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

MAIN REPORT

March 1997

EPDC International Ltd.

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PREFACE

In response to a request from the Government of the Democratic Republic of Sao Tome and Principe, the Government of Japan decided to conduct a feasibility study on Feasibility Study on Construction of Mini Hydro-Electric Power Station Project and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Sao Tome and Principe a study team headed by Mr. Shozo YUZAWA of EPDC International Ltd. 5 times during the period from February 1996 to February 1997.

The team held discussions on the project with officials and engineers concerned of the Government of Sao Tome and Principe, and conducted field surveys at the study area. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials and engineers concerned of the Government of the Sao Tome and Principe for their close cooperation extended to the team.

February 1997

Kimio Fujita
President
Japan International Cooperation Agency

March 1997

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Fujita,

Letter of Transmittal

We are pleased to submit to you the feasibility report on the Construction of Mini Hydro-electric Power Station in the Democratic Republic of Sao Tome and Principe. This report contains the advice and suggestions of the authorities concerned of the Government of Japan and your Agency, as well as those of the Government of Sao Tome and Principe.

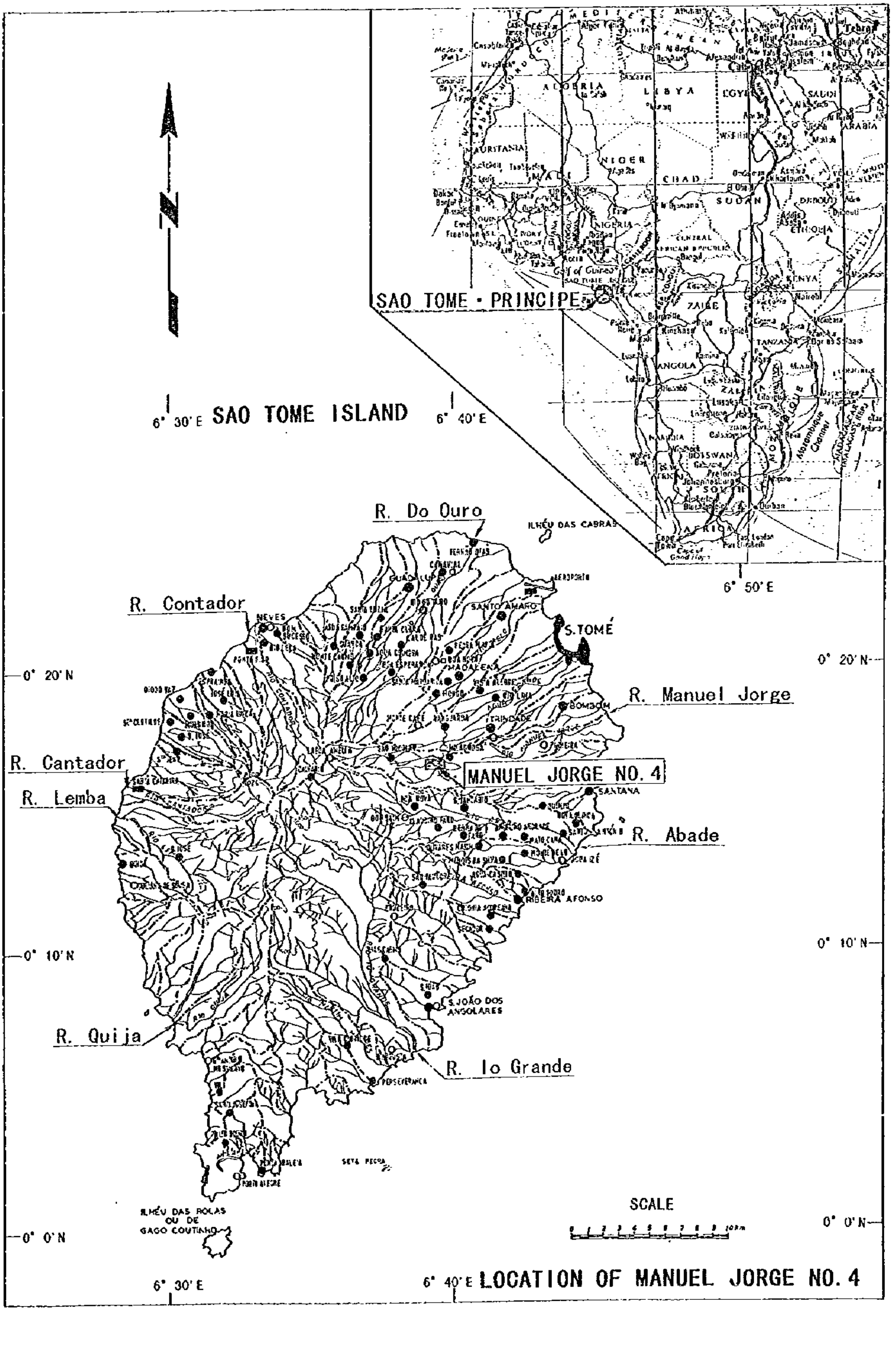
The Study Team, with the cooperation of the Ministerio do Equipament Social e Ambient of Sao Tome and Principe, carried out five field surveys from February 1996 to February 1997, and made the home works in Japan during the same period. The process in which six rivers are selected for the mini hydroelectric potential ones, and the feasibility studies on Manuel Jorge No. 4 selected, are covered in the present report.

We sincerely hope that this report will serve to push forward the earliest implementation of the present project, and the improvement and strengthening of the electric power supply capability of the Sao Tome areas, and thereby lead to the promotion of electric power development in Sao Tome and Principe.

We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs and the Ministry of International Trade and Industry. We also wish to express our deep gratitude to the authorities concerned of the Government of Sao Tome and Principe for the close cooperation and assistance extended to us during our study.

