7.3 Site Geology

7.3.1 Bayram Project

(1) Reservoir

(a) Topograpy

The Berta river on which the Bayram reservoir is planned, is the northernmost of the major tributaries which join the Çoruh river from the right bank inside Turkish territory. The total length is approximately 72 km, and Bayram dam is planned at approximately 32 km upstream from the confluence of the Çoruh river and the Berta river.

The length of the Bayram reservoir will be approximately 5.5 km along the mainstream Berta river (along the Şavşat river) and approximately 5 km along the tributary Meydancık river which flows in the Berta river on the right bank approximately 2.3 km upstream from the dam site.

The mainstream (Şavşat river) in the reservoir area flows from the end of the backwater to the confluence with the Meydancık river in roughly the northwest direction, and downstream from there to the dam site, flows in the west-southwest direction. The Meydancık river flows southwest as a whole, but inside the reservoir it indicates a flow of north to south.

The width at the high water level of EL. 740 m is approximately 380m on the dam axis, around 400 m in the vicinity of the upstream confluence point, and around 300 m further up the mainstream, while along the tributary Meydancık river, it is from 150 to 400 m.

The mountain surrounding the reservoir area, have many high peaks from around EL. 2,600 m to 3,415 m, those which have been named including Mt. Egripinar (3,054 m) and Mt. Ziyaret (3,200 m). Other than these high peaks there are many rugged mountains of EL. 1,000 to 2,000 m in the catchment area, topographical features of this reservoir area being that there are few flat parts on the river bed, and that the right and left banks of streams connect directly to steep slope.

In the reservoir area, landslide and large-scale colluvial footslope, and thin ridges adjacent to other river basins are not recognizable.

(b) Geology

In the surroundings of the Bayram reservoir area, as shown in Figure 7-2, there are the Berta Formation in Cretaceous time of the Mesozoic and mainly Quaternary deposits of terrace deposit, talus deposit, and alluvial deposit. The Yusufeli Formation and the İkizdere granitic rocks are not distributed directly on the foundation of this reservoir area, being mainly found in the Bağlık project area.

The Berta Formation mainly comprises various volcanic rocks (basalt, altered basalt, rhyolite, tuff, tuff breccia, volcanic breccia) and various sedimentary rocks (mudstone, sandstone, conglomerate, marl, limestone). Volcanic rocks are distributed at the reservoir foundation, with sedimentary rocks mainly distributed at high elevation of 1,000 m and over. Therefore, limestone which would have a relationship with watertightness of the reservoir is distributed far above the high water level of 740 m, in addition to which the thickness of a single layer is thin and it is judged that there will be no case of leakage from the reservoir due to karstic solution of limestone. With regard to the volcanic rocks in the reservoir area, there is no fear of leakage from the fact that this formation is an old one belonging to the Mesozoic and that the above-mentioned rocks are very thick. In actuality, in the results of the geological survey at the Bayram dam site also, ground-water levels are low on both abutments, while data suggesting the existing of underground open fracture leading to leakage of the reservoir cannot be seen in the results of permeability test.

Quaternary deposits, excepting the alluvial deposit, all are related to stability of slopes in the reservoir area. Particularly, it is necessary for attention to be paid to slope stability at places where taluses are distributed thickly and widely. As a result of investigations, it was found that almost all of the talus landforms were located below the reservoir high water level of EL. 740 m, but a part of the talus deposits distributed at the right bank immediately upstream of the dam site continues upward higher than EL. 740 m. when the lower parts of these taluses are submerged due to impoundment of water in the reservoir, there will be a possibility that parts higher than the impounded water level will become unstable. Hereafter, it is necessary for topographical and geological surveys to be made of i) the relation between high water level surface and range of talus distribution, ii) thickness, width, etc. of taluses above the high water level surface, and iii) inclination angle of talus slope with regard to taluses in this vicinity. (see "Stability of slope" in the next item)

The thickness of the alluvial deposit is approximately 33 m at the dam site.

(c) Engineering Geological Assessments

(i) Watertightness

The Berta Formation which comprises the reservoir foundation shows distribution of sedimentary rocks with thin intercalations of limestone at the upper part, but the limestone is at far higher than the high water level and is not directly related to the reservoir . The reservoir foundation of the Berta Formation are composed of the various volcanic rocks described above. The various layers are generally thick, and dense. Water flows can be seen in fullness in the surroundings of the dam site and the reservoir area, suggesting that there is sufficient ground water in the mountains. Further, there are no low col and thin ridge with which there would be concern topographically of leakage from the reservoir.

Judging by these topographical and geological conditions, it is thought water-tightness of the reservoir is amply assured.

(ii) Stability of Slope

Part of the talus deposit on the right bank immediately upstream of the dam site is distributed to higher than the high water level of the reservoir. However, in outward appearances, the scale of the deposit is small, and even if collapsing should occur at a part it would not be anything that would cause damage to this reservoir or dam. In any event, there is no special necessity for a geological investigation to be made at the feasibility study stage. It is at the definite design stage to follow, at the stage of studying the layout for roads in the vicinity of the dam and various facilities such as intake, when upon investigating the relative locations of the taluses deposit and various facilities, detailed geological investigations such as described should be implemented if necessary.

Other surface deposits are almost all lower than the high reservoir surface (EL. 740 m), or slopes are gently inclined and stable, and it is considered stability of slopes around the reservoir will not be impaired.

(2) Dam

(a) Topography

The proposed Bayram dam site is located approximately 32 km upstream of the confluence between the Çoruh river and the Berta river, and the river-bed elevation on the dam axis is approximately 635 m. The dam site proposed by the JICA Survey Team coincides with the site studied by EIE at the master plan stage.

The Berta river in this vicinity flows form northeast to southwest while meandering slightly.

The slope on the left bank at the dam site is inclined approximately 40 degrees from the river bed up to around EL. 720 m, while above EL. 720 m, an inclination of 25 degrees is presented.

As for the slope on the right bank,, it is inclined approximately 50 degrees in the vicinity of the river bed, and 30 degrees above EL. 660 m. These slopes have almost no topsoil and basement rock is exposed.

The width of the alluvial deposit on the axis of the dam is approximately 80 m, and the valley width at the high water level of EL. 740 m is approximately 380 m.

(b) Geology

At the dam site, as shown in Figs. 7-3 and 7-4, volcanic rocks such as basalt, altered basalt, volcanic breccia, and tuff of the Berta Formation and overlying terrace deposit, talus deposit alluvial, fan deposit, and alluvial deposit are distributed.

(i) Foundation Rock

- Rock Type and Lithology

The foundation rock of the dam site consists of basalt, altered basalt, volcanic breccia, and tuff. Basalt, altered basalt, and volcanic breccia are widely exposed on both banks, and are massive hard rocks presenting colors from greenish gray to dark gray, and it was confirmed under a microscope that primary minerals have mostly become replacement minerals due to replacement action in hydrothermal alteration. The tuff is a rock of banded structure presenting a greenish gray color, and solidification due to replacement action in hydrothermal alteration can be seen at downstream part on the right bank. This tuff layer has strike and dip of N70°E15° to 35°NW.

Further, as intrusive rocks, many dikes of basalt can be seen. Small-scale dikes not more than 100 cm in width are numerous, and contracts between the dikes and other rocks are in completely tight contact with other rocks.

The RQD values of these rocks are generally from 60% to 100%.

- Faults and Joints

Large-scale faults accompanied by wide sheared zones do not exist in the surroundings of the dam site. Faults have not been confirmed up to now at the dam site either.

Joints and cracks are seen irregularly overall, and are somewhat well-developed.

- Weathering

There is hardly any toposoil at this site, and outcropped rocks are discolored to a brown color at many places. Weathering and discoloration along discontinuity planes of joints and cracks are seen to reach into depths exceeding 50 m on both banks.

(ii) Surface Deposit

- Terrace Deposit

Terrace deposit is distributed in the vicinity of Bayram Village upstream on the right-bank side, and consist of cobbles of diameter 10 to 20 cm, sand, and silt.

- Alluvial Deposit

Alluvial deposit , according to the results of drilling at Drillhole SK-9 in the river bed, has a thickness of approximately 33 m. This deposit is mainly composed of cobbles from 8 to 30 cm in diameter and comprises sand-bearing gravel layers.

- Talus deposit

Talus deposit is distributed only in small scale at the foots of mountains on both banks and the vicinity of Bayram Village upstream on the right bank, the thickness generally being not more than 15 m.

(iii) Ground-water

Final water levels in drillholes carried out by EIE at the dam site are as shown in Figure 7-4. Ground-water levels are deep down on both banks, being at a depth of 94.9 m at Drillhole SK-7 on the right bank and 65.6 m at Drillhole SK-12 on the left bank. Although the ground-water levels are deep down on both banks, they rise up conforming to the topographies on both banks.

(iv) Permeability

At the dam site, permeability tests (Lugeon tests) utilizing drillholes were carried out at the master plan stage at a total of 13 drillholes, 579 stages, in 1,161 m. These tests were carried out at 2-m intervals on foundation rock excluding surface deposits.

The results of Lugeon tests are described below.

- Right Bank of Dam

Parts indicating high permeability of Lugeon values (hereinafter "Lu") 25 or over, were found not only near surface, but also at many places at depths of 50 to 100 m. In Drillhole SK-7, at a section from 80 m to 110 m in depth, a high permeability greater than Lu = 30 was indicated.

- River Bed

Basement rock under the river bed indicated Lu = 0 to 10 for low permeability throughout.

- Left Bank of Dam

The parts of high permeability with Lu = 25 or over are the vicinity of the ground surface to depth of 15 m and partially in a deeper zone of 15 m to 80 m.

(c) Engineering Geological Assessments

Judging by the geological conditions at the ground surface and the results of drilling including permeability tests, the following engineering geological assessments may be made of the dam site:

(i) Volcanic rocks such as basalt, volcanic breccia, and tuff distributed at the dam site, although showing development of joints and cracks to some extent, comprise rock bodies which are massive and hard, while parts of strong weathering are limited to several meters of the surface layer so that it is judged there is ample bearing strength as the foundation for the rockfill dam 145 m in height presently planned.

For example, uniaxial compressive strength of the bed rocks at the Bayram dam site is roughly 700 kgf/cm^2 to 1,000 kgf/cm^2 (According to the EIE's laboratory test results).

(ii) As planes of discontinuity in the foundation rock there are joints, cracks, and intrusion planes, while faults have not been confirmed to exist. Although intrusion planes are tightly contacted, weathering and discoloration along joint and crack planes to depths of more than 50 m may be seen at the abutments on both banks,

(iii) According to the results of Lugeon tests, many parts of high permeability of Lu = 25 or over are seen at both banks to depths of around 110 m from the ground surface, while deeper down, low permeability is indicated as a whole. On the other hand, the basement rock under the river bed indicates Lu = 0 to 10, and permeability is low on the whole. In these tests 60% were Lu = 5 or lower. Moreover, the ground-water table is found at about 70 m to 80 m depth below the ground surface of the dam crest (EL. 745 m) and it is ascending in parallel with the ground surface along the dam axis (see Figure 7-4).

The bedrock at this site is composed of hard volcanic rocks with no water permeating between mineral particles of rocks, so that the permeability of the bedrock is governed by the previously-mentioned discontinuity planes such as joints.

Accordingly, it is thought adequate waterstop treatment can be done for zone of high permeability by application of generally-used cement grouting.

(iv) Part of the foundation for rock zones of the dam will consist of alluvium of maximum thickness 33 m. This alluvium is made up mostly of gravel and sand and is thought to be more or less compacted.

(3) Powerhouse

(a) Topography

For the powerhouse, the plan is for an underground powerhouse to be provided on the right bank of the Bayram dam. This underground powerhouse site is located in a ridge extending in the southeast direction from the northwest, the overburden from ground surface to powerhouse being from 250 to 300 m.

(b) Geology

As shown in Figure 7-5, volcanic rocks of the Berta Formation such as basalt, altered basalt, volcanic breccia, and tuff are distributed in the surroundings of the powerhouse site, similarly to the dam site.

These rocks, as described previously in the clause at the dam site, have been subjected on the whole to the effects of hydrothermal alteration, but rock quality is hardly deteriorated, and the rocks are hard. According to the results of drilling at Drillhole SK-7AD made in the neighborhood of the powerhouse site, quite good cores have been recovered, with indicating high RQD values of 80 to 100%. The final water level in this drillhole is at EL. 650 m, which is fairly low, while Lugeon values indicate impermeability of Lu = 1 and under.

Prominent faults have not been confirmed in the surroundings of the powerhouse site in the surveys made up to this time. Prominent joints possessing directionality have not been found either.

(c) Engineering Geological Assessments

Judged by the geological conditions on the ground surface and the results from Drillhole SK-7AD in the neighborhood of the powerhouse site, the following engineering geological assessments may be made:

(i) Prominent faults are not recognizable in the surroundings of the powerhouse site.

(ii) According to the results of drilling carried out up to this time, volcanic rocks of the Berta Formation such as basalt, altered basalt, volcanic breccia, and tuff are distributed in the powerhouse site surroundings, the same as at the dam site. These rocks are all dense and hard, and RQD is of high values of 80 to 100%. The uniaxial compression tests were not executed, however, judging form the recovered core conditions of SK-7AD and as compared with the recovered cases at the dam site the compressive strength seems to be around 1,000 kgf/cm^2 or more.

Considered from such conditions of the bedrock, it may be judged that there will be no geological problem to make excavation of an underground cavern for the powerhouse difficult.

