Chapter 10

GEOLOGY

10. GEOLOGY

10.1 Regional Geology

10.1.1 Outline of Topography

A summit level map of Sao Tome Island was prepared based on a 1/75,000 scale topographical map to gain a concept of the island's topography in outline, and this is shown in Fig. 10-3. As this figure shows, the highest point on this island, Mt. Pico de Saotome (EL. 2,024 m), is at slightly west of the island center, besides which there is a succession of peaks taller than 1,500 m such as Mt. Pico Pequieno (EL. 1,995 m), Mt. Moro Pinheiro (EL. 1,612 m), Mt. Calvairo (EL. 1,595 m), and Mt. Pico de Ana Chaves (EL. 1,630 m). With these mountain bodies as sources, streams run down toward the seashore in radial form as shown in Fig. 10-4, a river system map of Sao Tome Island.

In contrast to the mountain body 1,500 m and higher at the center of the island, there are independent peaks in the form of small-scale spires of diameter 1 to 2 km scattered about in the southern part of the island. These independent peaks are of phonolite which is different from the basalt widely distributed on the island, and it is thought that this topography was formed by the fact that the phonolite had greater resistance to erosion than the surrounding rock masses. Other than this, the slopes on Sao Tome Island have gentle inclinations form north to east and south, and although there are flat areas developed around the shoreline, slopes are steep at the western part of the island with successions of precipitous cliffs, and flat areas along the seashore are narrow.

The major streams on the island are the Manuel Jorge River, the Abade River, the Io Grande River, the Quija River, the Xufe Xufe River, the Lamba River, the Cantador River, the Contador River, and the Do Ouro River. These rivers mostly have flow channels 12 to 15 km in length, the longest being that of the Io Grande with 24 km. The individual rivers generally possess rugged valleys on having eroded hard volcanic rocks. The average gradients from heads to mouths are 1/15 to 1/20 for rivers at the east side, and 1/5 to 1/10 at the west side with waterfalls to be seen here and there. Hardly any terrace deposits are developed at river banks. Consequently, there is practically no distribution of deposits at river beds except at river mouths and confluences of streams.

10.1.2 Outline of Geology

Sao Tome and Principe is situated in the Gulf of Guinea, Geological maps of the African Continent and the surroundings of Sao Tome Island are shown in Figs. 10-1 and 10-2, and a geological map of Sao Tome Island in Fig. 10-5.

Sao Tome Island is a volcanic island belonging to the Cameroon Volcanic Row formed along a tear in the southeast line of the Benue Graben. Volcanic rocks of the Cenozoic Era are distributed for more than about 1,000 km from Lake Chad on the African Continent, through Cameroon, Principe Island, Sao Tome Island, to Annobon Island. The volcanic rocks distributed in these regions are of a alkali olivine basalt-trachyte series.

The basement rock of Sao Tome Island is composed mainly of the abovementioned basalt of the Cenezoic Quaternary Period and pyroclastic rocks of the same character. These rocks are distributed in the form of alternations of lava flows and volcanic ejecta, and variations in facies of formations, ranges of stratum thicknesses and extents of beds vary in a complex manner.

As lava, other than basalt, although in small proportions, distributions of andesite and trachyte may be seen. In the southern part of the island, as mentioned in 10.1.1, there is terrain in the form of spires or independent peaks. This part is thought to have been formed by phonolite intruding the basalt, with the phonolite erupting from vents formed in the basement rock lava, and being stronger in resistance to weathering than surrounding rock, it had remained after erosion to result in the rugged landform. Volcanic rocks such as basalt and andesite, except for weathered surface layers, are generally fresh, hard, and massive. However, there are plate-like conditions, and loosening and weathering along cracks can be seen at these places. On the other hand, pyroclastic rocks which exist as alternations with lava, depending on particle sizes of gravels contained, may be subdivided as tuff breccia, tuff, and agglomerate, and although the breccias contained are mostly dense and hard, part of the matrix filling the interstices is tuffaceous and slightly soft.

Overlying the abovementioned basement rocks, are terrace deposits and recent river-bed deposits along rivers, while at lower parts of slopes there are talus deposits distributed, but all of these deposits are of small distributions and layers are thin. Terrace deposits and recent river-bed deposits are sand-gravel layers containing round pebbles and sub-breccias of various particle sizes, while talus deposits are soft and consist of gravel-bearing silt and clay.

10.2 Manuel Jorge Project Site

10.2.1 General

The geologic sequence and outlines of the geological distributions in the surroundings of the projected structure sites on the Manuel Jorge River selected for construction of the mini hydro power station are given in Table 10-1.

The geology in the surroundings of the project site, as mentioned in 10.1, Regional Geology, is that of wide distribution of volcanic rocks consisting of basalt and phonolite of the quaternary Period as basement rocks with intercalations of tuff breccia in thin layers. Overlying the basement rocks, there are terrace deposits at both banks along the river, river-bed deposits along the present river channel, and from the upper portions to parts of the lower portions of the slopes, talus deposits can be seen. Regarding basement rocks, they make up the main part of Sao Tome Island, are fresh and hard, and it is estimated that the thickness of the formation is more than several hundred meters. At outcrops where basalt and phonolite are weathered, discerning between the two is difficult, and although rocks were sorted for fresh boring cores and outcrops, differentiations were not made in geological maps and profiles.

Out the other hand, deposits distributed at the surface layer portion consist of the beforementioned gravel-bearing soil containing large amounts of hard rock fragments, and in local distributions layer thicknesses are mostly thin, being from several meters to around 10 m.

10.2.2 Intake Dam

(1) Geology

As candidate sites for the intake dam, 3 locations were selected between river-bed elevations of approximately 520 m to 470 m taking into consideration topographical and geological conditions.

The geological sections of the 3 intake dam sites and roughly along the river bed of the Manuel Jorge are shown in Fig. 10-7. The geological conditions of the individual dam sites are described below.

(a) Dam Site A

The width of the river bed at the intake dam site is approximately 15 m, the gradients of slopes at the banks being approximately 30 deg at the right bank and 50-60 deg at the left bank. There is a waterfall of a drop of about 7 m at 7 m downstream of the projected dam site.

At the left-bank side of the dam site, there is exposure of basalt turned red by hydrothermal alteration. Recent river-bed deposits are deposited at flat parts of the river bed, and the layer thickness conjectured from results of boring investigations at the intake dam site downstream is thought to be 2 to 3 m. talus deposits can be seen at the bottom of the right bank of the river.

(b) Dam Site B

The width of the river bed at the intake dam site is approximately 12 m, the slope gradients at both banks being 40 to 50 deg to present steep slopes. At part of the right bank there is overhanging of rock caused through erosion. There is a waterfall of about 8 m drop approximately 24 m downstream of the projected dam axis.

The Manuel Jorge River flows down on the right-bank side of the projected dam axis and fresh, hard basalt is exposed continuously from the river-bed portion to the right-bank slope. Of this, at the previously-mentioned overhang, slightly soft tuff breccia of layer thickness 1 to 2 m is distributed dipping approximately 50 deg toward the mountain side, and it is this part that has been eroded. The river bed has a distribution of river-bed deposits containing much cobbles of hard basalt 30 to 100 cm in size, the thickness of the layer being 1.4 m according to results from Drillhole DMD-2. Deeper than this there is distribution throughout of basalt which has turned reddish brown, weathering having occurred between 1.4 and 6.0 m with much cracking, but deeper than 6.0 m, the rock is massive.

(c) Dam Site C

The width of the river bed at the intake dam site is 10 m, the inclination at the right-bank slope being approximately 30 deg and that at the left-bank slope 50 to 60 deg and steep. The dam site is situated at a transition point in topography where from the narrowed part upstream terraces are developed and the two banks are eroded and gently sloped. At the bottom part of the slope on the left bank there is provided an intake and waterway for water supply to Milagrosa Village.

At the left-bank side for 20 m from above the beforementioned service waterway, there is exposure of massive and hard basalt. At the right-bank side, there are talus deposits above the river-bed deposits, and exposed rock cannot be seen at parts of low elevation.

From the results of Drillhole DMD-1 at this dam site, the layer thickness of topsoil and river-bed deposits together is more than 20 m, showing that deposits are thick at the river bed. The reason for these deposits being thick is that a waterfall with a drop of 18 m, the greatest in this survey area, is located 30 m upstream, and the projected dam site where boring was done corresponds to where the waterfall formerly dropped, so that the depth to bedrock is deep.

(2) Engineering Geological Evaluation

Of the three candidate sites for the intake dam, the upstream dam sites A and B may be judged to be favorable topography-wise and geology-wise as seen from an engineering geological point of view. That is, the dam sites are in the form of narrow valleys. River-bed deposits are 1 to 2 m and thin, and underlying them and at both banks are massive basalt and, partially, tuff breccia. Accordingly, it is thought these dam sites, as foundations for the projected intake dams, will have ample bearing strengths and watertightnesses.

On the other hand, since the downstream C dam site has thick river-bed deposits of gravel and sand, it will require appropriate measures to be provided regarding strength and watertightness as a foundation for a dam, and is undesirable from this point of view.

10.2.3 Headrace and Head Tank

(1) Geology

The headrace route and head tank, from the relation with the intake dam to be provided at the left-bank side of the Manuel Jorge River, are thought will be at EL. 520 to 500 m for dam sites A and B, and around 470 m in case of C. These project sites are at gently-sloped land of gradients 10 to 20 deg facing south toward the Manuel Jorge River, with the entire surface being used for cacao plantations.

Along the headrace route, basalt is distributed forming a steep cliff at the slope from the upstream site A to the downstream site C. Downstream from site C for approximately 700 m, although there are small outcrops of basalt sparsely scattered, the area has been made into cacao fields and is widely covered by talus deposits mixed with rock fragments. Farther south than the beforementioned 700 m, outcrops of basalt and phonolite are slightly more widely seen at slopes from EL. 490 m and lower. The basalt and phonolite at these outcrops are very hard and are massive. And at the flat area above the slope where the head tank is planned, talus deposits of rock fragments filled mainly with silt and sand are thought to be distributed for approximately 10 m.

In the range where the headrace and head tank structures are planned, and under present conditions, there are no signs of collapse or landslides occurring at the slope.

(2) Engineering Geological Evaluation

Condidered from the geology and stability of slopes of the headrace route and head tank site, and scales of the structures planned, it can be judged that there will be no problems regarding construction of the headrace and head tank at these sites.

10.2.4 Penstock and Powerhouse

(1) Geology

Regarding the penstock and powerhouse, boring investigations were made at two sites on the upstream and downstream sides of the benchmark, BM1, provided on the forestry road leading to Milagrosa Village. The geological sections of the two sites where investigations were made are shown in Figs. 10-8 and 10-9, and the geological conditions are described below.

(a) Upstream Proposal

The slope where the penstock is planned is slightly steep with gradients of 30 to 40 deg, above which there is the service waterway to Milagrosa Village. Approximately 15 m above the river bed of the Manuel Jorge there is a road, and both above and below this road are widely used as cacao fields.

Outcrops of very hard, massive phonolite may be seen at the upper part of the slope centered at the slope on the mountain side of the service waterway. However, according to the boring investigations made on the road at the lower part of the slope, bedrock is reached at a depth of 14.45 m, and talus deposits tend to be thick there. The talus deposits in this boring and in outcrops around the project site consist of rock fragments-bearing silt and clay, and they are well compacted.

(b) Downstream Proposal

The downstream proposal site shows topographical and geological characteristics similar to the abovementioned upstream proposal. That is, the slope at the planned site for the penstock is a slightly steep one with a gradient of approximately 40 deg, and the service waterway to Milagrosa Village is at the upper part. Approximately 15 m above the river bed of the Manuel Jorge there is a road, and that both above and below this road are widely used for cacao fields is also the same.

Outcrops of phonolite are seen at the mountainside above the service waterway, and outcrops of basalt below the road. The geological boundary between this phonolite and basalt is not clear being covered by talus deposits distributed centered at Drillhole PHD-1 made on the road. Both of the rocks are very hard and massive, and comprise bedrock in good condition. It was learned from the abovementioned boring investigations that the thickness of talus deposits is 9.1 m, underlying which there is weathered tuff breccia and hard basalt.

(2) Engineering Geological Evaluation

The projected penstock and powerhouse sites, considered from the geology and stability of the slope, and from the scales of the structures planned, may be judged not to pose any problem for construction of the penstock and powerhouse.

That is, the basement rocks have adequate strength as foundations for the penstock and powerhouse, while the talus deposits may be judged to have adequate load-bearing characteristics as they are composed of gravel-bearing coarse-particled deposits. Collapses and landslides are not seen in the surroundings of the project sites, and the sites are considered to be favorable from the standpoint of slope stability also.

Table .10-1 GEOLOGIC SEQUENCE IN THE PROJECT SITE

GEOLOGIC AGE	NAME OF STRATUM	GEOLOGIC COLUMN	GEOLOGIC PROPERTY	DISTRIBUTED AREA
QUATERNARY	DETRITUS, TALUS DEPOSIT	Dt	Rock fragments with silt & sand	Upstream portion of the canal. Lower portion of slopes.
	RIVER DEPOSIT	Rd	Gravel,hard rock ϕ 50-100cm	Along the bottom of the Manuel Jorge river.
	TERRACE DEPOSIT	Tr	Gravel with coarse sand. ϕ 30-80cm	Along the besides of the Manuel Jorge river.
	TUFF BRECCIA	Tb	hard breccia contained	Intercalated of the Volcanics.
	BASALT & PHONOLITE	Ba Phn	Very hard, Massive. Fresh. Sound	Basalt is exposed from intake damsites to the canal/ Phonolite is exposed around the headtank & Power house.

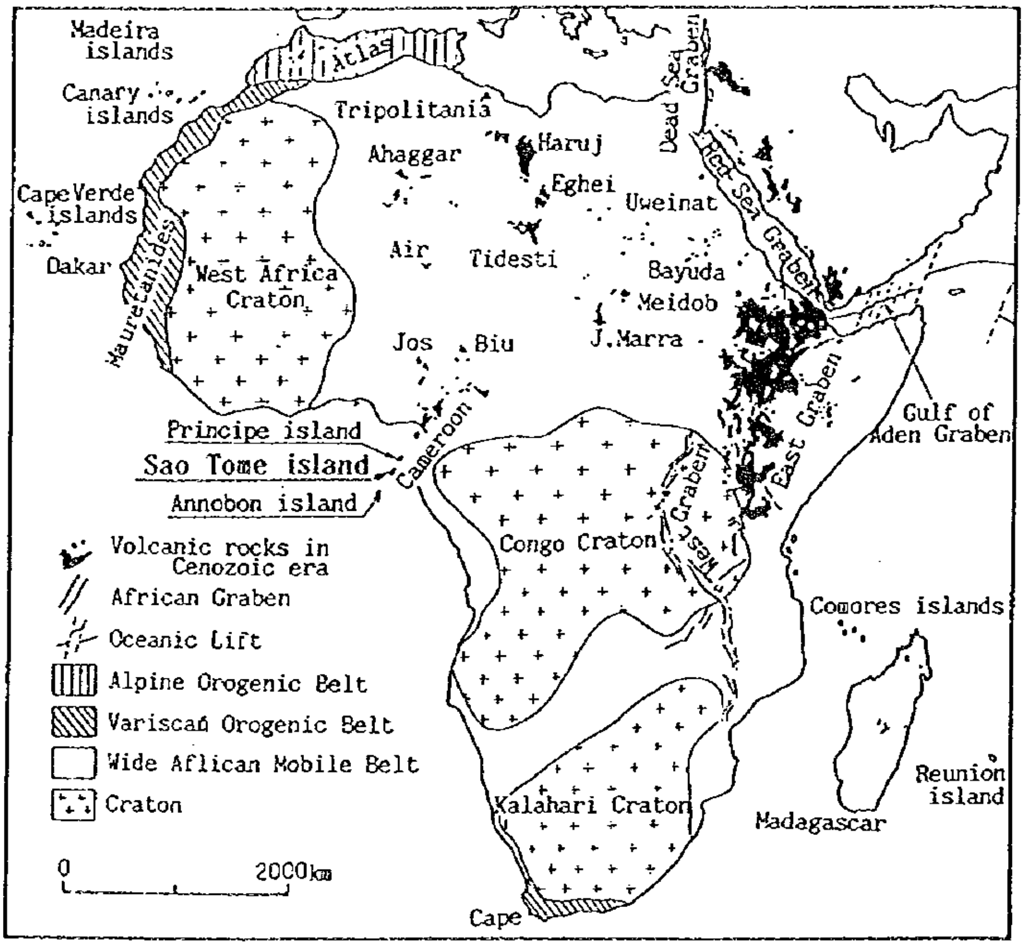


Fig. 10-1 Distribution of Volcanic Rocks and Graben in Africa
[This map is compiled from Geologecal World Atlas;Unesco(1975)]

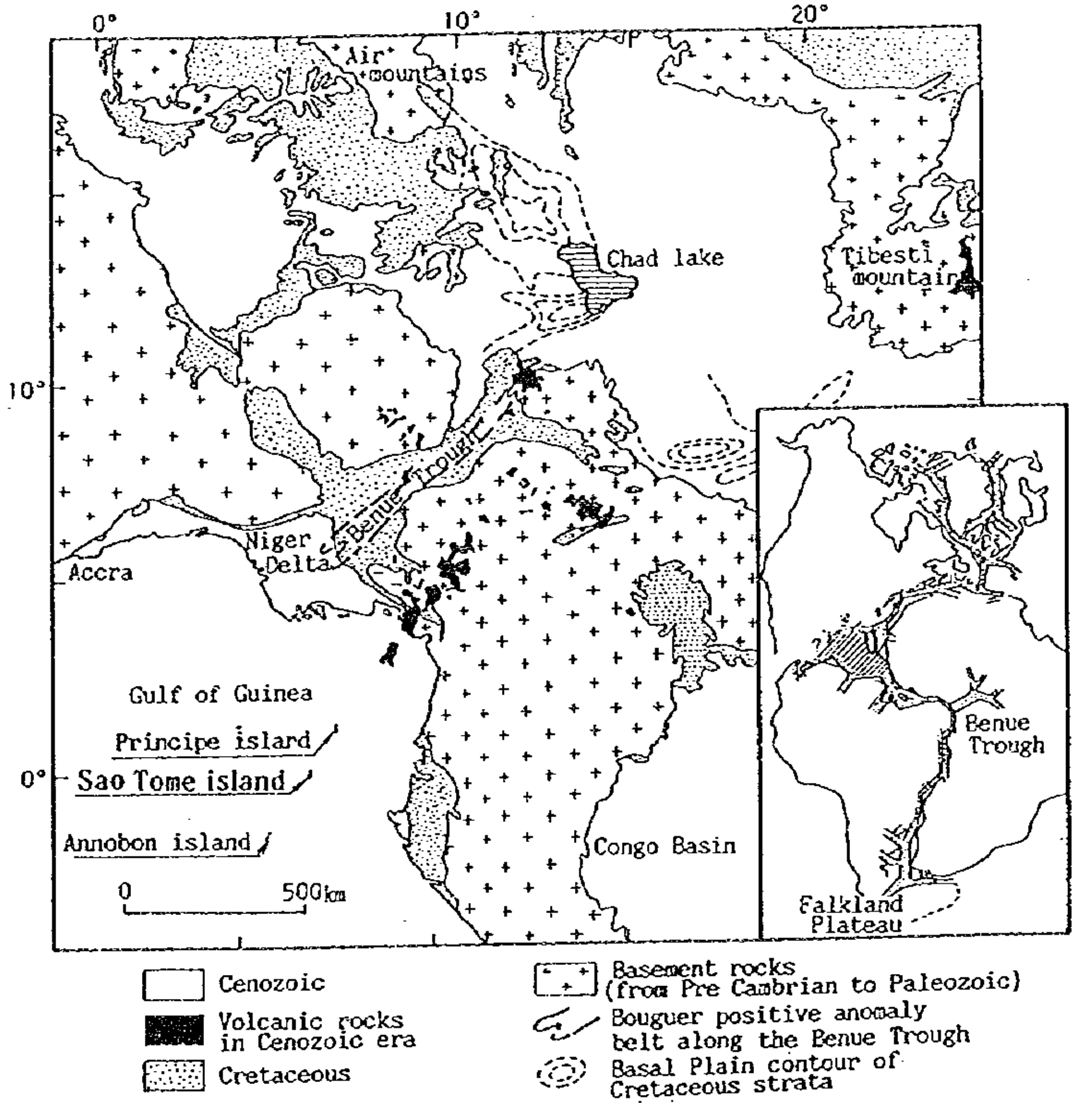


Fig. 10-2 Geological Map of Sao Tome Island and Its Vicinity

[This map is compiled from Geological World Atlas;Unesco(1975), Ajakaiye & Burke(1973),International Tectonic map of Africa;Unesco(1968),and Development of graben associated with the initial ruptures of the Atlantic Ocean;Burke(1976)]