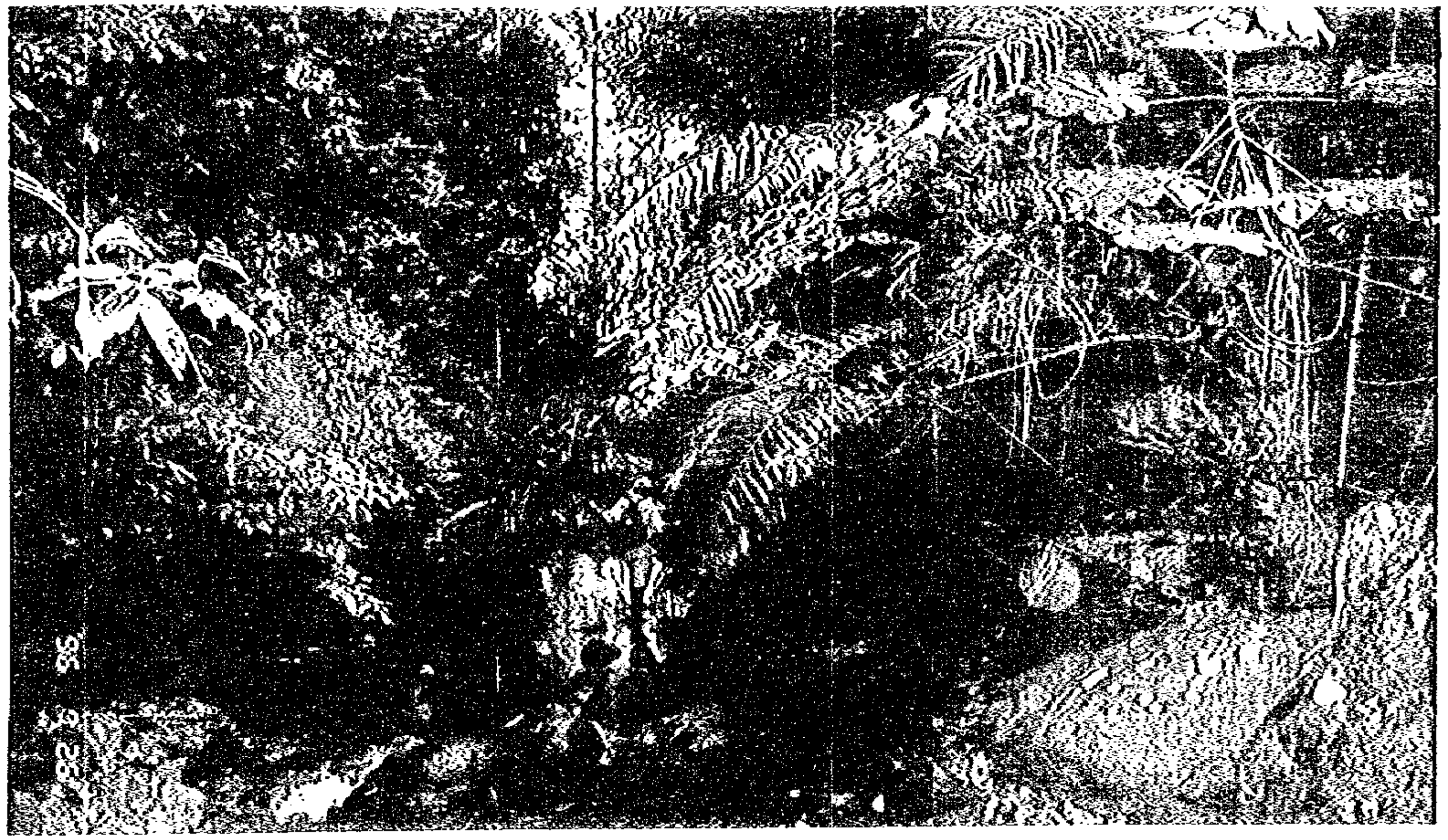
Very truly yours,

Shozo Yuzawa
Team Leader
Mini Hydroelectric Power Station Project

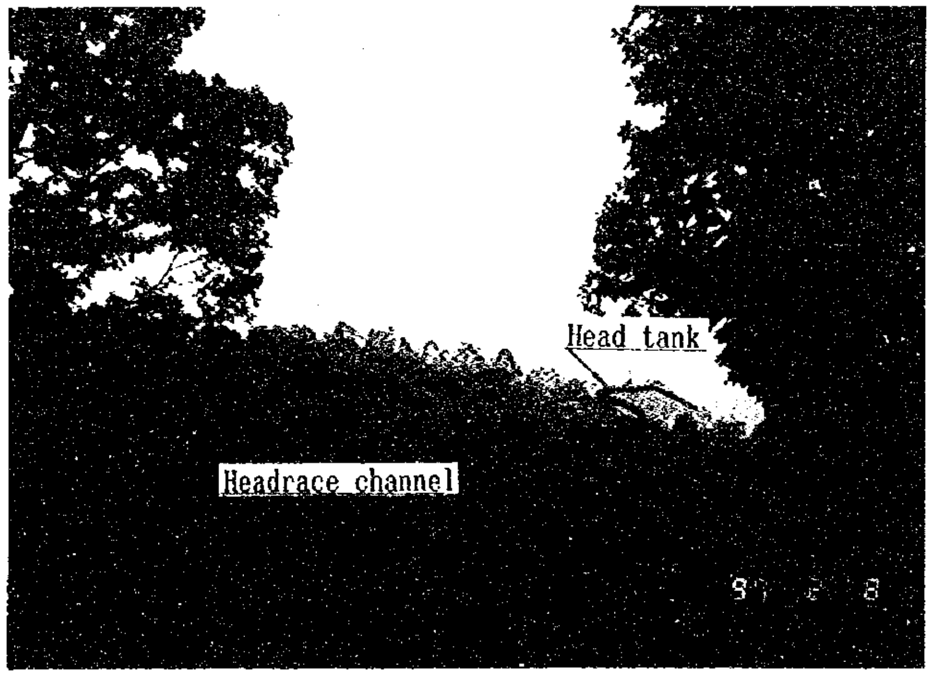


LOCATION OF MANUEL JORGE NO. 4

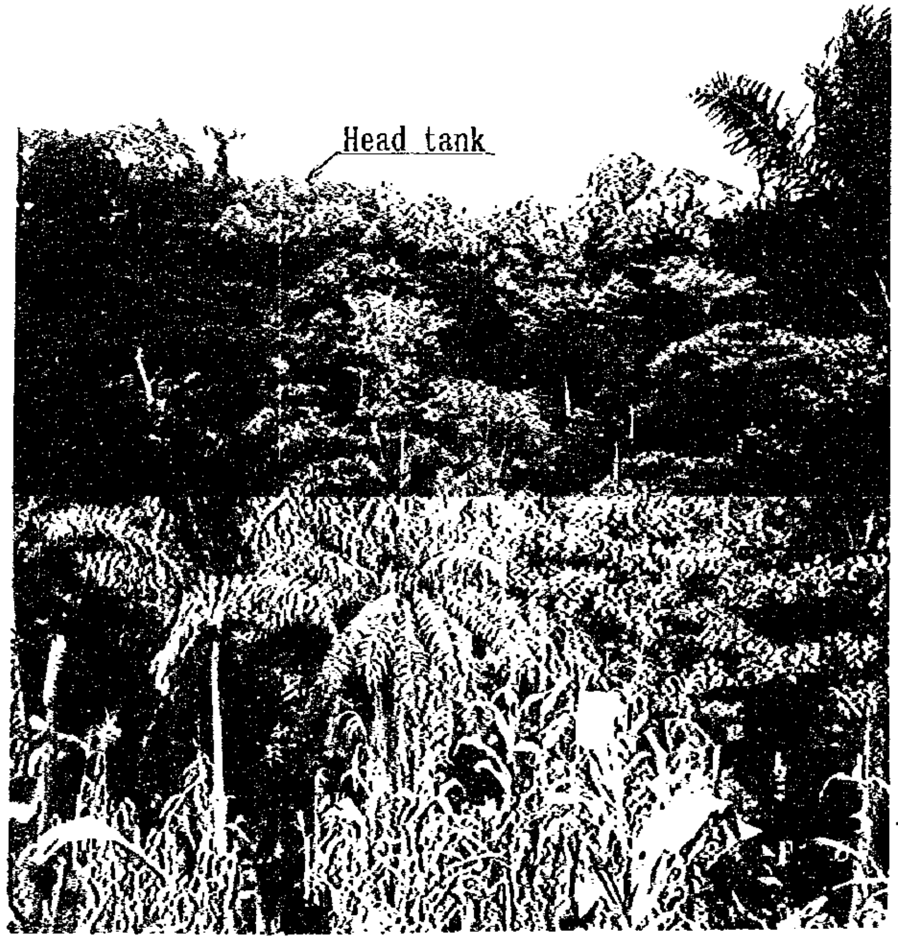
Intake-dame site viewed from left-bank downstream



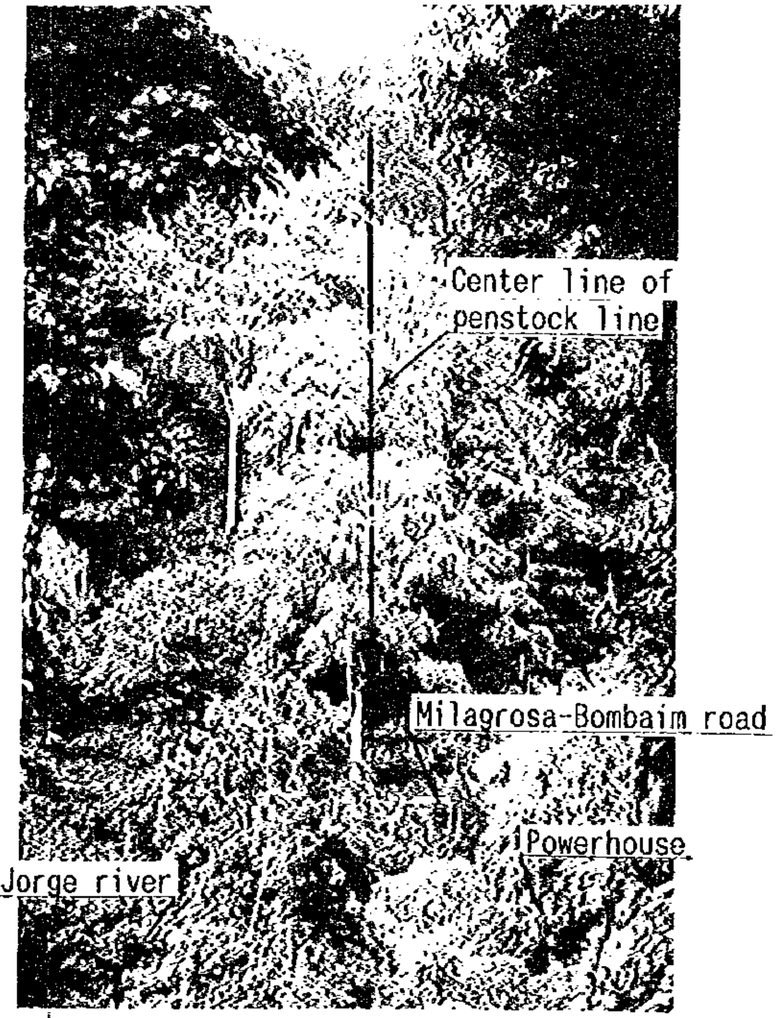
Downstream View from intake-dam site



Head tank site viewed from upstream



Head tank and penstock site



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

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.

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Chapter 1

INTRODUCTION

1. INTRODUCTION

1.1 Background of the Project

The Democratic Republic of Sao Tome and Principe is a newly founded country, having become independent from Portuga in July, 1975. It consists mainly of the two islands of Sao Tome and Principe approximately 280 km offshore of the Gabonese Republic on the west coast of Africa, and has a population of 125,000.

The majority of the population is concentrated on Sao Tome Island where the capital city of Sao Tome is located. The islanders mostly make their living engaged in cacao and coffee cultivation of plantation type. The country even now is proceeding with restructuring in accordance with the advises of the IMF and IBRD, but at present, with no significant resources or promising industries yet to be seen, the current GDP per capita is US$317 (1995) and the country is still of LLDC status.

At Sao Tome City (east coast side) and Neves City (west coast side) and their surrounding areas in the northern part of Sao Tome Island where the population is concentrated, there are 30 kV and 6 kV transmission lines and 380 V and 220 V distribution lines adequately provided, but seen from the standpoint of the entire island, the proportion of electrification (number of households) is estimated at approximately 45%. Even under these limitations, the demand for electric power is increasing yearly with increased demand from electric appliances and population growth and investment of foreign capital in the hotel business and light industries such as marine products processing.

Meanwhile, supply of electric power, as of March 1996, was being done for Sao Tome Island from the three power stations of Contador Hydroelectric Power Station 1,920 kW, Gue Gue Hydroelectric Power Station 320 kW, Sao Tome Diesel Power Station 3,920 kW, with the power generating capacity totaling 6,160 kW. However, the power generating facilities and transmission and distribution facilities have become too old and weakened for work due to shortage of foreign currency, and it is not possible to meet the maximum power demand of 4,995 kW. At the capital city of Sao Tome, planned outages on a rotational basis for individual districts have become routine, and the situation is under permanent power shortages. Large load facilities such as hotels, the United Nations offices, etc., as well as the official presidential residence and airport in Sao Tome City and its surroundings are coping by means of private power generation facilities.

With such a situation prevailing, increasing the power supply capacity to Sao Tome City and its surrounding area, whether by renovation of existing power stations or construction of new power stations, is a matter of great urgency for Sao Tome and Principe.

Supply of stable electric power is thought to eliminate dissatisfaction with planned power outages, increase employment opportunities through promotion of industry, and prove to be a great incentive for investment in light industries which will lead to economic development of Sao Tome and Principe.

The annual average growth rate of power demand from 1981 to 1994 was 5.7%, and an average growth rate hereafter of approximately 4.7% to 6.7% is forecast. However, under present circumstances in which the finances of Sao Tome and Principe is relying on aid from other countries, strengthening of electric power facilities is hardly progressing.

Empresa de Agua & Electricidade (EMAE), the agency responsible for electric power in Sao Tome and Principe, following a hydropower potential study by the U.S.S.R. in 1981, formulated an "Electric Power Master Plan" in 1992. In the reports of both it is recommended for the water resources and topographical features of Sao Tome Island to be utilized to develop the mini-hydropower potentials dotting the several river basins of the island such as the Manuel Jorge River, the Abade River and the Io Grande River.

Sao Tome and Principe considers energy-related undertakings for economic development and improvement of the people's livelihood the first priority project of the state, and is planning construction of new hydroelectric power stations which would make use of the abundant water resources in the country, be comparatively easy to operate and, moreover, would not require fuel. With shortage in supply of electric power becoming acute, this development survey was requested of Japan in aiming for realization of the power generation project, and in response, the Government of Japan dispatched a preliminary survey team to the field (November 19 to December 1, 1995), and along with making confirmations of the scope of the request, signed a Scope of Work (S/W) concerning the contents of the full-fledged study to be made.

1.2 Objective and Scope of Study

1.2.1 Objective

In this study, the optimum plan for construction of a mini-hydroelectric power station for increasing electric power supply to a part of Sao Tome, the capital city of Sao Tome and Principe, and its surrounding area was formulated and a feasibility study made for verification of the possibility of project implementation from the aspects of engineering, economics, and environment, and of technology transfer to counterparts on the Sao Tome side through this study.

1.2.2 Scope

A promising project proposal suitable for construction of a mini-hydroelectric power station is selected from among rivers having promising hydropower potentials within Sao Tome Island, and a construction candidate site is selected.

A feasibility study is to be carried out on the construction candidate site selected in this manner.

1.3 Contents and Schedule of Study

This investigation, based on Fig. 1-1, Survey Stages and Study Procedures, showing the flow of the contents and items of work, was carried out divided into the three stages of Preliminary Study, Basic Study, and Feasibility Study. Each of the stages consisted of work in Japan and work in the field. The members of the field survey team at the various stages were as listed below.

General Supervision/Power Generation Planning	Shozo Yuzawa	1st-5th Field Surveys
Civil Design	Kazuhiko Fushimi	1st, 2nd, 4th, 5th Field Surveys
Electrical Facilities	Toshimasa Fujiuchi	1st, 4th, 5th Field Surveys
Hydrological Analysis	Azuma Tsunoda	1st, 2nd Field Surveys
Ground Survey	Mitsuo Saito	2nd Field Survey
Geological Survey	Kazuhisa Takeda	1st-3rd Field Surveys
Environmental Survey	Ryozo Ohno	2nd, 4th Field Surveys
Economics, Finance	Taiji Nagayoshi	4th Field Survey
Interpreters	Mari Kobayashi	1st Field Survey
	Yoshiko Fukushima	2nd-5th Field Survey

Figure 1-2 shows the implementation schedule of survey works in which it is indicated that the Survey Team submitted reports at each stage with explanations and question-and-answer sessions held with the agencies concerned of the Sao Tome and Principe Government, particularly, Ministerio do Equipumento Social e Amibiente (MESA) and Empresa de Aqua e Electricidade (EMAE).

Topographical and geological surveys were carried out by the GERI-Loison firm of Gabon from the middle of July to the middle of October 1996, while environmental studies were made by the Agroconsulta firm of Sao Tome from the end of July to the beginning of November 1996.

