ETHIOPIA

FEASIBILITY REPORT ON POWER DEVELOPMENT AT LAKE TANA REGION

MARCH 1977

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of Ethiopia the Government of Japan agreed to conduct a feasibility study of the Lake Tana Area Electric Power Development Project in Ethiopia and commissioned the Japan International Cooperation Agency to execute the study.

The Agency dispatched a survey team of six specialists with Mr. Yutaka Narita, Electric Power Development Co., Ltd., as chief from March 10 to March 29, 1976 (20 days) and another of eight specialists from September 1 to September 27, 1976 (27 days) for field investigations.

The survey team examined data on the Lake Tana Area furnished by the Government of Ehiopia and carried out field investigations of the project area with the cooperation of the Ethiopian Electric Light & Power Authority.

This Report is the product of studies on data collected in the field and results of field investigations.

It is sincerely hoped that this Report will contribute to electric power development in the Lake Tana Area and thus serve to strengthen the friendly ties between Ethiopia and Japan.

In closing, it is wished to commend the members of the mission for their great efforts in conducting the study and to sincerely thank all those persons concerned in the Government of Ethiopia and the Japanese Embassy in Ethiopia for their cooperation and the Ministry of Foreign Affairs and the Ministry of International Trade and Industry for their assistance in making possible the survey.

March 1977

Shinsaku Hogen, President

Japan International Cooperation Agency

LETTER OF TRANSMITTAL

Mr. Shinsaku Hogen, President
Japan International Cooperation Agency

Dear Sir :

Submitted herewith is a report on a Feasibility Study of an electric power development project under consideration for the area surrounding Lake Tana, Ethiopia.

For the purpose of studies on this Project, the survey mission conducted a First-Stage Field Investigation from March 10 to 29, 1976 and a Second-Stage Field Investigation from September 1 to 27, 1976. In Ethiopia, with the cooperation of the Ethiopian Electric Light & Power Authority (EELPA), the survey team gathered relevant data and information, investigated the topography, geology and hydrology of the project site and its surrounding area, made surveys of the demand areas concerned, and on returning to Japan compiled the results of the investigations in the form of this Report which is now respectfully submitted.

The principal aims of the Study have been to make a forecast of electric power demand for the area around Lake Tana and to formulate the optimum schemes for Lake Tana Regulating Dam, expansion of electric power sources and interconnected power transmission according to the scope of work requested by the Ministry of Planning and Development of the Government of Ethiopia and EELPA.

The key points of the development project consist of Lake Tana Regulating Dam, additional installation of a No. 3 unit at the existing Tis Abbay Power Station, new construction of Tis Abbay No. 2 Power Station and a power transmitting and transforming plan. Of these, construction of the regulating dam, the No. 3 Unit of Tis Abbay Power Station and transmission lines will require a period of approximately 3 years and it is desirable for these to be commissioned by the beginning of 1983, while operation of Tis Abbay No. w Power Station should be started by the beginning of 1986.

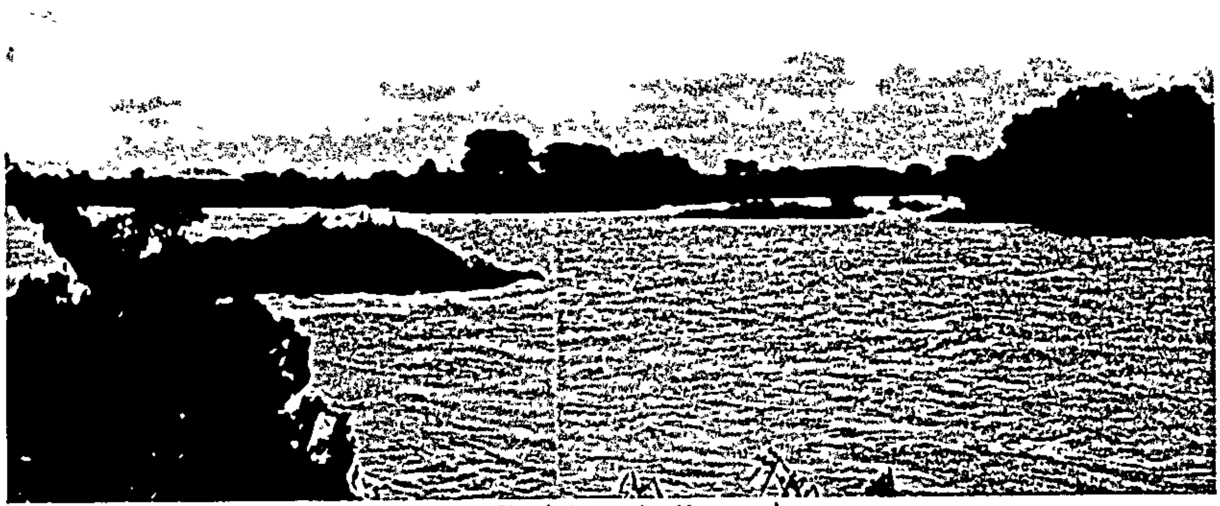
The total amount of investment required for implementation of the Project is estimated to be Birr (Eth$) 43, 300, 000 (approx. ¥6, 062, 000, 000). Although this investment amount is considered to be small compared with the benefits to be gained through realization of the Project, it will be difficult to procure this solely from domestic funds, and it is looked forward to that economic and technical cooperation between the governments will hereafter be further promoted. It is sincerely hoped that electric power development in the area around Lake Tana will be expedited as a result of submittal of this Report.

In presentation of this Report, it is wished to express the sincerest gratitude to all those concerned at the Ethiopian Electric Light & Power Authority and other agencies of Ethiopia, the Japanese Embassy in Ethiopia and the Japan International Cooperation Agency for their considerable cooperation in accomplishing the Study.

Respectfully yours,

Y. Narita

Yutaka Narita, Chief
Survey Team for Electric Power
Development Plan for Lake Tana Area,
Ethiopia



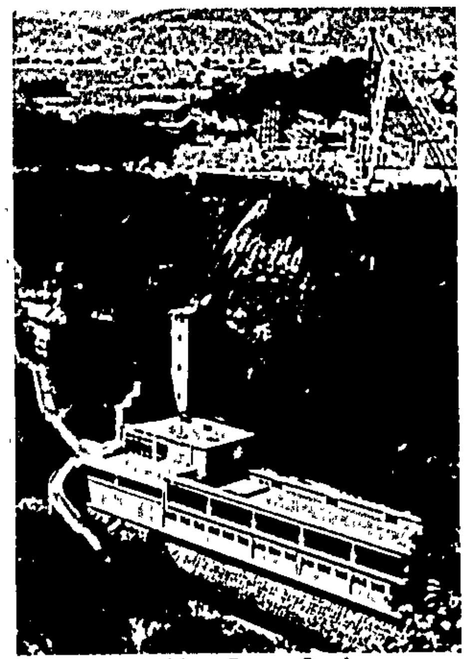
Dam Site (Alternative Upstream)

Dam Site (Proposed Downstream)


Low-water season

Tis Isat Falls


High-water season

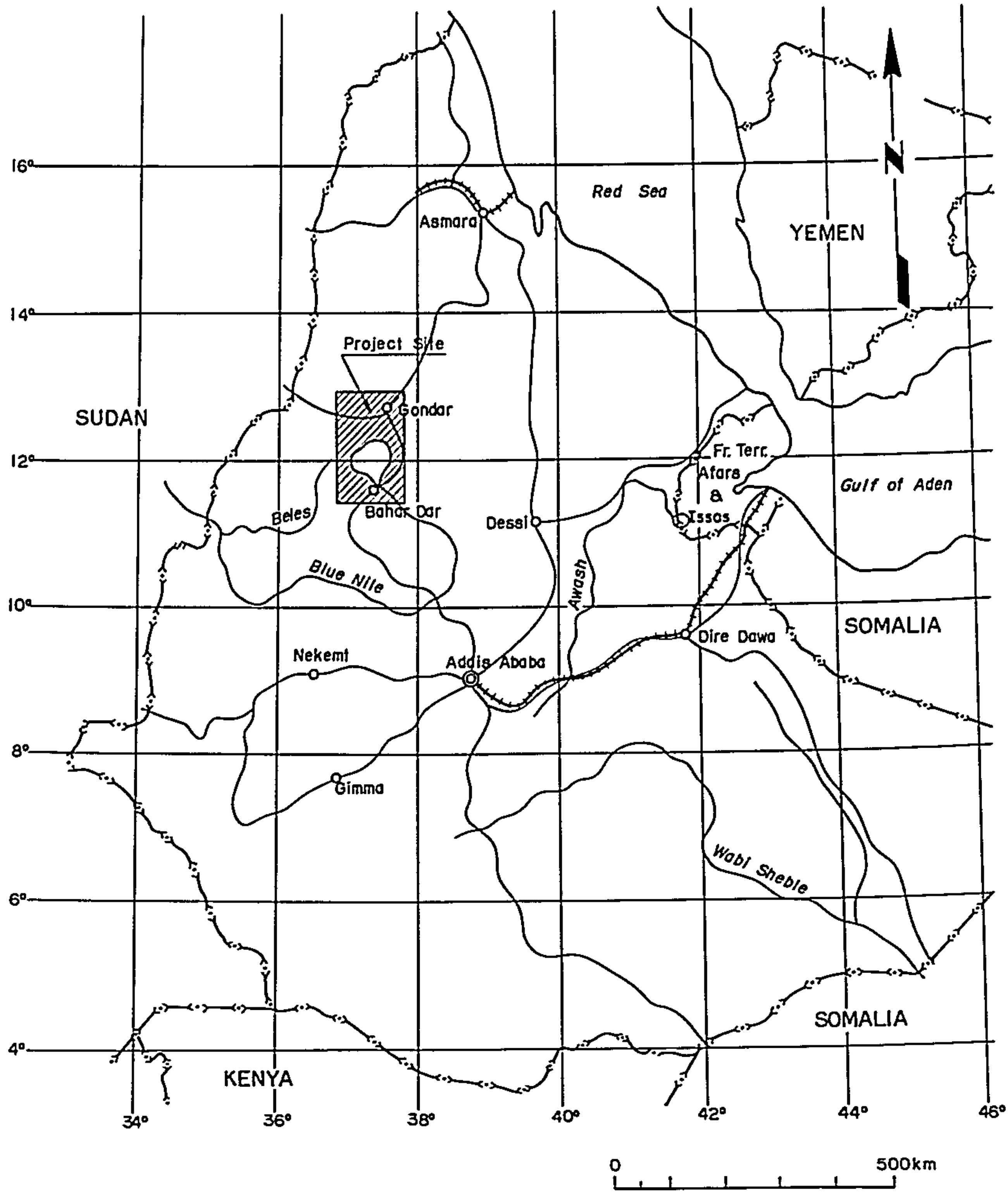

Tis Abbay Power Station

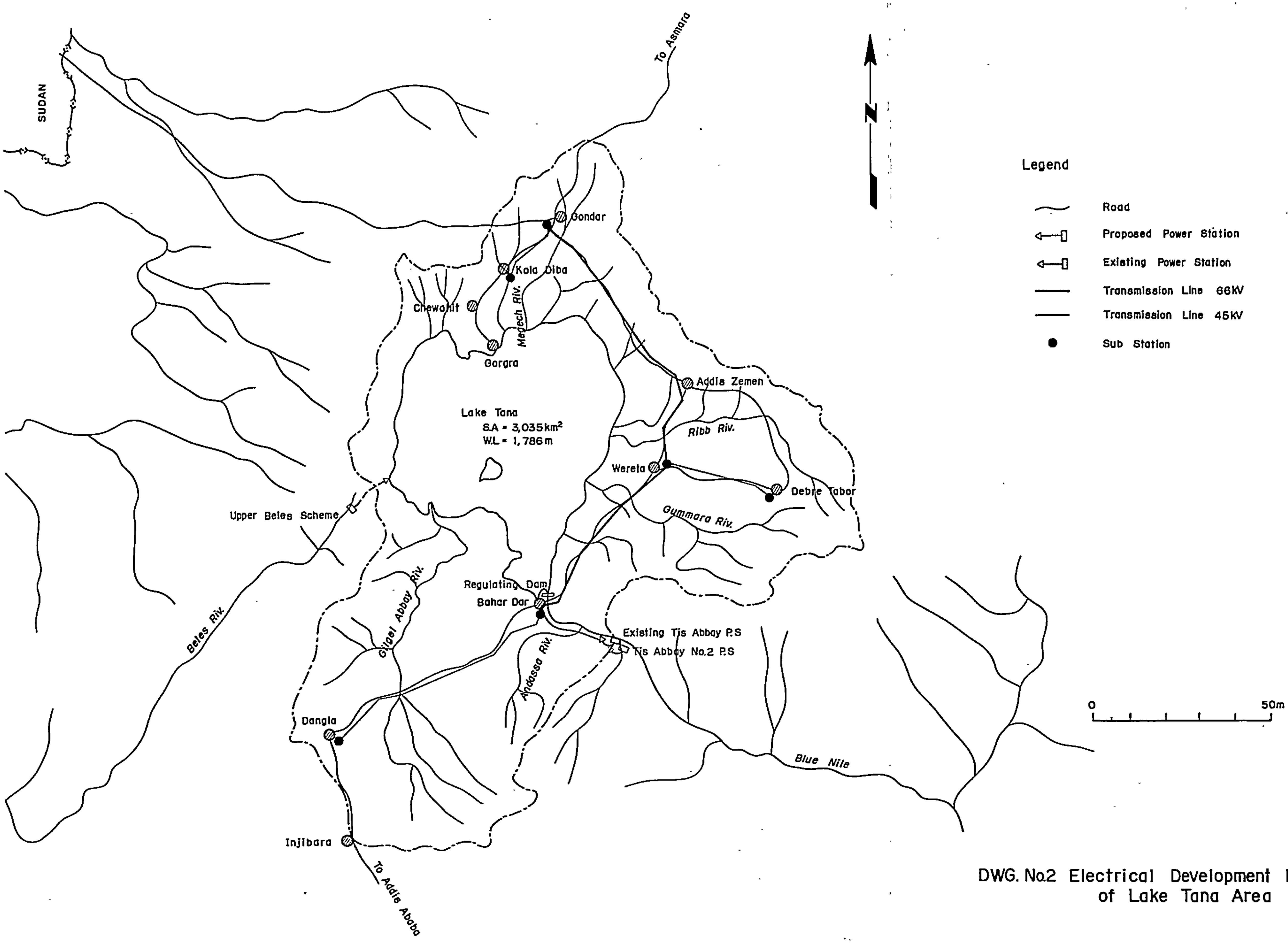

Low-water season

Downstream of Tis Abbay Power Station


High-water season

DWG. No.1 Key Map of Lake Tana Project





DWG. No.2 Electrical Development Plan
of Lake Tana Area

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DRAWING LIST

CHAPTER 1

INTRODUCTION

CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF SURVEY

This survey was for the purpose of conducting a technical examination and an economic evaluation at the feasibility study stage regarding an electric power load forecast for the Lake Tana Area, a Lake Tana regulation plan, an expansion plan for Tis Abbay Power Station and an interconnected power transmission plan for the Lake Tana Area, and to carry out preliminary designing for major structures.

In the examination of the regulating dam plan, power generation plan and the power transmission plan, the Upper Beles Project expected to be implemented in the future was kept in mind the this was given full consideration particularly in studying the regulating dam plan.

1.2 AUTHORIZATION

The Ethiopian Electric Light & Power Authority (EELPA) is engaged in electric power generation, transmission and distribution for entire Ethiopia, and in the Lake Tana Area is supplying electricity to the municipalities and communities of Bahar Dar, Gondar, Azezo, Kola Diba, Wereta, Debre Tabor and Dangla. Of these, Bahar Dar is being supplied from Tis Abbay Hydroelectric Power Station and the others from diesel power stations. At Bahar Dar, there is restriction of supply during the low-water season with regard to the demand of the electric boilers of Bahar Dar Textile Mills S.C., the largest customer in the region, while increases in power demand in districts being supplied by diesel are now restricted due to sharp rises in oil costs and importation costs of diesel generating equipment.

The Ethiopian Government is aiming for overall electrification of the national territory according to a long-range plan as a link in the establishment of a base for social and economic development. As a program for the future, it is being called for that the Interconnected System service area centered at Addis Ababa be expanded gradually thus reducing non-interconnected (self-contained) system service areas.

With such a background, in response to the request of the Government of Ethiopia, the Government of Japan in 1973 commissioned the Overseas Technical Cooperation Agency (present Japan International Cooperation Agency) to make a survey for formulation of a long-range electric power program for all of Ethiopia, and that agency dispatched a survey mission to Ethiopia, the report of which was submitted in 1974. In that report, the survey mission made a study on the timing for electric power development throughout Ethiopia, formulated a plan for power interconnection with the existing Interconnected System (ICS) accompanying the development, and examined the optimum timing for implementation of interconnection for each region. In the case of the Bahar Dar Region, it was recommended that an electrification plan for the Lake Tana Area be implemented with the highest priority among self-contained systems since it is a region where regional interconnection can be readily accomplished through regulation of Lake Tana.

Based on this recommendation, EELPA, through the Planning Commission of the Government of Ethiopia requested the Government of Japan for a study of the feasibilities of regulation of Lake Tana, expansion of Tis Abbay Power Station, and expansion of the power transmission system of the surrounding area of Lake Tana from Tis Abbay to Gondar.

Responding to this request, the Government of Japan dispatched a Survey Mission through the Japan International Cooperation Agency on two occasions for 20 days from March 10 to March 29, 1976 and 27 days from September 1 to September 27, 1976 to carry out field investigations.

1.3 ITEMS OF INVESTIGATION

The items investigated by the Survey Mission were the following:

(i) Electric power load forecast for the surrounding area of Lake Tana.

(ii) Optimum plans for the various sectors of Lake Tana regulation, power generation, power transmission and power transforming in order to be able to cope with demand as predicted from the present point in time.

1.4 COMPOSITIONS OF SURVEY TEAMS

The names, affiliations and specialties of members of the Survey Missions are given below.

First Field Survey Team (March 10 ~ 20, 1976, 20 days)

Chief	Yutaka Narita,	EPDC,*	General Supervision
Member	Tetsuro Kobayashi,	EPDC,	Load Forecast, Economic Analysis
Member	Hiroshi Suetomi,	EPDC,	Geology
Member	Tomio Watanabe,	EPDC,	Electricity
Member	Yoshihiro Nakazawa,	EPDC,	Civil Engineering Planning
Member	Shinichi Tanabe,	Ministry of International Trade and Industry,	Civil Engineering

Second Field Survey Team (September 1 ~ 27, 1976, 27 days)

Chief	Yutaka Narita,	EPDC,	General Supervision
Member	Tetsuro Kobayashi,	EPDC,	Load Forecast, Economic Analysis
Member	Hiroshi Suetomi,	EPDC,	Geology
Member	Yoshihiro Mitsui,	EPDC,	Power Transmission
Member	Yoshihiro Nakazawa,	EPDC,	Civil Engineering Planning
Member	Haruo Onda,	EPDC,	Power Generation & Transforming
Member	Shinichi Ueda,	EPDC,	Civil Engineering Designing
Member	Kokichi Inoue,	Japan International Cooperation Agency	Work Coordination

* Electric Power Development Co., Ltd.

CHAPTER 2

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 2. CONCLUSIONS AND RECOMMENDATIONS

2.1 CONCLUSIONS

As a result of field investigations and the examinations made based thereon, the conclusions below have been obtained regarding the electric power development plan for the Lake Tana Area.

2.1.1 Basic Scheme of Project

(1) The water resources of Lake Tana are estimated to be about 3,600 million m^3 annually. At present, the only utilization of this water inside Ethiopia is by Tis Abbay Power Station on the Blue Nile approximately 35 km downstream from the outlet of Lake Tana, and the available discharge of the power station is only about 16% of the total runoff. In order to correct the present situation in which the output of this power station is decreased during high- and low-water seasons and to be in step with the expansion of hydro-electric power sources in the Lake Tana Area, a regulating dam is to be constructed at the outlet of the lake for discharge of a suitable amount of water to the Blue Nile, and in addition, for diversion of a suitable amount of water to the Upper Beles River in the future, thus effectively utilizing these abundant water resources.

Regarding the water levels of the lake in this case, it will be most reasonable and economical for a maximum water surface level of 1,787.50 m and a minimum water surface level of 1,785.00 m to be adopted, and by regulating and discharging the water between these two levels amounting to a volume of 7,786 million m^3, on the Blue Nile it will be possible to supplement the flow to the existing Tis Abbay Power Station in the low-water season, prevent reduction in output due to rise in tailrace outlet water level during the high-water season, additionally install Tis Abbay No. 2 Power Station, and mo moreover, secure discharge to Tis Isat Falls for tourism purposes even in the low-water season. Further, by diverting approximately one half of the Lake Tana discharge to the Upper Beles River in the future, it will be possible to secure water required for electric power generating and irrigation in the Upper Beles Project.

The planned water levels of the lake are roughly within the past upper and lower limits of natural water levels. On comparison of the results of calculations of water levels regulated through gate operation with the present water level fluctuations, the times during each year at which maximum and minimum water levels will be reached will be set back somewhat, but the trend in water level variation will not be changed. Consequently, it is thought there will be no inconveniences caused with respect to pastureland and cultivated fields around the lake or to the liner service between Bahar Dar and Gondar.

With regard to a location for the regulating dam, two sites, one at a place called Chara Chara (approximately 1.2 km upstream of Abbay Bridge) immediately downstream of Debre Marian Lagoon at the outlet of the lake, and the other approximately 200 m upstream of Abbay Bridge were studied. As a result, the downstream proposal has been recognized as being superior from the aspects of construction costs and work execution conditions.

(2) As an electric power source expansion plan utilizing the water of the Blue Nile regulated and discharged according to the abovementioned scheme, the addition of a No. 3 unit at the existing Tis Abbay Power Station and new construction of Tis Abbay No. 2 Power Station may be considered.

In such case, with regard to the addition of a No. 3 unit at the existing power station, electrical equipment of identical specifications as the existing No. 1 and No. 2 units should be installed for power generation of a maximum 3,840 kW, while the new Tis Abbay No. 2 Power Station would be located at the right bank of the Blue Nile approximately 100 m downstream from the existing power station. A maximum of 15 m^3/sec. of water is to be taken in from the end of the existing power station waterway, a headrace of 187.6 m provided, and with a standard effective head of 46 m, a maximum of 5,700 kW of electric power is to be generated.

(3) The electricity produced at Tis Abbay Power Station and Tis Abbay No. 2 Power Station are to be transmitted to regions around Lake Tana by the existing 45 kV transmission line between Tis Abbay and Bahar Dar and the newly constructed transmission lines listed below.

66 kV Trunk Transmission Line

Bahar Dar ~ Gondar	165 km

45 kV Branch Transmission Lines

Bahar Dar ~ Dangla	85 km
Wereta ~ Debre Tabor	44 km
Gondar ~ Kola Diba	29 km

Through construction of these interconnected transmission lines, cheap electricity utilizing the abundant water can be supplied replacing existing diesel power to electrified communities such as Gondar - Azezo, Debre Tabor, Wereta and Dangla, while villages such as Chewahit, Gorgora, Addis Zemen and Injibara - Addis Kidame can newly be supplied with electric power, thus contributing to economic development in the area surrounding Lake Tana.

(4) The construction cost of implementing the above will be Birr (Eth$) 43,300,000 (approx. ¥6,062,000,000) at 1976 present worth.

Project	Total		Foreign Currency		Domestic Currency	
	Birr(Eth$)	¥1,000	Birr(Eth$)	¥1,000	Birr(Eth$)	¥1,000
Regulating Dam	10,174,000	1,424,360	6,162,000	862,680	4,012,000	561,680
Tis Abbay PS No. 3 Unit	4,238,000	593,320	3,691,150	516,761	546,850	76,559
Tis Abbay No. 2 PS	12,052,000	1,687,280	8,706,430	1,218,900	3,345,570	468,380
Transmission Line, Sub-stations, Telecommunications System	16,836,000	2,357,040	9,878,420	1,382,979	6,957,580	974,061
Total	43,300,000	6,062,000	28,438,000	3,981,320	14,862,000	2,080,680

2.1.2 Relation with Electric Power Demands

A forecast of future power demands has been made taking into overall consideration the actual loads of power demands in the project area, restricted demand due to insufficiency of supply capacity and other causes, planned demand based on future factory expansion plans and industrial estate development plans, anticipated demand due to conversion from diesel engines to electric motors, and trends in population and income levels according to demand area.

The electric boilers of Bahar Dar Textile Mills S. C. which account for a large portion of the power demand of the area are supplied by contract with off-peak power, and a study was made of the two alternatives of the kilowatt demand of the boilers not being included, "Case A", and being included, "Case B", and in the economic analysis described later, it was found that the electric power development shceme corresponding to Case A was more economical than that corresponding to Case B, and the results of load forecasting corresponding to Case A will be described here.

The actual load of the entire project area as of 1976 is a total of approximately 5,460 kW at peak load (of which 4,230 kW is in the Bahar Dar Region), the maximum demand in case of the boilers being off-peak is estimated to be approximately 3,190 kW (Bahar Dar, 1,960 kW) and a maximum of approximately 7,460 kW including potential demand.

In 1983, it is estimated that the maximum demand will be 9,070 kW at the generating end and 8,450 kW at the outgoing end of 15 kV (of which 3,430 kW will be for the Bahar Dar Region), and it will be necessary for the regulating dam and the No. 3 unit of Tis Abbay Power Station to be commissioned by the beginning of 1983. The present average annual supply capacity of Tis Abbay Power Station of 6,670 kW will then be increased to 10,560 kW.

In 1986, it is estimated that the maximum demand will be 11,320 kW at the generating end and 10,410 kW at the outgoing end of 15 kV (of which 3,850 kW will be for the Bahar Dar Region), and it will be necessary for Tis Abbay No. 2 Power Station to start operation by the beginning of 1986. The supply capacity will then be 15,820 kW.

After Tis Abbay No. 2 Power Station has gone into operation it will be possible to cope with demand with the supply capacity of the Tis Abbay generating system until 1990, but a shortage in capacity will be produced in 1991 and it will be necessary for supplemental power to be supplied from some other new source. The development of the Upper Beles Project may be considered as promising in such a case.

2.1.3 Economic Analysis

Either a system of generating hydroelectric power utilizing the water of the Blue Nile and supplying the power by interconnected transmission lines or a system adding diesel power stations according to demand can be considered for power supply to the Lake Tana Area. As a result of studies, since it was considered that it would be more economical to switch to the hydroelectric power supply system through transmission lines rather than to continue with diesel power generation, and from the viewpoint of supplying electric power at minimum cost, a study was made regarding the timing of conversion.

In making the studies, the two discount rates of 8% and 10% were considered, while analyses were made in correspondence with the two load forecasts of Case A and Case B as described in 2.1.2. The results may be summarized as follows:

i. Case A is more economical than Case B.

ii. In case of a discount rate of 8% it will be most economical to convert to the hydroelectric power supply system at the beginning of 1982.

iii. The timing for conversion in case of a discount rate of 10% will be most economical during 1983 to 1988, but the difference during this period will be slight.

iv. Considering that a discount rate of 8% reflects long-term international interest rates, it will be suitable for conversion to a hydroelectric power supply system to be made at a time as soon as possible after 1982.

2.1.4 Financial Analysis

The most important point in a financial analysis is to confirm whether income is commensurate with funds invested. Comparing the average annual energy sales income converted to present worth with the average annual energy expenses including capital and operation and maintenance cost, the income/expense ratio is approximately 1.2 in case of an interest rate of funds procured of 10%, and approximately 1.6 in case of rate of 8%.

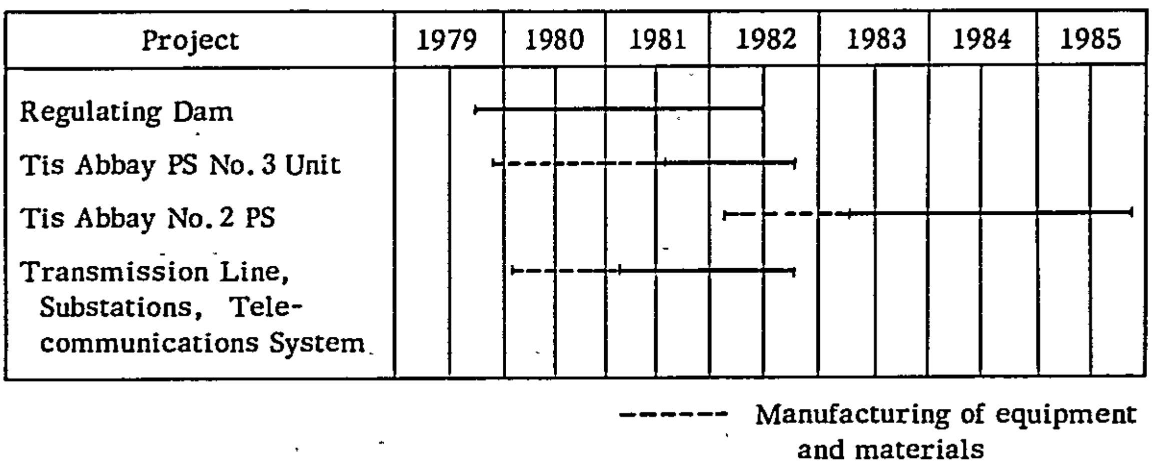
The results of computing power supply cost based on average annual energy expenses and average annual energy supply are as follows:

Category	Interest Rate 8 %		Interest Rate 10 %	
	Eth¢	¥	Eth¢	¥
Power generating expense	5.00	7.00	5.74	8.03
Transmitting, transforming, distributing expense	3.75	5.25	4.28	6.00
Total	8.75	12.25	10.02	14.03

This cost is high compared with that of the existing ICS, but since the supply cost of diesel power generation of SCS is Eth¢15.5 (¥21.70, exclusive of interest), and the supply cost of this plan including interest is considered to be approximately half of that of existing diesel power stations, while moreover, there is the merit of good supply stability. Furthermore, the cost of this Project includes the capital cost and operating cost of the regulating dam which actually would be a common facility with the Upper Beles Project.

2.1.5 Construction Period

As a result of studies of the load forecast and economic analysis described above, and in consideration of the scale, geographical and natural conditions of the project, and further, taking into account the various procedures required up to the time of carrying out work hereafter, it is thought proper for the construction schedule to be as indicated below.



2.1.6 Basic Specifications of Principal Structures

(1) Regulating Dam

Lake Tana Plan	Max. Water Level	EL. 1,787.50 m
	Min. Water Level	EL. 1,785.00 m
	Available depth	2.50 m
	Effective capacity	7,786 million m^3
Dam	Length	440.00 m
Overflow section	Type	Concrete
	Crest	EL. 1,783.00 m
	Length	87.00 m
	Height	7.50 m (max. W.L. above foundation)
	Dam volume	4,100 m^3
Non-overflow section	Type	Earthfill
	Crest	EL. 1,788.00 m
	Length	353.00 m
	Height	7.00 m
	Dam volume	27,000 m^3
	Slope gradient	Upstream 1 : 2.5, Downstream 1 : 3.0
Gate	Type	Steel roller gate
	Number	5
	Dimensions	W 15.00m x H 5.00m
	Max. water passage volume	1,280 m^3/sec.

(2) Tis Abbay Power Station No. 3 Unit

Turbine	Type	Vertical Francis
	Rated capacity	3,960 kW
	Available discharge	10 m^3/sec.
	Head	46 m
	Speed	375 rpm.

Generator	Type	3-ph, synchronized
	Rated capacity	4,800 kVA
	Frequency	50 Hz
Main Transformer	Type	3-ph, 2-winding, oil-immersed, self-cooled
	Rated capacity	4,800 kVA
	Rated voltage	47.25/6.3 kV
	Frequency	50 Hz

(3) Tis Abbay No. 2 Power Station

Power Generation Plan	Generation system	Run-of-river
	Max. available discharge	15 m^3/sec.
	Standard effective head	46 m
	Max. output	5,700 kW
Headrace	Type	Reinforced concrete, culvert
	Shape	Semi-circular top, rectangular bottom
	Length	187.6 m
	Inner diameter	W 2.48 m, H 2.73 m
Penstock	Type	Reinforced concrete, partially steel-lined
	Length	Vertical shaft 41.2 m, horizontal shaft 48.5 m
	Inner diameter	1.8 m
Turbine	Type	Vertical Francis
	Output	5,880 kW
	Speed	375 rpm.
	Number	1
Generator	Type	3-ph, synchronized air duct circulating type
	Capacity	7,100 kVA
	Voltage	6.6 kV
	Frequency	50 Hz

Main Transformer	Number	1
	Type	3-ph, oil-immersed, self-cooled
	Capacity	7,100 kVA
	Voltage	47.25/6.6 kV
	Number	1

(4) Transmission Line

Type	Trunk Line	Branch Line		
Sector	Bahar Dar ~ Gondar	Bahar Dar ~ Dangla	Wereta ~ Debre Tabor	Gondar ~ Kola Diba
Distance	165 km	85 km	44 km	29 km
Voltage	66 kV	45 kV		
Electric system	3-phase, 3 wire	3-phase, 3 wire		
Number of circuits	1 circuit	1 circuit		
Conductor	160 mm^2 AAAC	80 mm^2 ACSR		
Overhead ground wire	22 mm^2 GSC	22 mm^2 GSC		
Insulator	254 mm suspension insulator	254 mm suspension insulator		
Support	Wood pole and steel tower	Wood pole	Wood pole and steel tower	Wood pole
Grounding system	Solid grounded system	Non-grounded system		

2.2 RECOMMENDATIONS

(1) Based on the results of 2.1, "Conclusions", it is desirable for the regulating dam, No. 3 unit, and transmission and transforming facilities to be commissioned by the beginning of 1983, and the No. 2 Power Station by the beginning of 1986. Accordingly, it will be necessary for preparations for construction starts to be made as soon as practicable considering the respective construction periods.

In other words, preparatory work such as arrangements for funds, definite designs, and land acquisition payments for the dam, power stations, and transmission and transforming facilities should be positively carried out.

(2) The items for investigation required to be made in advance for the definite design are the following:

i. Surveying of the topography of the river for the sector from Debre Marian Lagoon at the outlet of Lake Tana to 300 m below Abbay Bridge (scale, 1/1,000).

ii. Core boring investigations regarding Tis Abbay No. 2 Power Station.

iii. Investigation of qualities and available quantities through surveys (scale, 1/1,000) of aggregate borrow areas and soil material borrow areas.

iv. Obtaining a water level-flow rating curve for the low-water season gaging water level of the Blue Nile downstream of Tis Abbay Power Station.

v. Surveying and investigations regarding the transmission line route are to be executed at the stage of definite design.

(3) There are some damaged parts at the "diversion cofferdam" upstream of the intake of the existing Tis Abbay Power Station and the "Deepened Abbayed Branch". These damaged portions comprise one reason for lowering of output during the low-water season, and it is desirable for repairs to be made.

CHAPTER 3

OUTLINE OF PROJECT AREA

CHAPTER 3 OUTLINE OF PROJECT AREA

3.1 GENERAL SITUATION

Lake Tana, the source of the Blue Nile, is situated in the northern part of Ethiopia and has a surface area of 3,035 km^2 (width, 60km; length, 70km), water level elevation of 1,786 m, and maximum depth of 14 m, while its catchment area is approximately 15,000 km^2 with numerous rivers and streams flowing into the lake from the surrounding mountainlands. The major streams feeding the lake are the four rivers, the Gilgel Abbay, the Megech, the Gumara and the Ribb. The Blue Nile flows out from Lake Tana at a comparatively narrow point at the eastern outskirts of the city of Bahar Dar at the southern end of the lake, flows down approximately 35 km in a southeast direction where it forms the famous Tis Isat Falls to drop into a gorge having a depth of about 45 m. The river flows down this deep canyon for approximately 800 km to reach the Ethiopian-Sudanese border approximately 650 km beyond which it merges with the White Nile.

Because of the topographical restrictions at the outlet and the large capacity of the lake, the water level of the lake rises gradually during the rainy season to reach its maximum level in September at the end of the rainy season, after which it slowly falls to reach its minimum water level in June. The annual water level variation is approximately 1.6m, while the past maximum water level was 1,787.53m (September 16 ~ 18, 1964) and the past minimum water level 1,785.08m (June 16, 1970).

The areas to the north and east of the lake consist of gently-sloped, flat land spreading out to a distance, while the area to the south is a vast plateau formed of lava flows, rocky hills, low marsh areas, and mountainous terrain.

The Lake Tana Region, in spite of being located near the equator, has a comparatively mild climate because of its high elevation. The annual climate may be roughly divided into two seasons — rainy and dry. The rainy season may be divided into a minor rainy season in April and May, and a major rainy season from June through September. The annual rainfall is 1,300 ~ 1,700 mm or an average of 1,500 mm at Bahar Dar, and 850 ~ 1,450 mm or an average of 1,150 mm at Gondar, indicating that the south region of the lake has a tendency for more rain than the north region.

There is diurnal difference in temperature, but the temperature is comparatively uniform throughout the year and the mean annual temperature is 18.5 °C at Bahar Dar and 19.7 °C at Gondar. The annual average daily maximum and minimum temperatures at Bahar Dar are 26.3 °C and 10.7 °C respectively, and those at Gondar are 26.3 °C and 12.4 °C respectively. The coldest month at Bahar Dar is December with a mean temperature of 16.1 °C while the warmest month is May averaging 21.0 °C. At Gondar, these months are December with 18.6 °C and April with 22.3 °C, respectively.

The principal municipalities and communities in the catchment area are Gondar and Azezo (population, 60,000), Kola Diba (6,500), Chewahit (4,500) and Gorgora

(2,260) in the north region, Addis Zemen (9,000), Wereta (5,500) and Debre Tabor (12,000) in the east region, Bahar Dar (34,000) in the south region, and Dangla (8,600) and Injibara-Addis Kidame (7,500) in the southeast region.

Of these, Bahar Dar situated at the southern end of Lake Tana is one of the foremost industrial cities of Ethiopia having the Bahar Dar Textile Mills with modern facilities and the Academy of Pedagogy, while there is Bahar Dar Airport within the city limits. Gondar was the capital of the Ethiopean Empire in olden days, and prospers today as the capital of Begedimir Province. Gondar Airport is located 15km south of the city.

The principal industries of the area are not much more than the textile mills at Bahar Dar and Cotton Ginning & Processing S.C. at Gondar in the way of manufacturing. Other than these there is farming, chiefly in grains, cattle and sheep raising, and there are secondary processing industries for leather, seed oils and honey.

Most of the above communities have developed along National Route No. 3 running between Addis Ababa and Asmara. Bahar Dar at the southern end of Lake Tana is located 578 km away from Addis Ababa, while Gondar in the region north of the lake is 172km from Bahar Dar, 582 km from Asmara, and secondarily processed agricultural products of this area are shipped out via Asmara to be exported from the port of Massawa.

A road connecting National Route No. 3 with National Route No. 1 is presently being constructed with aid from the People's Republic of China, of which approximately half of the stretch between a point around 4km north of Wereta and Debre Tabor is about completed.

There is regular liner service between Bahar Dar and Gorgora at the northern end of the lake.

3.2 ELECTRIC POWER SITUATION OF ETHIOPIA

Until the governmental change of 1974, electric power supply in Ethiopia had been carried out for the entire land except for the northern part of Eritrea Province by EELPA, the Asmara Massawa district of Eritrea Province by the privately owned Societa Elettrica dell' Africa Orientales, SEDAO, and a small area in Eritrea of five communities covered by Compania Nazionale Impresse Elettriche (CONIEL), but since the change in government, these private power companies have been expropriated, and EELPA is now carrying out power generation, transmission and distribution for the entire country as the sole national electric power company. However, there are still suppliers of community-owned facilities at small communities remaining, but these are all under the technical and financial supervision of EELPA.

The energy sales for the entire country in 1972 was approximately 377 GWh, of which 80% was supplied by EELPA.

The total capacity of the electric power enterprises as of the end of 1975 was 223 MW in hydroelectric power, and 67 MW in thermal power (including 33 MW of generating capacity of the defunct SEDAO), a total of 290 MW.

The electric power facilities are divided into the Interconnected System of 230kV, 132kV and 45kV lines centered around Addis Ababa and self-contained systems in the provinces. The installed capacity of EELPA, (excluding 33 MW of thermal facilities of the defunct SEDAO), divided according to the two types of systems is as shown below.

(Unit : MW)

Item	ICS	SCS	Total
Hydro	214	9	223
Thermal	12	22	34
Total	226	31	257

The installed capacity of self-contained systems is about 31 MW of which hydroelectric power constitutes approximately 9 MW, the major part of which is the 7.6 MW of Tis Abbay Power Station which supplies to Bahar Dar.

3.3 ELECTRIC POWER SITUATION OF PROJECT AREA

The principal power generating facilities in the project area are Tis Abbay Hydroelectric Power Station and Gondar Diesel Power Station.

Tis Abbay Power Station is a hydroelectric power station which was constructed with the aid of Yugoslavia taking advantage of the natural head of Tis Isat Falls approximately 35 km downstream from the outlet of Lake Tana to the Blue Nile and operation was started in 1964. It is designed for maximum discharge of one turbine at $10m^3$/sec, rated head of 46 m, and installed capacity of 3,840kW per unit. Waterway facilities such as the water canal and shaft are constructed for discharge of $30m^3$/sec and the powerhouse is built to accomodate three units. There are two turbine-generator units (7,680kW) presently installed and space for a third unit is provided, but it has not yet been installed. The manufacturer of the existing turbine-generators is Titovi Zawadi Ljumbletana of Yugoslavia.

The electric power generated is conducted to Bahar Dar Substation by a 45kV, sinble-circuit transmission line of approximately 30km, and from this substation is led out a single circuit of 15kV for Bahar Dar Textile Mills S.C.

The facilities at Gondar Diesel Power Station consist of four units totalling 1,450kW, and the electric power generated is transmitted to the city of Gondar and the surrounding area including Azezo and Kola Diba by three 15kV circuits.

Other than the above, there are small-scale diesel power facilities at Debre Tabor (owned by EELPA), Wereta (owned by community) and Dangla (owned by municipality) supplying electricity to their respective districts.

The load situations of the various power stations as of 1976 are as indicated in the table below.

Power Station	Owner	Installed Capacity kW	1976 Demand	
			Maximum Power Demand kW	Annual Energy Demand MWh
Tis Abbay Hydro	EELPA	3,840 x 2 = 7,680	General 670 Textile 3,560 Sub-total 4,230	General 1,809 Textile 20,681 Sub-total 22,490
Gondar Diesel	EELPA	1,450	1,065	3,175
Debre Tabor Diesel	EELPA	238.5	55	72
Wereta Diesel	Community	42	42	61
Dangla Diesel	Municipality	64	76	115
Total		9,474.5	5,468	25,913

The Bahar Dar district supplied with electricity from Tis Abbay Power Station has shown a trend for demand to be slowed due to the economic recession following the oil crisis of 1973 and the change of government in 1974, but unlike Gondar and Debre Tabor, supply to customers in general is not being restricted. However, with respect to the electric boilers of Bahar Dar Textile Mills S.C., the contract is for supply of electricity at off-peak hours, and supply is cut off when there is a shortage of supply capability so that there is presently frequent restriction of supply during low-water seasons.

Since Tis Abbay Power Station is a run-of-river type power station having no regulating reservoir, regulation of discharge in the wet and dry seasons cannot be performed, and it has the drawbacks that each year, in the low-water season from March to June, the output drops to around 50 30% because of lack of river runoff, while conversely, in the high-water season the water level around the power station outlet rises excessively to reduce head and greatly lower generating capacity. These drawbacks would become even more extreme when generating facilities are expanded.

The following are conceivable as factors for increasing electric power demand in the project area :

1 Factory expansion plans at Bahar Dar Textile Mills. Reopening of the Academy of Pedagogy at Bahar Dar.

2 Hotels with modern facilities presently under construction at Bahar Dar and Gondar and scheduled to open in 1977.

3 Factory expansion plans at Cotton Ginning & Processing S.C. in Gondar and the water supply plans for the city.

4 The population of the project area is said to be approximately 150,000 at present, but the population growth rates of the various communities are considerably higher than the national average, and is estimated to be about 6.5% per year.

5 The kWh/capita increases accompanying growth in GNP/capita.

6 There is considerable restriction of supply at Gondar, Debre Tabor, Wereta and Dangla because of shortage of supply capacity or difficulty of fuel oil transportation and there is potential general demand.

7 There is a fair amount of potential demand at Chewahit, Gorgora, Addis Zemen, Injibara-Addis Kidame which are not presently being supplied with electricity.

8 All communities have flour mills for producing materials for the staple food of the residents with almost all of them driven by diesel engines so that demand can be expected on electrification.

CHAPTER 4

LOAD FORECAST

CHAPTER 4 LOAD FORECAST

4.1 FUNDAMENTAL CONDITIONS

4.1.1 Data and Field Investigations

(1) Data and Information

As forecasts of power demand in the area around Lake Tana there is an old one made in the early 1960s by the Bureau of Reclamation, U.S. Department of the Interior, and another one prepared later in 1972 by EELPA as a part of the program in the electric power sector of the Fourth Five-Year Plan (FFYP).

In 1973, a long-range electric power development plan for entire Ethiopia was formulated by experts from EPDC of Japan on which occasion a fairly detailed load forecast predicated on interconnection was made for the Lake Tana Region also. However, this load forecast lacked back-up checks through field investigations due to limitations on time available.

To cope with the new situation brought about by the oil crisis of 1973 and the change in government in 1974, EELPA has newly prepared revised data based on the abovementioned EPDC forecast.

For the present electric power development scheme for the area around Lake Tana, using the previous EPDC load forecast and the revised data of EELPA as references, and in combination with the results of the field investigation described below, it has been endeavored to gain a more accurate grasp of actual loads, restricted demand, potential demand and planned demand, based on which future demand is forecast.

Reference data used for forecasting were the power generation and sales records of the various branches of EELPA from 1964 through 1974, operation records of Bahar Dar Substation, Tis Abbay Power Station, Gondar Power Station and Debre Tabor Power Station in 1975 and 1976, and statistics of the Central Statistics Office.

(2) Investigation

A load forecast must be formulated based on overall consideration of actual demand and restricted demand due to shortage of supply capacity and other reasons at present, planned demand based on plant expansion plans and industrial estate establishment plans for the future, and population trends and income levels by town. For this reason, a field investigation was conducted divided into the two stages of March and September, 1976, and investigations were made through consumers in general and principal factories of the various communities concerning the actual situation in electric power consumption and future planned demand. The major items of survey were the following:

(a) Grasping of an overall concept through enquiries on long-range schemes of regional development to the provincial administrators of Bahar Dar and Gondar.

(b) Making enquiries on and obtaining various data regarding the present situation of power demand from the chiefs of municipalities or kabale of Wereta, Addis Zemen, Debre Tabor, Kola Diba, Chewahit, Gorgora, Dangla and Injibara.

(c) Making enquiries of the general managers and chief engineers of Bahar Dar Textile Mills S.C. and Gondar Cotton Ginning & Processing S.C., the major industries in the project area, regarding plant expansion plans, and observation of the states of operation of the plants.

(d) Enquiries of the EELPA branch managers of Bahar Dar, Debre Tabor and Gondar regarding the situations of power demand and supply, supply restriction, waiting customers, etc.

(e) Investigation of states of operation of engines at flour mills, oil crushing mills, etc. in each town.

(f) Investigations of states of power generation, fuel consumption and load restriction based on daily and monthly operation records of the various power stations and substations.

(g) Exchange of opinions on the industrialization scheme for the Lake Tana Region at the Planning Commission Office in Addis Ababa and examination of the prospects with regard to time of realization.

4.1.2 Service Area

The load forecast is to be made setting up the following as service areas to be supplied electric power through interconnection in this scheme based on overall consideration of populations and power demands (including potential demands), distances of power transmission from Tis Abbay Power Station, transmission capacities and other factors with respect to the various communities.

(1) Bahar Dar area

Load forecasting for this area is to be done separating the power demand into the two parts of urban demand of Bahar Dar City and the large-scale demand of Bahar Dar Textile Mills S.C. in the outskirts.

(2) North Region

Other than the Gondar ~ Azezo ~ Kola Diba area presently being supplied, the non-electrified communities of Chewahit and Gorgora are included.

(3) East Region

The three districts of Debre Tabor, Addis Zemen and Wereta are included in this region. Of these, Debre Tabor is in the service area of EELPA while Wereta has a township-operated power station, but Addis Zemen is not yet being supplied with electric power.

(4) South Region

The three districts of Dangla, Injibara and Addis Kidame are included in this region. Of these, Dangla has been supplied with electric power by the municipality from relatively long time ago, but the remainder consists of still non-electrified communities.

4.1.3 Method of Estimating Potential Demand

Estimation of the potential demand presently existing is an important factor in forecasting future power demand, especially of non-electrified communities and districts still at initial stages of electrification. In this connecton, our method of estimation is as follows:

(1) Estimation of Residential (including Commercial) Potential Power Demand

Ordinarily, standard household expenditures for residential electric power may be considered to be approximately 3% of income, while the results of field investigations made by the Survey Mission at several non-electrified communities (Addis Zemen, Injibara, etc.) in the project area show that household expenditures for lighting by kerosene lamps or other means are as indicated below, and it was found that seen from the state of personal incomes in rural areas they almost coincide with standard expenditures in case of electric power.

- High income households (approx. 10% of total) Eth$ 5.00 ~ 6.00/month
- Middle income households (approx. 20% of total) Eth$ 3.00 ~ 4.00/month
- Low income households (approx. 70% of total) around Eth$ 1.50/month

Since the unit sales price of EELPA for residential use is presently about E¢ 18.00/kWh, if the above expenditures of households are converted into terms of power consumption, the figures would be the following:

- High income 28kWh/month (330kWh/year)
- Middle income 17kWh/month (200kWh/year)

Other than income levels, the electrification stage is governed by supply capacity of power stations and the state of power distribution networks. The electrification stage of various areas in Self-Contained Systems are scattered roughly between 20 to 30% according to statistical data of EELPA.

In the case of the present project area, unlike other self-contained systems supplied by diesel, power supply of high profitability is anticipated, so that construction of distribution networks may be expedited and it can be expected that as a consequence the electrification stage will become higher as a matter of course.

On the other hand, however, it will be necessary to consider the factor of the unwakened taste for electricity among the population at the initial stage of electrification.

In view of the above, for the time being, in estimating the present potential demand, it is considered that of the total number of households in the area about the upper 25% in income level will be objects of electrification, while for the average power consumption per household, the weighted average of the respective consumptions of these upper and middle income classes are taken for an assumption of 250kWh/year.

(2) Estimation of Potential Power Demand for Street Lighting

In case power supply to residents is commenced, this is always accompanied by electric power for street lighting. The extent of power consumption for street lighting is governed by the degree of economic development of the community, while at the same time it may be considered to be proportional to the scale of community and its population.

According to the records for the project area in 1976, the consumption at the city of Bahar Dar was 5kWh/capita year, while at the city of Gondar it was 3.8kWh/capita per year. Taking these records into consideration, the potential demand for street lighting of communities at the initial stage of electrification and communities as yet not electrified is estimated to be 3 kWh/capita. year.

(3) Conversion of Flour Mills to Utilization of Electric Power

Other than at Bahar Dar and Gondar, there are no enterprises in the project area which can be considered as comprising industries. However, in every district there are several flour mills directly tied to the livelihood of the people and practically every one of these mills is driven by diesel engine. According to trial calculations of conversions of horsepowers of these engines to electric motors, the fuel cost is presently roughly E¢16 ~ 17/kWh which is slightly lower than the prevailing unit sales price of EELPA, but when the future price of fuel oil and the unreliability of supply are considered, it is thought that rapid conversion to use of electricity will be seen following completion of the Lake Tana Project.

On looking at the present situation of demand and supply in the project area with the above thinking as a basis, the result is as described in the following sections.

4.2 PRESENT SITUATION OF DEMAND AND SUPPLY IN PROJECT AREA

4.2.1 Bahar Dar Area

(1). City of Bahar Dar

Bahar Dar is a city at the south end of Lake Tana located on National Route No. 3 approximately 578 km northwest of Addis Ababa. The Blue Nile which flows down through the outskirts east of the city becomes the famous Tis Isat Falls approximately 30 km downstream from the outlet of the lake, immediately below which there is the existing Tis Abbay Hydroelectric Power Station.

Elevation	approx. 1,800 m
Mean annual temperature	19 °C

(a) Economic Situation

i Population

- 1971 25,100
- 1974 29,490
- 1976 34,000

Consequently, annual growth rate is 6.3% and the total number of households is estimated to be about 6,800.

Of the population in the surrounding area 90% is comprised of farmers, while the majority of those residing in the city are engaged in small-scale commerce, services and other activities. During the past dozen years or more, construction works of Tis Abbay Power Station, a textile factory, roads and bridges, a technical school and the Academy of Pedagogy have gone on, while recently, construction of Hotel Tana has been in progress, and each time the required labor has been provided by residents of the area.

ii City Planning

The potential for future commercial and industrial development of this district has attracted attention, and since 1950 city planning has been done on several occasions. The present city planning is based on plans made up by Battelle Institute (West Germany), and development of the city in the three stages below is aimed at with the goal of making it an industrial city.

- First Stage 30,000 population
- Second Stage 100,000 population
- Third Stage 300,000 population

According to data obtained at the Provincial Administration, it is planned for the city to be divided into an administrative district, an industrial district, a commercial district, an educational district and other districts, and at present, although unsurfaced, streets laid out in orderly fashion are beginning to appear.

(iii) Economic Outlook

Other than Bahar Dat Textile Mills S.C. described later, economic activity in this district consists of not much more than commerce and tourist hotels, but the surrounding area has plentiful production of various grains, oil seeds and palms, while livestock resources are also abundant. From such a standpoint, the possibility of development of the following manufacturing facilities are cited.

- Cattle slaughterhouses
- Meat canning factories
- Soap and gelatin factories
- Leather tanneries
- Breweries
- Brickyards and ceramics factories

(b) Actual Situation of Electric Power Supply

i Electric Power Facilities

Electric Power is being supplied to this district from Tis Abbay Power Station (installed capacity: 3,840kW x 2 units) which started operation in 1964. The power generated at this station is sent approximately 30km to Bahar Dar Substation by a 45kV, single-circuit transmission line, and from this substation are led out one 15kV line for general demand in the city and two 15kV lines to the textile company described later.

ii Demand and Growth Rate

The trend in power demand during 1971 ~ 1976 may be tabulated as indicated below.

Item	1971	1973	1975	1976
Energy at Consumers End (MWh)				
Residential Use	-	457	515	-
Tariff No. 8 & No. 19	-	-	42	-
Commercial Use	-	193	176	-
Street Lighting Use	-	206	157	-
Industrial Use	-	732	744	-
Total	1,413	1,599	1,634	1,728

Item	1971	1973	1975	1976
Energy at 15kV Outgoing (MWh)	1,553	1,745	1,739	1,809
Peak Load (kW)	570	640	640	670
Number of Customers	1,326	1,510	1,925	2,133
Distribution Loss Ratio (%)	9	9	6	6
Load Factor (%)	31	31	31	31

(Note) Peak load is estimated assuming that load factor would be about 31%.

According to the above table, whereas the growth rates in the number of customers are 6.7% for 1971 ~ 1973 and 13% for 1973 ~ 1976, the growth rates in energy consumption are only 6% for 1971 ~ 1973 and 2.9% for 1973 ~ 1976.

On scrutinizing the slowdown in increase of consumption by the type of demand, it is seen that consumption in commercial and street lighting uses has decreased while consumption for industrial use has been at almost the same level. In contrast, consumption for residential use has shown growth of 6.4% annually during the two-year period of 1973 ~ 1975.

The Bahar Dar district, unlike the Gondar and Debre Tabor districts, is not restricted with respect to power supply, and it is surmised that the economic recession after the oil crisis and change in government is a major cause.

(c) Sinking Power Demand

In 1973, the Academy of Pedagogy, a very large training center for teachers was opened in the city, but because trainees have been away on campaigns in the provinces since 1974, activity at the academy had been stopped until recently. The capacity of the electrical equipment of this institution is 208kW.

The peaking diversity of these equipment is estimated to be approximately 70%, and the annual operating time about 3,000 hours (load factor, 34%). Consequently,

Annual energy demand	438MWh
Maximum power demand	146kW

The above demand has been potential up to this time, but the trainees have begun to return in stages recently, and it is expected that this training center will commence full activity one or two years later.

(d) Waiting Power Demand

Power demand presently confirmed as being waiting demand is of Hotel Tana now under construction. The total capacity of electrical equipment as informed by a hotel engineer will be 100kW, and it is said the peaking diversity will be approximately 70%, while the load factor, although differing by season, will be an average of about 30%. Consequently,

Annual energy demand	184 MWh
Maximum power demand	70 kW

It is assumed that this hotel will also start business one or two years later.

(2) Bahar Dar Textile Mills S.C.

This textile company is one of the largest enterprises in Ethiopia with 2,500 employees and is supplied with energy by two 15kV circuits from the adjacent Bahar Dar Substation of EELPA. Of the two circuits, one is for various motors in the factory while the other is for steam generation by electric boilers.

(a) Installed Capacity

i Electric Boilers

There is a total of 3 boilers which serve concurrently as furnace boilers.

- Nominal output	1,250kW x 3 units
- Operating output	800 900kW
- Steam generation	1,000kg/hr
- Manufacturer	Mascarini
- Annual operating hours	
	A system whereby boilers are stopped for maintenance for 6 hours in the morning every Sunday is adopted. However, the contract with EELPA is for off-peak power supply to be cut at any time when there is shortage of power

ii Furnace Boilers

There is a total of 3 boilers, the largest of which is as indicated below.

- Steam generation (nominal)	4,000 kg/hr
- Fuel consumption	5,000 lt/day
- Fuel used	Fuel oil No.6
- Manufacturer	Steamblock

The other two boilers are said to be both of steam generation capacity 1,000 kg/hr.

iii Diesel Generators

There are the three diesel generators indicated below, but they are all for stand-by use.

- Continuous load (nominal) 338 kW x 2 units
  (actual capacity both about 200 kW)
- Continuous load (nominal) 1,170 HP (825 kW) x 1 unit
  (actual capacity about 600 kW)

iv Water Pumps

- 30 kW x 1 unit
- 25 kW x 4 units

v Motor Facilities of the Factory

At present a First-Stage Expansion Plan is being implemented. The peak load of the factory prior to this expansion was approximately 1,260 kW.

(b) Expansion Plan of the Factory

i First-Stage Expansion Plan

According to the general manager and chief engineer of Bahar Dar Textile Mills S.C., a total of 11 types of motors for an aggregate of 486 kW had been ordered for air conditioners, twisters, humidifiers, shearers, jiggers and pumps for the First Expansion Plan considered for 1974 ~ 1976, and as of March 1976, equipment corresponding to 206 kW has already been delivered and had gone into operation. It is estimated that the peak load in connection with motors of the factory after completion of the First-Stage Expansion Plan will be increased to about 1,500 kW.

ii Second-Stage Expansion Plan

The Second-Stage Expansion Plan is presently at the stage of examination, and it is intended for the plan to be completed 3 to 4 years after the First-Stage Plan. The Second-Stage Plan may be divided into a plan for increasing various motors in the factory and a plan for increasing electric boilers. According to the general manager, the former consists mainly of additional installation of 200 looms (existing, 410 looms) and 12,000 spindles (existing, 20,000 spindles), while the latter aims for additional installation of two electric boilers, each of 1,000 kW. Further, the general manager is hoping that, the situation allowing, the three present furnace boilers can be changed over to electric boilers.

In the event the Second-Stage Expansion Plan is implemented, the power demand of motors of the plant will be increased by approximately 40 ~ 50 % over that at the completion of the First-Stage Plan, and the outlook is that peak load will be increased to at least about 2,100 kW. As for the peak load of electric boilers, even if switching of furnace boilers to electric boilers is not considered, it is estimated that the present load of approximately 3,000 kW will be increased to 5,000 kW.

(c) Power Demand and Supply situation (State of Operation of the Factory)

The state of power consumption of Bahar Dar Textile Mills S.C. during 1971 to 1976 is as shown in the table below.

Item		1971	1973	1975	1976
Annual Energy Consumption					
Motors (MWh)		7,930	7,515	8,480	8,262
Electric Boilers (MWh)		11,575	7,499	9,711	12,419
Total		19,504	15,014	18,191	20,681
Peak Load					
Motors (kW)		1,170	1,260	1,410	1,290
Electric Boilers (kW)		2,760	2,850	2,940	2,760
Overall peak load	(1)	3,750	3,720	3,855	3,560
Load Factor					
Motors (%)		77	68	69	73
Electric Boilers (%)		48	30	38	51
Peaking Diversity (%)	(2)	89	90	87	87

(Note 1) Peak loads indicated for motors, boilers and overall peak are for the respective months in which maximums were recorded.

(Note 2) The peaking diversity factors for motor and boiler demands are monthly average values.

From the above table and the monthly power consumption records, the following conclusions are reached:

i The load factors in terms of annual averages are approximately 70% for motors and the like and approximately 42% electric boilers.

ii The load of electric boilers is cut off from supply when the capability of Tis Abbay Power Station is insufficient, but every year for the half-year of the high-water season, a load factor of 50% or more is recorded.

iii After completion of the regulating dam, electric power can be generated to the limit of installed capacity almost all of the time, and it will be possible for a load factor of 50% to be maintained throughout the year with regard to power consumed by electric boilers.

(d) Special Consideration to be Paid for Electric Boilers

i Conversion to Virtual Off-Peak Operation

The contract of power supply between EELPA and Bahar Dar Textile Mills S.C. provides that electric boiler loads will be supplied with off-peak power, and for this reason capacity charges are not alloted for power consumed by electric boilers. However, on looking at the actual state of power supply, there is a considerable surplus in the supply capability since the scale of power demand in Bahar Dar including demand by motors of the Textile Mills S.C. is small compared with the existing installed capacity of Tis Abbay Power Station, and under the present circumstances, the power demand of electric boilers is satisfied without limitation except during the low-water season, so that actually, it cannot be said this is off-peak load.

Nevertheless, when the regulating dam is completed and power supply is made through transmission lines to various towns other than Bahar Dar, it will become necessary for operation of electric boilers to be switched to strict off-peak operation from the relation with load of the system as a whole. Even then, it will be possible for operation of electric boilers to be carried out at a load factor of 50% as will be described in item 4.5.2. (2).

ii Establishment of Appropriate Tariff Rate

According to the chief engineer of the Textile Mills S.C., the costs required for generating 1 kg of steam with electric boilers and furnace boilers respectively, are as indicated below.

- Electric Boiler — 1 kWh of electric energy/1.3 kg of steam (therefore, 0.077 kWh of electric energy/1 kg of steam)
- Furnace Boiler — 1 kg of heavy oil (No. 6)/13 kg of steam (therefore, 0.077 kg of heavy oil/1 kg of steam)
- Actual price — Electric energy: E¢ 1.3/kWh (special rate); Heavy oil (No. 6): Eth$ 252/ton

According to the above specific consumptions and prices, the cost of 0.77kg of heavy oil is E₵1.94. Consequently, for the textile company, if the allowable limit of consumption cost of 1kWh of boilers is assumed to be equal to the cost of equivalent fuel oil, there is an allowance for adjustment of E₵1.94/0.77 = E₵2.52/kWh to be made in the current special tariff rate for electricity of E₵1.30/kWh.

It would not be useless here to compare the special tariff rate for electric boilers with the cost per kWh at the outlet of substation obtained by dividing the annual expenses of Tis Abbay Power Station, 45kV transmission line and Bahar Dar Substation by the 15kV outgoing energy. The energy cost at the outlet of Bahar Dar Substation according to the record for 1974 (10-month data) is as shown below.

- Annual cost	(power station)	Eth$278,379
- Annual cost	(transmission line)	Eth$ 10,737
- Annual cost	(substation)	Eth$ 22,634
	Total	Eth$311,750

(includes depreciation but not interest)

- Energy supplied	(15kV outgoing)	16,361 MWh
- Energy cost	(15kV outgoing)	E₵1.90/kWh

Further, according to records for 1975, the energy supplied at the outlet of substation was 19.937MWh, and the annual power generation cost was Eth$349,817. Therefore, if it is assumed that the annual costs of the transmission line and the substation increase at the same rate as the annual cost of the power station, the total annual cost will be approximately Eth$392,800, and the cost of supply per kWh at the outlet of substation in 1975 will be E₵1.97.

