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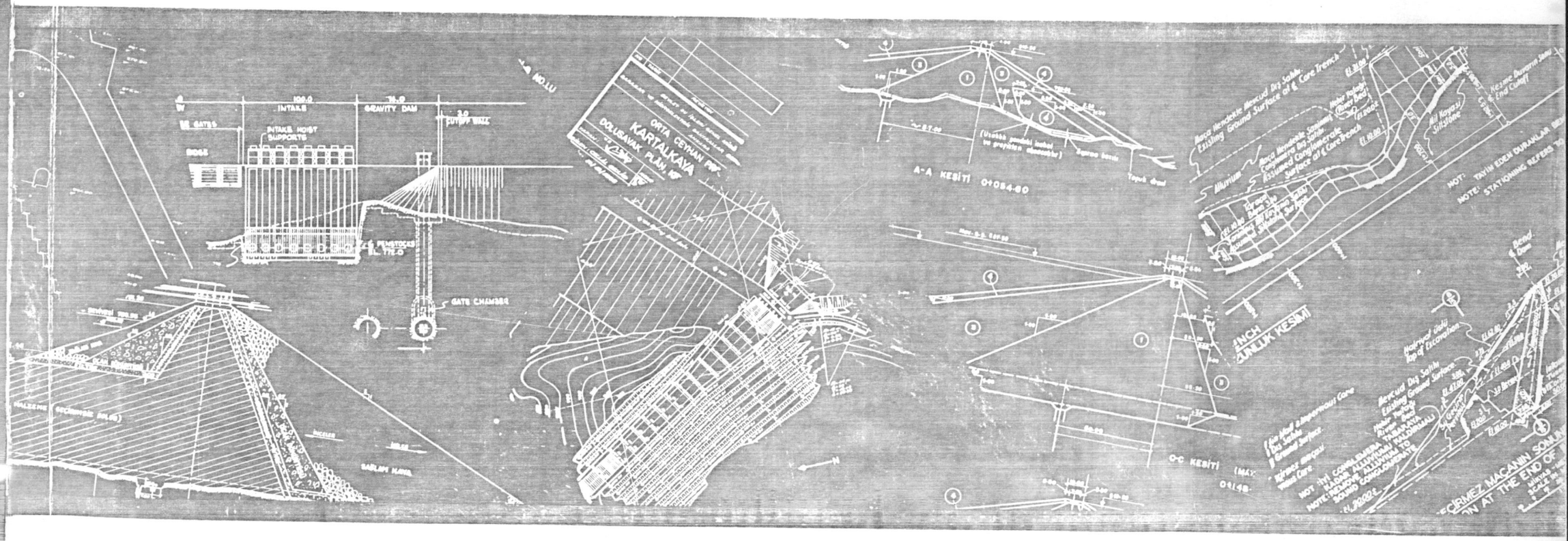
large dams in Turkey



Orhan M. URAL
and
Ünver UNGAN

1967

LARGE DAMS IN TURKEY

by
Orhan M. URAL
and
Ünver UNGAN

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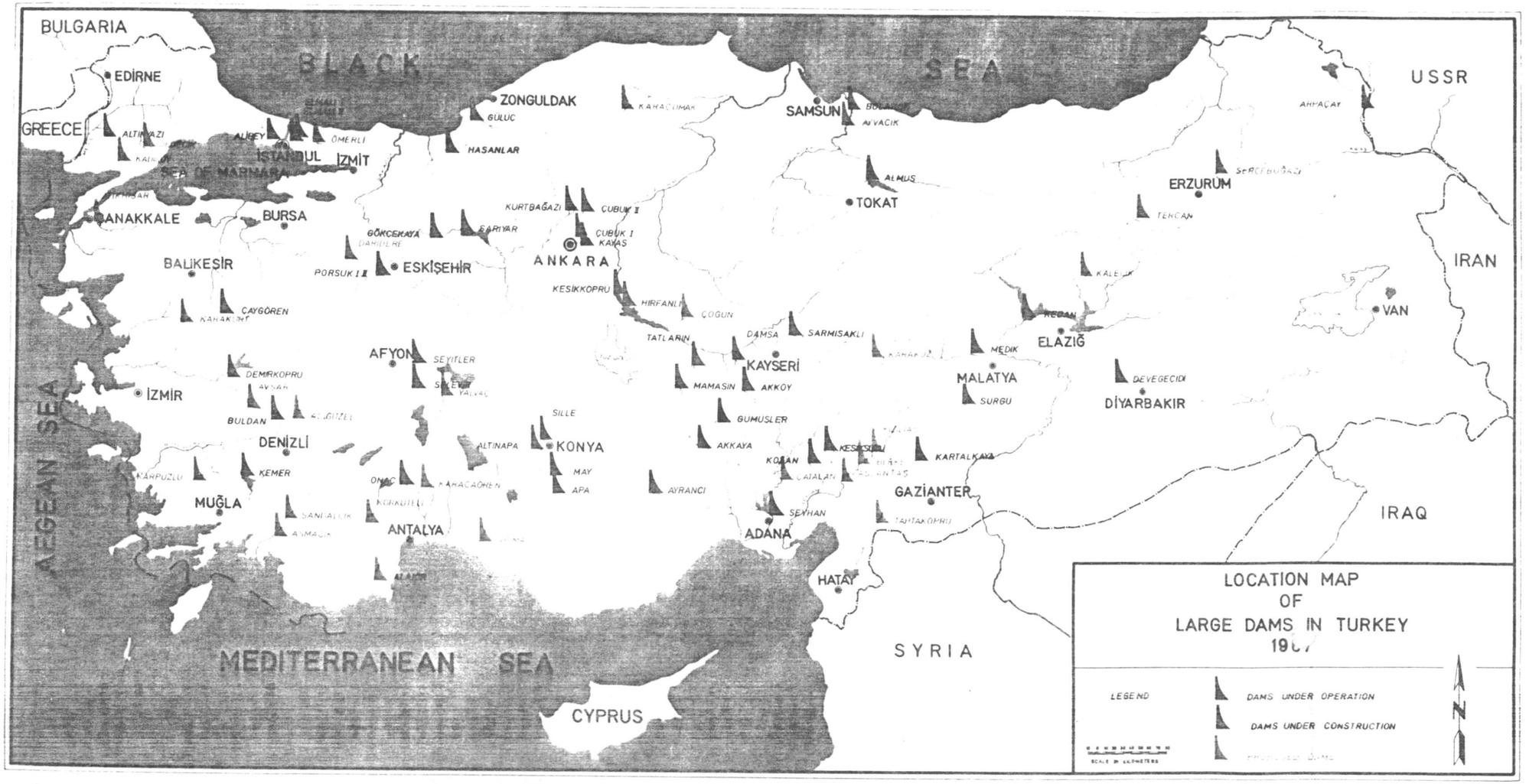
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DAMS UNDER OPERATION
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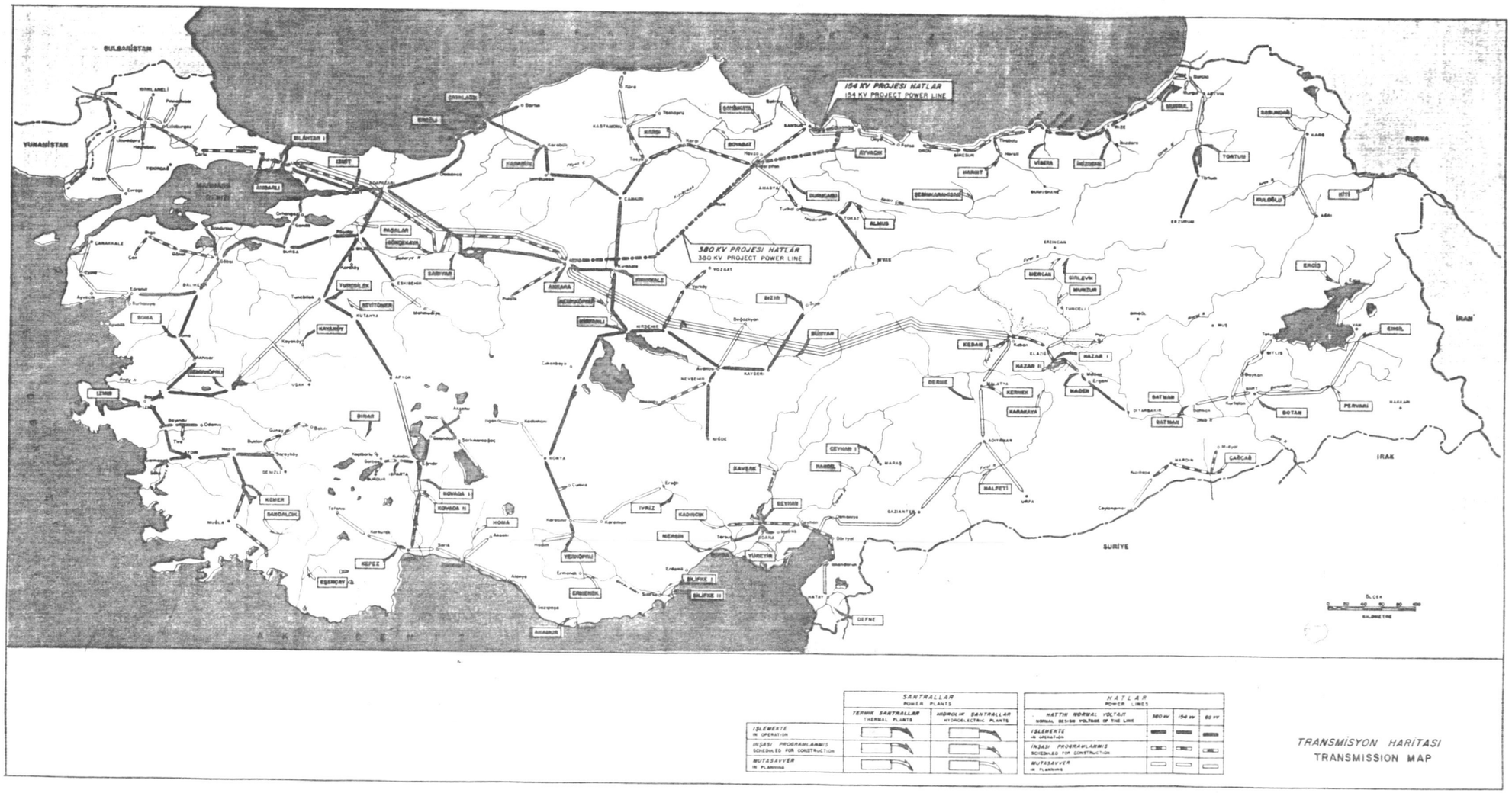

TRANSMİSYON HARİTASI
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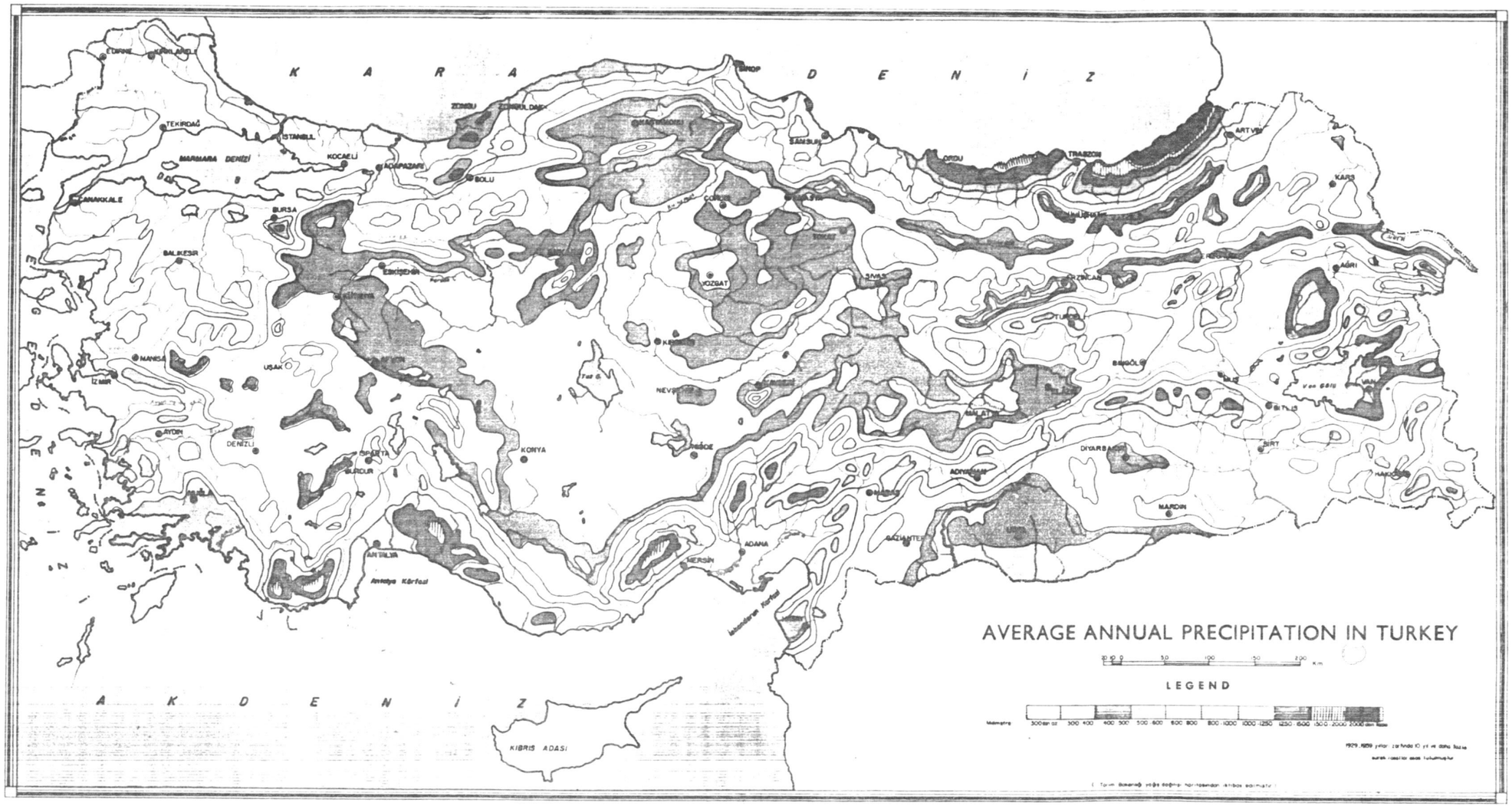
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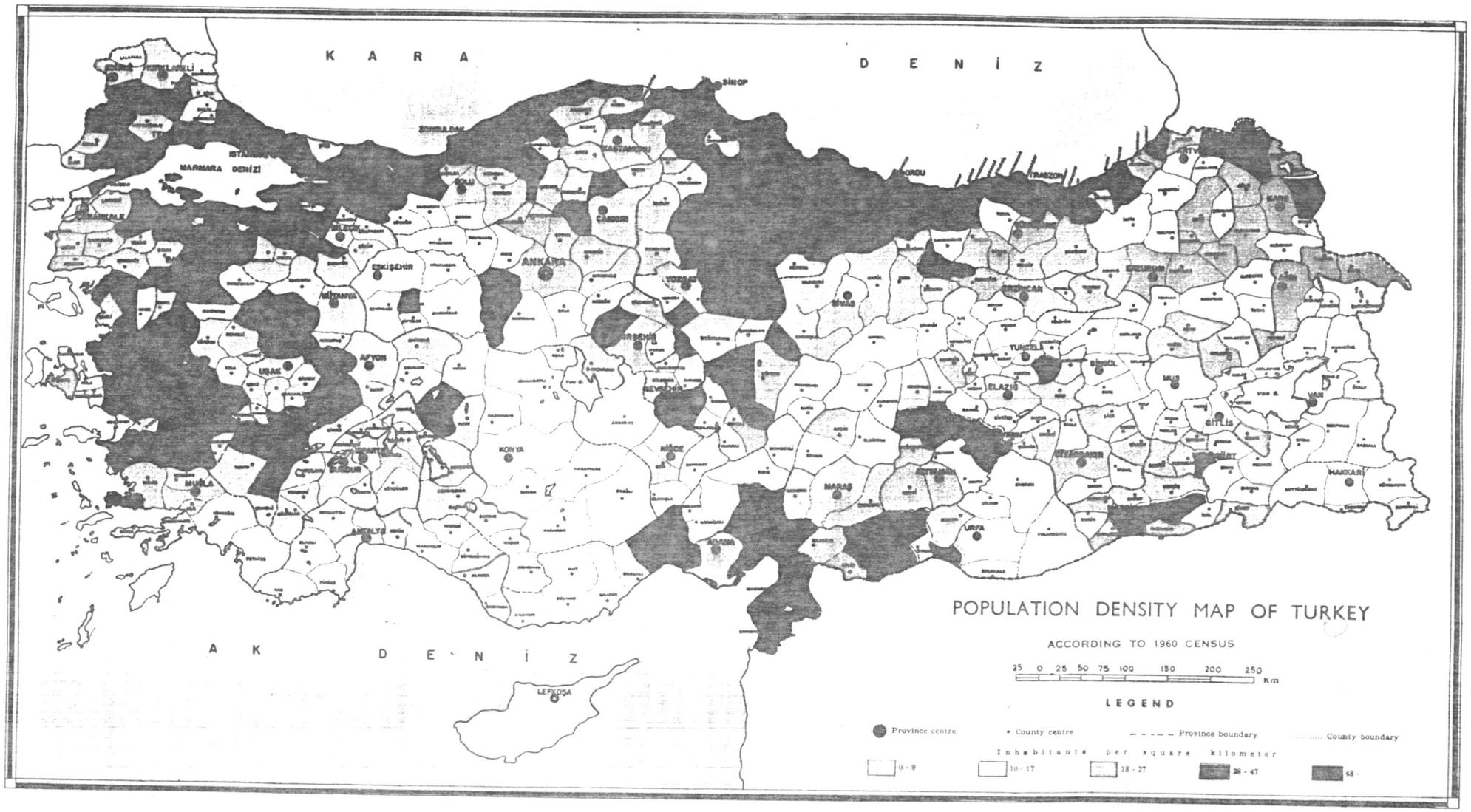
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POPULATION DENSITY MAP OF TURKEY
ACCORDING TO 1960 CENSUS
25 0 25 50 75 100 150 200 250
Km
LEGEND
Province centre
County centre
Province boundary
County boundary
Inhabitants per square kilometer
0 - 9
10 - 17
18 - 27
28 - 47
48 -

AKKÖY DAM

p257

Akköy dam is located on **Asarcık** Creek 7 km southwest of the town of **Yeşilhisar** in the province of **Kayseri.** Its purpose is to provide water for the irrigation of 425 hectares of land and flood protection.

Geology and the Foundation

The dam is located in an arid - semi - arid mountainous region with steep, short and dry valleys joining with the Asarcık valley, vegetation cover being almost non - existent.

The alluvium in the river bed is 2 - 3 meters thick, overlying the bedrock which consists of partly to moderately decomposed gabbro. The thickness of the gabbro formation is in excess of 50 meters and covers large areas in the left abutment foundation and the vicinity of the dam axis. The right abutment is partly covered by a layer of volcanic tuff which is generally poorly cemented or loose. The dam embankment was moved slightly upstream to exclude most of the tuffs and consequently stripping required in the foundation remained within reasonable limits.

The spillway is located in the right abutment and has its foundation in sound to moderately decomposed gabbro.

The diversion tunnel which, after the construction of the foundation was converted into the irrigation outlet, is located in the left abutment and was driven in sound gabbro. A grout curtain extends to a depth of 25 meters under the dam.

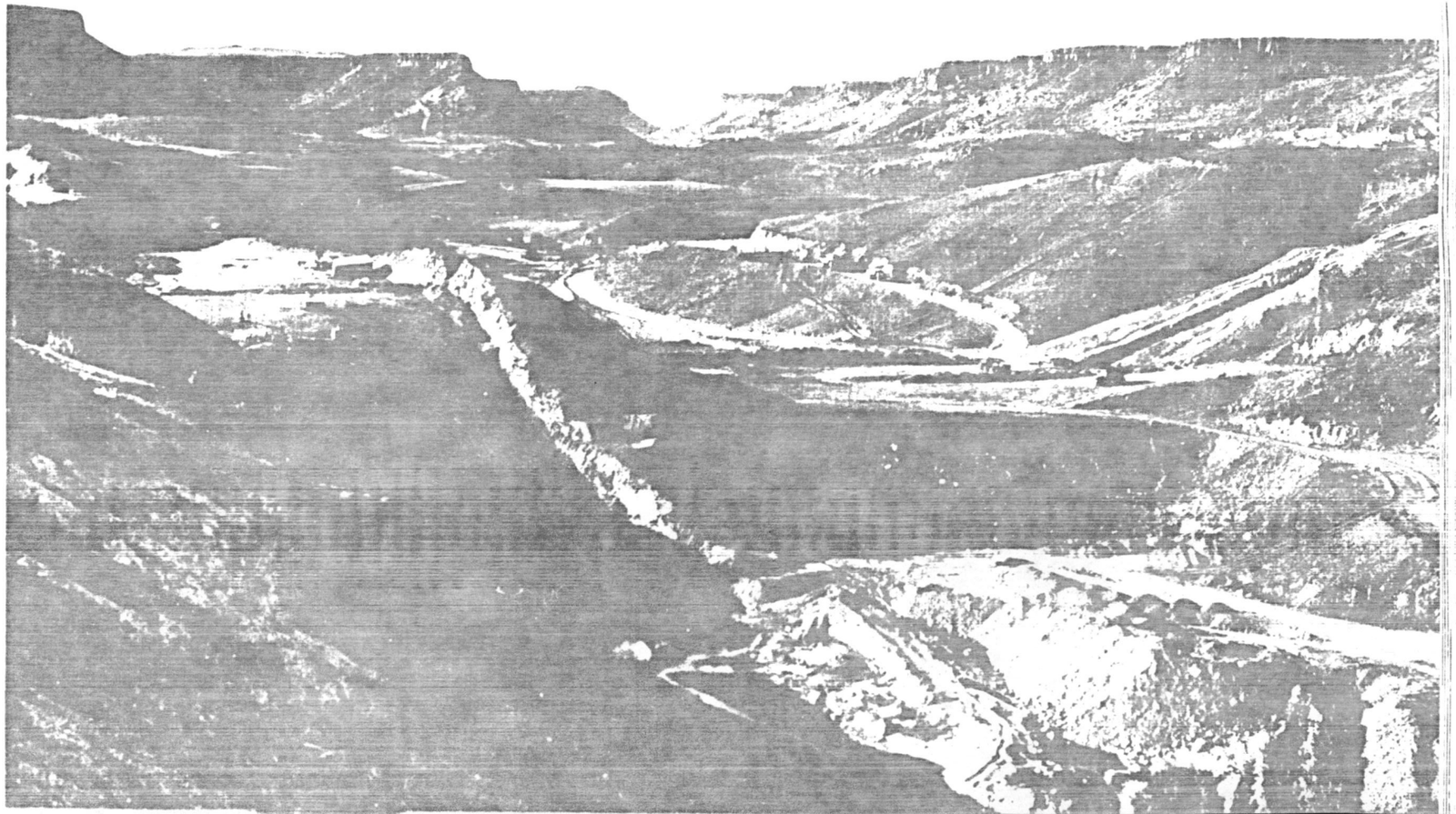


Fig. 5.030
Downstream view of the embankment and the spillway construction, Akköy Dam.

Hydrological Data

Drainage area	:	208 km²
Mean annual precipitation	:	302 mm
Estimated annual average runoff	:	4×10^6 m³

Reservoir Data

Dead storage volume	:	1.5×10^6 m³
Minimum water surface elevation	:	1264.50 m
Net usable storage volume	:	6.0×10^6 m³
Gross reservoir capacity	:	7.5×10^6 m³
Normal water surafce elevation	:	1276.25 m
Maximum reservoir volume	:	10.25×10^6 m³
Maximum water surface elevation	:	1279.50 m
Maximum reservoir surface area		1.05 km²

Dam Embankment Data

Type	:	Earth and Rockfill
Height above lowest foundation	:	43.50 m
Height above ground level	:	41.50 m
Crest length	:	198.00 m
Crest width	:	10.00 m
Crest elevation	:	1281.00 m
Total embankment volume	:	430.00 m³

Spillway Data

Type	:	Ungated, free overfall
Crest length	:	60.00 m
Crest elevation	:	1276.25 m
Desing flood peak flow	:	762 m³/sec
Spillway maximum discharge	:	744 m³/sec
Type and length of discharge chute	:	Trapezoidal cross section concrete lined 110.00 m

Diversion Data

Type	:	Tunnel, circular concrete lined
Diameter	:	2.00 m I. D.
Length		212.00 m
Design flood peak flow	:	15 m³/sec

Outlet Works Data

Intake structure	:	Drop inlet, circular bellmouth entrance with trashracks
Intake sill elevation	:	1234.00 m
Upstream conduit length	:	56.00 m (including vertical intake shaft)
Downstream conduit diameter and length	:	0.45 m I. D. steel pipe, 116.00 m
Emergency valve	:	0.40 m I. D. butterfly valve
Regulating valve	:	0.45 m I. D. Howell - Bunger
Discharge capacity	:	0.330 m³/sec

The Dam Embankment

The dam embankment is shown in the design drawings reproduced here. On account of the decomposed state of most of the rock obtained from the required excavation of the spillway and the nearby quarries, the slopes of the dam are not steep. The central core of compacted lean clays (1) is constructed with material obtained from borrow pits. (3') designates earth - like material obtained from the decomposed zones of the spillway, and is placed in layers and compacted with 20 ton crawler type tractors, (F) is filter which consists of pit - run sand and gravel placed against clean quarry fines on the rockfill side. (4') designates slightly to moderately decomposed gabbro obtained from the spillway and quarries and placed in 0.90 m thick layers. Larger size material is placed near the outer slopes of the shells. The core and the shells are placed on stripped sound rock.

The construction of the project started in 1964 and is scheduled to be completed towards the end of 1967. The contracting firm is **Elsel İnşaat Ltd. Şirketi.** The estimated total cost of the project is 10,390,950 TL.

The dam was designed and is being supervised by **DSI.**

ALMUS DAM

The dam is located on **Yeşilırmak** River 3.5 km northeast of the town of **Almus** in the province of **Tokat.** The project is a multipurpose one providing flood protection, irrigation and power production.

Before the construction of the dam, only 3950 hectares of irrigable land in the valleys located around Tokat could be irrigated and frequent floods caused yearly damages amounting to 900,000 TL.

Almus makes possible irrigation of 13400 hectares of land and its powerplant will have an annual power output of 80 × 10^6 KWh.

Geology and foundation

The dam is located in a gorge cut through by the river in a large mass of andesitic lavas, agglomerates and tuffs. Lower part of the foundation is made up of fine grained sound andesite, moderately fractured and containing several minor faults. Upper parts of the left and the right abutments consist of thin beds of volcanic breccia, agglomerates and large masses of coarse grained, partly to completely decomposed andesite.

A short distance from the dam axis, in the right abutment, a younger formation of reddish shales, sandy shales and conglomerates overlay the andesite mass and dip at an angle of 25 degrees in a northeasterly direction. While this formation covers the lower right hand side of the reservoir area, larger part of the reservoir is in a formation of sandy marls and sand stones of Eocene age.