Training in Japan concerning this Project was participated in by Mr. Isaque Braganca Gomes Cravid (Electrical Engineer) of MESA, who made a tour of hydroelectric power stations including those of EPDC and public agencies, and also held mutual discussions regarding the Sao Tome Mini Hydro Project.

1.4 Existing Reports

Data and information concerning electric power facilities in their present states, standards and regulations concerning electric power facilities, and data and information concerning the environment necessary for carrying out investigations were collected and studied, and especially, regarding renovation and development plans concerning electric power facilities, the three reports below were studied. Namely,

(1) Ricomendacdes para aproveitamento des recursas hidro-energetlcos da Republica Democratica de Sao Tome e Principe, URSS Guidroproekt Fitlat de Leninegrado, 1981

(2) Master plan for electrification of Sao Tome island covering a period of 1991 to 2010, EDF International, 1993

(3) Etudes Geologiques concertant la Centrale Hydro-electrique de Rio Contador, le Centro Ricerche Geologiche S.r.l., 1995

Fig.1-1 Survey Stage and Study Procedure

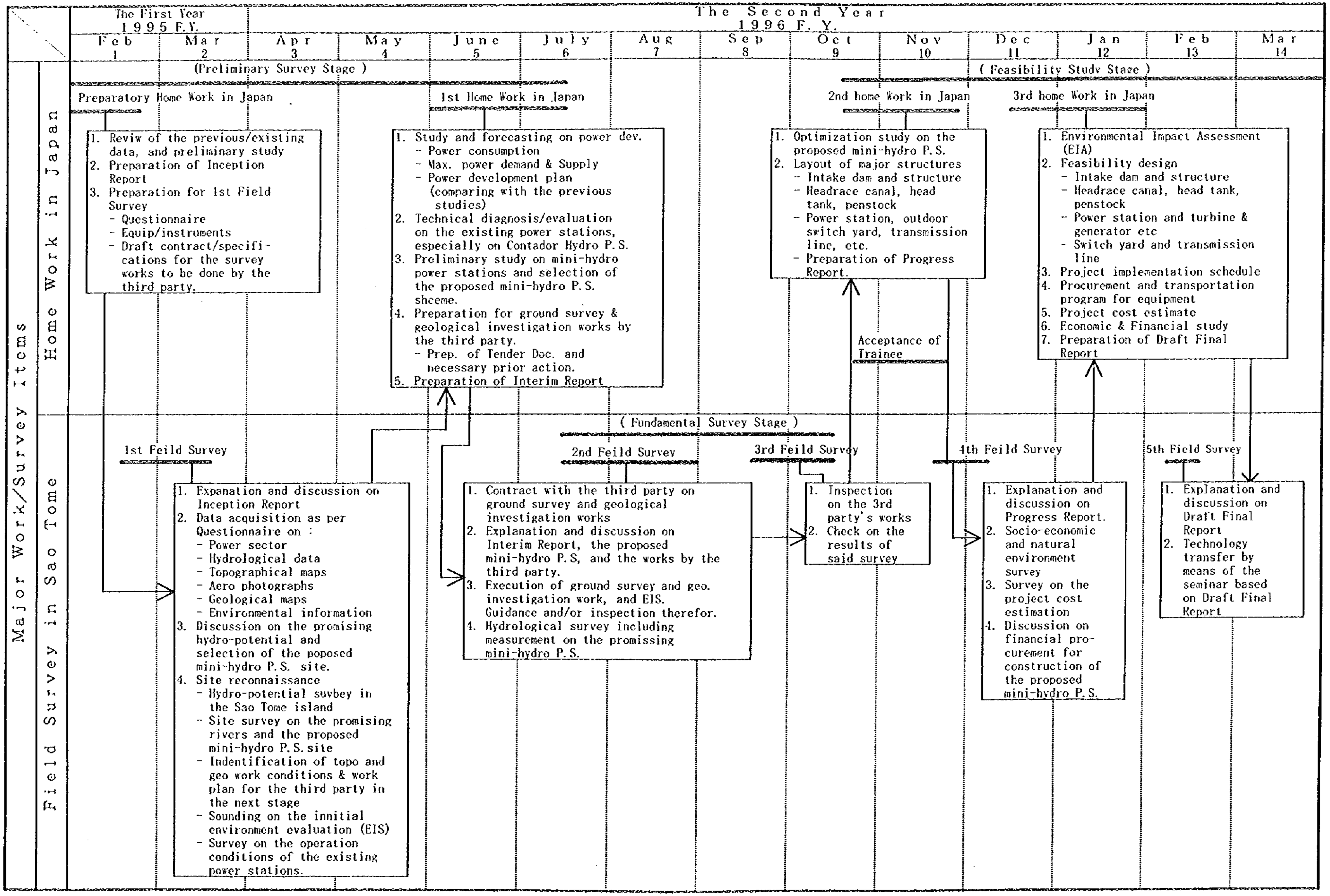


Fig. 1-2 Execution of Study

	1995 (FY)			1996 (FY)											
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Stage		(Preliminary Survey Stage)								(Fiasibility Study Stage)					
							(Fundamental Survey Stage)								
Home Work		Preparatory Work				1st				2nd		3rd			
Field Surbey			1st				2nd		3rd		4th			5th	
(Re-entrust)							Ground Survey, Geological Investigation, and EIS								
Report															
Inseption Report		△													
Interem Report							△								
Progress Report											△				
Draft Final Report													△		
Final Report															△

Chapter 2

GENERAL OUTLINE OF DEMOCRATIC REPUBLIC OF SAO TOME AND PRINCIPE

2. GENERAL OUTLINE OF DEMOCRATIC REPUBLIC OF SAO TOME AND PRINCIPE

2.1 Geography

Republico Democratica de Sao Tome et Principe became independent from its suzerain country Portugal on July 1, 1975. Its capital is at Sao Tome. The country consists of the two islands of Sao Tome Island in the Gulf of Guinea off West Africa roughly on the equator, approximately 280 km offshore from the continent, and Principe Island 200 km to the north-northeast, and five other small islands. The area is 836 km^2 for Sao Tome Island and 128 km^2 for Principe Island, a total of 1,001 km^2, inclusive of other small islands, and less than one half the area of the metropolis of Tokyo. Both Sao Tome Island and Principe Island are volcanic in origin. The highest peak on Sao Tome Island reaches to 2,024 m and at its base are spread out tropical jungle and fertile cultivated land.

2.2 Climate

The climate is an equatorial oceanic one and is divided into the three seasons of major rainy season (January - June), dry season (July - September), and minor rainy season (September - December). The annual average rainfall on Sao Tome Island from 1985 to 1990 exceeded 7,000 mm at the southwest part, which gradually decreases going toward the northeast to become approximately 1,000 mm in the vicinity of Sao Tome City. The island belongs to a temperate, high-humidity zone, and the annual mean temperature is approximately 25°C. Fig. 13.1 is a climatic map of Sao Tome Island.

2.3 Population

The total population in 1992 was 121,000. Of this number, 33% was urban population and 67% rural. The population of the capital city of Sao Tome was approximately 30,000 as of 1985. The population density is 121 capital/km^2, and the population growth rate from 1985 to 1992 was 2.3%/yr.

2.4 Economics

The per capita income in Sao Tome and Principe is US$317 (1995). Sao Tome and Principe is a mini state which had a ruinous economic situation of a real economic growth rate in 1985 - 1992 of an annual average - 1.8% and an outstanding foreign debt at the end of 1995 of about 300 million dollars.

After independence from Portugal in 1975, a central planning economic system was adopted, with the economy centered on the main industry of cacao production, but production which had been 11,600 tons in 1974 fell to 4,580 tons in 1995, and with debt accumulating, serious economic difficulties were faced by the country.

The Sao Tome and Principe Government pushed forward with an economic liberalization policy from 1985, actively invited participation of foreign enterprises in cacao production, and promoted liberalization of the market and distribution. Meanwhile, in the middle of 1987, restructuring was started with support from the World Bank for rehabilitation of state finances, increase in agricultural production centering on cacao, and development of tourism and marine product industries as key points, while the currency, the dobra, was devalued in stages and wages of farmers were raised, but acceleration of inflation, decrease in purchasing power, and rise in unemployment were brought about, and with outstanding foreign debt, an economic situation fraught with difficulties continues to prevail.

Agriculture is the principal industry of this country accounting for about 30% of gross domestic product ant 95% of export revenues, with most of wage earners being farmers. Particularly, cacao comprising 90% of exports and taking up 46% of cultivated area is the main product. Besides cacao, copra palm, oil palm and coffee are also cultivated, but these are of small scale, while livestock raising and fishing have not attained modern status. As for factories, they are of a degree consisting of plants for agricultural product processing, beer, ceramics, and lumber. Foodstuffs and living necessities of the people cannot be supplied domestically and imports are being relied on (imports of foodstuffs made up 20 to 30% of the whole with the total amount of foodstuff imports in 1990 having been 7.8 million dollars).

Sao Tome and Principe had kept to a commodity price control system from the time of independence, but since 1987, it has been gradually liberalizing prices. The exceptions were six strategic foodstuffs, petroleum products, and pharmaceutical, besides which prices of public services such as electricity, water supply, transportation, communication, etc. are decided by the government.

The inflation rates and commodity price indices from 1991 to 1995 are as given below.

Year	1991	1992	1993	1994	1995
Inflation rate	52.7	27.3	21.8	37.7	24.6
Commodity price index	173.3	220.7	268.8	370.2	461.1

Since 1985, liberalization has been proceeding in economic aspects, and cooperation with foreign countries has progressed accompanying political stability, and although liberalization is beginning to be taken up in social policies, this is not going ahead as hoped for due to the economic difficulties which still prevail.

2.5 Energy Resources

As stated in 1.1, Background of the Project, EMAE, following the hydropower potential study by Russia in 1981, set up a National Energy Electric Power Master Plan in 1995 with the technical cooperation of France. The reports of both studies recommend development of the mini-hydropower potential in the form of run-of-river hydroelectric power stations making use of the water resources and topographical features of Sao Tome Island.

The degree of dependence by the Sao Tome and Principe Republic on imports for energy supply easily exceeds 90%, and the situation is such that the imbalance in energy supply will naturally be a matter of concern into the future. Accordingly, to aim to secure without delay stable supply of energy which is absolutely necessary for economic activity and the people's livelihood is without mistake the urgent and basic demand in the energy policy of Sao Tome and Principe. In coping with this demand, it is important to implement measures necessary for stability of supply and prevent outflow of foreign currency through utilization of domestic energy as the first priority. Prevention of foreign currency outflow, that is, realization of the hydropower potential as clean energy utilizing the abundant rainfall and topography of Sao Tome Island is an important factor directly leading to improvements in the national living standard and efficiency of agriculture. Regarding development sites, there are abundant with favorable siting conditions, and it will be necessary for medium- and small-scale development projects to be pushed forward step by step giving consideration to trends in demand, degree of urgency, and fund availability for the various sites already investigated and totalling approximately 20,000 kW in potential.

Regarding thermal or diesel power generation, inexpensiveness or stability of supply giving consideration to prevention of foreign currency outflow from a long-range point of view should be strongly demanded. It is also necessary to consider how to deal with environmental problems such as noise and gas emission. Consequently, although initial investment is small compared with hydropower, it is necessary to deal with this with great care except in a case of extreme urgency.

Chapter 3

MANUEL JORGE
HYDRO POWER PROJECT AREA

3. MANUEL JORGE HYDRO POWER PROJECT AREA

3.1 Outline of Catchment

At slightly to the west of roughly the center of Sao Tome Island there is the highest peak of the island, Mt. Pico de Sao Tome, EL. 2,024 m, to which are tied numerous mountains of elevations higher than 1,500 m. Major rivers flow down in radial form from this mountain block toward the seashore, one of which is the Manuel Jorge River. This river runs down through the northeast part of the island, adjacent to the catchments of the Abade River to the south and the Aqua Grande River to the north, going east along the south sides of communities such as Trindade and Bombom.

