REPORT ON PRIORITY STUDY
OF HYDROELECTRIC PROJECTS
IN THE REPUBLIC OF TURKEY

KIZILIRMAK RIVER —— İNÖZÜ PROJECT
DICLE RIVER —— ILISU PROJECT
SEYHAN RIVER —— KAVŞAK PROJECT
DALAMAN RIVER —— DALAMAN PROJECT

MAY 1971

by

Japanese Experts on Hydroelectric Development

OVERSEAS TECHNICAL COOPERATION AGENCY

C O N T E N T S

LETTER OF TRANSMITTAL

November, 1970

Mr. Semih Üzel, General Director
Elektrik İsleri Etüt İdaresi
Ankara, Turkey

Dear Sir:

Representing the team of Experts dispatched by the Japanese Government, the undersigned take pleasure in submitting herewith the report on priority studies of four hydroelectric projects in Turkey.

At the request of the Government of the Republic of Turkey, the Government of Japan entrusted to the Overseas Technical Cooperation Agency (OTCA) with the task to send three experts from the Ministry of International Trade and Industry and the Electric Power Development Company.

After short term investigations and studies, the Experts recommend the KIZILIRMAK - İNÖZÜ Project as the first priority of development among the four projects studied. This project is very promising that we consider the feasibility study should be started in the nearest future. Further investigation program necessary for the feasibility study is recommended in this report.

Though the other three projects have several problems technically and economically at present, some of them may be solved after further investigations or studies on other alternatives. These are described in this report.

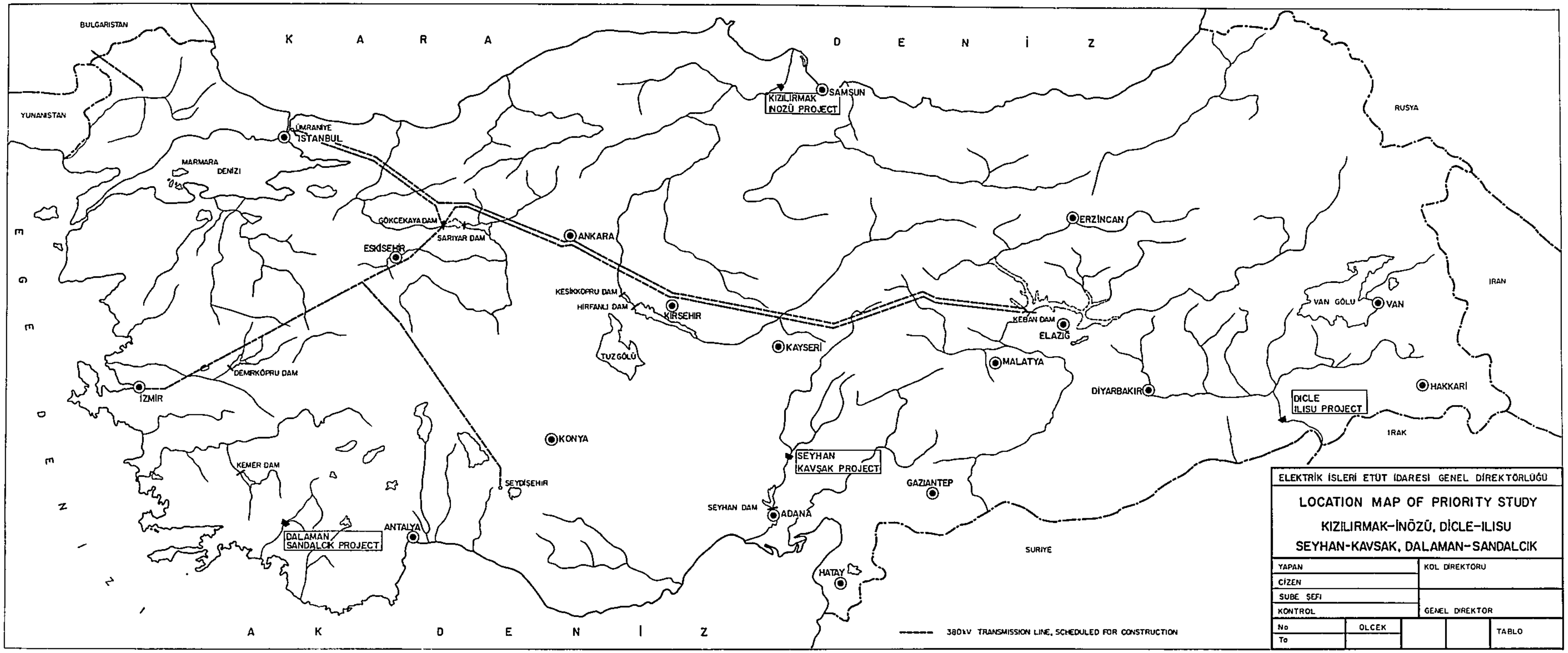
It is my sincere hope that this report, which is the outcome of the cooperation of the people of Republic of Turkey and Japan, will prove to be useful in some way or other for the future development of Turkey as well as for the promotion of friendship and economic cooperation between two countries.

On behalf of the Experts, I would like to take this opportunity to express our sincere appreciation and gratitude to Mr. Semih Üzel, the General Director of the Electrik İsleri Etüt İdaresi (EİE) and engineers of EİE for their generous assistance and cooperation, as well as to the Embassy of Japan and Anakara office of Electric Power Development Company for their warm hospitality extended to the Experts during their stay in Turkey.

Respectfully yours,

Yasushi Takaishi

on behalf of
The Experts of Japan


ELEKTRİK İŞLERİ ETÜT İDARESİ GENEL DİREKTÖRLÜĞÜ
LOCATION MAP OF PRIORITY STUDY
KIZILIRMAK-İNÖZÜ, DİCLE-ILISU
SEYHAN-KAVSAK, DALAMAN-SANDALCIK
YAPAN
ÇİZEN
ŞUBE ŞEFİ
KONTROL
KOL DİREKTÖRÜ
GENEL DİREKTÖR
No
To
ÖLÇEK
TABLO
380kV TRANSMISSION LINE, SCHEDULED FOR CONSTRUCTION
K A R A D E N İ Z
A K D E N İ Z
E G E D E N İ Z İ
BULGARİSTAN
YUNANİSTAN
RUSYA
İRAN
IRAK
SURİYE
MARMARA DENİZİ
ÜMRANİYE
İSTANBUL
KIZILIRMAK İNÖZÜ PROJECT
SAMSUN
GÖKÇEKAYA DAM
SARIYAR DAM
ESKİŞEHİR
ANKARA
KESİKKÖPRÜ DAM
HİRFANLI DAM
KIRŞEHİR
TUZ GÖLÜ
KAYSERİ
ERZİNCAN
KEBAN DAM
ELAZIĞ
MALATYA
DİYARBAKIR
VAN GÖLÜ
VAN
HAKKARİ
DİCLE ILISU PROJECT
DEMİRKÖPRÜ DAM
İZMİR
KONYA
SEYDİŞEHİR
KEMER DAM
DALAMAN SANDALCIK PROJECT
ANTALYA
SEYHAN KAVSAK PROJECT
SEYHAN DAM
ADANA
GAZİANTEP
HATAY

I. PREFACE

I.1 Purpose and Scope of Study

In order to meet the rapidly growing demand of power in Turkey, which is predicted to be as much as 12% annually for the time to come, Elektrik İsleri Etüt İdaresi and Stone and Webster Overseas Consultants Inc. (SWOCI) jointly made a priority study in 1967. It recommended the construction of several hydroelectric projects and thermal (including nuclear) projects in the period up to 1982.

About the projects to be completed after that period, E.İ.E. is now continuing studies and investigations. In March 1970 E.İ.E. requested the Japanese Government to send three experts to study the priority order of development of three projects which E.İ.E. selected, and later one more project was added. Those are Kızılırmak-İnözü, Dicle-Ilısu, Seyhan-Kavşak and Sandalcık-Dalaman.

This report, in accordance with above mentioned objective, gives the priority and further investigation required as the result of studies of natural condition, technical problems and economical analysis.

I.2 Procedure of Study

The Experts stayed in Turkey from 16th of September to 19th of November. In that period they made field reconnaissance with emphasis on inspection of topography and geology at four project sites with the assistance of E.İ.E. personnel. And at Ankara, they prepared a report based on information obtained by the reconnaissance and made available by E.İ.E. engineers.

The present state of investigations by E.İ.E. on those four projects are different respectively. Some of them are finished already to the preliminary stage, and some are under investigation now. In every case, E.İ.E. has made laborious studies on the projects to their present stage of investigation. Fortunately the Experts could inspect many drill cores and adits in the field, and geological reports and geological maps were available as well as technical reports, maps and annual records of discharge data covering a long period.

For economical analysis of the projects, the method used in SWOCI report are applied with some revision by changing the foreign currency rate and interest to 1 $ = 15 TL. and 8% respectively.

Because of the limited time for this study, the method of economical analysis of the projects, which are used in the priority study of SWOCI and E.İ.E. 1967, is applied with the above mentioned modifications.

But projects which have been studied here are all expected to be in operation after 1982, and composition of electric energy supply corresponding to demand at that time is thought to change remarkably from now.

And SWOCI's assumption of supplying peaking energy by gas-turbine of one hour operation per day, seems not suitable, because of various unsolved problems about its life and maintenance cost.

So it seems better to study the method of economical analysis, considering various conditions which are assumed to exist at the time those projects are in operation.

The names and specialities of the three experts dispatched by the Japanese Government through the Overseas Technical Cooperation Agency (Japan) are as given below.

Yasushi Takaishi	Senior Civil Engineer Electric Power Development Company
Taketoshi Fujita	Consulting Geologist Electric Power Development Company
Yoshiaki Shimada	Senior Civil Engineer Ministry of International Trading and Industry

II. CONCLUSION AND RECOMMENDATION

As a result of the below mentioned studies, it is concluded that the İNÖZÜ project should be the first in order of priority, because the results of tentative analysis show it to have higher possibility to be feasible and it has not many major technical problems to be solved by further investigation as in the case of the other three projects.

It is recommended that studies and investigations of further stage, as described in the next chapter, should be carried out. After that stage, feasibility study should be conducted as soon as possible.

III. SUMMARY AND FURTHER INVESTIGATION

III.1 KIZILIRMAK - İNÖZÜ Project

a) Summary

İnözü project is located not far from the Black Sea Coast Highway and also from a main transmission line which is expected to be constructed in the near future.

The Kızılırmak, the third largest river in Turkey, has an average discharge of about 170 m^3/sec. at the proposed dam site and this discharge is somewhat regulated by the enormous reservoir of Hirfanli.

The project has no leakage problem due to karstic limestone from which many projects in Turkey suffer.

The width of the river is not very narrow but any type of dam may be acceptable topographically.

The foundation rocks composed of hard pyroclastics are somewhat jointed but the depth of weathering is very shallow and big fault may not be encountered in it. Deep river deposit reaching 60 m. is somewhat a problem, though it can be overcome without technical difficulty. No big problems are anticipated for the construction of the dam and appurtenant structures, even an underground powerplant.

Concerning the construction materials, the rockfill material can be quarried around the dam site, and the filter material and concrete aggregate can be acquired from the deep river deposits. Impervious material of 1.000.000 m^3, which is almost the required volume, is expected to be available at a point around 4 km. upstream of the dam site. Besides, abundant material was confirmed in the area about 11 km. downstream of the dam site.

In order to make the economical analysis, a tentative plan was made and construction costs were estimated. The results are summarized below.

High water elevation	174.0 m.
Effective storage capacity	2.4×10^9 m^3
Dam	Rockfill
Maximum height from foundation rock	175.0 m.
Crest length	544.0 m.
Volume of embankment	10.5×10^6 m^3
Powerplant	Underground
Installed capacity (125,000 kW x 4)	500,000 kW
Rated head	97.0 m.
Powerhouse discharge	604.0 m^3/sec.
Average annual energy output	$1,353 \times 10^6$ kWh
Project cost	$1,766 \times 10^6$ TL.

Results of economical analysis of the project are shown below.

Annual Benefit	177×10^6 TL.
Annual Cost	160×10^6 TL.
Surplus Benefit	17×10^6 TL.
Benefit-Cost ratio	1.10

As this project is a peaking power station near Bafra plain, it is necessary to reregulate the peak discharge. Although, no detail study was performed about this problem at this time, according to the report prepared by DSI, Derbent site, located 22 km. downstream of İnözü site, is considered to be suitable to have enough capacity by constructing a low dam. This reregulating dam and powerplant may have only little effect on the overall economics of İnözü project.

b) Recommendation

As mentioned above, Kızılırmak-İnözü project has few problems technically and is estimated to be feasible economically. According to our studies, since the other three projects have problems big or small, this project is considered to have the first priority. Besides, this project is so promising that the feasibility study should be conducted in the nearest future.

Further investigations described hereinafter are necessary for conducting the feasibility study. Rock condition is very sound so that some investigations are considered to be sufficient on the abutments. On the other hand, investigations on the river deposits and impervious material will be essential.

Concerning Derbent reregulating pond, as the team did not make a field reconnaissance, we are not in a position to comment about the detail investigation program. However, ordinary investigation might be done considering the geological condition.

1) Gaging of river water level near the proposed powerplant site to investigate the tailwater and flood discharge water levels.

2) Reservoir area: Geological mapping on 1/25.000 scale map to confirm the stability of slopes. Photo-interpretation shall be helpful.

