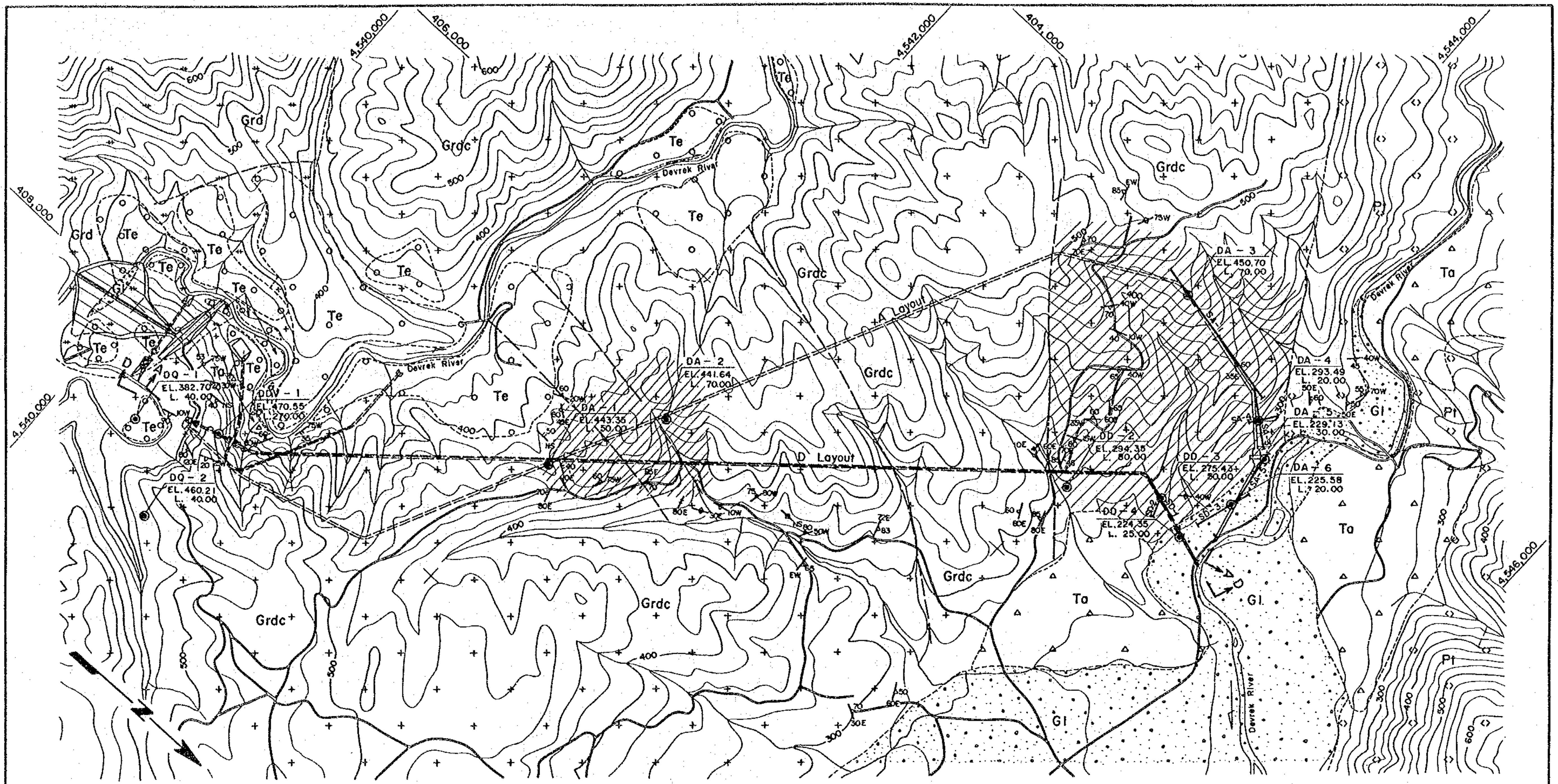


Legend

Quaternary	Gl	Riverbed deposits
	Ta	Talus deposits
	Te	Terrace deposits
Lower Middle Jurrassic	Grd	Granodiorite
	Grdc	Granodiorite (Coarse)
Age Unknown	Pt	Porphyry

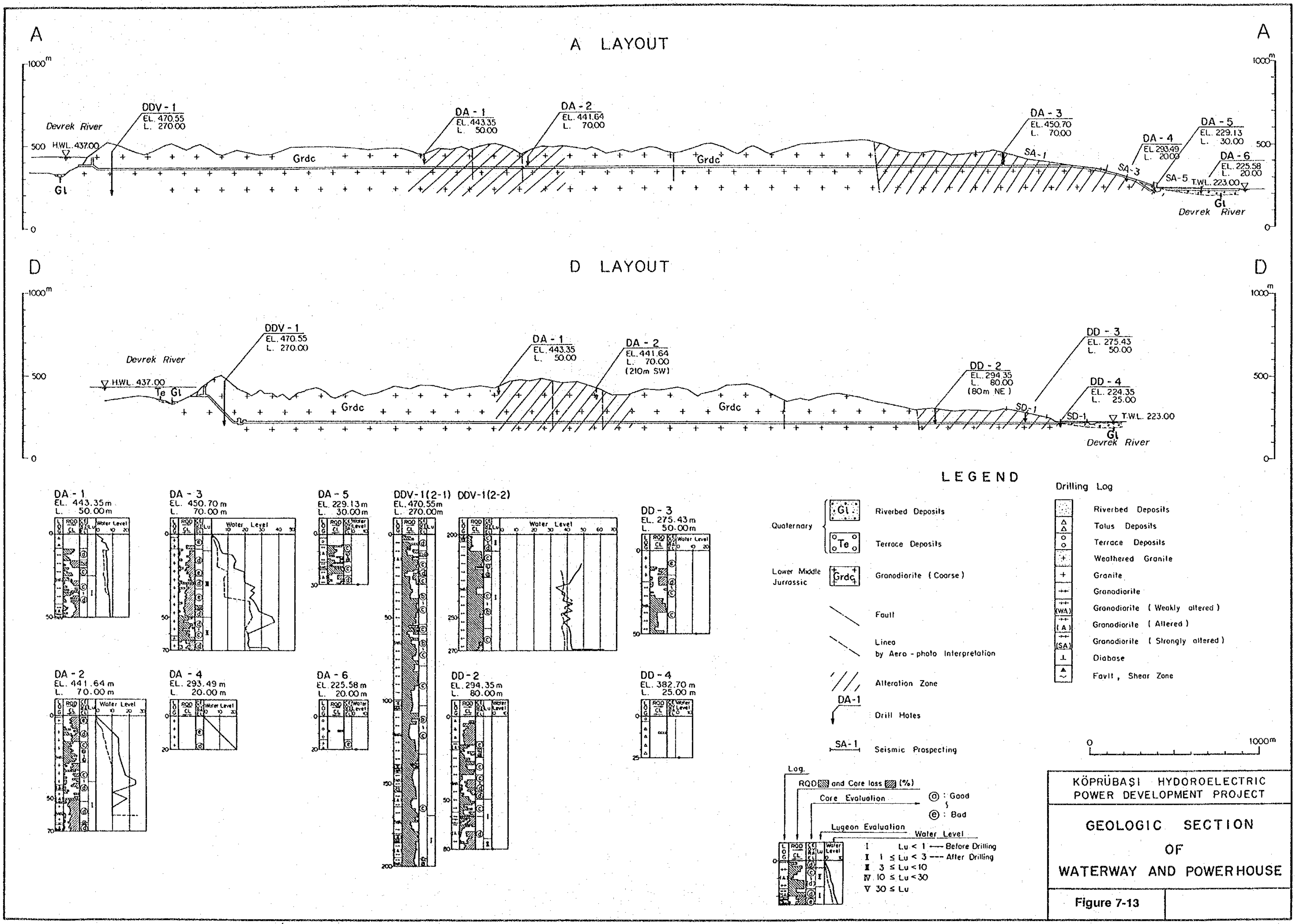
- Geological boundary
- Strike and dip of bedding
- Strike and dip of schistosity
- Strike and dip of joint
- Strike and dip of fault
  sh: width of sheared zone in cm
- Lineament pattern by aero – photo interpretation
- Alteration zone
- DA – 1 EL. 443.35 L. 50.00 Drillholes
- SA-1 Seismic prospecting

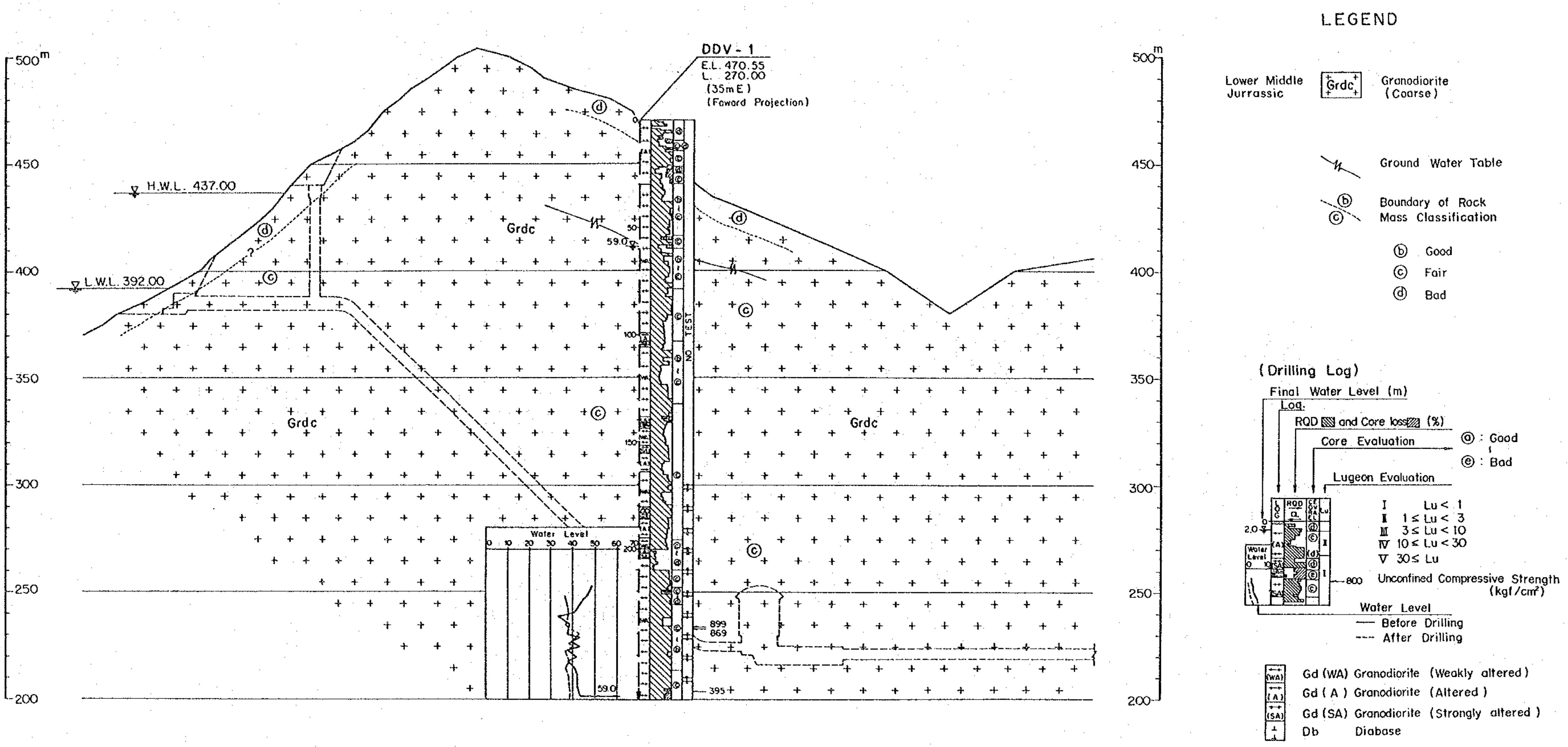
0 1000m

KÖPRÜBAŞI HYDROELECTRIC POWER DEVELOPMENT PROJECT

GEOlOGIC PLAN OF WATERWAY AND POWERHOUSE

Figure 7-12


A LAYOUT
Devrek River
H.W.L. 437.00
DDV - 1
EL. 470.55
L. 270.00
DA - 1
EL. 443.35
L. 50.00
DA - 2
EL. 441.64
L. 70.00
DA - 3
EL. 450.70
L. 70.00
DA - 4
EL. 293.49
L. 20.00
DA - 5
EL. 229.13
L. 30.00
DA - 6
EL. 225.58
L. 20.00
Grdc
SA-1
SA-3
SA-5
T.W.L. 223.00
Gl
D LAYOUT
DDV - 1
EL. 470.55
L. 270.00
DA - 1
EL. 443.35
L. 50.00
DA - 2
EL. 441.64
L. 70.00
(210m SW)
DD - 2
EL. 294.35
L. 80.00
(80m NE)
DD - 3
EL. 275.43
L. 50.00
DD - 4
EL. 224.35
L. 25.00
H.W.L. 437.00
Te Gl
SD-1
T.W.L. 223.00
DA - 1
EL. 443.35 m
L. 50.00 m
DA - 3
EL. 450.70 m
L. 70.00 m
DA - 5
EL. 229.13 m
L. 30.00 m
DDV-1(2-1) DDV-1(2-2)
EL. 470.55 m
L. 270.00 m
DD - 3
EL. 275.43 m
L. 50.00 m
DA - 2
EL. 441.64 m
L. 70.00 m
DA - 4
EL. 293.49 m
L. 20.00 m
DA - 6
EL. 225.58 m
L. 20.00 m
DD - 2
EL. 294.35 m
L. 80.00 m
DD - 4
EL. 382.70 m
L. 25.00 m
Water Level
LEGEND
Quaternary
Gl Riverbed Deposits
Te Terrace Deposits
Lower Middle Jurassic
Grdc Granodiorite (Coarse)
Fault
Linea by Aero - photo Interpretation
Alteration Zone
DA-1 Drill Holes
SA-1 Seismic Prospecting
Drilling Log
Riverbed Deposits
Talus Deposits
Terrace Deposits
Weathered Granite
Granite
Granodiorite
Granodiorite (Weakly altered)
Granodiorite (Altered)
Granodiorite (Strongly altered)
Diabase
Fault, Shear Zone
Log.
RQD and Core loss (%)
Core Evaluation
Ⓐ : Good
Ⓔ : Bad
Lugeon Evaluation
Water Level
I Lu < 1 —— Before Drilling
II 1 ≤ Lu < 3 ---- After Drilling
III 3 ≤ Lu < 10
IV 10 ≤ Lu < 30
V 30 ≤ Lu
0 1000m
KÖPRÜBAŞI HYDROELECTRIC POWER DEVELOPMENT PROJECT
GEOLOGIC SECTION OF WATERWAY AND POWERHOUSE
Figure 7-13



Grouping of Rock Classification

Symbol Mark of Grouping	Rock Classification* for Drilling Core	Remarks
ⓐ	W • 1 H • 1 C • 1	Rock condition is very hard and fresh, and consists of massive blocks without cracks.
ⓑ	W • 1 ~ 2 H • 2 ~ 3 C • 1 ~ 2	Rock condition is hard and fresh, and contains relatively less cracks.
ⓒ	W • 1 ~ 3 H • 2 ~ 3 C • 1 ~ 4	Rock condition is relatively hard but contains many small cracks. A little altered properly due to weathering.
ⓓ	W • 2 ~ 4 H • 3 ~ 4 C • 3 ~ 5	Considerably weathered rock mass. Rock mass has many cracks and rock can be crushed easily from any part other than crack.
ⓔ	W • 4 ~ 5 H • 4 ~ 5 C • 4 ~ 5	Rock condition is remarkobly soft. The rock forming minerals and grains are weathered and altered to second minerals. Fault or crushed zone.

Note * Detailed breakdown of "W", "H" and "C" are shown in the right table.

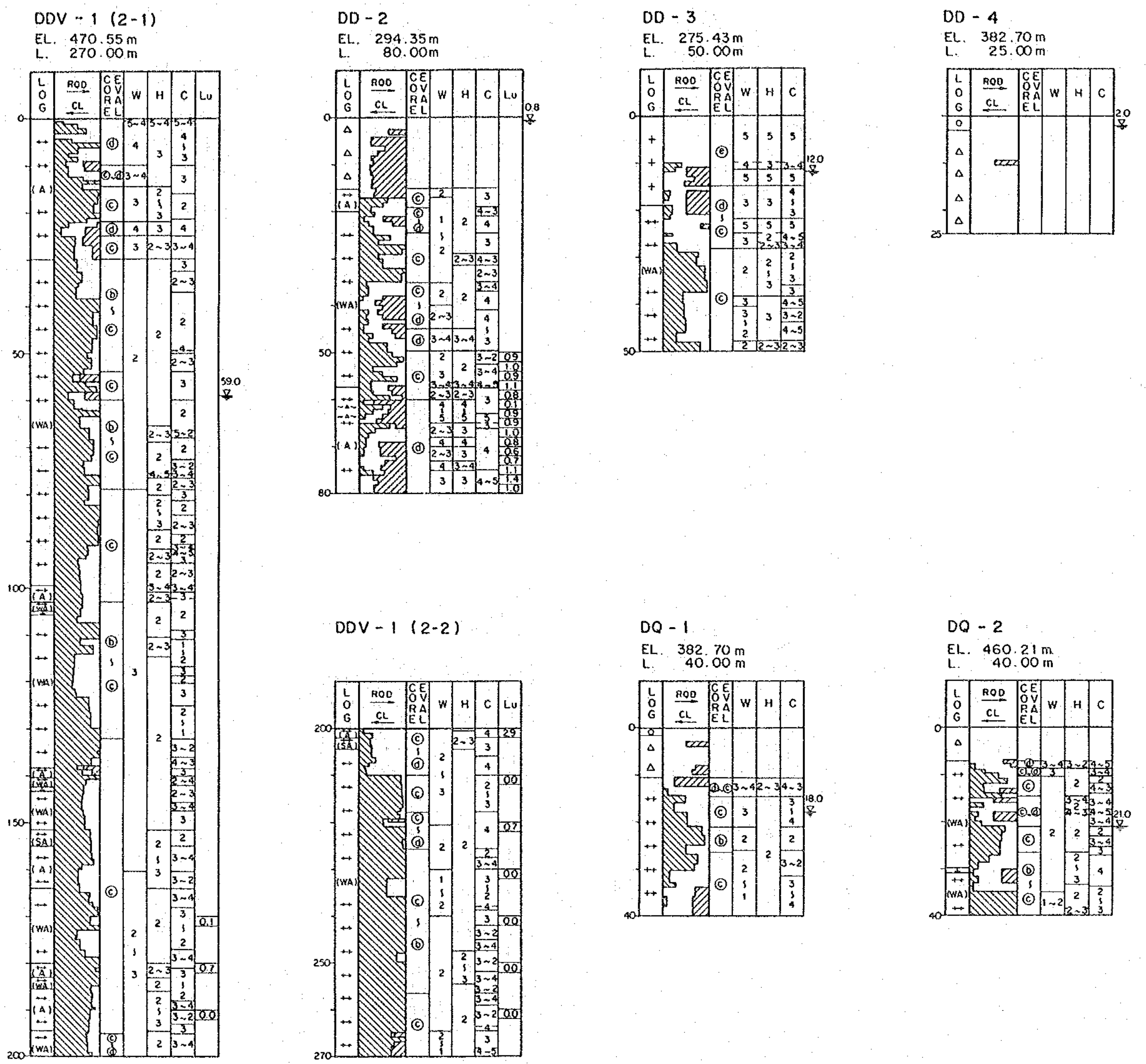
Standard of Rock Classification for Drilling Core

W	Weathering	H	Hardness	C	Interval of Cracks
1	Very fresh. No weathering of mineral component.	1	Very hard. Broken into knifeedged pieces by strong hammer blow	1	Over 30cm
2	Fresh. Some minerals are weathered slightly. Usually no brown crack.	2	Hard. Broken into pieces by strong hammer blow.	2	10 ~ 30 cm
3	Fairly fresh. Some minerals are weathered. Cracks are stained and with weathered material.	3	Somewhat brittle. Brokem into pieces by medium hammer blow.	3	3 ~ 10 cm
4	Weathered. Fresh portions still remain partially.	4	Very brittle. Easily broken into pieces by medium hammer blow.	4	1 ~ 3 cm
5	Strongly weathered. Most minerals are weathered and altered to second minerals.	5	Soft. Able to dig with hammer.	5	Under 1 cm

KÖPRÜBAŞI HYDROELECTRIC POWER DEVELOPMENT PROJECT

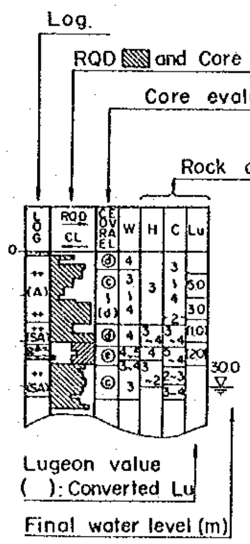
GEOLOGIC SECTION OF UNDERGROUND POWERHOUSE

