

TIME REPUBLIC OF TURKEY MINHSTRY OF PUBLIC WORKS AND SETTLEMENT GENERAL DIRECTORATE OF STATE HYDRAULIC WORKS

FEASIBILITY STUDY

ON

KÖPRÜBAŞI HYDROELECTRIC POWER DEVELOPMENT PROJECT

FINAL REPORT

december 11774

ELECTRIC POWER DEVELOPMENT CO., LTD.

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JAPAN INTERNATIONAL COOPERATION AGENCY

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国際協力事業団 28152

PREFACE

In response to a request from the Government of the Republic of Turkey, the Government of Japan decided to conduct a Study of Köprübaşı Hydroelectric Power Development Project for the Republic of Turkey and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to the Republic of Turkey a study team headed by Mr. Mamoru TAKAHASHI and Mr. Taisuke HASEGAWA of EPDC Co., Ltd., five times during the period from October 1992 to September 1994.

The team held discussions on the project with officials concerned of the Government of the Republic of Turkey and conducted the survey. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of electrification program in the Republic of Turkey and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Turkey for their close cooperation extended to the team.

December 1994

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

Dear Mr. Fujita

Letter of Transmittal

We are pleased to submit to you the feasibility report on the Köprübaşı Hydroelectric Power Development Project of the Republic of Turkey. The report contains the advice and suggestions of authorities concerned of the Government of Japan and your Agency as well as the formulation of the above mentioned project. Also included are comments made by the State Hydraulic Works of the Republic of Turkey during technical discussions on the draft report which were held in ANKARA of the Republic of Turkey.

This report presents a scheme of development for Hydraulic Power Project in accordance with the demand forecast up to 2010. Upon completion of each stage of the Project, the shortage of power will be eliminated, thus greatly contributing to the improvement in stability of electric power net works around ANKARA City.

In view of the urgency of power development in the Republic of Turkey and of the need for socio-economic development of the Republic of Turkey as a whole, we recommend that the Government of Turkey implement this Project as a top priority.

We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, and the Ministry of Public Works and Settlement. We also wish to express our deep gratitude to the State Hydraulic Works (DSI) and other authorities' concerned of the Government of the Republic of Turkey for the close cooperation and assistance extended to us during our investigations and study.

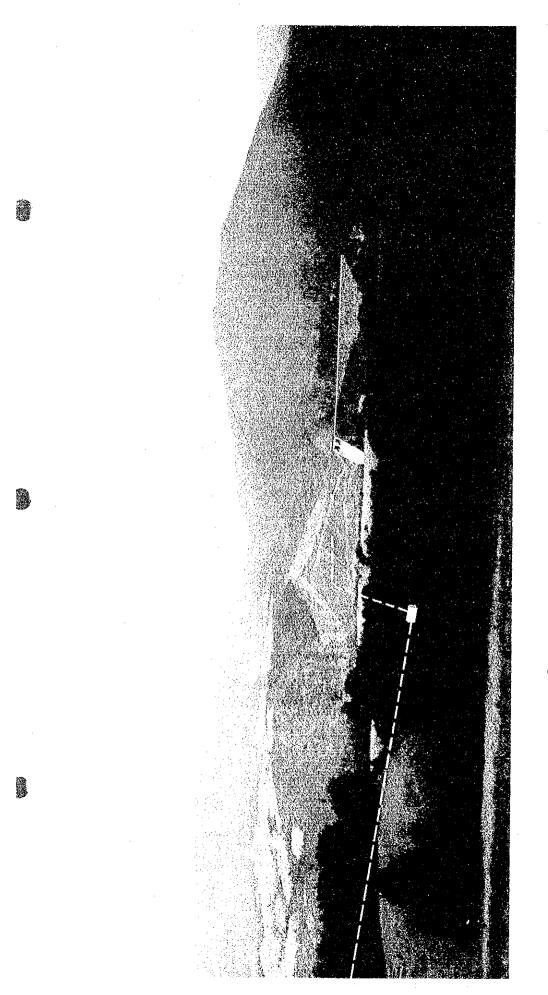
Very truly yours,

Taisuke Hasegawa' Team Leader Köprübaşı Hydroelectric Power Development Project

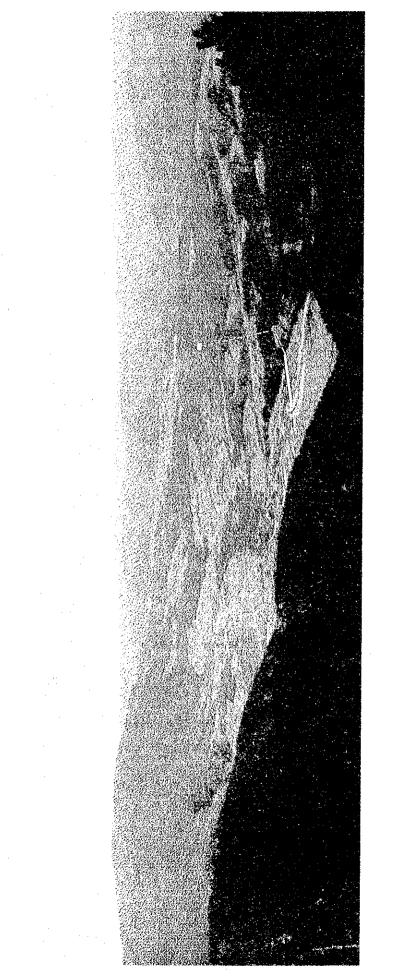


Composite Photograph of Dam and Appurtenance Structure

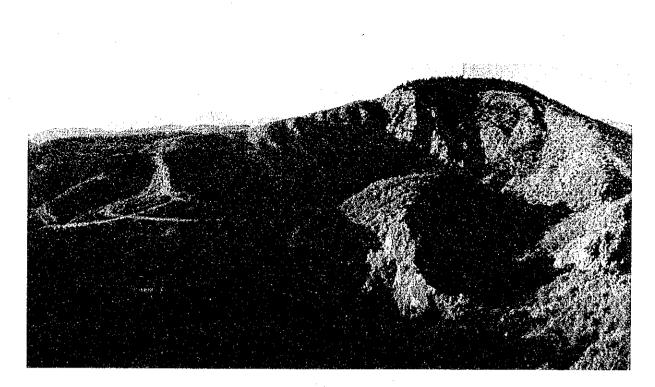
View from upstream left bank



Composite Photograph of Dam Spillway and Power Structure View from downstream left bank



Composite Photograph of Tailrace Tunnel and Channel View from downstream left bank



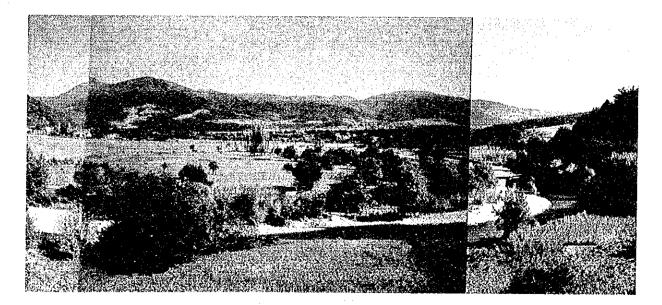
Rock Material Quarry, located 1 km upstream from Dam. View from left bank



