CHAPTER 6 METEOROLOGY AND HYDROLOGY

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CHAPTER 6 METEOROLOGY AND HYDROLOGY

6.1 Outlines of Meteorology and Hydrology in the Project Area

6.1.1 Hydrology

The Berta basin, which contains the project area, is situated in the northeast part of the drainage area of the Çoruh river. The drainage area of the Berta river is 2,315 km^2, which is about 12 percent of the 19,750 km^2 drained by the Çoruh river.

The Berta basin is surrounded by lofty mountain ranges rising to over 2,000 m above sea level (hereinafter referred to as A.S.L.), the highest being Mt. Karçal (3,415 m A.S.L) in the north. The average basin elevation is 1,800 m A.S.L.[1]

The Berta river is composed mainly of three tributaries, the Meydancık, the Şavşat and the Ardanuç, the drainage areas being 577.3 km^2, 586.1 km^2 and 572.0 km^2 respectively.[1]

The Meydancık river, which extends the furthest distance upstream from the project site, originates in the northeast of the Berta basin and follows a southeasterly course. It then meets with the Şavşat river coming from the east to form the Berta river. After confluence, it changes its course to the southwest and runs, with a bed slope of approximately 1/100, through a narrow, steep-sided valley in which the proposed dam sites are located. This topography continues to immediately upstream of its confluence with the Ardanuç river. It finally joins the Çoruh river about 10 km upstream of the city of Artvin, at which point its overall length is 72 km.[1]

Generally, the lower lying areas of the Berta basin are of rocky terrain with little vegetation, while the terrain higher than 1,000 m A.S.L is rich in vegetation and sparsely cultivated.[2]

6.1.2 Meteorology

The lower reaches of the Çoruh river are subject to the East Black Sea Climate in which the annual precipitation at some meteorological stations is over 2,000 mm. The upper reaches of the river are subject to great influence from the Continental Climate, which is characterized by its rigorous but arid climate; winters are long and cold and summers hot and dry.[2] The Berta basin also shows some characteristics of the Continental Climate, but is predominantly subject to the East Black Sea Climate.

Precipitation in northern Turkey, including the Çoruh basin, results primarily from cyclonic frontal storms.[3] In the case of the Çoruh basin, easterly or southeasterly winds moving in from the Black Sea carry with them numerous storm fronts. These storms, occurring primarily during the winter months, are forced to rise and lose their moisture by the topographic barrier formed by the mountains situated in the north of the basin. In winter, precipitation falls in the form of snow at the higher elevation and this results in a snowmelt pattern of runoff at the runoff gauging stations in the basin. The lower portion of the basin receives most of its precipitation in the form of rain. Observed mean annual precipitation over the Berta basin varies from 761 mm at Veliköy meteorological station (hereinafter referrred to as M.S.) to 450 mm at Ardanuç M.S. The annual mean precipitation over the basin was previously estimated at 624 mm by EİE based on the isohyetal map.[1]

Figure 6-1 shows the seasonal variation of the precipitation at meteorological stations in the Berta basin. It can be said that although there is a seasonal variation, it rains almost every month and an extreme dry season is not recognized.

Maximum snow cover depths previously recorded are 125 cm at Şavşat M.S.,125 cm at Veliköy M.S. and 214 cm at Meydancık M.S.

The average annual temperature at Şavşat M.S., which is at an elevation of 1,100 m A.S.L., is 9.8°C ; extremes have varied from a minimum of -19.9°C to a maximum of 38.8°C. The seasonal pattern of maximum, minimum and mean temperatures are illustrated in Figure 62.

Monthly maximum surface wind velocity and its direction observed at the Artvin M.S. from 1959 to 1990 are shown in Table 6-1.

Table 6-1 Monthly Maximum Wind Velocity at Artvin M.S.

(unit : m/s)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Max.
Velocity	18.8	22.1	21.8	21.4	18.8	21.5	17.8	16.0	17.5	15.2	24.2	23.0	24.2
Direction	SE	SSE	NW	NWN	W	SSW	NW	WNW	NW	SW	NW	SE	NW

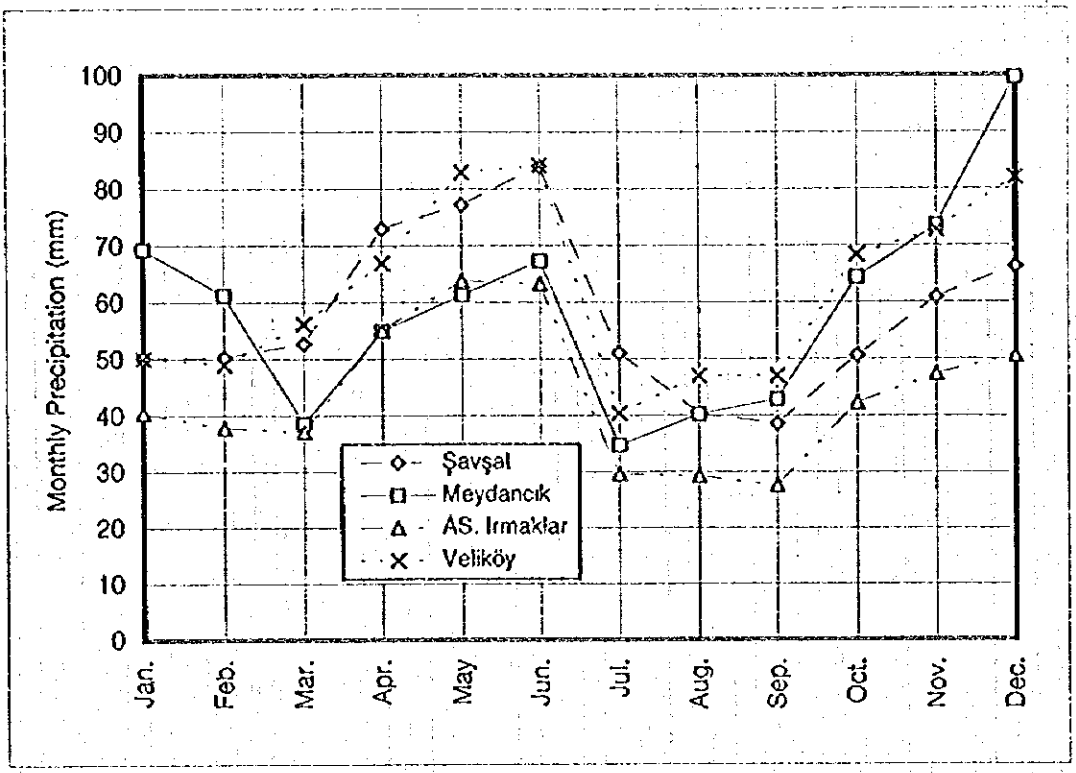


Figure 6-1 Monthly Precipitation at Meteorological Stations

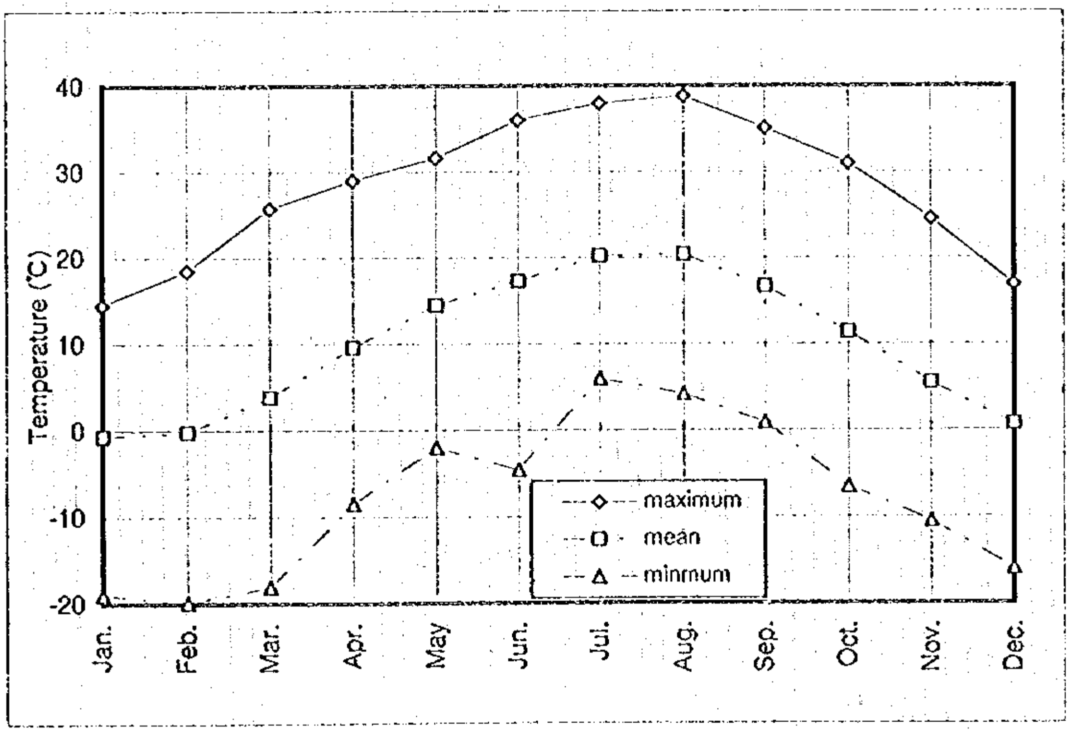


Figure 6-2 Monthly Mean, Max. and Min. Temperature at Şavşat M.S.

6.2 Runoff Study

6.2.1 Available Runoff Data

The descriptions of EİE's runoff gauging stations situated in and around the project area are listed in Table 6-2. The locations of these stations are shown in Figures 6-3 and 6-4. Of these, the runoff gauging stations (hereinafter referred to as G.S.) No.2333 and 2334 were newly established in 1989.

Table 6-2 Descriptions of Gauging Stations

Station	River	Elevation (m)	C.A (km^2)	Available Period of records
2305-Peterek	Çoruh	653	7,272	1942-1994
2315-Karşıköy	Çoruh	57	19,654	1965-1994
2322-Altınsu	Çoruh	201	18,326	1972-1994
2326-Dutulu	Meydancık	875	247	1982-1994
2327-Çiftehanlar	Berta	570	1,223	1982-1994
2328-Ferhatlı	Ardanuç	365	547	1982-1994
2333-Şavşat	Mansuret	830	330	1990-1994
2334-Bağlık	Berta	385	1,541	1990-1994

6.2.2 Monthly Inflows at Dam Sites

(1) Periodicity of Hydrological Data Observations

The observation period of runoff data in the Berta basin is relatively short (1982-1994), so therefore the periodicity was examined by use of the annual precipitation recorded at Artvin M.S. from 1946 to 1994.

The predominant period of the annual precipitation series was determined to find the maximum value of c_L^2 in the following equation:[4]

$$C_L^2 = \left\{\frac{2}{N}\sum_{t=1}^{N}\left((x_t - \bar{x})\cos\left(\frac{2\pi}{L}\right)t\right\}^2 + \left\{\frac{2}{N}\sum_{t=1}^{N}\left((x_t - \bar{x})\sin\left(\frac{2\pi}{L}\right)t\right\}^2 \qquad \text{Eq.(6-1)}$$

where

N = sample size

x_t = *annual precipitation series*

$\bar{x}$ = *mean of annual precipitation series*

L = certain period (< N - 1)

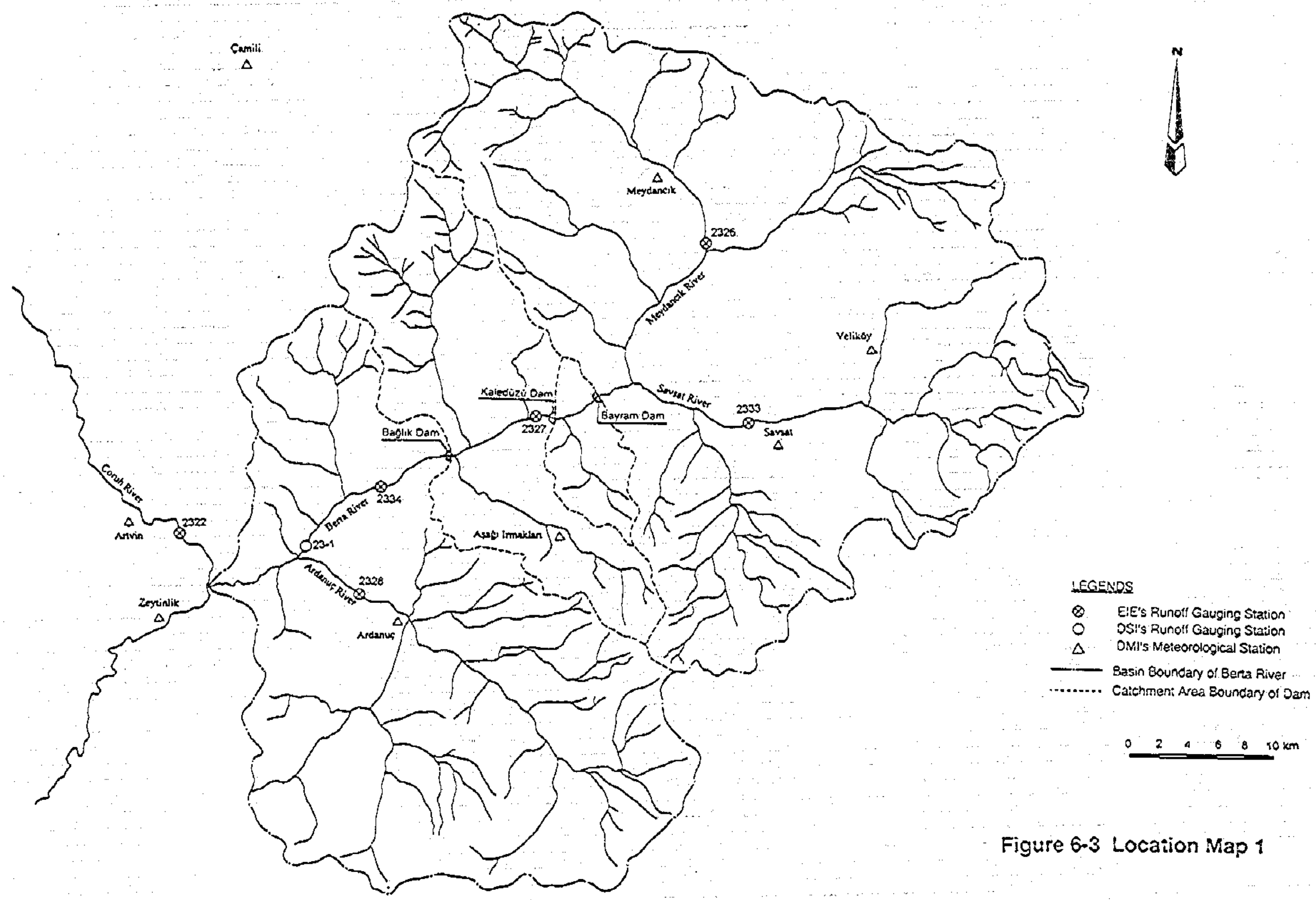


Figure 6-3 Location Map 1

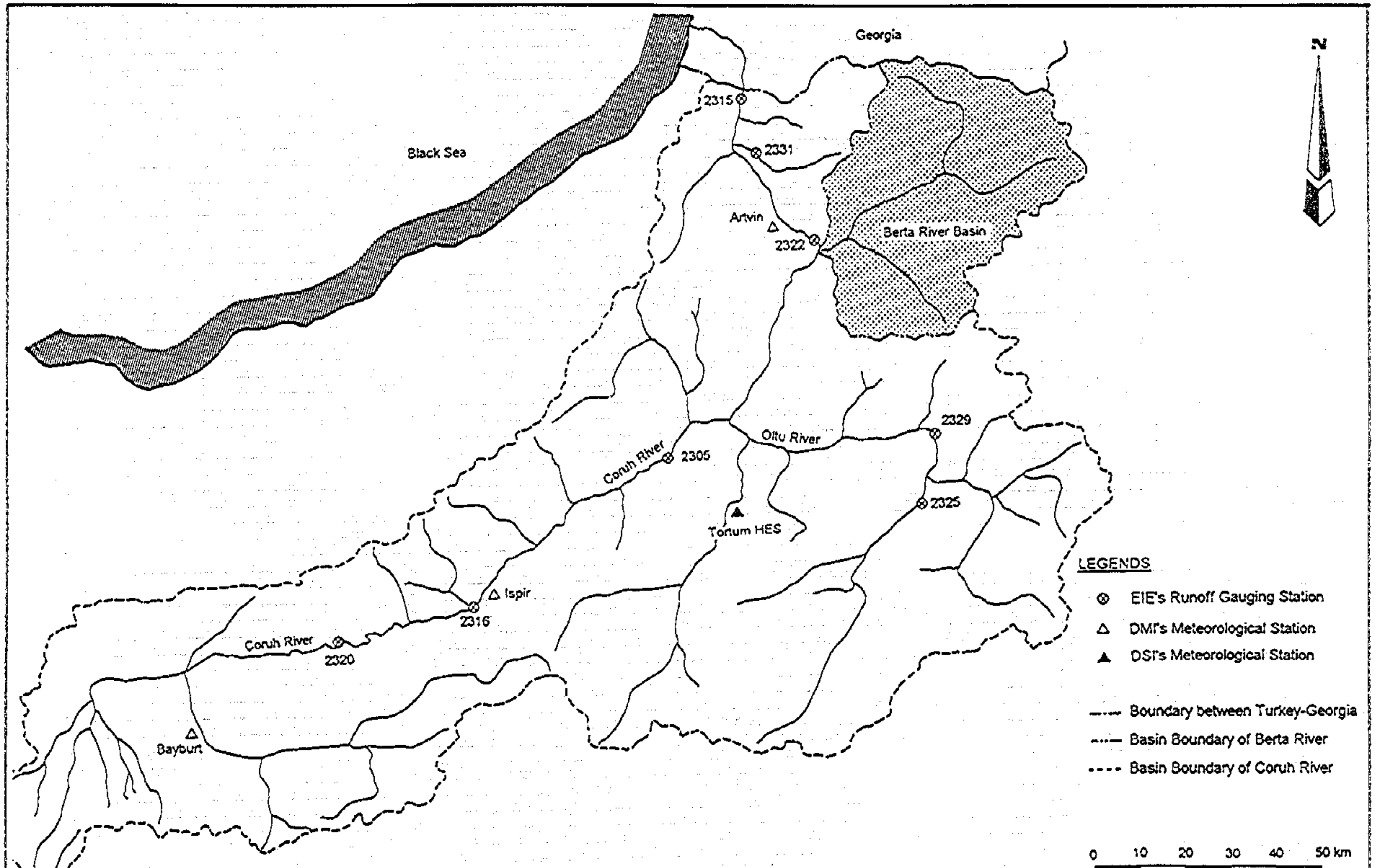


Figure 6-4 Location Map 2

The result of the analysis is shown in Figure 6-5. From the figure, the predominant period can be inferred as 23 to 24 years. Therefore, data series need be extended.

(2) Extension of Mean Monthly Runoff Data

The mean monthly runoff at G.S.No 2327 and 2334 was extended back to water year 1942 by using the correlation with runoff at stations in the vicinity. The regression lines used in this study are shown in Figures 6-6 to 6-10 and they are summarized in Table 6-3.

Table 6-3 Correlation Analysis of Runoff Gauging Station

(unit:m³)

Station	Years	Independent Variable (x)	Regression Equation	Common Observation Period	R^2
Altınsu (2322)	1942-1964	2305	$logY = 0.907logX + 0.594$	1972-1994	0.9746
	1965-1971	2315	$Y = 0.8571X - 41.764$	1972-1994	0.9755
	1972-1994	Observed Value			
Bağlık (2334)	1942-1982,Oct	2322	$Y = 0.1567X + 1.2494$	1990-1994	0.9394
	1982,Nov.-1989,Sep.	2327	$Y = 1.3082X - 0.145$	1990-1994	0.9904
	1990-1994	Observed Value			
Çiftehanlar (2327)	1942-1982,Oct.	2322	$Y = 0.1011X^{1.0383}$	1990-1994	0.9002
	1982,Nov.-1994,Sep.	Observed Value			

Note; Unless otherwise noted, *Years* begin in October.

(3) Verification of Runoff Data Series

In order to check the consistency of the obtained monthly runoff data series, the double-mass curves were used, in which annual precipitation at Artvin M.S. for the water years 1948 to 1994 were used. In Figure 6-11, the double-mass curve for station No.2305 changes its slope at the water year 1959. As station histories are not available for the earlier years, the reason for the break could not be determined. But runoff before 1959 is on the conservative side, and therefore no adjustment was made to the data series obtained by correlations in the previous section. On the other hand, in both Figures 6-12 and 6-13, the double mass-curves for runoffs at G.S.No.2315 and No.2322 show no significant break in slope.

Furthermore, as shown in Figure 6-14, the double-mass curve of the cumulative estimated runoff series for G.S.No.2327 plotted against cumulative runoff observed at G.S.No.2305 for the water years 1942 to 1994, which is virtually an unbroken straight line, indicates that the obtained data series by correlation analysis is consistent although the applied equations are different over that period.