Figure 7-14



LEGEND

Rb	Riverbed Deposits (Clay)
Rb	Riverbed Deposits (Silt)
Rb	Riverbed Deposits (Sand)
Rb	Riverbed Deposits (Gravel)
Ta	Top Soil
Re	Residual Soil
Te	Terrace Deposits
Dg	Weathered Granite
Gr	Granite
Dgd	Weathered Granodiorite
Gd	Granodiorite
Gd (WA)	Granodiorite (Weakly altered)
Gd (A)	Granodiorite (Altered)
Gd (SA)	Granodiorite (Strongly altered)
Fgd	Fine - grained Granodiorite
Db	Diabase
	Core Loss
F	Fault
Shr	Shear zone
Br	Braccia



ⓐ : Good
⌇
ⓔ : Bad

W : Weathering
1 : Fresh
⌇
5 : Decomposed

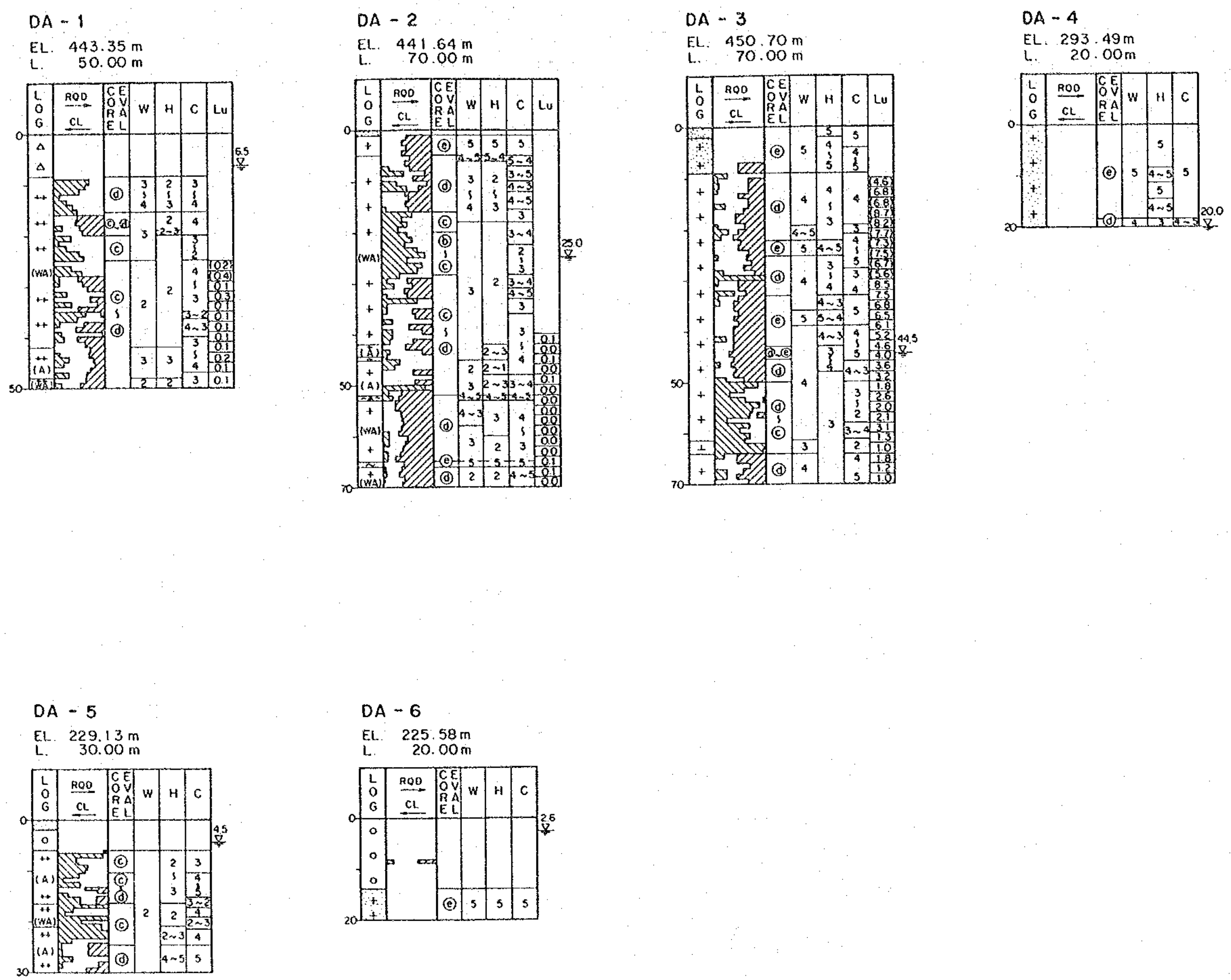
H : Hardness
1 : Hard
⌇
5 : Soft

C : Joint interval
1 : Stick (Over 30cm)
⌇
5 : Grain (Under 1 cm)

KÖPRÜBAŞI HYDROELECTRIC POWER DEVELOPMENT PROJECT

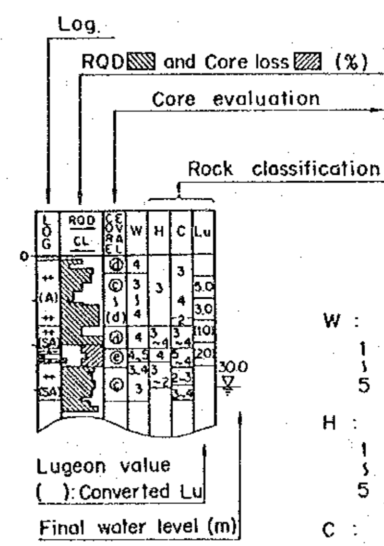
GEOLOGIC LOG OF DRILLHOLES AT D LAYOUT AND QUARRY SITES

Figure 7-15



LEGEND

Rb	Riverbed Deposits	(Clay)
Rb	Riverbed Deposits	(Silt)
Rb	Riverbed Deposits	(Sand)
Rb	Riverbed Deposits	(Gravel)
Ta	Top Soil	
Re	Residual Soil	
Te	Terrace Deposits	
Dg	Weathered Granite	
Gr	Granite	
Dgd	Weathered Granodiorite	
Gd	Granodiorite	
Gd (WA)	Granodiorite	(Weakly altered)
Gd (A)	Granodiorite	(Altered)
Gd (SA)	Granodiorite	(Strongly altered)
Fgd	Fine - grained Granodiorite	
Db	Diabase	
	Core Loss	
F	Fault	
Shr	Shear zone	
Br	Breccia	



W : Weathering
1 : Fresh
5 : Decomposed

H : Hardness
1 : Hard
5 : Soft

C : Joint interval
1 : Stick (Over 30cm)
5 : Grain (Under 1cm)

KÖPRÜBAŞI HYDROELECTRIC POWER DEVELOPMENT PROJECT

GLOLOGIC LOG OF DRILLHOLES AT A LAYOUT

Figure 7-16

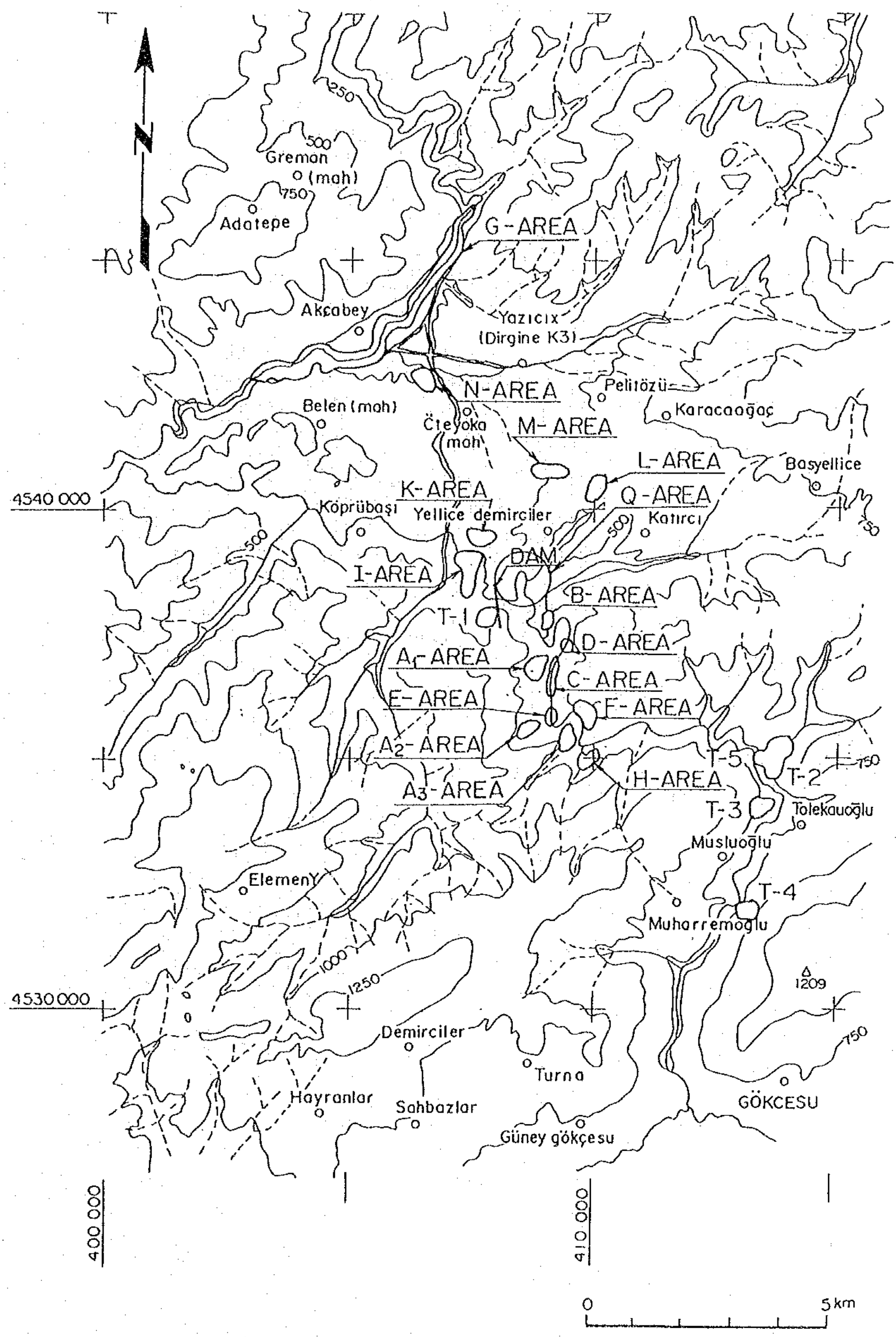
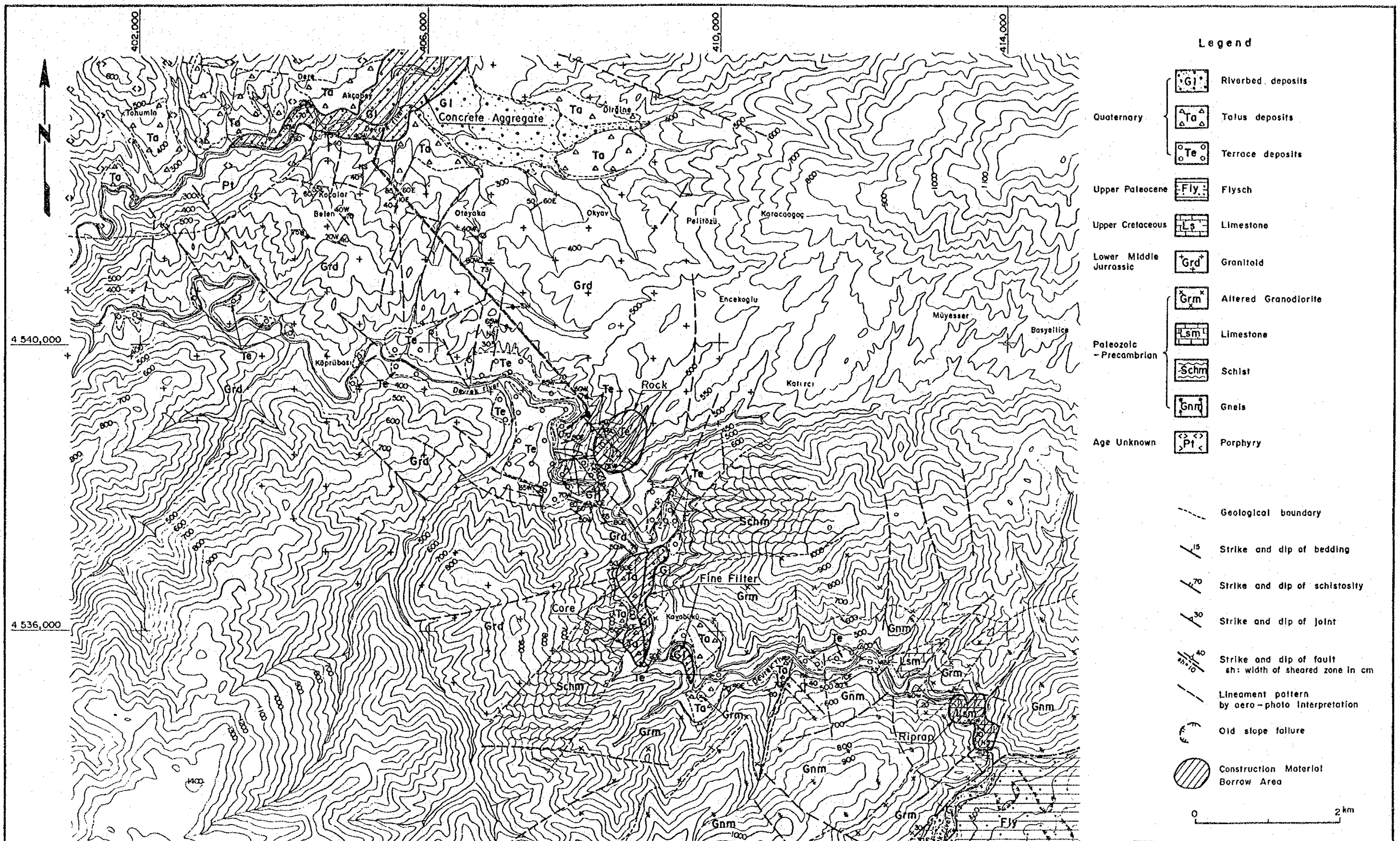


Figure 7-17 Location of DSI's Investigation Areas for Construction Materials



KÖPRÜBAŞI HYDOROELECTRIC POWER DEVELOPMENT PROJECT

LOCATION OF CONSTRUCTION MATERIAL BORROW AREA

Figure 7-18

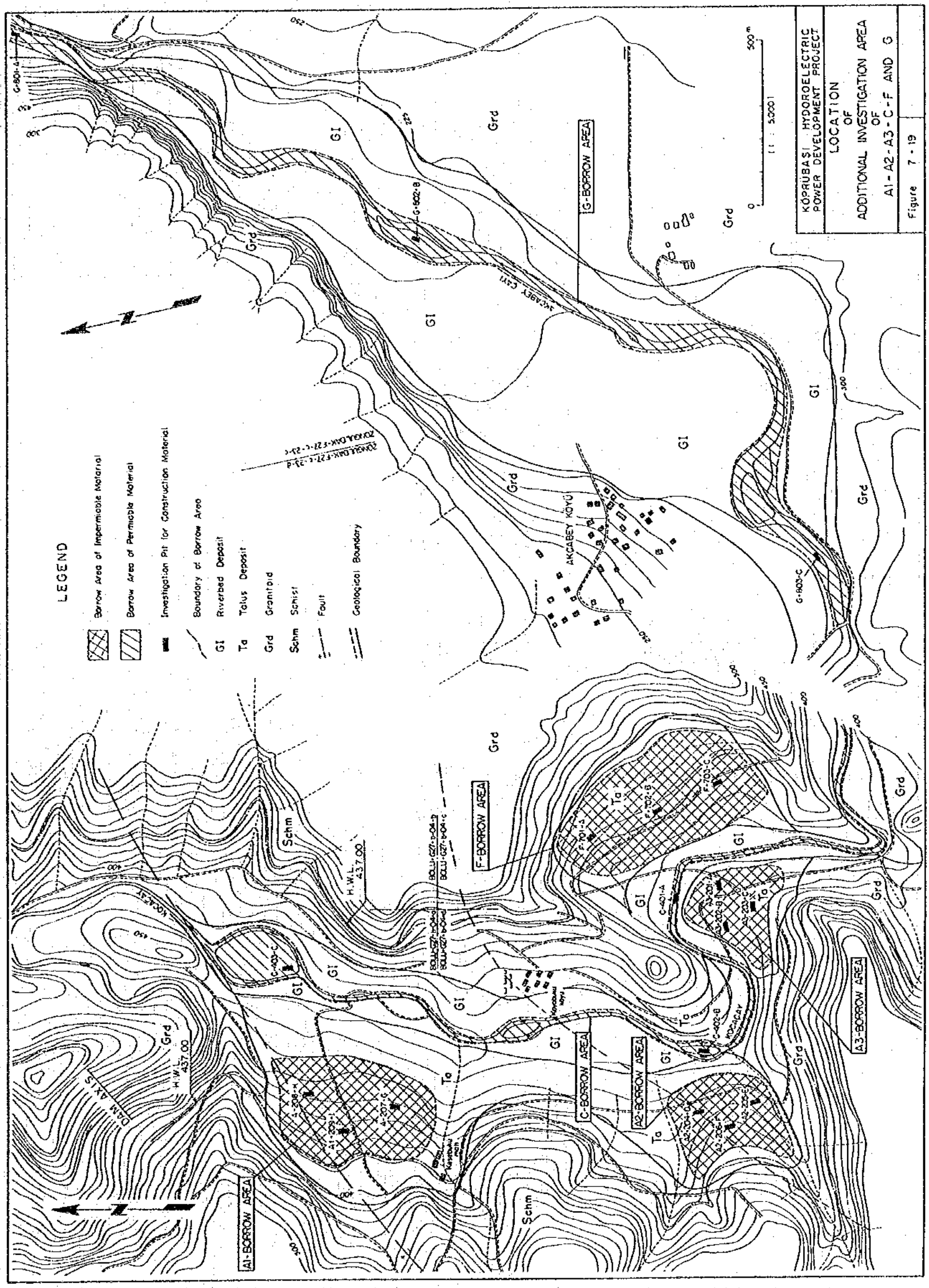


Figure 7-19 Location of Additional Investigation Area of A_1, A_2, A_3, C, F and G