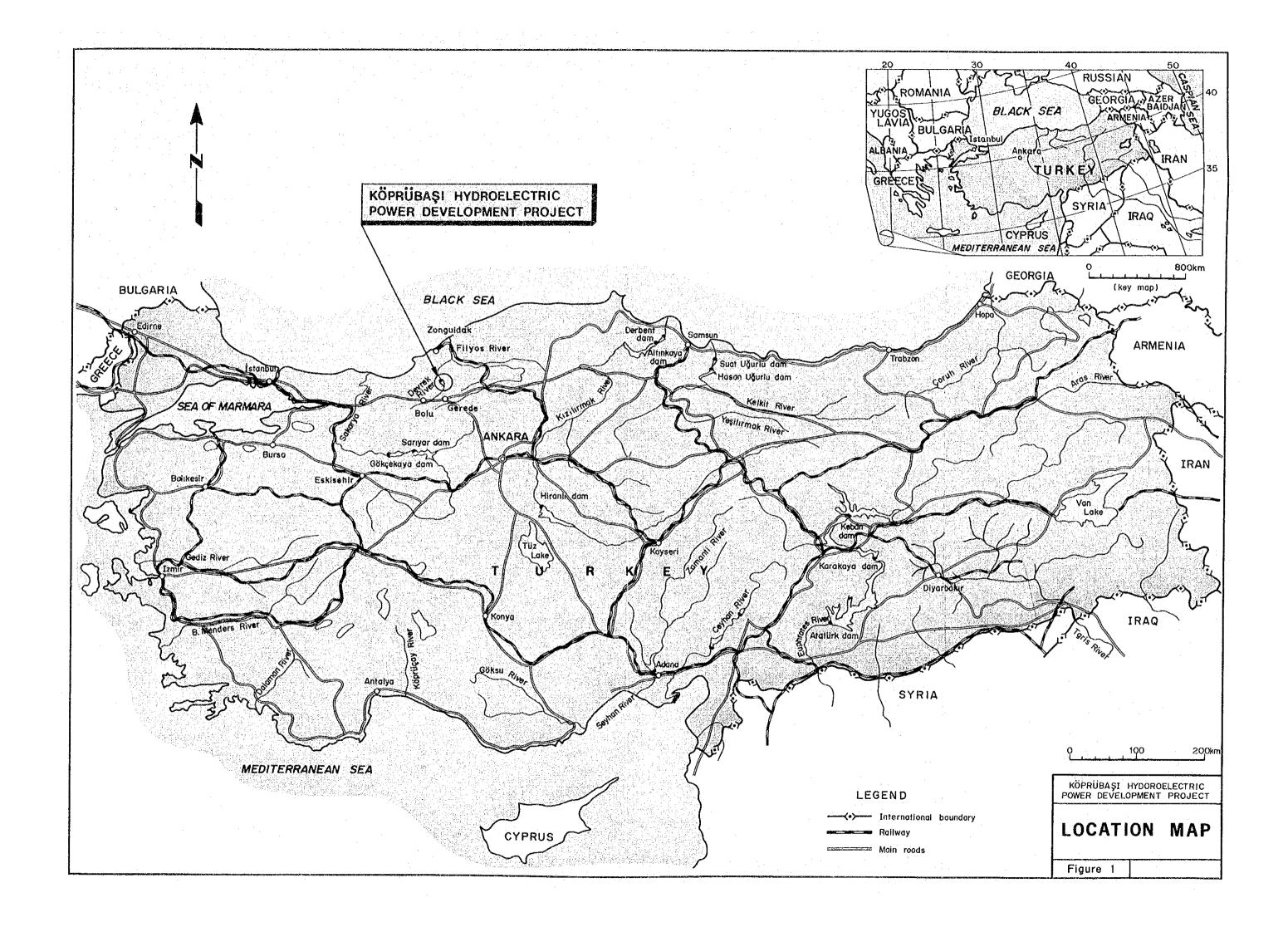
Riprap Material Quarry, located 16 km upstream from Dam. View from left bank