3) Dam site: Additional adits at El. 180 m. on the left abutment, at El. 180 m. and 125 m. on the right abutment.

Drilling and permeability test in the river deposit along the dam axis and vicinity. Every effort should be made to obtain data on the groutability and stability of alluvium.

Detail geological mapping using 1/1.000 scale map.

4) Quarry: Geological mapping around the dam site using 1/5.000 scale map.

5) Filter material and Concrete aggregate: Laboratory test on samples taken from test pits in the flood plain of the river side.

6) Borrow area: Test pits, core boring and laboratory test on materials in Keslik, Kolay and Kapukaya areas.

7) River water quality analysis in the course of a year, taking periodical samples.

III.2 Dicle River - Ilısu Project

(a) Summary

The Dicle, known in English as Tigres, is a large international river which originates in Turkey. It has an average run-off of 540 m^3/sec. at project site. The site is located in the southeastern part of Turkey near the Syrian border and somewhat far from the big energy consumption area.

E.İ.E. has made laborious investigations for utilizing this plentiful run-off at the downstream reach of the Dicle river in Turkey, and selected Ilısu B site in 1970 after long year of studies and investigations, because the geological condition along the river presents difficult problems.

The study area comprises Germav formation, Becirman limestone, Gercüş formation, Midyat limestone and Şelmo formation in the order from lower to upper, stratigraphically. Several parallel dome shaped anticlines exist in the general direction of E-W crossing the Dicle river. Germav, and Gercüş formations crop out in limited areas around the eroded anticline axis, and another wide area is covered with only Midyat limestone.

Midyat limestone is highly karstic and many springs from this formation are seen along the Dicle. Gercüş formation is gypsiferous formation and deeply decomposed in general. Nine dam sites among eleven proposed sites were affected directly from these unfavorable Gercüş and/or Midyat formations.

Ilısu A and B sites are located on Germav formation which is exposed like a window by erosion of the Dicle river at the dome-shape Germav anticline. Germav formation consists of mainly marly claystone and has neither leakage problem as Midyat limestone nor solution or rebound problem as gypsiferous Gercüş formation.

Germav formation, existing at high elevation along Germav anticline, is expected to act as a barrier against leakage which may take place through the Midyat and the other formations from the reservoir.

The vicinity of the Ilısu site is widely eroded and forms a small basin between a narrow gorge on the upstream and downstream of this eroded section. At Ilısu B site, the left abutment is formed by a cliff up to 120 m. high from the river bed. On the other hand, the right bank has a long gentle slope of around 10^{o}. The width of the river is estimated to be approximately 150 m. including the right bank flood plain. Consequently, the crest length is estimated to be as long as 1,530 m. at the elevation of 515 m. In this case, the dam height is about 130 m.

No top soil covers the left abutment. Terrace deposit estimated to be around 20 m. deep exists on the gentle slope of the right bank. This terrace deposit consists of round gravel and is well cemented. It is considered to have enough bearing strength for the proposed rock-fill dam, but permeability must be confirmed. The bedrock crops out on the river bed in places. The depth of river deposit is considered to be shallow.

The foundation rock, mostly marly claystone, is bedded thinly or thickly with horizontal bedding planes. The rock is not so strong and can be scratched by knife and also broken by strong hammer blow. It is considered to have enough bearing strength and shearing strength for a concrete gravity dam of the proposed height.

However, the rock characters, easily eroded by running water and scaling on the ground surface, should be taken into consideration in the design of appurtenant structures.

Neither deep weathering and nor big fault are seen on the widely stripped cliff of the left bank.

Concerning the construction materials, rock-fill material and transition material of an embankment dam with upstream asphalt impervious facing whivh is tentatively planned, can be quarried from the Midyat limestone which is distributed about 2 km. downstream of the dam site. Also concrete aggregate must be obtained from a quarry due to lack of alluvial deposit. It may be difficult to obtain the large amount of impervious material around the project area.

In order to make economical analysis, a tentative plan was made taking into account various conditions of this project. The dam in the river channel is considered to be a concrete gravity structure and the dam for the right bank is considered to be a rockfill structure with upstream asphalt impervious facing. The results are summarized below:

High water elevation	510.0 m.
Effective storage capacity	4.5×10^9 m^3
Dam	Concrete gravity and rock-fill
Maximum height from foundation rock	130 m.
Crest length	Concrete dam in river channel 650 m. Embankment dam on the right bank 880 m.
Volume	Concrete dam 2.94×10^6 m^3 Embankment dam 6.90×10^6 m^3
Powerplant	Outdoor
Installed capacity 150,000 kW x 4	600,000 kW
Rated head	95.0 m.
Powerhouse discharge	740 m^3/sec.
Average annual energy output	$3,134 \times 10^6$ kWh
Project cost	$3,140 \times 10^6$ TL.

Results of economical analysis are shown below:

Annual Benefit	286×10^6 TL.
Annual Cost	267×10^6 TL.
Surplus Benefit	19×10^6 TL.
Benefit-Cost ratio	1.07

In this tentative plan, peaking capacity is considered to be not so big, and no irrigable area exist on the downstream, but because the site is located not far from the border, it seems necessary to construct a small pond at a suitable site somewhere downstream of this site for reregulating the peak discharge of the plant. At this time no detail study was performed on this problem.

(b) Recommendation

As mentioned above, the result of our study indicates that Dicle-Ilısu project may be feasible. However, as the investigation on this site was started recently, there remain some problems to be investigated as follow. Furthermore, investigation to locate a narrow dam site, for example by drilling at the entrance to Çelikan gorge should be executed to find a more economical dam site. Besides, study and investigation of the reregulating pond is necessary.

(1) Study of topography using a detail map to select the best dam axis, protection against scaling of marly shale and extent of curtain grouting.

(2) Gaging the river water level near the proposed powerplant site to study the tailrace and flood discharge water levels.

(3) Reservoir area: Elevation of Germav formation along Germav anticline should be investigated in more detail in the vicinity of the project area.

(4) Dam site: Drilling and permeability tests on the right bank to know the depth and condition of terrace deposits. Detail geological mapping using 1/1.000 to 1/5.000 scale map. Mapping area should be extended to the uppermost reach of Çelikan gorge (Baniga dam site) in order to look for suitable quarry and dam site possibility.

(5) Borrow area: Excavation of test pits at selected areas where material is available and testing at laboratory of samples taken.

(6) Baniga dam site (entrance of Cerikan gorge):

- Drilling from river level to confirm Gercüş formation. Further investigation should be performed depending on the result of this hole.

III.3 Seyhan-Kavsak Project

(a) Summary

Kavşak project is located about 70 km. north of Adana, main city in Çukurova, which is one of the biggest energy consumption area in Turkey. It is also not so far from the route of 380 kV transmission line which is under construction connecting Keban and Istanbul.

Drainage area and average discharge of the Seyhan river at Kavşak site is about 13,000 km^2 and 125 m^3/sec. or 3.9 x 10^9 m^3 per year respectively. Seyhan dam and powerplant located about 60 km. downstream of Kavşak site are being operated for irrigation of 154,000 ha land and for generating of 284 x 10^6 kWh annually. Two projects are proposed between Kavşak site and this existing Seyhan dam.

Because of advantageous location, E.İ.E. proposed a big dam on Kavşak site as a key dam of the river development plan, and carried out laborious investigation from 1963 to 1968.

The dam site and reservoir area along the Zamanti river comprise of the Permo-Carboniferous limestone. The reservoir area of the Gökdere river comprise of mainly schist, quartzite, sandstone and marble of Silurian period with intercleted Devonian formation. Therefore karstic problem is the most important in this project. There is no detail information in regard to karstick phenomena in the reservoir area but some karstic features are seen in the dam site as mentioned below.

Many long drill holes and exploratory adits have been executed into Permo-carboniferous limestone which is distributed in most of the dam site except the upper level of the left bank. Somewhat karstic phenomena are seen in the adits and in the recovered cores. Three faults, more than 3 m. wide each are found in Adit R3A-1. Although, continuity of these faults has not been defined, it can be observed in the adit that the widths of these faults change in short distances. However, there are no significant open joints along which solution has occurred, and also faults has little gouge in general except for the above mentioned one. The results of water pressure tests generally show watertightness of rock except for a few portions. Under the river bed, especially below 25 m. the rock is entirely impermeable. No big karstic spring has been found in the vicinity of the dam site. It seems to be possible to reduce the leakage water to a negligible amount by extensive curtain grouting.

The dam site is located in the Central Taurus mountains and the valley is narrow, steep and "V" shaped. However, at the dam site, higher than El. 490 m. on the left bank is a gentle slope. Crest length and height of dam at El. 490 m. will be 468 m. and 207 m. respectively.

Limestone crops out on the steep slopes and slope wash materials deposit on the foot of slopes in places. Shale is distributed on the gentle slope of the left bank overlying with thick topsoil. River deposit is around 13 m. deep.

Limestone is dark grey and strong, and is medium to massively bedded. Generally its strike across the river and the dip is about 35^{o} - 50^{o} towards the downstream. Rock is highly faulted and shows secondary folding. But almost all of the faults have little gouge and joints are closed as mentioned before.

Shale on the left bank has marly character and soft in general. It is encountered with wide shear zone and decomposed into clayey material in many places. A structure which would a big load on this shale is considered unfavorable. From this point of view, embankment dam is likely to be more suitable at this site. Careful treatment of this shale will be necessary even for foundation of embankment dam.

No great difficulty is anticipated in the excavation of underground structure, including powerplant, power tunnel and diversion tunnel in limestone, judging from the geological condition in the adits. Of course, big faults as seen in Adit RSA-1 must be avoided by coreful investigation before the final layout is prepared. It is better to estimate the cost of concrete lining for underground structres at this stage of study.

Not only rock-fill material, but filter and concrete aggregate will have to be quarried because of scarcity of river deposit. Most of the rocks found in the vicinity of the dam site, except shale, are considered to have good character for these materials.

It is obvious that enough quantity of impervious material cannot be obtained in the vicinity of the dam site and it is assumed that the material will be obtained from a borrow area located south of Kabasakal village, 25 - 30 km. away from the dam site. However, the probable borrow area has not been investigated.

In order to make economical analysis, one of the alternative plan (EL. 490 m) was taken from E.İ.E. technical report (1970) as a tentative plan. Revision was made to some items, mainly adding 2,800 m. of grout curtain in both abutments. Construction cost was estimated with revised unit prices. The results are summarized below:

High water elevation	485 m.
Effective storage capacity	697×10^9 m^3
Dam	Rock-fill
Maximum height from foundation rock	207 m.
Crest length	468 m.
Volume of embankment	10.70×10^6 m^3
Powerplant	Underground.
Installed capacity 85,000 kW x 4	340,000 kW
Rated head	172 m.
Powerhouse discharge	232 m^3/sec.
Average annual energy output	$1,622 \times 10^6$ kWh
Project cost	$2,127 \times 10^6$ TL.

Results of economical analysis are shown below.

Annual Benefit	173.5×10^6 TL.
Annual Cost	184.3×10^6 TL.
Surplus Benefit	$- 10.8 \times 10^6$ TL.
Benefit-cost ratio	0.94

The abovementioned results of economical analysis show that this tentative plan is not economical.

Estimated cost of this tentative plan includes the cost of grout curtain extending along about abutments, namely on the right bank up to 2,100 m. and on the left bank up to 900 m. to prevent leakage of water which might occur through karstic limestone in both banks. It is difficult to know at present whether this amount of grout curtain is enough or not. But it seems that treatment against leakage may be possible, though a certain amount of expenditure would be required.

Setting aside this unsolved problem, this tentative plan may become economical by modifying the project features, such as lowering the dam height, or adding little more peaking capacity. It is believed that this can be done without much difficulty.

The value of the potential of Kavşak project is not too small to abandon without due considerations. It would be worthwhile to carry out more studies to get the best alternative along with investigations to determine the necessary extent and method of treatment of the abutments to reduce the amount of leakage to within tolerable amount.

(b) Recommendation

As mentioned above, the possibility of leakage through karstic limestone and/or possible seams or faults and the method to prevent leakage would govern the feasibility of this project.

Though laborious geological investigations had been performed, unfortunately, the data collected so far are not in detail as to enable an approach to the solution of this difficult problem. It is therefore recommended that further detail studies be conducted to reveal the geological condition of the entire project area.

(1) Adits and drill cores should be inspected again in detail. Method of description of adit sketch and drilling log should be improved.

(2) Geological plan should be prepared by detail field mapping. Results of photo-interpretation should be confirmed in the field.

Direction, width and other phenomena of faults or shear zones should be checked in detail and noted on the map.

(3) Geological sections with close spacing on various directions including the horizontal direction should be prepared based on the results of revision of existing investigation works and of geological mapping. Geological structure, especially continuity of faults or shear zones and distribution of shale at the left bank should be shown definitely.

(4) Adit excavation and/or drilling to confirm the continuity of wide fault zones which were found in Adit-RSI on the right bank and adit excavation to clarify the karstic phenomena in limestone which is underlain by shale on the left bank is recommendable at this stage. Further additional investigation works should be studied and commenced after completion of the above mentioned studies.

Along with the above mentioned geological study of karstic problem, studies to modify the tentative plan, investigations on impervious material and geological conditions of underground structures and also run-off gaging water near the proposed powerplant should be carried out.

