JAPAN INTERNATIONAL COOPERATION AGENCY
THE DEMOCRATIC REPUBLIC OF SAO TOME AND PRINCIPE
MINISTERIO DO EQUIPAMENT SOCIAL E AMBIENTE

No. 2

FEASIBILITY STUDY ON CONSTRUCTION OF MINI HYDRO-ELECTRIC POWER STATION IN THE DEMOCRATIC REPUBLIC OF SAO TOME AND PRINCIPE

SUMMARY

March 1997

EPDC International Ltd.

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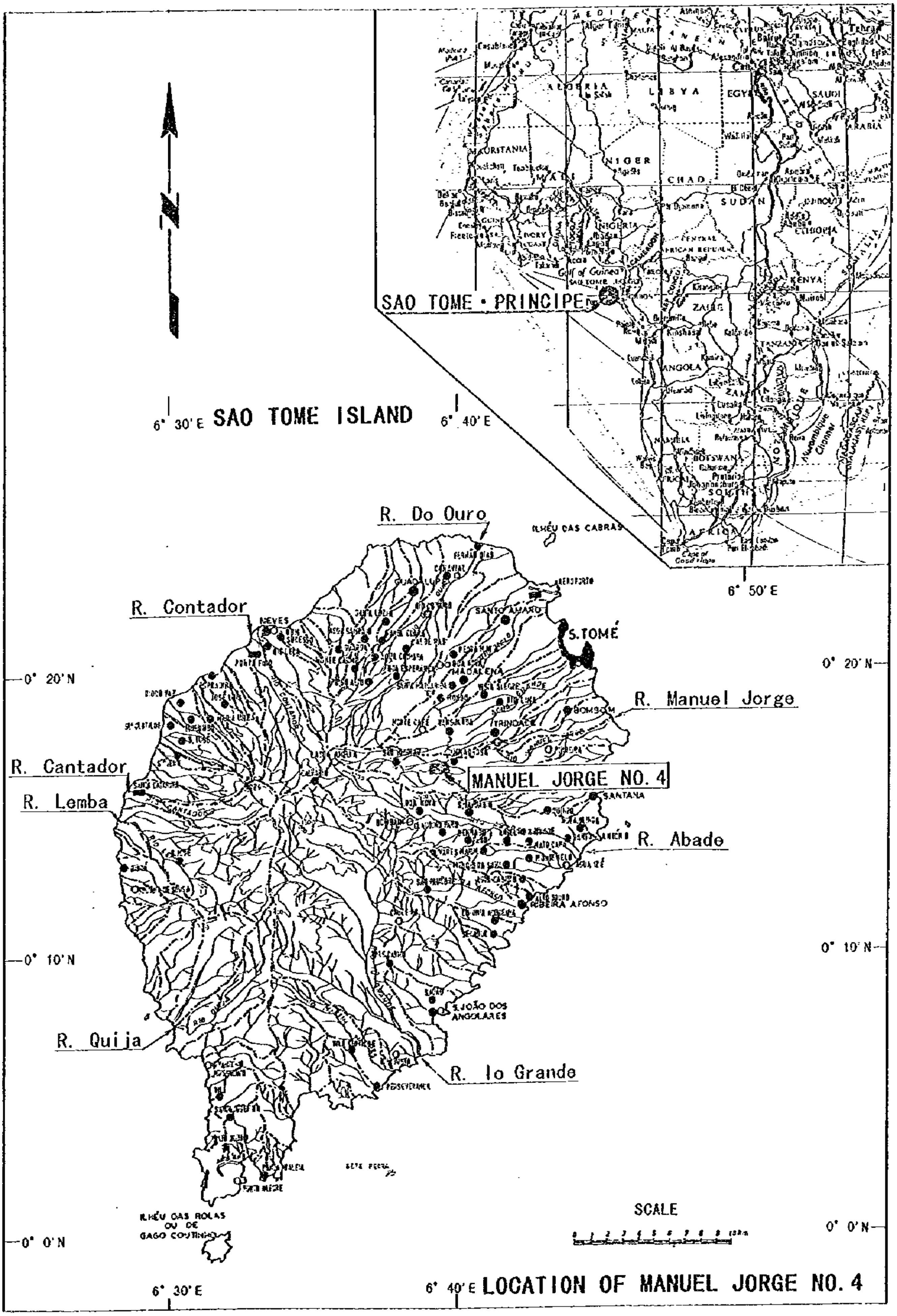
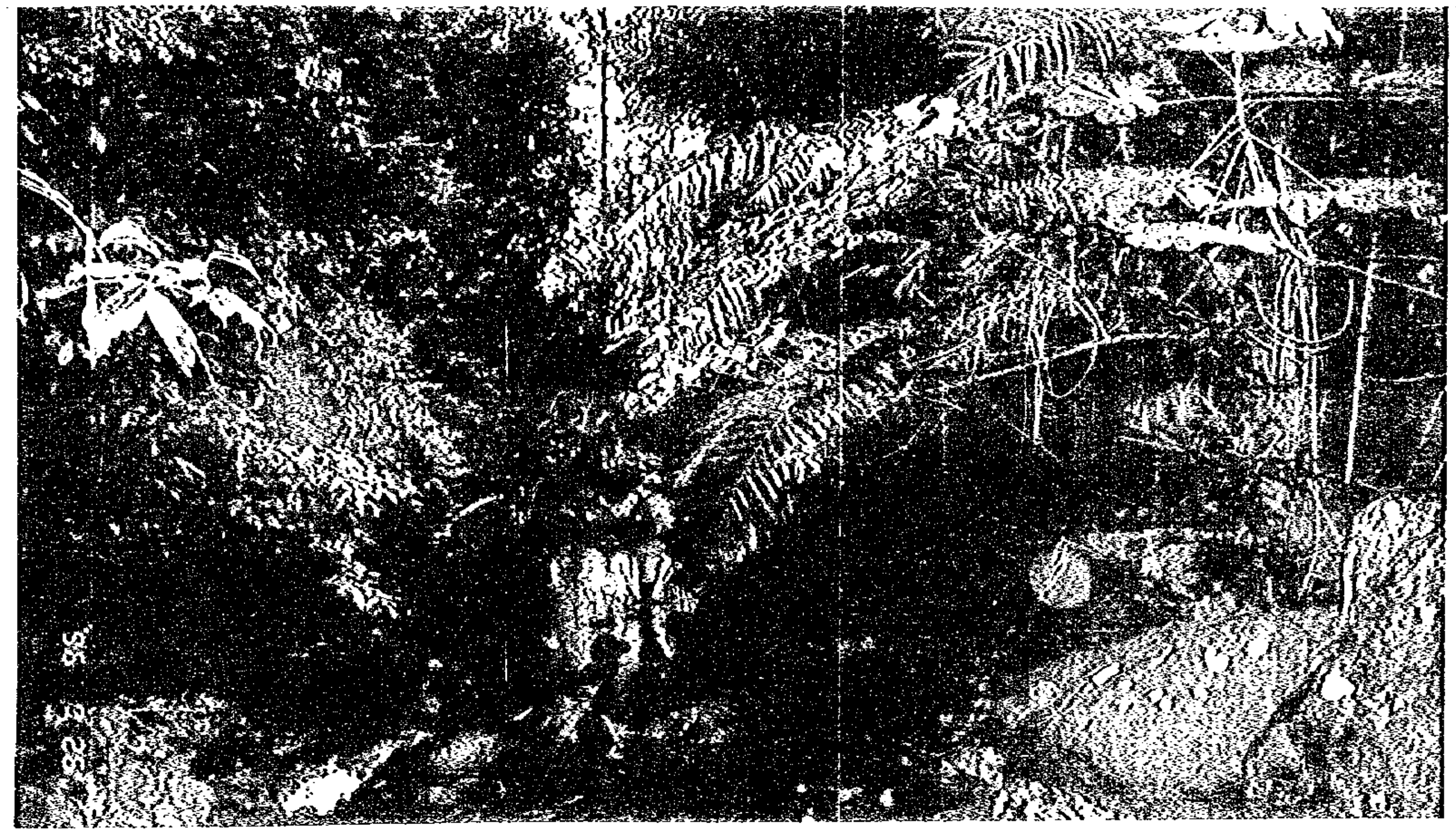
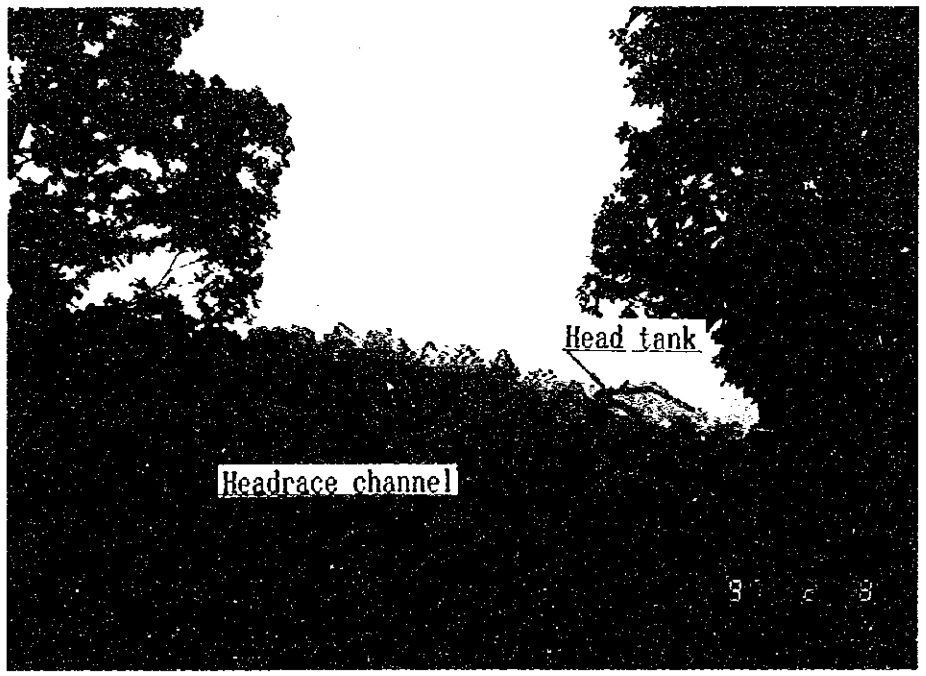


LOCATION OF MANUEL JORGE NO. 4

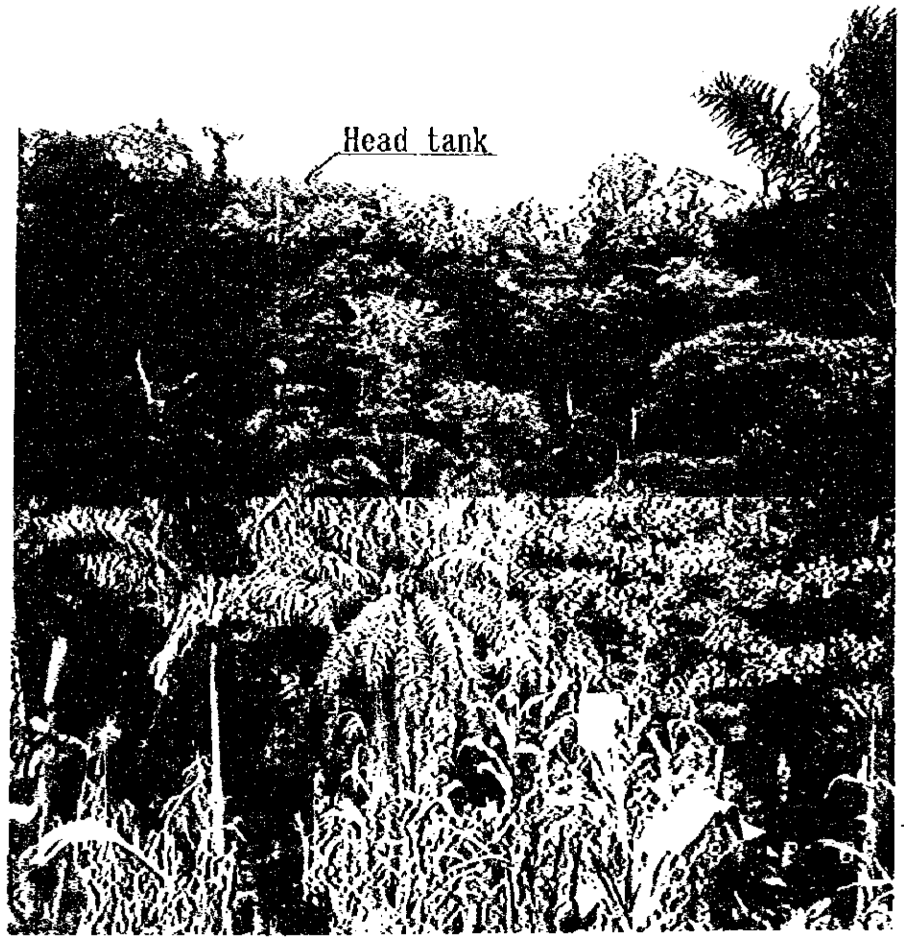
Intake-dame site viewed from left-bank downstream



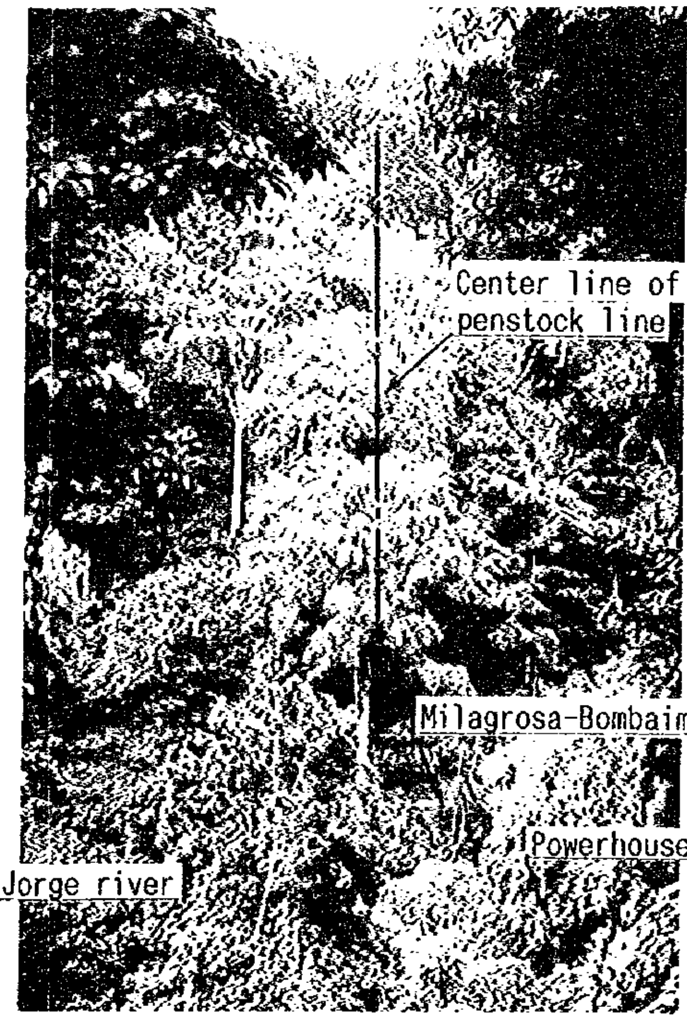
Downstream View from intake-dam site



Head tank site viewed from upstream



Head tank and penstock site



Penstock line & powerhouse site viewed from right bank of Santa Luzia village

Sao Tome and Principe

Mini Hydro Power Development Project Study Summary

1. Background and Antecedents of Request

The Democratic Republic of Sao Tome and Principe is an island country located off the west coast of the African Continent. It is composed of the two islands of Sao Tome and Principe, has an area of 1,001 km^2, and a population of approximately 120,000. Electric power supply in Sao Tome and Principe is being carried out by the Empresa de Aqua e Electricidade (EMAE). At present there are three main power stations (Contador Hydro Power Station: 1,920 kW, Gue Gue Hydro Power Station: 320 kW, Sao Tome Thermal Power Station: 5,200 kW) on Sao Tome Island, and the installed generating capacity is approximately 7,440 kW. Electric power demand is increasing year after year (annual average approximately 6%), but under the circumstances in which the finances of the country depend on aid from other countries, increasing electric power facilities is not making any progress at all, and with calls for new contracts demanded by hotels and others, and together with the capacity of generating facilities which cannot be operated at present because of trouble, the amount of shortage in supply is close to 5,000 kW.

The country has marked out energy-related undertakings as national projects, for economic development and improvement of the people's livelihood, and has plans for construction of new hydroelectric power stations which would make use of the abundant water resources (rivers and streams) in the country, which will not require fuel costs, and will be comparatively easy to operate. With electric power supply short, the Government of Japan was requested to carry out this development study for realization of the power generation project.

JICA carried out a preliminary study in November 1995 (with Terms of Reference signed on November 27), and a full-fledged study was started in February 1996.

2. Objectives of Study

This study has the purposes of examining the feasibility from the aspects of engineering, economics, and environment upon formulating the optimum plan for construction of a small-scale hydroelectric power station to assume power supply to a part of Sao Tome, the capital city of Sao Tome and Principe, and to realize technological transfer to the Consultant's counterpart on the Sao Tome and Principe side through this study.

3. Period and Other Particulars of Full-fledged Study

(1) Consultant EPDC International Ltd.

(2) Overall Contract Period February 1996 - March 1997

(3) Field Surveys

1) 26 Feb. '96 - 22 Mar. '96 (Explanation of Inception Report, other)
2) 15 Jul. '96 - 4 Sept. '96 (Explanation of Interim Report, other)
3) 23 Sept. '96 - 18 Oct. '96 (Inspection of Site Investigation Results, other)
4) 25 Nov. '96 - 7 Dec. '96 (Explanation of Progress Report, other)
5) 3 Feb. '97 - 16 Feb. '97 (Explanation of Draft Final Report, other)

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Conclusions

The Government of the Democratic Republic of Sao Tome and Principe, with the consideration that for improving the people's livelihood and making progress in the direction of economic self-sufficiency, it would be indispensable to eliminate the chronic shortage in supply of electric power, has plans for construction of mini hydro power stations making use of the abundant water resources in the country and not depending on imported fuel which adversely affects its international balance of payments.

The survey team, based on field investigations over five different occasions and the results of discussions with the various Sao Tome and Principe government agencies concerned, has prepared a Mini Hydro Power Development Project Feasibility Study Report, in which the conclusions are as follows:

(1) Six rivers were taken up as streams for mini hydro power development, mini hydro power schemes were formulated based on 1/10,000 scale topographical maps and field reconnaissances, and comparison studies were made. The project sites are all favored with much rainfall, and are considered to be suitable for mini hydro power development from the aspects of both topography and geology. As a result of studies, it was found that the Manuel Jorge No. 4 and Abade hydro power sites were economically superior to other sites. Upon a comprehensive study of power station scales, degrees of accessibility required for construction and maintenance, and impacts on the surrounding environment, it is judged that Manuel Jorge No. 4 should be developed at an early date, this project being favored with optimum conditions for a power station of this scale.

(2) The optimum scale of the Manuel Jorge No. 4 Hydro Power Project is for the intake and discharge water levels to be at EL. 507 and 388.4 m, respectively, for effective head of 109.17 m and maximum available discharge of 0.31 m^3/sec to obtain maximum power of 230 kW and annual energy production of 1,252.6 MWh. The intake dam is to be a Tyrolean type considering the sand-gravel deposits existing immediately upstream. The headrace would be an open canal of a length of approximately 1,200 m and gradient of 1/500. The head tank would be capable of storing 12 hours of dry-season runoff, while the turbine is to be a cross-flow type. The electric power generated would be sent to Trindade Substation by a 30 kV transmission line of approximately 5 km. Operation and maintenance after completion of these facilities can be adequately performed by Sao Tome and Principe technical personnel based on the technology gained in experience with existing hydro power stations. The overall work schedule consisting of additional investigations for construction, definite design, various procedural matters, and construction up to completion will require approximately 2 years.

(3) At present, existing power generation and transmission facilities on Sao Tome are almost all antiquated, repairs are not being quickly made due to lack of funds, and installed capacity cannot be fully demonstrated, causing a chronic shortage of electric power. Plans for construction of new power stations are not proceeding as conceived because of difficulty in procuring foreign currency funds.

