JAPAN INTERNATIONAL COOPERATION AGENCY

THE REPUBLIC OF TURKEY
MINISTRY OF PUBLIC WORKS AND SETTLEMENT
GENERAL DIRECTORATE OF STATE HYDRAULIC WORKS

FEASIBILITY STUDY
ON
KÖPRÜBAŞI HYDROELECTRIC
POWER DEVELOPMENT PROJECT

FINAL REPORT

DECEMBER 1994

ELECTRIC POWER DEVELOPMENT CO., LTD.

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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

December 1994

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.

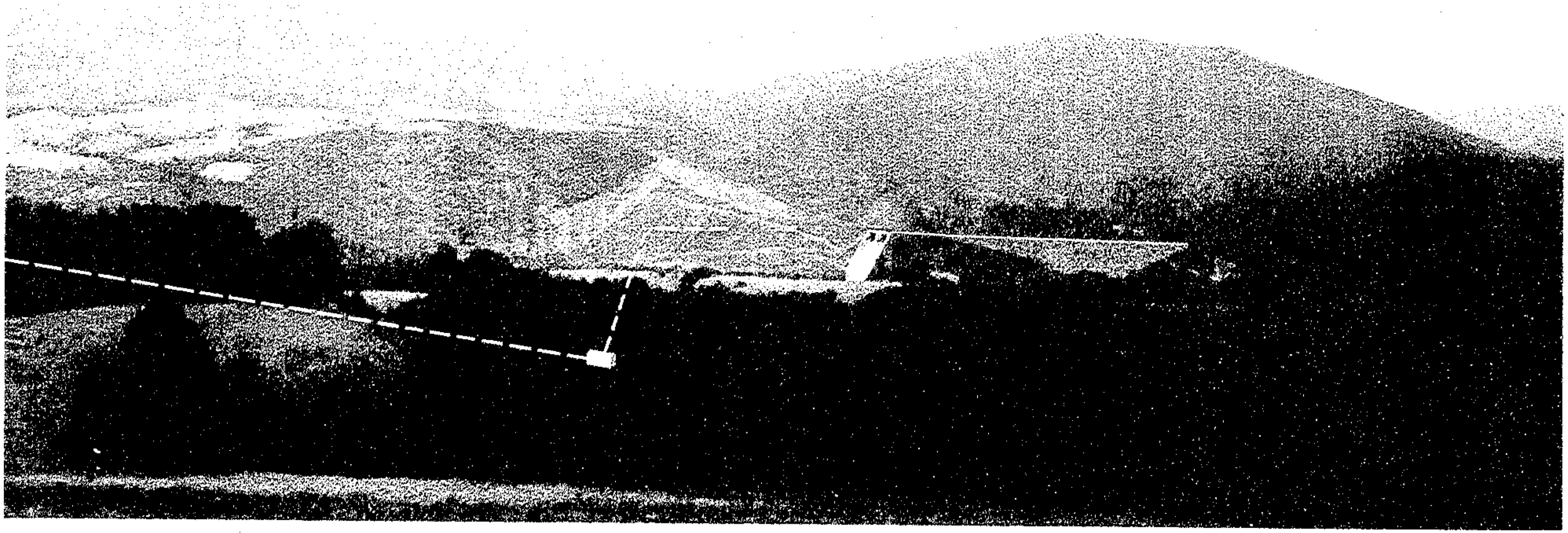
We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs, and the Ministry of Public Works and Settlement. We also wish to express our deep gratitude to the State Hydraulic Works (DSI) and other authorities' concerned of the Government of the Republic 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