III.4 Dalaman-Sandalcık Project

(a) Summary

The Dalaman river is located in south western Turkey, which is one of the big energy consuming areas. The river has an average run-off of 29.8 m^3/sec at Sandalcık site. According to the previous study, flood control and irrigation of 14,000 ha in Dalaman plain were included in the Dalaman river development plan, as well as developing hydroelectric potential of 327 MW (Maximum output) and 1,453.6 x 10^6 kWh (average annual energy) in 4 projects.

However, after numerous geological investigations performed at the dam site and in the reservoir area, it had been revealed that there is fear of leakage from the reservoir through the karstic limestone which is a very serious problem.

According to our studies on the information made available by E.İ.E.

geologist and by our field inspections, it seems technically difficult and economically unfeasible to prevent the leakage from the reservoir that may occur after impounding of water.

Consequently, it is concluded that the Sandalcık project should be dropped from further study. Result of study to locate an alternative site at the upstream of Sandalcık show that it is impossible to develop the upstream reach economically because of the small amount of river discharge and the difficulty to obtain enough head.

At the middle and downstream course of the river, the river discharge becomes relatively large, so it seems advisable to conduct desk studies and geological reconnaissance of this river reach.

IV. KIZILIRMAK RIVER BASIN — İNÖZÜ PROJECT

IV.1 General Condition

The Kızılırmak river has the second largest drainage area in Turkey flowing mainly through the central Anatolian plateau east of Ankara and pouring into the Black Sea at the town of Bafra about 50 km west of Samsun. Bafra plain, covering 62,500 ha, is typical delta formed by the Kızılırmak river.

There are two existing dams on the Kızılırmak river. Hirfanli dam which has quite big storage capacity is located around middle reach of the river, about 80 airline km southeast of Ankara. Kesikkopru dam is located 25 km downstream of Hirfanli dam. Installed capacity of their power plant is 96,000 kW and 76,000 kW respectively.

Many projects have been considered on the river upstream and downstream of existing dams. İnözü project is the most downstream one among them. Record of the İnözü gaging station which is located 7 km downstream of the proposed project site shows the average discharge of 169.4 m^3/sec.

IV.2 Previous Study and Development Plan

Three alternative dam sites have been investigated successively on the downstream reaches of the Kızılırmak river. They are located at about 3.5 km interval. Asar dam site which was investigated during 1960 - 1967 period is located at a limestone gorge. 23 drill holes were drilled in a total length of 2,300 m and big faults were found at the site to run oblique to the river course. İnözü-A dam site has a large flood plain on the right bank and the cross section of the river is of a considerable size. 102 holes were drilled in a total length of 5,438 m during 1967 - 1969 period. Alluvial deposit about 60 m deep and terrace deposit 25 m thick were confirmed in the river channel and on the left abutment, respectively.

İnözü-B dam site, which is the most upstream of the alternatives, has rather narrow river section. The investigation works started in July 1969 in succession to field reconnaissance. The works are still continuing.

SWOCI study(1) considered only Inözü-A site.

The VII Regional Office of DSI prepared a preliminary study report(2) on İnözü-B dam and Derbent regulating dam sites. In this report, a dam 185 m high above the foundation is proposed at İnözü-B site to hold water up to a normal high water level of 195 m to feed a powerplant with a total capacity of 900 mW of which 300 mW is by reciprocal turbines for pump storage.

The project name "İnözü" is used exclusively for İnözü-B site at present.

IV.3 Available Data

(1) Hydrographic Data

E.İ.E. has twenty gaging stations on the Kızılırmak river. İnözü gaging station located 7 km downstream of İnözü-B dam site is the most appropriate source to supply data for planning of this project.

Name of Station	Drainage Area km^2	Altitude m	Discharge during gaging period m^3/sec. Average	Min.	Max.	Gaging period
İnözü	75,120.8*	60	180.742	18.4	1,673.0	1960 - 1968

* Drainage area at İnözü-B site is 74,666 km^2.

(2) Topographic Maps and Airphotos

Topographic survey to provide basis for 1/1,000 scale map has been finished recently and cross section along the tentative dam axis is available by now. Topographic map is expected to be completed very soon. Airphotos of 1/35,000 scale are available over all project area.

(3) Geological Investigation

12 drill holes in a total length of about 1,630 m, and 3 adits in a total length of 305 m have so far been carried out. Drilling and adit-excavation are still being continued.

(4) References

1. Power resources priority Study
SWOCI 1968

2. Lower Kızılırmak Project, Altınkaya (İnözü-B) and Derbent dams
Reconnaissance Summary Report
DSI VII Region 1969

IV.4 Reservoir Geology

İnözü-B reservoir area is composed mainly of flysch formation of upper Cretaceous and metamorphic series of Paleozoic. According to the 1/500,000 scale geological map, two kinds of limestones are distributed; one belongs to Jurassic, another belongs to metamorphic series. However, their distribution are limited in the drainage area. In the reservoir area, on the whole, top-soil is not thick and weathering of rock is not severe.

No landslides of substantial scale are anticipated nor any topographical or geological factor is involved which might cause leakage of water from the reservoir. Although, a reconnaissance should be performed in the reservoir area to confirm the non-possibility of land slides.

IV.5 Topography of Dam Site

The Kızılırmak river, as a whole, flows in a direction from WSW to ENE in the project area, but it bends towards ESE immediately downstream of dam axis. Accordingly, the mountain slope on the left bank is concaved and right bank slope is convexed around the dam axis. Around the dam site, on the left bank of the river, there exist two ravines on the upstream and downstream side of the dam respectively, about 650 m apart from each other. On the right bank, also, a ravine is located 400 m upstream of the dam axis and another ravine is located 700 m downstream from the dam axis. The downstream ravine on the left bank is located near the dam axis and it dissects deeply. Therefore, necessity of curtain grouting should carefully be studied of this ridge.

There are no extensive flat land along the river, but small fans created by the ravines and narrow flood plains are found scattered along the river. The mountain slope on the bank is rather steep in general. The dam site was selected at the narrowest cross section of the valley.

At the dam site, the width of the river channel is 80 m, and there exists a flood plain of 55 m wide on the left bank. The slope of the valley around the dam axis is 33° at the left bank and 28° at the right bank. The width of the valley is 540 m at the elevation of 180 m which is considered to be the elevation of the dam crest. In this connection, the height of the dam above the river bed is 120 m. However, since the river deposit which exists at the dam site to a depth of 57 m will be excavated, embankment will be actually be 177 m high.

IV.6 Geology of Dam Site

(1) Overburden on the Abutments

The bedrock crops out widely and thin top soil scattered over small area. No significant slope wash deposit is found on the dam site. Big pine trees and bushes cover the slopes relatively thickly.

(2) River Deposit

River deposit of 57 m depth at the deepest point has been confirmed to exist by 4 drill holes which were drilled in the river channel and left bank flood plain along the dam axis.

As it is difficult to recover 100 per cent of sand and gravel by core drilling, gradation of river deposit can not exactly be known. Judging from the observation of the deposits on the river side and lifted cores, the deposits are composed of well graded gravel, sand and silt. Gravels, mostly less than 10 cm in size, are round, hard and not deteriorated.

Permeability tests applying the open end method have been performed every 1.5 m depth in drill holes. The result of the tests show coefficient of permeability mostly in the range of 10^{-2} cm/sec to 10^{-4} cm/sec.

(3) Bed Rock

According to the 1/500,000 scale geological map prepared by MTA, flysch formation belonging to upper Cretaceous is widely distributed in this area. The dam site is composed of two different lithological units, namely massive andesitic rock and well bedded sedimentary rock. Bedded tuff is distributed on all right abutment and upstream part of left abutment. On the other hand, massive andestic rock is distributed on the left abutment. The latter overlies the former stratigraphically. It is considered that the contact runs parallel with bedding plane of upper unit having a strike of N 80° E and a dip of 35 - 40° SE.

Both rock units are green in colour having pyroclastic character. Massive rock partially contains a few volcanic blocks of up to 10 cm in size and designated as tuff breccia. Overlying bedded strata are composed of alternations of shaly layers and sandstone like layers and are classified as tuffite.

Tuff breccia distributed on the left bank is massive, compact and very hard. Tuffite distributed mainly on the right bank is also very hard in unweathered condition. Although the outcrops of fine-grained tuffite are weathered and soft on the ground surface, it is also as hard as tuff breccia in unweathered condition.

No significant fault is anticipated. Although beddings are clearly seen in tuffite unit, they adhere tightly. Joints striking N 20° W - N 20° E and dipping 80° W are encountered in both rock units predominently across the river.

Rocks are somewhat cracky in general. It is noticed in adits and on the drilled cores that joints and cracks are coated by limonite even at deep portion from the ground surface. Dripping water from the joint is seen at several points in adits.

IV.7 Construction Materials

(1) Rock fill Material

Tuff breccia distributed on the left bank is massive and hard. Tuffite distrituted on the right bank is also hard but it is bedded thinly or thickly. These rocks, especially massive one, which are distributed widely in the vicinity of the dam site have good quality for rock fill material. Thickness of the topsoil and weathered zone is very thin in general.

(2) Filter Material and Concrete Aggregate

At the upstream and downstream sides of the dam site, a large quantity of sand and gravel are deposited. Flood plains scattered along the river are neither wide nor high from river level. Majority of the deposits lie below the water level. The quality of this river deposits are considered to be good for filter material and also concrete aggregate.

(3) Impervious Core Material

Three barrow areas are proposed as follows,

(a) Kesilik Area

The area is located on the left bank about 4 km upstream of the dam site. Slope wash deposits lie at the elevation from 60 m to 90 m in the area approximately 1 km long along the river and 200 m wide. The area was investigated by 6 test pits and samples were analysed at laboratory. Three pits reached bed rock at the depth of about 4 m. Another three pits about 6 m depth could not reach bed rock. As the average depth of this area to bed rock could, accordingly, be estimated as 5 m, this area could produce material in a quantity of approximately 1,000,000 m^3.

According to the laboratory test results and observation in the field, the material contains relatively large amount of oversided blocks, and the gradation is different place by place.

Although this area may not be satisfactory for the purpose in view of the quantity and quality of available material, investigation should be made further of this area to confirm its acceptability; the area is superior to other area with respect to location requiring the shortest handling distance to construction site.

(b) Kapikaya Area

This area is located on the right bank about 5.5 km downstream of the site. Slope wash material and decomposed schist are distributed in an area 1.5 km by 0.5 km forming gentle slope. This area had been investigated with several test pits. This area could produce material in sufficient quantity since all pits did not reach bed rock and the area is very wide. Results of laboratory test show that the soil consists of rather fine-grained material and few coarse material. Kapikaya, relatively big village, is located in this area. A long bridge will be necessary to connect the area and the road on the left bank.

(c) Kolay Area

This area is located on the left bank about 11 km downstream of the dam site and at the elevation from 50 m to 150 m. Slope wash material covers the terrace deposits in the area 1.5 km by 0.6 km. The area was investigated by 24 test pits and samples were analyzed in laboratory. According to the test result and observation made at the field, soil consists mostly of particles finer than No. 200 sieve mesh.

IV.8 Technical Study

As described above, this project site has no big geological problem which requires special treatment, except for deep alluvium on river bed. Considering the abutment conditions, it seems possible to construct concrete arch dam only if conventional treatment is applied. As regards the deep alluvium in the river bed, excavation could be possible without much trouble in view of its depth of 57 m which was confirmed by drilling. It will not be impossible to prevent leakage of water by grouting.

Geological conditions of reservoir area, water ways and power house site are considered to involve no substantial problem.

Due to topographical condition of the site, the ratio of dam height to crest length will be 1/3.1 at El 180 m. However, the valley opens widely as far as some kilometers upstream, the reservoir could be provided with a fairly big capacity.

As to discharge of river, though it is rather small comparing with drainage area, the amount of natural discharge is sufficient enough for generating of bulk electricity. In addition, fairly amount of the discharge can possibly be controlled by upstream Hirfanli reservoir.

Therefore it seems to be very promising to construct power station having big reservoir at this site.

For preliminary study one tentative plan was formed-up based on the conditions described below.

(a) Effective capacity of reservoir should be decided by mass curve and reservoir capacity curve, considering that reasonable amount of discharge of river should be controlled and that dam height should be as low as possible.

(b) Type of dam should be rockfill type by the reason that excavated material of spillway is available for rockfilling and impervious material can be obtained neighbouring area.

(c) Alluvium in the river bed should be excavated under impervious core section.

(d) Spillway and diversion tunnel should be on the right bank due to the topographical condition.

(e) Power house should be located on the right bank and be of underground type. Downstream portion of diversion tunnel should be utilized as tailrace, considering lay out of spillway and diversion tunnel.

(f) Flood discharge is assumed as 8,900 m^3/sec referring to SWOCI report.

(g) Capacity of diversion tunnel should be 1,700 m^3/sec considering recorded max. flow at İnözü gaging station.

Features of the plan are as summarized in the following pages, and the result of economic analysis for the plan is as below which shows that the plan is feasible from economic point of view,

Annual Benefit	177×10^6 TL.
Annual Cost	160×10^6 TL.
Surplus Benefit	17×10^6 TL.
Benefit/Cost	1.10

For the present study, economic analysis was tried only for one alternative. But it seems possible to improve the feasibility, if further studies be exerted with respect to the type of dam, treatment of alluvium in the river bed, type and location of powerhouse, dam height, effective capacity of reservoir, installed capacity of powerplant and etc.