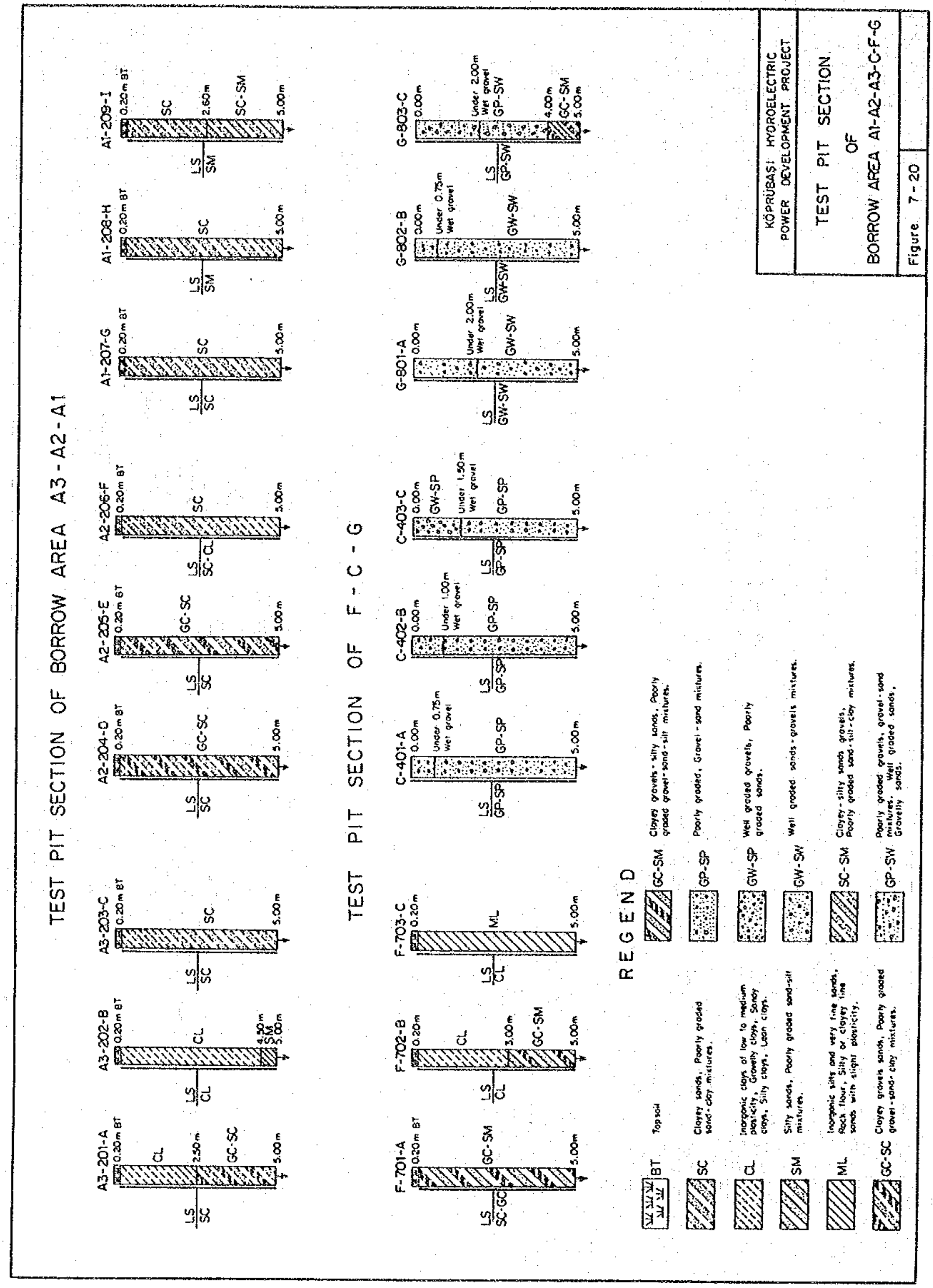


Figure 7-20 Test Pit Section of Borrow Area A_1, A_2, A_3, C, F and G

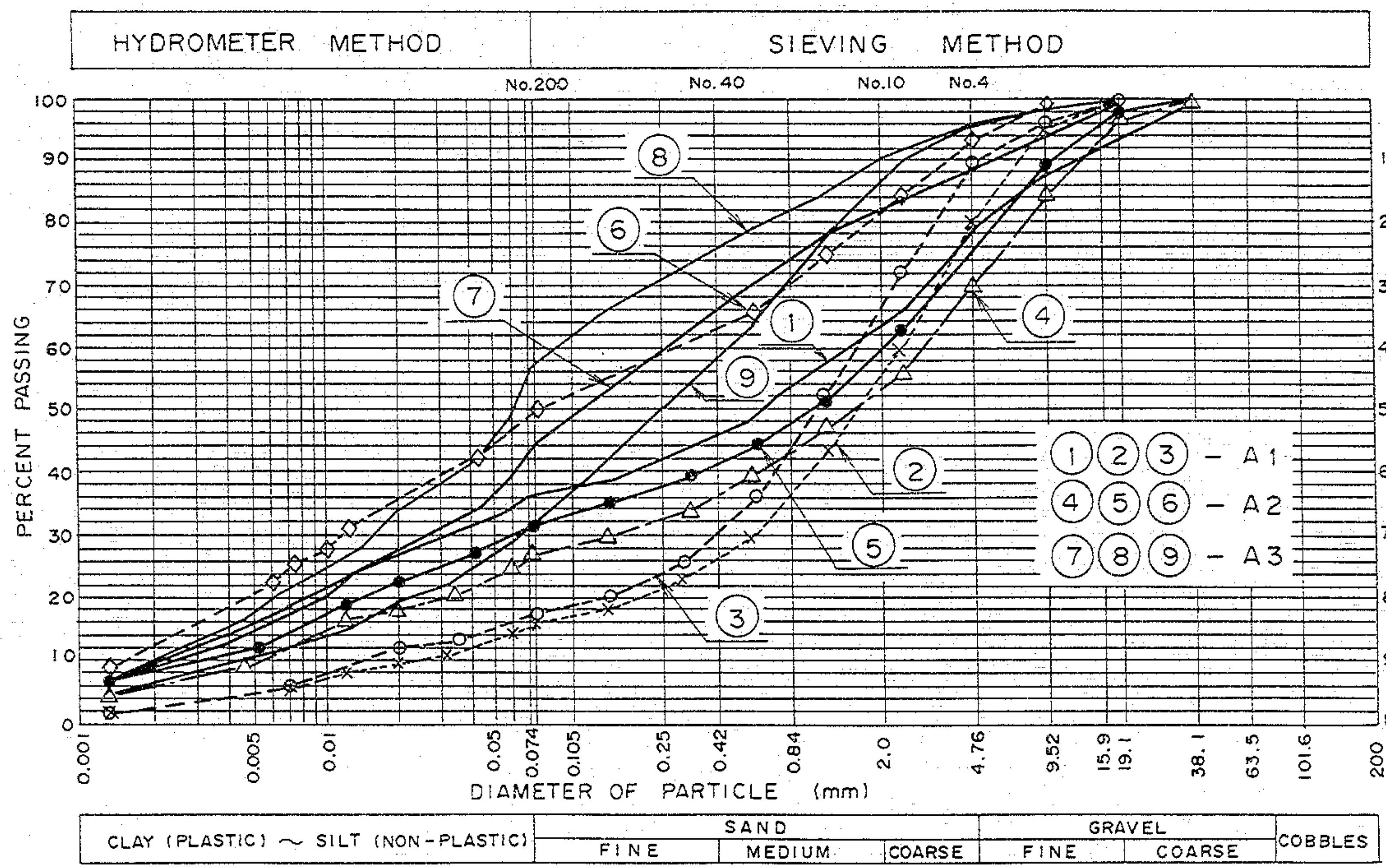


Figure 7-21 Gradation Analysis of Additional Test on A-Area

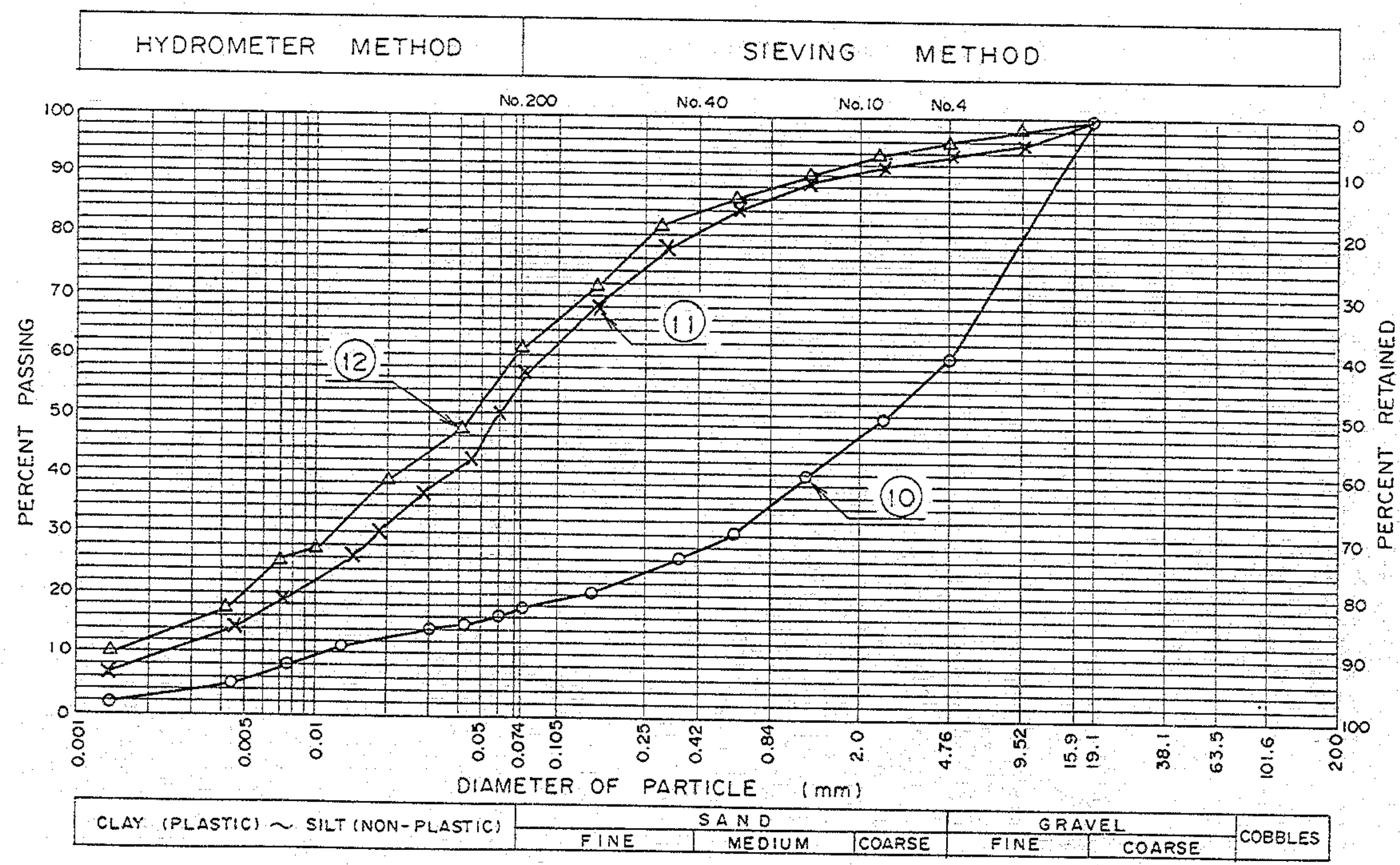


Figure 7-22 Gradation Analysis of Additional Test on F-Area

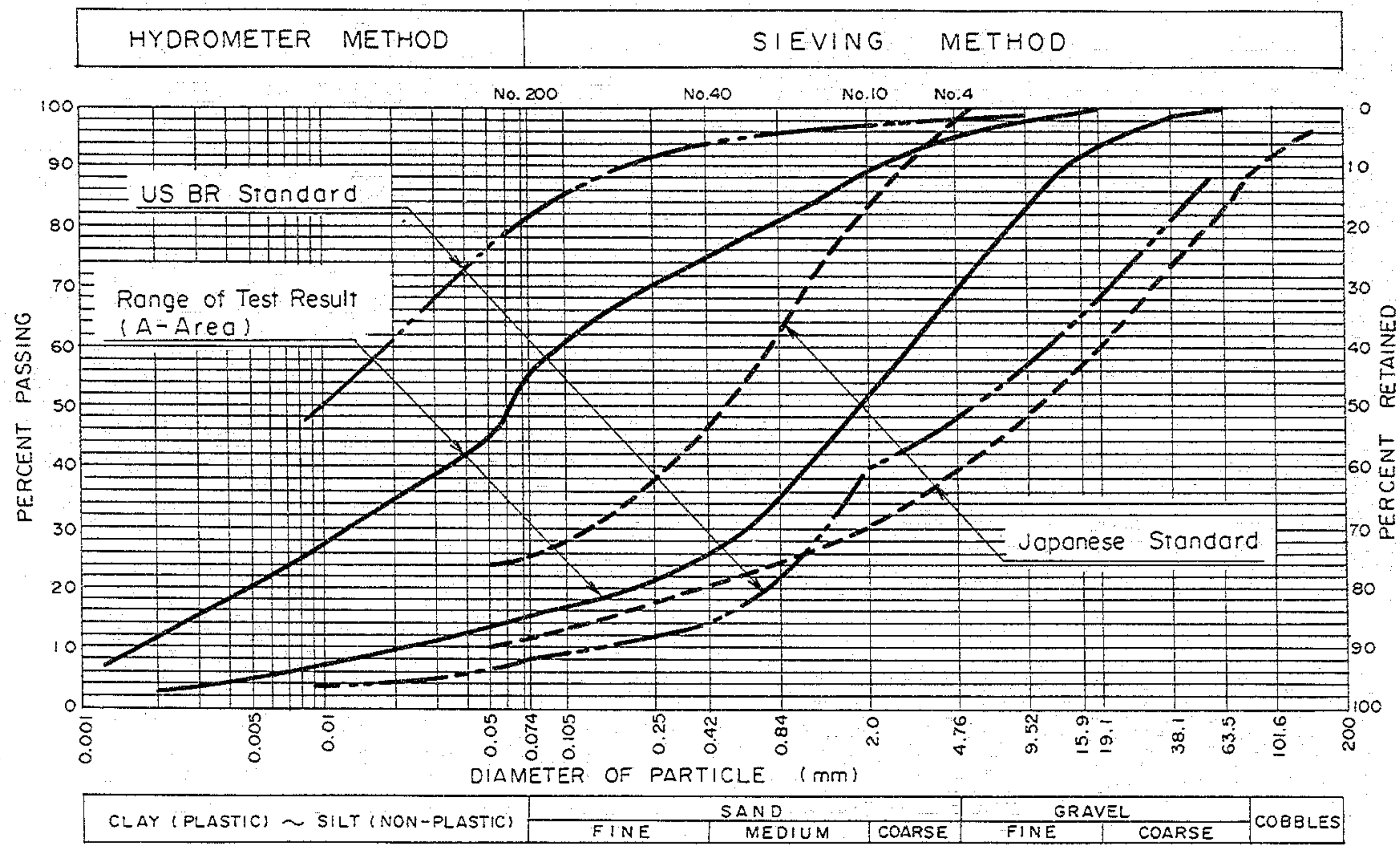
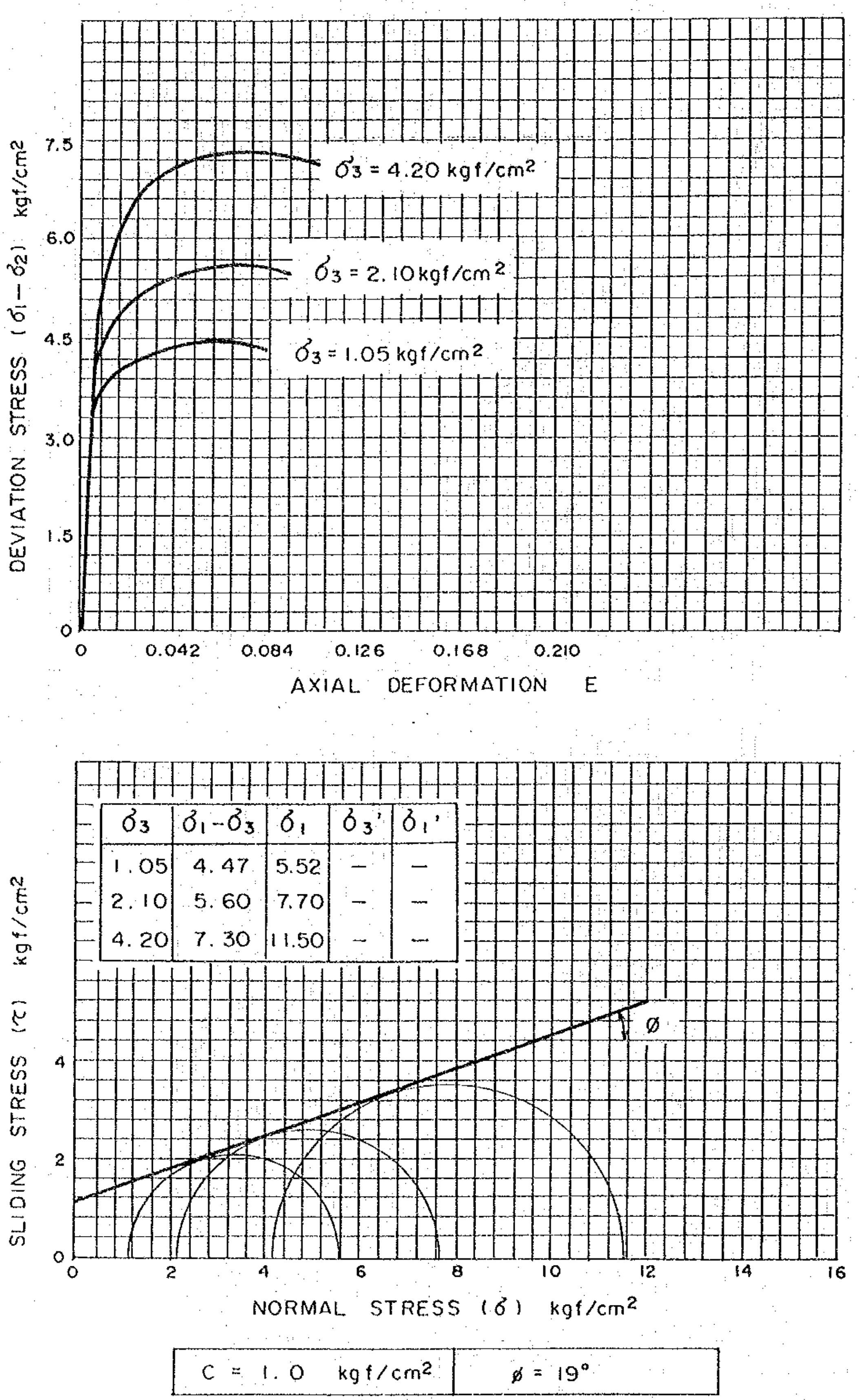


Figure 7-23 Relation between Gradation Test Result and Standard Grain Size Distribution (A-Area)



σ_3	$\sigma_1 - \sigma_3$	σ_1	σ_3'	σ_1'
1.05	4.47	5.52	–	–
2.10	5.60	7.70	–	–
4.20	7.30	11.50	–	–

Figure 7-24 Triaxial Shear Test Result (UU)-example (A-2 Area, Test Number A2.204-d)