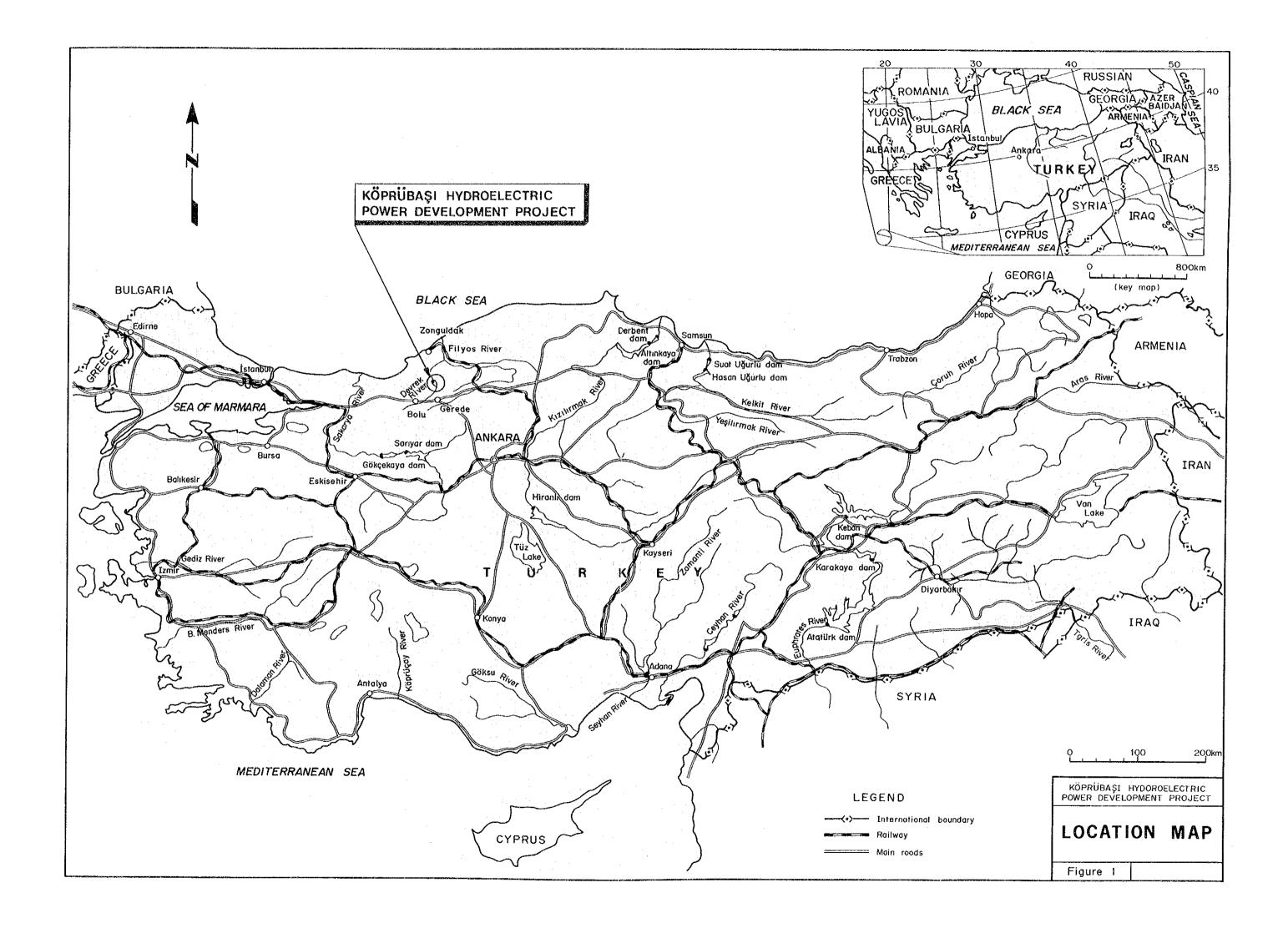


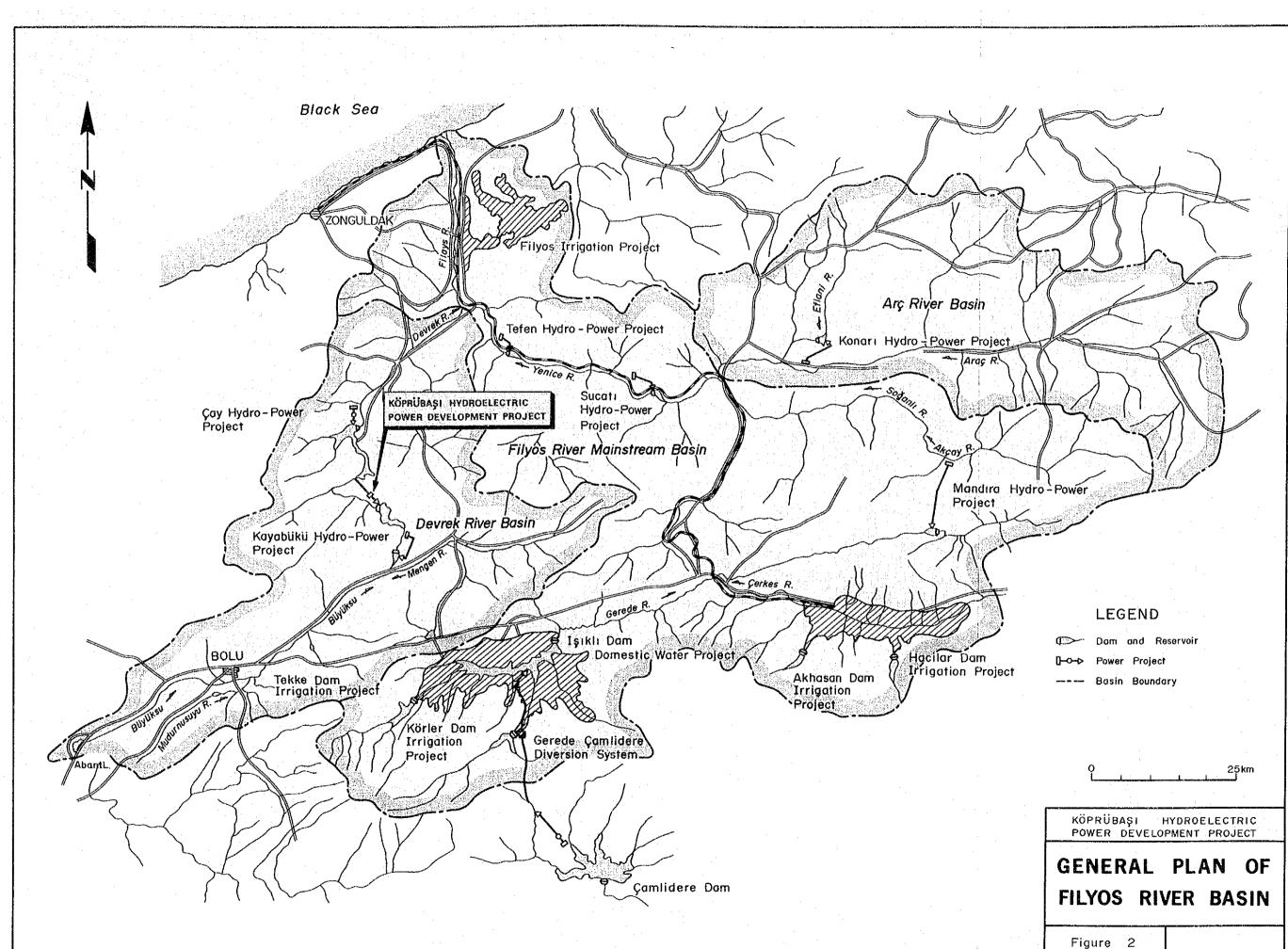
Impervious Core Material and Borrow Area and Fine Filter Material Borrow Area, located 5 km upstream from Dam. View from left bank



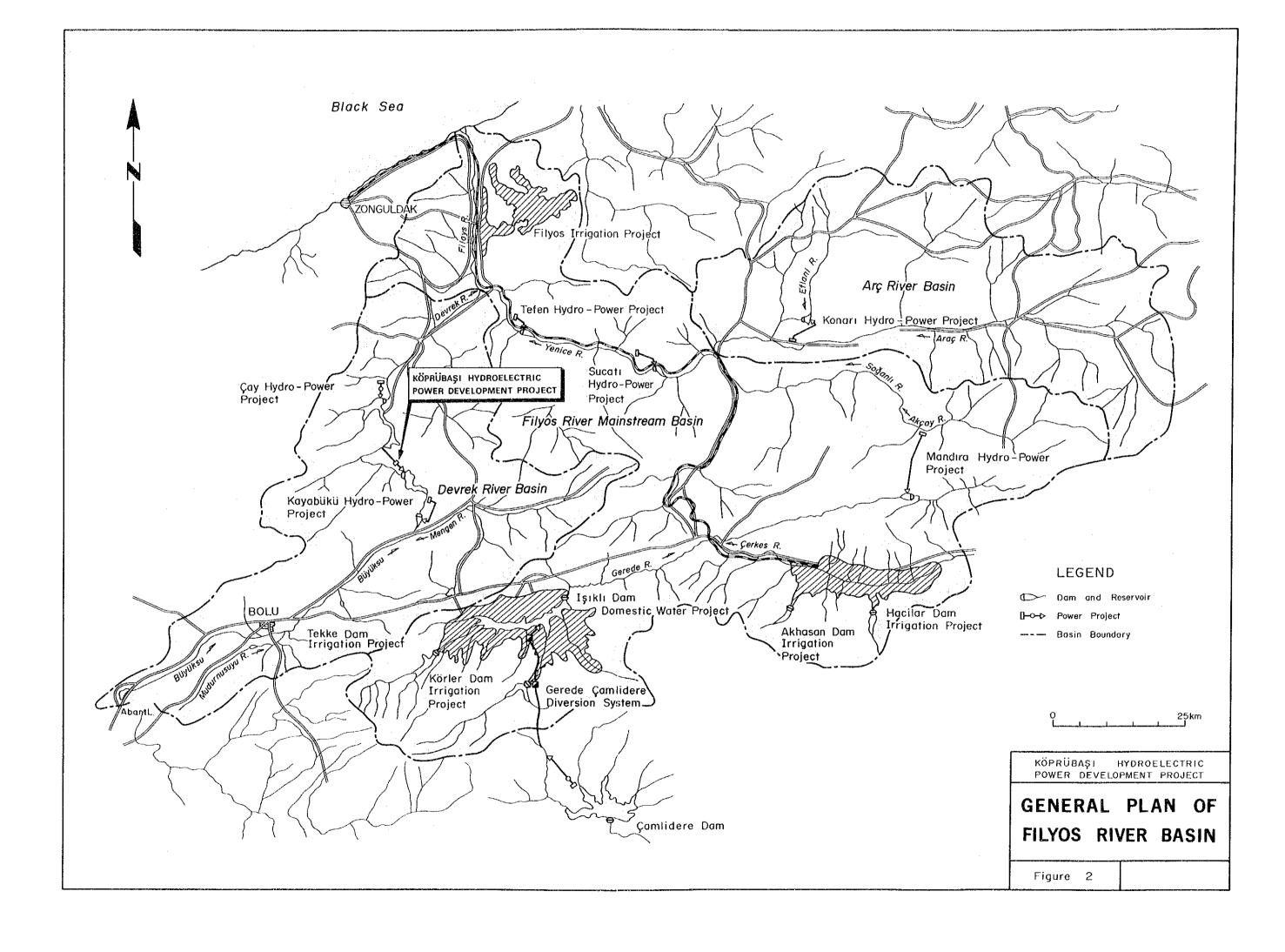
Concrete Aggregate Borrow Area, located around Tailrace Outlet View from right bank