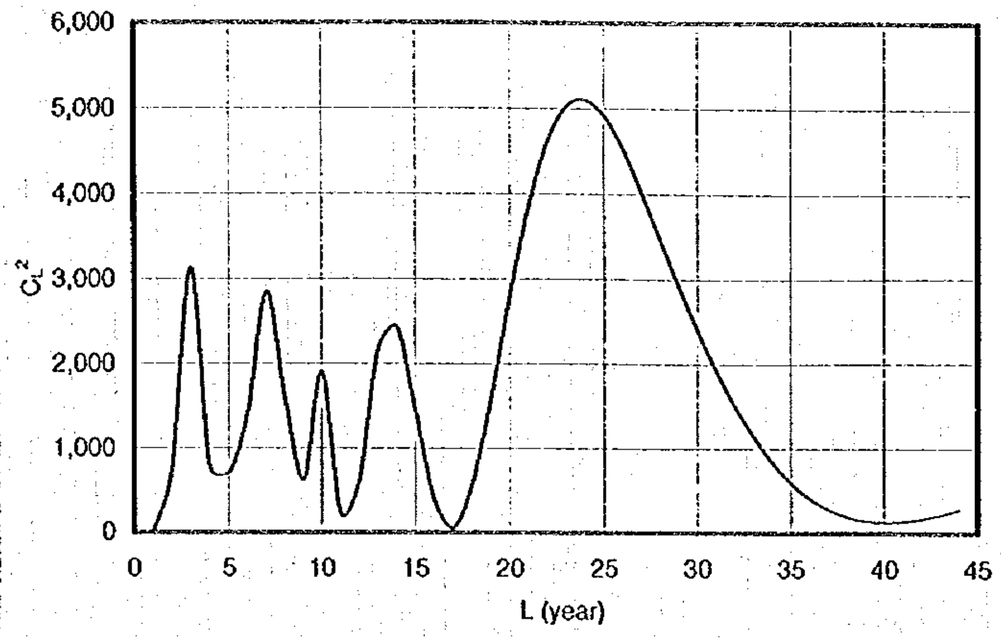


Figure 6-5 Periodicity of Annual Precipitation observed at Artvin M.S.

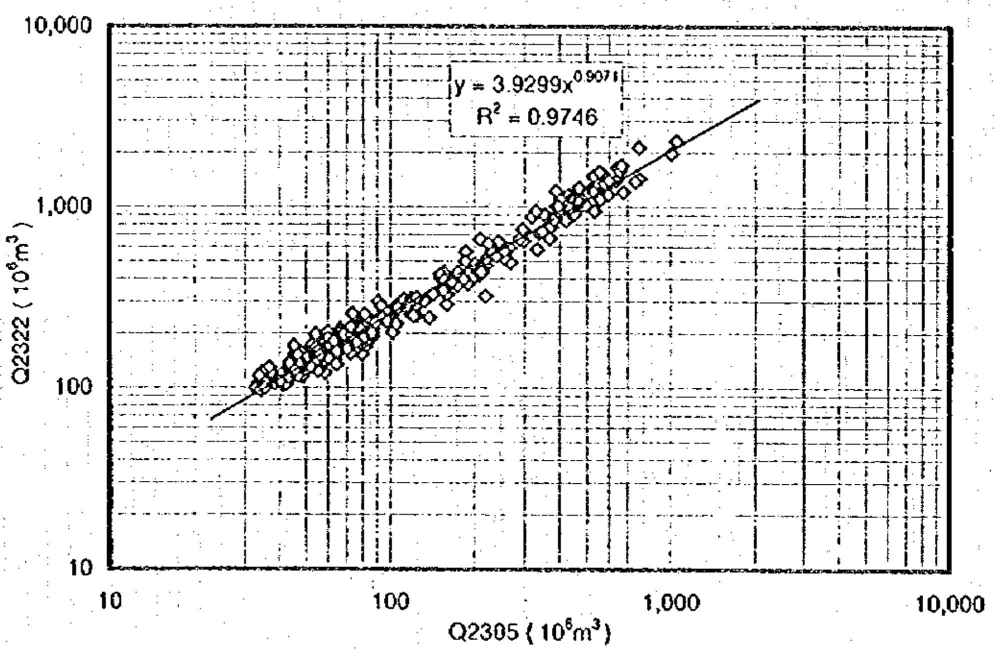


Figure 6-6 Correlation between Runoff at G.S. No.2305 and No.2322

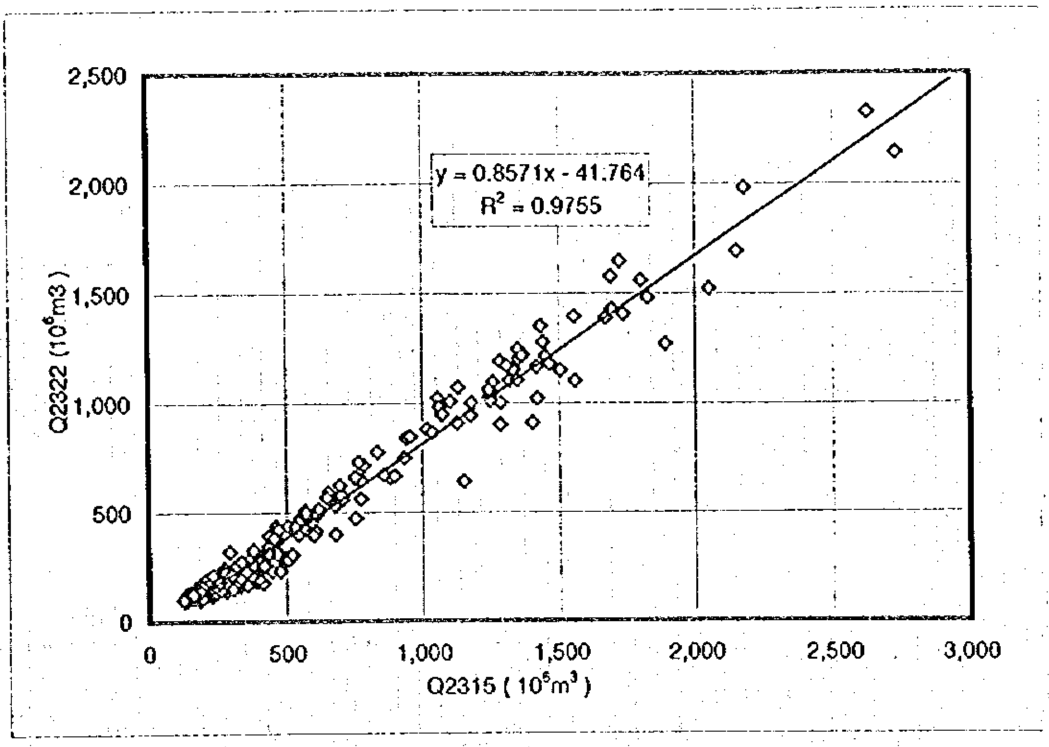


Figure 6-7 Correlation between Runoff at G.S. No.2315 and No.2322

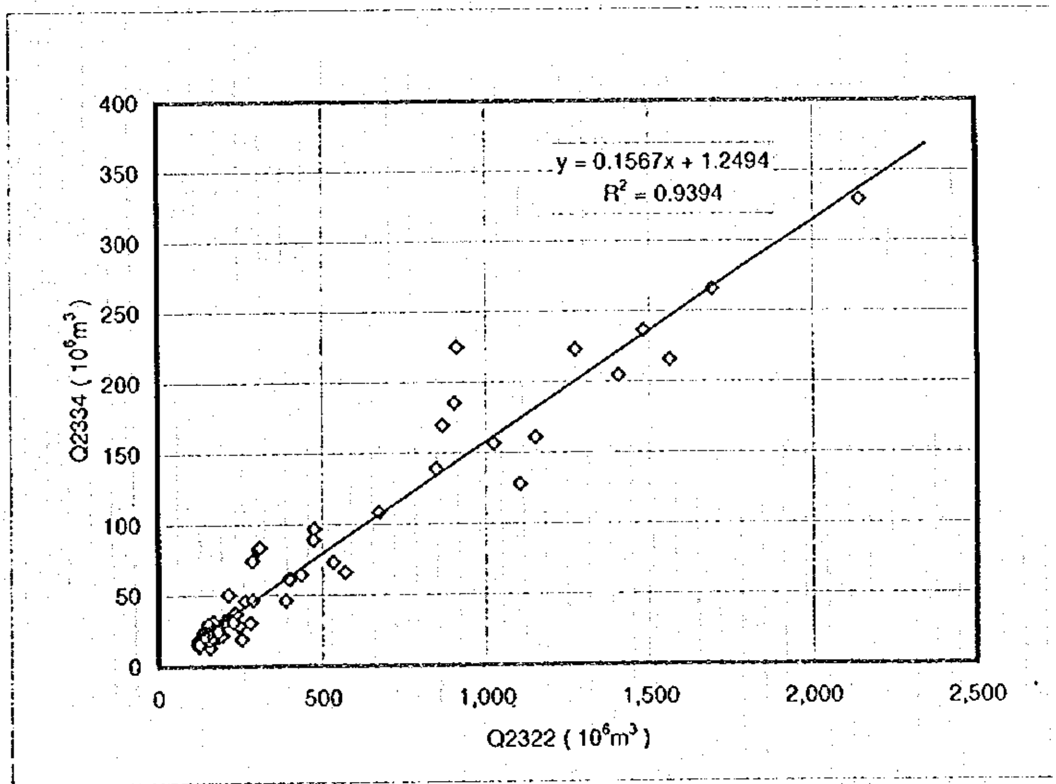


Figure 6-8 Correlation between Runoff at G.S. No.2322 and No.2334

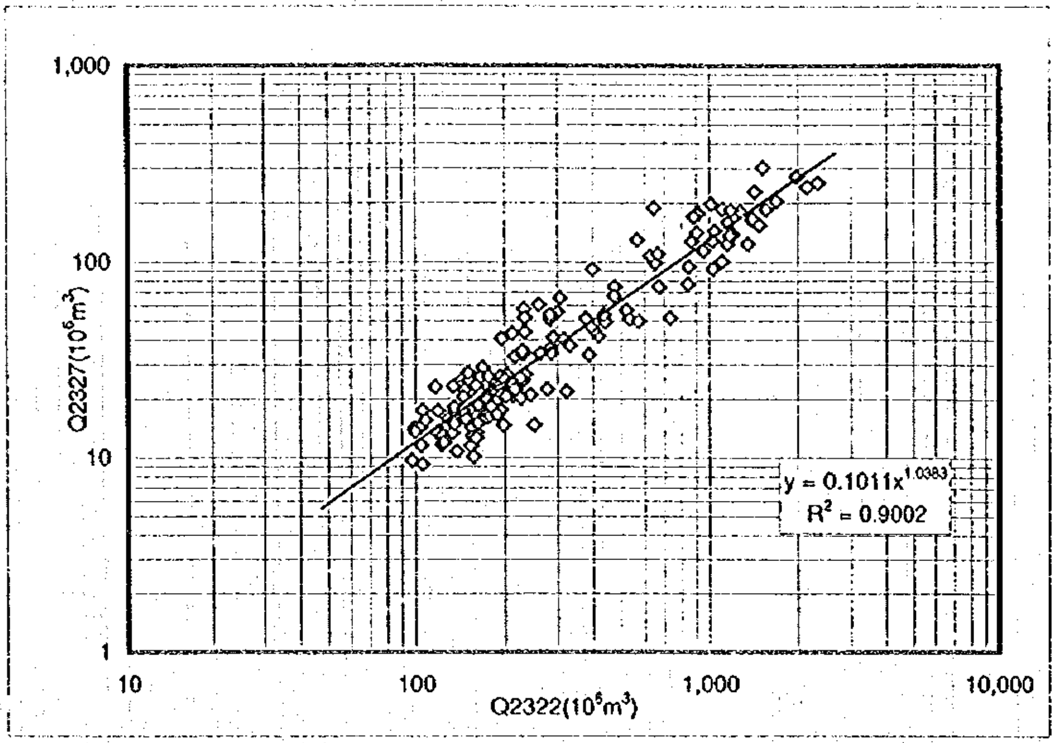


Figure 6-9 Correlation between Runoff at G.S. No.2322 and No.2327

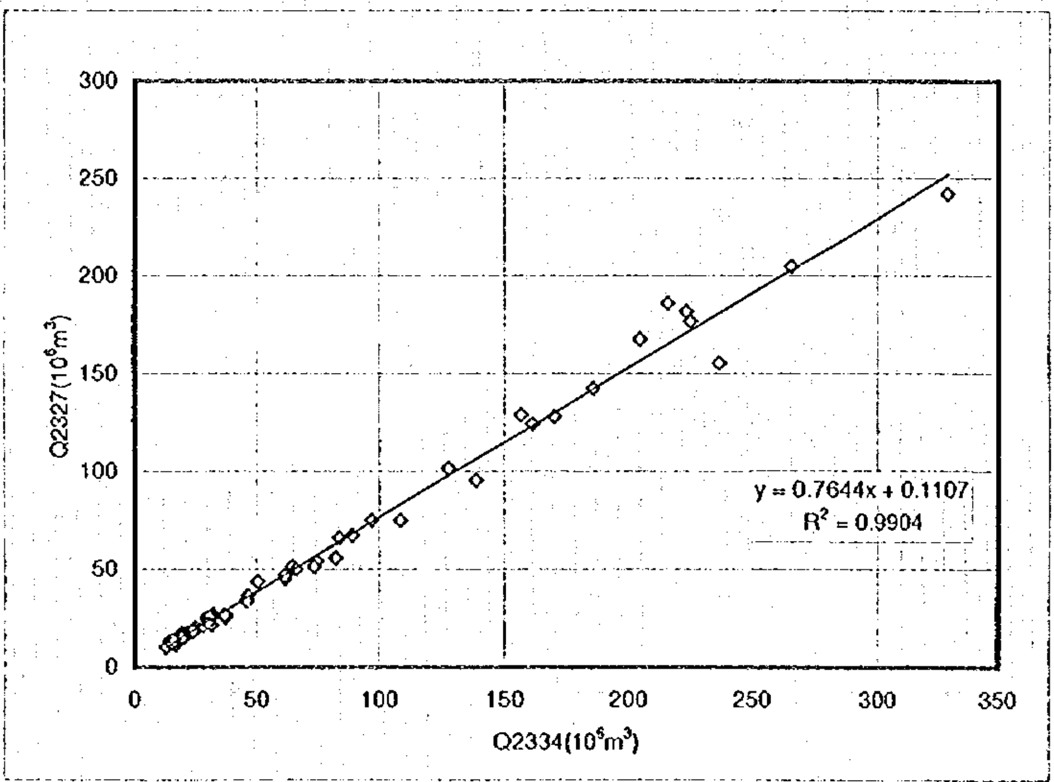


Figure 6-10 Correlation between Runoff at G.S. No.2334 and No.2327

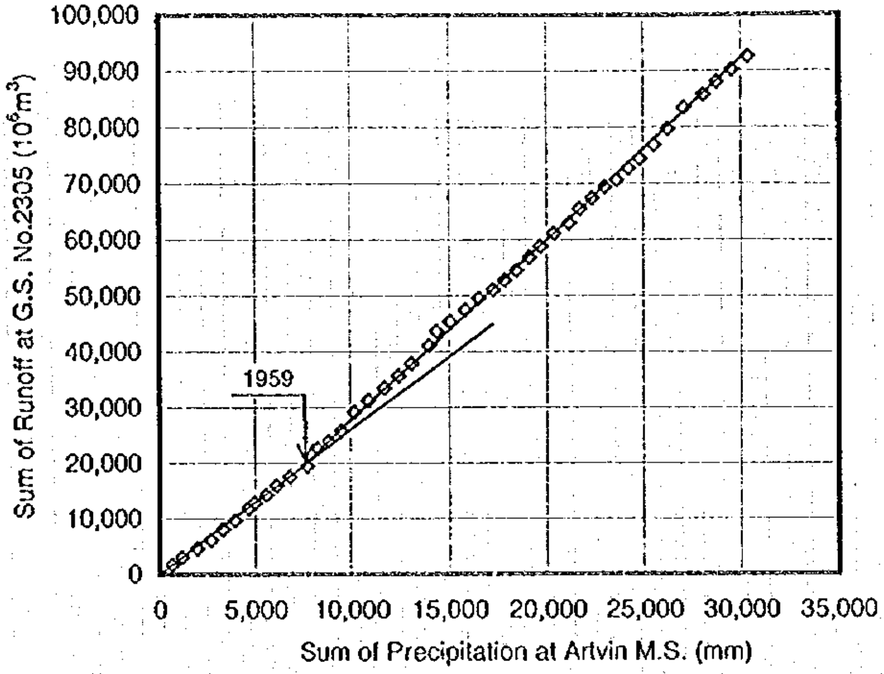


Figure 6-11 Double-mass Curve of Precipitation at Artvin M.S. and Runoff at G.S. No.2305

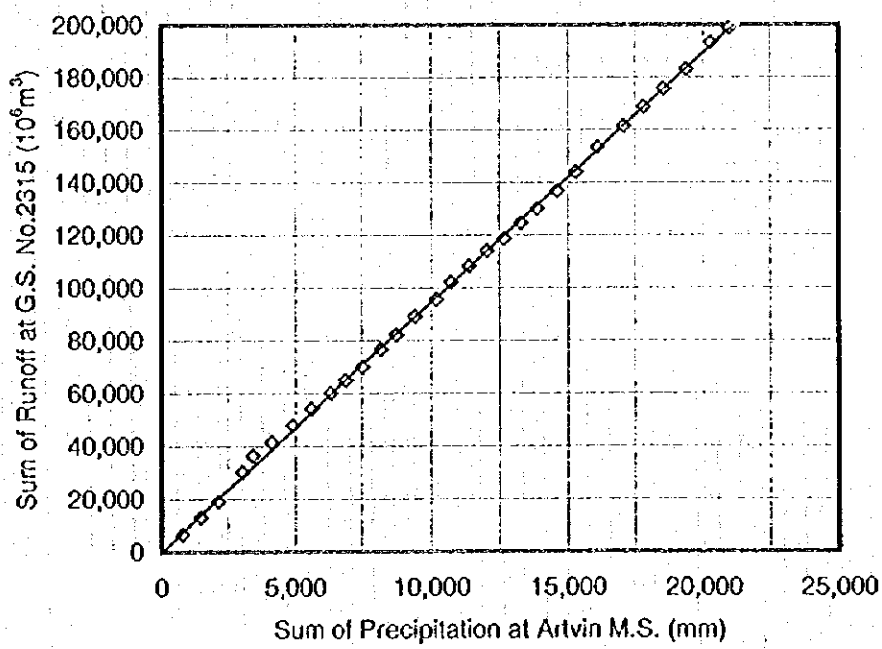


Figure 6-12 Double-mass Curve of Precipitation at Artvin M.S. and Runoff at G.S. No.2315

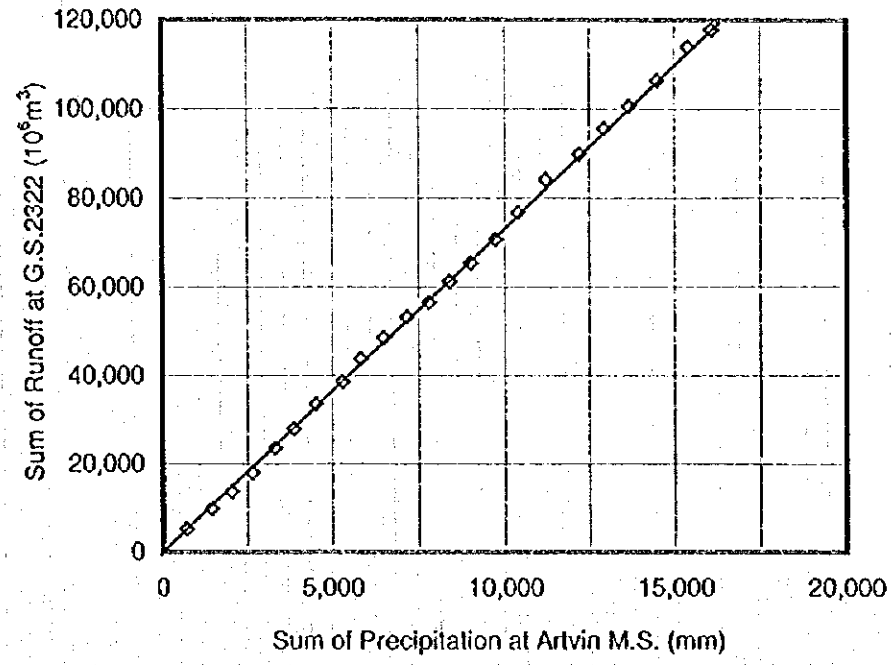


Figure 6-13 Double-mass Curve of Precipitation at Artvin M.S. and Runoff at G.S. No.2322

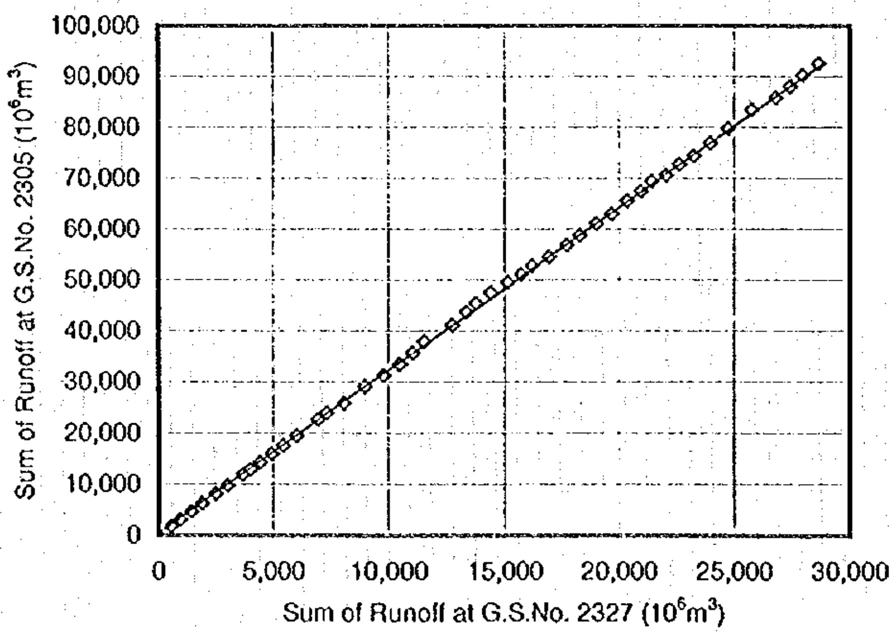


Figure 6-14 Double-mass Curve of Sum of Runoff at G.S. No.2305 and G.S. No.2327

(4) Estimates of Monthly Inflows at Dam Sites

The monthly inflows at dam sites were calculated by the following equations.

$$Q_{Baglik} = Q_{2334} - (Q_{2334} - Q_{2327}) \times \left(\frac{A_{2334} - A_{Baglik}}{A_{2334} - A_{2327}} \right) \qquad \text{Eq.(6-2)}$$

$$Q_{Bayram} = Q_{2327} \times \frac{A_{Bayram}}{A_{2327}} \qquad \text{Eq.(6-3)}$$

$$Q_{Kaleduzu} = Q_{2327} \qquad \text{Eq.(6-4)}$$

The estimated monthly inflows are shown in Tables 6-4, 6-5 and 6-6.