One of the four principal zones of earthquakes in Turkey is the Northern Anatolian fault band running from the **Marmara** basin in the west, through **Kelkit** valley, which is only 8 km away from the dam axis, towards east as

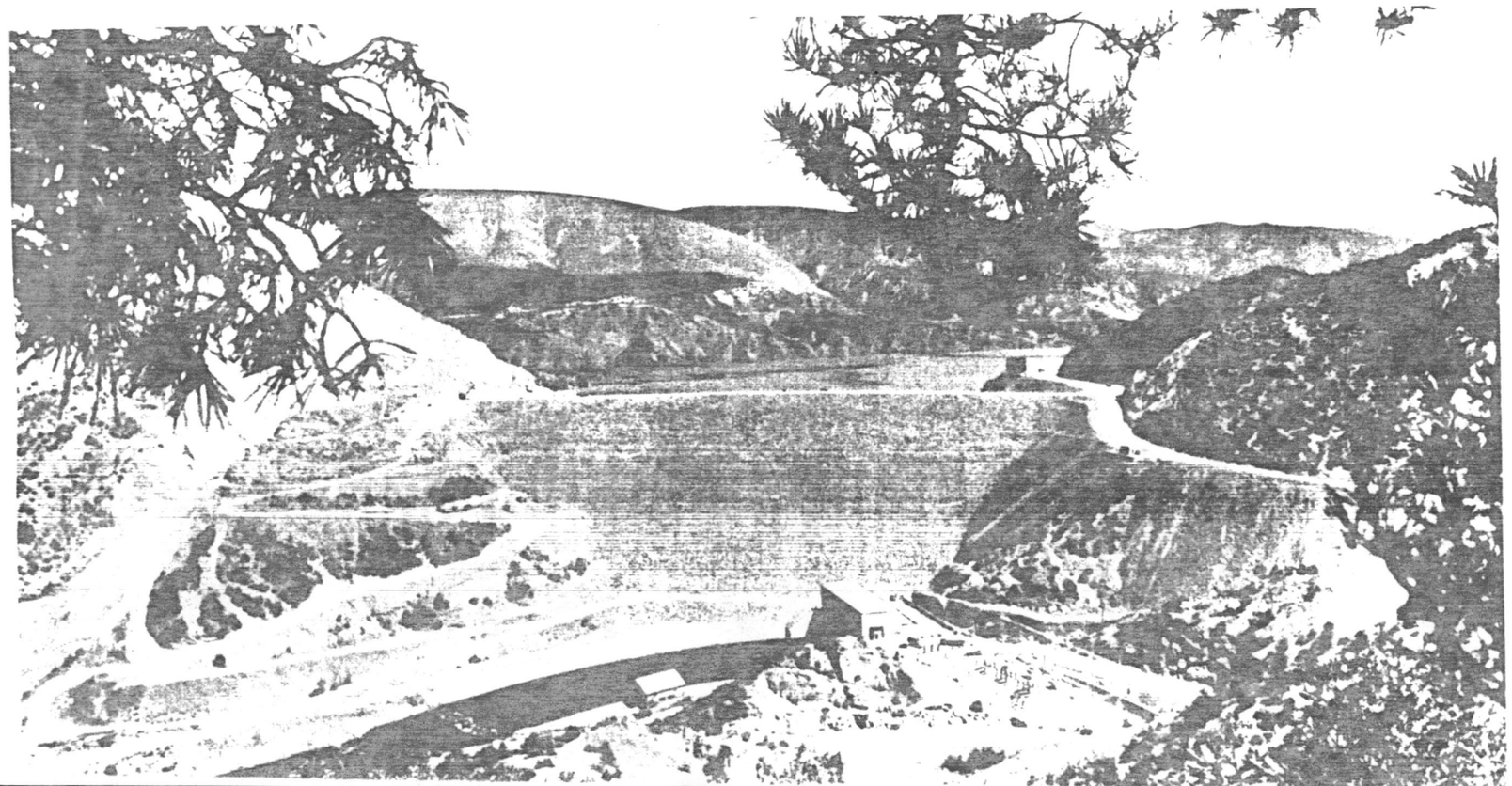


Fig. 4.060
General view of Almus Dam and powerplant.

far as the **Aras** valley. Almus valley is roughly parallel to this active belt and for this reason, serious considerations have been given to possible effects of intense earthquakes and measures have been taken to make the dam resistant to such effects.

A 3 meter deep cut-off trench was excavated in the sound foundation rock and 3 lines of cap grouting with a 42 meter deep curtain grouting was carried out. This curtain was extended to include the spillway foundation in the right abutment and carried deeper in the left abutment, to intersect with the tunnel consolidation grouting holes.

An alluvial deposit of maximum 15 m depth was almost completely removed under the foundation of the dam, since it contained layers of silty and clayey material.

The Embankment

The height of the dam embankment is 93.5 meters from the foundation and 78.5 meters high from the river bed. It is a zoned earthfill structure having a large rock toe and a downstream shell made with compacted decomposed rock. A thick core of silty-sandy clay forms the impervious central zone of the dam. This is followed by large free-draining zones in the upstream and the downstream. A one meter thick layer of rip-rap provides protection of the upstream slope of the dam against wave action.

The slopes of the embankment are conservative and a horizontal earthquake acceleration of 0.15 g has been used in the stability analyses. The crest width and camber are larger than the usual, to counteract adverse effects of earthquake shocks and displacements.

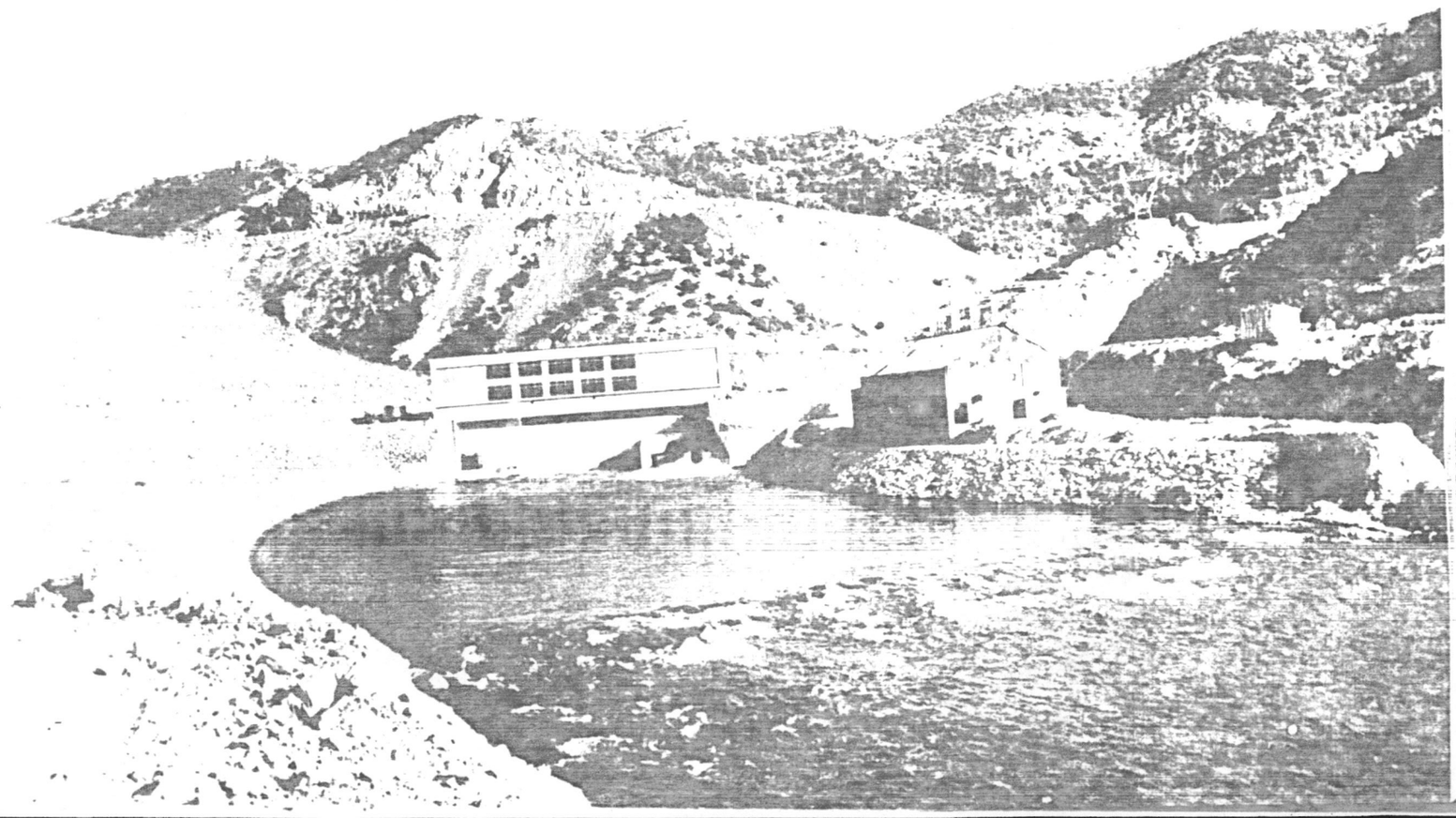


Fig. 4.061
Almus Powerhouse

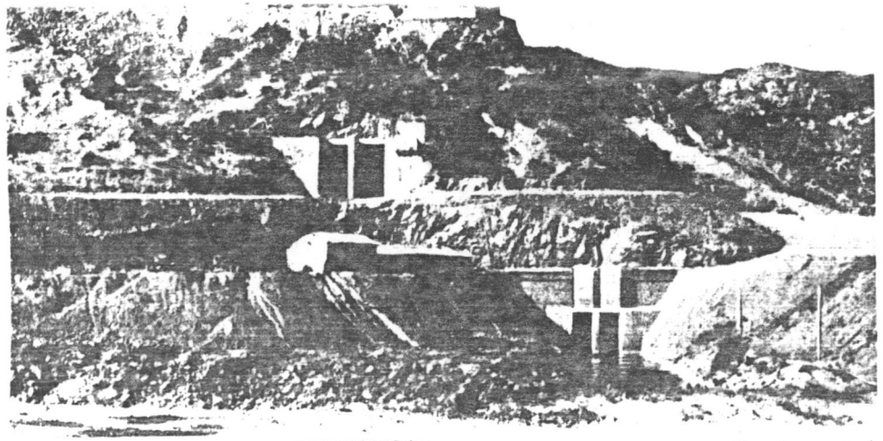


Fig. 4.062
Diversion and power intake, Almus Dam.

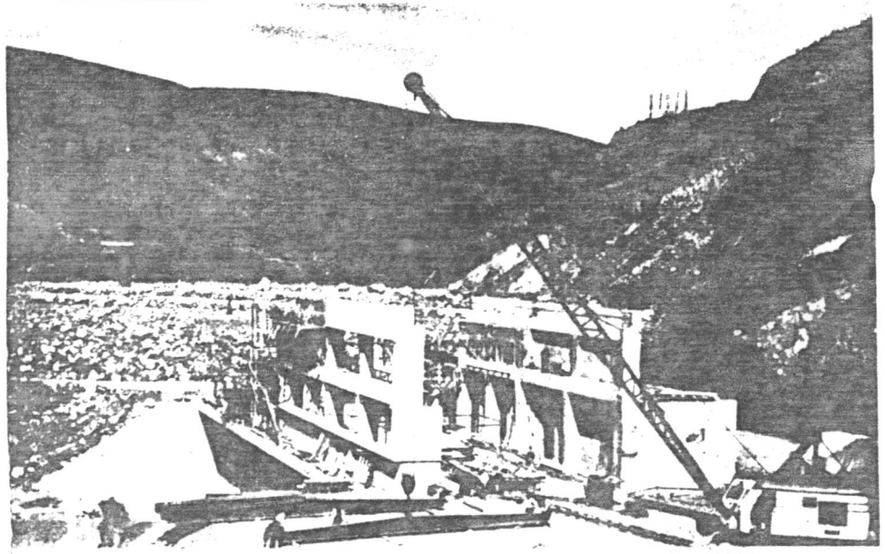


Fig. 4.063
Construction of the superstructure, Almus Powerhouse.

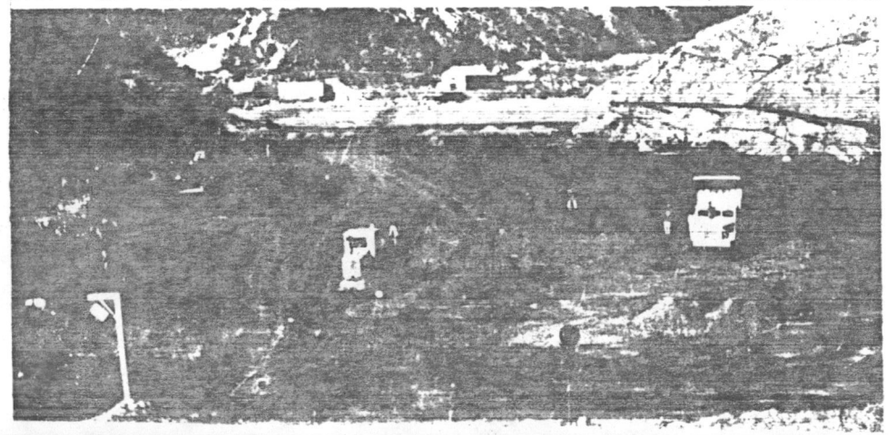


Fig. 4.064
Construction of the embankment

The materials for earthfill zones of the embankment were obtained from the borrow areas situated in the reservoir area, 1.5 km from the axis. Between the impervious and free-draining zones, transitions were provided.

Spillway excavation yielded a large percentage of decomposed andesite and all material from this source was utilized in the embankment, sound rock having been separated and placed in the toe of the dam. Both decomposed and sound rockfill zones were constructed in layers of a maximum thickness of 0.90 meters.

Diversion and power tunnel

The river was diverted through a tunnel driven in the left abutment through fairly sound andesite requiring supports only at certain fractured zones and the portals.

This tunnel is reinforced concrete lined and was converted into power tunnel after the diversion, connecting with the power intake by means of an inclined shaft and ending in a steel lined penstock. Four branches lead off from this main penstock into the powerhouse, feeding into three generating units and an irrigation outlet.

Power Tunnel and Penstocks

Concrete lined tunnel length	:	434.45 m
Steel lined tunnel length	:	51.55 m
Penstock diameter	:	4.00 m I.D.
Number of penstocks	:	3
Power tunnel intake	:	Trashracked entrance with emergency closure gate shaft 75 meters downstream from the intake

Powerhouse Data

Turbines :		
Type	:	Francis, vertical axis
Number	:	3
Make	:	J. M. Voith (Austria)
Maximum head	:	72.50 m
Maximum power	:	14,700 HP
Maximum rate of discharge	:	16.00 m³/sec
Speed	:	300 rpm
Generators :		
Type	:	Synchronous, vertical axis
Number	:	3
Make	:	Siemens - Schuckertwerk AG (West - Germany)
Rated capacity	:	13,000 KVA
Output voltage	:	10,600 V
Frequency	:	50 c/s

Plant :

Installed capacity	:	27 MW
Annual power output	:	80×10^6 KWh

Transformer :

Type	:	Outdoors, oil and air cooled
Number	:	3
Continuous capacity	:	11,250 KVA
High tension	:	154 KV
Low tension	:	10.6 KV
Make	:	Ansaldo San Giorgio (Italy)

Irrigation Outlets :

Irrigation penstock diameter	:	3.30 m I.D.
Outlet pipe diameter	:	1.70 m I.D.
Number	:	2
Emergency valve type and number	:	1.70 m I.D. butterfly valve, horizontal axis, 2
Regulating valve type and number	:	1.70 m I.D. Howell - Bunger, 2
Maximum capacity of each outlet	:	59.00 m^3/sec
Make of the valves	:	J. M. Voith (Austria)

Turbine valves :

Type	:	Horizontal axis butterfly valve
Diameter	:	2.30 m I.D.
Number	:	3
Make	:	J. M. Voith (Austria)

Power Tunnel Intake Closure gates:

Type	:	Roller gates 7.10 × 3.20 m
Number	:	2
Make	:	Neyrpic (France)

Draft tube gates :

Number	:	3
Make	:	Neyrpic
Dimensions	:	4.95 × 2.80 m

The construction started in 1959 and the dam and appurtenant structures were completed in 1966. Civil engineering works were carried out by the contracting firm of **Arı İnşaat,** while various European firms took part in manufacture and erection of the permenant equipment.

Planning, design and supervision of the project was carried out by **DSI.**

The total cost of the project is 168×10^6 TL.

Hydrological Data

Drainage area	:	2353 km^2
Mean annual precipitation	:	516 mm
Recorded maximum flow	:	289 m^3/sec.
Estimated annual average runoff	:	758.8×10^6 m^3
Probable maximum flood peak flow	:	2243 m^3/sec

Reservoir Data

Dead storage volume	:	138×10^6 m^3
Minimum water surface elevation	:	767.37 m
Net usable storage volume	:	812×10^6 m^3
Gross capacity of reservoir	:	950×10^6 m^3
Normal water surface elevation	:	804.50 m
Maximum reservoir volume	:	$1{,}035 \times 10^6$ m^3
Maximum water surface elevation	:	807.50 m
Maximum reservoir surface area	:	32.5 km^2
Maximum power pool elevation	:	804.50 m

Dam Embankment Data

Type	:	Earthfill
Height above lowest foundation	:	95.00 m
Height above ground level	:	78.00 m
Crest length	:	370.50 m
Crest width	:	12.00 m
Crest elevation	:	810.50 m
Total embankment volume	:	3.5×10^6 m^3

Spillway Data

Type	:	Free overfall side channel
Crest length	:	152.50 m
Crest elevation	:	804.50 m
Design flood peak flow	:	2243 m^3/sec
Design flood inflow volume	:	974×10^6 m^3
Maximum spillway discharge	:	1550 m^3/sec
Type and length of discharge chute	:	Trapezoidal cross section concrete lined, 609.00 m

Diversion Data

Type	:	Tunnel, circular, concrete lined
Diameter	:	7.00 m I.D.
Design flood peak flow	:	584.00 m
Length	:	315 m^3/sec

The diversion tunnel is used as a power tunnel, power intake being connected to the tunnel with an inclined shaft. At the downstream end of the tunnel 45.00 meters is steel lined.

AYVACIK DAM

The **Ayvacık** Dam site is located on the **Yeşilırmak** River 38 km upstream from the town of **Çarşamba** in the province of **Samsun** in northern Turkey. The purpose of the project is power generation with an annual energy output of $1{,}136 \times 10^6$ KWh.

Geology

At the Ayvacık Dam axis, the river flows between steep rock walls composed of massive to thinly bedded volcanic tuff, agglomerate, breccia and basalt. The strata strike N55°E and dip upstream about 22 degrees. In general,

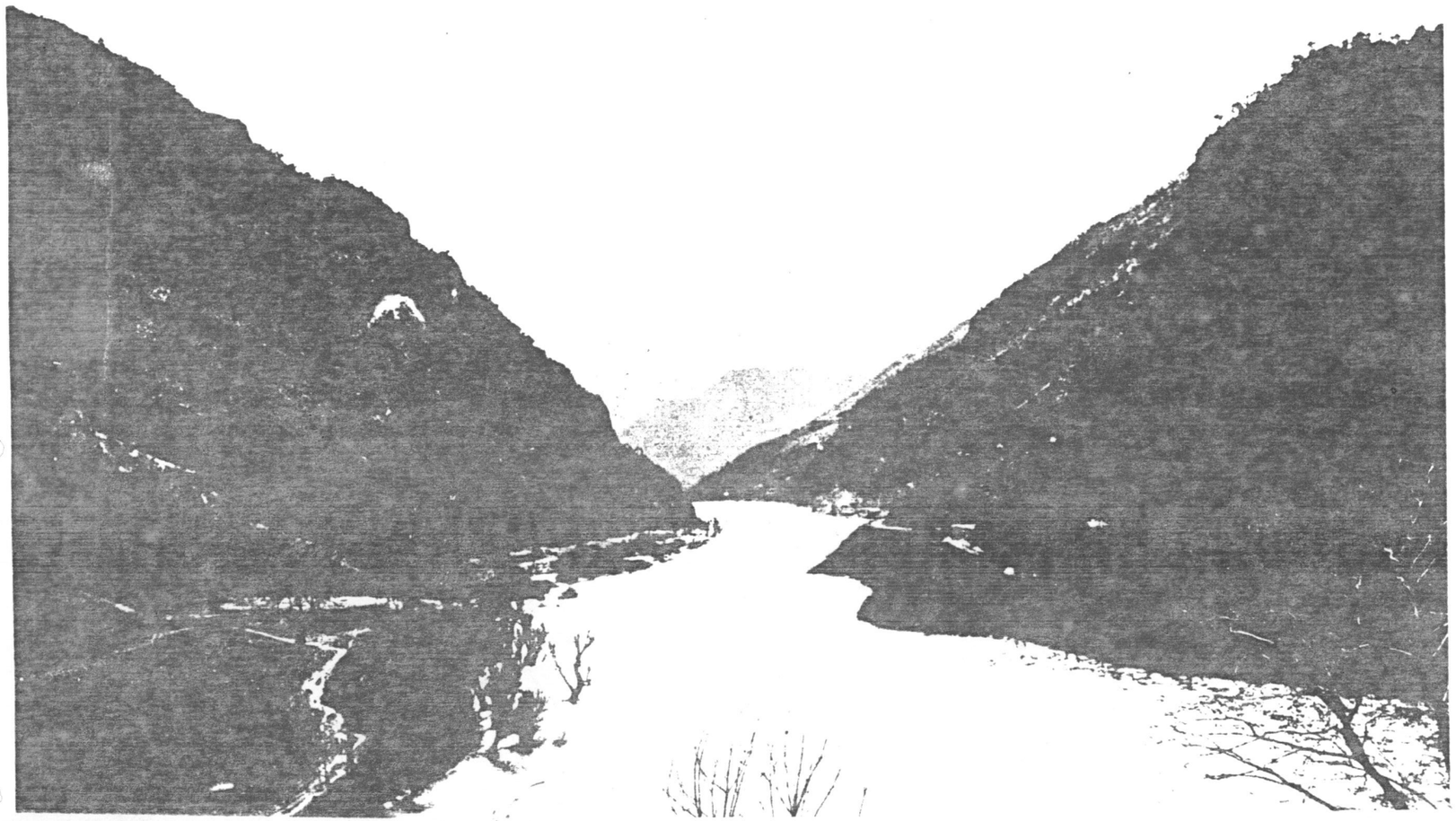


Fig. 6.023
Downstream view of the Ayvacık Dam site.

the rocks are well cemented and durable. A noteworthy structural feature is a set of near vertical joints which trend N50°W. Shearing is occasionally present parallel to this joint system and has developed occasional zones of clay gouge and crushed rock.

The project was studied by **Leedshill - Bechtel - IAS - Gizbili,** an American, Turkish partnership, and was found to be economically and technically feasible.

The steps have been taken by **DSI** for preparation of the preliminary and final design of the project, construction of which will be undertaken in 1969.

Hydrological Data

Drainage area	:	36,000 km²
Mean annual precipitation	:	530 mm
Average flow	:	133.20 m³/sec
Estimated annual average run - off	:	4.20×10^9 m³
Record period	:	25 years
Recorded minimum flow	:	10.70 m³/sec
Recorded maximum flow	:	1,706.00 m³/sec

Reservoir Data

Minimum operating W. S. EL.	:	154.50 m
Net usable reservoir volume	:	450×10^6 m³
Maximum water surface elevation	:	185.00 m
Maximum total reservoir volume	:	850×10^6 m³

Dam Data

Type	:	Concrete arch dam
Height above lowest foundation	:	168.00 m
Height above ground level	:	132.00 m
Crest length	:	415.00 m (523.00 m including spillways on both abutments)
Crest width	:	6.30 m
Crest elevation	:	188.00 m
Freeboard	:	3.00 m
Total concrete volume in arch dam	:	1,120,000 m³

Spillway Data

Type	:	Gated, ogee crest
Number of spillways	:	2, one at each abutment
Gate type and number	:	Radial gate, 2
Gate dimensions	:	16.50 m W by 11.00 m H
Crest elevation	:	174.00 m
Crest length	:	33.000 m (2×16.50)
Total crest length	:	66.00 m
Spillway design flood discharge	:	5,000 m³/sec

Diversion Data

Type	:	Tunnel, circular, concrete lined
Diameter	:	10.00 m I.D.
Length	:	255.00 m (approx.)
Discharge capacity	:	1,200 m³/sec
Upstream cofferdam crest elevation	:	85.00 m
Downstream cofferdam crest elevation	:	65.00 m

Power Intake and Penstocks

The intake structure is appended to the upstream face of the dam. It has fixed wheel gates and trashracks. Each penstock has a separate intake.

There are four steel lined 5.00 m I.D. penstocks embedded in the arch dam structure.

Power Plant Data

Turbines :

Type	:	Vertical Francis
Number	:	4
Horsepower	:	156,000 HP

Generators :

Type	:	Vertical
Number	:	4
Rated capacity	:	97,000 KVA
Power factor	:	0.90
Overload factor	:	0.15

Plant :

Installed capacity	:	400 MW
Annual energy production	:	1.136×10^6 KWh

BALAHOR DAM

The proposed **Balahor** Dam site is located on the **Yeşilırmak** River about 18 km upstream of the town of **Çarşamba** in the province of **Samsun.** Its purpose is to augment the irrigation requirements and to re-regulate discharges of the **Ayvacık** Power Plant and to produce energy. Average annual power output will be 164×10^6 KWh.

Geology

At the damsite the valley walls rise rather steeply on either side and consist of interbedded agglomerates, basalts, and other. related volcanic (pyroclastic) rocks. Subsurface explorations along the proposed dam axis show the river section to be underlain by about 50 meters of alluvial material. No undisturbed samples of the streambed alluvials were obtained, therefore, strength characteristics of alluvial material are unknown.

Embankment Data

Type	:	Rockfill with vertical core
Height above lowest foundation	:	33.00 m
Height from foundation to cut - off	:	30.00 m
Height above ground level	:	33.00 m
Crest length	:	300.00 m
Crest width	:	10.00 m
Crest elevation	:	63.00 m
Freeboard	:	2.00 m
Total embankment volume	:	1.45×10^6 m³

Reservoir Data

Minimum pool elevation	:	61.00 m.
Normal pool elevation	:	61.00 m.
Net usable volume	:	70×10^6 m³
Maximum pool elevation	:	62.00 m
Gross reservoir capacity	:	144×10^6 m³

Spillway Data

Type	:	Gated ogee crest
Gate type	:	Automatic radial gates
Crest elevation	:	48.60 m
Discharge capacity	:	5,000 m³/sec

Diversion Data

Type	:	Tunnel, circular, concrete lined
Diameter	:	6.25 m I.D.
Length	:	480.00 m
Upstream cofferdam crest elevation	:	38.00 m
Downstream cofferdam crest elevation	:	33.00 m

Power Intake and Conduit

The intake structure is at the entrance to the diversion tunnel equipped with a vertical lift gate.

The 6.25 m I.D. concrete lined tunnel is utilised for the power plant. The lower end of the tunnel is steel lined at the connection to the turbine scroll case.

Power Plant Data

Turbines :

Type	:	Kaplan
Number	:	1

Generators :

Type	:	Vertical axis
Number	:	1
Rated capacity	:	39,000 KVA
Power factor	:	0.80
Overload factor	:	0.15

Plant :

Installed capacity	:	40 MW
Annual energy production	:	164×10^6 KWh

The project was studied by **Leedshill - Bechtel - IAS - Gizbili,** an American - Turkish partnership, and was found to be technically and economically feasible.

The steps have been taken by the **DSI** for the preparation of the preliminary and final design of the project, construction of which will be undertaken in 1969.

Bayındır Dam is located on **Bayındır** Stream 12 km southeast of **Ankara** and is easily accessible from the Ankara - **Çorum** State Highway No. 2. It is an earthfill structure 30 meters high above ground level.