(iii) According to the results of Lugeon tests at Drillhole SK-7AD, impervious parts of Lugeon values 1 and under make up most of test sections for the underground powerhouse, and an extremely low permeability is indicated. Therefore, it is estimated that quantity of ground-water (spring water) coming into the underground cavern from the bedrock around the powerhouse site will be small.

(iv) In the vicinity of the underground powerhouse site, the only drillhole which has been made is the one hole of the previously-mentioned SK-7AD. Consequently, it will be necessary for investigations of drilling to be carried out to reveal the exact bedrock conditions, permeability, and hydrogeological conditions at the powerhouse location before commencing detailed designing hereafter.

(4) Tailrace Tunnel

(a) Topography

The tailrace is to be a tunnel of total length approximately 8,000 m to be provided running more or less parallel to the Berta river on the bank of the dam from the underground powerhouse extending northeast to southwest, crossing under the Berta river along the way from the right bank to the left bank.

Since the tailrace tunnel will pass (at around EL. 530 m under slopes of mountains from EL. 700 to 1,000 m, the overburdern of original ground will be comparatively thick, from 200 to 500 m. Where the Berta river is to be crossed under, the overburdern will be thinnest at 40 m.

(b) Geology

As shown in Figure 7-6, the Berta Formation is distributed along the tailrace tunnel route. The Berta Formation is composed of volcanic rocks such as basalt, altered basalt, volcanic breccia, tuff breccia, lapilli tuff, and tuff, and overlying sedimentary rocks such as limestone, calcareous sandstone, and mudstone. The thick limestone layers are distributed more or less horizontally, and are estimated to be in slight angular unconformity with the underlying the volcanic rocks, and are distributed at EL. 750 m and higher. Accordingly, they do not appear on the tailrace tunnel which passes at around EL. 530 m.

Basalt, altered basalt, and volcanic breccia are mainly distributed at the powerhouse side and outlet side of the tailrace tunnel route, while at the middle part which crosses the Berta river, and parts before and after, thick layers of greenish gray volcanic breccia and tuff are widely distributed. The former, although with some development of cracks, is generally hard and dense, but the latter is expected to be a slightly embrittled rock mass due to green alteration action. It is estimated that strata of greenish gray lapilli tuff and tuff appear in a section of approximately 3,400 m out of the total length of the tunnel of 8,000 m.

Thick surface deposits and landslide which would affect the tailrace tunnel and its outlet are not seen in particular.

(c) Engineering Geological Assessments

Judging by the geological condition on the surface and the results of Drillhole BYT-1 drilled at the river bed of the Berta river, the following engineering geological assessments can be made of the tailrace tunnel route:

(i) The volcanic rocks of the Berta Formation such as basalt, altered basalt, volcanic breccia, tuff breccia, lapilli tuff, and tuff, although with cracking developed in parts, are as a whole a hard rock body, and it may be considered that there will be no obstacle to tunnel excavation.

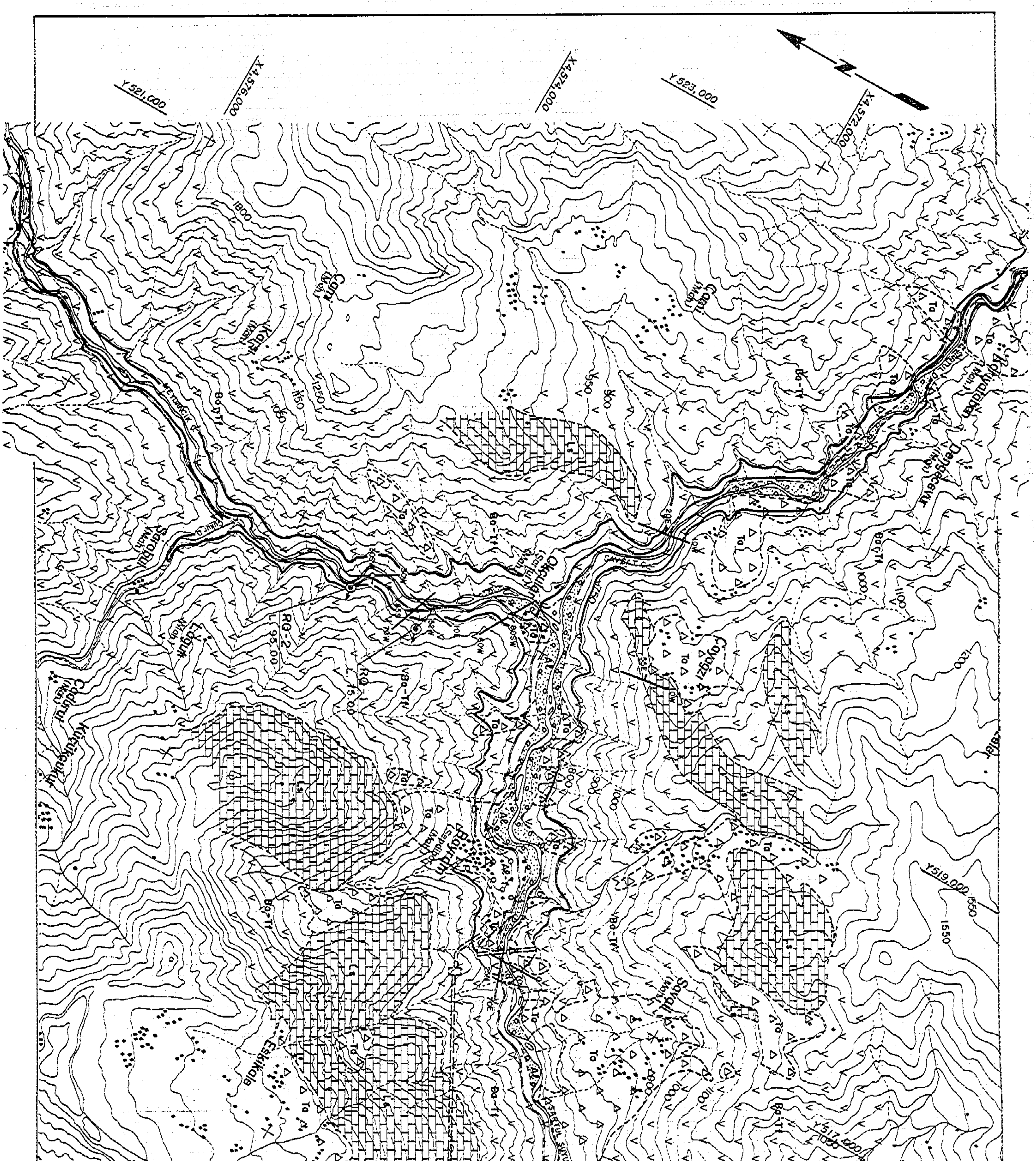
(ii) Prominent faults do not exist along the tailrace tunnel route. However, it is assumable that there will be arts where weathering has progressed due to thin overburden. Otherwise, joints and cracks are seen to have developed at geological boundaries between lava of basalt or altered basalt, and lapilli tuff and parts of intrusive rocks (mainly basalt). Because of this, reinforcing with suitable supports will be necessary in tunnel excavation at the previously-mentioned section.

(iii) The tailrace tunnel will pass under the Berta river. The depth from the ground surface to the proposed tunnel at this point is approximately 40 m. Drillhole BYT-1 has been made at this valley to investigate the depths of surface deposits. According to the results of these, the thickness of alluvial deposit over the tunnel route is approximately 18 m, and the thickness from the bedrock surface to the tunnel location is approximately 25 m. This part consists of lapilli tuff of greenish gray color, and besides development of joints and cracks, weathering has progressed slightly. Because of this, it will be necessary for suitable water spring countermeasures and supports to be provided in tunnel excavation at this section.

(iv) The ground-water conditions along the tailrace tunnel route are considered as follows:

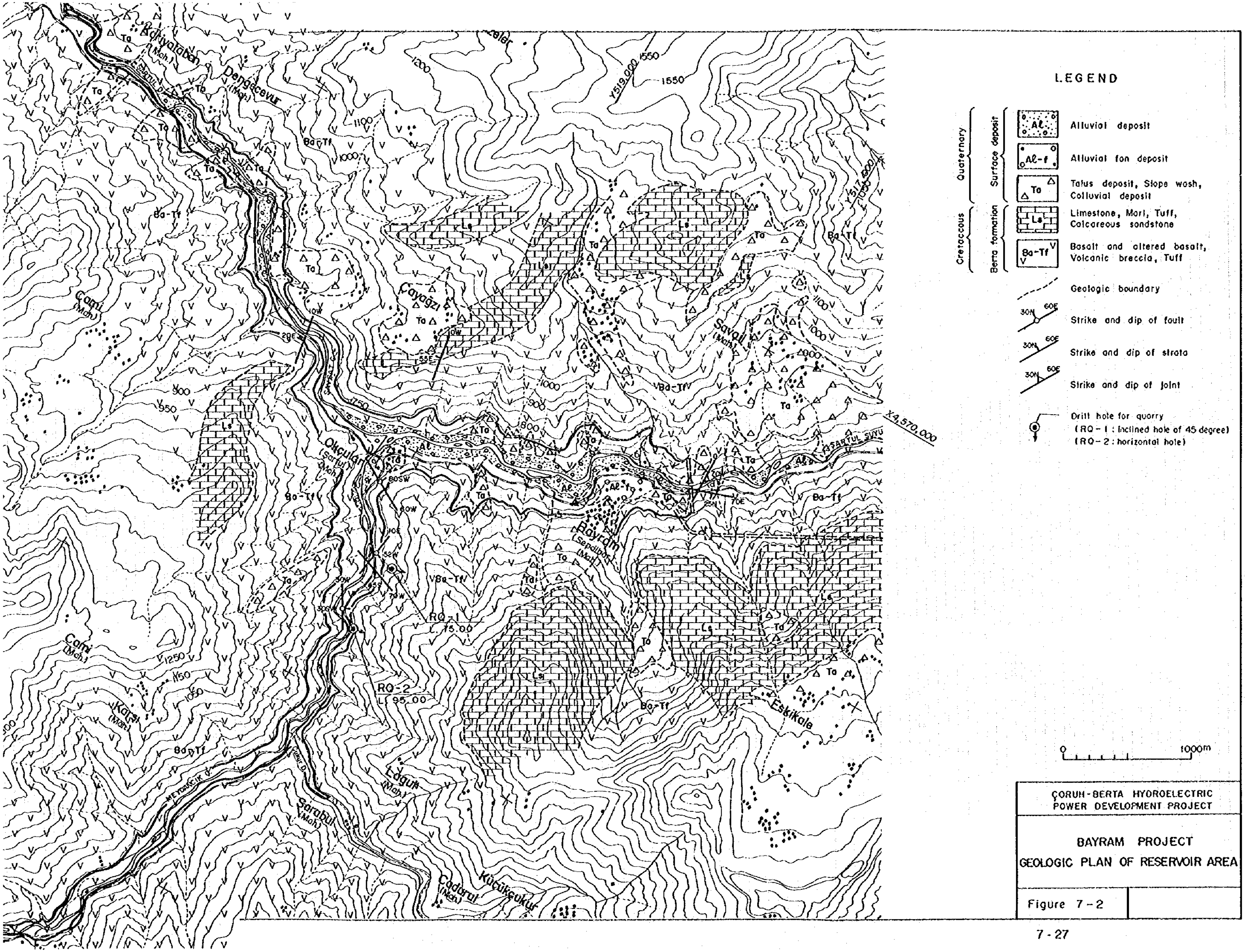
In the distribution area of volcanic rocks of the Berta Formation, as can be seen at the dam site, the rise of the ground-water level from the stream toward the mountain is very gradual, and it is estimated that the ground-water level along the tailrace tunnel which passes through the mountainland along the Berta river is also low. According to the results of Lugeon tests carried out at the dam site, the bedrock of depths greater than 100 m from the ground surface are impermeable or low permeable.

Consequently, the tailrace tunnel route is estimated to most pass through the bedrock where ground-water level is comparatively low and, moreover, permeability is also low, and it is estimated that basically, there is little springing of water into the tunnel. However, where the tunnel passes parts where cracks and joints are developed locally or where gullies are passed, it may be expected that local concentrated springing into the tunnel may be seen, and it is thought that adequate drainage facilities will be required in construction.