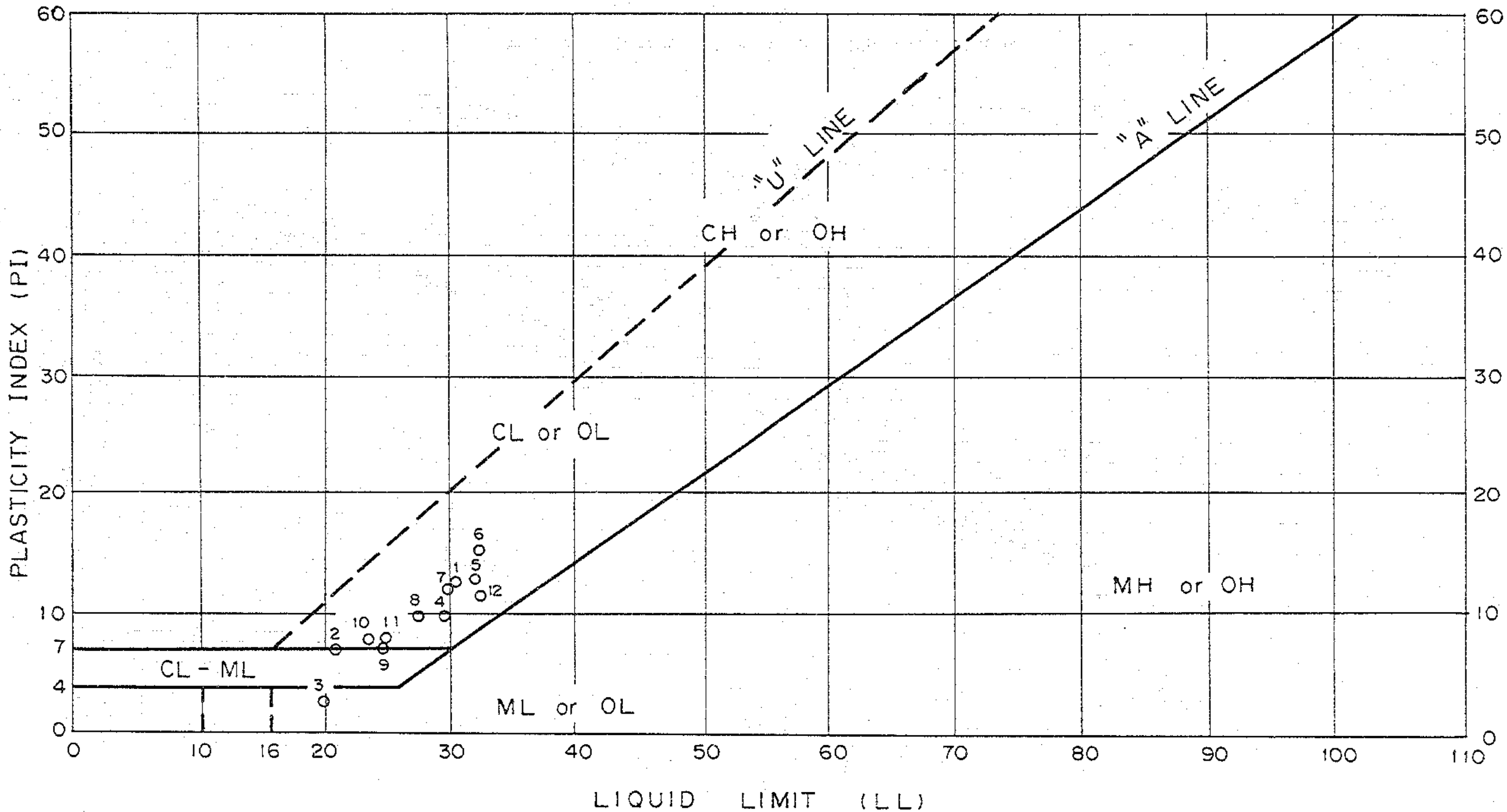


Figure 7-25 Plasticity Chart on Additional Soil Test

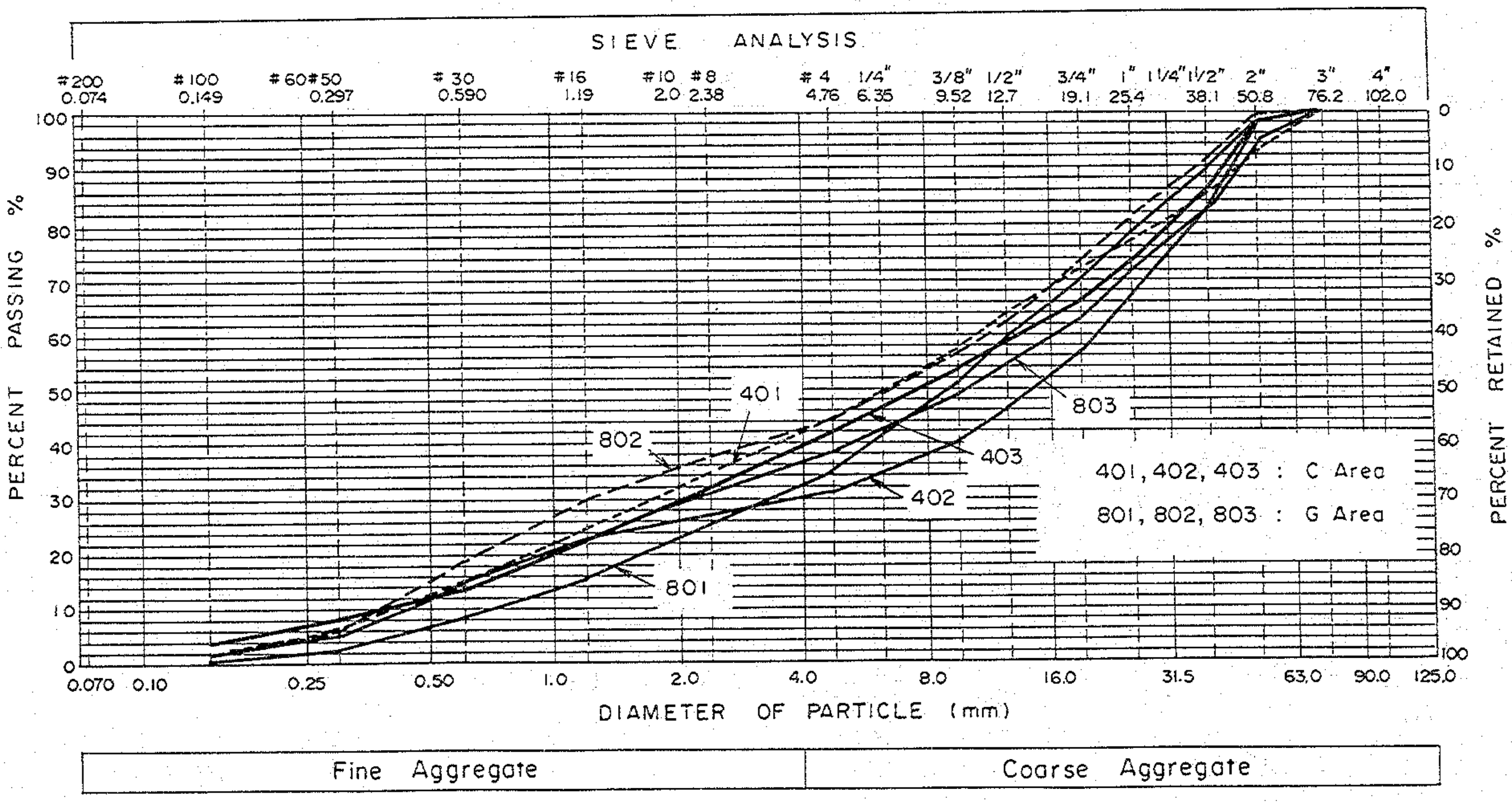


Figure 7-26 Gradation Analysis on Additional Test for C and G Area

Table 7-2 Outline of Additional Geological Mapping

Investigation Site/Area	Investigation Objective	Topographical Map Used	Remark
Damsite and surroundings (including power house site of Case D)	Preparation of engineering geological map for evaluating suitability of dam foundation rock	1/5,000 topographical map	Partially enlarged to about 1/1,000 as necessary and used during reconnaissance
Waterway route (Case A and Case D) and powerhouse site (Case A)	Preparation of engineering geological map for evaluating geological conditions of bedrock and hydrogeological conditions along waterway tunnel route	1/5,000 topographical map	(Ditto)
Limestone distribution area in reservoir area	Preparation of engineering geological map for evaluating waterightness of reservoirs	1/25,000 topographical map (1/5,000 topographical map used as necessary)	Concurrently serves as on-site confirmation of aerial-photo interpretation

Table 7-3 List of Additional Core-drilling Investigations

Drillhole No. (Temporary)	Location	Length (m)	Elevation (m)	Coordinate X	Coordinate Y	Water Measurement	Lugeon Test
DA-1	Headrace tunnel route - Case A	50.0	442.35	407,207.52	4,541,060.37	o	25.0 ~ 50.0 m
DA-2	Headrace tunnel route - Case A	70.0	441.64	406,637.66	4,542,341.05	o	40.0 ~ 70.0 m
DA-3	Surge tank site - Case A	70.0	450.70	404,411.42	4,543,853.42	o	10.0 ~ 70.0 m
DA-4	Penstock route - Case A	20.0	293.49	404,661.93	4,544,544.84	o	-
DA-5	Powerhouse site - Case A	30.0	229.13	404,778.36	4,544,698.57	o	-
DA-6	Tailrace canal route - Case A	20.0	225.58	405,057.20	4,544.721.52	o	-
DDV-1	Powerhouse site - Case D	270.0	470.55	408,206.77	4,540,749.22	o	170.0 ~ 270.0 m
DD-2	Tailrace tunnel route - Case D	80.0	294.35	405,550.55	4,545,050.00	o	50.0 ~ 80.0 m
DD-3	Tailrace tunnel route - Case D	50.0	275.43	405,264.17	4,544,050.41	o	-
DD-4	Tailrace canal route - Case D	25.0	224.35	405,346.89	4,544,646.09	o	-
DQ-1	Quarry site	40.0	382.70	408,426.05	4,540,366.51	o	-
DQ-2	Quarry site	40.0	460.21	408,750.87	4,540,723.95	o	-

Table 7-6 Standard of Rock Classification for Drilling Core

W	Weathering	H	Hardness	C	Interval of Cracks
1	Very fresh. No weathering of mineral component.	1	Very hard. Broken into knifeedged pieces by strong hammer blow.	1	Over 30 cm
2	Fresh. Some minerals are weathered slightly. Usually no brown crack.	2	Hard. Broken into pieces by strong hammer blow.	2	10 ~ 30 cm
3	Fairly fresh. Some minerals are weathered. Cracks are stained and with weathered material.	3	Somewhat brittle. Broken into pieces by medium hammer blow.	3	3 ~ 10 cm
4	Weathered. Fresh portions still remain partially.	4	Very brittle. Easily broken into pieces by medium hammer blow.	4	1 ~ 3 cm
5	Strongly weathered. Most minerals are weathered and altered to second minerals.	5	Soft. Able to dig with hammer	5	Under 1 cm

Table 7-7 Grouping of "Rock Classification"

Symbol Mark of Grouping	Rock Classification* for Drilling Core	Remarks
ⓐ	W = 1 H = 1 C = 1	W : Weathering degree
ⓑ	W = 1 ~ 2 H = 2 ~ 3 C = 1 ~ 2	H : Hardness
ⓒ	W = 1 ~ 3 H = 2 ~ 3 C = 1 ~ 4	C : Interval of cracks
ⓓ	W = 2 ~ 4 H = 3 ~ 4 C = 3 ~ 5	
ⓔ	W = 4 ~ 5 H = 4 ~ 5 C = 4 ~ 5	

Note: * Detailed breakdown of "W", "H" and "C" are shown in Table 7-8.

Table 7-13 Existing test Result of Construction Material (1/2)

Impermeable

Material	Fields	Classification of Soils	Gravel	Soil	Clay	Specific Gravity	Compaction (kg/m3)	Optimum Moisture (%) [10]	Consistency Limit: Liquid Limit(%)	Plastic Limit(%)	Plasticity Index(%)	Grain-size Analysis: -0.005mm (%)	-0.074mm (%)	-4.8mm (%)	Permeability (cm/sec)	Triaxial Compression: C (kg/cm2)	φ (° ′ ″)
A	1	GW-GM,GP-GM,GC	30.3	45.3	30.3	2.77	2.13	9.3	33.2	15.2	18.0	---	47	98	---	---	---
		SP-SM,SC,SC-CL				2.66	1.90	12.8	24.8	16.1	8.7		19	57			
B	1	SW-SM,SC-CL	21.0	44.6	34.4	2.85	2.19	9.1	36.0	18.5	17.5	---	38	83	---	---	---
						2.65	1.87	14.6	29.2	18.1	11.1		26	70			
E	1	SM-SC,SC-CL	22.4	43.4	24.6	2.70	2.08	9.2	32.6	15.1	17.5	---	45	95	---	---	---
						2.67	1.91	12.2	23.5	16.4	7.1		23	57			
F	1	GM-GC	38.5	43.8	17.7	2.82	2.20	8.2	26.5	15.9	10.6	---	23	71	---	---	---
		SW-SM,SM-SC,SM-SP				2.70	2.05	10.7	21.5	14.5	7.0		14	50			
H	1	GP-GM	44.4	41.6	14.0	2.73	2.07	10.0	30.7	19.9	10.8	---	20	66	---	---	---
		SW-SM,SP-SM				2.64	1.88	13.0	---	---	---		9	41			
I	0	GM-MH,GC	19.8	37.1	43.1	2.73	2.14	8.7	44.2	21.8	22.4	---	79	99	---	---	---
		SC-CL,SC,CL				2.62	1.70	19.0	26.7	20.9	5.8		7	38			
L	0	SM-SC,CL	10.0	39.8	50.2	2.71	1.97	12.7	48.9	19.9	29.0	---	76	99	---	---	---
						2.69	1.73	18.6	33.3	22.6	10.7		9	67			
M	0	SC-CL,ML,CL,CH	7.2	32.6	60.2	2.66	1.92	13.0	54.1	22.2	31.9	---	83	99	---	---	---
						2.57	1.64	21.7	33.8	19.1	14.7		48	86			
N	1	SW-SM,SC-CL,CL	8.0	49.3	42.7	2.70	2.08	9.9	40.3	20.5	19.8	---	59	97	---	---	---
						2.65	1.79	16.4	31.1	19.4	11.7		28	89			

Semipermeable

Material	Fields [2]	Classification of Soils	Gravel	Soil	Clay	Specific Gravity	Compaction (kg/m3)	Optimum Moisture (%)	Consistency Limit: Liquid Limit(%)	Plastic Limit(%)	Plasticity Index(%)	Grain-size Analysis: -0.074mm (%)	-4.8mm (%)	-15.0mm (%)	Permeability (cm/sec)	Triaxial Compression: C (kg/cm2)	φ (° ′ ″)
D	0	GM-GC	39.5	41.5	39.5	2.77	2.18	8.0	19.5	14.8	4.7	32	77	94	---	---	---
		SW-SM				2.72	1.96	10.4	---	---	---	6	43	73			
F	0	GM-GC	38.5	43.8	17.7	2.82	2.20	8.2	26.5	15.9	10.6	23	71	90	---	---	---
		SW-SM,SM-SC,SM-SP				2.70	2.05	10.7	21.5	14.5	7.0	14	50	73			
K	0	GW	24	48.5	27.3	2.73	2.10	9.7	32.4	17.6	14.8	57	99	100	---	---	---
		SW-SM,SP-SM,CL				2.66	1.87	14.0	---	---	---	15	37	68			

Permeable(for Concrete)

Material	Fields [2]	Classification of Coarse and Fine	Fine	Coarse	Other	Specific Gravity: Fine	Specific Gravity: Coarse	Unit Weight: Fine (kg/m3)	Unit Weight: Coarse (kg/m3)	Absorption: Fine (%)	Absorption: Coarse (%)	Washable Amount: Fine (%)	Washable Amount: Coarse (%)	Soundness: Fine (%)	Soundness: Coarse (%)	Abrasion Loss (%)	Alkali Reaction
C	0	GP-SP	36.7	58.6	4.7	2.66	2.69	1.78	1.98	2.7	0.9	9.31	0.23	14.2	19.4	---	---
						2.59	2.67	1.65	1.91	1.4	0.8	6.20	0.13	10.7	10.8		
G	1	GW-SW,GP-SP	39.3	56.0	4.7	2.71	2.75	1.82	2.00	2.0	0.8	8.89	0.40	12.9	23.3	---	---
						2.68	2.72	1.75	1.93	0.8	0.6	1.64	0.06	5.8	11.8		

Material	Fields [2]	Classification	Sieve Analysis (Percetage Passing) Fine(mm): 0.074 (%)	0.149 (%)	0.297 (%)	0.59 (%)	1.19 (%)	2.38 (%)	4.76 (%)	Coarse(mm): 4.76 (%)	9.52 (%)	19.10 (%)	38.10 (%)	63.00 (%)	76.20 (%)	Fineness Modulus: Fine (F.M.)	Coarse (F.M.)
C	1	GP-SP	0	9	21	54	73	89	100	0	21	48	77	95	100	2.54	7.54
			0	6	15	34	58	75	100	0	15	32	73	93	100	3.12	7.80
G	1	GW-SW,GP-SP	0	7	19	41	60	80	100	0	24	45	73	95	100	2.93	7.58
			0	3	10	21	49	77	100	0	21	40	65	81	100	3.40	7.74

Table 7-13 Existing test Result of Construction Material (2/2)

Rock

Material	Fields [2]		Specific Gravity	Unit Weight (kg/m3)	Absorption (%)	Abrasion Loss by Los-Angeles 100r. (%)	500r. (%)	Soundness (%)	Compression Strength (kg/m2)	&(Flost) (kg/m2)	
T1	1	Granadiorite	2.74	2.62	1.1	9.4	33.2	1.5	645	(590)	
T2	1	Crystalized limestone	2.74	2.68	0.4	5.6	25.1	0.5	845 805	(820) (760)	
T3	0	Gnays	2.69	2.52	1.4	7.8	40.3	2.0	830 805	(680) (585)	
T4	1	Limestone	2.76	2.65	0.5	6.0	24.0	1.5	1100 960	(980) (770)	
T5	1	Crystalized limestone	2.84	2.73	0.7	7.9	38.5	0.5	1090	(900)	

Table 7-14 Additional Test result of Impervious Core Material

Sample No.	Pit No.	Depth	Particle distribution		Atterberg Limit				Class	Specific Gravity gf/cm^3	in maximum frequency and optimum water content							
											$\gamma_{d\ max}$ gf/cm^3	W_{opt}	Shearing Strength (UU)			Per-meability k $\times10^{-4}$ cm/sec.	Shearing Strength (CU)	
			0.08 mm Sieved %	5 mm Sieved %	LL %	PL %	PI %	RL %					C kgf/cm^2	$\phi°$	q_u kgf/cm^2		C kgf/cm^2	$\phi°$
1	A_1-207-g	-	36.1	78.1	30.5	18.1	12.4	-	SC	2.78	1.91	13.0	0.75	19	3.21	5.37		
2	A_1-208-h	-	16.0	79.4	20.8	13.8	7.0	-	SM	2.77	2.05	9.5	0.60	28	1.29	44.4		
3	A_1-209-I	-	16.8	89.2	Not tested			-	SM	2.75	2.06	10.3	0.25	35	0.97	4.32		
4	A_2-204-d	-	26.4	69.2	29.6	19.7	9.9	15.0	SC	2.85	1.99	12.0	1.10	19	3.95	1.69	0	38
5	A_2-205-e	-	31.4	75.3	32.1	19.2	12.9	14.7	SC	2.85	1.94	13.0	1.00	19	3.65	1.67		
6	A_2-206-f	-	49.7	93.1	32.4	17.3	15.1	14.1	SC CL	2.82	1.83	15.8	0.70	13	2.46	0.22	0.43	18
7	A_3-201-a	-	44.2	88.1	30.0	18.1	11.9	-	SC	2.75	1.80	15.0	0.80	15	1.73	0.17	0.27	24
8	A_3-202-b	-	56.9	95.8	27.4	17.5	98.9	16.3	CL	2.73	1.90	13.8	0.90	19	2.77	0.004		
9	A_3-203-c	-	32.8	95.9	24.7	17.6	7.1	-	SC	2.74	1.94	11.6	0.65	27	2.71	0.11		
10	F 701-a	-	18.0	60.0	23.3	15.5	7.6	16.3	SC GC	2.79	2.09	8.6	0.35	26	2.19	1.48		
11	F 702-b	-	55.8	93.6	24.9	17.5	7.4	-	CL	2.75	1.76	17.5	0.90	18	2.11	0.002		
12	F 703-c	-	60.8	95.7	32.5	21.3	11.2	-	CL	2.76	1.73	17.5	1.00	15	2.65	0.06	0.30	21

Note:

1 TS-1900 has been taken as the basis in preparation of samples for test and in conduction of definition tests.

2 Sample shave been classified according to "Compound Ground Classification System".

3 Tests with three axes have been conducted under two different conditions. In the first test, samples have been fractured quickly under the conditions without drainage and consolidation (UU type test). Loading speed has been chosen as 0.5 mm/min.

4 Permeability tests have been conducted taking ASTM D 2434 basis for the grounds permeability coefficient is higher than 10^{-4}cm/s. Samples not conforming to have condition were subject to test in permeability device with decreasing level.

5 This report is not a geotechnical report but contains test results only. The report is a whole together with the pre-letter number B 0-9 1 DSI 0 16 08 00/93-129.

Table 7-15 Additional Test Result on Concrete Aggregates

No. of Sample	Unit Weight (gf/cm^3)				Specific Gravity		Absorption (%)		Amount Passing #200 Sieve (%)		Washable Amount (%)		Freezing Loss of Sodium Sulfate	Description
	Sand		Gravel		Sand	Gravel	Sand	Gravel	Sand	Gravel	Sand	Gravel	(X)	
	Loose	Dense	Loose	Dense										
C 401 a	1.54	1.77	1.66	1.81	2.66	2.69	1.6	1.0	5.00	0.26	1.31	0.26		
C 402 b	1.43	1.69	1.69	1.83	2.65	2.67	1.4	0.9	5.87	0.17	1.15	0.17		
C 403 c	1.53	1.79	1.68	1.84	2.72	2.71	1.3	1.0	9.00	0.26	5.41	0.38		
G 801 a	1.63	1.78	1.68	1.81	2.70	2.70	1.0	0.8	1.81	0.15	0.67	0.15		
G 802 b	1.59	1.76	1.69	1.83	2.69	2.71	0.9	0.7	2.57	0.05	0.27	0.09		
G 803 c	1.61	1.82	1.71	1.85	2.73	2.72	0.9	0.6	3.62	0.11	1.41	0.15		

Note: (X) This will be sent when tests are finished.
Other test results will be sent when they come from Technical Research Department

Table 7-16 Suitability of Aggregate

Sample Number	Physical Properties		Sieve Analysis	Description
	Sand	Gravel		
C-401 a	Percentage passing #200 sieve: high	-	Granulometry of sand and gravel is close to the limit	Can be used after sieved
C-402 b	Percentage passing #200 sieve: high	-	Granulometry of sand and gravel is in limits	Can be used after washing
C-403 c	Percentage passing #200: high Clay amount: high	Clay amount: high	Granulometry of sand and gravel is in limits	Can be used after washing
G 801 a	-	-	Granulometry of sand and gravel is outside the limits	Can be used after sieving
G 802 b	-	-	Sand granulometry is in limits Gravel is close to limits	Can be used
G 803 c	-	-	Sand and gravel granulometry are in limits	Can be used

Table 7-17 Test Results of Core Samples number DQ-1 and DQ-2

Drilling No.	Depth (m)	Specific Gravity (1)			(1) Absorption (%)	Pressure Resistance with Single axis (2)		Dimension (cm)
		(3) B.S.G.	(4) B.S.G S.S.D	(5) A.S.G		kPa	psi	
DQ-1	25.15-25.25	2.75	2.77	2.60	0.7	49,000	7,110	b: 5.4 h: 9.0
DQ-1	25.40-25.50	2.78	2.80	2.82	0.6	48,710	7,070	b: 5.4 h: 10.8
DQ-1	31.60-31.70	2.78	2.78	2.82	0.5	70,600	10,240	b: 4.1 h: 8.2
DQ-1	33.20-33.30	2.80	2.81	2.83	0.3	83,990	12,190	b: 4.1 h: 7.0
DQ-1	36.60-36.70	2.78	2.80	2.82	0.5	37,730	5,480	b: 4.1 h: 8.2
DQ-1	37.40-37.50	2.76	2.77	2.81	0.7	Sample crashed while being prepared		
DQ-2	36.65-36.80	2.79	2.80	2.83	0.6	70,070	10,170	b: 7.1 h: 12.1
DQ-2	36.80-36.90	2.76	2.79	2.83	0.8	26,950	3,910	b: 7.1 h: 10.2
DQ-2	37.90-38.15	2.75	2.77	2.81	0.9	45,570 72,520	6,610 10,530	b 7.1 h: 10.0
DQ-2	38.15-38.35	2.78	2.80	2.83	0.6	91,140 99.470	13,230 14,440	b: 7.1 h: 9.1

(1) ASTM C 127-88
(2) ASTM D 2938-86
(3) Relative Specific Gravity
(4) Specific Gravity
(5) Apparent Specific Gravity

Chapter 8 SEISMIC ANALYSIS

Chapter 8

SEISMIC ANALYSIS

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Chapter 8 SEISMIC ANALYSIS

8.1 Structural Geology of Turkey

8.1.1 Geological Outline

The Anatolian Peninsula region has been subjected to the repeated organic movements since the beginning of Paleozoic age, and presents a complex geology. Concerning the structural geology of Turkey, it can be classified into four east-west oriented tectonic zones. Namely, they are in order from the north, the Pontids, Anatolids, Taurids, and Border Folds as shown in Figure 8-1.