On completion of the electric power program for the surrounding area of Lake Tana, it will be necessary for the applicable tariff rate for boiler load to be reestablished at an appropriate level with the fuel cost of equivalent fuel oil as the limit on one side and the supply cost at the outlet of Bahar Dar Substation after completion of the Lake Tana Project as the other.

4.2.2 North Region of Lake Tana

(1) Gondar ~ Azezo

Gondar, besides being the capital city of Begemidar Province, was also an old capital of the former Empire. The city has developed around Fasil Castle, and provincial administrative agencies, public buildings and shops are concentrated at the central part of the city, while in the suburb area there are buildings of the Health College, a vehicle maintenance plant of the Ethiopian Highway Authority, Gondar

Cotton Ginning & Processing S.C. and others. The town of Azezo is situated about 13km south of the city and located 2km south of Azezo is Gondar Airport. The distance from Bahar Dar is approximately 172km by road and a well-maintained all-weather highway connects the two.

Elevation	approx. 2,100 m
Mean annual temperature	19.2 °C

(a) Economic Situation

i Population

The trend in regional population of Gondar and Azezo combined is as indicated below.

- 1971 46,980
- 1974 56,000
- 1976 60,000

Consequently, annual growth rate is 5%, and the total number of households is estimated to be about 12,000.

ii City Planning

According to data obtained at the Provincial Administration, a master scheme for a grand city plan by which the present city of Gondar will grow to the west and south has been formulated, and layouts have been decided on for administrative, educational, hospital and health care, commercial and other districts. These new districts are already being successively closed off with barbed wire.

iii Economic Outlook

The future economic development of the Gondar-Azezo district has a close connection with the local agriculture of the surrounding area. The main industry of this region from the past has been secondary processing of agricultural products and the products processed here have been shipped via Asmara to be exported from the port of Massawa. The following may be listed as having possibilities in the growth of secondary processing industries with agricultural products as raw materials.

- Flour and farinaceous products
- Soap, vegetable oil
- Canned vegetables, dried vegetables
- Export coffee beans
- Sausages, salamis, canned meat products

- Cheeses, butter, cream, canned or bottled milk
- Leather products

(b) Actual Situation of Electric Power Supply

i Electric Power Facilities

Electric power is being supplied by Gondar Diesel Power Station of EELPA where there are 4 generators for an installed capacity totalling 1,450kW.

688kVA (550 kW) x 2 units

250kVA (200 kW) x 1 unit

187kVA (150 kW) x 1 unit

Total 1,450 kW

Other than the above generating facilities, there is a Daihatsu engine No. 3 (645kW), but mechanical trouble occurred in this engine in November 1974 and it has remained in its damaged condition ever since. The supply capability of the power station has been insufficient because of this, and it has been one reason for the restriction of supply described later.

There are three 15kV distribution lines from Gondar Diesel Power Station as indicated below.

Fasil Line, Lemalino Line } Power transmission to greater part of Gondar

Tana Line .... Power transmission to part of Gondar, and Azezo and Kola Diba

ii Demand and Growth Rate

Statistics on the actual supply since 1964 are available and looking at the trend since 1971 it is as shown in the following table.

Item	1971	1973	1975	1976
Energy at Consumers End (MWh)				
Residential Use	-	719	799	-
Commercial Use	-	293	289	-
Street Lighting Use	-	207	226	-
Industrial Use	-	1,145	1,347	-
Total	1,777	2,364	2,661	2,553

Item	1971	1973	1975	1976
Energy at 15kV Outgoing (MWh)	2,133	2,732	3,223	3,175
Peak Load (kW)	600	870	1,238	1,065
Number of Customers	2,875	3,334	3,930	4,039
Distribution Loss Ratio (%)	16.7	13.5	17.4	19.6
Load Factor (%)	40.5	35.9	29.7	34.0

According to this table, the rate of increase in the number of customers is an annual average of 7.7% for 1971 ~ 1973, and 8.6% for 1973 ~ 1975 to show a favorable growth, whereas energy consumption has slowed from an annual rate of increase of 15.5% for 1971 ~ 1973 to 6.1% for 1973 ~ 1975. The demand for 1973 ~ 1975 by category of consumers shows annual average growth rates of 5.4% for residential use and 8.5% for industrial use, whereas demand for commercial use has decreased and that for street lighting has remained practically stagnant.

iii Restriction of Power Supply

The outage of one generator since November 1974 as stated previously has made itself shown in the form of restriction of power demand, while in addition, energy demand is also restricted through unscheduled stoppage for the purpose of saving fuel oil.

According to the results of study of the operation diary of Gondar Power Station the blackout situation due to fuel conservation is as follows:

(i) Complete Interruption (All three distribution lines)

1974	32 hours/year
1975	459 hours/year
1976	862 hours/year

(ii) Annual Rate of Restriction including Partial Interruption

Basides complete blackouts, there are frequent interruptions of supply of one or two of the three distribution lines. Although it is difficult to accurately grasp the state of restriction including these interruptions, estimation to some extent may be made based on the consumption of fuel oil The months in fiscal 1976 during which there were no stoppages of supply were the four months of November 1975, and January, March and April 1976, and the average monthly fuel oil consumption for the two months of greatest fuel consumption was approximately 110,000lt.
In contrast, the total annual consumption of that fiscal year was 1,156,500lt. Consequently, the annual rate of demand restriction through savings of fuel oil is estimated to be the following:

1,156,500 lt/(110,000 lt x 12) = 87.6%

(iii) Estimation of Unrestricted Total Power Demand (1976)

The actual demand of this district in 1976 according to the preceding table consists of 3,176 MWh in terms of energy and peak load of 1,065kW at the 15kV terminal, and when the beforementioned restriction rate is taken into account, the unrestricted demand may be estimated to be as follows:

Annual energy demand	3,175MWh/0.876 = 3,626MWh
Maximum power demand	1,380kW

(assuming load factor to be 30% as in previous year)

Consequently, it is estimated that there was a restricted demand of 1,380kW - 1,065kW = 315kW during 1976.

(c) Waiting Demand

i Water Supply System

Construction on the water supply system is presently going on steadily in the city of Gondar. According to the authorities carrying out this work, the electric power required by motors after completion will be 182kW. The annual operating hours are estimated from other actual cases to be about 1,500 hours at a load factor of approximately 17%.

Annual energy demand	273MWh
Maximum power demand	182kW

ii Hotel Goha

Construction of Hotel Goha is now in progress in Gondar. According to a hotel engineer, the total capacity of electrical facilities to be installed in this hotel will be 100kW, peaking diversity 70%, and annual load factor approximately 30%. Therefore,

Annual energy demand	184 MWh
Maximum power demand	70kW

(d) Planned Demand

Planned demand of high probability of being realized is presently the expansion plan for Gondar Cotton Ginning & Processing S.C. This factory was established in 1972, and the number of employees is 300 permanent and 150 temporary workers. The existing facilities are as listed below.

- Total output of motors 130HP (98kW)
- Average monthly energy comsumption 20 ~ 25MWh

- Maximum monthly power demand — 60 ~ 70kW (peaking diversity approx. 70%)
- Load factor — approx. 50%
- Annual production of cotton — 90,000 ~ 110,000 tons

According to the general manager of the factory, a first-stage expansion plan of the factory is presently being carried out, while a second-stage expansion plan is scheduled for implementation in succession.

i · First-Stage Expansion Plan

The first-stage expansion plan is scheduled to be completed during 1977. This plan calls for annual production of cotton to be expanded from 120,000 tons to 150,000 tons, while as a new enterprise, it is intended to start oil extraction from oil seeds such as cotton seed, oil seed and sesame seed. It is scheduled for a total of 120 HP (90kW) in the form of various motors to be added due to this expansion.

ii Second-Stage Expansion Plan

The second-stage expansion plan is scheduled to be started at an early date with completion within five years from now. This plan aims at increase of cotton production from 200,000 tons annually to 250,000 tons, and on completion of the plan the installed capacity of the factory is scheduled to be more or less doubled.

iii Planned Demand by Stage

The planned demand (additional demand) of each stage on the assumption that the required amount of power can be supplied without any restriction is estimated to be the following:

- Additional Demand due to First-Stage Plan
  - Annual energy demand — 276MWh
  - Maximum power demand — 60kW
- Additional Demand due to Second-Stage Plan
  - Annual energy demand — 570MWh
  - Maximum power demand — 130kW

(2) Kola Diba

Kola Diba is a small but lively town, situated about 22km southwest of Azezo. Administrative agencies, a school, a market, a clinic and small shops are found at the central part of the town, while further, there are six flour mills, four of them inside the town and the remaining two in the outskirts. In addition, it is planned for an international airport to be constructed in the future on a vast flatland which extends out on the south side of the road running from Azezo to Kola Diba. For the moment, however, this grand project remains at the conceptional stage.

(a) Population

1971	5,000
1974	6,010
1976	6,500

The annual growth rate is 5.4%, and according to the Regional Administrator the total number of households is estimated to be about 1,300.

(b) Actual Situation of Electric Power Supply

The supply of electricity to Kola Diba by a 15kV line from Gondar Power Station was started at the end of 1973. However, because of the shortage of supply capacity of the power station, and for the purpose of economizing fuel oil, the supply of electricity is now extremely restricted. In this connection, the actual load in 1976 is recorded as follows (the individual figures indicated below are already included in the corresponding figures in the table in item (1). (b). ii.

- Annual energy demand — 36 MWh
- Maximum power demand — 16 kW (estimated load factor 25%)
- Number of Customers — approx. 190

(c) Potential Power Demand

i Residential and Street Lighting Uses

On the assumptions described in item 4.1.3 that under normal conditions, the standard rate of electrification should be about 25%, the annual energy consumption per household about 250kWh and average energy requirement per capita for street lighting about 3kWh, the total power demand for residential and street-lighting uses at Kola Diba under unrestricted conditions can be estimated to be as follows:

- Annual energy demand — 101 MWh (81 MWh for residential, 20 MWh for street lighting)
- Maximum power demand — 46 kW (estimated load factor, 25%)

Accordingly, by deducting the figures of actual demand indicated in item (2).(b) from the above figures, it is possible to estimate that the potential power demand for residential and street-lighting uses will be 65 MWh in annual energy and 30kW in maximum power demand, respectively.

ii Flour Mills

Of the six existing flour mills two are already electrified, but the remaining four are still operated by diesel engines because of the shortage of electric power supply. Therefore, if sufficient electricity could be supplied in the future, the remaining mills would also be electrified in a very short time. According to the operators of the mills, the capacities and operating hours of engines are the following:

- Capacities of engines

Nominal capacity	Converted capacity in kW
108 HP x 1 unit	approx. 50kW
108 HP x 1 unit	approx. 30kW
70 HP x 1 unit	approx. 25kW
45 HP x 1 unit	approx. 15kW
	Total 120kW

- Annual operating hours

  12 hr/day for 3 months of the busiest farming season (25 days per month)

  8 hr/day for 4 months of the busy farming season (25 days per month)

  4 hr/day for 5 months of the slack farming season (25 days per month)

Therefore, the annual operating hours are estimated to be about 2,450 hours, and if these mills were to be electrified it is estimated that the annual energy demand would be as follows:

- Annual energy demand

  120kW x 2,450 hours = 294 MWh

iii Water Distribution System

This town has a water distribution system operated by diesel engines. In the future, these engines will also be converted to electric motors. The capacities and operating hours are the following:

- Capacities of engines

Nominal capacity	Converted capacity in kW
11 HP x 2 sets	approx. 8kW each

- Operating hours

  It takes 4 hours for one engine to fill a reservoir and the two engines are alternated every day. Therefore, the annual operating hours are estimated to be about 1,460 hours.

- Annual energy demand

  8 kW x 1,460 hours = 12 MWh

iv Estimated Total Potential Demand

As the result of the investigations described in (i), (ii) and (iii) above, the total potential power demand for residential use, street lighting, flour mills, water distribution system, etc. is estimated to be as follows:

- Annual energy demand 371 MWh
- Maximum power demand 158 kW

(3) Chewahit

Chewahit is situated about 16 km southwest of Kola Diba and is surrounded by fertile farms and plantations. This is a typical farm village with good harvests of various kinds of agricultural products, especially oil seeds. The population growth rate here is very high due to a large influx of people migrating in from surrounding areas.

(a) Population

1971	3,000
1974	3,550
1976	4,500

Consequently, the annual growth rate is 8.5%, and, according to the Chief of the Kabale, the total number of households is estimated to be about 900.

(b) Actual Situation of Electric Power Supply

Electricity is not being supplied as yet.

(c) Potential Power Demand

i Residential and Street Lighting Uses

Based on the assumptions described in item 4.1.3, the potential power demand for residential and street lighting uses is estimated to be as follows:

- Annual energy demand 70 MWh
- Maximum power demand 32 kW (estimated load factor, 25%)

ii Flour Mills

There are four flour mills operated by diesel engines. If supply of electricity were to be realized, these engines would be converted to electric motors in a very short time. According to the operators of the mills, the capacities and operating hours of engines are the following:

- Capacities of engines

Nominal capacity	Converted capacity in kW
70 HP x 2 units	approx. 30kW each
60 HP x 2 units	approx. 25kW each
	Total 110kW

- Annual operating hours

  12 hr/day for 7 months of the busy farming season (25 days per month)

  6 hr/day for 5 months of the slack farming season (25 days per month)

Therefore, the annual operating hours are estimated to be about 2,850 hours, and if these flour mills were to be electrified it is estimated that the annual energy demand would be as follows:

- Annual energy demand

  110kW x 2,850 hours = 314 MWh

iii Estimated Total Potential Demand

From the figures indicated in (i) and (ii) above, the total potential power demand in Chewahit is estimated to be as follows:

- Annual energy demand 384 MWh
- Maximum power demand 142 kW

(4) Gorgora

Gorgora is a small port town on the northern shore of Lake Tana, situated about 17km southwest of Chewahit. At present, one school, one workshop for watercraft, a building of the Marine Department, army barracks, and a villa which had belonged to the ex-Emperor are the main establishments of this town.
The scenic beauty of this town as a port has drawn attention, and construction of a tourist hotel is being contemplated, but the plans have not yet been made concrete.
There is a regular liner service between Bahar Dar and Gorgora, while further,

an all-weather highway running from Gondar to Gorgora via Azezo and Kola Diba, Chewahit is always well-maintained.

(a) Population

1976	2,260

According to the Regional Administrator, the annual population growth rate is estimated to be about 6%, and the total number of households 450.

(b) Actual Situation of Electric Power Supply

The workshop for watercraft is equipped with one diesel power set of 12.5kVA (10kW) which belongs to the Marine Department. However, power supply for general use has not yet been realized.

(c) Potential Power Demand

i Residential and Street Lighting Uses

Based on the assumptions described in item 4.1.3, the potential power demand for residential and street lighting uses is estimated to be as follows:

- Annual energy demand — 35MWh
- Maximum power demand — 16kW (estimated load factor, 25%)

ii Flour Mills

Actually, there are three flour mills operated by diesel engines. If supply of electricity were to become unrestricted, these mills would be electrified in a very short time. The capacities and operating hours of these engines are the following:

- Capacities of engines

Nominal capacity	Converted capacity in kW
108 HP x 2 units	approx. 35kW each
70 HP x 1 unit	approx. 25kW
	Total 95kW

- Annual operating hours

Each mill is operated 8 hours per day on the average. However, the two engines of 108 HP are being operated 25 days per month contrasted to 10 days per month for the engine of 70 HP. Therefore, the annual operating hours are 2,400 hours for the two 108 HP engines, and 960 hours for the 70 HP engine.

- Annual energy demand

  If these engines were to be converted to electric motors, it is estimated that annual energy demand would be as follows:

  (70kW x 2,400hr) + (25kW x 960 hr) = 192 MWh

iii Estimated Total Potential Demand

Based on the abovementioned figures, it is possible to estimate that the total potential demand including residential use, street lighting, and the watercraft workshop would be as follows:

- Annual energy demand . 250MWh
- Maximum power demand 121kW

(d) Planned Demand

Although the construction plan for a tourist hotel at Gorgora has not yet become concrete, the power requirements of the hotel can be counted as planned demand. According to the Regional Administrator and hotel manager at Gondar, this plan is said to be a very realistic one for the near future. The scale of this hotel has not yet been made clear, but it would be permissible to consider that it will be at least half that of Hotel Tana or Hotel Goha which are now under construction. Therefore, as planned demand, the following power demand may be counted:

- Annual energy demand 92MWh
- Maximum power demand 35kW

4.2.3 East Region of Lake Tana

(1) Debre Tabor

During the Italian occupation, a simple road was constructed to link up Dessie, Debre Tabor, Addis Zemen and Gondar, but maintenance of the road was poor, and accordingly, the utility value of this road was extremely low. The fact is that the section of this road between Debre Tabor and Addis Zemen has been abandoned since a number of years ago. Around 1970, cotton plantations were successfully developed at Tendaho, and since then, in order to transport raw materials from Tendaho to Bahar Dar, the necessity of developing an all-weather road connecting National Route No. 1 with National Route No. 3 taking Debre Tabor as an intermediate point had become pressing. This all-weather road, financed by the People's Republic of China, is now under construction. At present, about one half of the section from a point 4km north of Wereta to Debre Tabor has been completed, but the remaining half-section still remains in very poor condition for communication. During the rainy season it is almost impossible to travel this remaining section by automobile, but it is expected that by the end of 1977 the entire stretch 4km north of Wereta to Debre Tabor will be successfully completed. Indeed, the economic development of Debre Tabor may be said to depend solely on construction of this road.

Elevation	2,950 m
Mean annual temperature	16.5°C

(a) Economic Situation

i Population

1971	8,770
1974	10,600
1976	12,000

Consequently, the annual growth rate is 6.5%, and according to the chief of the community, the total number of households is estimated to be about 2,400.

ii Industrial and Economic Outlook

Like in other districts, the industries in this district depend much on the agricultural economy of the surrounding area. The main products here have traditionally been honey and butter, while at present it is expected that a lumber factory will be constructed to utilize the abundant forest resources of the district. In any case, Debre Tabor is situated at a very important place on the connecting road between National Route No. 1 and National Route No. 3. Therefore, when the entire length from Woldiya to Wereta is successfully completed several years from now, it can be expected that this town will show remarkable development as an intermediate center dealing in various goods and products from both eastern and western parts of Ethiopia.

(b) Actual Situation of Electric Power Supply

i Generating Facilities

In 1974, the Debre Tabor Branch of EELPA was opened and supply of electricity was started at the end of that year. The power station is equipped with two diesel power sets. The installed capacity is as follows:

170kW x 1 unit	
68.5kW x 1 unit	
Total 238.5kW	380/190 V

ii Actual Power Demand and Growth Rate

Because of the short period of time elapsed since commissioning, and partly for the purpose of restriction of supply caused by reasons described hereinafter, the scale of power demand is still very small.

Item	1975	1976
Energy Sales (MWh)	56.4	58.3
Annual Generation (MWh)	68	72.1
Peak Load (kW)	55	55
Number of Customers	321	323
Distribution Loss Ratio (%)	17	19
Load Factor (%)	14	15

Note : Regarding ratios of composition, residential use comprises 77%, street lighting 14%, commercial use 2%, and industrial use 7%. There is only one industrial-use customer.

iii Restriction of Power Supply

As in the Gondar district, the power supply in the Debre Tabor district is extremely restricted. The reason for this is mainly the difficulties of fuel oil transportation because of the extremely bad road conditions. The fuel oil is transported from Addis Ababa, and the power station is equipped with two fuel reservoirs of 25,000 lt capacity each. However, the transportation of fuel oil is presently limited to only 4 trips during the dry season. For this reason, the supply of electric power in this area is still limited to 6 hours per day.

(c) Potential Power Demand

i Residential and Street Lighting Uses

If the assumptions described in item 4.1.3 were to be applied to this area also, the number of residential customers under unrestricted conditions would become approximately 600. In this case, whereas there are 323 existing customers, about 280 customers may be considered as waiting. Actually, however, according to the Branch Manager, it is considered that there will be about 500 waiting customers of various kinds in this area. This figure on waiting customers is not unreasonable when the difficulties in procurement of oil, the alternative energy source to electricity, is taken into account. (If 500 waiting customers were to be supplied with electricity, the electrification rate in the Debre Tabor district would reach 34%, comparable to that in the Gondar district).

Based on the assumptions in 4.1.3 and on the abovementioned information, it is possible to estimate unrestricted total power demand for residential and street lighting uses as follows:

- Annual energy demand 242 MWh
- Maximum power demand 110 kW (estimated load factor, 25%)

Accordingly, by deducting the figures of actual demand indicated in (b) ii from the above figures, it is possible to estimate that the potential power demand for residential and street-highting uses will be 184 MWh in annual energy and 55 kW in maximum power demand, respectively.

ii Flour Mills

There are eight flour mills operated using diesel engines. If enough electricity could be supplied, these mills would be electrified in a very short time. The capacities and number of units are six units of 30 HP each (22 kW each), one unit of 20 HP (15 kW) and one unit of 18 HP (13 kW). Therefore, the total converted capacity is about 160 kW.

As for operating hours, these mills are operated 8 hr/day for the five months of the busy farming season and 4 hr/day for the seven months of the slack farming season. The number of working days per month is said to be 20 days on the average, so that the total operating hours is only 1,360 hours per year. The table below shows comparisons of operating hours between several of the towns concerned.

Locality	Population	Capacity (kW)	Operating Hours
Wareta	5,500	158	2,250
Addis Zemen	9,000	160	2,250
Kola Diba	6,500	120	2,200
Debre Tabor	12,000	160	1,360

The above comparisons make clear that the capacities and operating hours of flour mills at Debre Tabor are excessively small in relation with the population of the district. Evidently, this is due to the difficulties of transportation and the comparatively high price (E₵48/lt) of fuel oil.

Consequently, a separate reasonable estimate of power demand of the flour mills at Debre Tabor under normal conditions should be carried out based on the average figure for the above three towns. In this case, the required capacity and annual operating hours can be estimated to be about 250 kW and 2,250 hours respectively. Therefore, the unrestricted power demand of the flour mills is estimated to be as follows:

250 kW x 2,250 hours = 563 MWh

iii Estimated Total Potential Demand

From the figures indicated in i and ii above, the total potential power demand including residential use, street lighting and flour mills is estimated to be as follows:

- Annual energy-demand 747 MWh
- Maximum power demand 305 kW

(d) Planned Demand

Regarding projects to be realized in the not-too-distant future, there are various plans now under consideration, including the beforementioned lumber plant project. Of these, the most urgent is the water distribution project which envisages pumping up and diverting water to the town from the Chagn River running about 5 km away from the town. The proposed year of completion and other details are not yet clear. However, if the plan for supply of electric power to this district by transmission line from the Lake Tana region becomes concrete, this water distribution project would be very promising. In this connection, taking into account the fact that there are similar topographic conditions in the Gondar district, the water supply system would require 182 kW of power with load factor of approximately 17%, and it would be possible to estimate the power demand of the water distribution system in the Debre Tabor district in proportion to the ratio between the populations of these two towns. In this case, against a population of 60,000 of the Gondar district, the population of Debre Tabor is about 12,000. Therefore, the power demand of the water distribution system may be estimated as follows:

- Annual energy demand 54 MWh
- Maximum power demand 36 kW

(2) Wereta

Wereta is a small but busy merchant town situated along National Route No. 3 about 61 km north of Bahar Dar. The town has administrative agencies, one gasoline station, two bakeries, six flour mills and one oil seed mill. It is presently planned for an experimental farm for sugar cane and rice to be developed in the future. There are many small shops located along the road.

(a) Population

1971	4,050
1974	4,810
1976	5,500

Consequently, the annual growth rate is 6.3%. And according to the chief of the community, the total number of households is estimated to be about 1,100.

(b) Actual Situation of Electric Power Supply

Since 1974, electric power has been supplied to the residents from a small diesel power station owned by the community. The details are the following:

- Installed capacity: 52.5 kVA (42 kW) x 1 unit
- Fuel rate: 10 lt/hr (0.238 lt/kWh)
- Operating hours: 4 hr/day (18:30 to 22:30)
- Annual generation: 61,320 kWh
- Number of customers: approx. 600
- Number of lamps: 40 W x 1,000 lamps
- Electricity tariff: Eth$ 1.5/lamp per month

Consequently, the unit price of electricity is estimated to be (Eth$ 1.5 x 1,000 lamps x 12 months)/61,320 kWh = E¢29.4/kWh. This price is about 1.6 times the average price applied by EELPA for residential use.

In spite of this high price level, about 600 households have been electrified (electrification rate, 55%). This fact is worthy of note even considering that this is a merchant town.

(c) Potential Power Demand

i Residential and Street Lighting Uses

According to the chief of the community, there are still many waiting customers because of shortage of capacity of the existing power station, but the number of these waiting customers has not been made clear. Based on the number of existing customers and other assumptions described in 4.1.3, unrestricted total power demand for residential and street lighting uses can be estimated to be as follows:

- Annual energy demand: 167 MWh
- Maximum power demand: 76 kW (estimated load factor, 25%)

Consequently, by deducting the figures of actual demand indicated in (2), (b) from the above figures, it is possible to estimate that the potential power demand will be 106 MWh in annual energy and about 34 kW in maximum demand respectively.

ii Flour Mills

At present, there are six flour mills and one oil seed mill. The capacities and operating hours of these mills are the following:

- Capacities of engines

Nominal capacity	Converted capacity in kW
70 HP x 4 units	25 to 30 kW each
20 HP x 2 units	15 kW each

24 HP x 1 unit	18 kW (oil seed mill)
	Total 158 kW

- Annual operating hours

  · 10 hr/day for 6 months of the busy farming season (25 days per month)

  5 hr/day for 6 months of the slack farming season (25 days per month)

Therefore, the annual operating hours are estimated to be about 2,250 hours, and if these mills were to be electrified, it is estimated that the annual energy demand would be as follows:

- Annual energy demand

  158 kW x 2,250 hours = 356 MWh

iii Estimated Total Potential Demand

From the figures indicated in i and ii above, the total potential demand at Wereta can be estimated to be as follows:

- Annual energy demand 462 MWh
- Maximum power demand 192 kW

(3) Addis Zemen

Addis Zemen is a lively town of medium scale, situated along National Route No. 3 about 19km north of Wereta. Various kinds of agricultural products are produced in the surrounding area, especially oil seeds. There are a bus stop, gasoline station, school, shops and flour mills.

(a) Population

1971	5,560
1974	6,720
1976	9,000

Consequently, the annual growth rate is 6.5%, and according to the chief of the community, the total number of households is estimated to be about 1,800.

(b) Actual Situation of Electric Power Supply

Until 1973, there was a small diesel power set for private use owned by a merchant operating an oil mill, and a part of the energy produced had been supplied to residents. This supply has been stopped, however, since 1974.

(c) Potential Power Demand

i Residential and Street Lighting Uses

Based on the assumptions described in item 4.1.3, the potential power demand for residential and street lighting uses can be estimated to be as follows:

- Annual energy demand 140 MWh
- Maximum power demand 64 kW (estimated load factor, 25%)

ii Flour Mills

There are five flour mills and one oil seed mill. If supply of electricity were to be realized, these mills would be electrified in a very short time. The capacities and operating hours are the following:

- Capacities of engines

Nominal capacity	Converted capacity in kW
70 HP x 5 units	30 kW each
15 HP x 1 unit	approx. 10 kW (oil seed mill)
	Total 160 kW

- Annual operating hours

10 hr/day for 6 months of the busy farming season
(25 days per month)

5 hr/day for 6 months of the slack farming season
(25 days per month)

Therefore, the annual operating hours are estimated to be about 2,250 hours, and if these mills were to be electrified, it can be estimated that the annual energy demand would be as follows:

- Annual energy demand

160 kW x 2,250 hours = 360 MWh

iii Estimated Total Potential Demand

- Annual energy demand 500 MWh
- Maximum power demand 224 kW

4.2.4 South Region of Lake Tana

(1) Dangla

Dangla is situated about 85 km south of Bahar Dar and is surrounded by very populous villages. This town is a medium-scale commercial and agricultural community. Administrative agencies, a school (high school level), a clinic, a market and flour mills are found at the central part of the town, and along National Route No. 3, there are shops, a gasoline station, a lumber plant, a water supply station, etc.

(a) Population

1971	4,960
1974	5,600
1976	8,600

Consequently, the annual growth rate is 11.5% on the average between 1971 and 1976. This is a very high level compared with other urban areas. The total number of households is estimated to be about 1,700.

According to the chief of the municipality, the total population including rotary population such as itinerant venders, teachers and others will have reached approximately 10,900 as of September 1976.

(b) Actual Situation of Electric Power Supply

Since 1966, electricity has been supplied to residents from a small diesel power station which belongs to the municipality. The details are as follows:

- Installed capacity — 80 kVA (64 kW) x 1 unit
- Fuel rate — 17 lt/hr (0.266 lt/kWh)
- Operating hours — 4.5 hr/day (18:30 to 23:00)
- Annual generation — 105,120 kWh
- Number of customers — approx. 780
- Number of lamps — 60 W x 1,460 lamps
- Electricity tariff — Eth$ 1.5/lamp per month

Consequently, the unit price of electricity is estimated to be (Eth$ 1.5 x 1,460 lamps x 12 month)/105,120 kWh = E¢ 25/kWh. This price is very high for the residents compared with that applied by EELPA, but the fact that 780 out of 1,700 households are electrified (electrification ratio, 45%) is worthy of note.

(c) Power Facilities of Water Supply System

Recently, a water distribution station was constructed to supply water to a part of this town by diesel power. The capacity and operating hours are the following:

- Installed capacity: 15 kVA (12 kW) x 2 units (1 unit is for stand-by use)
- Water reservoir: 150,000 lt
- Operating hours: 16 hr/week (832 hours per year)
- Estimated annual generation. 12 kW x 832 hours = 9,980 kWh

(d) Potential Power Demand

i Residential and Street Lighting Uses

Because of shortage of capacity of the power station, the supply of electric power is extremely restricted at present. According to the chief of the municipality, at least about 60% of all households in this district will become customers for electricity if supply of electric power is not restricted because the district has a relatively long history of utilizing electricity and the residents are oriented towards utilization of electric power.

If 60% of all residents are to be electrified, the average energy consumption per household is estimated to be about 150 kWh/yr based on the specific energy consumptions by class indicated in item 4.1.3.

Therefore, the unrestricted total power demand for residential and street lighting uses is estimated to be as follows:

- Annual energy demand: 179 MWh
- Maximum power demand: 82 kW (estimated load factor, 25%)

Accordingly, by deducting the figures of actual demand indicated in (1), (b) from the above figures, it is possible to estimated that the potential power demand for residential and street lighting uses will be 74 MWh in annual energy, and 18 kW in maximum power demand respectively.

ii Flour Mills

There are thirteen flour mills being operated using diesel engines. If supply of electricity were not restricted, these engines would be converted to electric motors.. The capacity and operating hours of these mills are the following:

- Capacity of engines

Nominal capacity	Converted capacity in kW
20 HP x 13 units	15 kW each
	Total 195 kW

- Annual operating hours

  12 hr/day for 7 months of the busy farming season

  (25 days per month)

  6 hr/day for 5 months of the slack farming season

  (25 days per month)

Therefore, the annual operating hours are estimated to be about 2,850 hours, and if these mills were to be electrified, it is estimated that the annual energy demand would be as follows:

- Annual energy demand

  195 kW x 2,850 hours = 556 MWh

iii Estimated Total Potential Demand

From the figures indicated in i and ii above, the total potential power demand at Dangla can be estimated to be as follows:

- Annual energy demand 630 MWh
- Maximum power demand 213 kW

(2) Injibara and Addis Kidame

Injibara is situated along National Route No. 3 about 35km south of Dangla. This town was built on a mountain along the road, and its topographic conditions are extremely inconvenient for economic development. Therefore, for a number of years, removal of the town to a flat area which extends from a point one kilometer down from the present location has been envisaged. Recently, the removal of the town was petitioned based on a resolution of the majority of the residents, and the decision of the Central Government is being awaited. The farms of this area produce two crops a year, and it is said the town is relatively wealthy.

Addis Kidame, a small village situated in the middle between the two towns of Dangla and Injibara, is favored with convenience of communication, and is surrounded by fertile farms.

(a) Population

The populations of Injibara and Addis Kidame are not included in the demographic data of the Central Statistics Office, but according to the chief of the Kabale, the populations of both districts are recorded as follows:

Injibara	5,000	1976
Addis Kidame	2,500	1976
Total	7,500	

(Estimated number of households : 1,500)

As for the annual growth rate of population, it is estimated to be about 4.5% including migration in from surrounding villages.

(b) Actual Situation of Electric Power Supply

The supply of electricity has not yet been realized. The residents are using kerosene lamps or paraffin oil for domestic lighting.

(c) Potential Power Demand

i Residential and Street Lighting Uses

Based on the assumptions described in item 4.1.3, the potential power demand for residential and street lighting uses can be estimated to be as follows:

	Injibara	Addis Kidame	Total
- Annual energy demand	78 MWh	39 MWh	117 MWh
- Maximum power demand	36 kW	18 kW	54 kW

ii Flour Mills

There are nine flour mills, five of them at Injibara and the remaining four at Addis Kidame. If electricity supply were to be realized, these mills would be readily electrified. The details are as follows:

- Capacities of engines

Nominal capacity	Converted capacity in kW
(Injibara)	
24 HP x 2 units	18 kW each
18 HP x 3 units	13 kW each
Sub-total	75 kW

(Addis Kidame)

18 HP x 4 units	13 kW each
Sub-total	54 kW
Total	129 kW

- Annual operating hours

  (Injibara)

  12 hr/day for 12 months (20 days per month)
  Accordingly, the annual operating hours are estimated to be about 2,880 hours.

  (Addis Kidame)

  The annual operating hours are estimated to be about 2,850 hours (almost the same as for Injibara).

- Annual energy demand

  (Injibara)

  75 kW x 2,880 hours = 216 kWh

  (Addis Kidame)

  54 kW x 2,850 hours = 154 kWh

  Total 370 kWh

iii Estimated Total Potential Demand

From the figures indicated in i and ii above, the total potential power demand at Injibara and Addis Kidame is estimated as follows:

	Injibara	Addis Kidame	Total
- Annual energy demand	294 MWh	193 MWh	487 MWh
- Maximum power demand	111 kW	72 kW	183 kW

4.2.5 Summary

The results of investigations by town described under item 4.2.1 ~ 4.2.4 hereinbefore may be tabulated as Table 4-1, the gist of which is briefly given below.

(1) The actual load of the whole project area as of 1976 is 25,913 MWh in terms of annual energy demand and a total of 5,468 kW in terms of peak load, but when potential load is included the annual energy demand is estimated to be 30,603 MWh and maximum power demand 7,467 kW.

(2) Planned demand is predetermined power demand aristing from projects under construction as well as various construction plans and factory expansion plans which

have a high probability of being realized by around the end of 1981, and is estimated to be 15,376 MWh in terms of annual energy and 3,393 kW in terms of peak load.

Table 4-1 Actual Situation of Power Demand (1976)

Region	Community	Annual Energy Demand (MWh)					Maximum Power Demand (KW)				
		Actual Load	Sinking Demand	Potential Demand	Total	Planned Demand	Actual Load	Sinking Demand	Potential Demand	Total	Planned Demand
Bahar Dar Area	Bahar Dar	1,809	438	-	2,247	184	670	146	-	816	70
	Textile Mills S. C.	20,681	-	-	20,681	4,983 8,760	3,560	-	-	3,560	810 2,000
	Total	22,490	438	-	22,928	13,927	4,230	146	-	4,376	2,880
North Region of Lake Tana	Gondar Azezo	3,175	-	451	3,997	1,303	1,065	-	315	1,538	442
	Kola-Diba		-	371		-		-	158		-
	Chewahit	-	-	384	384	-	-	-	142	142	-
	Gorgora	-	-	250	250	92	-	-	121	121	35
	Total	3,175	-	1,426	4,601	1,395	1,065	-	736	1,801	477
East Region of Lake Tana	Debre Tabar	72	-	747	819	54	55	-	305	360	36
	Wereta	61	-	462	523	-	42	-	192	234	-
	Addis Zemen	-	-	500	500	-	-	-	224	224	-
	Total	133	-	1,709	1,842	54	97	-	721	818	36
South Region of Lake Tana	Dangla	115	-	630	745	-	76	-	213	289	-
	Injibara	-	-	294	294	-	-	-	111	111	-
	Addis Kidame	-	-	193	193	-	-	-	72	72	-
	Total	115	-	1,117	1,232	-	76	-	396	472	-
Whole Project Area		25,913	438	4,252	30,603	15,376	5,468	146	1,853	7,467	3,393

Remarks

(1) Values of actual loads such as Bahar Dar (including Textile Mills S. C.), Gondar and Debre Tabor being supplied electricity by EELPA are values at 15-kV outgoing point.

(2) Power generation of the workshop owned by the Marine Department at Gorgora is included in potential demand.

(3) The actual load of Dangla is the total of the power generated by the power station of the municipality and the generating facilities for the water supply system.

(4) Of the planned demand for Bahar Textile Mills S. C., the figures on the upper line are for motors, and the figures on the lower line for electric boilers planned to be additionally installed.
Energy demand for electric boilers was calculated for 1,000 kW x 2 units at a load factor of 50%.
As for motors, the estimated peak load of 2,100 kW on completion of the Second Stage Expansion Plan less the peak of 1,290 kW for 1976 was taken to be the planned power demand, while the annual energy demand of 13,245 MWh in case of 2,100 kW at load factor of 72% less the energy demand of 8,262 MWh for 1976 was considered as the planned energy demand.

4.3 METHOD OF FORECASTING

4.3.1 Basic Consideration

The ultimate goal of the electric power scheme for the surrounding area of Lake Tana is to supply stable and inexpensive hydroelectric power by interconnecting transmission lines to eliminate the high-cost diesel power generation utilized in the past, thereby enhancing the economic and financial effects for EELPA, and the nation as a whole. Consequently, it becomes an important objective of study to determine the optimum timing for transmission line construction, and for this purpose it is necessary for prediction of electric power demand to be made over an extra-long range. With this as a consideration, the load forecast is made according to the following basic principles.

(1) Period of Forecast

Although for the term of load forecast it is necessary to take the period of increase in demand to the limit of transmission capacity at the selected voltage, the length of such a period is not clear. Therefore, for the time being, the forecast period is taken to be 30 years from 1977, and if necessary for the purposes of economic calculations of Chapter 12, the demand curve for the 30-year period is to be extrapolated without reservation.

(2) Basic Method of Forecasting

(a) Initial Five-Year Forecast (1977 ~ 1981)

Taking the procedural and technical conditions of the project into consideration, approximately 5 years from now will be required for completion of the regulating dam, and transmission and transforming facilities. Meanwhile, it is thought there is extremely little possibility for diesel power generating facilities to be increased in the project area during this period. Consequently, the load forecast is made considering the following items regarding the demands at various districts during this period.

(i) In the Bahar Dar area where demand restriction is not being carried out, commercial and street lighting demand is rather on the declining side compared with the 1973 record where residential demand indicates annual growth rate of 6.4%. Such a condition is abnormal, and it is inconceivable that it will continue for a long time. The total demand in the city for 1976 showed a growth rate with a slight rising trend over the previous year and was 5.8%. In this present report, it is forecast that total demand including commercial, street lighting and industrial demands will increase at a growth rate of 6.4%, equal to residential demand. As for the demand of the Academy of Pedagogy which presently is sinking demand and the demand of Hotel Tana which is planned demand, these are expected to be brought in as actual demand from 1977 and 1978, but for both it is forecast that the energy demands for the first year will be one half those for full operation.

(ii) Regarding the demand of Bahar Dar Textile Mills S.C., it is assumed that the First Stage Expansion Plan will be completed during 1977, while installation of the various motors and two new electric boilers of the Second Stage Expansion Plan will be completed by the end of 1981.

(iii) With respect to the Gondar ~ Azezo district, there presently exists a state of considerable supply restriction so that during 1973 ~ 1975 an annual growth rate of 6.1%, less than half the rate in the past, was shown. It is forecast that this condition will continue for another 5 years until 1981.

Of waiting demand or planned demand, it is assumed that the demand of the water supply system will become actual demand from 1977, and the new demand of Hotel Goha and Cotton Ginning First Stage Expansion Plan from 1978. In this regard, when load factor of this district in the past is considered, the peak load of the district will roughtly reach the limit of capacity (1,450 kW) of Gondar Power Station in 1980, but it is assumed that a generator will not be additionally installed and peak load at limit of installed capacity will continue until 1981.

(iv) Severe power restriction is presently going on in the Debre Tabor district also, but this is mainly due to the extreme difficulties of transporting fuel oil. However, it is expected that a new road between Wereta and Debre Tabor will be completed some time during 1977. At present, the peak load of this district is only about 55 kW, but as described in item 4.2.3 (1), there is potential residential and street lighting demand of approximately 55 kW, while the existing potential demand of flour mills is 160 kW. It is estimated that these potential demands will successively be converted into actual demand during 1978 ~ 1981 to increase to the full supply capacity of the power station. Further, it is considered that additional demand of flour mills and planned demand of the water supply system will become actual demand at an early stage after realization of the Lake Tana Project.

(v) At districts such as Wereta and Dangla where electricity is being supplied from power stations owned by municipalities, most of the demands are potential because of the small supply capacities of the power stations. It may be considered that these potential demands will gradually increase in step with population growth of the municipalities as with potential demands of other non-electrified communities. Accordingly, it is forecast that these potential demands will increase during this period in proportion to the population growth rates indicated item 4.3.2 (3).

(b) Forecast for Following 25-Year Period (1982 ~ 2006)

This period corresponds to an extra-long-range forecast. Meanwhile, with the oil crisis of 1973 ~ 1974 as a turning point, the economic trend since then has completely changed from the trend up to that time and the tempo of increase in power demand has been slowed down greatly.

Consequently, it is not possible to extrapolate the long-term trend durve of the period prior to 1973, while performance records from 1973 and after are available for only 2 or 3 years, which moreover, are for a period of abnormal economic and political situations, and a trend curve for the future cannot very well be established based on these records.

Incidentally, the various countries of the world all have economies which differ in scale, development level and individual income level, but it is known that there is a fairly good correlation between per capita energy consumption level and per capita GNP, while there is also a correlation between the growth tempos of GNP/capita and kWh/capita. Trend curves plotted based on these correlations are valid for extra-long-range periods and it is possible to macroscopically approximate load forecasts for the distant future.

Accordingly, the load forecast for the 25-year period from 1982 to 2006 will be made based on the growth rate of kWh/capita obtained from the abovementioned macroscopic long-range forecast and the forecast of regional population increase. Details of this method are given in 4.3.2 below.

4.3.2 Macroscopic Method of Forecasting

The parameters necessary for load forecasting by the macroscopic method are the following:

- Present GNP/capita.
- Growth rate of GNP/capita in immediate near future estimated from past performance and present economic trend.
- Degree of variation in growth rate in accordance with scale of GNP/capita.
- Present kWh/capita.
- Degree of variation in growth rate of kWh/capita in accordance with variation in GNP/capita.

In regard to the above, the economic situation since 1973 has shown fairly violent fluctuations compared with before 1973, while the present situation in 1976 still cannot be said to be normal. Consequently, for the parameters in forecasting to be appropriate, an approximate prediction of GNP/capita and its growth rate at the time when the economy will have returned to a normal condition is necessary. In this connection, the IBRD has recently estimated that the present inflation (annual average of about 12%) will continue until around 1979 after which there will be a return to normal. Taking these into consideration, examinations of the various parameters are made in the following and predictions are made as well.

(1) GNP/capita and its Growth Rate

(a) Estimate of Present Growth Rate of GNP

Regarding GNP, only figures up to 1973 have been announced and data for the subsequent period have not been published. Therefore, the elasticity coefficient of the growth rate in energy production in contrast to the growth rate of GNP is obtained for 1967 ~ 1973, and next, the state of slow-down in the growth rate in energy production during 1973 ~ 1975 is investigated in comparison with growth rate for 1967 ~ 1973. The growth rate in GNP for 1973 ~ 1975 is thus estimated taking into consideration the rate of slow-down in the kWh growth rate from 1973 in contrast to the kWh growth rate prior to 1973, and the abovementioned elasticity coefficient. The results are as indicated in Table 4-2, and the following summarization may be made from the table.

(i) On looking at the growth rate of GNP (converted to 1960/61 value considering implicit price factor) for the 6-year period of 1967 ~ 1973, this is found to be an annual rate of 3.9%. This rate is constant with practically no variation between the first-half 3 years of 1967 ~ 1970 and the latter half 3 years of 1970 ~ 1973. Further, the growth rate of GNP/capita is an annual rate of 1.4%.

(ii) In contrast, the nationwide energy production during this period showed an annual average growth rate of 7.7%. Of this energy production, the energy production of EELPA in 1973 was approximately 365 GWh, while that of other electric power enterprises was approximately 94 GWh, and the annual average growth rates during the 6-year period are recorded as being 8.3% for the former and 6.3% for the latter. The growth rate for kWh/capita was an annual rate of 5.1%.

(iii) Based on the above, the following values are obtained as the elasticity coefficient of growth of kWh against the growth in GNP.

- Elasticity coefficient of growth rate of kWh against growth rate of GNP 1.97
- Elasticity coefficient of growth rate kWh/capita against growth rate of GNP/capita 3.64

(iv) Now, on looking at the growth rate of energy production in 1973 ~1975, the energy production of EELPA in 1975 was approximately 390 GWh with the growth rate having dropped to an annual rate of about 3.5%. Although data are not available for private and community owned power stations, it is estimated that their growth rates were about the same.

(v) However, that the growth rate of energy demand since the oil crisis has dropped to less than half of the long-term average of 7.7% up to that time is an abnormal phenomenon, and this phenomenon is thought to have occured due to the influence of the unsettled condition during the change in government aggravating the economic instability caused by the oil crisis. Although there is no basis for computing transient decrease in demand due only to economic factors, for the time being an intermediate figure of 5.6% between 7.7% growth rate in the past and the 3.5% growth rate in item (iv) above is taken as the growth rate for the transient recession period following the oil crisis. Further, since it is inconceivable that the elasticity coefficient between GNP growth rate and kWh growth rate would vary sharply within two or three years, if the corrected growth value of 5.6% for energy demand were to be divided by the elasticity coefficient of 1.97, it is estimated that the growth rate of GNP during

Table 4-2 Elasticity of Growth Rate in Energy Production in Contrast to Growth Rate of GNP

Item	1967	1970	1973	Average Annual Growth Rate
1. Total Population (1,000)	23,400	25,195	27,130	2.5 %
2. GNP at Market Prices (Eth$ million)	3,588	4,441	4,972	5.6 %
3. Implict Price Factor (1960/1961 = 100)	108.7	120.9	119.7	
4. GNP at 1960/1961 Value (Eth$ million)	3,301	3,673	4,154	3.9 %
5. GNP/Capita (Eth$)	141.1	145.8	153.1	1.4 %
6. GNP/Capita (US$)	68.1	70.4	74.0	
7. Total Energy Production (GWh)	294	368	459	7.7 %
8. KWh/Capita (KWh)	13	15	16.9	5.1 %

9. Coefficient of Elasticity

(1) Elasticity of growth rate in energy production against growth rate of GNP 1.97

(2) Elasticity of growth rate in KWh/Capita against growth rate of GNP/Capita 3.64

Sources: - Statistical Abstract 1971 and 1974 (Population, GNP and Implict price factor)

- United Nations Statistics (Total energy production)

Table 4-3 Estimate of GNP and Total Energy Production in the Coming Years

Item	1974	1975	1976	1977	1978	1979
1. Total Population (1,000)	27,800	28,500	29,220	29,950	30,700	31,460
2. GNP at 1960/1961 Value (Eth$ million)	4,270	4,389	4,512	4,638	4,768	4,900
3. GNP/Capita (Eth$)	153.6	154.0	154.4	154.9	155.2	155.0
4. GNP/Capita (US$)	74.2	74.4	74.6	74.8	75.0	75.3
5. Growth Rate of GNP/Capita (%)	0.3	0.3	0.3	0.3	0.3	0.3
6. Total Energy Production (GWh)	475	490	509	527	545	564
7. KWh/Capita (KWn)	17.0	17.2	17.4	17.6	17.8	18.0

Note: Above table is established on the assumption that the annual growth rate of population is 2.5%, the growth rate of GNP 2.8% and annual growth rate of total energy production 3.5%.

1973 ~ 1975 was roughly 2.8%.

(b) Estimate of Growth Rate of GNP in Immediate Near Future

Next, assuming that a low-growth period of annual growth rate of GNP of 2.8% and growth rate of nationwide annual energy production of 3.5% will continue until around 1979 as predicted by the IBRD, the prediction of GNP for 1974 ~ 1979 would be as shown in Table 4-3. The various parameters for the representative years of 1967, 1973 and 1979 taken from Tables 4-2 and 4-4 are as follows:

Item	1967	1973	1979
GNP (Eth$ million)	3,301.1	4,153.5	4,900.0
GNP/capita (US$)	68.1	74.0	75.3
kWh/capita (kWh)	13.0	16.9	18.0

Indicating here the average annual growth rates of GNP and GNP/capita for the representative years, they are the following:

Item	1967 ~ 1973	1973 ~ 1979	1967 ~ 1979
Average Growth Rate of GNP	3.9 %	2.8 %	3.3 %
Average Growth Rate of GNP/capita	1.4 %	0.3 %	0.8 %

Although there is no way of predicting the extent to which GNP growth rate will bounce back at the beginning of the economic recovery period of Ethiopia estimated to be in 1980 and thereafter, it is possible at least for the following estimates to be made:

(A) Most optimistic estimate ...... recovery to growth rate of 1967 ~ 1973 period

(B) Most pessimistic estimate .....growth rate of present (1973 ~ 1975 ~ 1979) continues permanently.

The above (A) and (B) may be said to be the upper limit and lower limit respectively of the forecast of growth rate. For the present Report, an intermediate figure between the upper and lower limits is taken, applying the average annual growth rate for the long period of 12 years from 1967 to 1979. Accordingly, the necessary parameters at the starting point for the forecast are as follows:

- GNP/capita US$ 75.3
- growth rate of GNP/capita 0.8 % annually
- kWh/capita . 18 kWh

(2) Growth Rate of kWh/capita

(a) Correlation between Scale of GNP/capita and its Growth Rate

As stated previously, the result of statistical studies of many countries shows that there is a rough correlation between the scale of GNP/capita and its growth rate, and the growth rate increases while GNP/capita is between US$500 ~ 1,000, while it is seen to decrease gradually when this bracket is exceeded.

Such a correlation differs considerable of course depending on the country, but on dividing into high, low and middle groups according to level of growth rate and plotting the respective trend curves, the results are as shown in Fig.4-1.

In this figure, on plotting the most optimistic estimate, the most pessimistic estimate and an intermediate estimate between the two, the three different estimates indicated in item 4. 3. 2.(1). (b), it is clearly seen in the interim that there is coincidence with the typical trend curve for the low group.

(b) Correlation between Scale of GNP/capita and Growth Rate of kWh/capita

In the same manner, it may generally be recognized that there is a rough correlation between the scale of GNP/capita and growth rate of kWh/capita. The relations in illustrated forms are as shown in Figs. 4-2 and 4-3.

From these figures, it may be seen that the energy production per capita of Ethiopia as a whole is slightly higher than the average value for the world. Since the specific energy generation is 18 kWh corresponding to US$75.3, with this as a starting point, it is possible to roughly estimate the specific power generation corresponding to the scale of the future GNP/capita of Ethiopia from the trend curve for the country plotted against the average trend curve for the world.

(c) Average Annual Growth Rate of kWh/capita

Based on the growth rate of GNP/capita as seen from Fig.4-1, the GNP/capita of Ethiopia from 1980 and after may be predicted to be as shown in Table 4-4. And, the figures for kWh/capita corresponding to those for GNP/capita of each year in the third column read from Fig.4-2 are as shown in the fourth column of Table 4-4.

Taking the kWh/capita for each year of the fourth column mentioned above for every 10 years, the average annual growth rates for these periods are as follows:

Table 4-4 Growth Rate of KWh/Capita corresponding to Growth in GNP/Capita

Year	Growth Rate of GNP (%)	GNP/Capita (US$)	KWh/Capita (KWn)	Average Annual Growth Rate of GNP/Capita (%)
1979		75.3	18	
1980	0.81	75.9	18	
81		76.5	19	
82		77.1	19	
83		77.8	20	
84		78.4	20	
85		79.0	21	3.8
86		79.7	22	
87		80.3	23	
88	0.83	81.0	24	
89		81.7	25	
1990		82.3	26	
91		83.0	27	
92		83.7	28	
93		84.4	29	
94		85.1	30	
95		85.8	31	3.3
96		86.5	32	
97		87.2	33	
98		88.0	34	
99		88.7	35	
2000		89.4	36	
1		90.2	37	
2	0.86	90.9	38	
3		91.7	39	
4		92.5	40	
5		93.3	41	2.7
6		94.1	42	
7		94.9	43	
8		95.7	44	
9		96.6	45	
2010		97.4	47	
11		98.2	48	

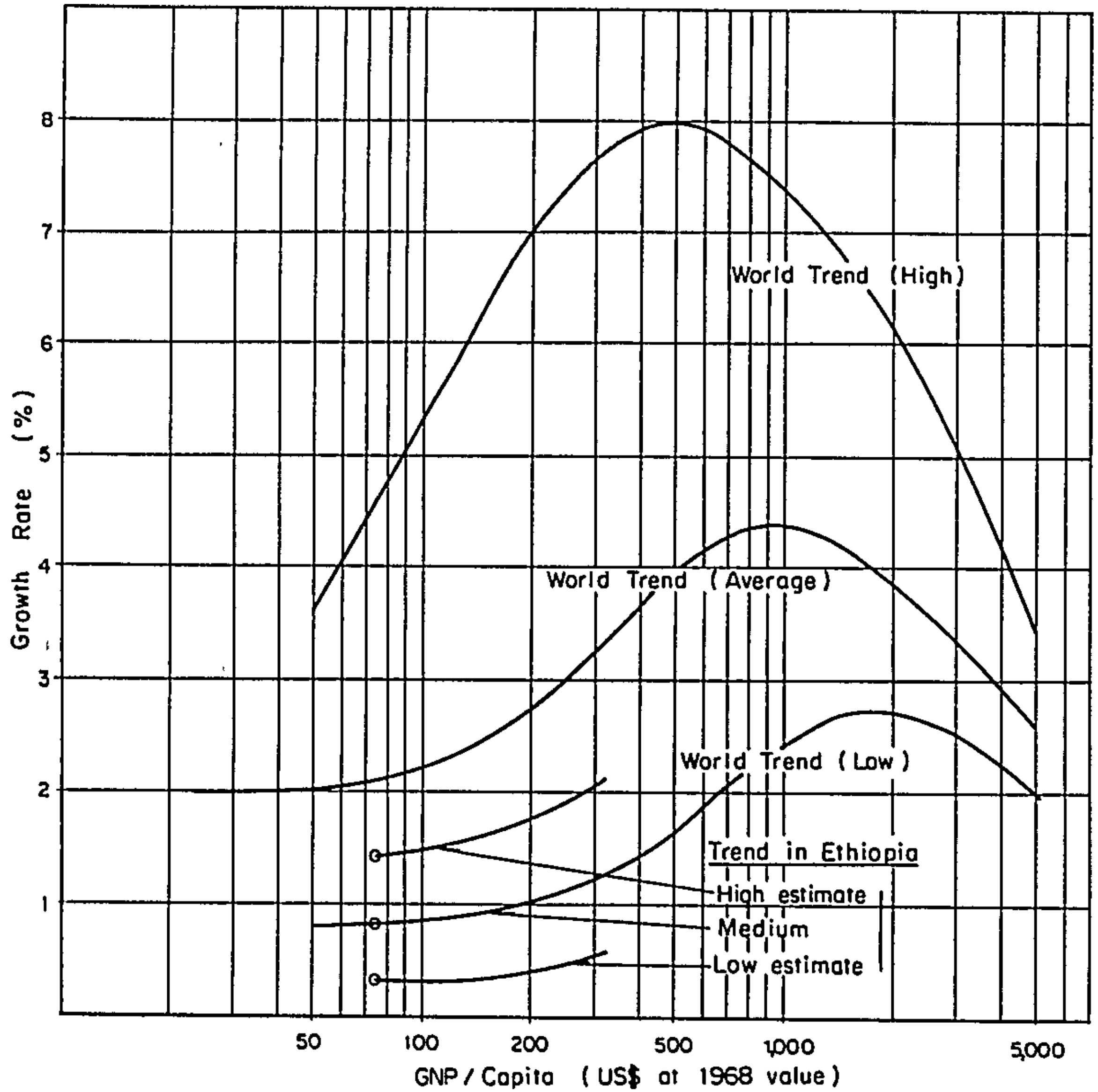


Fig. 4-1 Rate of Growth of GNP/ Capita

GNP/ Capita (US$)	Growth Rate (%)	Mean Value
75.3	0.80	
		0.81
80	0.82	
		0.83
90	0.84	
		0.86
100	0.87	
		0.89
110	0.90	
		0.92
120	0.93	
		0.94
130	0.95	

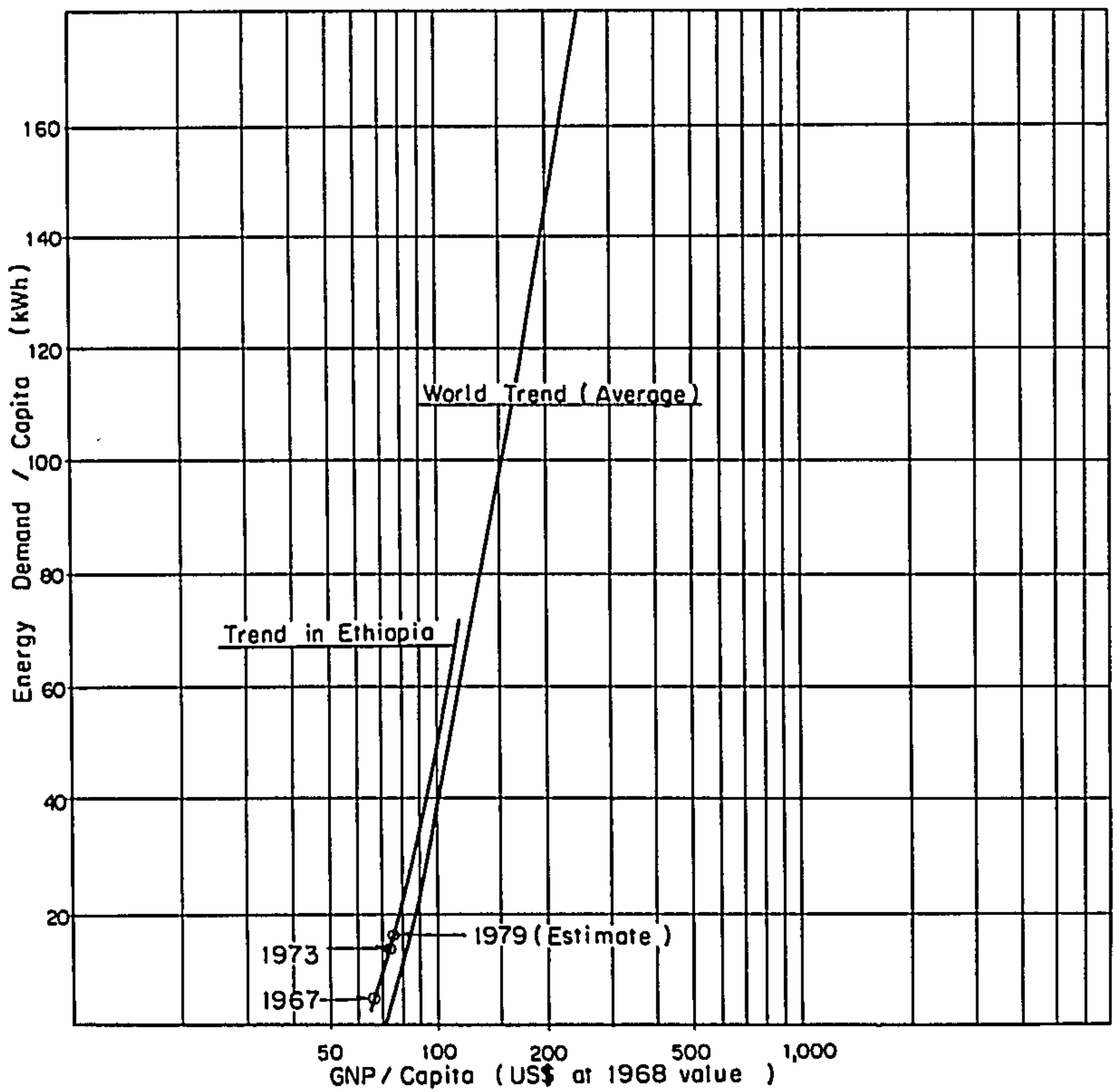


Fig 4-2 Demand Path Chart of Electricity in Ethiopia

GNP/Capita (US$)	kWh/Capita (kWh)
75.3	18
76.0	16
80.0	22.5
85.0	30
90.0	37
95.0	43
100.0	50

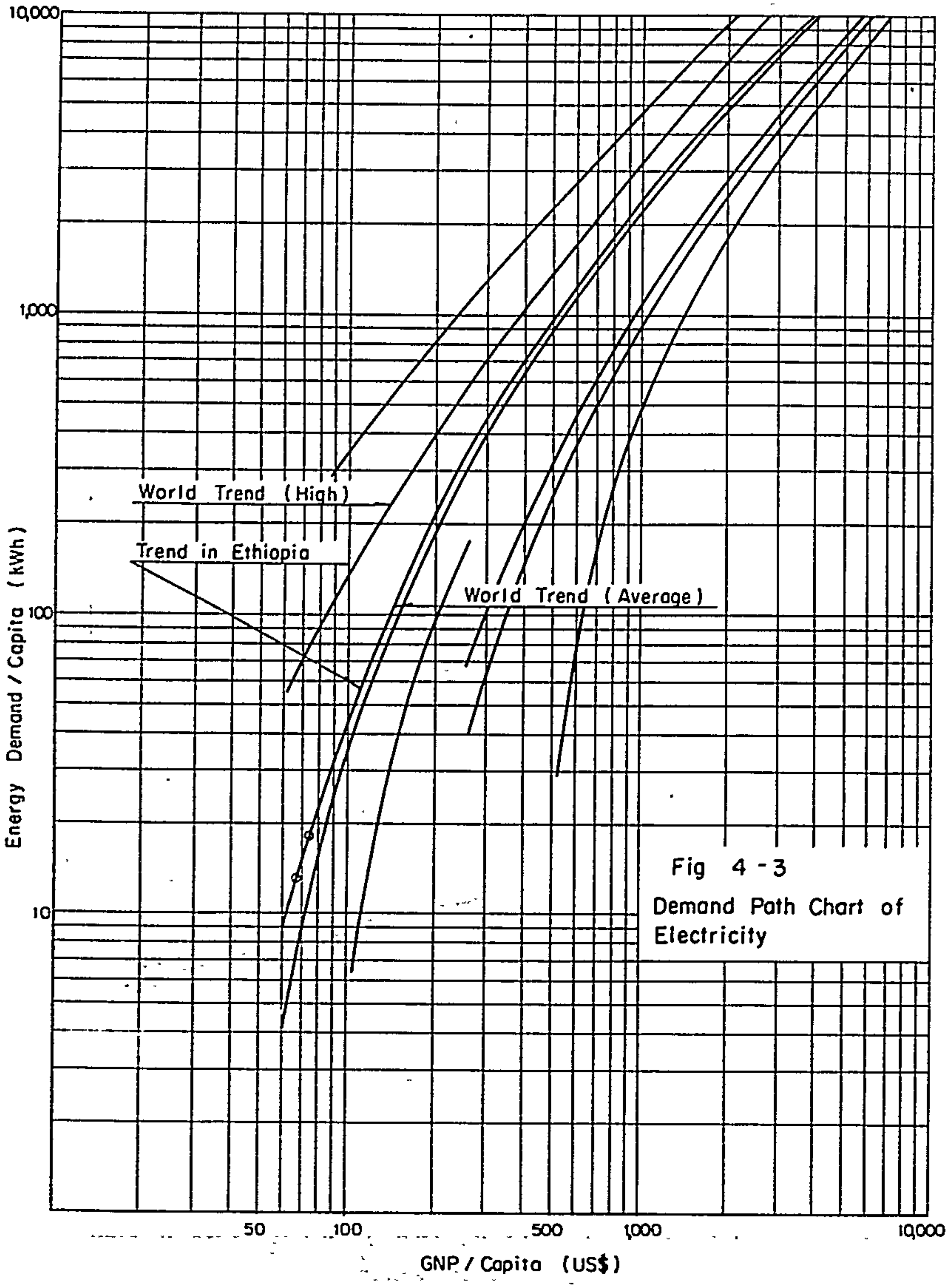


Fig 4-3
Demand Path Chart of Electricity

- 1980 ~ 1990 Average annual growth rate 3.8 %
- 1990 ~ 2000 " 3.3 %
- 2000 ~ 2010 " 2.7 %

(3) Growth Rate of Power Demand in Project Area for Following 25-Year Period

The average annual growth rate of kWh/capita indicated in item 4.3.2 (2) (c) is the average for all of Ethiopia with a population growth rate of 2.5 %. However, the trend in population of Ethiopia according to official data of the Central Statistics Office, is that for so-called urban areas of 2,000 population or more, in addition to increase in the average annual birth rate of 2.5 %, there is additional migration of 4 % from rural areas, and it has been announced that the growth rate is a total of 6.5 %. In case of forecasting the electric power demand of a specific area, grasping the population trend of the area becomes a basic condition.