Cretaceous — Berta formation

Quaternary — Surface deposit

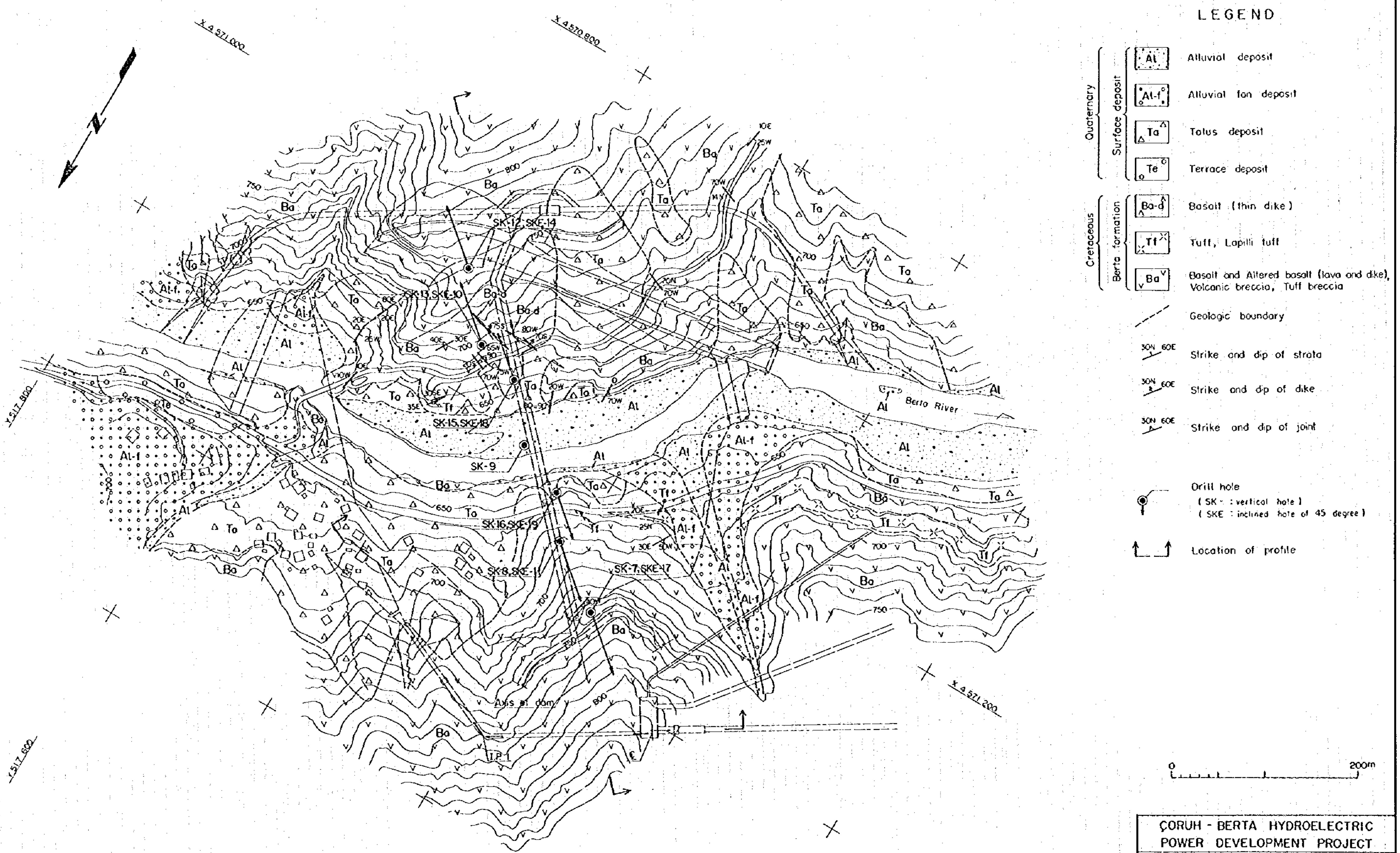


ÇORUH-BERTA HYDROELECTRIC POWER DEVELOPMENT PROJECT

BAYRAM PROJECT

GEOLOGIC PLAN OF RESERVOIR AREA

Figure 7-2

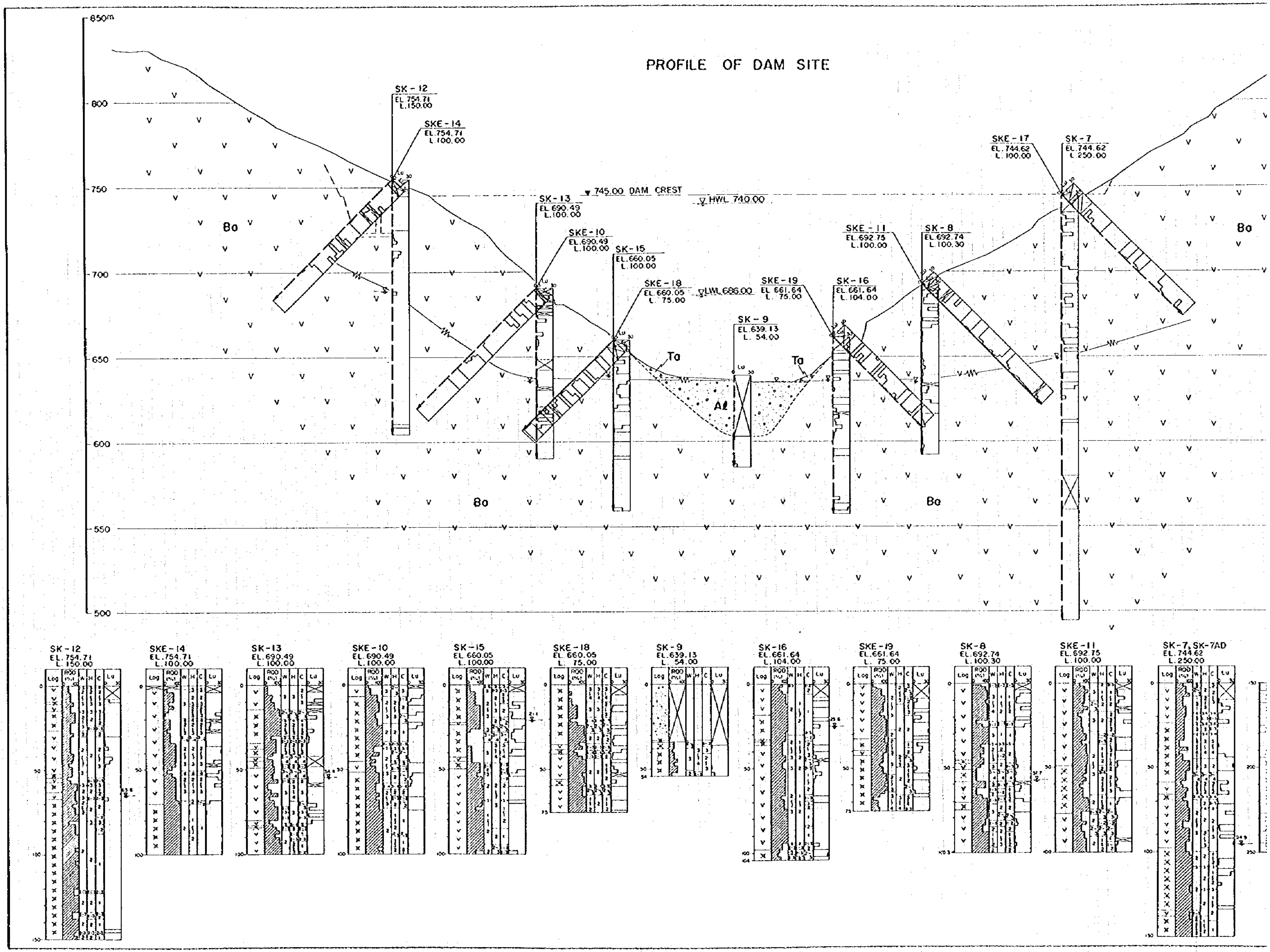


ÇORUH - BERTA HYDROELECTRIC POWER DEVELOPMENT PROJECT

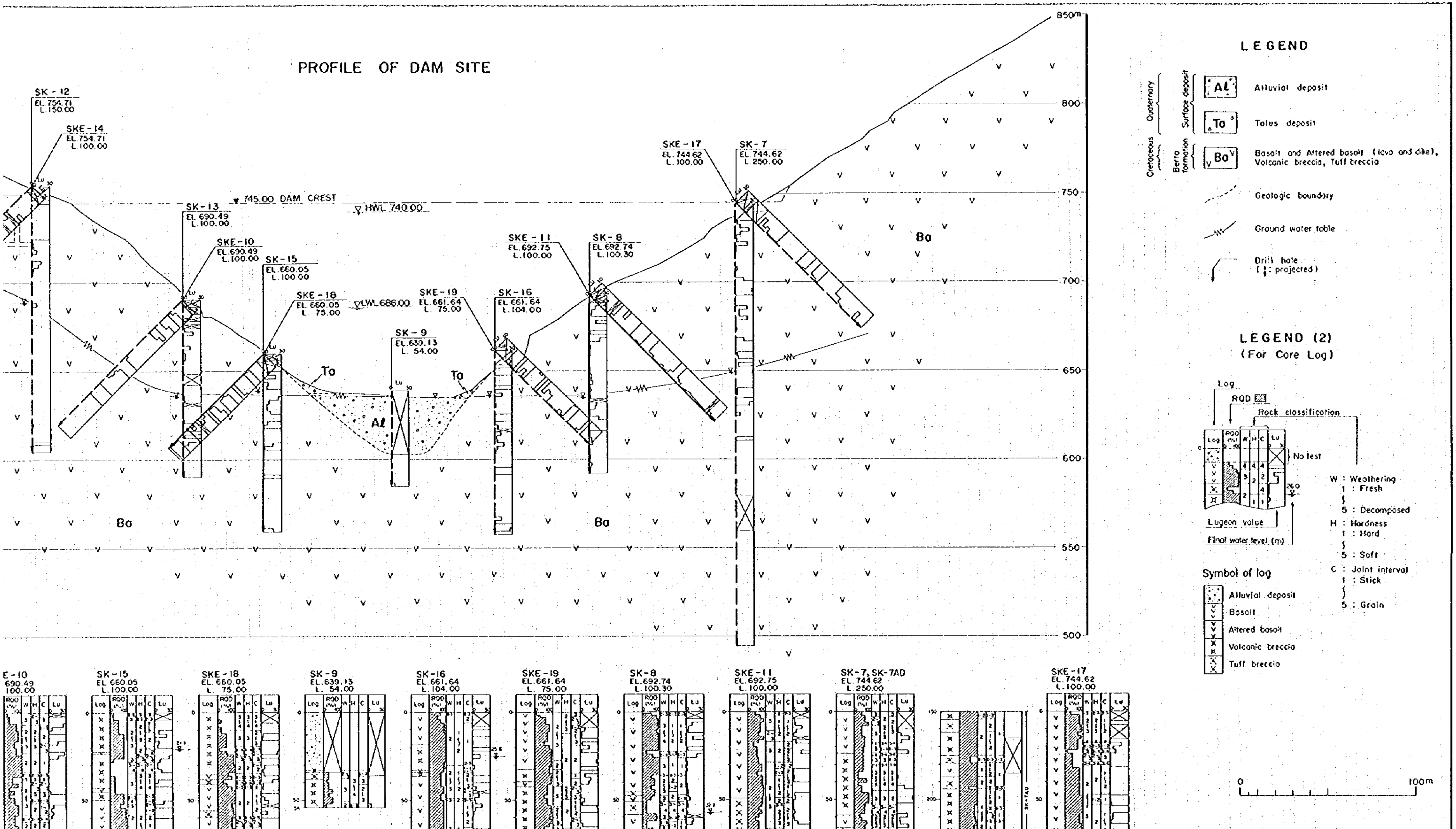
BAYRAM PROJECT

GEOLOGIC PLAN OF DAM SITE

Figure 7 – 3



PROFILE OF DAM SITE
850m
800
750
700
650
600
550
500
745.00 DAM CREST
HWL 740.00
LWL 686.00
Bo
Ta
Al
SK-12 EL.754.71 L.150.00
SKE-14 EL.754.71 L.100.00
SK-13 EL.690.49 L.100.00
SKE-10 EL.690.49 L.100.00
SK-15 EL.660.05 L.100.00
SKE-18 EL.660.05 L.75.00
SK-9 EL.639.13 L.54.00
SKE-19 EL.661.64 L.75.00
SK-16 EL.661.64 L.104.00
SKE-11 EL.692.75 L.100.00
SK-8 EL.692.74 L.100.30
SKE-17 EL.744.62 L.100.00
SK-7 EL.744.62 L.250.00
SK-7, SK-7AD EL.744.62 L.250.00
Log
RQD (%)
W
H
C
Lu