Table 6-4 Monthly Inflows at Bağlik Dam Site

Dam Site : Bağlik

Area : 1508.6 km^2

(unit: $10^6 m^3$)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1942	44.7	85.0	45.1	40.1	46.1	72.3	300.6	322.1	143.8	74.7	41.2	33.6	1249.4
1943	38.2	44.0	42.9	33.4	28.2	36.5	109.1	158.2	100.6	56.0	35.4	27.7	710.0
1944	29.8	31.7	31.4	27.6	29.4	66.3	106.6	344.6	173.7	101.9	39.6	30.7	1013.4
1945	28.2	31.5	23.4	21.0	18.6	25.2	82.1	149.0	115.8	53.8	27.3	21.1	596.9
1946	23.2	22.5	21.9	27.1	19.2	33.4	98.9	160.7	133.2	68.3	42.9	27.2	678.4
1947	41.2	31.0	25.3	24.8	25.4	70.3	98.9	80.7	63.5	33.0	21.8	19.1	534.9
1948	23.3	37.8	25.6	24.3	22.9	25.4	105.7	159.0	138.1	47.2	28.0	26.2	663.5
1949	25.5	22.8	19.8	19.1	17.1	30.4	67.3	149.8	84.7	31.1	22.9	20.2	510.7
1950	21.5	19.5	18.5	17.5	17.7	39.8	128.2	159.0	87.0	49.6	25.8	18.6	602.8
1951	32.3	26.9	23.6	22.0	20.1	31.8	102.3	126.9	106.5	47.5	28.0	28.3	596.4
1952	49.0	37.6	28.5	26.2	29.1	37.4	135.6	149.8	108.2	64.9	31.0	23.1	720.5
1953	21.2	20.0	18.8	17.3	18.2	23.5	95.5	154.8	114.1	56.6	32.1	29.5	601.7
1954	25.5	25.2	20.7	20.9	23.0	43.3	134.0	207.7	152.8	83.7	37.6	28.1	802.4
1955	25.6	23.1	21.7	18.0	18.2	28.0	59.4	94.6	56.2	22.3	15.2	14.6	397.0
1956	15.1	15.1	16.8	15.5	22.1	28.7	100.6	126.9	110.7	53.2	25.2	20.5	550.6
1957	19.0	17.5	16.1	13.5	19.1	52.4	104.0	151.5	124.9	54.8	26.2	21.1	620.2
1958	21.2	21.7	20.9	18.5	18.6	39.3	106.5	154.8	114.1	48.2	24.1	23.3	611.2
1959	22.6	21.8	22.3	22.3	17.2	43.3	109.1	183.9	140.5	64.2	35.1	27.1	709.4
1960	36.2	32.9	26.4	44.7	70.9	102.8	235.3	267.1	160.9	85.7	41.2	25.1	1129.1
1961	24.5	21.7	20.3	14.6	15.4	29.2	104.0	122.7	82.1	25.2	13.8	13.2	486.7
1962	15.0	18.3	27.6	21.1	22.6	82.0	136.4	175.7	113.2	50.7	23.6	22.7	709.0
1963	23.2	23.4	24.1	25.4	26.2	37.6	188.1	291.6	266.2	147.3	60.0	29.7	1142.7
1964	29.0	25.9	24.7	23.4	22.4	48.4	144.6	211.7	154.4	52.1	28.0	24.6	789.3
1965	39.9	28.4	38.0	25.7	21.8	85.3	164.1	191.7	135.3	59.3	18.7	12.7	820.8
1966	42.6	45.2	30.3	32.3	35.5	48.7	135.2	217.4	114.0	47.9	19.6	18.7	787.5
1967	15.8	12.6	15.6	13.1	14.9	34.7	107.9	225.7	116.9	97.6	43.9	32.6	731.3
1968	28.8	33.5	73.4	44.1	40.9	81.0	348.4	392.3	196.4	92.5	46.3	36.5	1414.0
1969	35.2	32.3	32.0	19.8	20.2	53.1	148.8	238.0	85.2	30.3	17.8	19.9	732.7
1970	49.0	28.7	27.2	26.0	30.3	55.0	139.9	126.6	57.9	31.3	23.5	25.0	620.4
1971	51.3	34.5	31.3	25.1	29.8	68.3	99.7	197.9	131.5	46.6	37.5	16.5	769.9
1972	28.9	27.0	34.2	24.8	24.5	45.0	181.2	170.4	152.8	68.3	30.2	33.6	820.9
1973	30.6	30.6	23.9	22.0	31.3	40.6	102.9	190.3	147.2	66.3	24.9	18.6	729.4
1974	23.3	28.8	25.3	20.0	17.9	51.5	76.6	193.7	92.4	29.6	20.0	34.4	613.6
1975	20.8	20.4	20.1	20.0	18.2	48.6	171.6	159.1	111.5	39.5	18.8	19.7	668.2
1976	28.4	22.1	19.6	21.3	21.0	49.1	155.9	255.9	166.6	79.6	30.6	25.5	875.6
1977	40.3	29.0	25.5	21.1	21.7	39.6	102.5	185.2	120.9	54.1	28.4	23.3	691.6
1978	29.9	27.2	22.0	20.7	30.4	57.6	146.8	244.9	155.7	75.7	35.0	22.7	868.8
1979	25.1	26.1	26.9	29.1	33.6	49.1	116.7	198.6	156.9	78.0	31.4	18.9	790.5
1980	27.1	47.5	38.5	27.5	27.3	62.7	188.6	216.7	90.9	38.6	25.4	21.1	812.1
1981	27.4	28.4	27.7	23.2	22.5	42.5	87.6	165.2	189.1	71.7	31.0	27.2	743.6
1982	27.7	28.4	31.7	28.4	22.2	33.3	118.5	159.1	66.3	48.0	29.9	19.9	613.4
1983	32.3	29.7	17.3	22.3	18.1	73.7	166.6	219.6	137.9	43.2	12.3	11.8	784.6
1984	29.6	52.8	26.9	22.8	22.9	77.7	127.1	177.5	98.9	63.0	28.6	16.1	744.0
1985	13.7	20.2	17.1	16.6	20.2	66.6	238.9	236.7	72.7	27.0	18.2	29.4	777.3
1986	52.1	37.0	32.7	26.2	30.5	65.9	185.1	204.4	175.7	68.9	16.4	17.1	911.9
1987	22.4	18.7	17.2	20.5	56.1	43.9	229.7	324.2	146.6	27.9	26.3	34.9	968.4
1988	27.9	26.4	25.7	29.5	42.1	117.6	292.6	348.8	210.7	96.5	51.8	45.1	1314.7
1989	65.4	53.7	48.3	33.3	33.0	241.6	388.2	253.3	141.0	43.7	14.7	19.8	1336.1
1990	21.4	20.5	18.8	12.9	18.0	63.2	157.2	259.6	134.5	60.1	20.2	19.1	805.6
1991	24.8	44.7	27.7	20.2	23.1	94.7	153.8	125.3	105.2	44.8	21.1	15.2	700.7
1992	14.0	16.6	17.8	15.4	14.4	45.6	181.2	228.3	212.7	71.2	30.5	24.4	872.1
1993	79.5	72.3	36.2	31.5	30.9	59.9	219.0	320.6	200.8	64.5	29.7	23.8	1168.8
1994	19.6	49.8	32.1	30.8	29.3	82.0	220.1	165.3	87.0	36.2	22.9	16.3	791.4
Ave.	30.4	30.8	26.9	23.9	25.9	56.7	151.0	201.8	129.4	58.0	28.5	23.7	786.9

Table 6-5 Monthly Inflows at Bayram Dam Site

Dam Site : Bayram

Area : 1159.0 km²

(unit: $10^6 m^3$)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1942	33.8	66.5	34.1	30.1	34.9	56.1	248.1	266.6	115.2	58.0	30.9	24.9	999.1
1943	28.6	33.2	32.3	24.7	20.6	27.2	86.3	127.2	79.3	42.8	26.3	20.2	548.8
1944	21.9	23.4	23.1	20.2	21.6	51.2	84.2	285.9	140.3	80.4	29.7	22.6	804.5
1945	20.6	23.2	16.9	14.9	13.1	18.3	64.1	119.5	91.8	41.1	19.9	15.0	458.5
1946	16.7	16.1	15.7	19.8	13.6	24.7	77.9	129.3	106.3	52.8	32.3	19.9	525.1
1947	30.9	22.8	18.4	18.0	18.4	54.4	77.9	62.9	48.9	24.4	15.6	13.5	406.1
1948	16.8	28.2	18.6	17.6	16.4	18.4	83.5	127.9	110.4	35.7	20.5	19.0	513.1
1949	18.5	16.3	14.1	13.5	12.0	22.4	52.0	120.2	66.2	22.9	16.5	14.3	388.9
1950	15.3	13.8	13.0	12.3	12.4	29.9	102.2	127.9	68.1	37.7	18.8	13.1	464.5
1951	23.8	19.6	17.0	15.7	14.3	23.5	80.7	101.1	84.2	36.0	20.5	20.7	457.3
1952	37.2	28.1	20.9	19.1	21.3	27.9	108.4	120.2	85.6	50.0	22.8	16.7	558.1
1953	15.1	14.2	13.3	12.1	12.8	16.9	75.1	124.4	90.5	43.3	23.7	21.7	463.1
1954	18.5	18.3	14.7	14.9	16.5	32.6	107.0	168.9	122.7	65.4	28.1	20.5	628.2
1955	18.6	16.7	15.5	12.6	12.8	20.5	45.6	74.4	43.0	16.0	10.5	10.0	296.1
1956	10.4	10.4	11.7	10.7	15.8	21.0	79.3	101.1	87.7	40.6	18.3	14.6	421.7
1957	13.4	12.2	11.2	9.2	13.5	40.0	82.1	121.6	99.4	41.9	19.1	15.0	478.7
1958	15.1	15.5	14.9	13.0	13.1	29.4	84.2	124.4	90.5	36.6	17.4	16.8	470.9
1959	16.2	15.6	16.0	16.0	12.0	32.6	86.3	148.9	112.5	49.5	26.1	19.8	551.4
1960	26.9	24.3	19.2	33.8	55.0	81.1	192.3	219.4	129.5	67.0	30.9	18.2	897.7
1961	17.7	15.5	14.5	10.0	10.7	21.4	82.1	97.6	64.1	18.3	9.4	8.9	370.2
1962	10.3	12.9	20.2	15.0	16.3	64.0	109.0	141.9	89.8	38.6	17.0	16.3	551.3
1963	16.7	16.9	17.4	18.4	19.0	28.1	152.4	240.4	218.7	118.1	46.1	21.8	913.9
1964	21.2	18.9	17.9	16.9	16.1	36.7	115.9	172.3	124.0	39.7	20.4	17.8	617.8
1965	29.9	20.8	28.4	18.7	15.6	66.7	132.2	155.4	108.1	45.5	13.2	8.5	643.0
1966	32.1	34.2	22.3	23.9	26.4	36.9	108.0	177.2	90.4	36.4	13.9	13.2	614.8
1967	11.0	8.5	10.8	8.9	10.3	25.7	85.3	184.2	92.8	76.9	33.1	24.1	571.5
1968	21.1	24.8	57.0	33.2	30.7	63.2	289.2	327.1	159.4	72.6	35.0	27.2	1140.5
1969	26.2	23.9	23.6	14.0	14.4	40.5	119.3	194.7	66.6	22.3	12.5	14.1	572.2
1970	37.2	21.0	19.8	18.9	22.3	42.0	111.9	100.9	44.4	23.0	16.9	18.1	476.5
1971	39.1	25.6	23.0	18.2	21.9	52.8	78.6	160.6	104.9	35.3	28.0	11.5	599.5
1972	21.2	19.7	25.3	18.0	17.7	34.0	146.6	137.4	122.7	52.8	22.2	24.9	642.6
1973	22.5	22.5	17.3	15.8	23.1	30.4	81.2	154.3	118.1	51.2	18.1	13.1	567.5
1974	16.8	21.1	18.3	14.2	12.6	39.2	59.6	157.1	72.6	21.7	14.2	25.5	473.0
1975	14.8	14.5	14.3	14.2	12.8	36.9	138.5	128.0	88.3	29.6	13.2	13.9	519.0
1976	20.8	15.8	13.8	15.2	14.9	37.3	125.3	209.9	134.3	62.1	22.5	18.5	690.5
1977	30.2	21.3	18.5	15.0	15.5	29.7	80.9	150.0	96.1	41.3	20.7	16.8	536.0
1978	22.0	19.8	15.8	14.7	22.4	44.1	117.7	200.5	125.2	58.9	26.0	16.3	683.5
1979	18.2	19.0	19.6	21.3	24.9	37.2	92.7	161.2	126.2	60.8	23.1	13.3	617.6
1980	19.8	36.0	28.8	20.1	19.9	48.3	152.8	176.6	71.3	28.9	18.5	15.1	636.0
1981	20.0	20.8	20.2	16.7	16.2	32.0	68.6	133.1	153.2	55.6	22.8	19.9	579.1
1982	20.2	21.2	23.6	21.2	16.5	24.8	88.0	118.1	49.3	35.7	22.3	14.9	455.9
1983	24.0	22.1	12.9	16.6	13.5	54.7	123.7	163.1	102.4	32.2	9.2	8.8	583.3
1984	22.1	39.3	20.1	17.0	17.1	57.7	94.4	131.8	73.5	46.8	21.3	12.0	553.2
1985	10.3	15.1	12.8	12.4	15.1	49.5	177.4	175.7	54.0	20.1	13.6	21.9	577.9
1986	38.8	27.5	24.3	19.5	22.7	49.0	137.4	151.7	130.5	51.2	12.3	12.8	677.8
1987	16.7	14.0	12.9	15.3	41.7	32.7	170.5	240.6	108.9	20.8	19.6	26.0	719.6
1988	20.8	19.7	19.2	22.0	31.4	87.4	217.2	258.9	156.4	71.7	38.5	33.5	976.6
1989	48.6	39.9	36.0	24.8	24.6	179.3	288.1	188.1	104.7	32.5	11.0	14.8	992.4
1990	16.8	15.5	14.0	9.7	13.6	48.7	117.6	194.1	90.4	44.4	14.3	14.2	593.5
1991	19.3	32.4	20.0	15.6	17.3	71.1	122.1	96.2	71.0	32.0	15.8	11.4	524.1
1992	11.1	10.9	13.1	12.8	12.5	34.5	134.8	147.2	176.3	48.7	24.3	17.8	644.0
1993	52.8	51.3	23.8	24.0	20.5	42.6	172.4	229.4	158.7	47.5	21.3	17.4	861.7
1994	16.7	41.3	25.4	24.4	23.8	62.4	167.5	121.3	63.9	25.4	16.7	13.0	601.7
Ave.	22.4	22.7	19.7	17.4	18.9	42.8	118.4	159.4	101.6	44.2	21.0	17.2	605.8

Table 6-6 Monthly Inflows at Kaledüzu Dam Site

Dam Site : Kaledüzu

Area : 1213.9 km²

(unit: $10^6 m^3$)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1942	35.6	70.2	35.9	31.8	36.8	59.2	261.8	281.3	121.6	61.2	32.6	26.3	1054.4
1943	30.1	35.0	34.1	26.1	21.7	28.7	91.1	134.3	83.7	45.2	27.8	21.4	579.2
1944	23.1	24.7	24.4	21.3	22.8	54.0	88.9	301.8	148.1	84.8	31.4	23.8	849.1
1945	21.8	24.5	17.8	15.8	13.8	19.3	67.6	126.1	96.9	43.4	21.0	15.9	483.9
1946	17.6	17.0	16.5	20.9	14.3	26.1	82.2	136.5	112.2	55.7	34.1	21.0	554.2
1947	32.6	24.1	19.4	19.0	19.4	57.4	82.2	66.4	51.6	25.7	16.4	14.2	428.6
1948	17.7	29.8	19.6	18.5	17.3	19.5	88.1	135.0	116.5	37.7	21.6	20.1	541.6
1949	19.5	17.3	14.8	14.3	12.6	23.6	54.9	126.9	69.9	24.2	17.4	15.1	410.4
1950	16.2	14.6	13.7	13.0	13.1	31.5	107.8	135.0	71.9	39.8	19.8	13.8	490.2
1951	25.2	20.7	18.0	16.6	15.1	24.8	85.2	106.7	88.9	38.0	21.6	21.8	482.6
1952	39.2	29.6	22.0	20.1	22.5	29.5	114.4	126.9	90.3	52.8	24.1	17.6	589.1
1953	15.9	15.0	14.0	12.8	13.5	17.9	79.3	131.3	95.5	45.7	25.0	22.9	488.8
1954	19.5	19.3	15.5	15.7	17.5	34.4	112.9	178.3	129.5	69.1	29.7	21.7	663.0
1955	19.6	17.6	16.4	13.3	13.5	21.6	48.1	78.5	45.4	16.9	11.1	10.6	312.5
1956	11.0	11.0	12.4	11.3	16.7	22.2	83.7	106.7	92.5	42.8	19.3	15.4	445.1
1957	14.2	12.9	11.8	9.7	14.3	42.2	86.7	128.4	104.9	44.2	20.1	15.9	505.2
1958	15.9	16.4	15.7	13.7	13.9	31.0	88.9	131.3	95.5	38.6	18.4	17.7	497.0
1959	17.1	16.4	16.9	16.9	12.7	34.4	91.1	157.1	118.7	52.2	27.5	20.9	581.9
1960	28.4	25.7	20.3	35.6	58.0	85.6	203.0	231.6	136.6	70.7	32.6	19.2	947.4
1961	18.7	16.4	15.3	10.6	11.2	22.6	86.7	103.0	67.6	19.3	10.0	9.4	390.7
1962	10.9	13.6	21.3	15.9	17.2	67.6	115.1	149.8	94.7	40.7	16.0	17.2	581.8
1963	17.6	17.8	18.4	19.5	20.1	29.6	160.8	253.7	230.8	124.6	48.6	23.0	964.5
1964	22.4	19.9	18.9	17.8	16.9	38.8	122.3	181.9	130.9	41.9	21.6	18.8	652.1
1965	31.5	21.9	30.0	19.7	16.5	70.4	139.5	164.0	114.0	48.0	13.9	9.0	678.6
1966	33.9	36.1	23.6	25.2	27.8	39.0	114.0	187.0	95.4	38.4	14.7	14.0	648.8
1967	11.6	8.9	11.4	9.3	10.8	27.2	90.0	194.4	97.9	81.1	35.0	25.4	603.1
1968	22.2	26.2	60.1	35.1	32.4	66.7	305.2	345.2	168.2	76.6	37.0	28.7	1203.7
1969	27.6	25.2	24.9	14.8	15.2	42.7	125.9	205.5	70.3	23.5	13.2	14.9	603.9
1970	39.3	22.2	20.9	20.0	23.5	44.3	118.1	106.4	46.8	24.3	17.9	19.1	502.9
1971	41.2	27.0	24.3	19.2	23.1	55.7	82.9	169.5	110.7	37.2	29.5	12.1	632.7
1972	22.4	20.8	26.8	18.9	18.7	35.8	154.7	145.1	129.5	55.7	23.5	26.3	678.2
1973	23.8	23.7	18.2	16.7	24.4	32.1	85.7	162.8	124.6	54.0	19.1	13.8	599.0
1974	17.7	22.2	19.4	15.0	13.3	41.4	62.9	165.8	76.6	22.9	15.0	26.9	499.2
1975	15.6	15.3	15.1	14.9	13.5	38.9	146.1	135.1	93.2	31.2	14.0	14.7	547.8
1976	21.9	16.7	14.6	16.1	15.8	39.3	132.3	221.5	141.8	65.5	23.8	19.5	728.7
1977	31.9	22.5	19.6	15.9	16.4	31.3	85.3	158.3	101.4	43.6	21.9	17.7	565.7
1978	23.2	20.9	16.6	15.6	23.6	46.6	124.2	211.6	132.1	62.1	27.5	17.2	721.4
1979	19.2	20.0	20.7	22.5	26.3	39.3	97.8	170.2	133.2	64.1	24.4	14.1	651.8
1980	20.9	38.0	30.4	21.2	21.0	51.0	161.3	186.4	75.2	30.5	19.5	15.9	671.2
1981	21.1	21.9	21.4	17.6	17.1	33.8	72.4	140.5	161.7	58.7	24.1	21.0	611.2
1982	21.3	22.3	24.9	22.3	17.5	26.2	92.9	124.7	52.0	37.7	23.6	15.7	481.1
1983	25.4	23.3	13.6	17.5	14.3	57.8	130.6	172.1	108.1	33.9	9.7	9.3	615.6
1984	23.3	41.4	21.2	17.9	18.0	60.9	99.7	139.1	77.6	49.4	22.5	12.7	583.8
1985	10.8	15.9	13.5	13.1	15.9	52.3	187.2	185.5	57.0	21.2	14.3	23.1	609.9
1986	40.9	29.1	25.7	20.6	24.0	51.7	145.0	160.1	137.7	54.1	12.9	13.5	715.3
1987	17.7	14.7	13.6	16.1	44.0	34.5	179.9	254.0	114.9	21.9	20.7	27.4	759.5
1988	21.9	20.8	20.2	23.2	33.1	92.2	229.2	273.2	165.1	75.7	40.7	35.4	1030.7
1989	51.3	42.1	38.0	26.2	26.0	189.3	304.0	198.5	110.5	34.3	11.6	15.6	1047.4
1990	17.8	16.4	14.8	10.2	14.3	51.4	124.2	204.9	95.4	46.9	15.1	15.0	626.3
1991	20.4	34.2	21.1	16.4	18.2	75.0	128.8	101.5	74.9	33.7	16.7	12.1	553.1
1992	11.7	11.5	13.8	13.5	13.2	36.4	142.3	155.3	186.1	51.4	25.7	18.7	679.7
1993	55.7	54.2	25.1	25.4	21.6	45.0	182.0	242.1	167.4	50.1	22.5	18.4	909.4
1994	17.6	43.5	26.8	25.7	25.2	65.9	176.8	128.0	67.4	26.8	17.6	13.7	635.0
Ave.	23.6	23.9	20.8	18.4	20.0	45.2	125.0	168.2	107.2	46.6	22.2	18.2	639.4

6.3 Evaporation Study

6.3.1 Available Evaporation Data

There is no meteorological station measuring the evaporation quantity in the Berta basin. In the Çoruh basin, monthly evaporation records at the meteorological stations at İspir, Bayburt and Tortum H.E.S. are available. The evaporation quantities (mm) are measured by using the U.S. Weather Bureau Class A Pan.