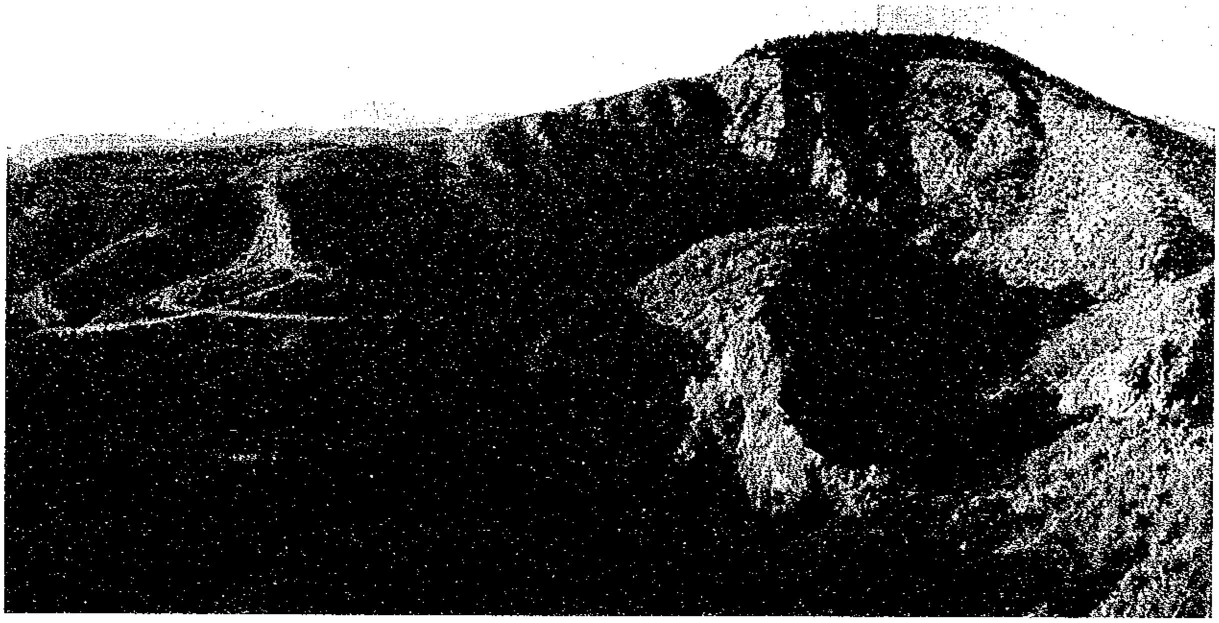
View from upstream left bank



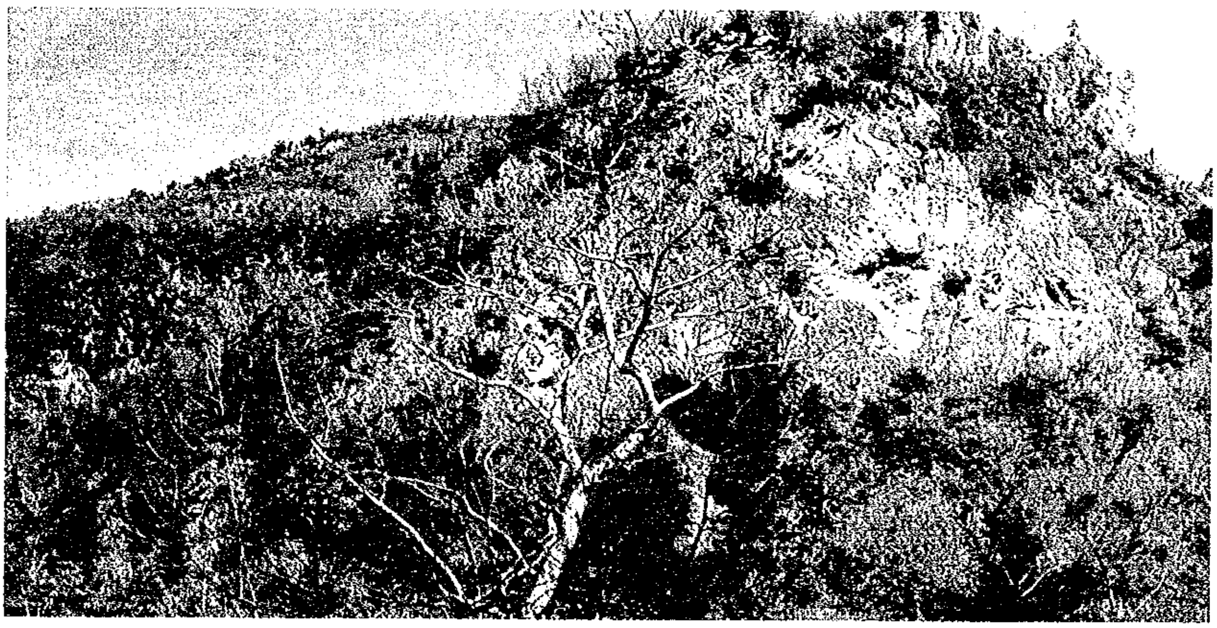
Composite Photograph of Dam Spillway and Power Structure