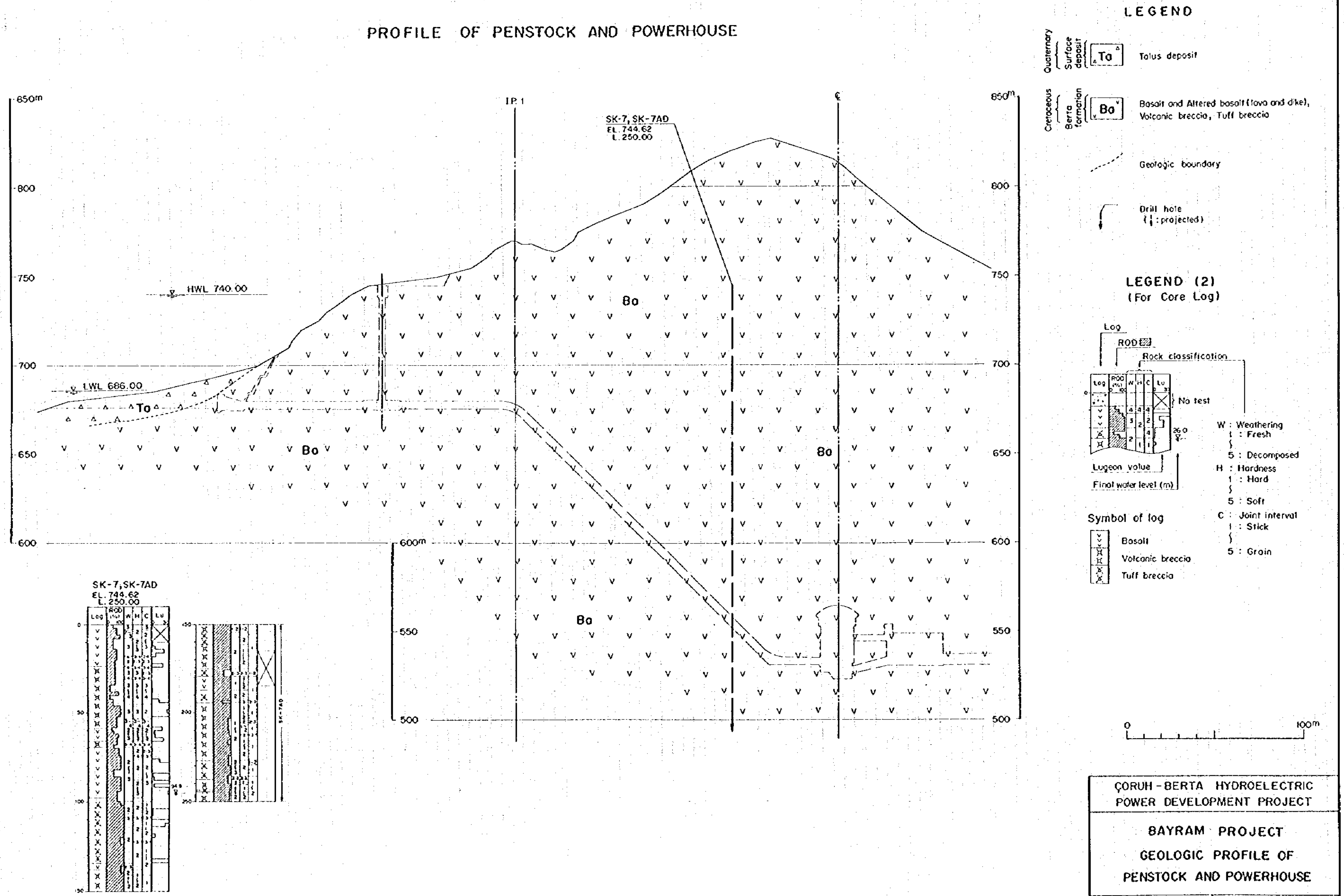


ÇORUH - BERTA HYDROELECTRIC POWER DEVELOPMENT PROJECT

BAYRAM PROJECT

GEOLOGIC PROFILE OF DAM SITE

Figure 7-4

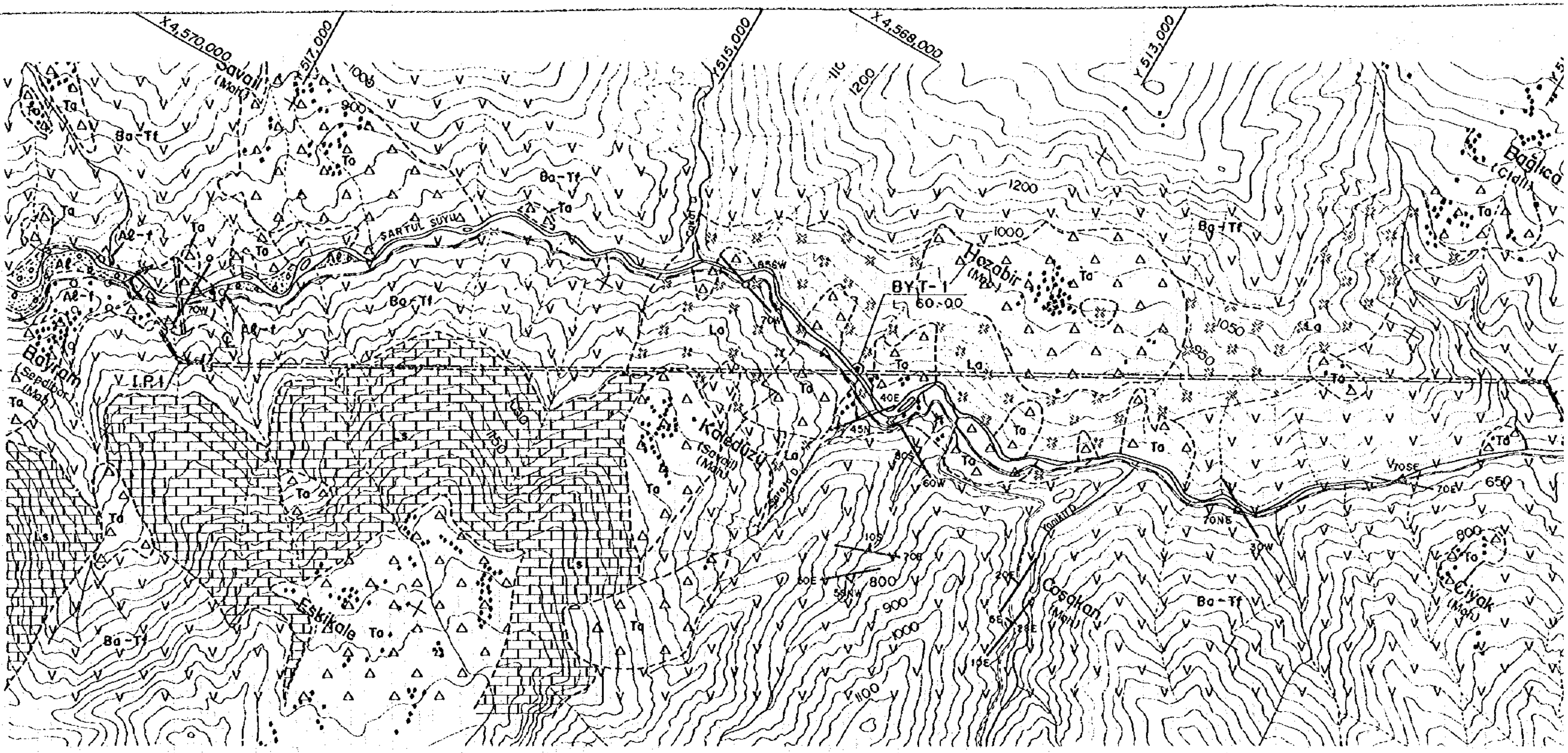


ÇORUH - BERTA HYDROELECTRIC POWER DEVELOPMENT PROJECT

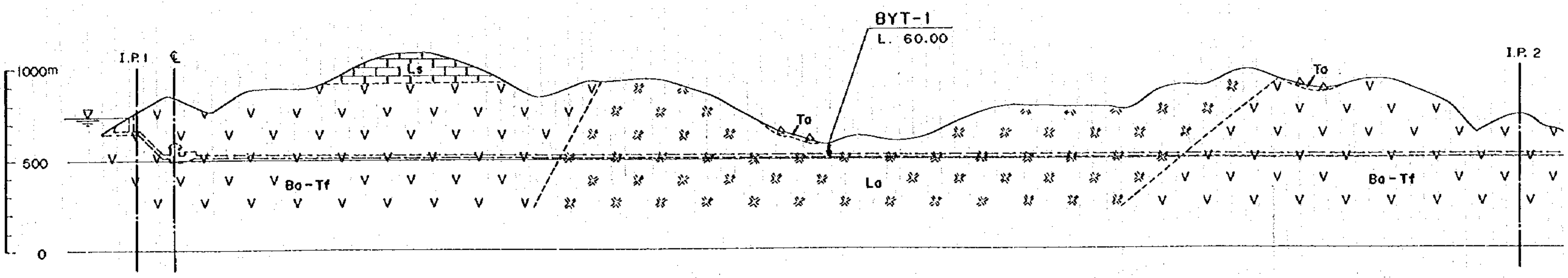
BAYRAM PROJECT

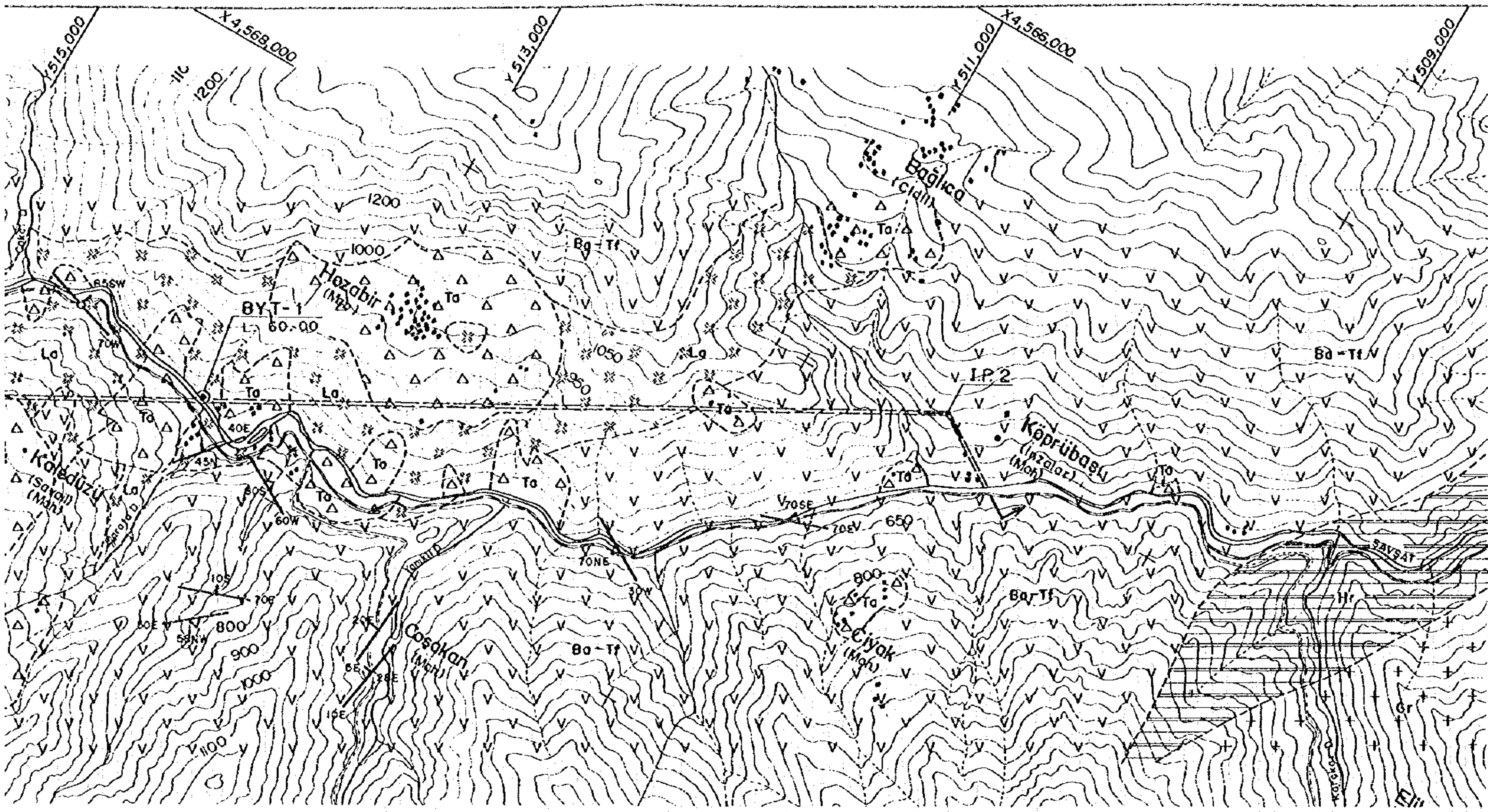
GEOLOGIC PROFILE OF PENSTOCK AND POWERHOUSE