The electric power supply structure of Sao Tome and Principe is made up approximately 70% by thermal, and it is necessary for hydroelectric power stations to be developed regardless of scale; Manuel Jorge No. 4 Hydro Power Station would respond to this demand.

(4) The transmission line in this Project would be connected to Trindade Substation, and besides making it possible for villages in the vicinity of the Project such as Santa Clara and Milagrosa to be electrified, the situation at Trindade, the administrative center of the Me-Zochi District, which has been plagued by chronic power outages, can be improved.

(5) The construction cost would be US$4,754 x 10^3 including preparatory works, civil works, hydraulic and electro-mechanical equipment, and also transmission line construction cost, and engineering fee. Therefore, the annual capital cost would be 8.174% of the investment cost, or US$388.5 x 10^3, and the operation and maintenance cost US$47.5 x 10^3, a total of US$436 x 10^3. In case a diesel power station is taken as the alternative facility, the annual cost would be US$79 x 10^3. The benefit/cost ratio calculated from this would be 79/436 = 0.18, much lower than the economic break-even point of 1. However, if grant aid were to be assumed for the entire construction cost, the benefit/cost ratio would become 1.66 and higher than 1.

The FIRR is calculated at minus 1.90% for the operation period of 35 years, so that the Project is not viable. However, the Project should be considered sanguinely for the reasons given below.

To elaborate, in view of the foreign trade structure and situation of foreign liabilities of Sao Tome and Principe, thermal power generation which is dependent on imported fuel is not suitable for the country. Through realization of this Project, it will be possible for approximately US$74 x 10^3 in foreign currency to be saved annually, which corresponds to an amount equal to 1.4% of the country's annual exports and 6.7% of fuel imports, which would be not a small contribution in improving the international balance of payments of the country. The foreign liabilities of Sao tome and Principe outstanding as of 1995 were in excess of 300 million U.S. dollars, and the situation is that any further increase in the liabilities is impossible.

At present, imports of Sao Tome and Principe are approximately 5 times greater than exports, with food imports alone exceeding total exports. Accordingly, achieving self-sufficiency in foodstuffs is a matter of paramount concern, and for this purpose, eliminating the shortage in electric power supply is urgently needed to promote the weak processing and storing facilities of agricultural and marine products.

(6) This project site and its surrounding area comprise a comparatively well-balanced environment as a result of long years of agricultural activities. This Project is of extremely small scale and will have hardly any impact in the present state of the natural environment.

(7) The cost required for operation and maintenance after completion of this Project can be met within the range of electric power sales revenue, and at the same time that a considerable effect as mentioned above can be looked forward to, there will be a contribution to improvement of the people's livelihood over a broad scope, and the significance of implementing this Project is judged will be great.

Taking the above into consideration comprehensively, implementation of this Project is of exceeding significance, and it is thought appropriate for the necessary preparatory works to be done in continuation to the present study.

1. Selection of Mini Hydro Power Devdopment Project

Selection of the stream for the mini hydro power development project was done considering precipitation, topography, and economics based on 1/10,000-scale topographical maps, and keeping in mind the hydro power master plans formulated by the U.S.S.R. and the French Electricity Directorate in 1981 and 1993, respectively.

The project site to be selected was to have a catchment area of approximately 10 km^2 and head of approximately 40 m or more, and from the north, the six rivers of Do Ouro, Manuel Jorge, Abade, Cantador, Io Grande, and Lemba were taken up.

Economic comparisons of the various projects were made using indices with the product of catchment area, total head, and average rainfall in catchment taken as the numerator and the product of waterway length and average waterway excavated cross-sectional area as the denominator. As a result, it was learned that the Manuel Jorge No. 4 and Abade sites were superior compared with other sites, and it was decided that the Manuel Jorge No. 4 site should be the feasibility study site for the reasons given below, where a table of the comparison study of the two is shown.

Hydro Power Project	Manuel Jorge No. 4	Abade No. 1*
Topography & Geology	The geology of basalt as basement rock is the same for both rivers, but the topography is more rugged at the Abade with both waterway length and waterway excavated cross-sectional area approximately double those of Manuel Jorge No. 4.	
Stream runoff Ratio	Approx. 1:2	
Access Conditions	Numerous roads and paths from intake dam to powerhouse for easy access.	Deeper in the mountains than Manuel Jorge, and especially, access in rainy season work will be difficult without large-scale improvement of existing roads.
Transmission Line	5 km to Trindade, planning along roa possible.	Approx. 15 km to Trindade, deeper in than Manuel Jorge, requires felling of trees and widening of roads for maintenance.
Environment	Milagrosa and Santa Clara are locatec in project site involving some amount of problems concerning compensation, but hardly any problem from standpoint of environmental preservation.	Access, transmission line route, and power generation structures further in mountains than Manuel Jorge and require separate EIS from viewpoint of natural forest and environment preservation.
Power Station Output	Approx. 230 kW (Max)	Approx. 800 kW (Max)

Hydro Power Project	Manuel Jorge No. 4	Abade No. 1*
Construction Cost	Approx. US$4.5 - 5.0 x 10^6	Approx. US$8.0 - 12.0 x 10^6 (excluding new construction and/or improvement of transmission line and access road)
Economics	Not economical with ordinary loan	Better than Manuel Jorge, but still not economical with ordinary loan.
Development Timing	Start-up by 2000 A.D. possible as emergency power station to deal with supply capability shortage. Even 1993 Master Plan schedules commissioning in 2001.	Early development planned according to EMAE-EDF Master Plan of 1993, and said approved for partial loan from African Development Bank, but construction not yet started.
Direct Income Effect	Both projects would connect to Trindade Substation making possible electrification of Bombaim, Santa Clara, and Milagrosa, and also make possible distribution to Trindade subject to chronic power outages for various reasons. Reduction in imports of diesel fuel and savings in foreign currency possible.	

* Abade No. 1 is about the same as No. 3 of 1993 master plan.

2. Electric Power Demand Forecast

EMAE's major generation facilities, as of March 1996, consist of three power stations: Sao Tome Diesel Power Station (5,200 kW), Contador Hydro Power Station (1,920 kW), and Gue Gue Hydro Power Station (320 kW), totaling 7,440 kW. On the other hand, the maximum power consumption as of 1994 was 4,995 kW, which would be regarded as the maximum power supply capability in the Sao Tome system.

The average annual growth rate in electric power demand (generating end electric energy) from 1981 to 1994 was 5.68%. Load restrictions were carried out in 1995, with a reduction from 1994. Therefore, 1995 was not taken into consideration. On examining the growths in individual years, there was a high growth of 34% from 1983 to 1984, while from 1987 to 1989 there were very high growth rates of 25.3%, and 22.1%, as well. The maximum power in the case is forecast to be almost doubled in 10 years or in 2005, and increased by 2.7 times in 15 years, or in 2010.

Regarding the maximum power forecast, a 50% load factor was applied. The load factor of Sao Tome is currently 30% - 40%, although it is generally around 60%. It is expected that the present load factor will be improved in the future.

The forecast, however, does not include approximately 2,235 kW of potential demand from the TV stations and hotels which expect to receive power from EMAE. The demand for half of the population on the island is also not included as these are no concrete electrification plans, although they are not presently benefited from electrification. New electrification will be impossible due to the fund shortage under the existing condition that the power supply is short. Then the power demand is forecast only from the power consumption increase in the already electrified. When considering the potential demand only, a maximum of 1,340 kW shall be added to the forecast value based on the load factor of 60% calculated from the receiving power. As these potential consumers already own private generating facilities, it is considered unnecessary for EMAE to supply them with power without delay, so that it is not taken in this forecast.

3. Electric Power Development Plan

Based on the national energy master plan made in 1993, the scenario of the mid- period power development plan until 2010 has been modified according to the actual situation by combination of hydro-power and thermal power as shown below.

Year	Power station	Output (kW)
1996	Abade No. 3 hydro-power 870 kW x 2	1,740
1997	Expansion Sao Tome thermal power	1,200
2000	Manuel Jorge No. 4 hydro-power	650
2001	Manuel Jorge No. 3 hydro-power	1,100
2003	Abade No. 1	1,500
2005	Manuel Jorge No. 2 hydro-power	750
2006	Lemba hydro-power	3,000
2010	Ouro hydro-power	1,000
	Diesel	1,000

It seems that Manuel Jorge No. 3 and 4 of Scenario above do not take into account the intake-water quantities into several villages along the Manuel Jorge river, so that the installed capacities of both projects are thought to be larger than should be. The Manuel Gorge No. 4 of the present Report is therefore different from them.

According to the plan, the current power shortage is covered by the urgent thermal power and thereafter, power resources are developed centering on hydro-power. Hydro-power development of the River Manuel Jorge is a large project next to the Abade River project which is the likeliest in the master plan. The urgent thermal power station as one of the immediate measure is to be an extension of the Sao Tome Diesel of 1,200 kW in 1997. The Abada hydro-power station could raise only part of the construction fund and work has not been started, therefore making operation start in 1996 impossible. It will be the present situation that the above scenario has to be revised according to the actual circumstances.

In these circumstances above, the following revised development plan was prepared by the JICA study team after close consultation with EMAE, which is considered to be the optimum plan:

Year	Power Station	Output (kW)
1997	Expansion Sao Tome Diesel	1,200
2000	Manuel Jorge No. 4 Hydro P/S	230
2001	Abade No. 3 Hydro P/S	1,740
2004	Abade No. 1 Hydro P/S	1,500
2007	Camba Hydro P/S	3,000

The above development plan is considered to reflect the actual circumstances. In fact, the Abade hydro-power station will preferably be implemented after the Manuel Jorge No. 4, in consideration of the access condition of the former that (1) it is located deeper in the mountains than Manuel Jorge, (2) the rainy season works will be difficult without large-scale improvement of existing road, (3) the Abade project will require separate E/S from view point of natural forest and environmental preservation, and (4) more construction cost is required than the Manuel Jorge.

The optimum development plan is shown in Table 5-3 and Figure 5-3, together with the unrevised or present plan. In studying the optimum power development plan, the unrevised plan values were used concerning output of development sites other than Manuel Jorge.

It is generally accepted that a reserve ratio of about 30% of the maximum demand is necessary in developing countries and very particularly in a weak power system. It is assumed in this study that even if the maximum hydro-power and thermal power units (Contador 960 kW and Sao Tome thermal power ABC-3 1280 kW) are suspended by accident, power supply can be made by other stations. The reserve ratio in 1996 is 43%, and that of 30% of demand is used after the reserve ratio drops below 30% of demand.

Even though all the preparatory work starts shortly in regard to the implementation, start of the Manuel Jorge hydro-power station will be in or after 1999. In the present supply shortage condition, the development of new, high reliability power sources without regard to the scale is necessary.
The results of the studies are shown in Table 5-3 and Figure 5-3, which were prepared based on consultation with EMAE.

The output of Manuel Jorge No. 4 Hydroelectric Power Station would be approximately 230 kW, and start of operation will be possible in the year 2000. In the situation that construction and repairs of power stations have been not made according to the expected schedule, Manuel Jorge No. 4 is regarded to respond to such difficulties even though it is small. The maximum power demand at this time is forecast to be 6,540 kW, a small proportion of the planned demand and supply balance. The following will be duly reminded as a whole regarding the merits to be obtained through development of this project:

(1) Practically all existing power generation and transmission facilities are antiquated, renovations cannot be made quickly due to lack of funds, so that the installed capacity cannot be fully demonstrated, and this is a cause of chronic electric power shortage.

(2) It is not easy to build new power stations to go forward as planned due to difficulty in procuring foreign currency funds.

(3) The composition of electric power sources of EMAE has a high proportion of thermal (approximately 70%), and when diversification of power sources is considered, it is necessary for hydro to be developed regardless of the scale of development.

(4) Fuel for diesel power stations is completely dependent on imports from other countries, and use of foreign currency can be reduced through development of a hydro power station.

(5) The transmission line would be connected to Trindade Substation, and it will be possible for Santa Clara, Milagrosa and other villages, where there are about 90 families or 500 inhabitants, to be electrified, while it will be possible for power to be distributed to Trindade which is subjected to chronic power outages for various reasons though it is administrative center of the District.

The electric power of Manuel Jorge No. 4 would be connected to the interconnected system at the abovementioned substation.

4. Present Situations of Existing Power Stations (as of March 1996)

4.1 Contador Hydro Power Station

It is now thirty (30) years since this power station was completed and it is thought that if repairs and improvements were to be made at the locations of civil structures and if electrical machinery were to be exchanged, the service life of the power station can be extended for several decades more. The following repair and improvement works will be required to be done:

(1) Repairs of access road

(2) Removal of sand-gravel and driftwood from upstream of the intake dam. Improvement of intake forebay partition wall into a side overflow-type intake weir. Replacement of all inoperative gates.

(3) Regarding the headrace, restoration work at the waterway end at Pc13 was completed at the end of 1996, but since this is unstable from a long-term viewpoint, it will be necessary for a permanent measure to be provided at an early date.

(4) Regarding the head tank, periodic checks for leakage and crack occurrence.

(5) At the steep slope of the penstock, removal of loose rocks about to fall.

(6) It will be necessary to budget at an early date installation of entrance door leafs and glass panes for windows of the powerhouse, and installation of lighting at places where necessary.

(7) Electro-mechanical equipment including turbine and generator needs to be completely replaced.

4.2 Gue Gue Hydro Power Station

Deteriorated parts are not recognizable at present, but it is necessary for sand-gravel deposited in the settling basin immediately downstream of the intake dam to be removed with priority over everything else. Next, the sediment deposited at the intake dam must be removed and at the same time the intake screen needs to be inspected and repaired or improved.

4.3 Sao Tome Thermal Power Station

Except for ABC-3 and DORMAN which were added last year, ABC-1, Cummins-2 and Cummins-3 have become deteriorated with time, and for improvement of the reliability of the electric power system as a whole, it is thought these need to be renewed at an early date.

From the standpoint of noise pollution it is desirable for the power station to be relocated to the outskirts of town.

5. Hydrology

5.1 Calculation of Runoff

The amount of runoff data of the Manuel Jorge River which can be used for planning was limited, and the daily runoff and specific runoff per 10 km^2 for the 4-year period from October 1988 to September 1992 of the project site on the Manuel Jorge River were estimated from comparison studies of daily runoff data of similar streams in the neighborhood.

Daily runoff data of Pian-Pian Gauging Station on the Manuel Jorge River are given in the 1989/90 runoff yearbook as a water level and runoff hydrograph prepared by the Resources Research Institute of Portugal (no entry in the 1988/89 yearbook). On the other hand, there are measured runoff data (a number of water level and runoff data) for checking annual water level-runoff hydrographs estimated by MESA since 1989. It was decided to estimate the long-term runoff of the Manuel Jorge River using these two kinds of data.

In the vicinity of the Manuel Jorge River there is the Abade River to the south and the Do Ouro River to the north. The water level data of Bombaim Gauging Station (catchment area: 12.0 km^2) on the Abade River upstream stretch, although with some unrecorded periods along the way, are available for a 3.6 year period from January 1989 to the middle of September 1992, while on the Do Ouro River, there are two gauging stations, the upstream Boa Esperanca (13.8 km^2) and Central A. Neto (48.0 km^2), and water level data from October 1988 to April 1991, although with some blank periods along the way, can be used. For the latter, there are additional data, although with considerable unrecorded periods along the way, up to June 1992 which can be used. Water levels of the Manuel Jorge River which can be used are for roughly 1.5 years from January 1990 (with blanks) to April 1991.

Fortunately, the periods during which observation were not made on the three streams differ with no cases overlapping, and by supplementation using one of the data, it was possible to estimate the runoff at the Manuel Jorge (Ponte) site for the roughly 4 year period from October 1988 to September 15, 1992.

In case of a small-scale power station of run-of-river type such as in this Project, only parts of large runoffs such as during floods are utilized for power generation, and rather, the scale is decided by the runoff during low water periods in the dry season. Although the correlations between these rivers cannot be said to be of high degrees, the calculations are based on runoffs of long periods (7 month periods from February to August) taking into consideration runoff of the dry season, and it is thought these are runoff data which can adequately be used in studying the Project.

Figure 7-10 shows the results of runoff calculations for the Pian-Pian Ponte site on the Manuel Jorge River.

5.2 Flood Discharge

There are three rainfall observation stations, namely, Bombaim, Monte Café, and Trindade, in the vicinity of the Manuel Jorge, with data available for 29 years, 24 years, and 18 years, respectively, and the probability rainfalls at the Manuel Jorge No. 4 site based on these are as follows:

Return Period (1/n yr)	Probable Rainfall (mm/day)
5	128
10	154
20	179
50	212
100	236

The catchment area for this Project is comparatively small at 10.8 km^2 so that the Rational Method was used for calculation of design runoff, and as a result, a 100 year return period design flood discharges of 210 m^3/sec for the powerhouse site, and 180 m^3/sec for the intake dam site were obtained.

6. Manuel Jorge No. 4 Power Development Project

6.1 Waterway Route

Studies of the three alternative routes of Case A, Case B, and Case C shown in Figs. 8-2 and 8-3 were made under the conditions below.

- Catchment area, stream discharge duration, topography upstream of intake site, topography of waterway route, etc. were taken into consideration for the type of power generation. Basically, because of the large differences between 355 day runoff and 35 - to 95 day runoffs (0.055 m^3/sec and 0.3 m^3/sec), in order not to allow ineffective discharge (power generation stoppage) at time of dry season runoff, in one method a head tank is provided for a storage capacity of about 12 hours of dry season runoff, stopping power generation for about 12 hours daily to store and regulate water for power generation for firm peak operation during peak hours, and a method of installing two turbine-generator units with operation carried out with one unit in the dry season, for studies of two systems.

- The waterway is to be of concrete with the cross section square, the top provided with cover plates of precast concrete.

- The waterway is to be made by excavating the mountainside by bench cutting and then trench cutting at the mountain side of the bench. A road of 2 m width for construction and maintenance and inspection is to be provided on the river side of the open canal.

- The pipe diameter of the penstock is to be based on flow velocity of 2 m/sec.

- The turbine is to be cross flow type in consideration of effective heads and available discharges (He = 119 - 94 m, Omax = 0.30 - 0.32 m^3/sec) of the various cases.

- The discharge water level is to be 2 m below the 100 year return period design flood discharge level, which is higher than the ordinary water level of the Manual Jorge River.

- In calculation of annual electric energy production, roughly 35 day runoff of 3 year average discharge duration was adopted for maximum available discharge in each of the cases, while as firm discharge, the discharge which can be secured for 355 days out of 365 was taken.

- Construction costs were estimated using unit prices as of January 1996, with preparatory works costs, civil works, hydraulic equipment, power generating equipment, transmission line construction, and engineering expenses included among the items. Repairs are to be made at parts where necessary so that intake for the Milagrosa District can be made even at low water, with repairs made at parts necessary along the length of approximately 1.5 km in order that leakage will not occur from the waterway, the cost of this being included in the construction cost.

- Regarding the benefit in the economics, a diesel power station of 1,000 kW was taken as the alternative thermal power, with the kW and kWh unit costs of the alternative thermal as the kW and kWh values of hydro, the values of output (kW) and annual electric energy (kWh) of hydro as benefit, while on the other hand, for costs, 8.147% and 1% of construction cost were taken as depreciation cost and administrative costs, respectively, and from these B/C, the ratio between annual benefit and annual cost, and B - C, the difference between the two, were obtained.

The results of examination are as given in the table below.

	Case A	Case B	Case C
Catchment Area (km^2)	8.31	8.32	9.23
Intake Water Level (m)	522	507	470
Discharge Water Level (m)	388.4	388.4	369
Effective Head (m)	119.14	111.87	94.27
Max. Available Discharge (m^3/sec)	0.3	0.3	0.32
Max. Output (kW)	242	227	204
Annual Energy Production (MWh)	1,376	1,292	1,169
Construction Cost (US$)			
1 Unit Proposal	4,748 x 10^3	4,410 x 10^3	4,478 x 10^3
2 Unit Proposal	5,096 x 10^3	4,679 x 10^3	4,672 x 10^3

	Case A	Case B	Case C
B/C			
1 Unit Proposal	0.213 (1.951)	0.215 (1.974)	0.191 (1.752)
2 Units Proposal	0.185 (1.701)	0.189 (1.730)	0.171 (1.565)
B-C (US$)			
1 Unit Proposal	$-343 \times 10^3 (45 \times 10^3)$	$-318 \times 10^3 (43 \times 10^3)$	$-332 \times 10^3 (34 \times 10^3)$
2 Units Proposal	$-381 \times 10^3 (36 \times 10^3)$	$-348 \times 10^3 (34 \times 10^3)$	$-355 \times 10^3 (26 \times 10^3)$

Figures in parentheses indicate cases when amounts corresponding to construction cost or reasonable investment have been provided as subsidy or grant aid. The construction costs in the above table are estimated to compare the three cases so that the Case B cost is different from Table 11-1.