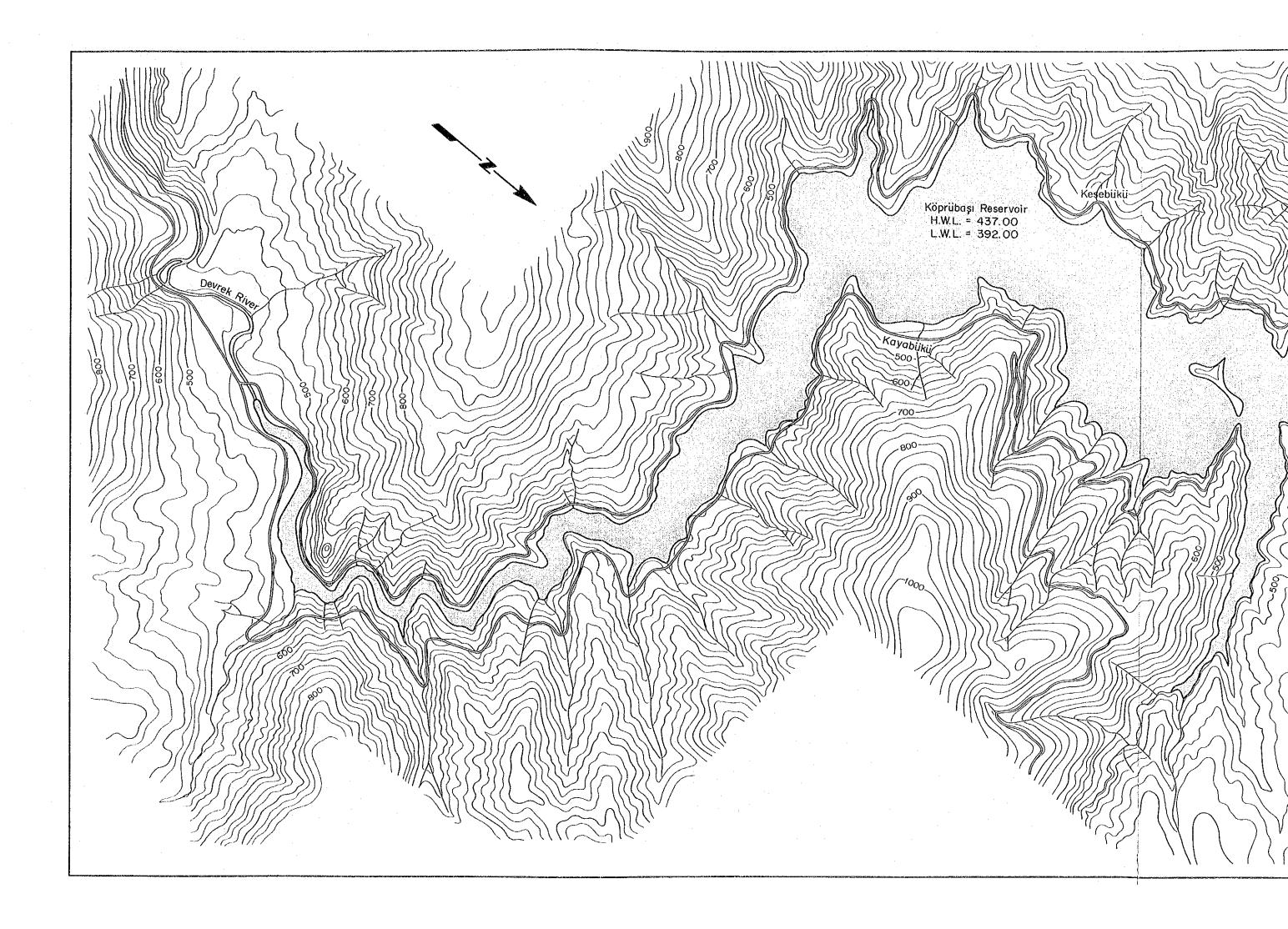


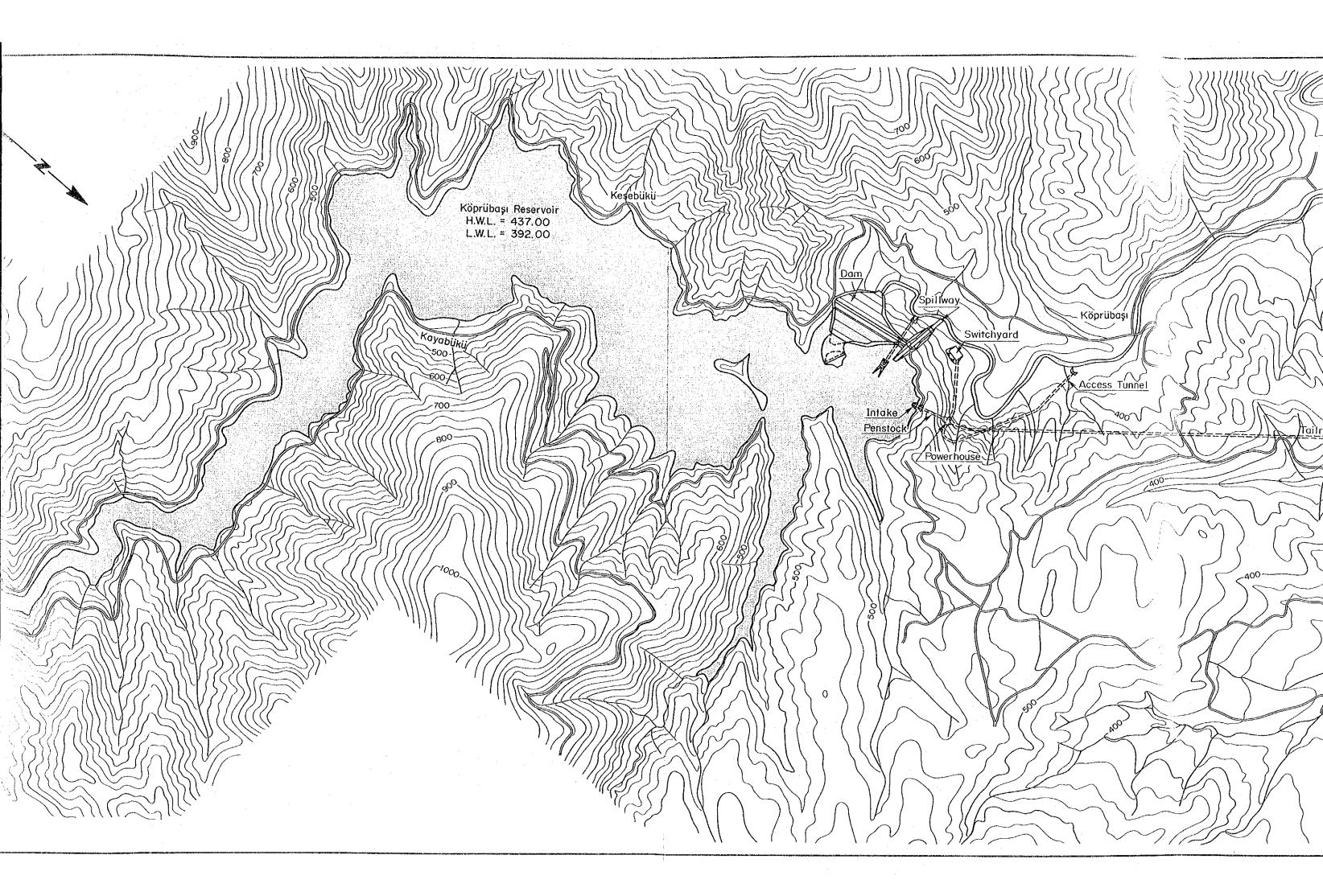




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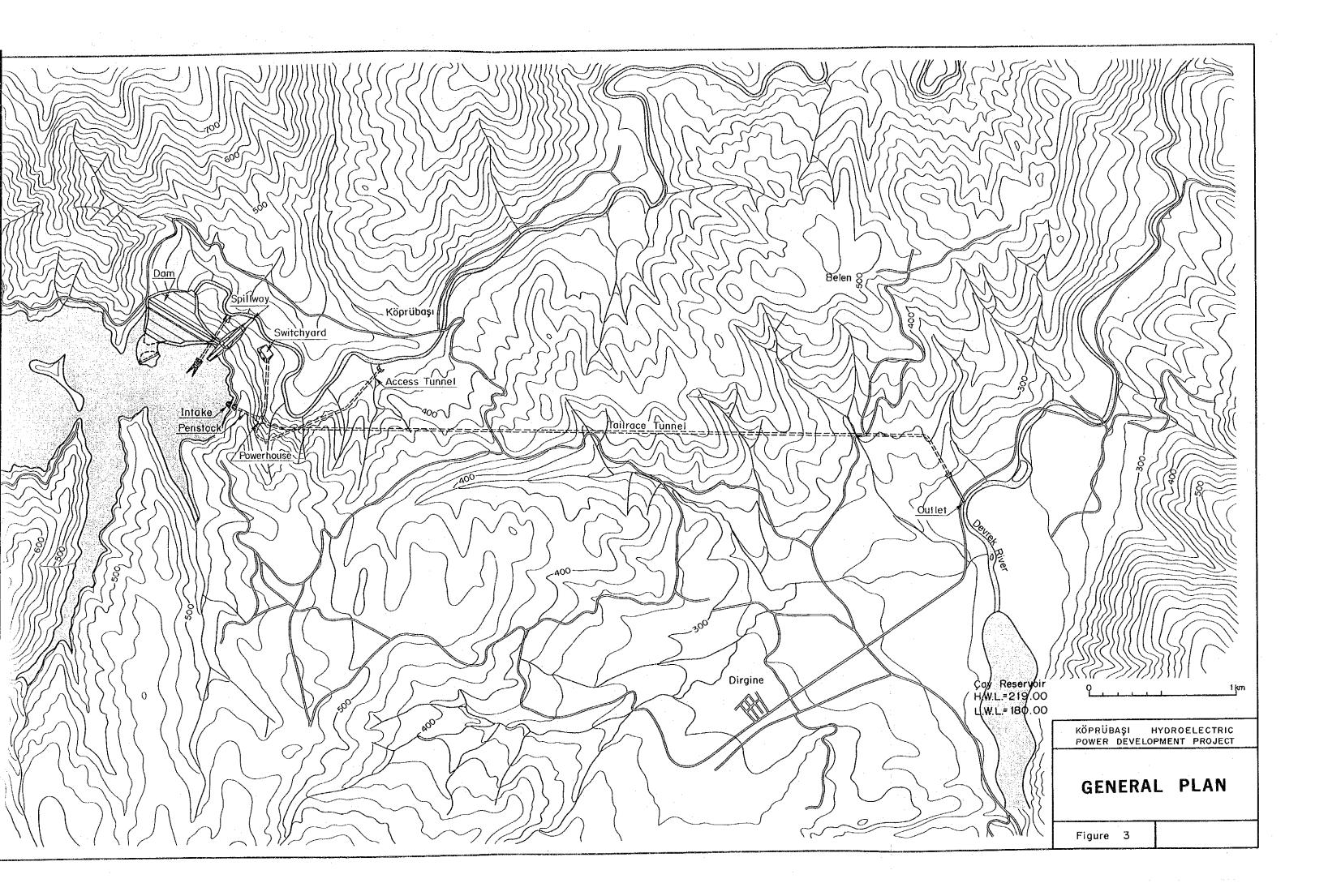


Table of Contents

· ·

		:	. (
		Pac	ıe
1.1			leita
Summ	nary	S	1
Conclu	lusion & Recommendation	R -	1
QUIIQI		.r ·	- 1
Chant	ter 1 INTRODUCTION		
onapo			
1 1	Background of the Project	1	່. ງ
7.47		1 -	2
1.2	Objective of Study	t [']	٨
1.2		ι	4
1.3	Field Investigation during the Study	L -	٨
1.0	Field investigation during the Study	• • •	4
1.4	The Record of Dispatched Team and		
T • Z		L -	1
		. –	4
Chante	er 2 GENERAL SITUATION IN THE REPUBLIC OF TURKEY		
0.1			
2.1	Geography	2 –	7
£. • .		, –	т
2.2	Climate	2	5
412			2
	2.2.1 Air Temperature	<u>:</u> _	2
		· -	
· · ·			7
2.3	Population	·	5
200			5
2.4	Economy	_	E
4 • T		-	<u>ر</u>
2.5	Energy Resources		0
60 † J			7
2.6	Transportation and Telecommunication	-	14
4.0	remeption and referentiation		3.4

<u>Page</u>

	Chapter	3 GENERAL SITUATION IN PROJECT AREA AND SURROUNDINGS			
	3.1	General Situation in Project Area	3	-	1
	1. S.		۰.		
		3.1.1 General Situation	3		1
		3.1.2 Water Resources Development Plan and		, ,	
		its Present State	3		2
			·	• •	
	3.2	General Situation in Project Area	3	-	5
	· · ·	3.2.1 Landform and General Natural State	3		5
	· · ·	3.2.2 Natural and Social Environment		→	
				:	
	Chapter	4 ELECTRIC POWER IN TURKEY			
	4.1	Present Situation of Electricity	. 4	••••	1
	4.2	Electric Power Utilities	4	_	ર
			A .		
	4.3	Electric Power Facilities	4	 	6
					Ū
	4.4	Electric Power Supply and Demand	4	•	9
					-
			•		
	Chapter	5 POWER DEMAND FORECAST AND POWER DEVELOPMENT PLAN			
			_		_
	5.1	Power Demand Forecast	5	-	1
			_		
		5.1.1 Power Demand Analysis			
		5.1.2 Power Demand Forecast			
1		5.1.3 Power Demand Forecast by TEK	5		16
	с ^	Development Dies fan Deven Devend and			
	5.2	Development Plan for Power Demand and	~		
		Supply Balance	5	-	17
	· .	5.2.1 Power Development Plan	5		17

ii

<u>Page</u>

	5.2.2	Demand and Supply Balance	5	=	18
	5.2.3	Necessity of Köprübaşı Power Station and			
· .	4) 1	its Commissioning Year	5	-	18
13	•	and the second			
Chapte	r 6 METEO	ROLOGY AND HYDROLOGY			
6.1	Outline	of Meteorology and Hydrology	6	-	1
	6.1.1	General	6	- .	1
	6.1.2	Meteorological and Hydrological			
			6	-	2
	6.1.3	Meteorology and Hydrology of Project Area	6	-	2
•					
6.2	Runoff	at Project Site	6	-	10
	at a s		÷.,		
	6.1.2	Representative Gauging Stations	6	-	10
	6.2.2	Catchment Area of Damsite	6	-	10