The Manuel Jorge River has many tributaries coming in from the right-bank side at its upstream and midstream stretches, but few at its downstream stretch. The length of the river is 22.9 km, the catchment area at the mouth is 36.4 km^2, with river gradients approximately 1:8 at the upstream part, approximately 1:14 at the midstream part, and approximately 1:25 on average. There are a number of waterfalls of heights 10 to 20 m approximately 20 km upstream from the mouth, and at the downstreammost waterfall, the water retained in the basin is utilized and this water on being drawn becomes drinking and miscellaneous-use water, and irrigation water for villages in the neighborhood. As of the time of surveys in March and July of 1996, intake quantities were 36 ltr/sec for the former and an average of 25 ltr/sec for the latter.

Both banks at the upstream part are covered by tropical forests and tall grasses, so that unobstructed views are had at only river channels. Downstream of the abovementioned waterfall, cacao is being cultivated at the left-bank side down to the edge of the stream.

The annual mean temperature for the 24-year period from 1967 through 1990 at Lagoa Amelia, a representative meteorological observation station in the Manuel Jorge catchment, was 17.8°C, the average annual precipitation 2,615.1 mm, with much rainfall in October-November, about 30% being concentrated in that period. The average precipitation in the dry season of June-August is 30 to 60 mm. The annual evaporation is around 276 mm and low. The mean temperature at Uba Budo in the downstream area is 24.4°C, the precipitation is 1,266 mm with much rain in October-November, while in the dry season of June-August it is 10 to 20 mm and extremely small. The annual average evaporation is approximately 660 mm.

On the Manuel Jorge River, at a site 10 km upstream from the mouth, there had been two observation stations under MESA, a high water level-discharge observation station and a low water one at Pian-Pian, but observations could not be continued due to lack of funds for maintenance and administration, and with observation equipment removed, neither of the stations is now in use.

What can be used at present are, besides a small number of data from runoff yearbooks, water level observation data from 1990, and 7 or 8 runoff measurement data.

At the downstream part of this river is Gue-Gue Hydro-electric Power Station (320 kW) operated and maintained by EMAE. According to the National Energy Master-plan in 1993 there are plans for new hydroelectric power stations at two places on the upstream stretch of this river.

As described in detail in Chapter 8, sites suitable for mini hydro power projects on the principal rivers of all of Sao Tome Island were selected at the preliminary study stage. These were, from the north, on the 6 rivers of Do Ouro, Manuel Jorge, Abade, Cantador, Io Grande, and Lemba. The economics of these were compared and the candidate sites on the Manuel Jorge River and the Abade River were found to be superior to the others, while the difference between the two was not great. Regarding the mini hydro power site of the Manuel Jorge River, existing roads and small paths can be used for access from the intake dam to the powerhouse more than at other rivers, and this is extremely convenient for construction and for operation and maintenance. Meanwhile, concerning energy production, it would be required for power transmission to be done from individual power stations to Sao Tome City, the main load center, and the Manuel Jorge hydro power site is 12 km from Sao Tome City and close. Furthermore, it is only 5 km from Trindade Substation planned as the connecting point, and this is an extremely welcome point for Trindade Village which suffers from a chronic shortage of electric power.

3.2 Villages

Characteristics of colonial times remain at the project site and its surrounding area, and plantations with cacao the main product are typical. Still today, there are administrative buildings and residential buildings at the centers where laborers gather together, and the centers of the individual plantations comprise villages. Milagrosa and Santa Clara at the project site and Quinta das Flores and Santa Luzia in the surrounding area are four such villages, and all are in the Me-Zochi Region. The population of this region is 29,758. The present states of these four villages and the situations regarding domestic water supply are described below.

(1) Milagrosa

Milagrosa is set up comparatively well as a plantation, and has a population of approximately 400 living divided into approximately 80 households. Service water is taken in from the Manuel Jorge, but the shortages of good-quality water and electric power are hindering development of this district, and because of low purchasing power, only food locally produced is being consumed. Public transportation services do not exist. There are approximately 20 television sets in the village and these comprise the main source of information and entertainment for the villagers.

This is essentially an agricultural area and there is no manufacturing industry. People cannot sustain an adequate livelihood with income from agriculture, and part of the villagers are moonlighting outside Milagrosa. The principal agricultural product of this area is cacao, the income from cacao being approximately US$820 per farmer, the highest in the villages of the region.

(2) Santa Clara

This village is located downstream of the project area and the population is approximately 60. Differing from Milagrosa, the residents do not have privately-owned land, with the plantation administered by a single owner. The annual incomes of laborers are fairly low. The village has no school nor health center and the people are obliged to rely on Milagrosa..

(3) Quinta das Flores

This is situated at a higher elevation than the previously-mentioned two villages and the village road for access is not passable unless by a four-wheel-drive vehicle. A population of approximately 40 people live here engaged in agriculture.

(4) Santa Luzia

This village is located at the right bank of the Manuel Jorge River and there are 35 villagers. Similarly to the case of Santa Clara, the villagers work as laborers under the management of a medium-size plantation (Empresa Agricola). Like the other villages, cacao is the principal agricultural product.

The domestic water supply is not from the Manuel Jorge but is being obtained from a source in the area.

3.3 Industries

(1) Agriculture

Plants grown in agriculture at the project site and its surroundings are cacao (Theobroma cacao) and banana (Musa sp.) which make up the greater part, combinations of which are located under tall trees such as palms (Elaes quineensis) and breadfruit trees (Antocarpus communis).

(2) Manufacturing

There is nothing resembling a manufacturing industry in this area and its neighborhood. There are a cacao fermenting and drying plant, an automobile repair shop of the days when this was a state-run enterprise, and a wood-working plant, but none of these is presently in operation.

Water resources at this project site and its surrounding area are adequate, and besides the Manuel Jorge River, there is a spring at the Aqua Panada River and drinking water for Milagrosa and Santa Clara, and if necessary, irrigation water can be supplied. Milagrosa has three other water sources (springs).

However, under present circumstances, the abovementioned four villages depend on the river water of the Manuel Jorge for the greater part of domestic service water, and this water is being utilized for irrigation of plantations and vegetable gardens, drinking water, and motive power sources for small power generators. There are also intake waterways, and although differing according to season, the requirements of each village are known. Consequently, in case of planning a hydroelectric power station, securing this domestic water supply must be taken into consideration.

(3) Transportation and Public Facilities

Santa Clara and Milagrosa have a road in good condition which passes by and are connected to Trindade and Sao Tome City which are centers of the area. Although extremely convenient distance-wise, there are no public transportation facilities connecting the project site with the outside and adjacent areas.

There is no power distribution network in the area of the project site and its surroundings, while there is a great lack of public facilities with only one school, one health center, and one emergency clinic at Milagrosa. The emergency clinic can deal with minor injuries, but in case of anything serious, people must go to the Central Hospital of Sao Tome.

3.4 Flora and Fauna

The project site and its surroundings have forests which could well be considered as being preserved, and which are fulfilling their role as watershed protection forests, while there are also waterfalls. As previously mentioned, there are also cacao and banana being widely cultivated and which mingle with various other trees.

Of terrestrial life, various species of birds are of overwhelmingly large number. There are also monkeys and damage is done to agricultural crops such as cacao and banana. As for aquatic animals, few or practically none exist, but there are crustaceans (fresh water shrimp) and small fish (terrapia introduced locally which have become acclimatized).

The country is a favorable habitat for birdlife, and there are numerous kinds of birds acclimatized and living in the project area and its adjacent areas and places which have been changed into agricultural fields.

Chapter 4

ELECTRICITY UTILITIES

4. ELECTRICITY UTILITIES

4.1 Present Conditions

The power utility services, from power generation to transmission and distribution on Sao Tome Island, are managed by a national enterprise, the Electric Power Division of Empresa de Agua a Electricidade (EMAE). Due to a small transmission and distribution capacity, however, only a specific area in the northern part of the island in and around the capital of Sao Tome City, where the population is concentrated, is electrified, leaving most of the island still unelectrified.

As of March, 1996, EMAE's total installed capacity was 7,440 kW; 5,200 kW by thermal power and 2,240 kW by hydro power. The total energy generation in 1995 was 18,664 MWh.

Due to aged facilities, the power generation capacity cannot adequately respond to the power demand (max. 4,995 kW). Even Sao Tome City is liable to power outage which is practiced almost for each half of the city on each alternate day. Almost all the street lighting is also liable to be turned off at night, a practice which promotes a high incidence of theft, thereby resulting in major security problems.

In response to the power shortage, heavy consumers such as hotels and UN related offices, and important national facilities such as the President's residence, hospitals, and the airport are equipped with in-house emergency generators.

For instance, Solar Construcoes S.A.R.L, the nation's largest general constructor, has its own generators which supplies electricity to its offices and own hotel (one of the most renowned hotel in the country), this being quite independent from the EMAE system. (The supply reliability of that firm at present is considered higher than that of EMAE.)

EMAE's power source depends on three power stations only; the Sao Tome Thermal Power Station (5,200 kW diesel power station) in the center of Sao Tome City, Gue Gue Hydro Power Station (320 kW) approximately 10 km southeast of Sao Tome City, and Contador Hydro Power Station (1,920 kW) approximately 20 km northwest of Sao Tome City. All these power stations are concentrated in the north of Sao Tome Island.

The recent total generated energy has not increased over that of the previous year because of unavoidable power outages for 7 to 8 hours daily due to the supply shortage, despite a large latent demand. (Approximately 50% of the total generation facilities are unable to provide their full capacity due to troubles with the electro-mechanical and civil facilities.) This situation has still not been corrected to the present time.

4.2 Organization of EMAE

The national enterprise, Empresa de Agua e Electricidade (EMAE) is organized under the Ministro do Equipamiento Social e Ambiente (MESA). Figure 4.1 is the organization chart of MESA under which EMAE is situated. The EMAE organization is detailed in Fig. 4.2 and Fig. 4.3.

The management of EMAE is determined by a Board of Directors consisting of the following members.

- MESA representative
- Representative from the Ministry of Economy and Finance
- Representative from the Ministry of Health
- Representative from an energy related bureau
- EMAE President
- Representative of EMAE employees (directly elected)

The organization of the Electric Power Department in charge of the Power Division is described in Fig. 4.3. The majority of EMAE employees belong to the Electric Power Department which is responsible for the entire technical field of the electric division and water division. The operation division, maintenance division, and project planning division are also included in this Department.

4.3 Outline of Supply Facilities

4.3.1 Power generation facilities

EMAE"s major power generation facilities consist of three power stations; the Sao Tome Thermal Power Station, Contador Hydro Power Station and the Gue Gue Hydro Power Station. The major power generation facility on Sao Tome Island which is connected to the EMAE system as of March, 1996, is described in the following table:

Type of power station	Power station	Generator	Generator rating(kVA)	Generator output (kW)	Operation commencement
Thermal power	Sao Tome	ABC-1	1,200	960	1991
		ABC-2	1,200	960	1993
		ABC-3	1,600	1,280	*Under construction, Mar. 1996
		CUMM-1	-	-	Eliminated
		CUMM-2	1,000	800	1987
		CUMM-3	1,000	800	1987
		Dorman	500	400	1995
Hydro power	Contador	#-1	1,200	960	1967
		#-2	1,200	960	1967
	Gue Gue		400	320	Feb. 1995 * Entirely renovated
Total			9,300	7,440	

There are also two hydro power stations which are not connected to the EMAE system and which are operated for specific districts. (Total output; 35 kW + 70 kW = 105 kW) In addition, some generators are installed individually in the large enterprises and operated independently from the EMAE power network. As of March, 1996, only two generators (rated output; 1,760 kW) were operated at the Sao Tome Thermal Power Station. Only one generator is operated at the Contador Hydro Power Station (rated output 960 kW providing 680 kW - 1,000 kW) since the coil of the other generator is burnt and the water intake has been reduced due to land slides at that intake. The Gue Gue Hydro Power Station was operated at only 150 kW, which is less than 50% of its rating (320 kW), due to a water intake drop in the dry season. Thus, most of the existing facilities are too old or deteriorated to perform at full capacity, thereby resulting in chronic power shortage.