Therefore further studies and investigations should be continued for the feasibility study on this project.

Since the location of İnözü project is not far from Bafra plain, it is necessary to provide a reregulating pond for peaking power station. No investigation has been performed of this subject, but according to the report prepared by DSI in 1969, it may be possible to provide a sufficiently large effective capacity amounting $70,000 \times 10^3$ m^3 by constructing 32 m high rockfill dam for a 40,000 kW power station at Derbent site about 25 m downstream of İnözü site.

By the DSI report, there will be no substantial problem in constructing a low dam at the site. Construction cost of Derbent project which is estimated in the report will increase by 20% for this measure, but the increase will have only minor effect on the economic condition of İnözü project.

SUMMARY OF İNÖZÜ TENTATIVE PLAN

1.	Hydrology	
	Catchment area	74,666 km^2 at İnözü site
		75,121 km^2 at İnözü gaging station
	Annual run-off at İnözü gaging Station (During past 6 years)	maximum 7,027x10^6 m^3 (222.79 m^3/sec)
		average 5,332x10^6 m^3 (169.44 m^3/sec)
		minimum 2,626x10^6 m^3 (83.77 m^3/sec)
	Design flood discharge	8,900 m^3/sec
2.	Reservoir	
	Surface area	65 km^2
	Total storage capacity	4,000 x 10^6 m^3
	Effective storage capacity	2,400 x 10^6 m^3
	High water level	174 m
	Low water level	140 m
	Available drawdown	34 m
3.	Installed capacity	
	Maximum output	500,000 kW (125,000 KW x 4)
	Maximum discharge	604 m^3/sec (151 m^3/sec x 4)
	Firm discharge	154.4 m^3/sec
	Effective head	97 m
	Annual energy production	1,353 x 10^6 kWh
4.	Dam	
	Type	Rock fill with Central core
	Height	175 m (above foundation rock)
		125 m (above bottom of river)
	Crest length	544 m
	Volume of embamkment	10,500 x 10^3 m^3
	Crest elevation	180 m
	Upstream slope	1:2.5
	Downstream slope	1:2.0
	Crest width	10 m

5. Spillway

Type	Gated chute spillway
Capacity	8,900 m^3/sec

6. Diversion

Design capacity	1,700 m^3/sec
Number and type	2 Concrete lined tunnel
Length	1.2 km

7. Penstock

Type	Concrete lined penstock
Number	2 line, each bifurcating
Length	400 m x 2

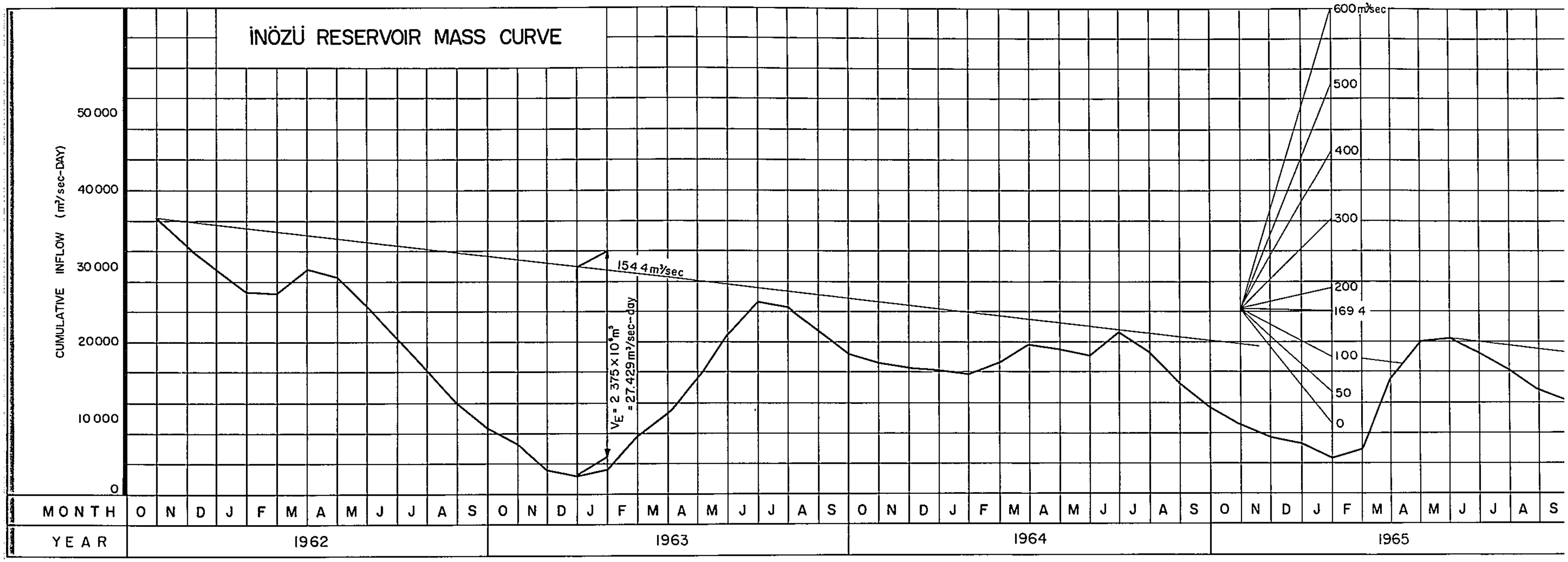
8. Power plant

Type	Underground
Installed capacity	125,000 kW x 4
Type of turbine	Francis
Discharge	151 m^3/sec x 4

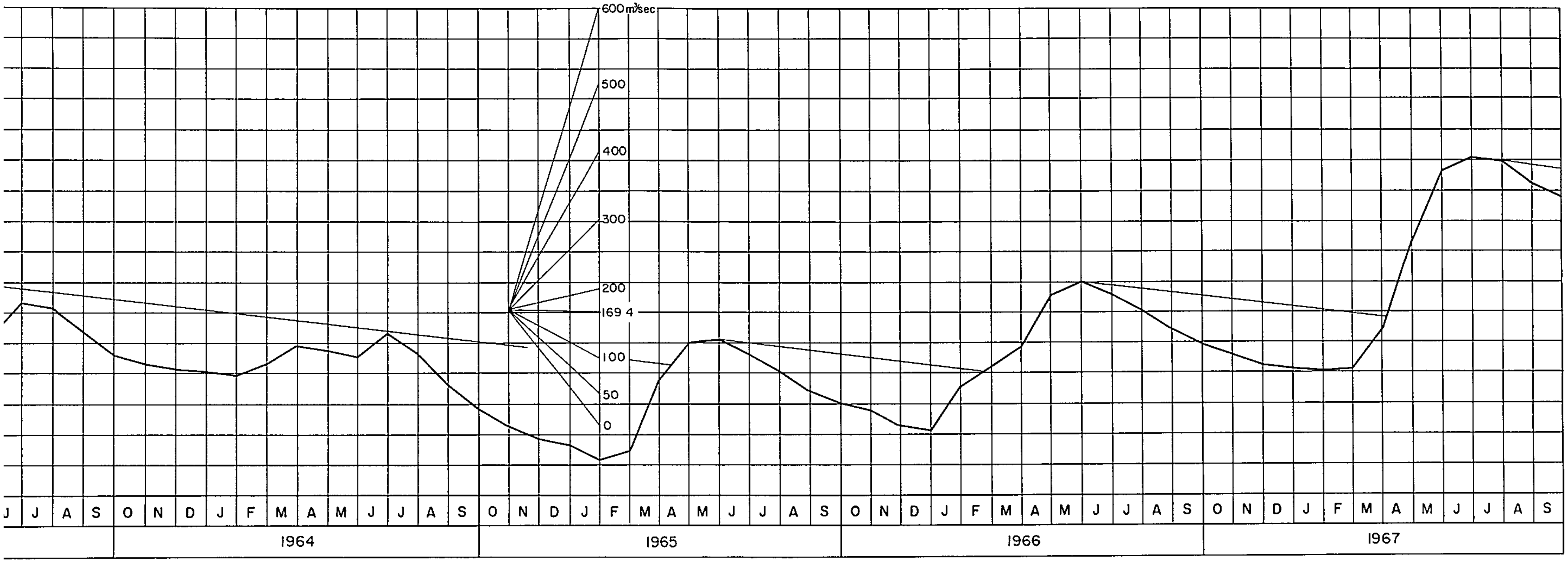
9. Project cost	1,766 x 10^6 TL.
	3,530 TL/kW
	1.31 TL/kWh

COST ESTIMATE OF İNÖZÜ TENTATIVE PLAN

NO.	DESCRIPTION	TOTAL 10^3 TL.	LOCAL 10^3 TL.	FOREIGN 10^3 TL.	REMARKS
1	Main dam	204,750	79,853	124,897	
2	Spillway	72,622	28,323	44,299	
3	Gate	12,276	4,788	7,488	
4	Coffer Dam	17,769	6,930	10,839	
5	Diversion tunnel	45,390	17,702	27,688	
6	Intake	27,085	10,844	16,241	
7	Penstock	39,565	15,430	24,135	
8	Powerhouse	65,752	25,643	40,109	
9	Power station equipment	294,082	64,698	229,384	
10	Surge tank	1,500	585	915	
11	Tailrace	20,864	8,137	12,727	
12	Others	13,000	507	12,493	
	Sub total	814,655	263,440	551,215	
13	Temporary facilities	30,142	11,748	18,394	
14	Access road	10,000	3,900	6,100	
15	Road relocation	20,000	7,800	12,200	
	Sub total	874,797	286,888	587,909	
16	Engineering and administration	131,220	91,854	39,366	
	Sub total	1,006,017	378,742	627,275	
17	Contingency	201,203	75,748	125,455	
	Sub total	1,207,220	454,490	752,730	
18	Land	217,000	217,000	0	
	Sub total	1,424,220	671,490	752,730	
19	Interest during construction	341,813	161,158	180,655	6 years, interest rate of 8% p.a.
	Grand Total	1,766,033	832,648	933,385	



İNÖZÜ RESERVOIR MASS CURVE
CUMULATIVE INFLOW (m³/sec-DAY)
50 000
40000
30 000
20000
10 000
0
154.4 m³/sec
V_E = 2 375 × 10⁶ m³
= 27.429 m³/sec-day
600 m³/sec
500
400
300
200
169 4
100
50
0
MONTH
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S
YEAR
1962
1963
1964
1965


600 m³/sec
500
400
300
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169 4
100
50
0
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S
1964
1965
1966
1967

V. DICLE RIVER BASIN — ILISU PROJECT

V.1 General Condition

The Dicle, known in English as Tigres, has a catchment area of 38,295 km^2 at Cizre nearby the Syrian border and flows into Persian gulf through Syria and Iraq. The average discharge of the Dicle river is 540 m^3/sec. at Rezük gaging station which is located 20 km.upstream from the Ilısu dam site.

South eastern part of Turkey is less developed one of this country. There is no big industry in this region. But recently the oil fields have been developed and already 40% of the petroleum consumption in Turkey are produced and 14% of the consumption are refined at Batman refinery which is located 80 km. far from Ilısu project site.

The diversion dams for irrigation are planned and some of them are under construction on the upper tributaries of the Dicle river. However, the big hydroelectric potential of this river has not been developed yet. The proposed Ilısu dam has not benefit for irrigation because no considerable irrigable land exists in downstream area.

V.2 Previous Study and Development Plan

The Dicle river has been studied by E.İ.E. since 1954 with respect to hydrology, reservoir geology and the conceivable dam sites. After reconnaissance studies on the river basin, these detailed studies have been concentrated on the downstream reach of the Dicle river, because geologically better dam sites can be found and much bigger hydroelectric potential can be developed on the downstream stretch. Further detailed studies of development plan on the overall river basin are considered to be started after conclusion of the studies is reached on downstream dam sites. Eleven alternative dam sites which are rather closely located have so far been proposed on this downstream stretch. They are, from upstream to downstream, Rezük I, Rezük III, Rezük II, Pireder, Dermah, Ilısu B, Ilısu A and four more sites on the Celikan gorge. Rezük I, II and Dermah dam sites were investigated by means of core boring in 1955 and 1956. Rezük III and Pireder dam sites were proposed in 1968[(1)] by Dr. Kemal Erguvanli after his comprehensive geological studies on the Dicle river basin between Hasankeyf and Dermah.

After a study[2] by E.İ.E. geologists was over for 35 km-long area on the Dicle river between Dermah and Bafi, Ilısu A dam site was selected in 1970 together with another four dam sites on Çelikan gorge which is located downstream of the Ilısu basin. It was also revealed by this study that there is no dam site suitable on the downstream stretch from Bafi.

E.İ.E. geologists are making reservoir studies over upstream area of Hasankeyf now. Those two areas are neighbouring to the area Dr. K. Erguvanli studied.

According to the above-mentioned studies, these proposed dam sites, except Ilısu site, have geologically adverse character due to gypsiferous formation and karstic limestone. These unfavorable strata are not exceptionally encountered in the Ilısu area which is a very small piece of land.

Ilısu A site, downstream axis was investigated by means of exploratory adits and core borings in 1969. The result showed that the foundation is in an unfavoured condition including fracturing, thermal alternation and hot spring which are due to faulting. Therefore dam axis was relocated to Ilısu B site about 1.4 km upstream of Ilısu A site.

At present, core borings are under progress at this Ilısu B site. The project name "Ilısu" will be used for exclusively for Ilısu B site hereinafter.