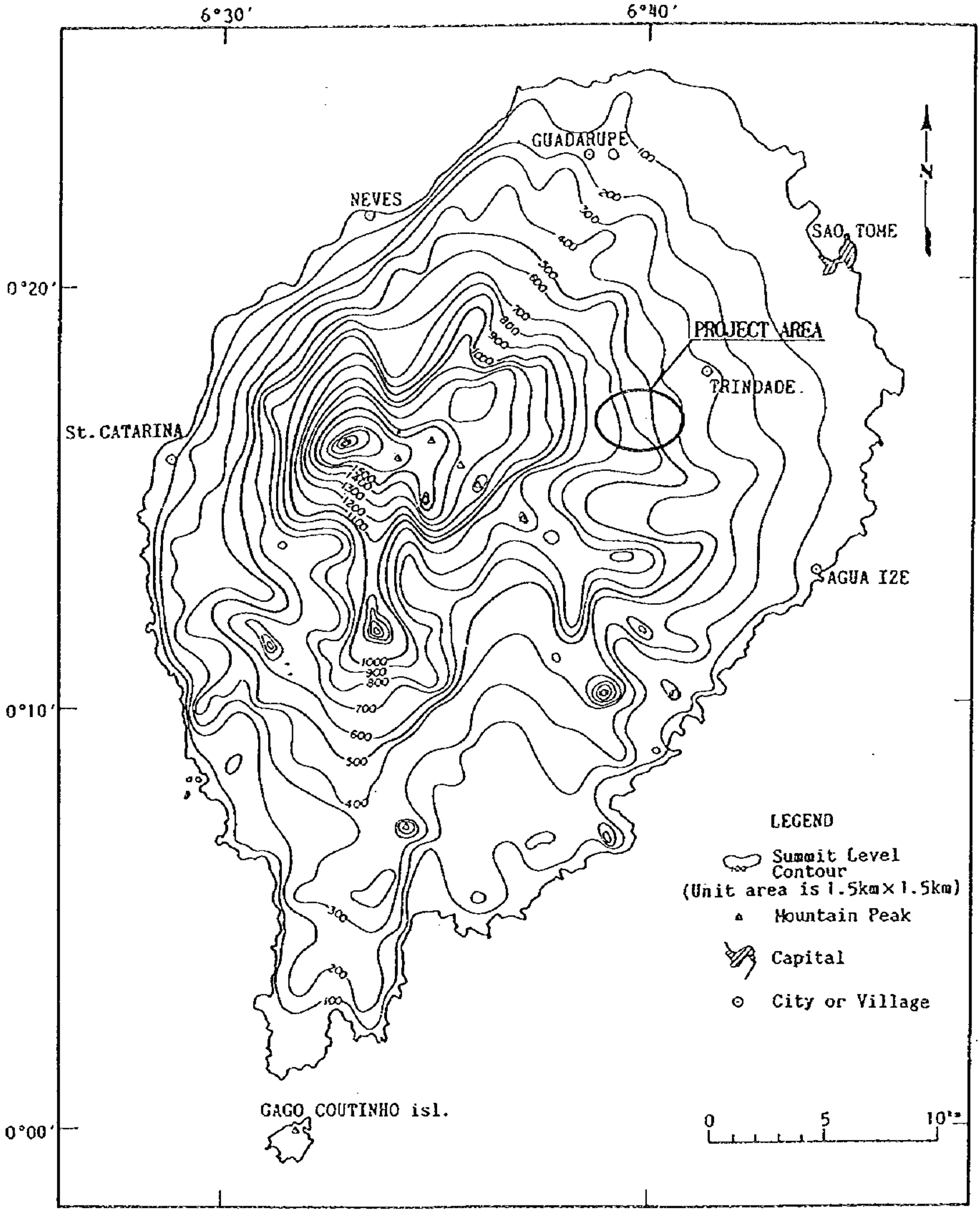


Fig. 10-3 Summit Level Contour Map of Sao Tome Island

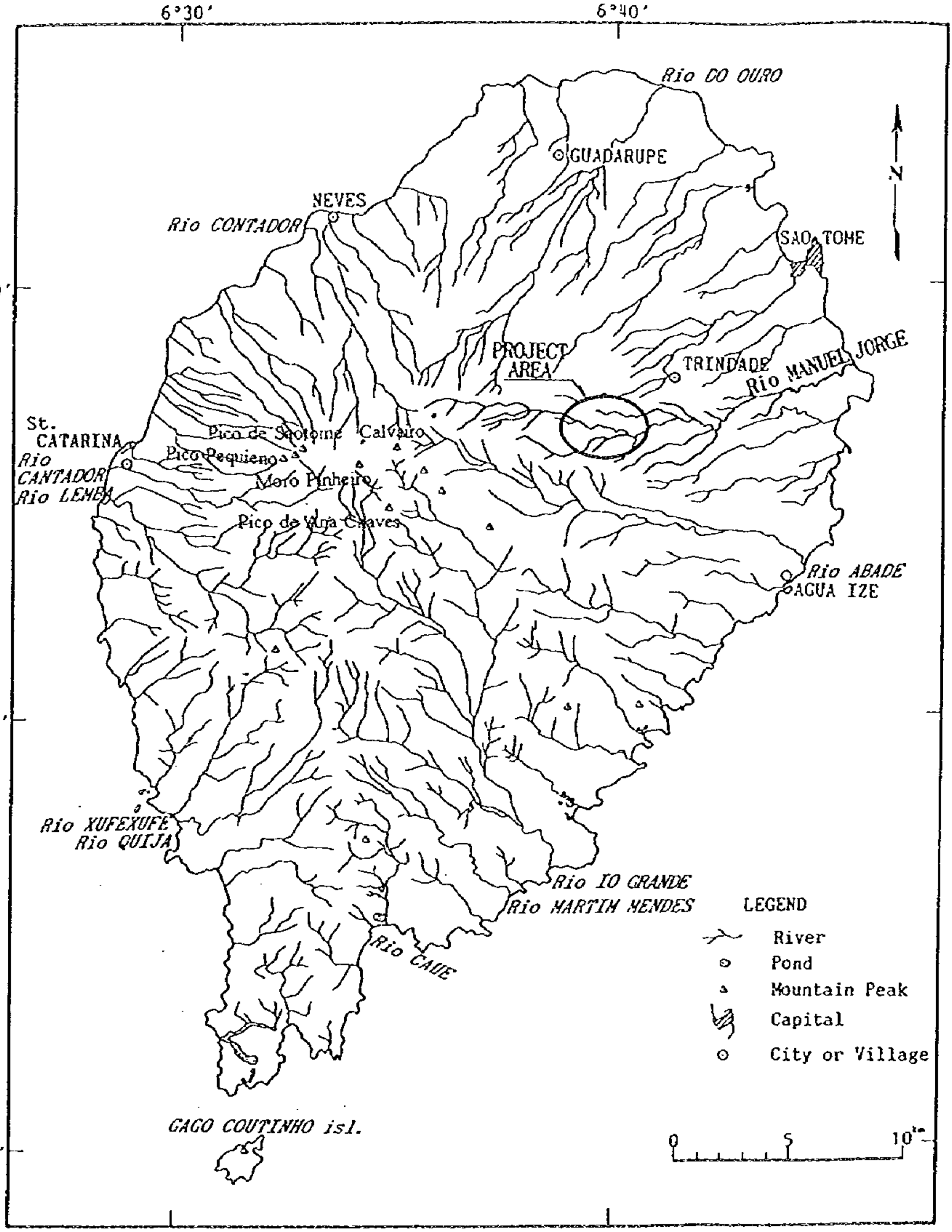


Fig. 10-4 Drainage System of Sao Tome Island

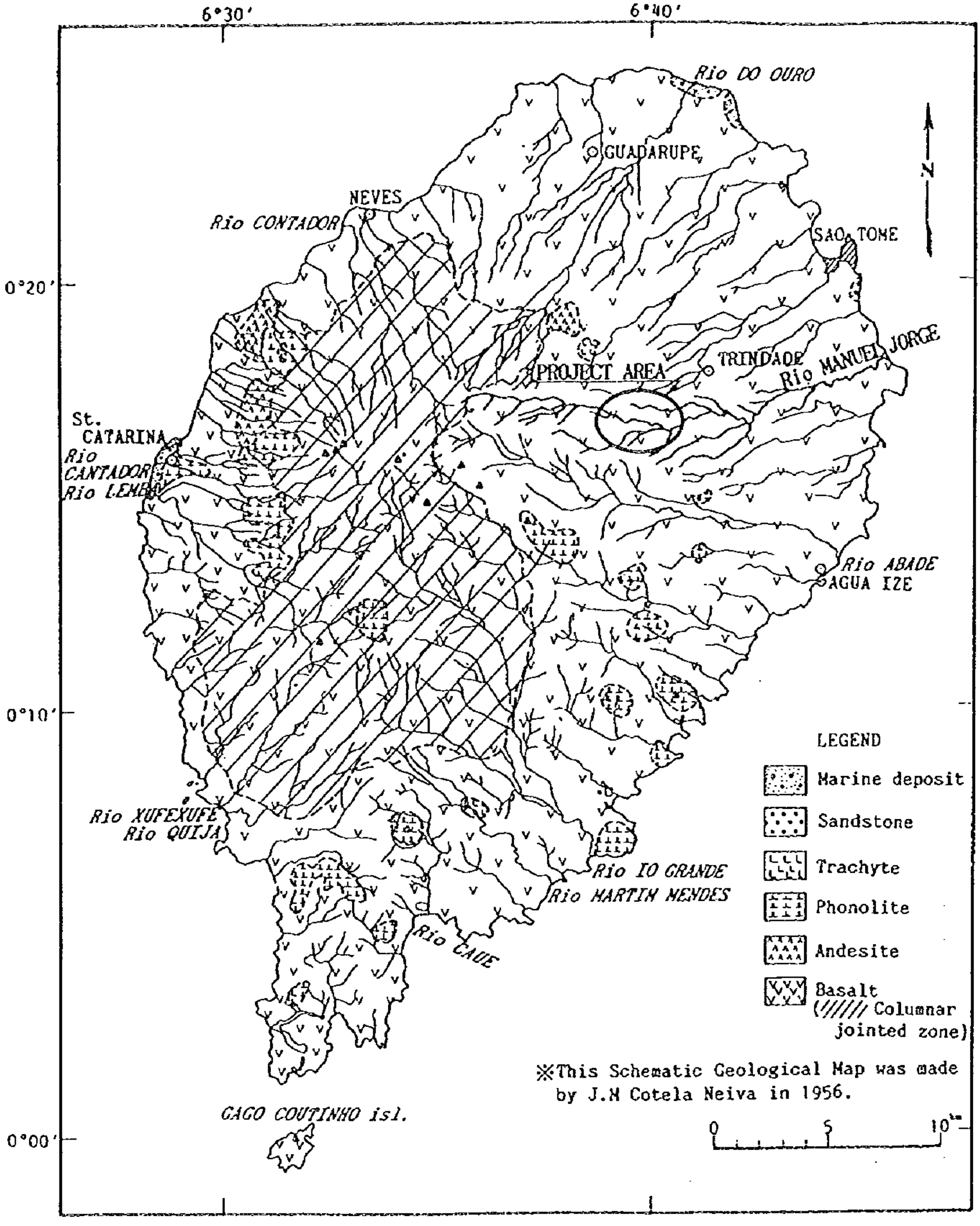
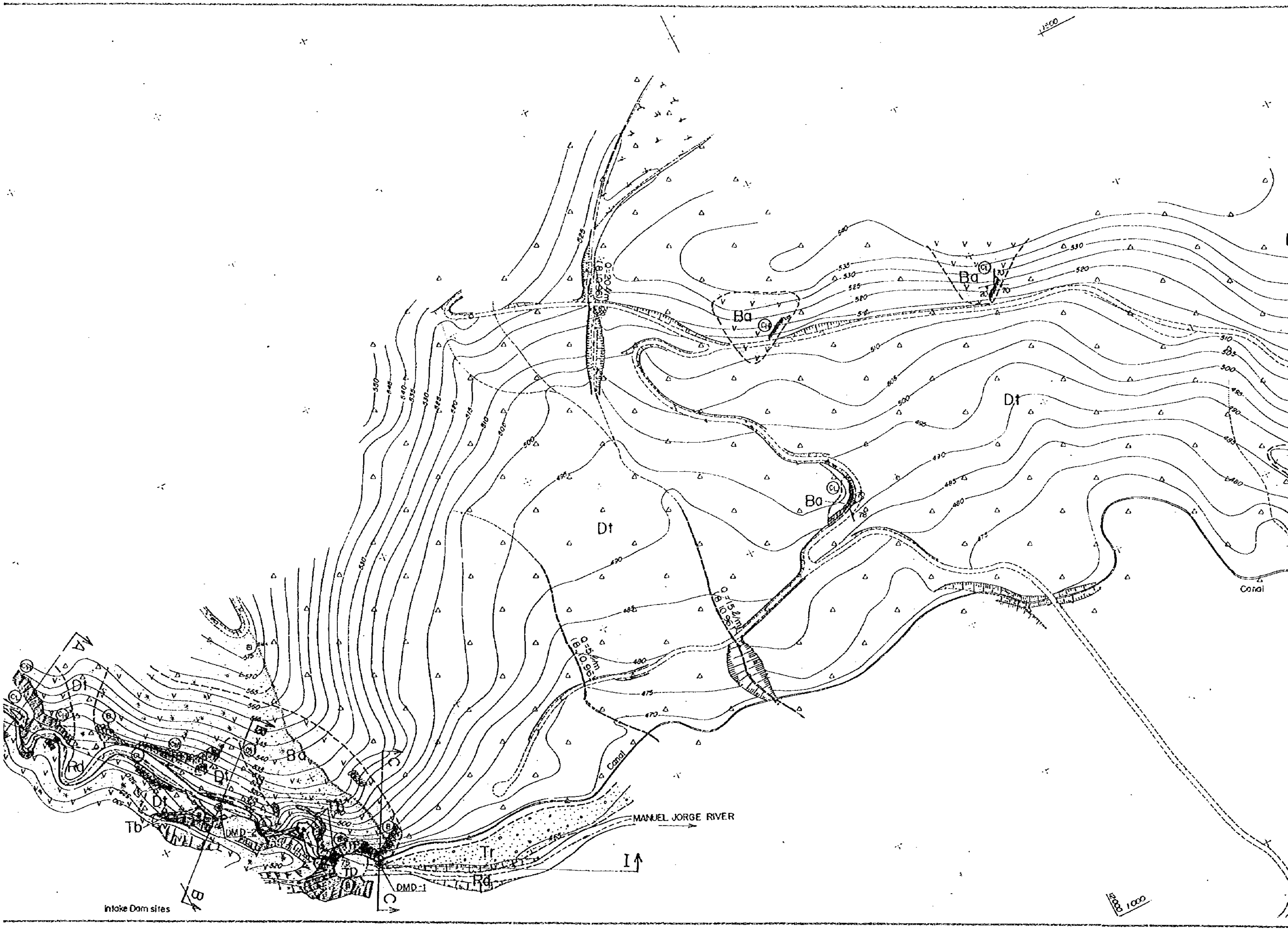
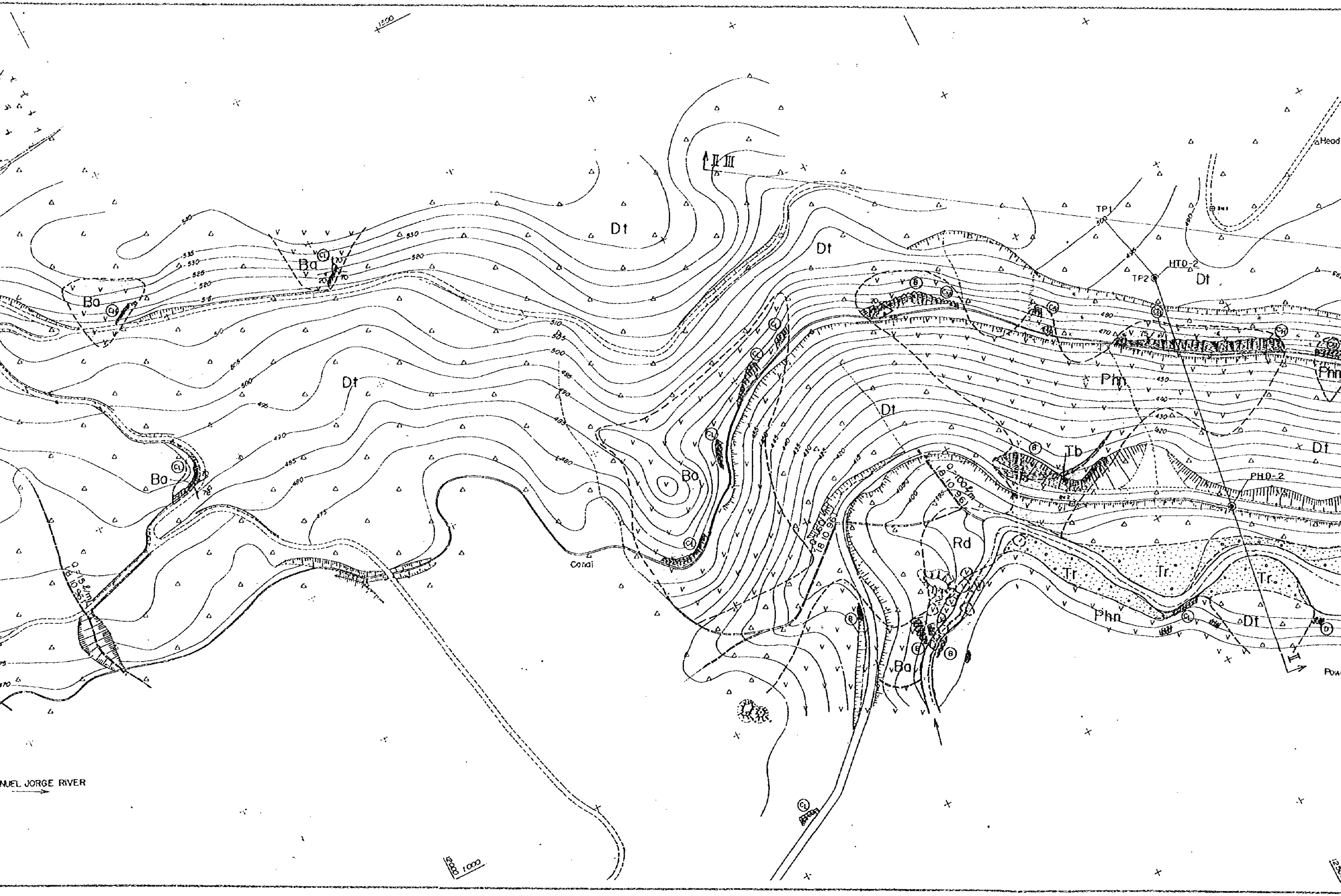


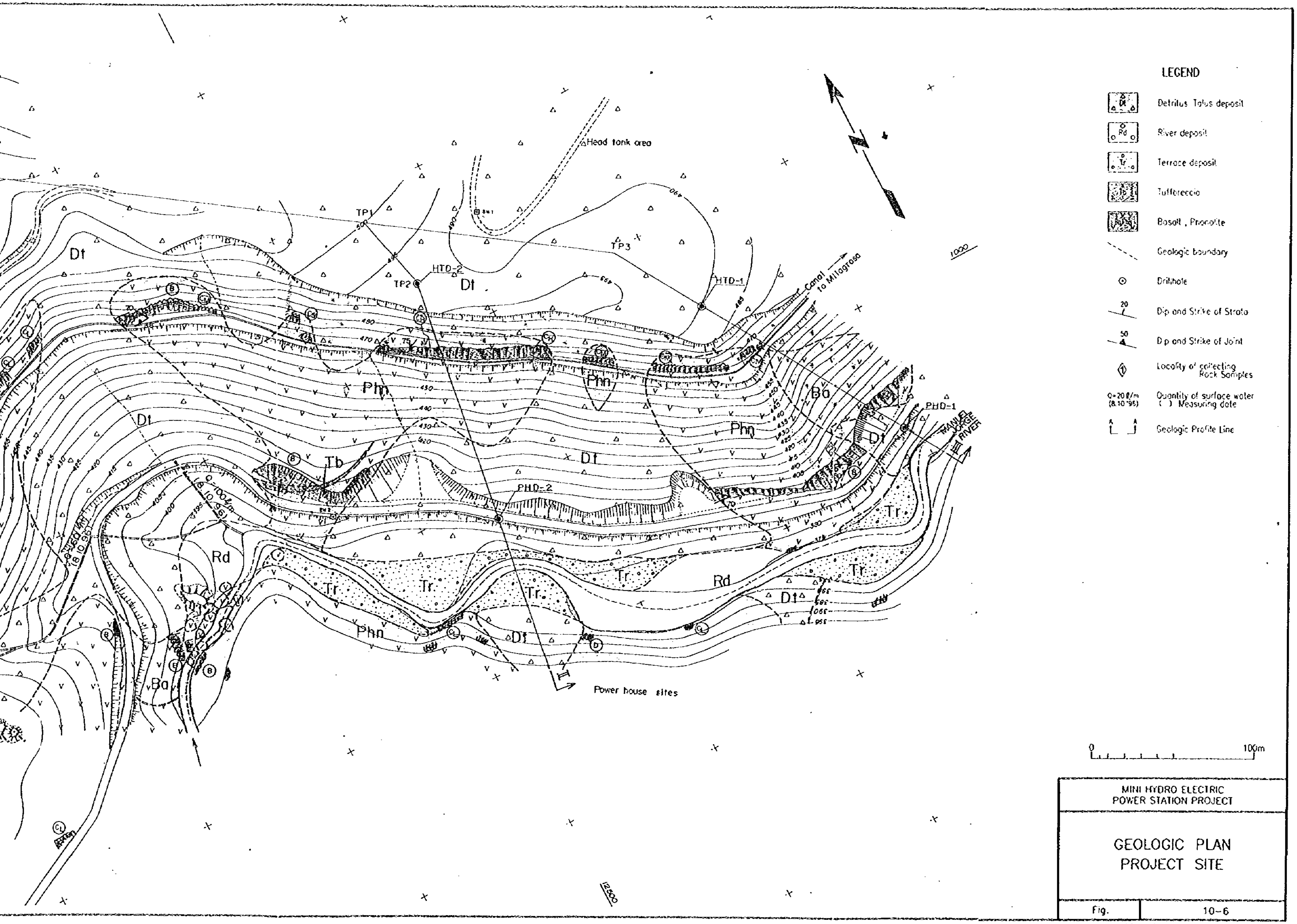
Fig. 10-5 Geological Map of Sao Tome Island