Scrutinizing meteorological data observed at each station, such as relative humidity and surface wind velocity, it was found that Bayburt has the most similar climate to that of the Berta basin. The observed monthly Class A Pan evaporation quantities at Bayburt M.S. are shown in Table 6-7.

Table 6-7 Observed Monthly Class A Pan Evaporation quantities at Bayburt M.S.

(unit: mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1977	D	D	D	-	-	133.0	178.0	192.0	137.0	43.5	D	D
1978	D	D	D	-	127.0	159.0	206.0	183.0	157.0	77.1	D	D
1979	D	D	D	-	121.0	140.0	176.0	201.0	159.0	66.2	D	D
1980	D	D	D	-	121.0	178.0	230.0	185.0	144.0	75.3	D	D
1981	D	D	D	-	98.0	137.0	198.0	183.0	135.0	78.0	D	D
1982	D	D	D	-	105.0	152.0	160.0	168.0	117.0	73.1	D	D
1983	D	D	D	-	99.0	148.0	191.0	176.0	132.0	68.2	D	D
1984	D	D	D	-	92.2	138.0	198.0	148.0	153.0	79.2	D	D
1985	D	D	D	-	102.0	148.0	171.0	191.0	130.0	52.4	26.8	D
1986	D	D	D	-	-	141.0	186.0	181.0	127.0	-	D	D
1987	D	D	D	-	136.0	127.0	153.0	152.0	112.0	57.7	D	D
1988	D	D	D	-	89.0	99.2	138.0	149.0	97.6	50.7	D	D
1989	D	D	D	-	125.0	136.0	171.0	-	116.0	50.9	D	D
1990	D	D	D	-	82.2	127.0	136.0	133.0	99.8	53.2	D	D
1991	D	D	D	72.0	86.8	123.0	144.0	149.0	119.0	60.6	D	D
1992	D	D	D	-	92.4	150.0	142.0	97.3	52.4	-	D	D
1993	D	D	D	-	63.1	97.9	140.0	123.0	105.0	63.2	D	D
1994	D	D	D	-	-	-	-	128.0	122.0	-	D	D

D; unmeasurable due to frost

-; no data available

6.3.2 Reservoir Evaporation

(1) Correlation between Monthly Mean Temperature and Monthly Evaporation

Figure 6-15 shows the relation between monthly mean temperature and evaporation quantity at Bayburt M.S. The regression line is expressed as follows.

$$E = 10.267T - 18.704 \qquad \text{Eq.(6-5)}$$

where

E = *monthly evaporation quantity (mm)*

T = *monthly mean temperature (°C)*

(2) Estimates of Monthly Mean Temperatures at Reservoir Surfaces

Eq.(6-6) expresses the relation between the monthly mean temperatures at Artvin M.S. and Şavşat M.S. (refer to Figure 6-16)

$$T_{Savsat} = \alpha T_{Artvin} + \beta \qquad \text{Eq.(6-6)}$$

where

$\alpha = 1.1927,\ \beta = -4.3455$

And then, assuming that the temperature at a certain location is predominantly dependent on its elevation, the temperatures at reservoir surfaces are given by;

$$T_{dam} = \alpha' T_{Artvin} + \beta' \qquad \text{Eq.(6-7)}$$

where

T_{dam} = *monthly mean temperature at reservoir surfaces (°C)*

T_{Artvin} = *monthly mean temperature at Artvin M.S. (°C)*

$\alpha' = (\alpha - 1)(h_{Artvin} - h_{dam})/(h_{Artvin} - h_{Savsat}) + 1.0$

$\beta' = \beta(h_{Artvin} - h_{dam})/(h_{Artvin} - h_{Savsat})$

h_{Artvin} = *elevation at Artvin M.S. (= 597m)*

h_{Savsat} = *elevation at Şavşat M.S. (= 1,100m)*

h_{dam} = *elevation at reservoir surfaces (m)*

Substituting the above values, the equation for each dam site is expressed as follows;

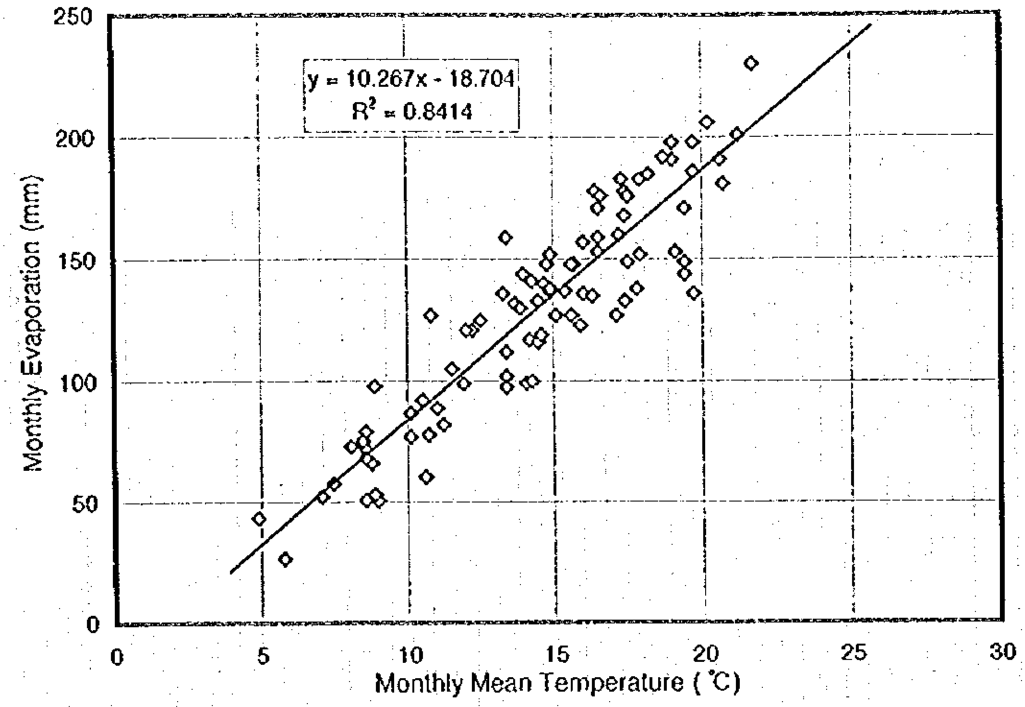


Figure 6-15 Correlation between Monthly Mean Temperature and Monthly Evaporation observed at Bayburt M.S.

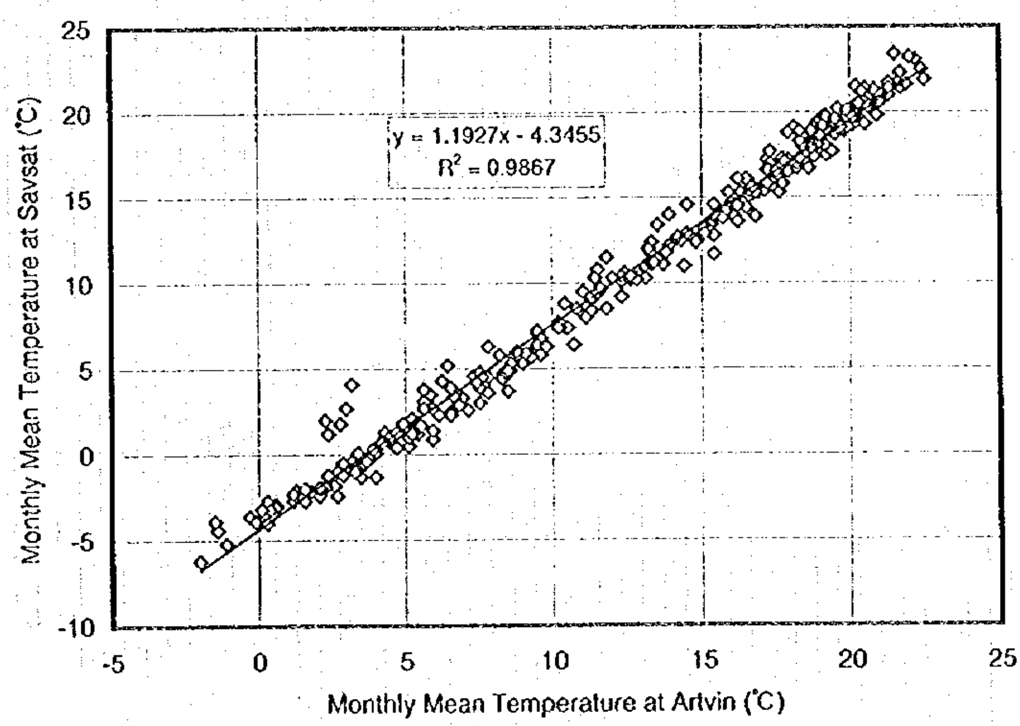


Figure 6-16 Correlation between Monthly Mean Temperature at Artvin M.S. and Şavşat M.S.

Table 6-8 Temperature at Reservoir Surface Levels

Dam Site	Water Level (m)	Equation
Bağlık	570	$T = 0.9897T_{Artvin} + 0.2333$
Bayram	745	$T = 1.0567T_{Artvin} - 1.2786$
Kaledüzü	720	$T = 1.0417T_{Artvin} - 1.0626$

(3) Estimates of Reservoir Evaporation

The reservoir evaporations are calculated by multiplying Eq.(6-5) by a pan coefficient of 0.7.[5] The results are tabulated in Tables 6-9, 6-10 and 6-11.

Table 6-9 Reservoir Evaporation at Bağlik Dam Site

E = 0.7X(10.267XT - 18.704) (mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1948	-	-	-	-	-	139.4	143.6	147.2	114.5	82.5	46.2	6.4	-
1949	0.0	0.0	37.7	46.9	115.9	135.8	137.2	132.3	105.2	83.2	73.2	22.7	890.2
1950	0.0	0.0	32.0	110.9	106.7	115.2	130.8	128.0	133.7	81.8	66.1	39.8	944.9
1951	15.6	19.2	72.5	91.0	106.7	120.9	139.4	151.5	120.2	59.0	61.8	14.9	972.6
1952	18.5	27.7	42.6	66.1	94.6	114.5	139.4	147.9	141.5	115.9	64.0	47.6	1,020.3
1953	34.1	19.2	16.3	77.5	108.1	132.3	140.8	145.8	113.8	93.1	24.9	0.0	905.8
1954	0.0	9.9	48.3	57.6	118.7	137.2	152.9	155.0	130.1	107.4	81.8	54.0	1,053.0
1955	34.8	53.3	52.6	73.2	108.1	131.6	145.8	145.8	128.7	115.9	61.1	21.3	1,072.2
1956	23.4	25.6	21.3	82.5	86.7	122.3	133.0	146.5	105.2	78.9	38.4	1.4	865.2
1957	0.0	30.5	34.1	84.6	116.6	133.7	149.3	154.3	143.6	98.1	56.9	37.0	1,038.8
1958	33.4	32.7	53.3	75.4	121.6	129.4	134.4	140.8	111.6	86.7	52.6	24.1	996.1
1959	33.4	0.0	24.1	79.6	99.5	122.3	148.6	140.1	96.7	64.7	59.7	44.1	912.9
1960	27.0	19.9	43.4	74.6	115.2	123.7	143.6	130.1	121.6	102.4	74.6	41.2	1,017.4
1961	8.5	17.7	20.6	83.2	113.8	128.7	131.6	138.0	97.4	91.0	54.0	31.3	915.7
1962	14.9	25.6	61.1	66.8	105.9	118.7	138.7	140.1	120.2	91.7	74.6	47.6	1,006.0
1963	25.6	44.8	25.6	64.0	93.1	115.2	134.4	135.8	124.4	91.7	54.7	12.8	922.1
1964	0.0	12.8	41.2	60.4	89.6	127.3	130.8	123.0	114.5	90.3	44.1	4.2	838.2
1965	4.9	13.5	47.6	64.7	105.9	125.9	131.6	138.0	118.0	61.8	48.3	34.8	895.1
1966	47.6	44.1	54.7	86.0	98.8	118.0	142.2	144.4	111.6	108.1	91.0	44.1	1,090.7
1967	7.8	0.0	29.8	67.5	108.1	107.4	125.2	128.0	107.4	96.0	49.8	9.2	836.1
1968	0.0	9.2	31.3	80.3	113.8	113.8	132.3	131.6	126.6	87.5	72.5	24.9	923.6
1969	14.9	19.9	40.5	61.1	105.2	137.2	123.0	134.4	110.9	69.0	49.8	37.0	902.9
1970	22.0	39.1	52.6	95.3	99.5	115.9	140.1	124.4	105.9	70.4	63.3	12.1	940.6
1971	24.9	11.3	51.9	66.8	108.8	114.5	136.5	130.1	127.3	71.1	51.9	0.0	895.1
1972	0.0	4.9	28.4	98.1	96.0	125.2	140.1	148.6	116.6	103.8	42.6	0.0	904.4
1973	0.0	30.5	30.5	69.0	91.7	106.7	132.3	122.3	111.6	93.9	27.0	4.9	820.4
1974	0.0	22.0	46.9	50.5	102.4	123.0	128.0	127.3	108.1	120.9	56.2	25.6	910.8
1975	7.1	0.0	41.9	97.4	101.7	134.4	140.1	133.7	111.6	78.2	49.0	3.5	898.7
1976	0.0	0.0	28.4	76.1	84.6	110.9	129.4	125.2	105.9	83.9	64.0	32.0	840.4
1977	0.0	43.4	40.5	76.8	98.8	118.0	129.4	131.6	110.9	56.2	56.9	5.7	868.1
1978	7.8	34.8	55.4	62.6	97.4	108.1	131.6	118.7	118.7	89.6	27.0	18.5	870.2
1979	17.0	23.4	56.2	76.1	110.2	120.2	122.3	147.9	118.7	81.8	61.1	11.3	946.3
1980	0.0	11.3	41.9	62.6	103.8	127.3	142.9	130.1	101.7	81.8	54.7	32.0	890.1
1981	30.5	26.3	41.9	56.2	83.2	122.3	142.9	130.1	121.6	100.3	41.2	49.0	945.6
1982	1.4	3.5	25.6	78.9	101.0	115.9	119.5	128.7	113.1	79.6	35.5	7.1	809.7
1983	0.0	12.8	31.3	76.1	103.1	115.9	135.1	121.6	106.7	79.6	51.9	22.0	856.0
1984	24.9	17.0	49.8	69.0	98.1	113.8	124.4	111.6	123.7	83.2	53.3	3.5	872.3
1985	19.9	0.0	19.2	70.4	112.3	117.3	115.9	141.5	103.8	69.7	65.4	5.7	841.1
1986	9.9	19.2	34.1	83.2	72.5	120.2	132.3	146.5	124.4	82.5	34.8	8.5	868.1
1987	16.3	25.6	20.6	56.9	106.7	113.8	134.4	124.4	104.5	78.2	52.6	16.3	850.3
1988	0.0	17.0	37.7	73.9	91.7	118.0	135.1	131.6	107.4	86.7	28.4	22.0	849.6
1989	0.0	0.0	44.1	98.1	98.1	122.3	128.0	145.1	115.9	84.6	51.2	5.7	893.0
1990	0.0	12.8	32.7	65.4	87.5	119.5	133.0	125.2	115.2	83.9	58.3	27.7	861.0
1991	0.7	2.1	33.4	83.9	93.1	121.6	140.8	133.0	110.2	103.8	56.2	9.9	888.7
Ave.	12.3	18.2	39.0	74.4	101.7	121.7	135.1	135.4	115.5	86.8	54.2	21.0	914.9

-; no data available

Table 6-10 Reservoir Evaporation at Bayram Dam Site

E = 0.7X(10.267XT - 18.704) (mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1948	-	-	-	-	-	138.7	143.3	147.1	112.1	78.0	39.2	0.0	-
1949	0.0	0.0	30.1	40.0	113.7	134.9	136.4	131.1	102.3	78.7	68.1	14.2	849.5
1950	0.0	0.0	24.0	108.3	103.8	112.9	129.6	126.6	132.6	77.2	60.5	32.4	908.0
1951	6.6	10.4	67.3	87.1	103.8	119.0	138.7	151.6	118.2	52.9	55.9	5.8	917.3
1952	9.6	19.5	35.4	60.5	90.9	112.1	138.7	147.8	141.0	113.7	58.2	40.8	968.2
1953	26.3	10.4	7.3	72.6	105.3	131.1	140.2	145.6	111.4	89.4	16.4	0.0	856.1
1954	0.0	0.5	41.5	51.4	116.7	136.4	153.1	155.4	128.8	104.5	77.2	47.6	1,013.3
1955	27.1	46.8	46.1	68.1	105.3	130.4	145.6	145.6	127.3	113.7	55.2	12.7	1,023.7
1956	14.9	17.2	12.7	78.0	82.5	120.5	131.9	146.3	102.3	74.2	30.9	0.0	811.3
1957	0.0	22.5	26.3	80.2	114.4	132.6	149.4	154.7	143.3	94.7	50.6	29.4	998.1
1958	25.6	24.8	46.8	70.4	119.7	128.1	133.4	140.2	109.1	82.5	46.1	15.7	942.4
1959	25.6	0.0	15.7	74.9	96.2	120.5	148.6	139.5	93.2	59.0	53.7	37.0	863.7
1960	18.7	11.1	36.2	69.6	112.9	122.0	143.3	128.8	119.7	99.2	69.6	33.9	965.2
1961	0.0	8.9	11.9	78.7	111.4	127.3	130.4	137.2	93.9	87.1	47.6	23.3	857.6
1962	5.8	17.2	55.2	61.3	103.0	116.7	138.0	139.5	118.2	87.8	69.6	40.8	953.0
1963	17.2	37.7	17.2	58.2	89.4	112.9	133.4	134.9	122.8	87.8	48.3	3.5	863.4
1964	0.0	3.5	33.9	54.4	85.6	125.8	129.6	121.3	112.1	86.3	37.0	0.0	789.5
1965	0.0	4.3	40.8	59.0	103.0	124.3	130.4	137.2	115.9	55.9	41.5	27.1	839.4
1966	40.8	37.0	48.3	81.8	95.4	115.9	141.8	144.0	109.1	105.3	87.1	37.0	1,043.4
1967	0.0	0.0	21.8	62.0	105.3	104.5	123.5	126.6	104.5	92.4	43.0	0.0	783.7
1968	0.0	0.0	23.3	75.7	111.4	111.4	131.1	130.4	125.0	83.3	67.3	16.4	875.3
1969	5.8	11.1	33.2	55.2	102.3	136.4	121.3	133.4	108.3	63.5	43.0	29.4	842.9
1970	13.4	31.6	46.1	91.6	96.2	113.7	139.5	122.8	103.0	65.1	57.5	2.8	883.2
1971	16.4	2.0	45.3	61.3	106.1	112.1	135.7	128.8	125.8	65.8	45.3	0.0	844.7
1972	0.0	0.0	20.2	94.7	92.4	123.5	139.5	148.6	114.4	100.7	35.4	0.0	869.5
1973	0.0	22.5	22.5	63.5	87.8	103.8	131.1	120.5	109.1	90.1	18.7	0.0	769.8
1974	0.0	13.4	40.0	43.8	99.2	121.3	126.6	125.8	105.3	119.0	49.9	17.2	861.4
1975	0.0	0.0	34.7	93.9	98.5	133.4	139.5	132.6	109.1	73.4	42.3	0.0	857.4
1976	0.0	0.0	20.2	71.1	80.2	108.3	128.1	123.5	103.0	79.5	58.2	24.0	796.3
1977	0.0	36.2	33.2	71.9	95.4	115.9	128.1	130.4	108.3	49.9	50.6	0.0	819.9
1978	0.0	27.1	49.1	56.7	93.9	105.3	130.4	116.7	116.7	85.6	18.7	9.6	809.8
1979	8.1	14.9	49.9	71.1	107.6	118.2	120.5	147.8	116.7	77.2	55.2	2.0	889.2
1980	0.0	2.0	34.7	56.7	100.7	125.8	142.5	128.8	98.5	77.2	48.3	24.0	839.4
1981	22.5	18.0	34.7	49.9	78.7	120.5	142.5	128.8	119.7	97.0	33.9	42.3	888.5
1982	0.0	0.0	17.2	74.2	97.7	113.7	117.5	127.3	110.6	74.9	27.8	0.0	760.9
1983	0.0	3.5	23.3	71.1	100.0	113.7	134.2	119.7	103.8	74.9	45.3	13.4	802.9
1984	16.4	8.1	43.0	63.5	94.7	111.4	122.8	109.1	122.0	78.7	46.8	0.0	816.6
1985	11.1	0.0	10.4	65.1	109.9	115.2	113.7	141.0	100.7	64.3	59.7	0.0	791.0
1986	0.5	10.4	26.3	78.7	67.3	118.2	131.1	146.3	122.8	78.0	27.1	0.0	806.7
1987	7.3	17.2	11.9	50.6	103.8	111.4	133.4	122.8	101.5	73.4	46.1	7.3	786.7
1988	0.0	8.1	30.1	68.9	87.8	115.9	134.2	130.4	104.5	82.5	20.2	13.4	796.1
1989	0.0	0.0	37.0	94.7	94.7	120.5	126.6	144.8	113.7	80.2	44.5	0.0	856.6
1990	0.0	3.5	24.8	59.7	83.3	117.5	131.9	123.5	112.9	79.5	52.1	19.5	808.2
1991	0.0	0.0	25.6	79.5	89.4	119.7	140.2	131.9	107.6	100.7	49.9	0.5	845.0
Ave.	7.4	11.7	31.5	69.3	98.5	119.9	134.1	134.5	113.2	82.6	47.7	14.2	864.3