(a) Population Growth Rate

Of the populations by district indicated below, those for 1971 are based on the official data of the Central Statistics Office, while those for 1976 are as obtained directly from the chiefs of kabale or through regional administrators, and the accuracies are said to be very high.

Locality	1971	1976	Av. Annual Growth Rate
Bahar Dar	25,100	34,000	6.3 %
Gondar-Azezo	46,980	60,000	5.0 %
Kola Diba	5,000	6,500	5.4 %
Chewahit	3,000	4,500	8.5 %
Gorgora	(3,000)	2,260	6.0 %
Debre Tabor	8,770	12,000	6.5 %
Wereta	4,050	5,500	6.3 %
Addis Zemen	5,560	9,000	6.5 %
Dangla	4,960	8,600	11.5 %
Injibara	-	5,000	4.5 % (Injibara and Addis Kidame)
Addis Kidame	-	2,500	

Of the above, the figure for Gorgora in 1971 was published as 3,000 but this included surrounding villages, while the figure for 1976 is for the town alone. According to the Chief of Kabale, the population growth rate of the town only is 6 %. As for Injibara and Addis Kidame, the figures for 1971 could not be obtained, but according to the Chief of Kabale, the population growth rate of this district is low, and it is said to be about 4 %.

Hence, the following summarization may be made regarding the population growth rates of the abovementioned districts:

(i) For the regions other than the South Region of Lake Tana, the population growth rates of the individual towns are more or less the same as the 6.5% growth rate announced by the Central Statistics Office.

(ii) The population growth rate of Injibara including Addis Kidame is slightly on the low side, and this is due in great part to the topographical conditions of Injibara. It is thought the removal of this town to a flat area along the highway will be realized in the immediate near future, and after the removal, there will be migration into the town from rural areas and the growth rate should approach the average of 6.5%.

(iii) The population growth rate of Gondar City is slightly on the low side, but if city planning should progress, it may naturally be expected that the level of the growth rate will be raised.

(iv) The population growth rate of Dangla is very high and this is due to the extremely populous farming villages in the surrounding area in addition to which transportation is convenient. However, it is inconceivable that population growth will continue at the high rate of 11.5% in the future also. As an extremely approximate prediction, it is assumed that for a five-year period from now (until 1981), the rate will be an intermediate one of 9% between the present rate and the national average of 6.5%, after which the rate will become 6.5% as in other regions.

As the conclusion of the above, regarding the population growth rate of the project area required for load forecasting, the national average of 6.5% will be used throughout in this Report (except for Dangla which will be considered as having a rate of 9% until 1981 and 6.5% thereafter).

(b) Growth Rate of Electric Power Demand

The 25-year forecast for the period following the initial 5-year period for which a forecast was indicated in item 4.3.2 is in the category of an extra-long-range forecast. In making a load forecast for this period, data sufficient to make a so-called analytical forecast such as construction plans of factories and infrastructure in the project area do not exist.

Therefore, the growth rate in nationwide energy demand (kWh/capita) estimated by the macroscopic method is combined with the population growth rate of the project area to make the load forecast for the following 25-year period, and the growth rate of power demand thus determined will be the following:

Period	Growth Rate of Energy Demand
1982 ~ 1990	annual rate 10.5 %
1990 ~ 2000	annual rate 10 %
2000 and after	annual rate 9.4 %

(c) Considerations on Estimated Growth Rate of Demand

(i) In the past, the tempo of rural electrification was greatly influenced by efforts of EELPA in construction of a distribution network based on its policy regarding electric power supply. In this respect, construction of distribution networks for diesel systems of high costs only served to impair the financial system of EELPA, and it may be said that in self-contained systems, although there was potential demand, the tempo of this being converted to actual demand was slow. Consequently, the growth rate in this load forecast must not be judged by the past growth rate in demand of the diesel system areas.

(ii) In the past, the forecast method of taking an annual rate of 7% as the minimum load forecast was adopted in Ethiopia, and this is meaningful as an international standard only when based on the average population growth rate of 2.5% for the entire country, and the growth rate in kWh/capita in this case, is an annual rate of 4.4%. In contrast, the growth rates in kWh/capita in the present load forecast are more conservative at 3.8% (1982 ~ 1990), 3.3% (1990 ~ 2000) and 2.7% (after 2000). If a growth rate in power demand of 7% annually were to be applied to the project area which has a population growth rate of 6.5%, the growth rate in kWh/capita would be 0.3% annually, and when the elasticity coefficient of 3.64 of electric power to GNP is considered, the result will be an irrational one that there will be no increase in GNP/capita semi-permanently.

4.4 LOAD FORECAST BY REGION

(1) Load Factor

Of the three districts of Bahar Dar, Gondar and Debre Tabor presently being supplied with electricity by EELPA, the load factor of the demand in the city of Bahar Dar is indicated at a constant 31% while that in Gondar is 34%. In the case of Debre Tabor, the load factor is a mere 15%, but this is due to extreme restriction of supply (6 hours of supply per day). As for Bahar Dar Textile Mills S.C., the load factor of electric power for motors is an average 72% and that of electric boilers is an annual average of 42%. However, it has been confirmed from actual performance that a load factor higher than 50% is indicated for electric boilers in the high-water season, and when the regulating dam of Lake Tana is completed and stable supply of electricity is carried out, it is estimated that a load factor of about 50% will be recorded throughout the year.

In the case of non-electrified areas and areas at the initial stage of electrification, the proportion of the demand of flour mills is especially large in the potential demand. Because of this, the level of load factor will differ by area depending on the length of operating hours of engines of these flour mills.

In this load forecast, the load factors are estimated to be as follows:

(a) Forecast for Initial Five Years (1977 ~ 1981)

- Bahar Dar (city) — 31 ~ 33 %
- Textile Mills motors — 72 % constant
  electric boilers — 42 % constant
- Gondar ~ Azezo district — 34 ~ 36 %
- Kola Diba — 25 % constant

  (However, when potential demand is considered, the load factor in 1976 is estimated at approximately 33 %)
- Debre Tabor — 15 ~ 25 %

  (The load factor in 1976 is estimated at approximately 29 % when potential demand is considered)
- Wereta — 18 ~ 23 %

  (The load factor in 1976 is estimated at approximately 25 % when potential demand is considered)
- Dangla — 19 ~ 26 %

  (The load factor in 1976 is estimated at approximately 29 % when potential demand is considered)
- Other unelectrified towns ......load factor was estimated based on potential energy demand and maximum power demand in 1976.

(b) Forecast for Following 25 Years (1982 ~ 2006)

It is estimated that load factors will rise 1% every three years in all districts. Further, for Debre Tabor, Kola Diba, Wereta and Dangla, the load factors for 1982 are forecast to be the load factors estimated for 1976 including potential demands as in the case of unelectrified communities.

As for the power demand of motors at the factory of Bahar Dar Textile Mills S.C., the load factor is taken to be constant at 72% as in the past, but for demand of electric boilers, the load factor is taken to be constant at 50%.

(2) Distribution Loss Ratio

The distribution loss ratio at the receiving end of the 15-kV line in Bahar Dar was 9% up to 1973 while in 1974 and after, a normal figure of 6% was indicated. Contrasted to this, in the case of the Gondar district, the loss ratio of the three 15-kV distribution lines was 13.5% in 1973, but from 1974, since the 15-kV Tana Line was extended accompanying the start of supply to Kola Diba, the loss ratio became as high as 17 ~ 19%. Of this, it is not clear what the extent of loss from distribution lines in the city may have been. In the present load forecast, it is assumed that the loss ratio in the city of Bahar Dar including the 15-kV line will be 6%, the loss ratio for the Gondar ~ Azezo district (with Kola Diba predicted separately) will be lowered from the present 13.5% to 10% with improvement of the distribution network by 1981, while the loss ratio of Debre Tabor will also be lowered from the present 17 ~ 19 % to around 10%. Further, it is estimated that distribution loss ratios of other towns will all be 10% of energy at 15-kV bus terminals.

(3) Peaking Diversity Factor between Regions

When the various towns are interconnected by transmission lines, the peak loads of the various areas will not necessarily occur at the same time. However, in the case of the Lake Tana Project area, almost no differences can be recognized in the aspects of climatic conditions and demand structures, while the peak load of the factory of Bahar Dar Textile Mills S.C. occurs at the same time as that of Bahar Dar City. Therefore, peaking diversity factor between regions are not considered in the present load forecast.

4.5 DEMAND AND SUPPLY BALANCE AND CONCLUSIONS

4.5.1 Annual Energy Production and Dependable Capacity

The supply capability of Tis Abbay Power Station at present is 58,446 MWh in annual energy production and 6,670 kW in average annual output, and on completion of the regulating dam the annual energy production and dependable capacity will be as follows (see 8.2.3):

Condition	Annual Energy Production (MWh)	Dependable Capacity (kW)
Case of No. 1 and No. 2 units	63,296	7,060
Case of No. 3 unit added	94,910	10,560
After construction of Tis Abbay No. 2 PS (using 15 m^3/sec)	142,324	15,820

4.5.2 Demand and Supply Balance and Conclusions

(1) Reserve Capacity

Regarding reserve capacity, the concept adopted in Ethiopia is to take one generator unit of the maximum capacity in the system plus 10% of the remaining total capacity in case of the Interconnected System which is composed of a group of hydroelectric power stations. As for the diesel power stations of Self-Contained System in various districts, the concept is to take a capacity corresponding to 25% of the peak load in each district as the reserve capacity of that diesel power station.

However, in this project area, the number of generators of the existing Tis Abbay Power Station will be three units, while Tis Abbay No. 2 Power Station is being planned for one generator from the aspect of stressing economy. Consequently, since it will be a small power system with only four generators altogether, it is not appropriate from the aspect of economy to consider one of these units as reserve capacity.

As for the existing diesel power station in the Gondar district, a proposal to retain it as reserve capacity is extremely uneconomical compared with the merit of diverting the generators to other districts and operating them at all times. Therefore, in the case of this project, provision of a reserve generator will not be considered from the standpoint of emphasizing economy, even through there may be some sacrifice of stability of supply. However, although the Tis Abbay power system will be capable of generating power to the limit of installed capacity practically all of the time, since dependable peaking capacity is applied as the supply capability in the balance of demand and supply, it may be said that there is a slight amount of reserve capacity offered by the difference between installed capacity and dependable peaking capacity.

Further, as indicated in 4.5.3 below, the possibility for electric power to be supplementally supplied from Upper Beles Project from 1991 may be considered, and from that time reserve capacity can be expected of the large power source of Upper Beles Project.

(2) Considerations to be paid to Electric Boilers of Bahar Dar Textile Mills S.C.

At present, the contract is for supply of electric power to be made at off-peak hours for the electric boilers of Bahar Dar Textile Mills S.C. Consequently, there would be the following two proposals in formulating a supply system for electric boilers.

(a) The load factor of the electric boilers is fairly high at around 50%, while the load factor of the system as a whole not including the electric boilers is about 40%. Therefore, in order to improve the investment effect of generating facilities as much as possible, if the system of always operating electric boilers in off-peak hours of the entire power system were to be strictly observed, it will not be necessary to include the kW demand of the electric boilers in the demand and supply balance. In such case the load factor of the entire system including electric boilers will be at an extremely high level of 73% in 1982, 72% in 1983, 68% in 1985 and 58% in 1990, so that implementation of a closely-watched supply system will be necessary.

(b) From the aspect of emphasizing economy, the standpoint of (a) above is desirable. However, since the load factor of the electric boilers is fairly high, load will be apt to arise in the peak hours of the entire system. In such case, it is questionable whether supply to the electric boilers can be cut at any time disregarding the operating conditions of the textile factory. When taking such a viewpoint, it will be necessary to include the kW demand of the electric boilers in the demand and supply balance.

(3) Demand and Supply Balance

On making load forecasts for the various districts based on the above conditions, they are as in the attached Table 4-5 (1) ~ (11) and Tables 4-6 (1) ~ (2). On calculating power demand and supply balances based on these load forecasts and the dependable peaking capacity of the Tis Abbay power system described in 4.5.1, the results will be as shown in Table 4-7 and Fig. 4-4. With the case of kW demand of electric boilers not included in the demand and supply balance as "Case A," and the case of inclusion as "Case B," the following conclusions are obtained:

(a) The timing for construction of the regulating dam and transmission lines will be determined as a result of the economic analysis of Chapter 12, and unless these are constructed the annual power demand indicated in the load forecast will not be converted to actual load, but if it is hypothesized that the dam and transmission lines are commissioned in 1982, the required tempo for additional capacities considering only the requirements from power demand will be the following:

Case A..... Addition of the third unit of the existing power station at the beginning of 1983 and commissioning of Tis Abbay No. 2 Power Station at the beginning of 1986 will be necessary.

Case B ...... Commissioning of the additional third unit of the existing power station at the beginning of 1982 immediately followed by commissioning of Tis Abbay No. 2 Power Station around the beginning of 1983, the next year, will be necessary.

(b) After start of operation of Tis Abbay No. 2 Power Station, the demand can be met up to 1990 with the supply capacity of the Tis Abbay power system in the "Case A," but from 1991 there will be a shortage in the supply capacity. In contrast, in the "Case B," there will be a shortage of capacity of the Tis Abbay power system as early as 1986. However, even in the "Case B," by shifting part of the demand of electric boilers during peak hours of the whole system to off-peak hours, it will be possible to meet the demand with the supply capacity of the Tis Abbay power system until 1990, but a shortage in supply capacity will arise in 1991.

(c) In either case, it will become necessary for supplementary power to be received from some other new power source. Although conclusions have not yet been reached regarding such a new power source, the proposal for developing the Upper Beles Project described in 4.5.3 is promising.

4.5.3 Load Forecast for Interconnected System and Timing of Implementation of Upper Beles Project

The supply capacity of the Tis Abbay power system is thought to be sufficient for meeting the total demand of the area until around 1990 through shifting of the kW demand of the electric boilers of Bahar Dar Textile Mills S.C. to off-peak hours, but from 1991 there will be a shortage in dependable peaking capacity. The Upper Beles Project may be cited as a prospective project in the vicinity of the project area to serve supplementary power. However, since Upper Beles Project would be a large-scale power source, its main purpose would be supplying electricity to the Interconnected System (ICS) centered around Addis Ababa, and consequently, its order of priority for development must naturally be determined based on economic comparisons with other alternative projects.

On looking at ranking studies made in the past regarding future projects for ICS, the preliminary report prepared by Acres International recommends the following order of development:

First priority	Malka Wakana and Amalti Finchaa Diversion	180 MW
Second priority	Upper Beles Project	200 MW
Third priority	Gogeb Project	600 MW

Later, in 1974, a revised report of Acres International recommended the following order of development:

First priority	Raising Finchaa Dam by 2 m
Second priority	Installation of 90 MW of gas turbine
Third priority	Development of 152 MW of Malka Wakana

Making a load forecast for ICS and carrying out a ranking study of future projects to meet demand is outside the scope of this present Report, but if the Lake Tana Project is realized, the various benefits below would be newly considered in formulating the Upper Beles Project.

(a) Merely by connection with Bahar Dar Substation (about 60-km from project site), it will be possible to satisfy the large power demand of the Lake Tana Region for which the groundwork already exists without additional investment for transmitting and transforming facilities.

(b) The border region adjacent to Sudan to the west of Gondar is a prominent cotton growing area, and power supply for development of cotton ginning and processing can be secured.

(c) Electric power necessary for the facilities of the textile mills at Bahar Dar to be vastly expanded can be secured.

(d) By utilizing the abundant bamboo resources at the middle stretch of the Beles River and the water of Lake Tana, it would be possible to develop paper manufacturing, for instance, at Bahar Dar. Also, an irrigation project along the middle reaches of the Beles River would contribute greatly to agricultural development.

(e) By extension of the transmission line to north of Gondar, economical regional electrification will be possible.

When the various additional benefits mentioned above are considered, there will be a possibility for the ranking order of the Upper Beles Project to come ahead of the Malka Wakana project.

At present, the total installed capacity of the power stations of ICS is 213.8 MW and dependable peaking capacity 203.3 MW, but as reserve capacity of the system one unit of the largest size of 33 MW (Finchaa Power Station) and capacity corresponding to 10% of the dependable peaking capacity remaining in the system after deduction of the 33 MW, or a total of 50 MW is taken as the reserve capacity. Such an arrangement is adequate in the way of securing reserve capacity, but even if stability of supply were to be sacrificed to an extent, it would rather match the actual situation of Ethiopia more to take only the one unit of maximum capacity as the reserve capacity.

Based on the above thinking, on determining the timing required for commissioning of the Upper Beles Project in accordance with the load forecast of Acres International, the following are obtained (see Table 4-8).

- 1991 Commissioning of No.1 and No.2 units of Upper Beles Power Station, total 100 kW
- 1995 Commissioning of No.3 and No.4 units of Upper Beles Power Station, total 100 MW
- 1998 Commissioning of Malka Wakana Power Station

Table 4-5(1) Load Forecast by Town

Bahar Dar town

Year	Annual Energy Demand (MWh)					Load Factor (%)	Peak Load (kW)
	Consumers' end				Outgoing of 15 kV		
	Existing	Potential	Planned	Total			
1973	1,588			1,588	1,745	31	640
1974	1,623			1,623	1,727	31	640
1975	1,634			1,634	1,739	31	640
1976	1,728	(622)		1,728	1,809	31	670
1977	1,839	219		2,058	2,189	31	810
1978	1,956	530		2,486	2,645	32	940
1979	2,081	622		2,703	2,876	32	1,030
1980	2,215	622		2,837	3,056	32	1,080
1981	2,356	622		2,978	3,168	33	1,100
1982				3,290	3,500	33	1,210
1983				3,636	3,868	33	1,330
1984				4,018	4,274	34	1,440
1985				4,440	4,729	34	1,580
1986				4,906	5,219	34	1,750
1987				5,421	5,767	35	1,880
1988				5,990	6,372	35	2,080
1989				6,619	7,041	35	2,290
1990				7,315	7,782	36	2,470
1991				8,047	8,561	36	2,720
1992				8,851	9,416	36	2,980
1993				9,736	10,357	37	3,200
1994				10,710	11,394	37	3,520
1995				11,780	12,532	37	3,870
1996				12,959	13,786	38	4,140
1997				14,254	15,164	38	4,550
1998				15,680	16,680	38	5,010
1999				17,248	18,349	39	5,370
2000				18,973	20,184	39	5,910
2001				20,756	22,080	39	6,460
2002				22,708	24,157	40	6,890
2003				24,842	26,428	40	7,540
2004				27,177	28,912	40	8,250
2005				29,732	31,630	41	8,800
2006				32,527	34,603	41	9,630

Notes : 1. Annual load growth - 10.5% (1980 to 1990), 10% (1990 to 2000) and 9.4% (2000 to 2010).

2. Distribution loss is estimated to be 6% constant.

Table 4-5 (2) Load Forecast by Town

Bahar Dar Textile Mills S.C.

Year	Annual Energy Demand			Load Factor		Peak Load		
	Motors (MWh)	Boilers (MWh)	Total (MWh)	Motors (%)	Boilers (%)	Motors (kW)	Boilers (kW)	Total (kW)
1973	7,515	7,499	15,014	68	30	1,260	2,850	3,720
1974	7,982	10,617	18,599	74	39	1,230	3,120	4,035
1975	8,480	9,711	18,191	69	38	1,410	2,940	3,855
1976	8,262	12,419	20,681	73	51	1,290	2,760	3,560
1977	9,460	11,040	20,500	72	42	1,500	3,000	3,960
1978	9,460	11,040	20,500	72	42	1,500	3,000	3,960
1979	9,460	11,040	20,500	72	42	1,500	3,000	3,960
1980	9,460	11,040	20,500	72	42	1,500	3,000	3,960
1981	9,460	11,040	20,500	72	42	1,500	3,000	3,960
1982	11,350	17,520	28,870	72	50	1,800	4,000	
1983	13,250	21,900	35,150	72	50	2,100	5,000	
1984	13,250	21,900	35,150	72	50	2,100	5,000	
1985	13,250	21,900	35,150	72	50	2,100	5,000	
1986	13,250	21,900	35,150	72	50	2,100	5,000	
1987	13,250	21,900	35,150	72	50	2,100	5,000	
1988	13,250	21,900	35,150	72	50	2,100	5,000	
1989	13,250	21,900	35,150	72	50	2,100	5,000	
1990	13,250	21,900	35,150	72	50	2,100	5,000	
1991	13,250	21,900	35,150	72	50	2,100	5,000	
1992	13,250	21,900	35,150	72	50	2,100	5,000	
1993	13,250	21,900	35,150	72	50	2,100	5,000	
1994	13,250	21,900	35,150	72	50	2,100	5,000	
1995	13,250	21,900	35,150	72	50	2,100	5,000	
1996	13,250	21,900	35,150	72	50	2,100	5,000	
1997	13,250	21,900	35,150	72	50	2,100	5,000	
1998	13,250	21,900	35,150	72	50	2,100	5,000	
1999	13,250	21,900	35,150	72	50	2,100	5,000	
2000	13,250	21,900	35,150	72	50	2,100	5,000	
2001	13,250	21,900	35,150	72	50	2,100	5,000	
2002	13,250	21,900	35,150	72	50	2,100	5,000	
2003	13,250	21,900	35,150	72	50	2,100	5,000	
2004	13,250	21,900	35,150	72	50	2,100	5,000	
2005	13,250	21,900	35,150	72	50	2,100	5,000	
2006	13,250	21,900	35,150	72	50	2,100	5,000	

Notes : - Peaking diversity factor is estimated to be about 90%.

- After completion of 2nd stage expansion programme, load is assumed to be constant.

Table 4-5(3) Load Forecast by Town

Gondar - Azezo

Year	Annual Energy Demand (MWh)					Load Factor	Peak Load
	Consumers end				Outgoing of 15 kV		
	Existing	Potential	Planned	Total		(%)	(kW)
1973	2,364			2,364	2,732	36	870
1974	2,520			2,520	3,051	33	1,060
1975	2,661			2,661	3,223	30	1,238
1976	2,553	(457)	(846)	2,553	3,175	34	1,065
1977	2,709	273		2,982	3,447	34	1,160
1978	2,874	365	276	3,515	4,040	34	1,360
1979	3,049	457	276	3,782	4,322	35	1,410
1980	3,235	457	276	3,968	4,484	35	1,450
1981	3,433	457	276	4,166	4,629	36	1,450
1982	3,793	457	561	4,811	5,346	36	1,700
1983	4,192	457	846	5,495	6,106	36	1,940
1984				6,072	6,747	36	2,140
1985				6,710	7,456	37	2,300
1986				7,414	8,238	37	2,540
1987				8,193	9,103	37	2,810
1988				9,053	10,059	38	3,020
1989				10,003	11,114	38	3,340
1990				11,053	12,281	38	3,690
1991				12,158	13,509	39	3,950
1992				13,374	14,860	39	4,350
1993				14,712	16,347	39	4,780
1994				16,183	17,981	40	5,130
1995				17,800	19,778	40	5,640
1996				19,581	21,757	40	6,200
1997				21,539	23,932	41	6,660
1998				23,693	26,326	41	7,330
1999				26,062	28,958	41	8,060
2000				28,669	31,854	42	8,660
2001				31,363	34,848	42	9,470
2002				34,312	38,124	42	10,120
2003				37,537	41,708	43	11,070
2004				41,065	45,628	43	12,110
2005				44,926	49,918	43	13,250
2006				49,149	54,610	44	14,170

Notes :
1. Annual load growth - 10.5% (1980 to 1990), 10% (1990 to 2000) and 9.4% (2000 to 2010).
2. Distribution loss is estimated to be 10% after 1982.

Table 4-5 (4) Load Forecast by Town

Kola - Diba

Year	Annual Energy Demand (MWh) Consumers end Existing	Potential	Planned	Total	Terminal of 15 kV	Load Factor (%)	Peak Load (kW)
1973							
1974	18			18	20	25	9
1975	36			36	40	25	18
1976	36	(371)		36	40	25	18
1977	38	(395)		38	42	25	19
1978	41	(420)		41	45	25	21
1979	43	(448)		43	48	25	22
1980	46	(477)		46	51	25	23
1981	49	(508)		49	54	25	25
1982	54	280		334	371	33	130
1983	60	620		680	756	33	260
1984				751	834	33	290
1985				830	922	34	310
1986				917	1,018	34	340
1987				1,014	1,127	34	380
1988				1,120	1,244	35	410
1989				1,238	1,376	35	450
1990				1,368	1,520	35	490
1991				1,505	1,672	36	530
1992				1,655	1,839	36	580
1993				1,820	2,022	36	640
1994				2,003	2,226	37	690
1995				2,203	2,448	37	750
1996				2,423	2,692	37	830
1997				2,666	2,962	38	890
1998				2,932	3,258	38	980
1999				3,226	3,584	38	1,070
2000				3,548	3,942	39	1,150
2001				3,882	4,313	39	1,260
2002				4,247	4,719	39	1,380
2003				4,646	5,162	40	1,470
2004				5,083	5,648	40	1,610
2005				5,560	6,178	40	1,760
2006				6,083	6,759	41	1,880

Notes :
1. Annual load growth - 10.5% (1980 to 1990), 10% (1990 to 2000) and 9.4% (2000 to 2010).
2. Distribution loss is estimated to be 10% after 1988.
3. Kola - Diba is already connected with Gondar - Azezo area, and figures shown before 1981 are included in the corresponding figures of Gondar - Azezo area.

Table 4-5 (5) Load Forecast by Town

Chewahit

Year	Annual Energy Demand (MWh) Consumers end Existing	Potential	Planned	Total	Terminal of 15 kV	Load Factor (%)	Peak Load (kW)
1973							
1974							
1975							
1976		(384)		(384)	(427)	(34)	(142)
1977		(409)		(409)	(454)	(34)	(150)
1978		(436)		(436)	(484)	(34)	(160)
1979		(464)		(464)	(516)	(34)	(170)
1980		(494)		(494)	(549)	(34)	(180)
1981		(526)		(526)	(584)	(34)	(200)
1982		290		290	322	34	110
1983		642		642	713	34	240
1984				710	789	34	260
1985				784	871	35	280
1986				867	963	35	310
1987				957	1,063	35	340
1988				1,058	1,176	36	370
1989				1,169	1,299	36	410
1990				1,292	1,436	36	450
1991				1,421	1,578	37	490
1992				1,563	1,736	37	530
1993				1,720	1,911	37	590
1994				1,892	2,102	38	630
1995				2,080	2,311	38	690
1996				2,289	2,543	38	760
1997				2,518	2,797	39	820
1998				2,770	3,078	39	900
1999				3,046	3,384	39	990
2000				3,351	3,723	40	1,060
2001				3,665	4,072	40	1,160
2002				4,010	4,456	40	1,270
2003				4,387	4,874	41	1,360
2004				4,806	5,333	41	1,490
2005				5,251	5,834	41	1,620
2006				5,745	6,383	42	1,740

Notes :
1. Annual load growth - 10.5% (1980 to 1990), 10% (1990 to 2000) and 9.4% (2000 to 2010).
2. Distribution loss is estimated to be 10% after 1982.
3. Load factor in 1976 is estimated to be 34% because of high proportion of flour mills consumption.

Table 4-5 (6) Load Forecast by Town

Gorgora

Year	Annual Energy Demand (MWh)					Load Factor	Peak Load
	Consumers end				Terminal of 15 kV		
	Existing	Potential	Planned	Total		(%)	(kW)
1973							
1974							
1975							
1976		(250)		(250)	(278)	(26)	(121)
1977		(266)		(266)	(296)	(26)	(130)
1978		(284)		(284)	(316)	(26)	(140)
1979		(302)		(302)	(336)	(26)	(150)
1980		(322)		(322)	(358)	(26)	(160)
1981		(343)		(343)	(381)	(26)	(170)
1982		190	46	236	262	26	120
1983		418	92	510	567	26	250
1984				564	627	26	270
1985				622	691	27	290
1986				688	764	27	320
1987				760	844	27	350
1988				840	933	28	380
1989				928	1,031	28	420
1990				1,026	1,140	28	460
1991				1,129	1,254	29	490
1992				1,241	1,379	29	540
1993				1,366	1,518	29	600
1994				1,502	1,669	30	640
1995				1,652	1,836	30	700
1996				1,818	2,020	30	770
1997				1,999	2,221	31	820
1998				2,199	2,443	31	900
1999				2,419	2,688	31	990
2000				2,661	2,957	32	1,060
2001				2,911	3,234	32	1,150
2002				3,185	3,539	32	1,260
2003				3,484	3,871	33	1,340
2004				3,812	4,236	33	1,460
2005				4,170	4,633	34	1,550
2006				4,562	5,069	35	1,650

Notes : 1. Annual load growth - 10.5% (1980 to 1990), 10% (1990 to 2000) and 9.4% (2000 to 2010).

2. Distribution loss is estimated to be 10% after 1982.

3. Load factor in 1976 is estimated to be 26%.

Table 4-5(7) Load Forecast By Town

Debre Tabor

Year	Annual Energy Demand (MWh)					Load Factor	Peak Load
	Consumers end				Outgoing of 15 kV		
	Existing	Potential	Planned	Total		(%)	(kW)
1973							
1974							
1975	56			56	68	14	55
1976	58	(747)		58	72	15	55
1977	62	(796)		62	75	15	57
1978	66	50		116	136	20	80
1979	70	100		170	195	25	90
1980	75	200		275	308	25	140
1981	80	370		450	500	25	230
1982	88	570	27	685	761	29	300
1983	96	1,250	54	1,400	1,556	29	610
1984				1,547	1,719	29	670
1985				1,709	1,899	30	720
1986				1,889	2,099	30	800
1987				2,087	2,319	30	880
1988				2,306	2,562	31	950
1989				2,549	2,832	31	1,040
1990				2,816	3,129	31	1,150
1991				3,098	3,442	32	1,230
1992				3,408	3,787	32	1,350
1993				3,748	4,164	32	1,480
1994				4,123	4,581	33	1,590
1995				4,536	5,040	33	1,740
1996				4,989	5,543	33	1,920
1997				5,488	6,098	34	2,050
1998				6,037	6,708	34	2,250
1990				6,640	7,378	34	2,470
2000				7,305	8,117	35	2,650
2001				7,991	8,879	35	2,900
2002				8,742	9,713	35	3,170
2003				9,564	10,627	36	3,370
2004				10,463	11,626	36	3,690
2005				11,446	12,718	36	4,030
2006				12,522	13,913	37	4,290

Notes : 1. Annual load growth - 10.5% (1980 to 1990), 10% (1990 to 2000) and 9.4% (2000 to 2010).

2. Distribution loss is estimated to be 10% after 1982.

3. Load factor in 1976 including potential demand is estimated to be 29%.

Table 4-5 (8) Load Forecast by Town

Wereta

Year	Annual Energy Demand (MWh)					Load Factor	Peak Load
	Consumers end				Terminal of 15 kV		
	Existing	Potential	Planned	Total		(%)	(kW)
1973							
1974							
1975	55	(462)		55	61	17	42
1976	55	(462)		55	61	17	42
1977	59	(492)		59	66	18	42
1978	62	(524)		62	69	19	42
1979	66	(558)		66	73	20	42
1980	71	(594)		71	79	22	42
1981	75	(633)		75	83	23	42
1982	83	350		433	481	25	220
1983	92	773		865	961	25	440
1984				956	1,062	25	480
1985				1,056	1,173	26	520
1986				1,167	1,297	26	570
1987				1,290	1,433	26	630
1988				1,425	1,583	27	670
1989				1,575	1,750	27	740
1990				1,740	1,933	27	820
1991				1,914	2,127	28	870
1992				2,105	2,339	28	950
1993				2,316	2,573	28	1,050
1994				2,548	2,831	29	1,110
1995				2,802	3,113	29	1,220
1996				3,083	3,426	29	1,350
1997				3,390	3,767	30	1,440
1998				3,730	4,144	30	1,570
1999				4,103	4,559	30	1,730
2000				4,513	5,014	31	1,850
2001				4,937	5,486	31	2,020
2002				5,401	6,001	31	2,210
2003				5,909	6,566	32	2,340
2004				6,464	7,182	32	2,560
2005				7,072	7,858	32	2,800
2006				7,737	8,597	33	2,970

Notes :
1. Annual load growth - 10.5% (1980 to 1990), 10% (1990 to 2000) and 9.4% (2000 to 2010).
2. Distribution loss is estimated to be 10%.
3. Load factor in 1976 including potential demand is estimated to be 25%.

Table 4-5 (9) Load Forecast by Town

Addis Zemen

Year	Annual Energy Demand (MWh) Consumers end Existing	Potential	Planned	Total	Terminal of 15 kV	Load Factor (%)	Peak Load (kW)
1973							
1974							
1975							
1976		(500)		(500)	(556)	(28)	(224)
1977		(533)		(533)	(592)	(28)	(240)
1978		(567)		(567)	(630)	(28)	(250)
1979		(604)		(604)	(671)	(28)	(270)
1980		(643)		(643)	(714)	(28)	(290)
1981		(685)		(685)	(761)	(28)	(310)
1982		380		380	422	28	170
1983		836		836	929	28	380
1984				924	1,027	28	420
1985				1,021	1,134	29	450
1986				1,129	1,254	29	490
1987				1,247	1,386	29	540
1988				1,378	1,531	30	580
1989				1,523	1,692	30	640
1990				1,682	1,869	30	710
1991				1,850	2,056	31	760
1992				2,036	2,262	31	830
1993				2,240	2,489	31	920
1994				2,463	2,737	32	980
1995				2,709	3,010	32	1,070
1996				2,980	3,311	32	1,180
1997				3,279	3,643	33	1,260
1998				3,607	4,008	33	1,390
1999				3,967	4,408	33	1,520
2000				4,364	4,849	34	1,630
2001				4,774	5,304	34	1,780
2002				5,223	5,803	34	1,950
2003				5,714	6,349	35	2,070
2004				6,251	6,946	35	2,270
2005				6,839	7,599	35	2,480
2006				7,482	8,313	36	2,640

Notes :
1. Annual load growth - 10.5% (1980 to 1990), 10% (1990 to 2000) and 9.4% (2000 to 2010).
2. Distribution loss is estimated to be 10%.
3. Load factor in 1976 is estimated to be 28%.

Table 4-5 (10) Load Forecast by Town

Dangla

Year	Annual Energy Demand (MWh)					Load Factor	Peak Load
	Consumers end				Terminal of 15 kV		
	Existing	Potential	Planned	Total		(%)	(kW)
1973	95			95	105	19	64
1974	95			95	105	19	64
1975	95			95	105	19	64
1976	104	(630)		104	115	19	76
1977	113	(686)		113	126	19	76
1978	124	(748)		124	138	21	76
1979	135	(816)		135	150	23	76
1980	147	(889)		147	163	25	76
1981	160	(969)		160	178	26	76
1982	177	540		717	797	29	310
1983	195	1,183		1,378	1,531	29	600
1984				1,522	1,691	29	670
1985				1,682	1,869	30	710
1986				1,859	2,066	30	790
1987				2,054	2,282	30	870
1988				2,270	2,522	31	930
1989				2,508	2,787	31	1,030
1990				2,772	3,080	31	1,130
1991				3,049	3,388	32	1,210
1992				3,354	3,727	32	1,330
1993				3,690	4,100	32	1,460
1994				4,058	4,509	33	1,560
1995				4,464	4,960	33	1,720
1996				4,910	5,455	33	1,880
1997				5,402	6,002	34	2,020
1998				5,942	6,602	34	2,220
1999				6,536	7,262	34	2,440
2000				7,190	7,989	35	2,610
2001				7,866	8,740	35	2,850
2002				8,605	9,561	35	3,120
2003				9,413	10,459	36	3,320
2004				10,298	11,442	36	3,630
2005				11,267	12,519	36	3,970
2006				12,326	13,696	37	4,230

Notes :
1. Annual load growth - 10.5% (1980 to 1990), 10% (1990 to 2000) and 9.4% (2000 to 2010).
2. Distribution loss is estimated to be 10%.
3. Load factor in 1976 including potential demand is estimated to be 29%.

Table 4-5(11) Load Forecast by Town

Injibara - Addis Kidame

Year	Annual Energy Demand (MWh)					Load Factor	Peak Load
	Consumers end				Terminal of 15 kV		
	Existing	Potential	Planned	Total		(%)	(kW)
1973							
1974							
1975							
1976		(487)		(487)	(541)	(34)	(183)
1977		(518)		(518)	(576)	(34)	(190)
1978		(552)		(552)	(613)	(34)	(210)
1979		(588)		(588)	(653)	(34)	(220)
1980		(627)		(627)	(697)	(34)	(240)
1981		(667)		(667)	(741)	(34)	(250)
1982		370		370	411	34	140
1983		815		815	906	34	300
1984				901	1,000	34	340
1985				996	1,107	35	370
1986				1,100	1,222	35	400
1987				1,217	1,352	35	440
1988				1,345	1,494	36	470
1989				1,486	1,651	36	520
1990				1,642	1,824	36	570
1991				1,806	2,118	37	650
1992				1,987	2,208	37	680
1993				2,186	2,429	37	740
1994				2,405	2,672	38	800
1995				2,646	2,940	38	880
1996				2,911	3,234	38	970
1997				3,202	3,558	39	1,040
1998				3,522	3,913	39	1,140
1999				3,874	4,304	39	1,260
2000				4,261	4,734	40	1,350
2001				4,662	5,180	40	1,480
2002				5,100	5,667	40	1,620
2003				5,579	6,199	41	1,730
2004				6,103	6,781	41	1,890
2005				6,677	7,419	41	2,070
2006				7,305	8,117	42	2,210

Notes : 1. Annual load growth - 10.5% (1980 to 1990), 10% (1990 to 2000) and 9.4% (2000 to 2010).

2. Distribution loss is estimated to be 10%.

3. Load factor in 1976 is estimated to be 34% because of high proportion of flour mills consumption.

Table 4-6 (1) Forecast of Annual Energy Demand

(Whole Project Area)

(MWh)

Year	South Region			North and East Regions			Total (Terminal of 15 kV)	System loss (%)	Demand at Generating end	Remarks
	Bahar Dar	Dangla - Injibara	Sub-total	North Region	East Region	Sub-total				
1973	16,759	105	16,864	2,732		2,732	19,596			Demand in Bahar Dar includes town's demand as well as demand by motors and electric boilers installed in textile factory.
1974	20,326	105	20,431	3,051		3,051	23,482			
1975	19,930	105	20,035	3,223	129	3,352	23,387			
1976	22,490	115	22,605	3,175	133	3,308	25,913			
1977	22,680	126	22,815	3,447	141	3,588	26,403			
1978	23,145	138	23,283	4,040	205	4,245	26,528			
1979	23,376	150	23,526	4,322	268	4,590	28,116			
1980	23,556	163	23,719	4,484	387	4,871	28,590			
1981	23,668	178	23,846	4,629	583	5,212	29,058			
1982	32,370	1,208	33,578	6,301	1,664	7,965	41,543	4.20	43,364	
1983	39,018	2,437	41,455	8,142	3,446	11,588	53,043	4.20	55,368	
1984	39,424	2,691	42,115	8,997	3,808	12,805	54,920	5.00	57,810	
1985	39,879	2,976	42,855	9,940	4,206	14,146	57,001	5.00	60,001	
1986	40,369	3,288	43,657	10,983	4,650	15,633	59,290	6.00	63,074	
1987	40,917	3,643	44,560	12,137	5,138	17,275	61,835	6.00	65,782	
1988	41,522	4,016	45,538	13,412	5,676	19,088	64,626	7.00	69,490	
1989	42,191	4,438	46,629	14,820	6,274	21,094	67,723	7.00	72,820	
1990	42,932	4,904	47,836	16,377	6,931	23,308	71,144	6.90	76,417	
1991	43,711	5,506	49,217	18,013	7,625	25,638	74,855	6.90	80,403	
1992	44,566	5,935	50,501	19,814	8,388	28,202	78,703	7.00	84,627	
1993	45,507	6,529	52,036	21,798	9,226	31,024	83,060	7.00	89,312	
1994	46,544	7,181	53,725	23,978	10,149	34,127	87,852	7.00	94,475	
1995	47,682	7,900	55,582	26,373	11,163	37,536	93,118	8.00	101,215	
1996	48,936	8,689	57,625	29,012	12,280	41,292	98,917	8.00	107,518	
1997	50,314	9,560	59,874	31,912	13,508	45,420	105,294	8.00	114,450	
1998	51,830	10,515	62,345	35,105	14,860	49,965	112,310	9.00	123,417	
1999	53,499	11,566	65,065	38,614	16,345	54,959	120,024	9.00	131,894	
2000	55,334	12,723	68,057	42,476	17,980	60,456	128,513	10.25	143,110	
2001	57,230	14,407	71,637	46,467	19,669	66,136	137,773	10.25	153,422	
2002	59,307	15,228	74,535	50,838	21,517	72,355	146,890	10.25	163,574	
2003	61,578	16,658	78,336	55,615	23,542	79,157	157,393	10.25	175,270	
2004	64,062	18,223	82,285	60,845	25,754	86,599	168,884	10.25	188,066	
2005	66,780	19,938	86,718	66,563	28,175	94,738	181,456	10.25	202,066	
2006	69,753	21,813	91,566	72,821	30,823	103,644	195,210	10.25	217,383	

Table 4-6 (2) Forecast of Maximum Power Demand

(Whole Project Area)

(kW)

Year	South Region					North and East Regions			Total (Terminal of 15 kV)		System loss	Demand at Generating end		Load Factor (%)	
	Bahar Dar		Dangla - Injibara	Sub-total		North Region	East Region	Sub-total						(Case A)	(Case B)
	Without boilers	With boilers		Without boilers	With boilers				Without boilers	With boilers	(%)	Without boilers	With boilers	Without boilers	With boilers
1973	1,900	4,360	64	1,964	4,424	870		870	2,834	5,294					
1974	1,870	4,675	64	1,934	4,739	1,060		1,060	2,994	5,799					
1975	2,050	4,495	64	2,114	4,559	1,238	97	1,335	3,449	5,894					
1976	1,960	4,230	64	2,024	4,306	1,065	97	1,162	3,186	5,464					
1977	2,310	4,770	76	2,386	4,846	1,160	99	1,259	3,645	6,105					
1978	2,440	4,900	76	2,516	4,976	1,360	122	1,482	3,998	6,458					
1979	2,530	4,900	76	2,606	5,066	1,410	132	1,542	4,148	6,598					
1980	2,580	5,040	76	2,656	5,116	1,450	182	1,632	4,288	6,748					
1981	2,600	5,060	76	2,676	5,136	1,450	272	1,722	4,398	6,858					
1982	3,010	6,310	450	3,460	6,760	2,060	690	2,750	6,210	9,510	6.8	6,660	10,220	76.4	49.9
1983	3,430	7,720	900	4,330	8,620	2,690	1,430	4,120	8,450	12,740	6.8	9,070	13,670		
1984	3,540	7,830	1,010	4,550	8,840	2,960	1,570	4,530	9,080	13,370	7.0	9,760	14,380		
1985	3,680	7,940	1,080	4,760	9,050	3,180	1,690	4,870	9,630	13,920	7.0	10,350	14,970	67.6	46.7
1986	3,850	8,140	1,190	5,040	9,330	3,510	1,860	5,370	10,410	14,700	8.0	11,320	15,980		
1987	3,980	8,270	1,310	5,290	9,580	3,880	2,050	5,930	11,220	15,510	8.0	12,200	16,860		
1988	4,180	8,470	1,400	5,580	9,870	4,180	2,200	6,380	11,960	16,250	9.0	13,140	17,860		
1989	4,390	8,680	1,550	5,940	10,230	4,620	2,420	7,040	12,980	17,270	9.0	14,260	18,980		
1990	4,570	8,860	1,700	6,270	10,560	5,090	2,680	7,770	14,040	18,330	10.1	15,620	20,390	57.8	44.3
1991	4,820	9,110	1,860	6,680	10,970	5,460	2,860	8,320	15,000	19,290	10.1	16,690	21,460		
1992	5,080	9,370	2,010	7,090	11,380	6,000	3,180	9,130	16,220	20,510	10.1	18,040	22,810		
1993	5,300	9,590	2,200	7,500	11,790	6,610	3,450	10,060	17,560	21,880	10.1	19,530	24,300		
1994	5,620	9,910	2,360	7,980	12,270	7,090	3,680	10,770	18,750	23,040	10.1	20,860	25,630		
1995	5,970	10,260	2,600	8,570	12,860	7,780	4,030	11,810	20,380	24,670	10.2	22,690	27,470	52.1	43.1
1996	6,240	10,530	2,850	9,090	13,380	8,560	4,450	13,010	22,100	26,390	11.0	24,830	29,650		
1997	6,650	10,940	3,060	9,710	14,000	9,190	4,750	13,940	23,650	27,940	12.0	26,880	31,750		
1998	7,110	11,400	3,360	10,470	14,760	10,110	5,210	15,320	25,790	30,080	13.0	29,640	34,570		
1999	7,470	11,760	3,700	11,170	15,460	11,110	5,720	16,830	28,000	32,290	14.0	32,560	37,550		
2000	8,010	12,300	3,960	11,970	16,260	11,930	6,130	18,050	30,030	34,320	14.3	35,040	40,050	48.8	42.7
2001	8,560	12,850	4,330	12,890	17,180	13,040	6,700	19,740	32,630	36,920	14.3	38,070	43,080		
2002	8,990	13,280	4,740	13,730	18,020	14,030	7,330	21,360	35,090	39,380	14.3	40,950	45,950		
2003	9,640	13,930	5,050	14,690	18,980	15,240	7,780	23,030	37,710	42,000	14.3	44,000	49,000		
2004	10,350	14,640	5,520	15,870	20,160	16,670	8,520	25,190	41,060	45,350	14.3	47,910	52,920		
2005	10,900	15,190	6,040	16,940	21,230	18,180	9,310	21,490	44,430	48,720	14.3	51,840	56,850		
2006	11,730	16,020	6,440	18,170	22,460	19,440	9,900	29,340	47,510	51,800	14.3	55,440	60,440	46.9	43.0

Table 4-7 Power Demand and Supply Balance

(Whole Project Area)

Year	Annual Energy Balance (MWh)						Maximum Demand Balance (kW)						Remarks
	Case A (without boilers)			Case B (with boilers)			Case A (without boilers)			Case B (with boilers)			
	Demand	Supply	Balance	Demand	Supply	Balance	Demand	Supply	Balance	Demand	Supply	Balance	
1982	43,364	63,296	19,932	43,364	94,910	51,540	6,660	7,060	400	10,200	10,560	360	This table is established on the assumption that regulating dam and inter-connecting trans-mission lines are put into service in 1982.
1983	55,368	94,910	39,542	55,368	142,324	86,956	9,070	10,560	1,490	13,670	15,820	2,150	
1984	57,810	94,910	37,100	57,810	142,324	84,514	9,760	10,500	800	14,380	15,820	1,440	
1985	60,001	142,324	34,909	60,001	142,324	82,323	10,350	15,820	210	14,970	15,820	850	
1986	63,074	142,324	79,250	63,074	142,324	79,250	11,320	15,820	4,500	15,980	15,820	- 160	
1987	65,782	142,324	76,542	65,782	142,324	76,542	12,200	15,820	3,620	16,860	15,820	- 1,040	
1988	69,490	142,324	72,834	69,490	142,324	72,834	13,140	15,820	2,680	17,860	15,820	- 2,040	
1989	72,820	142,324	69,504	72,820	142,324	69,504	14,260	15,820	1,560	18,980	15,820	- 3,160	
1990	76,417	142,324	65,907	76,417	142,324	65,907	15,620	15,820	270	20,390	15,820	- 4,570	
1991	80,403	142,324	61,921	80,403	142,324	61,921	16,690	15,820	- 870	21,460	15,820	- 5,640	
1992	84,629	142,324	57,697	84,627	142,324	57,697	18,040	15,820	- 2,220	22,810	15,820	- 6,990	
1993	89,312	142,324	53,012	89,312	142,324	53,012	19,530	15,820	- 3,710	24,300	15,820	- 8,480	
1994	94,475	142,324	47,849	94,475	142,324	47,849	20,860	15,820	- 5,040	25,6[illegible]0	15,820	- 9,810	
1995	101,215	142,324	41,109	101,215	142,324	41,109	22,690	15,820	- 6,870	27,470	15,820	-11,650	
1996	107,518	142,324	34,806	107,518	142,324	34,806	24,830	15,820	- 9,010	29,650	15,820	-13,830	
1997	114,450	142,324	27,874	114,450	142,324	27,874	26,880	15,820	-11,060	31,750	15,820	-15,930	
1998	123,417	142,324	18,907	123,417	142,324	18,907	29,640	15,820	-13,820	34,570	15,820	-18,750	
1999	131,894	142,324	10,430	131,894	142,324	10,430	32,560	15,820	-16,740	37,550	15,820	-21,730	
2000	143,110	142,324	- 786	142,110	142,324	- 786	35,040	15,820	-19,220	40,050	15,820	-24,230	
2001	153,432	142,324	-11,098	153,422	142,324	-11,098	38,070	15,820	-22,250	43,080	15,820	-27,260	
2002	163,574	142,324	-21,250	163,574	142,324	-21,250	40,950	15,820	-25,130	45,950	15,820	-30,130	
2003	175,270	142,324	-32,946	175,270	142,324	-32,946	44,000	15,820	-28,180	49,000	15,820	-33,180	
2004	188,066	142,324	-45,742	188,066	142,324	-45,742	47,910	15,820	-32,090	52,920	15,820	-37,100	
2005	202,066	142,324	-59,742	202,066	142,324	-59,742	51,840	15,820	-36,020	56,850	15,820	-41,030	
2006	217,383	142,324	-75,059	217,383	142,324	-75,059	55,440	15,820	-39,620	60,440	15,820	-44,620	

- Timing of commissioning of generating facilities is as follows:

Case A

No.3 unit of Tis Abbay Power Station 1983

Tis Abbay No.2 Power Station 1986

Case B

No.3 unit of Tis Abbay Power Station 1982

Tis Abbay No.2 Power Station 1983

Table 4-8 Timing of Implementation of Upper Beles Project and kW load in Lake Tana area to be supplied by Upper Beles Project

Year	Peak Load (kW)			Supply Capability (kW)			Additional Capacity
	ICS	Load in Tana area to be supplied by U. Beles Project	Total (Case A)	Dependable capacity	Reserve capacity	Dependable peaking	
1981	145,000		145,000	203,000	33,000	170,000	
1982	155,000		155,000	203,000	33,000	170,000	
1983	166,000		166,000	203,000	33,000	170,000	
1984	178,000		178,000	233,000	33,000	200,000	GT 30 MW
1985	190,000		190,000	233,000	33,000	200,000	
1986	202,000		203,000	263,000	33,000	230,000	GT 30 MW
1987	215,000		215,000	263,000	33,000	230,000	
1988	229,000		229,000	263,000	33,000	230,000	
1989	244,000		244,000	293,000	33,000	260,000	GT 30 MW
1990	260,000		260,000	293,000	33,000	260,000	
1991	277,000	870	277,870	393,000	50,000	343,000	U.Beles 100 MW
1992	295,000	2,220	297,220	393,000	50,000	343,000	
1993	314,000	3,710	317,710	393,000	50,000	343,000	
1994	334,000	5,040	339,040	393,000	50,000	343,000	
1995	356,000	6,870	362,870	493,000	50,000	443,000	U.Beles 100 MW
1996	380,000	9,010	389,010	493,000	50,000	443,000	
1997	404,000	11,060	415,060	493,000	50,000	443,000	
1998	431,000	13,820	444,820	569,000	50,000	519,000	M.Wakana 76 MW
1999	459,000	16,740	475,740	569,000	50,000	519,000	
2000	488,000	19,220	507,220	569,000	50,000	519,000	
2001	519,000	22,250	541,250	645,000	50,000	595,000	M.Wakana 76 MW
2002	553,000	25,130	578,130	645,000	50,000	595,000	
2003	588,000	28,180	616,180	Additional new power project.			

Note : 1. Demand forecast in ICS area is based on the Report (1974) of Acres International Ltd.

2. Installation schedule of Gas Turbin up to 1990 is also based on the Report (1974) of Acres International Ltd.

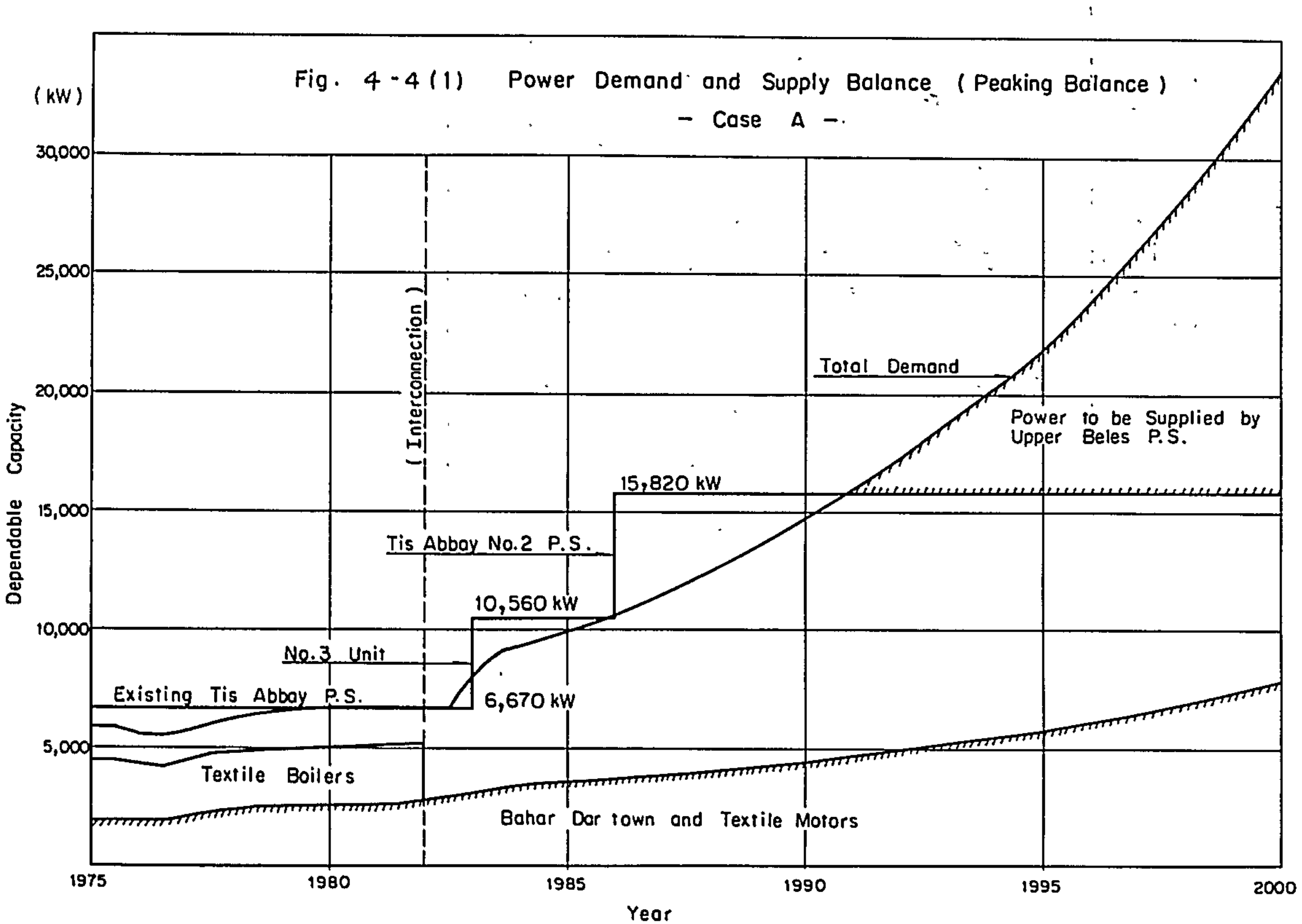


Fig. 4-4 (1) Power Demand and Supply Balance (Peaking Balance)
– Case A –
(kW)
30,000
25,000
20,000
15,000
10,000
5,000
Dependable Capacity
1975
1980
1985
1990
1995
2000
Year
(Interconnection)
Total Demand
Power to be Supplied by Upper Beles P.S.
15,820 kW
Tis Abbay No.2 P.S.
10,560 kW
No.3 Unit
Existing Tis Abbay P.S.
6,670 kW
Textile Boilers
Bahar Dar town and Textile Motors

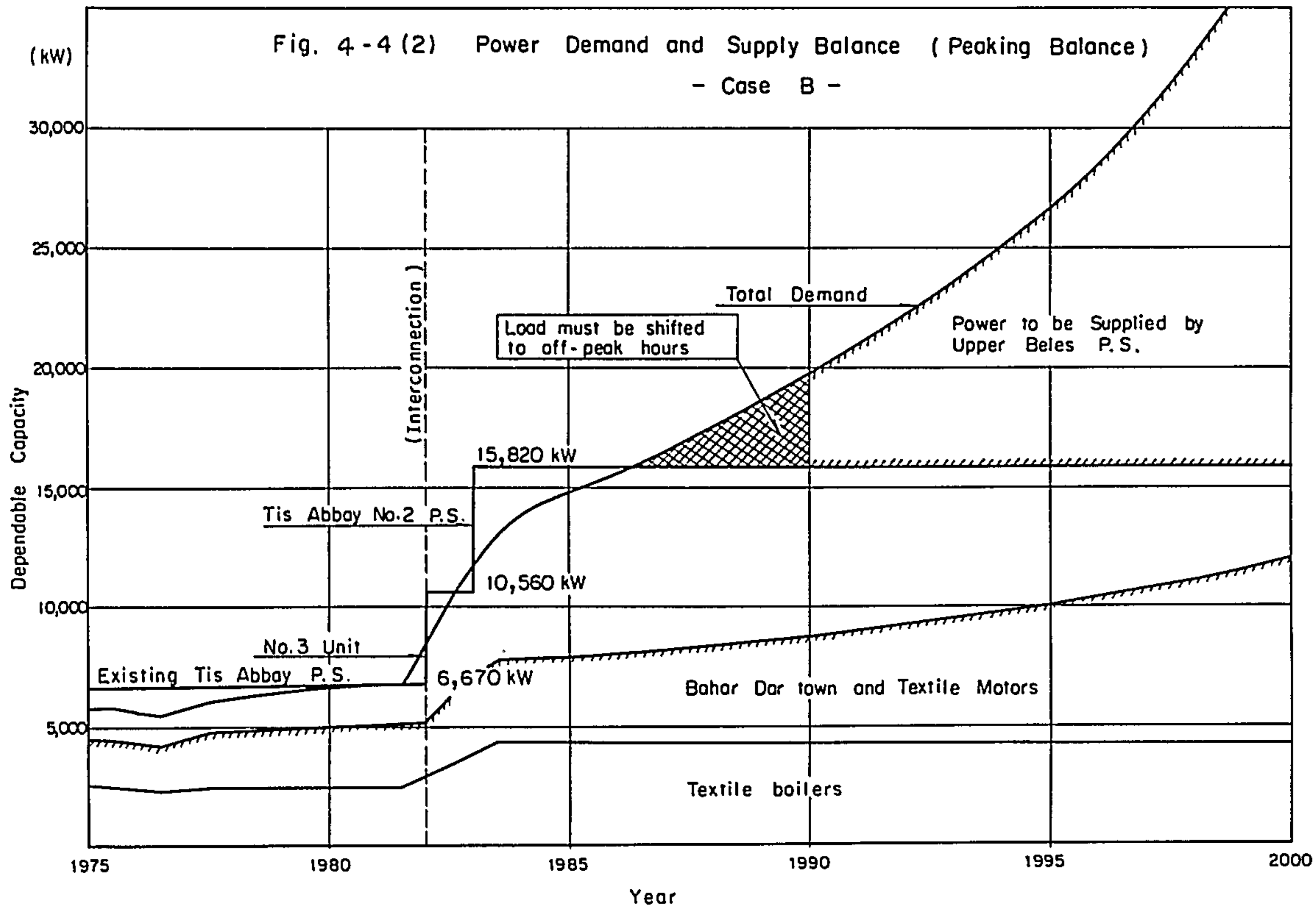


Fig. 4-4 (2) Power Demand and Supply Balance (Peaking Balance)
- Case B -

CHAPTER 5

HYDROLOGY

CHAPTER 5 HYDROLOGY

5.1 BASIC DATA

5.1.1 Gaging Stations and Meteorological Observation Stations

The locations of gaging stations and meterorological observation stations in the catchment basin of Lake Tana are as indicated in Fig. 5-1-1.

5.1.2 Catchment Area

The major rivers feeding Lake Tana are the Gilgel Abbay River from the southwest, the Gummara River from the southeast, the Ribb River from the east, and the Megech River from the north, while there are no large rivers to speak of flowing in from the western side of the lake.

In order to calculate inflow, the Lake Tana basin was divided into areas represented by the four rivers above and the respective catchment areas were measured using a 1/250,000 scale topographical map. The results are indicated below. To note, figures in EELPA data are adopted for catchment areas of gaging stations.

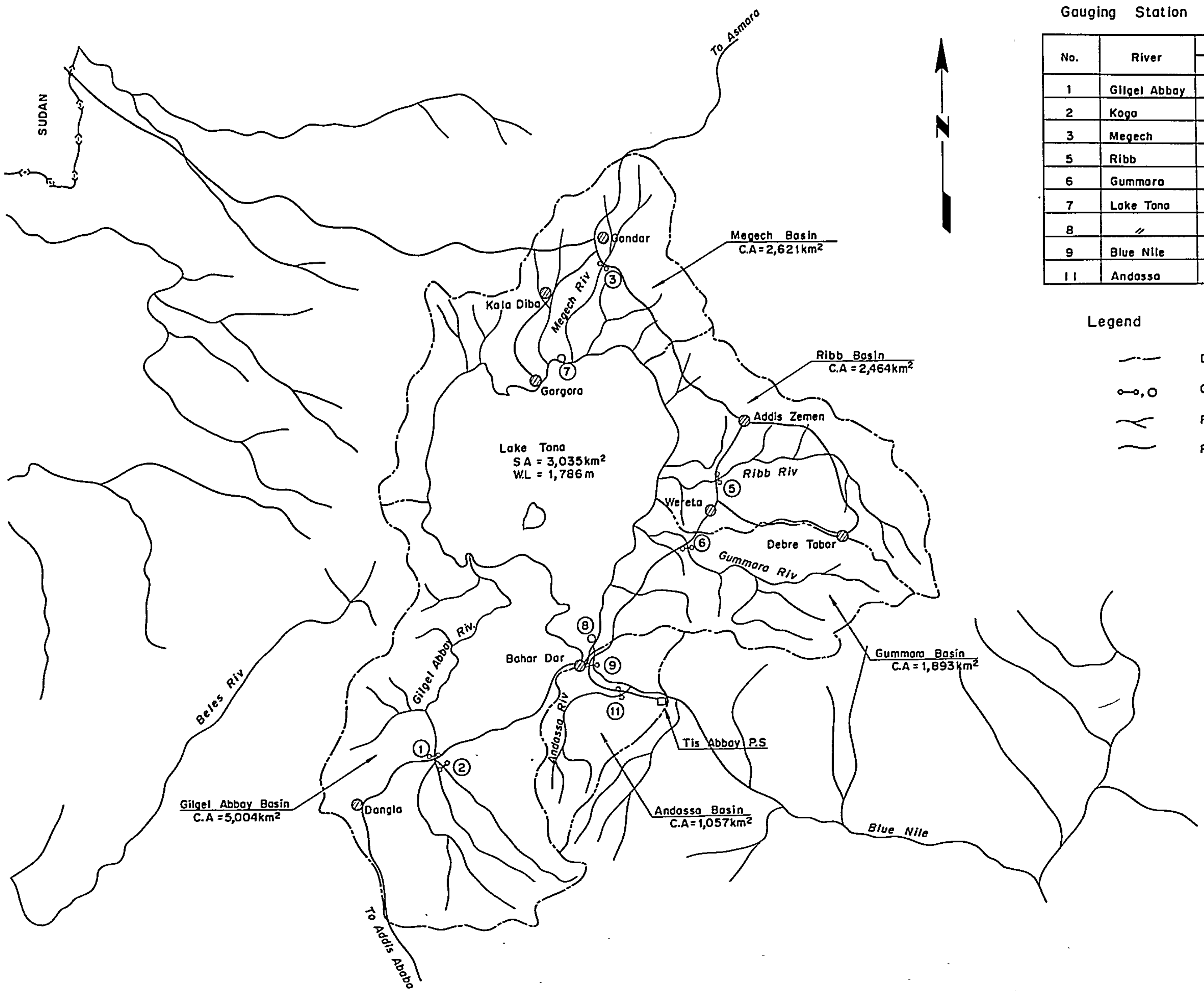
Basin applying Gilgel Abbay GS	5,004 km^2
Basin applying Gummara GS	1,893 km^2
Basin applying Ribb GS	2,464 km^2
Basin applying Megech GS	2,621 km^2
Lake Tana surface area	3,035 km^2
Total	15,017 km^2
Basin applying Andassa GS	1,057 km^2

5.1.3 Existing Data

The past rainfall, runoff and meteorological data of the various gaging stations and meteorological observation stations are as shown in Tables 5-1-1, 5-1-2, 5-1-3 and 5-1-4. Rainfall data at Bahar Dar and Gondar and discharge data at GS No. 9 before 1963 are eliminated, because they show numerous periods during which measurements were not made.