	6.2.3	Supplementation of Runoff Data	6	-	10
	6.2.4	Verification of Runoff Data	6	-	12
	6.2.5	Runoff at Damsite	6	ana a	13
6.3	Evapora	ition	6		26
	. .				
•	6.3.1	Data Used for Calculation of			
	e Alexandre de la composición de la compo	Evaporation	6		26
	6.3.2	Calculation Formula for Evaporation	6		26
4	6.3.3	Air Temperature	6	•••	26
-	6.3.4	Evaporation from Reservoir Surface	6	<u> </u>	27
6.4	Sedimen	ntation in Reservoir	6	-	33
· . ·		e con españa en esta en españa en entre esta en esta e			
n de la Maria	6.4.1	Data Used for Calculation of			
			6	-	33
	6.4.2	Suspended Load	6	_	34
	6.4.3	Bed Load	6		39
	6.4.4	Trap Efficiency of Reservoir	6	-	39

Page

	• •		Page
			· · · .
	6.4.5	Calculation of Sediment (by Weight)	
•		Entering Reservoir	6 - 39
	6.4.6	Sediment Density	6 - 40
	6.4.7	Design Sedimentation of Reservoir	6 - 41
6.5	Probabl	e Flood Discharge	6 - 45
	6.5.1	Data Used for Calculation of	·
- - -		Probable Flood Discharge	6 - 45
ļ	6.5.2	Probable Flood Discharge at Damsite	6 - 45
		and the second second product second seco	
6.6	Probabl	e Maximum Flood	6 - 51
		Probable Maximum Precipitation (PMP)	6 - 51
	6.6.2	Unit Hydrograph	6 - 53
	6.6.3	Probable Maximum Flood	6 - 53
	:		
Chapte	er 7 GEOLO	GY AND CONSTRUCTION MATERIAL	
:			
7.1	Geology		7 - 1
· ·	7.1.1	Introduction	7 - 1
	7.1.2	Outline of Investigation	7 - 2
	7.1.3	Regional Geology	7 - 6
	7.1.4	Site Geology	7 - 11
7.2	Materia	15	7 - 44
	7.2.1	Impervious Material (Core material)	7 - 45
	7.2.2	Filter Material	7 - 51
	7.2.3	Pervious Materials (Concrete Aggregates)	7 - 52
	7.2.4	Rock Materials	7 - 55

iv

<u>Paqe</u>

Chapter 8 SEISMIC ANALYSIS

8.1	Structural Geology of Turkey	8	1
	8.1.1 Geological Outline	8 -	1
	8.1.2 Neotectonics of Turkey	8 -	2
	8.1.3 North Anatolian Fault and East Anatolian		
	Fault	8 -	3
	8.1.4 General Seismicity of Turkey	8 -	4
8.2	Design Seismic Coefficient	8 -	9
	8.2.1 Conclusion	8 -	9
	8.2.2 Design Seismic Coefficient for		
	Existing Dams	8 -	10
1. 1.	8.2.3 Design Seismic Coefficient Calculation		
	at Project Site	8 -	10
· · ·	8.2.4 Analysis by DS1 \ldots	8 -	13
• •			
Chapte	9 DEVELOPMENT PLAN		
9.1	Review of Existing Development Plans	9	1
2.1	Actica of Barbering beveropment frame		
	9.1.1 Filyos River Basin Master Plan	9 -	1
· ·	-	9 –	2
9.2	Comparative Study of Alternative Development Plan	9 –	17
		9 -	17
	J.Z.I MCMOU OF COMPARALLO Sound I I I I I I		22
	J.Z.Z Majout		35
		9 – 0 .	55 54
	9.2.4 Power Station Scale	9 -	54
		9 -	58