-; no data available

Table 6-11 Reservoir Evaporation at Kaledüzu Dam Site

E = 0.7×(10.267×T - 18.704) (mm)

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1948	-	-	-	-	-	138.8	143.3	147.1	112.5	78.6	40.2	0.0	-
1949	0.0	0.0	31.2	41.0	114.0	135.0	136.6	131.3	102.7	79.4	68.8	15.4	855.3
1950	0.0	0.0	25.2	108.7	104.2	113.2	129.8	126.8	132.8	77.9	61.3	33.5	913.2
1951	7.9	11.6	68.1	87.6	104.2	119.2	138.8	151.6	118.5	53.8	56.8	7.1	925.2
1952	10.9	20.7	36.5	61.3	91.4	112.5	138.8	147.8	141.1	114.0	59.0	41.7	975.6
1953	27.4	11.6	8.6	73.3	105.7	131.3	140.3	145.6	111.7	89.9	17.6	0.0	863.2
1954	0.0	1.8	42.5	52.3	117.0	136.6	153.1	155.4	129.0	104.9	77.9	48.5	1,018.9
1955	28.2	47.8	47.0	68.8	105.7	130.5	145.6	145.6	127.5	114.0	56.0	13.9	1,030.6
1956	16.1	18.4	13.9	78.6	83.1	120.7	132.0	146.3	102.7	74.8	31.9	0.0	818.8
1957	0.0	23.7	27.4	80.9	114.7	132.8	149.3	154.6	143.3	95.2	51.5	30.4	1,003.9
1958	26.7	25.9	47.8	71.1	120.0	128.3	133.5	140.3	109.5	83.1	47.0	16.9	950.0
1959	26.7	0.0	16.9	75.6	96.7	120.7	148.6	139.6	93.7	59.8	54.5	38.0	870.7
1960	19.9	12.4	37.2	70.3	113.2	122.3	143.3	129.0	120.0	99.7	70.3	35.0	972.6
1961	0.3	10.1	13.1	79.4	111.7	127.5	130.5	137.3	94.4	87.6	48.5	24.4	865.0
1962	7.1	18.4	56.0	62.0	103.4	117.0	138.1	139.6	118.5	88.4	70.3	41.7	960.6
1963	18.4	38.7	18.4	59.0	89.9	113.2	133.5	135.0	123.0	88.4	49.3	4.9	871.8
1964	0.0	4.9	35.0	55.3	86.1	126.0	129.8	121.5	112.5	86.9	38.0	0.0	795.8
1965	0.0	5.6	41.7	59.8	103.4	124.5	130.5	137.3	116.2	56.8	42.5	28.2	846.6
1966	41.7	38.0	49.3	82.4	95.9	116.2	141.8	144.1	109.5	105.7	87.6	38.0	1,050.1
1967	0.0	0.0	22.9	62.8	105.7	104.9	123.8	126.8	104.9	92.9	44.0	1.1	789.8
1968	0.0	1.1	24.4	76.3	111.7	111.7	131.3	130.5	125.3	83.9	68.1	17.6	882.0
1969	7.1	12.4	34.2	56.0	102.7	136.6	121.5	133.5	108.7	64.3	44.0	30.4	851.5
1970	14.6	32.7	47.0	92.2	96.7	114.0	139.6	123.0	103.4	65.8	58.3	4.1	891.3
1971	17.6	3.4	46.2	62.0	106.4	112.5	135.8	129.0	126.0	66.6	46.2	0.0	851.9
1972	0.0	0.0	21.4	95.2	92.9	123.8	139.6	148.6	114.7	101.2	36.5	0.0	873.8
1973	0.0	23.7	23.7	64.3	88.4	104.2	131.3	120.7	109.5	90.6	19.9	0.0	776.3
1974	0.0	14.6	41.0	44.7	99.7	121.5	126.8	126.0	105.7	119.2	50.8	18.4	868.4
1975	0.0	0.0	35.7	94.4	98.9	133.5	139.6	132.8	109.5	74.1	43.2	0.0	861.7
1976	0.0	0.0	21.4	71.8	80.9	108.7	128.3	123.8	103.4	80.1	59.0	25.2	802.6
1977	0.0	37.2	34.2	72.6	95.9	116.2	128.3	130.5	108.7	50.8	51.5	0.0	825.9
1978	0.0	28.2	50.0	57.5	94.4	105.7	130.5	117.0	117.0	86.1	19.9	10.9	817.3
1979	9.4	16.1	50.8	71.8	108.0	118.5	120.7	147.8	117.0	77.9	56.0	3.4	897.4
1980	0.0	3.4	35.7	57.5	101.2	126.0	142.6	129.0	98.9	77.9	49.3	25.2	846.6
1981	23.7	19.2	35.7	50.8	79.4	120.7	142.6	129.0	120.0	97.4	35.0	43.2	896.6
1982	0.0	0.0	18.4	74.8	98.2	114.0	117.7	127.5	111.0	75.6	28.9	0.0	766.1
1983	0.0	4.9	24.4	71.8	100.4	114.0	134.3	120.0	104.2	75.6	46.2	14.6	810.5
1984	17.6	9.4	44.0	64.3	95.2	111.7	123.0	109.5	122.3	79.4	47.8	0.0	824.0
1985	12.4	0.0	11.6	65.8	110.2	115.5	114.0	141.1	101.2	65.1	60.5	0.0	797.3
1986	1.8	11.6	27.4	79.4	68.1	118.5	131.3	146.3	123.0	78.6	28.2	0.3	814.6
1987	8.6	18.4	13.1	51.5	104.2	111.7	133.5	123.0	101.9	74.1	47.0	8.6	795.8
1988	0.0	9.4	31.2	69.6	88.4	116.2	134.3	130.5	104.9	83.1	21.4	14.6	803.7
1989	0.0	0.0	38.0	95.2	95.2	120.7	126.8	144.8	114.0	80.9	45.5	0.0	861.0
1990	0.0	4.9	25.9	60.5	83.9	117.7	132.0	123.8	113.2	80.1	53.0	20.7	815.7
1991	0.0	0.0	26.7	80.1	89.9	120.0	140.3	132.0	108.0	101.2	50.8	1.8	850.8
Ave.	8.0	12.6	32.6	70.0	99.0	120.1	134.2	134.6	113.5	83.2	48.6	14.9	871.2

-: no data available

6.4 Sedimentation Study

6.4.1 Available Sedimentation Data

Table 6-12 shows descriptions of the sampling sites of the suspended load in the Çoruh Basin. There is no observation data on bed loads in the Çoruh Basin.

Table 6-12 Available Suspended Sediment Data

Station	River	Elevation (m)	Effective C.A. (km^2)	Available period of records	Number of Samples
2315-Karşıköy	Çoruh	57	18,308	Jun.1967 - Apr.1996	316
2316-İspir Köprüsü	Çoruh	1,170	5,505	Sep.1969-Apr.1996	305
2320-Laleli	Çoruh	1,365	4,759	Jul.1971-Nov.1983	88
2322-Altınsu	Çoruh	201	16,394	Mar.1984-Apr.1996	150
2325-Oltu	Oltu	1,135	1,800	Jun.1977-Apr.1996	217
2327-Çiftehanlar	Berta	570	1,223	Oct.1995-Oct.1996	13
2329-Çoşkunlar	Oltu	1,005	3,605	Oct.1991-Apr.1996	63
2331-Gündoğdu	Deviskel	560	94	Feb.1988-Apr.1996	71
2334-Bağlık	Berta	385	1,541	Oct.1995-Oct.1996	13

6.4.2 Suspended Load

(1) Estimates of suspended sediment during the runoff observation period

Table 6-13 shows the suspended load data observed at G.S.No. 2327, based on which the sediment rating curve shown in Figure 6-17 was constructed.

Table 6-13 Suspended Load observed at G.S.No.2327

Date observed	Discharge (m^3/sec)	Concentration (p.p.m)	Sediment discharge (ton/day)	Date observed	Discharge (m^3/sec)	Concentration (p.p.m)	Sediment discharge (ton/day)
1995, Oct. 11	11.559	65	64.92	1996, May. 7	59.637	190.7	982.61
1995, Nov.7	8.897	21.4	16.45	1996, Jun. 5	34.924	332.4	1,002.99
1995, Dec 5	7.315	27.8	17.57	1996, Jul. 3	10.394	24.9	22.36
1996, Jan. 9	9.149	31.7	25.06	1996, Aug. 6	4.236	31.3	11.46
1996, Feb. 7	4.945	2.2	0.94	1996, Sept. 11	5.356	59.1	27.35
1996, Mar. 5	5.302	19.1	8.75	1996, Oct. 16	7.756	45.3	30.36
1996, Apr. 2	21.705	393.6	738.2	-	-	-	-

The regression analysis gave the following relationship of the form.

$$q_s = 0.2116 q_w^{2.2582} \qquad \text{Eq.(6-8)}$$

where

q_s = *sediment discharge (ton / day)*

q_w = *water discharge (m^3 / sec)*

Furthermore, in order to avoid underestimating the mean sediment discharge, the following modification to the Eq.(6-8) was made.[4]

$$q_s = \alpha \times 0.2116 q_w^{2.2582} \qquad \text{Eq.(6-9)}$$

where

$\alpha = 10^{1.2s^2}$

$$s^2 = \sum_{i=1}^{n} \left(\log yi - \log \overline{yi} \right)^2 \Big/ (n-2) \cong 0.131$$

y_i = *actual sediment discharge (ton / day)*

$\overline{y_i}$ = *y_i on mean given x_i (ton / day)*

n = *data size*

Then, Eq.(6-9) becomes,

$$q_s = 0.2460 q_w^{2.2582} \qquad \text{Eq.(6-10)}$$

(2) Estimates of suspended sediment quantity over a long time period

Figure 6-18 shows the relation between monthly total sediment yield (ton) computed with Eq.(6-10) and monthly total runoff volume. The following equation was obtained by regression analysis.

$$Q_s = 0.9437 Q_w^{2.2765} \qquad \text{Eq.(6-11)}$$

where

Q_s = *monthly total sediment yield (ton)*

Q_w = *monthly total runoff volume ($10^6 m^3$)*

Monthly sediment yields over a long time period were computed by using Eq.(6-10) and Eq.(6-11). The results were summarized in Table 6-14.

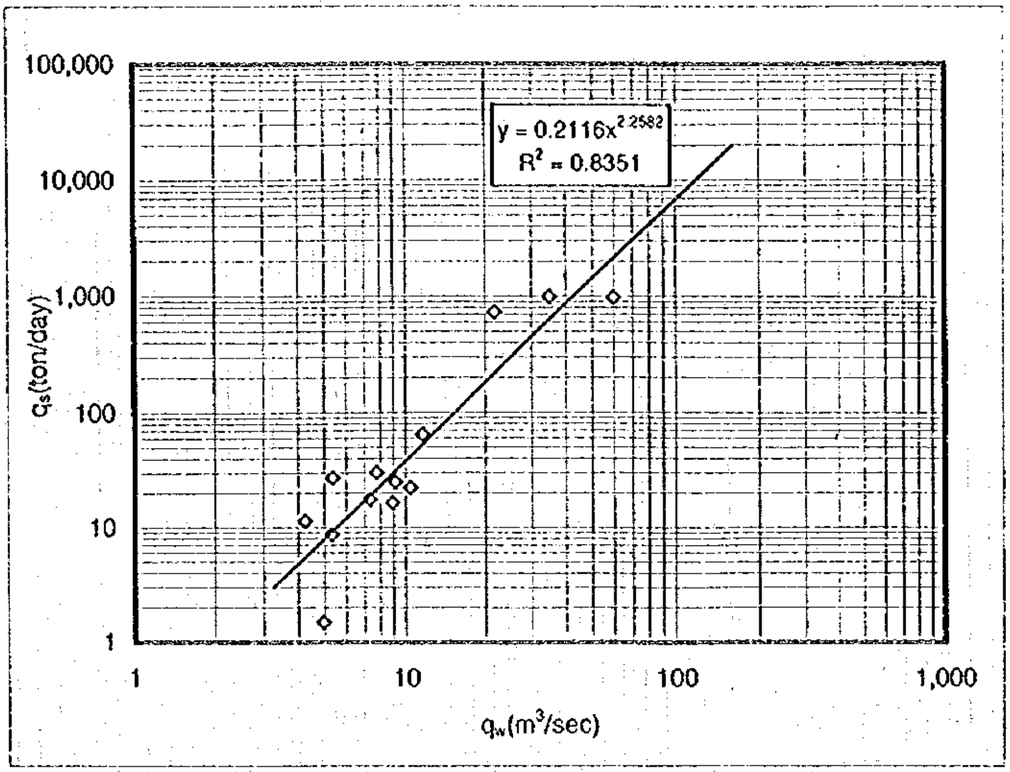


Figure 6-17 Correlation between Daily Runoff and Daily Sediment Discharge at G.S. No.2327

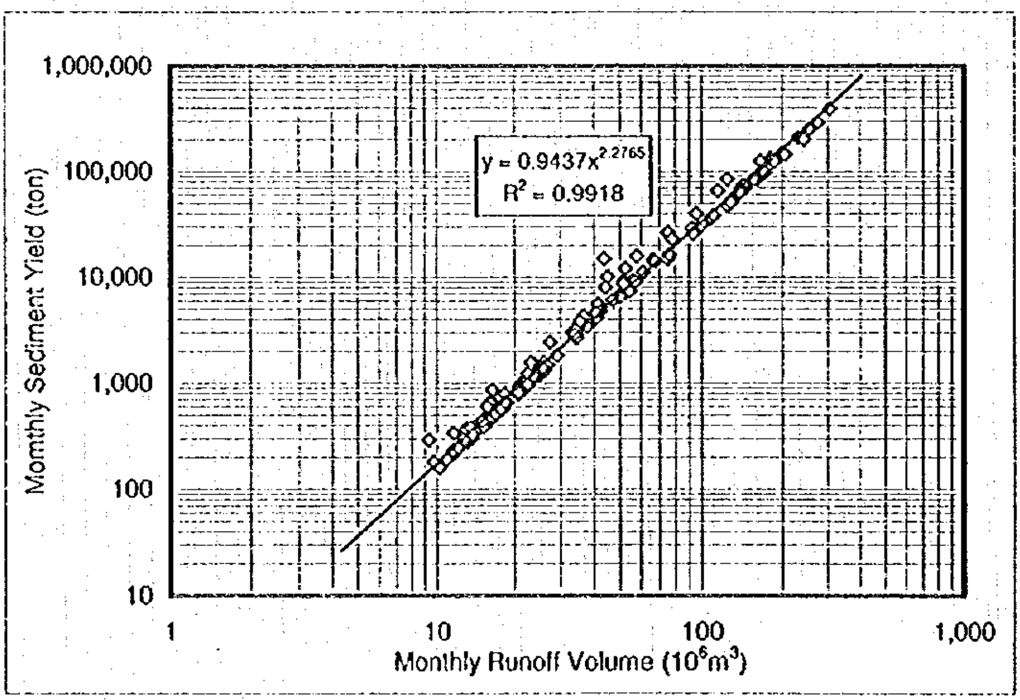


Figure 6-18 Correlation between Monthly Runoff Volume and Monthly Total Sediment Yield at G.S. No.2327

Table 6-14 Estimeted Monthly Sediment Yield at G.S.No. 2327

Station Name : Çiftehanlar
Station No. : 2327

Effective Drainage Area : 1223 km^2
Elevation : 570 m
Sediment Yield : 219 ton/year/km^2

(unit; ton)

Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Total
1942	3,217	15,049	3,283	2,477	3,464	10,231	301,541	355,207	52,600	11,043	2,637	1,613	762,361
1943	2,199	3,092	2,912	1,580	1,046	1,963	27,250	65,958	22,499	5,527	1,826	1,005	136,855
1944	1,201	1,400	1,363	997	1,163	8,290	25,774	416,719	82,375	23,181	2,406	1,290	566,156
1945	1,050	1,369	662	504	371	797	13,839	57,194	31,402	5,033	970	510	113,701
1946	648	598	560	953	405	1,580	21,607	68,464	43,808	8,904	2,912	962	151,400
1947	2,637	1,319	805	766	808	9,540	21,607	13,289	7,475	1,535	554	398	60,733
1948	655	2,138	828	728	624	812	25,291	66,788	47,759	3,661	1,032	872	151,191
1949	820	617	438	400	304	1,260	8,593	57,964	14,904	1,331	627	458	87,717
1950	535	419	368	323	330	2,434	40,039	66,788	15,898	4,137	844	372	132,486
1951	1,458	937	677	567	456	1,405	23,411	39,104	25,774	3,733	1,032	1,057	99,609
1952	4,006	2,113	1,078	877	1,127	2,092	45,761	57,964	26,753	7,885	1,321	644	151,621
1953	516	447	383	313	352	669	19,881	62,694	30,334	5,682	1,437	1,175	123,883
1954	820	795	485	497	634	2,975	44,454	125,696	60,712	14,513	2,119	1,039	254,739
1955	828	644	547	342	352	1,032	6,370	19,429	5,592	587	225	203	36,153
1956	221	221	290	238	574	1,096	22,499	39,104	28,258	4,887	797	475	98,661
1957	394	319	259	166	400	4,723	24,341	59,518	37,626	5,266	877	510	134,400
1958	516	547	497	368	376	2,349	25,774	62,694	30,334	3,859	713	658	128,684
1959	607	553	587	587	308	2,975	27,250	94,277	49,803	7,674	1,790	954	187,363
1960	1,925	1,526	894	3,217	9,766	23,657	168,946	228,080	68,627	15,337	2,637	787	525,399
1961	743	547	467	202	233	1,143	24,341	36,042	13,839	797	177	155	78,687
1962	218	357	997	510	609	13,822	46,422	84,552	29,808	4,366	677	611	182,948
1963	650	662	711	812	873	2,117	99,451	280,689	226,274	55,672	6,525	1,187	675,621
1964	1,118	854	759	664	593	3,902	53,311	131,601	62,253	4,657	1,027	748	261,487
1965	2,435	1,065	2,172	836	556	15,172	71,972	103,982	45,474	6,355	379	140	250,538
1966	2,870	3,309	1,254	1,464	1,835	3,946	45,392	140,140	30,286	3,809	426	381	235,113
1967	249	139	239	153	214	1,735	26,544	153,115	32,163	20,939	3,081	1,496	240,066
1968	1,100	1,601	10,581	3,105	2,593	13,414	427,628	566,000	110,123	18,389	3,498	1,964	1,159,997
1969	1,800	1,465	1,425	435	462	4,867	57,002	173,678	15,135	1,251	336	444	258,299
1970	4,016	1,096	957	662	1,247	5,291	49,265	38,870	5,999	1,349	668	781	110,400
1971	4,485	1,710	1,349	787	1,202	8,916	22,023	112,107	42,514	3,557	2,099	277	201,027
1972	1,114	943	1,676	764	742	3,262	91,068	78,627	60,755	8,901	1,244	1,612	250,708
1973	1,279	1,277	700	571	1,358	2,542	23,745	102,271	55,627	8,294	775	374	198,812
1974	657	1,101	803	448	339	4,531	11,746	106,545	18,379	1,181	447	1,700	147,878
1975	494	470	454	445	356	3,935	79,970	66,884	28,750	2,380	381	430	184,949
1976	1,066	573	423	524	504	4,032	63,708	206,088	74,624	12,867	1,281	819	366,510
1977	2,497	1,125	822	510	548	2,403	23,504	95,896	34,834	5,092	1,062	656	168,949
1978	1,213	959	568	488	1,260	5,923	55,268	185,814	63,553	11,417	1,782	613	328,859
1979	788	869	931	1,130	1,613	4,024	32,047	113,089	64,724	12,269	1,363	388	233,234
1980	951	3,732	2,236	987	970	7,267	100,106	139,079	17,648	2,261	813	514	276,563
1981	980	1,067	1,005	646	603	2,845	16,165	73,075	100,662	10,010	1,322	963	209,342
1982	999	970	1,180	920	601	1,334	26,060	47,800	7,161	3,417	1,184	462	92,089
1983	1,307	1,124	350	737	408	15,888	53,880	98,842	36,241	3,223	182	293	212,476
1984	1,173	5,626	1,001	567	643	11,235	30,854	68,318	23,309	6,626	1,236	297	150,886
1985	193	655	297	280	539	12,103	129,552	123,171	9,138	934	378	1,575	278,813
1986	4,183	1,825	1,356	777	1,510	9,188	69,813	84,541	63,579	7,392	375	381	244,921
1987	575	389	300	449	8,073	3,187	133,724	254,009	66,398	985	815	2,443	471,348
1988	990	936	816	1,066	3,030	29,312	210,349	293,557	125,557	16,533	4,660	3,863	690,668
1989	7,336	4,795	3,502	1,329	1,586	132,699	395,098	148,704	38,755	2,680	340	605	737,430
1990	645	864	435	161	401	9,323	85,152	144,720	40,102	6,096	388	438	288,726
1991	803	2,888	913	480	793	26,578	54,332	34,868	15,051	2,886	512	247	140,349
1992	220	235	337	304	302	4,352	74,856	85,266	125,081	8,712	1,404	657	301,726
1993	9,438	8,523	1,271	1,250	1,003	10,118	128,692	203,543	102,458	6,646	980	662	474,584
1994	591	15,029	1,480	1,314	1,422	14,702	113,917	50,862	14,161	1,486	569	328	215,861
Ave.	2,189	3,374	1,018	741	1,562	21,540	115,868	126,016	51,307	5,201	1,002	942	268,358

The annual average suspended sediment quantity for the water years 1942 to 1994 was estimated at 219 tonf/km^2. This figure can be applied to the whole basin, since there is no significant difference in vegetation and topography over the basin.