(1) Precipitation

As information for hydrologic analysis, the data from 1964 to 1974 at Bahar Dar at the south shore of Lake Tana and Gondar Airport at the north shore of the lake will be applied. Although there are two kinds of monthly data available, the figures indicated in the climatic data by year will be used here.



Gauging Station

No.	River	Cordinates		Drainage Area (km²)
		Lat.	Long	
1	Gilgel Abbay	11°-20'N	37°-04'E	1,600
2	Koga			220
3	Megech	12°-30'N	37°-26'E	519
5	Ribb	11°-58'N	37°-41'E	1,497
6	Gummara	11°-48'N	37°-37'E	1,239
7	Lake Tana			15,017
8	//			
9	Blue Nile	11°-35'N	37°-15'E	15,243
11	Andassa	10°-31'N	37°-28'E	660

Legend

- Drainage Area
- Gauging Station
- River
- Road

Fig. 5-1-1

Scale : Approx. 1:1,000,000

Basin of Lake Tana

Table 5-1-1 Precipitation Record

Observation Station	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Data Obtained
Bahar Dar													Monthly
Gondar													"
Addis Zemen													"
Dangila													"
Ingibara													"
Gorgora													"

Table 5-1-2 Discharge Record

Station	River	Catchment Area (Km^2)	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Data Obtained
No. 1	Gilgel Abbay	1,600													Daily
No. 2	Koga	220													"
No. 3	Megech	519													"
No. 5	Ribb	1,497													"
No. 6	Gummara	1,239													"
No. 9	Blue Nile	15,243													"
No. 11	Andassa	660													"

Table 5-1-3 Meteorological Record at Bahar Dar

Item	Year																Remarks
	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	
Air Temperature																	Monthly
Relative Humidity																	"
Sunshine Hour																	Daily
Wind Speed																	"
Evaporation																	

Table 5-1-4 Meteorological Record

Item, Station	Year															Remarks
	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	
Temperature																
Bahar Dar																
Gondar (Airport)																Average Daily Max.
Dangila																
Evaporation																
Bahar Dar																
Gondar (Airport)																
Relative Humidity																
Bahar Dar	from '52															
Gondar																

Further, since precipitation data will be necessary throughout the future, it is desirable for daily records to be kept in order as much as practicable.

(2) River Runoff

The data applied for calculation of inflow to Lake Tana required for studying the water balance of the lake are the records of the gaging stations No. 1 through No. 6, but all show numerous periods during which measurements were not made. Excluding the data of years during which there were lapses, there are data for only three years which can be used in relation to the various gaging stations, and daily runoff data were prepared for each river for 8 years estimating the runoffs during the missing periods by hydrographs referring to discharge trends and precipitation amounts in wet and dry seasons.

Regarding runoff estimation, theoretically, this should be done based on the correlation with precipitation, but was done by hydrographs because daily precipitation data were not available, and because the fluctuation ranges of daily runoffs at the various rivers were extremely great so that even if daily precipitation data were available it would have been difficult to follow the fluctuation ranges in terms of daily units, and in any event, it was thought there would be no great difference as a whole.

With respect to the outflow from Lake Tana, the daily records of Gaging Station No. 9 on the mainstream of the Blue Nile could be used without alteration.

Further, with regard to the remaining catchment area between the outlet of Lake Tana and the intake of Tis Abbay Power Station, the runoff data of Gaging Station No. 11 were applied.

(3) Lake Tana Water Level

Regarding water level observation data, there are the daily records of Gaging Station No. 7 at the north shore of the lake (Gorgora) and Gaging Station No. 8 at the south shore (Bahar Dar). However, there are many periods of no records in the case of Gaging Station No. 7, and therefore, the data of No. 8 were used.

In handling the values, the averages of every five days were used as daily water levels to eliminate the influence of waves.

(4) Evaporation

Measured values of evaporation are indicated in the climatic data as measurements at Bahar Dar (Table 5-1-5). These are data from 1964 to 1971 using Class A pan, but on comparison with data for the period from 1966 to 1974 obtained during the first field survey (March 1976), there are considerable differences in monthly evaporation quantities. However, since these measured values are not used as basic values in evaporation analysis, they are not especially taken up here.

(5) Temperature

Measured values of temperature at Bahar Dar and Gondar are as shown in Table 5-1-6 and 5-1-7.

Table 5-1-5 Evaporation at Bahar Dar

Unit; cm

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
1964	16.7	17.7	21.2	22.7	20.8	14.8	15.4	15.8	16.7	13.8	14.2	13.2	203.0
1965	14.6	17.2	-	22.2	-	18.0	16.8	13.5	17.3	15.4	12.1	12.7	(159.8)
1966	14.8	16.2	23.1	24.0	23.2	13.9	14.3	16.7	12.5	15.4	14.9	14.4	203.4
1967	16.5	18.8	22.5	24.4	22.6	18.0	16.7	16.2	12.8	16.2	13.7	13.0	211.4
1968	15.8	15.2	22.1	22.0	24.7	18.0	-	-	17.4	15.4	14.2	15.0	(179.8)
1969	15.9	17.9	21.6	24.3	24.1	19.1	16.8	13.8	15.0	16.8	16.8	17.2	219.3
1970	15.4	18.3	22.3	24.9	24.5	18.8	16.0	14.1	14.9	15.6	15.6	15.4	215.8
1971	17.1	18.6	25.6	25.9	20.4	16.1	13.1	11.8	12.2	16.3	15.9	16.0	209.0
Total	126.8	139.9	(158.4)	190.4	(160.3)	136.7	(109.1)	(101.9)	118.8	124.9	117.4	116.9	(1,601.5)
Average	15.9	17.5	(22.6)	23.8	(22.9)	17.1	(15.6)	(14.6)	14.9	1.56	14.7	14.6	(209.8)

Table 5-1-6 Monthly Average Temperature at Bahar Dar

Unit; °C

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Average
1964	15.6	16.2	19.2	19.4	19.2	16.6	15.5	15.4	16.4	17.0	15.1	13.8	16.6
1965	12.8	15.1	14.8	15.0	21.8	18.2	18.8	18.6	15.8	18.8	19.0	16.0	17.1
1966	18.0	19.0	20.8	21.5	19.7	19.3	18.9	19.0	19.2	19.8	19.3	16.6	19.3
1967	16.6	18.4	20.4	20.9	21.4	20.5	18.2	17.8	19.0	19.2	18.8	16.0	18.9
1968	16.6	16.7	19.2	19.4	21.2	19.1	18.6	19.8	19.2	19.8	18.7	17.0	18.8
1969	17.4	18.3	21.8	22.4	22.2	21.3	19.3	19.4	19.2	19.0	19.0	17.2	19.7
1970	15.8	18.8	20.0	21.8	21.6	20.2	18.6	18.5	18.8	19.1	17.6	16.2	18.9
1971	16.7	17.8	20.6	20.6	21.3	20.1	18.4	18.2	18.5	19.2	18.2	15.4	18.8
Average	16.2	17.5	19.6	20.1	21.1	19.4	18.3	18.3	18.3	19.0	18.2	16.0	18.5
Daily Max.	26.9	28.8	30.3	30.5	31.1	27.9	24.9	25.3	26.4	30.5	29.0	28.0	
Daily Min.	4.8	6.3	5.1	5.2	10.2	11.5	12.6	12.3	5.3	7.1	8.4	5.1	

Table 5-1-7 Monthly Average Temperature at Gondar

Unit; °C

Year \ Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Average
1964	-	18.0	21.2	22.5	21.2	19.0	17.2	17.2	17.8	-	18.0	16.9	(18.9)
1965	17.9	20.9	22.0	21.3	23.1	20.2	18.2	17.8	18.8	18.7	18.5	17.8	19.6
1966	19.0	19.8	21.4	20.0	21.4	19.4	18.2	18.0	18.6	18.7	18.0	18.3	19.2
1967	19.0	20.0	-	21.4	20.8	19.6	17.2	17.6	18.4	18.2	18.4	17.9	(19.0)
1968						No record							-
1969	-	19.6	20.8	21.9	21.4	20.4	17.8	18.0	19.0	19.3	19.8	19.6	(19.8)
1970	18.1	20.8	21.6	23.0	22.2	20.0	18.1	17.8	18.4	18.8	18.7	18.0	19.6
1971	18.2	20.3	22.0	22.4	20.8	19.2	17.8	17.6	18.2	18.7	18.6	17.2	19.3
Average	(18.4)	19.9	(21.5)	21.8	21.6	19.7	17.8	17.7	18.5	(18.7)	18.6	18.0	19.4
Daily Max.	28.0	30.0	33.0	29.8	30.5	26.7	23.2	23.5	25.4	26.4	27.4	27.7	
Daily Min.	9.4	6.0	9.3	10.4	13.7	13.5	13.0	12.5	11.7	11.2	10.2	8.6	

5.2 HYDROLOGIC ANALYSIS

5.2.1 River Characteristics

(1) Precipitation

The amount of precipitation in the Lake Tana Basin are being measured at Bahar Dar on the south shore of the lake and Gondar near the north shore. The precipitation records at these two locations from 1964 to 1974 are as shown in Fig. 5-2-1, Fig. 5-2-2 and Table 5-2-9 (1), (2).

According to these records, and extremely small amoutn of precipitation of 1,052 mm was recorded in 1972, but in general the records show 1,300 to 1,700 mm of precipitation.

On comparisons of average monthly precipitation quantities from 1964 to 1974 for each of the locations, differences in the trends are not seen, but it is indicated that Bahar Dar at the south shore is considerably rainy.

From April to June is a minor rainy season, while from July to September is a major rainy season, and consequently, the greatest rainfall is ordinarily recorded during the major rainy season, and on the average July has the most rainfall. The dry season is from November to March and there is practically no rain during this period.

(2) Runoff

The average monthly runoffs at the various gaging stations during 1964 to 1975 are indicated in Tables 5-2-10 (1) ~ (7). The specific runoffs per 100km^2 based on the average monthly runoffs during the above period are given in Table 5-2-1.

On looking at the specific runoffs of the various gaging stations in connection with inflows to the lake, those of the No. 1, No. 2 and No. 6 gaging stations are approximately double those of the No. 3 and No. 5 stations. In other words, the runoffs of the Gilgel Abbay River and the Gummara River flowing into the southern part of the lake are larger than the runoffs of the Megech and Ribb rivers flowing into the northern part. This can be comprehended from the fact that rainfall at Bahar Dar is greater than at Gondar to the north.

The only river or stream flowing out from Lake Tana is the Blue Nile and this outflow is being measured at Gaging Station No. 9 located approximately 4 km downstream from the outlet of the lake. That the specific runoff at this gaging station on the Blue Nile is small is because approximately one third of the inflow may be considered to be lost through evaporation at the surface of the lake and through infiltration. This will be described in detail in 5.2.2, "Water Balance of Lake Tana."

Although it may be considered that the Andassa River which flows into the Blue Nile between the outlet of Lake Tana and the intake of Tis Abbay Power Station would be influenced by rainfall in the Bahar Dar surroundings, the specific runoff according to the runoff data of Gaging Station No. 11 is small, being about the level at the northern part of the lake area. The reason for this may lie elsewhere, but since there is no great effect on the available water of Tis Abbay Power Station, this matter will not be pursued herein.

The discharge durations and discharge duration curves of the various rivers are indicated in Tables 5-2-11(1) ~ (6) and Figs. 5-2-3(1) ~ (6). The Gilgel Abbay River and the Gummara River show similar discharge duration trends, while the Megech and the Ribb also show trends similar to each other. As for the Blue Nile, it may be clearly seen that the inflow to Lake Tana is regulated naturally at the lake and is then discharged. The discharge of the Andassa River is similar to that of the Gilgel Abbay group. The specific runoffs of the various rivers have been compared, and looking now at discharge durations these also differ distinctly between the northern and southern parts of the lake.

The correlations between average monthly discharge and precipitation of the various rivers are indicated in Figs. 5-2-4(1) ~ (3). According to these figures, the peak discharges of the rivers with the exception of the Blue Nile come approximately one month after peaks in rainfall. Regarding the inflow to Lake Tana, as is clearly seen in the figures, the greater part of the annual inflow is concentrated in July ~ September, with especially the maximum inflow recorded in August. The inflow decreases from October to June with extremely small amounts especially during February ~ May. The trends of inflow by season expressed in terms of percentages are 1 ~ 6% of total annual inflow in January ~ March, 2 ~ 6% in April ~ June, 70 ~ 90% in July ~ September, and 6 ~ 18% in October ~ December.

As for the outflow to the Blue Nile, the trend is somewhat different because of the large surface area of the lake and the natural regulation of inflow due to the topographical restrictions at the outlet. This is manifested by the maximum outflow being deferred until September compared with the peak of inflow in August, and the outflow during the dry season being comparatively large due to the effect of storage in the lake. Regarding the seasonal trends in outflow expressed in terms of percentages as in the case of inflow, they are 13% in January ~ March, 3% in April ~ June, 39% in July ~ September, and 45% in October ~ December. Shifting these seasons over by one month each, the trends are 8% in February ~ April, 4% in May ~ July, 58% in August ~ October, and 30% in November ~ January.

(3) Lake Tana Surface Level

The natural fluctuations in the surface level of Lake Tana are indicated in Table 5-2-2 and Fig. 7-2-2.

According to these, the surface level of Lake Tana normally begins to drop from the middle of October, and after reaching the minimum level in the middle or at the end of June, begins to rise from the beginning of July, and the maximum water level is recorded at the end of September or the beginning of October. The peak outflow to the Blue Nile is naturally recorded around the time that the surface level of Lake Tana reaches its maximum.

Fig. 5-2-1 Annual Precipitation

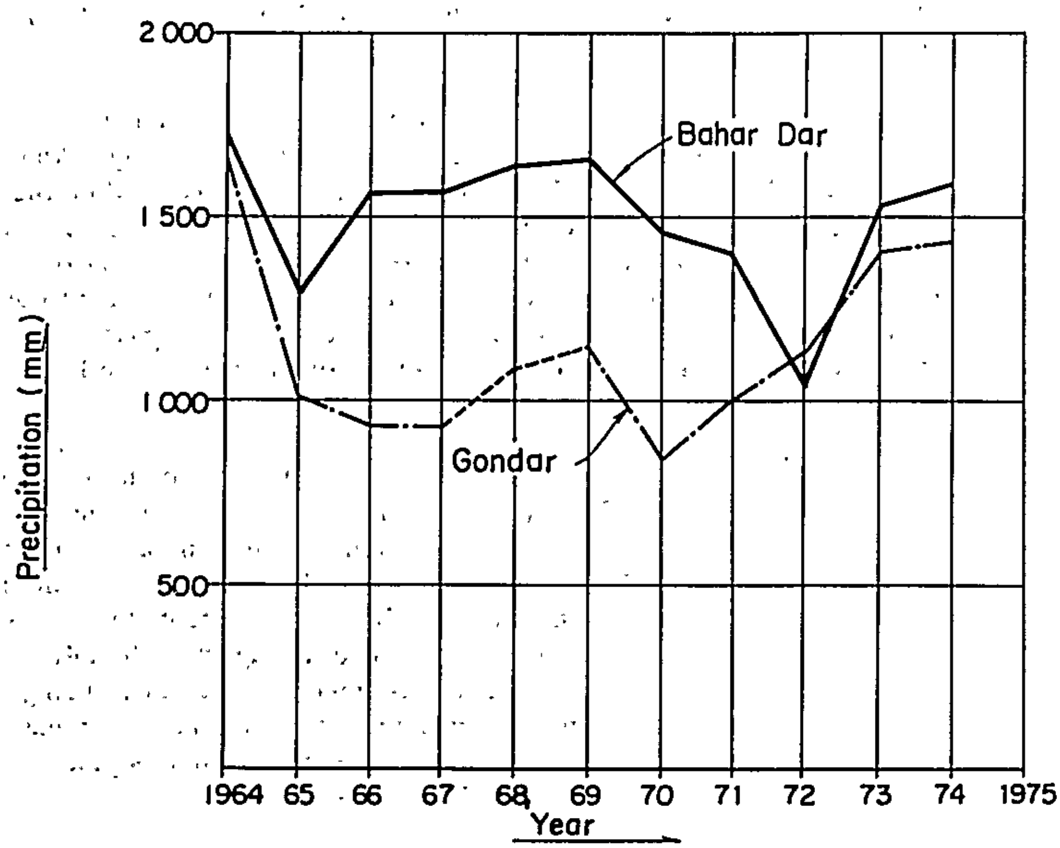


Fig. 5-2-2 Monthly Average Precipitation

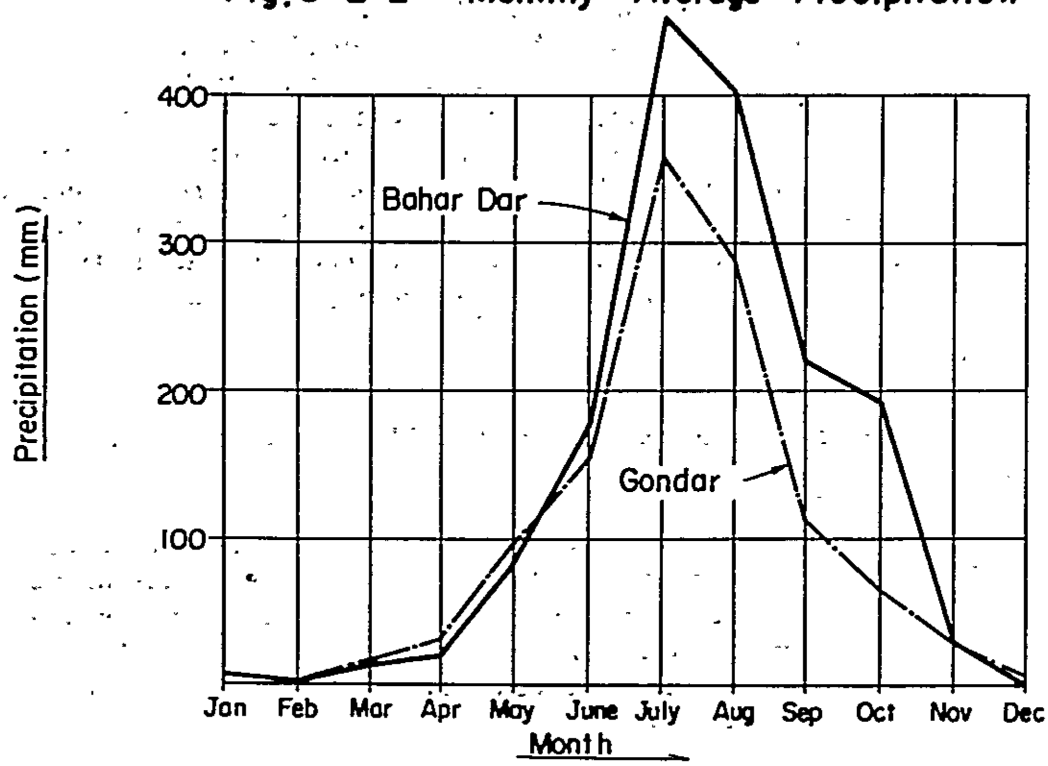


Table 5-2-1 Specific Average Discharge

(Unit: m^3/s per 100 Km^2)

Station	River	Catchment Area (km^2)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
No. 1	Gilgel Abbay	1,600	0.44	0.30	0.24	0.17	0.34	1.93	9.04	12.68	9.02	3.52	1.45	0.73	3.32
No. 2	Koga	220	0.60	0.50	0.42	0.36	0.39	0.68	4.85	8.58	5.65	2.54	1.30	0.90	2.23
No. 3	Megech	519	0.04	0.05	0.03	0.08	0.05	0.33	2.25	6.88	1.67	0.50	0.21	0.09	1.02
No. 5	Ribb	1,497	0.05	0.03	0.03	0.02	0.04	0.27	2.93	5.67	2.51	0.58	0.20	0.10	1.04
No. 6	Gummara	1,239	0.14	0.09	0.06	0.05	0.10	0.33	4.77	10.04	6.37	2.02	0.65	0.29	2.08
No. 9	Blue Nile	15,243	0.53	0.38	0.21	0.12	0.07	0.06	0.21	1.12	2.30	1.98	1.33	0.86	0.76
No. 11	Andassa	660	0.32	0.26	0.21	0.17	0.19	0.34	2.82	4.85	2.74	1.40	0.81	0.51	1.22

Fig. 5-2-3 (1) a Discharge Duration Curves at G.S No.1
1964 ~ 1967
Gilgel Abbay River C.A = 1.600 km²

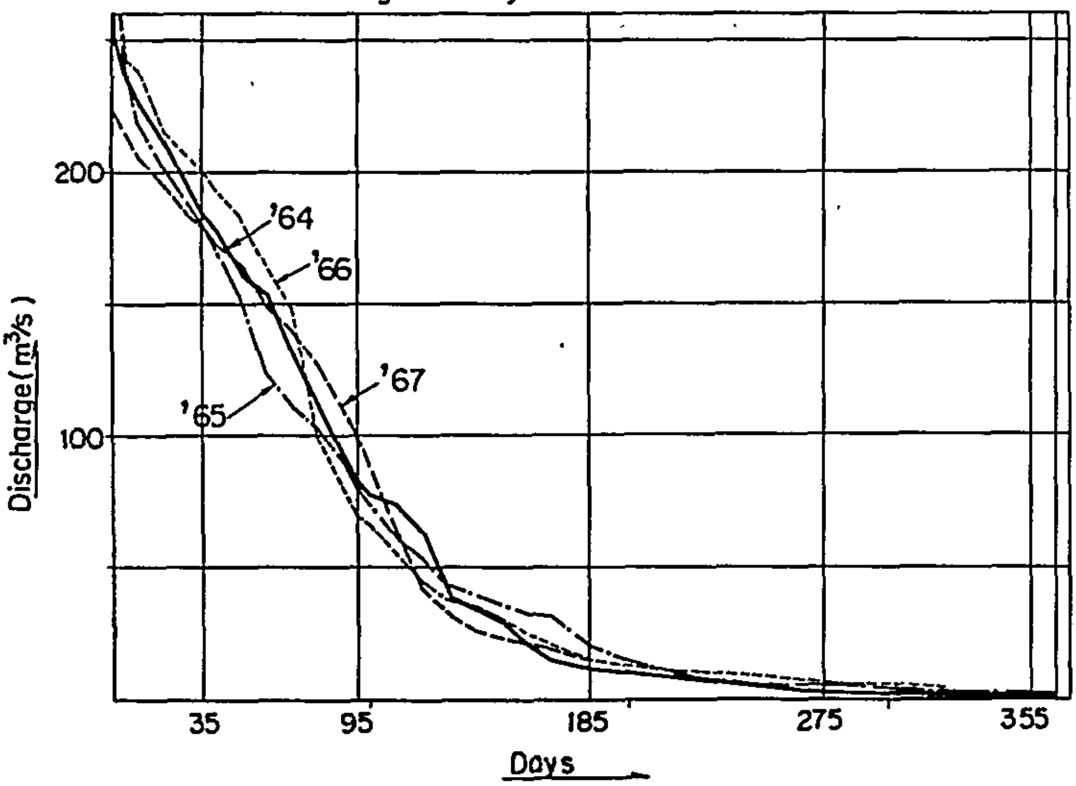


Fig. 5-2-3 (1) b Discharge Duration Curves at G.S No. 1
1968 ~ 1971
Gilgel Abbay River C.A = 1.600 km²

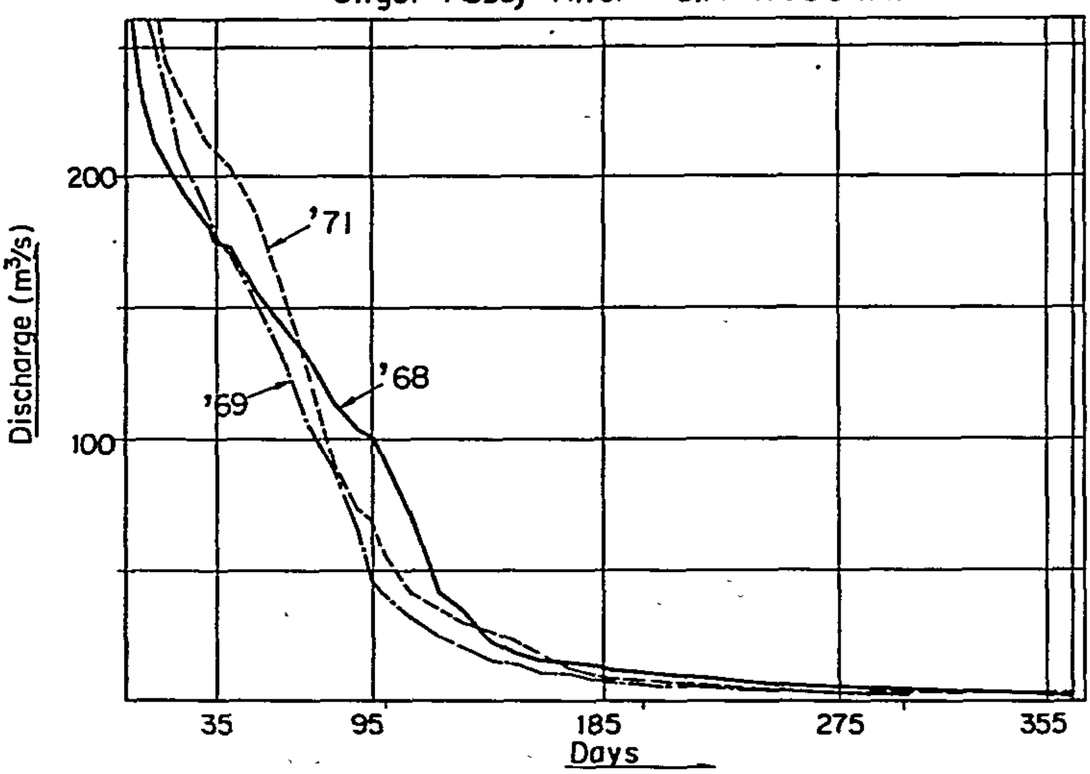


Fig. 5-2-3 (1) c Discharge Duration Curves at G.S No.1
1972 ~ 1975

Gilgal Abbay River C.A = 1.600 km²

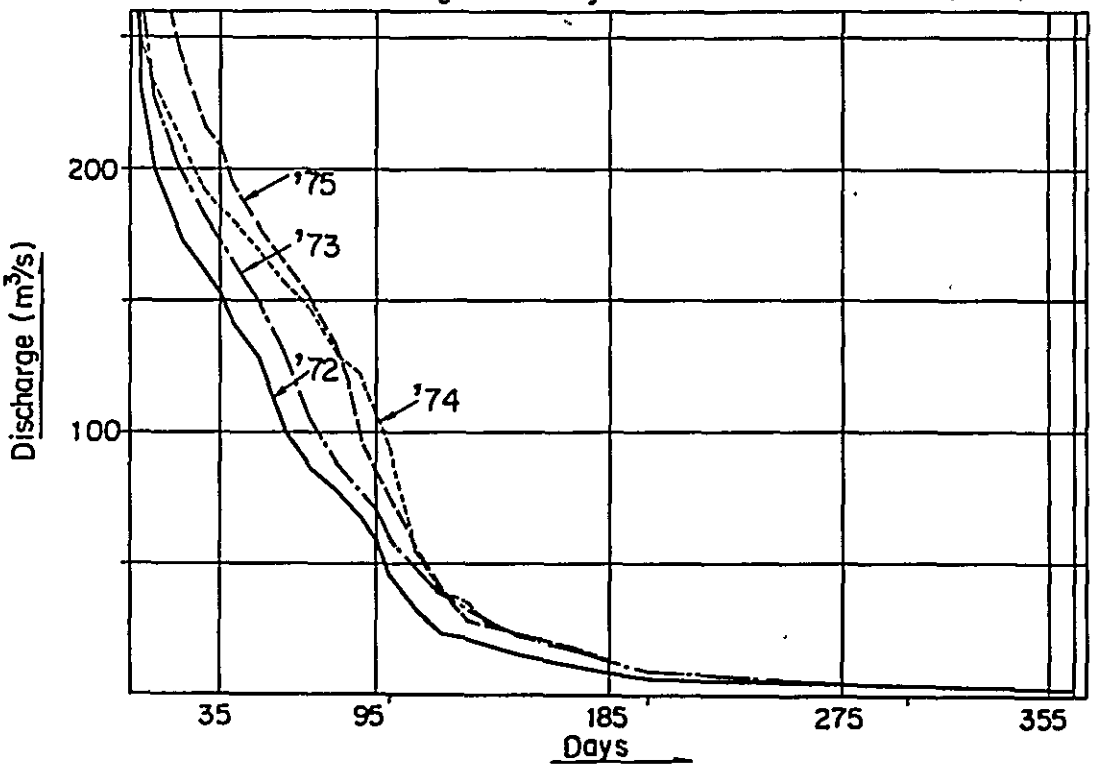


Fig.5-2-3(2)a Discharge Duration Curves at G.S No.3
1964 ~ 1967
Megech River C.A = 519 km²

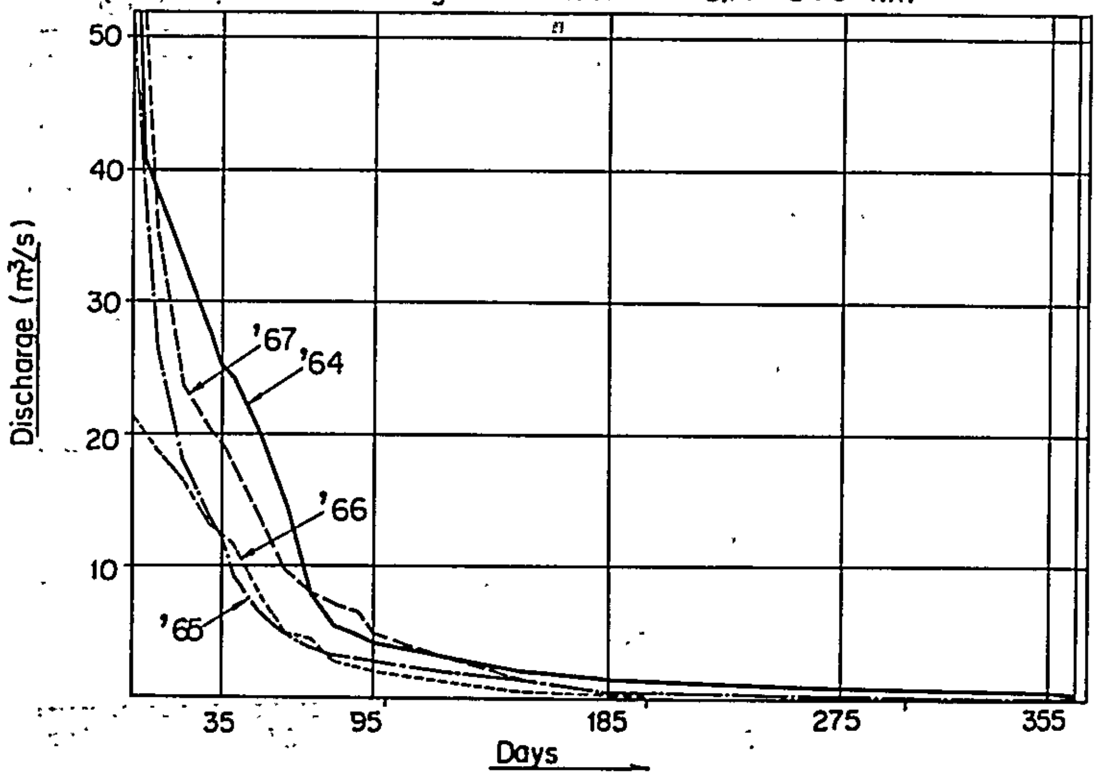


Fig.5-2-3(2) b Discharge Duration Curves at G.S No.3
1968 ~ 1971
Megech River C.A = 519 km²

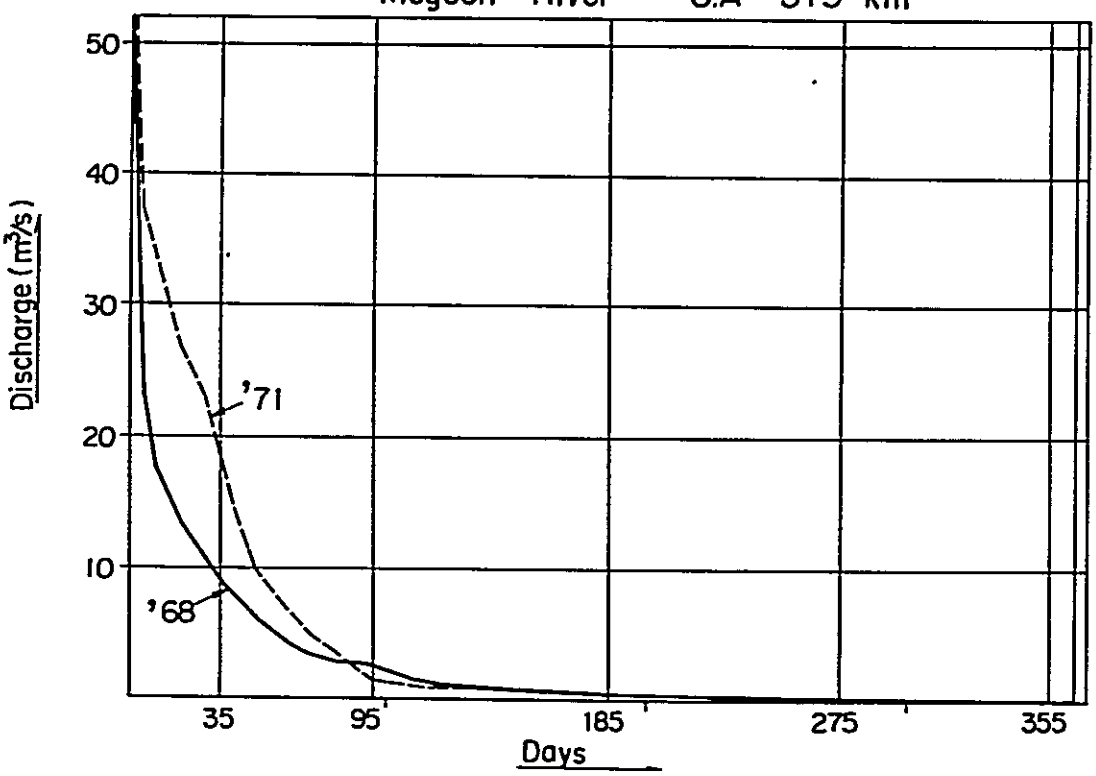


Fig. 5-2-3 (2) C: Discharge Duration Curves at G.S No. 3
1972 ~ 1975

Megech River C.A = 519 km²

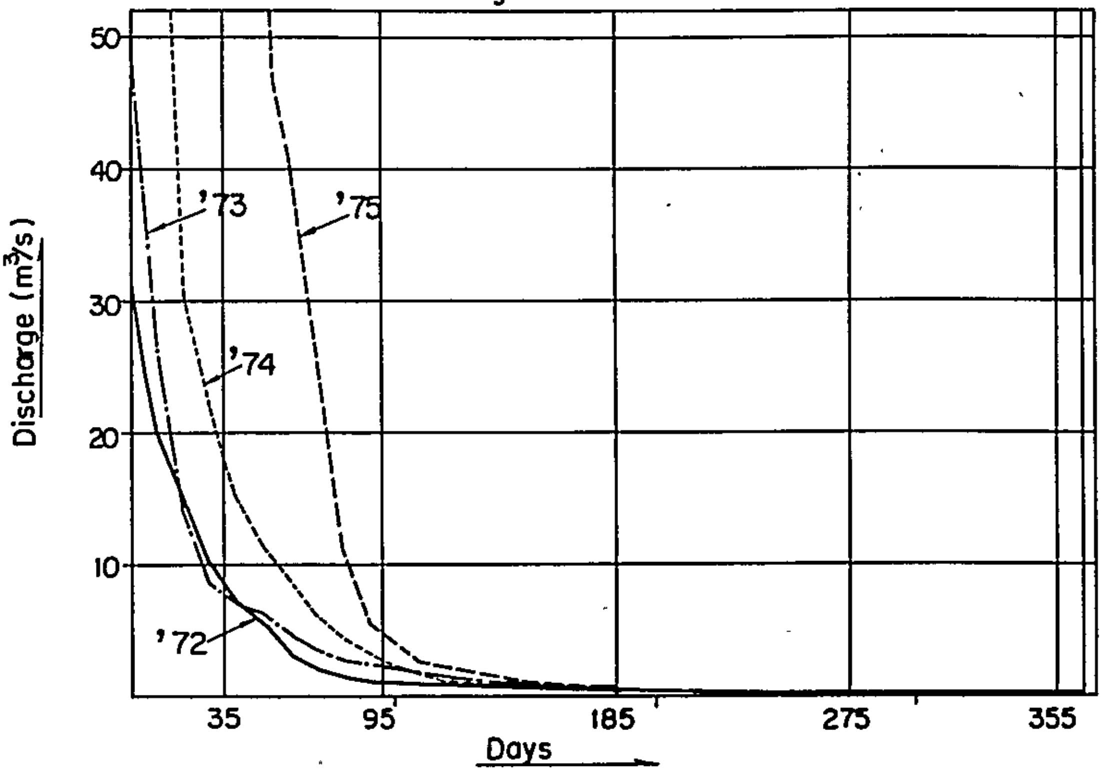


Fig. 5-2-3(3) a Discharge Duration Curves at G.S No.5
1964 ~ 1967
Ribb River C.A = 1.497 km²

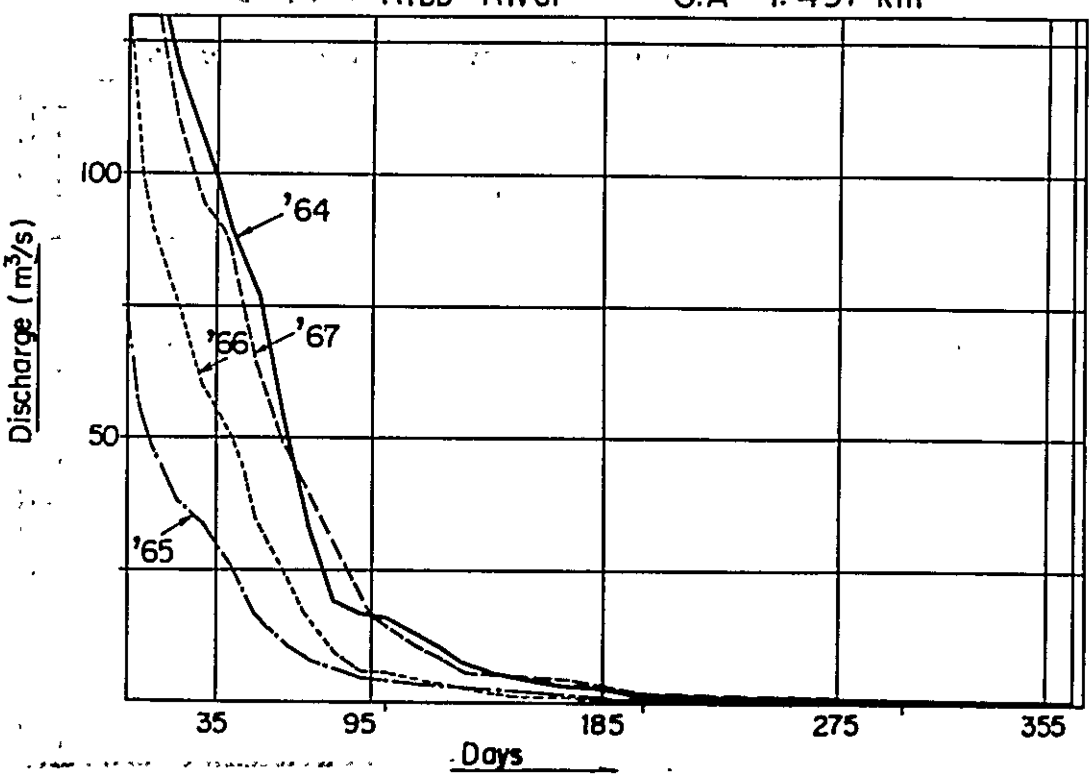


Fig. 5-2-3(3) b Discharge Duration Curves at G.S No.5
1968 ~ 1971
Ribb River C.A = 1.497 km²

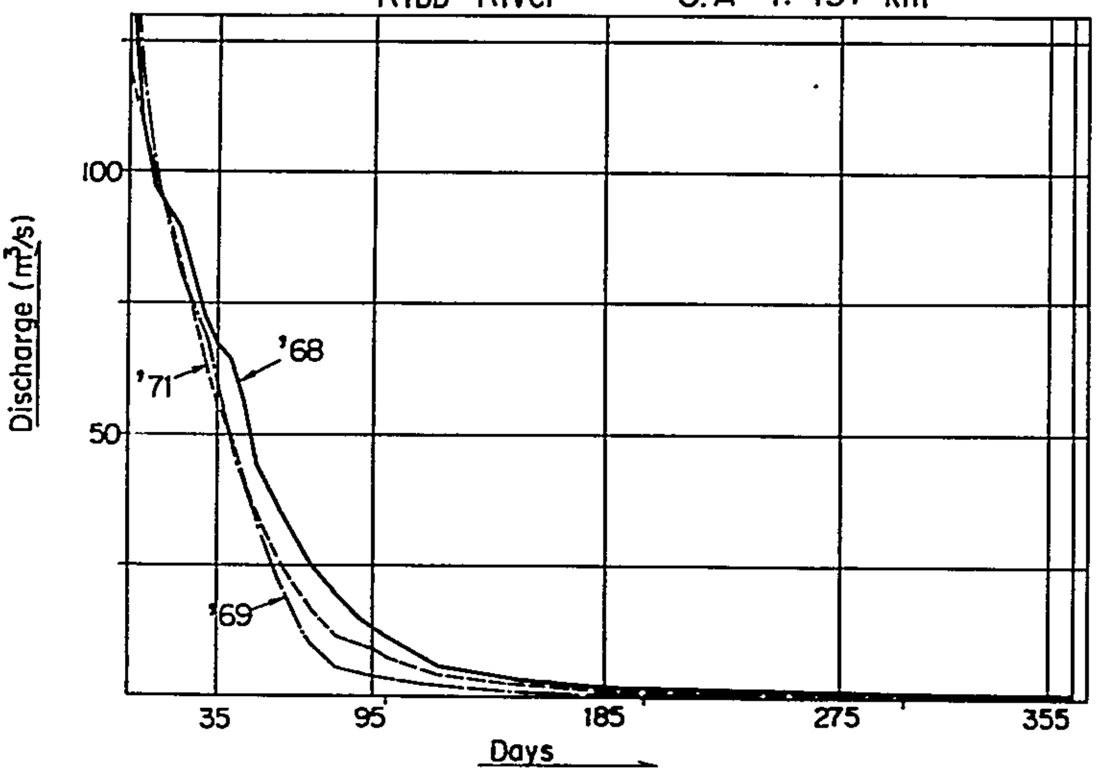


Fig. 5-2-3 (3) C   Discharge Duration Curves at G.S No.5
1972 ~ 1975

Ribb River   C.A = 1,497 km²

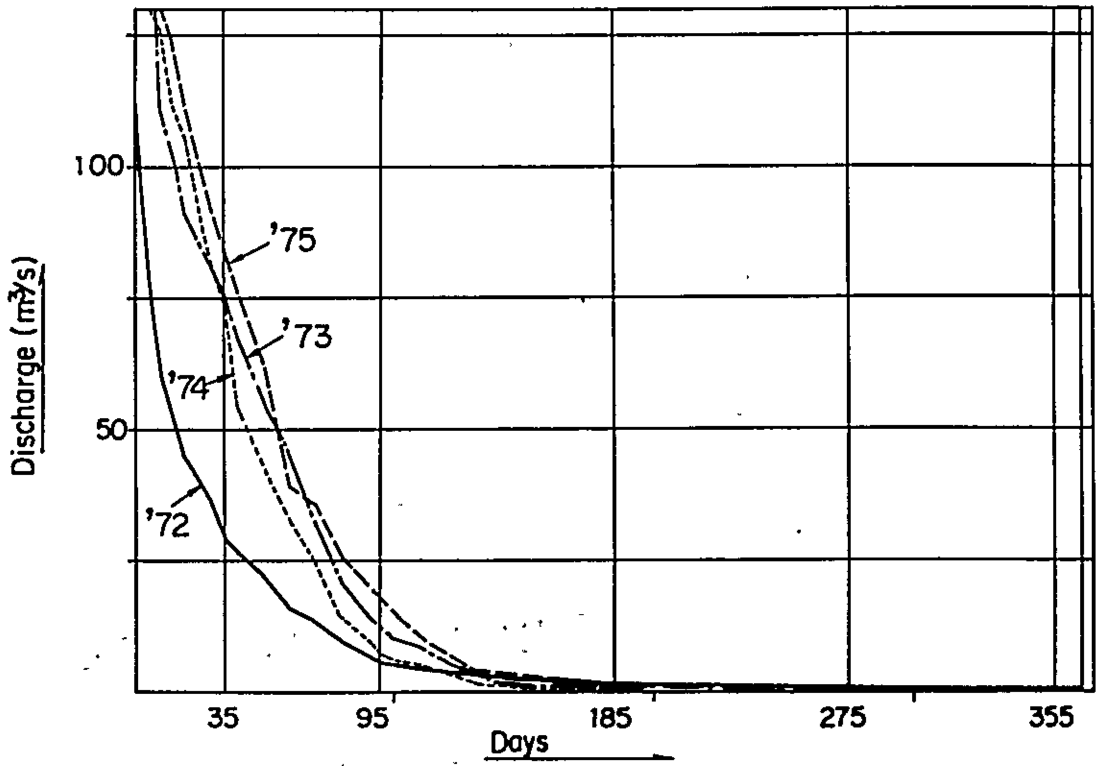


Fig: 5-2-3 (4) a   Discharge Duration Curves at G.S No.6
1964 ~ 1967
Gummara River   C.A = 1. 239 km²

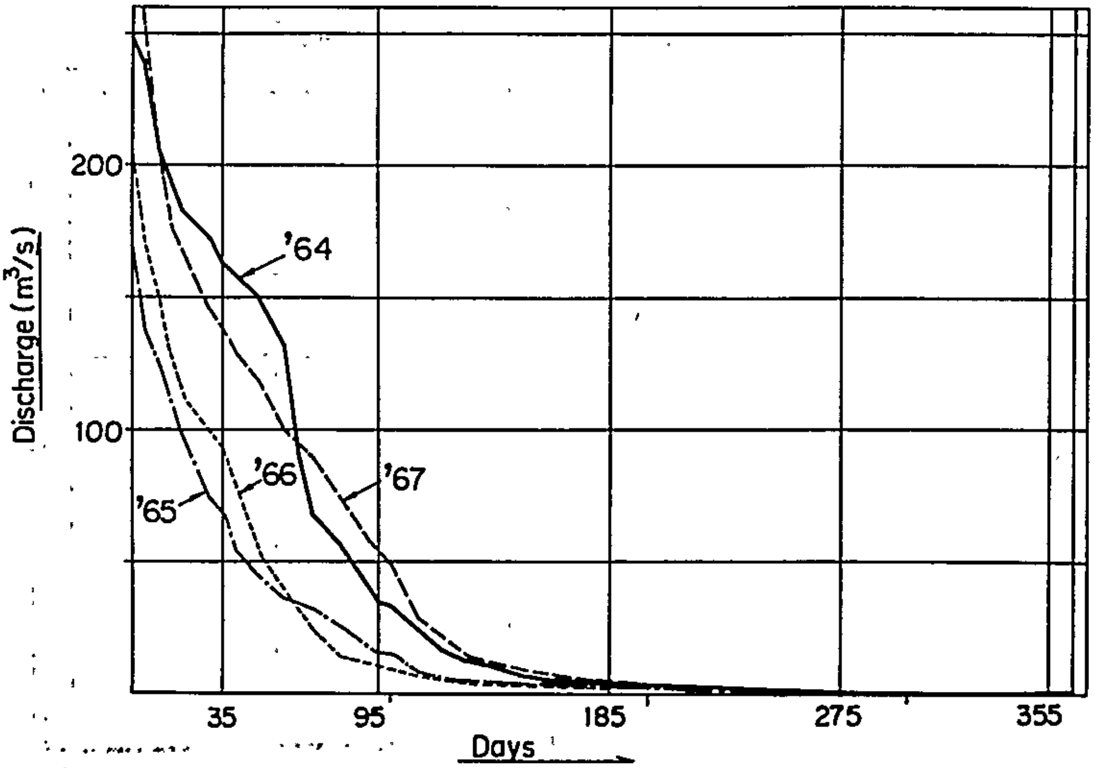


Fig. 5-2-3(4) b   Discharge Duration Curves at G.S No.6
1971 ~ 1975
Gummara River   C.A = 1. 239 km²

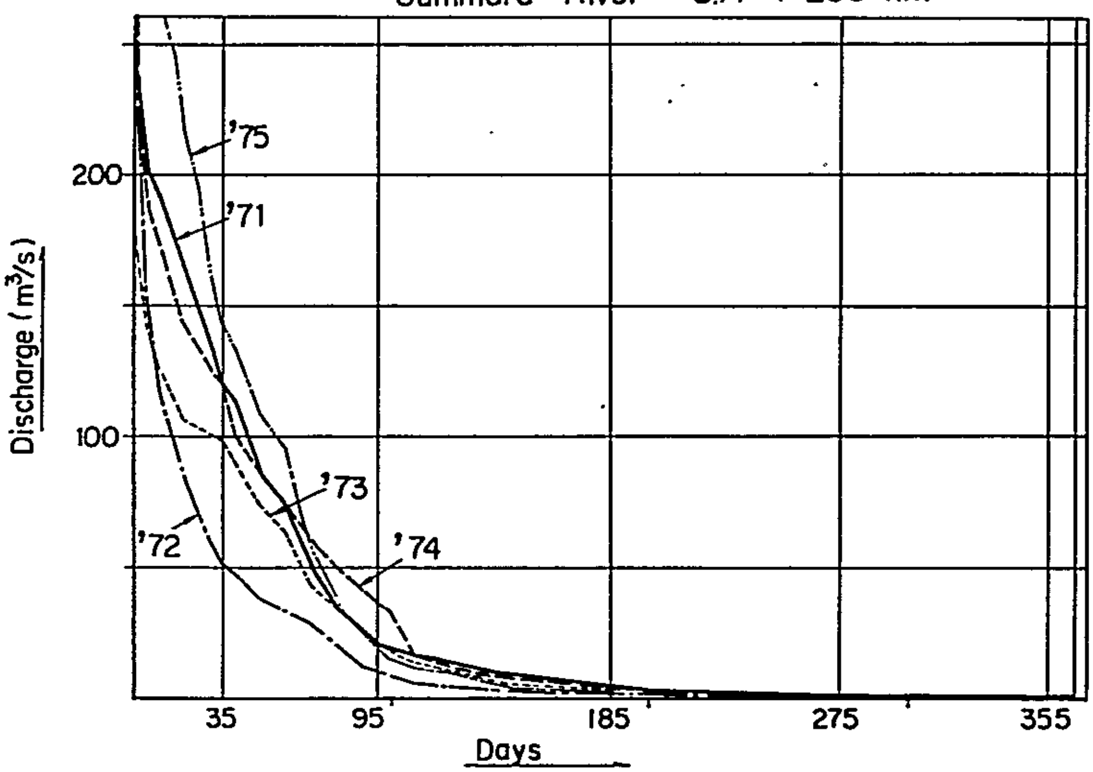


Fig. 5-2-3 (5) a Unregulated Discharg Duration Curves at G.S No.9 1964 ~ 1969

Blue Nile River C.A = 15.243 km^2

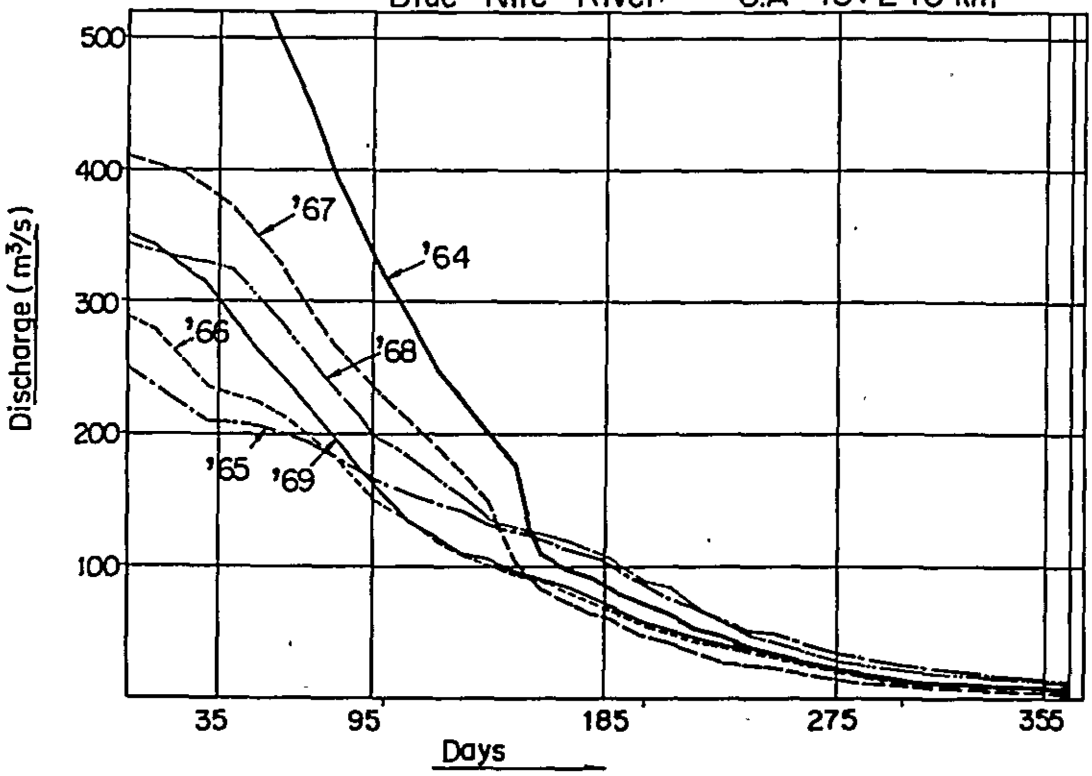


Fig. 5-2-3 (5) b Unregulated Discharge Duration Curves G.S No.9 1970 ~ 1975

Blue Nile River C.A = 15.243 km^2

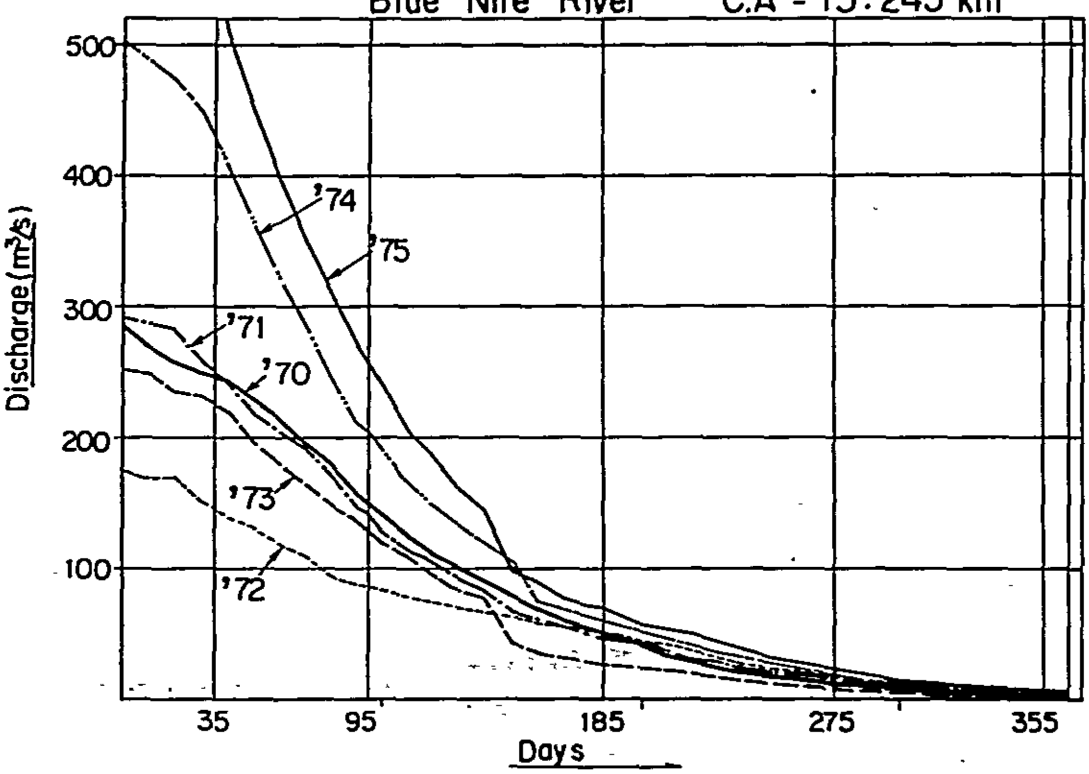


Fig. 5-2-3(6) a Discharge Duration Curves at G.S No. 11
1964 ~ 1969
Andassa River C.A = 660 km²

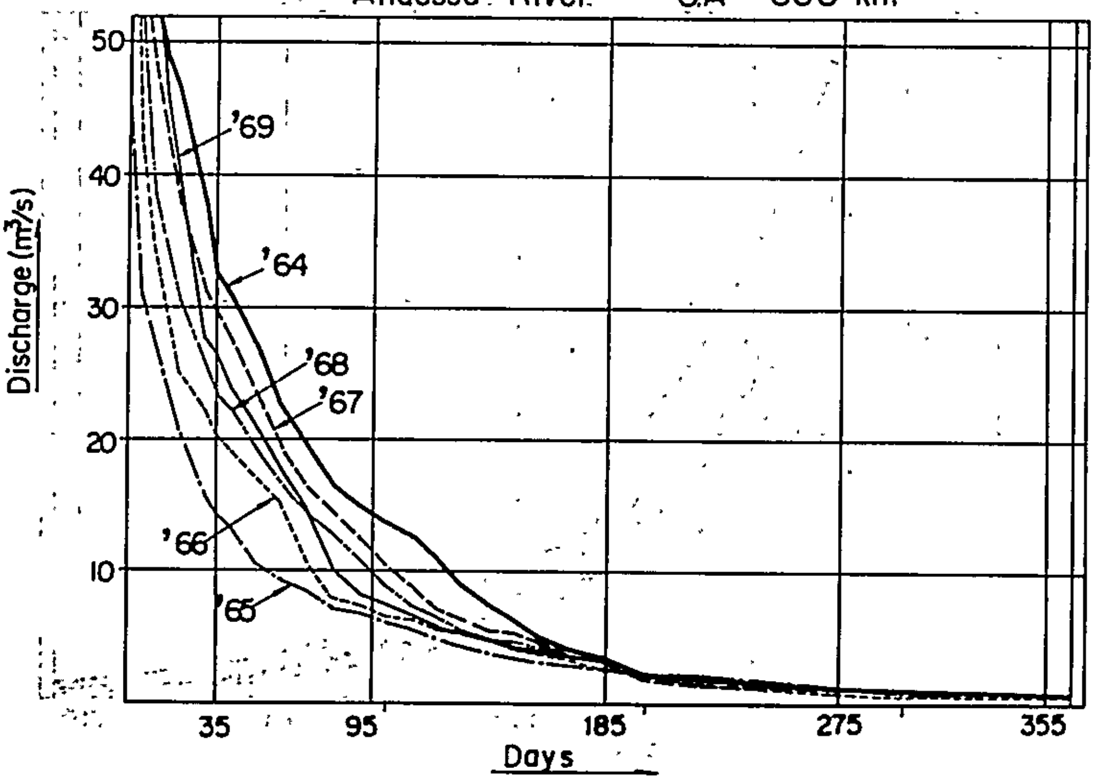
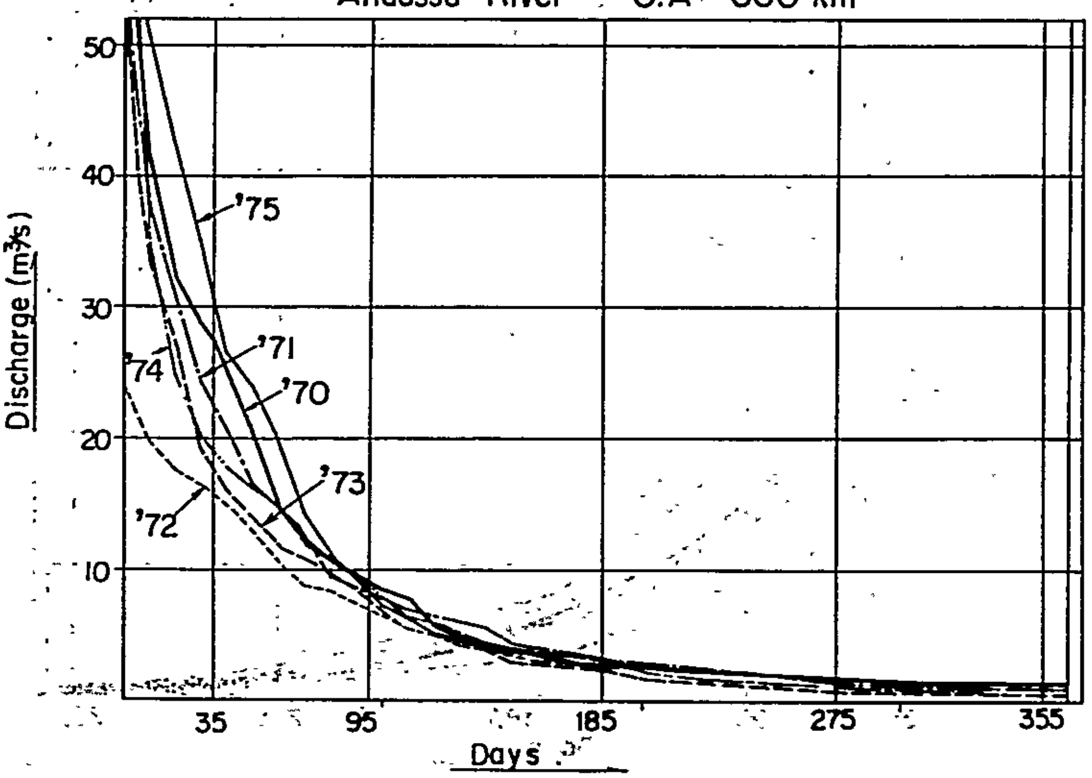
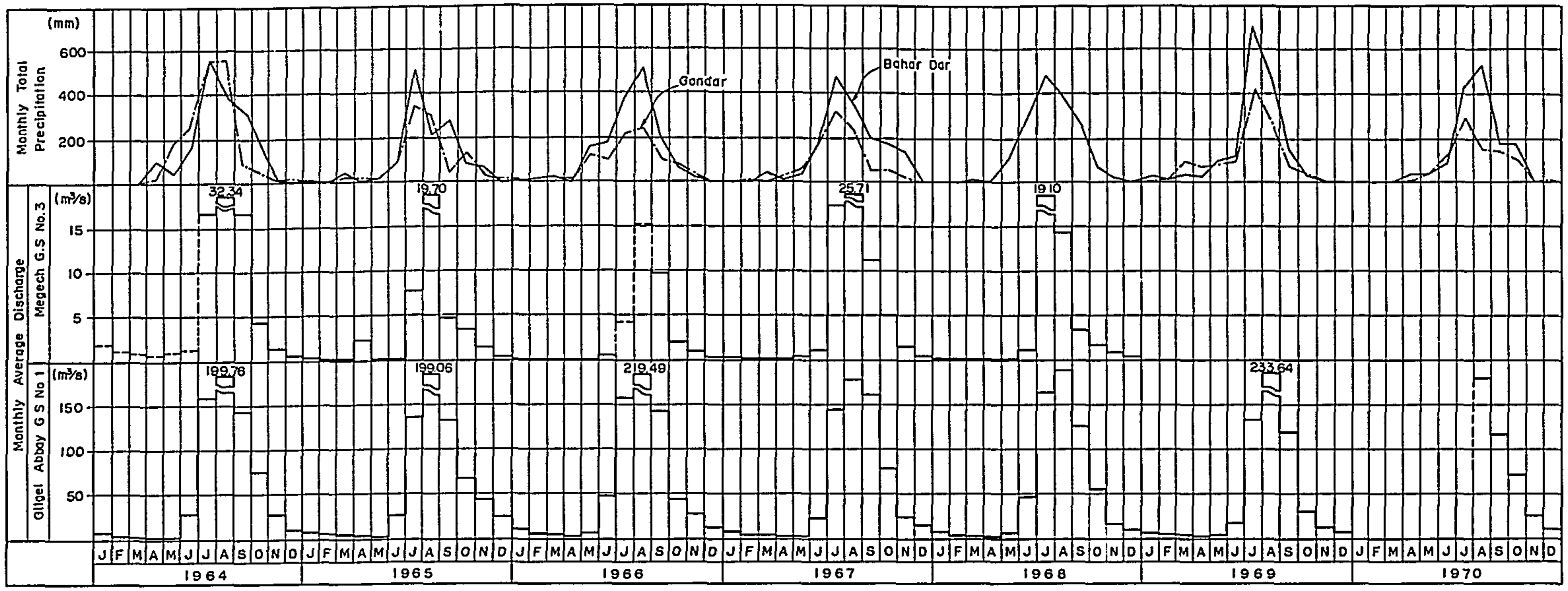