View from downstream left bank

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

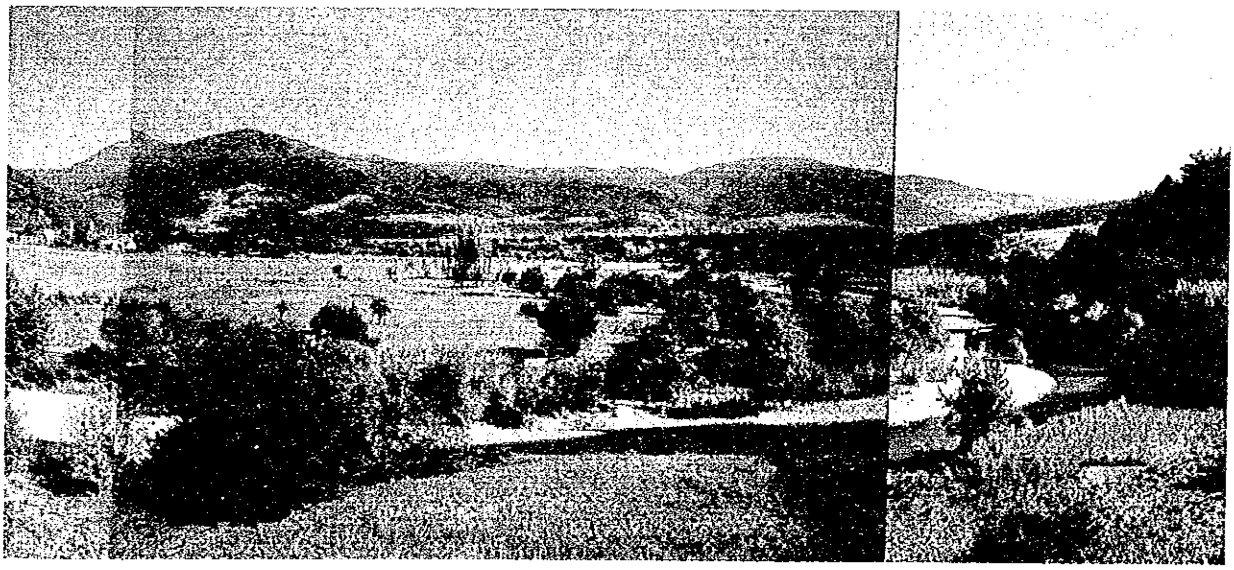


Rock Material Quarry, located 1 km upstream from Dam.
View from left bank

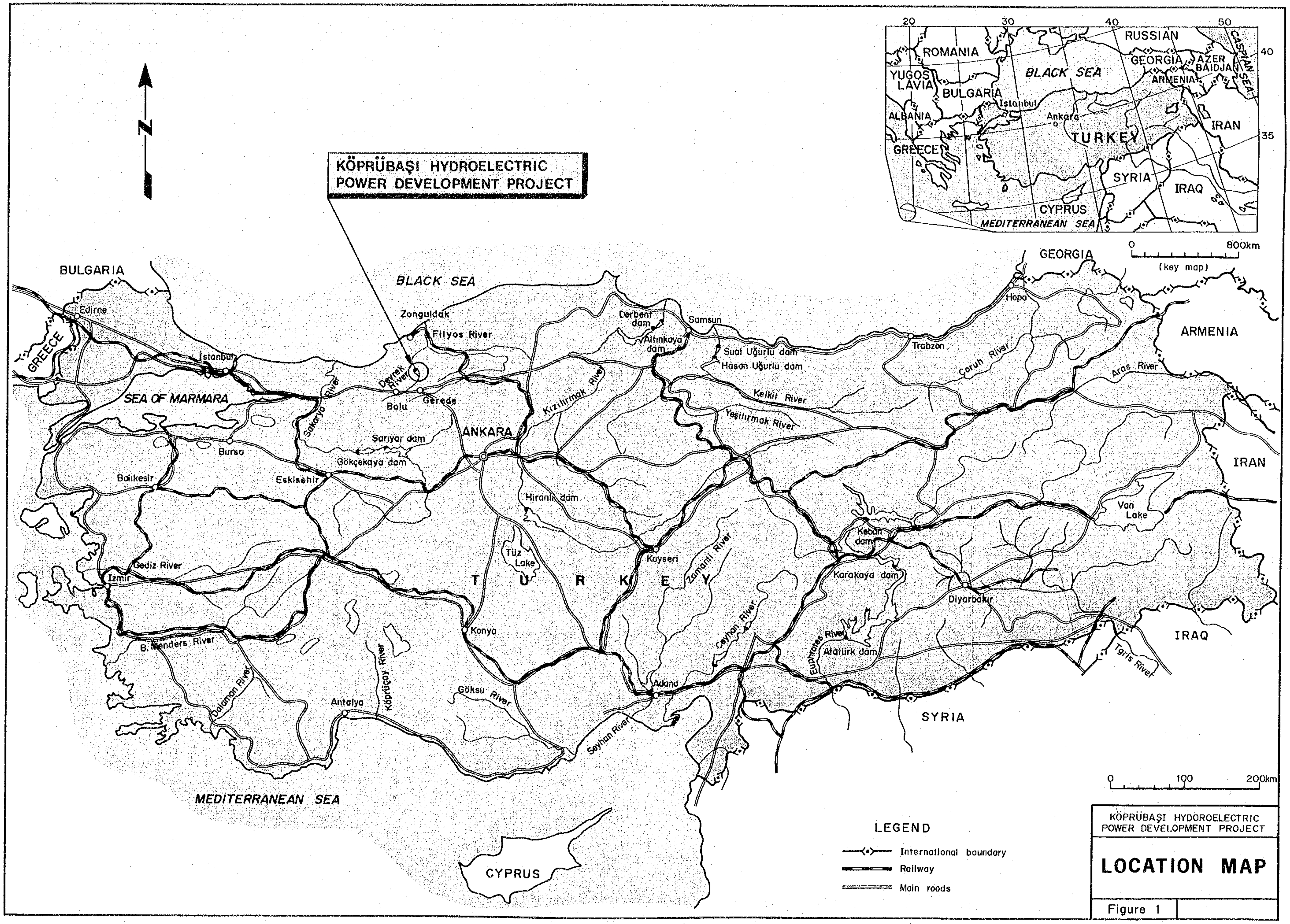