As a result, the six alternatives are all of low values, but of these, although by only a slight difference, the proposal of Case B (with Storage Capacity) of the head tank having a dry season regulating capacity (Ve = 2,400 m^3) has B/C of 0.215 and B - C of -US$317,543 which are superior to the B/C of 0.213 and B - C of -US$343,014 of the next best Case A. However, in the event a reasonable investment amount equivalent or a construction cost equivalent is provided as a subsidy or grant aid and the power station administration cost is considered as only the operation and maintenance cost (O&M cost), Case B will have B/C = 1.974 and B - C = US$42,951, and power station operation will be amply possible. Furthermore, if this site were to be developed from the point of view of effective utilization of water resources which comprise clean energy and recyclable energy, it will be possible to make savings in the cost of fuel oil which is a fossil energy by a quantity of 380 kl annually, about US$80,000, to lessen the financial burden on Sao Tome and Principe.

Therefore, it was decided to adopt Case B with Storage Capacity of the highest B/C and B - C of the three routes six cases and the maximum available discharge of this proposal was examined.

6.2 Maximum Available Discharge

Regarding the Case B with Storage Capacity proposal, the optimum discharge was determined according to the following:

- The maximum available discharge was studied for runoffs at mostly 5 day intervals of 15, 20, 25, 30, and 55 days of 3 year annual average runoff at the Manuel Jorge No. 4 site.

- Regarding construction cost, it was estimated for each maximum discharge for the same items as in the study of the optimum route.

- Regarding electric energy also, the head loss for each discharge quantity was calculated similarly to the study of the optimum route, and the standard turbine efficiency and generator efficiency for a cross flow turbine were used.

With the cost of the alternative capacity, diesel power generation, as the benefit (B) of hydro, and with the cost of hydro including depreciation cost and operation and maintenance cost (O&M cost) as C, the above cases were compared, and it was found that a maximum available discharge of 0.306 to 0.31 m^3/sec would be optimum. The maximum available discharge, Omax, was taken as 0.31 m^3/sec based on this result.

6.3 Optimum Pipe Diameter

With maximum available discharge as Qmax = 0.31 m^3/sec, the construction cost per meter of length, power generation loss, and annual energy los were calculated for every centimeter of penstock pipe diameter, and with the alternative thermal cost as the value of hydro power, the pipe diameter at which the total cost of minus benefit (considered as cost) and depreciation cost and operation and maintenance cost (O&M cost) in relation to construction cost would be minimum was determined. As a result, it was found that around D = 0.36 m gave the minimum value, and hence was optimum.

In Japanese Industrial Standards, there are specifications for pipes of inside diameter 0.343 m and 0.394 m close to inside diameter of 0.36 m, and it was decided to adopt steel pipe for general structural use of inside diameter 0.394 m and shell thickness of 6.4 mm with which head loss would be smaller.

6.4 Power Generation Plan of Optimum Scale

Maximum output, firm output, firm peak output, and annual energy production were calculated from maximum available discharge of Qmax = 0.31 m^3/sec, head loss and effective head based on penstock pipe diameter D = 0.394 m, and turbine generator efficiency, and the results of maximum output Pmax = 230 kW, firm output Pf = 36 kW, firm peak output Pfp = 73 kW, and annual energy production E = 1,253 MWh were obtained.

6.5 Development Scheme for Abade River

With regard to a development scheme for the Abade River, there have been studies made in the past by the French and others and development scales have been suggested, but with difficulty in fund procurement, development has not yet been realized.

Meanwhile, in carrying out the present mini hydro power development project survey, selection of streams for investigation was studied, as the result of which it was considered that the Abade River is a stream indicating an index value with hardly any difference from Manuel Jorge No. 4.

The data employed in the study of this site were as follows:

Topographical maps:	1/10,000, 1/25,000 entire project area
Runoff data:	Average discharge-duration chart prepared based on 4 year daily runoff from 1989 to 1992.

The locations on the Abade River which have favorable topographies for hydro power development are in the so-called Bombaim District from the Abade River river-bed elevation of 400 m, where the tributary Bomba River merges with the mainstream, to around EL. 500 m.

Power generation schemes of 3 routes 5 cases are as shown in Tables 8-17 and 8-18, with normal economic indices being B/C < 1, B - C < 0.

However, in case of development receiving a subsidy or grant aid and limiting power station administration cost to operation and maintenance cost (O&M cost), the economic indices will be as shown in Table 8-18 where all of the proposals will have high values of B/C > 1 (4.124 and higher) and B - C > 0 (US$246,434 and higher) and power station operation will be amply feasible.

Of these proposals, the one with the best economics is a combination of C-1 and C-2' of Case C which would have B/C = 0.488 and B - C = -US$455,018 when normal costs are considered but when only O&M cost only is considered B/C will become 4.475 and B - C US$336,577.

The amount of oil which can be saved at the alternative thermal (diesel power generation) when this case is developed will be approximately 1,650 ton annually, this fuel cost savings being estimated at approximately US$400,000.

7. Geology of Manuel Jorge No. 4

The intake dam site can be judged to be favorable from the standpoints of both topography and geology. That is, the topography of the dam site is in the form of a narrow canyon. River deposits are thin, being 1 to 2 m, while underlying the deposits and at both banks is basement rock consisting of massive basalt and tuff breccia at parts. Therefore, it is thought this dam site has adequate bearing power and watertightness as a foundation for the planned intake dam.

The geologies and stabilities of slopes at the waterway route and head tank site are thought to pose no problems for construction of a penstock and powerhouse in consideration of the scales of structures planned. That is, the basement rocks possess adequate strengths as foundations for the penstock and powerhouse, while as for talus deposits, they consist of gravel-bearing large--articled material and may be judged as being adequate in load-bearing property. Collapses and landslides are not seen at slopes around the project site and it is considered to be a favorable location from the standpoint of slope stability also.

8. Feasibility Design

This Project is for a so-called mini hydro power station of maximum available discharge 0.31 m^3/sec, effective head 109.17 m, and maximum output 230 kW. As civil structures for this Project, there are an intake dam and intake as water intake facilities, while as a headrace for conveying water for power generation and obtaining head, an open canal of gradient 1/500 is to be provided along the mountainside in view of the overall topography of the waterway route. Part way along the upstream portion of the headrace, it will be necessary to provide a regulating gate and spillway for cutting off water from the intake for repair of downstream structures and removal of sediment. A settling basin to allow sand and silt suspended in water taken in to settle and be removed is to be constructed, for conducting water approximately 1.2 km to the head tank. The water transmission cross section, since a comparatively small amount of water is conveyed, is to be inside width of 0.57 m and inside height of 0.72 m.

The head tank is not only for preventing large water level variation when starting generation and instantaneously supplying water for power generation without excess or shortage, and dispersing reaction energy (water hammer) accompanying cut-off of water flowing down the penstock when stopping power generation, but also, in this Project, for storing water to be supplied to eliminate ineffective discharge due to power generation stoppage at times of low water in the dry season.

The penstock is for conveying power generation water from the head tank to the powerhouse, and with the head between the head tank and the power station outlet 115.56 m (11.6 kg/cm^2), the inside diameter for withstanding this water pressure will be D = 0.394 m, and the length of the steel pipe will be L = 226 m.

At the powerhouse, water from the penstock is to be received with a reaction type cross flow turbine for converting velocity energy into electric energy for obtaining maximum power of Pmax = 230 kW and 1.25 GWh in annual energy production.

The flow duration in this area is broadly divided according to dry season and wet season, while this power station is to be operated as a base load power station through both wet and dry seasons. Especially, there is little rainfall in the dry season, and it will be necessary to give thorough consideration to operation under partial load. In such case, although maximum efficiency would be lowered somewhat, a cross flow turbine or a Pelton turbine which has a capability for operation under partial load in a broad range and with high efficiency will be more advantageous than a Francis turbine. Particularly, the construction of a cross flow turbine is simple, and it is cheaper than a Pelton or Francis turbine. Furthermore, maintenance is easy because of the simple construction, and it is possible to handle repair of the turbine during trouble at the site to a considerable extent.

In view of the above, a cross flow turbine is to be adopted. A cross flow turbine is being used at the downstream Gue Gue Hydro Power Station also.

Regarding the number of units of main equipment, a comprehensive judgment was made of operation in the wet and dry seasons, convenience in maintenance of equipment, etc., and 1 unit was adopted.

As the generator, a 3 phase, alternating current, synchronous generator was selected, and in order that voltage regulation of the power system would be amply possible, the power factor is to be 0.8 (lagging). It is to be noted that existing power stations are designed for generator power factor of 0.8 - 1.0. The main transformer is to be installed outdoors from the powerhouse. The control system is to be a manned system with operating personnel resident at all times.

Particulars and Specifications of Main Equipment

(1) Turbine

Type:	cross flow
Number of units:	1 unit
Normal effective head:	109.17 m
Available discharge:	6.31 m^3/sec
Rated output:	253 kW
Rotating speed:	1,000 rpm

(2) Generator

Type:	3 phase, A.C., synchronous generator
Number of units:	1 unit
Output:	290 kVA
Rotating speed:	1,000 rpm
Frequency:	50 Hz
Voltage:	400 V
Power factor;	0.8

(3) Main Transformer

Type:	Outdoor, 3 phase, oil-immersed, self-cooling type
Number of units:	1 unit
Rated output:	290 kVA
Voltage:	400 V/30 kV

9. Construction Program

The principal civil works in this Project are the following:

(a) Intake Dam

Width 11 m, height 2.0 m, concrete volume 210 m^3

(b) Headrace

Total length approx. 1,200 m, excavation volume 8,040 m^3, concrete volume 760 m^3, shotcrete area 760 m^3.

(c) Settling Basin

Length 25 m, width 3 m, depth 1.8 m, concrete volume 80 m^3.

(d) Head Tank

Excavation volume 10,070 m^3, concrete volume 600 m^3.

(e) Penstock

Steel pipe diameter 0.394 m, length 225.6 m, excavation volume 830 m^3, concrete volume 125 m^3.

(f) Powerhouse

Building width 5.5 m, length 14.9 m, floor area 82 m^2, excavation volume 860 m^2, 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 Domestic Water Supply Intake Facilities

Intake weir height 1.5 m, width 12 m, excavation volume 170 m^3, concrete volume 104 m^3.

Of concrete aggregates, fine aggregate is to be obtained and used collecting crude rock by drilling and blasting at the quarry, followed by crushing and screening. There are two organizations quarrying graywacke and basalt in the vicinity of Sao Tome City, crushing the rock and screening at aggregate plants.

Since the aggregate is crushed stone, the cement content of concrete will be somewhat higher than when using river aggregates, but this will be safer for concrete structures than using marine fine aggregate requiring removal of salts. As for supply of aggregates, since maximum volume of concrete placed in one day will be about 10 m3, there will be no problem.

Cement and reinforcing steel are not produced in Sao Tome and Principe and all quantities will depend on imports. The principal sources of imports are Portugal and South Africa. When importing from these countries, it appears that in the case of Portugal, a period of about 2 months will be required from ordering until delivery in the field. As for the case of South Africa, a private construction company has a liner service in operation so that it is capable of stable supply, but a monopolistic character may be seen, and it is expected that prices will be somewhat high.

A period of slightly less than 2 years will be required for the entire work of this Project from definite design to taking various procedures to completion of construction, the details of which are as shown in Fig. 11-10. About 5 months will be required as well for the basic design in advance to them.

10. Economic Evaluation and Financial Analysis

10.1 Economic Evaluation

For the methodology of economic evaluation of this project, the benefit-cost ratio method is used on the assumption that the present value of the total cost of construction of an alternative power plant is the benefit and that the present value of the total cost of construction of this project is the cost. As for the alternative power generation, diesel oil power generation plant that is installed in this country is used.

As shown in Table 14-1, the annual capital cost is US$388,553, which is 8.174% of the total investment cost and the annual operating and maintenance cost is US$47,535, making a total of US$436,088.

Assuming that the alternative project is a diesel oil power generation plant, the annual fixed cost would be US$5,174 and the variable cost would be US$73,856, making a total of US$79,030.

Using the above calculation, the benefit/cost ratio is 79,030/436,088 = 0.181, which is well bellow the break-even point of one (1) for the economic evaluation. However, due to the following reasons, we consider taking up this project positively on the assumption that the project be financed on a grant basis:

(1) The Democratic Republic of Sao Tome and Principe is not in a position to adopt a thermal power plant due to its trade structure and external debt situation.

(2) In view of the topography and the volume of water, this project has an optimal condition for a hydro-power plant for this size and its low investment efficiency can be justified.

(3) At present a little bit more than ten thousand households are provided with the electricity. If this project is implemented and the electricity produced thereby is used only for the households, approximately 2,500 households additionally would receive electricity, making the ratio of diffusion more than 60% from the current level of 50%.

(4) Implementation of this project would save the foreign currency of US$74 thousand compared to the installation of a thermal power plant. This saving of the foreign currency would equal to 1.4% of the annual export (US$5.1 million) and 6.7% of the annual fuel import (US$1.1 million) that would make a valuable contribution to the external balance.

(5) There is virtually no industry in the country and almost all industrial products including capital goods rely on import. The country has yet to get rid of mono-culture mainly based on cacao and relies on import for food. In consequences, import amounts to five times as much as export and the food import exceeds the total export. The most important task for the country at the moment would be to achieve food self-sufficiency. The top priority for this target would be development of fishery, making a full use of its abundant natural environment and resources. However, due to the lack of freezing and refrigeration facilities for the stock of fish, these bountiful natural environment and resources have not been utilized. The greatest barrier for this lack of these facilities is insufficient supply of electricity and even for this reason the development of electric power is essential. The development of fishery is needed not only for achievement of food self-sufficiency but also for acquisition of foreign currency as one of the most promising measures.

(6) According to the National Energy Master Plan formulated prepared in 1993, construction of a total of approximately 15,000 kW new electric power plants is planned. If all of these plants are built in the form of thermal power plant, annual import of fuel of 6 - 7 million US Dollars would be needed. In view of the above-mentioned external position of the country, this is not possible and all new installation of power plants should be by means of the hydro-electric power. EMAE itself made it clear that all new installations except an emergency case would be hydro-electric power.

(7) In summary with a view to achieving food self-sufficiency and producing a core export goods except cacao, thus making a step forward to an economic self-reliance,

insufficiency in electric supply shall be solved and the implementation of this project will lead the country to this direction.

10.2 Financial Analysis

Assuming the optimal case (maximum power, annual power generation and construction cost), FIRR has been calculated. Then, based on the sensitivity analysis of FIRR and analyses of ROE and cash flow, the condition for this project to be viable has been sought.

The FIRR, as defined as a discount rate which makes the present value of the financial benefit equal to that of the financial cost, is calculated at -1.90% for an operation period of 35 years. However, as mentioned in "Economic evaluation", it is desirable to consider positively to take up this project for the following reasons:

(1) In order for the country to achieve an economic self-reliance, the solution to the shortage in the electric supply is essential.

(2) The development of electric power generation shall rely on hydro-electric power plants.

(3) Although the investment efficiency of this project is very low, it is considered as inevitable due to the topography.

In case a grant is given to this project, the project will become viable. Assuming the tariff of 15 cent/kWh and the EMAE's share of 15% (the remaining 85% is covered by the grant), the project will earn an FIRR of 10.51% and become viable. However, if electricity tariff goes down to 10 cent/kWh --15 cent/kWh is high for the international standard, it would be necessary to decrease the EMAE's share to 7 to 8% to make the project viable. On the other hand, the ROE, which is commonly used by the corporations for profitability analysis will be -9.15 for the base case (EMAE's burden share is 100%) and 0.86% in case EMAE's burden share goes down to 15%. However, even in the latter case, if the electricity tariff goes down to 10 c/kWh, the ROE will be -5.29%.

Although the investment efficiency of this project is quite low from both economic and financial point of views, it would be considered inevitable due to the topographical conditions that this country occupies a very small island and that it is quite difficult to find a topographically better location. On the other hand, the solution to the electricity shortage is essential to the economic self-reliance and there would be no other way than mini hydro-electric power plants to develop electric power from the external point of view. Therefore, with a high hope that this project will be implemented, we hereby recommend that necessary preparatory works such as detailed designing be processed in continuation to the present study.

11. Environmental Impact Study

The situation of land utilizations of the project area and its vicinity remains similar characteristics to those of the colony era, at that time the wide land area of forest was developed into plantations. Cacao and coffee plantations are the typical style of them. At the central part of a plantation area, there are management and agricultural facilities, and living quarters for the laborers. Therefore, there are no independent villagers living alone outside of the plantation center. This means that the centers of plantations forms villages of the area. There are four such villages distributed in the project area and its vicinity, which are called Milagrosa, Santa Clara, Quinta das Flores and Santa Luzia. All of them belong to the District of Me-Zochi, of which total population is 29,758 at the time of the survey. There is no mining and manufacturing industries in the project area and its vicinity. There were fermentation and drying factory, and car repair and wood manufacturing facilities in Milagrosa in the past. These factory and facilities are now out of order and can not be used.

It is found that potential amount of water resources in the project area and its vicinity is enough for consumption by the concerned villages. In addition to Manual Jorge river, there is a spring on Aqua Panada flowing through this area. All of them will guarantee the potable water supply and irrigation when needed in Santa Clara and Milagrosa. Besides, there are other three small springs in Milagrosa area.

Most of the villages relay on the river water of Manuel Jorge, except that some of them obtain drinking water from other water sources. Water for irrigation and mini-power generators rely on Manuel Jorge. Water flow will be quite limited in dry season, and therefore water share between the project and existing needs of water in the concerned villages must be settled among concerned parties, so that the vested rights be preserved.

There are roads running through Santa Clara and Milagrosa, which connect Trindade town and Sao Tome city. The roads are in so-so condition. In the past, the plantation of Milagrosa took care of the transportation need around the nearby villages, but such service was terminated.

Public service facilities, including power distribution system, are quite poor in and around the project area and its vicinity. There is only one primary school (two class rooms), one health center and one emergency clinic in Milagrosa. People with seriously injured or sick must receive treatment in Sao Tome city hospital.

Apart from the west side of the area, there is a forest area which is being considered as a natural conservation area, and is the source of several rivers. Most of the area is covered by secondary forest mixed with the plantation trees of cacao, coffee and others. The secondary forest is composed of Pau Brancol (Tetrochidium didymostemon), Moindro (Aidia quintassi), Muandim (Penta clethra macrophylla) and Pau Sangue (Hurungana madagascariensis). Nearby the Manuel Jorge No. 4 site area, there are three waterfalls. Because of the small scale of the hydropower project, there will be no notable change to be caused to the existing landscape.

As the terrestrial fauna, there are various birds habitat in the area. Monkeys also habitat here which cause damage to cacao and banana in the plantation. There are very few aquatic fauna in this area. Some kind of surface water shrips and fishes are existing, but their inventories are very little.

A kind of owl, which is an endemic bird of Sao Tome island, habitats in the west side of the project area. It is notable that bird watching tour of foreigners has become famous in the recent years.

The agricultural activity going on now in the project area and its vicinity has come to a quite balanced condition due to its long term history accumulated to date. Sustainable development of the agriculture of this area is important to the socio-economic environment. Fortunately, the mini-hydropower is a small project and therefore the potential environmental impacts are quite limited and even negligible.

Tables 13.2 and 13.3 show the summary of socio-economic and natural environmental impact assessments of the project respectively, in which measures to mitigate potential impacts are also recommended.