At Ilisu site, necessary active storage capacity of 5×10^9 m^3 is estimated to be 30% of the annual run-off. Then, high water elevation is estimated to be 510 m or 520 m. Embankment volume was estimated for various height at Ilısu A site. Energy generation will approximately 4×10^9 kWh. Economic studies as well as study for optimum scale of development plan have not been started yet. The compensations for land and houses, the relocation of road and railway, which will be submerged under the reservoir have been roughly studied. The result of studies which have been done up to the present, are summarized in the "Interim Preliminary Report" in 1970[3].

V.3 Available Data

(1) Hydrographic Data

E.İ.E. has twelve gaging stations on the Dicle and its tributaries. The following is the data of major stations made available by the E.İ.E. engineers.

Name of Station	Drainage Area km^2	Altitude m.	Discharge during Gaging Period m^3/sec. Average	Min.	Max.	Gaging Period
Diyarbakir	6,298	564	71	3.10	2,640	1945 --
Sinan	4,988	518	169	9.54	1,476	1945 --
Beşiri	2,450	545	58	1.60	1,210	1945 --
Billoris	7,975	458	136	28.00	1,777	1945 --
Rezük	34,493	427	540	51.00	7,900	1955 --
Cizre	38,295	367				1945 --

The record obtained at the Rezük station which is located about 20 km upstream of Ilısu B site can be used for planning of Ilısu project.

(2) Topographic Maps and Airphotos

1/5,000-scale topographic map made by pantographic methods from 1/25,000-scale map has been used for Ilısu site tentatively. A photogramatric map of the same scale is expected to be available by the end of this year.

1/35,000-scale airphotos covering the dam site and reservoir area are available.

(3) Geological Investigation

Rezük I : 2 drill holes, 200.66 m. in total length

Rezük II : 19 drill holes, 1,412.88 m. in total length

Dermah : 52 drill holes, 3,426.38 m. in total length
1 adit, 153 m long

Ilısu A : 14 drill holes, 1.120 m. in total length
2 adits, 92.8 m. in total length

Ilısu B : 3 drilling machines under working, 2 in the river bed (incline hole), 1 in the right bank ravine.

(4) References

1. Report on Dicle River, Dam-site Possibilities and Engineering Geology of the Reservoirs between Dermah and Hasankeyf.
Dr. Kemal Erguvanli Professor of ITÜ, 1968
Appendix to (1)

2. Report on Dicle River, Geology of Dam-sites and Their Reservoirs between Dermah and Bafi.

A. Kırmacıoğlu, A. Ertünc, H. Taslica (E.İ.E. geologists), 1970.

3. Interim Preminary Report
On Dicle River Power Development and Ilısu Dam-site
Kemal Arkun (E.İ.E. adviser), 1970

V.4 General Geology

Following five formations, from upper to lower stratigraphically, are distributed in the project area.

Selmo formation; Miocene, 250-800 m thick.

Consisting of conglomerate, sandstone, limestone, siltstone, claystone with occasionally gypsum including. Distributing mainly upstream area of Rezük I and Dermah sites.

Midyat formation; Eocene, 500-750 m thick.

Consisting of sandstone-like marly limestone and dark marly limestone in lower levels and white to grey thick layered limestone in upper levels. Upper levels present karstic character. Distributing generally over the whole area in the Dicle river basin.

Gercüs formation; Paleocene-lower Eocene, 380-460 m thick.

Consisting of sandstone, conglomerate, clay-marl and gypsum layers. Croping out at the eroded cores of anticlines.

Becirman formation; Paleocene, 50-70 m thick.

Consisting of limestone, very hard and heavily jointed. Distributing as a transition zone from Germav formation to Gercüs formation.

Germav formation; upper Creteceous, 350-850 m thick.

Consisting of claystone, marl, marly limestone and sandstone. Exposing at the eroded cores of Germav and Kentalan anticlines.

Several parallel anticlines exist across the Dicle river in the general direction of E-W. Midyat formation crops out mostly along the Dicle river and another lower formations crop out in the limited area around eroded cores of anticlines. Many alternative dam sites suffer from unfavorable formations such as karstic Midyat and gypsiferous Gercüs. Only Ilısu site located on the Germav anticline is covered with the Germav formation which is the most favorable and lower most formation among the all distributed formations. Ilısu A site which is proposed formerly is located nearby the fault which is assumed to exist among the southern flank of Germav anticline. The results of core drillings and adits executed on this site show the foundation rock is much fractured due to abovementioned faulting. Ilısu B site, proposed site at present, is located about 1.4 km upstream of Ilısu A site and has good geological condition as explained in following article.

V.5 Reservoir Geology

In this river basin, leakage from reservoir through widely distributed Midyat limestone and intercalated gypsiferous Gercüs formation is most important problem influencing the selection of a dam site. Greater part of these formations will be submerged under the proposed Ilısu reservoir. However, the dam is located on Germav formation at Germav anticline and the formation is estimated to exist at higher elevation than proposed high water level along this anticline which extends crossing the river just like a barrier against leakage through overlain formations.

The landslide of 5-6 km^2 area is developed in the vicinity of upstream end of reservoir on the Zarova valley and many small landslides are reported at 4 km east of Hasankeyf covering 3 km stretch. These landslides may not pose big problem since they are located quite far from the dam site. Although another small landslides and rock falls are seen in the reservoir area, they are not anticipated to present the serious problem for reservoir.

V.6 Topography of Dam Site

The Dicle river flows in the direction from north to south having the river bed elevation of approximately 400 m at Ilısu dam site. Up-and down stream reaches of Ilısu area form gorge without any flat land on the river sides. Ilısu area forms small basin between them having gentle mountain slopes. At the dam site, the width of the river is estimated to be approximately 150 m including flood plain which exists on the right bank.

The left abutment is formed with steep cliff up to 120 m high from the river bed and gentle slope continues from there to the higher part. This left bank is dissected by narrow and deep ravines which are located at 350 m interval to each other.

On the contrary, a steep step of the right bank is only 10 m high and long gentle slope of around 10° continues from top of the step to the higher elevation. Shallow ravines dissect the right abutment.

The dam axis should be selected on the ridges which are formed between ravines on both banks. The height of dam is limited to less than 120 m due to the height of the cliff and width of the ridge on the left abutment. The crest length of Ilısu dam will be long due to gentle slope on the right abutment. The dam height and crest length are estimated to be 130 m and 1,530 m respectively at the crest elevation of 515 m.

V.7 Geology of Dam Site

(1) Overburden on the Abutments

Bed rock crops out widely on the steep cliff of the left abutment and no top-soil covers. A limited amount of slope wash material deposits along the skirt of the cliff.

Terrace deposit estimated to be around 20 m deep covers the lower slope of right bank. Bed rock crops out here and there, and thin top-soil less than 1 m thick covers the slope heigher than EL. 480 m. Terrace deposit consists of round gravel of less than 15 cm in diameter and is well cemented with sand and clay. It is considered to have enough bearing strength and strong sliding registance for proposed rock fill dam. However, permeability of this deposit should be confirmed by further investigations and grouting test is also recommended for establishment of curtain grouting plan.

(2) River Deposit

The bed rock crops out on the river bed in places and the thickness of river deposit is estimated to be very shallow in general. The deposit consists of mainly limestone gravel of less than 15 cm in diamter and few amount of sand.

(3) Bed Rock

The dam foundation rock is marly claystone which belongs to upper Cretaceous Germav formation. The rock presents dark grey colour and is compact but not so hard and can be scratched by knife and also broken by strong hammer-blow. Weak characters, such as for abrading and scaling are seen on the outcrops but depth of weathered zone is generally very shallow.

Horizontal beddings of which thickness differs are clearly seen but no any dislocation of strata are seen on the widely stripped cliff of the left bank. The bedding planes are tightly adhered and not deteriorated.

According to the above-mentioned rock character and geological structure, although the foundation rock is considered to have enough bearing strength and shearing strength for a concrete gravity dam of the proposed height, protection against abrading and scaling should be taken into consideration in the design of appurtenant structures.

V.8 Construction Materials

(1) Rock Fill, Filter Materials and Concrete Aggregate.

Not only rock fill material but also filter (transition) material and concrete aggregate including sand may have to be obtained from quarry because of lack of alluvial deposit. The Midyat limestone which is widely distributed surrounding Ilısu basin is considered of good quality for the materials. The escarpment located about 2 km downstream of the dam site can be proposed as a quarry site in view of its advantageous location.

(2) Impervious Material

The comprehensive field investigations looking for impervious material have not been completed yet. But according to the informations obtained up to present, it is difficult to secure the large amount of impervious material around the project area.

V.9 Technical Study

As described earlier, possible location for the dam site of this project could be selected only at a limited area, because of geological conditions. Immediately downstream of this area, an unfavorable fractured zone is considered to exist which is subjected to fault action and hot spring. At the point 2 km upstream, there is very likely another unfavorable geological formation consisting of Karstic Midyat limestone and gypsiferous Gercüs formation.

However, at the area where the dam is conceivable, Germav formation, consisting mainly of marly claystone which is free from problems of leakage pertinent to Midyat limestone and of solution or rebound as involved in the case of gypsiferous Gercüs formation, exists at higher elevation along Germav anticline, and is expected to make a natural barrier against leakage which may happen from reservoir through Midyat and other formation.

Some treatments are necessary for permeable terrace deposit on the right bank and erodible rock, but no serious problem is involved with respect to geology.

When viewed from topographical point, the ratio of dam height to crest length at around EL 510 m is 1/11.7, that is, the width of river is very big at the location of dam axis.

So, the dam will have a big volume to hold the water up to the required water level of reservoir.

As to discharge of the river, annual average run-off of 540 m^3/sec is sufficient enough to compensate for construction cost of large dam and long distance transmission line to the nearest point of trunk line.

And from political point of view, the development of this project has a significance for the development of under-developed eastern part of this country.

Therefore, though investigation of this project has not been wholly completed to provide a firm and final basis for any conclusion, it seemes advantageous to construct a big dam at this site and to develope a power plant which is to be fed by the reservoir to produce a large bulk of power, if no substantially adverse elements are revealed anew in the future study.

For preliminary study, a tentative plan was established on the basis of the conditions which are as described below.

(a) Effective capacity of reservoir should be decided by mass curve and reservoir capacity curve. Reasonable amount of discharge of river should be controlled and dam height should be as lower as possible.

(b) The dam should be combined type of concrete gravity with spill-way for river channel portion and asphalt-faced rock fill for right bank portion by reason that, in the case of absolute fill-type care of flood water during construction will be difficult and impervious core material are not available in sufficient quantity in neighbouring area.

(c) Terrace deposit on the right bank is to be treated by grouting and erodible rock around both abutments are to be protected by concrete.

(d) Over-flow type spill-way with control gate is to be set on concrete dam. Flood discharge is assumed as 20,000 m^3/sec referring to Interim Preliminary Report on Dicle River Development and Ilısu Damsite (August 1970 E.İ.E.)

(e) Power house is to be located on the left bank immediately downstream of dam, and be outdoor type.

General features of the tentative plan are summarized in the following pages.

Economic analysis of the plan resulted as below:

Annual Benefit	286×10^6 TL.
Annual Cost	267×10^6 TL.
Surplus Benefit	19×10^6 TL.
Benefit/Cost	1.07

The result shows that the plan is feasible from economic point of view.

For the present study, economic analysis was tried only for a plan and comparative study was not made on alternatives. However, it seems possible to improve the feasibility of this project if studies be made further with respect to dam height, effective capacity of reservoir, installed capacity of power plant, type of dam, type and location of power house and other elements which essentially influence the economy of this project.

Accordingly, it is requisite to continue further studies and investigations on feasibility level.

There is no irrigable area downstream of this project site, but the dam site is not far from the border. Therefore, it seems necessary to provide a small pondage at a suitable site somewhere downstream of the dam site in order to re-regulate peaking discharge of the project which, otherwise, would cause disadvantageous influence at the downstream. No detailed study was performed on this problem for the present study. However, it seems preferable to make investigation to locate the pondage somewhere around Çelikan Gorge.