MANUEL JORGE RIVER
Intake Dam sites
Canal
DMD-1
DMD-2
Dt
Ba
Rd
Tb
Tr



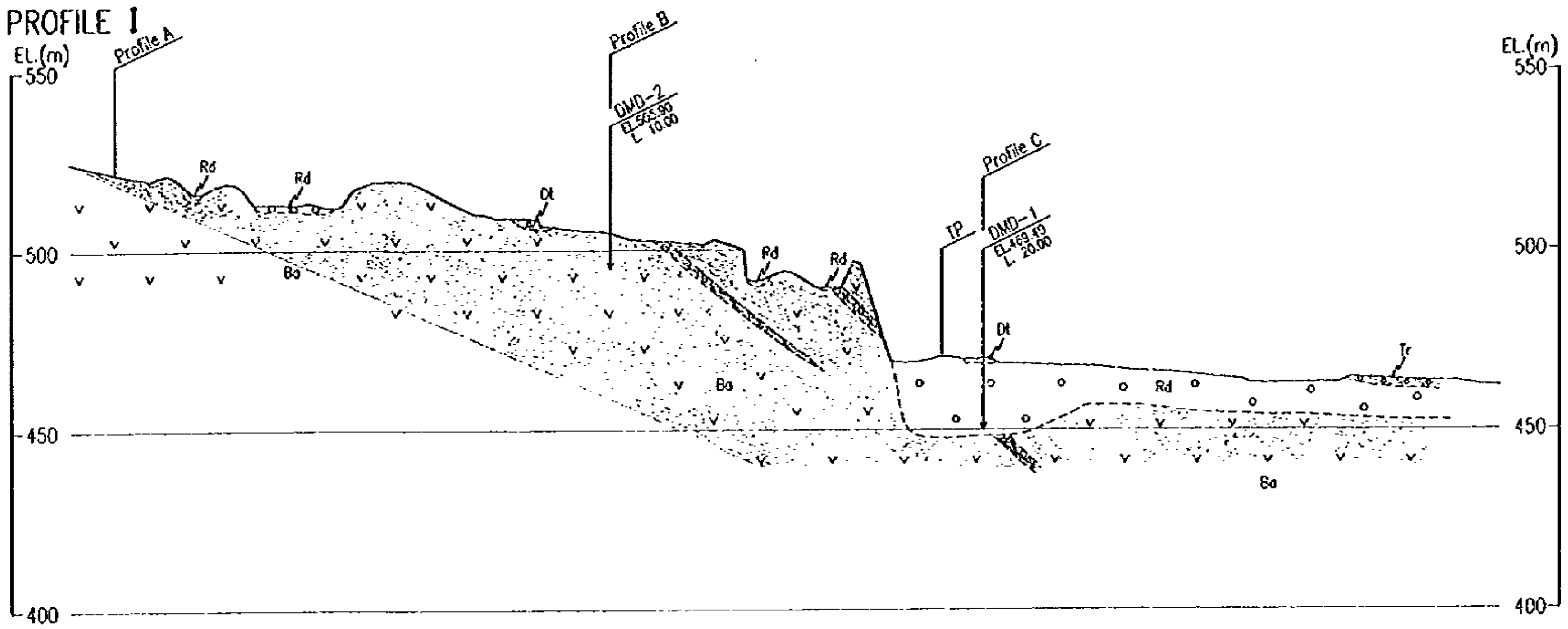
Dt
Ba
Phn
Tb
Rd
Tr
TP1
TP2
HTD-2
PHD-2
Corral
NUEL JORGE RIVER

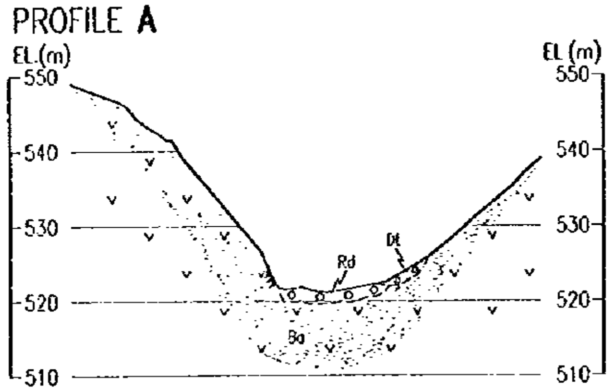


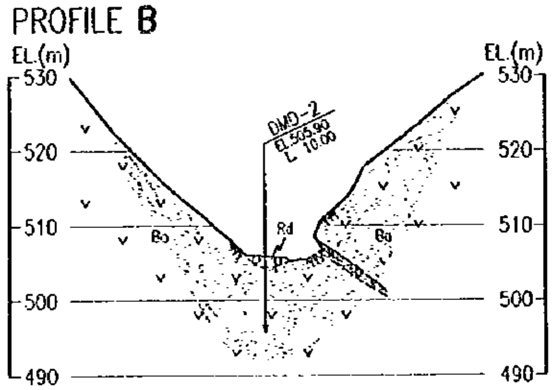
MINI HYDRO ELECTRIC
POWER STATION PROJECT

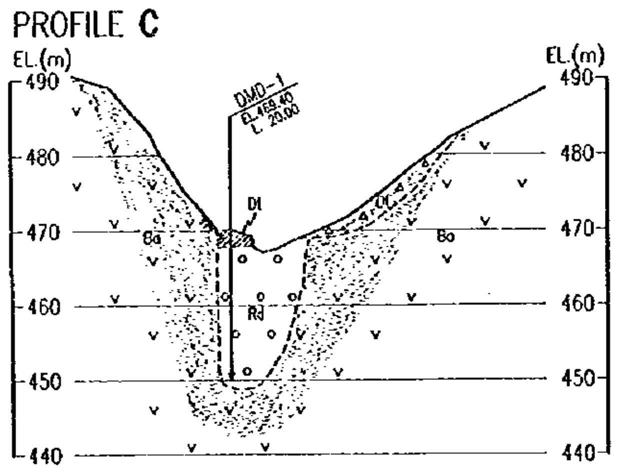
GEOLOGIC PLAN
PROJECT SITE

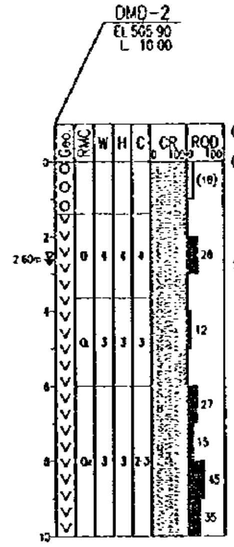
Fig. 10-6











Geological Description (DMD-2)

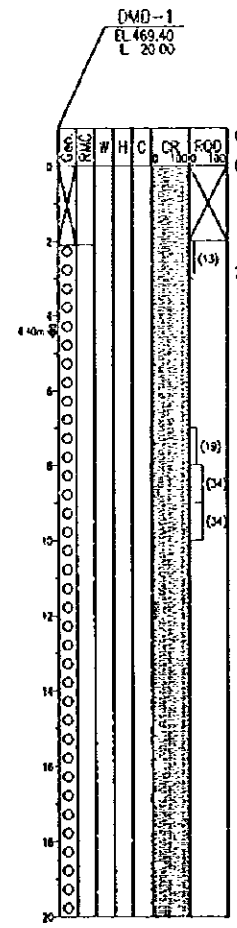
0 ~ 1.40m
Recent river deposit. Brown and Gray Gravel. Very hard.
Gravel in size of ϕ1 ~ 3cm are dominant.
0 ~ 0.60m Rock fragments with silt
Plants roots contained.

1.40 ~ 10.00m
Thermal altered basalt.
Basalt change reddish in color and slightly weak by thermal aleteration.

1.40 ~ 3.65m Reddish gray
Jointed basalt with silt and sand.
Rock fragments are 1 ~ 3cm in piece.

3.65 ~ 6.00m Reddish brown
Jointed basalt. Very hard.
The surface of rock fragments are stained by oxidation.

6.00 ~ 10.00m Reddish brown
Massive basalt. Very hard. Porous.
Slightly weathered.
Rocks are accompanied by calcite veins.



Geological Description (DMD-1)

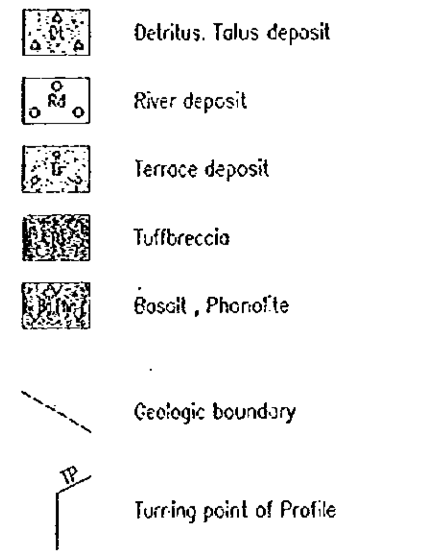
0 ~ 2.10m
Top soil and Bankment. Brown
Rock fragments ϕ1 ~ 3cm contained silt and coarse sand. Dry condition. Low plasticity.
Bankment was formed by the canal from cascade to Milagroso village.

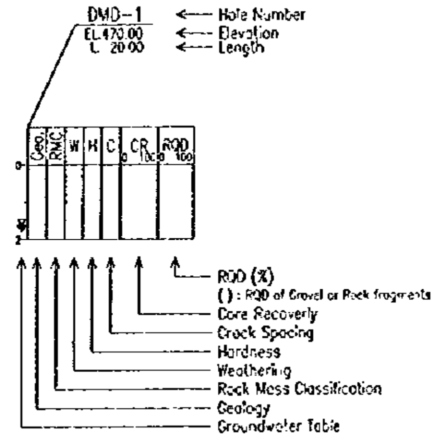
2.10 ~ 20.00m
Recent river deposit

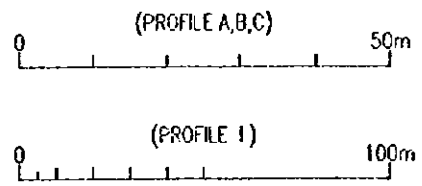
2.10 ~ 15.10m Gravel. Gray Brown
Rounded or subrounded gravel with medium to coarse sand. Gravel are originated from hard rock ; such as basalt and phonolite.
Ratio of including gravel is 80% approximately.
Cobble and Boulder size gravel are abundant.
Low plasticity.
12.1 ~ 13.5m is dominated by sand matrix.

15.50 ~ 20.00m Gravel. Black
Medium to coarse sand with gravel.
Gravel are composed mainly of pebble in size, partially cobble. Loose condition.

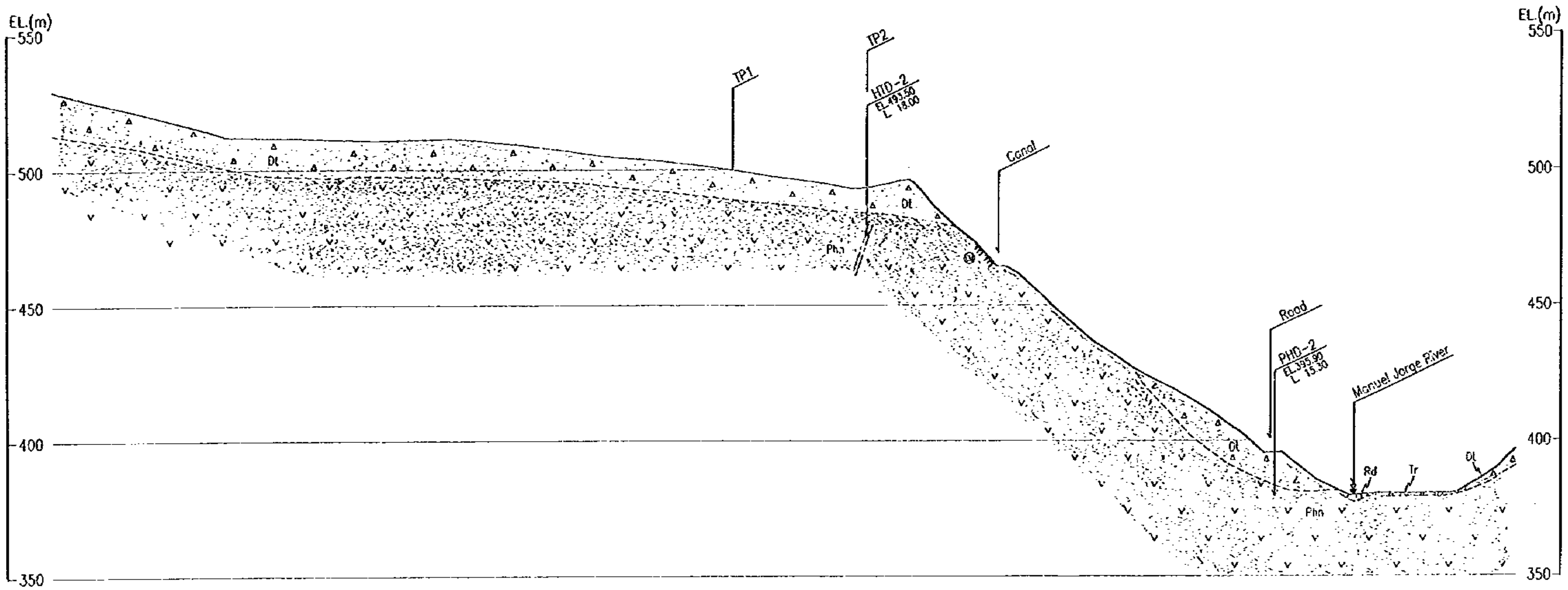
LEGEND

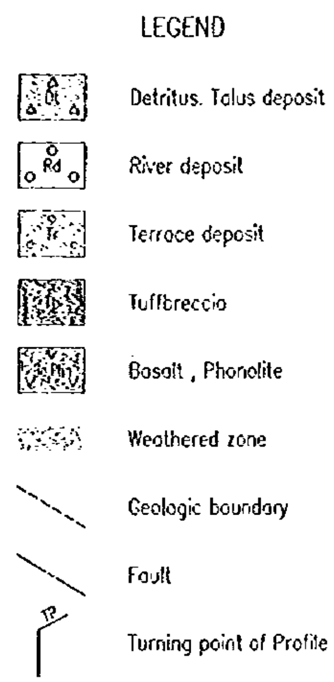


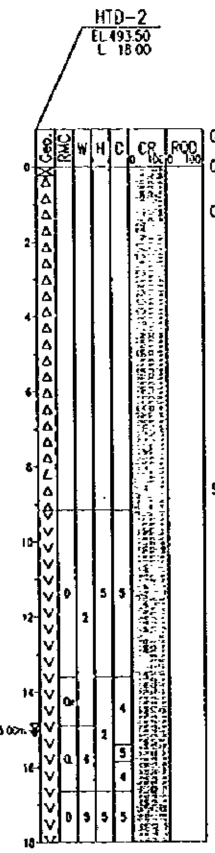




MINI HYDRO ELECTRIC POWER STATION PROJECT
GEOLOGIC PROFILE INTAKE DAMSITES
Fig. 10-7







Geological Description (HTD-2)

0 ~ 0.25m
Top soil Brown. Plants roots contained

0.25 ~ 9.15m
Detritus

0.25 ~ 3.65m Brown
Silt and clay with rock fragments.
Medium plasticity. Dry condition.

3.65 ~ 6.90m Gray and Brown
Rock fragments with silty sand.
ϕ3 ~ 5cm pebble ~ cobble in size.
Fresh , Very hard basalt and phonolite.
Silt of matrix has high plasticity , and with ϕ1 ~ 5cm rock fragments.

6.90 ~ 9.15m Brown
Rock fragments with silt and fine sand.
High plasticity , high water content.
Rock fragments are dominant by granule and pebble in size.

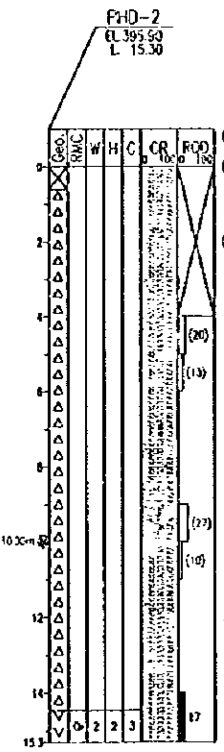
9.15 ~ 18.00m
Sheared and weathered phonolite.

9.15 ~ 13.60m Black
ϕ1 ~ 3cm rock fragments and medium to coarse sand , loose.

13.60m ~ 14.90m Dark gray
Fresh , Very hard glassy phonolite.
Well-jointed.

14.90 ~ 16.65m Brown
Rock fragments and coarse sand.
Weathered.

16.65 ~ 18.00m Brown
Silty sand loose condition.
Strongly weathered zone.



Geological Description (PHD-2)

0 ~ 0.60m
Top soil. Dark brown.
Sand and silt with rock fragments.
Dry condition , Medium to high plasticity.

0.60 ~ 14.45m
Detritus.

0.60 ~ 4.00m Dark brown and Gray
Rock fragments with silt and clay.
Ratio of including rock fragments is 70%.
Dry to slightly wet , high plasticity.

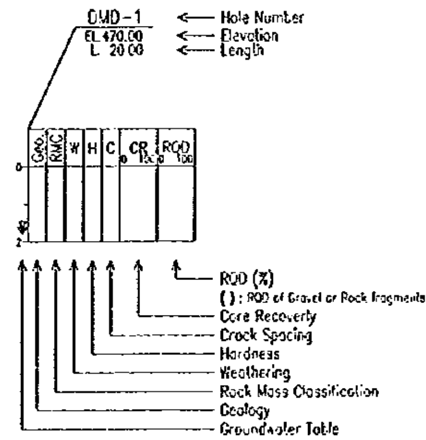
4.00 ~ 4.90m Gray
ϕ3 ~ 5cm rock fragments. Very hard.
The surface of fragments are somewhat stained by oxidation.

4.90 ~ 9.70m Brown
Silt and clay with rock fragments.
High water content , high plasticity.

9.70 ~ 11.45m Gray
Large derived stone. Very hard basalt.
Angular , cracks abundant.

11.45 ~ 14.45m Dark gray and Black
Sand with rock fragments.
Rock fragments in size of ϕ3 ~ 5cm are dominant.
Medium to coarse sand of matrix is well-sorted.

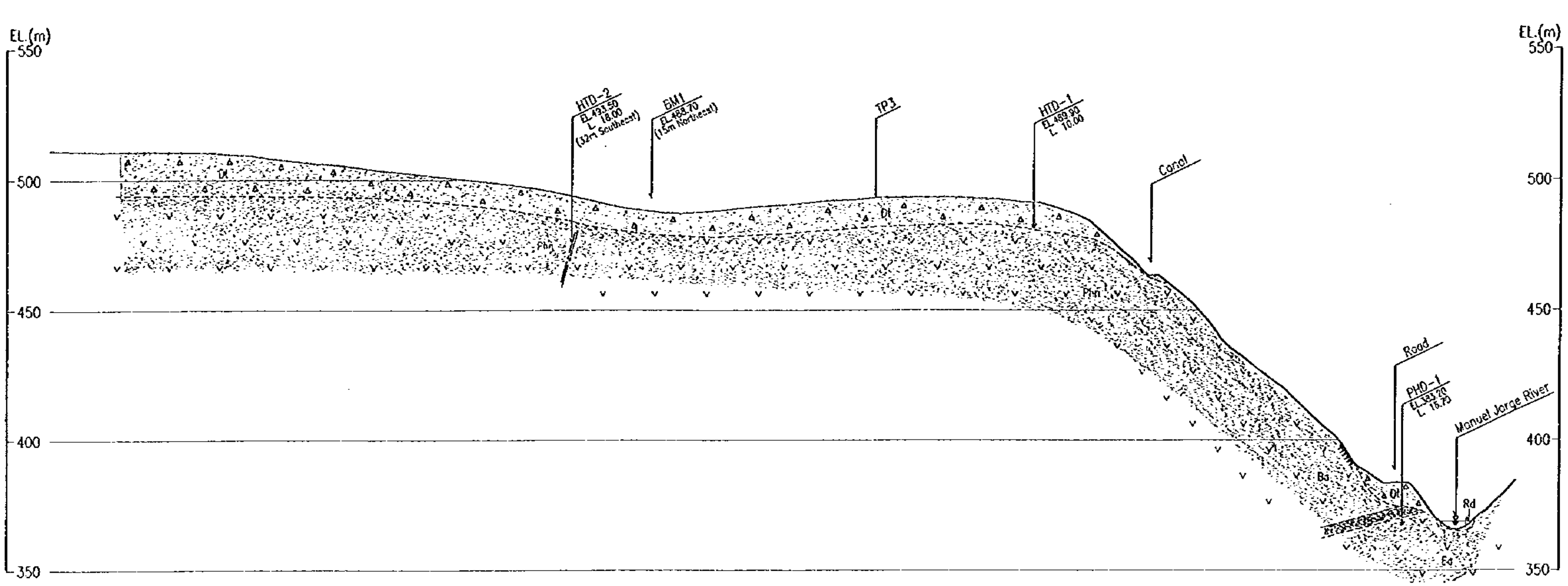
14.45 ~ 15.30m
Porous phonolite. Black.
Very hard , glassy.
Some cracks are stained by oxidation.