Table 5-2 Demand Forecast

Item / Year	Energy (Mwh)			Power factor(%)	Power (kW)			Expantion Plan of EMAE	Rate of Reserve (%)		
	High case	Middle case	Low case		High case	Middle case	Low case	Existent 7250kW	High case	Middle case	Low case
1996	23,184	22,966	22,749	50	5,293	5,243	5,194	9,260	74.9	76.6	78.3
1997	24,733	24,271	23,814	50	5,647	5,541	5,437	9,260	64.0	67.1	67.1
1998	26,385	25,650	24,929	50	6,024	5,856	5,692	9,260	53.7	58.1	62.7
1999	28,148	27,107	26,095	50	6,426	6,189	5,958	9,260	44.1	49.6	55.4
2000	30,028	28,647	27,317	50	6,856	6,540	6,237	9,910	44.5	41.6	58.9
2001	32,034	30,274	28,595	50	7,314	6,912	6,529	11,010	50.5	59.3	68.6
2002	34,174	31,994	29,934	50	7,802	7,305	6,834	11,010	41.1	50.7	61.1
2003	36,457	33,811	31,335	50	8,324	7,719	7,154	12,510	50.3	62.1	74.9
2004	38,893	35,732	32,802	50	8,880	8,158	7,489	12,510	40.9	53.3	67.0
2005	41,491	37,762	34,337	50	9,473	8,621	7,839	13,260	40.0	53.8	69.2
2006	44,263	39,907	35,944	50	10,106	9,111	8,206	16,260	60.9	78.5	98.1
2007	47,220	42,174	37,626	50	10,781	9,629	8,590	16,260	50.8	68.9	89.3
2008	50,374	44,570	39,387	50	11,501	10,176	8,992	16,260	41.4	59.8	80.8
2009	53,740	47,101	41,231	50	12,269	10,754	9,413	16,260	32.5	51.2	72.7
2010	57,330	49,777	43,161	50	13,089	11,365	9,854	19,260	47.1	69.5	95.5

Table 5-3 Analysis of Power Balance

Year	Power Demand (kW)	Plan by EMAE			Expansion Plan by JICA		
		Name of Power Station	Installed Capacity (kW)	Reserve (%)	Name of Power Station	Installed Capacity (kW)	Reserve (%)
			7,440			7,440	
1996	5,243	Abade 3 (1740)	9,180	75		7,440	42
1997	5,541	Expansion (1,200)	10,380	87	Expansion (1,200)	8,640	56
1998	5,856		10,380	77		8,640	48
1999	6,189		10,380	68		8,640	40
2000	6,540	Manuel Jorge 4 (650)	11,030	69	Manuel Jorge (230)	8,870	36
2001	6,912	Manuel Jorge 3 (1,100)	12,130	75	Abade 3 (1,740)	10,610	54
2002	7,305		12,130	66		10,610	45
2003	7,719	Abade 1 (1500)	13,630	77		10,610	37
2004	8,158		13,630	67	Abade 1 (1,500)	12,110	48
2005	8,621	Manuel Jorge 2 (750)	14,380	67		12,110	40
2006	9,111	Lemba (3,000)	17,380	91		12,110	33
2007	9,629		17,380	80	Lemba (3,000)	15,110	57
2008	10,176		17,380	71		15,110	48
2009	10,754		17,380	62		15,110	41
2010	11,365	Ouro 6 (1,000) Diesel (2,000)	20,380	79		15,110	33

Table 8-1 Comparative Study on Mini Hydro Power Projects in Sao Tome Island

Name of River and Name of Project	Catchment Area A: (km2) (1)	I.W.L (EL.m) (2)	T.W.L (EL.m) (3)	Gross Head H: (m) (4)=(2)-(3)	Length of Headrace L: (m) (5)	Avg. Annual Rainfall in the site, R: (mm) (6)	Avg. Excavation Area on Waterway, E: (m3/m) (7)	Value of Project (A*R*H)/(L*E)=(8)= (1)*(6)*(4)/((5)*(7))	Ranking
Do Ouro River									
Do Ouro No.1	14.74	400	320	80	1,020	2,030	11.4	206	10
Do Ouro No.2	15.61	300	220	80	1,550	2,030	2.1	779	6
Manuel Jorge River									
Manuel Jorge No.4	9.45	480	380	100	1,250	2,400	1.4	1,296	1
Manuel Jorge No.3	9.45	380	250	130	1,990	2,400	1.8	823	5
Abade River									
Abade No.1	15.81	440	310	130	2,650	2,780	1.7	1,268	2
Abade No.2	19.44	315	190	125	2,480	2,780	5.8	470	8
Cantador River									
Cantador	9.65	230	90	140	1,900	2,890	10.4	198	11
Cantador(alternative)	9.78	220	80	140	1,920	2,890	9.7	212	9
Io Grande River									
Io Grande (Ane Ghaves River)	10.35	405	230	175	1,330	3,330	4.6	986	3
Lemba River									
Lemba	33.26	70	30	40	2,060	4,330	3.1	902	4
Lemba (alternative)	32.71	80	30	50	2,760	4,330	4.2	611	7

Table 8-2 General Scheme Description of 6 Study Cases

Item \ Case	Unit	with Strage Capacity			without Strage Capacity			Remarks
		A	B	C	A	B	C	
Catchment Area	km2	8.31	8.32	9.23	8.31	8.32	9.23	
Intake Water Level	EL.m	522.00	507.00	470.00	522.00	507.00	470.00	
Head Tank Water Level	EL.m	511.92	503.96	465.98	511.69	503.84	465.86	
Outlet Water Level	EL.m	388.40	388.40	369.00	388.40	388.40	369.00	Minus 2m of F.W.L
Gross Head	m	123.52	115.56	96.98	123.29	115.44	96.86	Hg=H.T.W.L-T.W.L
Effective Head	m	119.14	111.87	94.27	118.91	111.75	94.15	
Power Discharge								
Maximum Discharge	m3/s	0.300	0.300	0.320	0.300	0.300	0.320	
Peak Farm Discharge	m3/s	0.110	0.110	0.110	-	-	-	Qf×24/12hrs
Farm Discharge	m3/s	0.055	0.055	0.055	0.055	0.055	0.055	97% Firm(355days)
Type of Turbine		Cross flow	Cross flow	Cross flow	Cross flow	Cross flow	Cross flow	
Power Output								
Maximum Output	kW	242	227	204	241	227	204	
Farm Peak Output	kW	81.0	76.5	66.9	-	-	-	
Farm Output	kW	38.8	36.4	29.5	39.5	34.6	29.8	
Annual Energy Production	MWh	1,376	1,292	1,169	1,375	1,289	1,168	
Power structure								
Intake Dam (L×H)	m	16×2.5	11×2.0	20×3.0	16×2.5	11×2.0	20×3.0	
Headrace Channel (L×B)	m	1,190×0.51	1,143×0.56	1,469×0.57	1,260×0.51	1,203×0.56	1,479×0.57	
Slop of Headrace Channel		1/300	1/500	1/500	1/300	1/500	1/500	
Head Tank Strage Capacity	m3	2,400	2,400	2,400	-	-	-	12hrs×Qf×3,600sec
Penstock (Φ×L)	m	0.44×286	0.44×224	0.45×140	0.44×286	0.44×224	0.45×140	v= 2m/s
Electromechanical Equipment								
Type of Turbine		Cross Flow	Cross Flow	Cross Flow	Cross Flow	Cross Flow	Cross Flow	
Installed Capacity of Turbine	kW	266	250	224	265	250	224	
Type of Generator		3-p Synchronous	3-p Synchronous	3-p Synchronous	3-p Synchronous	3-p Synchronous	3-p Synchronous	
Installed Capacity of Generator	kVA	306	287	258	305	287	258	
Transmission Line (30kV×1cct)	km	7.50	7.50	7.05	7.50	7.50	7.05	
Construction Cost	US$	4,748,856	4,410,253	4,477,753	5,096,362	4,678,683	4,671,787	
Construction Period	year	1	1	1	1	1	1	

Table 8-3 Study for Economical Route of Manuel Jorge No.4

Item	Unit	with Strage Capacity			without Strage Capacity			Remarks
		Case-A	Case-B	Case-C	Case-A	Case-B	Case-C	
1.Major Feature								
Catchment Area	km2	8.31	8.32	9.23	8.31	8.32	9.23	
Intake Water Level	EL.m	522.00	507.00	470.00	522.00	507.00	470.00	
Head Tank Water Level	EL.m	511.92	503.96	465.98	511.69	503.84	465.86	
Tailrace Water Level	EL.m	388.40	388.40	369.00	388.40	388.40	369.00	
Gross Head	m	123.52	115.56	96.98	123.29	115.44	96.86	
Effective Head	m	119.14	111.87	94.27	118.91	111.75	94.15	
Maximum Discharge	m3/sec	0.30	0.30	0.32	0.30	0.30	0.32	
Maximum Output	kW	242	227	204	241	227	204	
Firm Peak Output	kW	81.0	76.5	66.9	-	-	-	12hrs peak genaration
Firm Output	kW	38.8	36.4	29.5	39.5	34.6	29.8	97%(355days) Firm Output
Annual Energy Production	MWh	1,376	1,292	1,169	1,375	1,289	1,168	
Construction Cost (A)	US$	4,748,856	4,410,253	4,477,753	5,096,362	4,678,683	4,671,787	excl. Interest during Construction
2.Economical Index								
a) Construction Cost per kW	US$/kW	19,623	19,428	21,950	21,147	20,611	22,901	
b) Construction Cost per kWh	US$/kWh	3.45	3.41	3.83	3.71	3.63	4.00	
c) Benefit								
Loss Factor of Effective Output	%	2.9	2.9	2.9	2.9	2.9	2.9	
Loss Factor of Effective Energy	%	4.9	4.9	4.9	4.9	4.9	4.9	
Effective Output	kW	78.7	74.3	65.0	38.4	33.6	28.9	
Effective Energy	MWh	1,308.6	1,228.7	1,111.7	1,307.6	1,225.8	1,110.8	
kW Value	US$/kW	146.4	146.4	146.4	146.4	146.4	146.4	
kWh Value	US$/kWh	0.062	0.062	0.062	0.062	0.062	0.062	
Benefit of kW	US$	11,515	10,875	9,510	5,615	4,919	4,236	
Benefit of kWh	US$	81,132	76,179	68,927	81,073	76,002	68,868	
Total Annual Benefit (B)	US$	92,646	87,054	78,437	86,688	80,921	73,104	
d) Cost								CRF=0.08(1+0.08)^50/ {(1+0.08)^50-1}= 0.08174
Capital Recovery Factor: CRF	%	8.174	8.174	8.174	8.174	8.174	8.174	
O & M Cost	%	1.000	1.000	1.000	1.000	1.000	1.000	
Total Annual Cost (C-1)	US$	435,660	404,597	410,789	467,540	429,222	428,590	incl. Capital recovery cost
Total Annual Cost (C-2)	US$	47,489	44,103	44,778	50,964	46,787	46,718	excl. Capital recovery cost
c) Benefit Cost Ratio :(B)/(C-1)		0.213	0.215	0.191	0.185	0.189	0.171	
Benefit Cost Ratio :(B)/(C-2)		1.951	1.974	1.752	1.701	1.730	1.565	
d) Benefit - Cost : (B)-(C-1)	US$	-343,014	-317,543	-332,352	-380,852	-348,302	-355,486	
Benefit - Cost : (B)-(C-2)	US$	45,158	42,951	33,659	35,724	34,134	26,386	
e) Justifiable Investment Cost	US$	1,009,878	948,918	854,989	944,930	882,064	796,859	(B)/(0.0874+0.01)
f) Necessary Aid Fund	US$	3,738,978	3,461,335	3,622,764	4,151,432	3,796,619	3,874,928	(A)-{(B)/(0.08174+0.01)}

Table 8-12 Stduy of Optimum Water Discharge of Manuel Jorge No.4

Item	Unit	Maximum Power Discharge						Remarks
		0.277m3/sec	0.292m3/sec	0.300m3/sec	0.306m3/sec	0.320m3/sec	0.335m3/sec	
1.Major Feature								
Catchment Area	km2	8.32	8.32	8.32	8.32	8.32	8.32	
Intake Water Level	EL.m	507.00	507.00	507.00	507.00	507.00	507.00	
Head Tank Water Level	EL.m	503.96	503.96	503.96	503.96	503.96	503.96	
Outlet Water Level	EL.m	388.40	388.40	388.40	388.40	388.40	388.40	
Gross Head	m	115.56	115.56	115.56	115.56	115.56	115.56	
Effective Head	m	111.634	111.767	111.870	111.881	112.000	112.102	
Maximum Discharge	m3/sec	0.277	0.292	0.300	0.306	0.320	0.335	
Maximum Output	kW	208.9	220.5	226.7	231.3	242.3	253.7	
Firm Peak Output	kW	76.4	76.5	76.5	76.5	76.5	76.6	12hrs peak genaration
Firm Output	kW	36.3	36.3	36.4	36.4	36.4	36.4	97%(355days) Firm Output
Annual Energy Production	MWh	1,274.8	1,287.5	1,292.4	1,295.9	1,301.5	1,308.0	
Construction Cost (A)	US$	4,399,907	4,407,404	4,410,253	4,412,283	4,416,604	4,422,694	excl. Interest during Construction
2.Economical Index								
a) Construction Cost per kW	US$/kW	21,062	19,988	19,454	19,076	18,228	17,433	
b) Construction Cost per kWh	US$/kWh	3.45	3.42	3.41	3.40	3.39	3.38	
c) Benefit								
Loss Factor of Effective Output	%	2.9	2.9	2.9	2.9	2.9	2.9	
Loss Factor of Effective Energy	%	4.9	4.9	4.9	4.9	4.9	4.9	
Effective Output	kW	74.2	74.3	74.3	74.3	74.3	74.4	
Effective Energy	MWh	1,212.3	1,224.4	1,229.1	1,232.4	1,237.7	1,243.9	
kW Value	US$/kW	146.4	146.4	146.4	146.4	146.4	146.4	
kWh Value	US$/kWh	0.062	0.062	0.062	0.062	0.062	0.062	
Benefit of kW	US$	10,861	10,875	10,875	10,875	10,875	10,889	
Benefit of kWh	US$	75,163	75,911	76,203	76,408	76,739	77,125	
Total Annual Benefit (B)	US$	86,023	86,786	87,077	87,283	87,614	88,014	
d) Cost								CRF=0.08(1+0.08)^50/ {(1+0.08)^50-1}=
Capital Recovery Factor: CRF	%	8.174	8.174	8.174	8.174	8.174	8.174	
O & M Cost	%	1.000	1.000	1.000	1.000	1.000	1.000	0.08174
Total Annual Cost (C-1)	US$	403,647	404,335	404,597	404,783	405,179	405,738	incl. Capital recovery cost
Total Annual Cost (C-2)	US$	43,999	44,074	44,103	44,123	44,166	44,227	excl. Capital recovery cost
c) Benefit Cost Ratio :(B)/(C-1)		0.2131	0.2146	0.2152	0.2156	0.2162	0.2169	
Benefit Cost Ratio :(B)/(C-2)		1.955	1.969	1.974	1.978	1.984	1.990	
d) Benefit - Cost : (B)-(C-1)	US$	-317,624	-317,549	-317,519	-317,500	-317,565	-317,724	
Benefit - Cost : (B)-(C-2)	US$	42,024	42,712	42,975	43,160	43,448	43,787	
e) Justifiable Investment Cost	US$	937,684	946,001	949,177	951,420	955,023	959,380	(B)/(0.08174+0.01)
f) Necessary Aid Fund	US$	3,462,223	3,461,403	3,461,076	3,460,863	3,461,581	3,463,314	(A)-{(B)/(0.08174+0.01)}

Table 8-15 Study of Optimum Inner Diameter of Penstock Pipe (1/2)

Item	Unit	Inner Diameter : D (m)														
		0.31	0.32	0.33	0.34	0.35	0.36	0.37	0.38	0.39	0.400	0.410	0.420	0.430	0.440	0.450
Rated Generating Discharge :Qg	m3/sec	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310	0.310
Annual Power Discharge	m3/s-da	72.03	72.03	72.03	72.03	72.03	72.03	72.03	72.03	72.03	72.03	72.03	72.03	72.03	72.03	72.03
Average Power Discharge (72.03/365)	m3/sec	0.197342	0.197342	0.197342	0.197342	0.197342	0.197342	0.197342	0.197342	0.197342	0.197342	0.197342	0.197342	0.197342	0.197342	0.197342
Efficiency of T/G : ηtg (Avg. per Annum)		0.677	0.677	0.677	0.677	0.677	0.677	0.677	0.677	0.677	0.677	0.677	0.677	0.677	0.677	0.677
Generating Hour per Annum :Tg	hrs	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760	8,760
Manning's Roughness Coefficient of																
Penstock Steel Lining : n		0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120	0.0120
Fraction Loss Head at Generating																
hfg=(124.5*n^2/D^1.333)*v^2/(2g)	m	0.02980	0.02516	0.02135	0.01821	0.01560	0.01343	0.01160	0.01006	0.00876	0.00765	0.00671	0.00590	0.00520	0.00460	0.00408
Loss Power/Energy due to Friction																
Loss Power: Pg=9.8*hfg*Qg*ηtg	kW	0.039	0.033	0.028	0.024	0.020	0.018	0.015	0.013	0.011	0.010	0.009	0.008	0.007	0.006	0.005
Eg=Pg*Tg	kWh	342	288	245	209	179	154	133	115	100	88	77	68	60	53	47
(Quantities of Penstock per Meter)																
Thickness of Penstock Pipe t=0.006m	m	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Weight of Penstock, W=(D+0.006)π*0.06*7.85*1.06	t	0.050	0.051	0.053	0.055	0.056	0.058	0.059	0.061	0.062	0.064	0.066	0.067	0.069	0.070	0.072
Common Excavation of Penstock Line																
Vec={(D+1.35+0.5)+(D+1.35+1.0+0.5)}1/2*1.0*0.5	m3	2.660	2.670	2.680	2.690	2.700	2.710	2.720	2.730	2.740	2.750	2.760	2.770	2.780	2.790	2.800
Rock Excavation of Penstock Line																
Ver={(D+1.35+0.5)+(D+1.35+1.0+0.5)}1/2*1.0*0.5	m3	2.660	2.670	2.680	2.690	2.700	2.710	2.720	2.730	2.740	2.750	2.760	2.770	2.780	2.790	2.800
Saddle Concrete																
Vcs=(D+0.15)*0.56*0.4+{(d+0.35)+(d+0.53)}0.5*0.6*	m3	0.046	0.047	0.047	0.048	0.049	0.050	0.050	0.051	0.052	0.052	0.053	0.054	0.054	0.055	0.056
Anchor Block Concrete																
Vca=(D/0.43702)^0.5*90/224	m3	0.338	0.344	0.349	0.354	0.360	0.365	0.370	0.375	0.380	0.384	0.389	0.394	0.399	0.403	0.408
Gutter Conrete																
Vcg=0.053	m3	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053	0.053
Masonry Wall																
Amw=1.789	m3	1.789	1.789	1.789	1.789	1.789	1.789	1.789	1.789	1.789	1.789	1.789	1.789	1.789	1.789	1.789
Form Works																
Af=(D/0.43702)^0.5*340/224	m2	1.278	1.299	1.319	1.339	1.358	1.378	1.397	1.415	1.434	1.452	1.470	1.488	1.506	1.523	1.540
Weight of reinforcement steel bar																
Wr=Vcs*0.04+Vca*0.03	t	0.012	0.012	0.012	0.013	0.013	0.013	0.013	0.013	0.013	0.014	0.014	0.014	0.014	0.014	0.014

Table 8-15 Study of Optimum Inner Diameter of Penstock Pipe (2/2)