Riprap Material Quarry, located 16 km upstream from Dam.
View from left bank

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



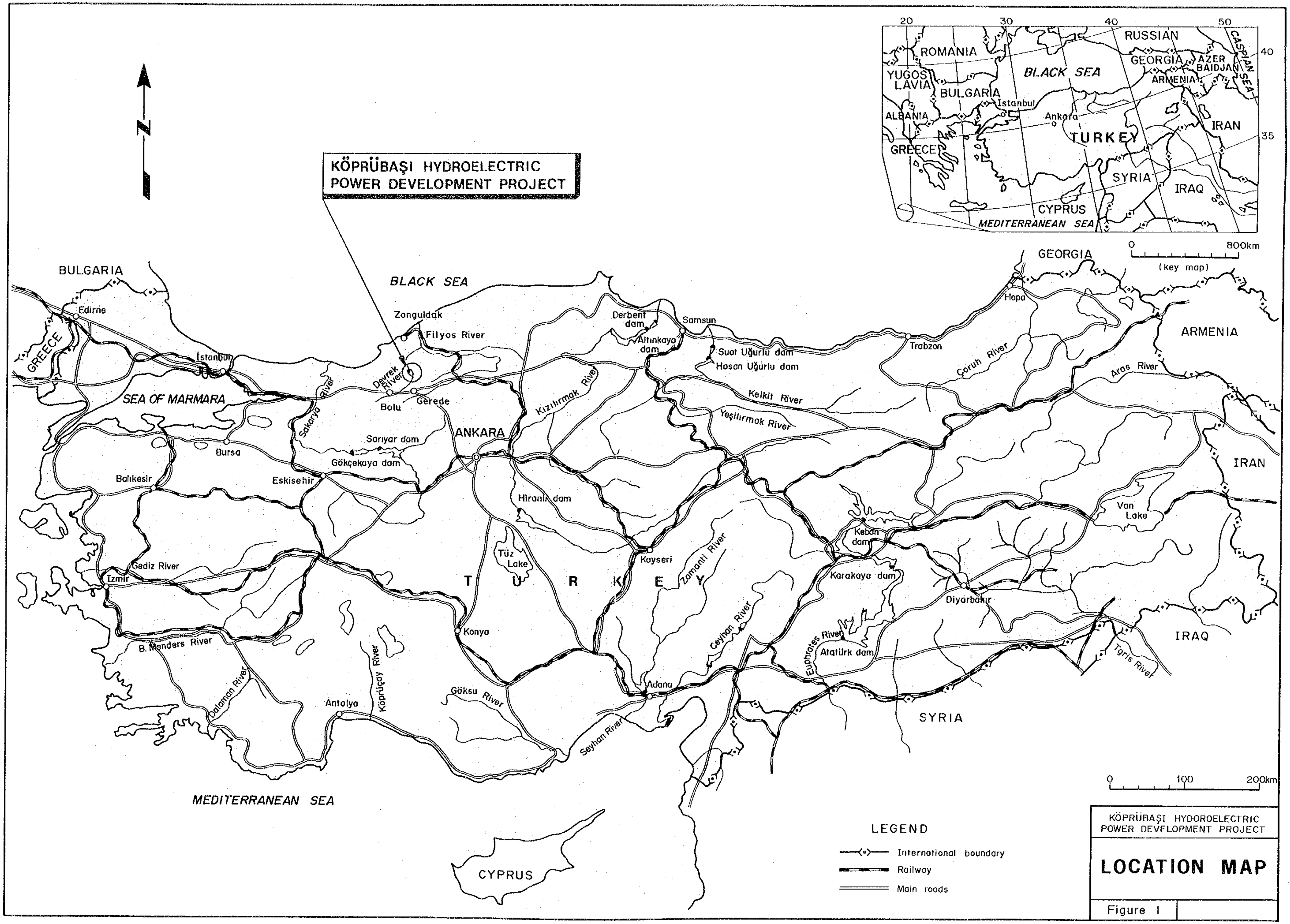
Concrete Aggregate Borrow Area, located around Tailrace Outlet
View from right bank