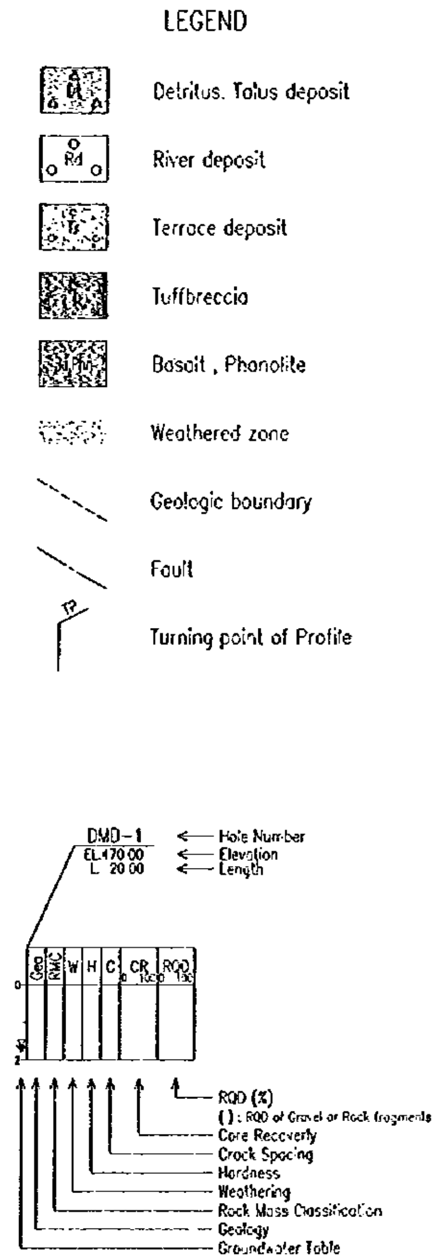


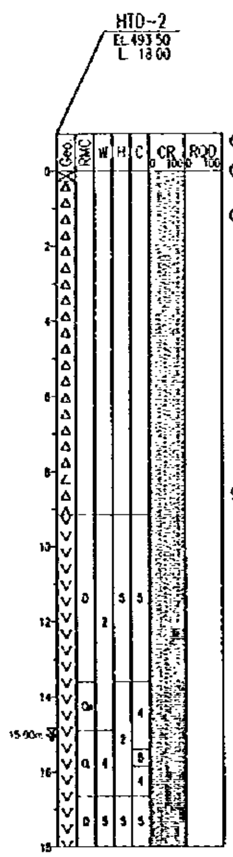
MINI HYDRO ELECTRIC
POWER STATION PROJECT

GEOLOGIC PROFILE
HEAD TANK to POWER HOUSE
(Up stream)

Fig. 10-8







Geological Description (HTD-2)

0 ~ 0.25m
Top soil Brown. Plants roots contained

0.25 ~ 9.15m
Detritus

0.25 ~ 3.65m Brown
Silt and clay with rock fragments.
Medium plasticity. Dry condition.

3.65 ~ 6.90m Gray and Brown
Rock fragments with silty sand.
ϕ3 ~ 5cm pebble ~ cobble in size.
Fresh , Very hard basalt and phonolite.
Silt of matrix has high plasticity , and with ϕ1 ~ 5cm rock fragments.

6.90 ~ 9.15m Brown
Rock fragments with silt and fine sand
High plasticity , high water content.
Rock fragments are dominant by granule and pebble in size.

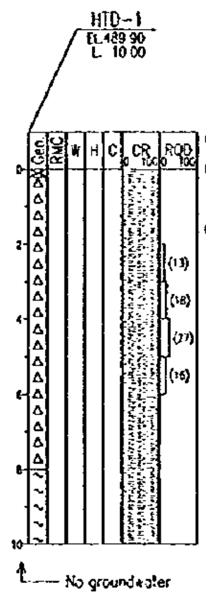
9.15 ~ 18.00m
Sheared and weathered phonolite.

9.15 ~ 13.60m Black
ϕ1 ~ 3cm rock fragments and medium to coarse sand , loose.

13.60m ~ 14.90m Dark gray
Fresh , Very hard glassy phonolite.
Well-jointed.

14.90 ~ 16.65m Brown
Rock fragments and coarse sand.
Weathered.

16.65 ~ 18.00m Brown
Silty sand loose condition.
Strongly weathered zone.



Geological Description (HTD-1)

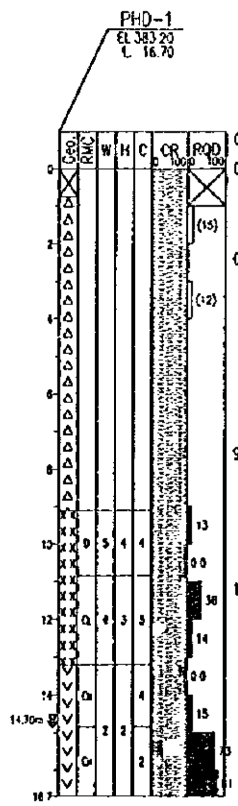
0 ~ 0.20m
Top soil. Dark brown
Plants roots contained.

0.20 ~ 10.00m
Detritus

0.20 ~ 4.30m Brown and Dark brown
Silt and Clay with rock fragments.
High plasticity , Wet condition under 3.45m.

4.30 ~ 8.00m Gray
Rock fragments.
ϕ3 ~ 10cm pebble ~ cobble in size.
Fresh. Very hard basalt are dominant.
Angular ~ subangular.
Fine sand and silt in matrix.
7.00 ~ 7.60m fine sand.

8.00 ~ 10.00m Red and Brown
High plasticity clay partially silt.
Compact , wet condition.
No rock fragment included.
Grain size of lower portion is more coarse than upper portion.



Geological Description (PHD-1)

0 ~ 0.75m
Top soil. Light brown.
Sand and silt with rock fragments.
ϕ1 ~ 2cm rock fragments. Plants roots contained Dry condition. Low plasticity.

0.75 ~ 9.10m
Detritus

0.75 ~ 2.85m Detritus Grey
ϕ5 ~ 10cm rock fragments.
Rock fragments are derived from hard basalt.

2.85 ~ 9.10m Detritus. Gray and Brown
Silt and clay with rock fragments.
Ratio of including rock fragments is 40 ~ 50%
Rock fragments are very hard , subangular in shape.
High water content , slightly loose.

9.10 ~ 13.20m
Tuff Breccia (ϕ1 ~ 3cm breccia contained)

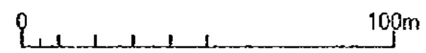
9.10 ~ 10.85m Reddish brown
Strongly weathered weak rock.
High water content.

10.85 ~ 13.20m Yellow and Reddish brown
Weathered and jointed rock.

13.20 ~ 16.70m
Basalt. Very hard.

13.20 ~ 14.85m Gray
Hard and massive.
Some surface of the rocks are stained by oxidation.

14.85 ~ 16.70m Dark Gray
Extremely hard , porous
Rocks are accompanied by calcite veins.

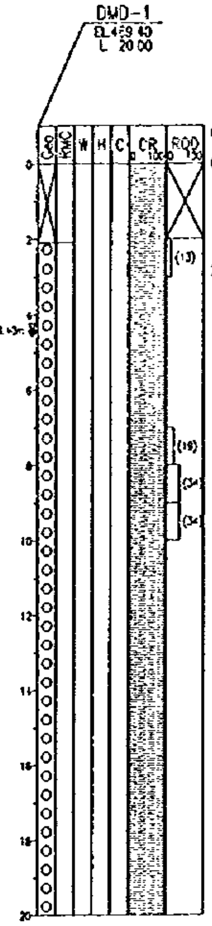


MINI HYDRO ELECTRIC POWER STATION PROJECT

GEOLOGIC PROFILE
HEAD TANK to POWER HOUSE
(Down stream)

Fig. 10-9

Geological Description (DMD-1)



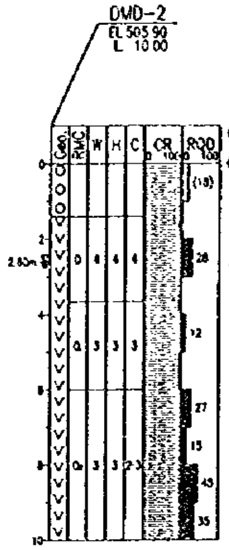
0 ~ 2.10m
Top soil and Bankment. Brown
Rock fragments φ1 ~ 3cm contained silt and coarse sand. Dry condition. Low plasticity.
Bankment was formed by the canal from cascade to Milagrosa village.

2.10 ~ 20.00m
Recent river deposit

2.10 ~ 15.10m Gravel. Gray Brown
Rounded or subrounded gravel with medium to coarse sand. Gravel are originated from hard rock ; such as basalt and phonolite.
Ratio of including gravel is 80% approximately.
Cobble and Boulder size gravel are abundant.
Low plasticity.
12.1 ~ 13.5m is dominated by sand matrix.

15.50 ~ 20.00m Gravel. Black
Medium to coarse sand with gravel.
Gravel are composed mainly of pebble in size, partially cobble. Loose condition.

Geological Description (DMD-2)



0 ~ 1.40m
Recent river deposit. Brown and Grey Gravel. Very hard.
Gravel in size of φ1 ~ 3cm are dominant.
0 ~ 0.60m Rock fragments with silt.
Plants roots contained

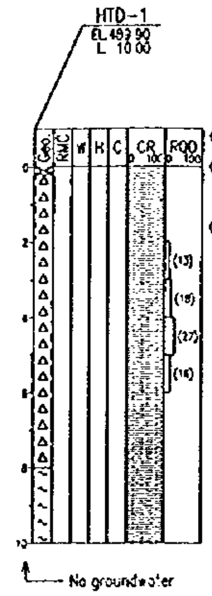
1.40 ~ 10.00m
Thermal altered basalt.
Basalt change reddish in color and slightly weak by thermal alteration.

1.40 ~ 3.65m Reddish gray
Jointed basalt with silt and sand.
Rock fragments are 1 ~ 3cm in piece.

3.65 ~ 6.00m Reddish brown
Jointed basalt. Very hard.
The surface of rock fragments are stained by oxidation.

6.00 ~ 10.00m Reddish brown
Massive basalt. Very hard Porous.
Slightly weathered.
Rocks are accompanied by calcite veins.

Geological Description (HTD-1)



0 ~ 0.20m
Top soil. Dark brown
Plants roots contained.

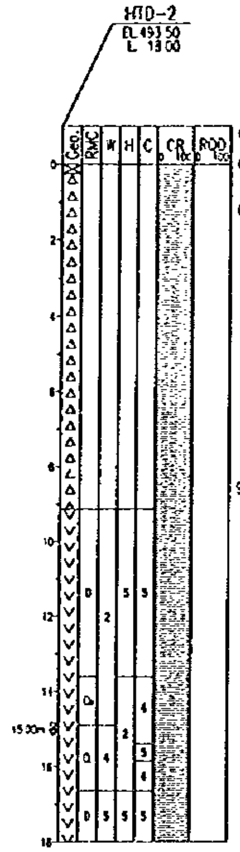
0.20 ~ 10.00m
Detritus

0.20 ~ 4.30m Brown and Dark brown
Silt and Clay with rock fragments.
High plasticity , Wet condition under 3.45m.

4.30 ~ 8.00m Gray
Rock fragments.
φ3 ~ 10cm pebble ~ cobble in size.
Fresh. Very hard basalt are dominant.
Angular ~ subangular.
Fine sand and silt in matrix.
7.00 ~ 7.60m fine sand.

8.00 ~ 10.00m Red and Brown
High plasticity clay partially silt.
Compact , wet condition.
No rock fragment included.
Grain size of lower portion is more coarse than upper portion.

Geological Description (HTD-2)



0 ~ 0.25m
Top soil Brown. Plants roots contained

0.25 ~ 9.15m
Detritus

0.25 ~ 3.65m Brown
Silt and clay with rock fragments.
Medium plasticity. Dry condition.

3.65 ~ 6.90m Gray and Brown
Rock fragments with silty sand.
φ3 ~ 5cm pebble ~ cobble in size.
Fresh , Very hard basalt and phonolite.
Silt of matrix has high plasticity , and with φ1 ~ 5cm rock fragments.

6.90 ~ 9.15m Brown
Rock fragments with silt and fine sand.
High plasticity , high water content.
Rock fragments are dominant by granule and pebble in size.

9.15 ~ 18.00m
Sheared and weathered phonolite.

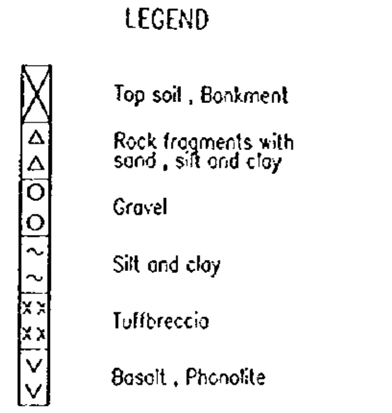
9.15 ~ 13.60m Black
φ1 ~ 3cm rock fragments and medium to coarse sand , loose.

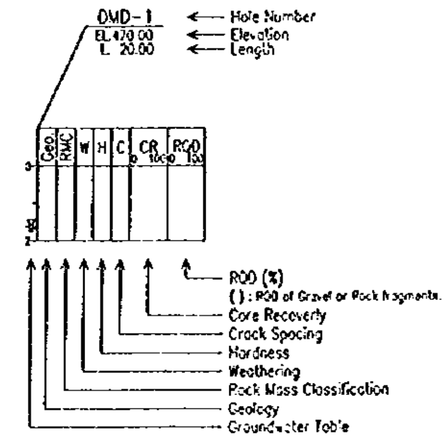
13.60m ~ 14.90m Dark grey
Fresh , Very hard glassy phonolite.
Well-jointed.

14.90 ~ 16.65m Brown
Rock fragments and coarse sand.
Weathered.

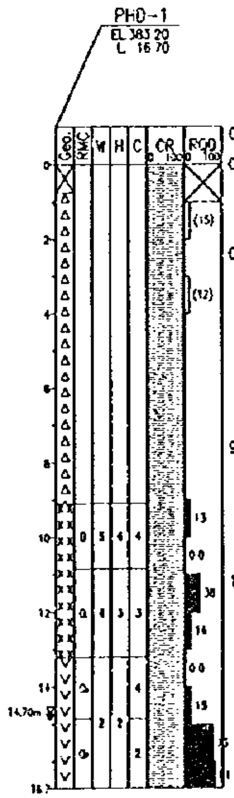
16.65 ~ 18.00m Brown
Silty sand loose condition.
Strongly weathered zone.

LEGEND





Geological Description (PHD-1)



0 ~ 0.75m
Top soil. Light brown.
Sand and silt with rock fragments.
φ1 ~ 2cm rock fragments. Plants roots contained. Dry condition. Low plasticity.

0.75 ~ 9.10m
Detritus.

0.75 ~ 2.85m Detritus. Gray
φ5 ~ 10cm rock fragments.
Rock fragments are derived from hard basalt.

2.85 ~ 9.10m Detritus. Gray and Brown
Silt and clay with rock fragments.
Ratio of including rock fragments is 40 ~ 50%.
Rock fragments are very hard , subangular in shape.
High water content , slightly loose.

9.10 ~ 13.20m
Tuff Breccia (φ1 ~ 3cm breccia contained)

9.10 ~ 10.85m Reddish brown
Strongly weathered weak rock.
High water content.

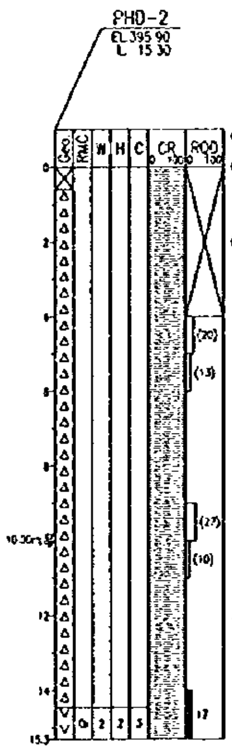
10.85 ~ 13.20m Yellow and Reddish brown
Weathered and jointed rock.

13.20 ~ 16.70m
Basalt. Very hard.

13.20 ~ 14.85m Gray
Hard and massive.
Some surface of the rocks are stained by oxidation.

14.85 ~ 16.70m Dark Grey
Extremely hard , porous.
Rocks are accompanied by calcite veins.

Geological Description (PHD-2)



0 ~ 0.60m
Top soil. Dark brown.
Sand and silt with rock fragments.
Dry condition , Medium to high plasticity.

0.60 ~ 14.45m
Detritus.

0.60 ~ 4.00m Dark brown and Gray
Rock fragments with silt and clay.
Ratio of including rock fragments is 70%.
Dry to slightly wet , high plasticity.

4.00 ~ 4.90m Gray
φ3 ~ 5cm rock fragments. Very hard.
The surface of fragments are somewhat stained by oxidation.

4.90 ~ 9.70m Brown
Silt and clay with rock fragments.
High water content , high plasticity.

9.70 ~ 11.45m Gray
Large derived stone. Very hard basalt.
Angular , cracks abundant.

11.45 ~ 14.45m Dark gray and Black
Sand with rock fragments.
Rock fragments in size of φ3 ~ 5cm are dominant.
Medium to coarse sand of matrix is well-sorted.

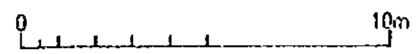
14.45 ~ 15.30m
Porous phonolite. Black.
Very hard , glossy.
Some cracks are stained by oxidation.

Standard of Three Fundamental Factors for Drilled Core

Weathering /Alteration		Hardness		Crack spacing	
1	Very fresh. No weathering/alteration of mineral component	1	Very hard. Broken into knife-edged pieces by strong hammer blow	1	Over 30 cm
2	Fresh. Some minerals are weathered/altered slightly. Usually no brown crack	2	Hard. Broken into pieces by strong hammer blow	2	10-30 cm
3	Fairly fresh. Some minerals are weathered/altered. Cracks are stained and with weathered/altered material	3	Brittle. Broken into pieces by medium hammer blow	3	3-10 cm
4	Weathered/Altered. Fresh portions still remain partially.	4	Very brittle. Easy broken into pieces by medium hammer blow	4	1-3 cm
5	Strongly weathered/altered. Most minerals are weathered/altered ben	5	Soft. Able to dig with hammer	5	Under 1 cm

Rock Mass Classification

Class	Description
A	The rock mass is very fresh, and the rock forming minerals and grains undergo neither weathering nor alteration. Joints are extremely tight and their surface have no visible sign of weathering. Sound by hammer blow is clear.
B	The rock mass is solid. There is no opening joint and crack. But rock forming minerals and grains undergo a little weathering and alteration in partly. Sound by hammer blow is clear.
CH	The rock mass is relatively solid. The rock forming minerals and grains undergo weathering except for quartz. The rock blocks are separated by strong hammer blow along joints. Clay minerals remain on the separation surface. Sound by hammer blow is a little dim.
CM	The rock mass is somewhat soft. The rock forming minerals and grains are somewhat softend by weathering, except for quartz. The rock blocks are separated by medium hammer blow along joints. Clay minerals remain on the separation surface. Sound by hammer blow is some what dim.
CL	The rock mass is soft. The rock forming minerals and grains are softend by weathering. The rock blocks are separated by soft hammer blow along joints. Clay minerals remain on the separation surface. Sound by hammer blow is dim.
D	The rock mass is remarkably soft. The rock forming minerals and grains are softend by weathering. The rock mass crush by light hammer blow. Clay minerals remain on the separation surface. Sound by hammer blow is remarkably dim.



MINI HYDRO ELECTRIC POWER STATION PROJECT

Log of Drillhole

Fig. 10-10

Chapter 11

FEASIBILITY DESIGN

11. FEASIBILITY DESIGN

11.1 Outline of Facilities

The scale of this Project, as indicated by the optimum scale described in Chapter 8, would be maximum available discharge of Q_{max} = 0.31 m^3/sec and effective head of H_e = 109.17 m for maximum output of 229 kW, constituting a so called mini-hydroelectric power station. As civil structures, there would be an intake dam and intake, while the headrace for conducting water to be used for power generation and obtain head is to be an open conduit of gradient 1/500 along the mountainside in view of the topography of the headrace route as a whole. Part way along the upstream portion of the headrace, it will be necessary to provide a regulating gate and spillway to shut off water from the intake for the purposes of repair of downstream structures and flushing out of sand. Also, a settling basin for settling and removal of silt and sand mixed in the water taken in is to be constructed. Water is to be conducted approximately 1.2 km to a head tank. Since a comparatively small volume of water is to be conducted, the cross-sectional area of flow is to be inside width of 0.57 m and inside height of 0.72 m.

The head tank will have the functions not only of preventing large water-level fluctuations when starting power generation, instantaneously supplying water for power generation without excess or shortage, dispersing reaction energy (water hammer) accompanying shut-off of water flowing down the penstock when stopping power generation, and at the same time, alleviating or suppressing water-level rise, but also in the case of this Project, storing water for supply to eliminate ineffective discharge due to power generation stoppage at time of low water in the dry season.

The penstock will conduct water for power generation from the head tank to the powerhouse. The head between the head tank and the powerhouse outlet will be HG = 115.56 m (11.3 kg/m^2), and the length of steel pipe of inside diameter D = 0.394 m to withstand this water pressure will be L = 224 m.

The powerhouse will receive water from the penstock at a reaction-type cross-flow turbine to convert the location and velocity energy into electric energy for generation of maximum power of P_{max} = 230 kW and annual energy production of 1.25 GWh.

11.2 Civil Structures

11.2.1 Intake Dam

Upstream of this intake dam is an extremely steep river gradient of 1/8, while river width is narrow at 10 to 15 m, and for water to be stored and regulated to supplement runoff in the dry season, the height of the intake dam would need to be raised as the river gradient is steep and the valley is narrow and there is no efficient pocket available, so that the topography is an extremely uneconomical one.

The 100 year design flood discharge of this site is around Qf = 180 m3/sec and large, the water-level rise during flood being as much as about 6 m.

Therefore, it was considered acceptable if in order to maintain a cross-sectional area of the river to allow the river flow during flood to run down as smoothly as possible, the dam is made as low as permissible stopping the river water and carrying out intake with no leakage even when runoff is small.

Regarding the dam foundation, according to the results of boring investigations, the basement rock of basalt can be reached about 1.5 m under the river-bed ground level so that the concrete dam is to be anchored on the basement rock with the crest of the dam at a height about 0.5 m above the present river bed, the dam length to be 11 m for a quite small-scale structure.