Its purpose is to supply public water to the city of Ankara and protect it from flood damages.

Geology and Foundation Treatment

Geological formations at the dam site are mainly of Paleozoic - Carboniferous age with Pliocene clay, sands and gravels in the left side of the reservoir area, where the borrow pits for semi - pervious zone material of the dam were located, and Quaternary talus deposits and alluviums. There is a thick alluvial deposit consisting of sands, gravels and silts with lenses of clay. Since its thickness is in excess of 22 meters and the top layers are fairly impervious, an anti - seepage upstream clay blanket was incorporated in the design of the dam rather than a deep positive cutoff that would require large amount of excavation, flat slopes and great expenditure of time and money.

The right and left abutments and the foundation rock consists of sandstones, micro - conglomerates, graywacke, shales, calcareous shales. The rock in the abutments is partly altered into clay especially near the surface. Stripping excavation in the abutments was carried out to an average depth of 1.50 meters. On the alluvial surface, under the dam and the upstream blanket, stripping was limited to the removal of vegetable matter and part of the soil, care being exercised not to remove any of the existing impervious deposits at the surface. A 2.0 meter - thick clay blanket was placed after the natural alluvial surface was rolled with several passes of sheep's foot rollers. The clay was placed, as in the case of the impervious zone of the dam, in 0.15 meter thick compacted layers at the optimum moisture content. This clay blanket extends 150 meters upstream from the upstream toe of the dam and joins with the partial cutoff trench and the impervious central zone of the dam.

Hydrology

Drainage area	:	70 km²
Mean annual precipitation	:	350 mm
Recorded minimum flow	:	0.000
Estimated annual average runoff	:	6×10^6 m³

Reservoir

Dead storage volume	:	1×10^6 m³
Minimum water surface elevation	:	972.00 m
Net usable storage volume	:	5.97×10^6 m³
Normal water surface elevation	:	985.00 m
Gross reservoir capacity	:	8.21×10^6 m³
Flood control volume	:	1.237×10^6 m³
Top of flood control elevation	:	986.52 m
Maximum water surface elevation	:	988.18 m
Maximum reservoir surface area	:	0.85 km²

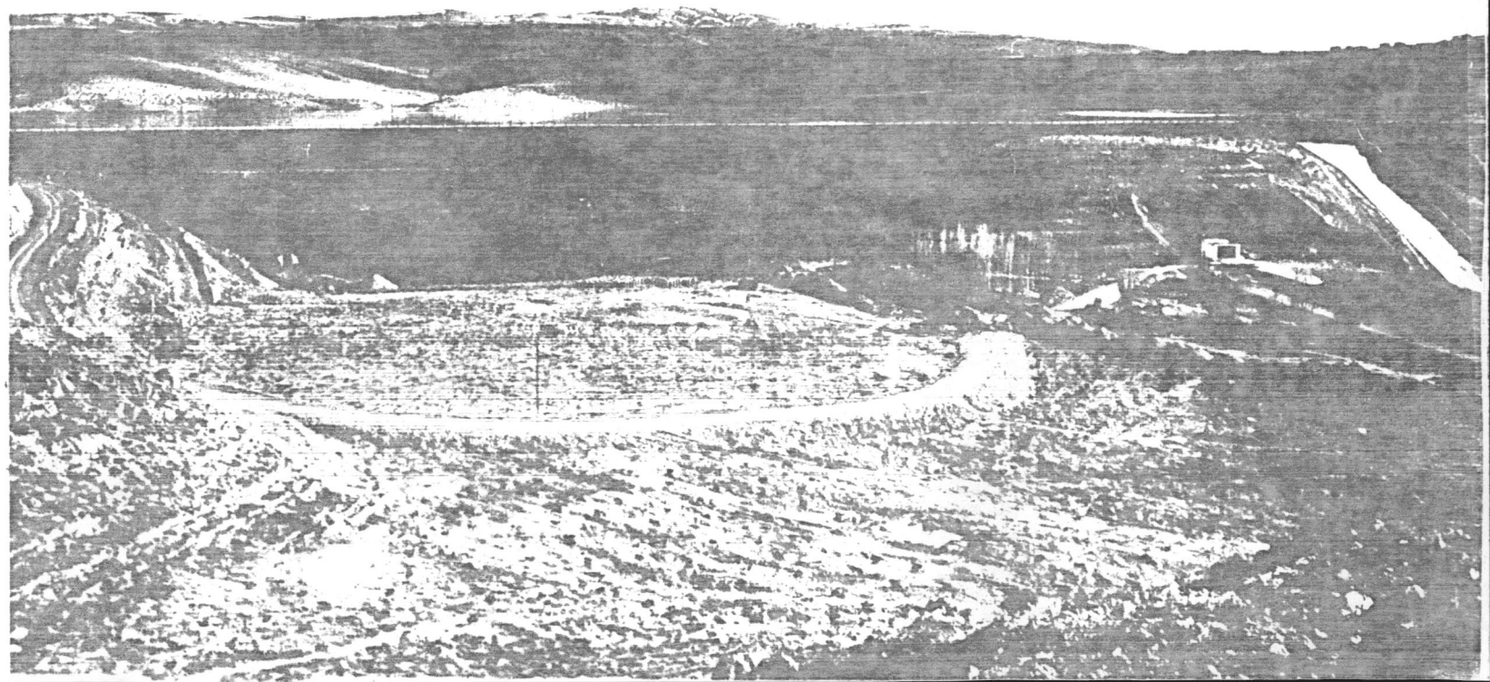


Fig. 4.042
Bayındır Dam.
View from downstream.

The partial cutoff trench is 5.0 meters deep and 10.0 meters wide in the alluvium, and 3.00 meters deep and 6.00 meters wide in the abutments. A concrete grout cap was constructed at the centre of this trench in the abutments. Curtain grouting to a maximum depth of 24.0 meters was carried out through a concrete cap with holes 3.0 meters between centres. Grout take was low due to tight structure of the rock.

Dam Embankment

The embankment consists of a large central zone of impervious core formed with material obtained from borrow areas located about 500 meters upstream from the dam axis. The material in this area is of CL, ML, SC character in general. This impervious zone is surrounded from the upstream and downstream by pervious zones of compacted sand and gravel. Pervious material was obtained from the river bed 1.5 km upstream of the dam axis. This material was placed in 0.30 meter lifts and compacted by 50 ton rubber tire rollers.

Upstream face of the dam is protected by a 0.60 meter thick layer of riprap obtained from a nearby limestone quarry.

The dam was designed and supervised by **DSİ** and constructed by the contracting firm of **Ara İnşaat Ltd.** between the years 1962 and 1965.

After the initial filling of the reservoir, a total leakage of approximafely 50 lt/sec was observed in the downstream drains of the dam. Amount of the leakage varies according to the level of water in the reservoir and it is quite clear. It is believed that about 2/3 of this results from the seepage through the foundation alluvial deposits, the rest being due to leakage through the abutments. A thorough investigation is being made to determine the source and quantity of the leakage correctly, in order to evaluate the efficiency of the upstream blanket and the grout curtains at the abutments.

The dam is owned by DSİ and supplies water to the city of Ankara.

Outlet Works

Intake structure sill elevation	:	972.00 m
Upstream tunnel length	:	92.00 m.
Downstream conduit diameter and length	:	1.00 m I. D. steel pipe, 110.00 m
Emergency gate size and type	:	1.00 m I.D., butterfly
Regulating gate size and type	:	0.80 × 0.80 m, slide gate
Discharge capacity of bottom outlet	:	8.675 m³/sec at W.S.El. 988.18 m
Water supply branch diameter	:	0.70 m I. D. steel pipe
Water supply branch discharge capacity	:	0.25 m³/sec

Dam Embankment

Type	:	Earthfill
Height above lowest foundation	:	31.00 m
Height from foundation to cutoff	:	4.00 m
Height above ground level	:	30.00 m
Crest length	:	437.00 m
Crest width	:	10.00 m
Crest elevation	:	990.00 m
Total embankment volume	:	550,000 m³

Spillway

Type	:	Ungated, free overfall, ogee
Crest length	:	30.00 m
Crest elevation	:	986.52 m
Type and length of discharge chute	:	Rectangular cross section, concrete lined, 145 m long
Design flood peak flow	:	250 m³/sec
Design flood inflow volume	:	3.5 × 10⁶ m³
Maximum spillway discharge	:	128.70 m³/sec

Diversion

Type	:	Tunnel, circular, concrete lined
Diameter	:	2.50 m I. D.
Length	:	205.00 m
Discharge capacity	:	125 m³/sec

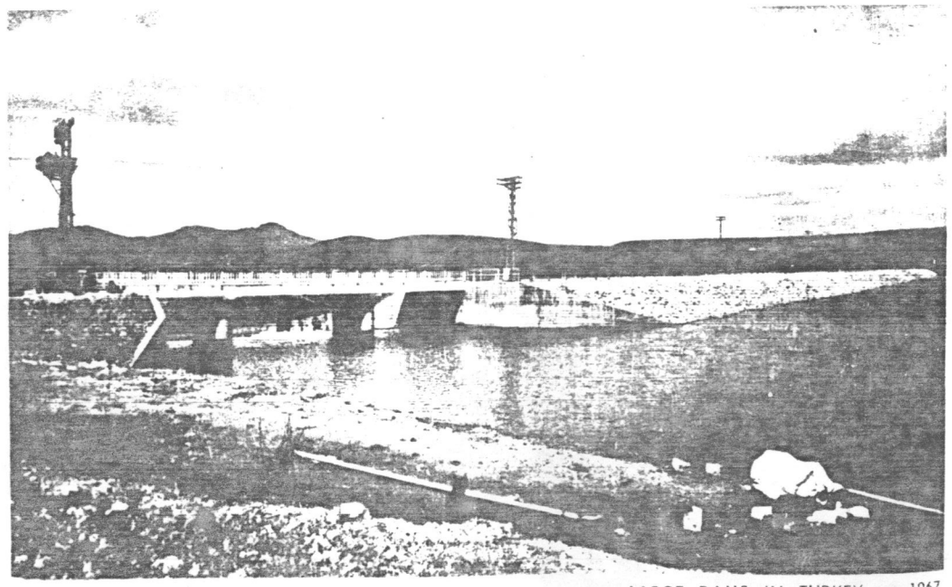


Fig. 4.043 Spillway, Bayındır Dam.

ÇUBUK I DAM

Çubuk I Dam is a concrete gravity dam located on **Çubuk** stream 12 km north of the city of **Ankara.** Its purpose is public water supply for Ankara.

The drainage area at the dam site is 720 km².

This dam is the first concrete gravity structure constructed after the establishment of the Turkish Republic.

Geology

At the vicinity of the dam axis the foundation and the abutments consist of andesites, dacites and agglomerates. This formation is moderately to completely decomposed and kaolinized zones in the abutments and the foundation had to be excavated and treated.

In the foundation a major kaolin zone, 10 - 20 meters wide and 33 meters deep from the ground level, was encountered. Excavation and treatment required by this and similar zones increased the cost and delayed the construction. Depth of the alluvium in the river bed was 17 meters. However, an average of 3 meters of decomposed rock had to be stripped in the general foundation area.

Hydrological Data

Drainage area	:	720 km²
Mean annual precipitation	:	450 mm.
Estimated annual average run - off	:	140×10^6 m³

Reservoir Data

Net usable storage volume	:	10×10^6 m³
Gross reservoir capacity	:	12.5×10^6 m³
Maximum reservoir volume	:	13.5×10^6 m³
Normal water surface elevation	:	906.61 m
Maximum water surface elevation	:	907.61 m
Maximum reservoir surface area	:	16.5 km²

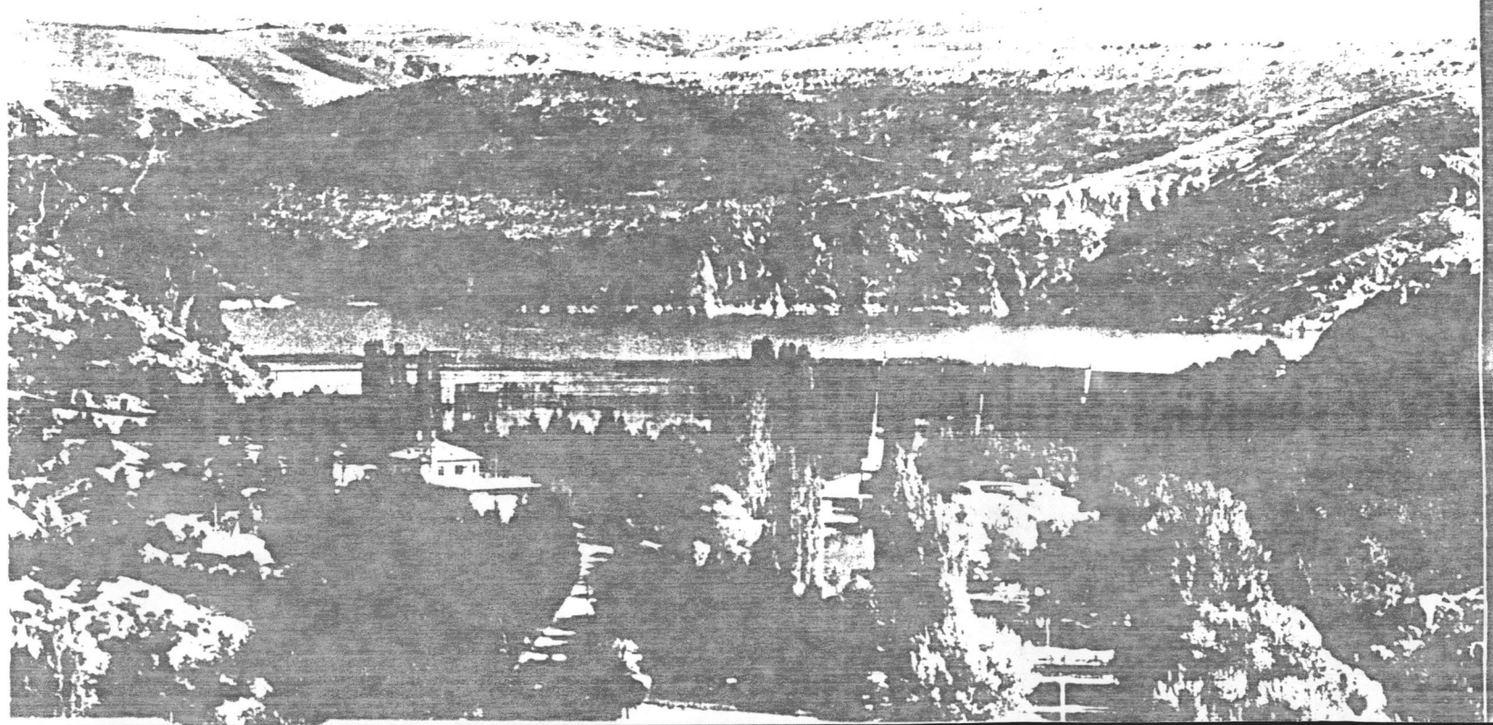


Fig. 2.01
General view of Çubuk Dam.

Dam Body

The dam has a circular axis with a radius of 220.0 meters. This layout is selected in order to increase the stability of the dam by arching action. A system of drainage galleries and shafts is located 4.50 m from the upstream face of the dam, to drain leakage water and to lessen uplift.

Concrete aggregate for the dam was obtained by crushing basic volcanic rocks located nearby. In general, cement content of the concrete was 216 kg/m³ for ordinary mass concrete. Upstream 2.30 meters of the dam was made with a special concrete containing 215 kg/m³ cement and 86 kg/m³ pozzolan, in order to provide an impervious barrier as well as increased chemical resistance. In the lowest lifts, rich concrete with 300 kg/m³ dosage of cement was used "to counteract the effect of the sulphates existing in the foundation,,.

The foundation trench upstream of the dam was backfilled with plastic clay.

Dam

Type	:	Concrete gravity, circular axis.
Height above lowest foundation	:	58.00 m
Height above ground level	:	25.00 m
Crest elevation	:	908.61 m
Crest lenght	:	250.00 m
Crest width	:	4.00 m

Spillway Data

Type	:	Gated, 5 - span
Crest length	:	2 - span part, 16.40 m 3 - span part, 19.88 m
Crest elevation	:	905.61 m
Type of gates	:	Electrical and manually operated taintor gates
Combined maximum discharge capacity	:	227 m³/sec.

Operation of Spillway

The normal water surface elevation is 906.61 m. Top of the gates in the closed position is at EL. 907.6 m. In the event of a flood the gates are lowered to accommodate passage of flood waters over the top of the gates. Only for exceptional floods, the gates are allowed to be lowered below EL. 906.61 m. During such a flood they are lowered all the way down below the spillway crest elevation.

To provide a greater reservoir capacity the gates are kept in the raised position with the maximum reservoir surface elevation being 907.61 m. To keep the reservoir at this elevation the gates are lowered accordingly, allowing discharge of excessive inflow.

An electrically operated automatic alarm system is activated when overtopping of the gates at EL. 907.61 m occurs.

Outlet Works

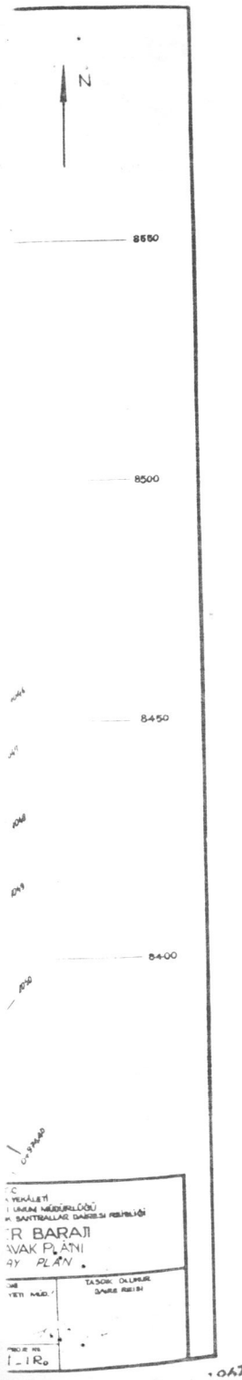
Bottom outlet consists of two steel pipes with diameters 0.70 m and 1.60 m. The 0.70 m diameter conduit is used to release water for downstream water - rights. The larger conduit is used only when a drawndown is required and also when additional discharge capacity, is required to augment the discharge of the spillways. Both pipes are equipped with regulating valves at the downstream ends and emergency closure bulkhead gates at the intake. These gates are operated both electrically and manually from a hoist platform on the crest of the dam. The intake is enclosed by a trashrack structure. Maximum combined discharge capacity of the conduits is 40 m³/sec.

Public water supply outlet is located on the right side. This outlet consists of two steel pipes, both 0.70 m in diameter, embedded in the concrete body of the dam at EL. 883.61 m, as in the case of the bottom outlet. In the control house, at the downstream face of the dam, each pipe is equipped with a regulating valve which is connected to a pipe leading to the city water treatment plant. The intake of each conduit consists of a reinforced concrete shaft attached to the upstream face of the dam, having 3 trashracked intake openings at various elevations. Each opening is equipped with a 0.50 m diameter gate. This arrangement allows drawing water from an elevation best suited to public supply needs. Bulkhead gate slots are provided at the entrance to each pipe for maintenance and repair purposes.

Construction

Construction started in 1929 and the first stage of the construction was carried out by the contracting firm of **İbrahim Tahsin ve Biraderleri.** The second and the final phase of the construction was executed by the contracting firm of **Fomsim Ltd.** The construction was completed in 1936. The total cost of the project was 3,500,000 TL.

Prof. Dr. Walther Kunze, with the collaboration of **DSİ** engineers, designed the dam and the appurtenant structures and acted as a consultant during the construction. The dam is owned by DSİ.



ÇUBUK II DAM

Çubuk II Dam is located on **Çubuk** Stream 54 km northeast of **Ankara** and 4 km upstream from the town of **Çubuk.** Its purpose is to supply water for domestic needs of the city of Ankara, and protection of Çubuk against floods.

Hydrological Data

Drainage area	:	190 km²
Mean annual precipitation	:	340 mm.
Average flow	:	1.20 m³/sec
Estimated annual average runoff	:	37×10^6 m³

Reservoir Data

Dead storage volume	:	2×10^6 m³
Minimum water surface elevation	:	1075.00 m
Net usable storage volume	:	22.6×10^6 m³
Gross reservoir capacity	:	24.6×10^6 m³
Normal water surface elevation	:	1113.00 m
Maximum reservoir volume	:	27.2×10^6 m³
Maximum water surface elevation	:	1115.25 m
Maximum reservoir surface area	:	1.285 km²

Dam Embankment Data

Type	:	
Height above lowest foundation	:	69.00 m
Height above ground level	:	61.00 m
Crest length	:	230.00 m
Crest width	:	10.00 m
Crest elevation	:	1117.00 m
Total embankment volume	:	1,100,000 m³

Geology of damsite and foundation

The dam is built at the narrowest point of a valley eroded by the river in a mass of volcanic rock. The abutment and the foundation are formed by alternating layers of andesitic and basaltic lava flows and volcanic agglomerates. The left abutment and the lower part of the right abutment are made up of sound andesite and well cemented agglomerates of a dark color and the foundation is in reddish colored andesite. The upper part of the right abutment, however, is in a formation of loose to poorly cemented agglomerate and this formation, which is the most recent volcanic deposit, extends into the reservoir on top of a steep slope formed by the lower more durable rocks. The spillway is also located in this agglomerate.

The tunnel was driven in the left abutment, through mostly sound agglomerates, short stretches of basalt and andesite rock and required very little support.

The original design included a downstream zone in the embankment, composed of rolled agglomerates to be obtained from the spillway excavation. However, very variable charecteristics of this material and difficulties anticipated in its compaction and selection led the designers to modify the embankment design, abandoning the use of this material.

The embankment is a zoned structure incorporating a large clay core and sand and gravel shells. The material for the core was lean sandy silty clay, obtained from borrow areas located about one km away from the dam, beyond the right abutment. The core was compacted in 15 cm thick layers at slightly dry of the optimum water content, by vibratory sheepfoot rollers. The shell material was obtained from borrow areas located 4 km downstream and was fairly clean, well graded sand and gravel. Smooth vibratory rollers were used in the compaction of this material.

Spillway Data

Type	:	Ungated, free overfall, ogee
Crest length	:	36.00 m
Crest elevation	:	1113.00 m
Design flood peak flow	:	500 m³/sec
Maximum spillway discharge	:	208 m³/sec
Type and length of discharge chute	:	Rectangular cross section, concrete lined, 213.0 m

Diversion Data

Type	:	Tunnel, circular, concrete lined
Diameter	:	3.00 m I. D.
Length		445.00 m
Design flood peak flow	:	30 m³/sec

Outlet Works Data

Intake structure	:	Drop inlet, circular bellmouth entrance with trashracks
Upstream pressure tunnel length	:	147.00 m
Downstream conduit diameter	:	0.90 m I. D. steel pipe
Downstream conduit length	:	321.00 m
Emergency gate	:	0.60 × 0.60 m
Public water supply branch pipe	:	0.70 m I. D. steel gate
Regulating gate of main pipe	:	0.60 × 0.60 m slide gate
Regulating gate of branch pipe	:	0.60 × 0.60 m slide gate
Discharge capacity of main pipe outlet	:	5.74 m³/sec at pool El. 1115.25 m

The construction was carried out by force-account, using **DSİ** personnel and equipment and started in 1961. The project completed in 1964 and the total cost was 33×10^6 TL.

The project was designed and supervised by DSİ.

DAMSA DAM

Damsa Dam is situated on **Damsa** Stream 11 km south of the town of **Ürgüp** in the province of **Kayseri.** The purpose of the project is to supply water for irrigation of 475 hectares of land.

Hydrological Data

Drainage area	:	79 km²
Mean annual precipitation	:	390 mm
Estimated annual average runoff	:	6.32×10^6 m³

Reservoir Data

Dead storage volume	:	0.13×10^6 m³
Minimum water surface elevation	:	1198.50 m
Net usable storage volume	:	3.14×10^6 m³
Normal water surface elevation	:	1212.00 m
Gross reservoir capacity	:	3.27×10^6 m³
Maximum reservoir volume	:	3.8×10^6 m³
Maximum water surface elevation	:	1213.50 m
Maximum reservoir surface area	:	0.48 km²

Geologoy

The geological formation of the dam site and the vicinity is volcanic with successive lava flows of basalt and andesite interlaid with tuffs and agglomerates. Part of the reservoir and the valley bottom is covered with thick layers of clay. The foundation was stripped off the top soil and a concrete cut-off wall, with a maximum thickness of 2.0 m and a maximum height of 3,00 m was anchored into sound foundation rock in the center of a 10.00 m wide core trench, to form a positive cut-of against leakage. The grout curtain was formed along the foundation of this cutoff wall

Dam Embankment

The dam embankment is a homogeneous earthfill, protected on the upstream face by a 0.80 m thick layer of riprap and 0.20 m thick layer of filter. The downstream face was protected against erosion by a 0.50 m. thick layer of quarry fines and cobbles. A rockfill downstream toe was constructed which also functions as a drain.

Spillway

The spillway is located in the left abutment and is flanked by the embankment. It has a crest length of 64.00 meters, curved in plan, projecting into the reservoir. The concrete lined discharge chute is 275 m long and ends in a dry creek formed in tuffs and agglomerates. Erosion at the end of the spillway chute caused concern during the operation of the dam, and for this reason flood discharges were controlled by the bottom outlet whenever possible.

Outlet Works

A tunnel, 2.00 m in diameter and 141.00 m in length, was driven in the left abutment. It contains a drop inlet type intake, a gate chamber located in an open cut in the foundation of the dam, 50.00 meters downstream from the axis of the corewall and a control house located at the downstream portal of the tunnel. A steel pressure pipe, 0.50 m in diameter and 66.0 m in length extends from the gate chamber to the control house. The discharge is controlled by a hollow jet valve, 0.50 m in diameter.

Dam Embankment

Type	:	Earthfill
Height above lowest foundation	:	26.00 m
Height from foundation to cutoff	:	3.00 m
Height above ground level	:	24.00 m
Crest length	:	470.00 m
Crest width	:	9.00 m
Crest elevation	:	1215.80 m
Total embankment volume	:	230.000 m³

Spillway

Type	:	Ungated, free overfall
Crest length	:	64.00 m
Crest elevation	:	1212.00 m
Design flood peak flow	:	150 m³/sec
Type and length of discharge chute	:	Trapezoidal cross section, concrete lined, 275 m

Diversion

Type	:	Tunnel, circular, concrete lined
Diameter	:	2.00 m I.D.
Length	:	141.00 m
Upstream cofferdam crest elevation	:	1198.00 m
Downstream cofferdam crest elevation	:	1195.00 m

Outlet Works

Upstream tunnel length	:	66.00 m
Downstream conduit diameter and length	:	0.50 m I.D. steel pipe,
Emergency gate	:	0.80 × 0.80 m slide gate
Regulating valve	:	0.50 m I.D. hollow jet valve
Maximum discharge capacity	:	3,115 m³/sec.

Construction of the dam was carried out between the years 1952 - 1956. The contractor was **Kâmil Özsarıyıldız Ltd.** The dam was designed and supervised by **DSİ** and is owned by DSİ.

The dam was raised by 0.80 m in 1958. Plans are underway to increase the height of the dam by an additional 8.50 meters. Along with the heightening of the embankment, the present intake will be replaced by a higher intake tower since, because of excessive silting, the present intake is nearly blocked, resulting also in decreased reservoir capacity. Operation of the dam during the last 10 years has shown that average annual inflow is greater than that estimated for the original project.