SUMMARY OF ILISU TENTATIVE PLAN

1. Hydrology

Catchment area	39,234 km^2 at Ilısu site
	34,493 km^2 at Rezük gaging station
Annual run-off at Rezük gaging	maximum 26,871x10^6 m^3 (852.08 m^3/sec)
Station (During past 9 years)	average 15,641x10^6 m^3 (495.98 m^3/sec)
	minimum 9,348x10^6 m^3 (296.42 m^3/sec)
Design flood	20,000 m^3/sec

2. Reservoir

Water surface area	110 km^2
Total storage capacity	7,000 x 10^6 m^3
Effective storage capacity	4,500 x 10^6 m^3
High water level	510 m
Low water level	480 m
Available drawdown	30 m

3. Installed capacity

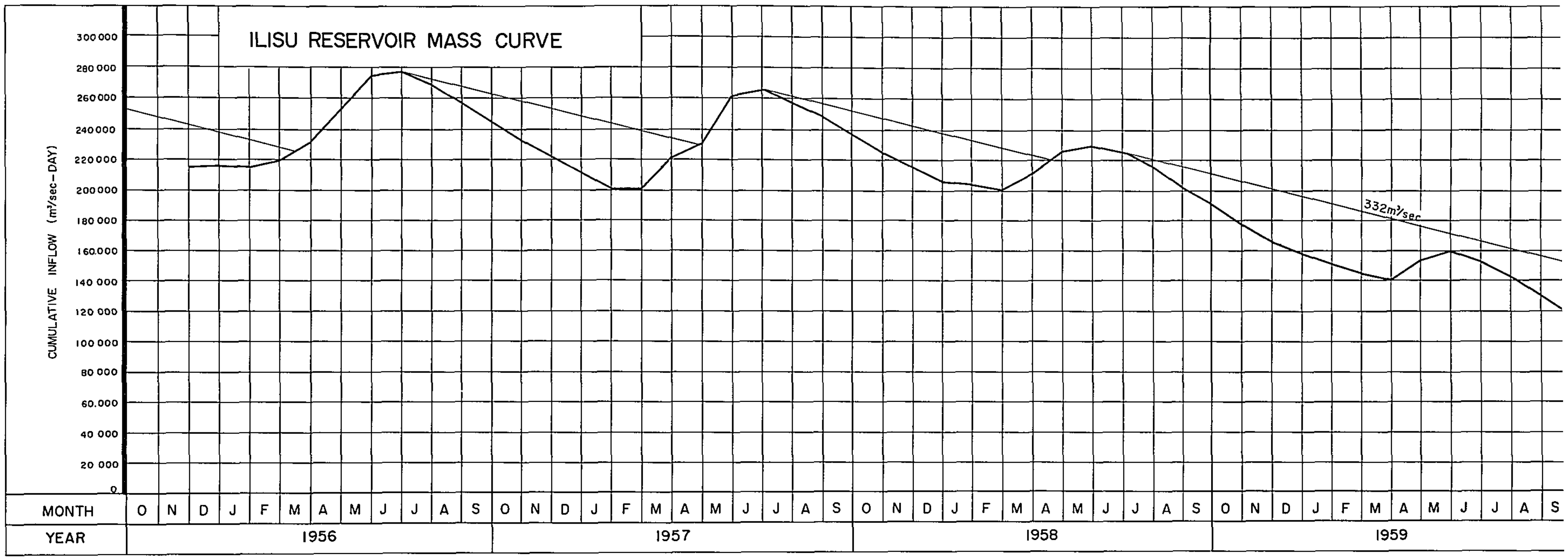
Maximum output	600,000 kW (150,000 kW x 4)
Maximum discharge	740 m^3/sec (185 m^3/sec x 4)
Firm discharge	332 m^3/sec
Effective head	95 m
Annual energy production	3,134 x 10^6 kWh

4. Dam

Type: Concrete gravity and Rock-fill with upstream asphalt facing

	Concrete gravity	Rock-fill
Height	130 m	90 m
Crest length	650 m	880 m
Volume	2,940x10^3 m^3	6,900x10^3 m^3
Crest elevation	515 m	515 m
Upstream slope	1:0.1	1:1.7
Downstream slope	1:0.8	1:1.6
Crest width		10m

5. Spillway	
Type	Gated crest overflow spillway
Capacity	20,000 m^3/sec
6. Penstock	
Type	Steel penstock
Number	4
Length	150 m
7. Power plant	
Type	Outdoor
Installed capacity	150,000 kW x 4
Type of turbine	Francis
Discharge	180 m^3/sec x 4
8. Project cost	3,140 x 10^6 TL.
	5,230 TL/kW
	1.00 TL/kWh



ILISU RESERVOIR MASS CURVE
CUMULATIVE INFLOW (m³/sec-DAY)
300 000
280 000
260 000
240 000
220 000
200 000
180 000
160.000
140 000
120 000
100 000
80 000
60.000
40 000
20 000
0
332m³/sec
MONTH
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S
YEAR
1956
1957
1958
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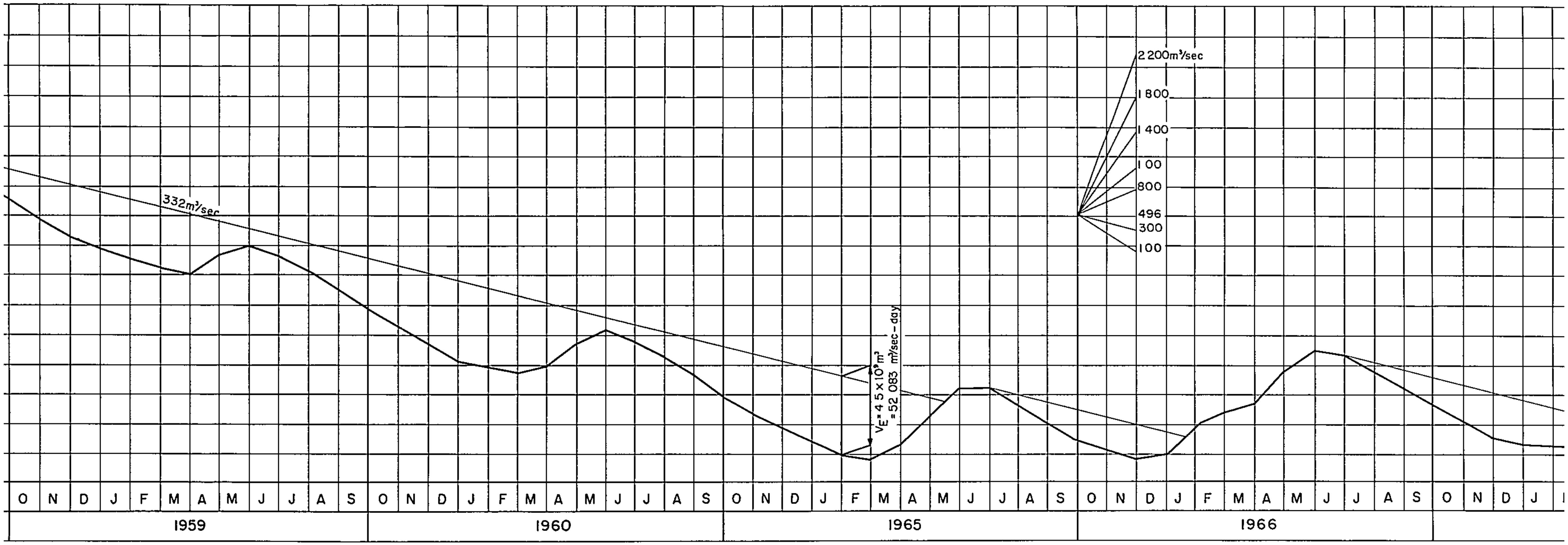
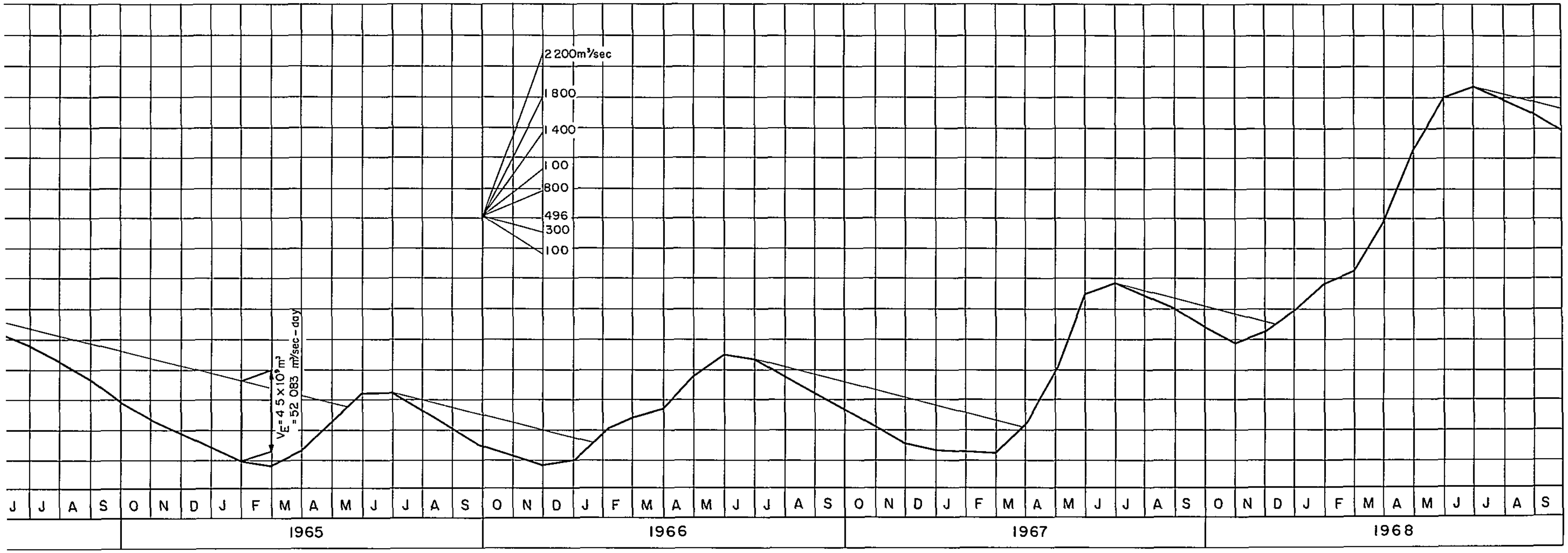


332m³/sec
2 200m³/sec
1 800
1 400
1 00
800
496
300
100
$V_E = 4.5 \times 10^9 m^3$
$= 52\ 083\ m^3/sec-day$
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J
1959
1960
1965
1966



2 200m³/sec
1 800
1 400
1 00
800
496
300
100
VE = 4 5 x 10⁹ m³
= 52 083 m³/sec - day
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S
1965
1966
1967
1968

COST ESTIMATE OF ILISU TENTATIVE PLAN

No.	DESCRIPTION	TOTAL 10^3 TL.	LOCAL 10^3 TL.	FOREIGN 10^3 TL.	REMARKS
1	Concrete dam	791,004	308,492	482,512	
2	Rockfill dam	231,718	90,370	141,348	
3	Intake	36,628	14,285	22,343	
4	Penstock	20,000	7,800	12,200	
5	Power house	70,250	27,398	42,852	
6	Power station equipment	338,888	74,555	264,333	
7	Tailrace	5,180	2,020	3,160	
	Sub total	1,493,668	524,920	968,748	
8	Temporary facilities	24,113	9,404	14,709	
9	Access road	33,000	12,870	20,130	
10	Hauling road	42,000	16,800	25,200	
11	Road relocation	15,000	5,850	9,150	
12	Railroad relocation	10,000	3,900	6,100	
	Sub total	1,617,781	573,794	1,044,037	
13	Engineering and administration	242,667	169,867	72,800	
	Sub total	1,860,448	743,611	1,116,837	
14	Contingency	372,090	148,722	223,368	
	Sub total	2,232,538	892,333	1,340.205	
15	Land	300,000	300,000	0	
	Sub total	2,532,538	1,192,333	1,340,205	
16	Interest during construction	607,809	286,160	321,649	6 years; interest rate of 8% p.a.
	Grand Total	3,140,347	1,478,493	1,661,854	

VI. SEYHAN RIVER BASIN — KAVSAK PROJECT

VI.1 General Condition

The Seyhan river whose origin is the Anti-Taurus range, flows south and pours into the Mediterranean Sea near the city of Adana. The Çukurova plain is fertile deltaic plain which is formed by the Seyhan river. This region is not only one of the biggest industrial areas in Turkey but also produces a large amount of agricultural products.

The Seyhan dam, completed in 1956, is located about 8 Km upstream from Adana where the river emerges from hills to the Cukurova plain. Existing Seyhan project was planned to irrigate 154,000 ha of land and to generate 284×10^6 kWh of electricity annually. The project also protect 85,000 ha of valuable land from the flood.

The proposed Kavşak dam site is located about 60 air line Km upstream of the Seyhan dam, just downstream of the confluence of two principal tributaries, the Zamanti and the Göksu rivers. Besides, two dams, Kirizli dam and Çatalan dam, are proposed between the Kavşak site and Seyhan dam. Therefore, the Kavşak dam is located uppermost and will significantly be a Key-dam in the development plan of the river basin as a whole.

The Seyhan river has a drainage area of about 20,000 Km^2 in total and 12,989 Km^2 at the Kavşak site. An average run-off at the Kavşak dam site is estimated to be 125 m^3/sec.

VI.2 Previous Study and Development Plan

A field camp was opened by E.İ.E. for drilling work in 1963 and closed in 1968. During the period, a map of 1/1,000 scale was prepared, and the geological investigations on the dam site were carried out by means of adits and core drillings as well as geological survey in the reservoir area.

The geological survey in the reservoir area was performed by Dr. S.O. Eroskay(1) in 1965. The results of geological investigations on the dam site were compiled in a report (2) in 1969 by E.İ.E. geologists.

The comprehensive water resources development plan of the Seyhan river basin was studied by IECO at DSI's request in 1966[3]. The IECO report includes, as a result of reconnaissance study, several possible power projects on tributaries upstream of Kavşak. The Kavşak and Kirizli projects are outlined in the report on the basis of the data made available by E.İ.E. Feasibility report on Çatalan project was also prepared by IECO [4] at the same time as above mentioned master plan study.

In 1967, a priority study of power resources in Turkey was performed by SWOCI[5] in compliance with E.İ.E.'s request. Kavsak project was proposed in this report as 246 m-high rock fill dam (crest elevation 530 m) having 19.50 x 10^6 m^3 of embankment volume with an underground powerstation to generate annual average energy of 1.850 gWh by four units of generaters of 110 mW each. Total construction cost was estimated as 1,896,620 x 10^3 TL.