In the Pontids, Cretaceous to Paleogene rhyolitics-basaltic volcanic rocks are predominant, while there is partial distribution of Jurassic to Cretaceous ophiolite. In the Anatolids, strongly deformed Eocene to Miocene marine clastic rocks and Quaternary volcanic rocks are distributed on the basement rocks of Jurassic to Cretaceous ophiolite and slightly metamorphosed rock. The continental deposits of Pliocene to Quaternary are distributed at the mountainland basins. The basement of the Taurids consists mainly of Precambrian to Mesozoic strata and ophiolite, while Eocambrian to Pliocene neritic sedimentary rocks are predominant in the Border Folds.

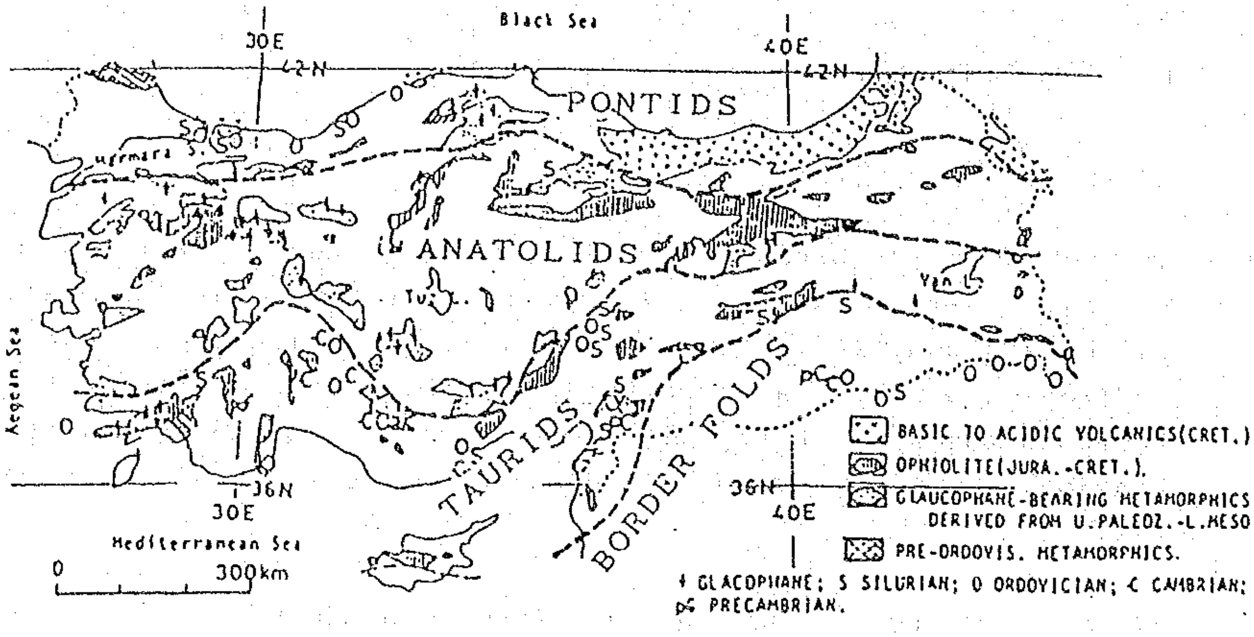

Figure 8-1 Tectonic Zone of Turkey (after Hirano, 1981)

8.1.2 Neotectonics of Turkey

Various plate tectonics models around Turkey have been proposed by McKenzie (1973), Alptekin (173), Papazachos (1974), Dewey & Sengor (1979), and others.

Turkey is surrounded by three macro-plates, i.e. Eurasian Plate, Arabian Plate and African Plate, as shown in Figure 8-2. Basically, Arabian and African Plates are drifting toward north relatively against Eurasian Plate causing the tectonic compressive stress field.

Moreover, many micro-plates such as Aegean Plate, Anatolian Plate (Turkey Plate) and Black Sea Plate are located in Republic of Turkey surrounded by the three macro-plates which are mentioned above.

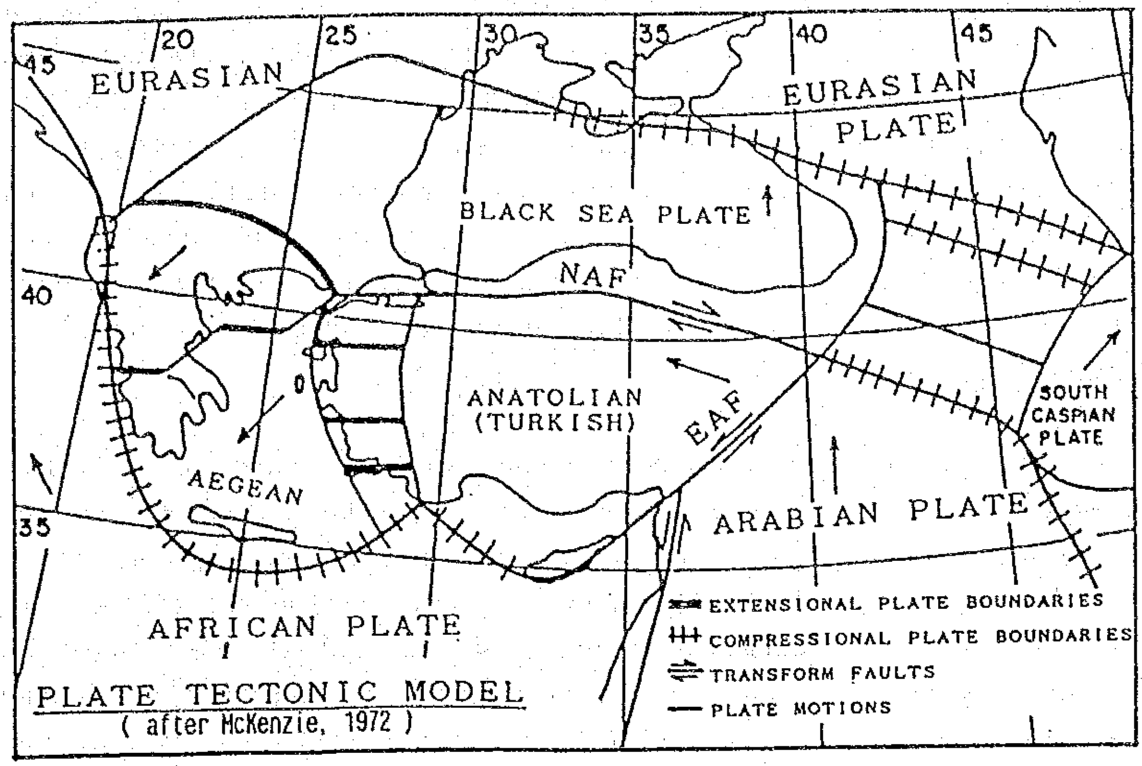

Figure 8-2 Typical Plate Tectonics Model

8.1.3 North Anatolian Fault and East Anatolian Fault

The Anatolian Peninsula region is divided by two transform faults named North Anatolian Fault (NAF) and East Anatolian Fault (EAF), which make up the plate boundaries as shown in Figure 8-2. Particularly, these two transform faults prominently divide the previously-mentioned tectonic zones.

The North Anatolian Fault extends east-west, presenting a gentle arc bulging northward at the northern part of Turkey and its total length is in excess of approximately 1,000 km. It is a morphologically distinct and seismically active right lateral strike-slip fault. The accumulated horizontal displacement of it was considered to be 70 to 80 km in the past, but recently, some researcher says that it should be 20 to 30 km, and this subject requires further study. The occurrence of the North Anatolian Fault is said to have been 10 to 12 million years ago, but the direction of displacement has not always been consistently right-handed horizontal and it appears there was a time in the middle of Pliocene Epock when a left-handed horizontal displacement was indicated. Many active faults, earthquake faults and mountainland basins are distributed along this fault, while there have been also volcanic activities, and it may be seen that this is a first-class structure of the Quaternary Period. These days many Japanese researchers have studied this fault by the method of trench and other geophysical investigations.

The East Anatolian Fault divides the Taurids, and on land it has a length of approximately 560 km with a strike of N60°E - S60°W. It shows a thrust-fault nature at the southwestern part, but a left-handed lateral displacement is prominent on the whole. It is covered by Quaternary volcanic rocks and the displacement topography is not always distinct, while the degree of activity is slightly lower compared with the North Anatolian Fault, but this is also a paramount structure of this region. The fault intersects the North Anatolian Fault east of Karlıova to comprise a triple junction. As a consequence, the Anatolian Plate sandwiched by the two faults would apparently shift south-westward.

As described in the foregoing, the neotectonics of Turkey are made complex reflecting the mutual movements between the plates in the field of tectonic stress from north-south compression caused by the northward-drifting Arabian Plate since the late Miocene Epoch.

8.1.4 General Seismicity of Turkey

(1) Seismological Outline

It is well known that many earthquakes have occurred in Turkey, which is located in Alphine-Himalayan seismic zone. As explained before, three macro-plates, develop the mutual movements around Turkey. And moreover, Micro-Plates develop the mutual complicated movements, in Turkey.

These micro-plates are small, but move rapidly. The cause of the local increase in Seismic activity of this region is attributed to the existence of these small but rapidly moving micro-plates.

Figure 8-3 clearly shows the distribution of the major fault systems in Turkey. It can be understood that the major faults are running along the border zone of the micro-plates which are mentioned above.

Shortly speaking, earthquakes in Turkey occur as a result of relative movements among the many macro/micro plates.

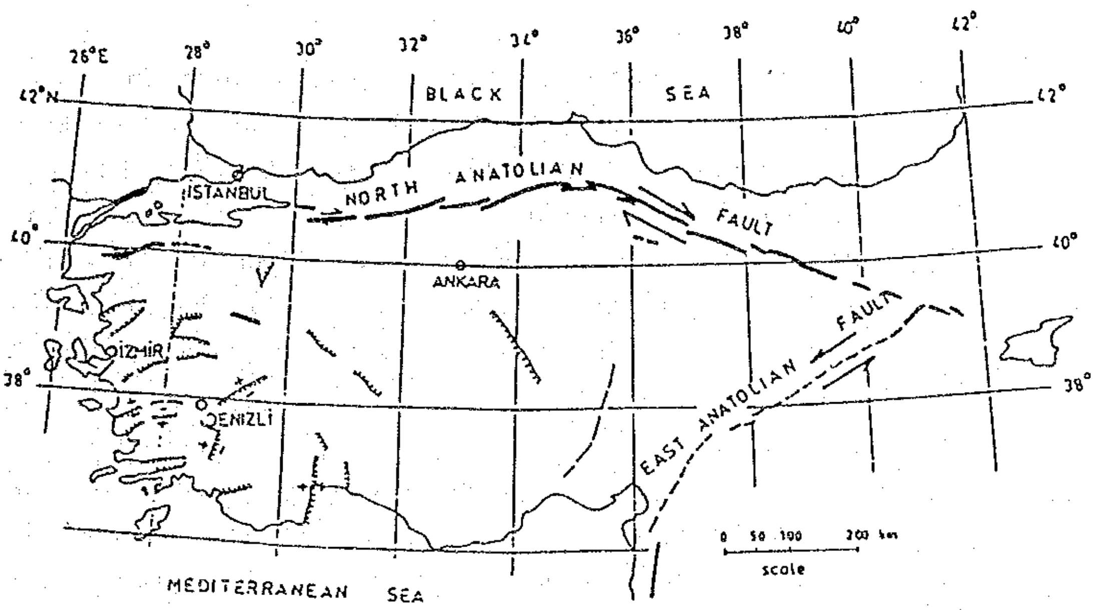

Figure 8-3 Major Fault Systems in Turkey

(2) Seismic Activities

Epicenters of 8,136 earthquakes which occur in Turkey during the period 1901 - 1987 are indicated in Figure 8-4. The location map of the larger earthquakes ($6 \leq M < 7$) of the period 1901 - 1987 is also given in Figure 8-5.

The seismic active zone for Turkey can be classified into four groups 1, North Anatolian Fault Region, 2, East Anatolian Fault Region, 3, West Anatolian Region, and 4, Other Regions, distribution of active faults, and occurrence of historical earthquakes into consideration.

The project area is located 27 km north to North Anatolian Fault and belongs to 1, North Anatolian Fault Region. Therefore, only 1, North anatolian Fault Region is described hereafter.

a) North Anatolian Fault Region

The North Anatolian Fault is a transform fault which is situated in the boundary between the Black Sea Plate and the Anatolian Plate (Turkey Plate). The number of earthquakes larger than magnitude 5.5 ($M \geq 5.5$) in the North Anatolian Fault region has exceeded 60 since 1900. They are the shallow-focal-depth earthquakes conforming to the right-lateral fault.

Meanwhile, the earthquake which occurred at Erzincan in 1939 at the eastern part of the North Anatolian Fault registered M 7.9, which is the strongest in this century in Turkey. Since then, earthquakes in this region have occurred every so many years, and it is well-known that the hypocenters of these earthquakes have shifted westward in a remarkably orderly manner.

According to the investigations thus far, the earthquake faults which were produced as results of these earthquakes do not strictly coincide in cases, but approximately, they are produced by repeated cycles of motion of the active faults running roughly parallel in the vicinity of the North Anatolian Fault. In view of the cumulative vertical displacement of the active faults and the vertical displacements of the individual earthquake faults the return period can be estimated to be of the order of several hundred or several thousand years (< 5,000 yr).

The earthquake faults are in a number of multiple echelon arrangements composed of segments made of echelon fissures, the smallest of which are ten and several centimeters. Small-scale echelon arrangements with segment lengths of less than several hundred meters are arrayed in correspondence with the lateral displacement of related transform faults. On the other hand, large-scale echelon arrangements of segment lengths ten and several kilometers do not necessarily correspond with related transform faults. This is because they are affected by geological anisotropies near the ground surface such as existing fissures and volcanic rock mass.

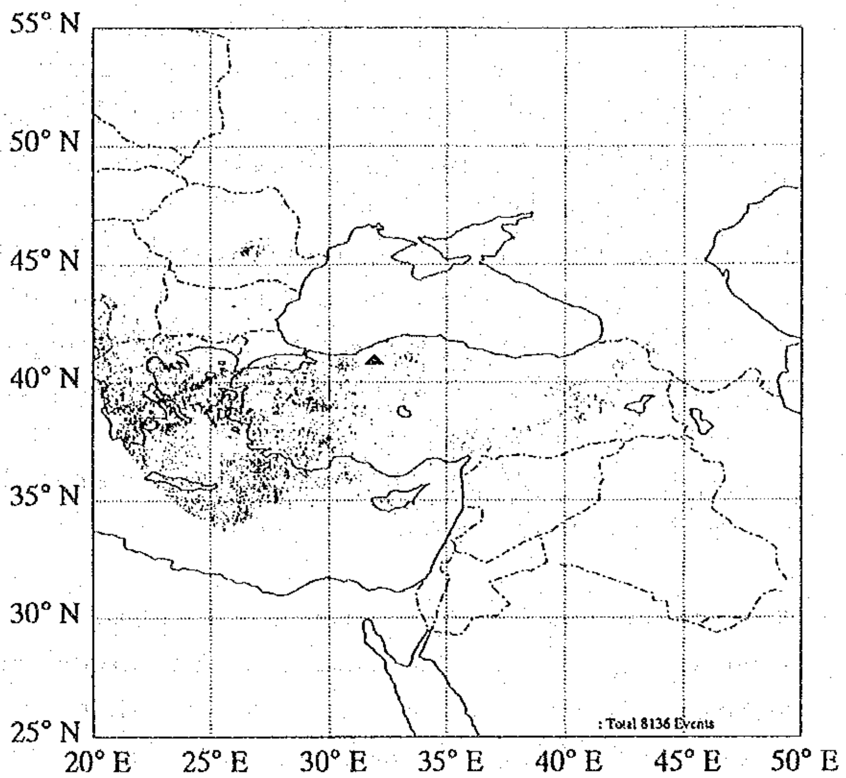

Figure 8-4 Seismicity of All Data in 1901 - 1987

Total Number of Plots in the Area of Δ ≤ 1000.0 (km) is 8136.

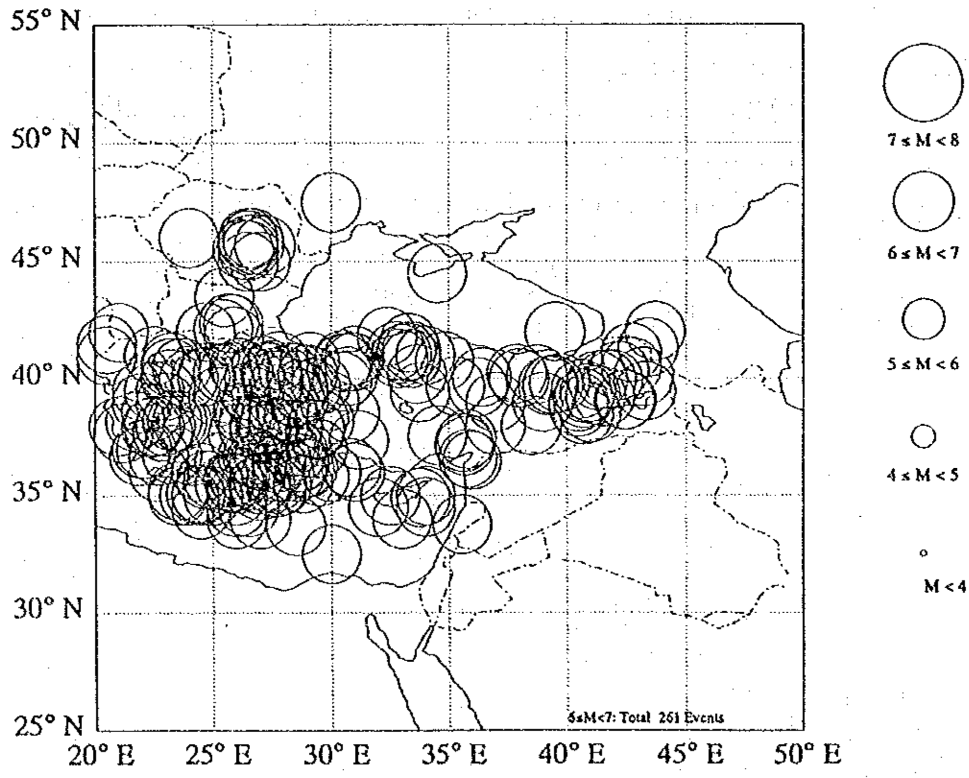

Figure 8-5 Seismicity of Magnitude 6 ≤ M < 7 in 1901 - 1987.

Total Number of Plots is 261.

8.2 Design Seismic Coefficient

8.2.1 Conclusion

The Project is located within 30 km north from the Northern Anatolia Fault Zone (NAF). It is also located at the second degree region and closes to the 1st degree region (the must hazardous one) on the Turkey Earthquake Regions Map.

A design seismic coefficient, which is utilized for studying a dam stability at the Project Site, is concluded to be 0.15 based on a fact that the coefficient of 0.15 was adopted on almost of the dams located at the 1st degree region as well as on a part of dams located at the 2nd degree region among 45 dams studied at detailed designs.

Then, seismic coefficients at the Project site are calculated by plural models utilizing 8136 seismicity data measured in Turkey for 87 years. As the results, all the calculated seismic coefficients are under 0.15. It is proved that the 0.15 is reasonable for the design seismic coefficient at the Project Site.

The followings are supporting sentences for the above conclusion.

8.2.2 Design Seismic Coefficient for Existing Dams

Design horizontal seismic coefficients, utilized for detailed designs on 45 existing and planned dams, are related to 5 degree regions, where are indicated in the seismic risk map for Turkey prepared by the Government of Turkey in 1972 as shown in Figure 8-6 and 8-7. The relationship indicates a reasonable trend, that is, the larger coefficients are adopted at higher risk regions, on the otherhand, the smaller coefficients at lower risks regions.

For example, the coefficient of 0.15 is adopted on 7 dams among 9 dams located in the 1st degree region. The coefficient of 0.10 is adopted on 6 dams, the 0.12 on 4 dams, and the 0.15 on 3 dams among 15 dams located in the second degree region.

Because the project is located at the 2nd degree region and closes the 1st degree region, the design seismic coefficient is determined to be 0.15.

8.2.3 Design Seismic Coefficient Calculation at the Project Site

(1) Seismicity Data

Seismicity data used in this study are based on those retrieved from 'The Earthquake Data File' compiled by NOAA (National Oceanic and Atmospheric Administration Environmental Data Service). Total number of the data amounts to 8136, covering a period from 1901 to 1987.