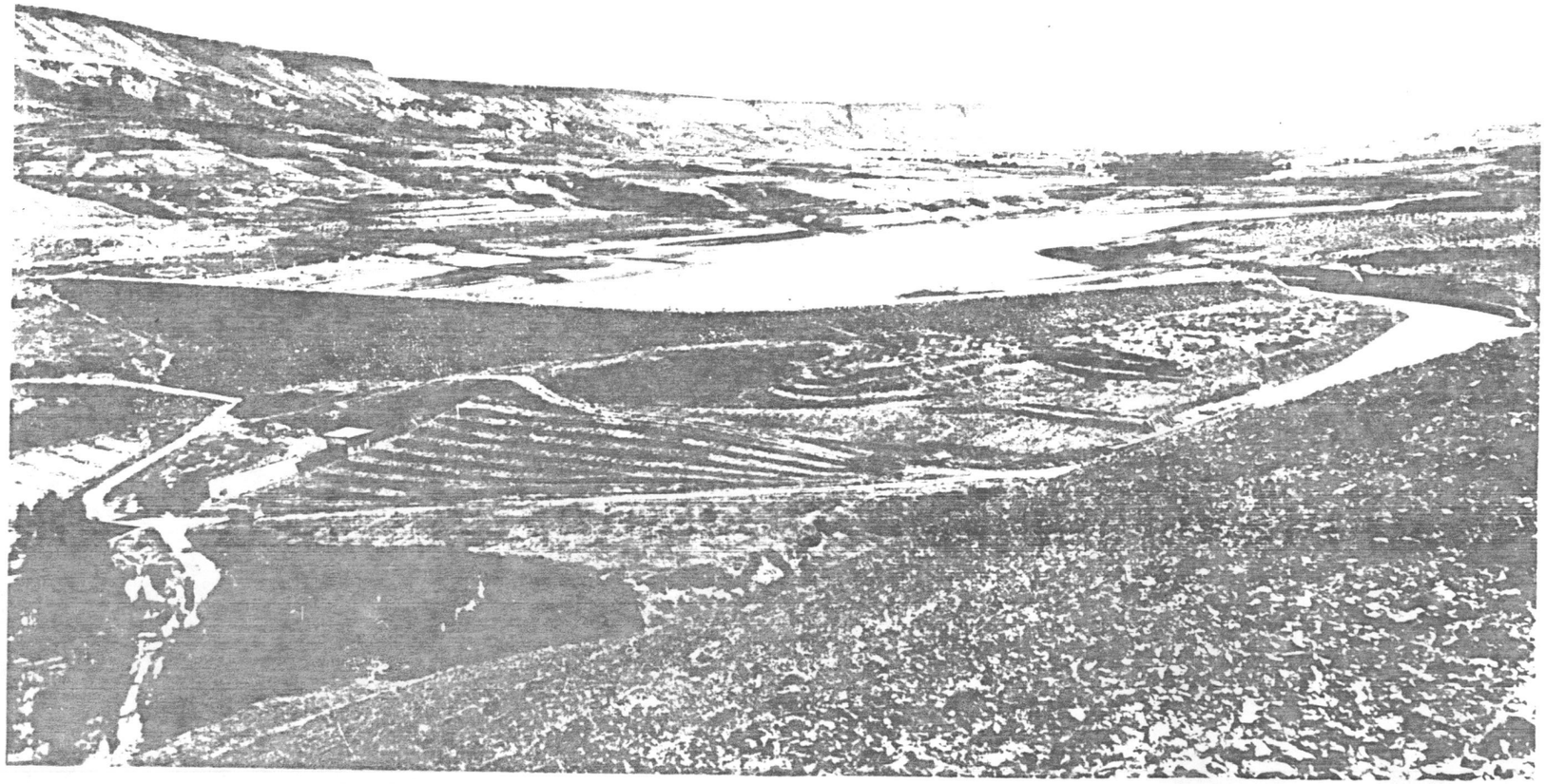


Fig. 3.05
General view of Damsa Dam.

GÜLÜÇ DAM

Gülüç Dam is located on **Gülüç** Stream, at a point about 10 km upstream from its outlet into the Black Sea.

The purpose of the project is to provide water for industrial use at the large iron and steel manufacturing complex, **Ereğli Demir ve Çelik Fabrikaları T.A.Ş.**, which is situated 8.5 km downstream from the dam.

Hydrological Data

Mean annual precipitation	:	1250 m.
Recorded minimum flow	:	0.321 m³/sec
Recorded maximum flow	:	400 m³/sec
Estimated annual average runoff	:	20×10^6 m³

Reservoir Data

Dead storage volume	:	1.7×10^6 m³
Minimum water surface elevation	:	11.90 m
Net usable storage volume	:	4.3×10^6 m³
Normal water surface elevation	:	18.50 m
Maximum reservoir volume	:	18.50 m
Maximum water surface elevation	:	6×10^6 m³
Maximum reservoir surface area	:	1.34 Km²

Dam Data

Type	:	Concr[illegible]vity
Height above lowest foundation	:	22.[illegible]
Height above ground level	:	[illegible]
Crest length	:	[illegible].00 m
Crest width	:	4.20 m
Crest elevation	:	20.50 m
Total volume of concrete	:	52,000 m³

Spillway Data

Type	:	Gated, 8 span, ogee
Gates	:	Radial type, 8.00 m W., 7.00 m H
Total crest length	:	64.00 m
Crest elevation	:	11.90 m
Design flood peak	:	2200 m³/sec
Maximum discharge capacity	:	2200 m³/sec

Diversion

Type	:	Open channel with gate control, located in the left abutment.
Channel bottom width	:	14.00 m
Channel length	:	164.00 m
Discharge capacity	:	400 m³/sec

Outlet Works

The intake of the outlet works is located near the right abutment, adjacent to the spillway spans. It consists of a bottom opening controlled by a radial gate discharging into the river channel, downstream.

This bottom outlet has a discharge capacity of 2 m³/sec, 1.3 m³/sec of which is allocated for the requirements of the iron and steel factory.

Geology and Foundation Treatment

The dam axis is located in a valley formed in volcanic breccia, successive basalt flows and thick layers of agglomerates. The depth of alluvial deposits exceeds 25 m in the deepest part of the foundation. Alluvium is composed of silts, sands and gravels with occasional lenses of clayey sands and silts.

The concrete overflow section rests on the alluvium. A concrete pile cutoff was constructed in front of the upstream toe of the dam and connected to the main slab of the dam with a concrete apron. The concrete pile cutoff is made up of one row of overlapping, 0.65 m dia. poured - in - place concrete piles. To insure complete water tightness of the curtain, cement grout was injected under pressure through pipes, placed in the piles for this purpose before the final stage of concreting.

Two rows of grout holes, one upstream and the other one downstream of the concrete pile cutoff, were sunk and clay slurry was injected through them under a pressure of maximum 3 atm.

Gravity section in the right abutment rests on 593 concrete - filled - steel - pipe piles which were driven to an average depth of 17 m.

Construction

Construction started in 1963 and was completed in 1966.

The main contractor for construction and erection was **Tekfen İnşaat Ltd.** of Ankara, Turkey. The permenant equipment was manufactured by **Aug. Klönne** of Dortmund, and **Siemens A. G.** of W. Germany. The cost of this main part of the work was 21×10^6 TL including the cost of the permenant equipment.

Pile driving in the right abutment was contracted by **Reha İren** and its cost amounted to 1.6×10^6 TL.

Concrete pile cutoff was constructed by **F. I. Verdi Kol. Ş.** and amounted to 4.3×10^6 TL.

The dam is owned by **ERDEMİR**, ie., Ereğli Demir ve Çelik Fabrikaları T.A.Ş.

The planning and preliminary design of the project was carried out by **E.I.E.** The final design and engineering supervision was by ERDEMİR.

Hasanlar Dam is situated on **Küçük Melen** River near the highway bridge at **Hasanlar** on the **Düzce - Yığılca** road. The purpose of the project is irrigation of 24,800 ha of land in the downstream **Düzce** Plain and control of floods up to 100 - year frequency.

Geology

The dam axis is located about 400 meters upstream from a Cretaceous limestone gorge. The foundation and the abutments are located in an ultrabasic intrusive formation (diabase). There is very little alluvium in the river bed and diabase is exposed in a very sound condition. However the abutments are covered with thick deposits of talus and decomposed diabase. This situation led to an increase in the volume of stripping carried out in the foundation of the dam.

Above the crest elevation in the right abutment a large outcrop of cretaceous limestone dips in a downstream direction. It is overlain uncomformably by an Eocene formation of flisch. The spillway is located in the right abutment in a sadle and is excavated mostly in Cretaceous limestone.

Cretaceous limestone appears to be pervious and several outcrops are visible in the reservoir. However, leakage paths through these limestones are thought to be cut off by underlying impervious formations with the result that leakage problems are not anticipated in the reservoir.

Hydrological Data

Drainage area	:	665 km²
Average flow	:	11.3 m³/sec
Estimated annual average run-off	:	340×10^6 m³
Record period	:	5 years
Recorded minimum flow	:	1.26 m³/sec
Recorded maximum flow	:	546.0 m³/sec
Maximum probable flood flow	:	1800 m³/sec
Maximum probable flood inflow volume	:	114.6×10^6 m³

Reservoir Data

Dead storage level	:	227.50 m
Dead storage volume	:	5×10^6 m³
Minimum water surface elevation	:	227.50 m
Normal water surface elevation	:	255.50 m
Net usable storage volume	:	50×10^6 m³
Gross capacity of reservoir	:	55×10^6 m³
Top of flood control water surface elevation	:	265.00 m
Flood control volume		40×10^6 m³
Maximum water surface elevation	:	271.30 m
Maximum reservoir capacity	:	112×10^6 m³
Maximum reservoir surface area	:	4.25 km²
Maximum reservoir length	:	11.0 km
Maximum reservoir width	:	2.0 km

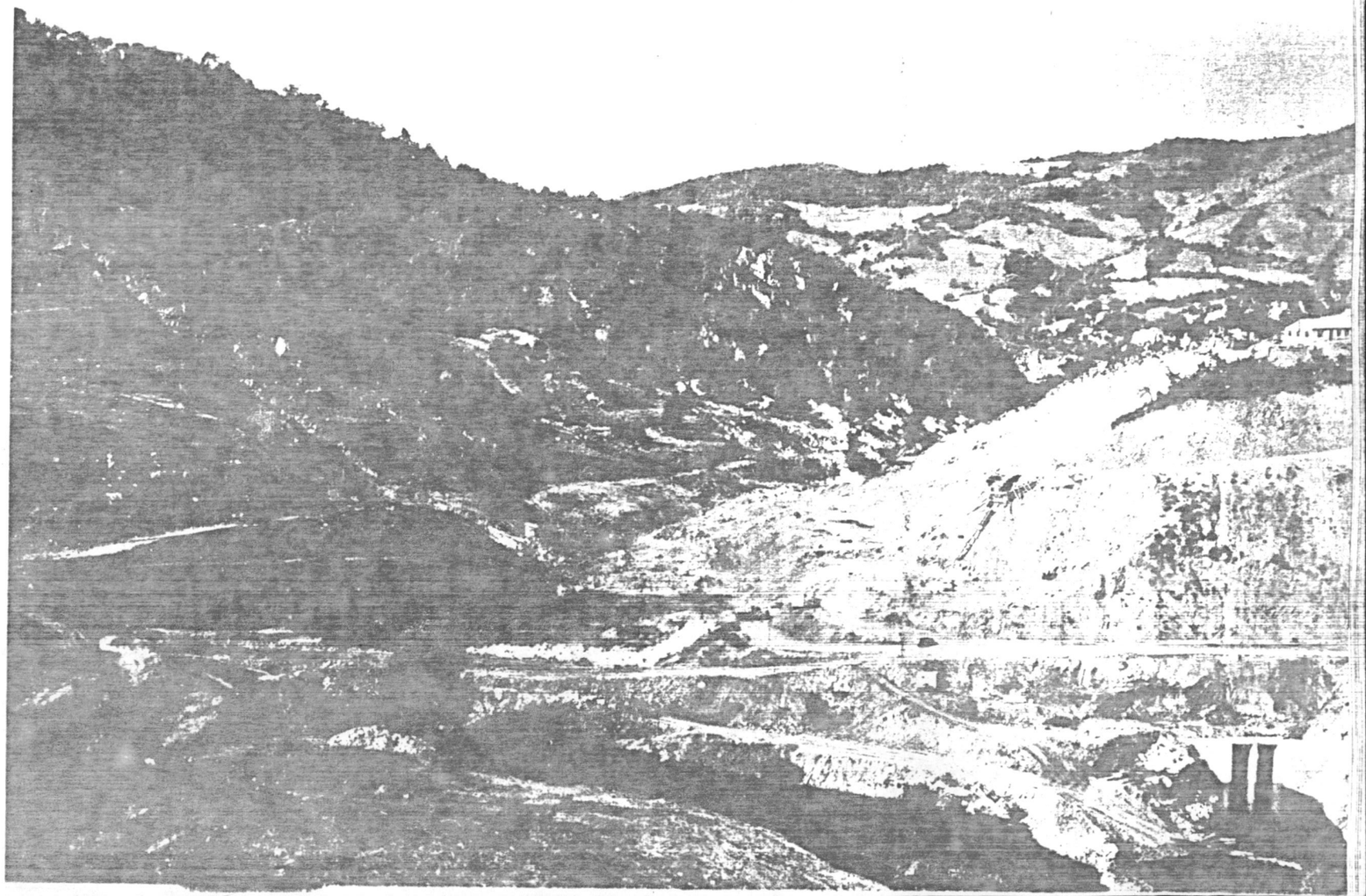


Fig. 5.017
Upstream view of the site, Hasanlar Dam.

Hasanlar Dam is a rockfill structure composed of a central clay core which is flanked by large filter zones with upstream and downstream shells of sound rock. The material for the rock fill zones is obtained from the required spillway excavation. The rather flat upstream and downstream slopes are the results of conservative observance of the earthquake effects to which this structure, located in a first degree earthquake zone, may be subjected.

Embankment Data

Type	:	Rockfill
Height from the lowest foundation	:	72.80 m
Crest length	:	310.00 m
Crest width	:	8.00 m
Crest elevation	:	272.80 m
Total embankment volume	:	1,651,000 m^3

Spillway

The spillway is a compound structure having two modes of operation.

Since the project is designed for controlling floods up to 100 - year frequency, a volume of 40×10^6 m^3 is allocated in the reservoir for this purpose. The lower orifice type spillway functions during such floods discharging a maximum of 105 m^3/sec which is the maximum capacity of the river bed downstream without inflicting any damage to the bordering lands.

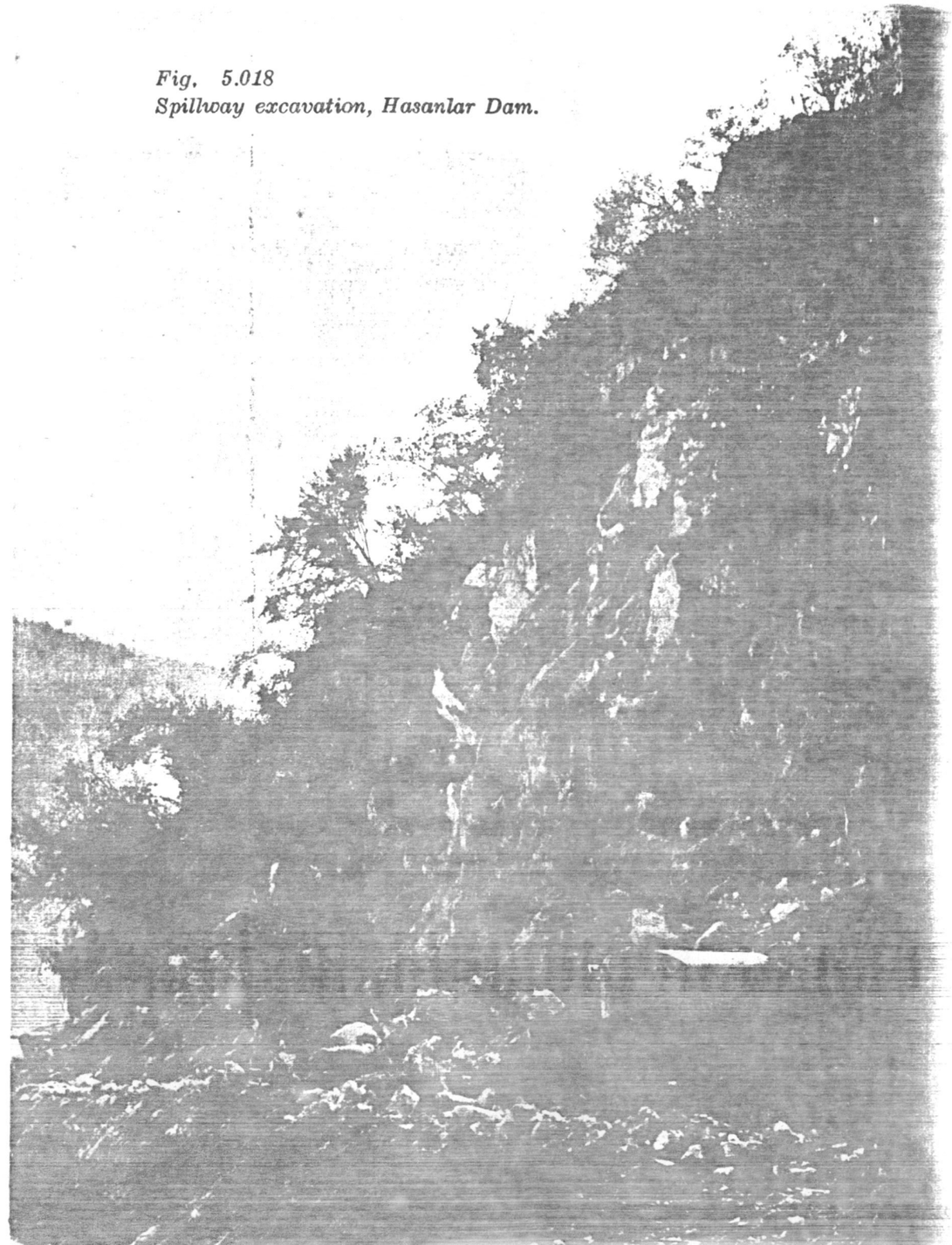
Floods of higher volume can be discharged by the upper ogee crested circular axis emergency spillway which has a crest length of 80.60 m. Maximum discharge capacity is 1330 m^3/sec. The outlet channel is concrete lined for the first 131.0 m. The chute ends in a pilot channel cut in the limestone of the gorge about 400 meters downstream from the dam axis.

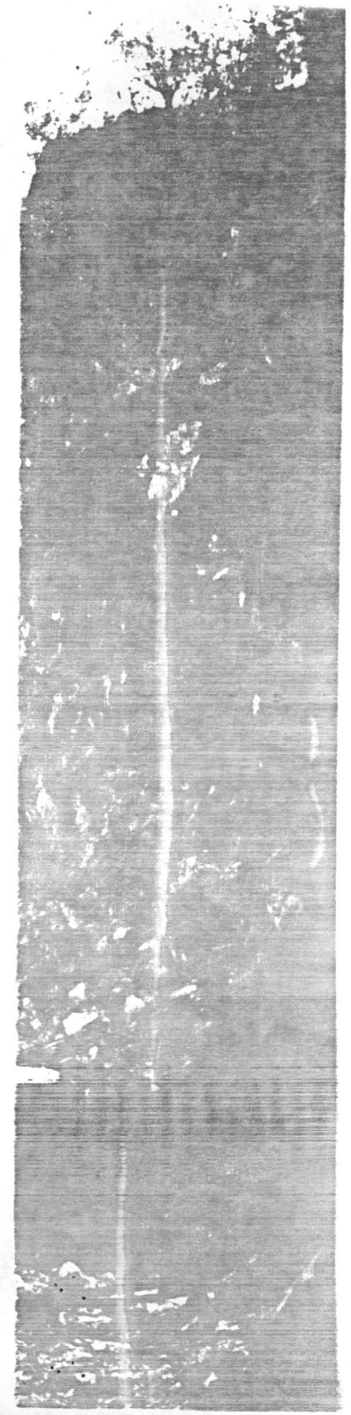
Diversion and Outlet Works:

During the construction, the river is diverted through a tunnel driven in diabase of the right abutment. A large tunnel (6.00 m ID) is required for the 10 - year frequency floods of this river. This tunnel will be utilized in the outlet works by concreting the mid - tunnel plug with a contracting transition through it for the installation of a 1.20 m - I.D. steel pipe in the downstream tunnel. This pipe is equipped with a butterfly emergency valve in the gate chamber, immediately downstream of the tunnel plug, and a Howell - Bunger free discharge regulating valve in the control house at the outlet portal of the tunnel.

Provision is made in the mid - tunnel plug for installation of a larger diameter pipe in the future to meet the increase in irrigation demands or to make possible modifications in the outlet works for power production. In view of the above future considerations the intake stucture is made larger and the means for easy closure of the inlet is provided.

Fig. 5.018
Spillway excavation, Hasanlar Dam.





Spillway Data

Lower spillway :

Type	:	Orifice
Dimensions and number	:	2.20 × 2.00, 2
Length	:	50.00 m
Maximum discharge with water level at EL. 267.36	:	105.0 m³/sec

Upper Spillway (emergency) :

Type	:	Free overflow, ogee crested, circular axis
Crest length	:	80.60 m
Crest elevation	:	267.36 m
Maximum discharge capacity	:	1330 m³/sec

Diversion Data

Type	:	Tunnel, circular, reinforced concrete lined
Diameter	:	6.00 m
Length	:	369.00 m
Discharge capacity for diversion	:	345 m³/sec
Upstream cofferdam crest elevation	:	221.50 m
Downstream cofferdam crest elevation	:	207.00 m

Outlet Works Data

Intake structure	:	Inclined, rectangular inlet with rounded corners
Pressure tunnel length	:	18.00 m
Steel pipe diameter	:	1.20 m I.D.
Emergency valve	:	Butterfly valve, 1.20 m I.D.
Regulating valve	:	Howell - Bunger valve, 0.90 m I.D.
Discharge capacity at Min. W.S. EL. 227.50	:	10 m³/sec

The project was designed and is being supervised by **DSİ**, the contract being awarded to the Construction Firm of **Mustafa Murtazaoğlu.**

The construction is scheduled to be completed in 1968. The estimated cost of the project is 32,808,000 TL.

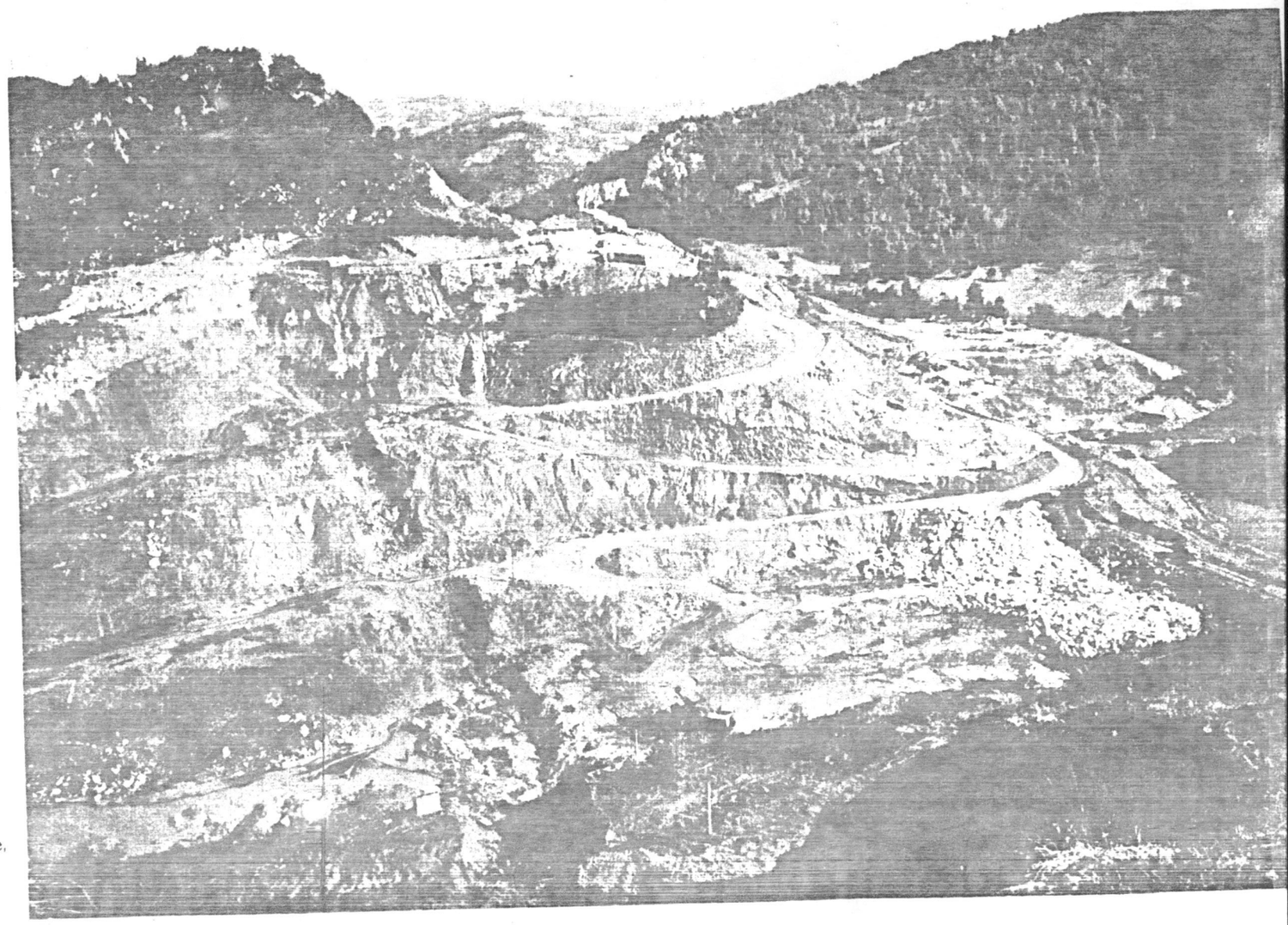


Fig. 5.019
View of the foundation and cut - off trench from the left abutment, Hasanlar Dam.

HIRFANLI DAM

Hirfanlı project is located on **Kızılırmak** river which is the longest river of Turkey, about 80 airline km to southeast of **Ankara,** in the central plateau. It is mainly a hydroelectric project which has secondary benefits of regulating the river for downstream irrigation development and flood protection. It is also the key storage project in the ultimate development scheme of Kızılırmak River.

The project includes the following principal features :

a) A rockfill dam 364 m in length at the crest with a maximum height of about 80 m.

b) A concrete, uncontrolled spillway located near the right abutment, having a crest length of 108 m.

c) Two reinforced concrete power intake structures, connecting with two 8 m I.D. concrete lined tunnels and four steel lined power conduits. The power tunnels were also used as diversion conduits during the initial stages of the construction.

d) A reinforced concrete powerplant at the downstream toe of the embankment, housing three 46,000 KVA generators and a space for future installation of a fourth unit of the same capacity.

e) An irrigation discharge valve to provide river flow to meet downstream requirements, in the case of complete stoppage of the units in the powerplant.