Fig. 5-2-3(6) b Discharge Duration Curves at G.S No. 11
1970 ~ 1975
Andassa River C.A = 660 km²





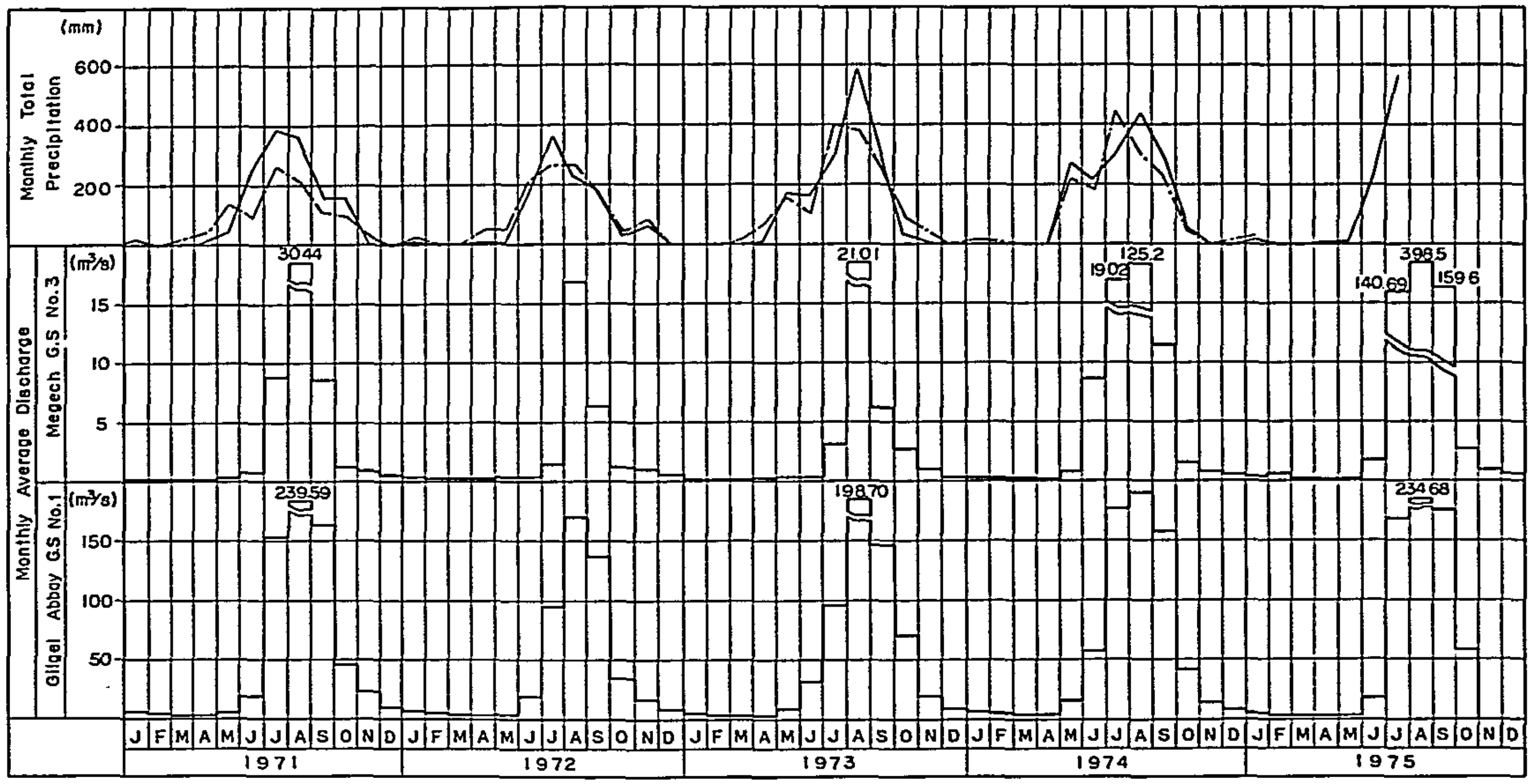


Fig. 5-2-4 (1)
Correlation Between
Discharge and Precipitation

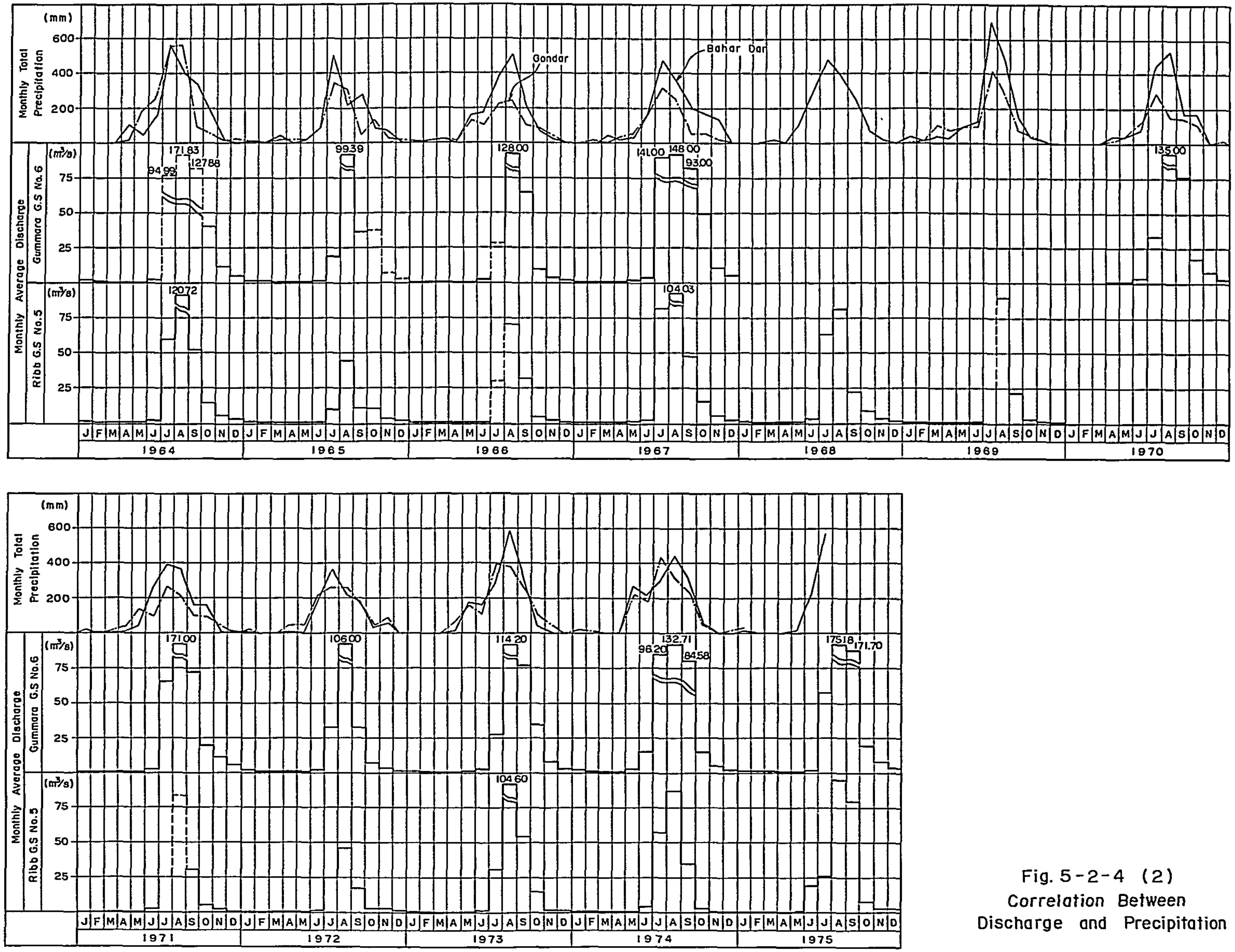
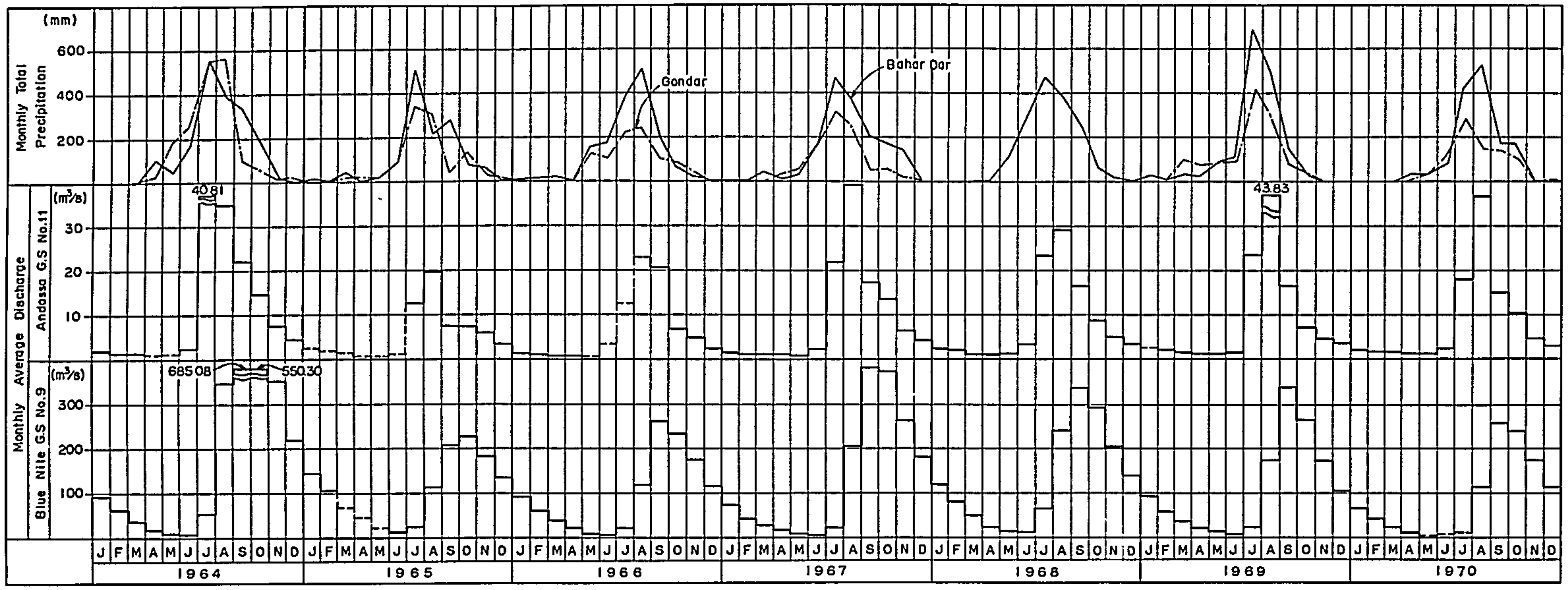


Fig. 5-2-4 (2)
Correlation Between
Discharge and Precipitation



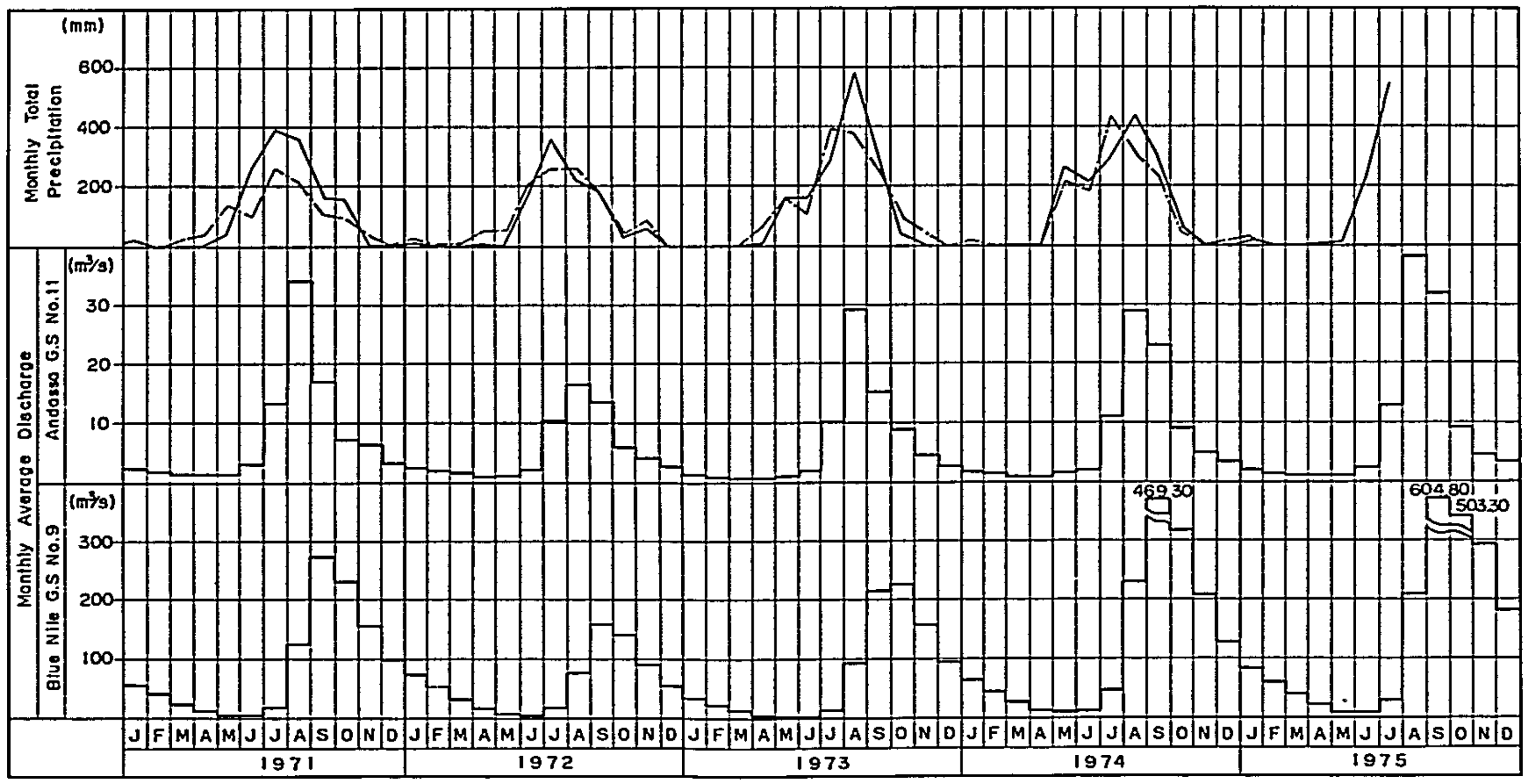


Fig. 5-2-4 (3)
Correlation Between
Discharge and Precipitation

Table 5-2-2 Monthly Fluctuation of Lake Surface Level

(By G.S. No. 8 Record at end of month)

Datum Point EL. = 1,784.515 m

Month	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	Average
Jan.	1.59	1.74	1.48	1.45	1.61	1.52	1.38	1.40	1.48	1.15	1.39	1.54	1.48
Feb.	1.42	1.59	1.37	1.23	1.40	1.30	1.25	1.25	1.29	1.03	1.23	1.41	1.31
Mar.	1.20	1.35	1.18	1.13	1.24	1.23	1.07	1.02	1.10	0.82	1.03	1.20	1.13
Apr.	1.04	1.18	1.02	0.99	1.01	1.06	0.92	0.82	0.92	0.64	0.86	0.97	0.95
May	0.93	1.03	0.90	0.76	0.94	1.00	0.76	0.80	0.80	0.58	0.88	0.78	0.85
June	1.01	0.98	0.88	0.69	1.08	0.83	0.65	0.77	0.81	0.62	0.98	0.88	0.85
July	1.81	1.29	1.33	1.50	1.73	1.37	1.14	1.35	1.19	1.17	1.65	1.42	1.41
Aug.	2.77	1.96	2.06	2.46	2.34	2.32	2.01	2.16	1.69	1.90	2.38	2.55	2.22
Sept.	2.89	2.06	2.19	2.52	2.40	2.33	2.15	2.32	1.83	2.12	2.37	2.85	2.34
Oct.	2.62	2.04	2.05	2.35	2.12	2.02	2.04	2.12	1.67	2.04	2.26	2.47	2.15
Nov.	2.29	1.88	1.82	2.09	1.91	1.77	1.78	1.86	1.49	1.78	1.94	2.12	1.89
Dec.	1.96	1.65	1.60	1.80	1.67	1.56	1.57	1.63	1.31	1.56	1.72	1.87	1.66
Max.	3.02	2.20	2.30	2.58	2.48	2.41	2.22	2.38	1.85	2.17	2.47	2.89	2.41
Min.	0.89	0.88	0.78	0.67	0.90	0.82	0.57	0.66	0.59	0.58	0.81	0.75	0.74
Diff.	2.13	1.35	1.52	1.91	1.58	1.59	1.65	1.72	1.26	1.59	1.66	2.14	1.67

(4) Design Flood Discharge

The design flood discharge is examined as the basic data for designing the regulating dam. The discharge to be considered is the sum of runoff at Gaging Station No. 9 and the Lake Tana surface level fluctuation converted into discharge as described in detail in 5.2.3, "Water Balance of Lake Tana," and the results obtained by the Gumbel Method based on past flood discharges are indicated in Tables 5-2-3(1) and (2) Figs. 5-2-5(1) and (2).

The 100 year probability flood is 2,300 m^3/sec, and Fig. 5-2-6 is assumed as the corresponding flood waveform. The waveform is based on the following concepts:

i. The maximum quantity of the sum of runoff at Gaging Station No. 9 and the natural surface level fluctuation converted into discharge is almost always produced in August.

ii. The total inflow of 100 year probability flood during July ~ September, the period of flooding, is 11,700 x $10^6 m^3$.

5.2.2 Water Balance of Lake Tana

(1) Inflow

The outline of the Lake Tana Basin is as indicated in Fig. 5-1-1. In order to calculate inflow into Lake Tana, the Lake Tana Basin was divided into areas represented by the four major rivers, and using runoff data of the gaging stations located on the respective rivers, the discharges of the areas were calculated by catchment area ratios.

Calculations were made for 8 years from 1964 to 1974 (excluding 1968, 1969 and 1970). Direct inflows due to precipitation were calculated averaging the monthly precipitations at Bahar Dar and Gondar.

As for the Gilgel Abbay Basin, there are two gaging stations, No. 1 and No. 2 (Koga River), but since the No. 2 station is on a tributary of the Gilgel Abbay River, the No. 1 station was taken as the representative gaging station.

As for the utilize of the water for the Lake Tana Basin, USBR study had the indications of future irrigation development. Future water demands are as follows. (Water Resource Commission)

Scheme	irri. area (ha)	irrigation demand ($10^6 m^3$)	
Megech	6,860	93	(1)
West	7,080	95	(2)
East	5,890	79	(2)
N.E. Tana	5,000	67	(2)
Ribb	15,270	194	(1)
Gumara	12,920	163	(1)
Gilgel Abbay	68,300	750	(1)
Total		1,440	

(1) Sources from reservoirs on individual streams
(2) Source pumping from lake

The consumptions are approximately 11.8% for the inflow 12,200 x $10^6 m^3$ into the lake. In case the agricultural project may be realistic, the inflow into the lake will reduce. However, regulation dam should be operated due to variation of the water level as described in Chap. 7. Therefore the above consumptions have no influence for the plan of the regulating dam. Calculations for the inflow into the lake were made without the above consumptions.

(2) Analysis of Water Balance

The water balance of Lake Tana is calculated by the Water Budget Method. This method is based on a simple principle and is expressed by the following equation:

$$I + P - O - E = \Delta S \quad \text{.......... (1)}$$

Where

- I : inflow from basin to lake
- P : direct precipitation into lake
- O : outflow from lake
- E : evaporation and infiltration from lake
- ΔS : storage in lake

Table 5-2-3 (1) Calculation of Probably Inflow Flood in Lake Tana

(By Gumbel's Method)

i	Date	Discharge x ($10^3\ m^3/s$)	x^2 ($10^6\ m^3/s$)
1	75. 8. 30	1.94199	3.771325160
2	64. 8. 19	1.65139	2.727088932
3	69. 8. 18	1.56970	2.463958090
4	67. 8. 24	1.51940	2.308576360
5	68. 8. 22	1.48541	2.206442860
6	70. 8. 24	1.46451	2.144789540
7	66. 8. 30	1.35199	1.827876960
8	65. 8. 18	1.35020	1.823040040
9	74. 8. 22	1.34000	1.795600000
10	71. 8. 19	1.22020	1.488888040
11	73. 8. 13	1.20820	1.459747240
12	72. 7. 8	1.17520	1.381095040
Σ		17.27819	25.398428272

$\overline{x_i} = 1.43985 \qquad \overline{x_i^2} = 2.116536$

$\overline{y_i} = 0.44861 \qquad \overline{y_i^2} = 1.210510$

$$\frac{1}{a} = \left\{\frac{\overline{x_i^2} - (\overline{x_i})^2}{\overline{y_i^2} - (\overline{y_i})^2}\right\}^{0.5}$$

$$= \left\{\frac{2.116536 - (1.43985)^2}{1.210510 - (0.44861)^2}\right\}^{0.5} = \sqrt{\frac{0.043368}{1.009259}}$$

$$= 0.20729$$

$$b = \overline{x_i} - \left(\frac{1}{a}\right)\overline{y_i}$$

$$= 1.43985 - 0.20729 \times 0.44861$$

$$= 1.34686$$

$$\therefore X_T = 0.20729\ Y_T + 1.34686$$

Fig. 5-2-5 (1) Inflow Flood Frequency

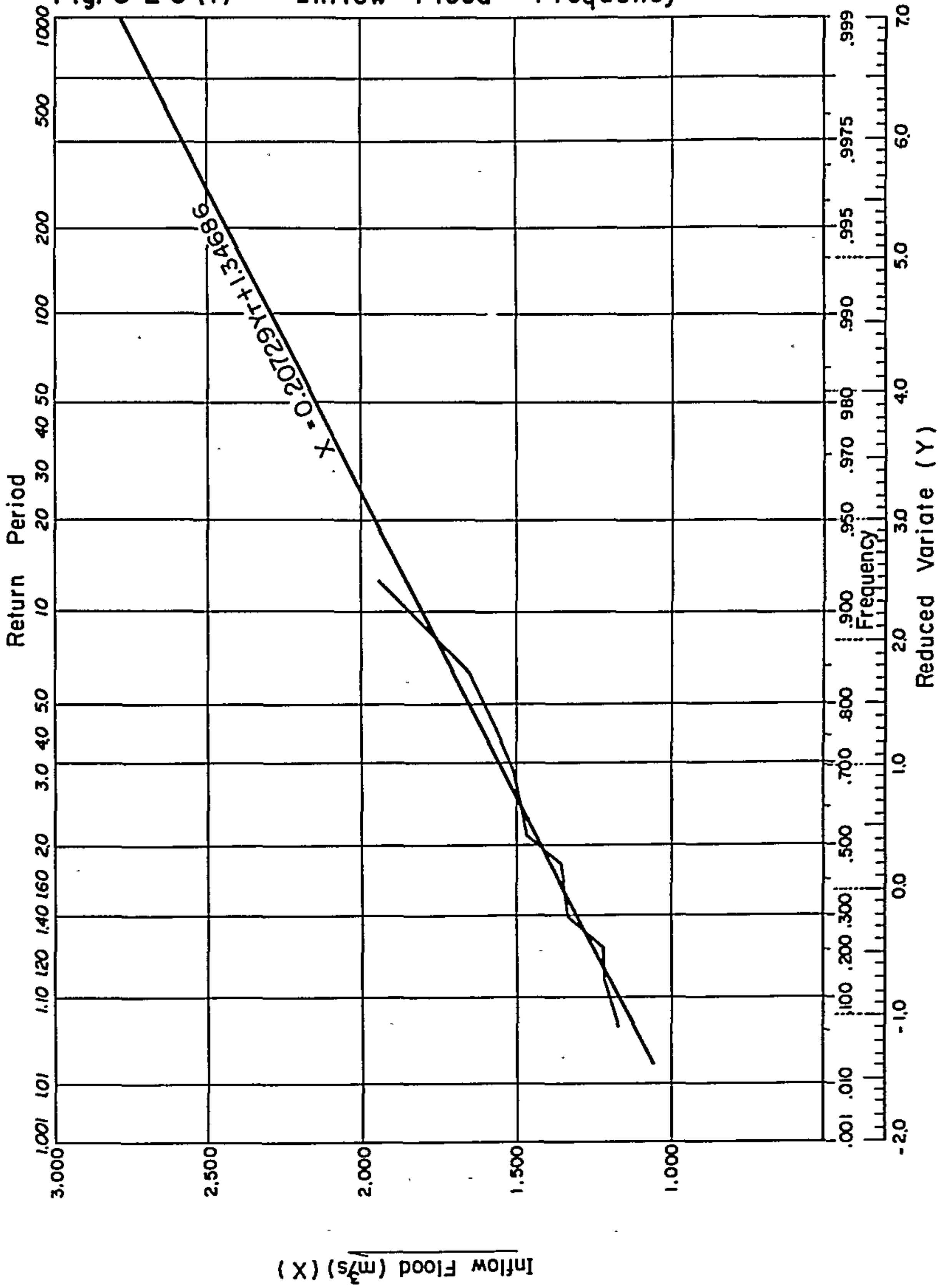


Table 5-2-3 (2) Calculation of Probably Inflow Flood Discharge in Lake Tana during Rainy Season (July to Sept.)

i	Year	x ($10^9 m^3$)	x^2 ($10^{18} m^3$)
1	1964	8. 699	75. 673
2	1975	8. 185	66. 994
3	1967	7. 089	50. 254
4	1974	6. 121	37. 467
5	1969	5. 848	34. 199
6	1971	5. 729	32. 821
7	1968	5. 665	32. 092
8	1970	5. 365	28. 783
9	1973	5. 232	27. 374
10	1966	5. 034	25. 341
11	1965	4. 250	18. 063
12	1972	3. 633	13. 199
Σ		70. 850	442.260

$\overline{x_i} = 5.90417$ $\overline{x_i^2} = 36.85500$

$\overline{y_i} = 0.44861$ $\overline{y_i^2} = 1.210510$

$$\frac{1}{a} = \left\{\frac{\overline{x_i^2} - (\overline{x_i})^2}{\overline{y_i^2} - (\overline{y_i})^2}\right\}^{0.5}$$

$$= \left\{\frac{36.85500 - (5.90417)^2}{1.21051 - (0.44861)^2}\right\}^{0.5}$$

$$= 1.40622$$

$$b = \overline{x_i} - \left(\frac{1}{a}\right)\overline{y_i}$$

$$= 5.90417 - 1.40622 \times 0.44861$$

$$= 5.27332$$

$$\therefore X_T = 1.40622\ Y_T + 5.27332$$

Fig. 5-2-5(2) Inflow Flood Discharge (July to Sept. Period)

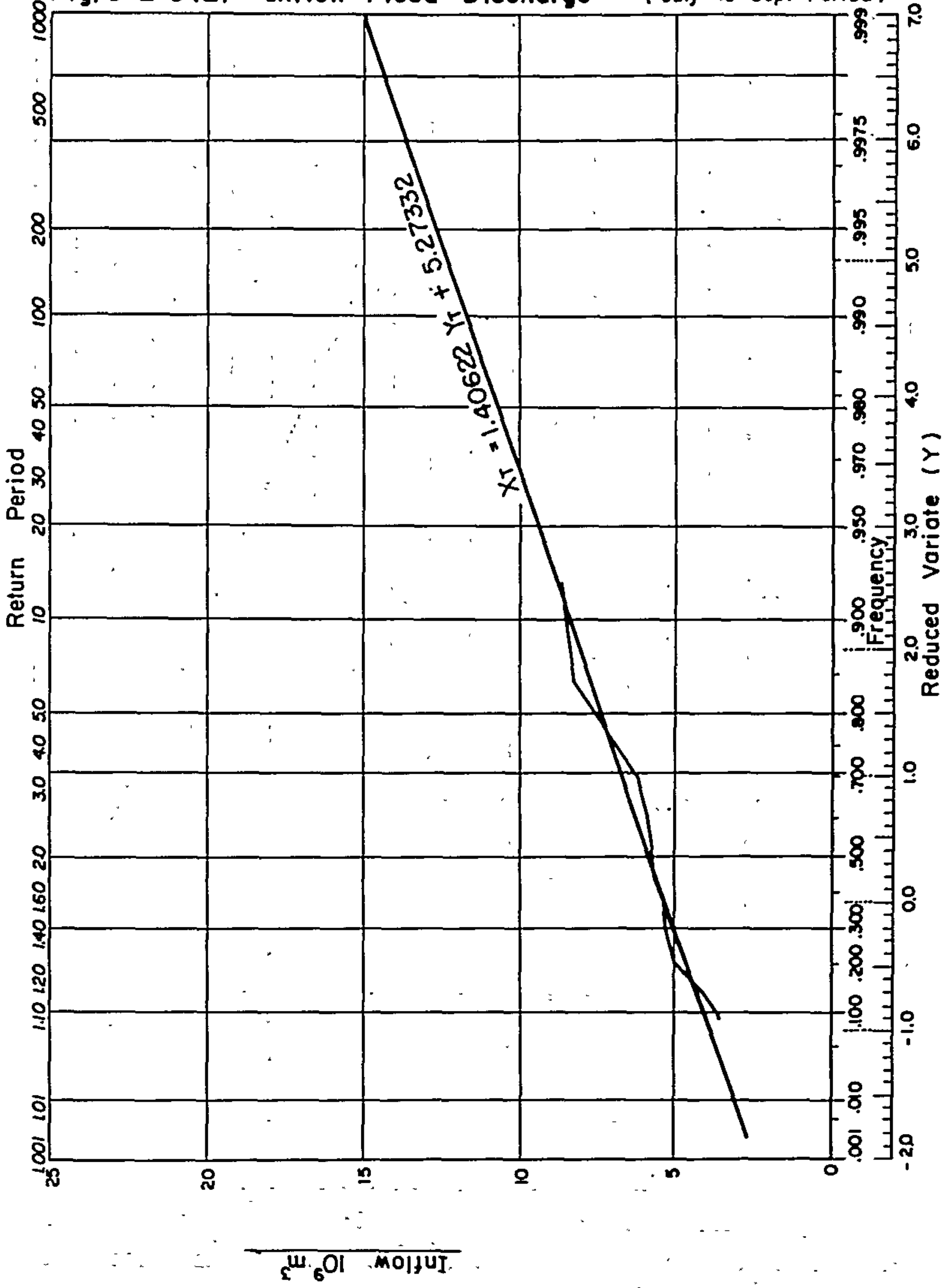
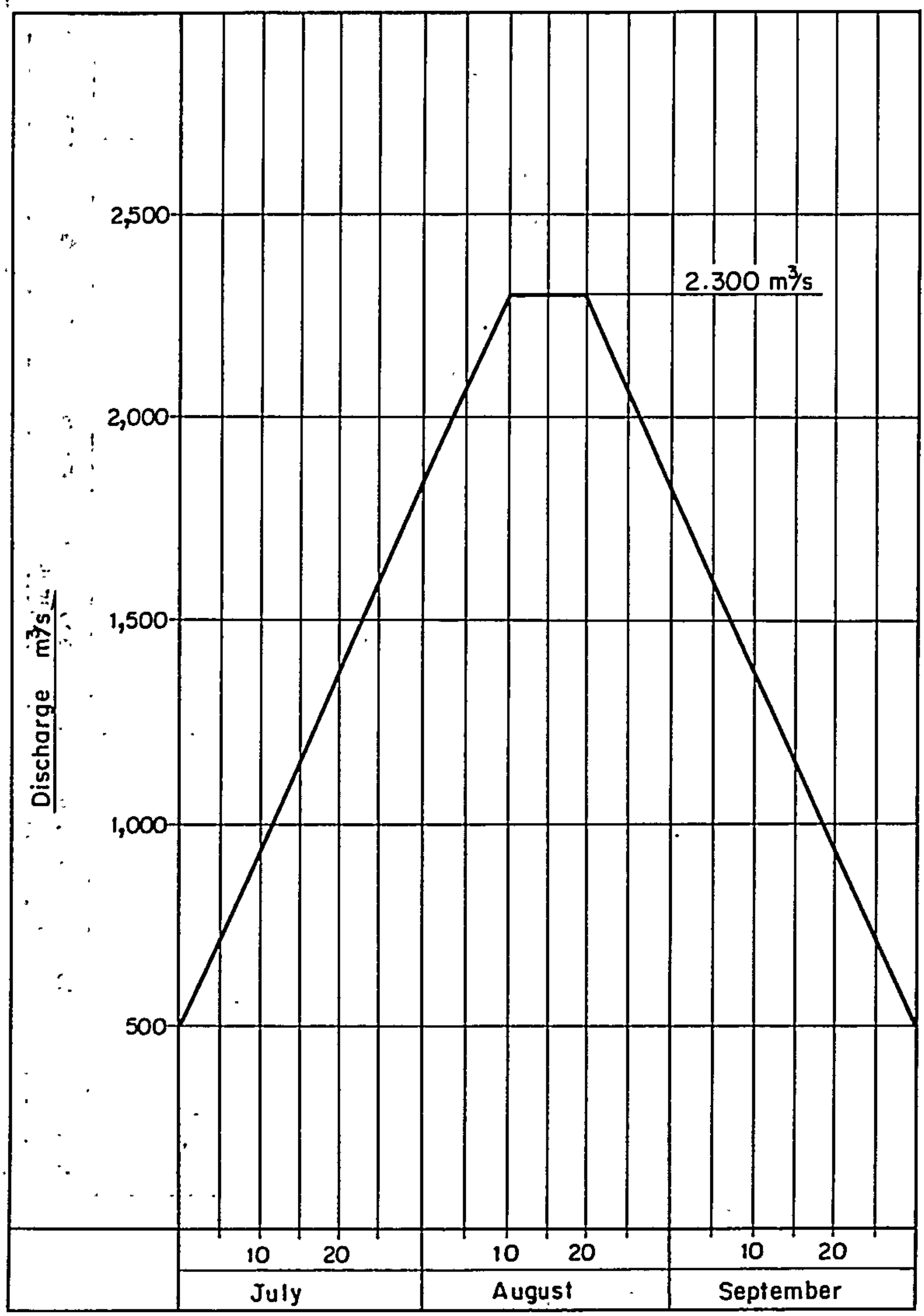


Fig. 5-2-6 Design Inflow Flood (100 Years)



Of the above, (I + P) is calculated as inflow in 5.2.2(1), (O) is the runoff measured at Gaging Station No.9, while (ΔS) is obtained as storage from the surface level measured at Gaging Station No.8. As for (E), this is examined in 5.2.3, "Evaporation," but an accurate estimate is difficult to make because of insufficient data. Therefore, Eq. (1) is modified into the form given below to calculate (E) inversely.

$$E = (I + P) - (O + \Delta S) \qquad (2)$$

The results of daily calculations for 8 years from 1964 to 1974 (excluding 1968 ~ 1970) using Eq. (2) are indicated in Tables 5-2-4, 5-2-13(1), (2) and Figs. 5-2-7(1) ~ (3).

According to the above, the annual inflow into Lake Tana during 8 years in the past was 10 billion to 15 billion m^3 of which 2 billion to 6.5 billion m^3 was discharged into the Blue Nile. In the relation between the two, it is indicated that outflow is increased or decreased in proportion to the amount of inflow. At the same time, this relation is roughly similar for the amount of storage.

However, such a prominent proportional relationship cannot be seen for (E), (evaporation and infiltration), which is maintained within the range of 8 billion to 10 billion m^3. This trend is apparent in the monthly diagrams, and variations are particularly small in the dry season. This is assumed to be due to temperatures in Ethiopia being more or less constant throughout the year, while the humidity is low during the dry season.

In any event, the amount of evaporation and infiltration from Lake Tana is as much as approximately 50 ~ 70% in a wet year and 70 ~ 90% in a dry year.

5.2.3 Evaporation

In order to gain a quantitative grasp of the amount of evaporation included in (E) examined under 5.2.2 (2), an examination is made based on the Penman Method.

Penman's formula is as indicated below.

$$H_o = R_A(1-r)(0.2 + 0.48\frac{n}{D}) - \sigma T_a^4 (0.47 - 0.077\sqrt{ed})(0.2 + 0.8\frac{n}{D})$$

$$E_a = 0.35(e_a - e_d)(0.5 + 0.54\ U_2)$$

$$E_o = \frac{\Delta H_o + rE_a}{\Delta + r}$$

$$\Delta = \frac{e_s' - e_a}{t_s' - t_a}$$

where

RA	:	insolation outside atmosphere (ly/day), Table 5-2-19
r	:	reflectivity at ground surface = 0.06
n	:	number of hours of sunshine per day, Table 5-2-16(1), (2)
D	:	possible number of hours of sunshine per day, Table 5-2-17
σ	:	Lummer & Pringsheim constant = 117.4×10^{-9} cal/day/cm^2
t_a	:	mean temperature (^oC), Table 5-2-14
Ta	:	mean temperature ($t_a + 273$)
e_a	:	saturated water vapor pressure at T_a (mmHg)
h	:	relative humidity, Table 5-2-15
e_d	:	water vapor pressure in atmosphere = he_a
U_2	:	average wind speed 2 m above ground, Table 5-2-18
t_s'	:	$t_a + 0.1$
e_s'	:	saturated water vapor pressure at t_s'
γ	:	pshychrometer constant = 0.49
E_o	:	evaporation (mm/day)

Calculations were made by the nomogram of Fig. 5-2-8. The results are given in Table 5-2-5.

These values are approximately 70% compared with measurements by Class A pan. On collating the calculation results against the results of water balance calculations, approximately 50 ~ 80% of the water lost from the lake is due to evaporation, and the remainder would be due to infiltration. This infiltration is found to be concentrated in the rainy season when the surface level of the lake is high as seen from the monthly water balance diagram (Fig. 5-2-7(3)), and it is estimated that water is infiltrated into the ground surrounding the lake as the surface level rises.

5.2.4 Sedimentation in Lake Tana

Sediment suspended in flowing water or transported along the beds of rivers of the Lake Tana Basin enters Lake Tana. The Ethiopian Government Water Resource Authority has collected samples of sediment in suspension from many rivers and streams to carry out analyses of the percentages of sediment, and of these the analysis results for five rivers of the Lake Tana Basin are indicated in Table 5-2-6.

Sediment versus flow curves are prepared for the various gaging stations using the suspended sediment sample data. In essence, runoff at the time of sampling (m^3/sec) is converted to monthly runoff (m^3) and the monthly sediment quantity (m^3) is obtained from the percentage of sediment (Table 5-2-7). The relation between monthly runoff and monthly suspended sediment of the table is plotted, and the correlation between the two for each river is obtained as shown in Fig. 5-2-9. From the monthly runoffs of the representative year, 1974, the monthly sediment quantities are read off using the curves for the five rivers in the catchment basin and these are added up (Table 5-2-8).

The result obtained is a total of 8,750,000 m^3 of suspended sediment entering Lake Tana from the Gilgel Abbay, Koga, Megech, Ribb and Gummara rivers. Of the total catchment area of the Lake Tana Basin of 15,000km^2, the catchment areas of these rivers comprise 8,440km^2. The quantity of suspended sediment in flowing water differs greatly according to the size of river discharge and it has been observed that sediment increases sharply with increase in discharge. Therefore, it is thought that the quantity of suspended sediment from small tributaries not included in the above will be small. And the quantity of flowing sediment on the riverbed will be small. Accordingly, it is estimated that the quantity of suspended sediment entering Lake Tana is 10,000,000m^3 annually.

Of the fine particles in the flowing water, a part will be deposited at the lake bottom and a part will flow out to the Blue Nile. Of the sediment deposited at the lake a part will settle near the inlets to the lake, and the quantity remaining without further being transported will affect the reservoir capacity in the future. If particle-size data of the samples were available it would be possible to predict the quantity to some extent, but since there are no such data it is difficult to gain an accurate grasp of the quantity. There is a large proportion of fine particles, however, according to the inspections of the Survey Mission, and it is thought the ratio of settlement and deposition is small. It is therefore estimated that deposition near the mouths of rivers will be half of the entire quantity at most. In such case it may be estimated that approximately 5 million m^3 of fine particles will be deposited in the effective storage capacity of the lake. During a period of 50 years from now the deposition will be 250 million m^3, and in 100 years 500 million m^3, about 3% and 6% respectively of the effective storage capacity of the lake.

Fig. 5-2-7 (1) Water Balance of Lake Tana

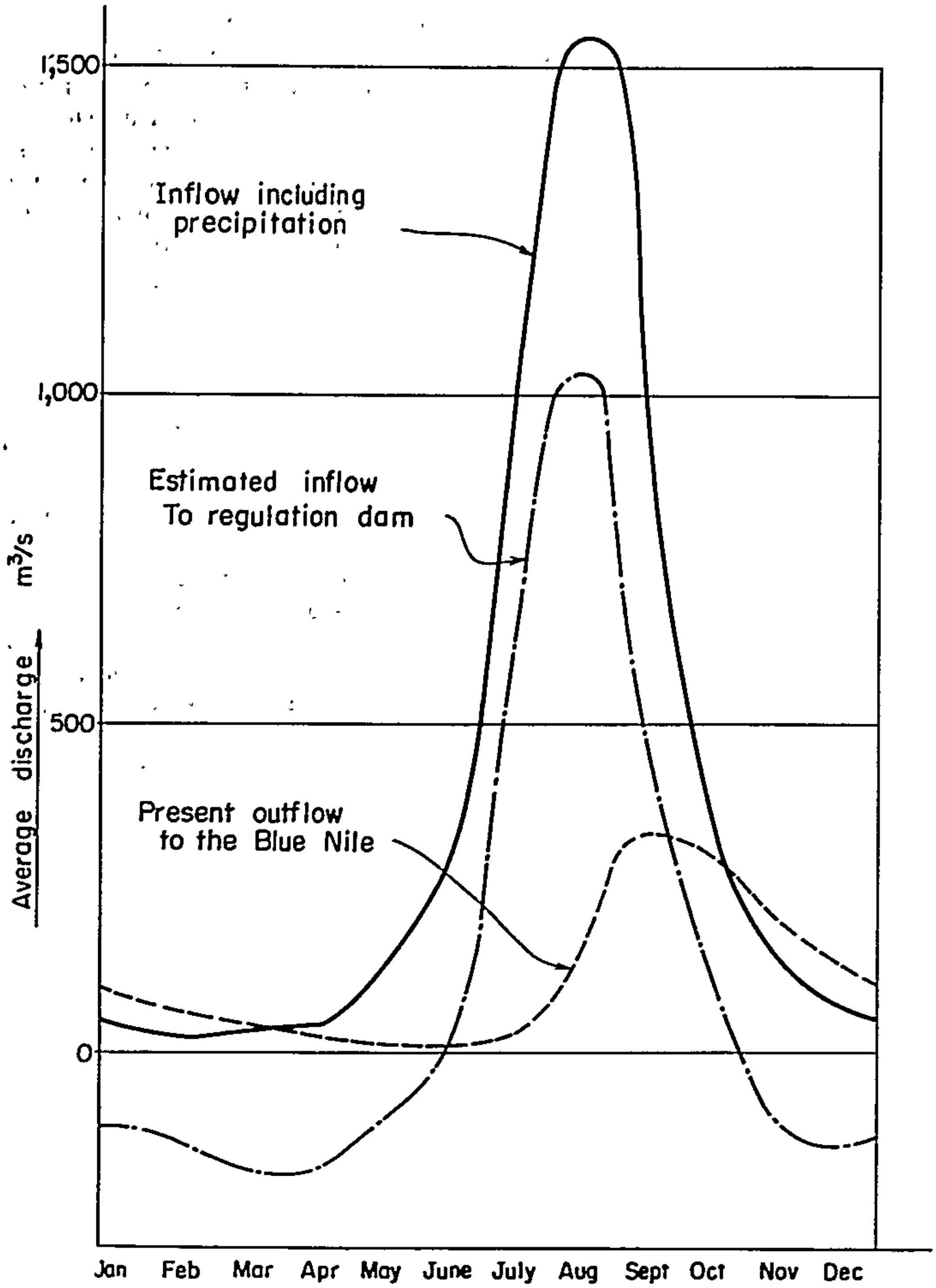


Fig. 5-2-7 (2) Annual Water Balance of Lake Tana.

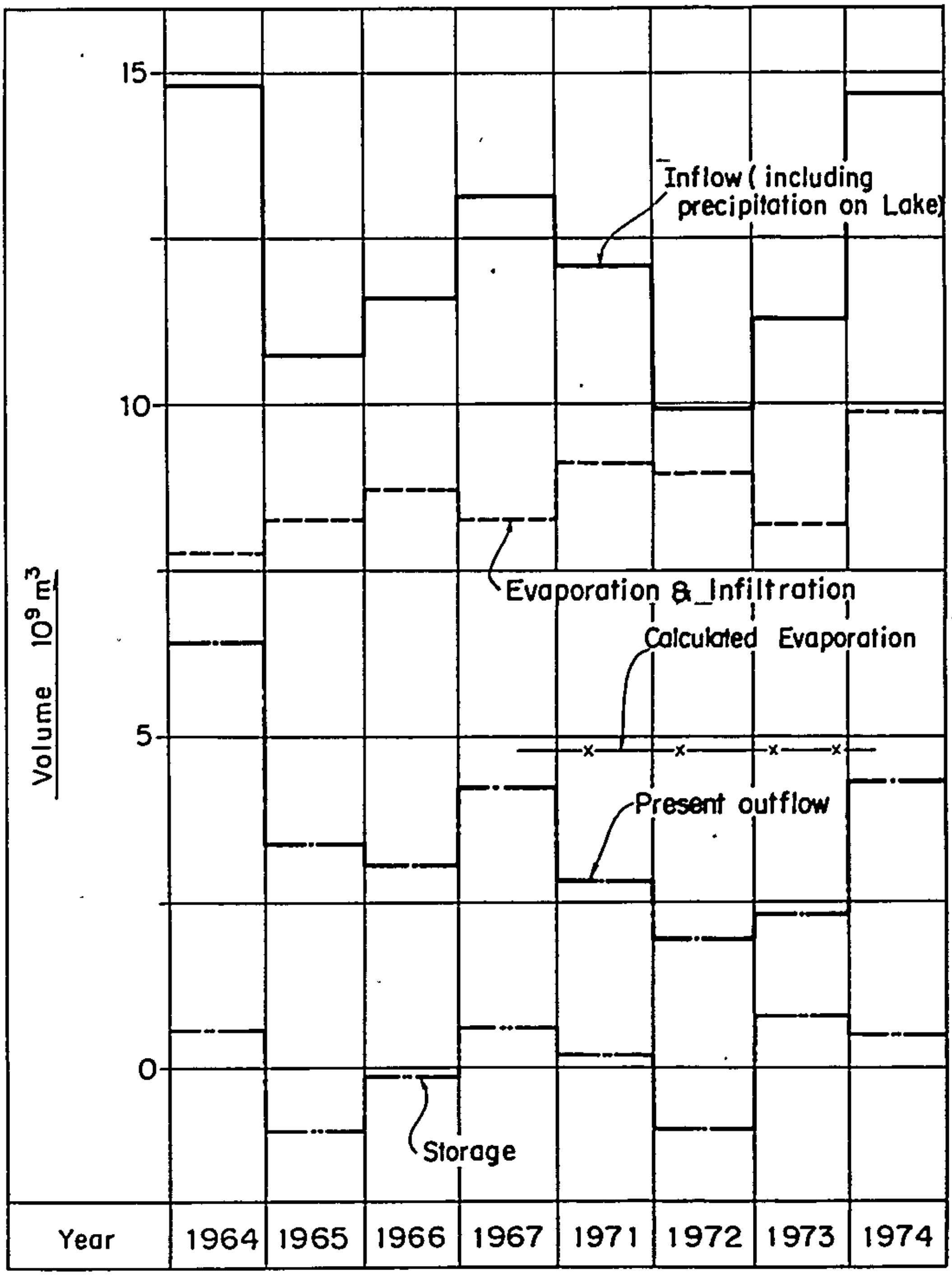


Fig. 5-2-7 (3) Monthly Average Water Balance of Lake Tana.

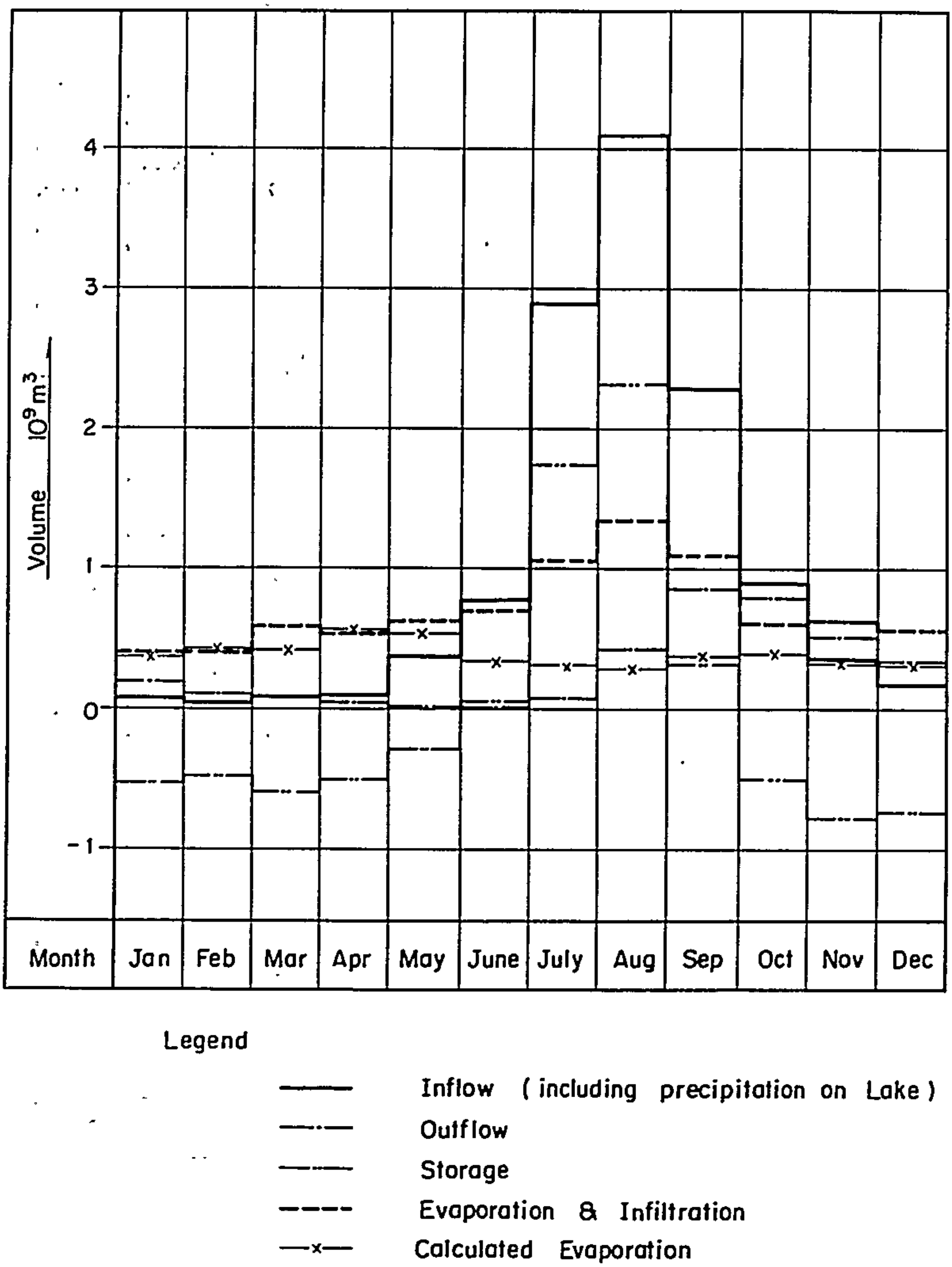


Table 5-2-4 Monthly Average Water Balance of Lake Tana

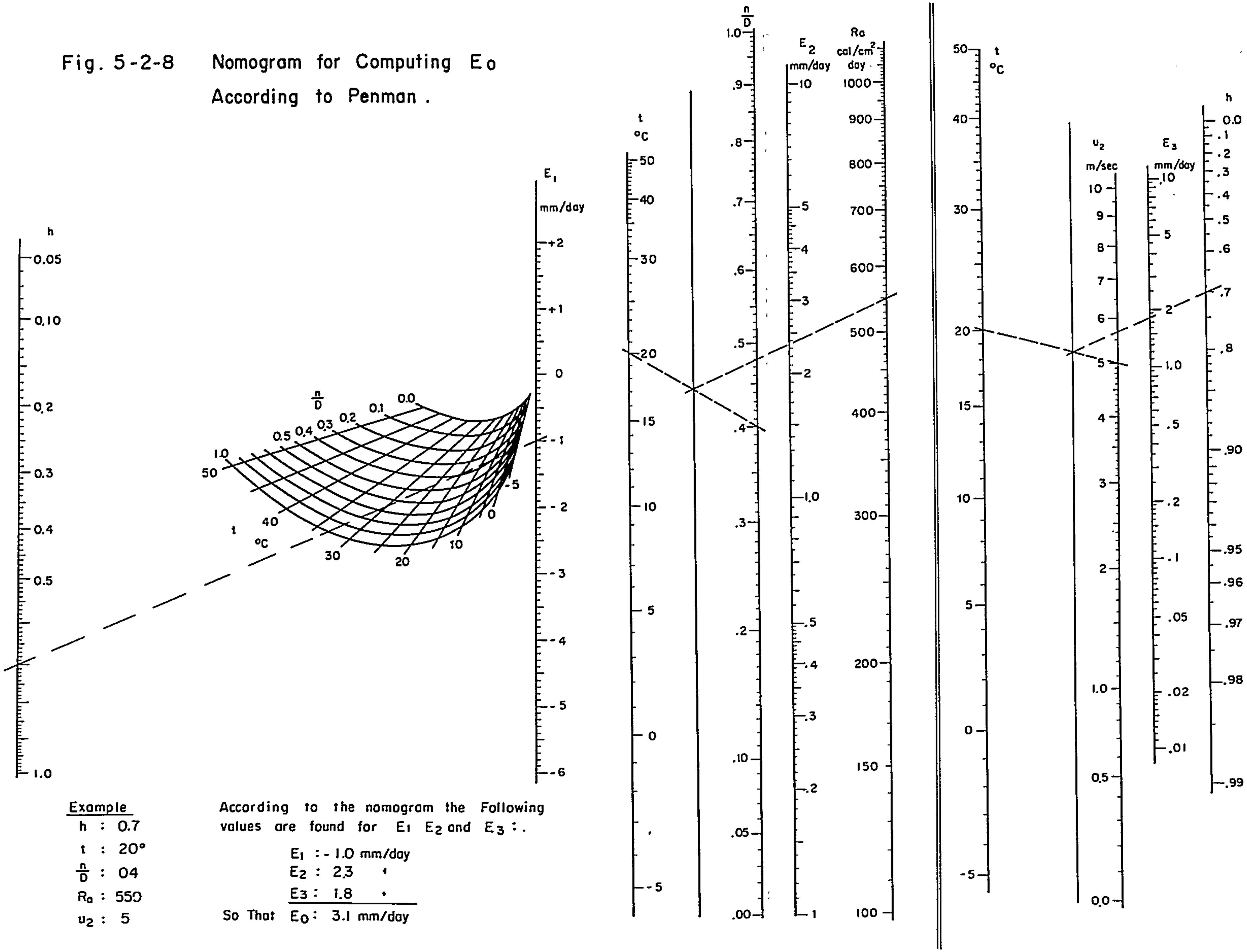
(Unit: m^3/s-day)

Month	I	O	S	E
Jan.	1, 123	2, 485	- 6, 095	4, 733
Feb.	633	1, 542	- 5, 589	4, 680
Mar.	1, 102	1, 066	- 6, 794	6, 830
Apr.	1, 215	589	- 5, 752	6, 378
May	4, 411	333	- 3, 295	7, 373
June	9, 029	248	578	8, 203
July	33, 501	882	20, 292	12, 327
Aug.	47, 660	5, 082	26, 918	15, 660
Sept.	26, 602	9, 977	3, 834	12, 791
Oct.	10, 588	9, 182	- 5, 704	7, 110
Nov.	4, 242	5, 967	- 9, 066	7, 341
Dec.	2, 087	4, 007	- 8, 518	6, 598
Total	142, 193	41, 360	809	100, 024
(m^3/s) Mean	389. 6	113. 3	2. 2	274. 0

Table 5-2-5 Lake Tona Evaporation Loss

Month	t (°C)	h	n/D	Uz (m/s)	Ra (ly/day)	E_1 (mm/day)	E_2 (mm/day)	E_3 (mm/day)	$E_o = E_1+E_2+E_3$ (mm/day)	E_o (mm/month)	Pan-Atype (mm/month)
Jan.	15.0	0.58	0.88	2.54	780	-2.00	4.75	1.30	4.05	125.55	159.0
Feb.	18.6	0.52	0.85	2.44	840	-2.10	5.40	1.61	4.91	137.48	175.0
Mar.	19.6	0.53	0.75	2.92	900	-1.90	4.40	1.90	4.40	136.40	226.0
Apr.	18.8	0.42	0.83	3.64	925	-2.27	5.85	2.70	6.28	188.40	238.0
May	19.7	0.54	0.79	3.28	915	-1.94	5.70	2.00	5.76	178.56	229.0
June	18.2	0.74	0.49	1.92	900	-1.12	4.20	0.75	3.83	114.90	171.0
July	17.1	0.82	0.49	1.77	905	-1.10	4.10	0.47	3.47	107.57	156.0
Aug.	16.6	0.85	0.44	1.17	915	-0.90	3.90	0.31	3.31	102.61	146.0
Sept.	17.1	0.80	0.81	1.31	905	-1.60	5.50	0.45	4.35	130.50	149.0
Oct.	17.3	0.71	0.83	1.64	865	-1.75	5.35	0.75	4.35	134.85	156.0
Nov.	16.1	0.64	0.85	2.42	800	-1.88	4.50	1.12	3.74	112.20	147.0
Dec.	14.7	0.63	0.83	1.89	760	-1.85	4.46	0.95	3.56	100.36	146.0
Average	17.4	0.65	0.74	2.25	867.5	Total -20.41	58.11	14.31	52.01	1,579.38	2,098.0

Fig. 5-2-8 Nomogram for Computing E_o According to Penman.



Example
h : 0.7
t : 20°
$\frac{n}{D}$: 04
R_a : 550
u_2 : 5

According to the nomogram the Following values are found for E_1 E_2 and E_3 :.

E_1 : - 1.0 mm/day
E_2 : 2.3 "
E_3 : 1.8 "
So That E_o : 3.1 mm/day

Table 5-2-6 Summary of Sediment Analysis

Station	Date sediment sampled	Water discharge in m^3/sec during sampling	Sediment discharge in tons/day	% of sediment by volume	% of sediment by weight
Ribb river near Addis Zemen	June 16, 1960	0.252	44.2	0.064	0.184
Gilgel Abbay river near Bahar Dar	May 9, 1961	1.77	26.0	(0.006)*	0.015
"	July 5, "	42.13	1,699.2	0.017	0.042
"	Aug. 12, "	180.20	29,673	0.068	0.173
"	Sept. 23, "	159.10	13,471	0.034	0.089
"	Oct. 7, "	94.00	6,211	(0.027)	0.069
"	Nov. 8, "	21.10	447	(0.009)	0.022
"	July 24, 1964	174.00	8,793	(0.021)	0.053
"	Aug. 11, "	216.90	65,455	(0.126)	0.316
Gummara river near Bahar Dar	July 27, "	195.00	109,214	(0.235)	0.587
"	Aug. 13, "	189.00	118,342	(0.263)	0.658
Koga river near Bahar Dar	Aug. 11, "	21.28	6,367	(0.126)	0.314
Megech river near Azezo	July 28, "	24.62	8,711	(0.148)	0.371
Ribb river near Addis Zemen	" "	155.00	63,165	(0.171)	0.427
Gummara river near Lake Tana	June 22, 1968	3.48	3,849	0.49	1.16
Ribb river near Addis Zemen	June 22, "	1.99	531	0.14	0.28
Megech river near Azezo	" "	0.34	162	0.24	0.50
Ribb river near Addis Zemen	July 7, "	32.50	23,861	0.35	0.77
"	July 8, "	96.70	32.270	0.14	0.35
"	Aug. 20, "	123.00	44,566	0.16	0.38
"	Sept. 3, "	37.00	12,348	0.15	0.35
Megech river near Azezo	July 15, "	7.10	609	(0.036)	0.09
"	July 23, "	5.99	742	(0.052)	0.13
Gummara river near Bahar Dar	July 8, "	43.54	8,303	(0.08)	0.20
"	July 23, "	108.99	15,588	(0.06)	0.15
"	Aug. 6, "	138.05	-	-	-
Gilgel Abbay near Bahar Dar	July 22, "	213.90	28,553	(0.056)	0.14
Koga river near Bahar Dar	Aug. 12, "	17.40	2,488	(0.06)	0.15
"	Aug. 26, "	24.10	3,677	(0.06)	0.16

* Specific gravity is assumed 2.5 for (   ).