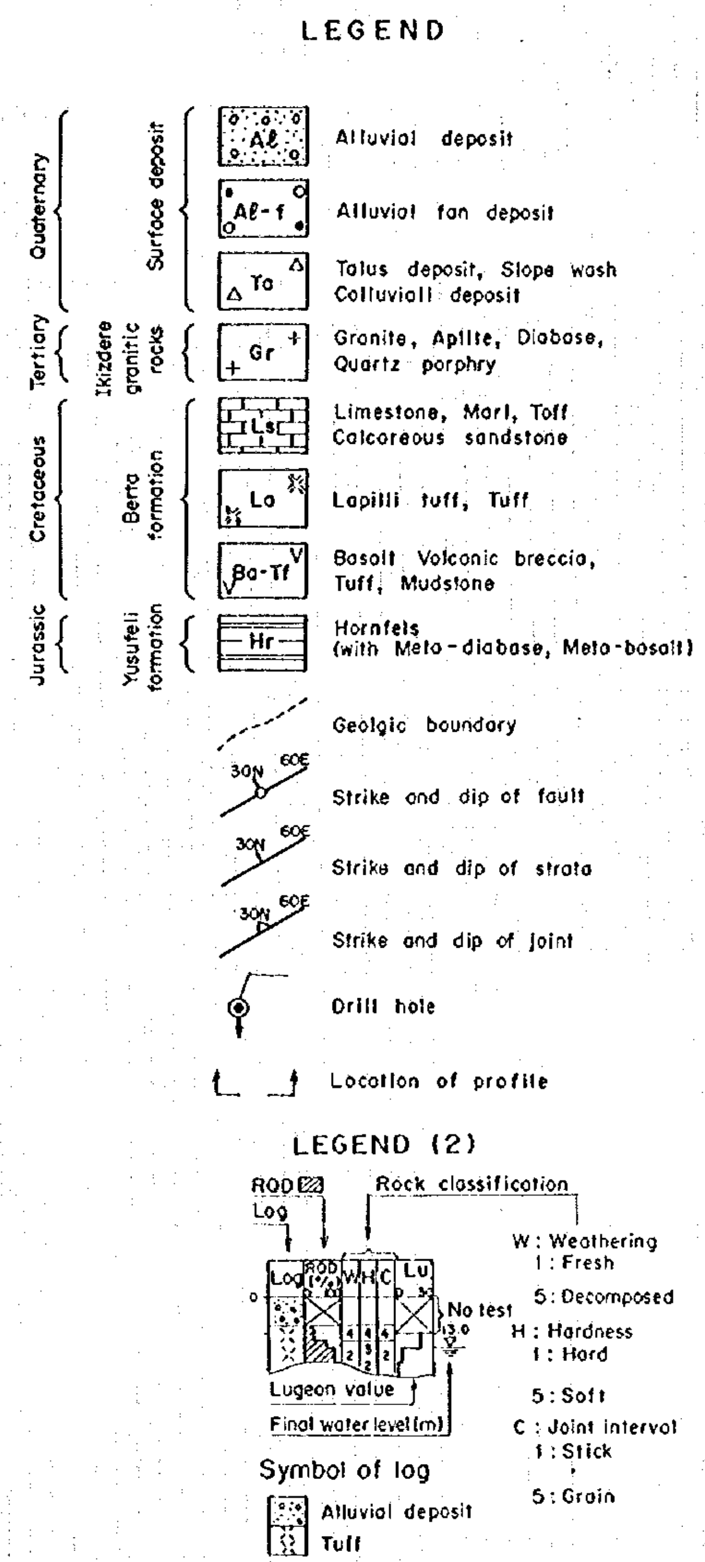
Figure 7-5



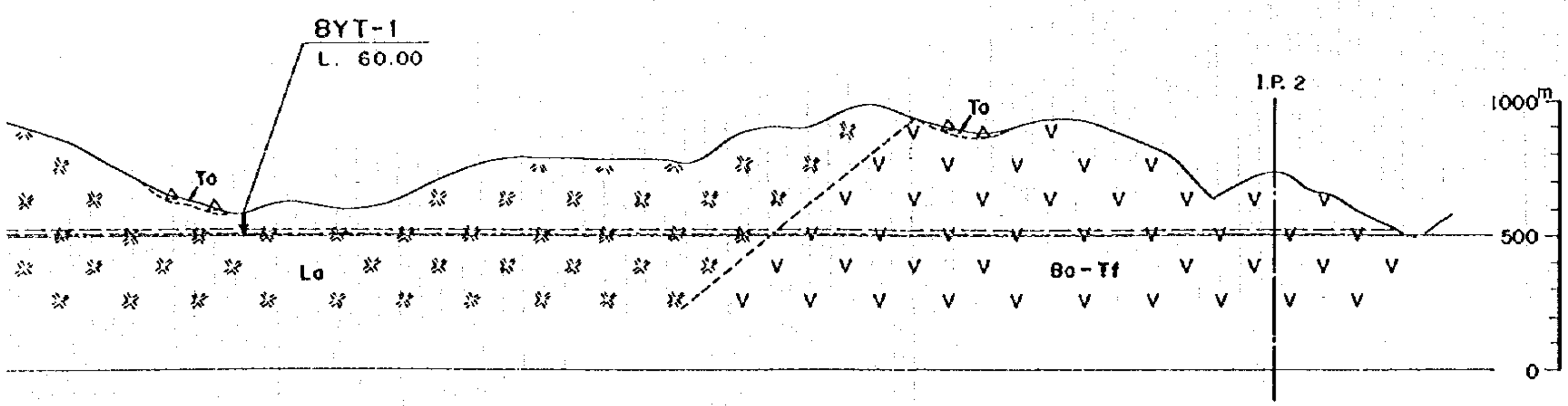
PROFILE OF WATERWAY

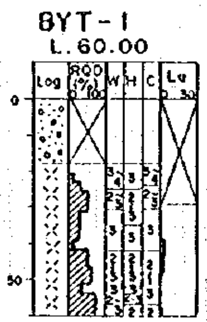






PROFILE OF WATERWAY





ÇORUH-BERTA HYDROELECTRIC
POWER DEVELOPMENT PROJECT

BAYRAM PROJECT
GEOLOGIC PLAN AND PROFILE
OF WATERWAY (TAIL RACE)

Figure 7-6

7.3.2 Bağlık Project

(1) Reservoir

(a) Topography

The Bağlık dam site is located approximately 13 km downstream from the Bayram dam site and approximately 19 km upstream from the confluence of the Çoruh river and the Berta river. The dam site proposed by the JICA Survey Team is approximately 150 m upstream of the location where EİE carried out drilling investigations at the master plan stage.

The length of Bağlık reservoir is approximately 7 km along the Berta river mainstream, and although there are a number of short tributaries which flow into the reservoir, gradients of slope are steep, and there is only one tributary on the left bank immediately upstream of the dam where a pond of length approximately 800 m is formed.

The mainstream is the reservoir area flows roughly in the southwest, while the tributary mentioned above flows from south to north.
The width of the reservoir when high water level is taken to be EL. 530 m will be approximately 165 m on the axis of the dam axis and 50 to 80 m in the vicinity of the midstream part of the reservoir.

The topography surrounding the reservoir area is as described in the clause on Bayram reservoir, with steep mountain terrain presented, and especially, in this reservoir area, distributions of the Yusufeli Formation and the İkizdere granitic rocks are found so that there are numerous places where steep cliffs rise directly from river banks.
Landslide are not seen inside the reservoir area, but at the left bank approximately 7 km upstream from the end of the reservoir backwater, there is so called Savail Landslide. In contemplating the Bağlık project, considerations were given in order not to include this landslide area in the reservoir. Other than this there are no large-scale or thin ridge adjacent to other river basins.

(b) Geology

The Bağlık reservoir area, as shown in Figure 7-7, is composed of the Yusufeli Formation belonging to the Jurassic time of the Mesozoic era, the Berta Formation of the Cretaceous age in the same era, and the İkizdere granitic rocks which intrude into these formations. Of these, the granitic rocks are distributed immediately downstream of the dam site, while the Yusufeli Formation can be seen at the dam site and the upstream stretch of approximately 1.5 km. Further upstream from this is a continuous distribution of volcanic rocks of the Berta Formation up to the Bayram reservoir area. The geological condition of this reservoir is that distribution of Quaternary deposits (surface deposits) overlying basement rocks is extremely small.

The Berta Formation widely distributed in the vicinity of backwater of the reservoir is as described in the clause on the Bayram reservoir, and in this reservoir area thick limestone layer of the Berta Formation are located at even higher elevations and are unrelated to watertightness of the reservoir.

The Yusufeli Formation in this vicinity consists mainly of hornfels and hornfelsed sandstone and slate, altered diabase, altered basalt, and quartz porphyry, an intrusive rock, and as a whole, it is a hard and dense, stable rock body; there is no problem as a reservoir foundation.

Regarding surface deposits, as mentioned above, there is no conspicuous distribution at the foundation of this reservoir and its surroundings. The thickness of the alluvial deposit is not more than 6 meters.

(c) Engineering Geological Assessments

(i) Watertightness

The sedimentary rocks of the Yusufeli Formation and the volcanic rocks of the Berta Formation in the reservoir area are basically impermeable strata. Water flows can be seen in valleys in the dam site and reservoir area surroundings to suggest that abundant ground water exists. Topographically also, there are no saddles or thin ridges where leakage would be of concern. At the dam site, the existence of ground-water at elevation higher than the river bed has been confirmed. Consequently, judging by such topographical and geological conditions, it is considered that watertightness of the reservoir is amply assured.

(ii) Stability of Slope

As previously mentioned, surface deposits (taluses, terraces, etc.) are scarce as a whole inside this reservoir and steep slope are formed directly from the river bed. Steep cliffs are prominently seen in the part of the Berta Formation where more or less horizontal deposits of lapilli tuff and tuff are distributed, but they are not seen in the reservoir area. Both banks in the reservoir where the Berta Formation and the Yusufeli Formation are distributed are steep cliffs or steep slope. With regard to stability of the steep cliffs and slopes after impounding of water in the reservoir, there are no places seen to be especially unstable. Existing landslide topographies are not seen in the reservoir, while there is no possibility of new landslides or slope failure occurring due to water impoundment.

(2) Selection of Bağlık Dam Site

The dam axis which was selected in the Master Plan Report prepared by EIE was located at a gorge where is about 150 m downstream from new drillholes BGA-1, BGA-2 and BGA-3 recommended by the JICA Survey Team. The fifteen boreholes (1,579 m in total length) have been drilled at this gorge site so far. The reasons why the JICA Survey Team shifted new Bağlık dam site from the gorge site is about 150 m upstream site are as follows:

a) The foundation at the gorge site (hereafter old dam site) is composed of granite. The topography at the old dam site forms steep gorge and no overburden can be found on the ground. Exposed granite can be seen at whole area of the site and granite itself is quite hard.

b) However, three directional clear joints are developed remarkably in granite mass and when selecting concrete gravity type dam at the old dam site, excavation depth for dam foundation will be estimated to be 40 - 50 m in horizontal depth at both banks between EL. about 469 m (river bed) and EL. about 533 m (dam crest).

That is to say, granite mass which forms the gorge can be seen to be stable rock mass, however the rock mass form the ground to several to meters deep is actually cut by three directional joints and it looks like heap of large blocks.

c) Moreover, although there are some difference of the conditions on the joint planes (e.g. very tight joint plane or loose plane, fresh plane or weathered plane etc.), it must be evaluated that joints are developed as far as much deeper than the above-mentioned depth.

Accordingly, when the watertightness for the foundation surrounding the dam site is studied, curtain grouting should be designed sufficiently in horizontal and in vertical direction.

d) As above-mentioned geological judgments could be done, the studies whether the gorge site is really suitable dam site or not and whether other alternative dam site can be selected or not were executed.

As the result of the study, it was judged that there is possibility which the dam site can be selected in a Yusufeli formation area, so two drillholes of BGA-1 and BGA-2 (each 100 m length) at both banks of the temporary dam axis, BGA-3 (80 m length) at the river bottom and BGA-15 (130 m length) at the proposed underground powerhouse site were drilled.

The following engineering geological data were obtained by geological mapping on the ground surface in the Yusufeli formation area and by above-mentioned four boreholes.

a) The Yusufeli formation at this new proposed site consists of hornfels of sandstone and slate origin, and their strike and dip are approximately N45 - 60E, 15 - 30SE. The directions of such strike and dip cross the dam axis obliquely with shout 60 degree and dip to the lift bank side with about 25 degree.

Interbeds of sandstone and slate at this site are hornfelsed under the influence of intrusive granite, accordingly they are hard in general and especially at the river bed, they are fresh and massive.

b) Irregular cracks are found at the out-crops here, however no remarkable joints are seen such as granite at the old EIE's dam site.

c) Judging from these geological view points, no singular geologic phenomena can be seen in the Yusufeli formation area. Accordingly, if normal geological results are obtained by subsurface geological investigations such as drilling, it can be judged that the site has possibility as a suitable dam site.

d) By the results of BGA-1 and 2 located at both abutments, it has been confirmed that the ground water table is found at the depth of 35-40 m below the crest (EL. 533 m) of the proposed dam and the gradient of ground water table is ascending nearly in parallel with the slope of ground surface. Moreover, there are high permeable portions patially below the ground water table, however, as a whole the bed rock of the Yusufeli formation below the ground water table can be judged to be low permeable or impermeable bed rock.

e) According to the results of BGA-3 drilled at the river bottom, the permeability of the bed rock under river deposits (6 m) is generally 2 Lu to 0 Lu excepting 10 Lu at the test section between 17 m and 22 m in depth.

f) Concerning the proposed underground powerhouse site, BGA-15 (130 m length has length) has been drilled. The results show that there are high permeable zones due to the oxidated cracky zones at the depth between 0 m (top of hole) and about 80 m, must be tight rock. By the way, the top of powerhouse is roughly located at about 120 m (EL. 425 m) below the ground surface.

Judging from above-mentioned various data, it is clear that there are sufficient possibilities to select the dam site in the Yusufeli formation area. Therefore, the JICA Survey Team has shifted the location of the Bağlık dam site from the old dam site (the stage of Master Plan Report) to about 150 m upstream site in the Yusufeli formation area in this report of the Feasibility Stage.

(3) Dam

(a) Topography

The Bağlık dam site is located approximately 19 km upstream from the confluence of the Çoruh and Berta rivers, and the elevation of the river bed on the axis of the dam is approximately 467 m. As previously mentioned, the dam site proposed by the JICA Survey Team is approximately 150 m upstream from the location where EİE carried out drilling investigations at the master plan stage. The Berta river at the dam site flows east to west in a roughly straight line.

The slope on the left bank at the dam site is inclined approximately 55 degree in the vicinity of the river bed, and at EL. 485 m and higher, the inclination is approximately 42 degree. As for the slope on the right bank, it is inclined approximately 55 degree in the vicinity of the river bed and about 40 degree above EL. 505 m. These slopes have practically no surface soil and basement rocks are exposed.

The width of the river bed on the dam axis is approximately 30 m and the valley width at the high water level EL. 530 m is 165 m.

(b) Geology

At the dam site, as shown in Figures 7-8 and 7-9, the Yusufeli Formation consists of hornfels of slate and sandstone origin are distributed. This hornfels is metamorphic rock which was metamorphosed by intrusion of the İkizdere granitic rocks. Immediately downstream of the dam site the İkizdere granitic rocks which have intruded into the Yusufeli Formation are distributed. Overlying these are talus deposit and alluvial deposit.

Drilling at the dam site proposed by the JICA Survey Team were carried out one drillhole (BGA-1) at the left bank, one drillhole (BGA-2) at the right bank and one drillhole (BGA-3) on the river bed already completed.

