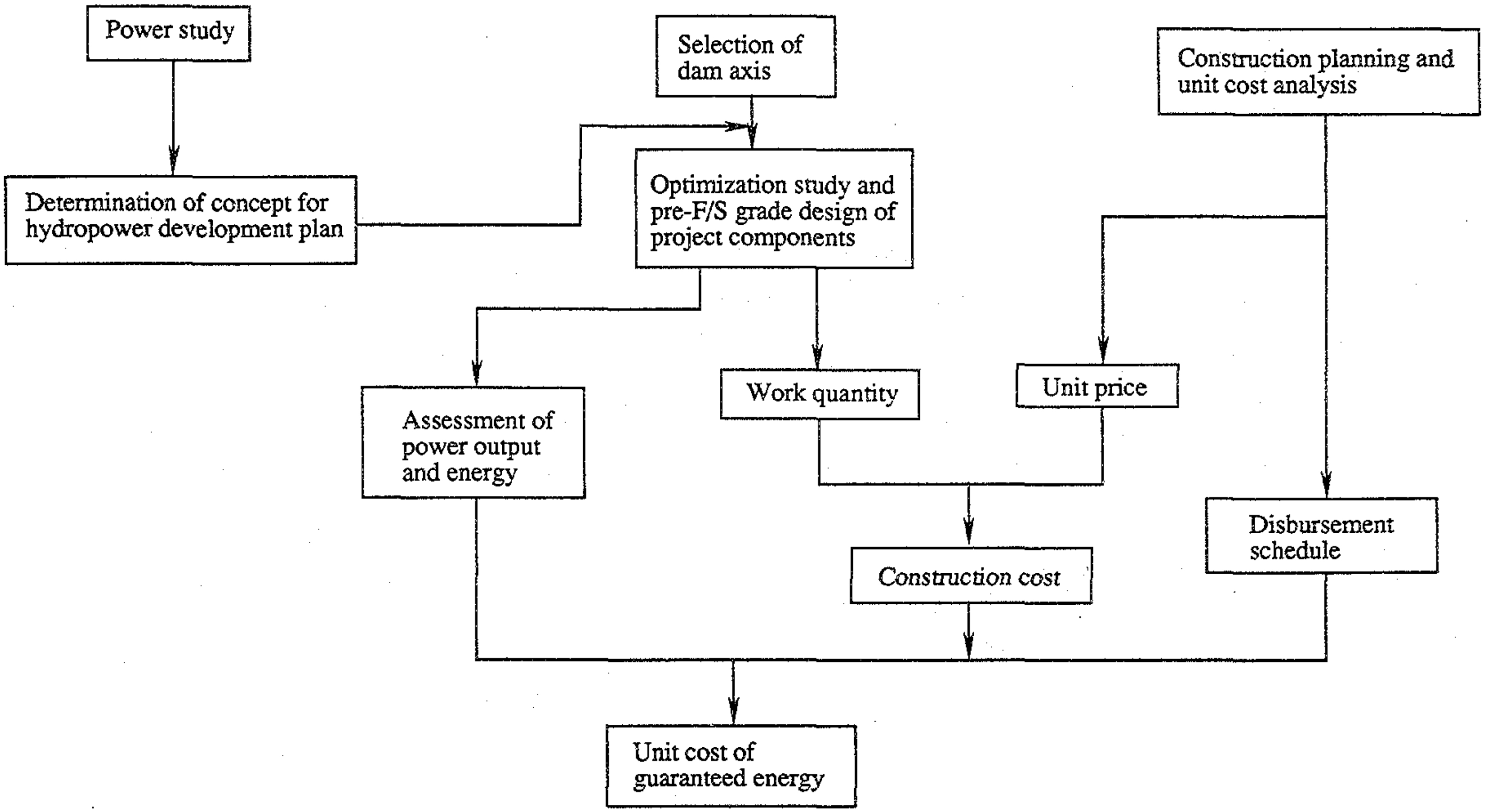
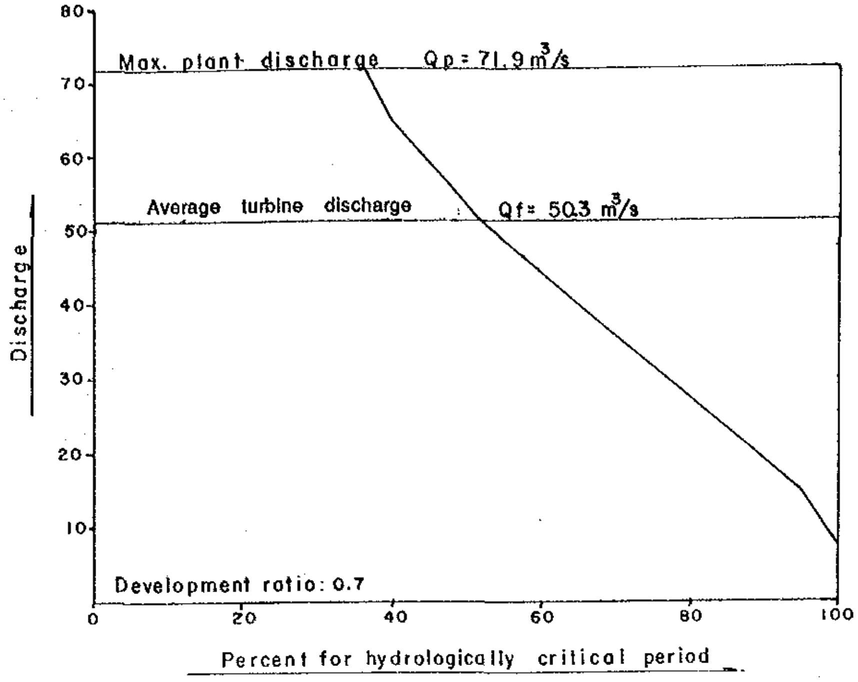
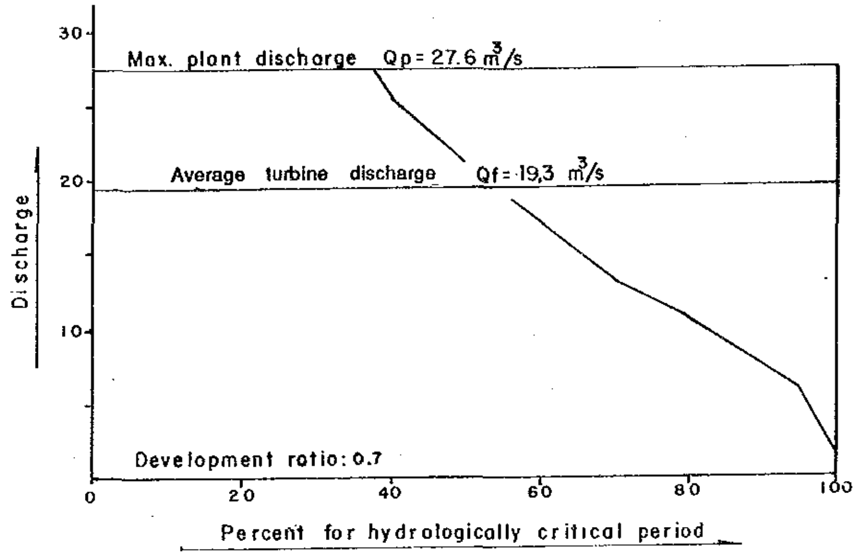