Location of all the data is plotted in Figure 8-4 in which the Köprübaşı project site (40°59'17", 31°54'31"E) is shown by a triangle. Numbers of the data in each year during the period are shown in Table 8-1, together with accumulative numbers from 1901. General aspects of the data such as magnitude and epicentral distance can be seen in Table 8-2.

(2) Attenuation Models

Of previously proposed attenuation models which express peak acceleration, A (gal), in terms of earthquake magnitude, M, and hypocentral distance, R (km), or epicentral distance, D (km), five models shown below are used in this study.

$$\log A = 3.090 + 0.347M - 2 \log (R+25) \quad (1)$$

proposed by C. Oliveira[1]

$$\log A = 2.674 + 0.278M - 1.301 \log (R+25) \quad (2)$$

proposed by R.K. McGuire[2]

$$\log A = 2.041 + 0.347M - 1.6 \log D \quad (3)$$

proposed by L. Esteva and E. Rosenblueth[3]

$$\log A = 2.308 + 0.411M - 1.637 \log (R+30) \quad (4)$$

proposed by T. Katayama[4]

$$\log (A/640) = (D+40) \; (-7.6+1.72M-0.1036M^2)/100 \quad (5)$$

proposed by S. Okamoto[5]

For all the data described earlier, peak accelerations are calculated by using the above attenuation models, and maximum accelerations in each yearlong interval are found to be as shown in Table 8-3.

(3) Statistical Analysis of Maximum Accelerations

The Seismicity data are available for successive 87 years from 1901 to 1987. Hence, a probabilistic model based on the "Theory of Extreme Values" can be established by setting an equal time interval to one year.

Although a probability function of the maximum acceleration expected at the project site is not known, it is reasonable to suppose that the function should be associated with the third type asymptotic distribution by Gumbel 1958. Refer to Figure 8-8 to 8-12.

The Table 8-4 shows the maximum acceleration expected at the Project site for different 7 return periods of 10, 50, 100, 200, 500, 1000, and 10000 years. The maximum accelerations for a return period of 10000 years are estimated to be 83, 163, 129, 134, and 223 gal by the model (1), (2), (3), (4), and (5). The 223 gal estimated by the Okamoto model is the maximum one among 5 and may probably be an overestimation.

(4) Horizontal Seismic Coefficient

A horizontal seismic coefficient (Kh) at the ground level is generally estimated by the following equation.

$$Kh = R \times A / 980 \qquad (6)$$

where,

R : Conversion factor
A : Maximum horizontal acceleration of earthquake motion (gal)

The Technical Guideline of Seismic Design of Nuclear Power Plants in Japan proposes 0.4 to 0.6 as the conversion factor (R). A large conversion factor should be adopted for an earthquake motion with long-period components predominant. A small conversion factor should be adopted for an earthquake motion with short-period components predominant.

The horizontal seismic coefficients at the Project site are calculated by the equation (6) based on the maximum accelerations as follows:

Attenuation Model	(1)	(2)	(3)	(4)	(5)
Maximum Acceleration (gal)	83	163	129	134	223
Seismic Coefficient (R=0.4)	0.03	0.07	0.05	0.05	0.09
Seismic Coefficient (R=0.6)	0.05	0.10	0.08	0.08	0.14

Since the design seismic coefficient of 0.15 covers all the figures shown above, the 0.15 is reasonable.

8.2.4 Analysis by DSİ

DSİ prepared A Report of Earthquake Risk Analysis of Köprübaşi, Doğanözü and Peçenek Dam Sites in May 1992. In the report, maximum acceleration at the Project site is estimated by Poison probability theory and Estava reduction relation using 136 seismicity data $M \geq 4.0$. The analysis predicted that the maximum acceleration is relatively bigger and the design seismic coefficient at the Project site might be more than 0.15.

The analysis suggests that much attention should be paid on the seismic design in the detailed design stage.

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4) Katayama, T.; Fundamentals of Probabilistic Evaluation of Seismic Activity and Seismic Risk (in Japanese), SEISAN-KENKYU (Monthly Journal of Institute of Industrial Science, University of Tokyo), 27-5 (1975), 1-11.

5) Okamoto, S.; Introduction to Earthquake Engineering 2nd ed., University of Tokyo Press (1984), 152-154.

Table 8-1 Number of Earthquakes in a Year during the Period from 1901 to 1987

Year	N	Sum of N	Year	N	Sum of N
1901	5	5	1946	8	462
1902	4	9	1947	6	468
1903	9	18	1948	14	482
1904	10	28	1949	13	495
1905	13	41	1950	8	503
1906	2	43	1951	11	514
1907	7	50	1952	19	533
1908	11	61	1953	49	582
1909	8	69	1954	35	617
1910	6	75	1955	14	631
1911	5	80	1956	60	691
1912	9	89	1957	65	756
1913	4	93	1958	31	787
1914	3	96	1959	47	834
1915	2	98	1960	43	877
1916	2	100	1961	39	916
1917	4	104	1962	16	932
1918	11	115	1963	46	978
1919	11	126	1964	73	1051
1920	8	134	1965	111	1162
1921	6	140	1966	232	1394
1922	8	148	1967	202	1596
1923	6	154	1968	306	1902
1924	14	168	1969	215	2117
1925	21	189	1970	360	2477
1926	18	207	1971	206	2683
1927	8	215	1972	134	2817
1928	28	243	1973	123	2940
1929	7	250	1974	138	3078
1930	10	260	1975	280	3358
1931	9	269	1976	243	3601
1932	14	283	1977	140	3741
1933	7	290	1978	278	4019
1934	6	296	1979	269	4288
1935	10	306	1980	334	4622
1936	12	318	1981	568	5190
1937	7	325	1982	473	5663
1938	17	342	1983	508	6171
1939	16	358	1984	512	6683
1940	21	379	1985	421	7104
1941	19	398	1986	525	7629
1942	16	414	1987	507	8136
1943	13	427			
1944	19	446			
1945	8	454			

Table 8-2 Distribution of Magnitude and Epicentral Distance of the Seismicity Data

	Δ ≦ 50	< 100	< 200	< 300	< 400	< 500	< 600	< 700	< 800	< 1000	Total
M < 3.5	0	1	2	2	4	6	21	57	104	87	284
< 4.0	1	3	1	21	29	20	69	182	192	519	1037
< 4.5	0	6	19	64	87	102	376	671	519	1310	3154
< 5.0	2	8	40	91	89	107	312	325	252	580	1806
< 5.5	2	22	32	83	95	103	147	177	109	175	945
< 6.0	3	11	34	46	42	84	100	110	89	112	631
< 6.5	0	3	8	8	16	17	33	32	33	40	190
< 7.0	0	3	3	3	3	5	10	10	8	26	71
< 7.5	0	1	2	1	2	2	1	5	1	1	16
< 8.0	0	0	0	0	0	0	0	1	0	1	2
Total	8	58	141	319	367	446	1069	1570	1307	2851	8136

Δ : Epicentral Distance (km)
M : Magnitude

Table 8-3 Maximum Accelerations during a year from 1901 to 1987

year	Oliveira, C Eq. (1)	McGuire, R. K. Eq. (2)	Esteva, L. & Rosenblueth, E. Eq. (3)	Katayama, T. Eq. (4)	Okamoto, S. Eq. (5)
1901	2.54	16.55	2.34	6.32	1.54
1902	21.74	68.38	20.69	36.26	82.49
1903	0.62	8.50	0.90	3.81	0.02
1904	0.62	7.30	0.75	2.60	0.01
1905	2.24	16.58	2.22	7.06	1.63
1906	0.24	3.89	0.34	1.18	0.00
1907	3.38	20.06	3.05	8.09	3.40
1908	0.94	8.84	0.99	3.00	0.04
1909	0.88	9.55	1.06	3.83	0.09
1910	4.99	28.31	4.58	13.94	11.54
1911	0.65	8.14	0.86	3.27	0.03
1912	2.01	17.02	2.21	8.27	1.80
1913	0.71	8.27	0.88	3.19	0.03
1914	1.01	10.72	1.22	4.56	0.18
1915	0.30	4.19	0.38	1.19	0.00
1916	2.22	18.84	2.49	9.84	2.55
1917	0.56	6.68	0.67	2.28	0.00
1918	7.28	35.11	6.43	17.41	19.04
1919	8.76	39.31	7.68	19.76	24.67
1920	1.40	11.33	1.38	4.00	0.22
1921	1.44	11.85	1.45	4.40	0.28
1922	0.60	7.41	0.76	2.79	0.01
1923	2.19	15.37	2.08	5.95	1.15
1924	1.82	14.38	1.84	5.87	0.81
1925	3.92	21.46	3.47	8.43	3.99
1926	5.95	30.57	5.30	14.55	13.14
1927	1.09	10.76	1.24	4.33	0.17
1928	9.21	38.82	8.09	18.24	22.75
1929	7.78	34.01	6.83	15.04	16.19
1930	0.84	8.57	0.94	3.03	0.04
1931	1.21	10.28	1.21	3.55	0.12
1932	4.96	25.16	4.35	10.34	7.61
1933	4.05	22.24	3.59	8.99	7.94
1934	0.85	8.32	0.91	2.79	0.03
1935	1.61	14.10	1.75	6.18	0.79
1936	5.67	28.53	5.00	12.70	10.37
1937	0.72	7.69	0.81	2.62	0.02
1938	3.74	24.17	3.61	11.94	6.96
1939	3.71	24.98	3.69	13.06	7.78
1940	7.24	32.70	6.35	14.51	16.59
1941	1.80	13.12	1.70	4.70	0.47
1942	2.60	18.37	2.54	8.39	2.61
1943	12.13	51.99	10.67	30.54	46.86
1944	37.14	97.60	40.46	65.01	142.68

Table 8-4 Maximum Accelerations for Various Return Periods (gal)

Model (Eq. No.)	Proposer(s)	Return Period, Tr(year)						
		10	50	100	200	500	1000	10000
(1)	Oliveira, C.	12	27	34	42	53	61	83
(2)	McGuire, R. K.	47	79	93	106	122	134	163
(3)	Esteva, L. & Rosenblueth, E.	11	26	36	47	64	78	129
(4)	Katayama, T.	24	49	60	73	89	100	134
(5)	Okamoto, S.	39	111	139	163	187	201	223

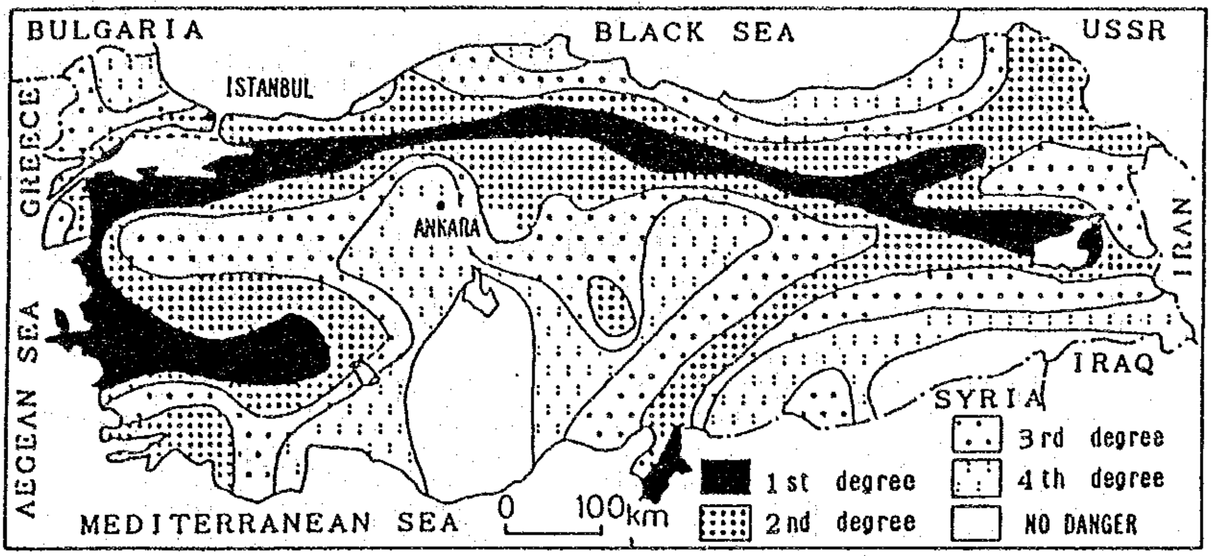

Figure 8-6 Seismic Risk Map for Turkey (1972)

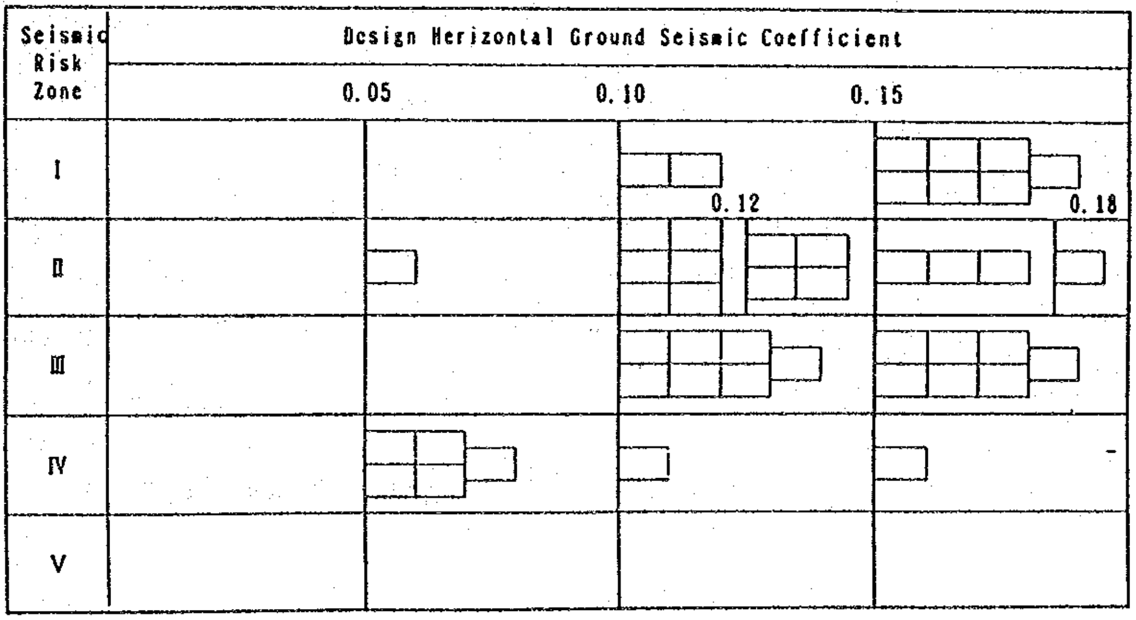

Figure 8-7 Design Seismic Coefficient used for Dams in Turkey

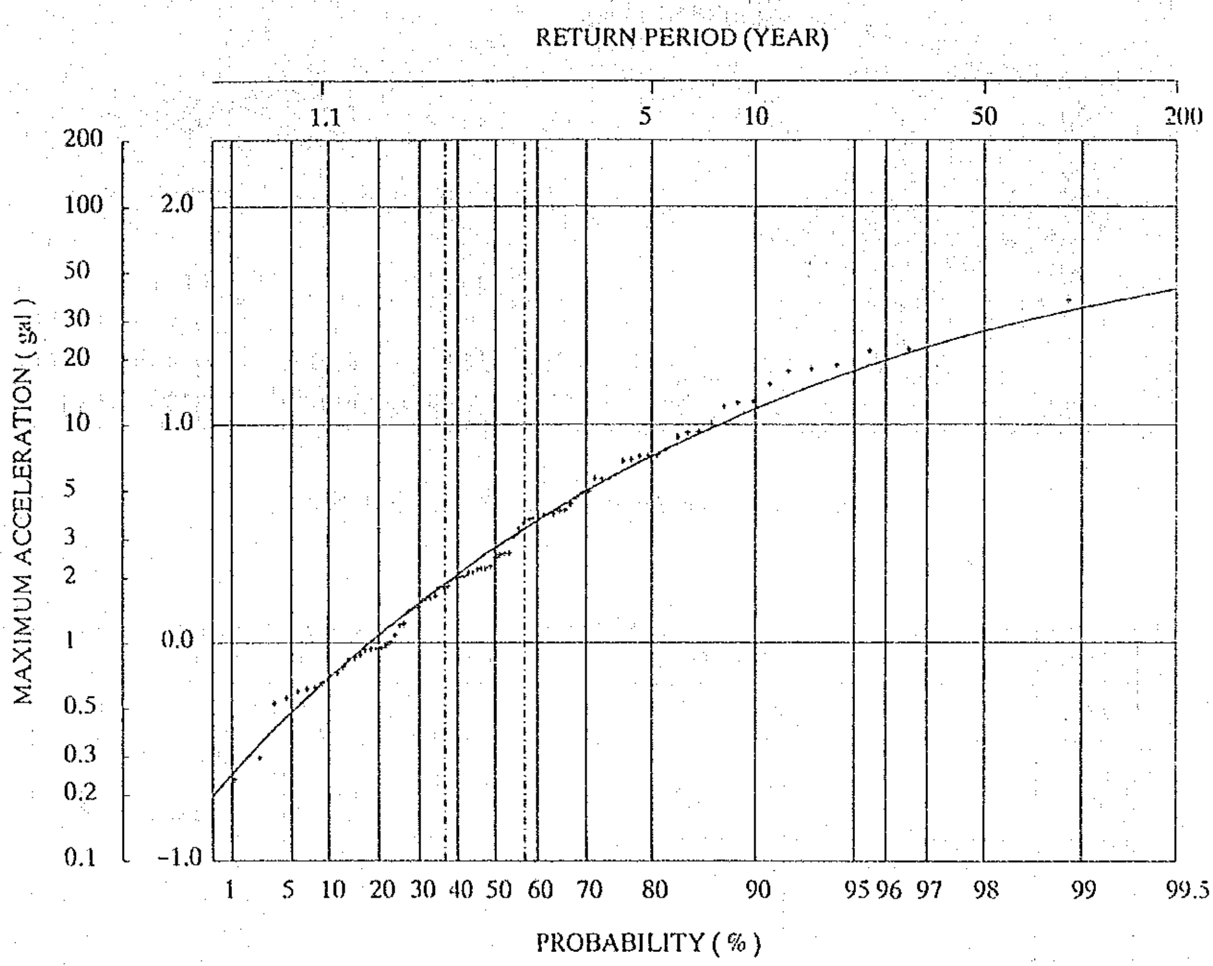

Figure 8-8 Return Period for Maximum Accelerations Calculated by Eq (1)

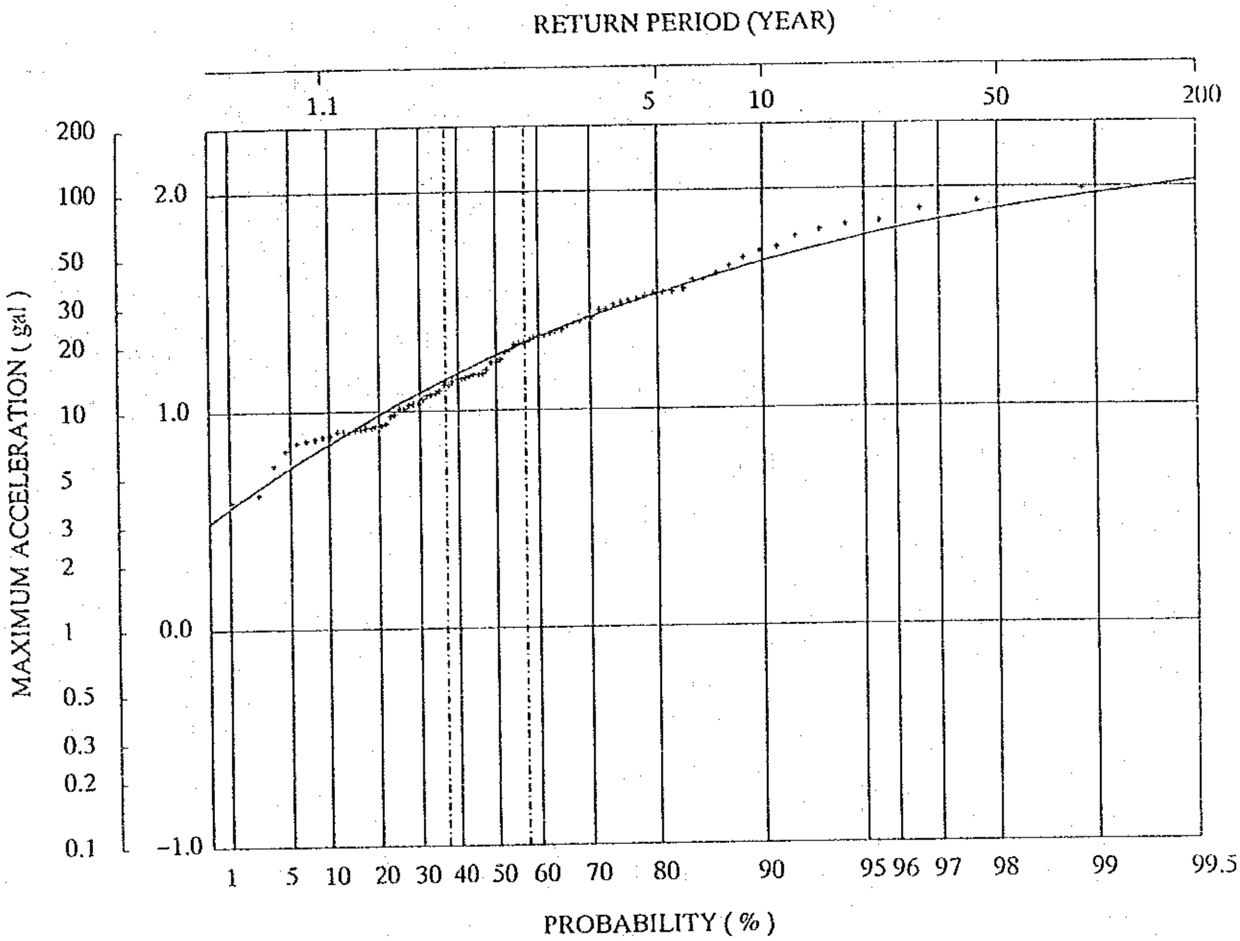

Figure 8-9 Return Period for Maximum Accelerations Calculated by Eq (2)