11.2.2 Intake Facilities

At the intake, the difference between water levels during flood and during low water is around 5 m and large for mini-hydro power generation. Consequently, a side intake facility, in order not to be affected by river flow during flood, will require excessively large gate and screen facilities and be uneconomical, while maintenance costs will be high.

In view of this, the intake in this Project is to be made a so-called Tyrolean type by which intake is done from the dam crest, with the screen, in order to prevent inflow of sand-gravel from the intake as much as possible, having screen spacing in the direction parallel to the dam axis 1 cm, with the inclination of the screen in the upstream-downstream direction 20 deg (the inclination at which sand will enter the least is said to be 30 deg). The width of installation of screen bars was made 4 m at which maximum available water can be amply taken in (see Fig. 11-).

Removal of trash easily caught on the screen is to be carried out daily or once every other day at times of normal water level, while after a flood, trash removal is to be done by rakes and other equipment.

11.2.3 Headrace Channel

The headrace for 40 m from immediately downstream of the intake provided in the intake dam is to be a reinforced concrete culvert buried on trench cutting of the left-bank river bed of the Manuel Jorge River in order that the waterway will not be damaged by debris flow during flood. The cross section of this culvert was made 0.7 m in height and width so that a person can enter and perform removal work in case sand-gravel should accumulate inside the culvert. A 5 m long side-overflow type spillway and gate are to be provided at the downstream end of the culvert, while at the downstream most end a regulating gate is to be provided so that water flow excessively taken in would be discharged from the side overflow spillway and gate, while with the regulating gate the discharge to the downstream would be adjusted, the waterway to be shut off when repairing or cleaning the downstream waterway.

As the section from this regulating gate to the head tank is to be an open concrete conduit of design cross-sectional area of flow of inside width 0.57 m and inside height 0.72 m, and with a waterway gradient of 1/500 and roughness coefficient of n = 0.015, it was made possible for maximum available discharge of 0.31 m³/sec to run down.

The open conduit is to be provided by trency cutting of the mountainside and with a construction access road cum inspection and maintenance road of width 2 m at the river side, the conduit is to be on the mountain side of the road.

The open conduit is to be provided with concrete covers 6 cm in thickness in order to prevent entrance of earth falling from the mountain-side slope of the trench cut and growth of grass.

Although gradient of slopes above existing roads in the vicinity of the project site are 1:0.2 to 1:0.3 at places of soil and stable, the slope gradients on the mountain side of the trench cut are to be made 1:0.7 to 1:1 for soil cuts at gentle slopes to protect this headrace from falling debris over a long term, while at rock masses a gradient of 1:0.3 is to be used, with shotcrete of thickness 10 cm applied at slopes where necessary in aiming for stability.

11.2.4 Settling Basin

Fundamentally, it would be ideal for a settling basin to be provided immediately downstream of the intake, but since the mountainside gradient at the section of approximately 120 m from the intake of this site is steep, at approximately 130 m downstream of the intake part way along the headrace where the slope is comparatively gentle, a water tank of length 26 m, width 3 m, and effective water depth of 1.5 m is to be provided and sand of particle diameter 0.5 mm and over mixed with the water taken in is to be made to settle and be removed. A spindle-type scour gate of width 0.65 m and height 0.57 m is to be provided at this settling basin.

At the river side of the settling basin, a side-overflow spillway which allows maximum available water of 0.31 m^3/sec to overflow with water depth 0.1 m and under, while further downstream, a stone-lined spillway of L = 125 m, width 1 m, and depth 0.5 m for discharge to the Manuel Jorge River at its closest part are to be provided.

Further, at the downstream end of the settling basin a spindle gate of width 0.72 m and height 0.72 m for flow regulation is to be provided in order that water taken in during sand flushing work inside the settling basin will not go downstream and sediment mixed with water can be efficiently discharged.

11.2.5 Head-tank

The head tank is to have a concrete wall of height 1.8 m or more which can secure a storage capacity of 2,400 m3 with effective water depth of 1.5 m at the gently sloped part of a ridge near EL. 505 m at a distance of 1,150 m from the intake, the bottom slab being of reinforced concrete 0.15 m in thickness. Underneath this concrete slab perforated pipe of Ø100 mm is to be buried in trenches to remove ground water from the original ground and leakage from the head tank, and to alleviate back pressure, the surroundings of the pipe filled with gravel to comprise a blind culvert.

A side-overflow type spillway (overflow water depth 0.15 m, length 3 m) allowing a maximum 0.31 m3/sec to overflow in case of power generation stoppage is to be provided at the river side of the head tank. The spillway below is to be stone-lined, having a width of 1.0 m and depth of 0.5 m, provided over a length of 180 m along the horizontally curved slope on the upstream side of the head tank going in the direction of the Manuel Jorge River.

Further, this head tank is to be provided with a water-supply valve of Ø50 mm to be prepared for water supply in case the domestic service water supply conduit to local communities such as Miragrosa is damaged and supply of drinking water is stopped, while still more, approximately 50 m of rigid polyvinyl chloride pipe of Ø50 mm is to be buried in a direction toward the existing water supply facility.

11.2.6 Penstock

The penstock pipe, other than being reduced near the turbine inlet valve, is to be of steel pipe of inside diameter 0.394 m, and a length of approximately 224 m is to be installed. Regarding the gradient of the penstock line, at the upper part, it is to be approximately 6 deg down a gentle slope for about 35 m, from where the part of more or less steepest gradient is to be 27 to 47 deg and comparatively steep. Further, around where the road along the left bank of the Manuel Jorge River is crossed, it becomes a steep slope, and especially, the 11 m of the section where the powerhouse below is entered from the road becomes extremely steep at 63 deg. There are 7 locations over the entire penstock route where anchor blocks will be required; the place where the largest block will be required is the intersection angle immediately above the road along the river.

The shell thickness of the penstock pipe, according to the Technical Standards for Gates and Penstocks of Japan, for pipe diameter of 0.394 m is $(D + 800)/400 = t$ (mm) as the minimum thickness. Since the calculated value would be smaller than the 6 mm which is the standard minimum plate thickness of steel pipe from $D.P/2.\sigma t.\eta w) + 0.002 < 6$ mm based on the design water pressure of 16 kgf/cm^2 taking into consideration water hammer at the bottommost part, it was decided that t = 6.4 mm for standard ready-made steel pipe inside diameter of D = 0.394 m indicated in 8.2.4 would be used throughout the length except for the reduction pipe immediately upstream of the powerhouse.

For saddles between anchor blocks, since flanges would be attached at both ends of each 6 m length ready-made pipe to join two lengths each, 12 m was taken as the standard spacing. In laying pipe, the middle point, 3 m, of 6 m unit pipe is to be placed at the center of a saddle giving consideration to make it possible for the intermediate 6 m pipe to be removable when making repairs in the future. At contact areas between steel pipes and saddles, steel plates coated with grease are to be laid allowing the steel pipe to freely move in expansion and contraction. Regarding expansion pipes, they are to be provided immediately downstream of individual anchor blocks making it possible for thermal expansion and contraction acting on lower steel pipes to be adjusted. At the lower penstock portion, where it crosses the road at the left bank along the river, an open cut of 1.0 m both in width and height is to be made so that steel pipe can be laid to have its top 0.3 m below the road surface, and this is to be lined with concrete to make it capable of withstanding loads such as of vehicles.

11.2.7 Powerhouse

For the powerhouse, the little slope of width 30 m sandwiched between the Manuel Jorge River and the left-bank road is to be excavated to provide a powerhouse building at the level of EL. 391 m (flood water level 390.4 m), and since the generating discharge water level is to be EL. 388.4 m, 2 m below the design flood water level, the foundation will be at EL. 386.4 m.

Consequently, since the generator hall will be lower than the flood water level, the perimeter is to have gravity-type concrete walls so that water pressures and earth pressures can be withstood, and moreover, leakage will not occur.

At surfaces of concrete walls subjected to earth pressures and water pressures, filter layers of gravel are to be provided aiming to alleviate the pressures.

As for the flood water level, it was determined upon making backwater calculations with 100 year design flood discharge of Qf = 209 m^3/sec using actual measurements of the transverse section of the river and also using Manning's roughness coefficient of n = 0.25.

The excavated slope between the powerhouse and the road is to be protected by a concrete retaining wall, while on the river side of the powerhouse, a revetment is to be provided with stone masonry so that the vicinity of the outlet will not be scoured by flood waters.

The powerhouse building is to accommodate a generator hall, office, battery room, and a restroom. It is to have a width of 5 m and length of 13 m, with the foundation, columns and beams of reinforced concrete, the walls being of brick with joint mortar. The roof is to be covered with corrugated asbestos sheet placed on the ridge. Windows of aluminium sashes and glass panes are to be provided at walls on all 4 sides.

11.2.8 Access Road to Powerhouse

The access road to the powerhouse is to be a gravel road of width 3 m from a point of the left-bank road at around EL. 397.4 m approximately 80 m downstream of the powerhouse going along the river side to the powerhouse at a gradient of 1/12.

The cut surface on the side of the existing road immediately above the access road is to be protected by a concrete retaining wall, while also at necessary places on the river side of the access road such as near the entrance, concrete retaining walls are to be constructed.

11.2.9 Existing Domestic Service Water Conduit

Regarding the existing domestic service water supply conduit to the local communities of Milagrosa and Santa Clara, the river flow at the intake point will be reduced due to this power development project, and especially, intake in the dry season will become difficult. The intake quantity required by this water supply system is 0.02 m^3/sec, and in order to make it easier for intake of this quantity to be achieved, a concrete weir of height 1.5 m and length 12 m is to be provided on top of the sand-gravel layer immediately upstream of the intake, with mortar grouted into the sand-gravel layer to prevent leakage from the foundation of the weir, and also with injection of neat cement grout performed as necessary. The existing conduit is antiquated, with heavy leakage, and repairs are necessary. Accordingly, waterproof mortar is to be applied at sections of heavy leakage, while at places where damage is especially severe, improvement works including side walls are to be carried out.

11.3 Main Electro-mechanical Equipment

11.3.1 Selection of Main Equipment

(1) Turbine

Judging from the plan specifications (effective head 109.17m and maximum power discharge $0.31m^3/3$), the horizontal shaft Pelton turbine, horizontal shaft Francis turbine or cross-flow turbine is considered as the turbine type.

The flow duration in this area is roughly classified into the dry season and rainy season and this powerhouse is operated as the base powerhouse in the dry and rainy seasons. Rainfall is small especially in the dry season and partial load operation must be fully considered.

When the above is considered, the cross-flow turbine and Pelton turbine are more profitable than the Francis turbine because the former have a wider range of partial load and higher efficiency during partial load operation although their maximum efficiency falls slightly.

Particularly, the cross-flow turbine has simple construction and is lower in cost than the Pelton or Francis turbine. Moreover, simple construction makes its maintenance easy and turbine trouble repair can be made locally to some extent. Therefore, use of the cross-flow turbine shall be recommended.

The cross-flow turbine is used also in the Gue Gue hydro power statopm downstream. One main equipment shall be used in consideration of operation in the dry and rainy seasons and easy of equipment maintenance.

(2) Generator

The three-phase, AC synchronous generator shall be used and the power factor and its power factor shall be 0.8 so that voltage regulation in the system can be done sufficiently.

The generator factor of the existing powerhouse is designed at 0.8 to 1.0.

(3) Main transformer

The main transformer shall be installed in the outdoors of the power house.

(4) Control system

The control system permanently stationed by the operator shall be used.

11.3.2 Salient Technical Specifications of Main Equipment

(1) Turbine

Type	Cross-flow turbine
quantity	1
Standard effective head	109.17 m
Power discharge	0.31 m^3/s
Standard output	253 kW
Revolutions	1,000 r.p.m

(2) Generator

Type	Three-phase, AC synchronous generator
Quantity	1
Output	290 kVA
Revolutions	1,000 r.p.m
Frequency	50 Hz
Voltage	400 V
Power factor	0.8

(3) Main Transformer

Type	Outdoor three-phase oil-immersed, self-cooling
Quantity	1
Rated output	290 kVA
Voltage	400 V/30 kV

(4) Power transmission line

Total length	5 km
Number of lines	1 line
Voltage	30 kV
Conductor type	Annealed copper strand wire
Section	From Manuel Jorge No. 4 powerhouse to Trindade substation

11.3.3 Salient Feature of Power House

This powerhouse shall be of the indoor type. Control panels of the turbine, generator and related auxiliary machines shall be installed in the generator room. The main transformer shall be installed on the mountain side of the powerhouse. The single line diagram of the powerhouse is shown in Fig. 11-12.

11.4 Construction Planning

11.4.1 General

The principal civil works in this Project are as follows:

(a) Intake Dam

Width 11 m, height 2.0 m, concrete volume210 m^3

(b) Headrace

Culvert:	inside width 0.7 m, height 0.7 m, length 40 m
Open conduit:	inside width 0.57 m, height 0.72 m, length 1,110 m
Bed excavation:	width approx. 2 m, length 1,150 m, V =
Shotcrete:	thickness 0.1 m, area760 m^2

(c) Settling Basin

Length 25 m, Vc = 80 m^3

Spillway: length 125 m, stone lining: A = 280 m^2

(d) Head Tank

Excavation: V =10,070 m^3

Retaining wall:	height 1.8 - 2.0 m, concrete volume Vc =370 m^3
Bottom slab:	thickness 0.15 m, area A =1,520 m^2
	concrete V =230 m^3
Spillway:	length 240 m, stone lining 530 m^2

(e) Penstock

Steel pipe:	diameter D = 0.394 m, length224 m
Anchor block:	7 places, and saddles 14 places
Excavation:	volume 830 m^3
Concrete:	volume 125 m^3

(f) Powerhouse

Building:	width 5 m, length 13 m, floor area 65 m^2
Excavation:	volume 200 m^3
Concrete:	volume 400 m^3

(g) Powerhouse Access Road

Length 72 m, width 3 m

Excavation:	volume 860 m^3
Concrete:	volume 205 m^3

(h) Local Service Water Supply System

Intake weir:	height 1.5 m, width 11 m
Excavation:	volume 660 m^3
Concrete:	volume 235 m^3

These works will require 12 months as shown in the time schedule of Fig. 11-10. Of these works, construction of the principal structures will be as described below.

11.4.2 Intake Dam

The annual rainfall in this project area is approximately 2,000 mm, and except for the minor rainy season from January to February and the dry season from the first part of June to the first part of September, it is the rainy season and there is much rain.

Because of this meteorological condition, it is essential for work on the intake dam, to be provided at a small, confined ravine, to be carried out with excavation, placement of dam concrete, and finishing of intake facilities to be done in the 3 months of the dry season. For this purpose, the approach to the dam site is to be achieved by going up a forestry road extending from the vicinity of the left-bank abutment of a bridge at elevation of approximately 432.5 m on the road at the left bank of the Manuel Jorge River, bench cutting a waterway bed upstream from a point crossing the waterway bed at the vicinity of approximately 470 m from the intake and using this as the access road to reach the dam site. Along this stretch, there is a section of approximately 100 m which is of steep gradient and is a continuation of a hard rock mass which requires blasting operations for construction to be done, and since shaping and protection of the slope face is required, a period of about 6 months will be needed.

The dam construction, because the river flow is 0.1 m^3/sec in the dry season and small, and since the work quantity is also small, can be completed in a 3 month period including appurtenant facilities, but the time of completion of the dam work will be governed by the work schedule concerning the rugged rock mass section.

11.4.3 Headrace Channel

The headrace work of length of approximately 1,150 m, excepting excavation close to the intake dam, will be from the road along the mountainside connecting to the existing forestry road at around EL. 515 m to the waterway bed at approximately EL. 505 m, along which temporary approach roads are to be provided at several places. The nearest parts of the waterway bed are to be reached by these and the waterway bed is to be provided by bench cutting in the upstream and downstream directions. Using this bed as a construction road, a trench for placing waterway concrete is to be excavated, while in parallel, open conduit concrete is to be placed. In this case, it will be optimum for trench cutting and concreting to be done going backward from the individual faces. For the waterway concrete, several sets of ready-made forms of around 6 m should be prepared to speed moving and installation, which will greatly facilitate execution of the headrace work as a whole.

11.4.4 Settling Basin and Head-tank

the settling basin is to be provided at around approximately 120 m downstream from the intake for reasons of topography, but since the work quantities for the basin proper are small, placing of reinforcing steel, erection of formwork, and concrete placement would be done seeking time openings in the overall headrace work, and a period of 2 months should be adequate.

Head-tank will comprise the largest concrete structure at this project site, with the excavation volume ----- m^3, concrete formwork ----- m^2, and concrete volume ----- m^3, the excavation and formwork erection for concrete placement taking up large proportions of the construction period. Because of this, it will be efficient if especially the wall formwork were to be fabricated beforehand as mobile forms of 6 to 9 m spans. The bottom slab concrete of the head tank will be of 15 cm thickness, and for construction of this, it will be necessary to pay attention to prevention of future uneven settlement through loosening of the foundation ground of the bottom slab when constructing blind culverts and other structures after excavation of the foundation.

11.4.5 Penstock and Spillway

The length of the penstock and spillway will be approximately 224 m, of which the greater part of a section of 200 m will consist of work at slopes of ---- deg to ---- deg. At the lower part of this pipeline work, there exists a road along the left bank of the Manuel Jorge River which is being used for general traffic so that thorough consideration must be given regarding rock falls and the like in penstock foundation excavation, concrete placement, and steel pipe installation, and particularly, with regard to rock falls, it will be necessary to provide measures such as erecting protective fences in parallel at the mountainside slopes.

For installation of penstock pipes it is conceivable to stretch cables along the center line of the penstock route to pull up or lower pipes from the riverside road and the access road at the head tank side, but since the weight of a single piece of steel pipe will be approximately 400 kg, it is also conceivable for pulling up or lowering by winch for transportation and installation.

11.4.6 Powerhouse

The powerhouse will be immediately below the road running along the left bank of the Manuel Jorge River, so that for safety of road traffic and giving consideration to accidents such as rock falls from excavated slopes, it is necessary to start from excavation of the access road and retaining wall work from the downstream side of the powerhouse.

In excavation for the powerhouse also, it will be important to cut down the mountainside from the shoulder of the existing road and perform foundation excavation of the powerhouse while carrying out rationing wall work..

Regarding work on the powerhouse building proper, it is necessary for perimeter wall work for the generator hall to be done up to higher than the design flood water level of 390.4 m immediately after placing foundation concrete, in consideration of preventing inundation of the powerhouse foundation due to flooding of the river.

11.5 Construction Materials

The sources of the major materials required in construction of the civil structures in this Project are as described below.

11.5.1 Concrete Aggregates

Of concrete aggregates, fine aggregates would consist of material collected at the seashore, and mountain sand manufactured by drilling and blasting rock at a quarry, crushing the rock and screening it.

Collection of fine aggregate at the seashore is under the jurisdiction of the Port and Harbor Bureau of Sao Tome and Principe, and is subject to approval of the Bureau.

The sources of this marine sand are the three places of the Ponta Fernao Dias site approximately 11 km Northwest of the capital city of Sao Tome, Praia Pombas approximately 6.5 km to the south-Southwest, and Praia Grande on the east coast close to the southern tip of Sao Tome Island.

Of these sites, the beach at Ponta Fernao Dias is narrow and collection is difficult.

In case of the Praia Pombas site, there has been excessive digging so that deposits have been depleted, and the Port and Harbor Bureau is encouraging collection at Praia Grande in the south where deposits are abundant. However, this Praia Grande site is at a long distance of approximately 60 km from Sao Tome, the capital, and transportation costs are high. Marine sand, of course, needs to be used upon washing and cannot be used for other than plain concrete.

As for mountain gravel, there are two organizations working quarries at the two places of Mesquita and Boa Morte on the left bank of the Mercal River which flows past west of Sao Tome City, where they quarry graywacke and basalt which are crushed and screened at aggregate plants.

Of the two, one is MESA which is directly producing coarse and fine aggregates totalling more than 100 m3/mo at Mesquita. The other is a private firm at Boa Morte with South African capital which uses crude rock of basalt to manufacture 300 m3 (including 25 m3 of sand) daily of road subbase course material and concrete aggregates of particle size 55 mm down to sand by screening.

Since the aggregates of the abovementioned two organizations consist of crushed stone, the cement content of concrete will be slightly higher than concrete using river aggregates, but they are safer for concrete structures than fine aggregate from the sea which needs to have its salt content removed.

As for aggregate supply capacity, since the maximum volume of concrete to be placed daily is around 10 m3, there will be no problem.

11.5.2 Cement and Reinforcing Bars

Cement and reinforcing bars are not being produced in Sao Tome and Principe, and imports are depended on for all requirements.

The main sources of imports are Portugal and South Africa. When importing from these countries, it appears that in case of Portugal about 2 months are required from ordering to delivery in the field.

On the other hand, in case of South Africa, a private construction company has a regular liner in service and there is capability for stable supply, but a monopolistic tendency can be seen and prices are somewhat high.