, v

		Page
0.2	Dermaturen Car Broject	9 70
9.3	Downstream Cay Project	
· · ·	9.3.1 Reservoir	9 - 70
	9.3.2 Power Station Scale	9 - 72
1. A.	9.3.3 Alternative Development Plan of	5 .2
	Çay Project	9 - 73
		5 75
•	n en en particular de la transforma en transforma en la seconda de la seconda de la seconda de la seconda de la Esta en la seconda de la se	
Chanter	10 TRANSMISSION LINE AND POWER SYSTEM ANALYSIS	
onapter		
10 1	Summary of Power System	10 - 1
10.1	Summary of Power System	. T.O
10.0	Transmission Line for Köprübaşı Power Station .	10 - 1
10.2	Transmission Line for Koprubaşı Power Station :	10 - 1
	10.2.1 Doute Currow	10 - 1
•	10.2.1 Route Survey \ldots	10 - 3
	10.2.2 Transmission Line	· TA - 2
10.0		10 - 4
10.3	Power System Analysis	10 - 4
	10 D. J. Coultries of Coston Colorlation	10 - 4
	10.3.1 Conditions of System Calculation	10 - 4 10 - 6
	10.3.2 Results of System Calculation	10 - 0
Chaptor	11 FEASIBILITY DESIGN	
Onapter		
11 1	Civil Norka	11 _ 1
11.1	Civil Works	11 - 1
11.1		
11.1	11.1.1 Dam	11 - 1
11.1	11.1.1 Dam	11 - 1 11 - 4
11.1	11.1.1 Dam	11 - 1 11 - 4 11 - 5
11.1	11.1.1 Dam	11 - 1 11 - 4 11 - 5 11 - 5
11.1	11.1.1 Dam	$11 - 1 \\ 11 - 4 \\ 11 - 5 \\ 11 - 5 \\ 11 - 6$
11.1	11.1.1 Dam	$11 - 1 \\ 11 - 4 \\ 11 - 5 \\ 11 - 5 \\ 11 - 6 \\ 11 - 6$
11.1	11.1.1 Dam	$11 - 1 \\ 11 - 4 \\ 11 - 5 \\ 11 - 5 \\ 11 - 6 \\ 11 - 6 \\ 11 - 7$
11.1	11.1.1 Dam	$11 - 1 \\ 11 - 4 \\ 11 - 5 \\ 11 - 5 \\ 11 - 6 \\ 11 - 6 \\ 11 - 7$
11.1	11.1.1 Dam	$11 - 1 \\ 11 - 4 \\ 11 - 5 \\ 11 - 5 \\ 11 - 6 \\ 11 - 6 \\ 11 - 7$
11.1	11.1.1 Dam	$11 - 1 \\ 11 - 4 \\ 11 - 5 \\ 11 - 5 \\ 11 - 6 \\ 11 - 6 \\ 11 - 7$
11.1	11.1.1 Dam	$11 - 1 \\ 11 - 4 \\ 11 - 5 \\ 11 - 5 \\ 11 - 6 \\ 11 - 6$
11.1	11.1.1 Dam	$11 - 1 \\ 11 - 4 \\ 11 - 5 \\ 11 - 5 \\ 11 - 6 \\ 11 - 6 \\ 11 - 7$
11.1	11.1.1 Dam	$11 - 1 \\ 11 - 4 \\ 11 - 5 \\ 11 - 5 \\ 11 - 6 \\ 11 - 6 \\ 11 - 7$

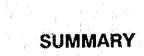
11.2	Electro	-Mechanical Equipment	11	- - -	10
· .	11.2.1	Selection of Number of Unit	11	·	10
	· · · ·	Type and Rating of Major Equipment	11		
		Main Circuit Equipment	11		12
11 - A.F		Telecommunication Equipment	11		
11.3	Transmi	ssion Line	11		14
	11.3.1	Transmission Line Route	11	-	14
	11.3.2	Conductor, Insulator and Ground-wire	11	e #	15
		Supporting Structure	11	-	15
e segu Ne segu					
Chapter	12 CONST	RUCTION PROGRAM AND CONSTRUCTION COST			
· · ·			• •		4
12.1	Construc	ction Program and Construction Schedule .	12	-	T
	12.1.1	Basic Conditions to Affect the			
	12,11,1	Construction Program	12		1
4 - A 2	12.1.2	Construction Program and Construction			
		Schedule	12		4
					÷
12.2	Estimate	e of Construction Cost	12		17
· · ·				ċ	
	12.2.1	Fundamental Matter	12	-	17
	12.2.2	Construction Cost	12		22
· .					
Chapter	13 Effect of	on Environment and Compensation			
	: 		10		1
13.1	Study M	iethod	13	-	1
13.2	Overal]	L Environmental Assessment	13		2

.

<u>Paqe</u>

,	Chapter	14 ECONOMIC AND FINANCIAL EVALUATION	•		
	14.1	Economic Evaluation	14		1
		14.1.1 Methodology	14	••	1
		14.1.2 Economic Costs of the Project	14	-	8
		14.1.3 Parameters and Economic Costs of			
	· .	Alternative Thermal Power Plant	14	-	10
		14.1.4 Economic Evaluation	14		14
-	14.2	Financial Evaluation	14	-	16
		14.2.1 Methodology	14	-	16
		14.2.2 Financial Costs of the Project	14	•	16
		14.2.3 Financial Revenue of the Project	14	-	17
		14.2.4 Financial Evaluation	14	-	17
	Chapter	15 LOAN REPAYMENT SCHEDULE			
	15.1	Basic Consideration	15	-	1
	15.2	Required Amount of fund	15	-	1
	15.3	Income and Cost	15		2
	15.4	Loan Repayment Schedule	15	-	3
	Chapter	16 THE FURTHER INVESTIGATION			·
	16.1	Geology	16	••	1 .
	16.2	Environment	16	-	2

viii



SUMMARY

This report concerns the feasibility study of the Köprübaşı Hydroelectric Power Development Project of the Republic of Turkey. The feasibility study has been conducted from 1992 to 1994 by the Japan International Cooperation Agency (JICA) under a technical cooperation program of the Government of Japan.

This report is submitted by JICA, through the Ministry of Foreign Affairs of the Japanese Government, to the General Directorate of State Hydraulic Work (DSI) of the Government of Turkey

A brief summary of the results of the feasibility study is presented in the following part of this section.

(1) Background of the Project

The Filyos River is located in a region with the greatest amount of rainfall in Turkey, but in spite of the fact that there are development plans for 192 MW and annual energy production of 680 MWh at 7 sites, the area is a virgin land where no electric power development at all has been done. Of the projects at the 7 sites the one with the highest priority is this Project. That the development of this river will be commenced with the cooperation of the Japanese Government is expected to have a great effect as a primer for stimulating development to cope with power shortages in the near future for Turkey where there has been a tendency for delay in preparations of development plans due to lack of funds.

Commissioning of Köprübaşı Power Station is planned for the year 2001. According to the forecast of TEK for that time the peak demand will be 22,610 MW, which will be as much as 2.3 times the 9,965 MW of peak demand in 1991, and there is a necessity for both hydro and thermal power stations to be developed nationwide with considerable speed. Although

Köprübaşı Power Station is of small scale, it is of a suitable degree as a hydropower station for handling a part of the power demand of 540 MW (in 2001) of the 154-kV system in the vicinity.