4.3.2 Transmission and transformation facilities

The interconnected transmission line between the three power stations and the main transmission line are 30 kV, and the lower system uses 6kV.

The 30 kV and 6 kV transmission routes are shown in Fig. 4.4. As of March, 1996, the 30 kV transmission line was approximately 70 km long and the 6 kV transmission line is approximately

33 km long. To date, the transmission line has presented no problems although some areas are brittle and require repair. No new transmission lines have been installed and they have not been expanded since investment in power generation facilities is the major priority due to the constant shortage of power supply facilities since 1991.

Most of the 30 kV and 6 kV transformation facilities are installed in buildings and are, therefore, in relatively good condition. (Some are installed on supports.) Some electric facilities such as transformers and breakers do, however, require repair or replacement due to oil leakage and other problems.

4.3.3 Distribution facilities

The distribution voltages are 380 V for the 3-phase and 220 V for the single phase. The frequency is 50 Hz. The distribution line is approx. 115 km long overall (95 km overhead and 20 km underground.) Identical to the situation of the transmission line, no new electrification plan has been progressed for the distribution line since 1991. The present distribution facilities require reinforcement and repair as some utility poles are now unstable and in some instances, the cables contact the trees and cause not a few accidents.

4.4 Power Demand and Supply

4.4.1 Outline of Power Demand

The energy consumption in 1994 and 1995 was 20,564 MWh and 18,664 MWh respectively. The details according to each sector are given below.

	1993	1994
Household use	50%	48%
General (public facilities)	21%	16%
National Corporation	8%	13%
Industrial use	6%	
Commercial use	13%	4%
Others	1%	5%

The actual power demand for 1993 and 1994, however, is believed to be greater than the figures above because the demand was controlled by cutting the load due to an insufficient supply power. The record of energy consumption from 1980 and 1995 is categorized in Table 4.1. The average growth in this period was 5.68%. According to the figures of 1993 above, approx. 50% of the power demand was for the household use, followed by a public demand of approx. 20%, and an approx. 13% commercial demand. The demand for industrial use was only approx. 6%, indicating that there are no large industrial or production activities on Sao Tome Island. The power demand for household use represents almost half the total demand. The major part of that is consumed for lighting. The diffusion ratio of electric appliances such as TVs, refrigerators and air conditioners is still very low and the average monthly energy consumption is approx. 40 kWh per residence. This is a relatively low figure when compared with other African nations in this area.

On the other hand, there is a new demand from the hotels and UN related offices in the already electrified district where the power supply remains inadequate. Despite this demand, electricity is still not supplied. The potential demand from these consumers is described in the following.

Potential demand of those requesting power service from EMAE

Potential consumer	Request power (kW)	No. of potential consumers	Electric charge category
Large consumers (individual)	650	180	Res.
Mira Mar Hotel	400	1	Com.
National TV station	100	1	Pub. Com.
Private TV station	15	1	Pub. Com.
UNDP (office)	320	1	Org. Inter.
Pousada Hotel	250	1	Com.
Club Santana	200	1	Com.
Smugglers	300		Diversos
Total	2235		

The max. demand power in 1994 was 4,995 kW. The max. demand including the potential demand (load factor of potential demand; 60%) estimated from this record is approx. 6,330 kW. (4,995 kW + (2,235 x 0.6) kW)

4.4.2 Characteristics of Power Demand

(1) Characteristics of Annual Load

Sao Tome Island is located almost right on the equator. As the Sao Tome City area, the largest power consumption area, faces the ocean at quite a low elevation, the temperature hardly fluctuates throughout the year, and the temperature remains high year-round. Accordingly, the power consumption also hardly fluctuates throughout the year.

Regarding the demand tendency over the period of a year, the max. demand increases toward the year's end. The reason for this is believed to be a growth in the diffusion of electric appliances, although that is very slow. Electrification has not expanded due to fund shortage and supply power shortage. Consequently, it is considered that demand increase due to electrification does not occur. The demand drops slightly in June and July when the temperatures are the lowest. This concludes that power consumption hardly fluctuates throughout the year.

(2) Characteristics of Daily Load

The daily load curve on the highest demand day in 1993 is shown in Fig. 4.5. The peak demand on that day was approx. 4,700 kW at 19:00 hrs. The load at midnight (approx. 40% of the peak demand) increased from approx. 05:00 hrs. to 3,000 kW and remained till approx. 17:00 hrs. It peaked at 4,700 kW at 19:00 hrs, dropping gradually to 00:00 hrs., and returned to the midnight load.

The day time load is approx. 60% of the peak load and almost flat, showing that most power is consumed by offices and stores. Despite rising outdoor temperatures, the flat power consumption clearly indicates that the diffusion of cooling equipment such as air conditioners is low. The daily peak time of 19:00 hrs. indicates a typical peak demand for lighting. The highest peak was approx. 2.3 times the midnight power consumption. The peak duration was approx. 4 hours.

Due to an insufficient supply power, EMAE turns off most street lighting in order to control the peak at night and to prevent the evening peak from overlapping the consumption for the street lighting.

4.5 Electric Charges

EMAE's electric charges are determined precisely according to the type of consignee, service contract (power supply), and power consumption. The significance of their electric charge is that foreign consumers are charged approx. 5 times more than the domestic consumer, thereby providing benefit to the people of Sao Tome e Principe. Also, charges to governmental organizations are lower than those to the general end-users. The electric charges applied since February, 1996, are described in Table 4.2.

The standard consumer in Sao Tome City is charged approx. 5,000 Dbs (approx. US$3) for an approx. 40 kWh monthly consumption. This is a large burden for the households of this country as the average monthly salary for a general laborer is only approx. US$15. Foreign residents in Sao Tome City are obliged to pay in US dollars. In reality, however, the charges are not collected efficiently due to a lack of watthour meters and an inadequate charge collection system.

4.6 Power Development Plan by EMAE

EMAE is doing its best to overcome the supply power shortage by focusing on the reinforcement of its existing facilities as well as on new power development.

The fuel for EMAE's thermal power generation is entirely dependent on import. Therefore, EMAE's priority is hydro power development in a move toward saving the fuel costs. However, all the new projects have been delayed due to lagging construction fund procurement. Consequently, local electrification and reliability improvement measures have seen not sufficient progress in the last few years. Also, there are few certain expansion plans for the future.

On the other hand, the existing power generation, transformation, transmission, and distribution facilities have been operated for a relatively long period since their installation times. For instance, the Contador Hydro Power Station has been operated for almost 30 years since 1967. With few proper maintenance and repair provided throughout this time, 100% station output could not be expected here.

Due to fund shortage, there are few reinforcement plans for these aged facilities. Therefore, their supply power and supply reliability is significantly low.

Despite such severe management conditions, EMAE has prepared a National Energy master plan for electrification of Sao Tome Island to be implemented between 1991 and 2010, with the technical cooperation from EDF International, France. This power source expansion plan is shown in Table 4.3.

According to this master plan, EMAE has projected the construction of the Blu Blu Power Station with 3,000 kW emergency thermal power (diesel) in a bid to temporarily eliminate the supply power shortage. In parallel to this project, they also plan to promote a fuel cost-free hydro power development as a priority.

The Blu Blu Thermal Power Station will be located in the suburbs of Sao Tome City between Contador and Central Sub-stations along the 30 kV transmission route. Relocation of the Sao Tome Thermal Power Station is also planned to eliminate the expected noise pollution.

In reality, most of such plans have not progressed as scheduled. It is told that, as of March, 1996, the civil structure related construction cost (approx. US$ one million) had been to be provided from the Africa Development Bank for Abade 3, however, the loan procurement for the electric component related construction cost had not been cleared, and EMAE has been seeking a loan provider.

4.7 Electrification Plan

According to the number of EMAE electricity service recipients, it is estimated that approx. 60,000 people currently receive electricity. The population at the end of 1995 is estimated at approx. 127,500, and therefore, the estimated electrification ratio is approx. 47%. The remaining 65,000 people do not receive electricity from EMAE. Of all the African nations in this general area, this electrification ratio is relatively low. The only electrified area is Sao Tome City and its suburbs, and most of the central island and southern island is unelectrified. Even in the electrified area, however, many people are unable to afford electricity due to high electric charges.

In response to frequent power outages, EMAE's first priority is to ensure the power supply in the electrified area. In reality, therefore, it is difficult to take measures for local electrification and EMAE has no definite electrification plan for such areas.

EMAE plans to promote electrification in local areas only after completing the power supply in the electrified area. Considering the current conditions, electrification will be expanded into local areas after 2000, at the earliest.

Table 4-1 Transitions of Electric Energy Consumption

Year	Energy Consumption									(MWh)	
	National Enterprises		Private Enterprises		Commercial		Public Institution		Residential		Total	
	Consumption	Rate (%)	Consumption	Rate (%)	Consumption	Rate (%)	Consumption	Rate (%)	Consumption	Rate (%)	Consumption	Rate (%)
1981	3,135		744		609		608	-	2,783		7,879	
1982	3,682	17.4	808	8.6	609	0	604	-0.6	3,416	22.7	9,119	15.7
1983	4,731	28.5	818	1.2	614	0.8	610	1.0	4,032	18.0	10,805	18.5
1984	4,525	-4.3	751	-8.2	606	-1.3	605	-0.8	4,140	2.7	10,627	-1.6
1985	5,573	23.2	1,028	36.9	821	35.5	625	3.3	4,664	12.7	12,711	19.6
1986	5,395	-3.2	870	-15.4	666	-18.9	662	5.9	4,411	-5.4	12,004	-5.6
1987	3,153	-41.5	1,609	84.9	-	-	730	10.3	4,327	-1.9	9,819	-18.2
1988											10,229	4.2
1989											15,017	46.8
1990											13,924	-7.3
1991											10,176	-26.9
1992											11,788	15.8
1993		8.4		6.4		13.3		20.8		50	13,036	10.6
1994		13.16		3.8		13.96		16.3		48.1	14,135	8.4
1995											11,538	-18.4

Table 4-2 Electrical Tariff of EMAE

as of January, 1996

		DBS	FRF
Residential (for Santomense)	< 40kWh	46.92	
	<300kWh	137.42	
	>300kWh	237.97	
Commercial	< 75kWh	204.45	
	> 75kWh	271.49	
Industrial	<100kWh	234.62	
	>100kWh	301.65	
Public Residential	<100kWh	402.21	
	>100kWh	469.24	
High Tension		237.97	
EMAE's Employee	< 40kWh	23.46	
	> 40kWh	68.71	
Public Company	<100kWh	301.65	
	>100kWh	368.69	
SOCOSTO	< 45kWh	498.98	
	> 45kWh	589.29	
EGC/FSI/BISTP	< 38kWh	204.44	
	> 38kWh	259.83	
CST	< 52kWh	204.44	
	> 52kWh	259.83	