Item	Unit	Unit Cost (US$)	D=0.31m Q't	D=0.31m Amount (US$)	D=0.32m Q't	D=0.32m Amount (US$)	D=0.33m Q't	D=0.33m Amount (US$)	D=0.34m Q't	D=0.34m Amount (US$)	D=0.35m Q't	D=0.35m Amount (US$)	D=0.36m Q't	D=0.36m Amount (US$)	D=0.37m Q't	D=0.37m Amount (US$)
1.Construction Cost																
(1)Direct Cost																
Common Excavation	m3	8	2.660	21	2.670	21	2.680	21	2.690	22	2.700	22	2.710	22	2.720	22
Rock Excavation	m3	56	2.660	146	2.670	147	2.680	147	2.690	148	2.700	148	2.710	149	2.720	150
Saddle Concrete	m3	316	0.046	15	0.047	16	0.047	15	0.048	16	0.049	15	0.050	16	0.050	16
Anchor Block Concrete	m3	300	0.328	102	0.344	103	0.349	105	0.354	106	0.360	108	0.365	109	0.370	111
Gutter Concrete	m3	315	0.053	17	0.053	17	0.053	17	0.052	17	0.053	17	0.052	17	0.052	17
Masonry Concrete	m2	27	1.789	48	1.789	48	1.789	48	1.789	48	1.789	48	1.789	48	1.789	48
Form Works	m2	40	1.278	51	1.299	53	1.319	52	1.339	54	1.358	54	1.378	55	1.397	56
Reinforcement Bar	t	920	0.012	11	0.012	11	0.012	12	0.012	12	0.013	12	0.013	12	0.013	12
Miscellaneous Works	LS		1	41	1	41	1	42	1	42	1	42	1	43	1	43
Sub-total of (1)			10	452	10	457	10	460	10	462	10	467	10	471	10	474
(2)Penstock Pipe	t	6,500	0.0498	324	0.0514	334	0.0530	345	0.0546	355	0.0562	365	0.0578	375	0.0593	386
(3)Administration Cost	LS	1,170	1	140	1	142	2	146	2	147	2	150	2	152	2	155
(4)Physical Contingency	LS	286	1	75	1	77	1	78	1	79	1	80	1	81	1	82
(A) Total of (1)+(2)+(3)+(4)				991		1,009		1,027		1,044		1,063		1,079		1,097
2.Capital Recovery Factor to the Construction Cost																
C.R.F=r(1+r)^n/((1+r)^n-1)		0.08174		0.08174		0.08174		0.08174		0.08174		0.08174		0.08174		0.08174
3.O & M Ratio		0.01000		0.01000		0.01000		0.01000		0.01000		0.01000		0.01000		0.01000
4.Annual Cost Ratio (2.+3.)		0.09174		0.09174		0.09174		0.09174		0.09174		0.09174		0.09174		0.09174
5.Annual Cost (1.× 4.)	LS			90.94		92.57		94.19		95.81		97.42		99.02		100.63
6.Annual Minus Benefit (Cost)																
(1)Loss Power of Output	kW		0.039		0.032		0.027		0.023		0.020		0.018		0.016	
(2)Loss Rate of kW	%	2.9														
(3)Loss Power and Benefit	kW	146	0.038	5.543	0.032	4.680	0.027	3.971	0.023	3.387	0.020	2.908	0.017	2.487	0.015	2.157
(4)Loss Energy of Output	kWh		341.58		288.38		244.73		208.71		178.82		153.87		132.96	
(5)Loss Rate of kWh	%	4.9														
(6)Loss Energy and Benefit	kWh	0.082	324.85	20.141	274.35	17.004	222.74	14.430	198.48	12.306	170.86	10.543	146.33	9.073	126.44	7.838
Total Cost (5.+6.(3)+6.(6))	US$			116.621		114.249		112.580		111.503		110.865		110.580		110.629

Item	D=0.38m Q't	D=0.38m Amount (US$)	D=0.39m Q't	D=0.39m Amount (US$)	D=0.40m Q't	D=0.40m Amount (US$)	D=0.41m Q't	D=0.41m Amount (US$)	D=0.42m Q't	D=0.42m Amount (US$)	D=0.43m Q't	D=0.43m Amount (US$)	D=0.44m Q't	D=0.44m Amount (US$)	D=0.45m Q't	D=0.45m Amount (US$)	Remarks
1.Construction Cost																	
(1)Direct Cost																	
Common Excavation	2.730	22	2.740	22	2.750	22	2.760	22	2.770	22	2.780	22	2.790	22	2.800	22	
Rock Excavation	2.730	150	2.740	151	2.750	151	2.760	152	2.770	152	2.780	153	2.790	153	2.800	154	
Saddle Concrete	0.051	16	0.052	16	0.052	14	0.053	17	0.054	17	0.054	17	0.055	17	0.056	18	
Anchor Block Concrete	0.375	112	0.380	114	0.384	115	0.389	117	0.394	118	0.399	120	0.403	121	0.408	122	
Gutter Concrete	0.053	17	0.053	17	0.052	17	0.053	17	0.053	17	0.052	17	0.053	17	0.053	17	
Masonry Concrete	1.789	48	1.789	48	1.789	48	1.789	48	1.789	48	1.789	48	1.789	48	1.789	48	
Form Works	1.415	57	1.434	57	1.452	58	1.470	59	1.488	60	1.506	60	1.523	61	1.540	62	
Reinforcement Bar	0.012	12	0.013	12	0.014	13	0.014	13	0.014	13	0.014	13	0.014	13	0.014	13	
Miscellaneous Works	1	43	1	44		44		44		45		45		45		46	10% of above
Sub-total of (1)	10	478	10	481		485		488		492		495		499		502	
(2)Penstock Pipe	0.0609	396	0.0625	406	0.0641	416	0.0656	427	0.0672	437	0.0688	447	0.0704	457	0.0720	468	
(3)Administration Cost	2	157	2	160		162		165		167		170		172		175	10% of (1)+(2)
(4)Physical Contingency	1	82	1	84	0	85	0	87	0	88	0	89	0	90	0	91	
(A) Total of (1)+(2)+(3)+(4)		1,114		1,132		1,149		1,166		1,184		1,201		1,218		1,235	
2.Capital Recovery Factor to the Construction Cost																	
C.R.F=r(1+r)^n/((1+r)^n-1)		0.08174		0.08174		0.08174		0.08174		0.08174		0.08174		0.08174		0.08174	r=8%
3.O & M Ratio		0.01000		0.01000		0.01000		0.01000		0.01000		0.01000		0.01000		0.01000	n=50years
4.Annual Cost Ratio (2.+3.)		0.09174		0.09174		0.09174		0.09174		0.09174		0.09174		0.09174		0.09174	
5.Annual Cost (1.× 4.)		102.23		103.83		105.42		107.01		108.59		110.17		111.75		113.33	
6.Annual Minus Benefit (Cost)																	
(1)Loss Power of Output	0.013		0.011		0.010		0.009		0.008		0.007		0.006		0.006		
(2)Loss Rate of kW																	
(3)Loss Power and Benefit	0.013	1.871	0.011	1.632	0.010	1.424	0.009	1.246	0.007	1.087	0.007	0.988	0.006	0.864	0.006	0.760	
(4)Loss Energy of Output	115.32		100.41		87.72		75.90		67.62		59.05		52.77		46.81		
(5)Loss Rate of kWh																	
(6)Loss Energy and Benefit	109.67	6.800	95.49	5.930	83.42	5.172	72.13	4.534	64.31	3.987	56.73	3.517	50.13	3.111	44.51	2.780	
Total Cost (5.+6.(3)+6.(6))		110.904		111.776		112.017		112.791		113.673		114.660		115.730		116.847	

Table 8-16 Optimum Development Plan of Manuel Jorg No.4 Project

Item / Case	Unit	Description	Remarks
1. Catchment Area	km2	8.32	
2. Intake Water Level	EL.m	507.00	
3. Head Tank Water Level	EL.m	503.96	
4. Outlet Water Level	EL.m	388.4	Minus 2m of F.W.L
5. Gross Head	m	115.56	Hg=H.T.W.L-T.W.L
6. Effective Head	m	109.17	
7. Power Discharge			
Maximum Discharge	m3/s	0.310	
Peak Firm Discharge	m3/s	0.110	Qf×24/12hrs
Firm Discharge	m3/s	0.055	Qf: 97% Firm(355days)
8. Power Output			
Maximum Output	kW	230	
Firm Peak Output	kW	73.1	
Firm Output	kW	35.9	
9. Annual Energy Production	MWh	1,252.6	
10. Power structure			
Intake Dam (L×H)	m	11.0×2.0	
Headrace Channel (L×B)	m	1,150×0.57	
Slop of Headrace Channel		1/500	
Head Tank Storage Capacity	m3	2,400	12hrs×Qf×3,600sec
Penstock (Φ×L)	m	0.394×225.6	Maximum v= 2.54m/s
11. Electromechanical Equipment			
Type of Turbine		Cross flow	
Installed Capacity of Turbine	kW	253	
Type of Generator		3-phase synchronous	
Installed Capacity of Generator	kVA	290	
Transmission Line (kV×km)	km	30kV×5.5	1cct
12. Construction Period	year	1	

Table 8-18 Respective Case of Abade River Development Schemes

Item \ Case	Unit	Case-A	Case-B B-1	B-2	B-2'	Total	Case-C C-1	C-2	C-2'	Total	Remark
1. Catchment Area	km2	9.10	9.10	9.10	13.06	-	9.19	9.19	13.15	-	
Main Stream	km2	9.10	9.10	9.10	9.10	-	9.19	9.19	9.19	-	
Tributary	km2	-	-	-	3.96	-	-	-	3.96	-	
2. Intake Water Level	EL. m	551.50	551.50	430.00	430.00	-	511.50	428.60	428.60	-	
3. Head Tank Water Level	EL. m	548.00	548.00	428.60	428.60	-	508.90	428.60	428.60	-	
4. Outlet Water Level	EL. m	375.00	430.00	318.00	318.00	-	428.60	318.00	318.00	-	
						228.60				190.90	
5. Gross Head (H.T.W.L-T.W.L)	m	173.00	118.00	110.60	110.60	228.60	80.30	110.60	110.60	190.90	
6. Effective Head	m	167.60	113.70	107.30	106.00	221.00	74.60	107.30	106.00	181.90	
						219.70				180.60	
7. Power Discharge											
Maximum Discharge	m3/s	0.78	0.78	0.78	1.12	-	0.78	0.78	1.12	-	Qmax=Qf×3≒40days Q
Farm Discharge	m3/s	0.259	0.259	0.259	0.372	-	0.261	0.261	0.374	-	95%firm(≒345days)
8. Power Output						1,240				990	
Maximum Output	kW	940	640	600	850	1,490	390	600	850	1,240	
Farm Output	kW	298.6	203.2	190.8	273.5	394.0	118.3	192.5	276.0	310.8	
						476.7				394.3	
9. Annual Energy Production	MWh	4,850	3,300	3,100	4,400	6,400.0	2,020	3,130	4,460	5,150.0	
						7,700.0				6,470.0	
10. Power structure											
Intake Dam (L×H)	m	20×2.25	20×2.25	-	20×2.25		20×2.25	-	20×2.25		
Headrace Channel (L×B)	m	1,020×0.8	1,020×0.8	670×0.8	670×0.9		520×0.8	-	-		
Inlet Channel (L×B)	m	-	-	-	1,000×0.6		-	-	1,750×0.6		
Head Tank (L×B)	m	39.72×4.0	39.72×4.0	12.0×25.0	12.0×25.0		30.0×4.0	12.0×25.0	12.0×25.0		
Penstock (Φ×L)	m	0.7×557.0	0.7×385.0	0.7×220.0	0.85×220.0		0.7×670.0	0.7×220.0	0.85×220.0		
Tailrace (L×B)	m	0.7×5.0	-	0.7×10.0	0.85×10.0		-	0.7×10.0	0.85×10.0		
11. Electromechanical Equipment											
Type of Turbine		Pelton	Pelton	Pelton	Pelton		Cross flow	Pelton	Pelton		
Installed Capacity of Turbine	kW	1,044	711	667	944		433	667	944		
Type of Generator											
Installed Capacity of Generator	kVA	1,106	753	706	1,000		459	706	1,000		
Transmission Line (kVA×cct)	km	16.5	16.3	0.9	0.9		16.3	0.3	0.3		
12. Construction Cost	US$	7,888,764	5,826,569	4,490,220	6,173,358	10,316,789	3,694,720	4,068,458	5,989,585	7,763,178	
13. Construction Period	year	1	1	1	1		1	1	1		
14. Economical Index											
Costruction Cost per kW	US$/kW	8,392				8,320				7,842	
						8,055				7,810	
Costruction Cost per kWh	US$/kWh	1.63				1.61				1.51	
						1.56				1.50	
Benefit Cost Ratio (B)/(C.1)		0.450				0.454				0.484	
						0.469				0.488	
Benefit Cost Ratio (B)/(C.2)		4.124				4.161				4.437	
						4.306				4.475	
Benefit-Cost(C.1)	US$	-398,394				-517,176				-367,627	
						-584,199				-455,018	
Benefit-Cost(C.2)	US$	246,434				326,118				266,936	
						396,839				336,577	
Justifiable Investment Cost	US$	3,546,122				4,679,375				3,755,911	(B)/(0.08174+0.01)
						5,633,941				4,724,443	(B)/(0.01)
Necessary Aid Fund	US$	4,342,642				5,637,414				4,007,267	(A)-{(B)/(0.08174+0.01)}
						6,367,986				4,959,862	(A)-(B)/0.01

Table 8-19 Economical Comparision of Combined Abade River Development Schemes

Item	Unit	Case A	Case B (B-1)+(B-2)	Case B (B-1)+(B-2')	Case C (C-1)+(C-2)	Case C (C-1)+(C-2')	Remarks
1.Major Feature							
Catchment Area	km2	9.10	9.10	13.06	9.13	13.15	
Intake Water Level (No.1 P/S)	EL.m	551.50	551.50	551.50	511.50	511.50	
Intake Water Level (No.2 P/S)	EL.m	-	430.00	430.00	428.60	428.60	
Head Tank Water Level (No.1 P/S)	EL.m	548.00	548.00	548.00	508.90	508.90	
Head Tank Water Level (No.2 P/S)	EL.m	-	428.60	428.60	428.60	428.60	
Tailrace Water Level (No.1 P/S)	EL.m	375.00	430.00	430.00	428.60	428.60	
Tailrace Water Level (No.2 P/S)	EL.m	-	318.00	318.00	318.00	318.00	
Total Gross Head	m	173.00	230.00	230.00	190.90	190.90	H.T.W.L-T.W.L
Total Effective Head	m	167.60	221.00	219.70	181.90	180.60	
Maximum Discharge (No.1)	m3/sec	0.780	0.780	0.780	0.780	0.780	
Maximum Discharge (No.2)	m3/sec	0.780	0.780	1.120	0.780	1.120	
Firm Discharge (No.1)	m3/sec	0.259	0.259	0.259	0.261	0.261	
Firm Discharge (No.2)	m3/sec	-	0.259	0.372	0.261	0.374	
Maximum Output (No.1)	kW	940	640	640	390	390	
Maximum Output (No.2)	kW	-	600	850	600	850	
Total Maximum Output	kW	940	1,240	1,490	990	1,240	
Firm Output (No.1)	kW	298.6	203.2	203.2	118.3	118.3	97%(355days) Firm Output
Firm Output (No.2)	kW	-	190.8	273.5	192.5	276.0	
Total Firm Output	kW	298.6	394	476.7	310.8	394.3	
Total Annual Energy Production	MWh	4,850	6,400	7,700	5,150	6,470	
Construction Cost (A)	US$	7,888,764	10,316,789	12,001,927	7,763,178	9,684,305	excl. Interest during Construction
2.Economical Index							
a) Construction Cost per kW	US$/kW	8,392	8,320	8,055	7,842	7,810	
b) Construction Cost per kWh	US$/kWh	1.63	1.61	1.56	1.51	1.50	
c) Benefit							
Loss Factor of Effective Output	%	3.7	3.7	3.7	3.7	3.7	
Loss Factor of Effective Energy	%	5.7	5.7	5.7	5.7	5.7	
Effective Output	kW	287.6	379.4	459.1	299.3	379.7	
Effective Energy	MWh	4,573.6	6,035.2	7,261.1	4,856.5	6,101.2	
kW Value	US$/kW	145.23	145.23	145.23	145.23	145.23	
kWh Value	US$/kWh	0.062	0.062	0.062	0.062	0.062	
Benefit of kW	US$	41,761	55,103	66,670	43,467	55,145	
Benefit of kWh	US$	283,560	374,182	450,188	301,100	378,275	
Total Annual Benefit (B)	US$	325,321	429,285	516,858	344,567	433,420	
d) Cost							CRF=0.08(1+0.08)^50/
Capital Recovery Factor: CRF	%	8.174	8.174	8.174	8.174	8.174	{(1+0.08)^50-1}=
O & M Cost	%	1.000	1.000	1.000	1.000	1.000	0.08174
Total Annual Cost (C-1)	US$	723,715	946,462	1,101,057	712,194	888,438	Incl. Capital recovery cost
Total Annual Cost (C-2)	US$	78,888	103,168	120,019	77,632	96,843	excl. Capital recovery cost
c) Benefit Cost Ratio :(B)/(C-1)		0.450	0.454	0.469	0.484	0.488	
Benefit Cost Ratio :(B)/(C-2)		4.124	4.161	4.306	4.438	4.475	
d) Benefit - Cost : (B)-(C-1)	US$	-398,394	-517,176	-584,199	-367,627	-455,018	
Benefit - Cost : (B)-(C-2)	US$	246,434	326,118	396,839	266,936	336,577	
e) Justifiable Investment Cost	US$	3,546,122	4,679,375	5,633,941	3,755,911	4,724,443	(B)/(0.08174+0.01)
f) Necessary Aid Fund	US$	4,342,642	5,637,414	6,367,986	4,007,267	4,959,862	(A)-{(B)/(0.08174+0.01)}

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$

Table 13-2 Summary of Potential Socio-economic Environmental Impacts and Their Preventions and Mitigations

Socio-economic Environmental Factors	Potential Impacts	Remarks (Description of the potential impacts and measures to prevent/mitigate the impacts)
1. Resettlement of villagers		
(1) Reservoir area	△	No villagers are living in the reservoir area.
(2) Water reduction area	△	No villagers are living in the water reduction area.
2. Industries		
(1) Agriculture		
1) Project area	O	The routes and space for construction of headrace channel and headtank will need some land and to cut some plantation trees. Compensation will be needed.
2) Downstream area	△	No impacts will be incurred to the downstream area.
(2) Forestry	△	Only a few trees would be cut.
(3) Fishery	△	No fishes are existing in the river.
(4) Manufacturing / mining	△	No manufacturing or mining industry is existing.
(5) Tertiary industry (handcraft, tourism, etc.)	△	No such industry is existing.
3. Transportation	△	Impact of construction of an access road is moderate and will improve transportation network of this area.
4. Other infrastructure		
(1) Education	△	No school is existing in the project area.
(2) Public health	△	No water born disease could be induced due to very smal scale of the reservoir.
(3) Cultural assets	△	No cultural assets are existing in the project area.
5. Water utilization		
(1) Project area amd its vicinity	O	The villages such as Milagrosa and Santa Clara are using the river water for drinking and plantation. Prior agreement between EMAE and the villagers for reasonable sharing of the river water must be achieved.
(2) Downstream area	O	Water quality of the discharge water from powerhouse shall be kept acceptable by preventing leakage of oil and other substances.

(Legend) ● : Significant impact O : Moderate impact △ : Negligible or no impact

Table 13-3 Summary of Potential Natural Environmental Impacts and Their Preventions and Mitigations

Natural Environmental Factors	Potential Impacts	Remarks (Description of the potential impacts and measures to prevent/mitigate the impacts)
1. Topography		
(1) Sedimentation in reservoir	△	Upstream of the reservoir is rich in forest and therefore the soil condition is stable.
(2) Impact on downstream waterway	△	Scale of the project is very small and therefore the impact to downstream is negligible.
(3) Impact to coastal area	△	No direct impact due to existing of Gue Gue power station.
2. Soil condition		
(1) Slope collapse	O	Measures must be taken to prevent slope collapse along the routes of headrace and penstock.
(2) Soil erosion	△	Water leakage from headrace must be avoid to prevent soil erosion along its route.
3. River water		
(1) Change in water system	△	No change to water way.
(2) Impact to water quality	O	Impact can be avoided by good maintenance of the powerhouse.
4. Biosphere		
(1) Impact to flora	△	Impact is negligible due to small scale of the project.
(2) Impact to fauna	△	Impact is negligible due to small scale of the project.
(3) Impact to aquaic organisms	△	No valuable aquatic organisms are existing in the project area.
(4) Impact to protected /valuable flora and fauna	△	No such flora and fauna are existing.
5. Impact on national and natural parks	△	No such parks are existing.
6. Atmosphere		
(1) Air polution during construction	O	Measures must be taken to mitigate dust generation.
(2) Offensive odors	△	No offensive odors will be generated.
7. Noise and vibration	O	Measures must be taken to mitigate the noise and vibration to be occured during construction and plant operation.