Figure 6-19 shows the relationship between the size of catchment area and sediment amounts for the river catchments in Turkey, which was originally made by EİE. From this figure, the annual sediment amount for the Bağlık dam site for a 50 percent upper prediction interval is 284,698 tons. This is converted to a sediment yield of 189 t/km^2. It can be said that this computed figure of 219 t/km^2 is reliable and on the conservative side.

6.4.3 Bed Load

The bed load quantity is generally expressed as a percentage of the suspended load. In this study, taking into account the steep topography of the Berta Basin, it was assumed as 20 %.[1]

6.4.4 Density of Sediment Accumulation

The average unit weight of sediment deposited in T years of operations was calculated by the following equation of Millar.[6]

$$W_T = W_1 + 0.4343K\left[\frac{T}{T-1}(\ln T) - 1\right] \qquad \text{Eq.(6-12)}$$

where

W_T = *average unit weight after T yeas of reservoir operation* (lb/ft^3)

W_1 = *initial unit weight* (lb/ft^3)

K = *density increase coefficient*

For initial density W1 and density increase coefficient K, the figures shown below were employed taking into consideration the sediment components ratio and operation condition of the reservoir.[9]

	sand	silt	clay
Ratio(%)	46	29	25
W_1 (lb./ft.^{3})	97	70	35
K	0	5.7	16

As a result, the average density of sediment accumulation after 50 years of operation was calculated as 1.298 t/m^3.

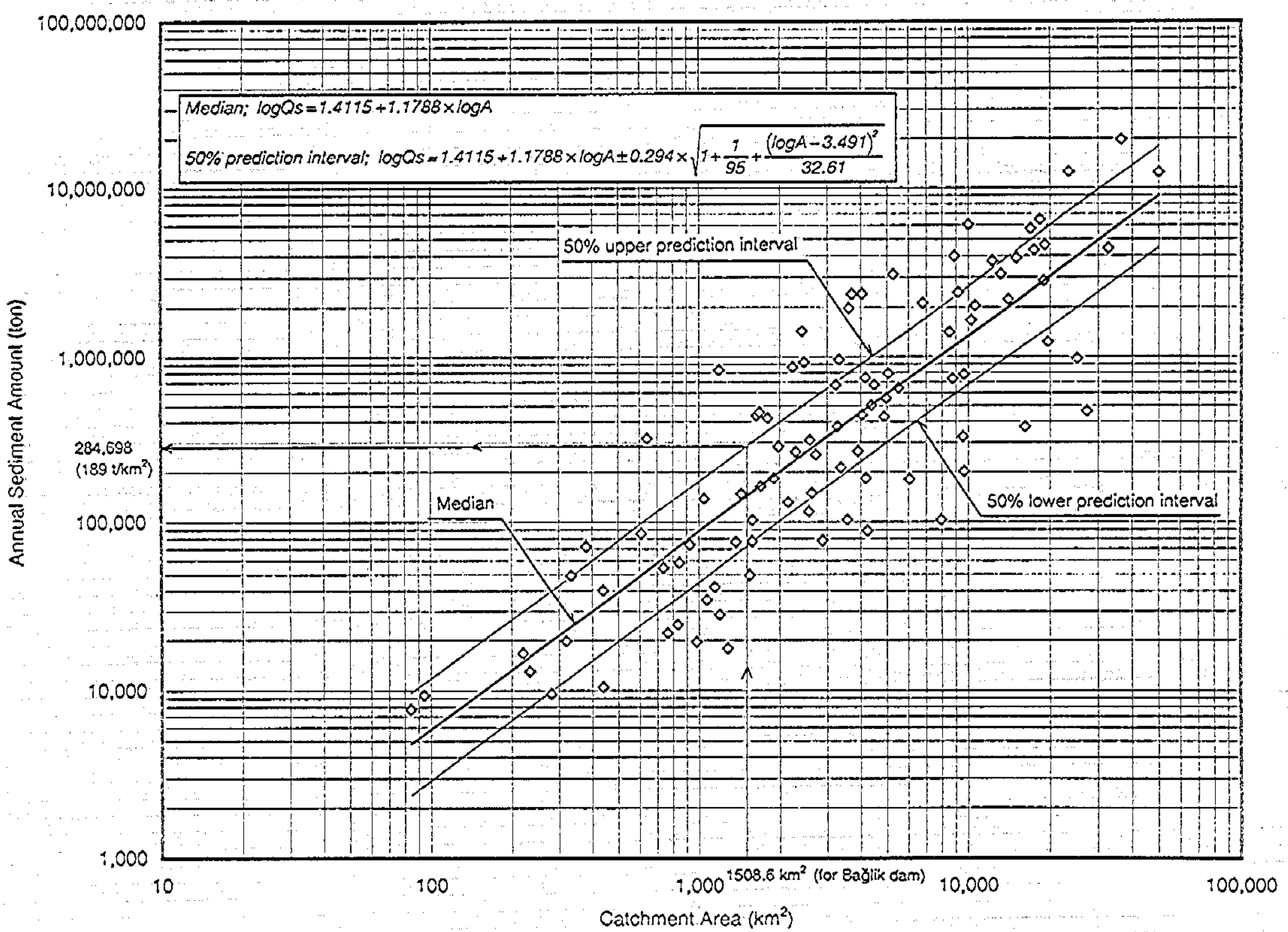


Figure 6-19 Relationship between Size of Catchment Area and Sediment Amounts in Turkey

6.5 Study of Probable Flood

6.5.1 Observed Annual Peak Discharge

The annual peak discharge observed at GS.No.2327, which has the longest observation period, is listed in Table 6-15.

Table 6-15 Annual Peak Discharge at G.S. No. 2327

Year	Date observed	Peak Discharge (m^3/sec)	Year	Date observed	Peak Discharge (m^3/sec)
1982	May 15	72.5	1989	Apr.14	214.0
1983	May 18	118.0	1990	Apr.27	289.0
1984	May 19	109.0	1991	May 2	109.0
1985	Apr.23	138.0	1992	May 30	163.0
1986	Jun.15	140.0	1993	Apr. 16	148.0
1987	May 2	181.0	1994	Apr.21	127.0
1988	May 19	186.0	-	-	-

6.5.2 Frequency Analysis on the Annual Peak Discharge

The probable flood discharge at G.S.No.2327 was computed in accordance with the Gumbel method.[4]

The probable flood discharge at each dam site was calculated on the basis that the specific discharge ($m^3/sec/km^2$) is constant in the basin. The results are shown below.

Table 6-16 Probable Flood Discharge at Dam Sites

(unit; m^3/sec)

	Drainage Area	Return Period (year)					
	(km^2)	2	5	10	25	50	100
No.2327	1,223	145.9	206.5	246.5	297.2	334.7	372.0
Bağlık	1,509	179.9	254.7	304.0	366.5	413.0	459.0
Bayram	1,159	138.2	195.7	233.6	281.6	317.0	352.0
Kaledüzü	1,214	144.8	204.9	244.6	294.9	332.2	369.3

6.6 Study of the Probable Maximum Flood (PMF)

6.6.1 Flood Discharge from the Probable Maximum Precipitation (PMP)

(1) Persisting 12-hour dew points

Vapor pressure values are observed at Artvin M.S. and Ardanuç M.S. three times a day, at 7 a.m., 2 p.m. and 9 p.m.

All values of the maximum persisting 12-hour vapor pressure, selected by 10-day intervals, were plotted against date observed and a smooth envelope drawn, as shown in Figure 6-20. Since both Artvin M.S. and Ardanuç M.S. are regarded as being located inside the rain area, the representative persisting 12-hour dew point was computed by averaging the values of both stations. Vapor pressures were transformed into dew points by using Figure 6-21. Both storm and maximum dew points were reduced pseudo-adiabatically to the 1,000 mb level by using Figure 6-22, so that dew points observed at stations at different elevations were comparable.[7]

(2) DAD Analysis of Major Storms

A depth-area-duration (DAD) analysis of major storms was made.[8] The obtained DAD values were maximized by multiplying the ratio of the precipitable water for the maximum 12-hour 1,000 mb dew point within 15 days of the storm date with that for the representative 12-hour 1,000 mb dew point for the storm.[7] The precipitable water was determined by using Figure 6-23. The ratios (r_m) of the maximum precipitable water (w_m) to the precipitable water (w_s) estimated for each storm are summarized as follows.

Table 6-17 Maximization of Major Storms

Storm date	Station numbers	Storm duration (hour)	Precipitable water for storm (w_s) (mm)	Maximum precipitable water (w_m) (mm)	$r_m=w_m/w_s$
1967, Dec. 3-4	4	60	16.51	33.78	2.05
1968, Apr. 18	4	18	34.54	47.00	1.36
1969, Oct. 28-30	7	48	19.30	49.53	2.57
1971, Dec. 24-25	6	48	12.75	27.74	2.18
1975, Mar. 3-4	7	30	13.34	29.21	2.19
1985, Dec. 5-6	5	48	14.61	29.20	2.00

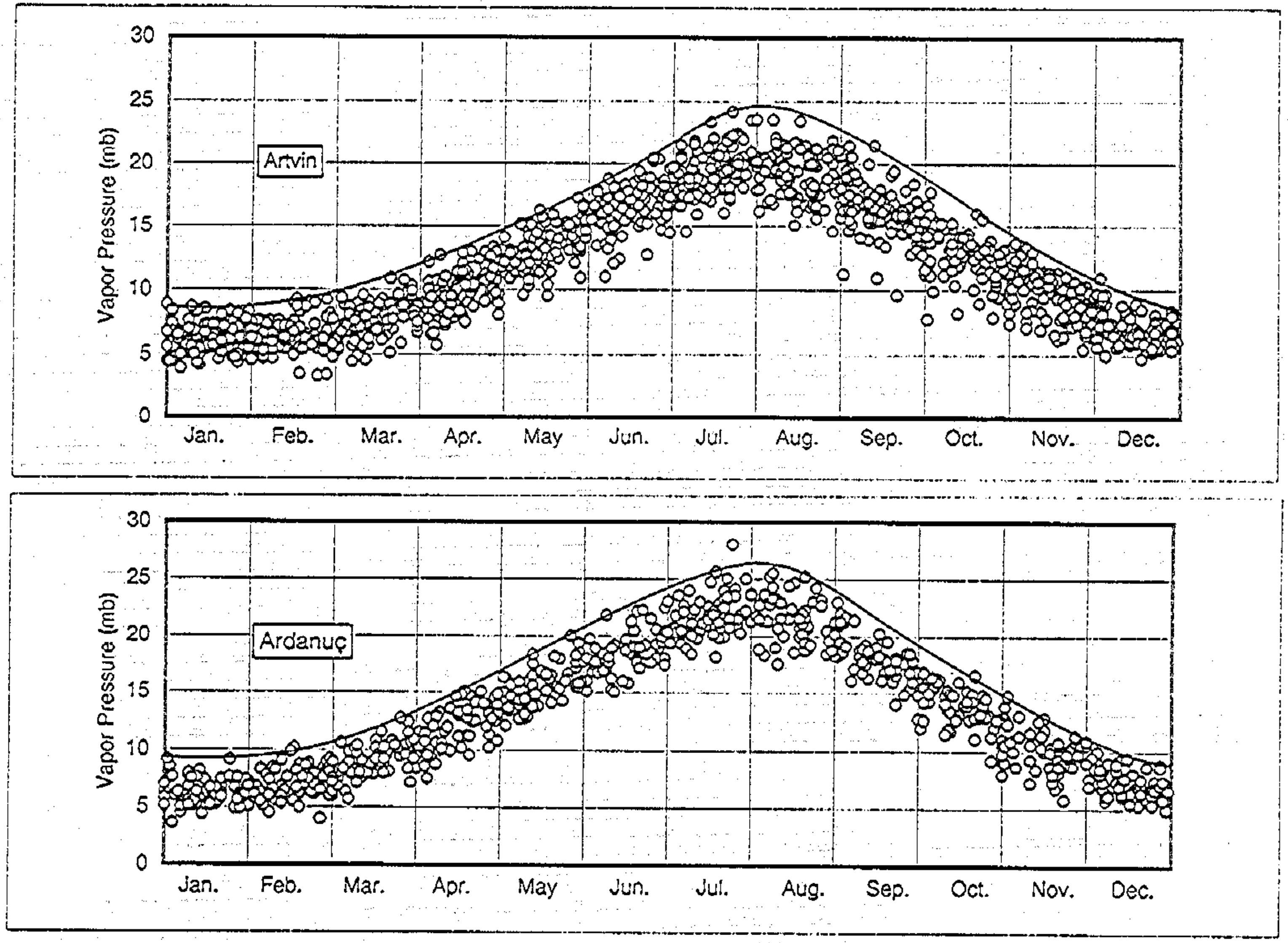


Figure 6-20 Enveloping Curves of Maximum Persisting 12-hour Vapor Pressure

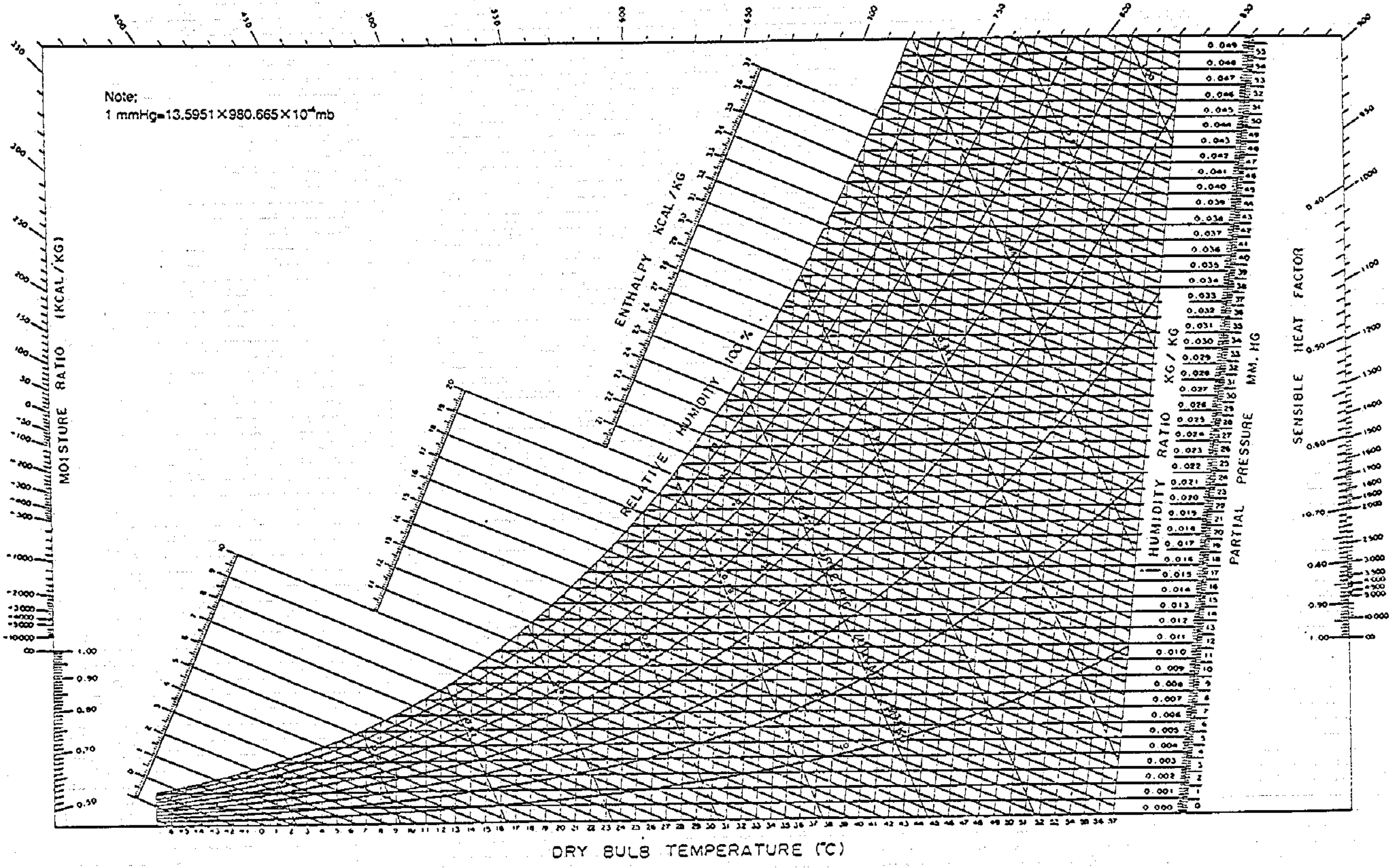


Figure 6-21 Variation of Vapor Pressure with Temperature at Percentage of Saturation

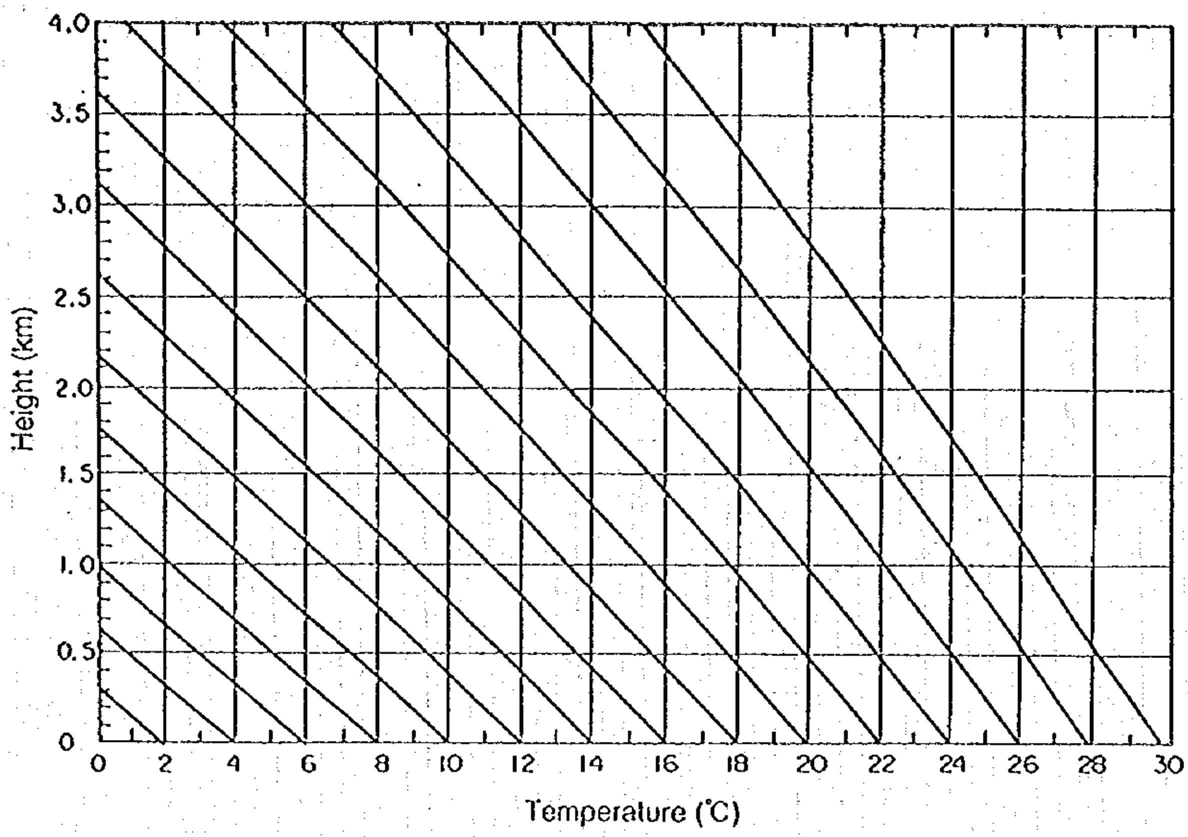
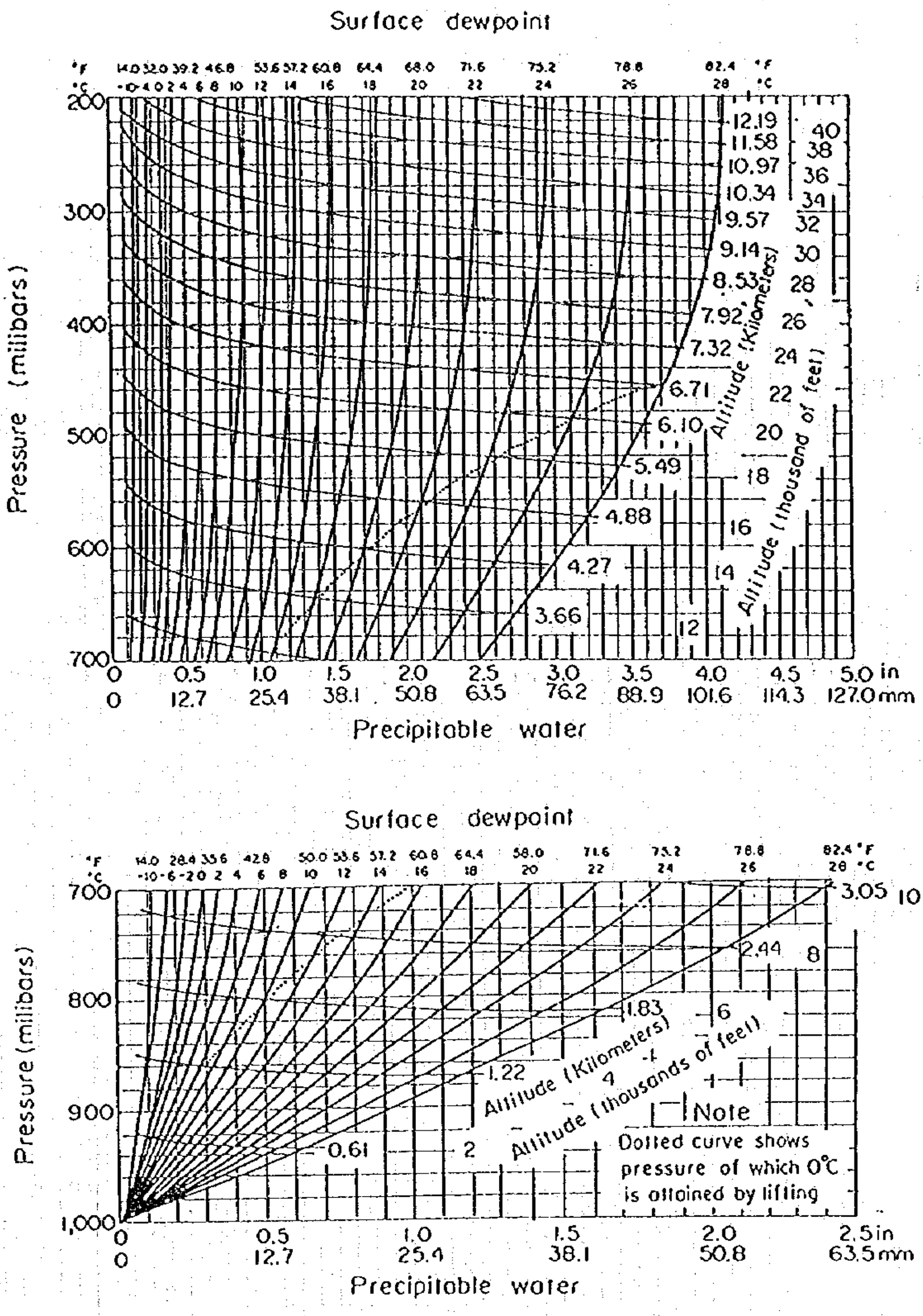


Figure 6-22 Pseudo-adiabatic Diagram for Dew Points Reduction to 1,000mb at Height Zero



Depths of precipitable water in a column of air of any height above the 1000-milibar level as a function of the 1000-milibar dewpoint, assuming saturation and pseudo-adiabatic lapse rate.
(U.S National Weather Service.)