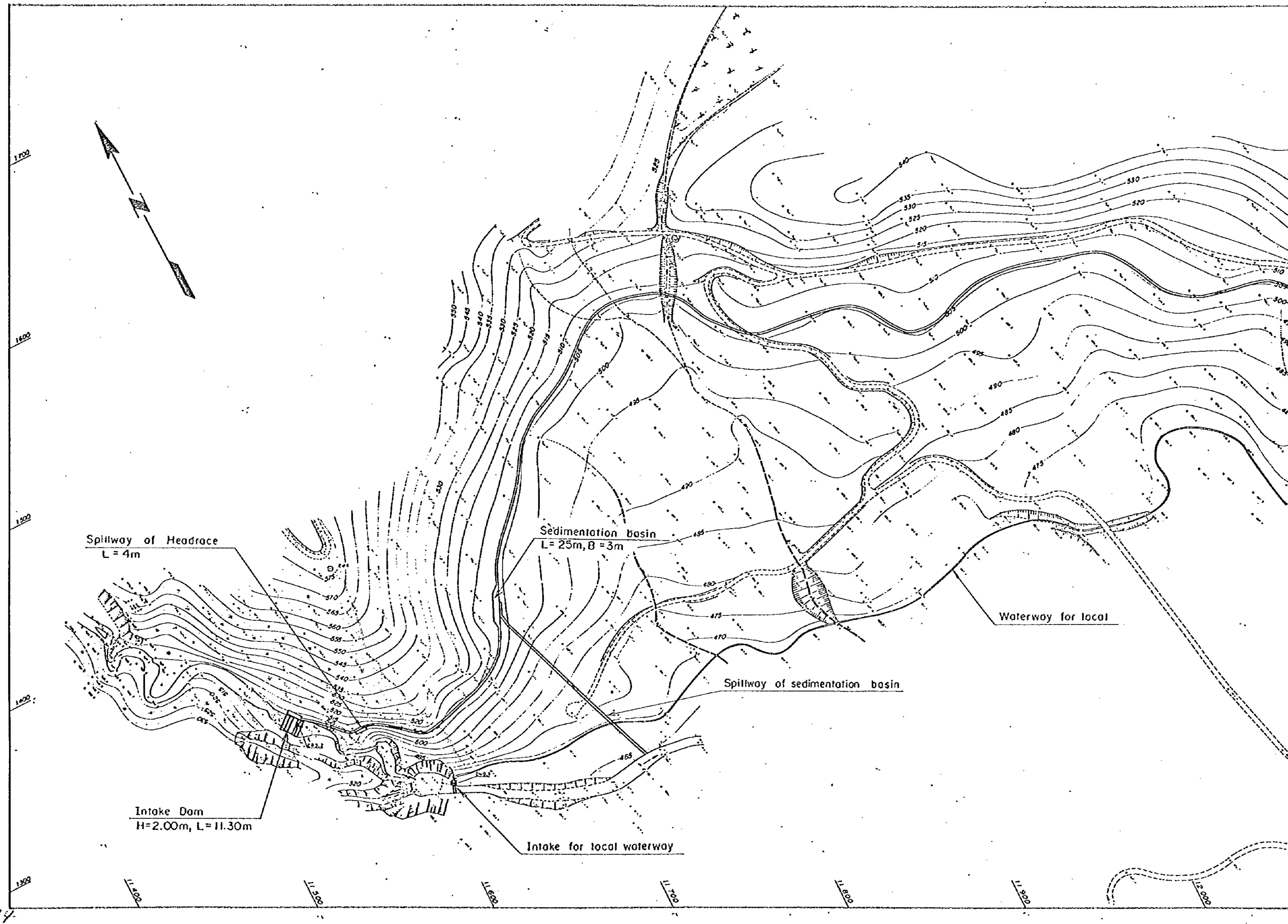
11.6 Construction Schedule

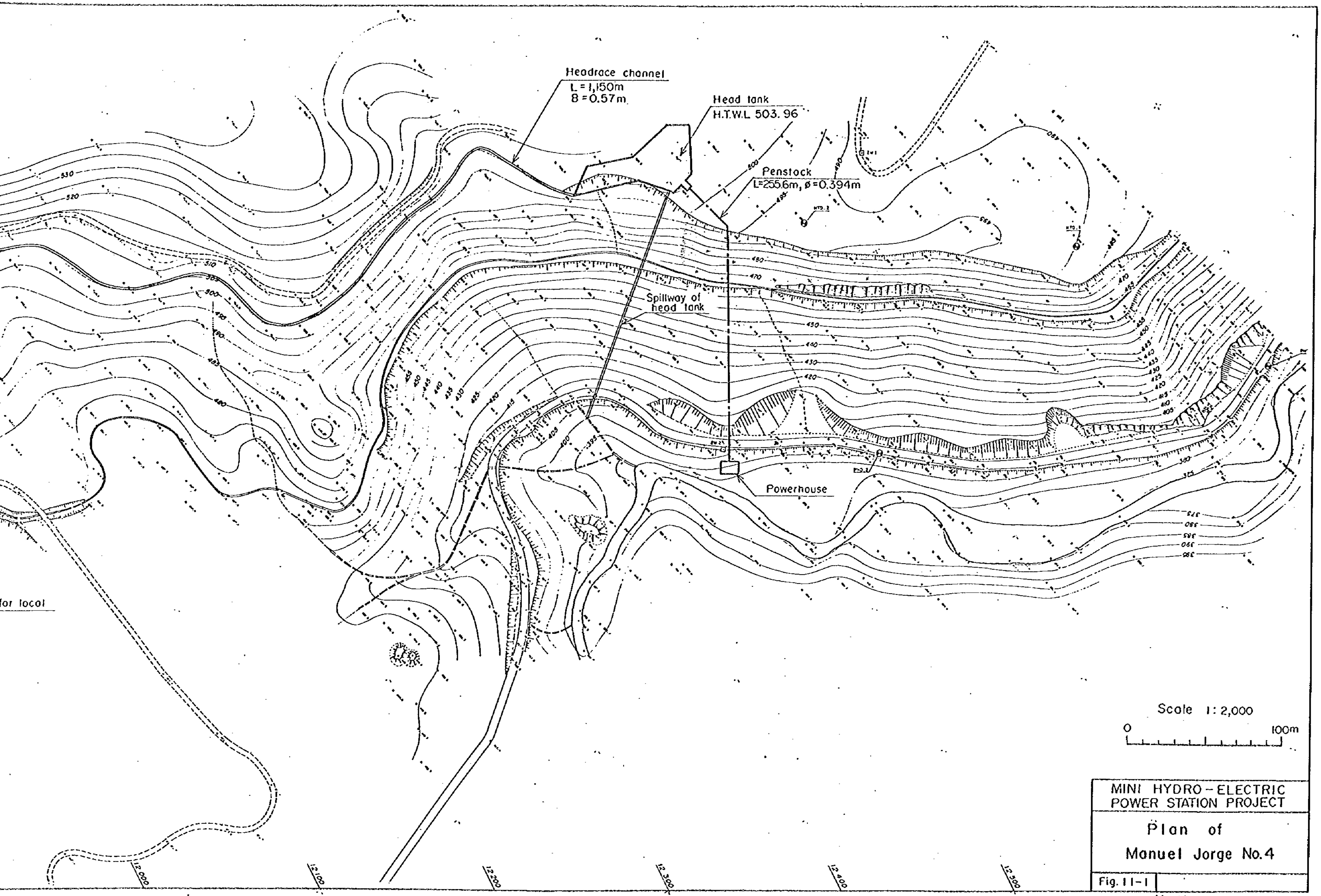
Definite design and various procedures for construction of this Project, and the overall time schedule until completion of construction work will require approximately 2 years, the details being as shown in Fig. 11-10. About 5 months will be required as well for the basic design in advance to them.

Table 11-1 Estimated Construction Cost of Munuel Jorge No.4

Unit:US$

Item	Amount	Remarks
A. Preparetion Works	138,379	P/H access road
B. Civil Works		
1. Intake Dame	121,881	
2. Sedimentation Basin	74,584	
3. Headrace Channel	617,311	
4. Head Tank	573,962	
5. Penstock and Spillway	99,398	
6. Powerhouse	354,178	
7. Intake & Channel for Local	93,437	
8. Disposal Area	41,998	10 % of Excavation
Sub-total	1,976,751	
C. Hydraulic Equipment		
1. Trashraks	13,050	
2. Gates	29,396	
3. Penstock	136,800	
Sub-total	179,246	
D. Electromechanical Equipment		
1. Turbine and Generator	926,800	
2. Transmission Line	311,300	
Sub-total	1,238,100	
E. Project Controlling		
1. Engineering Fee	720,000	
2. Administration Cost	60,000	
Sub-total	780,000	
F. Physical Contingency		
1. Preparation Works	13,838	10% of Direct Cost
2. Civil Works	197,675	10% of Direct Cost
3. Hydraulic Equipment	89,623	5% of Direct Cost
4. Electromechanical Equipment	61,905	5% of Direct Cost
5. Project Controlling	78,000	10% of Direct Cost
Sub-total	441,041	
Total (Project Cost)	4,753,516	≒4,754,000US$

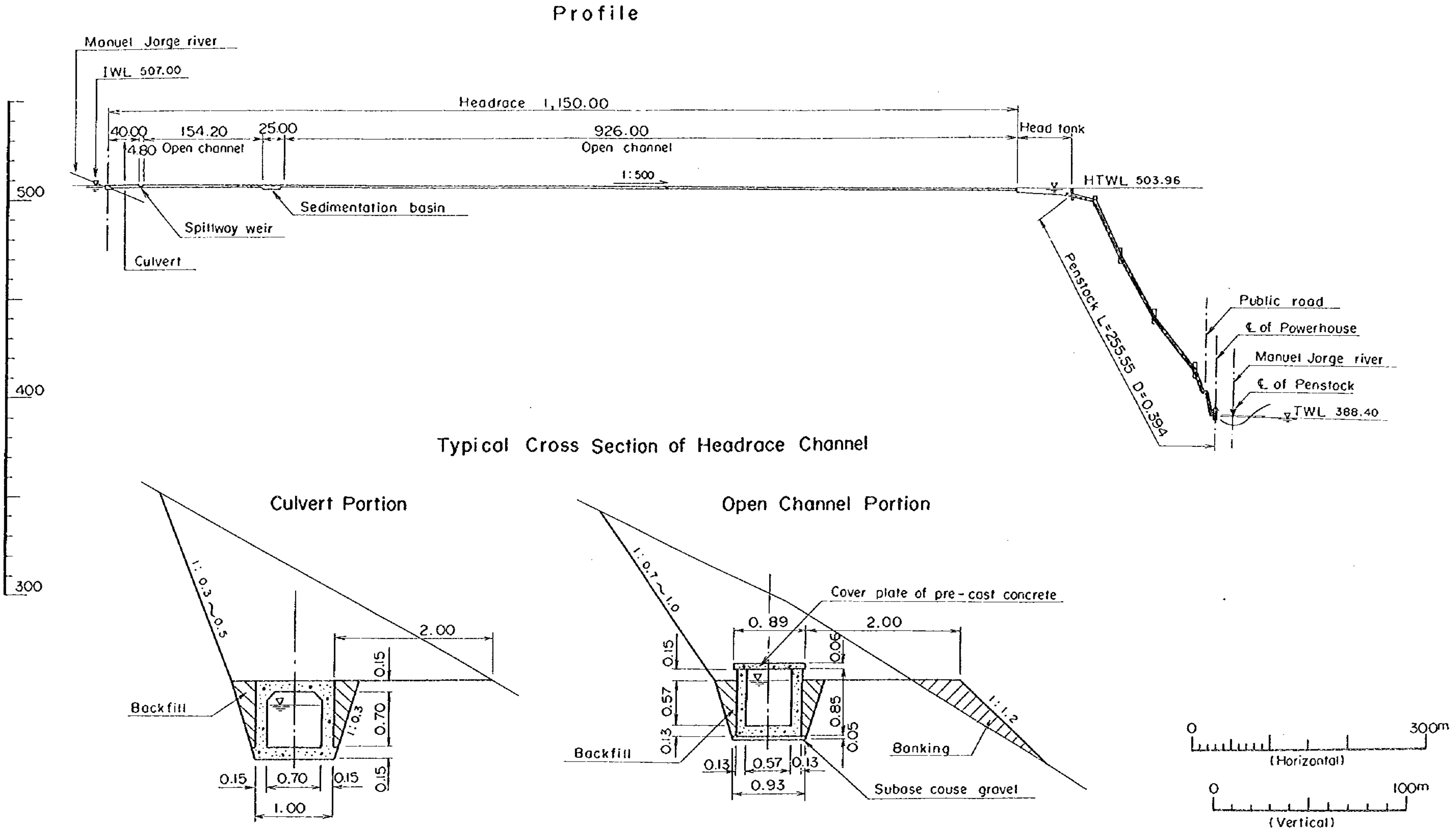

Spillway of Headrace
L = 4m
Sedimentation basin
L= 25m, B =3m
Waterway for local
Spillway of sedimentation basin
Intake Dam
H=2.00m, L=11.30m
Intake for local waterway
11,400
11,500
11,600
11,700
11,800
11,900
12,000
1700
1600
1500
1400
1300



MINI HYDRO-ELECTRIC POWER STATION PROJECT

Plan of Manuel Jorge No.4

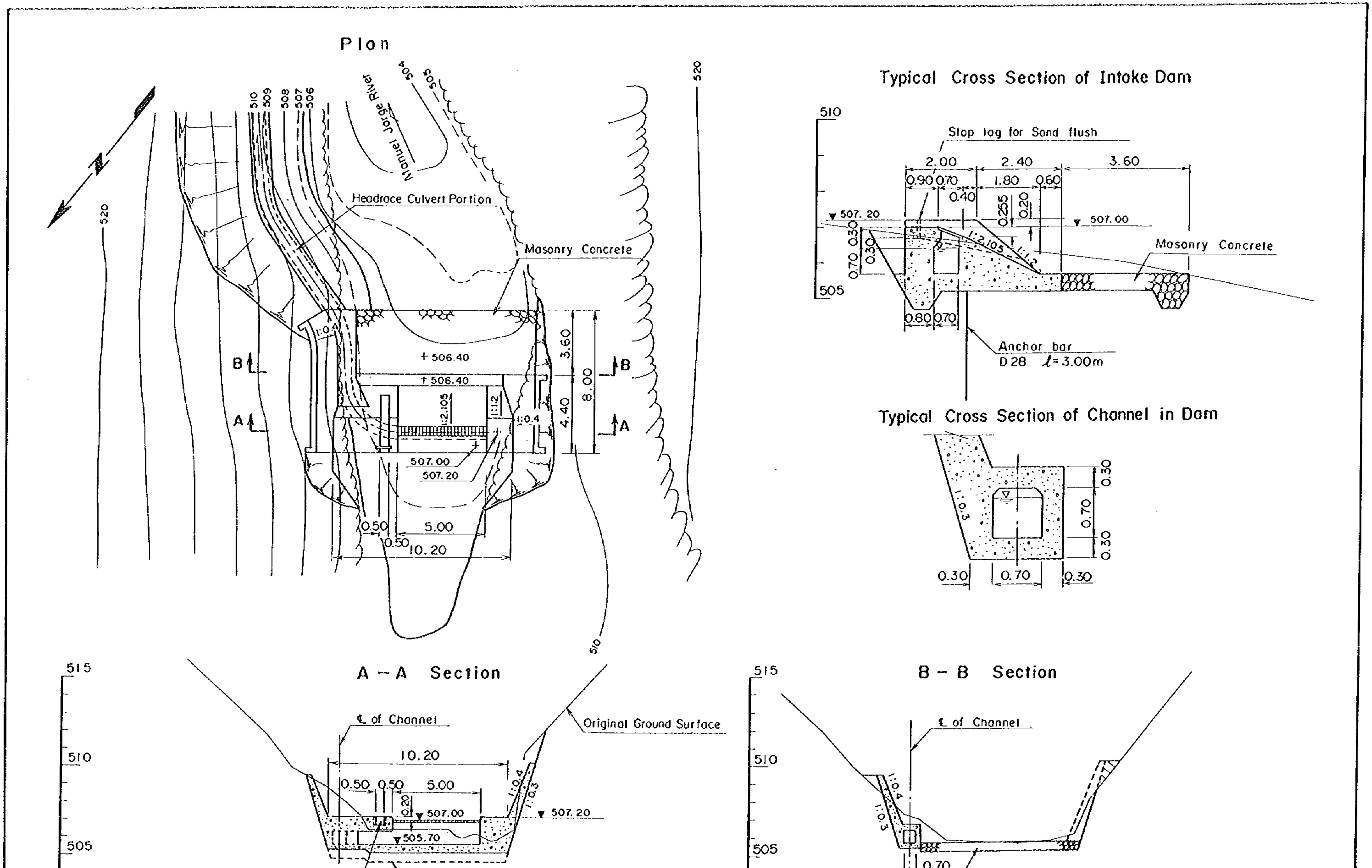
Fig. 11-1



MINI HYDRO-ELECTRIC POWER STATION PROJECT

Profile and Typical Cross Section of Water Way Manuel Jorge No.4

Fig. 11-2



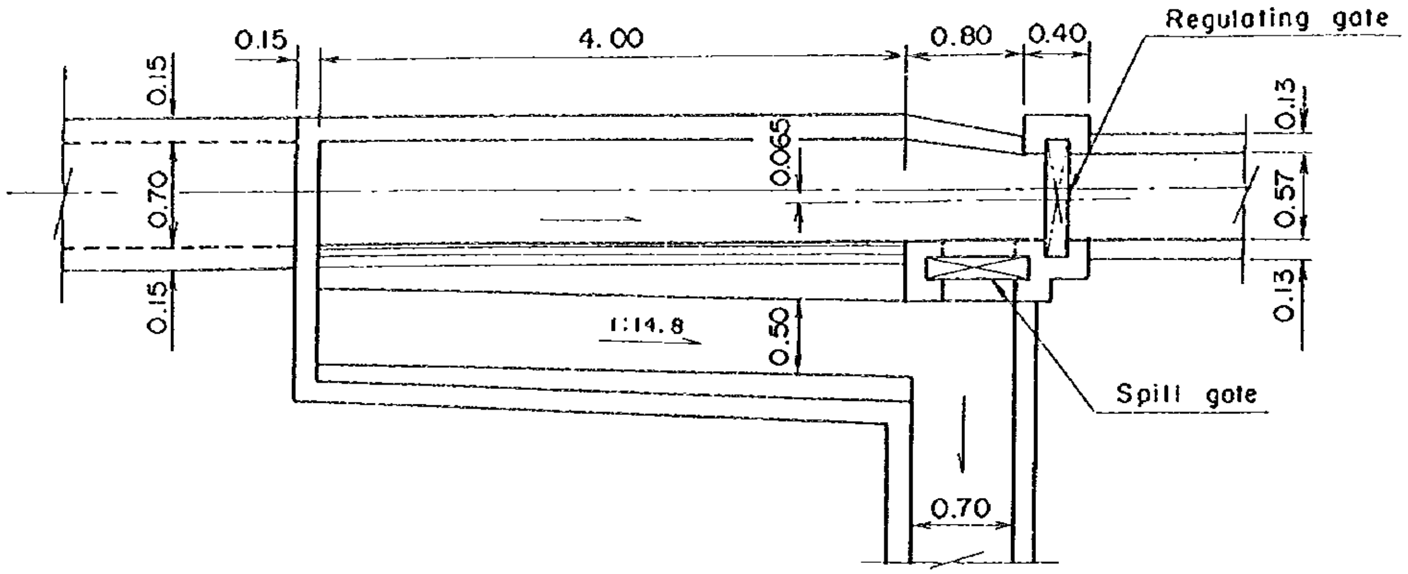
MINI HYDRO-ELECTRIC POWER STATION PROJECT