Table 5-2-7 Flow VS Sediment

River	Water discharge m^3/s	Monthly runoff 10^6m^3	% of sediment by volume	Monthly sediment 10^6m^3
Gilgel Abbay river	1.77	4.588	(0.006)	0.0002
"	42.13	109.200	0.017	0.018
"	180.20	467.078	0.068	0.318
"	159.10	412.387	0.034	0.140
"	94.00	243.648	(0.027)	0.066
"	21.10	54.691	(0.009)	0.005
"	174.00	451.010	(0.021)	0.095
"	216.90	562.205	(0.126)	0.708
"	213.90	554.429	(0.056)	0.310
Koga river	21.28	55.157	(0.126)	0.069
"	17.40	45.100	(0.06)	0.027
"	24.10	62.467	(0.06)	0.037
Megech river	24.62	63.815	(0.148)	0.094
"	7.10	18.403	(0.036)	0.007
"	5.99	15.526	(0.052)	0.008
Ribb river	155.00	401.76	(0.171)	0.687
"	1.99	5.158	0.14	0.007
"	32.50	84.240	0.35	0.295
"	96.70	250.648	0.14	0.351
"	123.00	318.816	0.16	0.510
"	37.00	95.904	0.15	0.144
Gummara river	195.00	505.440	(0.235)	1.187
"	189.00	489.890	(0.263)	1.284
"	3.48	9.020	0.49	0.044
"	43.54	112.855	(0.08)	0.090
"	108.99	282.502	(0.06)	0.170

Table 5-2-8 Monthly Suspended Sediment

River		C. A. Km^2	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
			Monthly runoff and suspended sediment in $10^6 m^3$												
Gilgel Abbay	Runoff, GS No. 1	1,600	16.6	10.4	9.6	6.4	40.4	148.6	435.8	512.8	407.8	112.5	36.7	20.4	
	" , whole basin	4,130	42.8	26.8	24.8	16.5	104.3	383.6	1124.9	1,323.7	1052.6	290.4	94.7	52.7	
	Sediment		0.005	0.003	0.002	0.001	0.02	0.14	0.7	3.0	0.6	0.003	0.02	0.007	4.501
Koga	Runoff, GS No. 2	220	3.1	2.3	2.3	2.0	3.9	3.9	31.1	44.5	36.3	14.1	6.1	4.3	
	" , whole basin	320	4.5	3.3	3.3	2.9	5.7	5.7	45.2	64.7	52.8	20.5	8.9	6.3	
	Sediment		0.001	0.001	0.001	0.001	0.002	0.002	0.03	0.06	0.04	0.01	0.003	0.002	0.153
Mege	Runoff, GS No. 3	519	1.0	0.7	0.5	0.2	2.1	22.5	50.9	338.0	29.9	4.4	2.3	1.9	
	" , whole basin	700	1.3	0.9	0.7	0.3	2.8	30.4	68.7	456.0	40.3	5.9	3.1	2.6	
	Sediment		0	0	0	0	0.001	0.02	0.06	1.0	0.03	0.002	0.001	0.001	1.115
Ribb	Runoff, GS No. 5	1,497	1.2	0.7	0.4	0.3	1.5	12.7	156.0	236.7	92.3	9.3	2.6	1.3	
	" , whole basin	1,790	1.4	0.8	0.5	0.4	1.8	15.2	186.6	283.1	110.4	11.1	3.1	1.6	
	Sediment		0	0	0	0	0	0.007	0.3	0.5	0.13	0.005	0.001	0	0.943
Gummara	Runoff, GS No. 6	1,239	6.8	3.0	2.1	1.5	8.4	39.2	257.7	355.5	219.2	48.5	13.7	5.9	
	" , whole basin	1,500	8.2	3.6	2.5	1.8	10.2	47.4	311.8	430.2	265.2	58.7	16.6	7.1	
	Sediment		0.003	0.001	0	0	0.004	0.04	0.58	0.9	0.45	0.05	0.008	0.002	2.038
Total	Sediment		0.004	0.002	0.001	0.001	0.007	0.069	0.97	2.46	0.65	0.067	0.013	0.005	4.249
Grand Total	Sediment		0.009	0.005	0.003	0.002	0.027	0.209	1.67	5.46	1.25	0.07	0.033	0.012	8.75

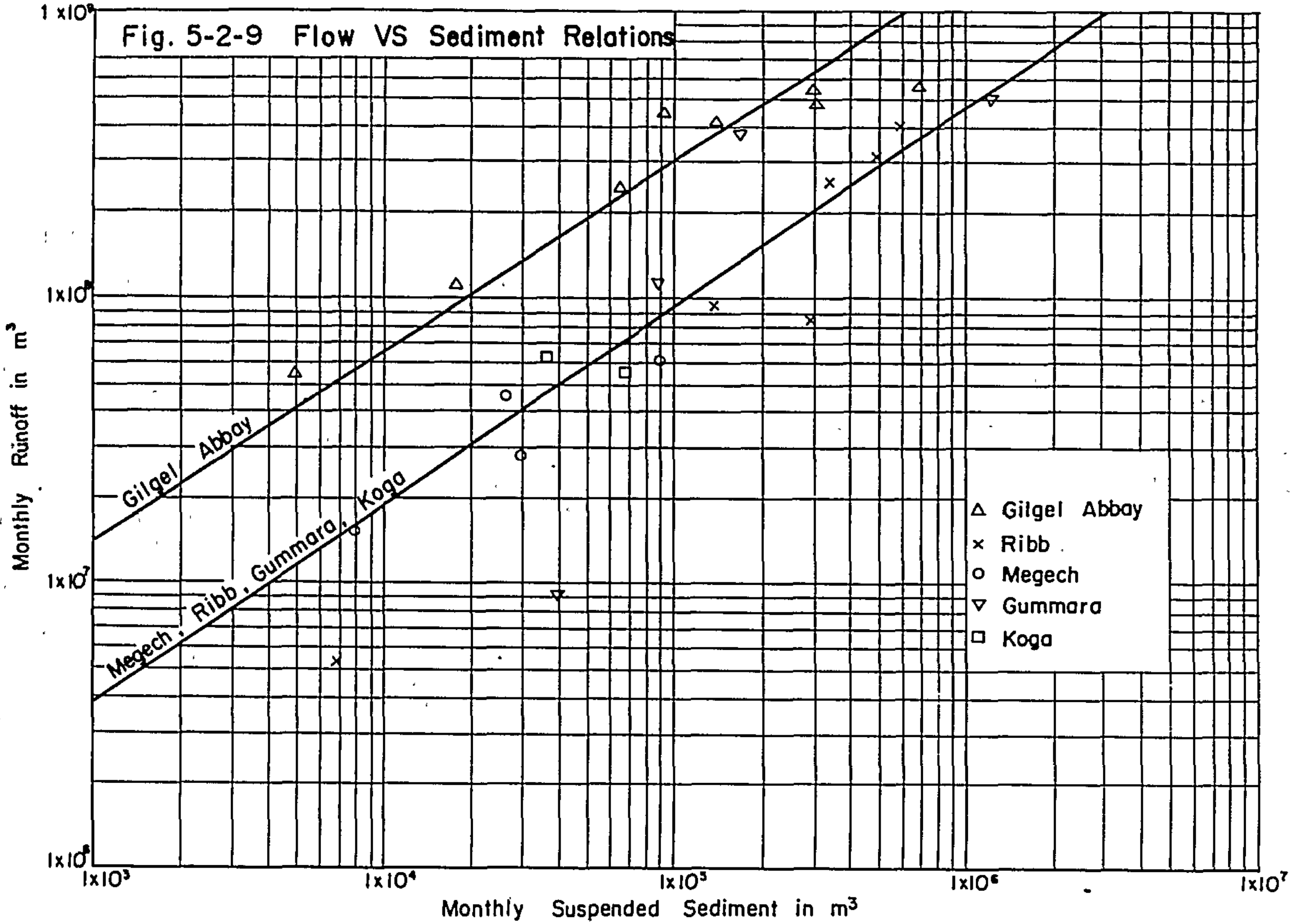


Fig. 5-2-9 Flow VS Sediment Relations

Table 5-2-9 (1) Monthly Total Rainfall

Station : Bahar Dar Location : Lat. 11°36' N, Long. 37°25' E, EL. 1,802

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1964	0.0	0.0	0.0	104.0	44.1	171.6	561.2	375.3	314.6	146.0	3.8	2.0	1,722.6
1965	13.0	1.5	43.6	7.0	12.8	75.1	513.3	206.6	272.6	81.7	66.0	0.0	1,293.0
1966	10.0	15.5	21.0	0.0	161.1	175.3	384.4	516.0	194.7	63.8	19.8	0.0	1,561.6
1967	0.0	0.0	35.9	11.6	28.2	165.4	469.6	350.0	196.6	167.9	134.1	0.0	1,559.3
1968	0.0	0.0	7.0	3.2	98.5	306.9	493.3	390.4	254.4	65.9	19.4	0.0	1,639.0
1969	30.0	8.0	30.7	25.4	96.1	108.9	703.0	459.6	149.2	31.2	4.0	0.0	1,646.1
1970	0.0	0.0	1.4	37.0	38.6	83.3	441.3	528.7	168.6	174.4	0.0	0.0	1,473.3
1971	15.0	0.0	4.0	10.2	41.1	252.4	387.8	363.9	156.6	159.7	5.1	0.0	1,395.8
1972	7.6	0.0	0.0	5.1	12.4	170.4	364.0	222.2	176.8	29.0	64.9	0.0	1,052.4
1973	0.0	0.0	0.9	7.5	168.4	160.1	292.6	593.0	268.0	37.5	6.1	0.0	1,534.1
1974	2.2	0.0	3.8	0.0	273.7	217.8	301.4	442.1	298.0	49.7	0.0	0.3	1,589.0
1975	14.5	5.5	0.0	7.4	8.6	217.3	558.0	-	-	-	-	-	-
Mean	7.7	2.5	12.4	18.2	82.0	175.4	455.8	404.3	222.7	91.5	29.4	0.2	1,502.1

Table 5-2-9 (2) Monthly Total Rainfall

Station : Gondar Location : Lat. 12°36' N, Long. 37°25' E, EL. 2,000

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1964	-	0.0	4.0	15.0	176.4	247.0	548.9	563.4	92.4	-	13.0	11.2	1,668.3
1965	8.3	0.0	23.4	19.3	17.8	81.3	351.1	391.6	43.6	122.3	27.3	13.5	1,009.5
1966	6.5	5.0	12.8	10.8	118.3	103.1	218.4	237.2	96.6	83.2	35.6	0.0	927.5
1967	0.0	8.5	-	30.3	54.7	161.6	319.5	229.7	50.4	53.4	18.8	0.0	926.9
1968	-	-	-	-	-	-	-	-	-	-	-	-	-
1969	-	12.3	88.8	72.4	82.0	66.8	424.8	268.5	70.8	40.0	3.8	0.0	1,150.2
1970	0.5	0.0	0.0	5.3	36.6	116.9	285.5	148.8	142.0	97.5	0.0	4.4	837.3
1971	0.0	0.0	22.0	42.4	138.0	93.6	261.0	208.9	103.4	57.1	31.2	0.0	957.6
1972	18.0	1.5	0.9	43.2	48.3	212.7	255.5	258.4	165.0	40.4	84.6	0.0	1,128.5
1973	0.0	0.0	11.9	63.5	160.0	103.7	400.7	377.5	147.3	99.8	43.9	0.0	1,408.3
1974	17.0	6.8	0.5	0.5	219.8	175.6	435.1	304.0	230.8	39.3	2.2	11.2	1,442.8
1975	26.9	-	1.0	-	-	308.9	468.0	-	-	-	-	-	-
Mean	7.0	3.1	15.0	27.5	95.6	153.7	360.8	289.5	114.2	66.3	26.0	4.0	1,162.7

Table 5-2-9 (3) Monthly Total Rainfall

Station : Addis Zemen | Location : Lat. 12°07' N, Long. 37°57' E, EL. 1,900

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1964	-	-	-	-	-	-	-	-	-	-	-	-	-
1965	-	-	-	-	-	-	-	-	-	-	-	-	-
1966	22.5	-	-	-	-	-	-	-	-	-	-	-	-
1967	-	-	-	-	-	-	-	-	-	-	-	-	-
1968	0.0	0.0	-	0.0	-	156.0	447.0	379.8	-	-	-	-	-
1969	-	-	-	-	-	-	382.6	206.2	-	15.9	0.0	0.0	-
1970	0.0	0.0	0 0	7.3	1.1	94.4	399.1	397.0	156.0	63.8	-	-	1,118.7
1971	-	0.0	0.0	21.5	64.8	174.1	279.3	283.7	178.0	23.5	8.8	0.0	1,033.7
1972	-	-	-	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5-2-9 (4) Monthly Total Rainfall

Station : Dangila | Location : Lat. 11°17' N, Long. 36°55' E, EL. 1,981

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1964	1.0	0.0	0.0	4.5	148.5	-	369.0	305.6	197.5	177.5	20.3	-	-
1965	15.5	8.6	75.5	28.0	29.1	282.6	352.9	375.0	102.1	109.3	139.9	14.2	1,523.7
1966	0.0	0.0	54.3	14.2	251.6	336.3	321.2	298.9	229.3	123.2	41.5	0.0	1,670.5
1967	0.0	0.0	81.3	7.5	74.6	170.1	295.2	165.5	204.9	128.3	82.4	0.0	1,209.8
1968	0.0	0.0	3.0	5.1	90.1	-	342.7	237.0	-	54.7	34.5	0.5	-
1969	31.1	9 7	68.5	61.0	112.0	163.0	-	-	-	-	-	-	-
1970	-	-	-	-	-	-	-	-	-	-	-	-	-
1971	-	-	-	-	-	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	-	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5-2-9 (5) Monthly Total Rainfall

Station : Ingibara

Location : Lat. 10°58' N, Long. 36°58' E, EL. 2,600

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1964	-	-	-	-	-	-	-	-	-	-	-	-	-
1965	-	-	-	-	-	-	-	-	-	-	-	-	-
1966	-	-	-	-	-	-	-	-	-	-	-	-	-
1967	0.0	0.0	63.6	38.4	74.4	259.9	490.8	454.4	299.1	136.2	119.1	-	-
1968	-	-	-	-	-	-	-	-	-	-	-	-	-
1969	-	16.9	111.3	34.0	123.8	-	-	671.8	278.1	90.8	-	-	-
1970	-	-	-	-	-	-	-	-	-	-	-	-	-
1971	-	-	-	12.5	57.0	58.0	68.0	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	-	-	-	-	-	-	-	-	-	-
1974	-	-	-	63.2	265.8	172.6	-	477.0	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5-2-9 (6) Monthly Total Rainfall

Station : Gorgora

Location : Lat. 12°15' N, Long. 37°18' E, EL. 1,830

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1964	-	-	-	-	-	-	-	-	-	-	-	-	-
1965	-	-	-	47.4	52.0	150.0	338.0	283.8	22.6	-	-	-	-
1966	7.0	-	-	-	-	-	-	380.8	94.0	86.0	13.0	0.0	-
1967	-	49.0	-	31.0	-	-	335.0	236.0	62.0	117.0	-	-	-
1968	-	-	-	-	-	-	-	-	-	-	-	-	-
1969	-	-	0.0	-	55.0	37.0	-	-	-	-	-	-	-
1970	-	-	-	-	-	-	-	-	-	-	-	-	-
1971	-	-	-	-	-	-	-	-	-	-	-	-	-
1972	-	-	-	-	-	-	-	-	-	-	-	-	-
1973	-	-	-	-	131.0	230.0	196.0	105.0	65.0	30.0	5.0	0.0	-
1974	-	-	-	-	-	-	-	-	-	-	-	-	-
1975	-	-	-	-	-	-	-	-	-	-	-	-	-
Mean	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5-2-10(1) Monthly Mean Discharge

Station : Gauging Station No. 1 River : Gilgel Abbay

C. A. : 1,600 Km^2

(Unit: m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1964	8.99	5.28	3.56	2.08	2.14	29.50	161.11	199.76	142.85	76.21	27.94	11.44	55.91
1965	8.06	6.36	4.75	4.32	2.64	25.63	135.75	199.06	133.30	67.69	44.23	24.79	54.72
1966	10.61	6.35	5.49	2.75	5.65	47.61	158.03	219.49	144.48	45.19	28.25	12.66	57.21
1967	7.01	4.74	4.80	2.58	3.40	21.80	144.77	178.80	161.69	78.49	24.10	15.43	53.97
1968	7.90	4.82	3.35	2.31	6.24	47.35	164.75	189.50	126.40	54.99	17.15	9.75	52.84
1969	6.84	4.65	4.14	2.42	3.55	16.67	132.93	233.64	118.83	30.64	12.75	7.33	47.87
1970	-	-	-	-	-	-	-	179.48	117.30	71.37	25.83	11.06	-
1971	6.42	4.42	3.39	2.73	4.76	19.98	153.68	239.59	164.36	46.89	23.55	9.74	56.62
1972	6.34	4.42	3.13	2.79	3.84	18.61	95.16	169.60	139.20	35.20	17.01	7.82	41.93
1973	5.04	3.99	3.01	3.00	8.89	31.70	96.50	198.70	147.20	70.37	18.93	8.72	49.67
1974	6.21	4.29	3.57	2.46	15.08	57.30	177.60	191.50	157.30	41.99	14.16	7.63	56.59
1975	4.24	3.68	3.14	2.60	2.92	23.78	170.20	234.68	178.19	57.60	24.91	13.56	59.96
Average	7.06	4.82	3.85	2.73	5.37	30.93	144.59	202.82	144.26	56.39	23.23	11.66	53.14

Table 5-2-10(2) Monthly Mean Discharge

Station : Gauging Station No. 2 River : Koga

C. A. : 220 Km^2

(Unit: m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1964	1.26	0.82	0.54	0.59	0.70	1.19	17.04	21.39	13.40	7.83	3.66	2.18	5.88
1965	1.61	1.37	1.29	1.06	0.74	1.09	5.11	12.00	6.61	6.13	4.27	2.53	3.64
1966	1.43	1.16	1.01	0.76	0.85	1.09	8.27	12.77	8.63	3.09	2.28	1.52	3.57
1967	1.13	0.99	0.94	0.75	0.67	1.57	12.08	19.04	12.96	6.45	2.96	2.06	5.13
1968	1.47	1.11	0.96	0.77	0.79	2.06	-	-	-	-	2.26	1.66	-
1969	1.35	1.10	1.02	0.78	0.77	1.33	-	-	13.06	3.84	2.38	1.85	-
1970	-	-	-	-	-	-	-	-	-	-	-	-	-
1971	1.63	1.35	1.17	1.04	1.07	2.01	8.99	20.87	10.69	4.36	3.57	2.14	4.91
1972	1.40	0.99	0.79	0.67	0.67	1.37	5.53	10.63	7.51	2.79	1.94	1.11	2.95
1973	0.92	0.80	0.71	0.68	0.82	1.21	6.74	19.64	9.00	4.44	1.99	1.40	4.03
1974	1.15	0.96	0.86	0.76	1.46	1.51	11.60	16.60	14.01	5.27	2.34	1.60	4.84
1975	1.32	1.41	1.05	0.88	0.88	1.94	20.63	36.86	28.33	11.68	3.97	3.64	9.38
Average	1.33	1.10	0.93	0.79	0.86	1.49	10.67	18.87	12.42	5.59	2.87	1.97	4.91

Table 5-2-10(3) Monthly Mean Discharge

Station : Gauging Station No. 3 River : Megech

C. A. : 519 Km^2

(Unit: m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1964	(2.00)	1.21	0.91	0.85	(1.06)	(1.34)	16.62	32.34	16.70	4.34	1.42	0.63	(6.66)
1965	0.27	0.13	0.20	2.35	0.049	0.238	7.82	19.70	4.74	3.44	1.35	0.38	3.39
1966	0.11	0.06	0.011	0.007	0.114	0.586	(4.31)	(15.18)	9.71	1.97	0.90	0.26	(2.79)
1967	0.228	0.095	0.135	0.211	0.349	1.10	17.30	25.71	11.18	5.10	1.54	0.476	5.28
1968	0.148	0.028	0.002	0.001	0.073	1.201	19.10	14.44	3.34	1.58	0.697	0.318	4.31
1969	-	-	-	-	-	-	-	-	-	-	-	-	-
1970	-	-	-	-	-	-	-	-	-	-	-	-	-
1971	0.19	0.10	0.03	0.02	0.31	0.86	8.85	30.44	8.49	1.20	0.89	0.53	4.33
1972	0.29	0.116	0.04	0.155	0.287	0.414	1.542	16.90	6.32	1.24	1.02	0.58	2.41
1973	0.10	0.054	0.089	0.283	0.429	0.472	3.192	21.01	6.19	2.86	1.103	0.192	3.00
1974	0.37	0.28	0.178	0.062	0.79	8.68	19.02	125.20	11.54	1.62	0.87	0.69	14.11
1975	0.36	0.649	0.068	0.045	0.069	1.806	140.69	398.50	159.60	2.79	1.04	0.54	58.85
Average	0.23	0.27	0.17	0.40	0.27	1.71	11.68	35.72	8.69	2.61	1.08	0.46	5.27

Table 5-2-10(4) Monthly Mean Discharge

Station : Gauging Station No. 5 River : Ribb

C. A. : 1,497 Km^2

(Unit: m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1964	1.02	0.59	0.22	0.28	0.40	2.02	60.09	120.72	52.54	15.00	6.01	2.79	21.80
1965	1.34	0.78	0.41	0.82	0.12	0.45	10.09	41.46	11.89	11.51	3.53	2.20	7.05
1966	0.84	0.73	0.80	0.47	(0.09)	(1.30)	(31.09)	74.62	33.44	4.95	2.55	1.19	12.80
1967	0 67	0.50	0.82	0.56	1.37	2.09	75.77	104.03	48.82	15.81	6.13	3.06	21.63
1968	1.36	0.90	0.64	0.60	0.80	3.78	63.57	81.80	22.51	8.67	3.73	1.75	15.84
1969	0.62	0.54	1.02	0.58	0.57	0.44	-	90.19	21.90	3.17	1.44	0.65	-
1970	0.47	0.28	0.21	0.07	-	-	-	-	-	-	1.76	0.91	-
1971	0.63	(0.41)	0.26	0.12	0.72	3.53	(26.38)	(85.25)	31.93	5.74	2.55	1.18	(13.37)
1972	0.76	0.43	0.18	0.26	0.25	1.83	24.87	46.89	18.40	3.74	2.91	1.93	8.45
1973	0.734	0.367	0.266	0.177	0.622	2.136	31.84	104.60	54.89	15.785	1.935	0.895	17.86
1974	0.439	0.279	0.142	0.111	0.541	4.90	58.26	88.36	35.62	3.46	0.984	0.471	16.13
1975	0.43	0.377	-	-	0.049	19.448	26.82	95.80	80.84	8.34	2.24	1.58	-
Average	0.78	0.52	0.45	0.37	0.54	4.06	43.91	84.85	37.53	8.74	2.98	1.55	15.52

Table 5-2-10(5) Monthly Mean Discharge

Station : Gauging Station No. 6 River : Gummara

C. A. : 1,239 Km^2

(Unit: m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1964	2.39	1.56	0.94	0.81	0.94	3.01	(94.99)	(171.83)	(127.88)	41.57	12.03	4.69	(38.79)
1965	1.847	1.128	0.697	0.767	0.385	1.168	18.959	99.39	37.433	(39.38)	(7.06)	3.10	(17.82)
1966	1.41	0.88	0.88	0.65	0.68	2.45	(27.88)	128.00	64.20	10.20	4.35	2.37	(20.49)
1967	1.20	0.93	1.41	1.02	2.41	3.95	141.00	148.00	93.00	49.60	11.70	5.60	38.32
1968	-	-	-	-	-	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	-	-	-	-	-	-
1970	-	-	-	0.454	0.624	4.608	32.905	135.31	76.093	24.302	8.222	3.72	-
1971	1.74	1.16	0.77	0.58	1.33	3.84	66.12	171.00	73.10	19.80	10.75	4.98	29.60
1972	2.15	1.27	0.79	0.514	0.656	2.45	32.53	106.00	32.97	7.38	3.26	2.20	16.01
1973	1.45	0.563	0.286	0.244	1.90	3.03	38.04	114.20	77.47	35.06	8.73	3.88	23.02
1974	2.55	1.24	0.78	0.575	3.122	15.12	96.20	132.71	84.58	18.11	5.28	2.20	30.21
1975	1.39	0.97	0.54	0.39	0.42	1.38	57.52	175.18	171.70	18.92	7.95	3.49	36.65
Average	1.79	1.08	0.79	0.60	1.25	4.10	59.16	124.42	78.95	24.99	8.03	3.62	25.78

Table 5-2-10(6) Monthly Mean Discharge

Station : Gauging Station No. 9 River : Blue Nile

C.A. : 15,243 Km^2

(Unit: m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1964	96.12	64.51	38.52	21.20	11.09	10.48	52.17	347.20	685.08	550.30	352.60	220.90	204.18
1965	144.95	104.46	(68.61)	(43.89)	(23.29)	13.68	25.89	114.77	208.50	229.00	186.26	134.06	(108.09)
1966	90.80	60.70	39.30	22.06	12.20	9.90	23.20	119.86	261.60	234.40	177.90	118.52	97.54
1967	75.12	46.30	28.80	18.13	9.95	5.53	24.49	204.71	383.70	375.00	263.70	181.40	134.74
1968	(120.03)	81.10	48.26	26.24	14.48	14.18	67.94	240.80	337.40	297.00	202.90	140.80	(132.72)
1969	95.16	60.91	37.99	23.21	14.71	8.61	25.41	176.39	336.80	263.10	173.10	108.13	(110.30)
1970	69.75	43.41	25.50	11.79	(3.91)	(7.09)	(11.35)	117.28	259.41	240.31	173.07	110.56	(89.62)
1971	59.44	41.70	26.77	14.49	7.20	5.35	20.13	126.72	276.00	231.70	156.79	99.74	88.84
1972	76.50	(52.87)	32.10	17.40	9.00	5.90	19.20	78.20	160.50	142.10	90.00	55.40	(61.59)
1973	34.60	23.10	13.70	6.04	2.82	3.00	13.39	91.30	215.90	228.00	158.20	95.30	73.36
1974	63.70	44.10	27.30	14.00	10.26	12.13	48.08	228.87	469.30	319.10	210.60	128.80	131.35
1975	84.00	60.80	40.10	21.60	10.20	7.16	29.90	207.70	604.80	503.30	293.30	179.20	170.17
Average	80.92	57.37	32.58	17.83	10.19	8.72	31.80	171.15	349.92	301.11	203.20	131.07	116.31

Table 5-2-10(7) Monthly Mean Discharge

Station ; Gauging Station No. 11 River : Andassa

C. A. : 660 Km^2

(Unit: m^3/s)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average
1964	(2.14)	1.48	1.32	(0.99)	(1.10)	2.31	40.81	35.22	22.12	14.91	7.72	4.27	(11.28)
1965	(2.70)	(2.00)	(1.66)	(0.88)	(0.92)	1.12	(12.26)	19.82	7.72	7.69	6.11	3.56	(5.58)
1966	1.65	1.25	0.94	0.87	(0.82)	(3.24)	(12.73)	(26.00)	20.39	6.72	4.99	2.64	(6.89)
1967	1.84	1.54	1.45	1.08	0.96	2.14	22.21	39.30	17.41	13.94	6.63	4.26	9.40
1968	2.46	2.02	1.55	1.20	1.33	3.51	23.44	29.30	16.62	8.98	4.96	3.31	8.22
1969	(2.57)	2.11	1.81	1.41	1.37	1.66	23.76	43.83	16.72	7.23	4.73	3.59	(9.31)
1970	2.42	2.26	1.96	1.57	1.48	2.75	18.01	36.80	15.15	10.44	4.80	3.05	8.39
1971	2.64	2.00	1.61	1.38	1.60	3.18	13.40	34.33	16.99	7.39	6.31	3.49	7.86
1972	2.52	2.08	1.74	0.88	1.02	2.14	10.42	16.92	13.56	6.12	3.99	2.77	5.35
1973	1.25	0.87	0.67	0.64	1.14	1.90	10.28	29.07	15.13	8.96	4.30	2.72	6.39
1974	1.93	1.46	0 84	0.74	1.40	1.78	10.99	28.96	23.20	9.27	4.91	3.45	7.37
1975	2.03	1.57	1.21	1.17	1.01	2.35	13.08	38.23	32.22	9.04	4.59	3.29	9.15
Average	2.08	1.69	1.37	1.09	1.25	2.26	18.64	31.98	18.10	9.22	5.34	3.37	8.03

Table 5-2-11(1) Discharge Duration at G. S. No. 1

Gilgel Abbay River C. A. = 1,600 Km^2

(Unit: m^3/s)

Year	Max.	35 days	95 days	185days	275days	355days	Min.	Mean
1964	284.50	186.60	83.32	12.30	4.04	1.11	0.07	55.91
1965	320.00	179.56	81.41	20.84	5.67	2.27	1.83	54.72
1966	283.24	201.13	70.09	14.62	5.67	2.05	1.39	57.21
1967	223.70	181.21	102.00	15.58	4.50	2.05	1.61	53.97
1968	266.99	174.39	99.57	12.20	4.78	1.83	1.39	52.84
1969	379.40	176.27	44.98	7.64	4.50	1.83	1.61	47.87
1970	-	-	-	-	-	-	-	-
1971	452.00	209.90	69.00	9.85	4.08	2.55	2.39	56.62
1972	284.00	153.90	59.00	8.46	4.08	2.55	2.39	41.93
1973	287.00	171.80	71.20	13.02	4.08	2.78	2.78	49.67
1974	294.50	187.00	108.90	13.45	4.74	2.35	2.35	56.59
1975	380.90	209.10	85.20	14.80	3.48	2.35	2.21	59.96
Average	314.2	184.6	79.5	13.0	4.51	2.16	1.82	53.14

Table 5-2-11 (2) Discharge Duration at G. S. No. 3

Megech River C. A. = 519 Km^2

(Unit: m^3/s)

Year	Max.	35 days	95 days	185 days	275 days	355 days	Min.	Mean
1964	117.0	25.59	4.57	1.36	0.91	0.43	0.18	-
1965	51.4	12.28	2.91	0.57	0.18	0.01	0.00	3.39
1966	21.5	12.50	2.01	0.32	0.06	0.00	0.00	-
1967	57.8	19.45	5.00	0.58	0.13	0.02	0.00	5.28
1968	51.5	8.84	2.39	0.38	0.03	0.00	0.00	4.31
1969	-	-	-	-	-	-	-	-
1970	-	-	-	-	-	-	-	-
1971	58.0	18.80	1.74	0.53	0.06	0.02	0.01	4.33
1972	31.4	8.60	1.30	0.50	0.15	0.02	0.02	2.41
1973	48.9	7.90	2.15	0.39	0.09	0.04	0.00	3.00
1974	1,000	18.20	2.81	0.75	0.31	0.04	0.03	14.11
1975	3,400	178.00	4.90	0.75	0.13	0.03	0.02	58.85
Average	483.8	31.0	2.98	0.61	0.21	0.06	0.03	-

Table 5-2-11 (3) Discharge Duration at G. S. No. 5

Ribb River C. A. = 1,497 Km^2

(Unit: m^3/s)

Year	Max.	35 days	95 days	185 days	275 days	355 days	Min.	Mean
1964	155.00	99.60	16.82	2.29	0.51	0.08	0.04	21.80
1965	72.20	30.00	4.60	1.35	0.55	0.00	0.00	7.05
1966	135.20	55.24	6.12	1.23	0.75	0.00	0.00	-
1967	174.40	92.40	16.64	2.53	0.60	0.35	0.31	21.63
1968	140.90	66.84	13.22	1.84	0.85	0.39	0.19	15.84
1969	149.00	58.10	3.49	0.82	0.56	0.16	0.10	-
1970	-	-	-	-	-	-	-	-
1971	120.30	56.50	9.00	1.31	0.44	0.04	0.04	-
1972	112.45	29.22	5.70	1.85	0.37	0.10	0.07	8.45
1973	235.00	76.00	12.64	1.02	0.38	0.17	0.15	17.86
1974	150.45	75.64	7.64	0.73	0.33	0.10	0.09	16.13
1975	141.10	84.83	17.79	1.90	0.31	0.02	0.00	
Average	144.2	65.9	10.3	1.53	0.51	0.13	0.09	-

Table 5-2-11 (4) Discharge Duration at G. S. No. 6

Gummara River : C. A. = 1, 239 Km^2

(Unit: m^3/s)

Year	Max.	35 days	95 days	185 days	275 days	355 days	Min.	Mean
1964	250. 0	166. 90	34. 10	3. 61	1. 25	0. 55	0. 40	-
1965	170. 4	68. 60	17. 00	2. 06	0. 85	0. 23	0. 12	-
1966	207. 0	95. 40	10. 50	2. 17	0. 85	0. 40	0. 36	-
1967	310. 0	138. 00	54. 00	4. 70	1. 08	0. 70	0. 64	38. 32
1968	-	-	-	-	-	-	-	-
1969	-	-	-	-	-	-	-	-
1970	-	-	-	-	-	-	-	-
1971	245. 8	119. 40	20. 50	4. 09	1. 06	0. 55	0. 50	29. 60
1972	247. 3	51. 40	10. 53	2. 23	0. 89	0. 46	0. 84	16. 01
1973	181. 4	99. 00	20. 67	3. 45	0. 86	0. 03	0. 01	23. 02
1974	287. 0	119. 60	35. 75	3. 64	1. 61	0. 53	0. 20	30. 21
1975	385. 0	145. 00	19. 79	2. 77	0. 59	0. 38	0. 36	36. 65
Average	253. 8	111.5	24. 8	3. 19	1.00	0.43	0.33	-

Table 5-2-11 (5) Unregulated Discharge Duration at G. S. No. 9

Blue Nile River C. A. = 15,243 Km^2

(Unit: m^3/s)

Year	Max.	35 days	95 days	185 days	275 days	355 days	Min.	Mean
1964	765.0	594.7	336.0	85.97	23.05	8.90	7.16	204.18
1965	252.0	212.0	168.4	105.20	36.00	13.00	11.60	-
1966	290.8	234.7	152.8	67.38	20.60	9.55	8.90	97.54
1967	411.6	380.0	237.7	61.71	16.70	5.11	4.64	134.74
1968	344.5	330.7	201.1	109.00	29.85	12.05	11.42	-
1969	351.4	303.1	166.9	73.00	21.76	7.80	6.67	110.30
1970	284.8	248.2	148.8	50.12	10.80	3.50	-	-
1971	293.0	256.3	140.2	48.70	14.70	5.03	4.29	88.84
1972	175.0	148.0	89.0	50.60	18.60	5.60	4.80	-
1973	252.0	228.0	128.7	27.80	7.30	2.10	1.90	73.36
1974	503.0	428.0	204.0	60.30	18.10	9.70	9.10	131.35
1975	690.0	531.0	256.0	69.70	22.20	6.20	5.30	170.17
Average	384.4	324.6	185.8	67.5	20.0	7.38	-	-

Table 5-2-11 (6) Discharge Duration at G. S. No. 11

Andassa River C. A. = 660 Km^2

(Unit: m^3/s)

Year	Max.	35 days	95 days	185 days	275 days	355 days	Min.	Mean
1964	97.79	32.48	14.12	3.58	1.38	0.80	0.80	-
1965	45.20	14.49	6.20	2.60	1.28	0.80	0.80	-
1966	60.78	20.40	7.25	2.60	1.10	0.74	0.68	-
1967	84.98	29.60	11.39	3.22	1.38	0.80	0.80	9.40
1968	64.71	23.26	10.10	3.10	1.68	1.11	1.11	8.22
1969	114.00	26.49	7.81	3.10	1.68	1.04	0.90	-
1970	84.33	27.35	9.30	2.83	2.00	1.34	1.34	8.39
1971	100.58	22.33	8.05	3.10	1.68	1.34	1.18	7.86
1972	24.33	15.72	7.14	2.70	1.50	0.76	0.65	5.35
1973	96.20	17.90	7.68	2.31	0.87	0.60	0.55	6.39
1974	134.00	19.31	8.65	2.92	1.29	0.55	0.43	7.37
1975	101.65	30.00	8.40	2.79	1.20	0.87	0.79	9.15
Average	84.1	23.3	8.84	2.90	1.42	0.90	0.76	-

Table 5-2-12 (1) Summarization of Inflow in Lake Tana

Year 1964 (Unit : m^3/s -day)

	Gilgel Abbay	Megech R.	Ribb R.	Gummara R.	Rainfall	Total Inflow
Jan.	871.76	312.25	51.90	113.42	0.00	1,349.33
Feb.	478.60	177.87	28.03	69.27	0.00	753.77
Mar.	344.96	142.83	11.33	44.70	70.77	614.59
Apr.	194.69	128.74	13.88	37.12	2,091.87	2,466.32
May	207.64	165.40	20.69	44.80	33,871.28	4,309.79
Jun.	2,799.55	202.41	99.96	137.86	7,350.54	10,590.31
Jul.	15,913.72	2,602.72	3,066.25	4,498.99	19,497.95	45,579.64
Aug.	19,054.32	5,062.97	6,159.93	8,138.28	16,437.97	54,853.46
Sep.	13,403.02	2,530.65	2,549.18	5,860.41	7,151.00	31,539.26
Oct.	7,388.87	674.54	755.62	1,978.24	2,565.00	13,362.28
Nov.	2,621.59	215.14	296.79	551.45	295.00	3,979.97
Dec.	1,109.38	100.90	142.43	221.50	262.00	1,836.21
Total	64,383.45	12,316.42	13,240.99	21,700.69	59,593.38	171,234.93

Year 1965

	Gilgel Abboy	Megech R.	Ribb R.	Gummara R.	Rainfall	Total Inflow
Jan.	781.28	40.70	68.01	87.18	376.00	1,353.17
Feb.	556.38	19.64	35.86	47.88	25.00	684.76
Mar.	460.37	32.11	21.00	33.02	1,176.08	1,722.58
Apr.	405.51	356.49	39.47	40.45	458.43	1,300.35
May	265.05	7.71	6.36	18.15	533.60	830.87
Jun.	2,404.86	33.84	22.39	53.54	2,761.05	5,275.68
Jul.	13,161.77	1,225.66	515.29	897.91	15,185.66	30,986.29
Aug.	19,299.67	3,083.74	2,127.54	4,710.31	8,924.09	38,145.35
Sep.	12,507.37	718.73	590.16	1,715.74	5,553.72	21,085.72
Oct.	6,562.59	539.71	584.03	1,864.97	3,588.16	13,139.46
Nov.	4,149.47	205.14	173.97	323.32	1,639.00	6,490.90
Dec.	2,403.83	59.08	113.21	146.83	479.14	3,202.09
Total	62,958.16	6,322.55	4,297.29	9,939.30	40,699.92	124,217.22

Table 5-2-12 (2) Summarization of Inflow in Lake Tana

Year 1966 (Unit : m^3/s-day)

	Gilgel Abbay	Megech R.	Ribb R.	Gummara R.	Rainfall	Total Inflow
Jan.	1,031.61	17.82	43.05	67.00	288.58	1,448.06
Feb.	555.76	8.15	33.50	37.85	359.02	994.28
Mar.	532.71	1.80	40.97	41.68	593.50	1,210.66
Apr.	257.80	1.01	23.36	29.82	189.69	501.68
May	547.53	17.77	4.36	31.15	4,911.24	5,512.05
Jun.	4,466.94	88.82	63.96	112.40	4,889.82	9,621.94
Jul.	15,321.46	674.90	1,586.37	1,320.51	10,590.22	29,493.46
Aug.	21.280.19	2,376.93	3,807.76	6,050.54	13,230.96	46,746.38
Sep.	13,555.52	1,471.45	1,651.40	2,943.16	5.116.38	24,737.91
Oct.	4,381.44	307.70	252.51	481.91	2,580.84	8,004.40
Nov.	2,650.68	136.45	126.07	199.28	974.79	4,087.27
Dec.	1,227.51	41.41	60.94	112.38	626.17	2,068.41
Total	65,809.15	5,144.21	7,694.25	11,427.68	44,351.21	134,426.50

Year 1967

	Gilgel Abboy	Megech R.	Ribb R.	Gummara R.	Rainfall	Total Inflow
Jan.	679.82	35.68	34.40	55.66	0.0	805.56
Feb.	415.39	13.49	23.03	40.20	147.53	639.64
Mar.	465.90	21.20	41.76	69.32	2,384.83	2,983.01
Apr.	251.67	31.93	27.41	46.61	737.70	1,095.32
May	329.26	54.70	70.00	104.88	1,453.78	2,012.62
Jun.	2,045.10	167.31	103.56	184.32	5,743.44	8,243.73
Jul.	14,036.12	2,708.17	3,866.14	6,626.54	13,862.55	41,099.52
Aug.	17,335.41	4,024.88	5,308.48	7,020.23	10,181.86	43,870.86
Sep.	15,170.78	1,693.05	2,114.66	4,233.52	4,336.56	27,548.57
Oct.	7,610.14	799.02	806.52	2,350.98	3,887.62	15,454,28
Nov.	2,261.65	233.06	302.95	537.29	2,687.28	6,022.23
Dec.	1,495.73	74.46	156.24	262.30	332.13	2,320.86
Total	62,096.97	9,856.95	12,855.15	21,531.85	45,755.28	152,096.20

Table 5-2-12(3) Summarization of Inflow in Lake Tana

Year 1971 (Unit : m^3/s-day)

	Gilgel Abbay	Megech R.	Ribb R.	Gummara R.	Rainfall	Total Inflow
Jan.	622.75	29.53	32.11	82.46	261.36	1,028.21
Feb.	386.71	14.28	18.98	49.68	0.0	469.65
Mar.	328.35	5.24	13.11	36.37	457.37	840.44
Apr.	256.26	3.71	5.88	26.40	922.11	1,214.36
May	461.59	48.07	35.75	63.93	3,147.12	3,756.46
Jun.	1,811.85	129.89	174.33	176.05	6,075.39	8,367.51
Jul.	14,898.93	1,385.44	1,346.08	3,131.76	11,396.03	32,158.24
Aug.	23,227.31	4,758.76	4,350.13	8,101.15	10,062.07	50,499.42
Sep.	15,297.85	1,286.36	1,577.28	3,351.68	4,568.40	26,081.57
Oct.	4,546.07	187.21	293.22	939.96	4,334.08	10,300.54
Nov.	2,209.76	135.00	122.33	488.40	637.56	3,593.05
Dec.	943.88	83.28	60.29	236.15	549.94	1,873.54
Total	64,991.31	8,066.77	8,029.49	16,683.99	42,411.43	140,182.99

Year 1972

	Gilgel Abboy	Megech R.	Ribb R.	Gummara R.	Rainfall	Total Inflow
Jan.	614.90	45.95	38.68	102.01	315.80	1,117.34
Feb.	401.35	16.96	20.37	56.41	25.46	520.55
Mar.	303.30	6.29	8.96	37.60	61.30	417.45
Apr.	261.86	23.19	12.77	23.58	983.58	1,304.98
May	372.10	44.97	12.93	31.10	3,901.48	4,362.58
Jun.	1,742.67	62.74	89.38	113.49	6,641.81	8,650.09
Jul.	9,225.68	241.48	1,268.85	1,540.77	9,798.41	22,075.19
Aug.	16,440.32	2,640.19	2,392.70	5,019.50	14,727.94	41,220.65
Sep.	13,033.22	958.00	908.40	1,511.30	7,394.08	23,805.00
Oct.	3,413.16	194.93	190.62	349.45	1,375.62	5,523.78
Nov.	1,596.31	154.53	143.81	149.37	1,586.20	3,630.22
Dec.	758.05	91.41	98.65	104.19	1,442.89	2,495.19
Total	48,162.92	4,480.64	5,186.12	9,038.77	48,254.57	115,123.02

Table 5-2-12(4) Summarization of Inflow in Lake Tana

Year 1973 (Unit : m^3/s-day)

	Gilgel Abbay	Megech R.	Ribb R.	Gummara R.	Rainfall	Total Inflow
Jan.	486.04	15.64	37.44	71.80	131.73	742.65
Feb.	349.18	7.56	16.93	24.09	0.0	397.76
Mar.	291.47	13.66	13.57	13.55	206.89	539.14
Apr.	281.41	42.88	8.72	11.20	1,206.66	1,550.87
May	861.62	67.21	32.43	87.91	3,027.34	4,076.51
Jun.	2,980.16	71.54	105.49	139.00	4,816.05	8,112.24
Jul.	9,361.86	499.76	1,624.93	1,282.38	13,432.42	26,201.35
Aug.	19,261.64	3,288.77	5,341.27	5,479.29	10,535.75	43,906.72
Sep.	13,813.85	937.80	2,710.30	3,361.18	5,880.42	26,703.55
Oct.	6,822.35	448.25	805.43	1,660.58	2,265.05	12,001.66
Nov.	1,776.55	167.06	95.55	400.11	1,907.46	4,346.73
Dec.	845.20	30.09	45.68	183.80	773.17	1,877.94
Total	57,131.33	5,590.22	10,837.74	12,714.89	44,182.94	130,457.12

Year 1974

	Gilgel Abboy	Megech R.	Ribb R.	Gummara R.	Rainfall	Total Inflow
Jan.	602.35	58.21	20.65	122.39	337.59	1,141.19
Feb.	375.92	39.34	12.77	53.79	118.02	599.84
Mar.	346.24	27.89	8.18	35.85	76.23	494.39
Apr.	230.66	9.46	5.48	26.35	10.53	282.48
May	1,460.70	123.63	28.51	147.62	8,668.19	10,428.65
Jun.	5,375.70	154.39	242.10	690.81	6,907.92	13,370.92
Jul.	17,233.46	2,926.58	2,958.19	4,361.92	12,936.95	40,417.10
Aug.	18,564.84	19,757.00	4,286.14	6,327.29	13,105.72	62,040.99
Sep.	14,762.42	1,703.40	1,692.57	3,869.54	9,284.34	31,312.27
Oct.	4,071.50	254.48	174.25	857.93	1,562.68	6,920.84
Nov.	1,328.90	131.92	48.58	241.85	36.87	1,788.12
Dec.	739.72	108.73	24.05	104.26	43.56	1,020.32
Total	65,092.41	25,295.03	9,501.47	16,839.60	53,088.60	169,817.11

Table 5-2-13 (1) Monthly Water Balance of Lake Tana

(Unit: m3/s-day)

Month	1964 I	1964 O	1964 S	1964 E	1965 I	1965 O	1965 S	1965 E
Jan.	1,349	2,980	- 6,490	4,859	1,353	4,494	- 7,700	4,559
Feb.	754	1,871	- 5,980	4,863	685	2,925	- 5,560	3,320
Mar.	615	1,194	- 7,590	7,011	1,723	2,127	- 8.360	7,956
Apr.	2,466	636	- 5,300	7,130	1,300	1,317	- 5,760	5,743
May	4,310	344	- 3,810	7,776	831	722	- 5,220	5,329
June	10,590	314	2,990	7,286	5,276	411	- 1,700	6,565
July	45,580	1,617	29,270	14,693	30,986	803	11,850	18,333
Aug.	54,853	10,763	34,640	9,450	38,145	3,558	23,490	11,117
Sept.	31,539	20,553	3,840	7,146	21,086	6,255	3,260	11,571
Oct.	13,362	17,059	-10,540	6,843	13,139	7,099	- 1,310	7,350
Nov.	3,980	10,581	-12,260	5,659	6,491	5,588	- 5,650	6,553
Dec.	1,836	6,841	-12,070	7,065	3,202	4,156	- 8,160	7,206
Total	171,234	74,753	6,700	89,781	124,217	39,455	-10,840	95,602
(m3/s) Mean	467.9	204.2	18.3	245.3	340.3	108.1	- 29.7	261.9

Month	1966 I	1966 O	1966 S	1966 E	1967 I	1967 O	1967 S	1967 E
Jan.	1,448	2,814	- 6,010	4,644	806	2,329	- 5,640	4,117
Feb.	994	1,700	- 4,280	3,574	640	1,260	- 7,460	6,840
Mar.	1,211	1,218	- 6,730	6,723	2,983	893	- 3,520	5,610
Apr.	502	661	- 5,150	4,991	1,095	544	- 4,860	5,411
May	5,512	378	- 3,680	8,814	2,013	309	- 7,050	8,754
June	9,622	297	- 680	10,005	8,244	166	- 1,940	10,018
July	29,493	719	15,890	12,884	41,100	759	28,430	11,911
Aug.	46,746	3,716	25,840	17,190	43,871	6,346	33,790	3,735
Sept.	24,738	7,848	4,250	12,640	27,549	11,511	2,400	13,638
Oct.	8,004	7,266	- 5,200	5,938	15,454	11,624	- 7,170	11,000
Nov.	4,087	5,336	- 8,320	7,071	6,022	7,911	- 9,640	7,751
Dec.	2,068	3,674	- 7,780	6,174	2,321	5,624	-10,210	6,907
Total	134,425	35,627	- 1,850	100,648	152,098	49,276	7,130	95,692
(m3/s) Mean	368.3	97.6	- 5.1	275.8	416.7	135.0	19.5	262.2

I : Inflow (including precipitation on Lake)
O : Outflow
S : Storage
E : Evaporation and Infiltration

Table 5-2-13 (2) Monthly Water Balance of Lake Tana

(Unit: m^3/s-day)

Month	1971				1972			
	I	O	S	E	I	O	S	E
Jan.	1,028	1,843	- 5,910	5,095	1,117	2,372	- 5,370	4,115
Feb.	470	1,168	- 5,290	4,592	521	1,533	- 6,510	5,498
Mar.	840	830	- 7,720	7,730	417	996	- 6,630	6,051
Apr.	1,214	435	- 6,720	7,499	1,305	522	- 6,210	6,993
May	3,756	223	- 1,280	4,813	4,363	281	- 4,400	8,482
June	8,368	161	- 540	8,747	8,650	177	1,010	7,463
July	32,158	664	20,710	10,784	22,075	596	13,600	7,879
Aug.	50,499	3,931	28,890	17,678	41,221	2,426	17,070	21,725
Sept.	26,082	8,281	5,010	12,791	23,805	4,815	4,720	14,270
Oct.	10,301	7,177	- 7,510	10,634	5,524	4,405	- 5,860	6,979
Nov.	3,593	4,704	- 9,360	8,249	3,630	2,701	- 6,370	7,299
Dec.	1,874	3,092	- 8,150	6,932	2,495	1,717	- 6,240	7,018
Total	140,183	32,509	2,130	105,544	115,123	22,541	-11,190	103,772
(m^3/s) Mean	384.1	89.1	5.8	289.2	314.5	61.6	- 30.6	283.5

Month	1973				1974			
	I	O	S	E	I	O	S	E
Jan.	743	1,074	- 5,600	5,269	1,141	1,974	- 6,040	5,207
Feb.	398	647	- 4,060	3,811	600	1,235	- 5,570	4,935
Mar.	539	423	- 6,920	7,036	494	847	- 6,880	6,527
Apr.	1,551	181	- 6,240	7,610	282	421	- 5,780	5,641
May	4,077	88	- 1,870	5,859	10,429	318	950	9,161
June	8,112	90	1,740	6,282	13,371	364	3,740	9,267
July	26,201	415	18,800	6,986	40,417	1,480	23,780	15,157
Aug.	43,907	2,831	25,510	15,566	62,041	7,090	26,130	28,821
Sept.	26,704	6,477	7,710	12,517	31,312	14,069	- 520	17,763
Oct.	12,002	7,068	- 3,150	8,084	6,921	11,755	- 4,890	56
Nov.	4,347	4,596	- 9,460	9,211	1,788	6,318	-11,460	6,930
Dec.	1,878	2,954	- 7,690	6,614	1,020	3,993	- 7,840	4,867
Total	130,459	26,844	8,770	94,845	169,816	49,864	5,620	114,332
(m^3/s) Mean	357.4	73.5	24.0	259.9	465.3	136.6	15.4	313.2

I : Inflow (including precipitation on Lake)
O : Outflow
S : Storage
E : Evaporation and Infiltration

Table 5-2-14 Monthly Mean Temperature

Station : Bahar Dar

N : 11°36'
E : 37°25'
EL : 1,802 m

(Unit: °C)

Year	Jan.	Feb	Mar.	Apr.	May	June.	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1961	18.1	19.0	18.4	18.8	20.6	19.8	18.2	17.4	18.3	18.6	18.4	17.0	
1962	-	-	-	-	-	-	19.3	18.2	18.4	18.1	18.0	16.7	
1963	16.1	17.3	19.0	19.4	20.1	19.4	-	18.7	18.8	18.8	18.9	15.9	
1964	17.0	17.8	19.9	20.0	20.6	19.2	18.2	18.1	18.4	18.1	16.8	15.5	
1965	15.4	17.8	20.3	21.0	21.9	21.0	18.8	18.3	18.5	18.8	18.3	15.7	
1966	16.7	-	20.1	20.4	21.2	19.4	19.5	18.4	18.7	19.2	18.2	15.5	
1967	15.1	16.8	19.0	19.5	20.2	19.8	17.8	17.8	18.5	18.1	17.2	15.1	
1968	15.3	14.8	18.4	19.1	20.8	19.3	18.5	18.8	18.8	16.2	-	15.0	
1969	18.4	17.8	21.1	21.4	21.8	21.0	18.3	18.4	19.0	18.9	17.9	16.3	
1970	15.3	18.0	19.6	21.5	21.5	20.4	18.1	18.4	18.5	18.8	16.6	18.2	
1971	15.6	20.4	19.6	20.5	21.1	19.4	18.1	18.1	21.7	19.0	18.0	14.8	
1972	17.0	16.9	20.1	20.9	21.6	19.7	18.8	18.6	18.5	19.4	19.0	17.5	
1973	17.1	19.0	22.5	23.4	21.3	19.7	18.4	18.1	18.5	19.0	18.1	15.2	
1974	17.0	19.3	19.6	21.5	20.4	19.0	17.7	18.2	17.9	18.0	15.1	14.5	
1975	15.0	18.6	19.6	18.8	19.7	18.2	17.1	16.6	17.1	17.3	16.1	14.7	

Table 5-2-15 Relative Humidity

Station : Bahar Dar

(Unit: %)

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1961	73	55	48	-	-	65	-	85	80	74	73	75	
1962	68	57	52	49	60	68	66	71	66	66	71	65	
1963	65	58	50	60	69	72	-	83	79	70	73	64	
1964	61	56	47	49	59	75	78	79	76	72	65	65	
1965	61	56	53	50	46	61	78	79	75	73	70	67	
1966	64	-	56	52	50	48	79	81	79	44	45	55	
1967	54	53	57	52	57	49	84	85	39	72	74	48	
1968	59	44	44	44	58	40	81	81	78	70	66	62	
1969	65	47	55	54	60	45	82	83	78	67	61	58	
1970	60	57	50	49	54	69	80	82	78	74	64	62	
1971	61	53	44	47	58	73	81	82	78	72	66	62	
1972	60	54	46	49	53	69	79	79	76	68	66	62	
1973	56	46	44	47	65	74	80	82	80	70	65	56	
1974	57	51	48	44	68	75	80	81	71	70	61	62	
1975	53	52	53	42	54	74	82	85	80	71	64	63	

Table 5-2-16 (1) Sunshine Hours

Station : Bahar Dar

Year : 1975 (Unit: hour)

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	-	-	-	10:10	11:55	11.00	5:30	2,05	6:40	6:05	8:30	10:15
2	-	-	-	10:37	11:20	8:35	6.40	6:30	0.00	9:50	8:37	10:15
3	-	-	-	10:41	11:15	7:50	6:25	3:15	5:23	7:40	10:40	10:13
4	-	-	-	10.41	11:10	3:25	4:25	0:00	7:50	10.00	10:50	10:30
5	-	-	-	10.37	11:10	4:15	4:30	0:50	5:30	9:30	10.00	10:15
6	-	-	-	10:36	11:28	3:20	4:25	4:45	5.00	10:35	8:45	9:30
7	-	-	-	8:56	8.03	8:21	4:30	2:55	4:40	9:50	10:35	9:00
8	-	-	-	10:45	8:15	4:37	6:00	6:40	5:43	7:05	10:20	6:47
9	-	-	-	10:46	6:40	8:35	5:47	0:15	3:30	7:20	10.35	9:20
10	-	-	-	10:42	8:18	7:17	4:25	1:27	0:36	8:40	10.45	8:47
11	-	-	-	10:50	9:05	10.50	3:30	3:50	2:43	10:35	10:40	8:30
12	-	-	-	11:00	10:30	7:40	7:45	5:25	6:07	4:10	10:32	7:50
13	-	-	-	9:38	11.05	10:00	6:15	6:07	6:07	4:40	10.30	10:10
14	-	-	-	10.55	10.58	9:50	5:30	1:35	7.00	9:00	9:30	10:17
15	-	-	-	10:50	10:45	7:30	4:35	2:20	6:57	10:05	8:40	10:15
16	-	-	-	11:15	9:23	8:15	2:10	2:30	0:50	10.50	9:32	10:15
17	-	-	-	11:43	7:47	4:52	5:10	5:47	3:53	11.02	9:50	9:45
18	-	-	-	4:41	8:32	2:55	6:30	6:20	7:23	10.55	10.42	10:20
19	-	-	-	9:19	7:35	6:00	6:40	5:23	2:20	10:37	8:50	10:05
20	-	-	-	9:45	7:00	5:05	7.45	8:50	6:50	9:15	8.07	10:10
21	-	-	-	11:11	7:50	5:30	5:23	3:30	7:10	8:45	6:30	10.02
22	-	-	-	10:30	10:42	2:35	6:17	2:35	7:07	10:20	10:15	9:45
23	-	-	-	10·25	11:10	2:20	9:17	5:25	6:10	10:20	10:35	8:57
24	-	-	-	11:19	5:25	5:40	4:32	4:45	7:53	10:00	10:45	8:25
25	-	-	-	11:18	11:18	5.00	8:20	3:37	4:47	10:35	10.35	10.00
26	-	-	-	11:30	8:58	3:35	6:35	7:50	7:27	10:37	10:35	10:27
27	-	-	-	11:35	9:47	3:10	4:50	6:12	7:40	10:17	10:40	10.50
28	-	-	-	5:15	10:59	7:17	2:27	2:20	7:27	10:25	10:37	10:17
29	-	-	-	8 05	6:02	6:10	3:20	0:17	6:13	10:35	10:30	9:50
30	-	-	-	11:05	7:00	5:35	0:00	5:23	6:47	9:40	10:30	9.18
31	-	-	-	-	6:55	-	1:20	2:50	-	8:35	-	8:20
Average	-	-	-	10:13	9:58	6:14	6:11	3:55	5:27	9:54	9.56	9:38

Table 5-2-16 (2) Sunshine Hours

Station : Bahar Dar

Year : 1976 (Unit: hour)

Date	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	10:17	10:17	6:04	9:37	6:34	8:21	4:05	-	-	-	-	-
2	10:13	10:10	9:13	10.20	1:40	8:43	8:27	-	-	-	-	-
3	10:07	6:50	7·30	10:13	10:10	8:42	6:37	-	-	-	-	-
4	10:17	6:13	6:17	8:33	10:10	8:20	9:00	-	-	-	-	-
5	10.20	10.17	6·17	0:00	10:23	7:54	5:30	-	-	-	-	-
6	10:00	10:23	10.30	4:37	11:19	7:10	6:30	-	-	-	-	-
7	10:20	9:13	10.00	8:27	10:32	5:36	6:00	-	-	-	-	-
8	10:07	10:20	7:03	7:03	8·43	6:23	1:17	-	-	-	-	-
9	10:10	10.03	10.40	9.37	4:51	5:23	5:05	-	-	-	-	-
10	10.23	10.27	10:30	11:10	7:41	7:55	5:35	-	-	-	-	-
11	8:40	10.23	7:13	11:17	8:39	7:06	6:13	-	-	-	-	-
12	10:00	10.17	8:27	11:07	6.48	7:25	7:10	-	-	-	-	-
13	10:30	10.20	9 00	0:00	5:55	9:36	9:07	-	-	-	-	-
14	10:33	10.13	9 40	5.20	11:00	5:48	8.20	-	-	-	-	-
15	10:27	0·00	9.50	11:13	2:59	5:27	6:13	-	-	-	-	-
16	10:27	10 40	10:17	11:23	3:45	6:24	4:04	-	-	-	-	-
17	10.20	10:33	9:50	11:10	2:36	8:18	4:05	-	-	-	-	-
18	10.23	10.40	9:30	10:05	8:15	8:00	5:33	-	-	-	-	-
19	10.20	10:40	10:30	10:13	8:06	6:06	4·07	-	-	-	-	-
20	10:23	10.40	10:10	9:04	10.10	5:37	2:23	-	-	-	-	-
21	9:30	10 03	9:13	11:07	9:41	6:05	5:03	-	-	-	-	-
22	10.27	10.20	9.05	11:07	7:38	5:06	4:27	-	-	-	-	-
23	10.36	9:30	7:00	10:40	7:40	9:32	5:00	-	-	-	-	-
24	10.30	6:27	9:33	11:10	8:43	5:47	0.20	-	-	-	-	-
25	10:13	9:00	8:27	11:17	4:53	6:28	2:23	-	-	-	-	-
26	9:19	10.43	9:37	11:00	7:00	7:40	6:07	-	-	-	-	-
27	10:36	10:36	10:27	10.20	10:36	0:00	7:07	-	-	-	-	-
28	10:20	9:27	9:46	11:27	8:38	0:00	8:27	-	-	-	-	-
29	10 27	5:36	7:40	11:20	7:54	4:49	8:13	-	-	-	-	-
30	10:17	-	10:36	11:10	8:39	6:24	5:17	-	-	-	-	-
31	10:20	-	10:10	-	10.57	-	2·00	-	-	-	-	-
Average	10:13	9.59	9:02	9:22	7:50	6:32	6:29	-	-	-	-	-

Table 5-2-17 Maximum possible number of hours of sunshine per day

Month	Sunrise		Sunset		Possible number	
	h	m	h	m	h	m
Jan.	6	21	17	57	11	36
Feb.	6	20	18	08	11	48
Mar.	6	06	18	11	12	05
Apr.	5	50	18	10	12	20
May	5	39	18	14	12	35
June	5	39	18	21	12	41
July	5	46	18	26	12	40
Aug.	5	51	18	18	12	27
Sept.	5	50	18	01	12	11
Oct.	5	49	17	43	11	54
Nov.	5	55	17	35	11	40
Dec.	6	08	17	42	11	34

Table 5-2-18 Wind Speed Station : Bahar Dar

At 2 m above ground (Unit: m/s)

Year		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1964 to 67	6:00	4-6	1-3	4-6	1-3	1-3	1-3	1-3	1-3	1-3	1-3	1-3	4-6
	12:00	4-6	4-6	7-10	7-10	4-6	4-6	4-6	4-6	4-6	4-6	4-6	4-6
	18:00	4-6	4-6	4-6	4-6	4-6	4-6	4-6	4-6	4-6	4-6	4-6	4-6
	Weight Av.												
1970	6:00	0.2	0.5	0.6	0.8	0.6	0.6	0	0.4	0.1	0	0.1	0
	12:00	5.2	7.4	6.0	6.7	6.4	5.4	2.3	4.0	4.8	4.4	6.4	5.1
	18:00	1.1	1.9	3.5	5.3	2.5	2.5	2.5	3.9	3.5	5.1	3.0	2.1
	Weight Av.												
1971	6:00	0	0	0	0.1	0.3	0	0.1	0	0	0.3	0.5	0
	12:00	6.1	5.6	6.0	6.2	5.4	3.8	3.5	3.7	3.7	4.5	4.5	4.5
	18:00	3.6	3.5	5.2	6.9	5.9	3.8	4.6	4.2	1.5	2.2	2.5	1.5
	Weight Av.												
1972	6:00	0.3	0.7	0	0.7	0.1	0.7	0.1	0	0	0.1	0.4	0
	12:00	4.8	5.2	5.9	5.6	5.7	5.2	3.4	3.2	4.3	4.7	4.3	5.2
	18:00	1.3	3.9	4.5	3.7	5.0	2.4	3.4	2.4	3.6	0.8	1.7	1.8
	Weight Av.												
1973	6:00	0	0.1	0.3	0.8	0.7	0.6	0.4	0.3	0.1	1.6	3.4	1.2
	12:00	4.4	6.7	5.2	6.0	4.3	3.7	3.3	4.5	5.0	6.2	7.2	8.2
	18:00	3.0	3.2	4.2	4.7	5.0	5.5	2.8	3.5	2.9	3.0	2.9	1.9
	Weight Av.												
1974	6:00	2.7	1.1	1.3	0	0	0.4	0	0	0	1.6	0.8	0
	12.00	6.3	7.0	7.6	8.1	6.1	4.8	3.9	4.8	5.0	6.5	8.3	8.3
	18:00	3.1	3.6	6.8	5.0	4.9	4.8	4.0	4.7	5.2	1.4	2.4	2.2
	Weight Av.												
1975	6:00	0	0	0	0.1	0.3	0.2	0.4	0.2	0	0.2	0.6	0
	12:00	8.0	6.9	8.1	10.0	8.5	5.2	4.0	2.9	4.0	5.2	7.5	6.6
	18:00	3.7	5.2	6.5	8.2	8.2	4.7	5.4	3.1	2.2	2.1	3.2	1.5
	Weight Av.	4.93	4.75	5.68	7.08	6.38	3.73	3.45	2.28	2.55	3.18	4.70	3.68

Table 5-2-19 Short-wave radiation flux at the top of the earth's atmosphere in cal. cm^{-2}. day^{-1} as a function of the month of the year and the latitude.