Figure 6-23 Depths of Precipitable Water in a Column of Air

The maximized rainfall data for each duration was plotted and by enveloping the values, the DAD curves of PMP in winter and spring were obtained as shown in Figures 6-24 and 6-25, respectively.

The maximized winter storms seem to provide the critical points for PMP but precipitation falling in the form of snow at the higher elevations in winter and spring is more critical for the maximum snowmelt. In this study, therefore, PMF in spring was closely studied.

(3) Determination of Design Rainfall

By use of Figure 6-24, PMP increments at 6-hour intervals were determined for each dam site. In order not to smooth out the peak discharge value, the maximum (first) 6-hour period was divided into 3 blocks (2-hour increments) by using Figure 6-26. Figure 6-26 is the average hourly rainfall distribution within 6 hours, which was constructed based on the pluviograph records of Artvin M.S.[3]

Furthermore, the obtained incremental rainfall was rearranged to give the greatest flood.

(4) Estimates of Excess Rainfall

In order to compute the excess rainfall, the SCS curve number method was applied in this study.[9] The land usage in Şavşat district is given below.

Table 6-18 Land Usage in Şavşat District

Land Use	%	CN	Product
Cultivated land	10.7	78	835
Pasture:poor condition	17.3	79	1,367
Pasture:good condition	12.4	61	756
Meadow	7.6	58	441
Forest	27.0	55	1,485
Residential	3.1	68	211
Others	21.9	72	1,577
Weighted average	100.0		67

(Source:1991 Census of Agriculture; Results of Village Survey)

Taking into consideration the values shown in Table 6-19,[10] the weighted curve number of the project area was estimated at 67.

Next, the excess rainfall was computed using Figure 6-27.[9] The results are summarized in Table 6-20.

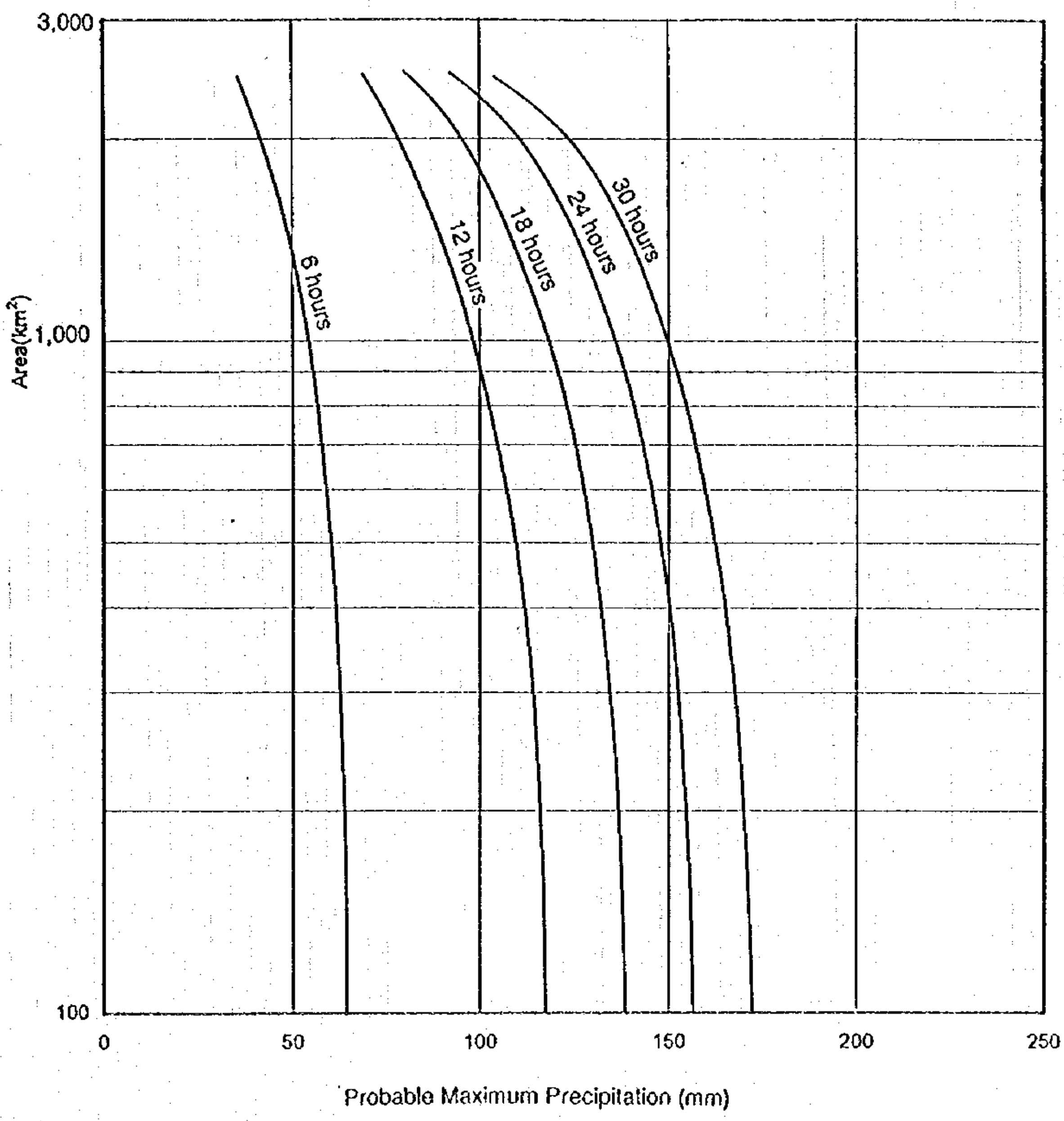


Figure 6-24 Enveloping-Depth-Area-Duration Curves of Probable Maximum Precipitation for Spring Storms

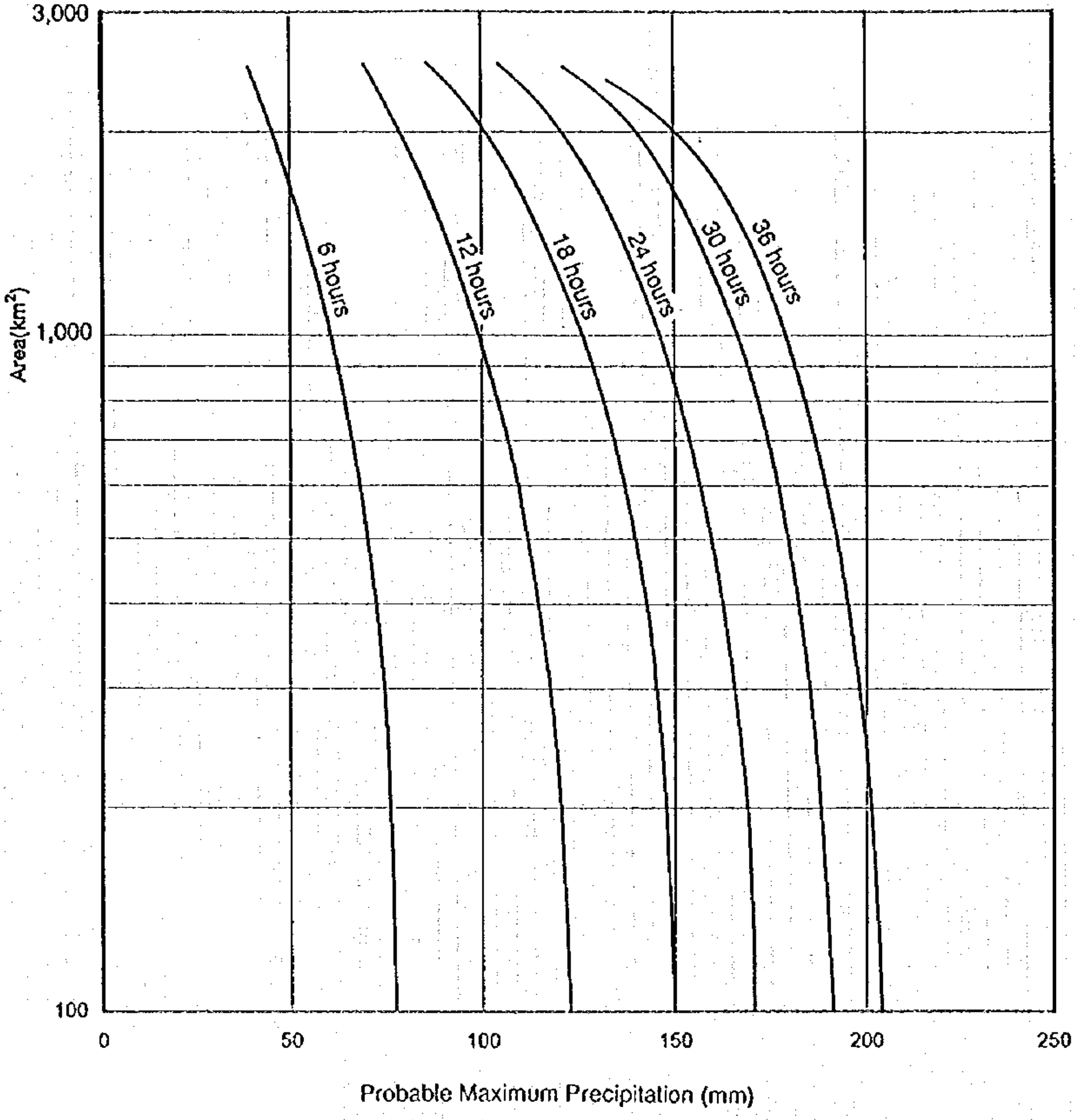


Figure 6-25 Enveloping-Depth-Area-Duration Curves of Probable Maximum Precipitation for Winter Storms

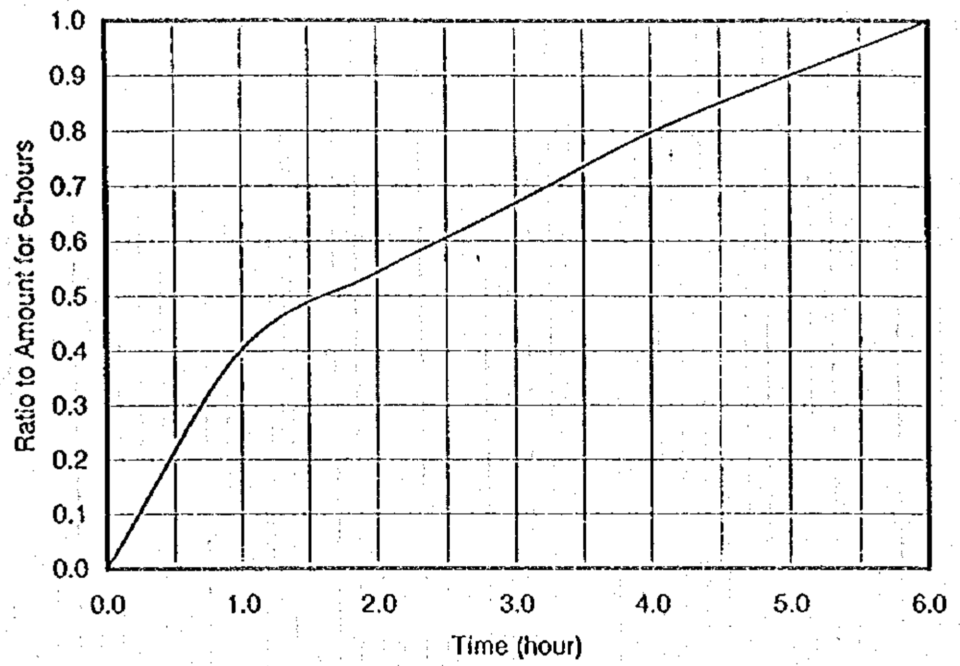


Figure 6-26 Average Hourly Rainfall Distribution at Artvin M.S.

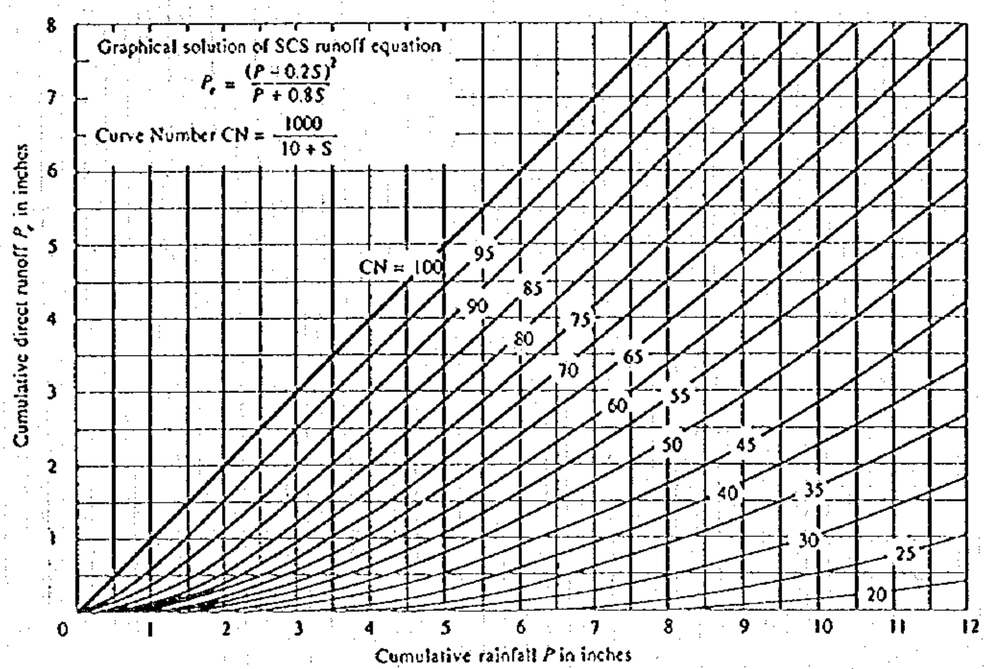


Figure 6-27 Direct Runoff from a Storm by the SCS Method

Table 6-19

Runoff curve numbers for selected agricultural, suburban, and urban land uses (antecedent moisture condition II, $I_a = 0.2S$)

Land Use Description		Hydrologic Soil Group			
		A	B	C	D
Cultivated land[1]: without conservation treatment		72	81	88	91
with conservation treatment		62	71	78	81
Pasture or range land: poor condition		68	79	86	89
good condition		39	61	74	80
Meadow: good condition		30	58	71	78
Wood or forest land: thin stand, poor cover, no mulch		45	66	77	83
good cover[2]		25	55	70	77
Open Spaces, lawns, parks, golf courses, cemeteries, etc.					
good condition: grass cover on 75% or more of the area		39	61	74	80
fair condition: grass cover on 50% to 75% of the area		49	69	79	84
Commercial and business areas (85% impervious)		89	92	94	95
Industrial districts (72% impervious)		81	88	91	93
Residential[3]:					
Average lot size	Average % impervious[4]				
1/8 acre or less	65	77	85	90	92
1/4 acre	38	61	75	83	87
1/3 acre	30	57	72	81	86
1/2 acre	25	54	70	80	85
1 acre	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.[5]		98	98	98	98
Streets and roads:					
paved with curbs and storm sewers[5]		98	98	98	98
gravel		76	85	89	91
dirt		72	82	87	89

[1]For a more detailed description of agricultural land use curve numbers, refer to Soil Conservation Service, 1972, Chap. 9

[2]Good cover is protected from grazing and litter and brush cover soil.

[3]Curve numbers are computed assuming the runoff from the house and driveway is directed towards the street with a minimum of roof water directed to lawns where additional infiltration could occur.

[4]The remaining pervious areas (lawn) are considered to be in good pasture condition for these curve numbers.

[5]In some warmer climates of the country a curve number of 95 may be used.

Table 6-20 Design Rainfall

(unit: mm)

	Dam Site	C.A. (km^2)	0 - 6 hr	6 - 12 hr	12 - 18 hr			18 - 24 hr
					12 - 14 hr	14 - 16 hr	16 - 18 hr	
PMP	Bağlık	1,509	19.8	39.0	26.0	12.2	9.7	16.8
	Bayram	1,159	19.8	42.1	28.6	13.4	10.6	17.9
	Kaledüzü	1,214	19.8	41.9	28.1	13.2	10.4	17.6
Loss	Bağlık	1,509	19.8	31.8	13.9	5.2	3.7	5.7
	Bayram	1,159	19.8	33.7	14.5	5.4	3.8	5.6
	Kaledüzü	1,214	19.8	33.6	14.3	5.4	3.7	5.6
Excess Rainfall	Bağlık	1,509	0.0	7.2	12.1	7.0	6.0	11.1
	Bayram	1,159	0.0	8.4	14.1	8.0	6.8	12.3
	Kaledüzü	1,214	0.0	8.3	13.8	7.8	6.7	12.0

(5) Estimates of the Flood Discharge from PMP

The estimates of the flood discharge were based on the SCS triangular hydrograph, defined as follows,[11]

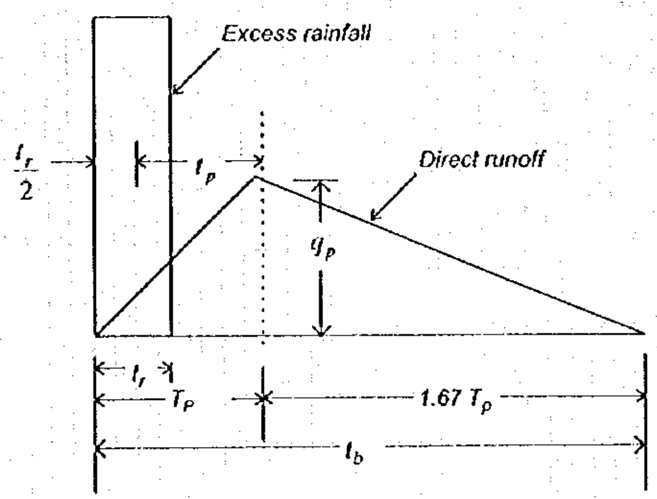


Figure 6-28 Triangular Unit Hydrograph

T_c = *time of concentration (hour)* = $0.0003245(L/\sqrt{S})^{0.77}$

L = *length of channel from devide to outlet (m)*

S = *average watershed slope*

t_r = *duration of effective rainfall (hour)*

t_p = *lag time (hour)* $\cong 0.6T_c$

T_p = *time from start of rise to peak discharge (hour)* = $\frac{t_r}{2} + t_p$

q_p = *peak discharge* $(m^3/s) = \frac{2.08A}{T_p}$

A = *catchment area* (km^2)

The parameters used in the analysis are listed below.

Table 6-21 Unit Hydrograph Parameters

Dam Site	L (km)	S	C.A. (km^2)	t_r (hour)	*) T_c (hour)	T_p (hour)	q_p (m^3/sec)
Bayram	46.9	0.027	1,159	2.0	5.15	4.09	589
				6.0	5.15	6.09	396
Bağlık	59.0	-	1,509	2.0	6.11	4.67	672
				6.0	6.11	6.67	471
Kaledüzü	50.7	-	1,214	2.0	5.46	4.27	591
				6.0	5.46	6.27	403

*) The figures for Bağlık and Kaledüzü dam sites were obtained by routing the flood for Bayram dam site, assuming flood wave propagates at the velocity of 12.6 km/hr.(Kraven's value).

The results of the computation for each dam site are shown in Figures 6-29, 6-30 and 6-31.