(Legend) ● : Significant impact O : Moderate impact △ : Negligible or no impact

Table14-1 Economical Evaluation

Item	Unit	Optimal Case	Remarks
Maximum Output	kW	230	
Firm Peak Output	kW	76.5	12hrs peak generation
Firm Output	kW	36.4	97%(355days) Firm Output
Annual Energy Production	MWh	1,253	
Construction Cost (A)	US$	4,753,517	excl. Interest during Construction
2. Economical Index			
a) Construction Cost per kW	US$/kW	20,667	
b) construction Cost per kWh	US$/kWh	3.79	
c) Benefit			
Loss Factor of Effective Output	%	2.9	
Loss Factor of Effective Energy	%	4.9	
Effective Output	kW	35.3	
Effective Energy	Mwh	1,191.2	
kW Value	US$/kW	146.4	
kWh Value	US$/kWh	0.062	
Benefirt of kW	US$	5,174	
Benefit of kWh	US$	73,856	
Total Annual Benefit (B)	US$	79,030	
d) Cost			CRF=0.08(1+0.08)^50/
Capita Recovery Factor : CRF	%	8.174	{(1-0.08)^50-1}=0.08174
O & M Cost	%	1.000	
Total Annual Cost (C-1)	US$	436,088	incl. Capital recovery cost
Total Annual Cost (C-2)	US$	47,535	excl. Capital recovery cost
c) Benefit Cost Ratio : (B) / (C-1)		0.181	
Benefit Coct Ratio : (B) / (C-2)		1.663	
d) Benefit - Cost : (B)-(C-1)	US$	-357,057	
Benefit - Cost : (B)-(C-2)	US$	31,495	
e) Justifiable Investment Cost	US$	861,459	(B)/(0.0874)-0.01)
f) Necessary Aid Fund	US$	3,892,058	(A)-{(B)/(0.08174-0.01)}

Table14-5 Sensitivity Analysis --- FIRR for 35 years

（Unit：%）

EMAE負担率	電気料金(c/kWh)								
	15c/kWh	14c/kWh	13c/kWh	12c/kWh	11c/kWh	10c/kWh	9c/kWh	8c/kWh	7c/kWh
5%	28.10	25.45	22.79	20.09	17.36	14.57	11.67	8.39	4.13
6%	23.87	21.64	19.38	17.10	14.77	12.37	9.82	6.74	2.83
7%	20.81	18.87	16.91	14.91	12.87	10.75	8.31	5.38	1.86
8%	18.49	16.76	15302	13.24	11.40	9.41	7.09	4.30	1.10
9%	16.65	15.10	13.52	11.90	10.21	8.27	6.05	3.42	0.49
10%	15.17	13.75	12.30	10.81	9.16	7.30	5.14	2.70	-0.02
15%	10.51	9.41	8.21	6.92	5.46	3.89	2.21	0.39	-1.61
20%	7.71	6.73	5.63	4.46	3.24	1-95	0.59	-0.87	-2.45
50%	0.95	0.38	-0.19	-0.79	-1.40	-2.04	-2.70	-3.37	-4-08
100%	-1.90	-2.23	-2.55	-2.89	-3.23	-3.57	-3.93	-4.29	-4.65

Financial Summary

(Unit：US$)

EMAE負担率 電気料金	100% 15c/kWh	50% 15c/kWh	20% 15c/kWh	15% 15c/kWh	15% 10c/kWh	7% 10c/kWh	5% 10c/kWh
FIRR	-1.90%	0.95%	7.71%	10.51%	3.89%	10.75%	14.75%
借入金	4,754,000	2,377,000	950,800	713,100	713,100	332,780	237,700
税引前利益	-435,057	-175,547,	-19,841	6,110	-37,731	3,791	14,170
税引後利益	-435,057	-175,547	-19,841	4,277	-37,731	2,653	9,920
ROE税引前	-9-15%	-7.39%	-20.9%	0.86%	-2.29%	1.14%	5.96%
ROE税引後	-9.15%	-7.39%	-2.09%	0.60%	-5.29%	0.80%	4.17%
現金収支単年	-296,357	-106,197	7,899	25,082	-16,926	12,362	16,855
現金収支累計	-1968,302	-732,262	9,362	130,525	-130,080	64,857	94,473
借入金返済年	237,700	118,850	47,540	35,655	35,655	16,639	11,885

税引き前利益から現金収支累計までの数字は借入金返済が開始される前年の操業開始後６年目の数字である。

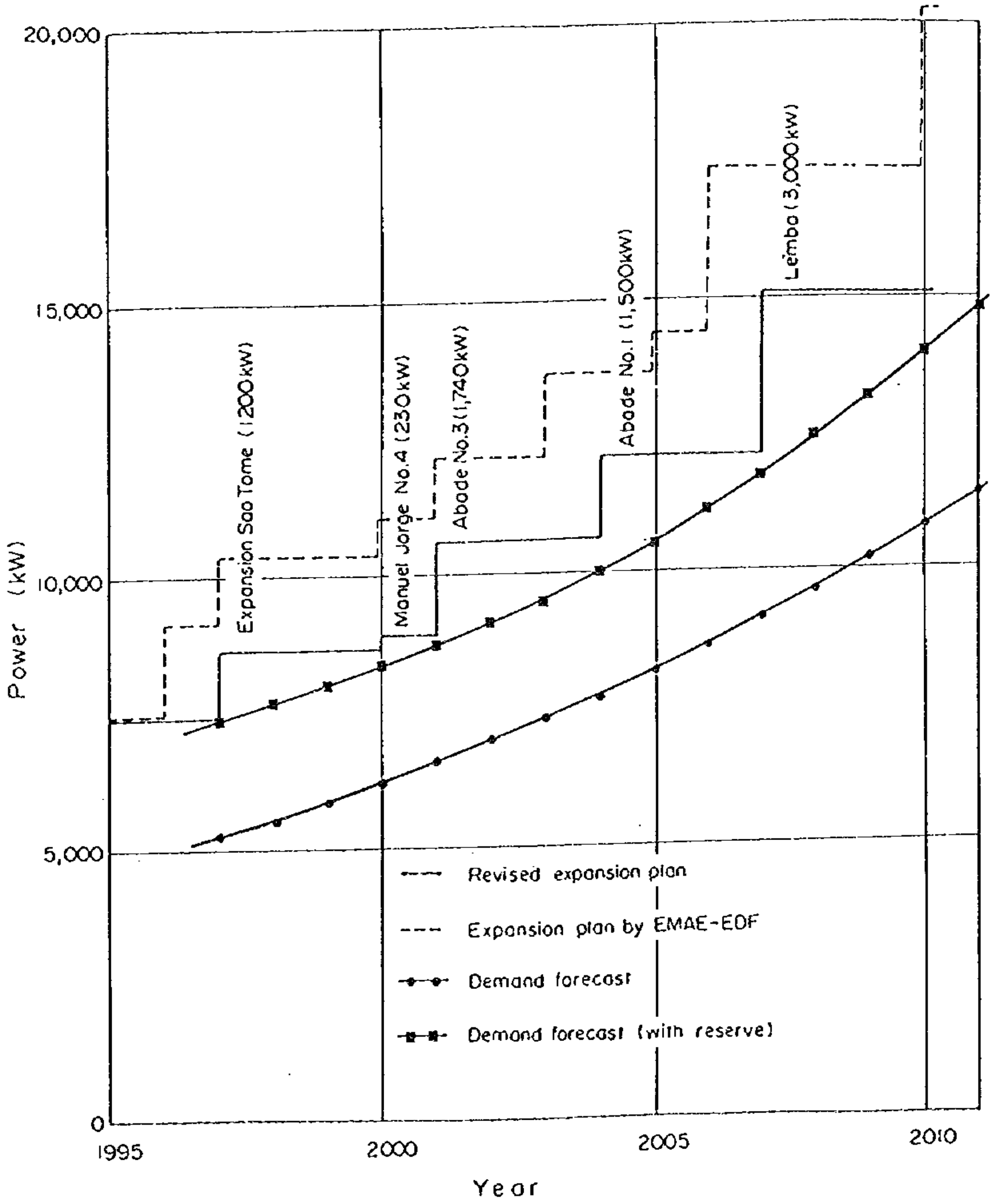


Fig. 5-3 Power Balance

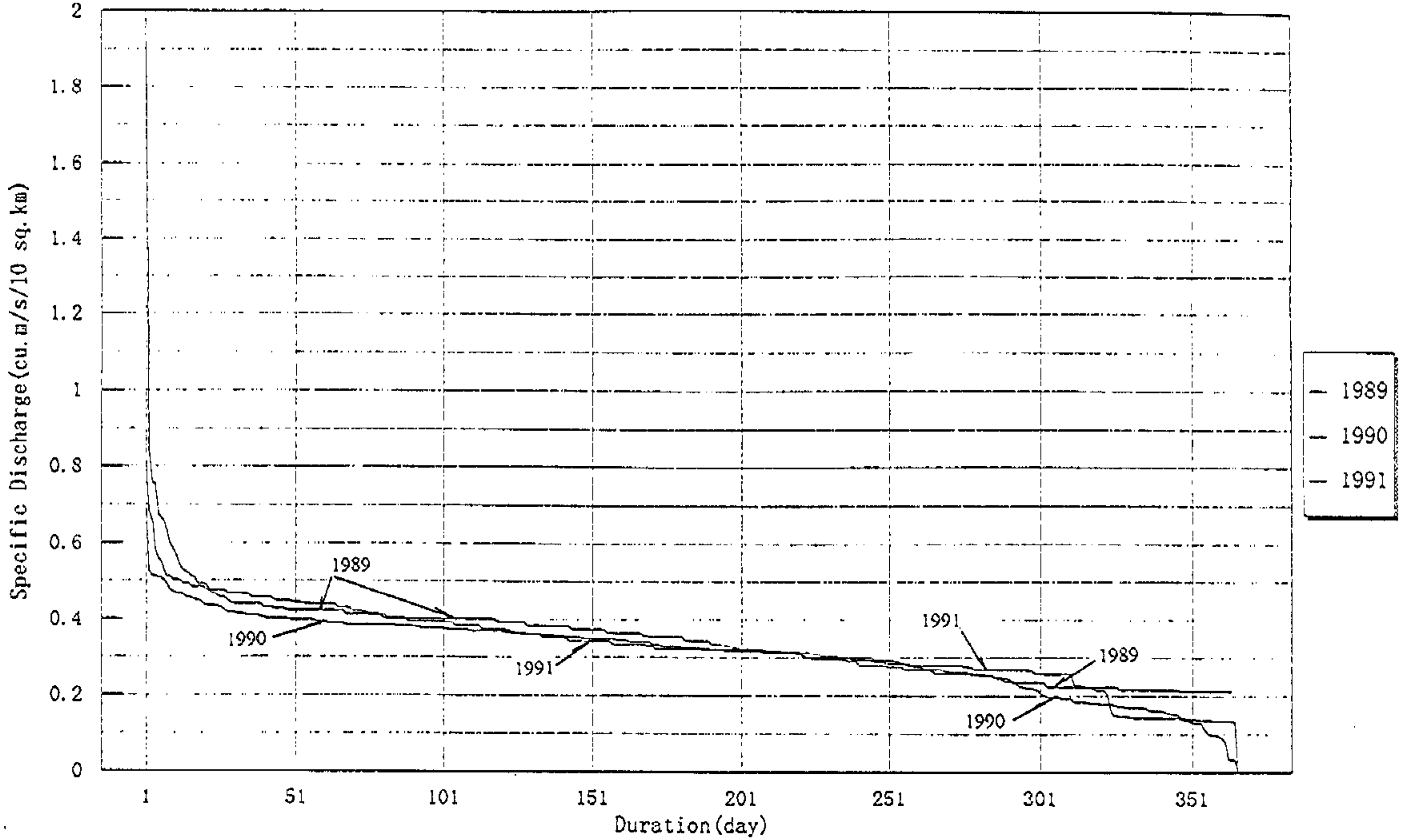
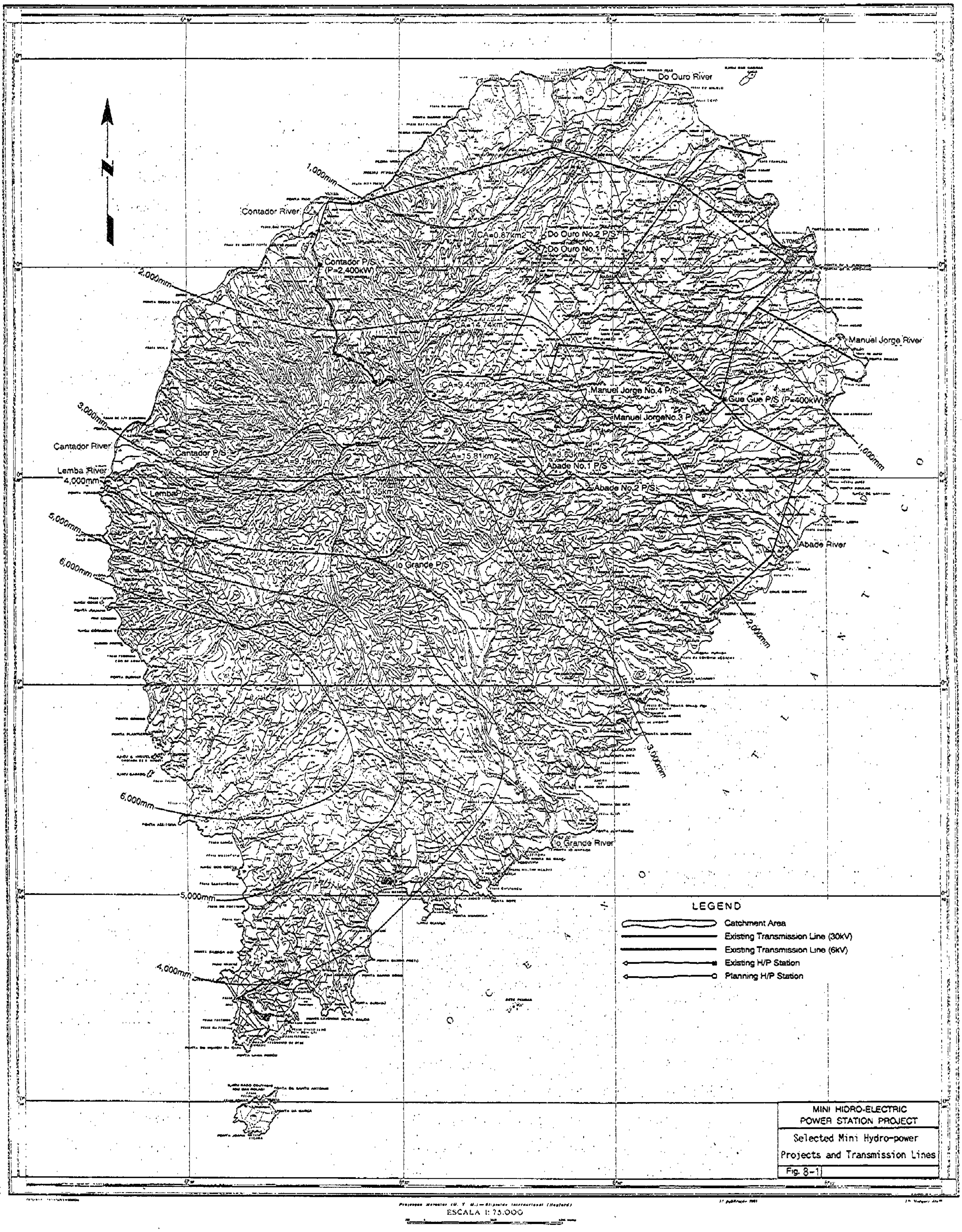


Fig. 7-10 Duration Curve of Specific Daily Discharge at Pian-Pian G.S.on the Manuel Jorge River
Year:1989-1991