Furthermore, there is only the 300 MW of Yenicata Thermal Power Station as a source for meeting this 540-MW demand, and a hydropower station of appropriate scale will make it possible for flexible operation of power stations to be carried out. In other words, it is considered that a hydropower station which is close to the load area and can be flexibly operated should be developed as soon as possible.

- (2) Electric Power Demand Forecast and Electric Power Development Program
 - 1) Electric Power Demand Forecast

1. - L

As a result of comparing the estimate according to the regression formula and the forecast by TEK, proximate values were obtained and the demand forecast of TEK was adopted.

Parenthetically, according to the electric power demand forecast (as of 1993), the maximum power demand in the year 2010 will be 43,590 MW and the electric energy production 271,450 GWh, and an annual growth rate of 8.0% and annual load factor of 71% are forecast. (See Table 5-7)

2) Electric Power Development Program

It was decided to follow the electric power development program of TEK, according to which the scale of electric power development from 1993 is to be 41,216 MW, the breakdown being 26,575 MW (64.5%) thermal and 14,641 MW (35.5%) hydro, and the installed

capacity in 2010 will total 60,056 MW (34,970 MW thermal, 2,000 MW nuclear, 23,086 MW hydro). (See Table 5-8)

(3) Power System Analysis

An analysis was carried out assuming the electric power system around the year 2001, the year of commissioning of Köprübaşı Power Station, in order to check the characteristics of power systems in the vicinity of the power station.

The results obtained were

a) that there is the effect of improving the characteristics of electric power systems in the neighboring area through interconnection with the 154kV system,

- b) that additions of 380/154-kV transformers at the Osmanca and Eregli substations can be delayed through reductions in electric power received from the 380-Kv system,
- c) that there will not be any problem with system stability and short-circuiting capacity in relation to the existing system accompanying commissioning of Köprübaşı Power Station.

(4) Meteorology and Hydrology

1) Dam-site Runoff

Projected dam site

Natural inflow

Specific runoff

14.4 m^3/s 7.2 $\ell/s/km^2$

Projected dam site (Master Plan) catchment area

 $1,994 \text{ km}^2$

2) Sedimentation

The annual suspended sediment volume at the projected dam site was determined to be as follows:

Projected site $Q_{SMD} = 313,060 \text{ t/yr}$ Based on the above, the sedimentation 50 years later is estimated as being

Projected site $S_{VU} = 15.50 \times 10^6 \text{ m}^3$

(5) Geology, Materials, and Earthquakes

1) Topography

1.

The Devrek River on which this project is located is a tributary of the Filyos River which empties into the Black Sea, and is one of the rivers in the Pontos folded mountain range belt which extends east-west. At both sides of the Devrek River there rise mountains of 1,000 to 2,000 m laid out in a southwest-northeast direction. Unstable topographic features such as large-scale landslides and collapses have not been found in the results of investigations which have been possible to carry out so far in this area.

2) Geology

All major civil structures in this Project are to be constructed in areas where Mesozoic granites are distributed. The river-bed deposits at the dam site have a thickness of 15 m, and are made up of sandgravel of 1 to 6 cm. An underground powerhouse is to be provided in the granites and the RQD values of boring cores drilled at the site are approximately 100% of good condition.

At the reservoir area, there are distributions of the abovementioned granites, Paleozoic-Precambrian metamorphic rocks and Cenozoic flysch rock bodies, and watertightness of the reservoir will be no problem.

3) Materials

(Core Materials)

Specific gravities are from 2.57 to 2.85 at all sites and satisfactory.

The results of compaction tests are 1.64 to 2.20 t/m³ at optimum water content and satisfactory.

Natural grain-size distributions are more or less good at all sites.

However, collection should be done at Site A.

(Filter Materials)

Specific gravities are from 2.66 to 2.82 at all sites and satisfactory.

The results of compaction tests are all in a range of 1.87 to 2.20 t/m³ at optimum water content and satisfactory.

The natural particle-size distributions are more or less satisfactory.

Concrete Aggregates

(Fine Aggregates)

1. 1. 1

Specific gravity Unit weight Absorption Gradation 2.59 - 2.71 1.65 - 1.82 t/m³ 0.8 - 2.7% Within limits

If the material were to be thoroughly washed with water it can be used as good-quality aggregate.

(Coarse Aggregate)

March 1997 March 1997 And Andrew March 1997	
Specific gravity	2.67 - 2.75
Unit weight	$1.91 - 2.00 \text{ t/m}^3$
Absorption	0.6 - 0.9%
Gradation	Within limits

Similarly to fine aggregate, the material can be used as good-quality aggregate if washed thoroughly with water.

(Rock Materials)

It was concluded that to use the granodiorite at Site Q would be suitable from the standpoint of distance and material quality.

4) Earthquakes

The project site is located 30 km to the north of the North Anatolian Fault and is in a zone of high seismicity where more than 60 earthquakes of magnitude 5.5 or greater have occurred since 1900 up to the present. (Second Degree Earthquake Risk Zone) Particularly, the Erzincan Earthquake of 1939 was of magnitude 7.9, the greatest earthquake of the century in Turkey.

Designing was done using earthquake data of 8,136 earthquakes recorded in Turkey during a period of 87 years. As a result of seismic coefficient calculations, the maximum was 0.15. Accordingly, 0.15 was adopted as the design seismic coefficient of this dam.

(6) Investigations for Environmental Assessment

- Physical and Physiological Environmental Characteristics and Utilization of Natural Resources Investigations were made regarding the items below, but nothing was found that would especially present obstacles to the Project.
 - Meteorological characteristics and meteorology

Geological characteristics

Hydrogeological characteristics

- Soil characteristics and conditions of use
- Characteristics of agricultural land
- Hydrological characteristics
- Present and planned utilization of surface water
- Aquatic organisms

Geothermal and hydrothermal resources

Protected areas

Forest resources

Flora and fauna

Animal husbandry resources

Mineral resources

Locations of high scenic value and recreation areas

Present pollution load of region

2) Socio-economic Environment

The main sources of income at Kayabuku Village planned for the reservoir are agriculture and logging with the annual income per household 10 million TL.

Population

The population of Kayabuku Village in November 1992 was 392, there being a large number of emigrant workers who are away.

Social Infrastructure and Services

The entire project area has only elementary schools. There is electricity and telephone service to an extent.

• Land Use

Only agricultural land and stock farms exist in the whole Kayabuku Village area.

Sanitation and Hygiene

There are no medical facilities at the villages in the project area, but neither are there any contagious diseases.

- 3) Results of Examination
 - The existence of precious fauna or flora has not been confirmed at this project site.
 - It is considered that extreme eutrophication will not be caused with the future water quality of the reservoir.

- With regard to pollution during construction the work is to be made to perform observing relevant laws and regulations.
- Regarding dislocation of inhabitants in the project area, it is desirable for consideration to be given to compensation, priority employment during construction, and effective utilization of the reservoir.

It is judged that implementation of this Project will not greatly affect the natural environment if the above measures are taken.

(7) Optimum Development Plan

waterway power The Köprübaşı Project is а dam and generation scheme in which a rockfill dam 110 m in height is to be constructed at a site on the midstream stretch of the Devrek River approximately 20 km downstream of its confluence with the Mengen River to provide a reservoir of effective storage capacity 163 x 10⁶ m³, conduct water to an underground powerhouse to be provided at the Dirgine district by a headrace tunnel 41.50 m in length and a penstock of 265 m, generate 70 MW of electric power with an effective head of 190 m and maximum available discharge of 43 m³/s, upon which discharge is to be done from the right bank of the Devrek River by a tailrace 4,900 m in length.

(8) Construction Program and Construction Cost

1) Construction Program

The structures in this Project are a rockfill dam of height 110 m, intake, penstock, underground powerhouse, and a tailrace tunnel of 4.9 km.

With start of operation of this Project in the year 2001, it will be necessary for preparations for start of construction to be made according to the schedule below.