Intake Dam

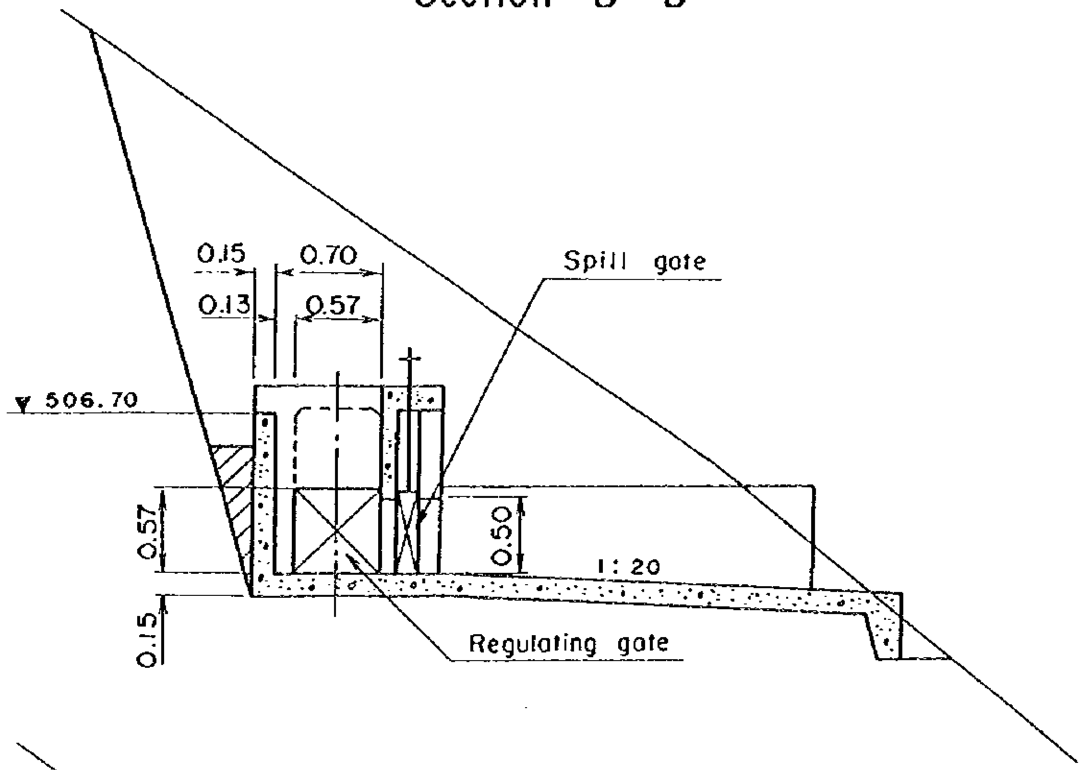
Manuel Jorge No.4

Fig. 11-3

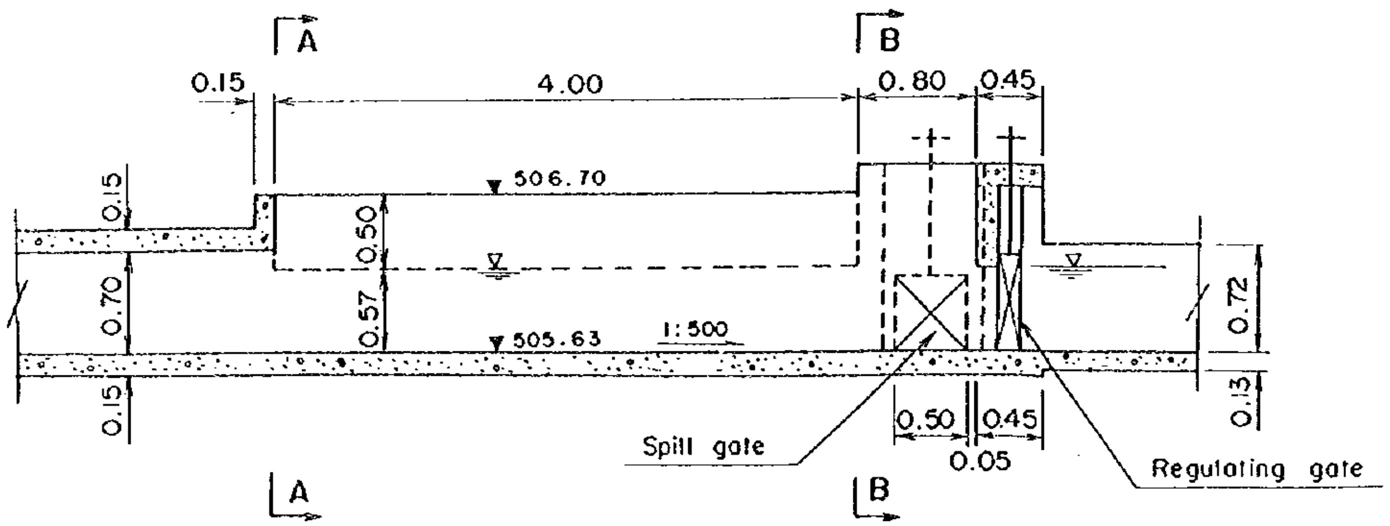
Plan



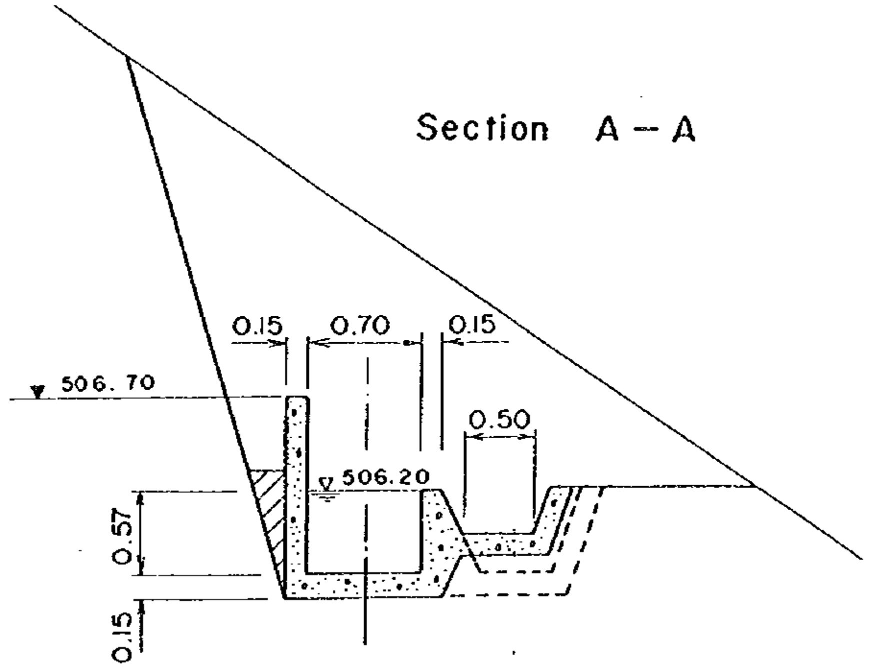
Section B – B



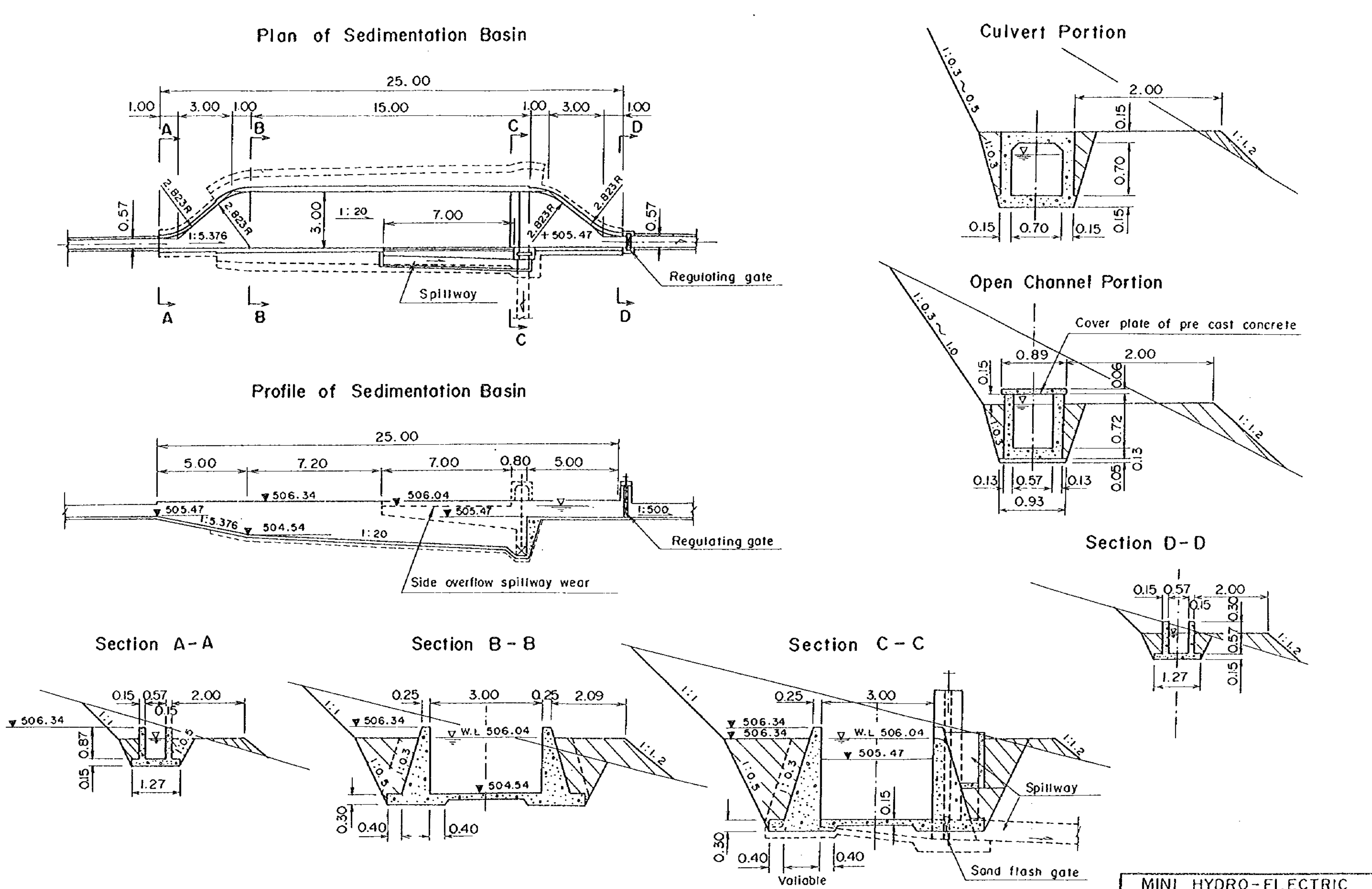
Profile



Section A – A



MINI HYDRO-ELECTRIC POWER STATION PROJECT
Spillway of Headrace Channel
Manuel Jorge No.4
Fig. 11-4