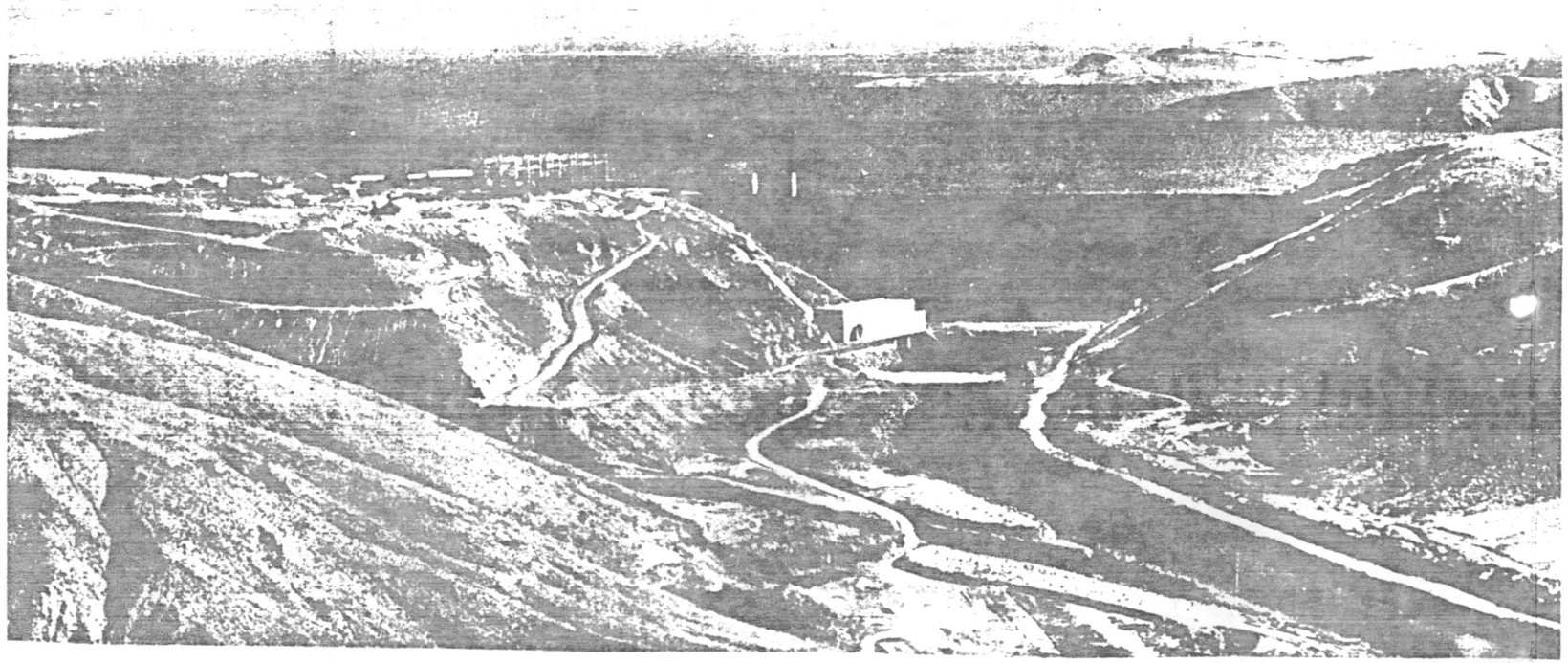


Fig. 3.53
General view of Hirfanlı Dam and reservoir.

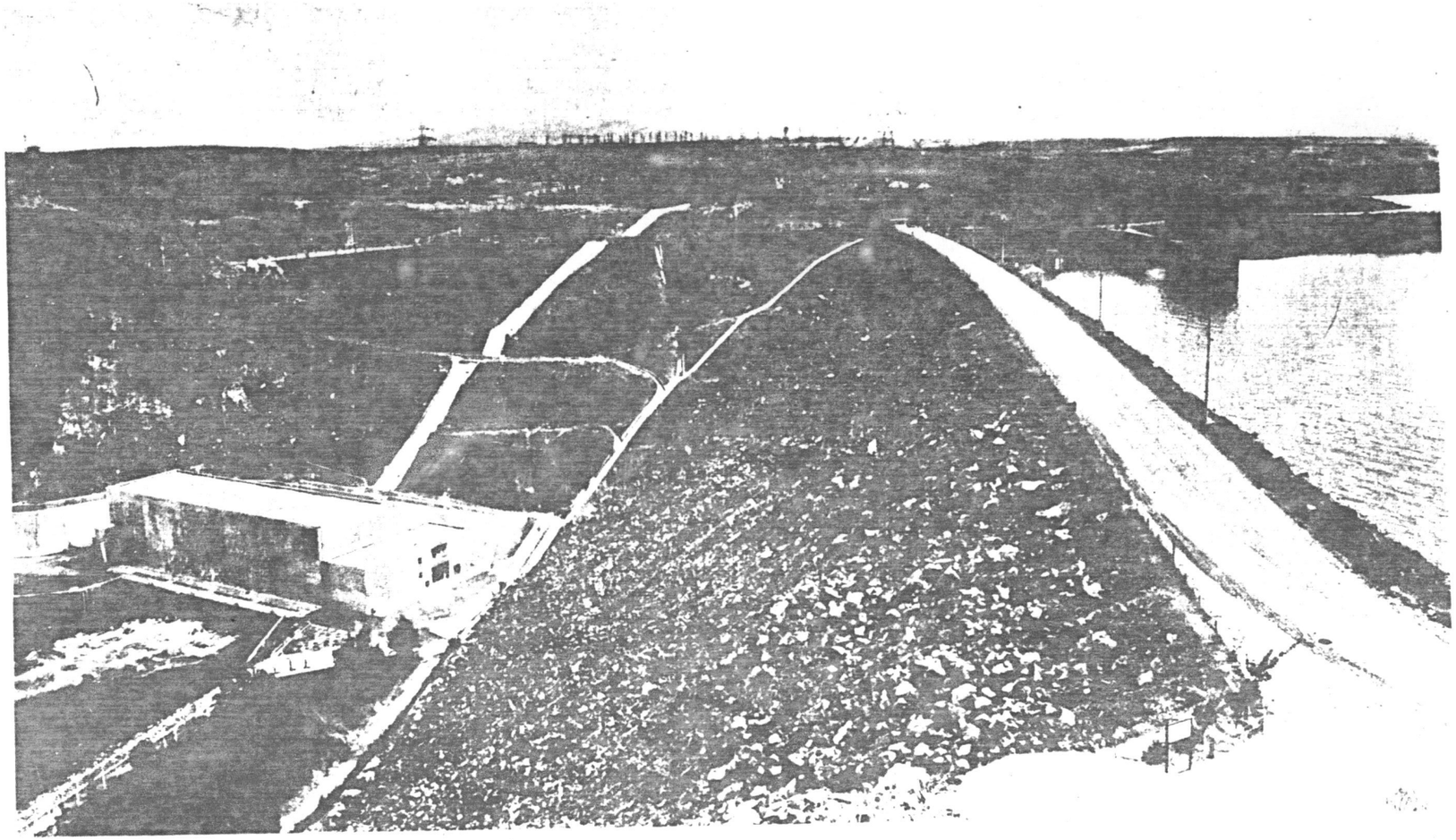


Fig. 3.54
Hirfanlı Dam, view from the left abutment

Geology and foundation treatment

The area in which Hirfanlı Project is located, is a continuation of **Kırşehir**-granilitic - granodioritic - noleanic massive. Rocks are of uralit - gabbro class containing fairly homogeneous fine and medium grains, dark green or black in colour. Fissures are abounding and sometimes filled with calcite. Probably because of such fissures that the gabbro was decomposed to great depths.

Top soil thickness varies between none and 5 m in the abutments. Abutments and the river bed was stripped to sound rock. River deposits were silt, sand and gravel and had a maximum thickness of 5 m.

The rock in the abutments and the foundation is gabbro of varying quality. A granodiorite dyke exists in the right abutment but its presence caused no serious difficulties during the construction.

Inclined thin core of the dam is anchored into the rock by means of a core trench excavated in the abutments and the foundation. Four rows of cap grouting with holes spaced at 2.5 m between centers and drilled to an average depth of 5 m, and one row of curtain grouting, with holes drilled at 2.5 m between centers, to a maximum depth of 34 m, was carried out in the bottom of the core trench, completely sealing off the foundation rock. The average grout take was 27.7 Kg of cement per m length of hole.

Embankment

Hirfanlı dam is an earth and rockfill structure having a inclined clay core and a steep (1 on 1.3) downstream slope. Originally it was designed as a homogeneous sound rockfill embankment with a thin inclined core and upstream and downstream filter zones between the core and rockfill. The main source for the embankment material was the spillway excavation and contrary to expectations, most of the blasted rock contained large percentage of fines and decomposed rock and was unsuitable as a material for sluiced dumped rockfill.

This situation required certain changes to be made in the cross section of the dam. The final typical cross section is shown in Fig. 3.62 Outside dimension of the embankment was kept unchanged, since the locations of the power intakes, powerplant etc., would not have permitted a significant modification. However, a large zone of rolled decomposed rock was incorporated and filters were accordingly modified. This design made optimum use of available excavation material in the fill possible and resulted in an economical solution, requiring only a small amount of wastage.

Sound rockfill was placed by dumping from high lifts and sluicing with high pressure jets. Decomposed rockfill zone was compacted by 50 ton rubber tired rollers, resulting in a semipervious to impervious fill. Sheepsfoot rollers were used to compact the clay core which was made with material obtained from borrow pits located in the reservoir area and placed in 15 cm hick compacted layers at the optimum water content.

Hydrological Data

Drainage area	:	26,200 km²
Mean annual precipitation	:	400 mm
Recorded maximum flow	:	1,045 m³/sec
Estimated annual average runoff	:	$2{,}993 \times 10^6$ m³
Average flow	:	95 m³/sec

Reservoir data

Dead storage volume	:	880×10^6 m³
Dead storage level	:	818.10 m
Minimum water surface elevation	:	842.00 m
Minimum power pool volume	:	4.2×10^9 m³
Maximum power pool elevation	:	851.00 m
Maximum power pool volume	:	5.98×10^9 m³
Maximum water surface elevation	:	856.55 m
Maximum reservoir volume	:	7.63×10^9 m³
Maximum reservoir surface area	:	320 km²

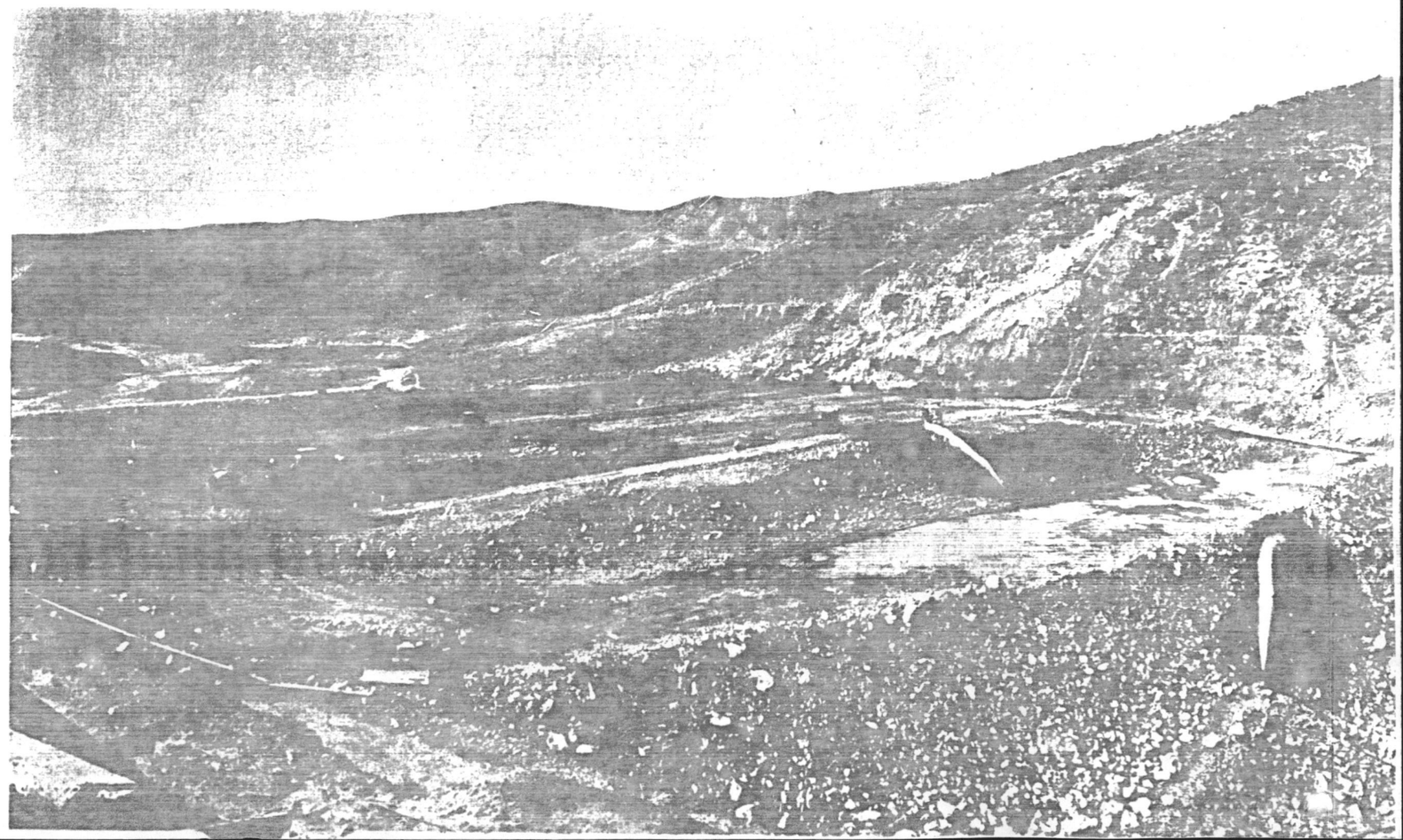


Fig. 3.55
Construction of the embankment.
Hirfanlı Dam.

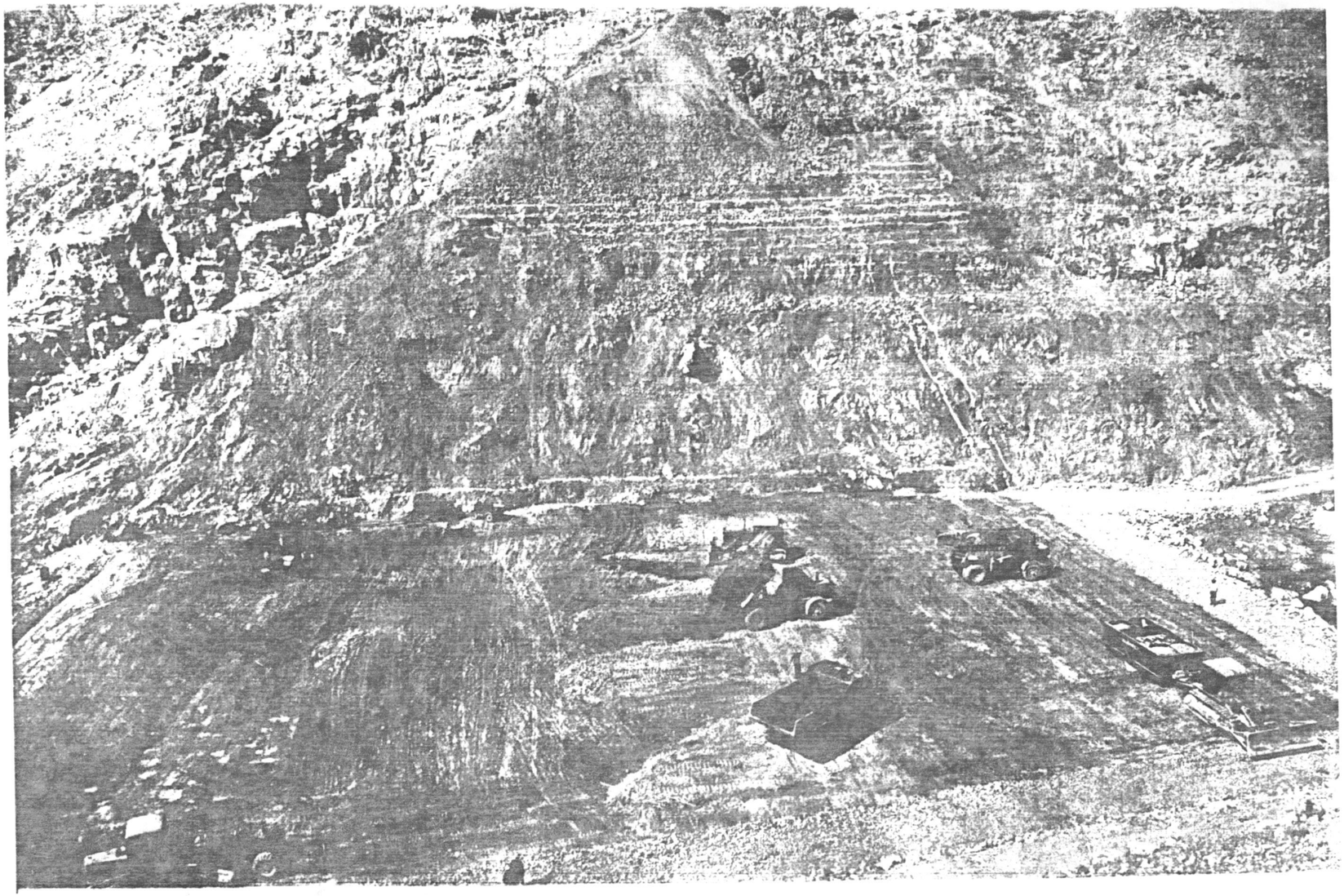


Fig. 3.56
Placement of decomposed rockfill in the foundation, Hirfanlı Dam.

Construction

Construction started with the diversion tunnels. Two 7 m I.D. tunnels were driven in the right abutment in hard to moderately decomposed gabbro. Only light supporting was required, excepting one location where a large cave - in caused delays and required adoption of special measures such as rock bolting and concentrated grouting

After joining with the power tunnels coming down from the intake structure, diversion tunnels continue as extensions of the power tunnels and their diameters increase to 8.00 m. Two steel penstocks embedded in concrete, branch off from each power tunnel to convey the water to four units in the powerplant.

Three units, each having a rated capacity of 46,000 KVA was installed and the powerplant is connected to the Northwestern Anatolian Power Network. The fourth unit will be installed in the near future.

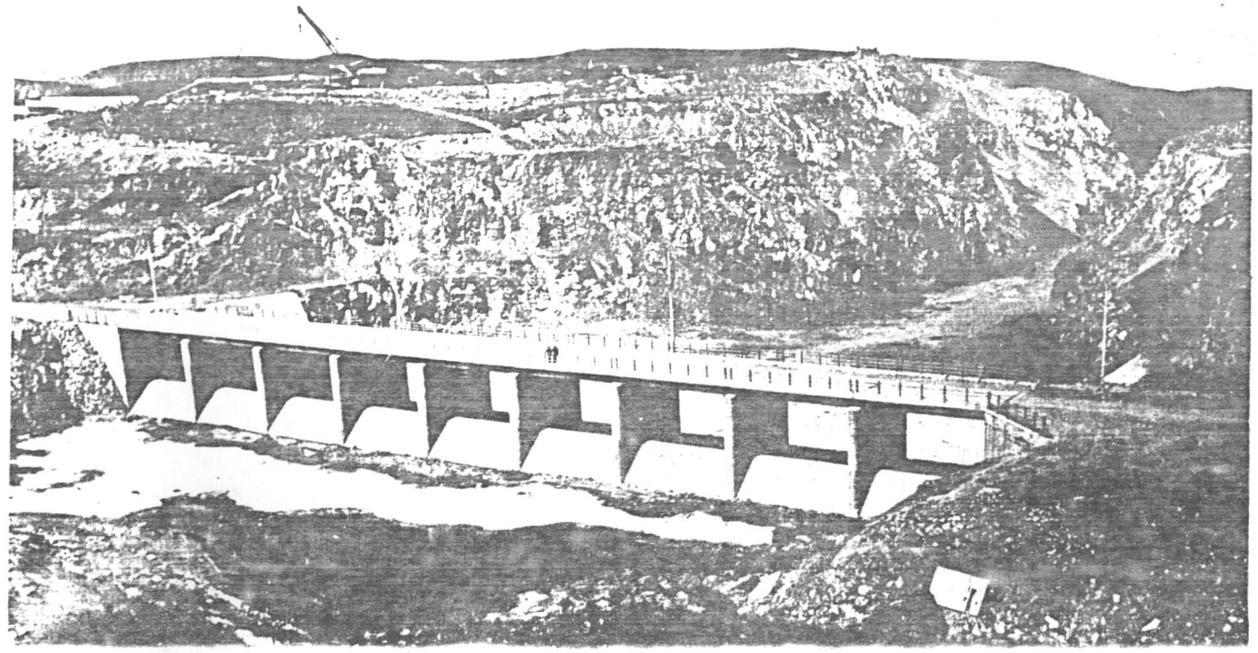
The construction of the project commenced in 1954 and it was put into commission in 1958. The civil engineering contractor was **Wimpey and Co. Ltd** of London, England. Permenant equipment was supplied and erected by **English Electric.**

The project was designed by **K.T.A.M. (presently T.A.M.S.)** Engineers of N.Y., N.Y., U.S.A., who also acted as consulting engineers during the supervision of the construction by **DSİ.**

The total cost of the project is 361 × 10^6 TL. and it is owned by DSI.

Fig. 3.57
Junction of the power and the diversion tunnels before the concreting of the plug.

Fig. 3.58
Spillway, Hirfanlı Dam.



Dam embankment data

Type	:	Rockfill with inclined clay core
Crest length	:	364.00 m
Crest width	:	10.00 m
Crest elevation	:	860.00 m
Height above lowest foundation	:	83.00 m
Height above ground level	:	78.00 m
Total embankment volume	:	2 × 10^6 m^3

Spillway data

Type	:	Uncontrolled concrete ogee.
Crest length	:	107.86 m
Crest elevation	:	851.00 m
Design flood peak flow	:	8,000 m^3/sec
Maximum spillway discharge	:	2,300 m^3/sec
Type and length of discharge chute	:	Unlined, cascade type.

Power plant data

Turbines

Type	: Vertical axis Francis
Number	: 3 units installed, space for 4 the unit provided
Speed	: 187.5 rpm
Rated capacity at full gate	: 49,000 HP
Design head	: 60.00 m
Design discharge	: 65.50 m³/sec
Minimum head	: 56.45 m
Maximum head	: 67.00 m

Generators

Type	: Vertical axis semi - umbrella
Number	: 3 initially, 4th future unit
Speed	: 187.5 rpm
Power factor	: 0.80
Rated capacity	: 46,000 KVA
Output voltage	: 10,600 V
Frequency	: 50 c/s
Phase	: 3

Transformers

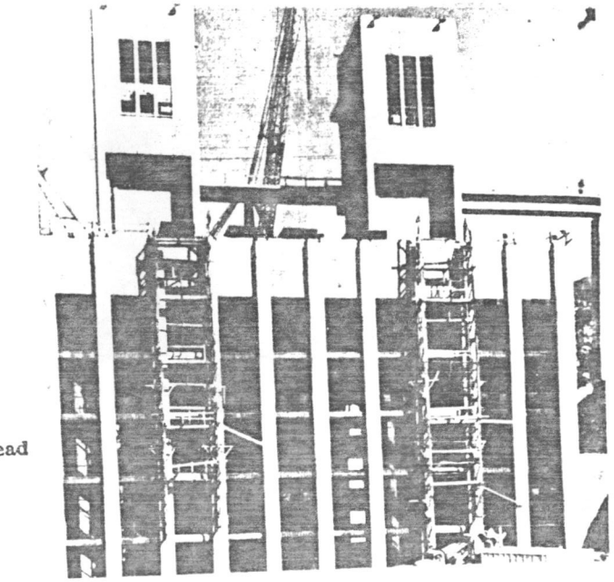
Type	: Oil immersed, outdoor type
Number	: 3 initially
Voltage	: 10.6 to 154 KV

Irrigation penstocks data

Number	: 1
Diameter	: 2.20 m I.D.
Length	: 141.14 m

Irrigation valves data

Type	: Howell - Bunger
Number	: 1
Diameter	: 1.65 m I.D.
Discharge capacity	: 20.00 m³/sec at 32.40 m head



Diversion data

Design discharge capacity	: 800 m³/sec
Type	: Circular, concrete lined tunnel
Length of tunnel No. 1	: 507.00 m
Length of tunnel No. 2	: 542.00 m

Intake structure data

Type	: Reinforced concrete intake tower trashrack structure
Gates	: Fixed wheel service gates 9.50 × 5.77 m Sliding bulkhead gates 6.37 × 11.66 m
Invert elevation	: 818.10 m

Power tunnel data

Type	: Reinforced concrete lined, circular
Number	: 2
Diameter	: 8.00 m
Length of tunnel No. 1	: 507.00 m (from diversion intake)
Length of tunnel No. 2	: 542.00 m (from diversion intake)

Power penstocks data

Type	: Steel liners, embedded in concrete
Number	: 4
Diameter	: 4.90 m I.D.
Length of Nos. 1, 2, 3 and 4	: 70, 57, 7[illegible] and 65 m respectively

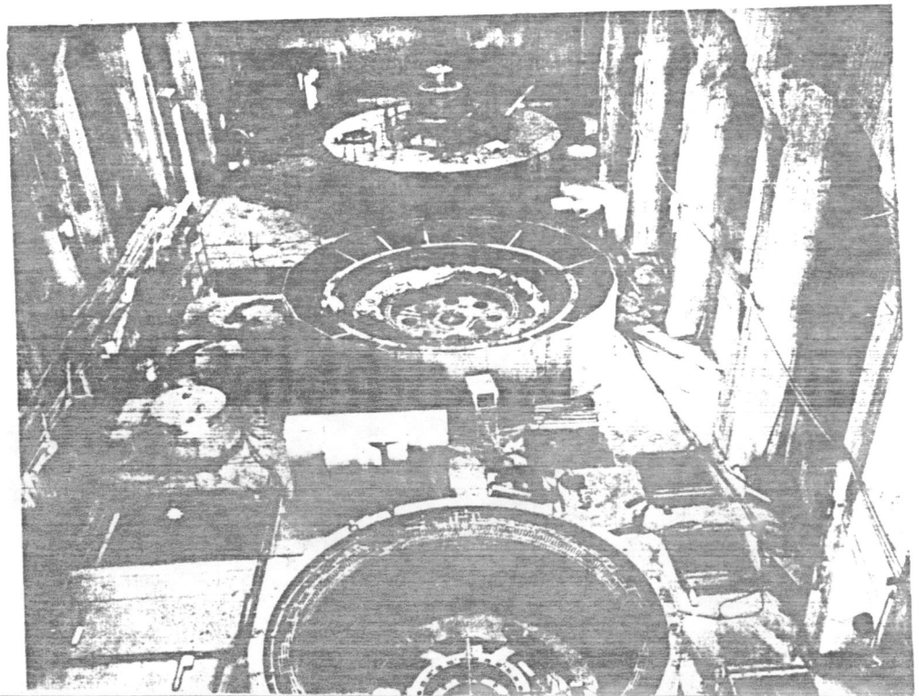
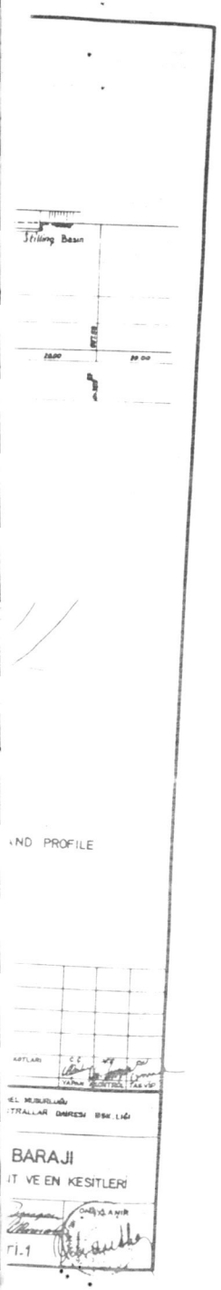


Fig. 3.60 Construction of the power intake structure

Fig.3.59 Erection of generators in Hirfanlı Powerhouse



KESİKKÖPRÜ DAM

Kesikköprü Dam and Power Plant is located on **Kızılırmak** River, 25 Km downstream of **Hirfanlı** Dam and 110 Km south - east of **Ankara.**

This project is the second stage in the Kızılırmak River Development Scheme and is built for the purpose of generating 250×10^6 KWh annually, with an installed capacity of 76 MW.