Fig. 6.1 STUDY PROCEDURE



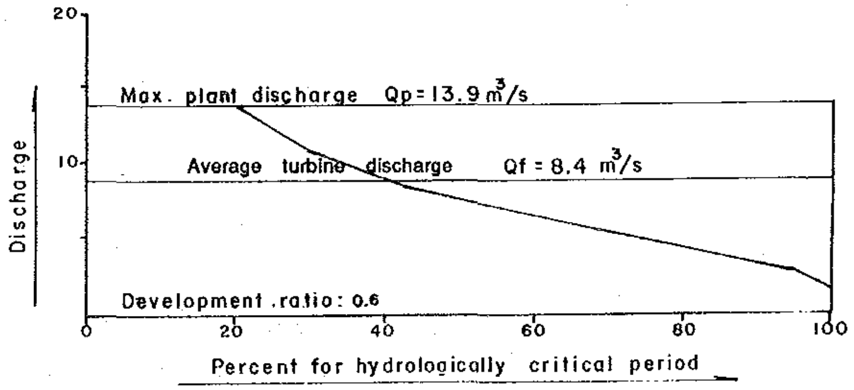
Salto Pilão (I) Scheme

Excess Percent (%)	Flow Discharge (m³/s)
1	562.0
5	318.0
10	204.0
15	155.0
20	121.0
30	83.9
40	64.6
50	53.1
60	44.4
70	35.7
80	27.4
90	18.9
95	15.0
100	7.3