KÖPRÜBAŞI HYDROELECTRIC POWER DEVELOPMENT PROJECT

LOCATION MAP

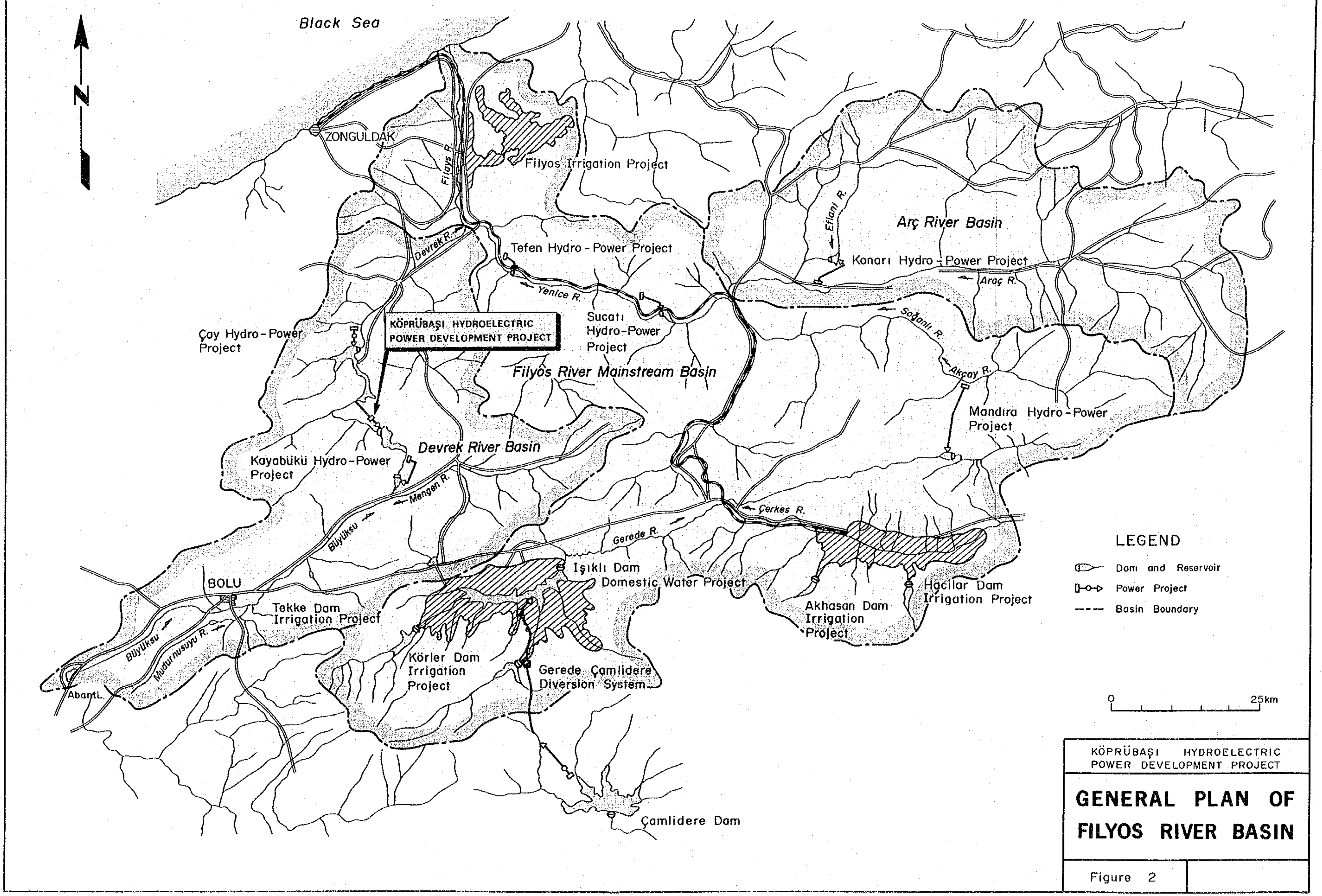
Figure 1



KÖPRÜBAŞI HYDROELECTRIC POWER DEVELOPMENT PROJECT

LOCATION MAP

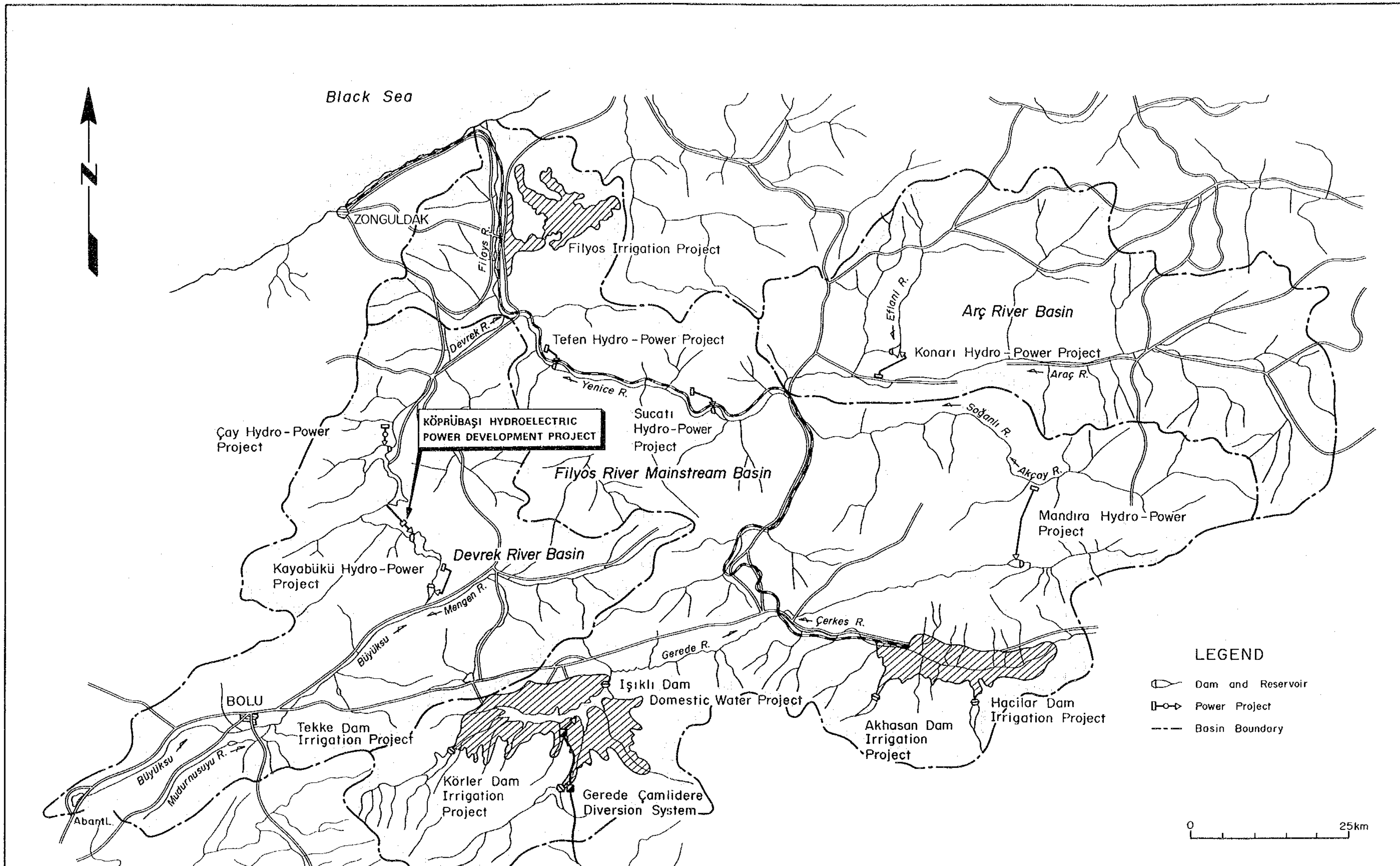
Figure 1



KÖPRÜBAŞI HYDROELECTRIC POWER DEVELOPMENT PROJECT

GENERAL PLAN OF FILYOS RIVER BASIN

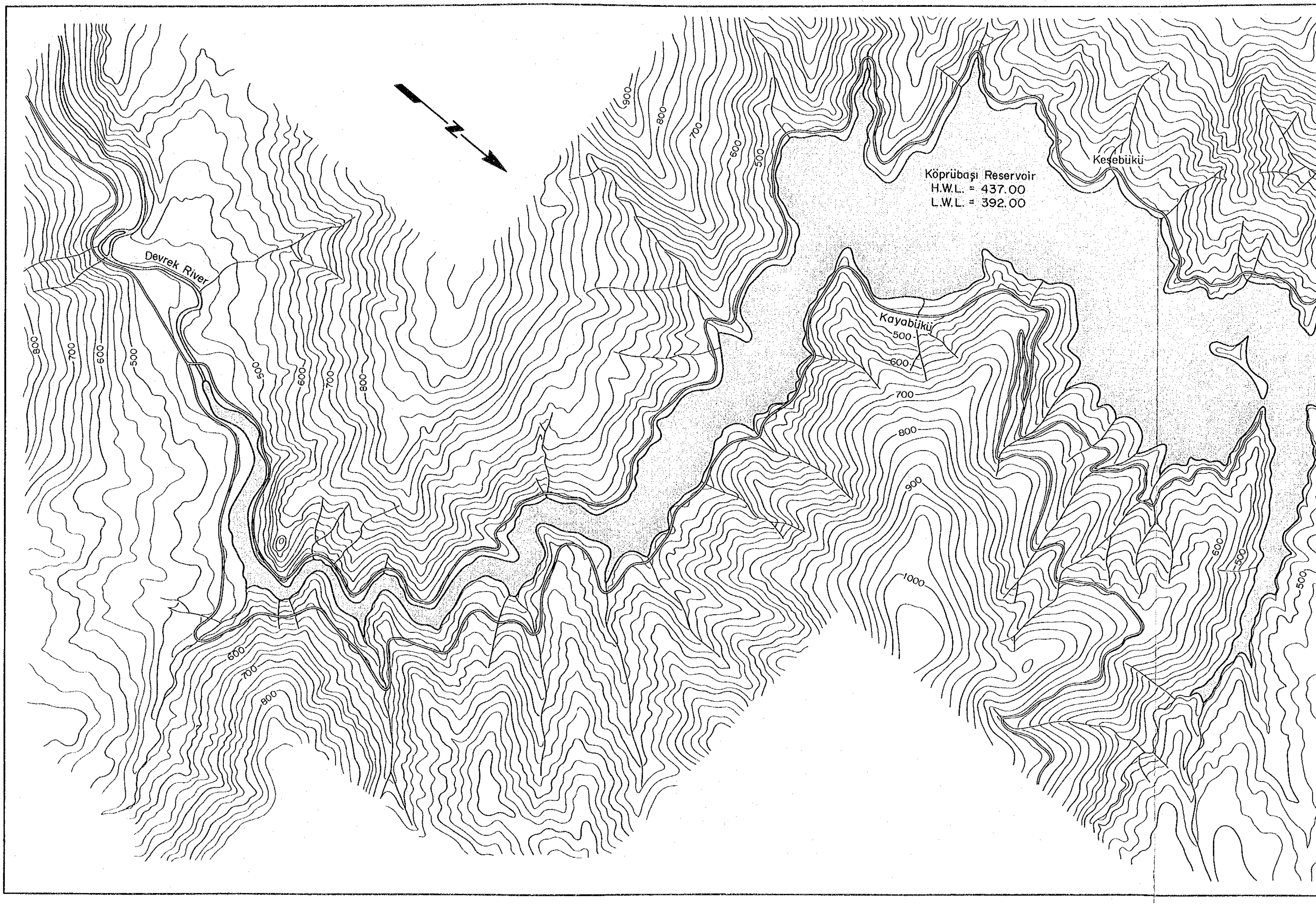
Figure 2

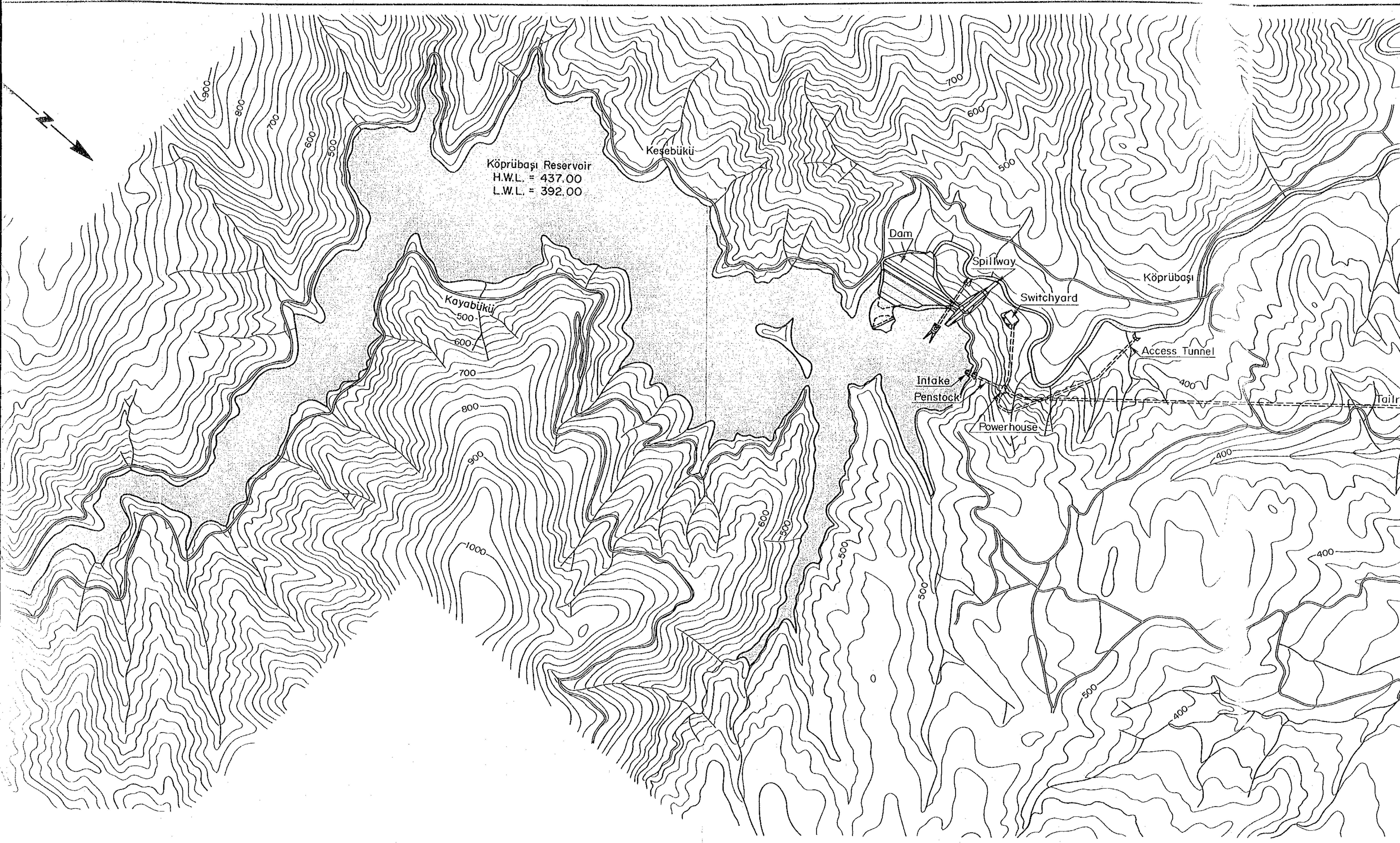


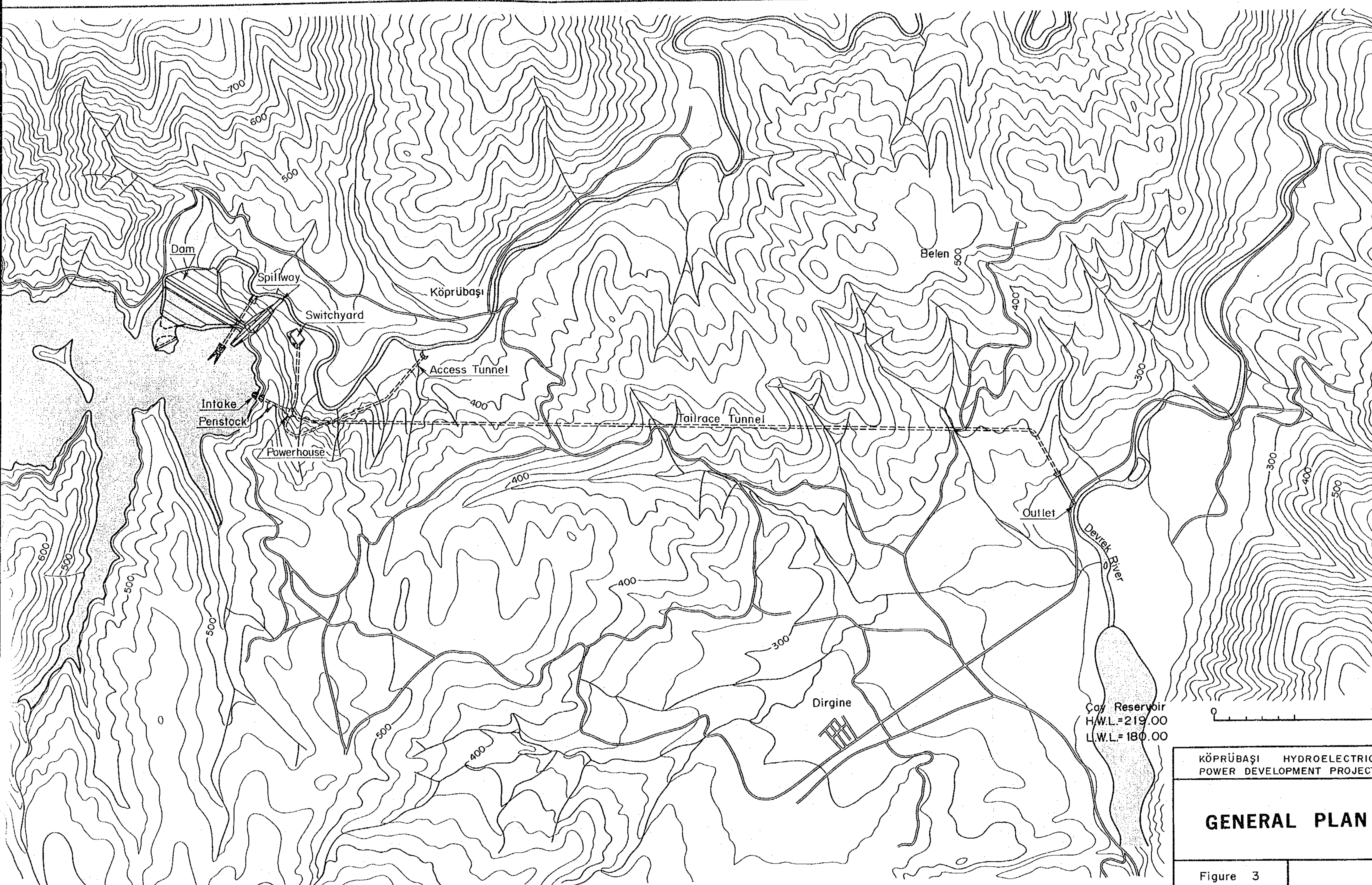
KÖPRÜBAŞI HYDROELECTRIC POWER DEVELOPMENT PROJECT

GENERAL PLAN OF FILYOS RIVER BASIN

Figure 2


N
Köprübaşı Reservoir
H.W.L. = 437.00
L.W.L. = 392.00
Kesebükü
Kayabükü
Devrek River
500
600
700
800
900
1000


Köprübaşı Reservoir
H.W.L. = 437.00
L.W.L. = 392.00
Kesebükü
Kayabükü
Dam
Spillway
Switchyard
Köprübaşı
Access Tunnel
Intake
Penstock
Powerhouse



KÖPRÜBAŞI HYDROELECTRIC POWER DEVELOPMENT PROJECT

GENERAL PLAN

Figure 3

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SUMMARY

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

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 154-kV 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	14.4 m^3/s
Specific runoff	7.2ℓ/s/km^2

Projected dam site (Master Plan) catchment area 1,994 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 t/yr

Based on the above, the sedimentation 50 years later is estimated as being

Projected site S_{VU} = 15.50 x 10^6 m^3

(5) Geology, Materials, and Earthquakes

1) Topography

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 sand-gravel 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/m^3 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/m^3 at optimum water content and satisfactory.