Hydrology

The drainage area at Kesikköprü damsite is about 26,530 Km^2. However, 26,170 Km^2 of this area belongs to the drainage area of Hirfanlı reservoir.

The annual precipitation varies between 600 mm and 800 mm for the upper parts of the river basin and between 200 and 400 mm for the lower basin.

Hydrology

Drainage area	:	26,530 Km^2
Mean annual precipitation	:	600 - 800 mm for upper basin, 200 - 400 mm for lower basin
Average flow	:	78 m^3/sec
Estimated annual average runoff	:	$3{,}000 \times 10^6$ m^3
Recorded maximum flow	:	1050 m^3/sec

Reservoir

Dead storage volume	:	35×10^6 m^3
Min. water surface elevation	:	772.48 m
Net usable storage volume	:	60×10^6 m^3
Gross capacity	:	$95 \times$ [illegible] m^3
Normal water surface elevation	:	785.55 m
Maximum water surface elevation	:	791.20 m
Maximum reservoir volume	:	110×10^6 m^3
Maximum reservoir surface area	:	8.45 Km^2

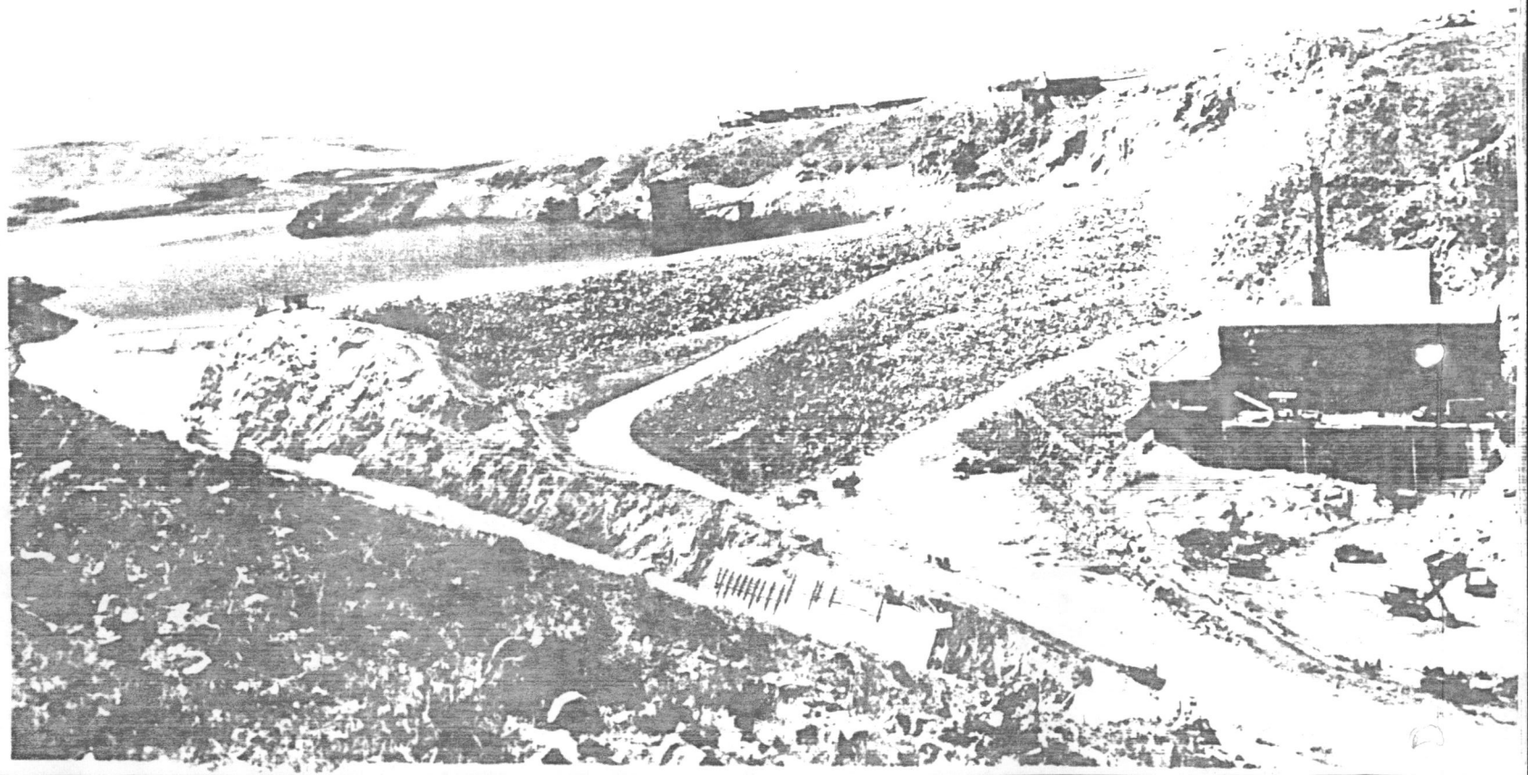


Fig. 4.048
General view of Kesikköprü Dam and Powerhouse. Photograph shows construction of the powerhouse, the spillway and the tailrace excavation. (Autumn 1966)

The actual regulation of the river takes place in Hirfanlı reservoir which has a maximum capacity of 5.9×10^6 m³. Kesikköprü reservoir, on the other hand, with a maximum volume of 95×10^6 m³ does not have sufficient capacity to regulate excess flow to be released from Hirfanlı reservoir, through Hirfanlı spillway and power plant. However, since Hirfanlı and Kesikköprü power plants work with different capacity factors, it is possible for the the downstream Kesikköprü reservoir to regulate outflow from Hirfanlı, excluding spillway discharges. Operation of Kesikköprü project is based on this principle.

Studies carried out by **E.I.E.** indicates that average useful discharge of Kızılırmak river is 78 m³/sec. The required reservoir capacity to regulate this mean flow is provided by Hirfanlı reservoir.

Reservoir

The normal water surface elevation is 785.55 which corresponds to the normal tailwater elevation of Hirfanlı powerplant. The volume of the reservoir at this elevation is 95×10^6 m³. The reservoir can be emptied or filled in 9 days with the average useful discharge of 78 m³/sec. To make optimum use of the available head, the water level will be maintained at or near El. 785.55.

The capacity factor of Hirfanlı power plant is 0.28, whereas for for Kesikköprü it is 78/220 = 0.355.

The reservoir volume at the minimum operating W. S. El. of 771.88 is 35×10^6 m³. It is estimated that about 6.3×10^6 m³ of sediment will be deposited in the reservoir and that it will be mostly the sediment carried into the reservoir by torrential streams located between Hirfanlı and Kesikköprü. Capacity of Hirfanlı reservoir is very large as compared with the annual runoff of the river, therefore, this reservoir is very effective in holding the silt carried by the river. The intake sill elevation was determined as 750.00 m which is 5.00 m higher than average river bed elevation and incorporates a large margine of safety from the point of view of siltation.

Geology and foundation treatment

The project is located in a canyon - like gorge entrenched by the Kızılırmak River near the village of Kesikköprü. In their broader relationships the rocks of the damsite are a part of granitoid strata which cover the Central Anatolia region and which are predominantly granodiorites and syenites, with subordinate gabbros and spilites. Upstream from the dam axis these rocks have intruded into older sediments to produce metamorphic hornfels which form a belt striking north and south, and dipping westward or to the left abutment at 30 to 50 degrees angles. All of these rocks have been subjected to intense deformation, apparently during several periods of relatively recent geologic time, with the result that they are broken by numerous steep angle faults.

Considerable masses of rock in the tunnel, dam and spillway foundations have been intensely crushed by faulting and subsequently further weakened by weathering. Such areas of the foundation are generally bounded by two or three fault planes which are conspicuous in their brightly coloured, clay filled gouge.

One such crushed fault zone occuring at the dam axis in the left abutment caused serious difficulties and a large slide which took place during the early stages of the construction as the result of excavation of talus and highly weathered and crushed rock at the toe of a steep slope, led to major modifications in the original design of the embankment and the tunnel.

Foundation treatment consisted of stripping all loose material in the thalweg region of the foundation where sound rock had a thin cover of alluvium, having a maximum depth of 2 m, stripping all talus and badly weathered rock which in certain places had a depth of 10 m or more, and removal of all loose material involved in the slide at the left abutment. The latter work was carried out with utmost care in order not to trigger futher movement in the upper parts of the slide area. Excavation as well as grouting of this part of the foundation was made in stages as the work in the dam progressed.

The grout curtain is located in front of the fault zone, in sound rock. Wherever necessary, a 1×1 m concrete grout cap was constructed. In the left abutment, grouting was carried out through pipes left for this purpose in the fill, after a surcharge of 10 to 12 m was obtained, in order to safeguard against any possible upheave.

A drainage tunnel driven in the left abutment, behind the powerhouse connects with the downstream portion of the original power tunnel and helps keep the downstream slope of the left abutment stable.

Spillway

The peak value of the maximum flood of Kızılırmak River is 8000 m³/sec. After routing through Hirfanlı reservoir a peak of 2300 m³/sec is discharged through Hirfanlı spillway into Kesikköprü reservoir. With the addition of 100 m³/sec to account for the probable flood inflow between Hirfanlı and Kesikköprü, the total flood inflow into Kesikköprü reservoir amounts to 2400 m³/sec with a duration of 14 days. Maximum discharge through Kesikköprü spillway is 2380 m³/sec after regulation in the reservoir.

The spillway is located in the right abutment and is a circular axis uncontrolled ogee type weir discharging into a concrete lined trapezoidal chute.

The spillway chute ends in the tailrace channel at a point about 500 m downstream from the powerplant. Since no erodible material exists in the 900 m long tailrace channel which was excavated in sound rock, building a structure to dissipate the energy of spillway discharge was not deemed necessary.

Powerplant

Requirements of North - West Anatolia Network indicated that the most economical plant capacity for Kesikköprü is 76.000 KW. Thus, two units, each having a capacity of 38,000 KW and a discharge of 110 m³/sec were installed.

Turbines are of vertical axis Francis type having a speed of 125 rpm. Two surge tanks are built at the end of the power tunnel in order to provide favourable speed regulation and to limit water hammer to admissible values since the present 9 m I.D. of the power tunnel is about the maximum size that could be constructed in the badly weathered and fractured rock of the left abutment.

Excavation in the tailrace channel resulted in a uniform bottom slope of 0.0011 and provided an additional net head of 3.30 m.

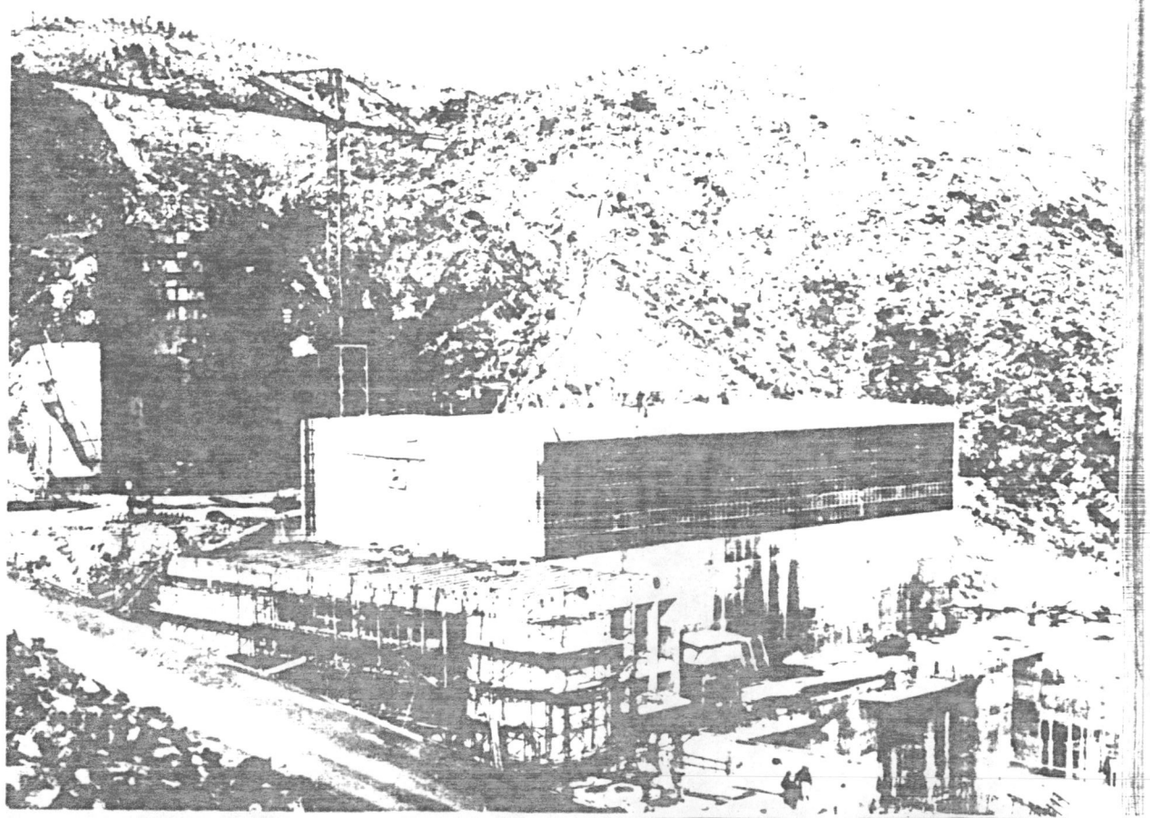
Dam Embankment

The embankment is an earth and rockfill structure 52.60 m high above lowest foundation. The dam was originally designed as a central clay core rock - fill structure but was later modified to make maximum possible use of available weathered rock obtained from the spillway excavation. Sound or slightly decomposed rock was placed in the outer zones of the dam and the central clay core was flanked by heavily weathered granitic rock. Upstream and downstream horizontal and chimney filters control drainage within the dam and preclude the possibility of piping due to possible heterogeneity in the weathered rock - fill.

Material for filters and clay core was obtained from borrow areas located in the reservoir. Clay core was placed in approx. 25 cm thick layers and was compacted by sheepsfoot rollers to 15 cm at optimum moisture content. Weathered and sound rockfill zones were placed in 90 cm thick layers and were compacted by 50 ton rubber tyred rollers.

Construction started in 1959 and the first civil engineering contractor was **Latif Sepil** of Ankara, Turkey. Important increases in quantity of the work items as well as material and labor costs led to termination of the contract in 1962. The contract for the remaining work was awarded to **Buros Ltd.** of Ankara, Turkey in 1963. The dam, powerhouse and appurtenant works were completed in 1966 and with the completion of mechanical and electrical installations in the powerplant, the project was put into commission in May 1967.

Fig. 4.049
Kesikköprü powerhouse. Photograph showing construction of the surge tank and the service block of the powerhouse.



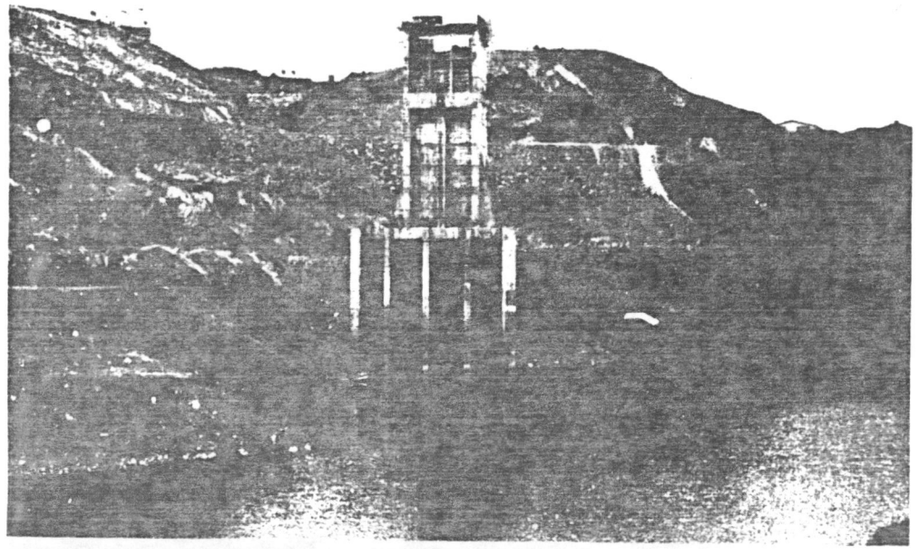


Fig. 4.050
Intake structure

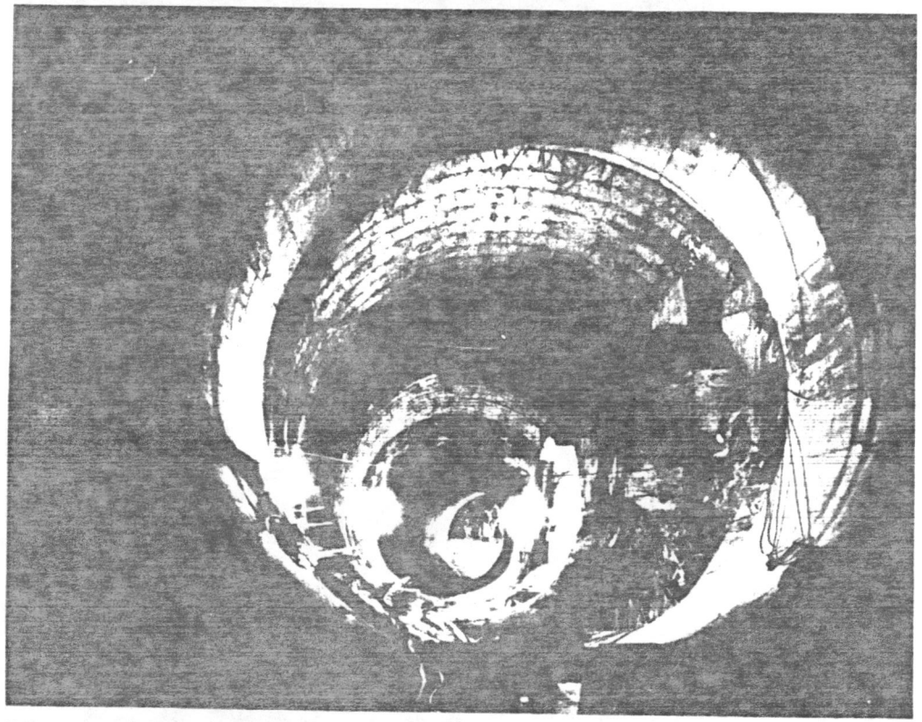


Fig. 4.051
Construction view of the power tunnel

Permenant equipment for the powerplant including intake gates and hoists, penstocks and surge tanks were manufactured and erected by various Italian firms represented by **Gruppo Industrie Elettro Meccaniche per Impianti All'espero** of Italy.

Planning and preliminary design of the project was made by **E.I.E.** and final design and engineering supervision was carried out by **DSI.** The project is owned and operated by DSI.

Total cost of the project, excluding expropriation costs, is 161 × 10^6 TL., 75.7 × 10^6 TL. of which is the cost of permenant equipment.

Embankment

Type	:	Earth and rockfill
Height above lowest foundation	:	52.60 m
Height above ground level	:	49.10 m
Crest length	:	265.00 m
Crest width	:	10.00 m
Crest elevation	:	793.10 m
Total embankment volume	:	900,000 m^3

Spillway

Type	:	Ungated, circular axis concrete ogee.
Crest length	:	86.00 m
Crest elevation	:	785.55 m
Type and length of discharge chute	:	Concrete lined trapezoidal 377 m long.
Maximum spillway discharge	:	2380 m^3/sec

Diversion

Type	:	Through part of power tunnel
Diameter	:	9.00 m I. D.
Length	:	445.22 m

Transformers

Type	:	Oil immersed forced air and oil cooled
Number	:	2
Rated capacity	:	47,500 KVA
Voltage ratio	:	10.6/154

Power Intake

Type	:	Free standing concrete tower, accomodating trashracks, gates and hoisting equipment.
Gates	:	2 fixed wheel service gates, 4.64 × 10.40 m 2 fixed wheel emergency gates, 4.80 × 11.20 m

Power Conduit

Type	:	Tunnel, circular reinforced concrete lined
Diameter	:	9.00 m I.D.
Length	:	266.90 m

Power Penstocks

Type	:	Steel liner embedded in concrete
Diameter	:	6.40 m I.D.
Number	:	2
Length	:	No. 1 penstock, 57.10 m; No. 2 penstock, 48.95 m.
Emergency valves	:	2, butterfly valve, 5.60 I. D.

Surge Tanks

Type	:	Differential
Diameter	:	15.25 m I.D.
Height	:	29.00 m

Irrigation Outlet

Irrigation penstock dia.	:	2.80 m I.D.
Length	:	Butterfly, 2.30 m I.D.
Emergency valve	:	Slide gate, 1.85 × 1.85 m
Discharge capacity	:	At min. W.S.EL. 52 m³/sec at nor. W.S.EL. 65 m³/sec

Turbines

Type	:	Vertical axis, Francis
Number	:	2
Speed	:	125 rpm
Rated capacity	:	53,000 HP (at net head of 39.63 m)
Maximum capacity	:	62,800 HP
Rated net head	:	39.63 m
Rated discharge	:	110 m³/sec
Maximum discharge	:	122.5 m³/sec

Generators

Type	:	Vertical shaft umbrella type
Number	:	2
Rated capacity	:	47,500 KVA
Maximum capacity	:	54,500 KVA
Power factor,	:	0.80
Output voltage	:	10,600 V
Frequency	:	50 c/s
Phase	:	3

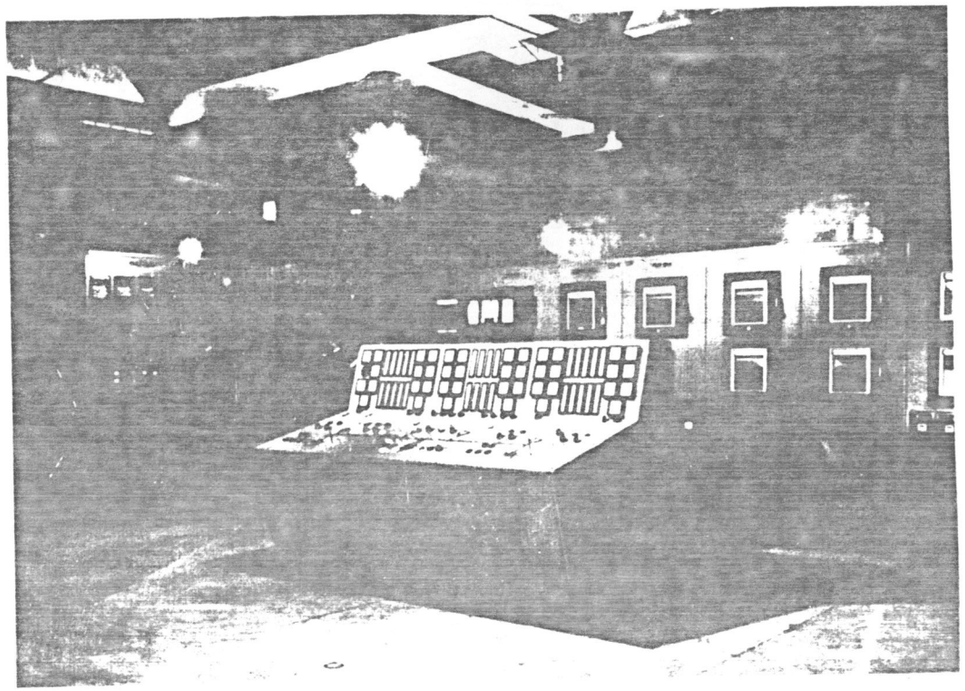


Fig. 4.052 Control room, Kesikköprü Powerhouse.

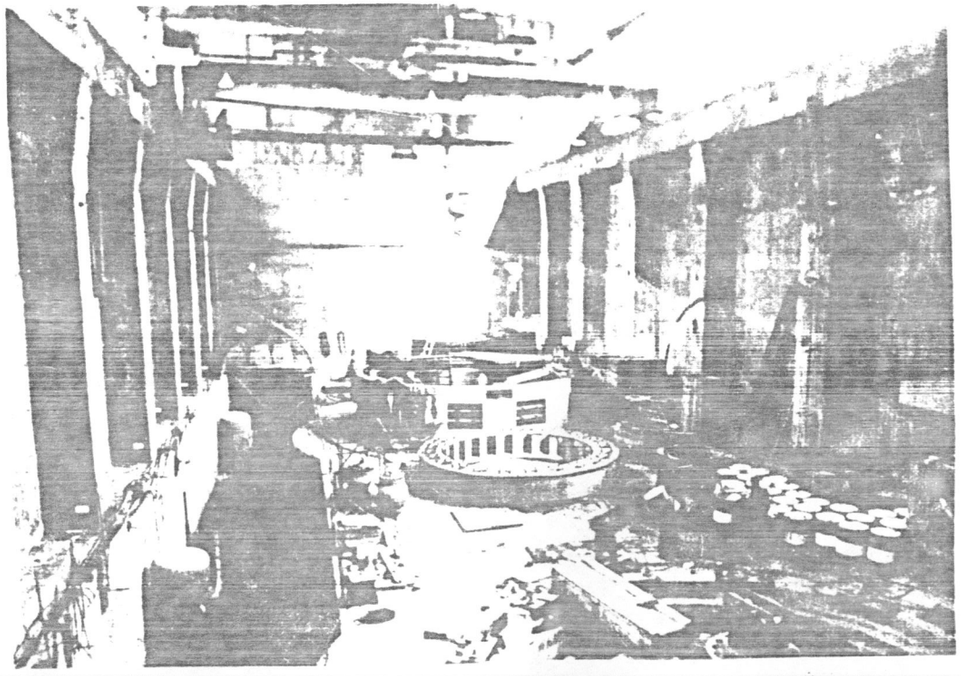


Fig. 4.053 Erection of generator in Kesikköprü Powerhouse.

Kurtboğazı Dam is situated in a gorge on **Kurtboğazı** Creek, 56 km from **Ankara** on the Ankara - **İstanbul** State Highway No. 35. The original purpose of the project, at the planning stage, was water supply of Ankara City. However, during the construction of the dam it was decided to utilize this water source for irrigation of **Mürted** Plain, downstream.