In 1970, E.İ.E. prepared the final report under the tile of "TECHNICAL REPORT"[6], which includes all of the results of study including hydrology, geology, construction material, layout and design, and cost estimate. The layout, design and unit price which applied in the E.İ.E. report are quite same as those in SWCCI report, but quantities have been revised by E.İ.E. Furthermore, E.İ.E. studied three alternative design with varied dam crest elevation of 530 m, 510 m and 490 m for comparison of economy.

Economic comparison as described in report for three alternative plans is as shown below;

		Crest elevation		
		530 m	510 m	490 m
Rated capacity	MW	440	400	340
Firm capacity y	MW	190	159	127
Firm energy	GWh	1,664.4	1,392.8	1,112.5
Average energy	GWh	1,980.0	1,832.4	1,621.7
Total construction cost	10^6TL	2,982.3	2,503.4	2,159.4
Capital cost per kW of rated capacity	TL/kW	6,777.9	6,258.5	6,351.1
Capital cost per kWh of average energy	TL/kW	1.51	1.37	1.33
Surcharge annual cost	10^6TL	257.6	216.8	187.2
Annual cost per kWh of rated capacity	TL/kW	585.0	542.0	550.6
Annual cost per kWh of average energy	Krs/kWh	13.0	11.8	11.5

VI.3 Available Data

(1) Hydrographic Data

There exists no gaging station at Kavşak dam site, but there are two gaging station about 4,5 km upstream of dam axis on the two tributaries respectively, namely the Gökdere station on Göksu river and Ergen Uşağı station on Zamanti river. There is no significant ravine between the dam axis and the gaging stations. Consequently, the river discharge which inflows into the reservoir can be obtained by adding the discharge recorded at the two stations.

Name of Station	Drainage Area km^2	Altitude m.	Discharge during Gaging Period $m^3/sec.$ Average	Min.	Max.
Gökdere	4,242,8	350	59,807	14,000	1,440,000
Ergen Uşağı	8,698,4	347	66,106	29,000	970,000
T o t a l	12,941,2		125,913	43,000	2,410,000

The gaging records at both stations are available for the period after December, 1938. The drainage area at the dam axis is 12,989,0 Km^2.

(2) Topographical Maps and Airphotos

Two kinds of 1/1,000 scale maps of the dam site were prepared; one on the basis of aerial photographs and the other through terrestrial photogrammetry. Airphotos of 1/35,000 scale are available on the dam site and the reservoir area.

(3) Geological Investigation

51 drill holes, 6,039 m in total depth and 20 adits 1,601 m in total length has been carried out at the dam site.

(4) References

1.- Geological Investigation of the Seyhan-Kavşak Reservoir Area
Dr. S.O. Eroskay 1965

2. Final Engineering Geology Report, Seyhan-Kavşak
Dam Site
E.İ.E. 1969

3. Water Resource Development, Seyhan Basin Project,
Master Plan
IECO 1966

4. Report on Technical and Economic Feasibility
Çatalan Project
IECO 1966

5. Power Resources Priority Study
SWOCI 1967

6. Seyhan-Kavşak Project, Dam and Hydroelectric
Powerplant, Technical Report
E.İ.E. 1970

VI.4 General Geology

According to Dr. S.O. Eroskoy's report, Seyhan dam site and its reservoir area are covered by following three geologic systems of Paleozoic era. The Cretaceous limestone exists in the upstream outside of reservoir area of the Zamanti river. Alluvial deposit and top soil are generally thin.

Permo-Carboniferous system:

Consisting mainly of grey-white, hard recrystallized limestone and few of weak shale. Distributing mainly over all of the dam site and along the Zamanti river up to the end of reservoir.

Devonian system:

Consisting of graywacke and sandstone with limestone lense. Cropping out near dam site crossing the Gökdere river. 1.5 km in maximum width and 5 km in length. Another Devonian outcrops are seen in the upstream of the reservoir in the Gokdere river.

Silurian system:

Consisting of schist, sandstone, quartzite, graywacke and marble. Distributing most widely in the reservoir area, from the left bank of downstream of the Zamanti river to almost all of the Gokdere river.

The project area is subjected to asymmetric dense folding; major ones having long continuity and minor ones terminating in short distance. The axis of major folds trend nearly N - S or NE - SW.

Many significant faults are drawn on the Dr. E.O. Eroskoy's geologic map. Some of them run along the contact between different geologic systems. Their strike are similar with that of major foldings and dip are nearly vertical. Numerous faults, having large or small shear zone are found in the adits at dam site.

VI.5 Reservoir Geology

As described above, the dam site and the greater part of the proposed reservoir area are occupied with Paleozoic limestone and marble. Although the Experts had not enough time for visiting the reservoir area, according to Dr. S.O. Eroskoy's report, there are natural bridge, caves, caverns and karstic springs at the different elevation in the Zamanti river basin. However, detail conditions and locations were neither explained in his report nor indicated in his geologic maps. Any description concerning karstic phenomena in the Gökdere river basin cannot be found in his report. He concluded in the Abstract of his report that "Any leakage in importance would not occur through the reservoir area."

Judging from inspections at dam site, the karstification of Permo-Carboniferous limestone has not so highly developed as to form a continuous cave which would conduct the reservoir water directly to the outside of the reservoir. However, as will be mentioned in the article VI.7, wide curtain grouting will be needed deep into both abutments in order to prevent leakage.

According to Dr. E.O. Eroskoy, no big landslide is anticipated in the reservoir area. However, on the left bank around 1 km downstream of dam site, a wide sliding area has been noticed by him and E.İ.E. geologist. The probable sliding volume was estimated at 50×10^6 m^3. Investigation will have to be performed to detail since if such big landslide might occur, the Kavşak power station would possibly suffer from some damage. Access road should be located on such a route as may well escape damage if the landslide should happen.

VI.6 Topography of Dam Site

No big flat land exists in the project area. The dam site also forms symmetrical steep V-shaped valley up to EL. 490 m, and above this elevation, steep slope continues on the right bank, but the slope changes into gentle gradient in the left bank. Too steep rises and over-hanging cliff should be trimmed under the core contact.

The river flows at EL. 286 m in a width about 30 m. The maximum height and crest length of the dam will be 207 m and 468 m respectively, if the elevation of crest is set at EL. 490 m.

VI.7 Geology of Dam Site

(1) Overburden on the Abutment

The above mentioned steep abutments which consist of limestone are naked without any top soil in almost all of the area. On the other hand, the gentle slope on the left bank which consists of shale is covered with thick slope wash material in general. The revealed maximum thickness of the slope wash material is 39.10 m at drill hole LS-25.

(2) River Deposit

On the river sides, there exists no flood plain deposit and running water washes directly rock wall. Two drill holes which were driven in the river bed confirmed the depth of the river deposit of 5.07 m and 13.55 m respectively.

(3) Bed Rock

Distribution

Limestone and marly shale which belong to Permo-Carboniferous period are distributed in the dam site and its vicinity. Limestone is much predominant than shale, namely, limestone covers almost all of the right bank, whole section of river bottom and the lower portion of the left bank up to around 490 m in elevation. The maximum depth of shale on the left bank was ascertained to be 170 m from the ground surface. Shale and limestone are alternated. However, they are not distinctly separated but show gradual transition from shale to limestone, or vice versa, except at several portions where both rocks are separated due to faults.

Lithologic Character of Limestone

Limestone is classified into two types. One is grey colored hard crystalline limestone and the other is black colored carbonaceous limestone. The black colored limestone exists under the river bed predominantly. The thickness of the carbonaceous horizon interbedded in the black limestone varies between 1 m and 70 cm. The thickness of the grey limestone beds varies from 5 to 80 cm. Both kinds of limestone are subjected to minor foldings and heavy fracturings.

Watertightness of Limestone

Many cracks, joints and faults are encountered in the adits and the drill holes. But most of them are closed or recemented. In the adits RA-1 on the right bank, three wide fault zones having an opening or filled red clay run nnn parallel with the river and dip nearly vertically. Their widths are suddenly change in short distance. It is considered that these zones have been enlarged due to karstification along the faults. The grey colored limestone includes few of karstic phenomena in drill hole on the left bank. However, according to the result of the inspection in all of the adits and drilled cores, 20 adits for 1601.65 m in total length and 51 drill holes for a total length of 6,039.22 m, karstification has not progressed so much as a whole. The result of the water pressure test performed in the drill holes at 2 or 3 m intervals shows 78% are less than 5 Lugeon and 6% are more than 25 Lugeon among the total tests of 1,065. The big water loss were occurred through the upper 20 m from rock surface. Black limestone under the river level is entirely watertight. The caves and cavities observed in the valley wall have no big depths. No karstic springs were found in the vicinity of the dam site.

Continuity of the above mentioned karstified fault zones has not been confirmed yet. But they should be plugged by concrete from the surface of the foundation to a certain depth below river level. The leakage water through somewhat karstic limestone may be decreased to allowable amount by rather extended curtain grouting.

Shearing Strength of Limestone

The strike of bedding across the river and the dip are about 35° - 50° towards the downstream in general. Many faults separate limestone into individual blocks. Such conditions are unfavorable for the foundation rock of a high arch dam.

According to E.İ.E. report, the downstream dipping carbonaceous layers do not seem to have sufficient shearing strenth and the report suggests the necessity of consolidation grouting into faulted abutments in order to make them behave as monolithic structure. However, in the case of proposed rock fill dam, it is considered that limestone has enough shearing strength and that it will be unnecessary to provide such measures as mentioned in E.İ.E. report.

Underground Structure in Limestone

The diversion tunnels, power tunnels and underground powerstation are proposed to be constructed in the limestone layer. No great difficulty is anticipated in the excavation of these underground structures. Of course, big faults as found in Adit RSA-1 must be avoided by careful investigation before final alyout is prepared. It is recommendable that cost estimation of concrete lining for these structures should be made at this stage of study.

Lithologic Character of Shale

Shale is yellow-green in color and soft in general. It can be scratched by nail even in fresh part. It is medium bedded and heavily folded and sheared. Wide shear zones encountered in the adits are altered into clayey material. Shale is marly and has slacking character due to contact with air or water. The results of the triaxial compression tests performed on sixteen samples taken from the drilled core and the adit show such low compressive strength as 95.5 kg/cm^2 in minimum, 859 kg/cm^2 in maximum and 371 kg/cm^2 in average. The results of water pressure tests performed in shale show its high watertightness, namely, all test results were less than 5 Lugeon.

Bearing Capacity of Shale

As easily understandable from the character of the shale which is described above, the shale has no sufficient bearing strength for foundation of concrete dam; Even in the case of fill-type dam, high dam is unfavorable. The sheared zone should be treated carefully at the foundation of proposed rock fill dam.

The spill way which is to be located on the shale should be paved by concrete.

V.8 Construction Materials

(1) Rock fill and Filter Materials and Concrete Aggregate

Not only rock fill material but filter materials and concrete aggregate should be quarried and produced artificially since natural material and aggregate are not available in sufficient quantity due to shallow and narrow river deposits. The Permo-Carboniferous limestone widely distributed in the vicinity of the dam site can be used for this purpose.

(2) Impervious Material

Three borrow areas had been investigated by means of test pit and laboratory test.

The results are as follows.

Kabasakal area; 20 km away from the dam site.
No promising results were obtained by the two test pits.

Taluyuruk area; 6 - 7 km downstream of the dam site and the access road will cross the landslide area.

Nine test pits were digged and approximately 200,000 m^3 of material is estimated to be obtained.

Köselelik area; 6 - 7 km away from the dam site.

Twenty test pits were digged and 116,000 m^3 material estimated available for the core material.

Required volume is estimated to be 1.17×10^6 m^3 and above mentioned proposed area can supply only several percent of required quantity. South of Kabasakal village, 25 - 30 km away from the dam site is considered only one possible borrow area to obtain sufficient quantity.

VI.9 Technical Study

As described above, Kavşak dam is proposed as a key dam for the development of the Seyhan river. The valley is narrow and steeply V-shaped. Rock around the dam site has sufficient bearing power for construction of a high dam over 200 m and no serious problems are particularly involved excepting that treatment of shale zone on the left bank is necessary. No big difficulty is also anticipated in the excavation of underground power house.

The Zamanti river originates in Anatolian plateau and passes through the land where precipitation is rather few. Therefore, the amount of discharge of river at Kavşak site seems rather small comparing with its catchment area. However, the discharge is sufficient to produce a big amount of energy by developing high head. And the location of this project is not far from the route of trunk transmission line and from major load center of this country.

However, the most important and fatal problem which is involved in the project is that karstic limestone is distributed at the project site. Results of water pressure test made on the rock shows that the rock is of high watertightness excepting a few parts, but it is probable that widely opened faults and cavities exists in the karstic limestone, though their width, number and continuity are not identified yet. An adit actually encountered a big fault. Then leakage of reservoir water may probably happen through such geological defects when dam is completed and water pressure becomes higher in accordance as impounding increases. Judging from the conditions of excavated adits and drilling-cores, treatment against the possible leakage is possible by the grouting and dental works with concrete. Therefore it is necessary to make further investigation to detect such defects to detail, and to decide range and extent to which grouting and dental treatment are required.