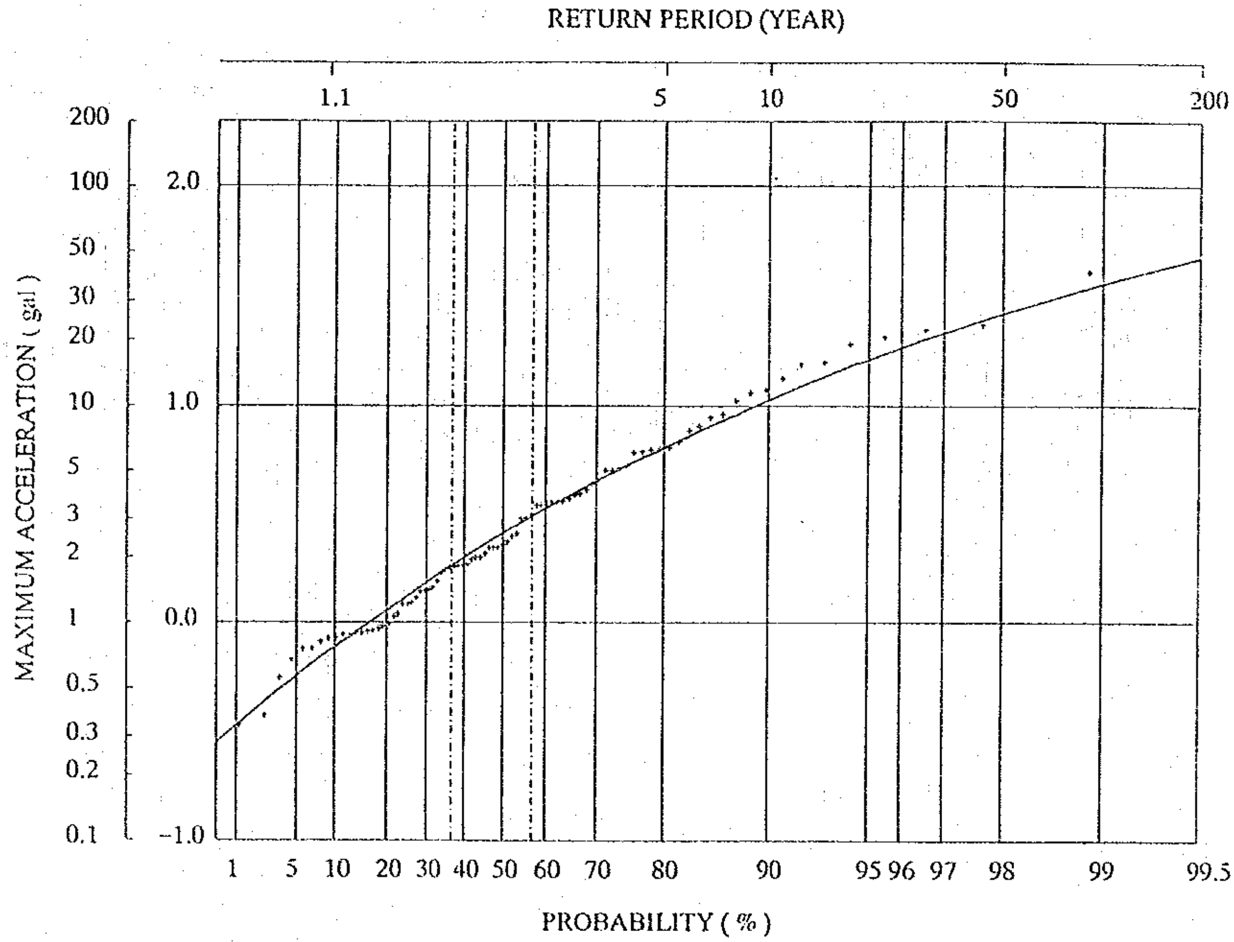

Figure 8-10 Return Period for Maximum Accelerations Calculated by Eq (3)

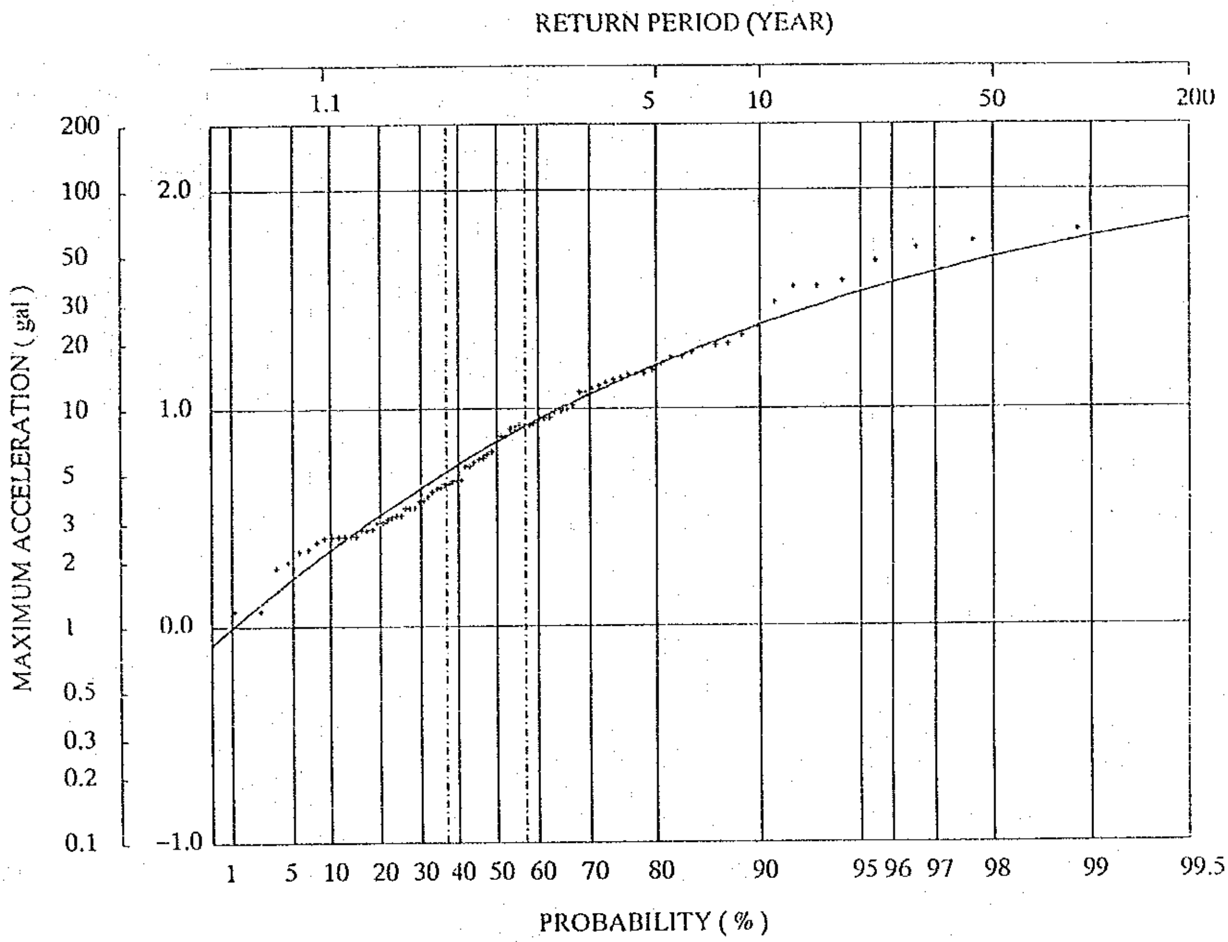

Figure 8-11 Return Period for Maximum Accelerations Calculated by Eq (4)

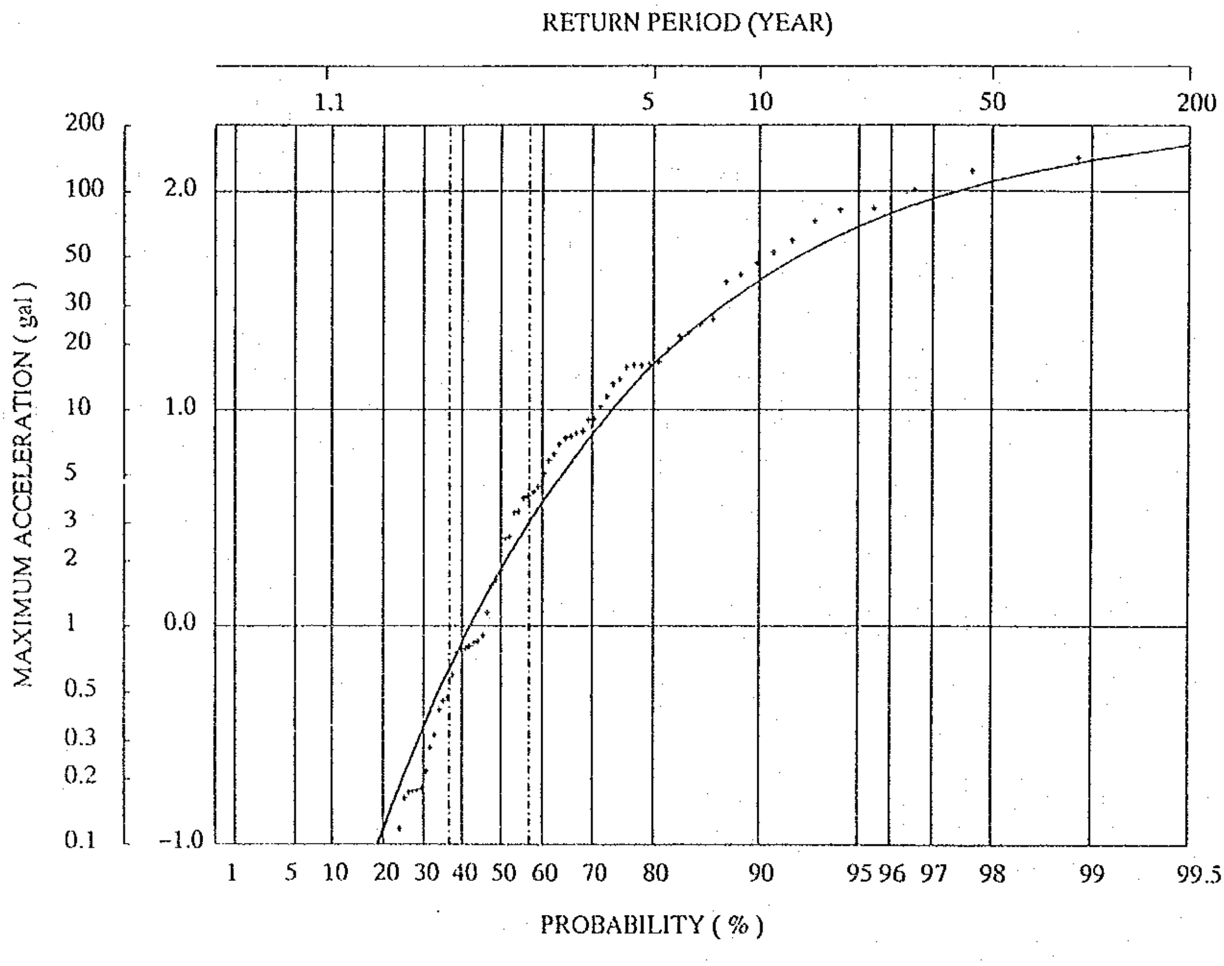

Figure 8-12 Return Period for Maximum Accelerations Calculated by Eq (5)

Chapter 9 DEVELOPMENT PLAN

Chapter 9

DEVELOPMENT PLAN

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Chapter 9 DEVELOPMENT PLAN

9.1 Review of Existing Development Plans

9.1.1 Filyos River Basin Master Plan

Hydroelectric power has not been developed at all up to now in the Filyos River Basin including tributaries. A Filyos River Basin Master Plan was prepared by DSI in 1987.

This Master Plan is a result of investigations and studies regarding electric power development schemes and irrigation and domestic water supply schemes for the Filyos River. As shown in Table 9-1 and Figure 9-1, seven electric power projects, five irrigation projects, and one domestic water supply project have been selected for the river basin development master plan.

Table 9-1 Development Scheme of Filyos River Master Plan Report

Scheme	Name of Project	Name of River	Development Scale
Electric Power	Kayabükü	Devrek	12MW
	Köprübaşı	Devrek	60MW
	Çay	Devrek	25MW
	Mandıra	Gerede	52MW
	Suçatı	Soğanlı	15MW
	Tefen	Soğanlı	10MW
	Konarı	Araç	18MW
Irrigation	Körler	Gerede	2,667ha
	Tekke	Gerede	11,317ha
	Akhasan	Çerkes	2,253ha
	Hacilar	Çerkes	5,705ha
	Filyos	Filyos	9,253ha
Domestic Water	Isıklı	Gerede	$265.79x10^6 m^3$/year

In the Master Plan Report the priorities of the abovementioned seven hydroelectric power development projects are given as shown in Table 9-2.

Table 9-2 Priority of Hydroelectric Power Development Project
in Filyos River Basin in Master Plan Report

Name of Project	Installed Capacity (MW)	Annual Energy Production (GWh)	Benefit Cost Ratio	Priority
Köprübaşi	60	210	1.67	1
Konari	18	52	1.41	2
Çay	25	108	1.25	3
Kayabükü	12	43	1.25	4
Tefen	10	53	1.25	5
Sucaty	15	81	1.21	6
Mandira	52	143	1.21	7

9.1.2 Review of Existing Development Schemes

(1) Confirmation of Project Sites

a) Outline of Filyos River Basin

The basin of the Filyos River System, as shown in Figure 9-1, can be broadly divided into the three subbasins of mainstream, Devrek River, and Araç River basins.

The Filyos River mainstream has its fountainhead at Mt. Korgu, and joined by tributaries at the left and right banks, changes its name from Uludere River, Ulusu River, Gerede River, Akçay River, Soğanlı River, Yenice River, to Filyos River while flowing down, and it ultimately empties into the Black Sea.

The Devrek River rises from Lake Abant, flows down as the Büyüksu River, merges with the Mengen River coming down from the right-bank side to become the Devrek River, and joins with the Filyos River from the latter's left bank.

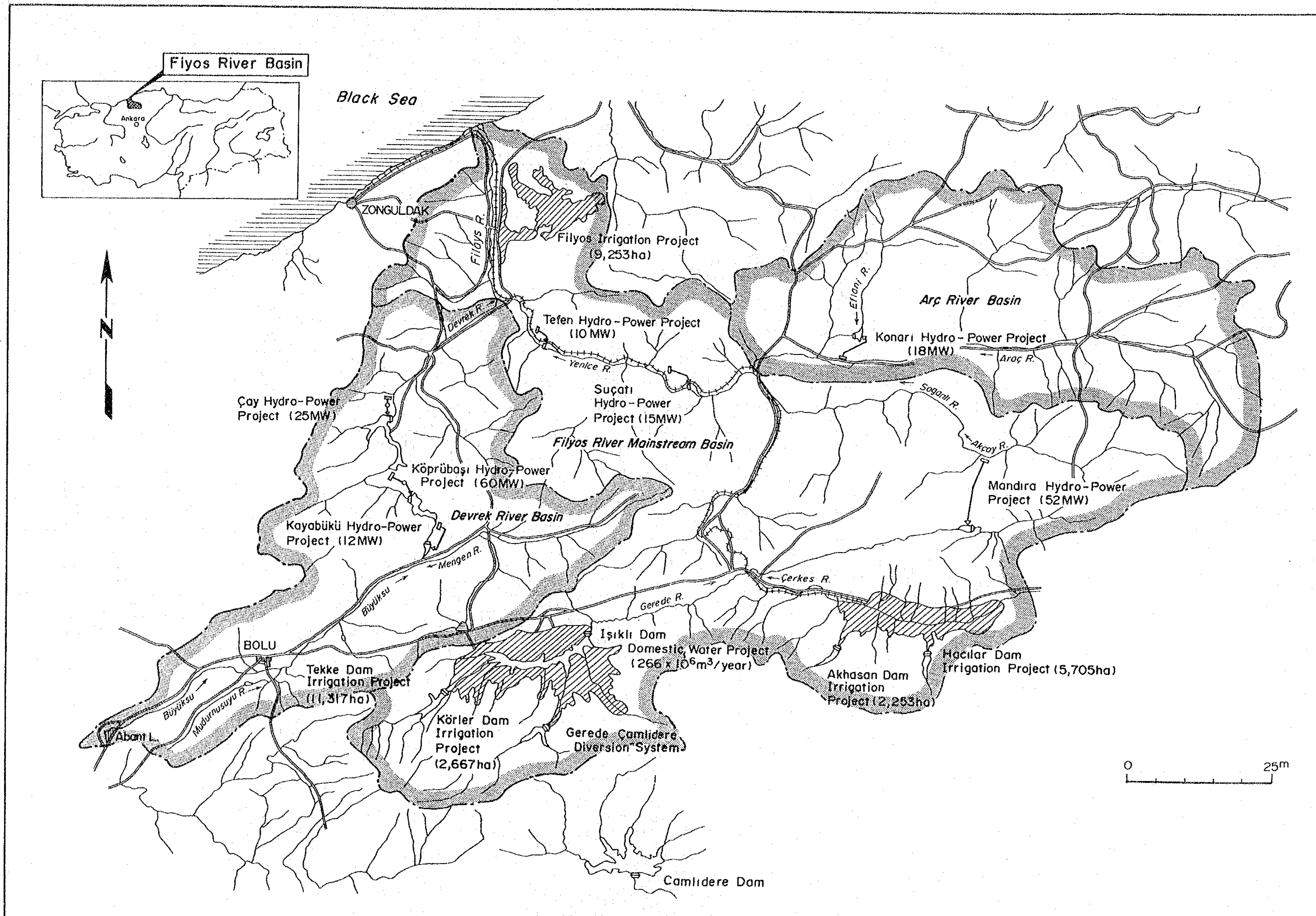

Figure 9-1 General Plan of Filyos River Basin Master Plan

The Araç River springs from Mt. Ilgaz, flows down as the Ilgaz River, and merging with the Basköy River coming in from the left-bank side, becomes the Araç River, and after being joined by the Eflani River from its right-bank side, joins the Yenice River at the latter's right-bank side.

b) Development Scheme for Filyos River Mainstream

On the mainstream of the Filyos River, the upstream part of the Uludere River comprising the headwaters area of the Filyos has river gradients of 1/70 and more, but the downstream part of the river, after entering the Gerede Basin, flows through a comparatively flat area in a straight line with a river gradient of less than 1/250. From the downstream part of the Gerede River to the downstream part of the Akçay River, the river gradient is around 1/70, and the stream meanders widely. From the Soğanlı River to the mouth of the Filyos River the average river gradient becomes less than 1/350, but there are places locally where the gradient is comparatively steep at around 1/100.

Since the catchment area is small at the upstream part of the Gerede River, that part cannot be considered for hydroelectric power development. Further, at the midstream and downstream parts of the Gerede, since the river flows down along the North Anatolian Fault, it is not appropriate to plan large-scale dams, while downstream of the Akçay River the valley width is large and it is a drowned valley covered by a thick alluvial layer, it is not appropriate to plan a large-scale dam at this part either.

On the other hand, for the middle stretch of the Gerede River, the Isıklı Project with the purpose of supplying domestic water to Ankara, the Körler and

Tekke projects with the purpose of irrigation, and on a tributary of the Gerede River, the Akhasan and Hacılar projects with the purpose of irrigation are proposed in the Master Plan Report. Consequently, there are only three sites of shortcutting the meandering part of the Akçay River from the downstream stretch of the Gerede River and, steep gradient existing at the downstream stretch of the Soğanlı River which are suitable for hydroelectric power development.