Hydrological Data

Drainage area	:	300 km²
Mean annual precipitation	:	400 mm
Estimated annual average runoff	:	26×10^6 m³ (excluding **Kışlacık** Diversion)

Reservoir Data

Dead storage volume	:	8.5×10^6 m³
Minimum water surface elevation	:	931.00 m
Net usable storage volume	:	83×10^6 m³
Gross reservoir capacity	:	91.5×10^6 m³
Normal water surface elevation	:	959.00 m
Maximum water surface elevation	:	961.75 m
Maximum reservoir surface area	:	5.48 km²

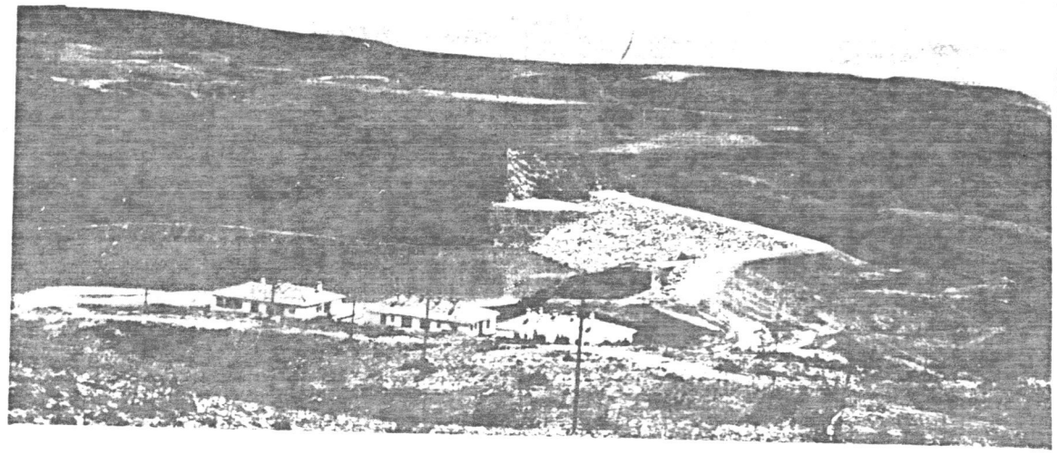


Fig. 4.097
View of the embankment from right abutment, Kurtboğazı Dam.

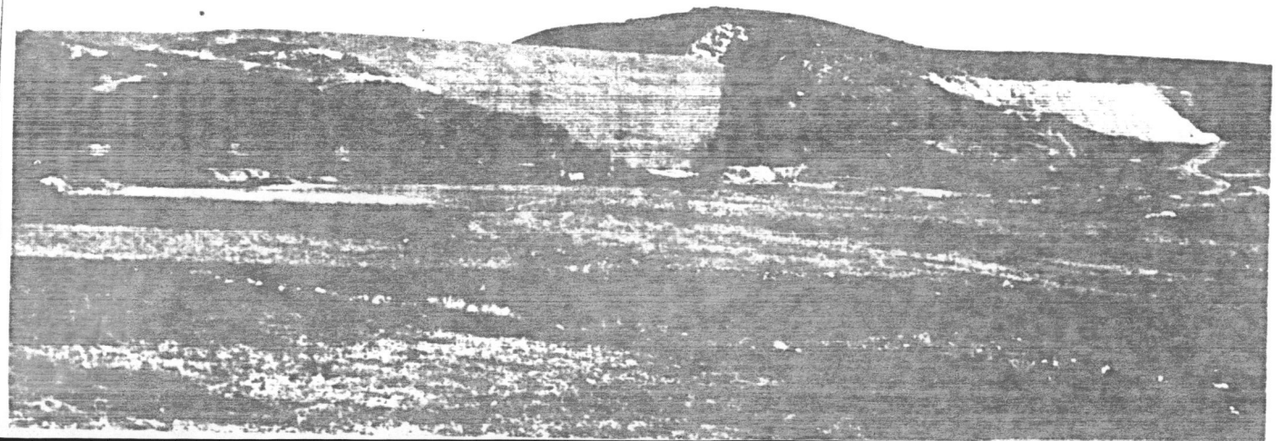


Fig. 4.098
Downstream view of the dam.

Dam Embankment Data

Type	:	52.50 m
Height above lowest foundation	:	51.50 m
Height above ground level	:	50.60 m
Crest length	:	332.00 m
Crest width	:	10.00 m
Crest elevation	:	963.00 m
Total embankment volume	:	834,000 m³

Spillway Data

Type	:	Ungated, free overfall, ogee
Crest length	:	
Crest elevation	:	959.00 m
Design flood peak flow	:	850 m³/sec
Maximum spillway discharge	:	292 m³/sec
Type and length of discharge chute	:	Concrete lined section 27.50 m, unlined section 100 m

Diversion Data

Type	:	Tunnel, c[illegible]r, conc[illegible] lined
Diameter	:	[illegible]n I.D.
Length		[illegible]9.14 m

Outlet Works

In the original outlet works design the downstream portion of the tunnel contained 1.50 m I.D. steel pipe. In the control house a 1.00 m I.D. pipe branched off for Ankara city public water supply.

However, while the dam enbankment construction was still underway and near completion, the outlet works design was altered. The new design comprises a 1.90 m I.D. main steel pipe which branches into a 1.70 m I.D. and 0.80 m 0.80 m I.D. steel pipes for the right and the left bank irrigation canals, respectively. The downstream end of the main steel pipe is equipped with a 0.80 × 0.80 m high pressure slide gate to regulate releases for downstream requirements along the stream.

Emergency valve of the system is a 1.90 meter - diameter butterfly valve. The regulating gates of the right and the left branch pipes respectively are 1.40 × 1.40 m. and 0.70 × 0.70 m slide gates.

At minimum water surface elevation the total irrigation requirement is 10 m³/sec; 8 m³/sec for the right bank, 2 m³/sec for the left bank irrigation canals. Since the discharges are relatively small, impact type stilling basins are used.

Geology and the foundation

The dam axis is located at a narrow gorge cut through a large andesite mass of Neogene age. A very pervious alluvium deposit, consisting of sands and gravels with occasional lenses of silt, fills the old valley, with a maximum depth of about 20 meters. Andesite is highly fractured but otherwise is in sound state at the abutments and the foundation. It is moderately to highly decomposed elsewhere in the neighborhood of the dam. The spillway is located in a deep cut in the left abutment and sound rock obtained from this excavation was used for the upstream slope protection of the embankment. The tunnel which after the diversion was converted into its present function of the bottom outlet, was driven in sound andesite requiring only slight support.

Part of the right abutment and the area beyond it are covered by thick deposits of Pleistocene sandy silts and clayey silts. They are practically impervious and the shallow right hand side of the dam rests on this formation. A cut - off trench was excavated under the clay core but the grout curtain which was constructed in the andesite formation was discontinued in the Pleistocene.

The Dam Embankment

As seen in the maximum cross section of the embankment, the dam consists of a large clay core flanked on either side by shells of compacted pervious sands and gravels. The clay core is carried down to the bedrock forming a positive cut - off. A grout curtain was carried out through holes bored at 3.00 meter spacing along a continuous 1.0 × 1.0 meter concrete grout cap and extended to depths given by the empirical formula of, $h = \frac{H}{3} + C$,

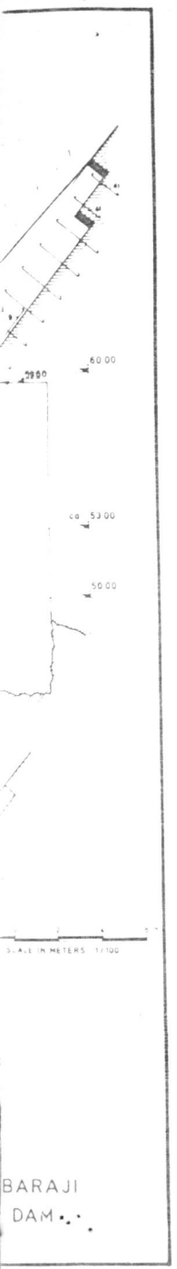
H being the static head at the top of the hole and taking C = 12.00 m.

Large takes were encountered and considerable amounts of cement were consumed during the treatment of the foundation.

Since the grading of the No. 3 material, obtained from the borrow pits in the river bed within short distances upstream and downstream of the axis, as well as that of the core material which consisted of gravelly, sandy - clay, were suitable, no filters were required at the transition of the core and the shells.

The construction of the project started in 1963 and the embankment, the spillway and the tunnel were completed in 1966. The contractor was **Atman Ltd.** A completion contract for the work left unfinished by the previous contractor, including erection of permenant equipment, irrigation conduit branches, stilling basins and the control structures, etc, has been awarded and will be executed during the year 1967.

The project was designed and supervised by **DSİ**, and the total cost up to date is 49,7 × 10⁶ TL.



Porsuk I Dam is located on **Porsuk** Stream, a tributary of **Sakarya** River, 25 km southwest of **Eskişehir.** The dam was constructed in 1948 for flood control and irrigation.

Geology and foundation treatment

Geological formation near the dam axis consists of ultrabasic rocks, mostly peridodite which contains serpentinized veins and decomposition zones near the surface. Depth of the alluvium in the river bed is 13 meters.

Two grout curtains, one at the axis of the dam, and the other 0.60 to 0.90 m downstream of the dam axis, were constructed. Maximum depth of the grout holes was 20 meters. Grouting was executed under 2 to 15 atmosphere pressure after the completion of the foundation excavation and before the placement of concrete. A drainage blanket was constructed in the foundation area downstream of the grout curtain with holes 5 - 7 meters deep and placed at 2 meters between centers. These holes were connected with 0.12 m diameter pipes to the upper drainage gallery.

Dam body

The concrete gravity dam is made up of 12 blocks, central blocks being 16.50 meters wide including the "shrinkage blocks,, between two adjacent blocks. The first block in the left abutment contains the chute of the side channel spillway.

A space of 0.80 m was left between adjacent blocks to minimize shrinkage effects. These spaces were concreted at the end of the construction and at low ambient temperatures, forming the "shrinkage,, blocks. No special water stops were utilized at the vertical joints against leakage. Vertical joints were grouted several years after the construction and most of the leakage was stopped by this means.

A drainage system of two horizontal galleries and a series of shafts connected to these galleries were constructed.

Aggregate for concrete was obtained from a borrow area located 28 km downstream from the dam. It contained light pebbles and gravels of volcanic origin and exhibited alkali reactivity. For this reason certain amount of deterioration on the exposed surfaces of the dam could be detected after only 18 years of operation.

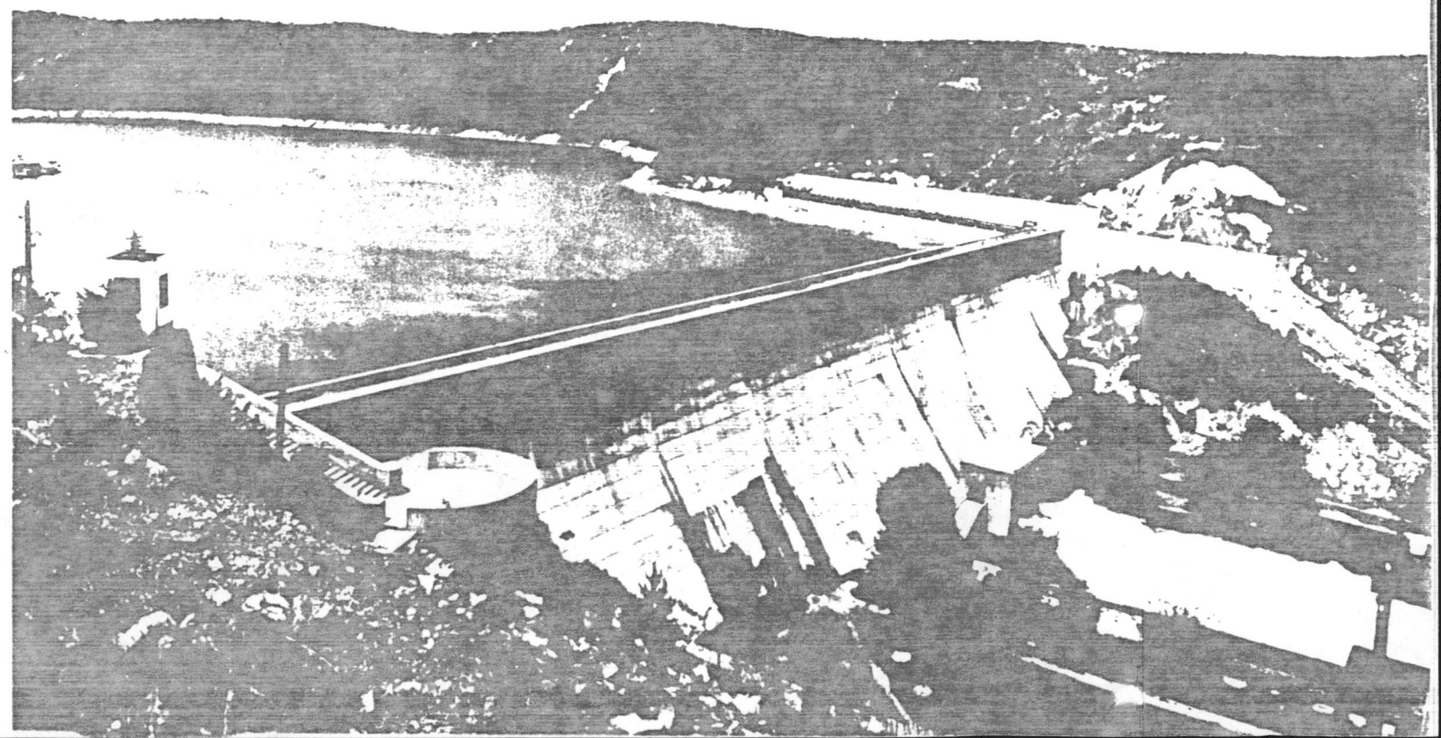


Fig. 2.04
View of the dam from the right abutment.

Hydrological Data

Drainage area	:	4500 km²
Mean annual precipitation	:	400 mm
Average flow	:	8.3 m³/sec.
Recorded minimum flow	:	1.78 m³/sec.
Recorded maximum flow	:	66 m³/sec.
Estimated annual average run - off	:	261.5×10^6 m³

Reservoir Data

Dead storage volume	:	2.5×10^6 m³
Minimum water surface elevation	:	845.50 m
Net usable storage volume	:	138.5×10^6 m³
Normal water surface elevation	:	867.00 m
Gross reservoir capacity	:	141.0×10^6 m³
Maximum reservoir volume	:	153.0×10^6 m³
Maximum water surface elevaarea	:	868.00 m
Maximum reservoir surface tion	:	12 km²

Spillway

A gated side channel spillway is located in the left abutment. Its chute is lined only halfway with concrete, the rest having an unlined base with masonry training walls. The length of the spillway crest is 73.50 meters and is made up of 15 spans.

With 1.00 meter surcharge the spillway has a discharge capacity of 150 m³/sec.

Spillway Data

Type	:	Gated, 15 span, side channel
Crest length	:	(15×4.90) 73.50
Crest elevation	:	867.00 m
Maximum discharge capacity	:	150 m³/sec
Type and length of discharge chute	:	Rectangular section, halfway lined with concrete, 19.00 m long.

Outlet Works

The outlet works are situated in the central block of the dam and consist of a trashrack structure of cage type, two 1.60 m I. D. steel lined irrigation conduits ending at emergency butterfly valves followed by regulating tube valves. No means of closure were provided at the entrance to the conduits. The valves are housed in the valve chamber located downstream of the dam. The tube valves discharge into a stilling basin formed at the toe of the dam.

Dam Data

Type	:	Concrete gravity
Height above lowest foundation	:	43.50 m
Height above ground level	:	30.50 m
Crest length	:	179.00 m
Crest width	:	4.85 m
Crest elevation	:	868.50 m
Maximum base width	:	29.00 m
Upstream slope	:	Vertical
Downstream slope	:	0.72 and 0.75
Volume of concrete	:	77,000 m³

Outled Works Data

Type	:	Steel lined conduit
Number	:	2
Diameter and length	:	1.60 m I.D. 15.00 m
Emergency valve type and diameter	:	Butterfiy valve, 1.60 m I.D.
Regulating valve type and diameter	:	Tube valve, 1.22 m outlet dia.
Combined discharge capacity	:	36 m³/sec

The construction started in 1943 and ended in 1948. The civil engineering contractor was **Hazakal Ltd.** Preliminary design was made by **Dr. Von Woldkirch,** and the final design by **H. Geiger,** in colloboration with **DSİ** engineers.

The cost of the project was 10,500,000 TL. The dam is owned by DSİ.

Increased downstream irrigation requirements cannot be met by Porsuk I Dam at the present. Construction is underway to heighten the dam by 18.20 meters. Detailed information regarding **Porsuk II** Dam is given in Chapter V of this book.

PORSUK II DAM

Porsuk II Dam is located on **Porsuk** Stream, a tributary of **Sakarya** River, 25 km southwest of **Eskişehir.** Porsuk II Dam is a heightening of **Porsuk I** Dam, which was constructed in 1948 for flood control and irrigation.

Increasing demands of irrigation and public water needs and future forecasts necessitated heightening of Porsuk I Dam by 18.20 meters. After completion Porsuk II Dam will be 64.70 meters high from the lowest foundation and 258 meters long at the crest, and will provide water for irrigation of 19,200 hectares of land and for public and industrial needs of Eskişehir, at the same time protecting that city from flood hazards.

The spillway is designed for a 100 - year frequency flood having a peak inflow of 875 m^3/sec and a 92 - hour inflow volume of 94×10^6 m^3 Hydraulic requirements are such that 100 - year frequency floods must be stored in the reservoir and only a maximum discharge of 36 m^3/sec must be released downstream, since the levees of Porsuk Stream within Eskişehir cannot accommodate a larger flow. It was assumed that the reservoir would be at the normal water surface elevation of 882.60 at the beginning of a 100 - year frequency flood. As an unfavorable condition, another 100 - year frequency flood was assumed to follow at the end of the first one. Under these circumstances the gates will be opened at the beginning of the second flood, to release an outflow equal to the inflow without any routing. The water level would be kept constant at the maximum water surface elevation of 885.20.

A critical condition will be the occurrence of the probable maximum flood which has a peak of 2080 m^3/sec and a 92 - hour inflow volume of 242×10^6 m^3, when the reservoir level is at EL. 882.60. As the maximum water surface elevation is reached with the incoming flood, the gates will be opened all the way up. Due to routing in the reservoir the maximum spillway discharge reaches a value of 713 m^3/sec under a head of 8.67 m, reservoir in the mean time reaching the elevation of 886.62 m.

1.00 meter high parapet wall will prevent any overtopping.

Diversion is planned in four stages making use of both outlet works systems. During the construction, diversion route is shifted from one system to the other as required.

Hydrological Data

Drainage area	:	5018 km^2 (including **Kargın** Creek which will be diverted into the reservoir)
Mean annual precipitation	:	400 m
Average flow	:	8.30 m^3/sec
Recorded minimum flow	:	1.78 m^3/sec
Recorded maximum flow	:	66 m^3/sec
Estimated annual average runoff	:	266×10^6 m^3

Reservoir Data

Dead storage volume	:	19×10^6 m^3
Minimum water surface elevation	:	852.40 m
Net usable storage volume	:	393×10^6 m^3
Gross reservoir capacity	:	412×10^6 m^3
Normal water surface elevation	:	882.60 m
Maximum reservoir volume	:	525×10^6 m^3
Maximum water surface elevation	:	885.20 m
Maximum reservoir surface area	:	25.7 km^2

Dam Data

Type	:	Concrete gravity
Height above lowest foundation	:	64.70 m
Height above ground level	:	49.70 m
Crest length	:	258.00 m
Crest width	:	4.50 m
Crest elevation	:	886.70 m
Upstream slope	:	Vertical
Downstream slope	:	1 on 0.85
Volume of concrete in the heightening section	:	148,000 m^3
Combined concrete volume	:	220,000 m^3

Diversion Data

Type	:	Utilization of outlet works systems
Porsuk I conduit diameter	:	1.60 m I.D. steel pipe
Porsuk I outlet works capacity	:	36 m³/sec
Porsuk II conduit diameter	:	2.30 m I.D. steel pipe
Porsuk II conduit discharge capacity	:	25 m³/sec under 4 m head, 50 m³/sec under 11.5 m head
Porsuk II conduit length	:	55.00 m

Outlet Works Data

Intake structure	:	Box type trashrack with circular bell-mouth entrance
Intake gate type	:	Fixed wheel gate.
Intake sill elevation	:	847.60 m
Conduit diameter	:	2.30 m I.D. steel pipe embedded in concrete
Conduit length	:	55.00 m
Branch pipe diameter and number	:	1.60 m I.D., 2
Emergency valves	:	1.60 m I.D. butterfly valve
Regulating valves	:	1.22 m outlet diameter tube valve
Combined maximum discharge capacity	:	50.69 m³/sec

Spillway Data

Location	:	Central blocks of the dam
Type	:	Gated, 2 - span
Gate type	:	Radial 11.00×7.55 m
Total crest length	:	22.00 m
Crest elevation	:	877.95 m
Maximum probable flood peak flow	:	2080 m³/sec
Design flood inflow volume	:	94×10^6 m³
Spillway maximum discharge	:	875.0 m³/sec

Geology and foundation treatment

Geological formation near the dam axis consists of ultrabasic rocks, mostly peridotite which contains serpentinized veins and decomposition zones near the surface. Depth of the alluvium in the river bed is about 13 meters.

Two grout curtains exist under the foundation of the old dam. The maximum depth of these grout curtains is 20 m. A drainage system also exists but observations indicated that it was only partially effective, large uplift pressures being present in the foundation. For this reason additional drainage measures were incorporated in the final design of the Porsuk II dam and this matter will receive great care during the construction. Additional grouting is also planned to limit seepage of water into the dam foundation.

Diversion

Selection of diversion facilities played an important part in the design of the dam and the ancilliary works, and in the preparation of the construction schedule.

The two alternatives for Porsuk II outlet works were (1) modification of the Porsuk I outlet works and (2) construction of Porsuk II outlet works at a different location. Since in this heightening construction the only means of diversion was through the outlet works, the first alternative offered one course whereas he second provided two courses for diversion, as well as flexibility for the construction of the dam. Selection of the former alternative would have hindered the progress of the construction because of several requirements that cannot be overlooked. These are, (1) maintaining irrigation water for downstream needs, (2) making provision in the reservoir for holding probable floods during the construction, (3) completing the construction in as short time as possible.

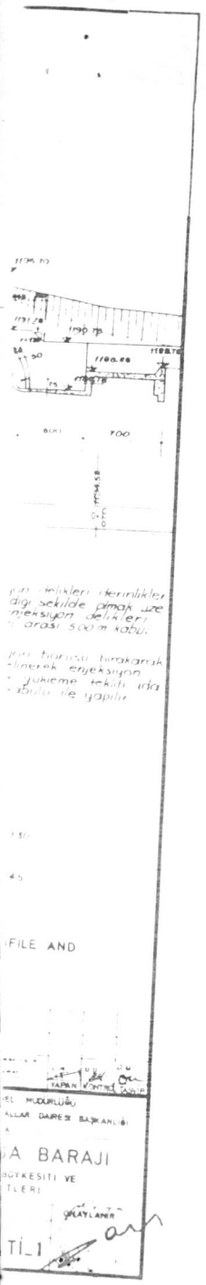
Construction

The construction of Porsuk II Dam is undertaken by the contracting firm of **Mühendisler İnşaat Ltd.** and, having started in late 1966, it is scheduled to be completed in 1970.

Estimated cost of the project including permenant equipment, but excluding expropriation costs, is 39.5×10^6 TL.

The project was planned and designed by **DSİ,** which is the owner.

The construction is being carried out under the engineering supervision of DSİ.



Sarıyar dam is located on **Sakarya** River, about 120 km to the north-east of Ankara. It is a multipurpose project, designed to provide storage for irrigation, flood control and power production of 400×10^6 KWh per year.

Geology and foundation treatment

Geological formation at the damsite consists of metamorphic rocks, mainly quartzites and schists. The rock in the steep abutments is sound and fresh with little or no soil cover. An alluvial deposit of about 10 m maximum thickness was removed from the foundation area. Excavation was carried down to a depth of 20 m from the river bed, in order to remove decomposed rock below the alluvium.

A grout blanket was constructed in the foundation through holes 9 m in depth and placed in three rows at 5 m between centers. One row of curtain grouting holes were drilled to a maximum depth of 75 m and grouting carried out at pressures up to 15 atm.

Large dykes of peridotite exist in the left abutment. Serpentinized seams and decomposed rock at the contact zones caused serious difficulties during the excavation of the diversion tunnel. Several cave-ins hindered the progress of work in the tunnel and eventually led to major design modifications. As a result, original design in which the diversion tunnel was to serve as a power tunnel after the completion of diversion, was abandoned and a separate power tunnel, located at a higher elevation, was driven through the left abutment. This tunnel is steel lined near the intake and outlet portals in order to safeguard against bursting.

Hydrology

Drainage area	:	41,778 km²
Mean annual precipitation	:	300 mm
Average flow	:	79.2 m³/sec
Recorded minimum flow	:	16.0 m³/sec
Recorded maximum flow	:	1614.0 m³/sec
Estimated annual average flow	:	1.98×10^9 m³

In 1963, however, the recorded inflow to the reservoir was in excess of 4.65×10^9 m³.