(i) Foundation Rock

- Rock Type and Lithology

The foundation of the dam is composed of gray to dark gray hornfels of slate and sandstone origin in the Yusufeli Formation. These rocks are widely exposed at the river bed and the slopes on both banks, and although joints are slightly numerous, they present a hard and dense rock. This Yusufeli Formation has strike and dip of N45° to 60°E15° to 30°SE.

The İkizdere granitic rocks widely distributed immediately downstream of the dam site consist of hornblende granite, the rock itself being hard and dense, but horizontal and vertical joints are prominently developed.

Furthermore, there is one dike of quartz porphyry seen as dike rock in the Yusufeli Formation near the dam site. This is a small-scale dike, which is vertical and of width less than 100 cm, contacts on the Yusufeli Formation being completely tight. The RQD values of hornfels at the dam site are generally from 30 to 80%.

- Faults, Joints

Large-scale faults with sheared zones of large width do not exist at the dam site and its surroundings. However, joints and cracks are seen overall in an irregular pattern, and are developed at intervals of 10 to 50 cm.

- Weathering

This site has practically no topsoil and the rocks which are exposed consist of parts which have been discolored brown and parts which are comparatively fresh. Weathering and discoloration along planes of discontinuity such as joints and cracks are prominently seen to depths of about 10 m.

(ii) Surface Deposits

- Alluvial deposit

Alluvial deposit, according to the results of Drillhole BGA-3 made in the river bed downstream of the dam site, has a thickness of approximately 6 m. This deposit consists of sand-bearing gravel with gravels of diameters from 5 to 30 cm as main.

- Talus Deposit

Talus deposit is distributed only in small scale at the foots of mountains on both banks, thicknesses generally being not more than 5 m.

(iii) Ground-water

The final water levels in the drillholes made at the dam site are as shown in Figure 7-9. Ground-water levels are deep down on both banks, being at a depth of 46 m at Drillhole BGA-1 on the left bank, and 47 m at Drillhole BGA-2 on the right bank. The ground-water levels on both banks, although slightly deep down, rise in accordance with topography.

(iv) Permeability

At the dam site, permeability by Lugeon tests utilizing drillholes have been conducted so far on a total of 243 m in 50 stages at 3 drillholes. These were performed on foundation rock excepting surface deposits.
The results of Lugeon tests are as described below.

- Right Bank of Dam

According to the results of Drillhole BGA-2, parts of high permeability with Lugeon values (hereinafter "Lu") of 30 or over exist at close to the ground surface down to 25 m and in the section from 45 to 55 m. From a depth of 70 m and beyond, impermeability of Lu = 1 and under is indicated.

- River Bed

Lugeon tests on bed rock at the river bottom were carried out by using Drillhole BGA-3 and the test results are as follows;

0 m to 6 m is sand and gravels of alluvial deposit. The permeability of bedorck is generally very low of 2 Lu ~) Lu excepting 10 Lu at the test section between 17 m to 22 m.

- Left Bank of Dam

According to the results of tests at Drillhole BGA-1, parts of high permeability of Lugeon values Lu = 30 and over exist from the surface to a depth in the vicinity of 37 m. From a depth of 67 to 77 m, there is a section of high permeability of Lu = 30 and over.

(c) Engineering Geological Assessments

Judged by the geological conditions on the ground surface and results of drilling including permeability tests, the engineering geological assessments below may be made on the dam site.

(i) The Yusufeli Formation distributed at the dam site is composed of hornfels of slate and sandstone origin. Although joints and cracks are slightly developed in these rocks, since they comprise hard and dense rock and since parts of strong weathering are limited to several meters near the surface, they are judged to be of CM-CH class according to Japanese CRIEPI Rock Classification, and there is ample bearing power as a foundation for a gravity type concrete dam of height 74 m. Because, the results of uniaxial compression tests carried out by using two (2) samples of BGA-3 show 828 kgf/cm^2 to 1,000 kgf/cm^2.

(ii) Joints and cracks exist as discontinuity planes in the foundation rock, while faults have not been confirmed. At the abutments on both banks, strongly weathered parts are seen to depths of 10 m along joint and crack planes. The İkizdere granitic rocks which are widely distributed immediately downstream of the dam site are very hard and dense themselves, but horizontal and vertical joints are prominently developed, and the surface layer portion is loosened as a whole.
Immediately downstream of the left-bank side of the dam site there is a dike of quartz porphyry existing as intrusive rock in the Yusufeli Formation. It is a small-scale dike of width approximately 100 cm, and the intrusion plane is in more or less tight contact.

(iii) According to the results of Lugeon tests, a part of high permeability of Lu = 30 and over is seen in the section of depth from the ground surface of 25 to 37 m, but deeper than this, low permeability or impermeability is indicated as a whole. On the other hand, the basement rock under the river bed is fresh and the permeability is assumed to be extremely low. The ground-water table is found in the depth of 35 to 40 m below the crest elevation and it is ascending in accordance with the slape of the dam axis.

The bedrock at this site consists of hard, dense hornfels, the permeability of the bedrock being governed by the previously-mentioned discontinuity planes such as joints.

Consequently, it is thought possible for water-stop treatment to be amply provided for zones of high permeability with cement grouting, the treatment which is generally used.

(iv) Landslides are not seen in the vicinity of the dam site, and talus deposit and alluvial deposit make up surface deposits, their thicknesses being less than 6 m. These deposits will be of no hindrance in excavation for the dam.

(4) Powerhouse

(a) Topography

For the power station, an underground powerhouse is planned to be constructed in the mountain on the left bank downstream of the dam.

This underground powerhouse would be located under the slope facing north with the overburden of original ground from the surface to the powerhouse 115 to 160 m.

(b) Geology

Figure 7-10 shows geological condition for the powerhouse site. The Yusufeli Formation consist of hornfels is distributed at the underground powerhouse site similarly to the dam site. Although joints and cracks are slightly developed, these comprise massive, hard bedrock, while parts of strong weathering (axidated cracky zones) are limited within 80 meters below the surface.

According to the result of BGA-15, the RQD value is from 60 to 80% close to the powerhouse site, permeability of the bedrock below 80 m depth such as 8 Lu to 0 Lu. This data suggest the bedrock below 80 m is tight rock.

In surveys made up to this time, prominent faults have not been confirmed at the powerhouse site and its surroundings. Prominent joints with directionality's are not seen either.

This underground powerhouse is located near the geological boundary (intrusion plane) between the Yusufeli Formation and the İkizdere granitic rocks, the boundary between the two being more or less tight, with the rocks comparatively hard.

(c) Engineering Geological Assessments

Judging by the geological conditions on the ground surface and the results of investigations such as by Drillhole BGA-15 provided at the underground powerhouse site, the engineering geological assessments below can be made.

(i) Prominent faults are not found at the powerhouse site and its surroundings.

(ii) According to the results of drilling carried out up to this time, the powerhouse site and its surroundings are composed of hornfels of the Yusufeli Formation similarly to the dam site. Although joints and cracks are slightly developed, the rock is thought to be hard and dense.
Considered from such a condition of the bedrock, it is thought there will be no problem geology-wise to make excavation of an underground cavern for the powerhouse difficult at this time.

(iii) According to the results of Lugeon tests at Drillhole BGA-15, deep parts are mostly difficulty permeable or impermeable with Lugeon value 5 or under, and low permeability is indicated as a whole. Therefore, it is estimated that the quantity of ground-water (spring water) running into the underground cavern from the powerhouse surroundings will be small.

(iv) In the vicinity of the underground powerhouse site, there is only one Drillhole BGA-15 on the left bank of the dam site which has been bored. Accordingly, before starting on detailed design hereafter, it will be necessary to carry out drilling investigation to make clear the exact state of the bedrock, permeability, and hydrogeological conditions at the powerhouse location.

(5) Tailrace Tunnel

(a) Topography

The tailrace is to be a tunnel of total length approximately 4,500 m extending northeast to southwest from the underground powerhouse on the left bank of the Berta river.
Since this tunnel will pass under (at around EL. 390 m) a large mountain of elevations from 600 to 840 m, the overburden of original ground is comparatively thick at 200 to 450 m. Even at a part of thinnest overburden, there is more than 170 m. Landslide which would affect the tailrace tunnel and its outlet are not seen in particular.

(b) Geology

As shown in Figure 7-11, although the Yusufeli Formation is distributed in the vicinities of the underground powerhouse and the outlet of the tailrace tunnel, the İkizdere granitic rocks are distributed at the greater part of the route. It is estimated that the İkizdere granitic rocks appear in a section of approximately 3,700 m out of the total length of the tunnel of approximately 4,500 m.
The Yusufeli Formation is composed of hornfels of slate and sandstone origin similarly to the dam and underground powerhouse sites. These rocks, although joints and cracks are slightly developed, comprise massive and hard rock bodies. The İkizdere granitic rocks consist of granite, and although the rock itself is very hard and dense, horizontal and vertical joints are prominently developed. Further, the tailrace tunnel will cut across the geological boundary between the Yusufeli Formation and the İkizdere granitic rocks, but there is tight contact at the boundary plane, and the rocks are comparatively hard and dense.
Inside these rock bodies, there are minor faults, joints, and cracks as discontinuity planes, but large-scale, prominent faults have not been confirmed to exist.
Thick surface deposits of a degree to affect the tailrace tunnel and its outlet are not seen in particular.

(c) Engineering Geological Assessments

Judging by the geological conditions at the ground surface and the results of boring investigations with Drillhole BGA-15 and SL-2 made at the dam site and boring investigations carried out at the master plan stage, the engineering geological assessments below may be made for the tailrace tunnel route.

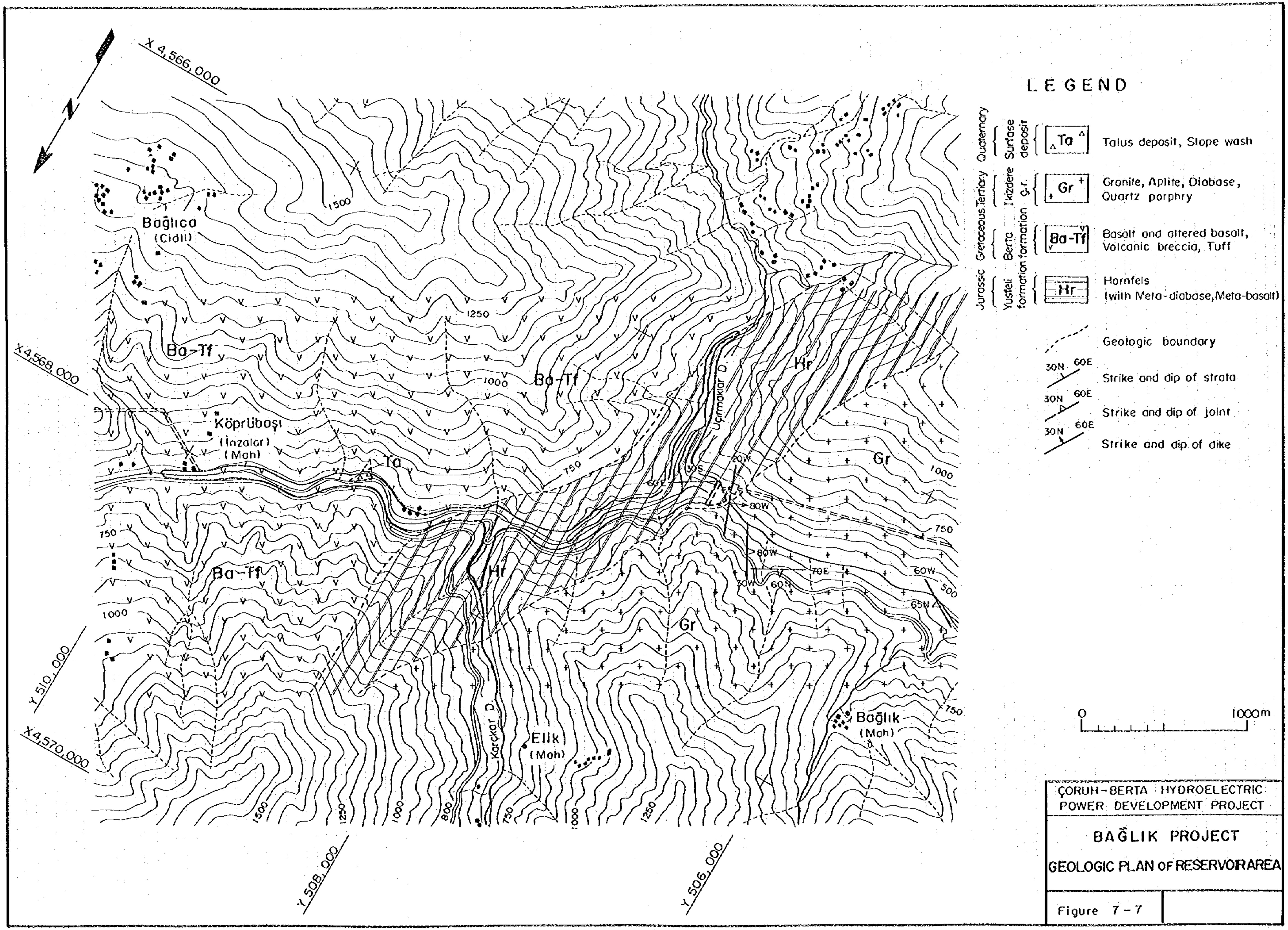
(i) The hornfels of the Yusufeli Formation and granite of the İkizdere granitic rocks along the tailrace tunnel route are hard and dense rocks although joints and cracks are developed at parts. The geological boundary (intrusion plane) between the Yusufeli Formation and the İkizdere granitic rocks tightly contact each other and the rocks are comparatively hard and dense. Consequently, it is thought these geological conditions will not be obstacles to tunnel excavation.