Month	Geographical latitude (degrees)																		
	North										South								
	90	80	70	60	50	40	30	20	10	0	10	20	30	40	50	60	70	80	90
Jan.	0	0	0	90	225	380	520	660	780	885	965	1020	1050	1055	1035	1000	1000	1035	1055
Feb.	0	0	70	215	360	505	630	750	840	915	960	975	965	925	865	785	695	645	660
Mar.	40	125	275	425	555	675	775	850	900	925	915	885	830	740	640	510	375	225	135
Apr.	470	480	565	670	750	845	895	920	925	900	840	765	665	545	415	280	130	15	0
May	900	890	855	890	930	965	975	960	915	850	755	650	525	390	250	110	10	0	0
June	1085	1075	1025	1000	1010	1020	1000	965	900	820	710	590	460	315	180	55	0	0	0
July	1010	995	945	945	970	985	990	960	905	830	730	615	480	345	205	75	0	0	0
Aug.	670	660	685	770	830	895	925	935	915	870	795	705	595	465	325	190	55	0	0
Sept.	170	255	385	510	640	740	820	875	905	905	875	820	750	650	525	390	250	100	15
Oct.	0	25	145	285	435	565	685	785	865	910	935	930	900	840	760	660	550	450	440
Nov.	0	0	15	120	265	415	560	685	800	890	955	1000	1020	995	975	920	885	905	920
Dec.	0	0	0	60	190	335	490	630	760	875	960	1025	1065	1080	1075	1060	1090	1140	1160

Compiled from data given by N. Robinson "Solar Radiation" 1966 and Sir Napier Shaw "Manual of Meteorology", vol II "Comparative Meteorology", 1928, Value of the solar constant: 2.0 cal. cm^{-2}. min^{-1} I. P. S. 1956.

CHAPTER 6

GEOLOGY

CHAPTER 6 GEOLOGY

6.1 SUMMARY

6.1.1 Method of Investigation

In order to understand the outline of geological conditions of the project area, published geologic maps [1], [2], [3], morphological maps [4], topographic maps [6] and literatures 2), 5), 7) were used as references.

Based on this understanding, engineering geological investigations required for Lake Tana flood regulation and electric power development were carried out regarding foundations of civil or electrical structures and natural construction materials for civil structures. The investigations consisted mainly of field surveys with excavation works - test pits, core borings - and especially, with regard to the damsite, permeability tests and, with the cooperation of the Civil Engineering Laboratory of EELPA, soil tests were performed as necessary. Further, photo-geological interpretations were done at the sites of major structures and their surrounding areas.

Geologic maps were prepared for the damsite, borrow area and Tis Abbay No. 2 Power Station site. In addition to the investigations mentioned above, microscopic examinations and brief laboratory tests of rocks were performed. An outline of geological investigations made up to the present is given in Table 6.1.

Field geological investigations were carried out in both the dry and rainy seasons of 1976, and interim reports were submitted to EELPA each time.

6.1.2 Findings and Considerations from Viewpoint of Engineering Geology

Summarizing the findings from the viewpoint of engineering geology with regard to this porject is described below.

1) Two locations, an upstream site and a downstream site, were investigated with respect to a damsite, and it was determined that the downstream site located immediately by National Route No. 3 is far superior concerning river handling, handling of the reef comprising the right bank, and transportation of construction materials.

2) The riverbed at the upstream site presently hinders smooth flow of the mainstream of the river. In order to secure the required flow in the dry season, reforming of the river channel will be necessary over a fairly wide area. Bedrock is widely exposed in this area and there are also some deposits of huge boulders.

3) Soil material required for the dam may be collected from the vicinity of the damsite. This material which is residual soil of basalt is of good quality, while the quantity available is also ample. Boulders found in the vicinity of

the damsite may be utilized as rock materials, but it is also possible to use fresh and hard basalt from the rock quarry where coarse aggregate for concrete is to be obtained. Sand is to be collected in the vicinity of Gorgora at the north shore of Lake Tana and transported by boat to Bahar Dar.

4) The site for Tis Abbay No. 2 Power Station has been selected at a location which is topographically the best in the narrow gorge. The foundations of the powerhouse and penstock will be located on fresh, hard basalt as in the case of the existing power station. The headrace will pass through a broad, flat area. This flat area, judging from the geological condition of the cliff on the Blue Nile side and of the existing channel, probably possesses adequate bearing capacity for the planning headrace waterway.

5) The geology along the 66 kV transmission line route is good as a whole. Lines will be supported most of the way by wood poles, but steel towers are to be provided on both sides of the Blue Nile crossing and at mountainland northwest of Addis Zemen. As a result of the examination of test pits excavated at the Blue Nile crossing, it is thought the ground can adequately support steel towers. Hard basalt is exposed widely at the mountainland northwest of Addis Zemen. There are distributions of thick talus deposits and terrace deposits at the Gondar side of this mountainland with spots where landslides or collapses might occur. Consequently, taking account of the occurrence of such thick overburden, the route of the transmission line should be selected.

For implementation of this project, it will be necessary to additionally carry out the following investigations.

1) The geological conditions of the foundations for concrete structures at the proposed damsite (downstream site) should be carefully investigated.

2) Soil tests are to be carried out on soil materials. As for sand material, the vicinity of the damsite is to be investigated in an effort to discover sand deposits.

3) Although the foundations for Tis Abbay No. 2 Power Station and the penstock will be located on good quality basalt, since excavation for the powerhouse foundation will be to a depth lower than the water level of the Blue Nile, core boring and permeability tests are to be carried out to study the amount of seepage water during construction. Further, the geological condition of the penstock shaft is to be explored by core boring.
The geology of the waterway route is to be checked by test pits. Since this route passes through the housing area of employees and the vicinity of the existing switchyard, thorough examination is to be made whether blasting will be required for excavation.

4) Thick talus deposits and terrace deposits cover a fairly wide area at part of the mountainland northwest of Addis Zemen and there is a possibility of landslides or collapses occurring. Accordingly, in order to secure the safety of the planned transmission line route, it is necessary for thorough care to be exercised in selection of the route.

Table 6-1 Principal geological works carried out

Geological mapping

Site	Scale	Remarks
Dam	1 : 2,500	Dwg. No. 11
Tis Abbay No. 2 PS	1 : 200	Dwg. No. 14
Borrow area	1 : 1,000	Dwg. No. 13

Test pit

Site	Number of pits	Length of pits (m)	Remarks
Proposed dam site	2	4.3 *	Dwg. No. 12
Alternative dam site	3	4.2	Dwg. No. 12
Sub total	5	8.5 *	
Borrow area	5	15.0	Dwg. No. 13
Total	10	23.5 *	

* including tube penetration of 1.2 m deep

Core boring

Site	Number	Length (m)	Remarks
Proposed dam site	10	154.29	Dwg. No. 12

Soil testing

Site	Sampling location**	Case	Remarks
Proposed dam site	3	21	Table 6-2
Alternative dam site	2	14	Table 6-3
Total	5	35	

** Sampled from test pit

6.2 REGIONAL GEOLOGY

6.2.1 General Description

The landform of Ethiopia according to W. M. Mesfin[5] may be broadly divided into the three physiographic regions below and as indicated in Fig. 6-1.

I. Northwestern highlands and associated lowlands

II. Southeastern highlands and associated lowlands

III. Ethiopian Graben, or Rift Valley

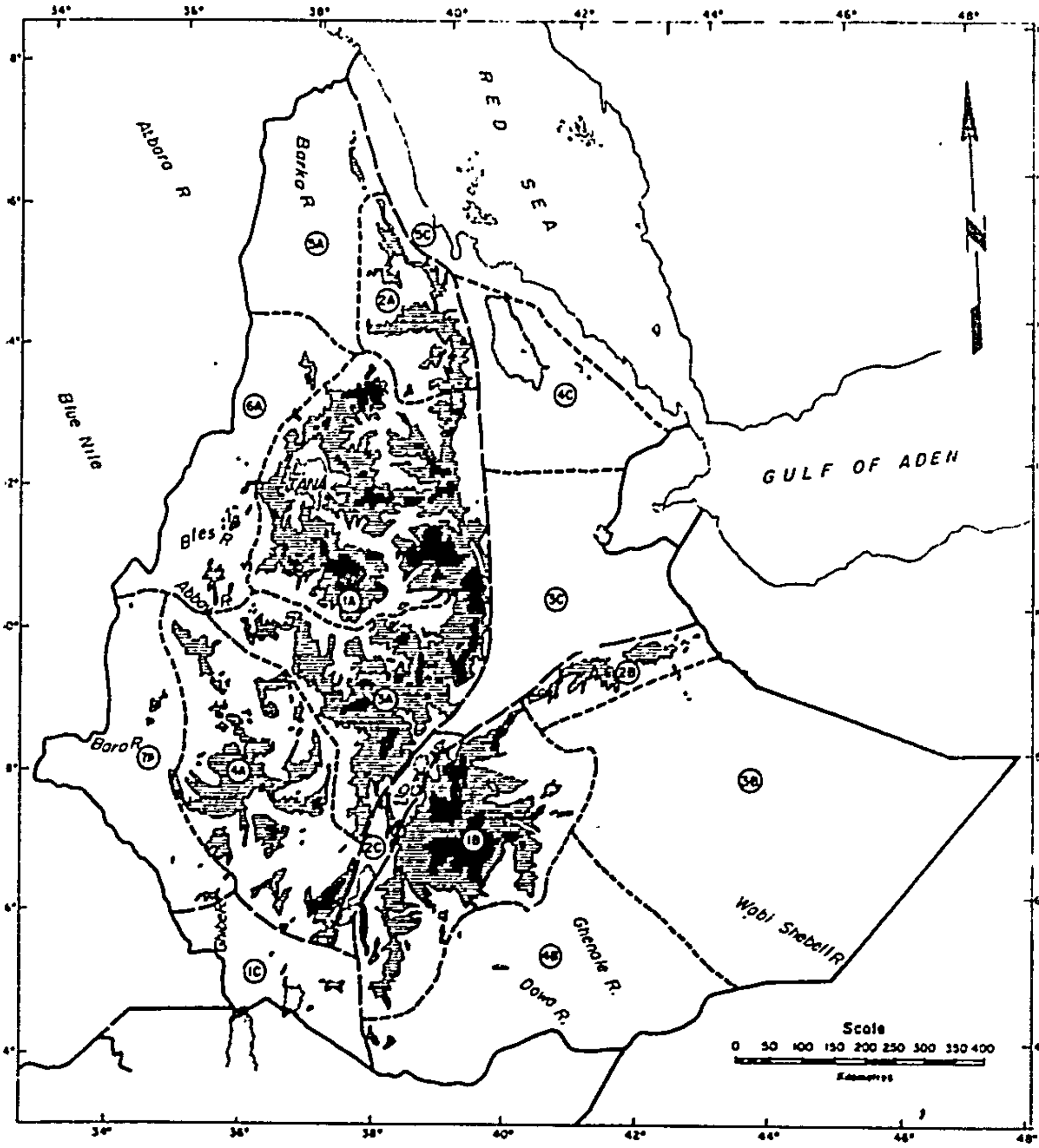
The Northwestern Highlands Region is comprised of plateaus of elevations from 2,000 m to 3,000 m and lowlands of river valleys dissecting the plateaus. There are mountain masses of elevation of 4,000 m and higher at the middle part and along the Ethiopian Graben comprising the eastern fringe, but the elevation gradually drops to the west in a transition to the plains of the White Nile. Meanwhile, the northern part of the highland is across the upstream plain of the Atbara River, a tributary of the Nile, and reaches out the coastal plain of the Red Sea, while the southern part of it reaches to the south end of the Ethiopian Graben. The rivers dissecting this plateau are short at the eastern side with gradients being steep as with rivers at the central part, whereas at the western part the river flows are long, and streams with large catchment areas such as the Atbara River and the Blue Nile flow down toward the White Nile.

The Southeastern Highlands Region faces the southern part of the Northwestern Highlands Region from across the Ethiopian Graben. The stretch of the Southeastern Highlands Region along the Ethiopian Graben is a continuous mountain range of elevation of 2,000 m or more with the center portion reaching as high as 4,000 m. A plateau of elevation under 2,000 m spreads out at the central and eastern part of this physiographic region with deserts formed in some parts. Long rivers, the Dowa, Ghenale and Wabi Shebella flow down this plateau in a southeasterly direction.

The Ethiopian Graben which runs roughly NNE-SSW divides the landform of the national territory into two. The Awash River runs down to the northeast in this graben, while at the southern part of the graben there are numerous lakes formed such as Ziway, Langano, Abiyata, Abaya and Chew Bohir.

The project area is at the northwest part of the Northwestern Highlands Region and is comprised of the source of the Blue Nile, Lake Tana and its surrounding area.

The distribution of rocks comprising the land is indicated in Fig. 6-2. According to V. Kazmin[2] and W. M. Mesfin[5], the oldest rocks are Precambrian sedimentary, effusive and intrusive rocks. These rocks have been subjected to metamorphism to a high or low grade, and are schists, gneiss or granite. Paleozoic rocks covering this basal complex were eroded to a great extent due to block uplift, but since there was a change to submersion in the Mesozoic Era, neritic sediments such as sandstone, mudstone and limestone were formed. Next, at the initial stage



From Mesfin W.M (1972) An introductory geography of Ethiopia

EXPLANATION

I NORTHWESTERN HIGHLANDS AND ASSOCIATED LOWLANDS
- (1A) The North-Central Masefs
- (2A) The Tigrean Plateau
- (3A) The Shewan Plateau
- (4A) The Southeastern Plateau
- (5A) The Barka Lowlands
- (6A) The Anghrib Lowlands
- (7A) The Baro Lowlands

II SOUTHEASTERN HIGHLANDS AND ASSOCIATED LOWLANDS
- (1B) The Ares - Bale Masefs
- (2B) The Harar Plateau
- (3B) The Shebelle Plain
- (4B) The Ghenale Plain

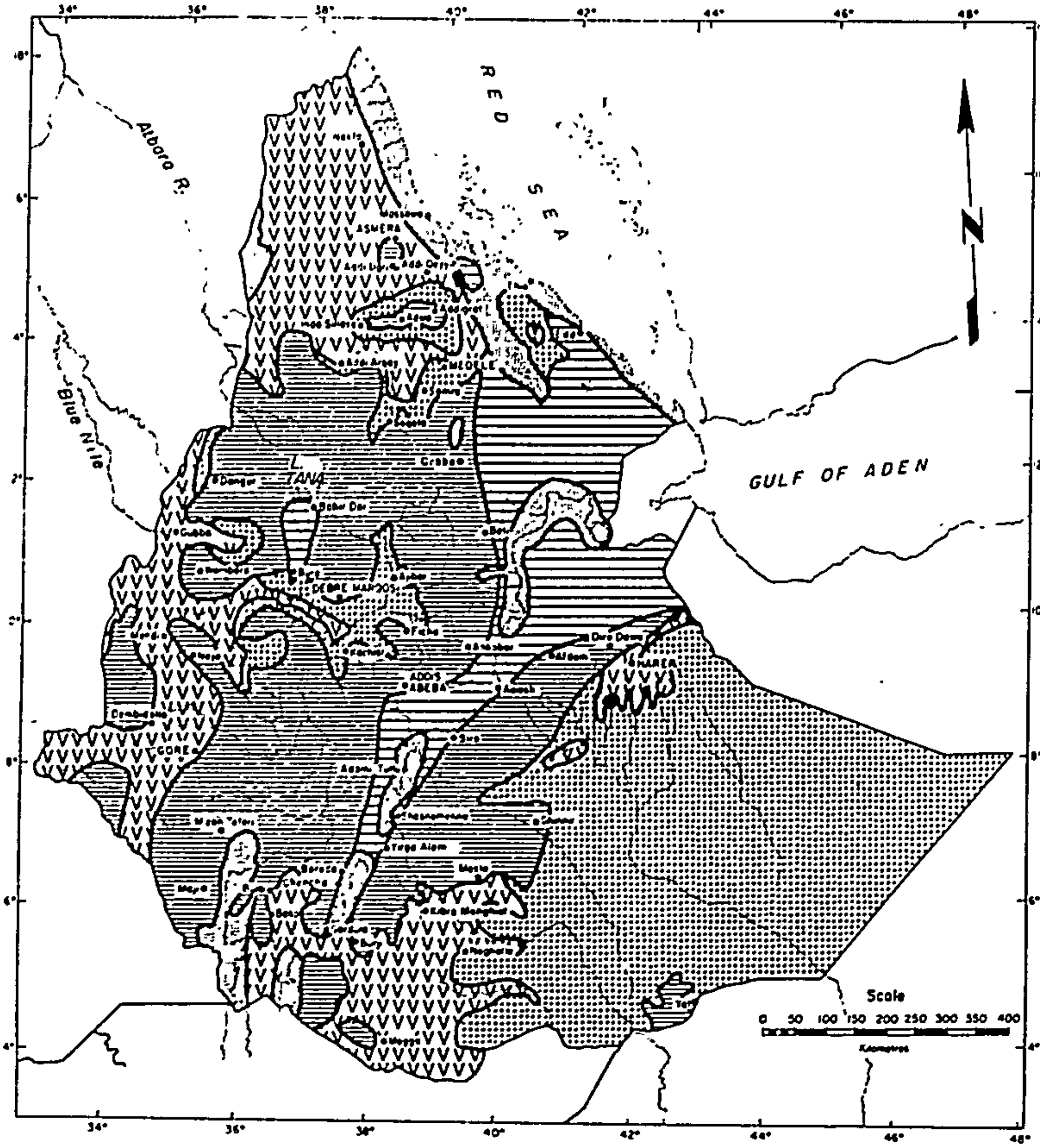
III THE ETHIOPIAN GRABEN OR RIFT VALLEY
- (1C) The Ghibe Trough
- (2C) The Lakes' Region
- (3C) The Awash Valley
- (4C) The Afar Depression
- (5C) The Coastal Plains

Elevation in metres

Over 4000
3000-4000
2000-3000
Below 2000
Below Sea Level

Fig. 6-1

PHYSIOGRAPHIC REGIONS OF ETHIOPIA



From Mesfin W.M. (1972) An introductory geography of Ethiopia

EXPLANATION

- VV Old Crystalline Rocks (Schists, Granite, Diorite)
- Old Marine Sediment (Sandstone, Limestone)
- Tertiary Trappean Lava
- Quaternary Lava (Aden Series)
- Quaternary Marine or Lacustrine Sediment (Mud, Sand, Clay)

Fig. 6-2

GEOLOGIC MAP OF ETHIOPIA

of the Cenozoic Era, fracturing occurred widely, and along with faulting, volcanism was occured in a vast area and there was eruption of a tremendous amount of basaltic lava - plateau lava. Following this, accompanying the diastrophism which formed the major tectonic lines including the Ethiopian Graben, volcanic activity again became prominent and numerous yonger volcanos comprised of olivine basalt emerged. The project area is at the northern part of the plateau basalt and the damsite and Tis Abbay No. 2 Power Station are located in a zone of younger volcanic rocks.

6.2.2 Types and Stratigraphy of Rocks and Deposits

The distributions of rocks and deposits comprising the project area are indicated in Fig. 6-3. Of these, the basement of the project area consists of basalt and tuff belonging to the Ashangi Group which is most widely distributed. These rocks, consisting of dark coloured, very hard and dipped lava flows, can be observed at the mountainland, northwest of Addis Zemen, numerous quarries along National Route No. 3, and cuts along roads in the vicinity of Gondar Airport.

Overlying these rocks there is a complex consisting of basalt, tuff and agglomerate belonging to the Shield Group, and younger olivine basalt which is distributed from the southern area of Lake Tana and along the Blue Nile.

The complex of the Shield Group forms several mountains such as Candah, Choke and Mangestu from the east to the south of Lake Tana more than 40 km away from the lake.

The younger basalt mass is being applied to the foundations of the dam and Tis Abbay No. 2 Power Station and to construction materials. This mass consists of a dark-colored, hard, thick formation observed at the river channel of the Blue Nile which forms a long, narrow gorge from Tis Issat Falls above Tis Abbay Power Station to the downstream area and quarries in the outskirts of Bahar Dar, while alternations of thin lava and mud flows are found in core borings at the damsite. The thick lava was formed as a result of several eruptions and the interior of the lava flow is massive, hard and uniform with few fissures, but the surface and bottom are vesicular in many parts. The thickness of a single lava layer is from less than 1 m to around 10 m and layers lie one on another with very gentle dipping in general. A microphotograph of younger basalt rock is shown in Photo. 6-1 along with an example of the condition of holes in vesicular basalt. The specific gravity and absorption of younger basalt is also given.

Covering this basaltic complex, there are wide distributions of Quatenary deposits of sand, silt, clay and mixtures of these with gravel at the middle and downstream areas of the Ribb River south of Addis Zemen and the north shore of Lake Tana. Areas close to the lake strand are swamps where highly plastic clay is deposited.

6.2.3 Geologic Structure

The formation of Lake Tana is said to have been the result of submersion or depression due to Quatenary diastrophism, and as indicated in Fig. 6-3, faults as if to surround the lake have either been recognized or assumed to exist. Presuming the lake as an origin of coordinate deviding into four quadrants and looking at the pattern of faults, there are the tendencies as indicated in the table below.

Quadrant	Tendency of strike of fault
I	Mainly N-S. However, E-W in southern marginal area.
II	NNE-SSW near Lake Tana. However, E-W in northern marginal area.
III	Faults rare in youger basalt, but indicate NNE-SSW trend in Ashangi Group.
IV	Concentric fault group parallel to coast line of Lake Tana and NNW-SSE to NW-SE faults crossing perpendicular to concentric group.

Of these faults, some of those west of Gondar Gorgora cut Quatenary deposits indicating there had been diastrophism up to a younger geological age.

6.2.4 Mineral Resources and Earthquakes

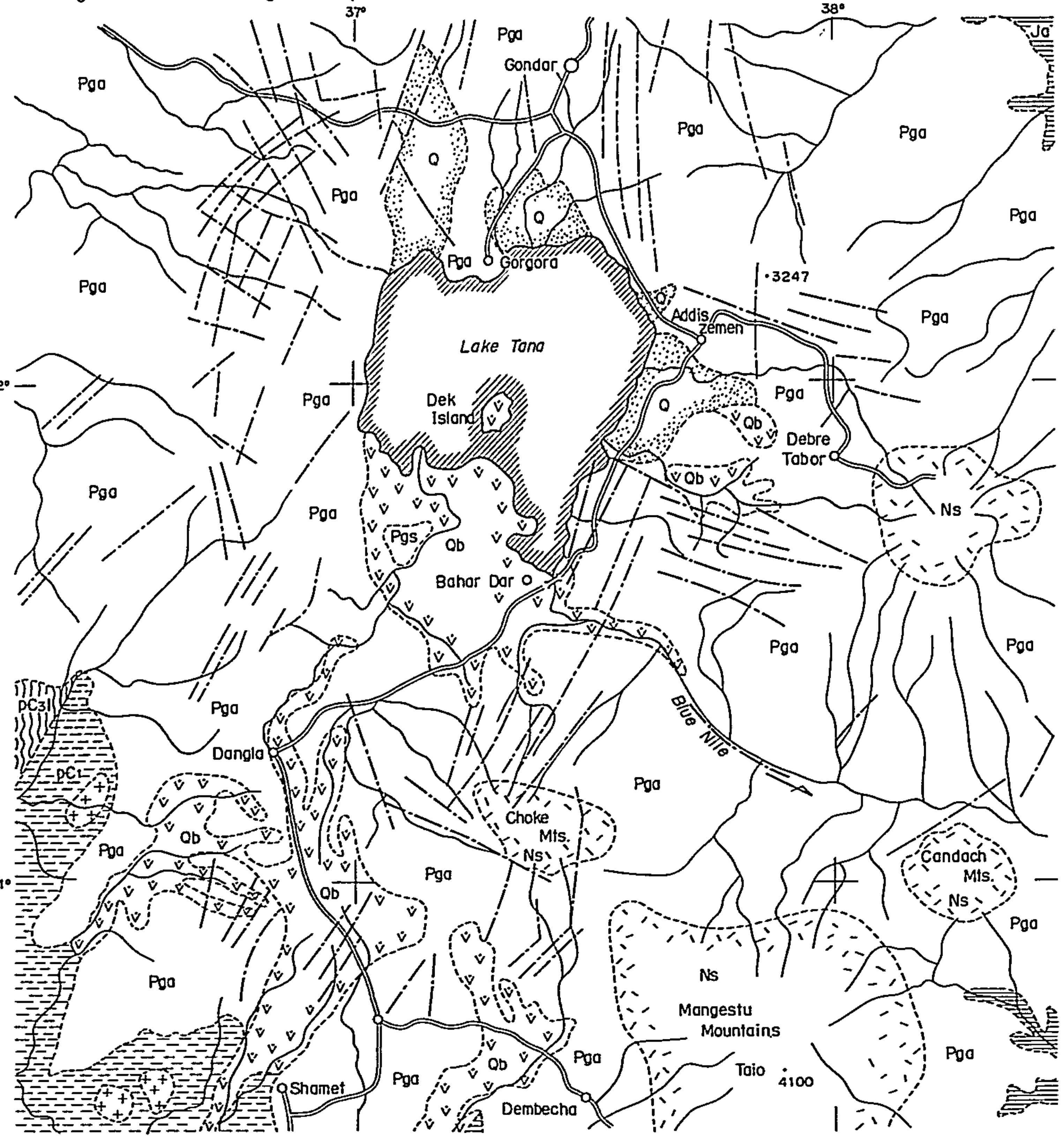
(1) Mineral Resources [7)]

It is looked forward to that there are mining resources in the project area and investigations are being carried out. Resources confirmed up to the present are coal and lignite, outcrops of which can be seen in the vicinity of Chelga 35km from Gondar along National Route No. 21 (Gondar Mettema). The area of the coal-bearing lacustrine deposits in estimated to be 15km^2 and that of lignite-bearing deposits more than 3km^2, and with further progress in the investigations, the reserves should become more accurately known, but it is expected there will be lignite deposits of approximately 150,000 m^3.

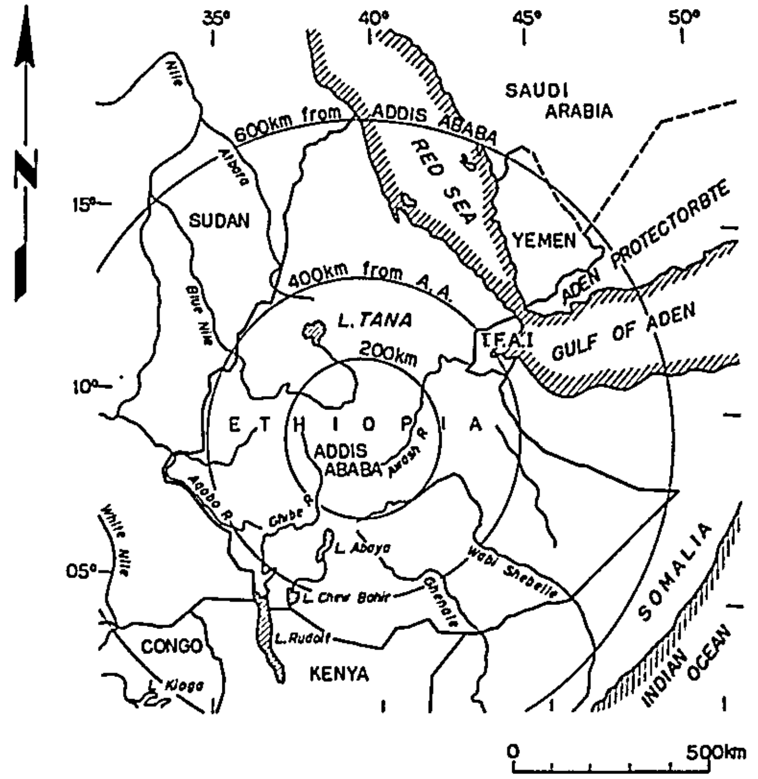
(2) Earthquakes

According to data of M. Barazani and J. Dorman (1967), there are no records of earthquakes of M (magnitude) $\geqq$ 4 and depth of focus more than 100 km in Ethiopia and the surrounding area during 1961 to 1967, but there has been a fairly large number of earthquakes of M $\geqq$ 4 and less than 100 km in depth at the Red Sea, Gulf of Aden and the Ethiopian Graben. However, the project area including Lake Tana has been subjected to Quatenary diastrophism, but there are no known active volcanos or hot springs, and it is assumed that the area is where the earth crust is stable. It may be considered from the fact that stone buildings in the ancient capital of Gondar have retained their original forms to a great extent is proof that large-scale earthquakes have not occurred.

Fig. 6 - 3 Geologic Map of Lake Tana and its surrounding



Index map



LEGEND

Cenozoic
- Q: Quaternary deposits; Gravel, sand, silt, clay
- Qb: Alkali olivine BASALT
- Ns: Alkali BASALT, TUFF, AGGLOMERATE (Shield Group)
- Pga: Alkali olivine BASALT and TUFF, rare RHYOLITE (Ashangi Group)

Meso-zoic
- Ja: Adigrat SANDSTONE (Antalo Group)

Precambrian
- + +: GRANITE; Past tectonic granitoid
- pC3l: CHLORITE SCHIST, QUARTZITE, Graphitic rocks, Intermediate metavolcanics. (Tsaliet Group)
- pC1: Lower complex undifferentiated

Fault

Remarks ;

This geologic map is cited from the essential part of GEOLOGIC MAP OF ETHIOPIA – Scale, 1:2,000,000 – by Ministry of Mines, ETHIOPIA (1973)

6.3 GEOLOGY OF REGULATING RESERVOIR AREA

The regulating reservoir of this project is Lake Tana itself. It is said that Lake Tana was formed as a result of submersion, warping or depression due to the Quaternary diastrophism, and the pattern of the faults drown in Fig. 6-3 substatiates this surmise. According to Dwg. 10, Lake Tana is extremely shallow, with the slope of the bottom especially gentle at the northeast and northwest parts of the lake. This is probably due to deposits at the lake bottom being thick at the northern part since the outlet of the water to the Blue Nile is at the southern part of the lake. The outlet to the Blue Nile at the south end was made by erosion of younger basalt which had dammed up the lake, and the width of the river is therefore narrow. Further, perhaps due to the location of the outlet having changed a number of times, natural levees of narrow widths have been formed, and due to downcutting by the river there are many locations where bedrock has been widely exposed at the riverbed. Since the area around the lake is of a low, flat topography, it becomes a flood plain of the rivers and streams feeding the lake during the rainy season. This flood plain remains in the form of swamps in the vicinities of the mouths of long rivers at the southern and eastern parts of the lake. Flood plains and the adjacent flat areas spreading out widely are larger at the southern and eastern districts around the lake whereas at the northeastern, southeastern and western districts there are mountain masses of elevation higher than 2,000 m which rise from comparatively narrow flatlands followed by hilly areas.

Flood plains and flatlands are mainly comprised of clay and silt, while at hilly areas there are distributions of residual soil of basalt and basaltic lava.

Whereas the rocks comprising the surrounding area of the lake are mainly basalts of the Ashangi Group, the rocks at the southern part of the lake and Dek Island are younger basalts. The highly viscous lava of the Ashangi Group forms volcanic plugs at places, while in the younger basalt area, a topography of volcanic craters remains such as at Dek Island.

Lake Tana and its surrounding area are not of a topography where leakage of storage water is feared, and soluble rock does not exist in the bedrock. The clay and silt covering the bedrock are essentially impervious and there is no permeable gravel layer. There are alternations of thin lava and mud flows at the younger basalts, and there is a fair degree of permeability around the ground surface, but according to the results of core boring and permeability tests at the damsite, permeability is decreased at deeper parts, and watertightness of the foundation can be secured with suitable waterproofing treatment where necessary.

Since the rise of water level caused by this project will be extremely slight, the problem of leakage of storage water will be greatly alleviated.

Since the elevation of the riverbed at the upstream damsite is slightly high for securing the required discharge in the dry season, reforming of the river channel will be required at this portion where bedrock is widely exposed. This bedrock has a large number of cracks and joints separating the rock into polygons, but the rock itself is hard basalt.

6.4 GEOLOGY OF DAMSITES

As damsites, the two sites, upstream and downstream, were selected and compared based on existing data and field reconnaissances. As a result of geological investigations including topographic examinations and test pits on the two sites, the downstream site was considered the proposed site and the upstream site the alternative site, and core borings are being carried out concentrated at the downstream site. As indicated in Dwg. No. 11, the damsites are in the vicinity of outlet of Lake Tana, that is, the upstream site is located approximately 1.2 km from Abbay Bridge while the downstream site is at a distance of 200 m from the bridge. The results of geological explorations carried out on the two sites are given in Dwg. 12. There is a natural levee of narrow width extending from the downstream site to the upstream site near the outlet of Lake Tana to separate the lake and the river channel leading to the Blue Nile.

6.4.1 Downstream Site [Proposed Site] (see Dwgs. 11 and 12)

The dam axis of this site is shown as A-A on Dwg. 11. Geological investigation works were carried out at the test pits excavated on the site to obtain data on the overburden of the land. These works were followed by core boring according to the following listed conditions assumed on the basis of the proposed dam and spillway location.

Name of hole	Coordinates X = Y =	Elevation of top of hole (m)	Direction	Length of hole (m)	Thickness of over-burden (m)
NB 1	1283 360 102 510	1,788.15	90°	16.26	10.17
NB 2	1283 315 102 495	1,782.35	do.	15.11	5.13
NB 3	1283 355 102 410	1,782.62	do.	15.17	8.27
NB 4	1283 320 102 375	1,783.45	do.	15.08	8.76
NB 5	1283 240 102 345	1,781.13	do.	15.31	3.07
NB 6	1283 305 102 315	1,782.44	do.	15.17	2.88
NB 7	1283 270 102 310	1,783.45	do.	15.15	5.53
NB 8	1283 295 102 300	1,782.67	do.	15.07	9.30
NB 9	1283 225 102 265	1,786.42	do.	15.55	0.44
NB 10	1283 190 102 210	1,787.73	do.	16.42	1.97

10 holes, 154.29 m in total

During the core boring, permeability tests were performed at all the holes (NB 1 - 10) and Standard Penetration Test (SPT) with the overburden at some selected holes (NB 2, 3, 4, 5, 6 and 7). The results of the geological investigation works are summarized on Dwgs. 12A and 12B.

On the other hand, soil tests were performed by EELPA using samples taken from the test pits. The results are shown in Table 6-2.

The left bank of the site is widely covered with topsoil, while bedrock is widely exposed at the right bank in the dry season. The dam axis is selected on Lower Reef avoiding the swamp where Test Pit No. 2 is located.

According to Table 6-2, the test data at NP-2 indicate the characteristics of marsh deposits which are fine grained, of high water content and low physical strength.

The data also show that the thickness of the deposit is not small. The swamp area around NP-2 was avoided for dam axis because of such unsuitable conditions.

Polygonal cracks with openings several centimeters or more in width are developed at the surface of the basalt exposed from the right river bank to Lower Reef giving an appearance of a stone pavement. Core borings NB 9 and NB 10 were drilled at Lower Reef to depths of approximately 15 m each and the findings were alternations of thin basaltic lava and brown or gray clay. These clays are thought probably to be volcanic mud flows. The results of permeability tests indicated fairly high permeability at a depth of 3.1 m at NB 9 and 3.2 m at NB 10, but the permeabilities are decreased at soil strata at greater depths. Casing tubes of drill holes were driven only to depths of 3.1 m and 3.2 m for NB 9 and NB 10, respectively. Consequently, it is thought the ground at greater depth is well consolidated, and it is estimated that excavation for the dam foundation will be approximately 3 m for the fill dam section when the proposed height and water level are taken into account. The water tables in drill holes were at a depth of 4.76 m (El. 1,781.66 m) for NB 9 and 2.35 m (El. 1,785.38 m) for NB 10. Since the proposed high water level is El. 1,787.5 m, the hydraulic head applied to the based by the impounded water will be small, but as the ground is comprised of clay and thin lava with many cracks it is thought necessary for suitable waterprofing treatment against high permeable portion.

It is desirable for the foundation of the concrete structure (spillway) to be placed on the thick lava flow. So the concrete structure is located near the strand of the right bank and investigations have been carried out by core boring of 5 holes. The results of investigation of these 5 bore holes show that thick lava flows are distributed to below the 3.1 m thick overburden at NB 5 and NB 6. Some portions of the lava flow have numerous cracks partially with clay intercalated. However, the site around NB 5 and NB 6 can be regarded as having enough to bear capacity for the designed structure, on the whole.

However, the area around NB 4 near the river center and that around NB 8 at the strand of the right bank encounter a thick and hard lava flow below the overburden approx. 9 m thick. The thickness of overburden at NB 7 is approx. 6 m. The portion below the overburden is covered partially with a 10 - 30 cm wide weathered and decomposed layer but a continuity of hard rocks is observed. At NB 4 and NB 7, Standard Penetration Test were made with the overburden. The data of the tests show that the N-value is in the 10 - 20 range for depths up to 2.5 m. But the measured values are considerably dispersed because of gravel and debris mixed in the overburden. At NB 8, penetration tests were performed in the deeper layer; N-values counted are approx. 50 - 80 at depths 3.77 - 4.22 m and approx. 60 at depths 7.01 - 7.03. The N-values tend to increase with depths but mixing of gravel and debris is expected because of the dispersion.

The results of permeability tests of rocks carried out on the proposed spillway site show high Lugeon's values when measured at a depth of approx. 3 m below the rock surface as identified by a Lugeon's value of 56 (converted value) at depths 6.21 - 8.97 m at NB 7. The values obtained inside the rock are found as small as approx. 2 - 15. Proper foundation treatment is required because the bedrock surface has numerous cracks with clay intercalated, thought the designed water pressure is not high. If it is difficult to remove all the thick overburden, special considerations will be required in design to aim at increasing the foundation bearing capacity and the stability of the structure.

The left bank at the site, according to the test data at NP 1, is covered with a silty clay layer with boulders. The results of core boring show that the overburden thickness is 5 - 6 m at NB 1 and NB 2 (right bank) and 8.3 m at NB 3 (riverbed). The rock below the overburden is hard at NB 2 and NB 3. It seems that, at NB 1, the layer at depths 8.7 - 10.1 m consists of gravel and the layer at depths 14.95 - 16.26 m consists of clay and sand intermixed with gravel. The results of permeability tests show 14 Lugeon's (converted) at the rock for NB 2 and 44 Lugeon's (converted) at the surface portion of the rock for NB 1. But the overburden deeper than 3 m seems well compact and has reasonable permeability. Thus the proposed site is considered having a satisfactory foundation for the fill dam under planning but the closest examination of ground conditions should always accompany with the embankment work.

6.4.2 Upstream Site [Alternative Site] (see Dwgs. 11 and 12)

The dam axis at this site is indicated as B-B on Dwg. 11. Three test pits have been excavated at this site and their geological logs are given in Dwg. 12. The results of soil tests conducted at EELPA using samples collected from the pits are shown in Table 6-3.

The left bank at this site is covered by silty clay intermixed with boulders, while outcrops of basalt with numerous cracks and separated along these cracks as well as boulder deposits are observed at the riverbed from upstream Chara Chara to the area around Fukur Island downstream of the dam axis. The flow of the mainstream near the dam axis is rapid as the water surface level is high because of the exposed bedrock and deposited boulders. At the right bank, the dam axis will be fixed to a natural levee —Upper Reef— which continues toward the downstream section, and this Upper Reef has deep channels at places eroded by running water. A number of the channels, as indicated in Dwgs. No. 11 and No. 12, are lower than the proposed high water level and it would be necessary to construct dikes. Boulders covering the surface of proposed dike sites should be removed prior to the construction of these dikes. Although there are outcrops of bedrock observed at the surface of Upper Reef, the width of the reef is narrow and it is thought the bedrock is loosened to a considerable depth. In case the bedrock is loosened the length of foundation treatment would be considerable since the crest of the dam will be long.

6.4.3 Comparison of Upstream and Downstream Sites

On comparison of the two sites from the viewpoints of topography and geology, the downstream site is superior to the upstream site for the reasons given below.

(1) The abutment at the left bank of the upstream site is of a topography that it protrudes toward the mainstream of the river, and since there are boulders deposited in the surrounding area, the distribution of basement strata to serve as the foundation is unknown. It is expected that the geology of the downstream site is that of well consolidated residual soil underlying silty clay intermixed with boulders.

(2) When constructing a dam at the upstream site it will be necessary to provide a number of dikes at Upper Reef which comprises the right bank of the Abbay mainstream. In addition, in case the permeability of the ground comprising the foundation of the dike is high, a long stretch of foundation treatment must be required.

(3) The upstream site has a rapid flow and has deposits of boulders so that river handling for construction of the dam will not be easy. In comparison, the downstream site has a river channel of suitable width and gentle flow, while deposits of boulders are extremely scarce and the configuration of the riverbed is superior to that of the upstream site. Furthermore, the small reefs scattered about can be utilized in handling of the river.

Table 6-2 (A)

Result of soil test in downstream dam site

ETHIOPIAN ELECTRIC LIGHT AND POWER AUTHORITY

CIVIL ENGINEERING DIVISION

MATERIALS TESTING LABORATORY

Plate 1 of 2

DATE RECEIVED. July 23rd, 1976

PROJECT. Lake Tana Regulation

SUMMARY OF TEST RESULTS

DATE REPORTED. September 21st, 1976

BY. Abayneh INESHESHA

Test pit NO.	Sample NO.	Depth cm	Natural water content %	Atterberg limits (Consistency)				Laboratory Proctor max. dry density		In-place density		Relative density %	Specific gravity	In-situ Unconfined strength		Direct shear tests			Permeability x 10 cm/sec	Mechanical sieve analysis (Passing U.S.STD. SIEVE %)					Soil classification
				L.L. %	P.L. %	P.I. %	S.L. %	Dry density gr/cc	Opt. moist. %	Dry density gr/cc	Opt. moist. %			Strength kg/cm²	Moist. %	Cohesion kg/cm²	Angle of internal friction	Water content %		Sieve #10 2.0 mm opening	Sieve #20 0.84 mm opening	Sieve #50 0.297 mm opening	Sieve #100 0.149 mm opening	Sieve #200 0.074 mm opening	(with suggested sub-groups)
NP-1	1	15.0	27.0	50.3	39.3	13.7	31.7	1.44	25.8	1.12	30.0	79.5	2.58	1.50	30.0	-	-	-	-	98.24	97.50	96.56	95.54	94.72	
	2	35.0	30.4	50.3	39.3	13.7	31.7	1.44	25.8	1.12	30.0	79.5	2.58	1.50	30.0	-	-	-	-	98.24	97.50	96.56	95.54	94.72	
	3	50.0	-	61.1	43.3	17.8	6.31	1.45	24.8	1.14	45.0	79.0	2.68	-	-	-	-	-	-	95.30	94.20	93.48	93.00	92.32	
	4	140.0	-	88.2	43.5	44.7	11.3	1.38	36.4	-	-	-	2.61	-	-	-	-	-	-	72.74	66.34	63.44	62.40	61.36	
	5	174.0	-	-	71.2	39.7	31.5	1.38	36.4	-	-	-	2.60	-	-	-	-	-	-	44.56	40.52	37.44	36.20	34.78	
	6	175.0	37.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	6	175.0	37.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	7	250.0 -300.0	47.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
NP-2	1	60.0	67.4	60.0	43.3	16.7	16.7	-	-	-	-	-	2.56	0.7	64.4	-	-	-	-	98.14	97.02	96.36	96.10	96.02	
	2	65.0	73.5	112.0	44.7	67.3	38.0	-	-	-	-	-	2.58	0.8	73.5	0.50	10.10	40.0	-	99.86	99.72	99.52	99.40	99.38	
	2	65.0	74.2	-	-	-	-	-	-	-	-	-	2.58	0.7	74.2	-	-	-	-	-	-	-	-	-	
	3	70.0	67.6	-	-	-	-	-	-	-	-	-	-	0.7	67.6	-	-	-	-	-	-	-	-	-	
	3	70.0	71.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	3	70.0	64.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	

ETHIOPIAN ELECTRIC LIGHT AND POWER AUTHORITY
CIVIL ENGINEERING DIVISION
MATERIALS TESTING LABORATORY

DATE RECEIVED.

PROJECT. Lake Tana Regulation

SUMMARY OF TEST RESULTS

DATE REPORTED. February 1977

BY.

Test pit NO.	Sample NO.	Depth cm	Natural water content %	Atterberg limits (Consistency)				Laboratory Proctor max. dry density		In-place density		Relative density %	Specific gravity	In-situ Unconfined strength		Direct shear tests			Free swell %	Mechanical sieve analysis (Passing U.S.STD. SIEVE %)					Soil classification
				L.L. %	P.I %	S.L %	P.L %	Dry density gr/cc	Opt. moist. %	Dry density gr/cc	Opt. moist. %			Strength kg/cm²	Moist. %	Cohesion kg/cm²	Angle of internal friction	Water content %		Sieve # 10 2.0 mm opening	Sieve # 20 0.84 mm opening	Sieve # 50 0.297 mm opening	Sieve # 100 0.149 mm opening	Sieve # 200 0.074 mm opening	(with suggested sug-groups)
1	1	20	25.70	58.6	22.3	32.0	36.3	1.40	32.0	-	-	-	2.66	2.2	25.8				38.0	100.0	100.0	98.4	96.0	92.6	
1	1	20	26.10																						
1	2	18-33	24.22	52.0	23.0	10.4	28.1	1.39	31.80	-	-	-	2.55	2.4	25.1				32.0	100.0	100.0	98.6	96.6	93.8	
1	2	18-33	25.80																						
1	3	40-55	35.50	56.0	21.8	21.5	31.2	1.40	29.60	1.16	35.8	83.0	2.64	2.2	35.8				30.0	100.0	99.6	99.4	98.6	97.4	
1	3	40-55	36.10																						
1	4	80	37.40	-	-	-	-	-	-	-	-	-	-	2.4	39.8				-	-	-	-	-	-	
1	4	80	42.25																						
1	5	120	39.00	-	-	-	-	-	-	-	-	-	-	2.4	39.5				-	-	-	-	-	-	
1	5	120	39.10																						
1	6	126	38.70	60.0	26.1	26.9	33.9	1.42	31.40	1.17	40.3	82.3	2.64	2.2	40.3				30.0	100.0	99.0	98.2	97.4	95.8	
1	6	126	40.25																						
1	7	145-150	39.28	62.4	31.1	26.4	31.3	1.44	31.0	-	-	-	2.55	2.2	39.5				30.0	100.0	98.6	96.6	94.4	91.0	
1	7	145-150	39.67																						
1	8	160	41.84	43.0	23.3	27.3	30.7	1.40	30.9	1.10	43.0	78.5	2.55	2.0	43.0				20.0	100.0	95.4	87.0	80.0	71.4	
1	8	160	44.09																						
1	9	212-227	48.15	-	-	-	-	-	-	-	-	-	-	2.2	49.0				-	-	-	-	-	-	
1	9	212-227	49.25																						
1	10	225	45.14	-	-	-	-	-	-	-	-	-	-	2.2	47.0				-	-	-	-	-	-	
1	10	225	47.71																						
1	11	35	49.16	-	-	-	-	1.40	30.9	1.0	51.2	71.4	-	2.0	51.2				-	-	-	-	-	-	
1	11	11	53.14																						
2	1	35	19.6	51.8	18.0	22.3	33.8	1.40	31.9	-	-	-	2.55	-	-				30.0	100.0	93.0	84.8	76.8	67.8	
2	1	11	19.0																						
2	2	35-71	23.9	63.0	27.8	20.6	35.2	1.39	31.9	1.18	23.9	85.0	2.64	2.4	23.9				40.0	100.0	100.0	99.0	97.8	96.2	
2	3	67-75	32.5	-	-	-	-	-	-	-	-	-	-	-	-				-	-	-	-	-	-	
2	3	67-75	31.8																						
2	4	90-234	32.23	53.2	23.7	25.3	29.5	1.40	31.1	-	-	-	2.55	-	-				23.0	100.0	90.8	76.2	66.4	56.2	
2	5	237-252	42.7	52.8	18.9	33.9	33.9	1.36	32.6	-	-	-	2.55	-	-				15.0	100.0	90.0	76.8	68.8	59.4	
2	5	237-252	42.5																						
2	6	285-300	31.6	-	-	-	-	1.36	32.6	1.18	32.0	86.7	2.55	2.8	32.0				35.0	-	-	-	-	-	
2	6	285-300	31.2																						
3	2	15-30	23.9	49.3	18.8	24.0	30.5	1.42	30.2	1.20	23.9	83.0	2.55	3.0	23.9					100.0	99.6	98.6	95.6	90.4	
3	3	45-50	22.4	-	-	-	-	-	-	-	-	-	-	-	-				-	-	-	-	-	-	
3	3	45-50	25.2																						
3	4	120	32.0	-	-	-	-	-	-	-	-	-	-	-	-				-	-	-	-	-	-	
3	4	120	33.9																						
3	5	140	31.2	54.3	19.9	23.5	31.4	1.40	29.4	-	-	-	2.55	-	-				30.0	100.0	99.0	97.2	94.6	90.6	
3	5	140	32.6																						
3	6	207	30.1	49.2	20.9	30.3	28.3	1.40	32.6	-	-	-	2.66	-	-				30.0	100.0	97.6	90.4	84.2	76.4	
3	7	270-280	42.3	56.5	26.7	34.1	29.8	1.42	30.0	-	-	-	2.55	-	-				25.0	100.0	95.6	88.2	82.0	73.8	
3	8	305-320	49.3	53.2	19.3	28.8	33.0	1.39	32.6	1.10	48.4	72.0	2.58	2.0	48.4				20.0	100.0	97.0	90.6	85.0	72.4	
3	8	305-320	47.5																						
4	1	18-33	23.0	-	-	-	-	1.41	31.6	1.20	23.2	85.0	-	2.8	23.2				-	-	-	-	-	-	
4	1	18-33	23.3																						
4	3	75	40.6	-	-	-	-	-	-	-	-	-	-	-	-				-	-	-	-	-	-	
4	3	75	40.5																						
4	4	130	41.5	53.0	23.0	22.4	30.0	1.41	31.6	1.20	35.6	85.0	2.66	2.3	35.6				35.0	100.0	98.4	95.0	91.4	86.4	
4	4	130	40.6																						
4	5	180	35.6	52.0	21.2	28.2	30.8	1.41	31.6	-	-	-	2.64	2.4	35.6				0.0	100.0	95.4	88.2	81.4	73.6	
4	6	225	44.7	52.5	24.2	23.7	28.3	-	-	-	-	-	2.64	2.2	44.7				10.0	100.0	95.6	84.6	77.6	69.5	
4	7	250	35.4	52.0	22.0	32.9	30.0	1.36	34.2	-	-	-	2.66	2.4	35.4				25.0	100.0	97.4	88.6	80.2	70.0	
4	8	207	30.7	52.8	22.9	32.7	29.9	-	-	-	-	-	2.64	-	-				20.0	100.0	95.6	83.2	76.6	66.8	
4	9	292-310	47.1	54.5	24.7	34.6	29.8	1.41	30.2	-	-	-	2.68	-	-				31.0	100.0	91.6	80.6	72.4	62.6	
5	1	5-20	27.7	51.0	24.3	31.4	31.7	1.43	29.4	-	-	-	2.64	2.4	28.8				28.0	100.0	99.2	97.4	94.4	90.0	
5	1	5-20	29.9																						
5	2	100	32.0	-	-	-	-	-	-	-	-	-	-	-	-					-	-	-	-	-	
5	2	100	28.8																						
5	3	170	38.9	51.7	18.2	21.1	33.5	1.39	31.6	-	-	-	2.55	2.2	38.9				30.0	100.0	95.2	87.2	80.4	72.4	
5	4	205-220	45.8	56.0	25.4	23.7	30.6	1.38	34.6	1.15	44.0	83.3	2.56	2.2	44.0				30.0	100.0	93.6	83.4	76.2	67.4	
5	4	205-220	43.2																						
5	5	243-255	45.9	68.5	35.2	20.2	33.3	-	-	-	-	-	2.65	-	-				28.0	100.0	98.6	95.0	90.4	84.0	
5	6	285-300	47.6	54.7	19.7	38.0	35.0	1.36	34.6	1.10	47.6	81.0	2.65	2.0	47.6				30.0	100.0	96.6	89.4	83.8	76.4	

* For Hydrometer Analysis whole workes, please see the attached test papers

Table 6-3

Result of soil test in upstream dam site

ETHIOPIAN ELECTRIC LIGHT AND POWER AUTHORITY
CIVIL ENGINEERING DIVISION
MATERIALS TESTING LABORATORY

DATE RECEIVED. July 23rd, 1976

PROJECT. Lake Tana Regulation

SUMMARY OF TEST RESULTS

DATE REPORTED. September 21st, 1976

BY. Abayneh INESHESHA

Test pit NO.	Sample NO.	Depth cm	Natural water content %	Atterberg limits (Consistency) L.L. %	P.L. %	P.I. %	S.L. %	Laboratory Proctor max. dry density: Dry density gr/cc	Opt. moist. %	In-place density: Dry density gr/cc	Opt. moist. %	Relative density %	Specific gravity	In-situ Unconfined strength: Strength kg/cm2	Moist. %	Direct shear tests: Cohesion kg/cm2	Angle of internal friction	Water content %	Permeability x 10 cm/sec	Mechanical sieve analysis (Passing U.S.STD. SIEVE %): Sieve # 10 2.0 mm opening	Sieve #20 0.84 mm opening	Sieve #50 0.297 mm opening	Sieve # 100 0.149 mm opening	Sieve # 200 0.074 mm opening	Soil classification (with suggested sub-groups)
	1	50.0	28.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
CP-1	2	60.0	26.6	63.2	31.0	32.2	15.3	-	-	-	-	-	2.68	-	-	-	-	-	-	69.01	67.85	66.83	66.72	65.95	
	3	120.0	29.6	58.7	30.9	27.8	21.2	1.41	33.3	-	-	-	2.68	-	-	-	-	-	-	13.04	12.26	11.88	11.68	11.52	
	1	40.0	56.5	81.0	50.0	31.0	24.0	1.28	24.4	-	-	-	2.68	-	-	-	-	-	-	99.68	99.26	99.02	98.88	98.72	
	1	40.0	50.8	81.0	50.0	31.0	24.0	1.28	24.4	-	-	-	2.68	-	-	-	-	-	-	99.68	99.26	99.02	98.88	98.72	
	1	40.0	54.5	81.0	50.0	31.0	24.0	1.28	24.4	-	-	-	2.68	-	-	-	-	-	-	99.68	99.26	99.02	98.88	98.72	
	1	40.0	54.7	81.0	50.0	31.0	24.0	1.28	24.4	-	-	-	2.68	-	-	-	-	-	-	99.68	99.26	99.02	98.88	98.72	
CP-2	2	50.0	67.6	87.6	38.0	49.6	21.7	-	-	-	-	-	2.58	0.5	67.6	0.7	15.0	38.6	-	99.76	99.28	99.00	98.88	98.46	
	2	50.0	63.6	87.6	38.0	49.6	21.7	-	-	-	-	-	2.58	0.5	67.6	0.7	15.0	38.6	-	99.76	99.28	99.00	98.88	98.46	
	3	70.0	-	72.0	31.9	40.1	22.3	1.26	34.8	-	-	-	2.52	-	-	-	-	-	-	99.98	99.92	99.78	99.74	99.66	
	4	120.0	63.2	47.7	26.5	21.2	32.3	-	-	-	-	-	2.68	-	-	-	-	-	-	18.18	13.18	10.34	9.34	8.28	
	4	120.0	60.2	47.7	26.5	21.2	32.3	-	-	-	-	-	2.68	-	-	-	-	-	-	18.18	13.18	10.34	9.34	8.28	
	1	70.0	-	67.1	52.0	15.1	45.0	-	-	-	-	-	2.54	-	-	-	-	-	-	57.66	57.00	56.36	55.90	55.56	
	2	75.0	31.1	65.0	44.8	20.2	45.3	1.19	40.0	-	-	-	2.70	-	-	-	-	-	-	36.58	36.10	35.60	35.16	34.76	
	2	75.0	32.6	65.0	44.8	20.2	45.3	1.19	40.0	-	-	-	2.70	-	-	-	-	-	-	36.58	36.10	35.60	35.16	34.76	
	2	75.0	34.1	65.0	44.8	20.2	45.3	1.19	40.0	-	-	-	2.70	-	-	-	-	-	-	36.58	36.10	35.60	35.16	34.76	
CP-4	2	75.0	36.6	65.0	44.8	20.2	45.3	1.19	40.0	-	-	-	2.70	-	-	-	-	-	-	36.58	36.10	35.60	35.16	34.76	
	3	95.0	22.8	47.1	33.0	14.1	53.7	-	-	-	-	-	2.62	-	-	-	-	-	-	48.14	44.26	40.16	37.21	35.43	
	3	95.0	18.5	47.1	33.0	14.1	53.7	-	-	-	-	-	2.62	-	-	-	-	-	-	48.14	44.26	40.16	37.21	35.43	
	4	120.0	19.4	61.7	38.7	23.0	35.6	1.35	22.5	-	-	-	2.69	-	-	-	-	-	-	7.29	6.69	5.99	5.55	5.31	
	4	120.0	20.8	61.7	38.7	23.0	35.6	1.35	22.5	-	-	-	2.69	-	-	-	-	-	-	7.29	6.69	5.99	5.55	5.31	

(4) The downstream site is extremely close to National Route No. 3 which is advantageous for construction and maintenance of the dam. In contrast, the upstream site is about 1.3km away from the national route with flood plains in between and is disadvantageous from the standpoint of transportation of construction materials.

6.5 DAM CONSTRUCTION MATERIALS (see Dwgs. No. 13)

6.5.1 Concrete Aggregates and Rock Material

Concrete aggregate and rock material may be quarried at Mt. Kubita of the Debanke mountain mass (El. 1,853m) along National Route No. 3 approximately 2.6km south-southwest of Bahar Dar. Further, detritus existing in and around damsite can be available for rock material.

Mt. Kubita is comprised of fresh and hard basalt and coarse aggregate is being supplied from here to the Hilton Hotel project which is under construction. The face of this quarry now has a width of about 80m and a height of about 50m. This basalt is thought to be adequate for the planned structures both quality-wise and quantity-wise.

Sand is to be collected at Velgi and Gorgora at the north shore of Lake Tana and transported to Bahar Dar by boat. Other than this sand, it will be worthwhile to consider manufacturing of sand from crushed rock of Kubita Quarry or collecting of sand from deposits at the Blue Nile and its tributaries.

6.5.2 Soil Material in Borrow Area

Proposed borrow area is located in a low, flat, wide tract at the foot of Mt. Taima (El. 1,871m) on the left bank of the Blue Nile and in a distance of approximately 500m south-southeast of Abbay Bridge. Residual soil is widely distributed at this flatland, and although there are scattered boulders at places, the northern part has thicker residual soil than the southern part, while there is little mixture of detritus. Reconnaissance of this area was done by pacing with metering tape and Brunton compass, and then the geological map prepared in 1/1,000 scale. After that, five test pits (each 3m in depth) were excavated. The results of surface geological investigations and test pits are contained in Dwg. No. 13.

The topsoil is plastic soil with mixtures of grass roots to depths of 20cm to 30cm under which there is residual soil of basaltic origin. The thickness of the residual soil has not been confirmed beyond 3m, but judged from the distribution of weathered bedrock, it is assumed the thickness will be greater at places. The residual soil consisted of silty clay indicates generally moderate cohesion and plasticity. There are some intercalations of thin layers of weathered pebble or of boulder layers of 1m thick as seen at BP 3, 4 and 5. It is intered that this material, if the intermixed boulders are removed, posseses sufficient shearing and compressive strength, watertightness and usability for earthwork as fill material. This area is close to the damsite with a paved road 6.5m in width leading to the damsite, in addition to which since it is a very gently sloped area, it is thought to be suitable for excavation and stockpiling of material.

It should be possible for the required volume (approximately 30,000m^3) to be obtained without affecting power distribution and telephone lines, but even in case there should be by chance a shortage, the requirement can be met by expanding the borrow area to the south.

6.6 GEOLOGY OF TIS ABBAY NO. 2 POWER STATION SITE AND WATERWAY ROUTE

With regard to this power station site, a geological map indicated in Dwg. 14 was prepared using a topographical map of 1/200 scale covering an area from the existing power station to about 200 m downstream. The Blue Nile in the vicinity of this site forms a narrow gorge, and the mainstream of the river flows east through the gorge in the form of rapids. The proposed power station is to be located at a very gently sloped area of a suitable expanse, and since it is estimated there is a layer of fresh, hard basalt under overburden which is not very thick, it may be said the conditions of location are good both topographically and geologically. Similarly to the existing power station, there is a steep cliff at the back of the new power station on top of which a broad flatland spreads out, but since this cliff is comprised of thick, continuous, fresh and hard basalt, it is not conceivable that landslides will occur. The geological structure of the cliff is given in Dwg. 14.

As shown in Dwg. 15, the foundation of the power station will be excavated to an elevation of approximately 1,570m. Therefore, although the slope is stabilized in its original form, thorough attention must be paid to slope stability after excavation. Further, since the elevation of the power station foundation will be lower than the water level of the Blue Nile, the permeability of the bedrock will need to be investigated and suitable treatment given in accordance with the results.

The course of the penstock will be an underground one because of the topographcal conditions, and it may be expected that good quality basalt such as that distributed in the area of the existing power station will be found for the shaft and adit. However, the rock will be loosened for a thickness of several meters from the top of the shaft.

The planned headrace passes a flat area and the route goes by the switchyard and the housing area of employees of the existing power station. Therefore, prior to excavation of the headrace, it will be necessary for studies to be made of blasting work, in effect, investigations of the places requiring blasting and of measures for preventing damage. Since the geology along the route is comprised of soil and weathered bedrock which are adequately consolidated, it is thought the headrace can be amply supported. Further, it appears there is also soil with intermixed gravel and boulders at parts of the route.

6.7 TRANSMISSION LINE ROUTE

The geology of the 66 kV transmission line to be newly constructed between Bahar Dar and Gondar will be described in this section. This transmission line has a route planned more or less along National Route No. 3, and geological investigations were made travelling the route by automobile at the end of the rainy season of 1976. The route investigated was classified accordant to sections A to N indicated in Dwg. 10 by the characteristics of topography and geology, and the outlines of these sections are given in Table 6-6. Besides these surface investigations, the conditions of the ground were investigated by excavating test pits at the crossing of the Blue Nile and at one bank of the Ribb River which is swampy where steel towers are to be provided. The distances from Bahar Dar read on the odometer of the automobile were adjusted by topographical maps.

The topographic and geologic conditions of the investigated route are described below evaluated as foundations for transmission line supports.

I. Flood Plain Area: The route of the transmission line has been selected at an elevation considerably higher than the normal water level of Lake Tana so that it is not a swamp where papyrus grows thickly, and is a flood plain which spreads widely at the banks on both sides of the rivers flowing into Lake Tana. These flood plains are inundated during the rainy season, but become grassy plains during the dry season, and cattle are let out for grazing. The flood plains are covered by extremely thin black humus soil under which there is fine grained soil of high plasticity. The soil at Test Pit No. 3 at one of the banks of the Ribb River, as listed in Table 6-3, is silty clay and the deeper portions are fairly well consolidated. Since the transmission line of this section is supported by wood poles, ground with bearing capacity should be found at a depth of about 3 m, and drilling of holes for wood poles would be easy, although there will be a necessity for considerations to be given against rotting.

II. Residual Soil Area: Residual soil is mainly distributed at the flat part of the highland. Dwg. No. 13 shows a geological log of a test pit at the location proposed for the borrow area which indicates distribution of residual soil and strongly weathered rock to a fairly great depth. This layer has boulders of hard basalt at places, while weathered rock with cracks may be encountered at other places at a depth of about 2 m. Since this soil is well-consolidated, it is thought to be adequate for supporting poles of the transmission line, while digging of holes for installing poles will be easy.