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Oct. 1992 - Sep. 1994	Feasibility Study
Oct. 1994 - Mar. 1995	Provision and Award of Final Design (6 months)
an a	Final Design (1 year)
Mar. 1996 - Dec. 1996	Financial Formulation (9 months)
Jan. 1997 - Dec. 1997	Bidding and Award of Contract for Construction (1 year)
	competator (1 Jeal)

Jan. 1998 - Dec. 2001

Construction (4 year)

The critical path of the Project is the powerhouse construction, and it is necessary for a proper schedule to be set up centered on this construction.

2) Construction Cost

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The time of estimation is to be the initial part of 1993 with US\$1 at 8,700 TL.

The total construction cost is to be $1,250,309 \times 10^6$ TL (approximately US\$144 x 10^6).

The attached table should be referred to for a breakdown. (Table 12-5)

(9) Economic Analysis and Financial Analysis

1) Economic Analysis

An imported coal-fired thermal power generating facility was selected as the economic benefit of this Project and as the alternative project for comparison.

The method adopted was to consider the economic cost of this alternative thermal power generating facility as the benefit of this Project and to compare this with the economic cost of the Project.

Unit: 10⁶TL

Köprübaşı <u>Hydropower</u>	Alternative Thermal	Difference	<u>Ratio</u>
Present Value (C)	Present Value (B)	(B-C)	(B/C)
939,686	1,378,629	438,944	1.47

It may be judged from the table above that the Project is superior to the alternative project.

2) Economic Internal Rate of Return

The discount rate (EIRR) at which the respective present values of the investment for this Project and that for the alternative thermal power will be equal in the first year of commissioning of the Project will be 28.98%, which is better than the 9.5% of the opportunity cost of capital, and it may be concluded from the above that this Project is feasible.

3) Financial Analysis

The result of financial analysis was a financial internal rate of return (FIRR) of 9.90%. This ratio is higher than the interest rate of 9.5% on borrowings in both local and foreign currencies. Consequently,

it may be said that this Project is feasible from not only the aspect of economic analysis, but also the aspect of financial analysis.

(10) Summary of the Project

River

Name of River	Devrek
Catchment Area	1,994 km ²
Annual Inflow	$454 \times 10^6 \text{ m}^3 (14.39 \text{ m}^3/\text{S})$
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Reservoir

High Water Level Low Water Level Available Drawdown Depth Sedimentation Level Gross Storage Capacity Effective Storage Capacity Reservoir Area

Dam

Type

Elevation of Dam Crest Height of Dam Length of Dam Crest Volume of Dam

Diversion Tunnel

Design Flood Type Number Inner Diameter Length

Outlet Equipment

Type Diameter Capacity 437.00 m 392.00 m 45.00 m 380.40 m 197.7 x 10^6 m³ 163.0 x 10^6 m³ 5.31 km²

Rockfill Dam with Center Core 441.00 m 110.00 m 540.00 m 5,025 x 10³ m³

350 m³/S Standard Horse Shoe One 6.00 m 390 m

Jet Flow Gate 1.50 m 33.1 m³/S at H.W.L 23.7 m³/S at L.W.L

Spillway

Design Flood Type Overflow Crest Elevation Width of Overflow Crest

Energy Killer System Type of Gate Number of Gate Size of Gate

<u>Power Intake</u>

Type Number Height Inlet Elevation Size

Type of Gate Number of Gate Size of Gate

Headrace Tunnel

Type

Number

Discharge Capacity Inner Diameter Length

Penstock

Type Number

Inner Diameter x Length Main Branch 2,500 m³/3 Shute with Gates 423.00 m 29.00 m (Including pier width 3.00 m) Ski Jump, Plunge Pool Radial Two Wide 13.00 m x Height 14.50 m

Inclined One 57.70 m 383.30 m Width 6.00 m x Height 7.50 m Vertical Shaft Two Wide 2.50 m x Height 5.00 m

Circular Pressure One 43.00 m³/s 3.40 m 41.50 m

Steel Embedded One Line and after Y branched Two Line

3.40 m x 250.10 m 2.20 m ~ 1.70 m x 16.92 m

Powerhouse

Туре

Size (Excavation Surface)

Access Tunnel

Туре

Size

Ventilation Tunnel

Type Size

Cable Tunnel Type

Size

Inspection Gallery

Туре

Size

Tailrace Chamber

Size

Underground

Width 16.00 m x Length 60.00 m x Height 35.30 m

Half Circle Half Rectangular, Concrete Lining Width 5.00 m x Height 5.00 m x Length 1,100 m Inclination 1:8.8 Elevation of Tunnel Exit 358.00 m

Half Circle Half Rectangular, Concrete lining Width 3.00 m x Height 2.80 m x Length 71.76 m Inclination: flat

Half Circle Half Rectangular, Inclined Concrete Lining Width 3.00 m x Height 2.80 m x Length 425.40 m Inclination 1:3.2

Half Circle Half Rectangular, Concrete Lining Width 2.0 m x Height 2.50 m x Length 126 m Inclination 1:29

Width 4.60 m x Height 16.00 m x Length 20.00 m

S. - 15

<u>Tailrace</u>

(Tunnel Portion) Type Max. Discharge

Inner Diameter Length Standard Horse Shoe 43.00 m³/s 4.60 m 4,899 m (Including Draft Length)

(Open Channel Portion) Type Bottom Width Length

Trapezoid 4.60 m 200 m

Development Plan

Standard Intake Water Level Standard Tail Water Level Gross Head Effective Head Maximum Discharge Unit Capacity Number of Unit Installed Capacity

Turbine

туре

Number Max. Discharge Turbine Output Revolving Speed

<u>Generator</u>

Type

Number

Rated Output Revolving Speed 422.00 m 223.00 m 199.00 m 190.00 m 43.00 m³/s 35 MW Two 70 MW

Vertical Shaft, Francis Turbine Two 43.00 m³/s 36,200 kW 429 rpm

Three Phases Alternating Current Synchronous Two 38,900 kVA 429 rpm

Frequency Voltage Power Factor

<u>Main Transformer</u>

Туре

Number Capacity Voltage

Switchyard

Bus System

Bus Number of Lines Connected Voltage Conductor Type

Annual Energy Production Average Energy

Firm Energy

Construction Period

Project Cost

50 Hz 11 kV 0.9 lag

Indoor, Water Cooling
Type Three Phase
Two
13,000 kVA
(Primary) 11.0 kV
(Secondary) 154 kV

Single Bus + Transformer Bus Aluminum Pipe 2 cct 154 kV ACSR

212.1 GWh 151.8 GWh

4 years

1,250,309 x 10⁶TL (About 144 x 10⁶US\$)

Unit Construction Cost at Sending End

Per kW Per kWh 17.9 x 10⁶ TL (2,053 US\$/kW) 5,895 TL (0.68 US\$/kW)

Economic Evaluation

EIRR	28.98%
FIRR	9.90%
Net Benefit	438,944 x 10 ⁶ TL
Benefit-Cost Ratio	1.47

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

- (1) Köprübaşı project should be developed as soon as possible because the project is feasible technically, economically and financially and it is possible to be commissioned the project in 2001 when lead time for final design, financial arrangement and construction period are taken into account.
- (2) In 2001 the peak capacity at that time according to the forecast of TEK will be 22,610 MW, 2.3 times the present. It is planned for new development of 7,671 MW of thermal and 3,544 MW of hydro, a total of 11,215 MW, to be made by 2001. Lignite coal-fired thermal using domestic resources amounting to 3,591 MW is included for development by that time, but the opposition of local residents concerning pollution problems is strong and it is becoming difficult for construction to be carried out according to schedule. It is considered that lignite thermal will be switched in the near future to imported coal-fired thermal or gas-fired thermal because of the problem of pollution.
- The possibility of thermal power station fuel being (3)replaced by imported fuel will become great in this way, and in this sense, it is necessary for development of the domestic energy of hydro to be hurried. Furthermore, the financial situation of the country has become especially adverse in recent years with large-scale projects placed in frozen condition, and it will be a good measure to develop electric power sources of medium and small scale which are near the load areas, and it is possible to avoid making the Diversifying electric power sources, power system large. developing sources close to load areas, cutting power transmission costs, and seeking improvement in stability comprise on-site type dispersed power sources recently talked about, and such development is the trend in the Just as with the relation between mainframe world. computers and personal computers, such electric power