(ii) Although faults of small scale are seen along the tailrace tunnel route, prominent faults which are continuous do not exist. However, there are parts near the small-scale faults and intrusive rocks where it can be seen that bedrock is deteriorated by hydrothermal alteration and joints and cracks are developed. Measures against spring water and appropriate steps such as providing supports will be necessary in tunnel excavation at these spots.

(iii) The condition of ground water along the tailrace tunnel route may be considered to be as follows:

In the distribution area of the Yusufeli Formation and the İkizdere granitic rocks, as can be seen in the investigation results of the Bağlık dam site planned at the master plan stage, the ground-water level rises gradually from the river side toward the mountain side, it is estimated that the ground-water along the tailrace tunnel which passes through mountainland by the Berta river will also be comparatively low. According to results of Lugeon tests carried out at the dam site, the permeability at 100 m and deeper from the ground surface is generally very low.

Therefore, it is estimated that most sections of the tailrace tunnel route will pass through bedrock where ground-water level is comparatively low and, moreover, permeability is also low, while water springing into the tunnel basically is little. However, joints and cracks are developed at parts and where gullies are passed, it may be expected that there will locally be concentrated water springing, and it is considered that thorough going drainage facilities will be necessary in construction.


N
X 4,566,000
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Y 506,000
Bağlıca
(Cidll)
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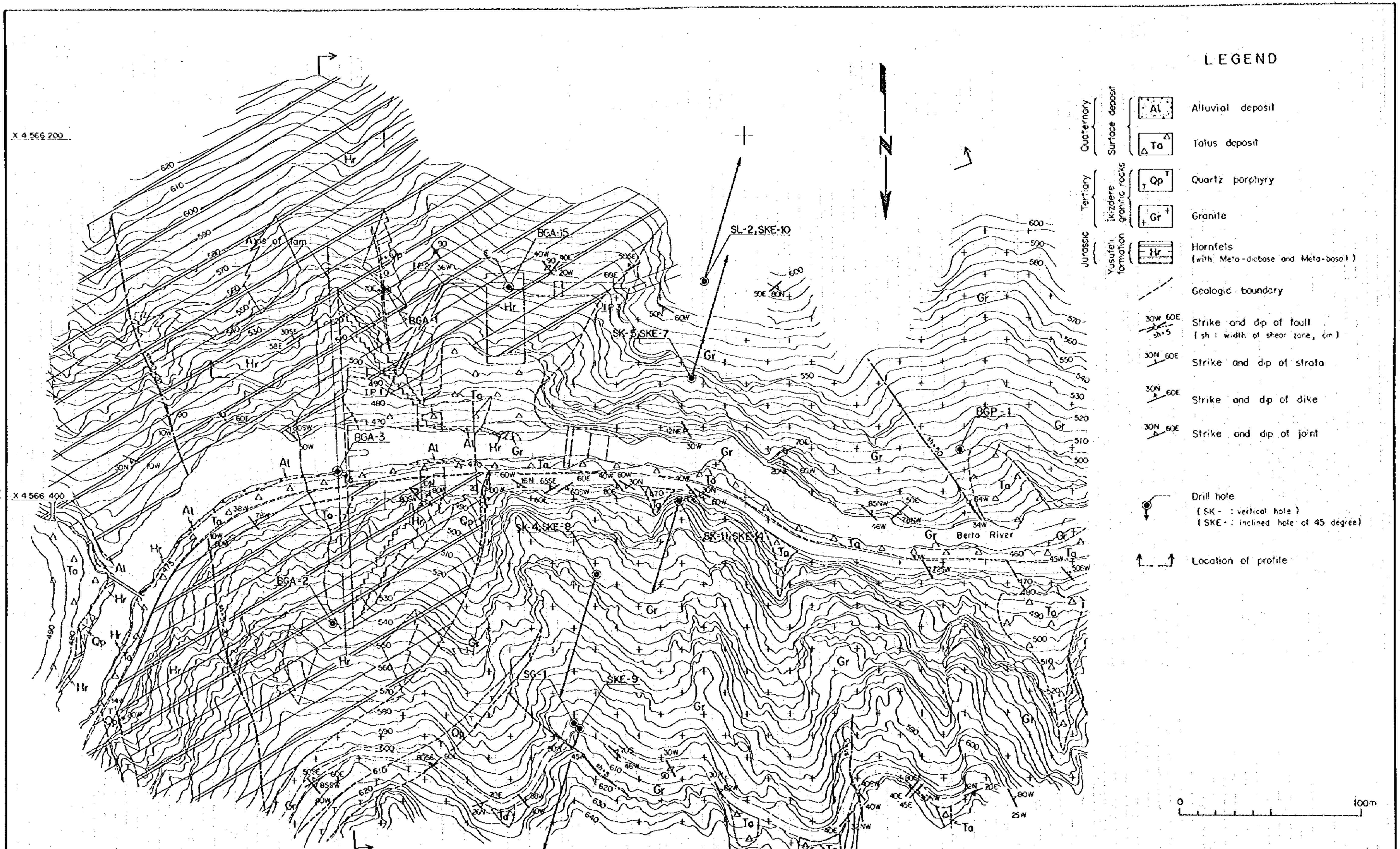
(Mah)
Ba-Tf
Ta
Hr
Gr
Uçurmaklar D.
Karçkar D.
Elik
(Mah)
Bağlık
(Mah)
1500
1250
1000
750
500
30S
60E
20W
80W
70E
60W
30W
60N
65N
LEGEND
Quaternary | Surfase deposit | Ta | Talus deposit, Stope wash
Tertiary | İkizdere g.r. | Gr | Granite, Aplite, Diabase, Quartz porphry
Cretaceous | Berta formation | Ba-Tf | Basalt and altered basalt, Volcanic breccia, Tuff
Jurassic | Yusfeli formation | Hr | Hornfels (with Meta-diabase, Meta-basalt)
Geologic boundary
30N 60E Strike and dip of strata
30N 60E Strike and dip of joint
30N 60E Strike and dip of dike
0 1000m
ÇORUH-BERTA HYDROELECTRIC POWER DEVELOPMENT PROJECT
BAĞLIK PROJECT
GEOLOGIC PLAN OF RESERVOIR AREA
Figure 7-7