Dalbergia Scheme

Excess Percent (%)	Flow Discharge (m³/s)
1	280.3
5	145.0
10	82.8
15	60.6
20	48.2
30	33.2
40	25.4
50	20.8
60	17.0
70	13.1
80	10.6
90	7.5
95	5.7
100	1.2



Benedito Novo Scheme

Excess Percent (%)	Flow Discharge (m³/s)
1	75.5
5	31.7
10	20.6
15	16.5
20	14.0
30	10.8
40	9.1
50	7.6
60	6.6
70	5.6
80	4.6
90	3.4
95	2.8
100	1.9

Fig. 6.2 RELATION BETWEEN MAXIMUM PLANT DISCHARGE AND AVERAGE TURBINE DISCHARGE

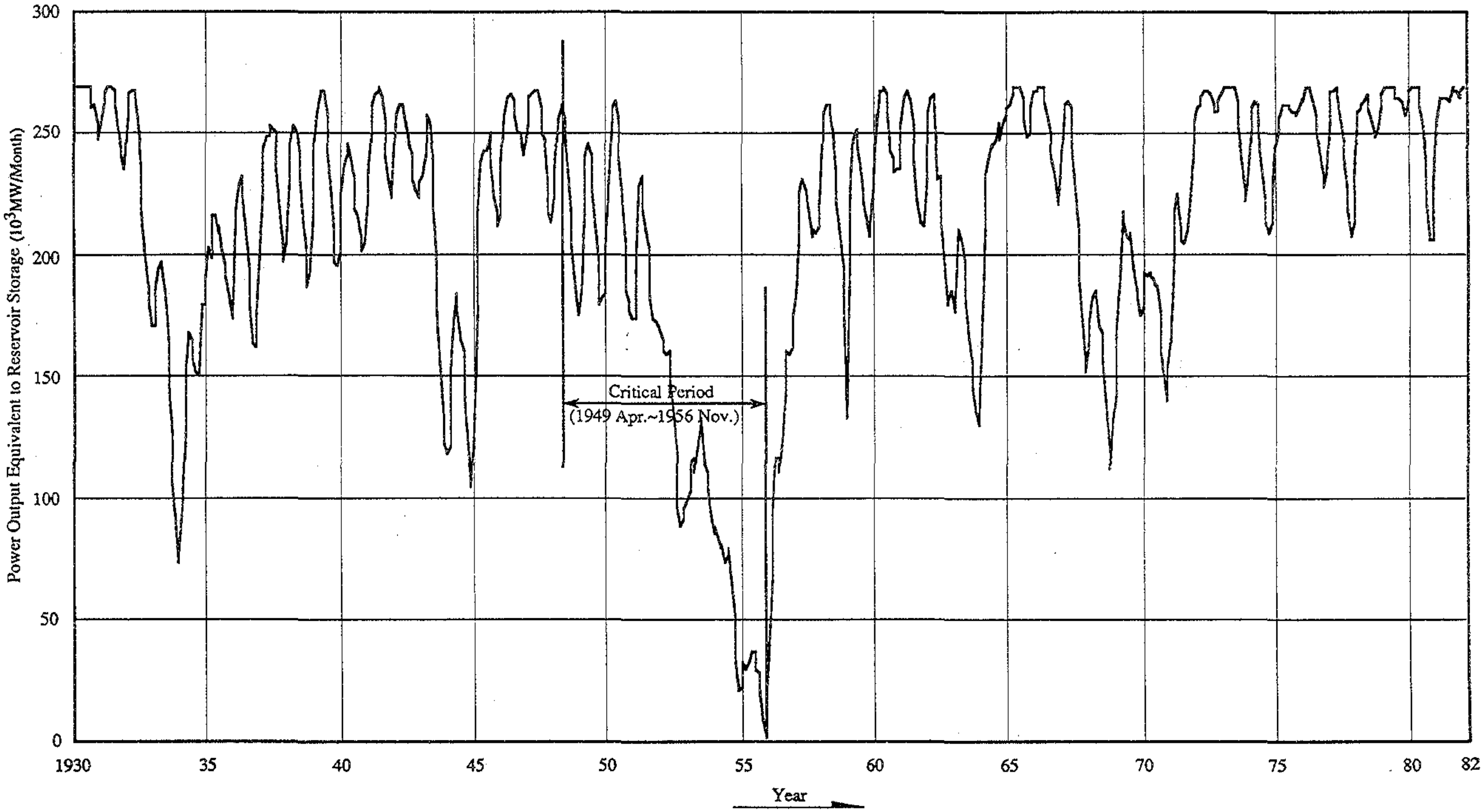