Accordingly, it is reasonable that only the three run-of-river power development schemes of the Mandıra Project shortcutting the meandering section from the Gerede River to the Akçay River, the Suçatı Project and the Tefen Project taking advantage of the heads at sections of steep gradient on the downstream part of the Akçay River, have been proposed in the Master Plan Report.

c) Development Scheme for Devrek River

On the Devrek River, at the upstream part of the Büyüksu River, the headwaters area, it is a rapid stream of gradient about 1/70, with the stretch downstream of this area immediately entering the Bolu Basin, where the river flows down in a straight line at a gradient of around 1/200 through an area which is in the form of a plain.

After becoming the Devrek River upon merging with the Mengen River, the catchment area is expanded and down to the Kayabükü district it is a rapid stream of a gradient of about 1/40.

At the stretch between the Kayabükü district and the Çay district, it is a gentle stream of average river-bed gradient around 1/240, and from the fact that it meanders widely to right and left, it is possible to obtain a considerable head with a comparatively short waterway by shortcutting, while there are dam sites favored with storage capacity.

The stretch downstream of the Çay district to the confluence with the Filyos River has a river gradient less than 1/500 with the stream flowing down in a straight line, the valley width being large and the river bed covered by a thick alluvial layer. As described here, only the stretch between the Mengen River confluence and the Çay district is suitable for electric power development.

Accordingly, it is reasonable that in the Master Plan the three schemes of the Kayabükü Project as a run-of-river scheme between the Mengen junction and the Kayabükü district, and the Köprübaşı Project and the Çay Project as dam-and-waterway schemes having reservoirs between Kayabükü and the Çay district have been proposed.

d) Araç River Development Scheme

The Araç River, at its upstreammost part, which is its fountainhead area, is of a gradient of about 1/50 to constitute a rapid stream, but from the fountainhead area to the downstream Yenice River confluence, the average river gradient is around 1/150, the flow is in a relatively straight line, the valley width is large and the river bed is covered by thick alluvium.

However, at the Eflani River, the largest tributary of the Araç River, the stretch upstream of the confluence with the Araç River has a river gradient of 1/20 or steeper to constitute a swift stream, while there is wide meandering so that by shortcutting, a large head can be obtained with a comparatively short waterway.

Therefore, it is only the downstream swift stream portion of the abovementioned Eflani River which is suitable for a power development project in the Araç River Basin.

Consequently, it is reasonable that the Konarı Project is proposed in the Master Plan as a run-of-river scheme at this site.

e) Confirmation of Projects

The power development projects proposed in the Master Plan as mentioned above include all of the sites thought to be suitable for electric power development in the Filyos River Basin and these are considered to be the only sites which are reasonable. Particularly, plans for irrigation have not been proposed in the Devrek River Basin and the three projects of Kayabükü, Köprübaşi, and Çay will be contemplated for electric power generation only.

(2) Review of Priority

As shown in Table 9-2, the Master Plan Report ranks the Köprübaşi Project out of the seven electric power development schemes proposed as having the highest priority. This priority was determined by the benefit-cost ratio (B/C) method, and this method, being widely used in the world for deciding priority, is reasonable.

(3) Reviewed ranks of the seven hydroelectric power development schemes by the 1993 price are shown in Table 9-3.

Table 9-3 Review of Priority of Hydroelectric Power Development Project in Filyos River Basin by 1993 Price

Name of Project	Installed Capacity (MW)	Annual Energy Production (GWh)		Benefit Cost Ratio	Priority
		Average	Firm		
Köprübaşı	60	210	153	1.50	1
Konarı	18	52	0	1.34	2
Çay	25	108	63	1.04	5
Kayabükü	12	43	9	0.83	7
Tefen	10	52	15	1.09	4
Suçatı	15	81	24	1.25	3
Mandıra	52	143	31	0.84	6

Although there is a difference in part from the order of priority given in the Master Plan Report, there is no change in the priority of the Köprübaşı Project according to these calculation results either. Therefore, the judgment of the Master Plan Report which had given first priority to the Köprübaşı Project is reasonable.

Regarding the Çay Project, although it has been given a lower priority than certain run-of-river type projects, it is considered worthy of being given a priority next to that of the Köprübaşı Project since it will have a reservoir so that the firm energy will be large and a stable output can be expected.

(3) Review of Devrek River Electric Power Development Schemes

a) Development Schemes Proposed in Master Plan

In the Master Plan the five schemes of the Gökçesu Project, the Kayabükü Project, the Köprübaşı Project, the Kurdeşe Project and the Çay Project were made the objects of study as shown in Figure 9-2.

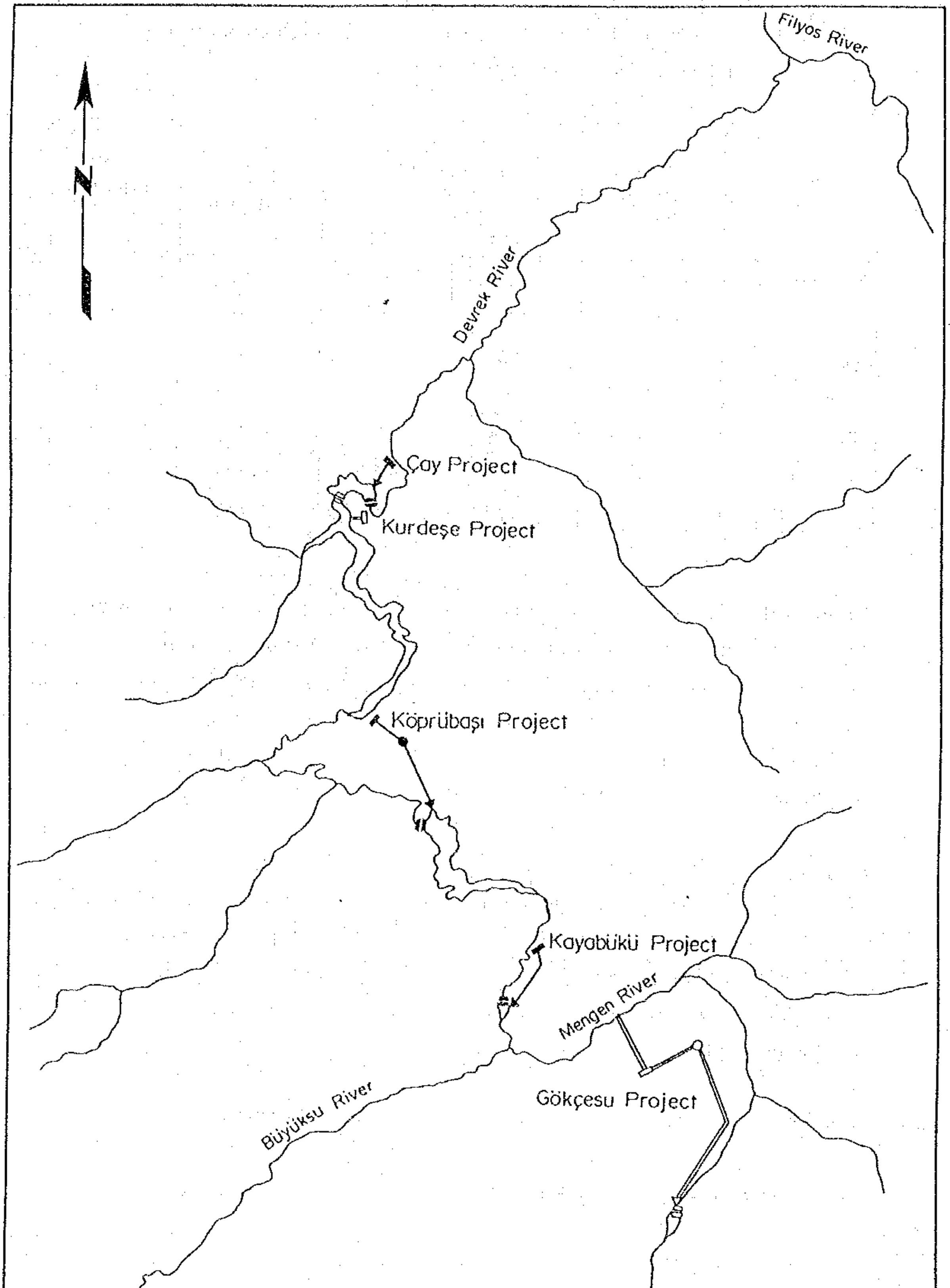

Figure 9-2 Alternative Hydroelectric Power Development Project in Devrek River in Master Plan Report

Of these, the Kurdeşe Project is an alternative layout scheme for the Çay Project, and as shown in Table 9-5, three cases each of development scales were selected and comparisons made, and the Çay Project was chosen.

The Gökçesu Project, the upstreammost scheme, being an independent run-of-river type project which has no relationship with the downstream Kayabükü Project either regionally or in power generation operation, was evaluated independently as shown in Table 9-5, and was eliminated as being economically unfeasible.

Table 9-4 Comparison of Kurdeşe and Çay Project in Master Plan Report

Name of Project	Catchment Area (km^2)	Installed Capacity (MW)	Annual Energy Production (GWh)	Construction Cost (10^6 TL)	Benefit Cost Ratio
Kurdeşe	2,422	15	65.3	15,419.1	1.06
		20	79.3	17,831.2	1.16
		25	92.5	21,051.1	1.18
Çay	2,422	20	85.5	16,784.9	1.30
		25	99.4	19,769.3	1.32
		30	111.9	23,158.0	1.32

Table 9-5 Economics of Gökçesu Project in Master Plan Report

Name of Project	Installed Capacity (MW)	Annual Energy Production (GWh)	Annual Surplus (10^6 TL)	Benefit Cost Ratio
Gökçesu	10	21.3	-58.6	0.89

As a result of study, the three projects of Kayabükü, Köprübaşi, and Çay were finally selected as electric power development sites in the Devrek River as shown in Figure 9-3.

These three are cascade projects where the tail water level of the upstreammost Kayabükü Project is made to coincide with the high water level of the Köprübaşı Project, and the tail water level of the Köprübaşı Project with the high water level of the Çay Project.

b) Review of Reasonability of Three-step Development Project

i) Relationship of Köprübaşi Project with Upstream and Downstream Projects

The Kayabükü Project, a scheme upstream of the Köprübaşı Project, is a run-of-river type at a section of rapid flow existing immediately downstream of the confluence with the Mengen River. The river-bed gradient downstream from the powerhouse site in the vicinity of the end of the Köprübaşı reservoir backwater becomes extremely gentle and the valley width also becomes wide. Consequently, even if the powerhouse location were to be moved downstream, the economics of the Kayabükü Project would not be improved as a result, and there is no necessity for the high water level of the Köprübaşı Project to be lowered for optimization of the Kayabükü Project. Accordingly, a study of the optimum powerhouse location of the Kayabükü Project is not to be necessary in the feasibility study of Köprübaşı Project but is to be made at the time of the feasibility study on the Kayabükü Project.

The Çay Project which is downstream from the Köprübaşı Project will have the tail water level of the Köprübaşı Project as its high water level. The Kurdeşe Project has a development area overlapping with the Çay Project. Compared with the Çay Project, it is possible to shorten the waterway length, but the dam volume would be more or less the same, and while the power generation capacity would be reduced 17%, the reduction in construction cost would be a mere 9%. Therefore, elimination of the Kurdeşe Project is reasonable, and in relation to the Köprübaşı Project there is no difference from the Çay Project. Thus, the review of the comparison study of the Kurdeşe and Çay projects, including optimization of the Çay Project, is to be done at the time of the feasibility study on the Çay Project.

ii) Development Area of Köprübaşı Project

The final Köprübaşi Project is a dam-and-waterway type development scheme consisting of constructing a rockfill dam of height 110m at a point approximately 20 km downstream of the confluence with the Mengen River at the middle stretch of the Devrek River to provide a reservoir of effective storage capacity $163 \times 10^6 m^3$, conducting water to a powerhouse provided at the Dirgine district by a headrace tunnel of 41.50m and a penstock of 265m for power generation of 70 MW with a total head of 190m and maximum discharge of 43 m^3/sec. After power generation, the water is to be discharged at the right bank of the Devrek River by a tailrace channel 4899m in length.

The river gradient between the dam and the power station outlet is 1/190, but since the Devrek River curves widely to the right at this stretch, a head of 123m would be obtained with a waterway of total length 4,750m by shortcutting inside this bend and the gradient according to the waterway length and head would be 1/39. Since the dam and powerhouse locations are at the upstream and downstream ends of this curved stretch, if the dam and powerhouse locations were to be moved upstream and downstream, respectively, the gradient according to the waterway length and head would be smaller than in the present scheme.

The dam site is located at the downstream end of the narrow portion below Kesebükü Village which is of basin form and suitable for a reservoir, while downstream from this point the valley width becomes large and the suitability as a dam site would be lost. On the other hand, at the upstream side, there is one location at the entrance to the narrow section downstream of Kesebükü Village which can be an alternative dam site, but the maximum limit to the high water level would be about the same as with the presently projected site because of the topography.

At the power station outlet site, the direction of flow of the Devrek River becomes parallel to the waterway route ridge, while at the downstream side, the fan-shaped topography at the Dirgine district spreads out in the form of paralleling the ridge of the waterway route, and the direction of the Devrek River meets at right angles with the waterway route ridge and flows down in a straight line.

Therefore, even if the powerhouse site were to be moved upstream from the presently projected site, there would only be a reduction in head and the waterway route would not be shortened, while on the other hand, if the powerhouse were to be moved in the downstream direction, there would be a detour made of the Dirgine fan area for a great increase in waterway length, and unless the high water level of the downstream Çay Project were to be lowered, there would be no increase in head.

However, although the waterway route in the present scheme connects the dam site and the outlet site by the shortest distance, there is a part of the headrace section with thin overburden, while the length of the penstock is long in comparison with the head.

Accordingly, the Köprübaşı Project requires optimization by a detailed comparison study upon setting up an alternative plan regarding the layout of various structures such as the dam and waterway, but concerning the reservoir and outlet locations, they are reasonable even when considering the relationships with the upstream and downstream plans.

iii) Reasonability of Three-step Development Plan

The electric power development scheme for the Devrek River which has been proposed in the Master Plan as described above as the cascade development scheme comprising the three projects of Kayabükü, Köprübaşı and Çay is basically reasonable and it is judged unnecessary to consider further division or amalgamation of projects.

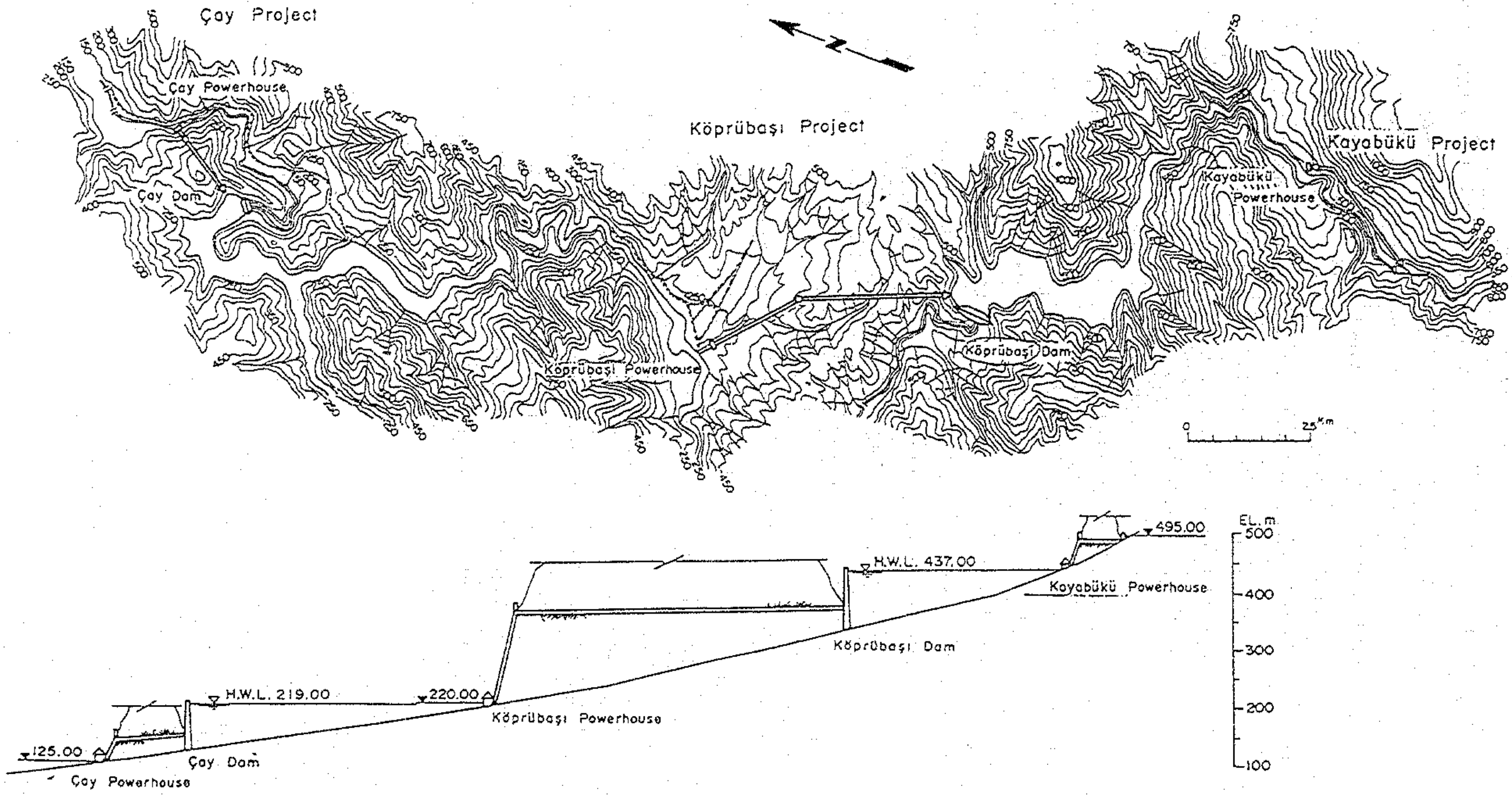

Figure 9-3 Devrek River Hydroelectric Power Development Plan in Master Plan Report

9.2 Comparative Study of Alternative Development Plan

9.2.1 Method of Comparative Study

(1) Basic Condition

The method used for a comparative study of the alternative development plan for optimization of the Köprübaşı Project is the Benefit Cost Method (BC Method) considering an alternative thermal power plant that would be built without the Köprübaşi project and taking the cost of the thermal power plant as the benefit of the project.

In order to select the optimum development plan an imported coal-fired thermal power plant which is supposed to be the future one of the main thermal power plants is used as the alternative facility to be installed in some sea coast region with an installed capacity of 300 MW.

As described in 9.1, Köprübaşı Project is to be developed as one of the three stage project between upperstream Kayabükü Project and downstream Çay Project. Alternative development plans of the Köprübaşı Project concerning dam site, waterway route, location and type of powerhouse and scale of reservoir are formulated and the optimum development plan is selected by comparison of these alternatives.

The annual surplus benefit (B-C) obtained from equalized annual costs (C) for the project life (50 years) of the hydropower facility, and the equalized annual cost (B) of the alternative thermal facility having an ability equivalent to the hydropower facility is used in the study as the indices. Market prices in January 1993 without import taxes are used in the comparisons.

The partial cost of the transmission line between the Powerhouse of the Köprübaşı Project and the load center which should be born by the Köprübaşı Project is counted up and the cost of transmission line between the alternative thermal power plant and load center is omitted.

Parameters of the alternative thermal power plant are as shown in Table 9-6.

(2) Equalized Annual Cost

The equalized annual cost of a hydropower facility consists of depreciation and operation-maintenance cost. This is estimated by multiplying the annual cost factor by the investment cost.

Equalized Annual Cost = Annual Cost Factor x Investment Cost
= Depreciation + Interest + Operation and Maintenance Cost

Depreciation + Interest = Investment Cost x Capital Recovery Factor

- Capital Recovery Factor = $\dfrac{i\,(1+i)^n}{(1+i)^n - 1}$

n: Service Life	Civil Facility	50 years
	Hydro-mechanical Facility	35 years
	Electro-mechanical Facility	35 years
i: Discount Rate	9.5%	

Civil Facility	9.6%
Hydro-mechanical Facility	9.9%
Electro-mechanical Facility	9.9%

- Operation and Maintenance Cost (Rate to Direct Cost)

Civil Facility	0.5%
Hydro-mechanical Facility	1.5%
Electro-mechanical Facility	1.5%

Accordingly annual cost ratios of facilities are as follows:

Civil Facility	10.1%
Hydro-mechanical Facility	11.4%
Electro-mechanical Facility	11.4%

(3) Benefit

The benefits of the Köprübaşı project are summarized according to the project cost, maintenance and operation costs, and the fuel cost of an alternative thermal-power plant as shown in Table 9-6. The effective power output and effective energy that are used in calculating the advantages of the project, are given according to the below conditions.

(a) The effective power output at the receiving end is expressed by the below equation. This equation reduces the station service rate by 0.3%, the forced outage rate by 0.3%, the scheduled outage rate by 2.0%, and the transmission loss rate by 1.4% from the firm peak output. The firm peak output is defined as the 95% probable output for the 43 year period.

$$\text{Effective power output} = (1 - 0.003) \times (1 - 0.003 \times (1 - 0.02) \times (1 - 0.014) \times \text{Firm peak output}$$