III. Rock Terrace Area: This area is of flat topography spread out broadly where hard, uniform lava deposited horizontally and not very much weathered is widely exposed. The bedrock where exposed at the surface has open cracks so that polygonal patterns are developed, but according to observations where quarrying has been done, the cracks are closed at around 2 m from the ground surface. Digging of holes for foundations of poles in this area is not as easy as for I and II above.

IV. Rocky Hill Area: The topography of this area is rugged compared with other areas, and basaltic lava is exposed widely at hillsides. Steel towers are to be provided at the mountainland northwest of Addis Zemen. If the locations of wood poles and steel towers were to be determined at deposits possessing adequate bearing capacity, labor for bedrock excavation would be reduced.

V. Thick Overburden Area: This area has a topography in which there are places thought to be the remains of landslides, and locations where terraces have collapsed. Consequently, when selecting the locations of poles or towers for the transmission line, care must be exercised to avoid places where such phenomena occur.

Steel towers will be erected at both banks of the Blue Nile where it is to be crossed. The foundations for these steel towers comprise soil in which boulders are mixed, and since the matrix soil in which boulders are embedded is well-compacted, it may be considered that this soil is quite capable of supporting steel towers.

The lot for Wereta Substation which is to be constructed midway along the planned transmission line is a flat area along the foot of the mountainland.

The outlines of the topography, geology and the structure of the investigated route are as indicated in Table 6-5.

Table 6-4 Geology along Highway Route No. 3 from Bahar Dar to Gondar

Section	Distance (km) From Bahar Dar	To	Sectional distance (km)	Characteristics of topography and geology
A	0	3.0	3.0	Plain and Abbay River: Locations of the Abbay River towers are composed of soil and fresh to somewhat weathered boulders. Boulders are tightly filled with compact silty clay. Most parts of this section are covered with soil to some depth, but the swampy areas locally exist along the Abbay River channel. At sta. 3km, New Abbay Bridge.
B	3.0	18.7	15.7	Rolling gentle hills: Most parts of this section ore covered with residual soil and weathered debris. Residual soil is generally thin, its thickness is thought to be 1.5m to 2m. Below the residual soil, there underlies the completely to heavily weathered rock. But small outcrops of weathered rock sporadically distribute along the course of some streams. There is a small scale quarry which worked at the time of Highway construction.
C	18.7	28.0	9.3	Flood plain: At sta. 25.0km, rock outcrops in valley.
D	28.0	40.0	12.0	Flat topped and gentle uplands: Grassland. Most of this section is covered with residual soil. Residual soil is generally thin, its thickness is probably less than 2m in most places.
E	40.0	48.1	8.1	Flood plain: Dark brown plastic clayey soil. At 44.6km, Gumara river.
F	48.1	61.4	13.3	Flat land between hills and gentle uplands: Small swampy areas are scattered in this section. Soil of uplands is fine grained and brown (residual soil ?) At sta. 61.0km, Werata substation - This site locates on very gentle hill, which may be composed of residual soil. At sta. 61.4km, Crossing point of road to Debre Tabor (under construction)

Section	Distance (km)		Sectional distance (km)	Characteristics of topography and geology
	From Bahar Dar	To		
G	61.4	79.6	18.2	Flood plain: At sta. 65.8km, Ribb river. Test pit No. 3 is dug at the left bank aparted from about 70m from the strand of the Ribb river. The log of Test pit No. 3 indicates in Fig. 6-5.
H	79.6	86.0	6.4	Plain: Mainly swampy. Creeks are dug along the both sides of Highway No. 3. At sta. 84.4km, Addis Zemen City.
I	86.0	98.2	12.2	Rocky hills: Rocks (BASALT) crop out in many places on the southeastern slope of the hills (Addis Zemen side). Stocks of basaltic rock stand at some places near the Highway No. 3. At sta. 94.0km, Pass of the hill.
J	98.2	120.0	21.8	Hills and uplands: Most parts of northwestern slope of hills are occupied with talus deposit. The areas of thick talus deposits seem to be landslid topography. These areas are found in many places. Besides, these landforms, there are horizontal lava flows in local. The foot of hills is covered with talus deposits composed of debris of pebble to gravel size, but small outcrops of rock are locally recognized.
K	120.0	128.4	8.4	Hills: The southeastern slopes (Addis Zemen side) are steeper than the northwestern one (Gondar side). Around the pass, the rocks widely distributed on the bill side. The hills form the rugged landscape where Maskar flowers bloom in September.
L	128.4	138.5	10.1	Uplands: Skirts of hills. Weathered rocks widely distributed. Over the half of rocky areas is composed of highly weathered rock. Some rocky areas are quarried for the macadam of Highway.
M	138.5	153.9	15.4	Rock terrace: Overburden is generally thin. There are small scale quarries in some places.
N	153.9	171.5	17.6	Uplands and foot of hills: The river flown from Gondar City, locally indicates bad erosive state around crossing point of Highway No. 3. But neibouring area of the Gondar Air Port is composed of the rock terrace. Most parts of this section is occupied talus deposit and scree.

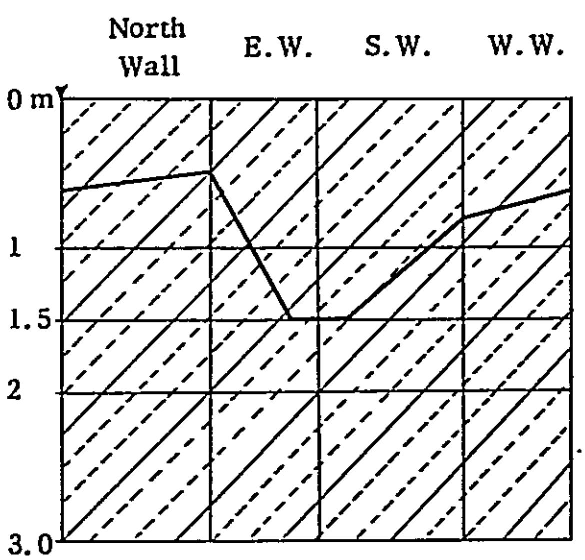
Table 6-5 Topographic and geologic composition of investigated route

Topographic andgeologic division	Name of section	Distance km 1/	Percentage (%) 2/	Remarks
Flood plain	C , E , G , H	42.0	24.5	Marshy in wet season.
Plain and flat land	A , F	16.3	9.5	F includes small swampy area.
Residual soil	B , D	27.7	16.2	
Rocky land rock terrace	L , M	25.5	14.9	L belongs to foot of hills
Rocky hill and upland	I , K , N	38.2	22.3	Especially I and K
Talus	J	21.8	12.7	

1/ Indicates the sum of sectional distances.

2/ Indicates the ratio to total distance of investigated routes.

Fig. 6-4 GEOLOGIC LOG OF TEST PIT NO. 3



CLAY; Silty, dark brown to dark, very hard in dry state, shrinkage cracked from top of pit to bottom.

CLAY; Silty, dark grey, somewhat compact to slightly loose, plastic, semi-impermeable, with no debris and pebbles, uniform.

Referances

1/ Geological Survey of Ethiopia, Ministry of Mines, Ethiopian Government (1973) Geological Map of Ethiopia, Scale 1 : 2,000,000

2/ V. Kazmin - Summarised by A.J. Warden (1975) Explanation of the Geological Map of Ethiopia ; Ministry of Mines, Energy and Water Resources, Geological Survey of Ethiopia.

3/ Considlio Nazionale Delle Ricerche - Italy (1973) Geological Map of Ethiopia and Somalia, Scale 1 : 2,000,000

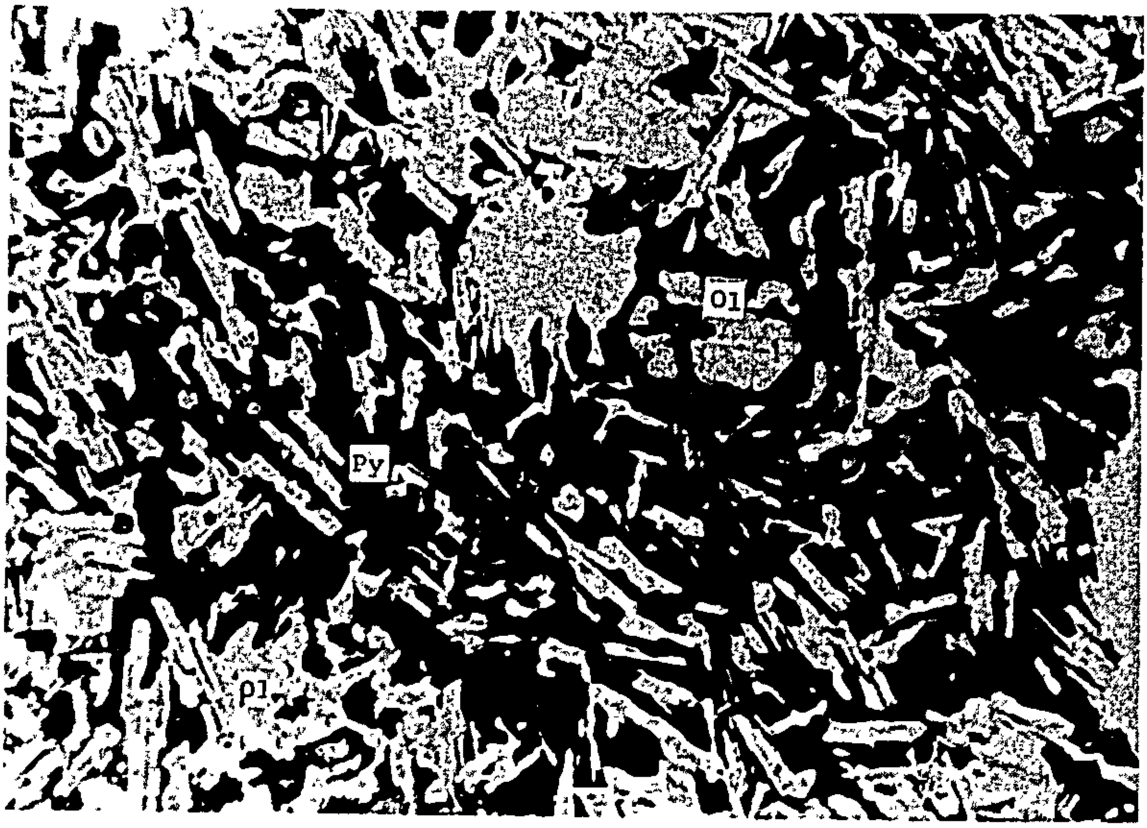
4/ Mesfin Wolde Mariam (1970) An Atlas of Ethiopia

5/ Mesfin Wolde Mariam (1972) An Introductory Geography of Ethiopia

6/ Topographic Map - Scale 1 : 250,000 - (1973), Sheet ND 37-13, ND 37-14, NC 37-1 and ND 37-2, Complied by Defence Mapping Agency, Topographic Center, Washington D. C.

7/ Ministry of Mines, Ethiopian Government (1966) Mineral Occurrences of Ethiopia.

Photo. 6-1 Petrography of rock



0 0.5mm

Rock name;

Alkali olivine basalt (dolerite)

Pl; Plagioclase Ol; Olivine Py; Pyroxine

Microphotograph of rock

0 2.0cm

Vesicle of rock

Specific gravity and absorption of rock

Basalt	Specific gravity		Absorption (%)
	Dry	Saturated	
Vesicular	2.28	2.36	3.4
Compact	2.87	2.92	0.9

CHAPTER 7

LAKE TANA REGULATION PLAN

CHAPTER 7 LAKE TANA REGULATION PLAN

7.1 BASIC DATA

7.1.1 Storage Capacity Curve of Lake Tana

"Hydrographic Investigation - Lake Tana, Ethiopia," approximate scale, 1 : 100,000, prepared in 1959 and made available to the Survey Mission by EELPA was used for calculation of the storage capacity of Lake Tana.

The shore line indicated in the above map is based on photography in 1958 by the Imperial ethiopian Mapping and Geography Institute and the elevation of the lake is not given. However, according to information from EELPA, the most frequent surface level of Lake Tana is said to be 1,786 m, and taking the shore line at 1,786 m, the storage capacity was calculated considering the lake surface area to be 3,035 km^2 at this level.

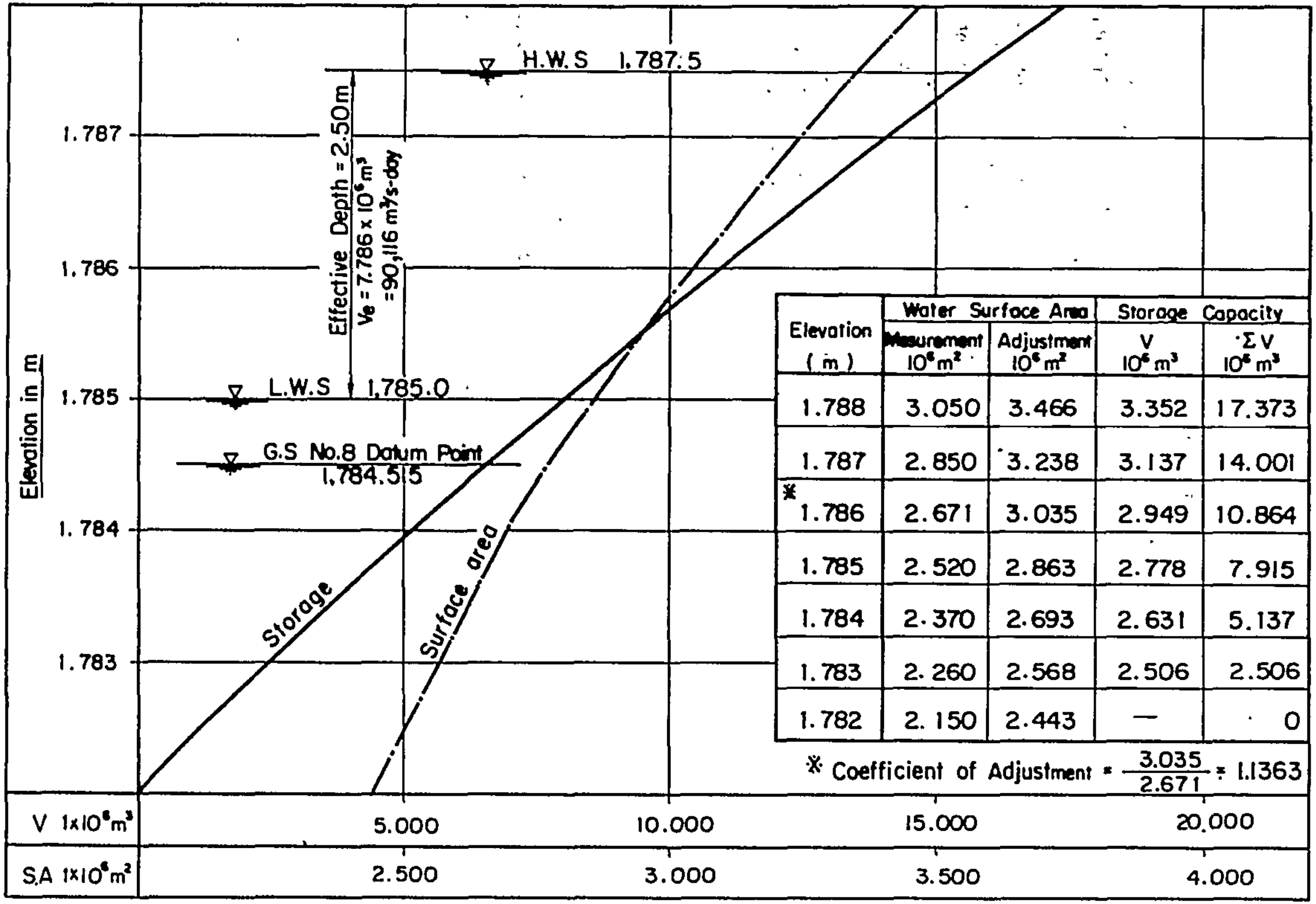
Measurement of the area was done on the map to -18 feet and elevation of 1,786 m as a result of which the area was corrected to 3,035 km^2 at El. 1,786 m with corrections made done to -18 feet upon which the storage capacity curve of the lake was prepared.

This is shown in Fig. 7-1-1. In the figure, curves for elevations above 1,786 m were obtained by extrapolation.

7.1.2 Discharge Data

The data used were the runoff data of Gaging Station No. 9 approximately 4 km downstream from the outlet of Lake Tana and surface level data from Water Level Gaging Station No. 8 at the south shore of the lake. The period covered by the data is 12 years from 1964 to 1975.

Fig. 7-1-1 Storage Capacity Curve of Lake Tana



Elevation (m)	Water Surface Area: Mesurement $10^6 m^2$	Water Surface Area: Adjustment $10^6 m^2$	Storage Capacity: V $10^6 m^3$	Storage Capacity: ΣV $10^6 m^3$
1.788	3.050	3.466	3.352	17.373
1.787	2.850	3.238	3.137	14.001
※ 1.786	2.671	3.035	2.949	10.864
1.785	2.520	2.863	2.778	7.915
1.784	2.370	2.693	2.631	5.137
1.783	2.260	2.568	2.506	2.506
1.782	2.150	2.443	—	0

※ Coefficient of Adjustment = $\frac{3.035}{2.671}$ = 1.1363

7.2 REGULATION PLAN

7.2.1 Assumption of Planned Water Surface Level

The natural fluctuation in the water surface level of Lake Tana, due to the topographical restrictions at the outlet to the Blue Nile and the large storage capacity of the lake itself, is one of slow annual rise and fall.

In effect, as shown in Table 5-2-2 and Fig. 7-2-2, the surface level gradually starts to rise from the beginning of July when the rainy season begins, and after reaching the maximum surface level in the middle of September when the rainy season ends, it gradually falls until the minimum surface level is reached at the end of June when the dry season ends. The average annual difference in surface level is approximately 1.6 m, and the past maximum and minimum surface levels have been recorded at 1,787.53 m (September 16 ~ 18, 1964) and 1,785.08 m (June 16, 1970), respectively.

According to the aerial inspection by helicopter during the Survey Mission's first-stage investigations, the area surrounding the lake is mostly an extremely flat region consisting of rich pastureland formed along the shore during the dry season and continuing on to cultivated fields. Raising the surface level of the lake by one meter through gate regulation would result in expanding the present shore line several kilometers out toward the surrounding area at certain places. Conversely, lowering the water level below the past minimum by artificial means would also be a problem, while further, this would hamper the regular liner service between Gorgora at the north shore and Bahar Dar at the south shore increasing danger of vessels running aground.

Other than the above, there is complete lack of knowledge at the present time regarding the influence of changing the surface level of the lake on the ecology of the surrounding area, while moreover, various other investigations of the area surrounding the lake are also extremely incomplete.

Based on such a situation, it is desirable to keep the surface level of Lake Tana after construction of a regulating dam within the past range of fluctuation. Accordingly, the following water surface levels are assumed, and a study will now be made whether these water levels will be mostly appropriate.

Max. water surface level	= 1,787.5 m
Min. water surface level	= 1,785.0 m
Effective depth	= 2.5 m
Effective storage capacity	= 7,786 x 10^6 m^3
	= 90,116 m^3/sec.day

7.2.2 Deepening of Riverbed at Outlet

In order to maintain the water surface level of Lake Tana within the present range of fluctuation as stated in the preceding section and still carry out effective regulation with an available depth of 2.5m, it will be necessary to deepen the riverbed at the outlet of the lake so that a crosssectional area of the stream allowing the regulated discharge to be made even at the minimum water surface level will be secured.

The extent to which the riverbed is to be deepened will be described in detail in Chapter 10, 10.1.3.

7.2.3 Examination by Mass Curve

The purpose of the Lake Tana Regulation Plan is to augment the supply of water to the existing Tis Abbay Power Station and the planned Tis Abbay No.2 Power Station during the low-water season and lowering water levels at power station outlets during floods while taking into consideration the quantity of water which is to be allotted in the future to the Upper Beles Project for power generation and irrigation through diversion from the west shore of Lake Tana to the Beles River, a tributary of the Blue Nile.

Therefore, the above purposes were considered comprehensively, and the most efficient discharge regualtion for Lake Tana was examined by a mass curve.

From Eq. (1) of Chapter 5,

$$(I + P) - E = (O + \Delta S) \quad \cdots\cdots\cdots\cdots \quad (2)$$

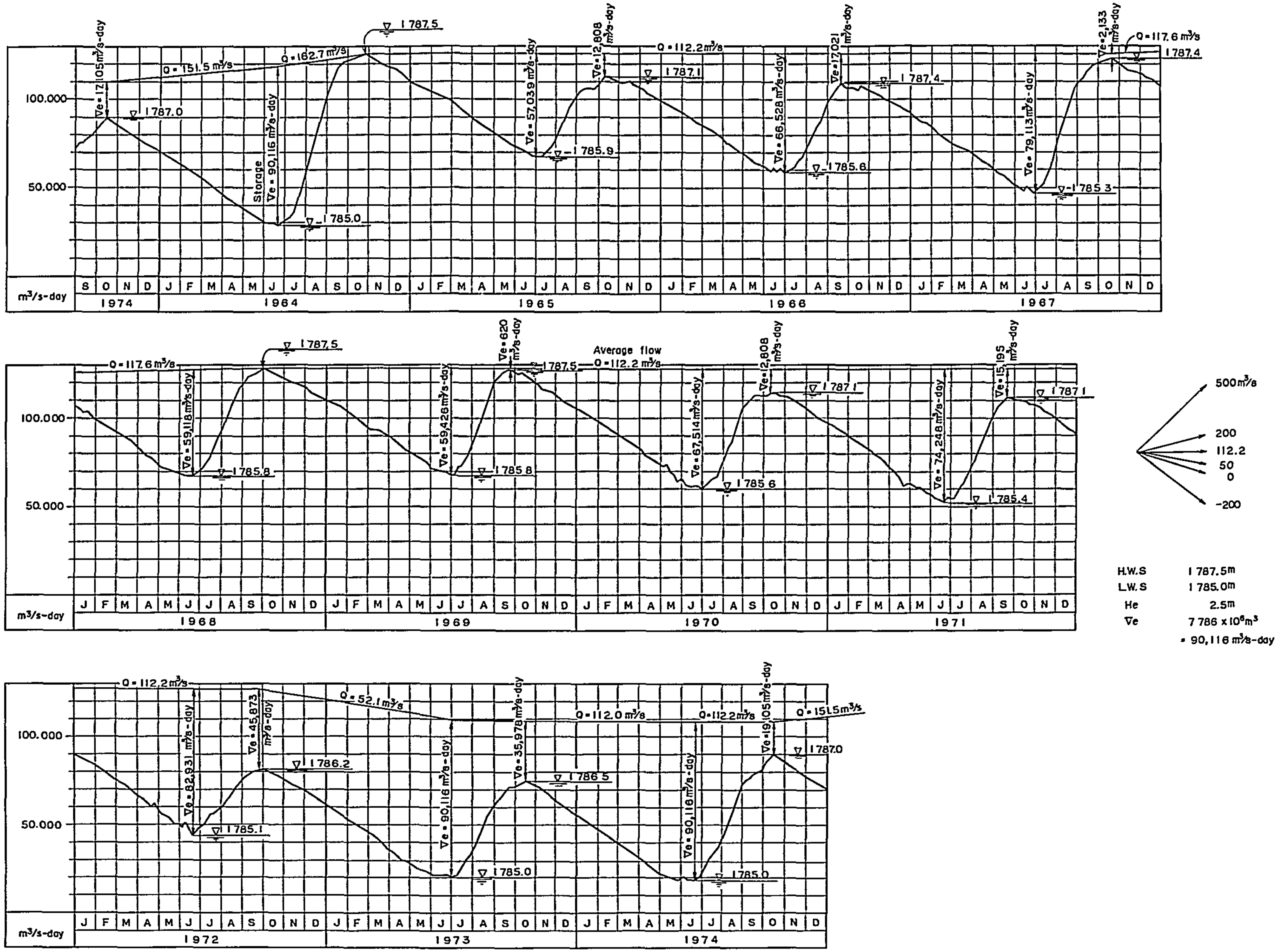
The discharge at the site of the regulating dam is the inflow to Lake Tana less the loss due to evaporation and infiltration, or the left side of Eq. (2), and the quantity may be calculated as the right side of Eq. (2). Therefore, the mass curve was prepared using (runoff at Gaging Station No.9 + storage in lake converted to runoff).

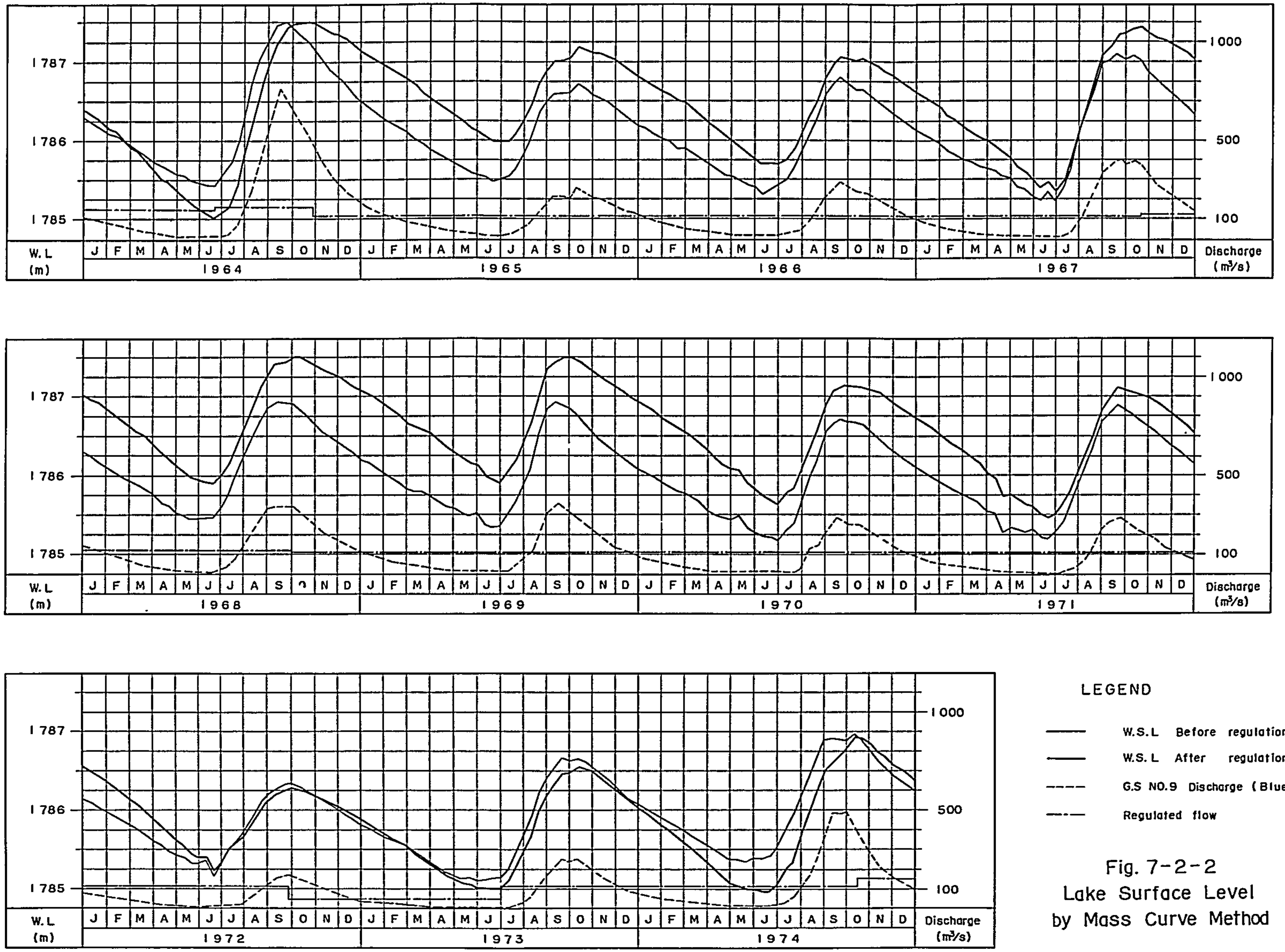
Next, with effective regulation within the planned water surface level range carried out by this mass curve, a planned discharge curve was established and calculations were made on regulation of Lake Tana based on this curve. The calculations were made for daily runoff during the 11-year period of 1964 ~ 1974 using an electronic computer (IBM-370).

The results of the above are indicated in Fig. 7-2-1 and Fig. 7-2-2.

According to the results, except for the wettest year and the dryest year, an 11 year average runoff of 112 m^3/sec can be secured as the planned discharge. In such case, the time at which the maximum is reached in the regulated Lake Tana water surface level will be approximately one month later than in the natural state.

Fig. 7-2-1 Inflow Mass Curve of Lake Tana





LEGEND

W.S.L Before regulation
W.S.L After regulation
G.S NO.9 Discharge (Blue Nile)
Regulated flow

Fig. 7-2-2
Lake Surface Level
by Mass Curve Method

7.2.4 Operation of Regulating Dam

(1) Rule Curve for Standard Water Surface Level

The results of the study by mass curve are as indicated in the above, according to which water surface levels beyond the upper and lower limits of the planned levels are of course never produced. The reason is that the runoff is a known quantity in the study by mass curve, while it is an unknown quantity in actual operation and operation of the dam will be executed estimating the runoff during a certain period.

With an ordinary reservoir, numerous facilities for runoff and meteorological observations are provided in order to predict inflow, and dam operation is planned predicting runoffs to rivers and streams from precipitation-runoff relationships based on abundant data and further adding meteorological information. Furthermore, it is common to carry out gate operation while making appropriate corrections observing variations in the water storage level.

Incidentally, although there is no way of making a comparison since the meteorological conditions are completely different, in Japan there is approximately one precipitation observation facility per 50km^2 of the catchment area of an important reservoir, while corresponding gaging stations are provided on inflowing rivers, with measured data all transmitted to the dam administration office and on being processed by computer, the timing of discharge, amount of discharge, degrees of opening of gates, etc. are determined based on the relation with the reservoir water surface level.

In the case of Lake Tana, it is extremely difficult to accurately and rapidly make predictions of inflow quantities in carrying out such controls because of differences in meteorological conditions, the extreme vastness of the catchment area, the shortage of various facilities, and further, the great quantity of loss from the lake surface. Furthermore, as seen from past data over a long period of time, there is a definite pattern to the fluctuations in water surface level. Therefore, it is thought the fundamentals for dam operation at Lake Tana should be for the standard water level of each season to be established, and the discharge quantity to be adjusted through control of the above.

Operation standards for Lake Tana were prepared based on the above thinking, and these are indicated in Fig. 7-2-3. The regulated surface level of the lake for each year was obtained from the regulation calculations for the 11-year period using the mass curve, and a median surface level was taken as the control standard, with 0.2 m below and above the maximum and minimum surface levels further considered as allowances in operation.

The planned discharges are to be Q_u = 160 m^3/sec and 110 m^3/sec in the rainy season and Q_L = 110 m^3/sec and 60 m^3/sec in the dry season, which means that when the surface level of Lake Tana drops below the standard level (V_S), the discharges are held to Q_u = 110 m^3/sec and Q_L = 60 m^3/sec to restore the water level, while when the level is higher than the standard, Q_u = 160 m^3/sec and Q_L = 110 m^3/sec are used to lower the level.

The results of daily calculations made based on these operation rules are given in Fig. 7-2-4. Calculations were made for 12 years adding 1975 to the period. According to the calculations, the only years in which there will be in conflict with the standard water surface level will be 1964 and 1975 in terms of maximum water level and 1973 in terms of minimum level, and these moreover, are for extremely short periods of time.

In this context, it is thought the above operation rules are more or less reasonable.

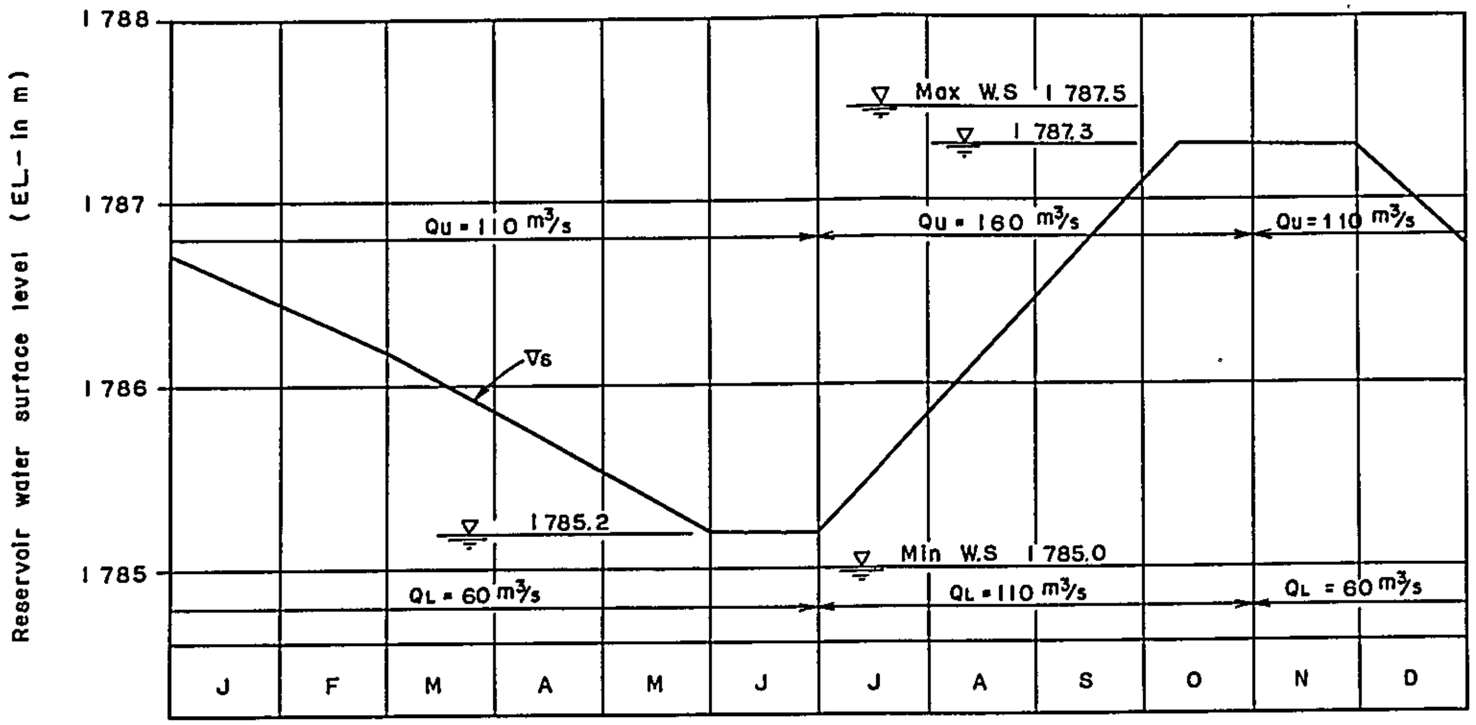
(2) Rule Curve during Flood

The operation rules and the calculated water surface levels considering the design flood inflow of Fig. 5-2-6 are shown in Fig. 7-2-5. Parenthetically, for rise in water level of Lake Tana during the rainy season, three water surface level lines were provided besides the standard surface level (V_S) and calculations were made varying discharges at 300 m^3/sec, 600 m^3/sec and 900 m^3/sec for each of these lines. In effect, if the surface level of Lake Tana were to rise in this manner even when such operation is carried out, this indicates inflow corresponding to a 100 year probability flood.

The phenomena of maximum water surface level being exceeded in 1964 and 1974 produced as a result of calculations according to the rule curve for the standard surface level are eliminated by applying the rule curve for flood periods.

(3) Closure

Explanations regarding rule curves are as in the foregoing, but special mention should be made here of the fact that these are tentative operation rules, and for actual dam operation in the future a plural number of V_S should be taken and the corresponding values of Q_u and Q_L varied to establish operation rules of high precision fully capable of coping with different inflows.



Month	∇_s		
	W.S (m)	10^6 m³	m³/sec - day
Jan.	1 786.45	4,336	50,185
Feb.	86.20	3,636	42,083
Mar.	85.85	2,486	28,773
Apr.	85.52	1,486	17,199
May.	85.20	586	6,782
Jun.	85.20	586	6,782
Jul.	85.82	2,386	27,616
Aug.	86.46	4,386	50,764
Sep.	87.10	6,436	74,491
Oct.	87.30	7,086	82,014
Nov.	87.30	7,086	82,014
Dec.	86.72	5,186	60,023

Symbols (Unit : m³/s – month)

- ∇_{n-1} : Storage at the end of previous month
- ∇_n : Storage at the end of current month
- ∇_s : Standard middle limit of storage
- ∇_{max} : Maximum storage
  - $= 7.786 \times 10^6 m^3 = 90{,}116$ m³/s-day
  - $= \begin{cases} 3{,}004 \text{ m}^3/\text{s} - 30\text{days} \\ 2{,}907 \text{ m}^3/\text{s} - 31\text{days} \end{cases}$
- ∇_{min} : Minimum storage = 0
- f_n : Overflow in current month
- Q_u : Standard upper limit of discharge
- Q_L : Standard lower limit of discharge
- q_n : Inflow in current month
- Q_n : Discharge in current month

Constants (Unit : m³/s – month)

Q_u = 110 m³/s Nov. to Jun.

160 m³/s Jul. to Oct.

Q_L = 60 m³/s Nov. to Jun.

110 m³/s Jul. to Oct.

Basic formula

$\nabla_{max} \geqq \nabla_{n-1} + q_n - Q_n \longrightarrow \nabla_n = \nabla_{n-1} + q_n - Q_n$

$\nabla_{max} < \nabla_{n-1} + q_n - Q_n \longrightarrow \begin{cases} \nabla_n = \nabla_{n-1} + q_n - Q_n - f_n \\ f_n = \nabla_{n-1} + q_n - Q_n - \nabla_{max} \end{cases}$

Operation rule

1. $\nabla_{n-1} + q_n > \nabla_s$
   (1) $Q_u \leqq \nabla_{n-1} + q_n - \nabla_s \longrightarrow Q_n = Q_u$
   (2) $Q_u > \nabla_{n-1} + q_n - \nabla_s \longrightarrow Q_n = \nabla_{n-1} + q_n - \nabla_s$
2. $\nabla_{n-1} + q_n < \nabla_s$
   (1) $Q_L \leqq \nabla_{n-1} + q_n - \nabla_{min} \longrightarrow Q_n = Q_L$
   (2) $Q_L > \nabla_{n-1} + q_n - \nabla_{min} \longrightarrow Q_n = \nabla_{n-1} + q_n - \nabla_{min}$

Fig. 7-2-3
Trial Operation Rule
for Lake Regulation

Fig. 7-2-4 Lake Surface Level by Trial Operation Rule

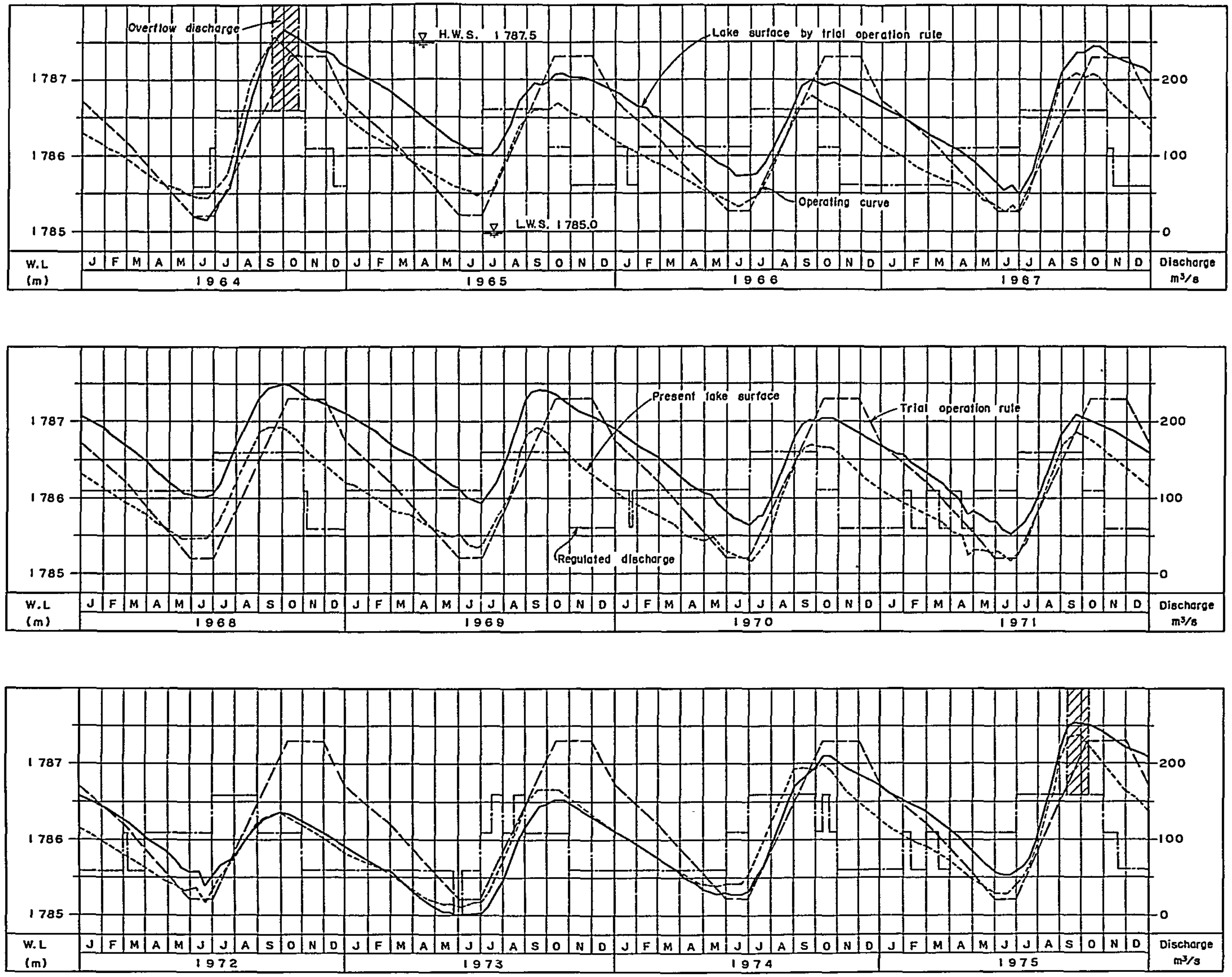
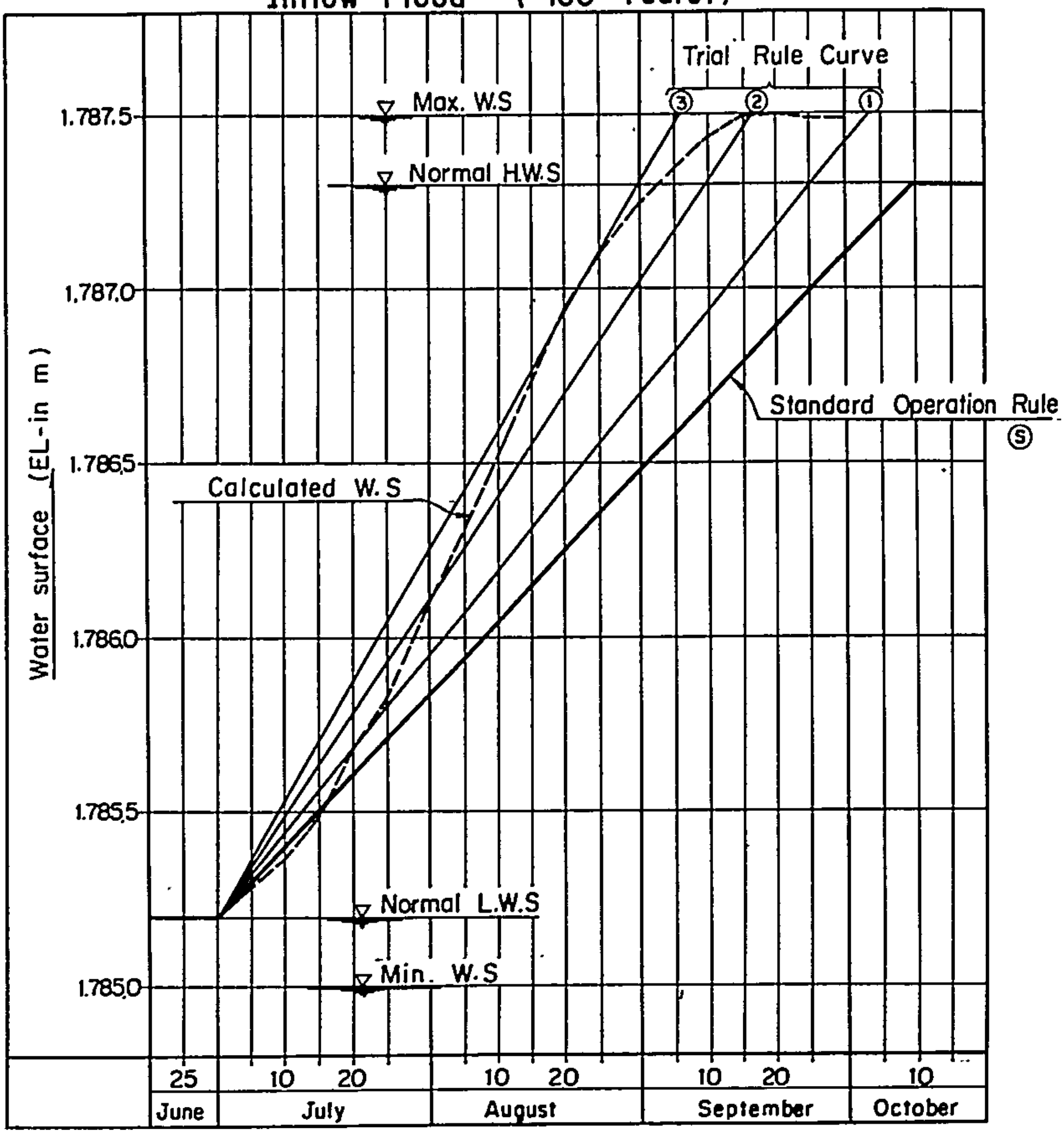


Fig. 7-2-5 Trial Tentatively Operation Rule for Design Inflow Flood (100 Years.)



Constant Discharge

Qu	= 160 m^3/s	for	⑤ ~ ①
〃	= 300 〃	for	① ~ ②
〃	= 600 〃	for	② ~ ③
〃	= 900 〃	after the Lake level reach ③	

7.3 DETERMINATION OF PLANNED WATER SURFACE LEVEL

In case the planned water surface levels of the lake were to be the range of the past maximum and minimum levels, the volume of water which could be utilized would be 7,786 million m^3, and it was confirmed that the water could be averaged out on an annual basis through appropriate regulation although there might be a number of exceptions. This is the same whether the flow is used only at the Blue Nile or whether it is used at both the Blue Nile and the Upper Beles.

Accordingly, in order to confirm whether these planned water surface levels would be the most appropriate, studies were made increasing and decreasing the planned water surface levels or storage capacity.

(1) Case of Maximum Water Surface Level Raised above Past Maximum and Minimum Water Surface Level at 1,785.00 m

From the inflow mass curves of Fig. 7-3-1 the effective capacity which can be fully regulated is 9,347 x 10^6 m^3, and the maximum water surface level in this case will be 1,788.00 m.

The water used at Tis Abbay Power Station and Tis Abbay No. 2 Power Station is not directly from Lake Tana, but water taken approximately 35 km downstream and and there is no merit at all in raising the maximum water surface level of the lake. Further, when Tis Abbay No. 2 Power Station is completed, the utility factor of the river will be 99.6%, and the increase in the amount of electric power through full regulation is extremely small. For the Upper Beles Project also, the merit of increase in electric power cannot be expected.

On the other hand, the effects of a rise in the maximum water surface level of 0.5 m will be an increase of approximately Eth$ 507,000 in the dam construction cost and a decrease in the riverbed deepending cost of Eth$ 300,000, and besides, there will be a necessity for compensation to be made to acquire a vast tract of land due to the increase in the area of impounded water of 110 km^2 and to pay for livestock such as cattle and sheep, so that this plan is clearly uneconomical.

(2) Case of Raising Maximum and Minimum Water Surface Levels without Changing Water Storage Capacity

There will be no increase at all in the amount of electric power produced at the Tis Abbay System power stations on the Blue Nile.

For the Upper Beles Power Station the head will be increased in accordance with rise in the water level of the lake, but the influence in view of the effective head of approximately 239 m is slight, and it is plain to see this would be uneconomical when the increase in dam construction cost is considered.

(3) Case of Lowering Maximum Water Surface Level with MinimumWater Surface Level at 1,785.00 m

To hold the design water surface level below the natural level is undesirable from a technical point of view. The discharge at the outlet of the lake with no dam at the past maximum water surface level of 1,787.53 m has been recorded as being approximately 760 m^3/sec. The design flood discharge is of course far greater than 760 m^3/sec and it is unreasonable for the riverbed deepening work to be made overly extensive to allow this water to be released from the dam gates.

If, for instance, the maximum water surface level were to be made 1,787.00 m, the volume would be 6,086 x 10^6 m^3, in which case according to the inflow mass curves the number of years in which discharge can be evenly regulated is 4 out of 11 years, and during the other 7 years it is not possible for uniform regulation to be carried out.

Meanwhile, as the influence on construction cost, it is estimated that there will be a reduction of Eth$470,000 for the dam and an increase of Eth$530,000 for deepening of the riverbed, and the tendency will be for construction cost to be increased.

(4) Based on the above, it may be said that a plan for a maximum water surface level of 1,787.50 m and a minimum water surface level of 1,785.00 m will be the most economical for achieving the desired purpose of regulation.

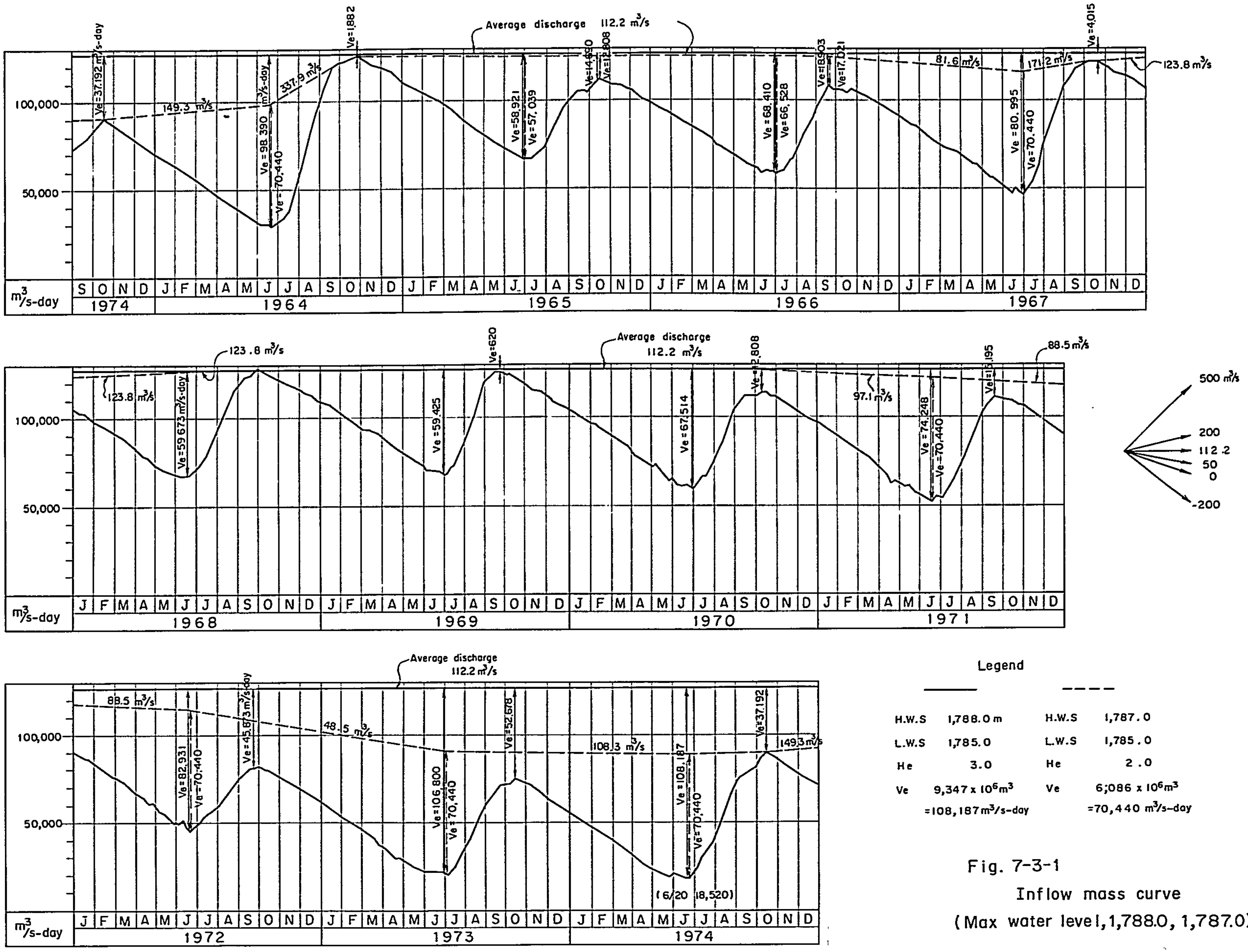


Fig. 7-3-1
Inflow mass curve
(Max water level,1,788.0, 1,787.0)

7.4 RELATION WITH UPPER BELES PROJECT

7.4.1 Outline of Upper Beles Project

This project would consist of diverting water of Lake Tana from the west shore of the lake to the Beles River by a waterway approximately 16km in length for power generation and irrigation, and according to the report of Acres International (December 1971), the scale of the project would be as indicated below (see Fig. 3-2).

Available discharge	98.0 m^3/sec
Effective head	239 m
Maximum output	200 MW
Energy production	964 x 10^6 kWh (load factor 55%)

A detailed examination of this project is not within the scope of the present Feasibility Study. For the present, an examination will be made only of the quantity of water which can be diverted to the Upper Beles Project through regulation of Lake Tana.

7.4.2 Quantity of Water Divertible

As examined in 7.2.4 the average discharge for 11 years is approximately 110 m^3/sec. In case the trial operation rule is followed, it will not be possible for perfectly uniform discharge to be made throughout the year, but it will be possible for this to be done roughly 70% of the year, and by improving the accuracy and increasing the varieties of operation rules this percentage can be made even higher. Consequently, in examining the water divertible to the Upper Beles Project, the study is made considering the regulated discharge of Lake Tana to be 110 m^3/sec.

The allotment of the planned discharge will be as follows:

Existing Tis Abbay PS (incl. No. 3 unit)	30 m^3/sec
Planned Tis Abbay No. 2 PS	15 m^3/sec
Tis Isat Falls tourist trade discharge	10 ~ 15 m^3/sec
Upper Beles diversion	50 ~ 55 m^3/sec
Total	110 m^3/sec

From the standpoint of effective utilization of water, since there is no question that it will be far more advantageous to divert to the Beles River as the power-water ratio is high, it will be necessary for studies to be made on the manner in which Tis Abbay Power Station should be used in the future, that is, whether it should be converted to a peak power station.

In any event, an average of 50 ~ 55 m^3/sec can be expected as the quantity of water divertible under present circumstances. In case of peak duration time of 12 ~ 13 hours (load factor 50 ~ 55%), the maximum available discharge will be 90 ~ 110 m^3/sec, and from this viewpoint the figures given in the Acres report are thought to be reasonable.

At the stage prior to implementation of the Upper Beles Project, the water which would go to that project will be discharged from the regulating dam. After implementation, the water regulated by the dam will be divided between discharge to the Blue Nile and diversion to the Upper Beles Project.

7.5 INFLUENCES ON LAKE TANA REGION AND BLUE NILE DOWNSTREAM AREA

7.5.1 Influences on Lake Tana Region

The planned water surface levels of the regulating dam have been decided on to be a maximum of 1,787.50 m and a minimum of 1,785.00 m so that they will approximately be within the upper and lower limits recorded in the past.

As a result of calculation of the lake water level through gate operation, the time at which the maximum and minimum water levels are reached each year will be set back slightly, but the trend in water level fluctuation will not be changed. Consequently, it is not thought that there will be serious hindrances to the pasture-land and cultivated field areas around the lake, or to the liner service on the lake.

7.5.2 Influences on Blue Nile Downstream Area

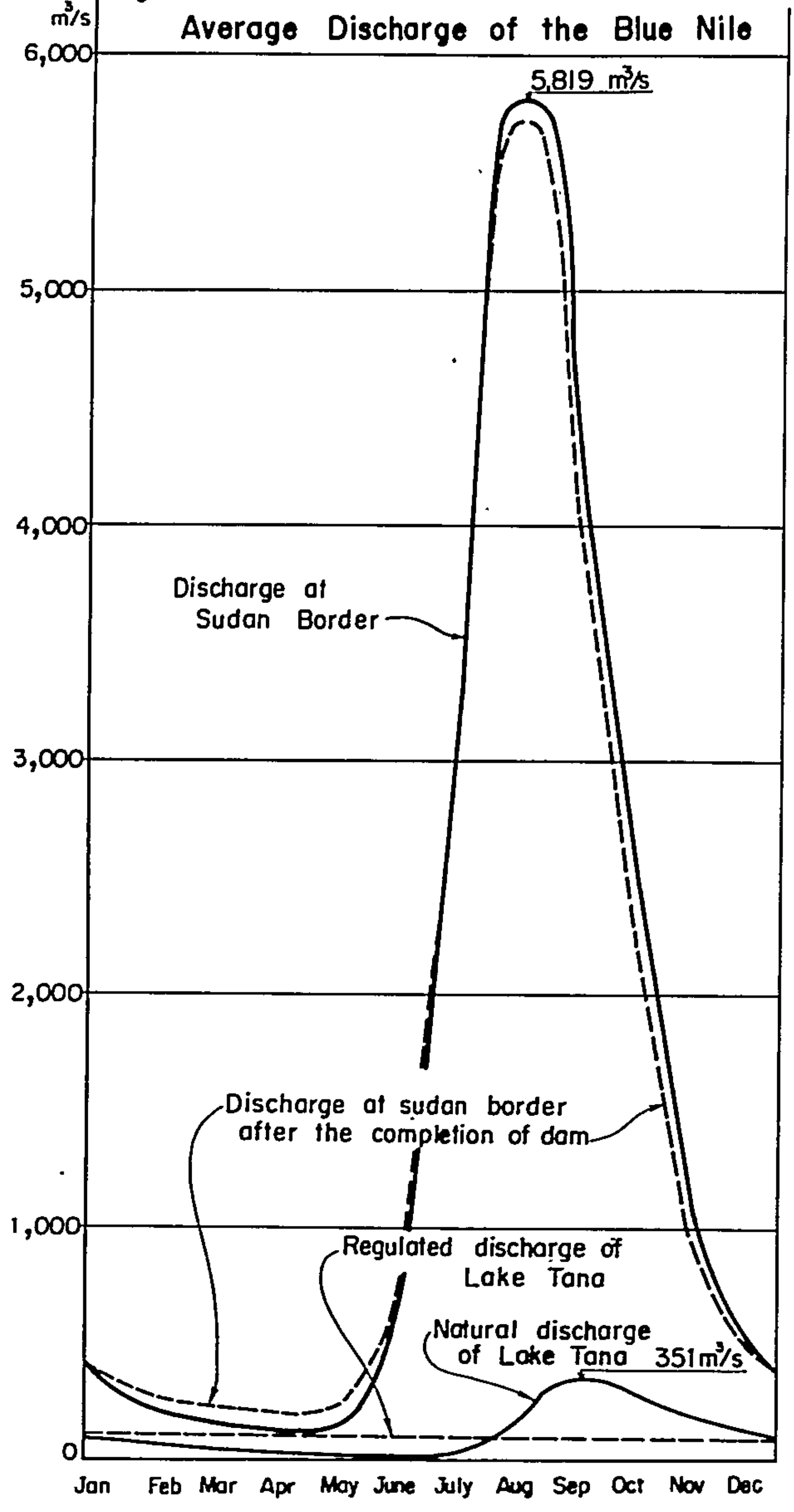
Lake Tana has a lake surface area of 3,035 km^2 and a catchment area of 15,000 km^2, while the annual precipitation in the basin is an average of 1,330 mm, a total of 20,000 million m^3. Of this amount the discharge to the Blue Nile is approximately 18%, or 3,600 million m^3.

The catchment area at the Sudanese border is approximately 175,000 km^2, and it is said precipitation is roughly between 1,200 and 1,800 mm.

It may be seen from the above that the proportion of the discharge from Lake Tana in the runoff in the vicinity of the border is extremely small. Using the runoff data of Gaging Station No.62 located near the Sudanese border and making a rough comparison of present runoff and regulated flow at the border and the Lake Tana outlet, the results are as shown in Fig.7-5-1 and Table 7-5-1, 7-5-2.

From this figure it may be seen that the influence is extremely small, especially in the high-water season. On the other hand, the runoff at the Sudanese border will be increased over the present during the low-water season of January ~ June due to the influence of Lake Tana regulation. The greatest increase is in April, approximately 100 m^3/sec (corresponding to 70% of the present). However, it may be considered that increase in runoff during the low-water season will generally improve the discharge conditions.

Fig. 7-5-1



Average Discharge of the Blue Nile
m³/s
6,000
5,000
4,000
3,000
2,000
1,000
0
5,819 m³/s
Discharge at Sudan Border
Discharge at sudan border after the completion of dam
Regulated discharge of Lake Tana
Natural discharge of Lake Tana 351m³/s
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec

Table 7-5-1 Mean Discharge at GS No. 62, Abbay River near Sudan Border

CA : 173,813 sq. km

Unit: m^3/s

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Max.	Min.
1975	-	-	156.97	106.45	151.32	1,460.48	5,861	6,302	2,794	1,582	1,081.2	582.4		8,350	81.6
1972	296	161	90.4	102.8	162	461	2,018	3,830	2,926	1,299	678	314		5,316	89
1971	273	146	80	80	160	604	2,544	6,052	4,442	2,226	1,134	509		3,918	80
1970	227	165	114	-	-	-	-	6,760	4,652	2,681	1,022	456		4,249	110
1969	282	204	296	155	210	668	2,874	7,154	4,284	1,632	739	374		10,000	110
1968	-	-	-	-	-	-	-	5,380	3,721	2,378	813	422		5,380	-
1967	-	-	-	-	-	-	-	5,778	5,239	3,826	1,428	455		6,790	-
1966	-	-	-	-	-	-	2,459	5,105	4,785	-	-	-		6,235	-
1965	416	269	164	184	74	-	-	4,938	3,583	-	-	-		6,610	-
1964	344	206	-	-	152	609	3,971	6,890	5,549	3,845	1,410	747		5,056	81
Average	306	192	150	126	152	760	3,288	5,819	4,198	2,436	1,038	520	18,985		

Table 7-5-2 Mean Discharge at GS No. 9, Abbay River near Bahar Dar

CA : 15,243 sq. km

Unit: m^3/s

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Max.	Min.
1975	84.0	60.8	40.1	21.6	10.2	7.16	29.9	207.7	604.8	503.3	293.3	179.2		690.0	5.3
1972	76.5	-	32.1	17.4	9.0	5.9	19.2	78.2	160.5	142.1	90.0	55.4		175	4.8
1971	59.44	41.7	26.77	14.49	7.2	5.35	20.13	126.72	276.0	231.7	156.79	99.74		293	4.29
1970	69.75	43.41	25.50	11.79	-	-	-	117.28	259.41	240.31	173.07	110.56		284.8	6.67
1969	95.16	60.91	37.99	23.21	14.71	8.61	25.41	176.39	336.8	263.1	173.1	108.13		351.4	1.42
1968	-	81.10	48.26	26.24	14.48	14.18	67.94	240.8	337.4	297.0	202.9	140.8		344.5	11.42
1967	75.12	46.30	28.80	18.13	9.95	5.53	24.49	204.71	383.7	375.0	263.7	181.4		411.6	5.11
1966	90.8	60.7	39.3	22.06	12.20	9.90	23.20	119.86	261.6	234.4	177.4	118.52		290.8	8.90
1965	144.95	104.46	-	-	-	13.68	25.89	114.77	208.50	229.0	186.26	134.06		252.0	11.60
1964	96.12	64.51	38.52	21.20	11.09	10.48	52.17	347.2	685.08	550.3	352.6	220.9		765.3	7.16
Average	88.0	62.6	35.3	19.6	11.1	9.0	32.0	173.4	351.4	306.6	207.0	134.9	1,430.9		