Fig.6.3 CRITICAL PERIOD IN INTERCONNECTION OF SOUTH AND SOUTHEAST SYSTEMS

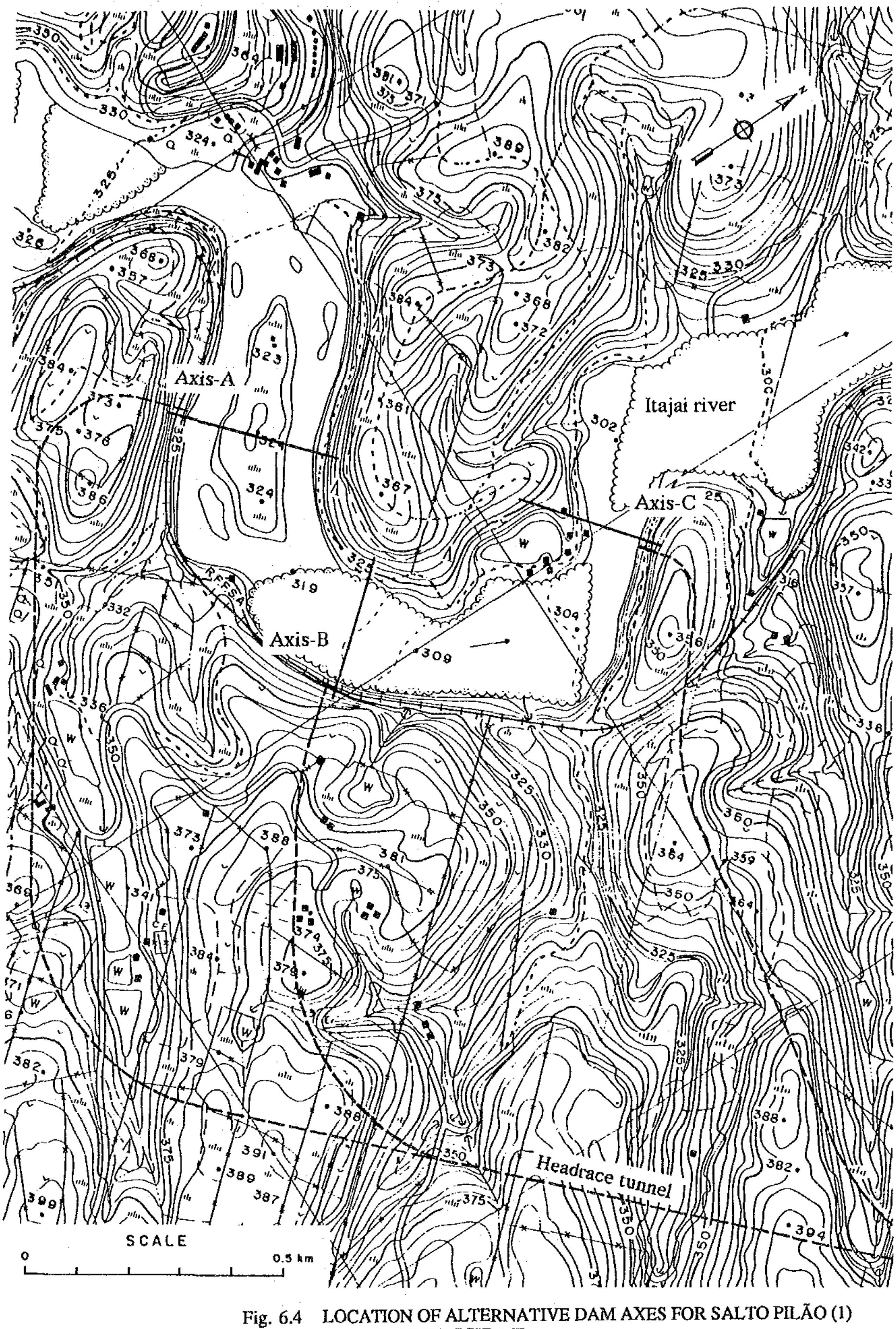


Fig. 6.4 LOCATION OF ALTERNATIVE DAM AXES FOR SALTO PILÃO (1) HYDROPOWER SCHEME