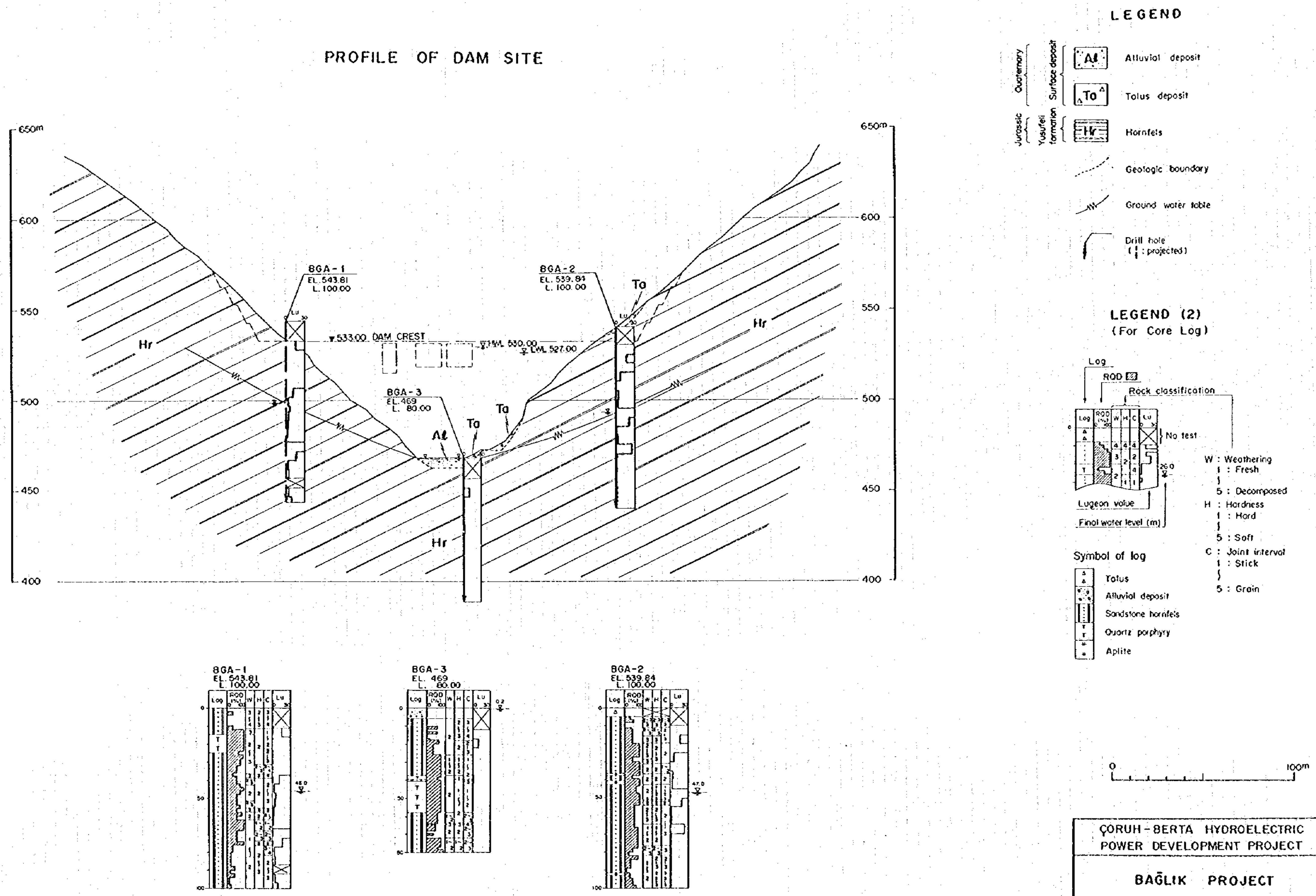


ÇORUH - BERTA HYDROELECTRIC POWER DEVELOPMENT PROJECT

BAĞLIK PROJECT

GEOLOGIC PLAN OF DAM SITE

Figure 7 – 8

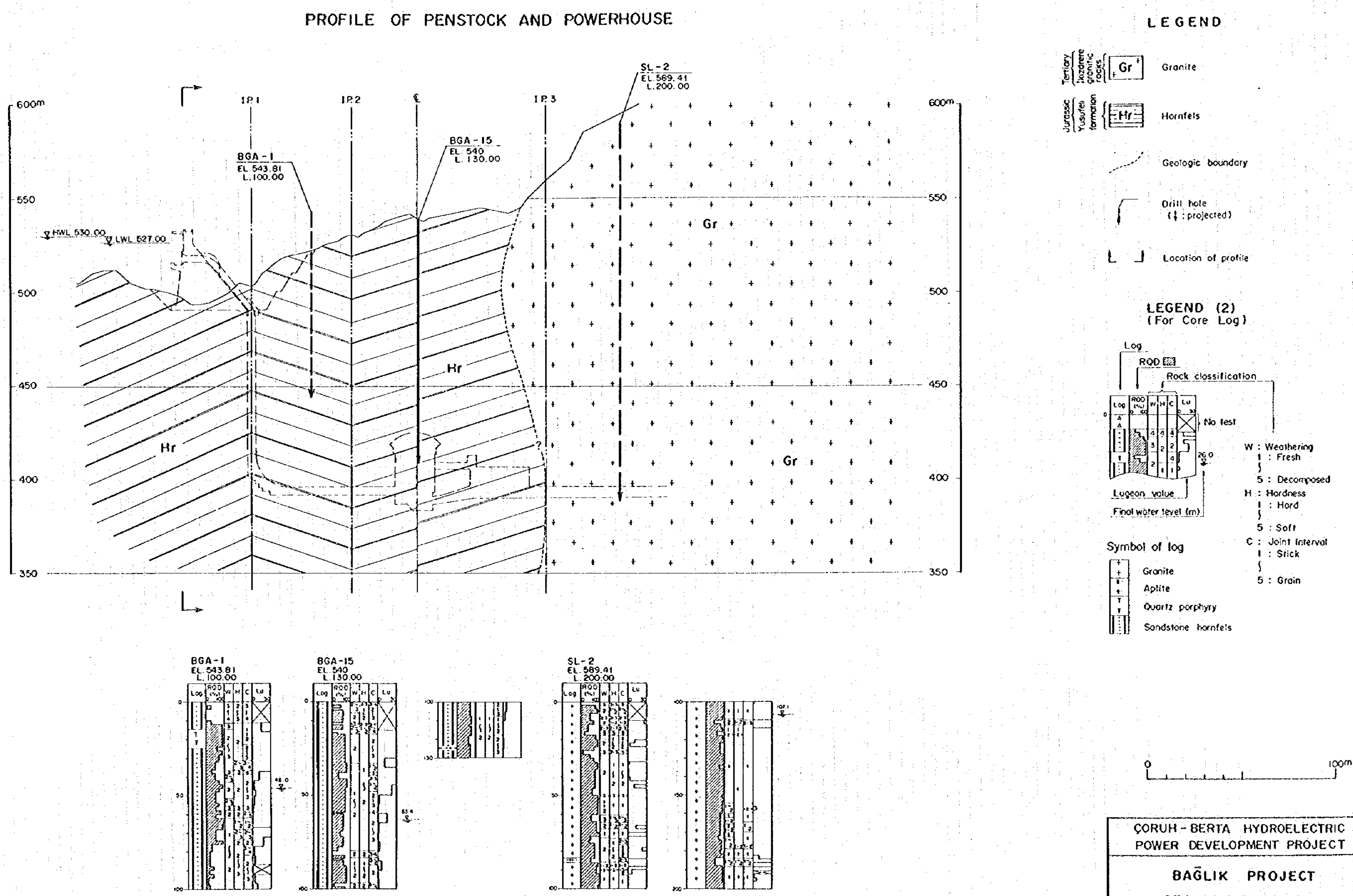


ÇORUH - BERTA HYDROELECTRIC POWER DEVELOPMENT PROJECT

BAĞLIK PROJECT

GEOLOGIC PROFILE OF DAM SITE

Figure 7 - 9

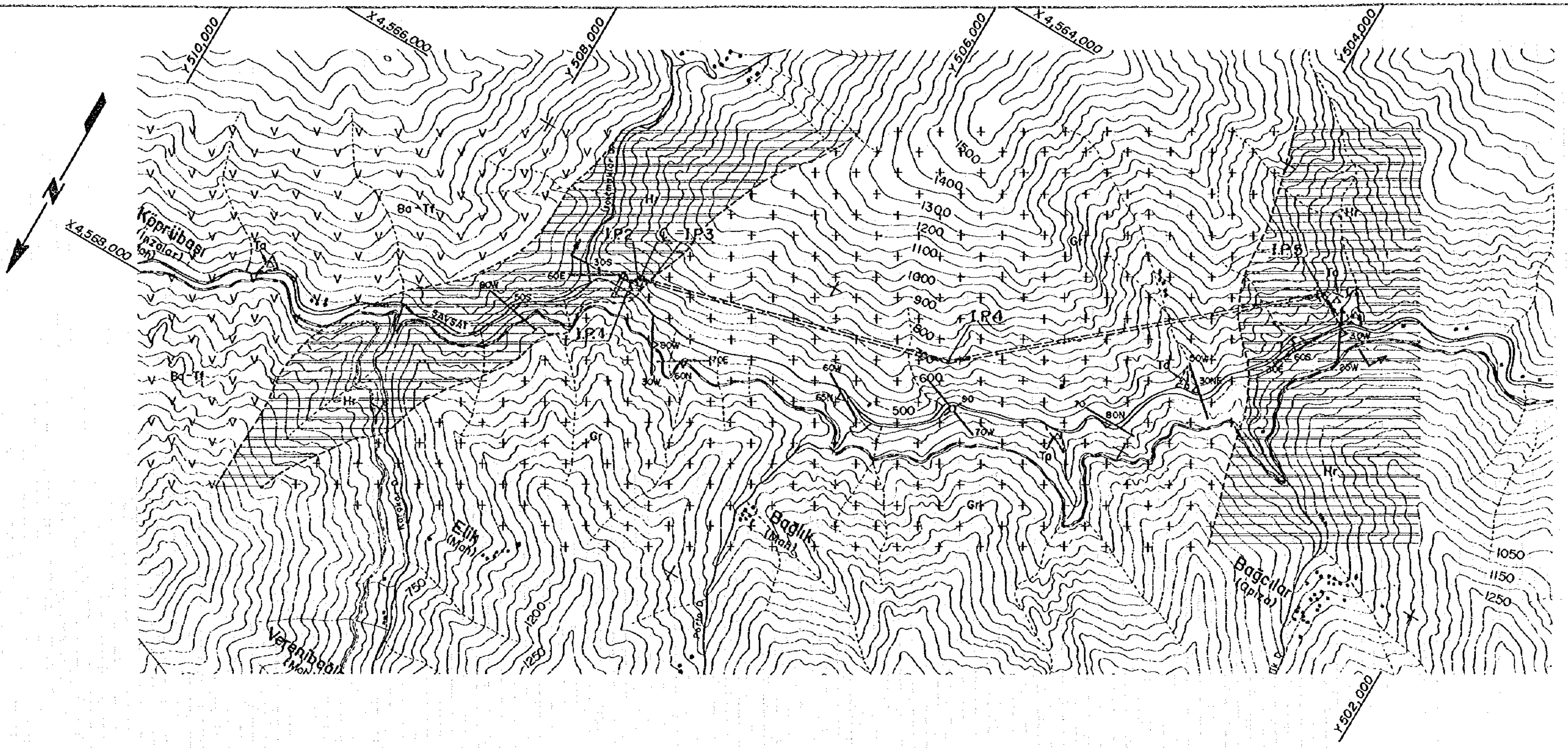


ÇORUH - BERTA HYDROELECTRIC POWER DEVELOPMENT PROJECT

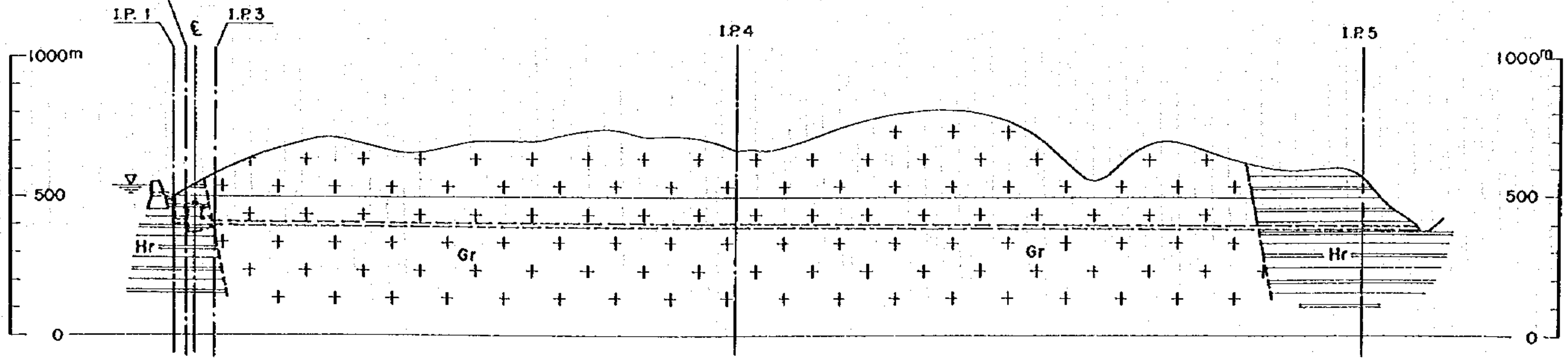
BAĞLIK PROJECT

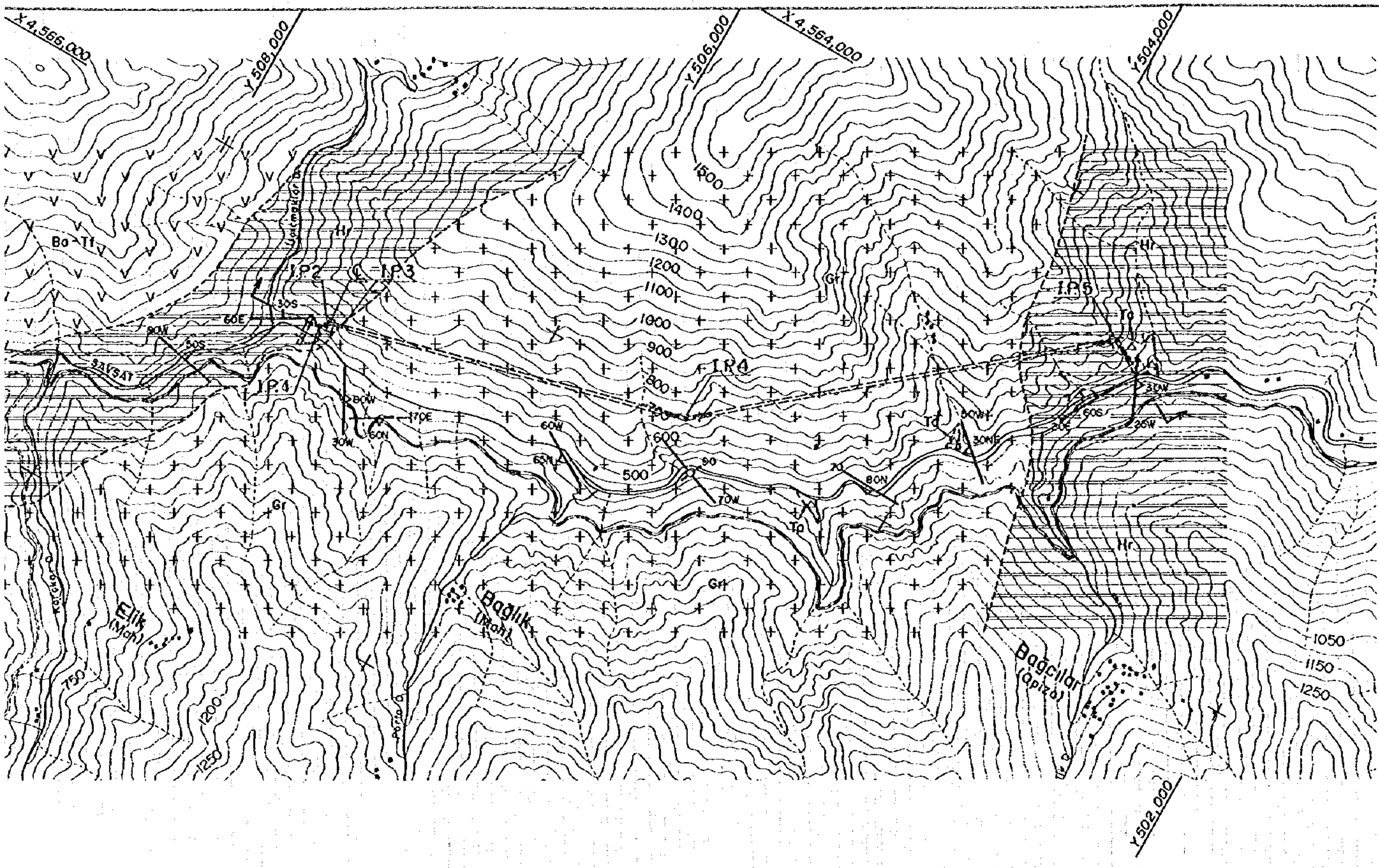
GEOLOGIC PROFILE OF PENSTOCK AND POWERHOUSE

Figure 7 - 10

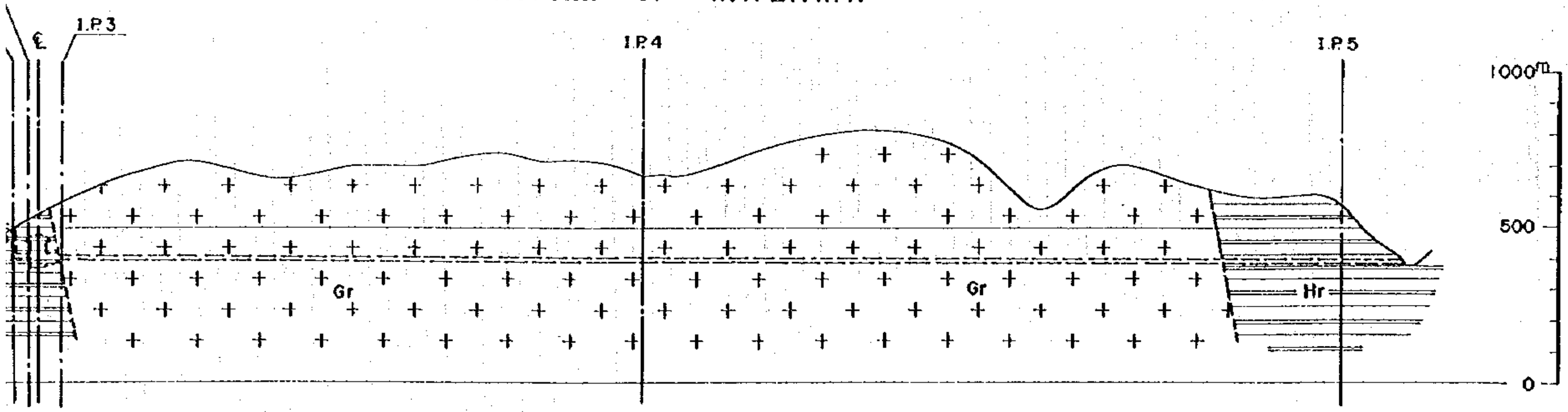


PROFILE OF WATERWAY





PROFILE OF WATERWAY



LEGEND

Quaternary	Surface deposit	Ta	Talus deposit, Slope wash
Tertiary	Kizodere granitic rocks	Gr	Granite, Aplite, Diabase, Quartz porphry
Cretaceous	Berta formation	Ba-Tf	Basalt and altered basalt, Volcanic breccia, Tuff
Jurassic	Yusfeli formation	Hr	Hornfels (with Meta - diabase, Meta - basalt)

- Geologic bounday
- 30N 60E Strike and dip of fault
- 30N 60E Strike and dip of strata
- 30N 60E Strike and dip of joint
- 30N 60E Strike and dip of dike
- Location of profile

0 — 1000m (PLAN)

0 — 1000m (PROFILE)

ÇORUH-BERTA HYDROELECTRIC POWER DEVELOPMENT PROJECT

BAĞLIK PROJECT
GEOLOGIC PLAN AND PROFILE OF WATERWAY (TAIL RACE)

Figure 7-11