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

Concrete Aggregates

(Fine Aggregates)

Specific gravity	2.59 - 2.71
Unit weight	1.65 - 1.82 t/m^3
Absorption	0.8 - 2.7%
Gradation	Within limits

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

(Coarse Aggregate)

Specific gravity	2.67 - 2.75
Unit weight	1.91 - 2.00 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

1) 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

The Köprübaşı Project is a dam and waterway power 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 163×10^6 m^3, 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 m^3/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.

Oct. 1992 - Sep. 1994	Feasibility Study
Oct. 1994 - Mar. 1995	Provision and Award of Final Design (6 months)
Apr. 1995 - Mar. 1996	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)
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

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 x 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: 10^6TL

Köprübaşı Hydropower	Alternative Thermal	Difference	Ratio
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 x 10^6 m^3 (14.39 m^3/S)
Reservoir	
High Water Level	437.00 m
Low Water Level	392.00 m
Available Drawdown Depth	45.00 m
Sedimentation Level	380.40 m
Gross Storage Capacity	197.7 x 10^6 m^3
Effective Storage Capacity	163.0 x 10^6 m^3
Reservoir Area	5.31 km^2
Dam	
Type	Rockfill Dam with Center Core
Elevation of Dam Crest	441.00 m
Height of Dam	110.00 m
Length of Dam Crest	540.00 m
Volume of Dam	5,025 x 10^3 m^3
Diversion Tunnel	
Design Flood	350 m^3/S
Type	Standard Horse Shoe
Number	One
Inner Diameter	6.00 m
Length	390 m
Outlet Equipment	
Type	Jet Flow Gate
Diameter	1.50 m
Capacity	33.1 m^3/S at H.W.L 23.7 m^3/S at L.W.L

Spillway

Design Flood	2,500 m³/3
Type	Shute with Gates
Overflow Crest Elevation	423.00 m
Width of Overflow Crest	29.00 m (Including pier width 3.00 m)
Energy Killer System	Ski Jump, Plunge Pool
Type of Gate	Radial
Number of Gate	Two
Size of Gate	Wide 13.00 m x Height 14.50 m

Power Intake

Type	Inclined
Number	One
Height	57.70 m
Inlet Elevation	383.30 m
Size	Width 6.00 m x Height 7.50 m
Type of Gate	Vertical Shaft
Number of Gate	Two
Size of Gate	Wide 2.50 m x Height 5.00 m

Headrace Tunnel

Type	Circular Pressure
Number	One
Discharge Capacity	43.00 m^3/s
Inner Diameter	3.40 m
Length	41.50 m

Penstock

Type	Steel Embedded
Number	One Line and after Y branched Two Line
Inner Diameter x Length	
Main	3.40 m x 250.10 m
Branch	2.20 m ~ 1.70 m x 16.92 m

Powerhouse

Type	Underground
Size (Excavation Surface)	Width 16.00 m x Length 60.00 m x Height 35.30 m

Access Tunnel

Type	Half Circle Half Rectangular, Concrete Lining
Size	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

Ventilation Tunnel

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

Cable Tunnel

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

Inspection Gallery

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

Tailrace Chamber

Size	Width 4.60 m x Height 16.00 m x Length 20.00 m

Tailrace

(Tunnel Portion)

Type	Standard Horse Shoe
Max. Discharge	43.00 m^3/s
Inner Diameter	4.60 m
Length	4,899 m (Including Draft Length)

(Open Channel Portion)

Type	Trapezoid
Bottom Width	4.60 m
Length	200 m

Development Plan

Standard Intake Water Level	422.00 m
Standard Tail Water Level	223.00 m
Gross Head	199.00 m
Effective Head	190.00 m
Maximum Discharge	43.00 m^3/s
Unit Capacity	35 MW
Number of Unit	Two
Installed Capacity	70 MW

Turbine

Type	Vertical Shaft, Francis Turbine
Number	Two
Max. Discharge	43.00 m^3/s
Turbine Output	36,200 kW
Revolving Speed	429 rpm

Generator

Type	Three Phases Alternating Current Synchronous
Number	Two
Rated Output	38,900 kVA
Revolving Speed	429 rpm

Frequency	50 Hz
Voltage	11 kV
Power Factor	0.9 lag

<u>Main Transformer</u>

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

<u>Switchyard</u>

Bus System	Single Bus + Transformer Bus
Bus	Aluminum Pipe
Number of Lines Connected	2 cct
Voltage	154 kV
Conductor Type	ACSR

<u>Annual Energy Production</u>

Average Energy	212.1 GWh
Firm Energy	151.8 GWh

<u>Construction Period</u> 4 years

<u>Project Cost</u> $1,250,309 \times 10^6$TL (About 144×10^6US$)

<u>Unit Construction Cost at Sending End</u>

Per kW	17.9×10^6 TL (2,053 US$/kW)
Per kWh	5,895 TL (0.68 US$/kW)

<u>Economic Evaluation</u>

EIRR	28.98%
FIRR	9.90%
Net Benefit	$438,944 \times 10^6$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.

(3) The possibility of thermal power station fuel being 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 power system large. Diversifying electric power sources, 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 world. Just as with the relation between mainframe computers and personal computers, such electric power