For a trial of economic evaluation, an alternative plan (EL. 490 m) proposed in the E.İ.E.'s technical report (1978) was tentatively resorted to. Some revision or modification was made on few factors including addition of grout curtain in a total length of 2,800 m at abutments. Unit prices were also revised for the estimation of construction cost.

Several features of the plan are as summarized in the following pages, and the result of economic analysis are, as below;

Annual Benefit	173.5×10^6 TL.
Annual Cost	184.3×10^6 TL.
Surplus Benefit	-10.8×10^6 TL.
Benefit/Cost	0.94

The result of economic analysis shows that this tentative plan is not sound from economic point of view.

Estimated cost of this tentative plan includes the cost of grout curtain over long distances on both abutments, i.e. about 2,100 m on right bank and 900 m on left bank, to prevent the leakage of water which might occur through karstic limestone. However, as mentioned before, applied quantity of grout-curtain is only rough estimate, or assumption which is tentatively considered for a trial evaluation in the present study and may actually be subjected to substantial modification by future study.

Setting this variable factor aside, the economy of the plan could probably be improved only if some modifications are applied to it. The modifications will include lowering of dam height, and increase of peaking capacity, etc., which may be effectuated without much difficulty.

In view of the facts that the project is favorably located and that it will have a significant downstream benefit which was not quantitatively counted for in the present study, the project involves significant merits. Therefore, the project should not be undervalued only for a reaon that the tentative study has resulted in a negative figure with respect to its economy.

Therefore, it is strongly recommended that studies be further made to improve the economy of the project and to find a best alternative. Studies and investigations are also required to definitively detect geological defects requiring treatment, as well as to find a cost-wisely best method of treatment.

SUMMARY OF KAVŞAK TENTATIVE PLAN

1.	Hydrology	
	Catchment area	12,950 km^2 at Kavşak site
		4,242 km^2 at Gökdere gaging station
		km^2 at Uşağı gaging station
	Annual run-off at Gökdere gaging station	maximum 1,440 m^3/sec
		average 59.80 m^3/sec
		minimum 14.00 m^3/sec
	at Uşağı gaging station	maximum 970,00 m^3/sec
		average 66.11 m^3/sec
		minimum 29.00 m^3/sec
	Design flood	7,000 m^3/sec
2.	Reservoir	
	Water surface area	28.9 km^2
	Total Storage Capacity	1,825 x 10^6 m^3
	Effective Storage Capacity	697 x 10^6 m^3
	High Water level	485.0 m
	Low Water level	457.8 m
	Available drawdown	27.2 m
3.	Installed Capacity	
	Max. Output	340,000 kW (85.000 kW x 4)
	Max. Discharge	232 m^3/sec
	Firm Discharge	
	Effective head	176.2 m
	Annual energy production	1,622 x 10^6 kWh
4.	Dam	
	Type	Rock fill with Central core
	Max. height	207.0 m
	Crest length	468.0 m
	Volume of Embankment	10,701,300 m^3
	Crest elevation	490.0 m
	Upstream slope	1 : 2.0
	Downstream slope	1 : 1.75
	Crest width	12 m

5.	Spillway	
	Type	gated chute spillway
	Capacity	7,000 m^3/sec
6.	Diversion	
	Design capacity	2,100 m^3/sec.
	Number and Type	1 concrete lined horseshoe-shaped tunnel
	Length	719.0 m
7.	Penstock	
	Type	Concrete lined
	Number	4
	Length	145 m x 4
8.	Power plant	
	Type	Underground
	Installed capacity	85 MW x 4 = 340 MW
	Type of Turbine	Vertical Francis
	Discharge	233 m^3/sec
9.	Project cost	2,127 x 10^6 TL.
		6,256 TL/kW
		1.31 TL/kWh

COST ESTIMATION OF KAVŞAK TENTATIVE PLAN

DESCRIPTION	TOTAL 10^3 TL.	LOCAL 10^3 TL.	FOREIGN 10^3 TL.	REMARKS
Main dam	453,811			
Spillway	100,525	93,625	6,900	
Diversion	45,586			
Intake Structure	11,293	11,043	250	
Intake Tunnel	14,997			
Vertical pressure shaft	15,981			
Valve Chamber	34,103	3,663	30,440	
Draft tube tunnel	12,103			
Tailrace	—	—		
Reinforcing Steel	30,000			
Power Station	44,920			
Busbar and Ventilation shaft	2,901			
Access and Construction tunnel	26,019			
Power Station Equipment	229,500	36,720	192,780	
Sub total	1,021,740	791,370	230,370	
Construction Roads and Bridge	27,000			
Const. Power and Temp. Facilities	22,500			
Access Road	35,000			
Road relocation	10,000			
Operation Village	6,000			
Sub total	1,122,240			
Revised Sub total	1,200,427			Local currency X 1.1
Engineering and Administration	180,064			
Sub total	1,380.491			
Contingency	276,098			
Sub total	1,656,589			
Land	5,059			
Sub total	1,661,648			
Interest	465,262			7 years 8%
Grand Total	2,126,970			

VII. DALAMAN RIVER BASIN — SANDALCIK PROJECT

VII.1 General Condition

The Dalaman river flows into the Mediteranean Sea through the Dalaman plain which is located around midway between İzmir and Antalya. The total catchment area is approximately 5,200 km^2 and the length of the main river is about 190 km. The average discharge of the Dalaman river at uppermost dam site (Sandalcık) and downmost site (Asmacik) is 29.80 m^3/sec. and 50.10 m^3/sec. respectively.

The hydroelectric potential of this river, which is situated in the area near a big energy consumption region has not been developed yet. The development of this river for hydropower could also contribute to irrigation for 14,000 ha of land and prevention of flood in the Dalaman plain.

VII.2 Previous Study and Development Plan

The study for the development of hydropower on the Dalaman river was started by the E.İ.E. in 1955. In 1966, EPDC prepared a comprehensive report(1) for the agricultural and hydroelectrical development of this river. The study was undertaken on the basis of a government to government cooperation between the Turkish and Japanese governments.

E.İ.E. has carried out laborious geological investigations(2) of the dam site and its reservoir area of Sandalcık which is the main dam recommended by EPDC for the first stage program. The revisions of the location and type of dam were tried according to the results of the investigations. However, no detailed studies were undertaken afterwards with respect to the design of Sandalcık dam as well as development plan of the Dalaman river basin because the possibility of leakage from the reservoir through karstic limestone has been revealed on this key project.

Summary of the four projects which are suggested in EPDC report are, from upstream to downstream, as follows;

	Sandalcık	Gürleyik	Göktaş	Asmacık	Total
Effective storage Capacity (X $10^6 m^3$)	665	115	120	2.2	902.2
Normal high water level (m)	705	270	145	71	
Tailrace water level (m)	270	145	71	30	
Maximum discharge (m^3/sec)	44.3	107.0	129.5	36.5	
Maximum output (MW)	150	100	66	11	327
Annual energy production (X 10^6kWh)	786.6	348.9	230.3	87.5	1,435.6

VII.3 Available Data

(1) Hydrographic Data

Run-off at various gaging stations are shown below:

Name of Station	Drainage Area Km^2	Altitude m.	Discharge during Gaging Period m^3/sec. Average	Min.	Max.	Gaging Period
Alcı	3,250.0	695	17.2	1.74	213.4	1940 - 1955
Suçatl	3,411.6	594	20.1	1.18	305.0	1960 -
Akköprü	4,510.0	118	57.7	11.10	870.0	1963 -
Fevziye	5,173.2	25	53.6	1.0	522.5	1940 - 1945 1952 - 1958
Ortaca Köprüsü						1969 -

(2) Topographic Maps and Airphotos

1/1,000 scale map and 1/5,000 scale map are available for the dam site and reservoir area, respectively. Airphotos of 1/35,000 scale cover the project site and reservoir area.

(3) Geological Investigation

Sandalcık : 48 drill holes of which depths vary between 60 and 330 m. were drilled at the dam site and reservoir area. Total depth of drill holes is 5,806.m.
6 exploratory adits, 1,985 m. in total length, were excavated on the A.B. and C. axes.

Asmacık : 3 drill holes, 169.30 m.

Göktas : 4 drill holes, 610.99 m.

(4) Reference

1. The Water Resources Development of The Lower Dalaman River in The Republic of Turkey,
B Basin Development Plan and Feasibility Study of the Sandalcık Project,
Overseas Technical Cooperation Agency, Government of Japan.
(Studies were carried out by EPDC.)

2. Dalaman - Sandalcık,
Dam Site and Reservoir Geology
Ziya Erol (E.İ.E. geologist) 1970

3. Dalaman - Sandalcık Project
Dam and Hydroelectric Powerplant Technical Report
Şadan Arican (E.İ.E. engineer) 1970

VII.4 General Geology

Geologic systems distributed in this project area are Permo-Carboniferous, Jurassic-Cretaceous, upper Cretaceous-Paleocene, and Tertiary series of which description are given below.

Permo-Carboniferous; Dark coloured limestone found in Gökcay gorge upstream of Karacan bridge is moderately thickly bedded (10 - 30 cm) and it containes chert bands.

Jurassic-Cretaceous; Grey coloured limestone distributed in Suçati gorge and in many surrounding places. It is crystallized and thickly bedded, extremely jointed, faulted and folded. Intensive karstification is developed along tectonic disturbance. The results of many core borings show this grey limestone underlies peridotite-serpentine complex and most of limestone outcrops are interconnected each other.

Upper Cretaceous-Paleocene; This series consists of flysch member and peridotite-serpentine member. Flysh member consists of interbedded marl, sandstone and limestone layers. Relatively large limestone blocks are found in several area. The marl is black and dark brown and flacky, laminated and microfolded in general.

It is assumed that flysch is deposited on the uneven surface of the grey limestone transgressively and unconformably. Flysch facies is overlain by peridotite-serpentine generally and flysch is altered into clayey material on the contact zone with peridotite. Following the intrusion, the peridotite covered the flysch due to thrusting forces.

Peridotite-serpentine is dark green and black. It is heavily jointed and deeply altered into talc, asbestos and sepiolitic clay. It lacks durability.

Tertiary series; This formation consists of marly limestone, conglomerates, limestone, marl and diatoms. These all rocks are weakly cemented and friable in general. Tertiary series presents gentle undulating folding.

Asymmetrical foldings trending NE - SW direction and longitudinal faults parallel to the fold axis are predominant in the Permo-Carboniferous and Jurassic-Cretaceous formations. These faults are normal fault and dip nearly vertical in general.

VII.5 Reservoir Geology

The Jurassic-Cretaceous grey limestone which is distributed at the dam site and downstream reach is widely overlaid by serpentine, flysch and Tertiary formation which are generally distributed in reservoir area. It was revealed by many drill holes that serpentine does not form a batholith underneath the grey limestone.

These overlying formations have own perched water table but some of them are karstic or fractured. Only the grey limestone controls hydrologic pattern of the area.

Soluted cavities are encountered in drilled cores. The karstification along the joints are found on the river side and inside of the adits in the dam site. Several sink holes and ponor were found in the outside of the reservoir area.

Big karstic springs are found 4.5 km downstream of the dam site at Koprugzi district. The total discharge of these springs (EL. 380 m) are around 8 - 10 m^3/sec. The absolute minimum ground water table was recorded as EL. 397 m. at drill hole No. 208. It means that the ground water table is 175 m. below the river level and the river is effluent.

It is assumed that above mentioned deep underground water course found at the dam site comes from the grey limestone outcrops which extend over a large area far above the proposed reservoir levels.

Finally, problem of leakage in the reservoir may be concluded as follow; As impounding progresses in the reservoir, pressured water may possibly percolate the small outcrop of flysch limestone and even thin portion of Tertiary formation, and finally communicates with main ground water flow in the grey limestone and spring out from the Koprugzi springs.

VII.6 Geological Problems of Dam Site

Suçati gorge has an advantageous valley shape for construction of a thin arch dam. A, B and C sites were investigated here. However, since geological conditions of the sites, as revealed in its investigation, are featured by karstic channel, wide sheer zones, mosaic faulting and heavy jointing, none of the sites could offer good foundation for a dam. Therefore another site was selected at the entrance of Sucati gorge (D site) to undergo investigation to locate a filltype dam. The results of several core brings performed at D site showed that the site consists of Tertiary formation which is not only originally poorly cemented, but also deeply decomposed. Therefore, it is considered that the geological condition of D site is also unfavorable for fill-type dam of proposed height.

VII.7 Technical Study

As described above, Sandalsık project was proposed as a key project for the development of the Dalaman river basin. However, geological investigations, which have so far been made in the dam site and reservoir area suggest possibility of leakage from reservoir after construction of dam is completed and river discharge is held in the reservoir. The limestone which is the major factor to cause leakage is considered to be distributed widely underneath the reservoir area, and it seems technically and economically unfeasible to prevent the leakage.

Accordingly, in order to develope the potential of the river at upper stream stretch, some alternative plans, which include construction of a lower dam at a site 10 km upstream of the proposed Sandalcık dam on Dalaman river as well as construction of a power station on the Husniye river and others, were taken up and studied. However, the results of studies showed that those alternatives are also all unfeasible because of less amount of river discharge and of difficulty to develope sufficiently large head, while their construction costs were estimated to be a considerable amount.

Then, it is concluded that it is not wise to proceed with further studies of the project at the proposed site. It seems preferable to continue preliminary studies and investigations to develope potential of the river at the middle or downstream reaches of the river, because river discharge is relatively large at these parts of the river.