Reservoir data

Dead storage elevation	:	430.50 m
Dead storage volume	:	400×10^6 m³
Minimum water surface elevation	:	445.00 m
Maximum power pool elevation	:	475.00 m
Maximum reservoir volume	:	1.9×10^9 m³

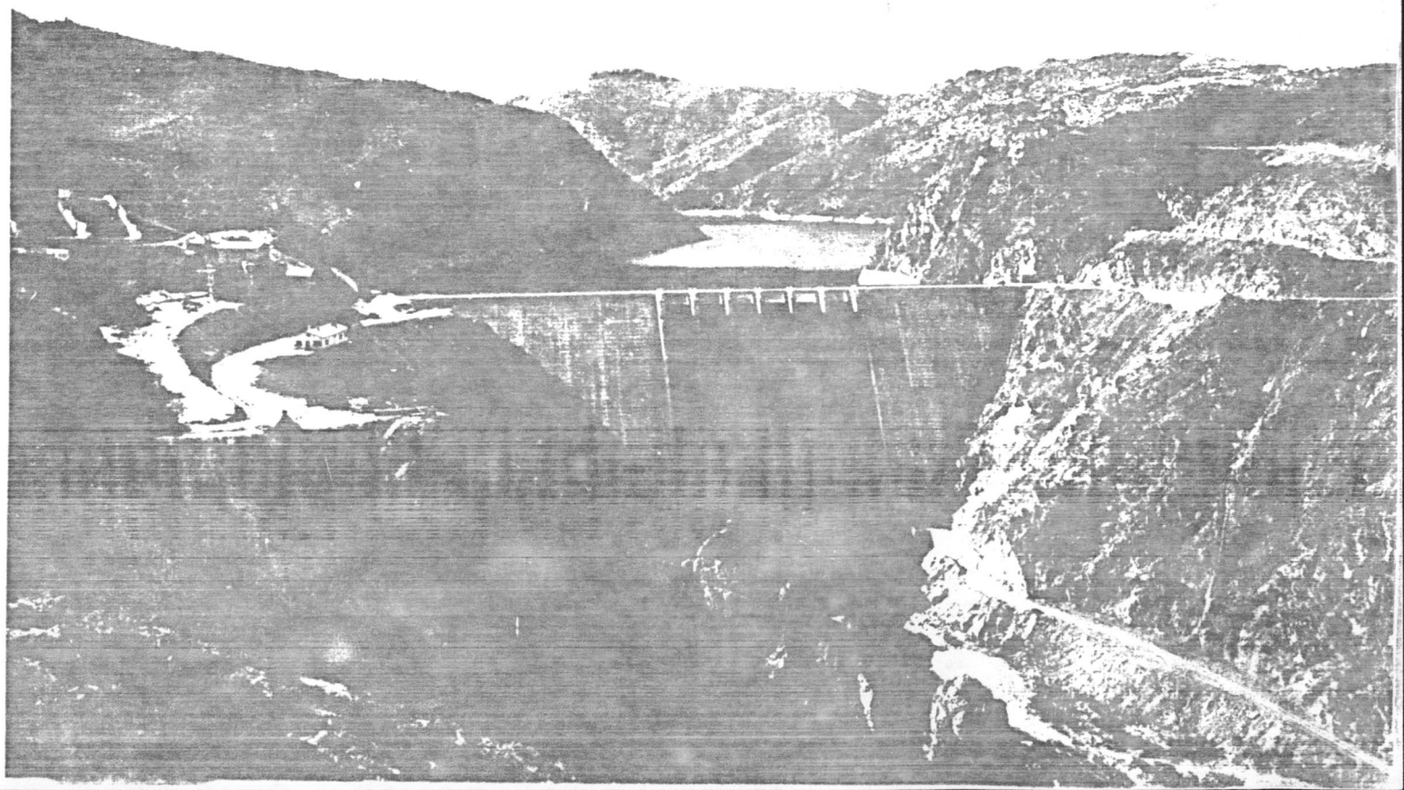
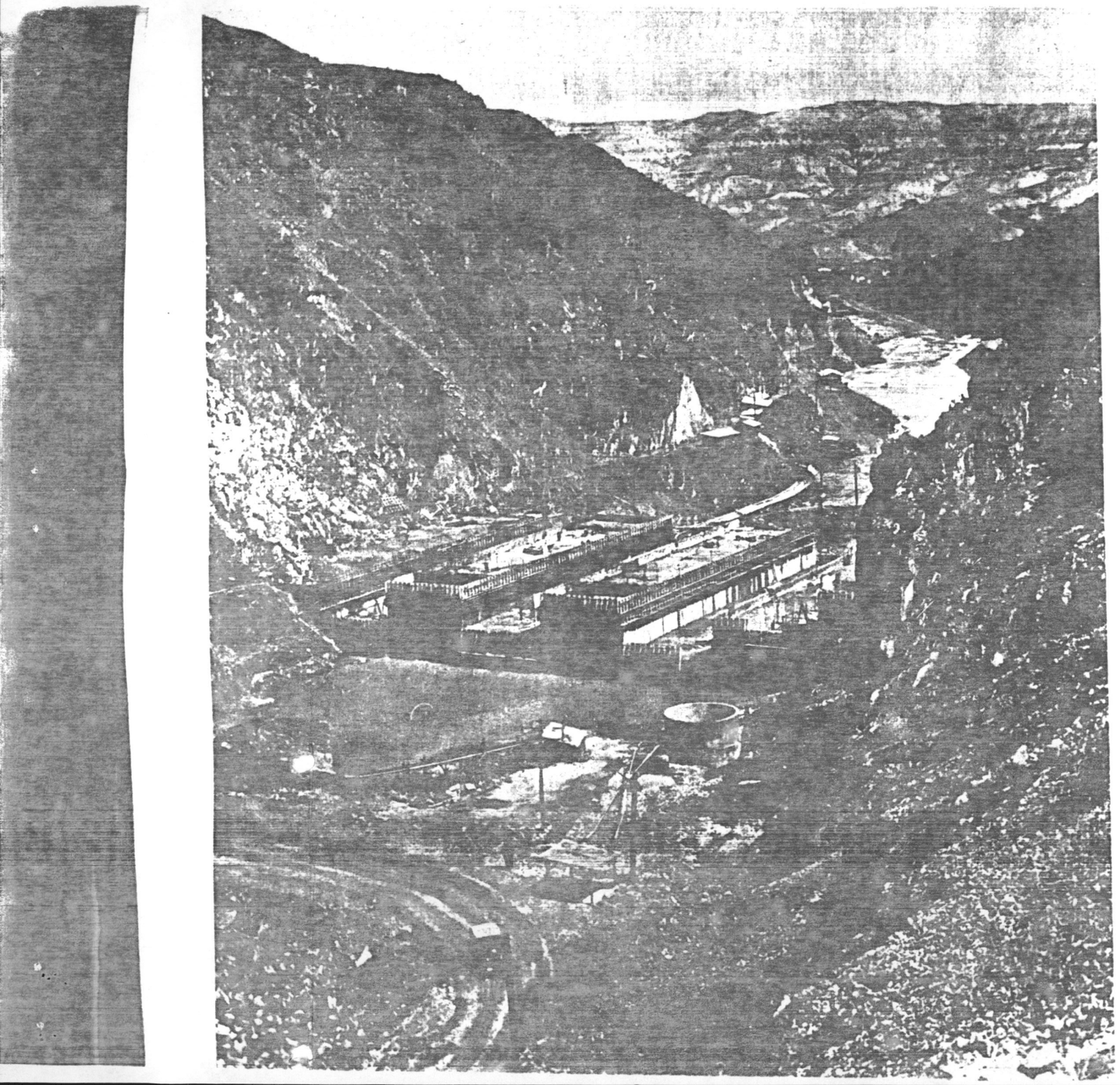


Fig. 3.09
General view of Sarıyar Dam.



Construction

Construction started in 1951 with the diversion tunnel work, which was undertaken bay **Galip Gordam,** a Turkish contracting firm. Power intake, power tunnel and concrete dam construction was undertaken by a German - Turkish joint venture called **Hochtief - Philipp Holzman - Siemens Bauunion - RAR.** The Power plant and appurtenant works construction started in 1952 with the award of the contract to the firm, **Türk - Amaç.**

Construction of the dam was completed in 1956, after a total 568,000 m^3 of concrete was placed during 26 working months.

Concrete aggregates were manufactured by crushing limestone obtained from quarries 2.5 Km upstream from the axis. Concrete was precooled by addition of chipped ice. Air entrained concrete with a cement content of 149 to 180 Kg per m^3 was used and consolidated with heavy internal vibrators. Low heat cement was used and no pipe cooling was required.

Vertical joints of the dam were provided with copper water stops and drainage pipes. Drainage of the dam is accomplished by means of a series of horizontal galleries and vertical shafts located near the upstream face.

The project was designed and supervised by the engineering firm, **Chas. T. Main Inc.,** Boston, Mass. U.S.A. and is owned by **Etibank.**

Spillway gates were manufactured by **M.K.E.** of Turkey, penstocks and the surge tank by **Voest,** generators by **A E G** of Germany, turbines by **Neyrpic** of France.

The power house contained two units of 44,444 KVA each originally and provisions for installment of two additional units of the same capacity were provided.

The cost of the project, including the two unit powerplant was 270 × 106 TL.

Construction and erection works in connection with the addition of two 44,444 KVA units to the existing powerhouse started in 1965 and were completed in 1967. The cost of this additional work including the cost of the permenant equipment, was 61 × 10 TL.

The new turbines were supplied by **Newport News Co.** and the generators and transformers by **Westinghouse Co.** of U.S.A.

Fig. 3.10
Construction of the foundation blocks.

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Type	:	Taintor gated
Number of gates	:	6
Dimension of gates	:	10 H × 11 W
Crest elevation	:	465.00 m
Maximum discharge capacity	:	7500 m³/sec

Power tunnel

Type	:	Reinforced concrete lined, circular.
Diameter	:	8.00 m I.D.
Length	:	945.00 m
Length of steel lined tunnel	:	133.00 m

Diversion tunnel

Type	:	Reinforced concrete lined, horseshoe.
Diameter	:	8.60 m
Length	:	1,090.00 m

Surge tank

Type	:	Restricted inlet type
Height	:	46.50 m
Diameter	:	28.00 m

Turbines

Type	:	Vertical shaft Francis
Number of units	:	4
Speed	:	187.5 rpm
Rated capacity	:	65,000 HP
Rated head	:	76.50 m
Maximum head	:	93.00 m

Generators

Type	:	Vertical shaft umbrella type
Number of units	:	4
Speed	:	187.5 rpm
Rated capacity	:	44,444 KVA
Output voltage	:	13,800 V
Power factor	:	0.90
Frequency	:	50 c/s

Transformers

Type	:	Oil immersed
Voltage	:	13.8 to 161 KV
Number	:	4

Concrete Dam

Height from foundation	:	108.00 m
Height from the river bed	:	90.00 m
Crest length	:	257.00 m
Crest width	:	7.00 m
Base width	:	95.00 m
Volume of concrete in dam	:	568,000 m³

View of the power plant and the surge tank

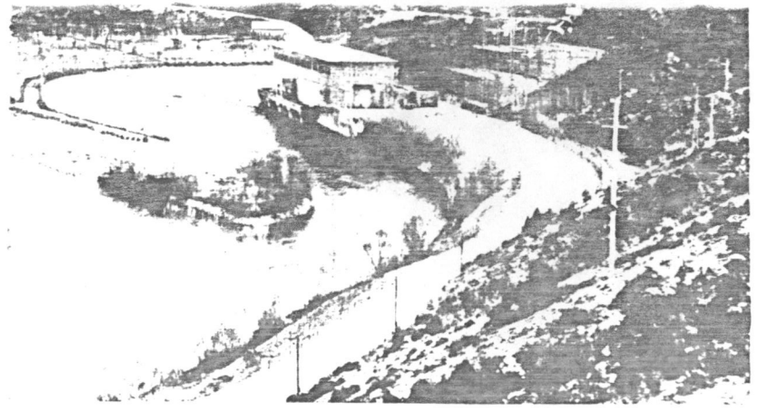


Fig. 3.12
Inside view of the powerplant after erection of the new units.

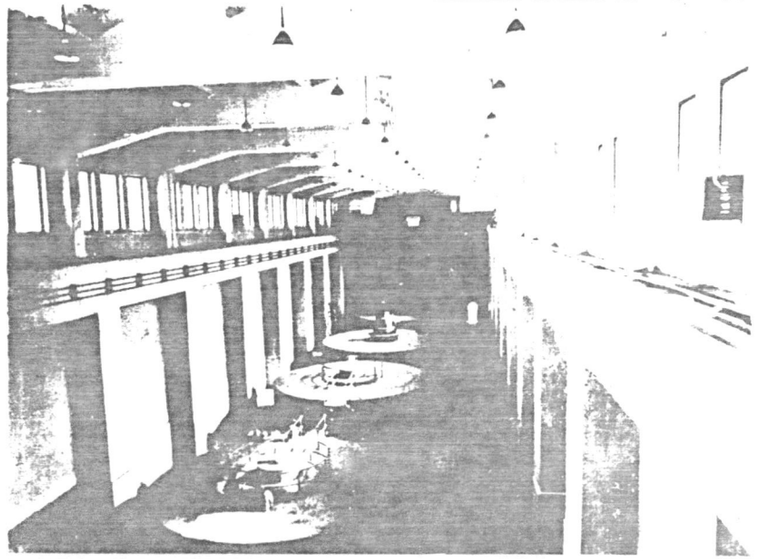
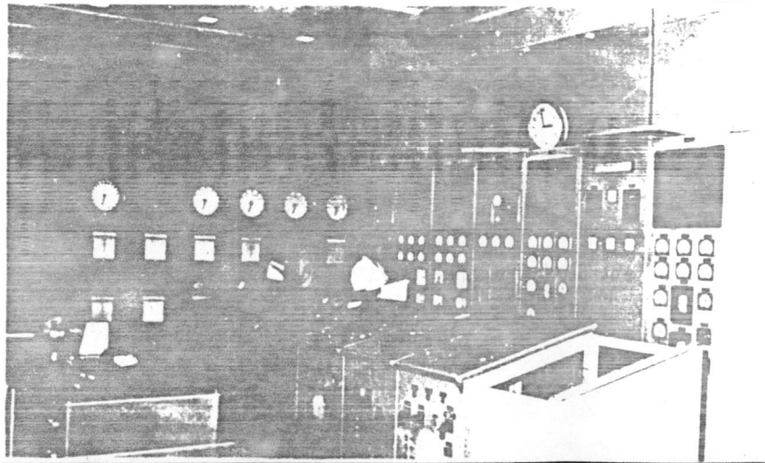


Fig. 3.13
Control room of the powerplant



SARMISAKLI DAM

Sarmısaklı Dam is an earthfill structure located on **Sarmısaklı** Creek, a tributary of **Kızılırmak** River, 30 km to the east of the city of **Kayseri.** Its purpose is to provide water for irrigation of 6000 gross hectares of land in the **Kayseri** Plain.

Dam Embankment

Foundation stripping uncovered large areas of undesirable soils consisting of fat clays, fine loose sands and silts. Considerable amount of excavation was required to remove such soils, and to place the embankment on a reliable foundation.

Hydrological Data

Drainage area	:	420 km²
Mean annual precipitation	:	400 mm
Recorded minimum flow	:	1.0 m³/sec
Estimated annual average run - off	:	49×10^6 m³

Reservoir Data

Dead storage volume	:	2×10^6 m³
Dead storage level	:	1180.10 m
Minimum water surface elevation	:	1183.23 m
Net usable storage volume	:	29.9×10^6 m³
Gross reservoir capacity	:	31.9×10^6 m³
Normal water surface elevation	:	1205.00 m
Maximum water surface elevation	:	1206.50 m
Maximum reservoir volume	:	35.5×10^6 m³
Maximum reservoir surface area	:	2.65 km²

Diversion Data

Type	:	Tunnel, circular, concrete lined
Diameter	:	2.50 m I.D.
Length	:	183.50 m
Upstream cofferdam crest elevation	:	1177.00 m

A positive cutoff trench was excavated down to the bed rock and a central row of grout curtain holes with two rows of cap grouting holes were drilled in the base of the trench. Earthquake effects were considered and fairly flat slopes were adopted in the design of the embankment which utilizes locally available materials to the maximum extent. Since all limestone outcrops are covered by the embankment and no other suitable rock is present within economical distances, a nearby deposit of well cemented volcanic tuffs in the left abutment was used to obtain rock for the protection of the slopes. This rock has surface hardening properties and weathers well in spite of the ease with which it can be quarried.

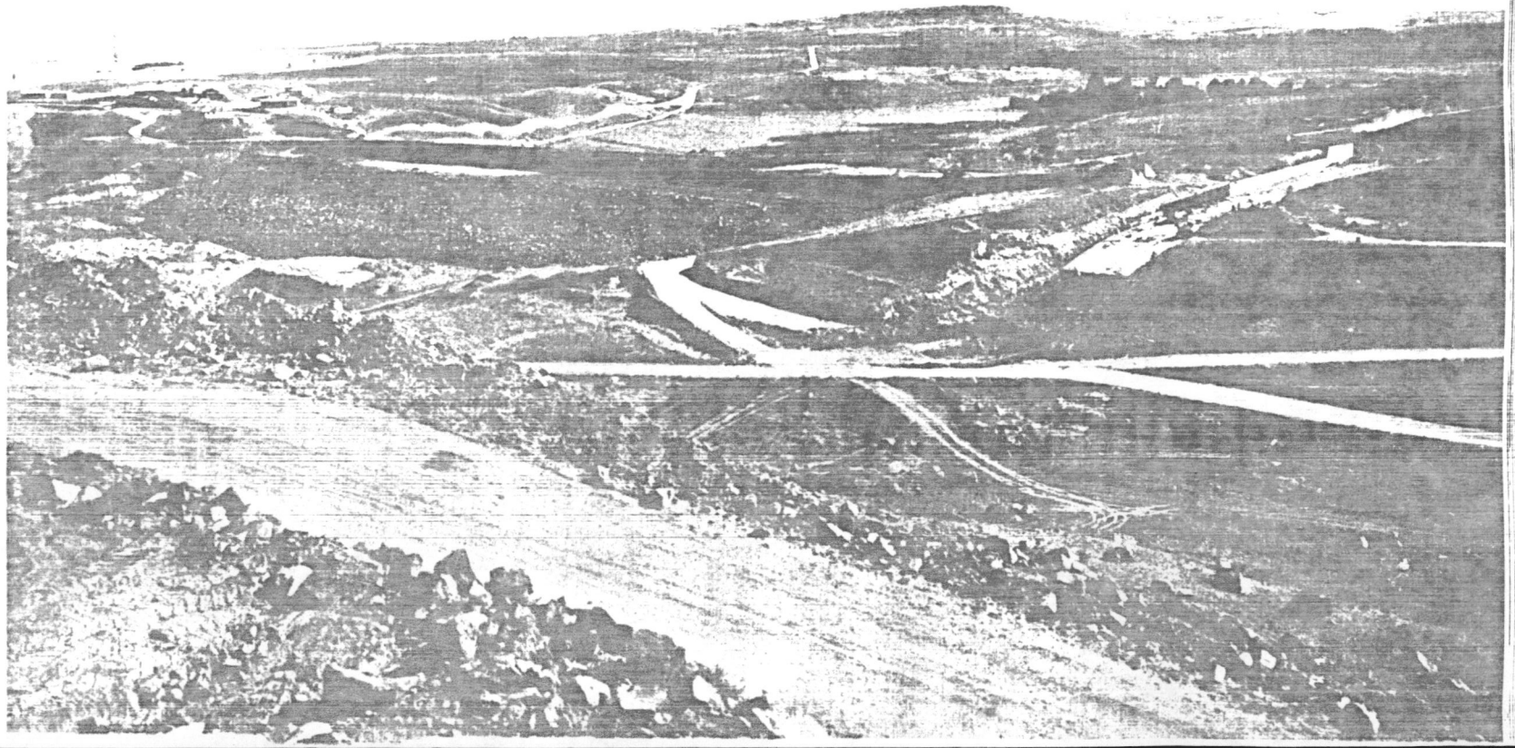


Fig. 5.001
Construction of the embankment and the spillway, Sarmısaklı Dam.

The estimated cost of the project is 17×10^6 TL.

The dam was planned, designed and is being supervised by **DSI.**

Geology and Foundation

Stratigraphy of the area containing the dam and appurtenant structures is as follows :

8. Talus deposts.
7. Alluvium
6. Volcanic tuffs of andesite composition
5. Andesite
4. Conglomerate - Sandstone - Limestone series
2. Limestone
3. Serpentinized land formation
1. Andesite

In addition to these, local deposits of calcareous tuffs can also be ovserved.

The dam spans a wide geological profile which starts with a 30 meter deep horizontal layer of conglomerates and claystones in the extreme right abutment, passes into a dense crystalline limestone mass, followed by thick serpentinized land formations in the thalweg region, then into poorly to moderately cemented fine sandstones and thin beds of sandstone limestone series in the left abutment.

The tunnel, in the right abutment, has its upstream portal in claystone, cuts through the dimestone massive and ends in reddish claystones and talus deposits. Heavy supporting was required in the sections of the tunnel outside the limestone.

Dam Embankment Data

Type	:	Earthfill
Height above lowest foundation	:	42.00 m
Height from foundation cut - off	:	5.00 m
Height above ground level	:	40.00 m
Crest length	:	578.00 m
Crest width	:	10.00 m
Crest elevation	:	1208.00 m
Total embankment volume	:	1.5×10^6 m³
Crest elevation	:	1205.00 m
Design flood peak flow	:	400 m³/sec
Design flood inflow volume	:	8.5×10^6 m³
Maximum spillway discharge	:	140 m³/sec
Type and length of discharge chute	:	Rectangular cross section, concrete lined. 130.00 m

Outlet Works

Intake structure	:	Drop inlet, circular bellmouth entrance with trashracks
Upstream pressure tunnel length	:	54.00 m
Downstream conduit diameter	:	0.90 m I.D. steel pipe
Downstream conduit length	:	132.00 m
Emergency gate	:	0.80×0.80 m slide gate
Regulating gate	:	0.80×0.80 m slide gate
Discharge capacity at		
EL. 1183.23 m	:	4.80 m³/sec
EL. 1205.00 m	:	7.92 m³/sec
EL. 1206.50 m	:	8.12 m³/sec

Fig. 5.002
Operation in the quarry for riprap material, Sarmısakh Dam.

TATLARIN DAM

Tatların Dam is constructed across **Derinöz** Creek 1.5 km south of the village of **Tatların** in the province of **Nevşehir.** The purpose of the project is irrigation of 238 hectares of land immediately downstream of the dam.

Tatların Dam has a small reservoir, gross capacity of which is 1.75×10^6 m³ at normal water surface elevation of 991.00. The net usable storage volume is 1.25×10^6 m³, and the dead storage volume is 0.5×10^6 m³. At the dam axis the drainage area is 2.56 km², and the estimated average annual run-off of Derinöz Creek is 8×10^6 m³.

The dam embankment consists of a thick central clay core flanked by upstream and downstream zones of permeable shells with transitions and filter-zones in between. The material for the clay core was obtained from borrow pits

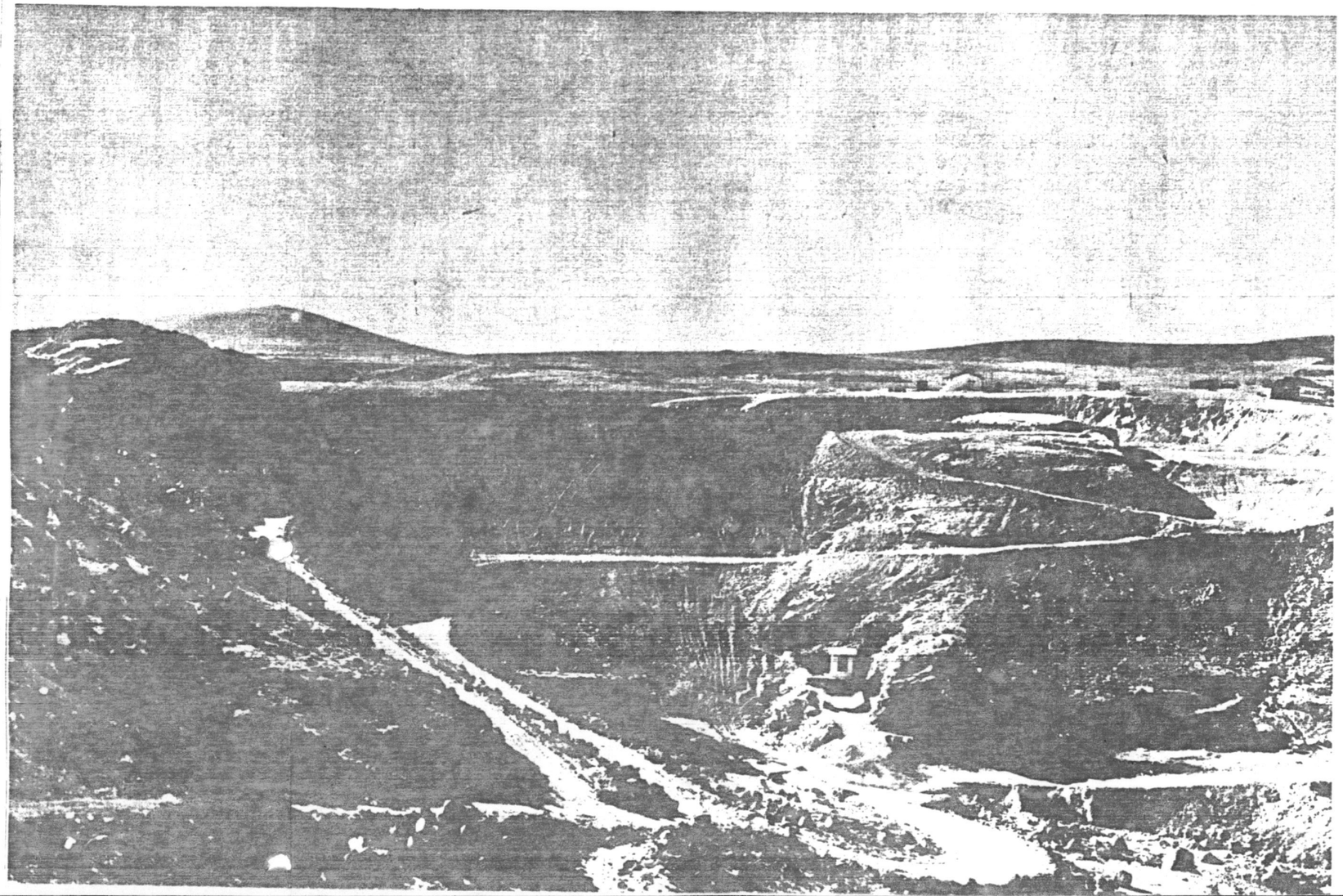


Fig. 4.103
Tatların Dam.
View from downstream.

2 km away from the dam site. The upstream and the downstream shells are made up of material obtained from the required excavations of the tunnel and the spillway and consist of fractured and partly decomposed syenite. These fills were constructed by spreading the material in 90 cm thick layers and compacting. Upstream and downstream toes of the embankment contain larger sized sound syenite.

The geology of the site is suitable for this type of construction. The right and the left abutments and the central portion rest on fairly sound syenite. About upper 10 meters of the reservoir wall in the right abutment comes in contact with a thick layer of bazaltic flow overlying the syenite. This layer of basalt is fractured and cavernous and the lower contact includes a 3.00 m thick layer of burnt clayey material. Problems of leakage and associated piping were anticipated in this region and the clay core of the dam, therefore, was extended 30.00 meters into the right abutment, providing a deeper cut-off in the basalt. Such penetration into the right abutment made possible connecting the clay core to tighter sections of the geological formation, in addition to increasing the length of seepage.

The spillway is located in the left abutment and is excavated in partially decomposed syenite. It is a free overflow ogee type concrete structure with a crest length of 50 meters. After a short lined portion the discharge chute ends abruptly at a sound syenite ledge. Discharged water will drop in cascades beyond this point, safely away from the toe of the dam.

Diversion was not a serious problem due to the fact that the stream is dry during most of the construction period. However, the outlet tunnel driven through the syenite of the left abutment has also served for diversion purposes. The tunnel, 2.00 meters in diameter, is concrete lined. The outlet works intake is of the circular bell mouth drop inlet type with trashracks. From the upstream pressure tunnel water is conveyed into a 0.45 m internal diameter steel pipe, through the concrete plug in the tunnel, located upstream of the dam axis. Immediately downstream of the tunnel plug there is a 0.45 m diameter butterfly valve for emergency closures and in the control house there is a Howell-Bunger valve 0.40 m in diameter, to regulate the releases.

The project was designed and supervised by **DSİ**, and the construction was carried out by the firm of **Daniş Türkmen.** The construction of the dam and appurtenant structures was completed in 1966. The total cost of the project was 5,042,000 TL.

Statistical data

Drainage area	:	256 km²
Estimated annual average run-off	:	8×10^6 m³
Estimated maximum probable flood peak flow	:	485 m³/sec
Embankment type	:	Earth and rockfill
Height above lowest foundation	:	42.50 m
Crest length	:	168.00 m
Crest width	:	9.00 m
Crest elevation	:	995.00 m
Total embankment volume	:	180,000 m³
Dead storage level	:	979.00 m
Minimum water surface elevation	:	979.00 m
Normal water surface elevation	:	991.00 m
Maximum water surface elevation	:	993.82 m
Dead storage volume	:	0.25×10^6 m³
Net usable storage volume	:	1.25×10^6 m³
Gross reservoir capacity	:	1.75×10^6 m³
Spillway type	:	Free overflow, ogee crest
Spillway crest length and elevation	:	50.00 m, 991.00 m
Spillway design flood peak flow	:	485 m³/sec
Spillway maximum discharge	:	485 m³/sec
Outlet tunnel diameter	:	2.00 m I.D.
Pressure tunnel length	:	27.00 m
Steel pipe diameter and length	:	0.45 m I.D., 116.35 m
Emergency valve type and diameter	:	Butterfly valve, 0.45 m
Regulating valve type and diameter	:	Howell - Bunger valve, 0.40

There are two intake structures. The one at the lower level, EL. 966.15, being a temporary intake to provide maximum benefit of the dead storage till such time when siltation renders this intake inoperative. The upper and permenant intake, sill elevation at 979.00, is of circular bellmouth drop inlet type, 1.50 m in diameter.