Foreigner(Residential)	< 40kWh	237.97	
	> 40kWh	321.76	
Foreigner(Commercial)	< 75kWh	589.26	
	> 75kWh	668.82	
Foreigner(Particular)	< 40kWh		1.24
	> 40kWh		1.68
Commercial	< 75kWh		2.00
	> 75kWh		2.27
Industrial	< 100kWh		1.69
	> 100kWh		2.00
Higy Tension	——		1.84
COCOSTO(40% EMFRF)	< 30kWh		2.00
	> 30kWh		2.27
EGC/FSI(50% EMFRF)	< 37kWh		2.00
	> 37kWh		2.27
CST(30% EMFRF)	< 23kWh		2.00
	> 23kWh		2.27

Table 4-3 Expantion plan of EMAE

Year	Name of power plant	Out put (kW)	Instaiied capacity
Urgent	Blu Blu(Diesel)	3,000	
1996	Abade 3	1,740	9,260
1997			
1998			
1999			
2000	Manuel Jorge 4	650	9,910
2001	Manuel Jorge 3	1,100	11,010
2002			
2003	Abade 1	1,500	12,510
2004			
2005	Manuel Jorge 2	750	13,260
2006	Lemba	3,000	16,260
2007			
2008			
2009			
2010	Ouro 6	1,000	17,260
	Diesel	2,000	19,260

ORGANIGRAMA DO MINISTERIO DO EQUIPAMENTO SOCIAL E AMBIENTE

Organigrama do Ministerio do Equipamento Social e Ambiente

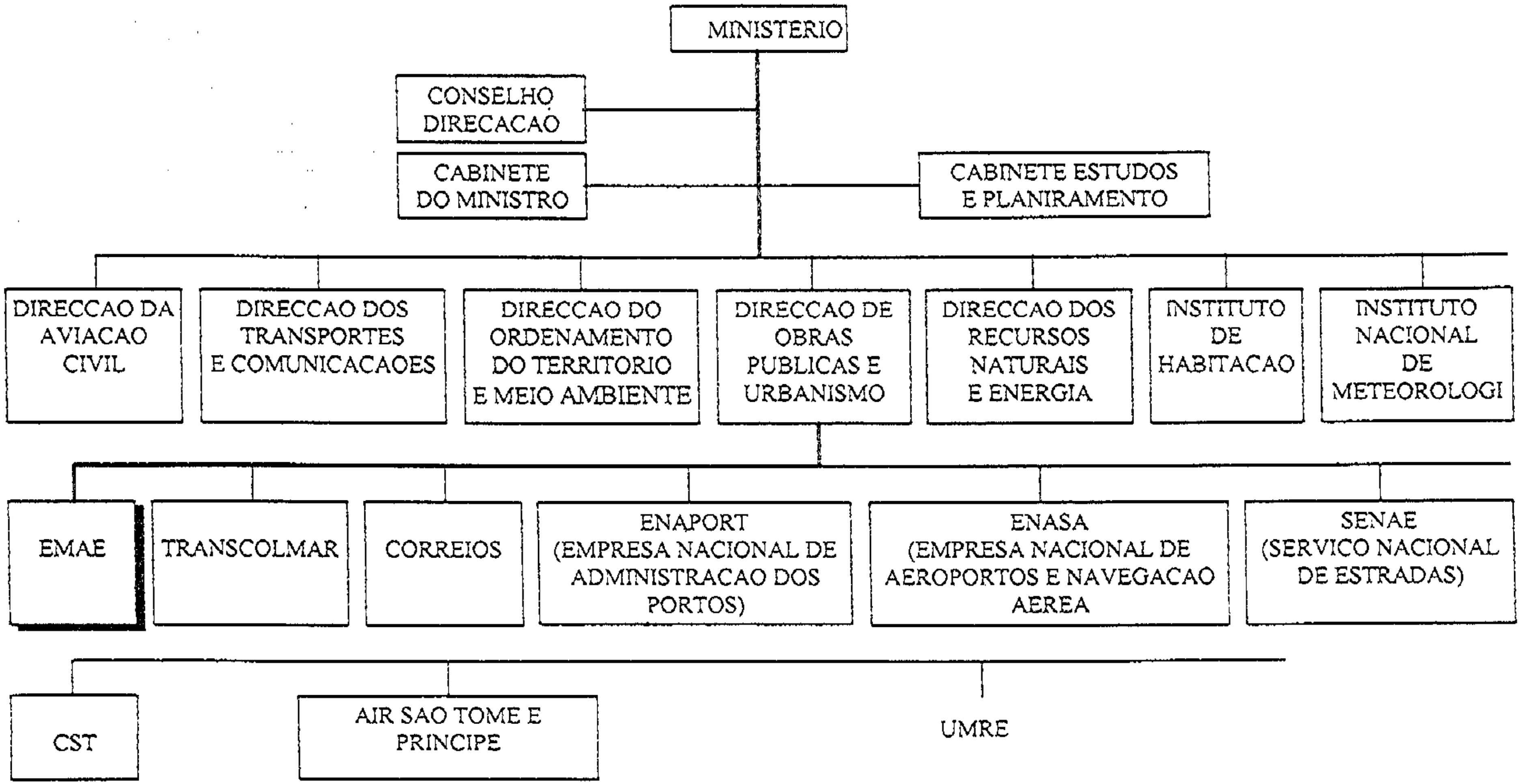
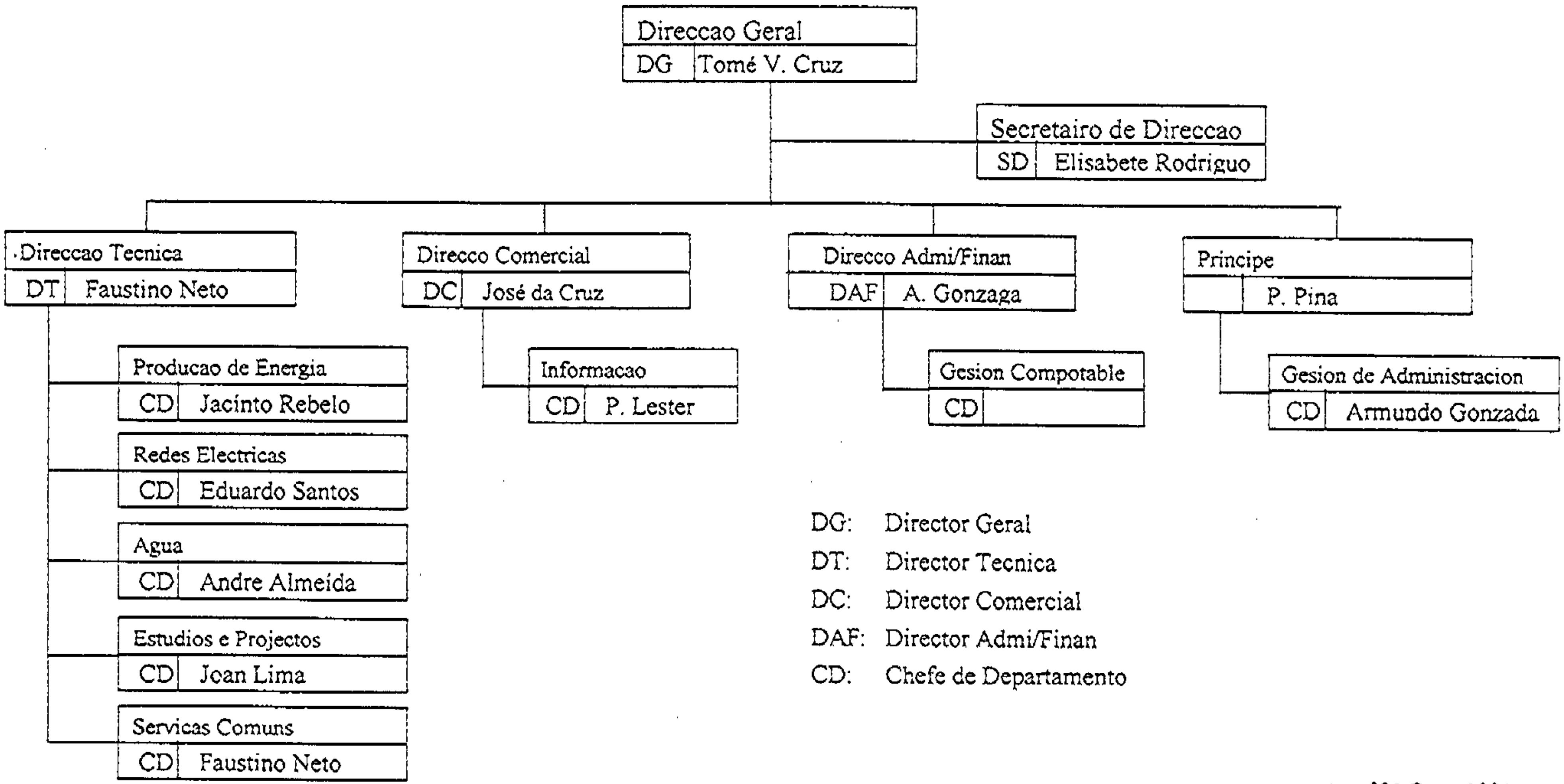


Fig. 4-1 Organization Chart of MESA

Organigrama de EMAE



DG: Director Geral
DT: Director Tecnica
DC: Director Comercial
DAF: Director Admi/Finan
CD: Chefe de Departamento