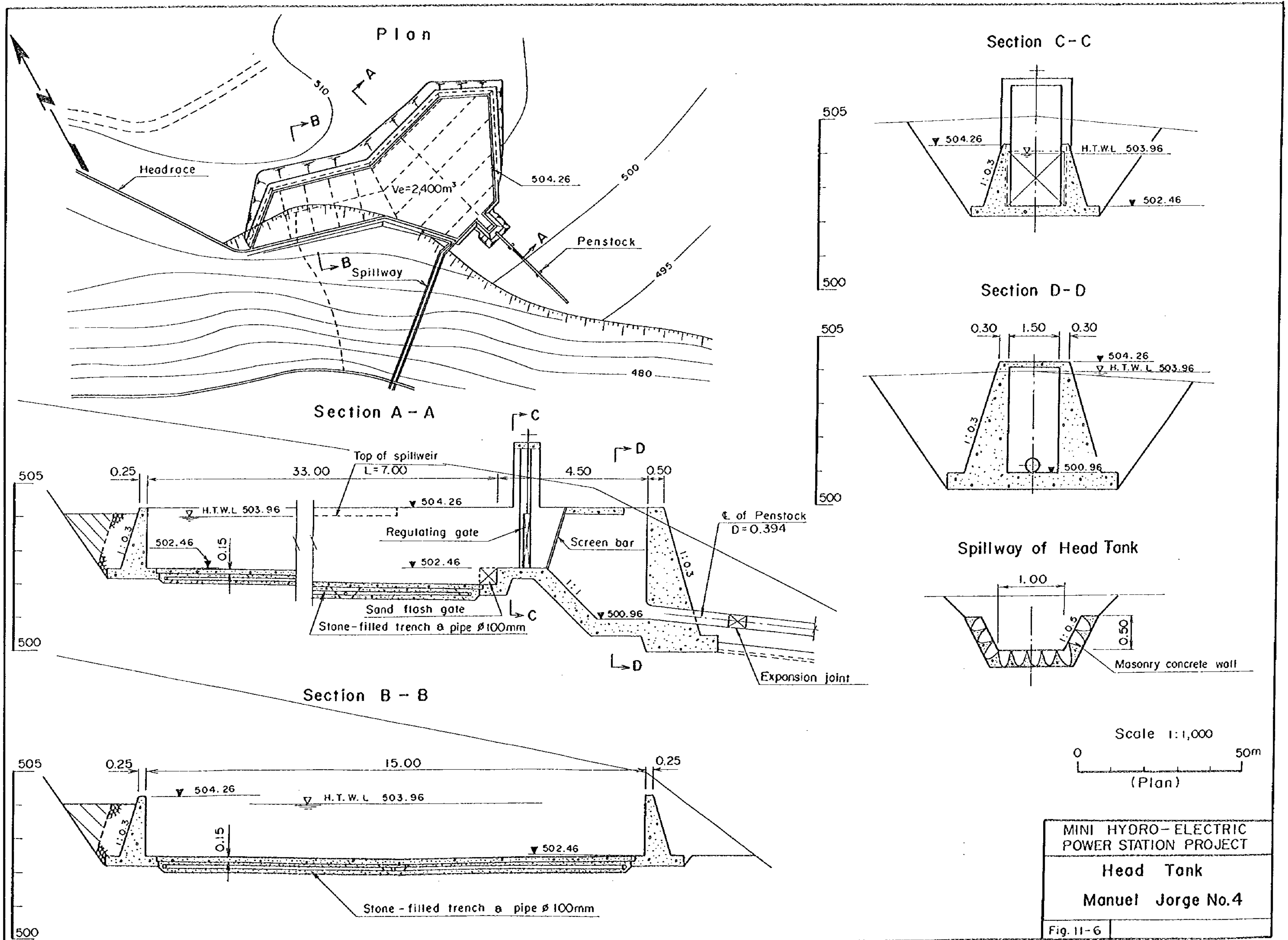


MINI HYDRO-ELECTRIC
POWER STATION PROJECT

Sedimentation Basin

Manuel Jorge No.4

Fig. 11-5

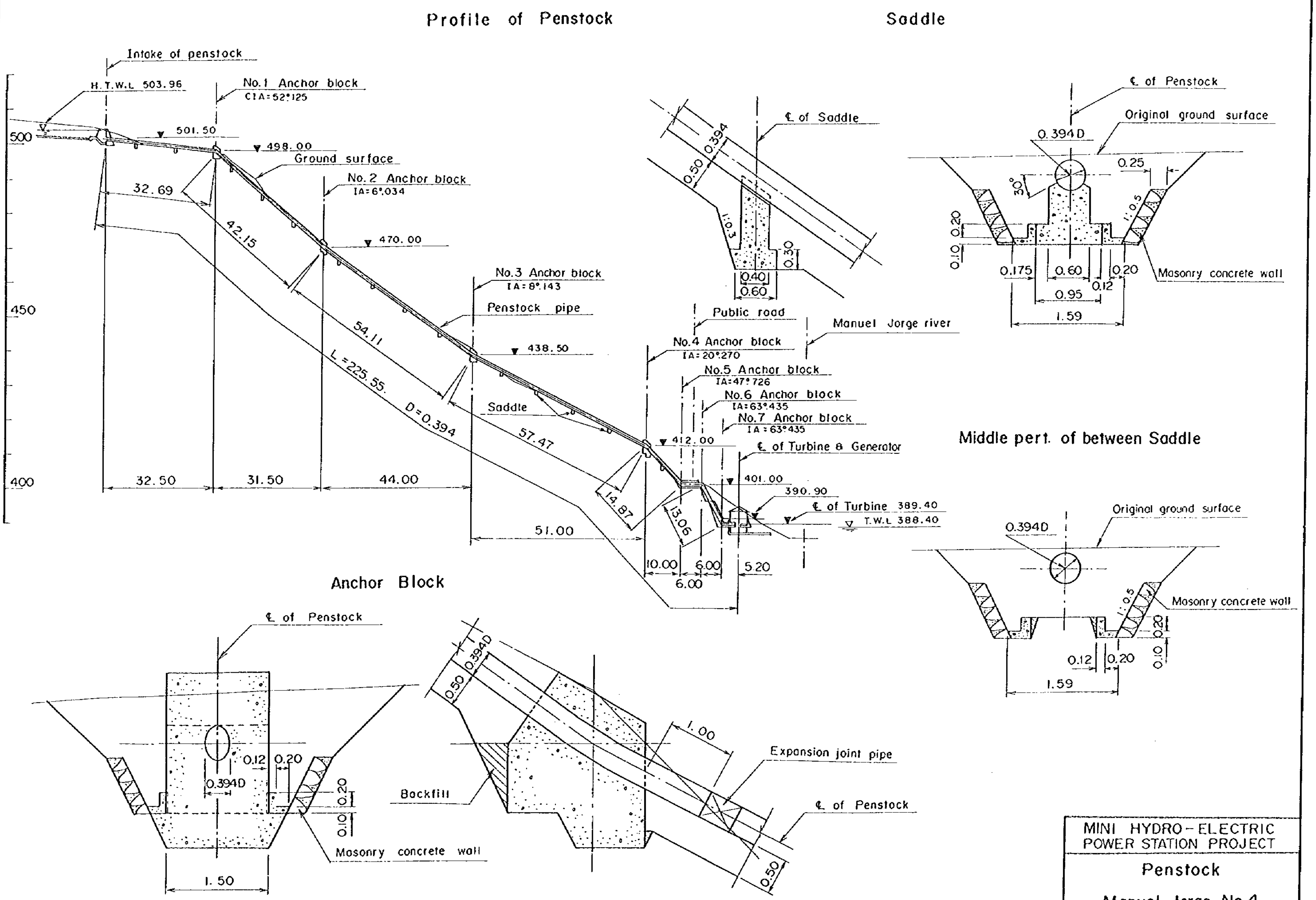


MINI HYDRO-ELECTRIC POWER STATION PROJECT

Head Tank

Manuel Jorge No.4

Fig. 11-6

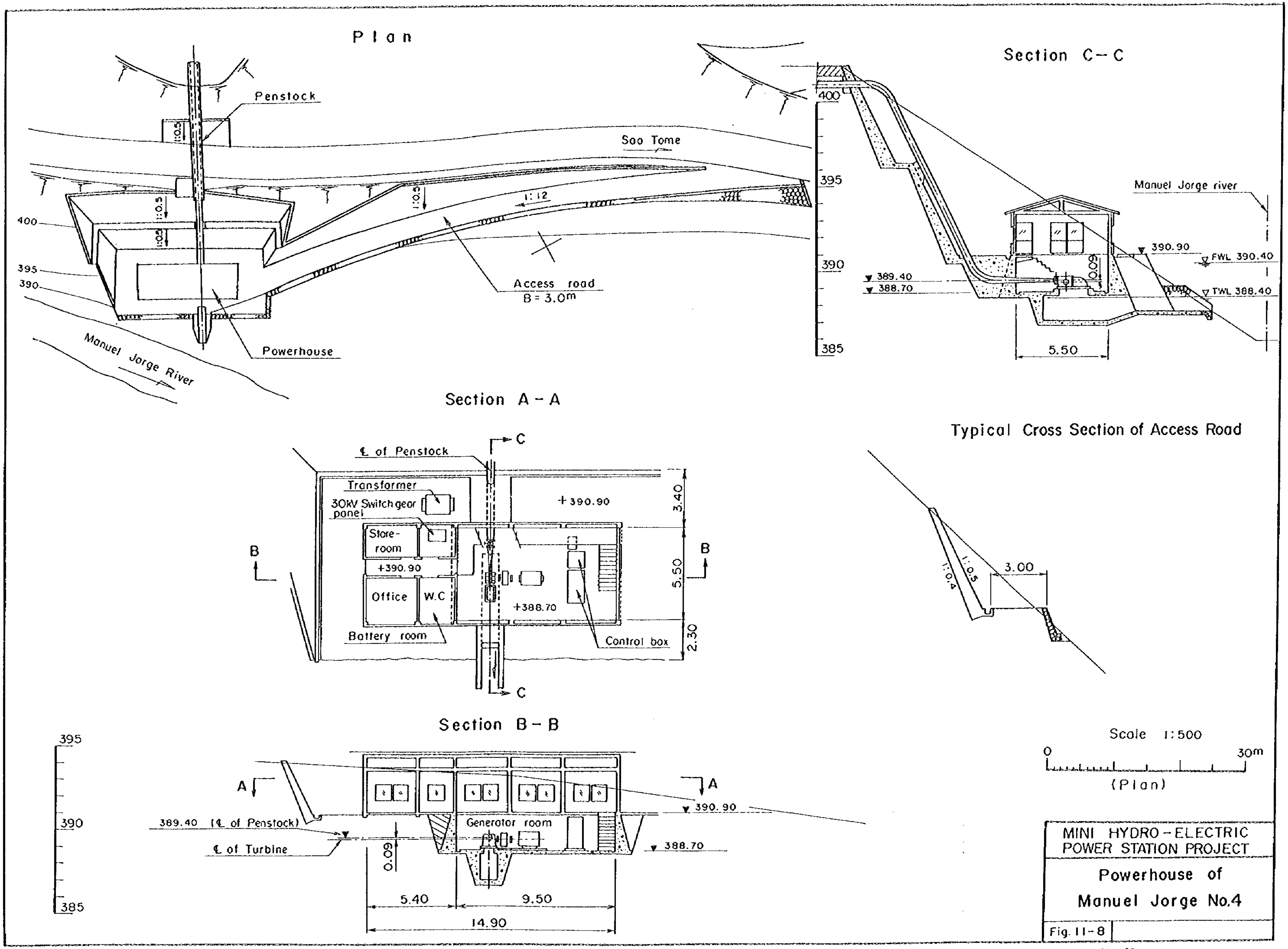


MINI HYDRO-ELECTRIC POWER STATION PROJECT

Penstock

Manuel Jorge No.4

Fig. 11-7

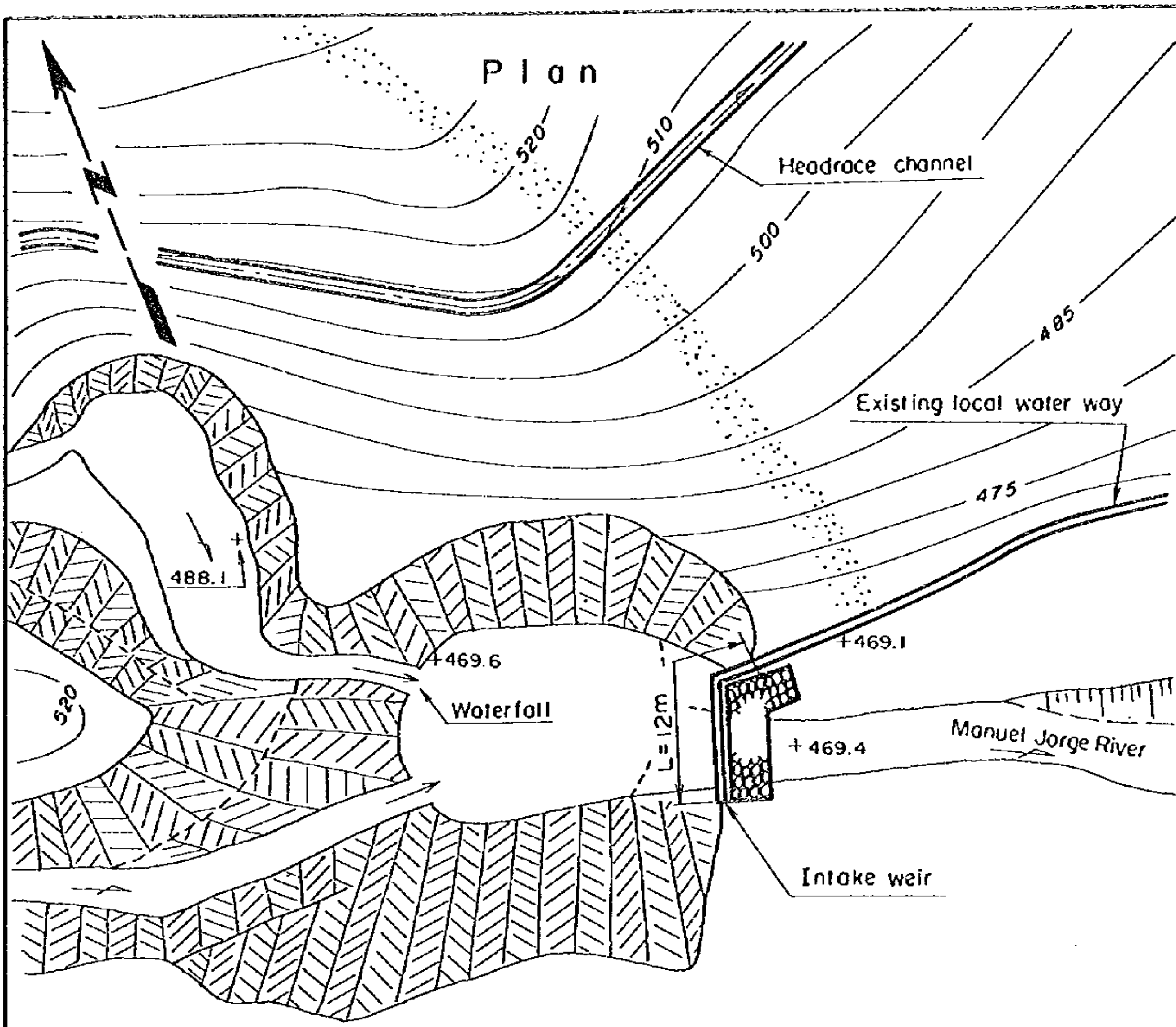


MINI HYDRO－ELECTRIC POWER STATION PROJECT

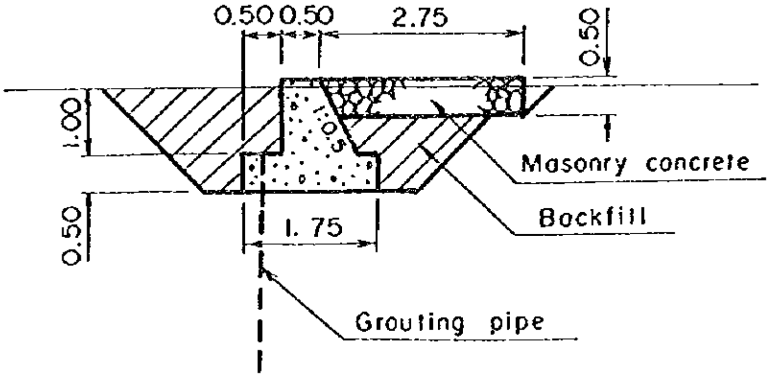
Powerhouse of Manuel Jorge No.4

Fig. 11－8

Plan



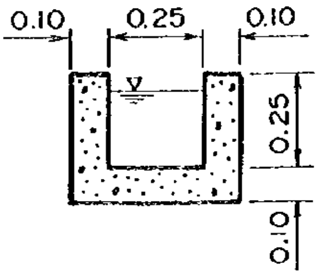
Typical Cross Section of Intake Weir



Scale 1 : 500

(Plan)

Cross Section of Reconstruction Channel



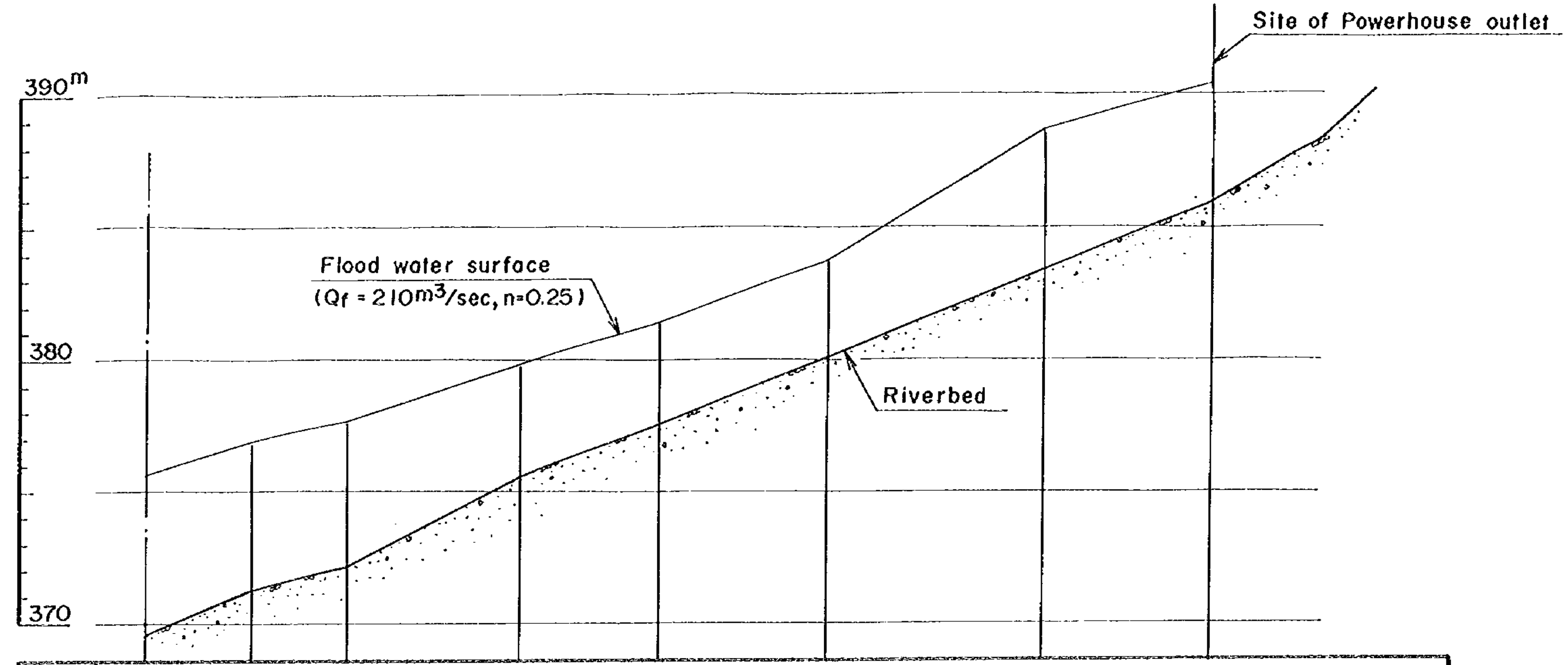
MINI HYDRO - ELECTRIC POWER STATION PROJECT
Intake Weir and Channel of Local Waterway Manuel Jorge No.4
Fig. 11-9

Work Item	Description	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24	Remarks
1. Definite Design			
2. Construction Works			
(1) Preparation Works	P/H Access road L81m×W3m	Preparation Works P/H Access Road	
(2) Intake Dam	L12m×H2m		
(3) Sedimentation Basin	L25×W3m		
(4) Headrace Channel	L1,150m×W0.57m		
(5) Head Tank	Ve=2,400m3 Ae=1,600m2		
(6) Penstock	L225.6m×φ0.394m		
(7) Powerhouse	L14.9m×W5.5m		
(8) Intake & Channel for Local Use			
(9) Turbine, Generator & Auxiliary Equipment	Turbine:253kW×1unit Generator:290kVA×1unit		
(10) Transmission Line	30kV×5.5km×1cct		
(11) Commissioning Test			
3. Taking Over			

MINI HYDRO - ELECTRIC POWER STATION PROJECT

Construction Schedule of Manuel Jorge No.4

Fig. 11-10



Cross Section Number	PHD-0	PHD-1	PHD-2	PHD-3	PHD-4	PHD-5	PHD-6	PHD-7
Flood Water Level (EL. m)	375.65	376.93	377.69	379.86	381.46	383.69	388.67	390.42
Ground Hight of Riverbed (EL. m)	369.60	371.30	372.17	375.60	377.60	380.10	383.40	385.90
Total Distance (m)	0.00	40.50	77.00	143.00	196.00	261.00	343.00	407.00
Distance (m)	—	40.50	36.50	66.00	53.00	65.00	82.00	64.00

MINI HYDRO – ELECTRIC POWER STATION PROJECT

Flood Water Surface at Tailrace of Manuel Jorge No. 4 Site

Fig. 11-11

Chapter 12

TRANSMISSION LINE

12. TRANSMISSION PLAN

12.1 Present Situation

The EMAE transmission system consists of 30kv and 6kv transmission lines. Figure 12-1 shows the transmission system of 30kv and 6kv on Sao Tome island.

The Contador hydro-power station, Sao Tome thermal power station and Gue Gue hydro-power station are interconnected by 30kV transmission line which is extended to the Ribeira Afonso district, southeast of Sao Tome city. 6kV transmission line is used to other power consumption locations, these being single transmission lines.

The EMAE has no expansion plans for future transmission lines at this time.

12.2 Transmission Plan from Manuel Jorge

Sufficient coordination was made with existing facilities and the following was studied (at the request of the EMAE) so that the power generated by the Manuel Jorge hydro-power station could be transmitted to Sao Tome city as well as to the Santa Clara and Milagrosa districts near the station.

12.2.1 Selection of Route

In selecting the transmission line route, the natural and social environments of the passing area were coordinated and technical matters were considered with special attention paid to the following;

(1) Valuable florae land areas are avoided and tree felling in natural forests and plantations is reduced as much as possible to maintain harmony with the natural environment.

(2) Residential areas, high productivity land and land where restoration is difficult including cacao fields are avoided to maintain harmony with the social environments.

(3) Harmony is obtained technically.

- High facility safety.
- Easy construction.
- Easy maintenance.
- Distances as short as possible.

The transmission line is connected to the Trindade Substation. The following A and B routes are then considered.

o **Route A**

This route connects the power station to the substation straight and passes mainly through cacao fields. In this case, the distance is approximately 4.3 km.

o **Route B**

This route transmits power along the road from the power station and most of the part can avoid passing the cacao fields. The distance in this case is approximately 5.0 km.

The routes are compared in the table below.

Item	Route-A	Route-B
Line distance	◎	O
Mountain passing	Δ	Δ
Crossing with other line	O	O
Cacao field passing	X	Δ
Material transport	X	◎
Easy maintenance	Δ	◎
Construction cost (1 for A)	1.0	1.1
Tree felling	X	◎
Comprehensive evaluation	O	◎

From the comprehensive study, Route B is adopted because the felling of local speciality cacao trees is limited and construction and future maintenance are easy.

In this case, the overall length of the transmission line is 5.0 km.

12.2.2 Facilities of Transmission Line

(1) Transmission voltage

The voltage is generally selected depending on the transmission capacity, conductor thickness, etc. However, selection from exiting voltage classes in concert with the existing power systems is more economical and advantageous in operation. Judging from the output (about 300 kW) of the Manuel Jorge hydro-power station, the transmission capacity is sufficient even when the transmission line uses the minimum conductor of 30kV and 6kV, existing voltages.

The EMAE basically uses 30kV for interconnection between power stations. It is feasible that the power generated by the Abade hydro-power station (about 1,000 kW) is also transmitted through the Manuel Jorge power station. In this case, 30 kV transmission line is used according to the existing concept.

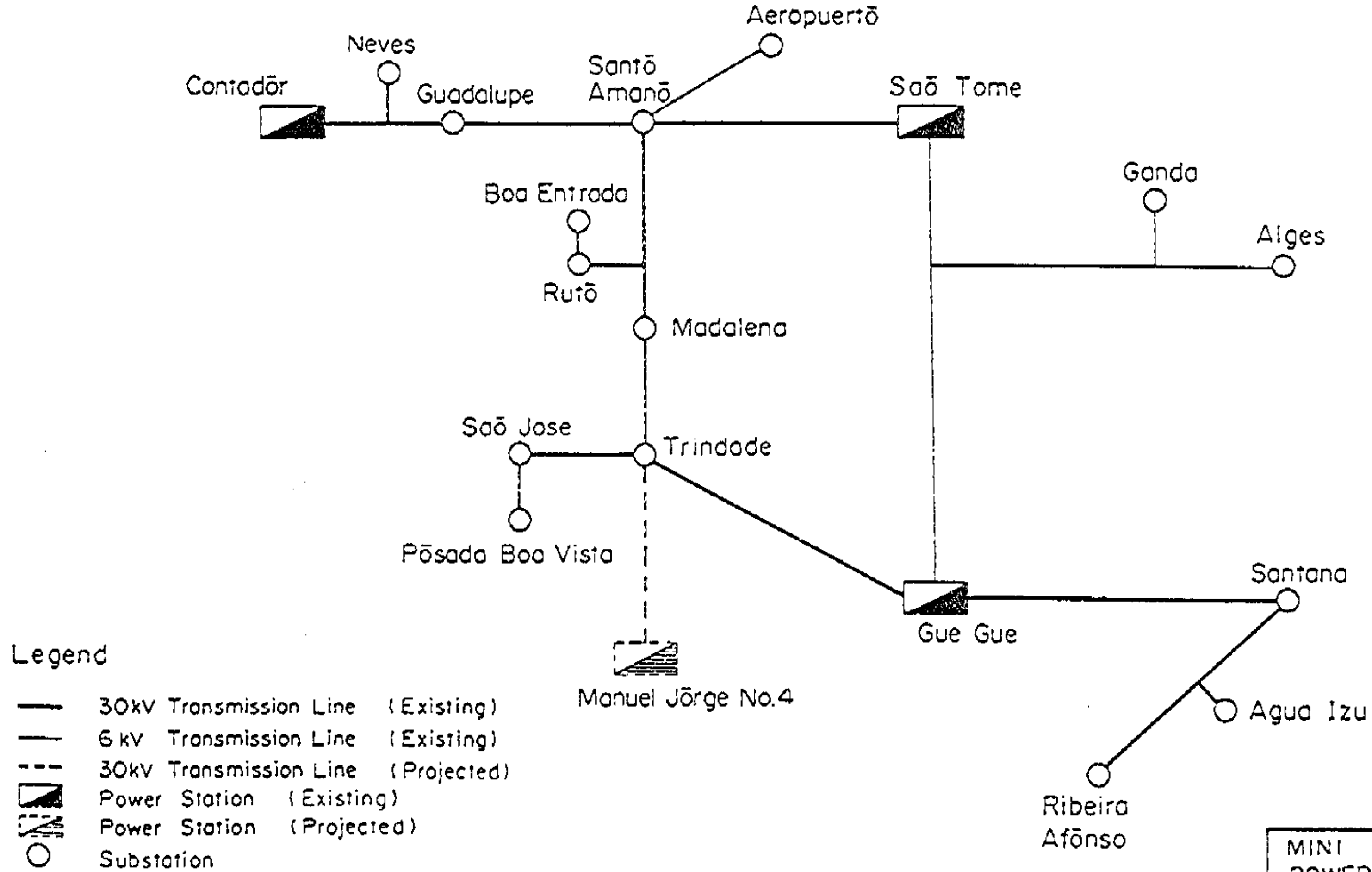
(2) Transmission line support structure

Concrete poles (transmission towers are also partially employed) are mainly used as the existing support structures (post).

Figure 12-2 shows the representative structure design. These concrete poles are domestically manufactured by the EMAE and are less expensive than imported units. There have been no problems with their durability. Therefore, the concrete poles used by the EMAE are adopted.

(3) Others

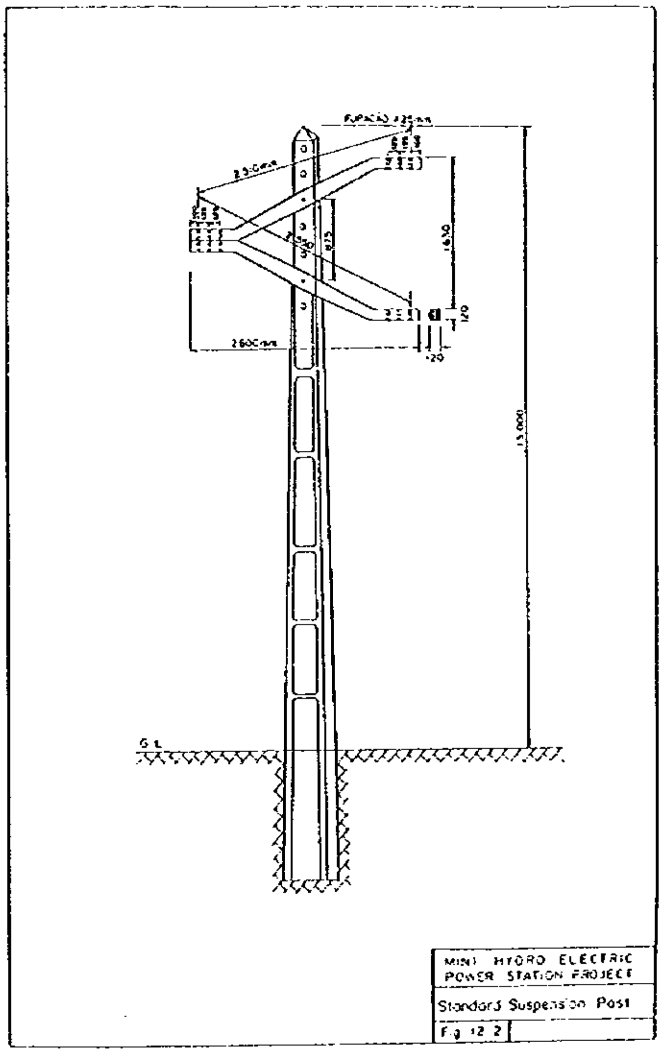
To also enable transmission to the Milagrosa and Santa Clara districts, at the request of the EMAE, the supply facility (transformation facility) to these districts is also considered on the way.

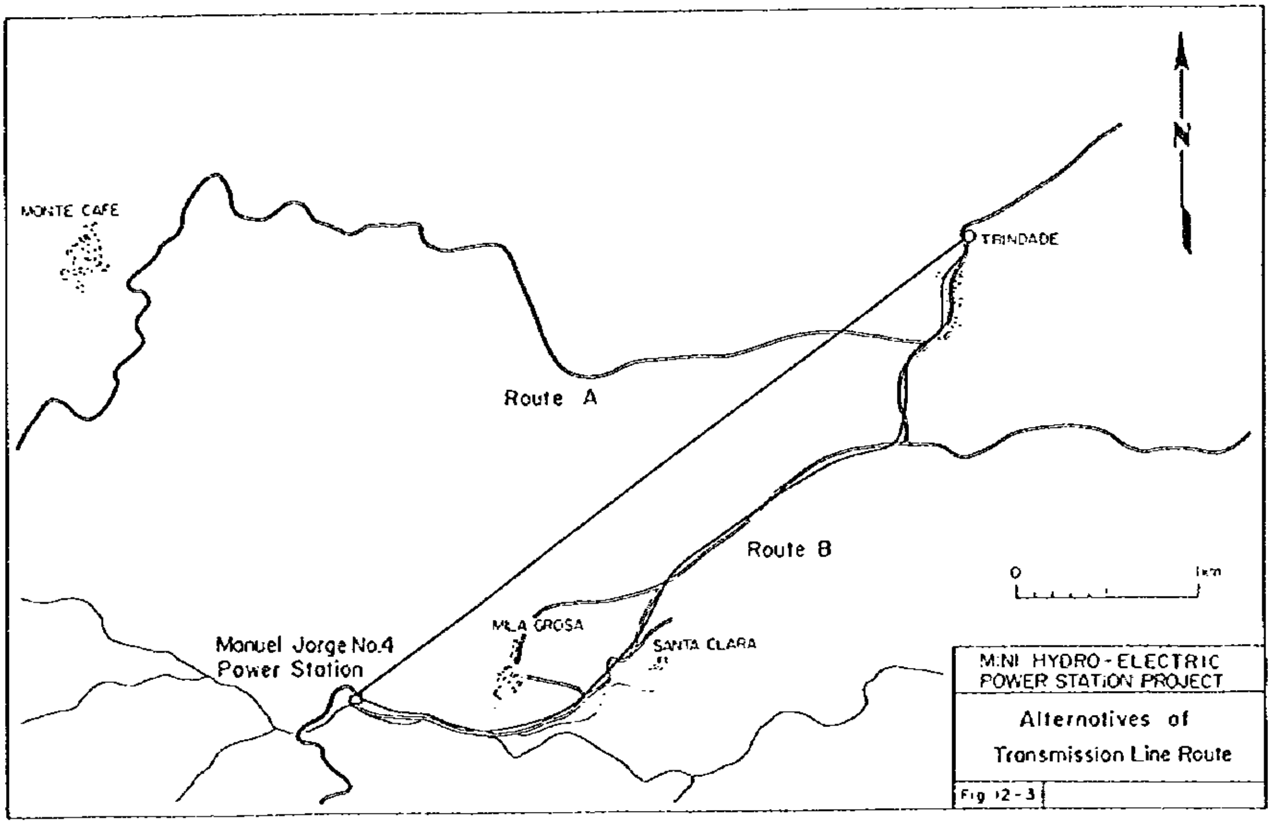


MINI HYDRO ELECTRIC POWER STATION PROJECT

Principal Transmission Line of EMAE

Fig. 12. 1


2600mm
1650
825
120
120
15 000
G.L.
MINI HYDRO ELECTRIC POWER STATION PROJECT
Standard Suspension Post
Fig 12.2


N
MONTE CAFE
TRINDADE
Route A
Route B
0
1km
MILA GROSA
SANTA CLARA
Manuel Jorge No.4 Power Station
MINI HYDRO-ELECTRIC POWER STATION PROJECT
Alternatives of Transmission Line Route
Fig 12-3