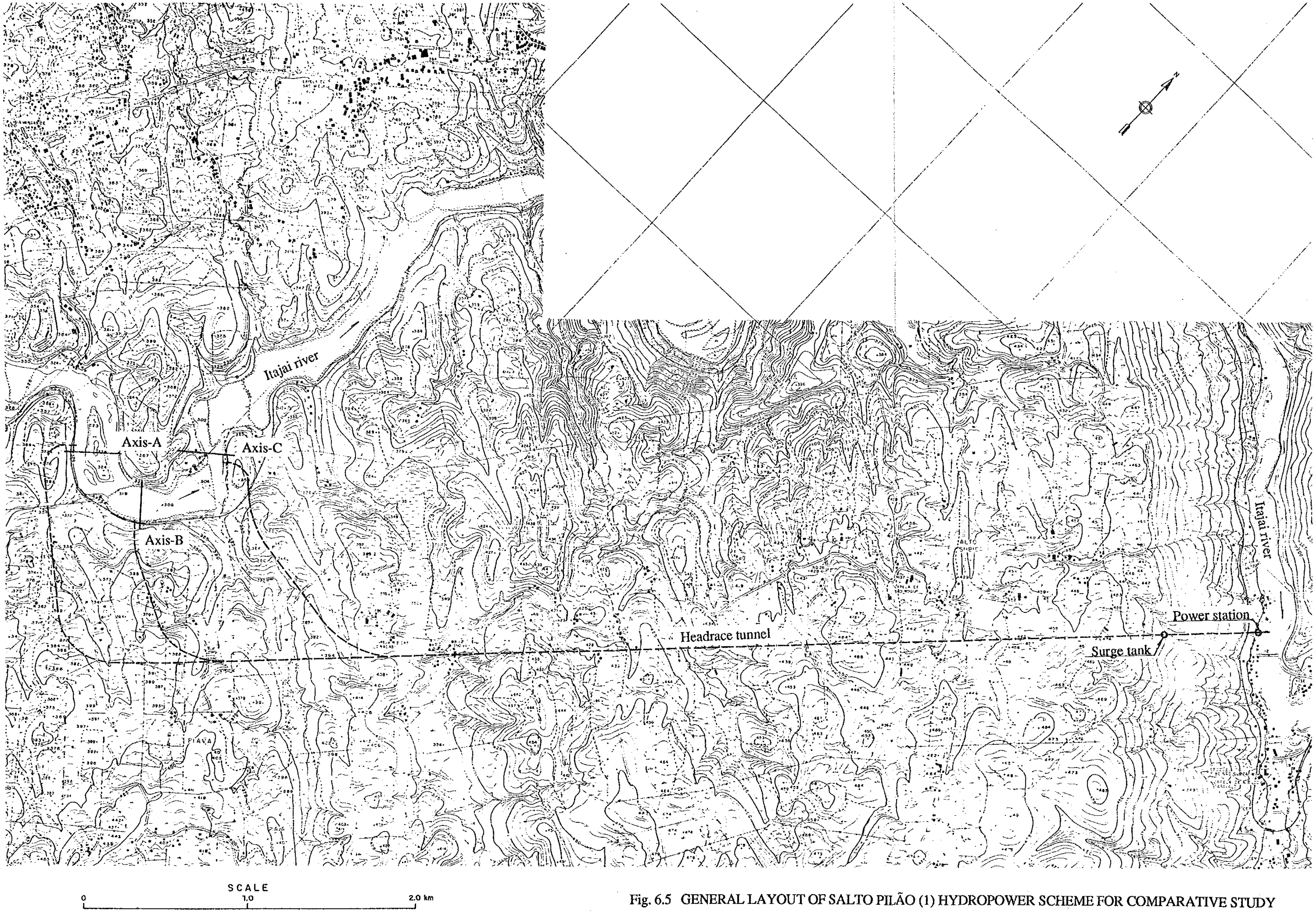


Fig. 6.5 GENERAL LAYOUT OF SALTO PILÃO (1) HYDROPOWER SCHEME FOR COMPARATIVE STUDY

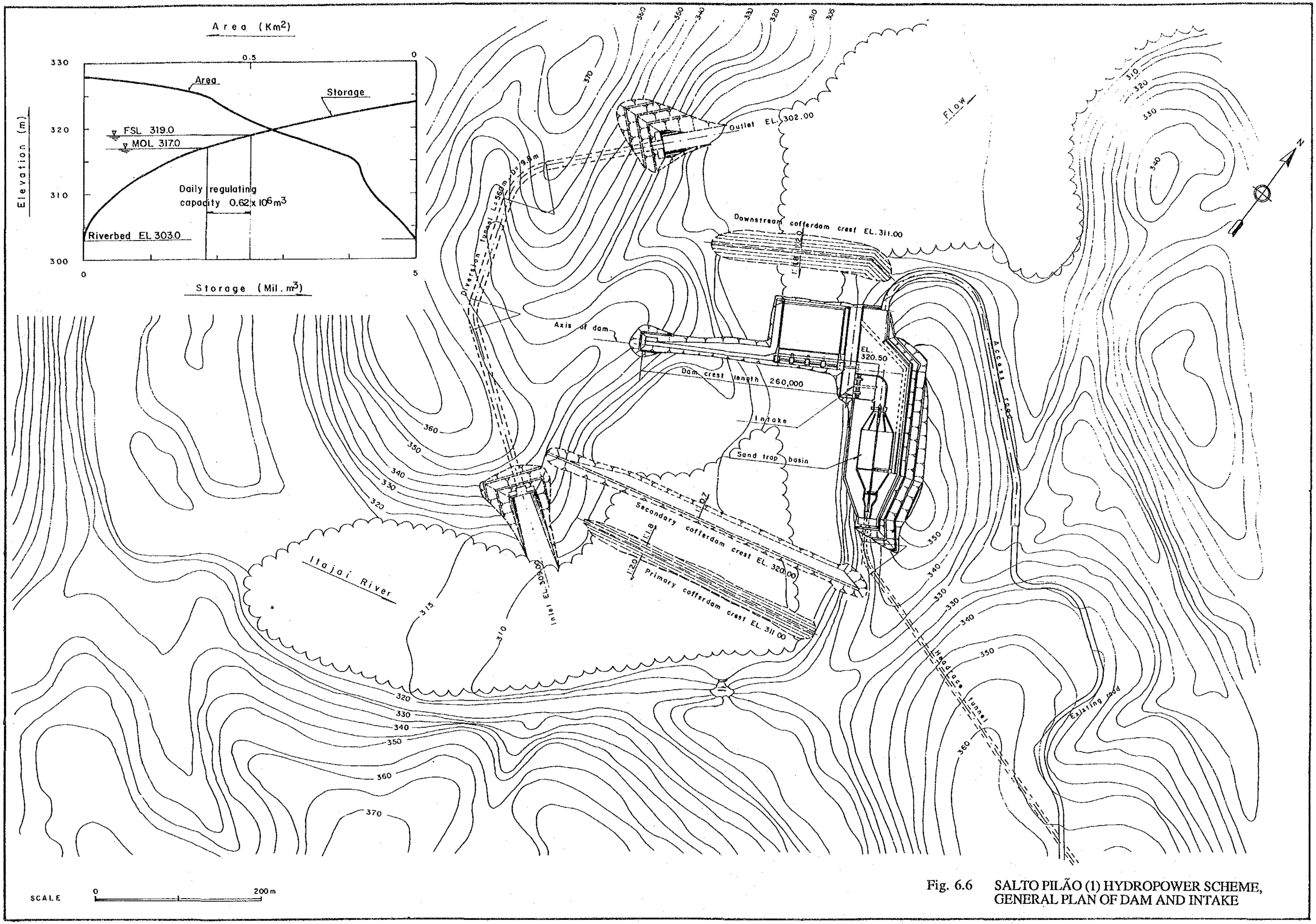


Fig. 6.6 SALTO PILÃO (1) HYDROPOWER SCHEME, GENERAL PLAN OF DAM AND INTAKE