As of 31 Dec., 1991

Fig. 4-2 Organization Chart of EMAE

EMAE - ORGANIGRAMA DA DIRECCAO TECNICA - NOV 93

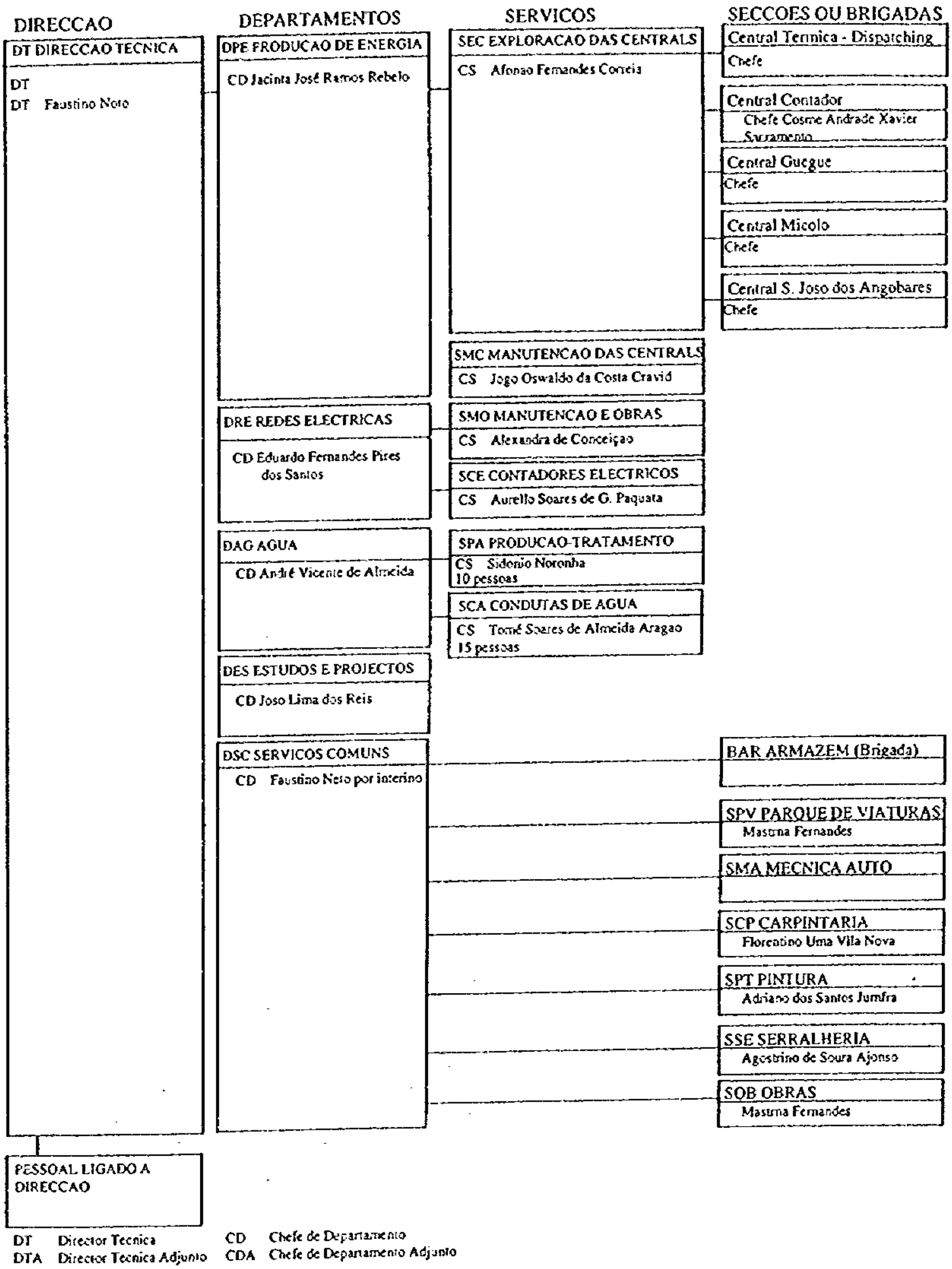


Fig. 4-3 Organization Chart of Technical Department of EMAE

COURBES DE CHARGES EN 1993-ABONNES ACTUELS

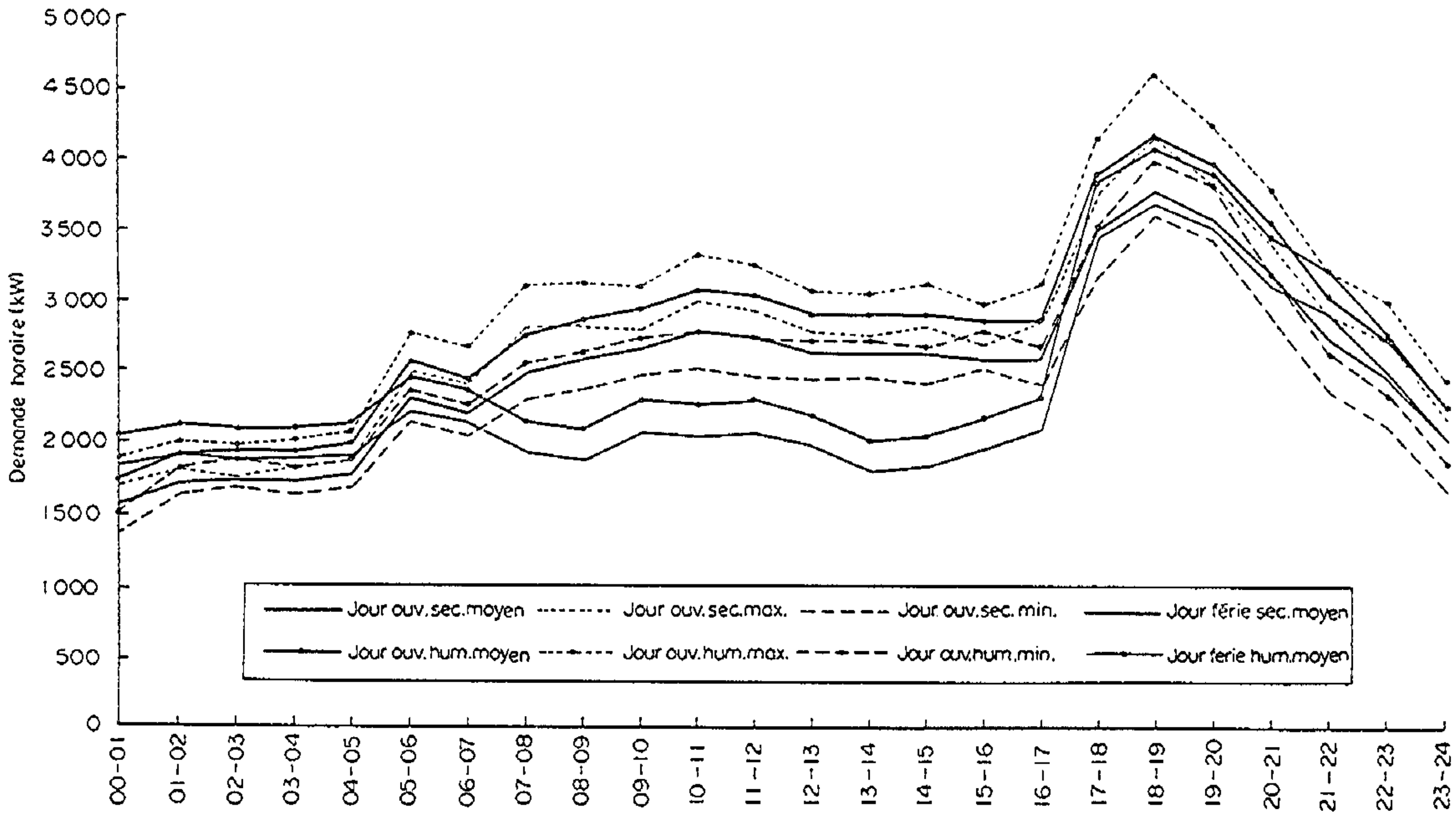


Fig. 4-4 Daily Load Curve

Chapter 5

POWER DEMAND FORECAST
AND
POWER SUPPLY PLAN

5. POWER DEMAND FORECAST AND POWER SUPPLY PLAN

5.1 Power Demand Forecast

5.1.1 Methodology

The power demand forecast method is mainly classified into the following two methods;

1) Macro forecast method
2) Micro forecast method

In the macro method the demand is forecast from the movement of the demand itself or from its relation with other factors, for instance;

1) Trends in power demand,
2) Correlation with economic indicators, and
3) Correlation with GDP growth.

In the micro method the demand content is analyzed in detail to forecast the demand from the relation between the factors, for instance;

1) Popularity of home electric appliances,
2) Analysis of changes in the industrial structure and power consumption due to technology improvement,
3) Analysis of demand structure estimated from the maximum power and analysis of the maximum load ratio change.

These methods are introduced simply as theoretical forecast methods. To determine the method, it is necessary, therefore, to study the regional characteristics of both the country as a whole and the subject area.

It is generally necessary to determine a goal for the economical activities and the national living standard when forecasting a long term demand. Therefore, the macro method is applied.

Contrarily, the micro method is applied to short term demand forecasting by accumulating the latest records.

Of the previously described macro methods, the correlation method with economic indicators is not applied to Sao Tome since their power consumption increases despite a negative GDP. Therefore, the demand for Sao Tome is forecast from past trends. It is necessary to consider as well that the demand has been recently controlled due to a supply power shortage.

5.1.2 Power Demand Forecast

The average annual demand growth ratio of power (generating end electric energy) between 1981 and 1994 was 5.68%. (The load was controlled in 1995, thus resulting in a lesser growth ratio than that of 1994. Consequently, the ratio for 1995 was not considered here.)

Regarding the annual growth ratio, the growth ratio from 1983 to 1984 was 34%, and from 1987 to 1989 was 25.3% and 22.1%. These were very high figures, the reason possibly being that electrification was expanded during these periods, although it must be noted that this is not absolutely clear. The ratios moved at an average of 5.68% although in some periods, the ratio was negative. Consequently, three cases were studied with the above demand growth record. 5.68% was applied as the Middle Case. Considering ±1%, 6.68% was applied to the High Case and 4.68% to the Low Case. The results of the study are provided in Table 5.2, Fig. 5.2 and Fig. 5.3.

The maximum power in the Middle Case is forecast to be almost doubled in 10 years or in 2005, and increased by 2.7 times in 15 years, or 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.

5.1.3 Result

The result of the power demand forecast is described in Table 5.2, Fig. 5.1and Fig. 5-2. This 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 there are no concrete electrification plans, although they are not presently benefited from electrification. Reinforcement is to overcome the present power shortage. New electrification planning will be impossible due to fund shortage under the existing condition that even the restorations of existing power facilities have not made with regularity. The power demand is forecast only from the power consumption increase in the already electrified area.

When considering the potential demand only, especially, a maximum of 1,340 kW is added to the forecast value based on the load factor 60% in this case, calculated from the receiving power. As these potential consumers already own private generating facilities, however, it is considered unnecessary for EMAE to supply them with power immediately. This factor is, therefore, not considered in this study.

5.2 Power Demand Forecast and Supply Plan

In studying the power demand and supply balance, in the case of a short-term plan, a supply plan is generally studied by placing emphasis on the electric energy (kWh). In the case of a ten-year or longer term plan, it is, however, usually studied by placing emphasis on kW rather than on kWh.

As this project extends over a long period until 2010, it was, therefore, studied by kW. Because the Sao Tome rivers present extensive discharge fluctuation, the power demand and supply balance is to be studied in full consideration of the firm output of hydro-power. The study is made based on the middle case of 5.68%, as mentioned in 5.1.2, as the power demand forecast value.

5.2.1 Estimation of Future Load Pattern

In studying the future supply plan, it is necessary to fully determine the seasonal and temporal features of the power demand. The past demands were analyzed and a future load pattern estimated.

Reference was made to the daily load curve of the maximum demand day in 1993 when no load limit occurred. The load characteristic of that day is described in Chapter 4, 4-4. This load curve shows almost the same pattern as that of other days.

The peak is around 19:00 hrs. and the night and day loads are about 40% of the peak load. It is a typical lighting peak type.

Sao Tome has no large plant construction plans for the future and, judging from the present GDP/capita, the spread of air conditioners appears low. For the next 10 years, the daily load curve may remain unchanged even if overall demand should increase.

5.2.2 Power Resources Development Plan

Based on the National Energey master plan made in 1993, the scenario of the mid- period power development plan until 2007 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
2007	Ouro hydro-power	1,000
	Diesel	1,000

It seems that Manuel Jorge No. 3 and 4 of EMAE-EDF 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 Sao Tome Diesel of 1,200 kV 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.

5.3 Optimum Power Development Plan

In these circumstances as mentioned already, 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.

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

5.3.1 Reserve Ratio

It is generally felt that a reserve ratio of about 30% of the maximum demand is necessary in developing countries and very particularly in a weak power system.

In this study it is assumed 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 can be supplied by other stations, and the reserve ratio of 30% of demand is used after the reserve ratio drops below 30% of demand.

5.3.2 Electric power Development Plan

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.

5.3.3 Necessity of Manuel Jorge No. 4 Power Station and Operation Start Time

As stated already, the output of the Manuel Jorge hydro-power station is 230 kW, its operation start is to be planned for 2000, and the maximum power demand is then expected at 6540kW. Regarding the supply and demand balance, the percentage of the Manuel Jorge hydro-power station is small but 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 through 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.