CARTA DA ILHA DE S. TOMÉ



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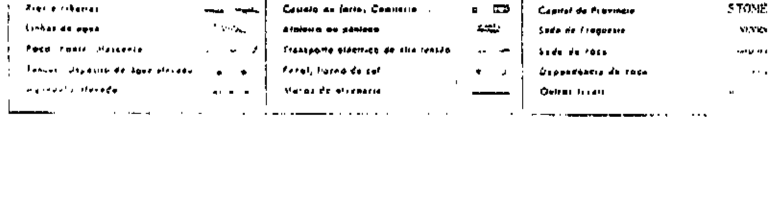
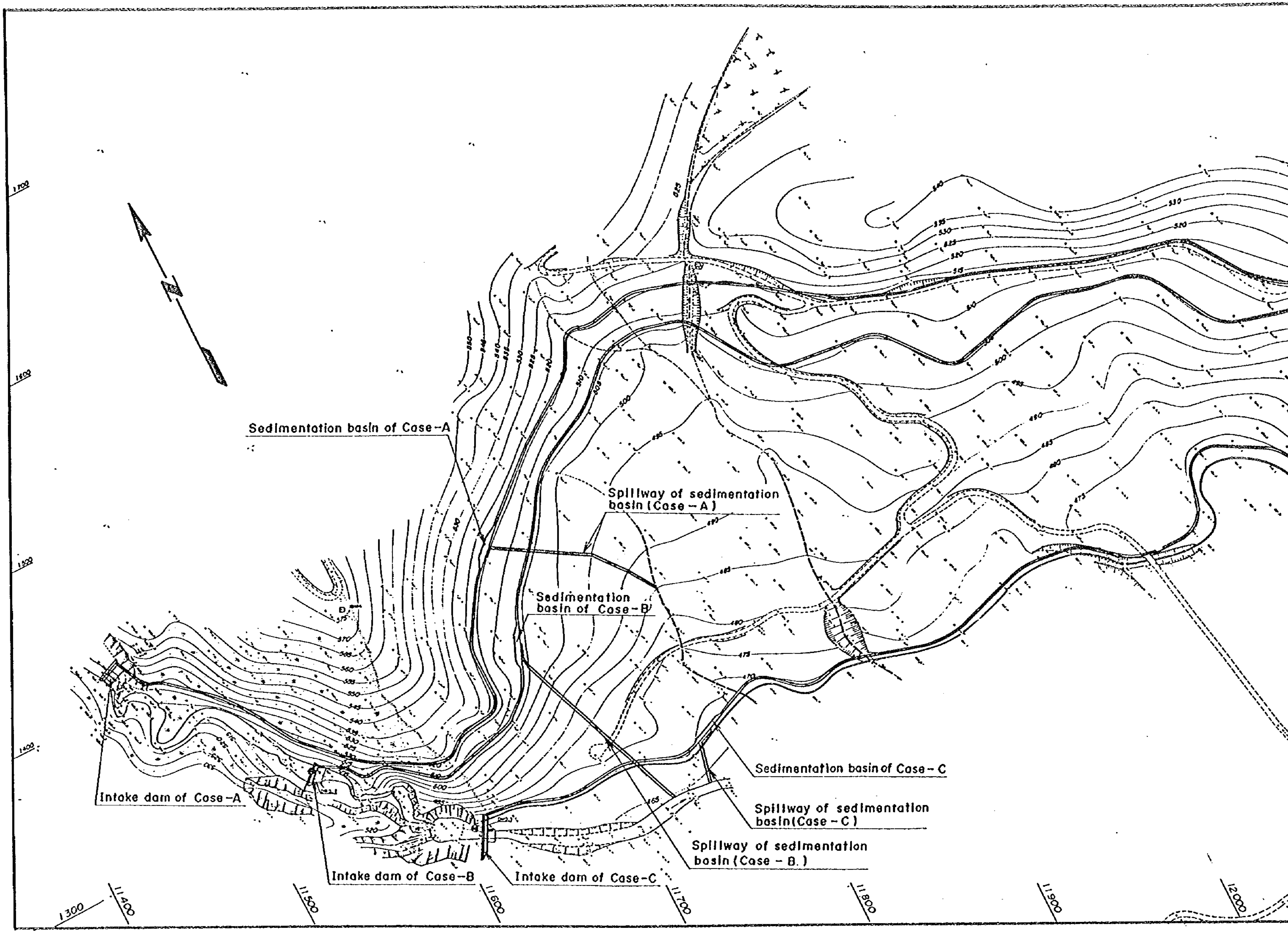
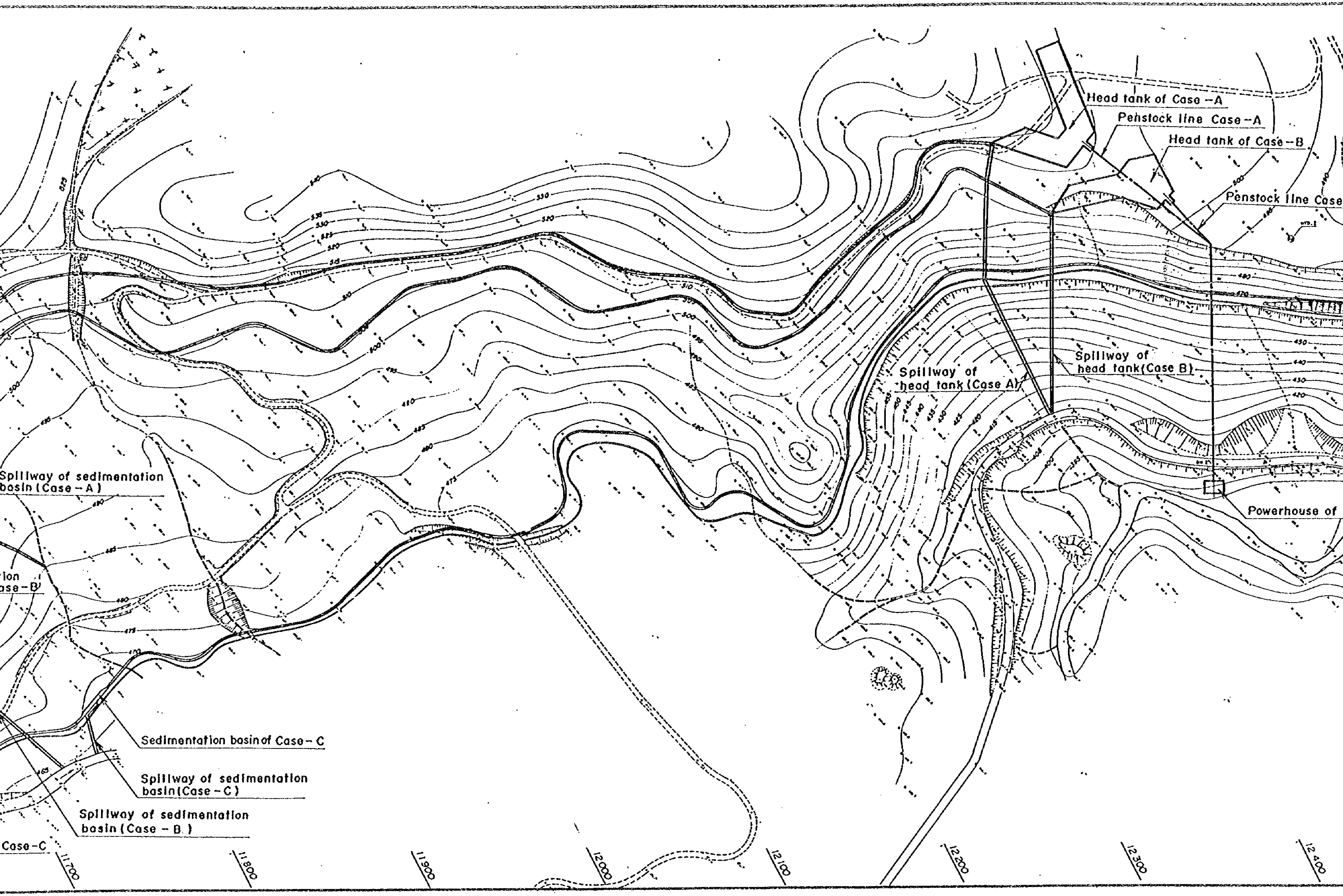
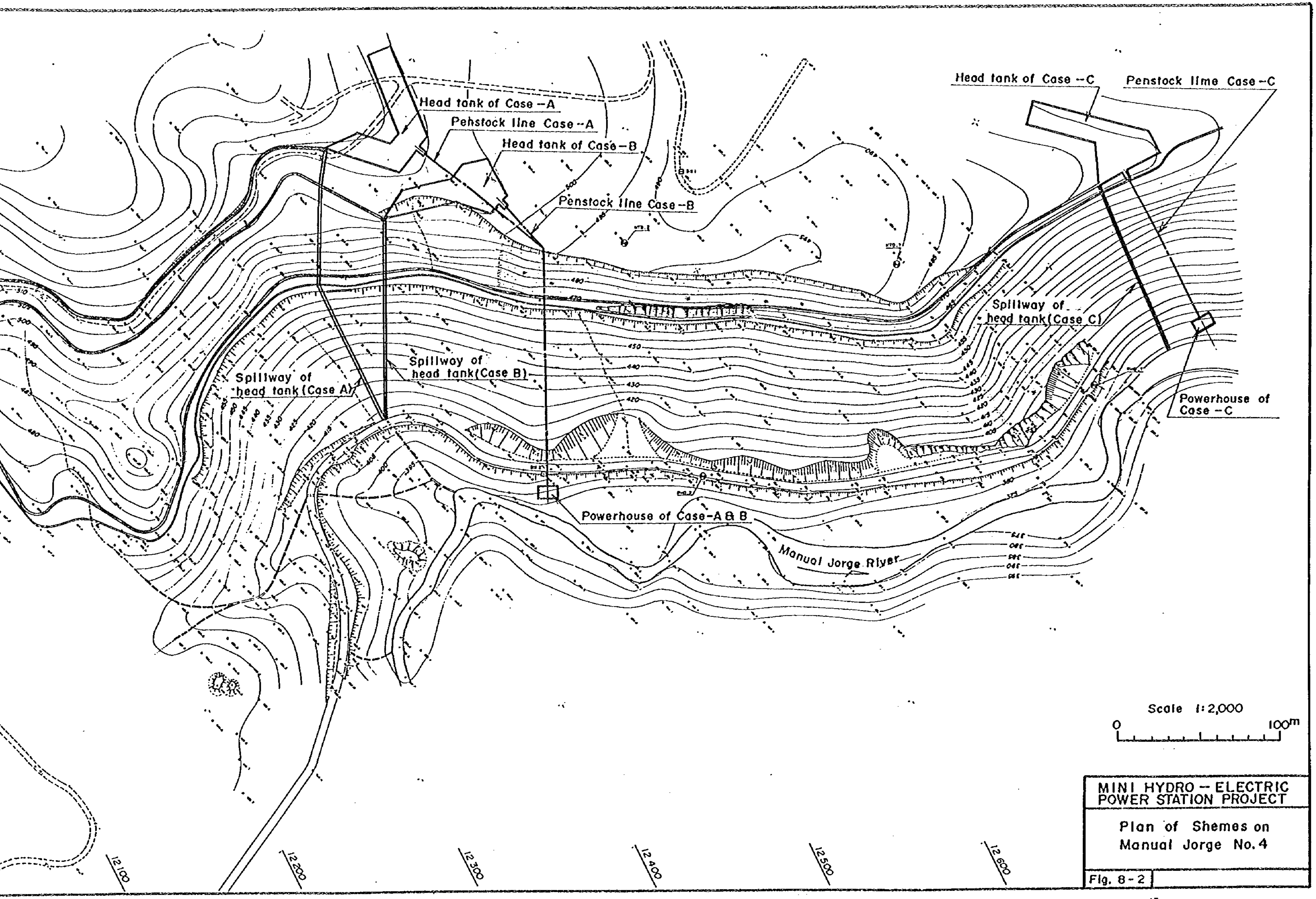
CONVENÇÕES





Sedimentation basin of Case-A
Spillway of sedimentation basin (Case-A)
Sedimentation basin of Case-B
Sedimentation basin of Case-C
Spillway of sedimentation basin (Case-C)
Spillway of sedimentation basin (Case-B.)
Intake dam of Case-A
Intake dam of Case-B
Intake dam of Case-C
1300
11400
11500
11600
11700
11800
11900
12000

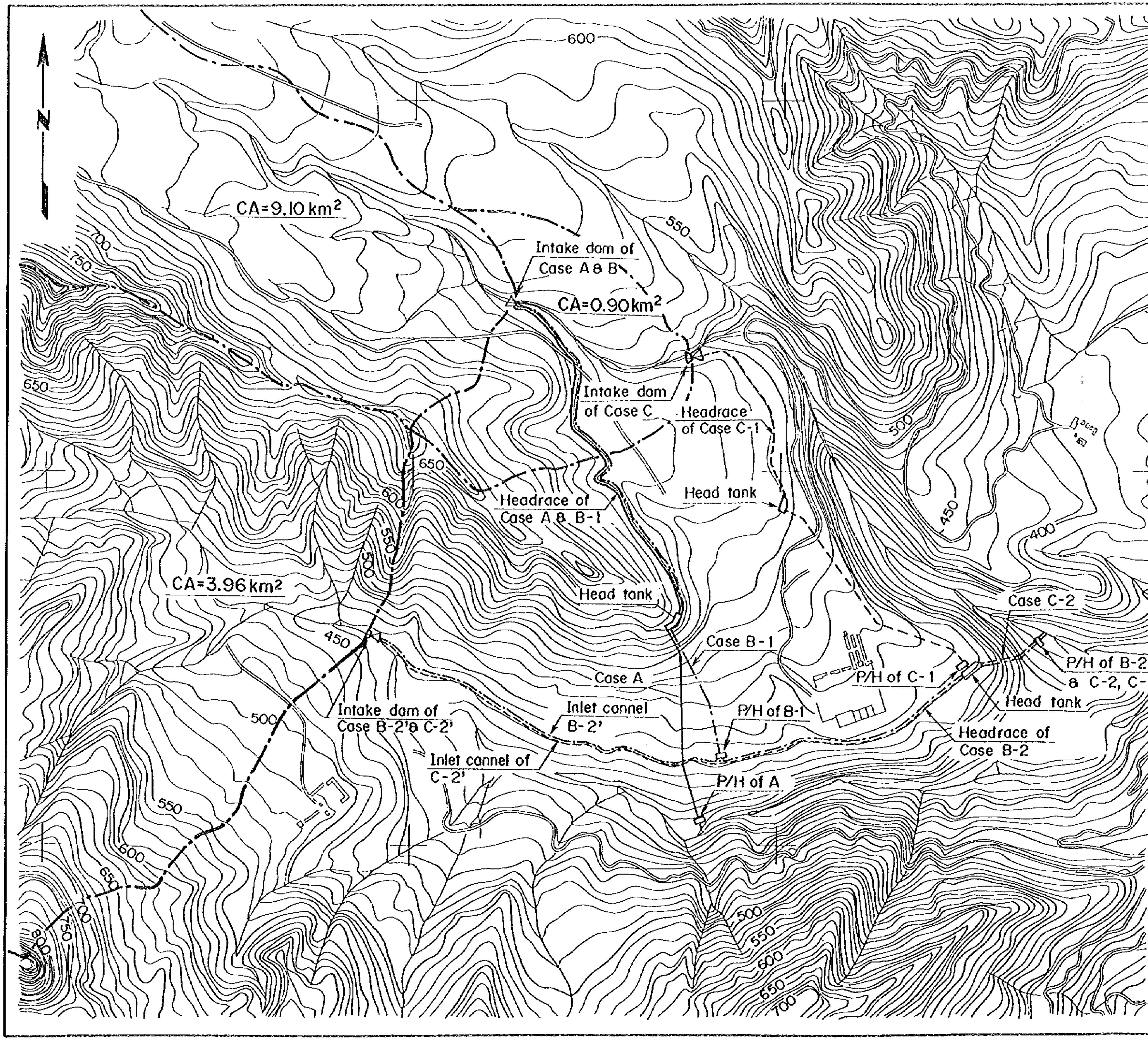

Head tank of Case - A
Penstock line Case - A
Head tank of Case - B
Penstock line Case
Spillway of head tank (Case B)
Spillway of head tank (Case A)
Powerhouse of
Spillway of sedimentation basin (Case - A)
ion
ase - B
Sedimentation basin of Case - C
Spillway of sedimentation basin (Case - C)
Spillway of sedimentation basin (Case - B)
Case - C
11,700
11,800
11,900
12,000
12,100
12,200
12,300
12,400