Table.5-1 Basic Data for Demand Forecast(1981～1995)

Year	Generated Energy			(Mwh)	Selled Energy(Mwh)		Maximum Power (kW)		Power factor	Loss	
	Hidro	Thermal	Total	Rate (%)		Rate (%)	kW	Rate (%)	(%)		Rate (%)
1981	7,415	2,612	10,027	—	7,879	—	2,289	—	50	2,148	21.4
1982	7,987	2,779	10,766	7.4	9,112	15.6	2,458	7.4	50	1,654	15.4
1983	6,081	5,475	11,556	7.3	10,805	18.6	2,638	7.3	50	751	6.5
1984	8,239	7,257	15,496	34.1	10,627	-1.6	3,538	34.1	50	4,869	31.4
1985	7,203	6,784	13,987	-9.7	12,911	21.5	3,193	-9.8	50	1,076	7.7
1986	6,903	7,763	14,666	4.9	12,003	-7.0	3,348	3.9	50	2,663	18.2
1987	6,724	5,248	11,972	-18.4	9,818	-18.2	2,733	-18.4	50	2,154	18.0
1988	7,992	7,006	14,998	25.3	10,229	4.2	3,424	25.3	50	4,769	31.8
1989	7,007	11,307	18,314	22.1	15,017	46.8	4,181	22.1	50	3,297	18.0
1990	7,571	9,410	16,981	-7.3	13,924	-7.3	3,877	-7.3	50	3,057	18.0
1991	7,164	11,948	19,112	12.5	10,176	-26.9	4,259	9.9	51.2	8,936	46.8
1992	6,286	13,265	19,551	2.3	11,788	15.8	4,464	4.8	50	7,763	39.7
1993	6,768	13,412	20,180	3.2	13,036	10.6	4,607	3.2	50	7,144	35.4
1994	4,894	15,670	20,564	1.9	14,135	8.4	4,915	6.7	47.8	6,429	31.3
1995	3,263	15,401	18,664	-9.2	11,538	-18.4	4,750	-3.4	44.9	7,126	10.8

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

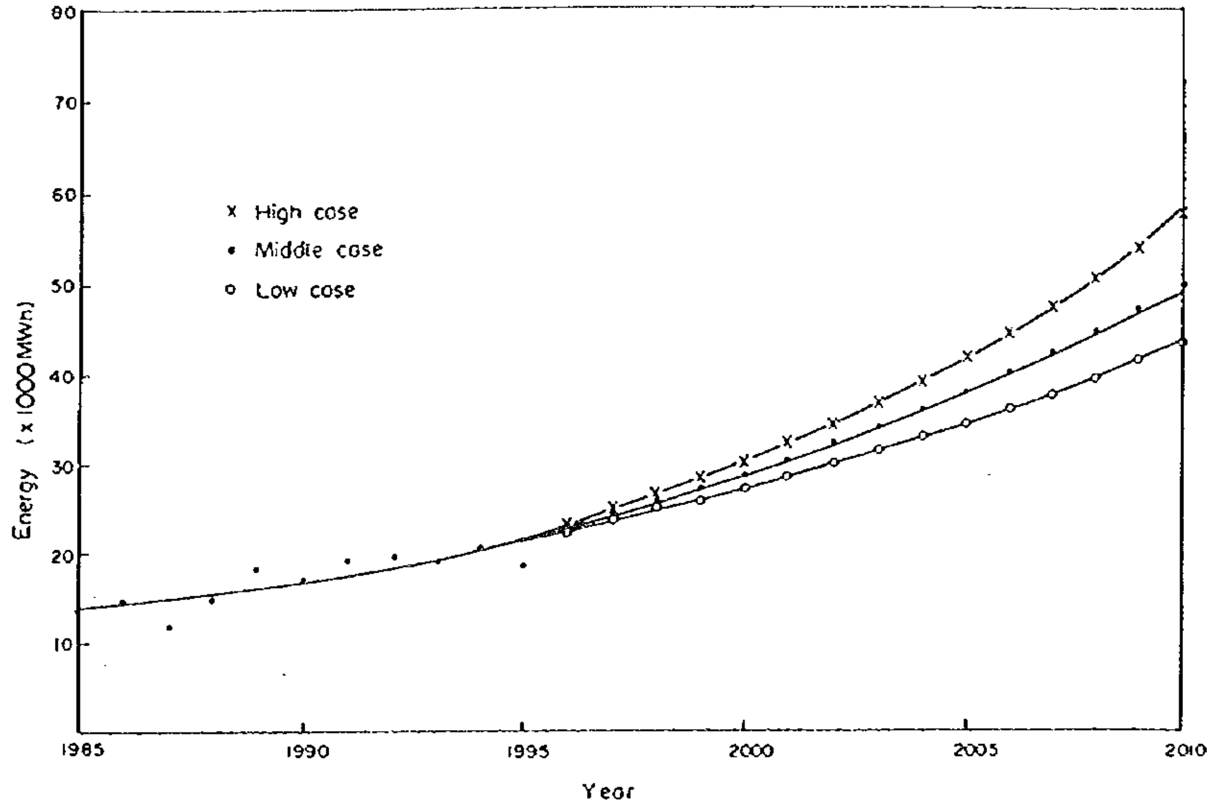


Fig. 5-1 Demand Forecast (Energy)

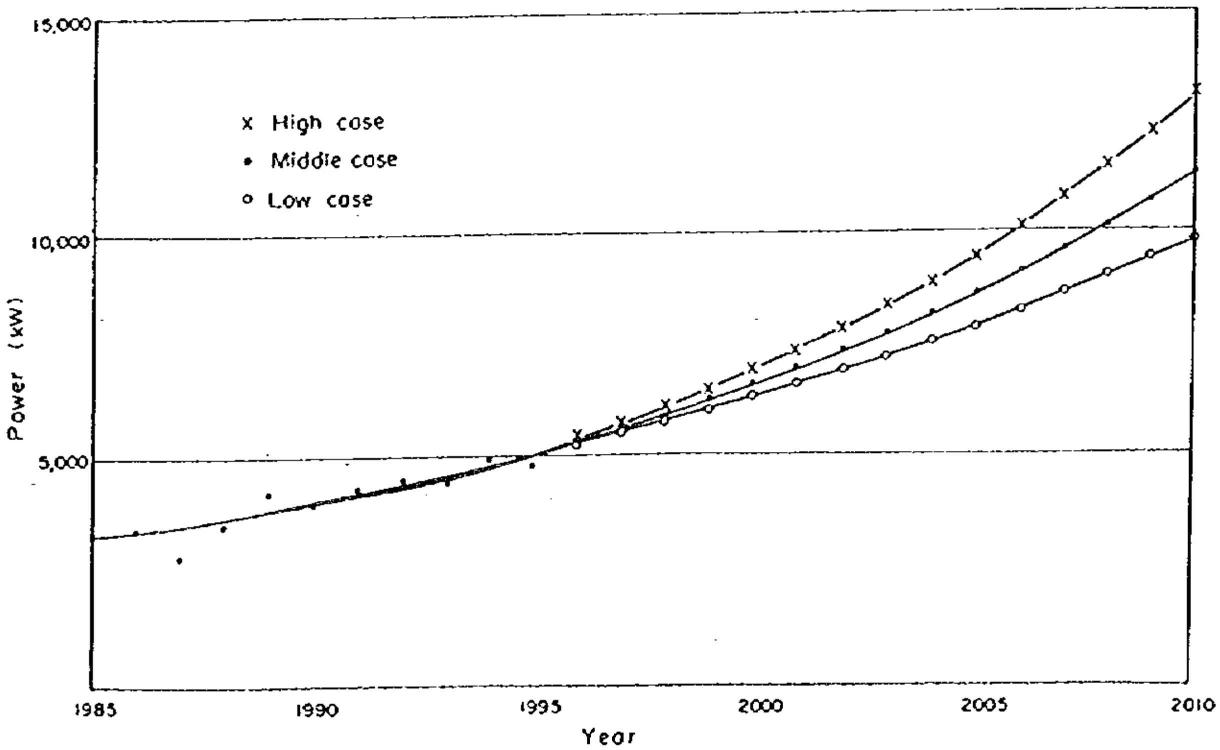


Fig. 5-2. Demand Forecast (Power)

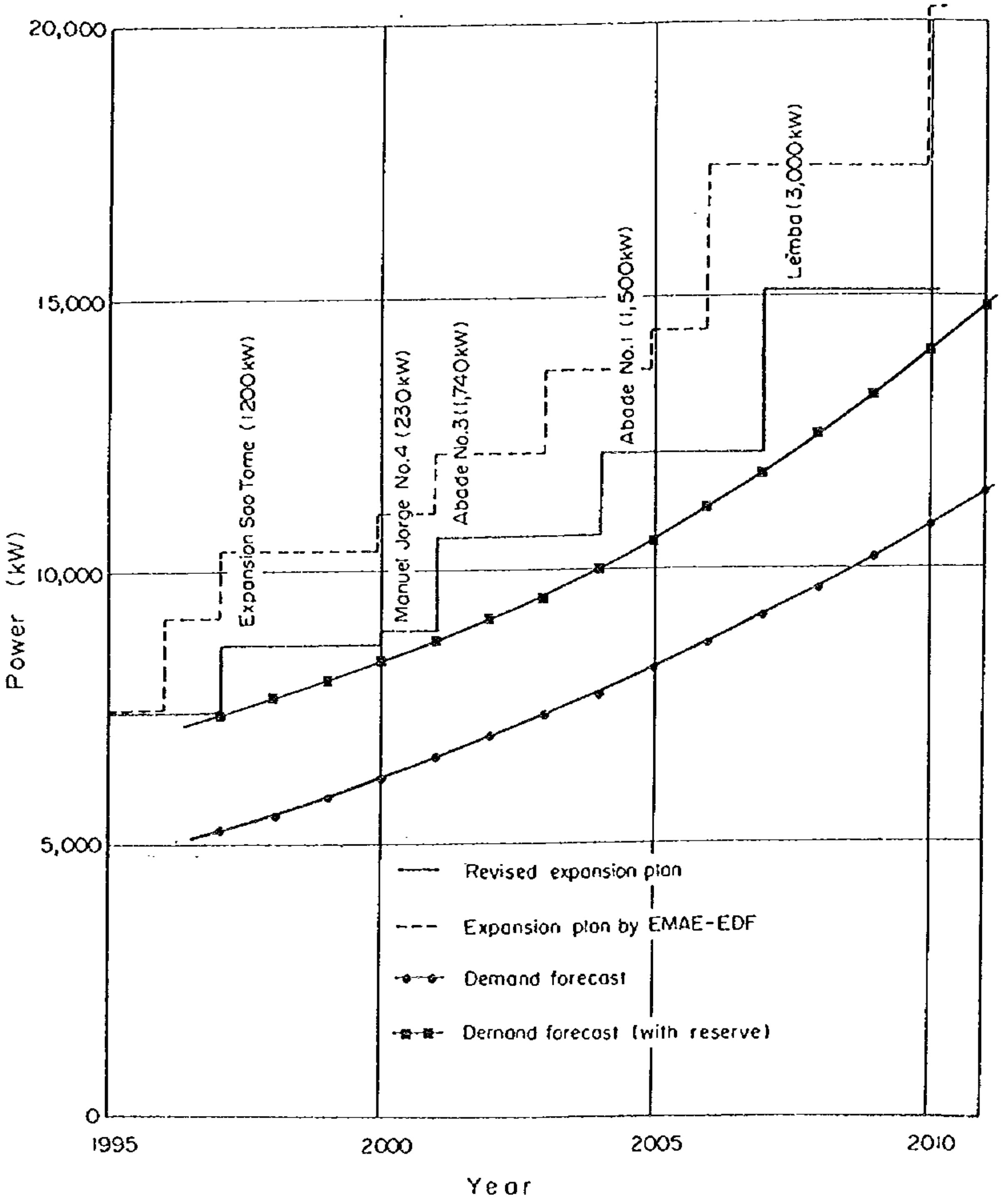


Fig. 5-3 Power Balance