MINI HYDRO -- ELECTRIC POWER STATION PROJECT

Plan of Shemes on Manual Jorge No. 4

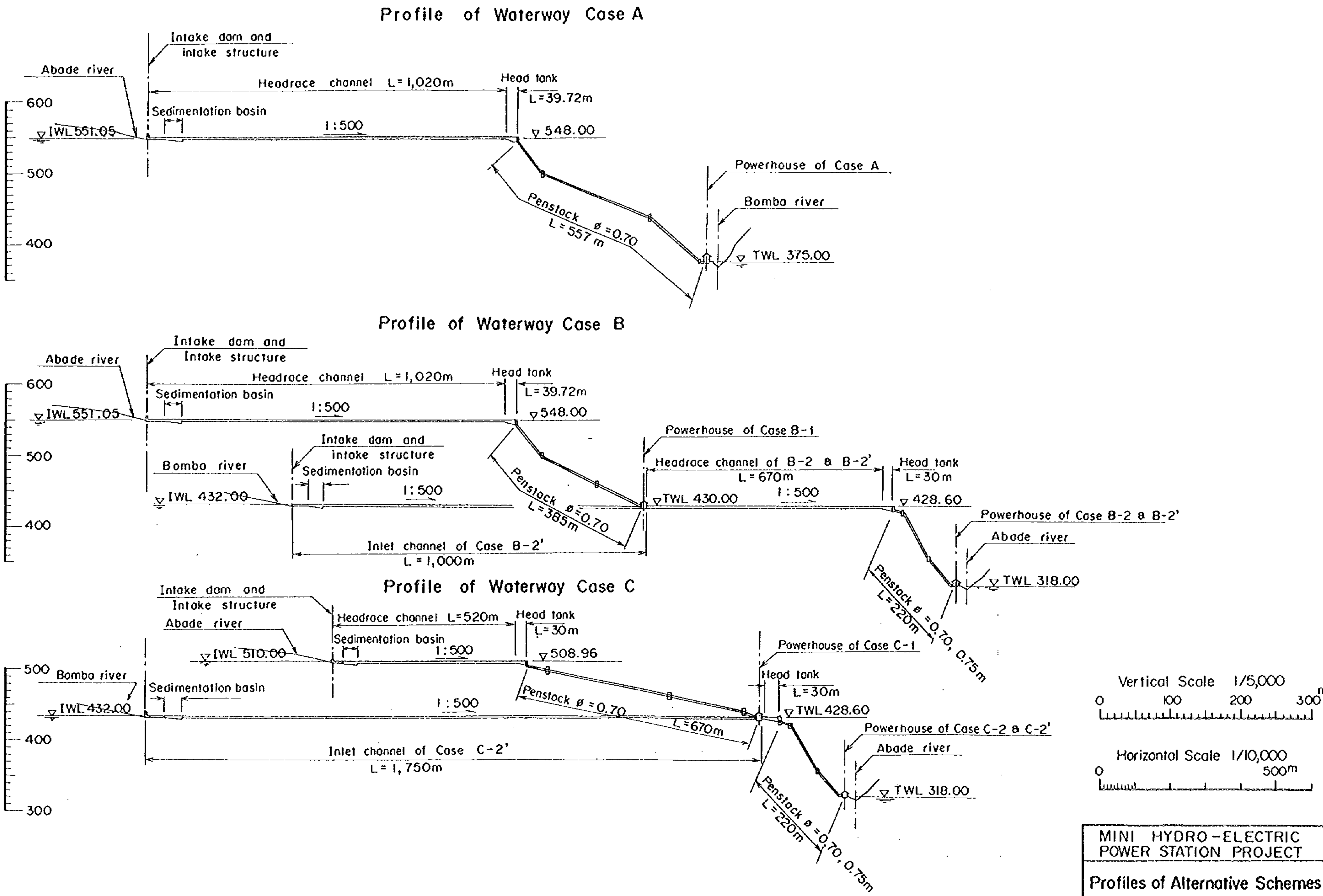
Fig. 8-2



MINI HYDRO-ELECTRIC POWER STATION PROJECT

Plans of Alternative Schemes Abade River

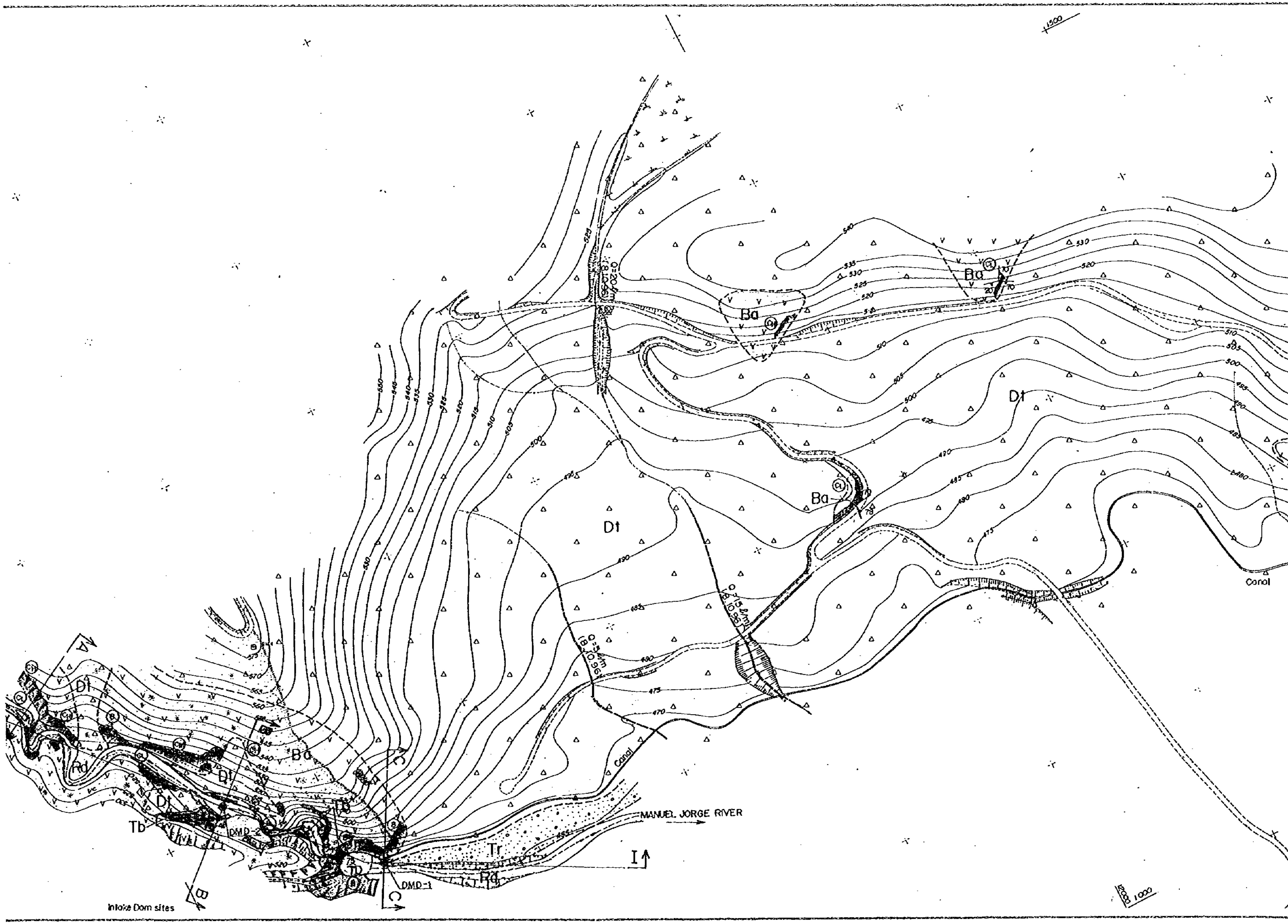
Fig. 8-9



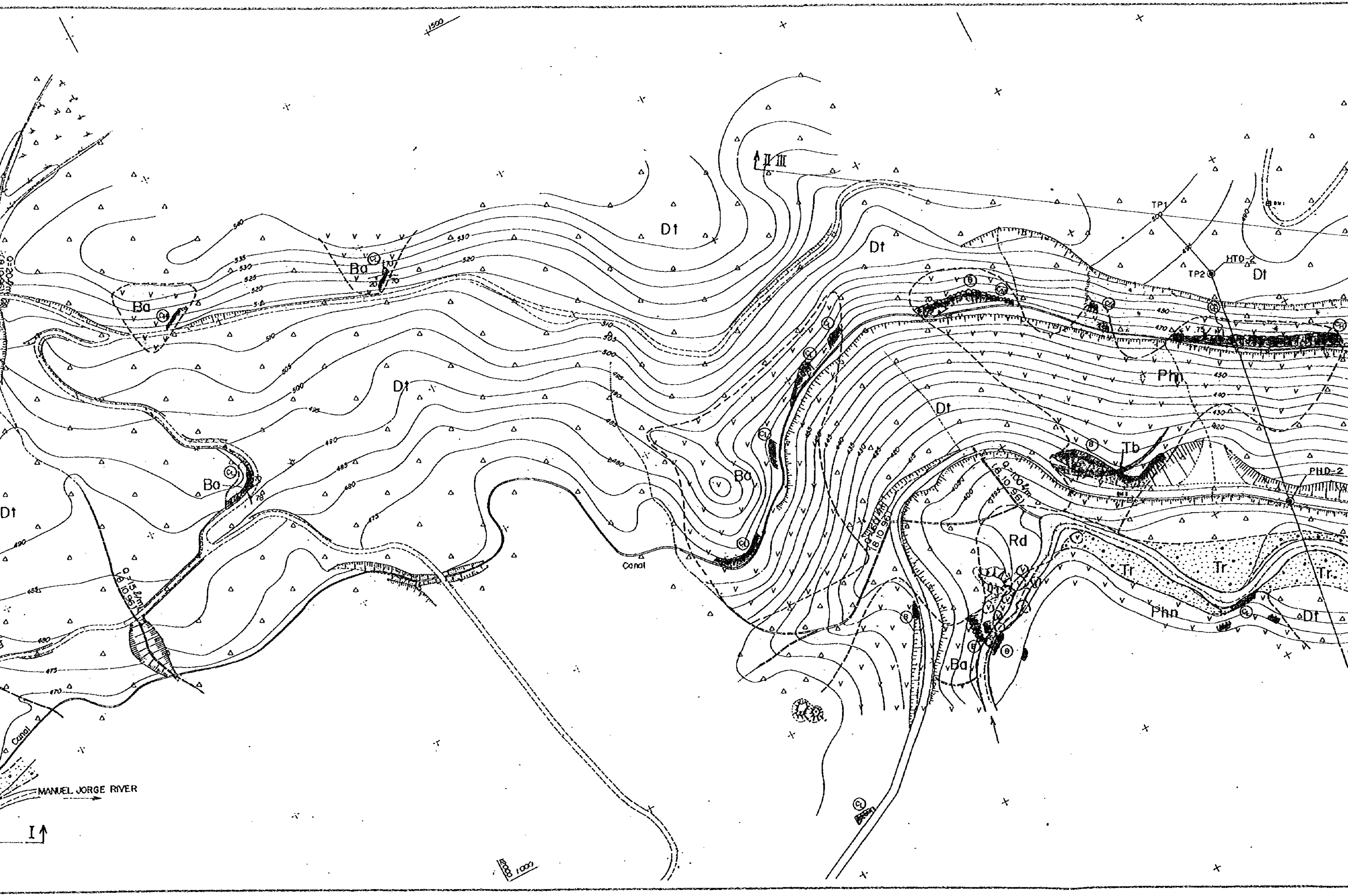
MINI HYDRO-ELECTRIC POWER STATION PROJECT

Profiles of Alternative Schemes Abade River

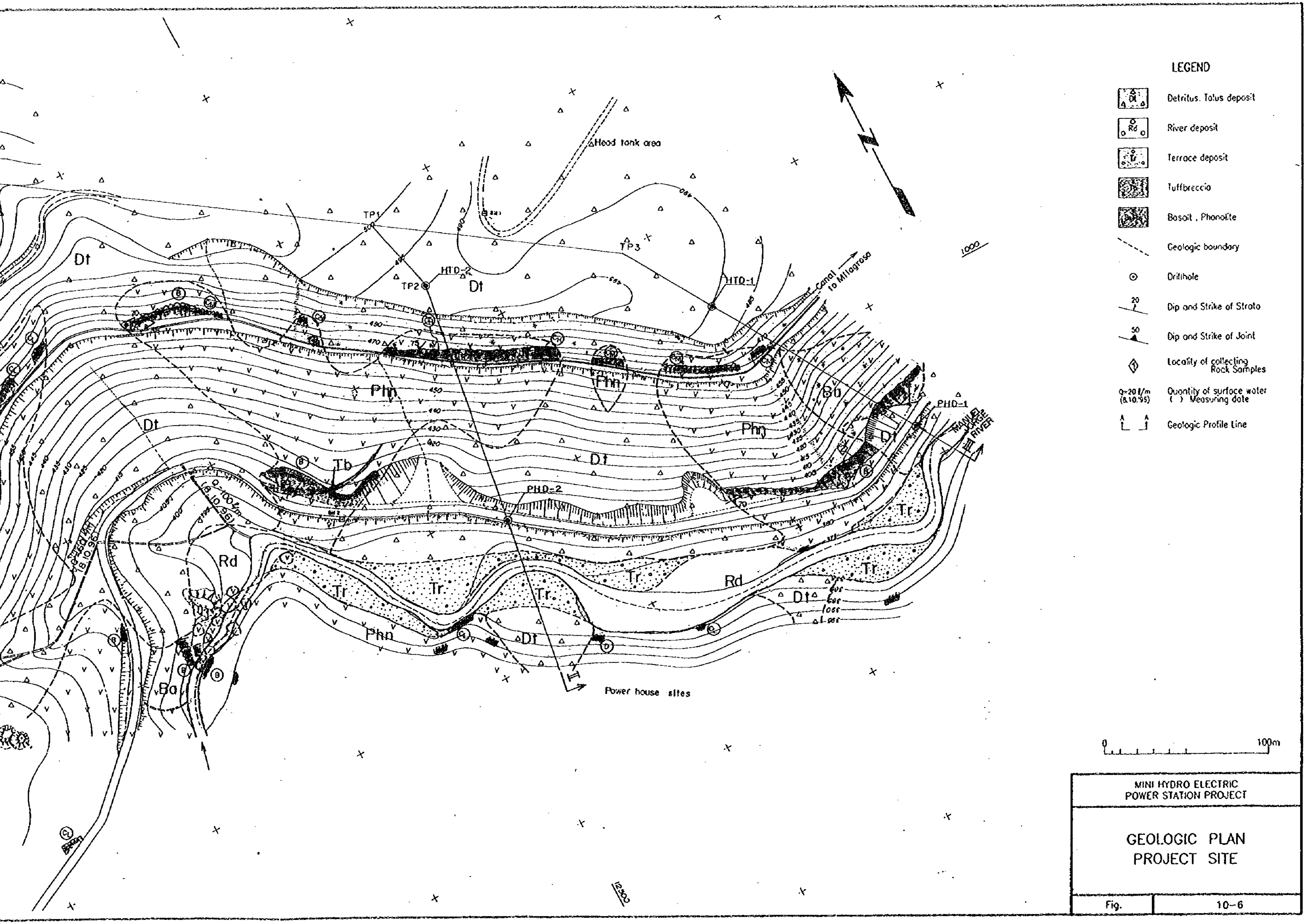
Fig. 8-10

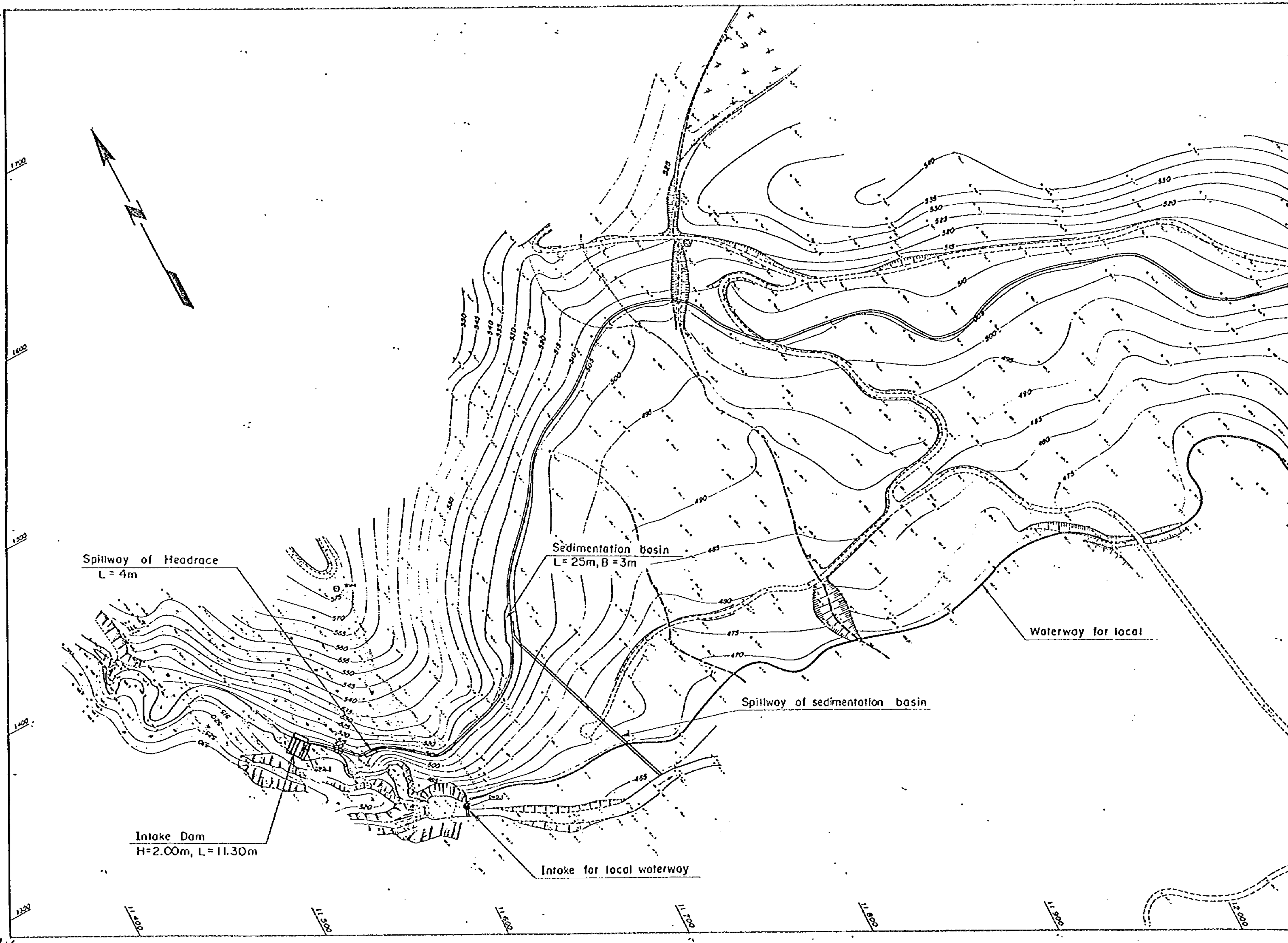


Dt
Ba
Tr
Rd
Tb
Canal
MANUEL JORGE RIVER
DMD-1
DMD-2
Intake Dam sites

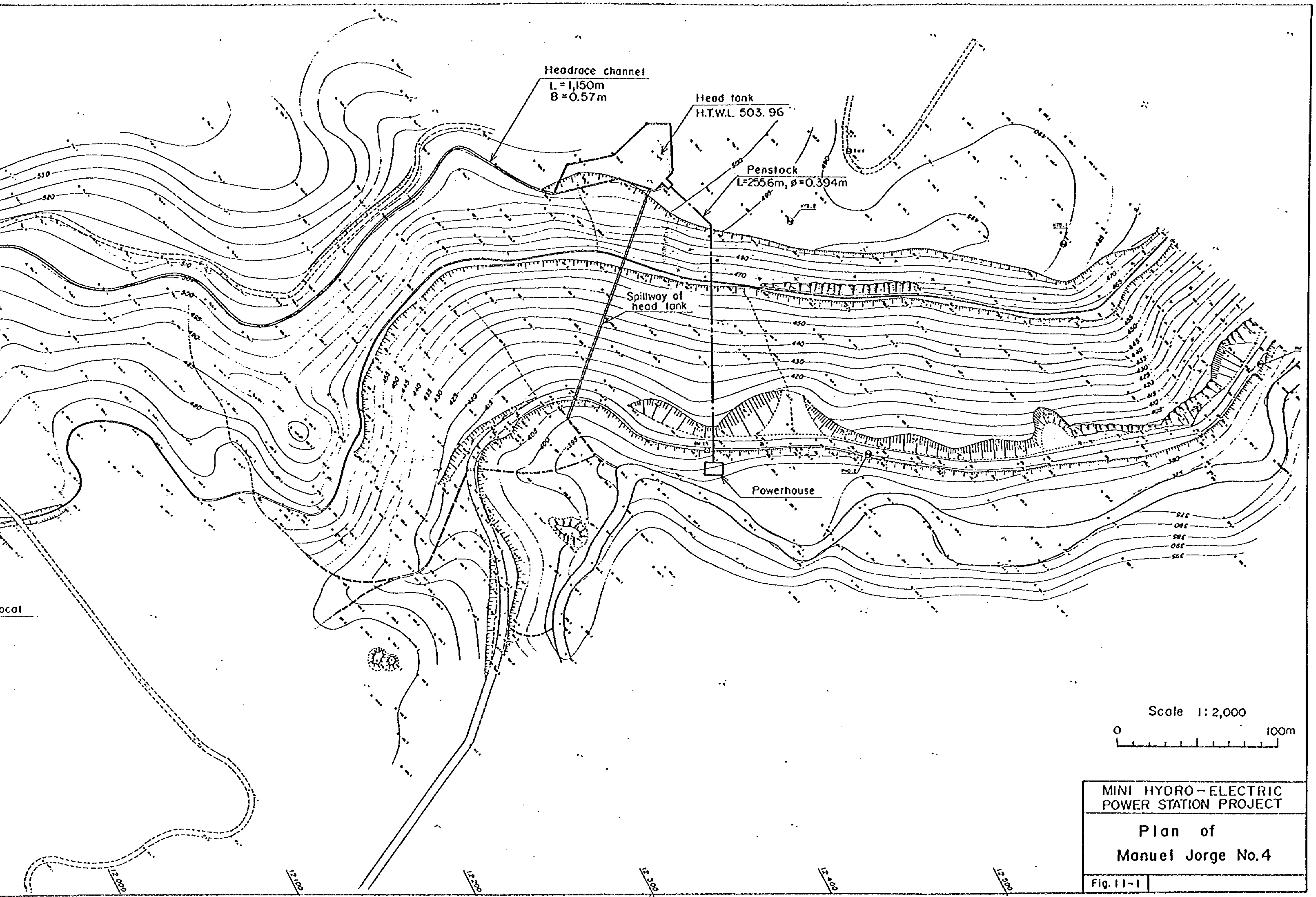


Dt
Ba
Phn
Tb
Rd
Tr
Canal
MANUEL JORGE RIVER
TP1
TP2
HTO-2
PHD-2
I
II III


LEGEND
Detritus. Talus deposit
River deposit
Terrace deposit
Tuffbreccia
Basalt , Phonolite
Geologic boundary
Drillhole
Dip and Strike of Strata
Dip and Strike of Joint
Locality of collecting Rock Samples
Quantity of surface water ( ) Measuring date
Geologic Profile Line
Head tank area
TP1
TP2
TP3
HTD-2
HTD-1
PHD-2
PHD-1
Canal to Milagrosa
MANUEL JORGE RIVER
Power house sites
Dt
Phn
Tb
Rd
Tr
Ba
0
100m
MINI HYDRO ELECTRIC POWER STATION PROJECT
GEOLOGIC PLAN PROJECT SITE
Fig. 10-6



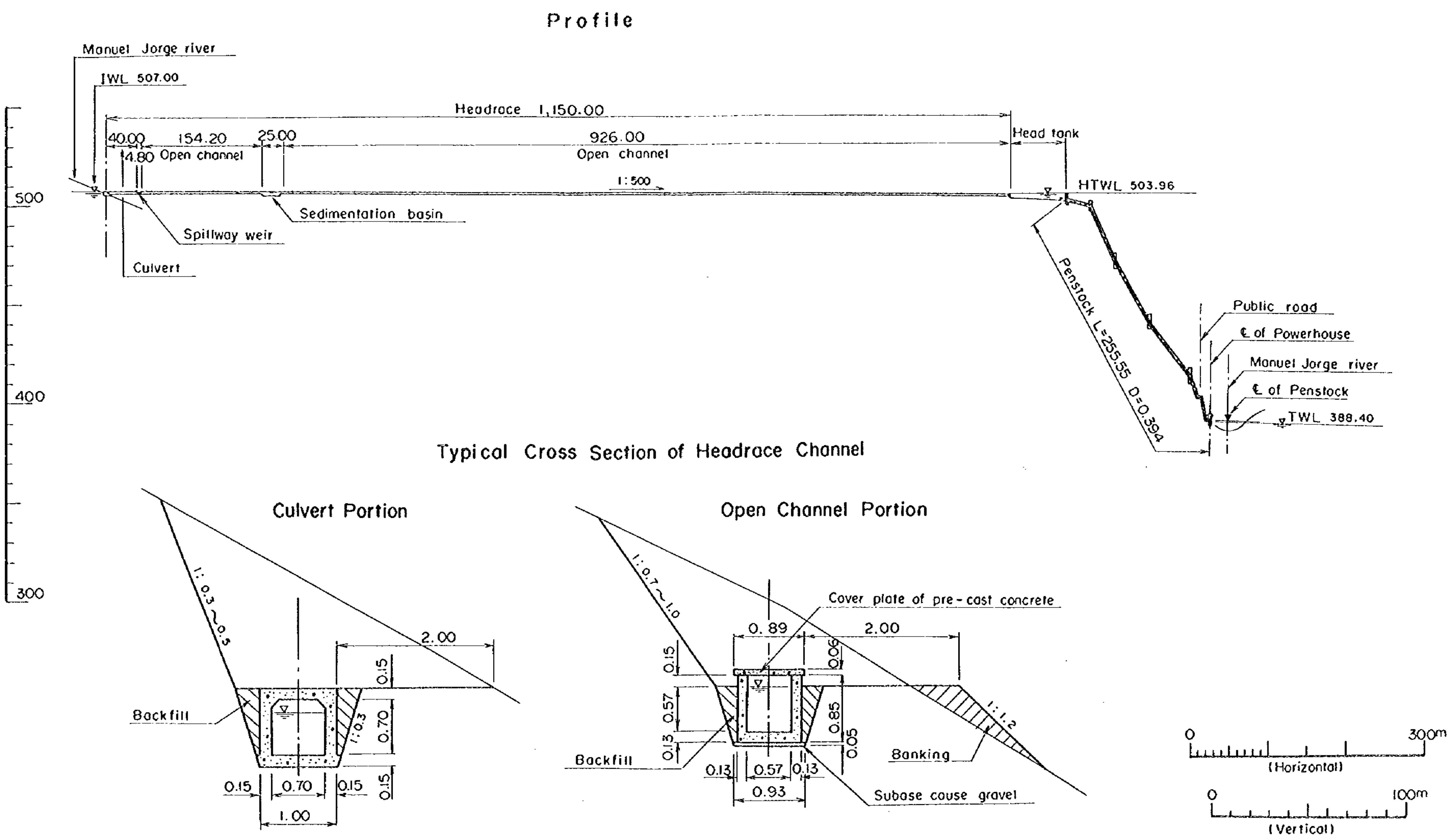
Spillway of Headrace
L = 4m
Sedimentation basin
L= 25m, B =3m
Waterway for local
Spillway of sedimentation basin
Intake Dam
H=2.00m, L=11.30m
Intake for local waterway



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

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

JICA