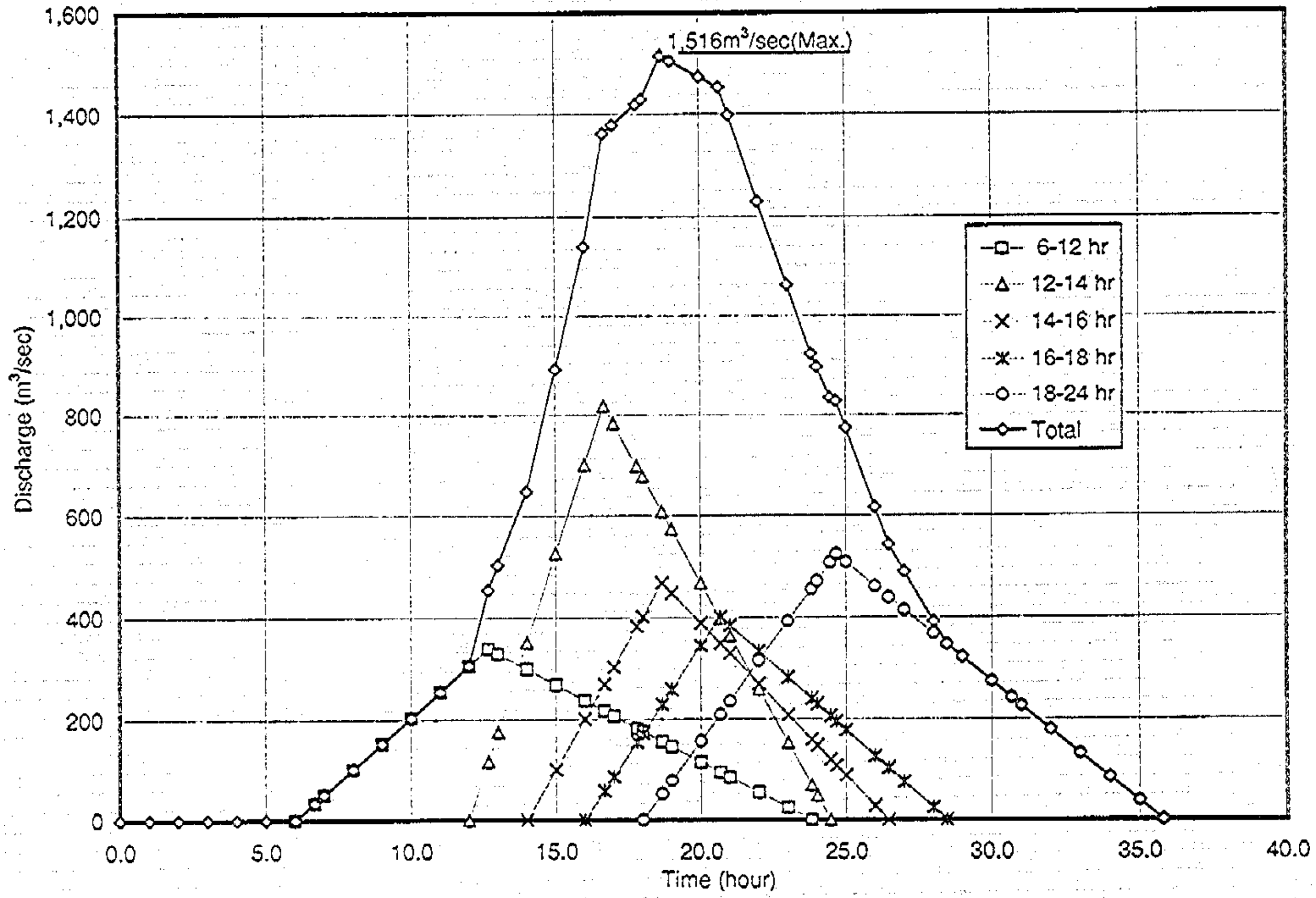


Figure 6-29 Flood Discharge from PMP at Bağlik Dam Site

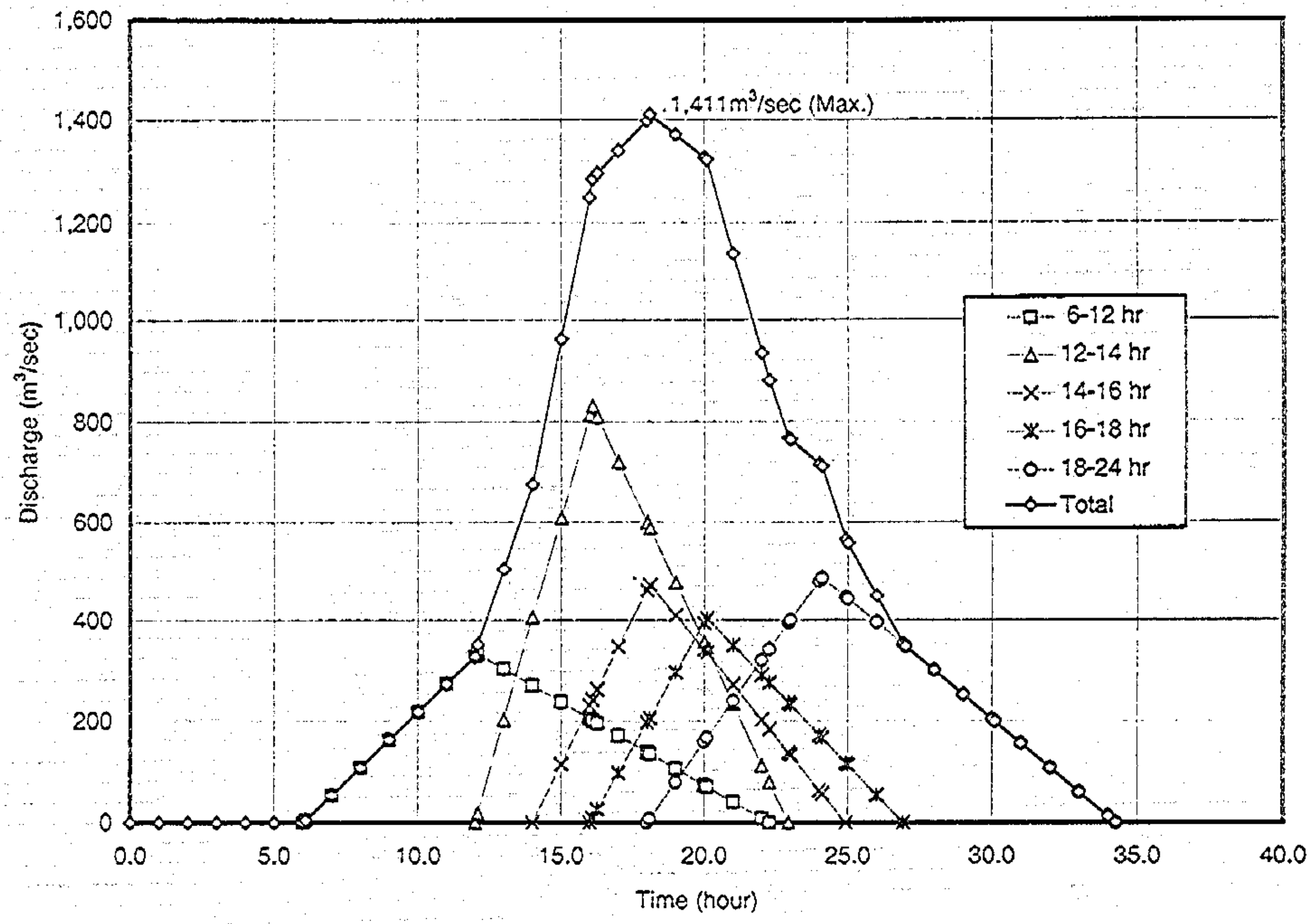


Figure 6-30 Flood Discharge from PMP at Bayram Dam Site

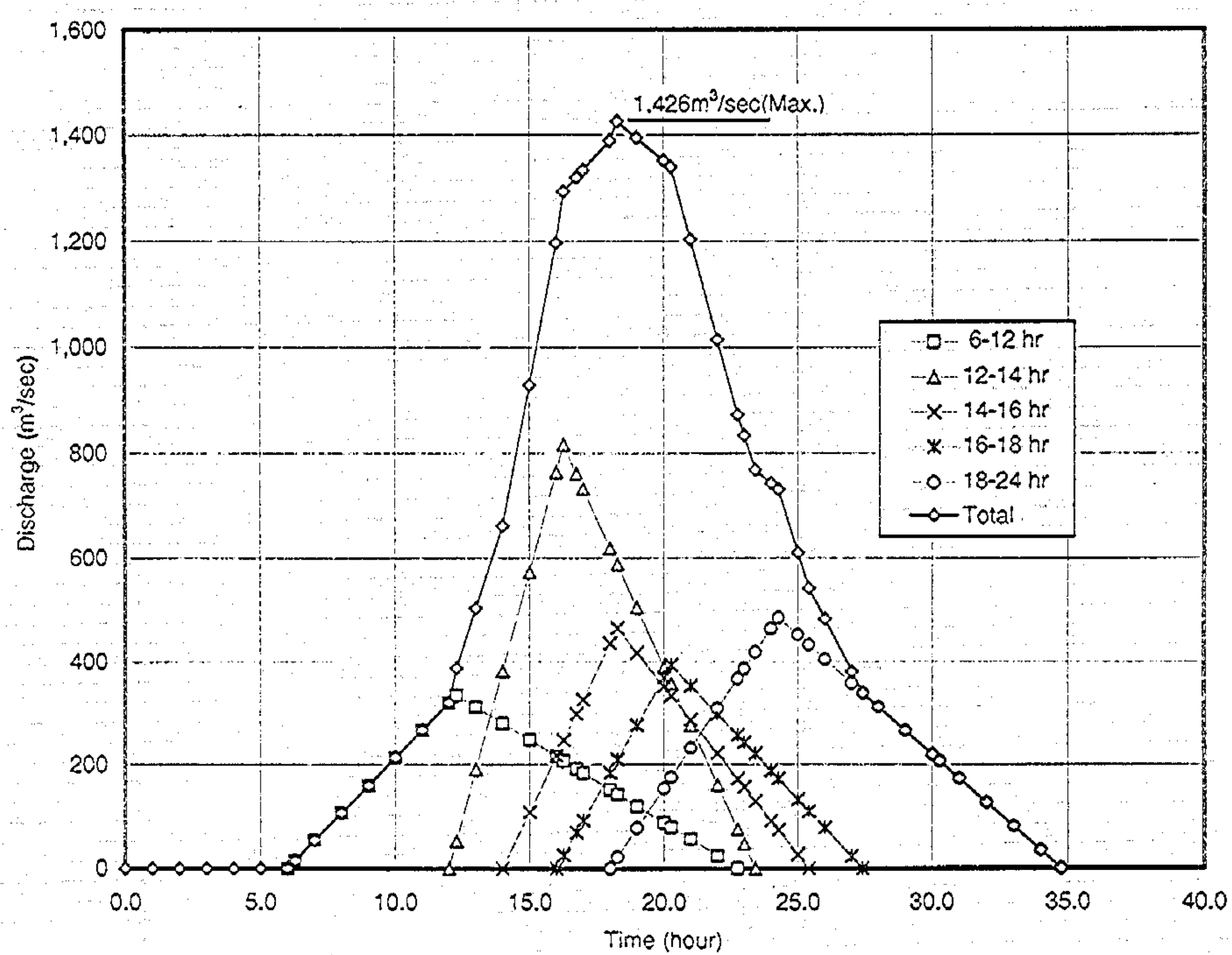


Figure 6-31 Flood Discharge from PMP at Kaledüzu Dam Site

6.6.2 Snowmelt Runoff

The snowmelt runoff previously calculated by EİE for the Berta Basin was applied to this study.[1] The results of this estimation are shown in Table 6-23.

6.6.3 Maximum Base Flow

By scrutinizing the daily runoff records at G.S.No.2327 and 2334, the maximum base flow at Bağlık, Bayram and Kaledüzü dam sites were determined as 39.0, 29.5 and 31.0 m^3/sec, respectively.

6.6.4 Estimates of PMF

The estimates of PMF at the proposed dam sites were based on the superposition of the runoff from PMP, the snowmelt runoff and the base flow.
Obtained hydrographs for dam sites are illustrated in Figures 6-32, 6-33 and 6-34. The results of maximum PMF value for each dam site are summarized below.

Table 6-22 Estimates of Maximum Value of PMF

unit (m^3/sec)

	Flood from PMP	Snowmelt runoff	Base flow	PMF
Bağlık	1,516	268.5	39.0	1823.5
Bayram	1,411	217.6	29.5	1658.1
Kaledüzü	1,426	217.6	31.0	1674.6

Figure 6-35 shows the peak discharge value of computed PMF for the planned and constructed dams in Turkey.

Table 6-23 Maximum Snowmelt Runoff for Each Dam Site

Day	Maximum Cumulative Temp. (℃)	Maximum Temp. Difference (℃)	Temp. Design Pattern (℃)	Temp. at Average Elevation (℃)	x 0.312	Bayram		Bağlik		Kaledüzu	
						Daily Snowmelt Volume (10^6 m^3)	Daily Snowmelt Discharge (m^3/sec)	Daily Snowmelt Volume (10^6 m^3)	Daily Snowmelt Discharge (m^3/sec)	Daily Snowmelt Volume (10^6 m^3)	Daily Snowmelt Discharge (m^3/sec)
1	19.0	19.0	14.6	6.2	1.934	10.0	115.7	12.3	142.4	10.0	115.7
2	38.7	19.7	16.7	8.3	2.590	13.3	153.9	16.4	189.8	13.3	153.9
3	56.3	17.6	17.6	9.2	2.870	14.8	171.3	18.2	210.6	14.8	171.3
4	73.0	16.7	19.0	10.6	3.307	17.0	196.8	21.0	243.0	17.0	196.8
5	88.9	15.9	20.1	11.7	3.650	18.8	217.6	23.2	268.5	18.8	217.6
6	106.1	17.2	19.7	11.3	3.526	18.2	210.6	22.4	259.3	18.2	210.6
7	119.5	13.4	18.5	10.1	3.151	16.2	187.5	20.0	231.5	16.2	187.5
8	138.0	18.5	17.2	8.8	2.746	14.1	163.2	17.4	201.4	14.1	163.2
9	152.6	14.6	15.9	7.5	2.340	12.0	138.9	14.9	172.4	12.0	138.9
10	172.7	20.1	13.4	5.0	1.560	8.0	92.6	9.9	114.6	8.0	92.6

(1) Maximum Snowmelt Rate : 0.312cm/℃-day
(2) Lowest Elevation of Maximum Snowmelt for 10 days : 1,900 m
(3) Average Elevation of Area above 1,900 m
- Bayram Dam : 2,300 m
- Bağlik Dam : 2,300 m
- Kaledüzu Dam : 2,300 m

(4) Area above the Elevation of 1,900 m
- Bayram Dam : 515.0 km^2
- Bağlik Dam : 635.0 km^2
- Kaledüzu Dam : 515.0 km^2

(5) Temperature Decrease Rate : 0.7℃/100 m

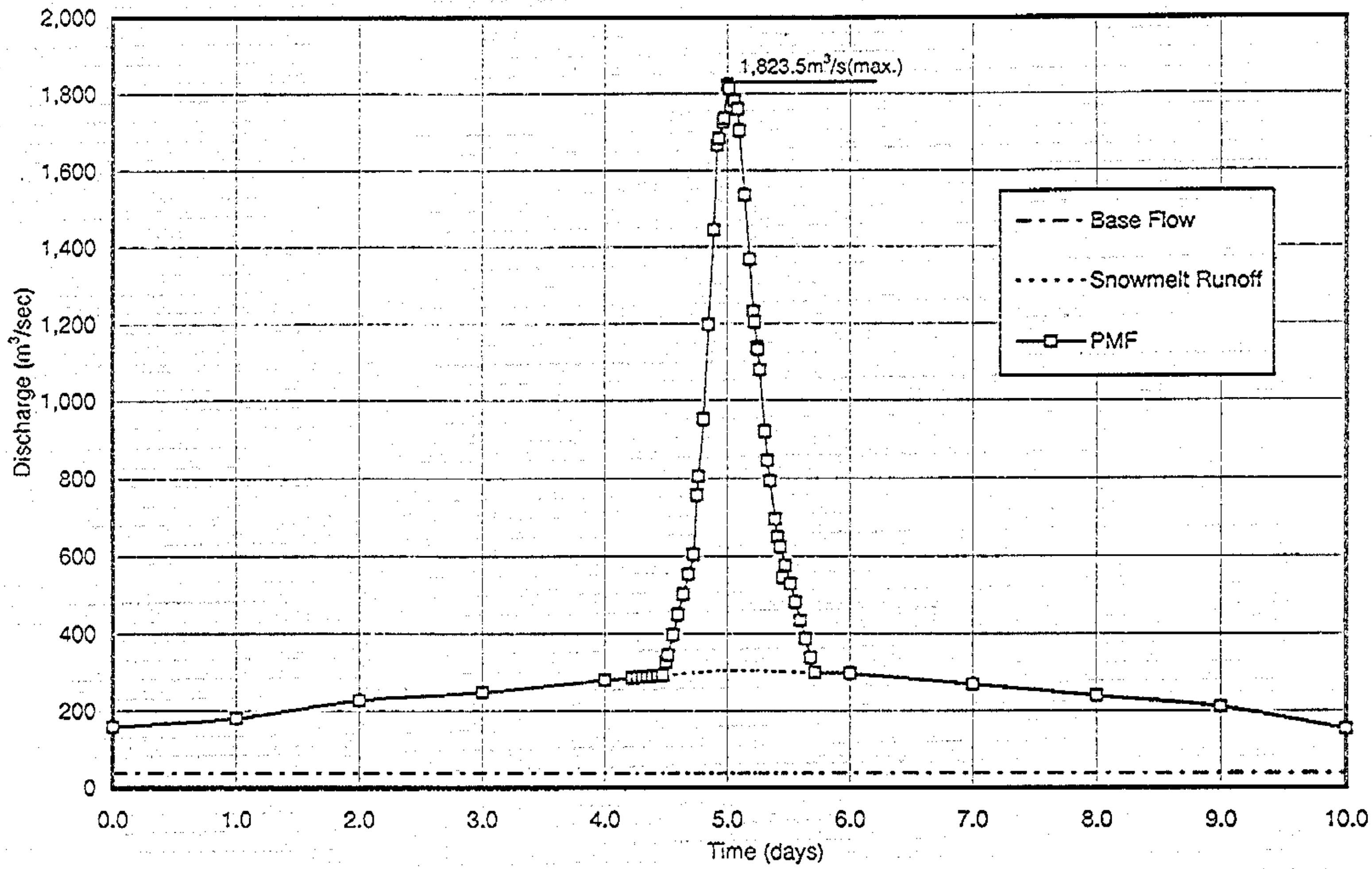


Figure 6-32 Hydrograph of PMF at Bağlik Dam Site

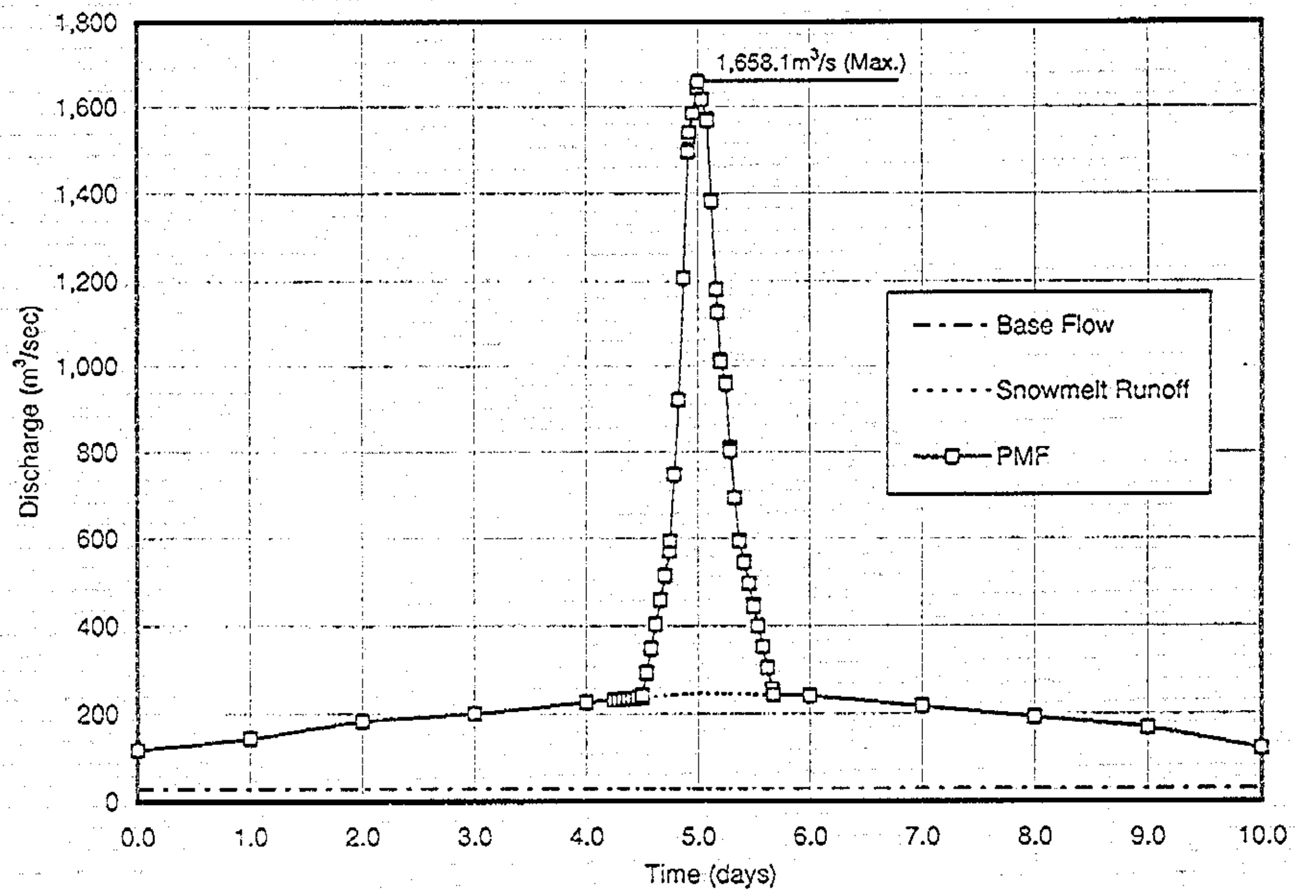


Figure 6-33 Hydrograph of PMF at Bayram Dam Site

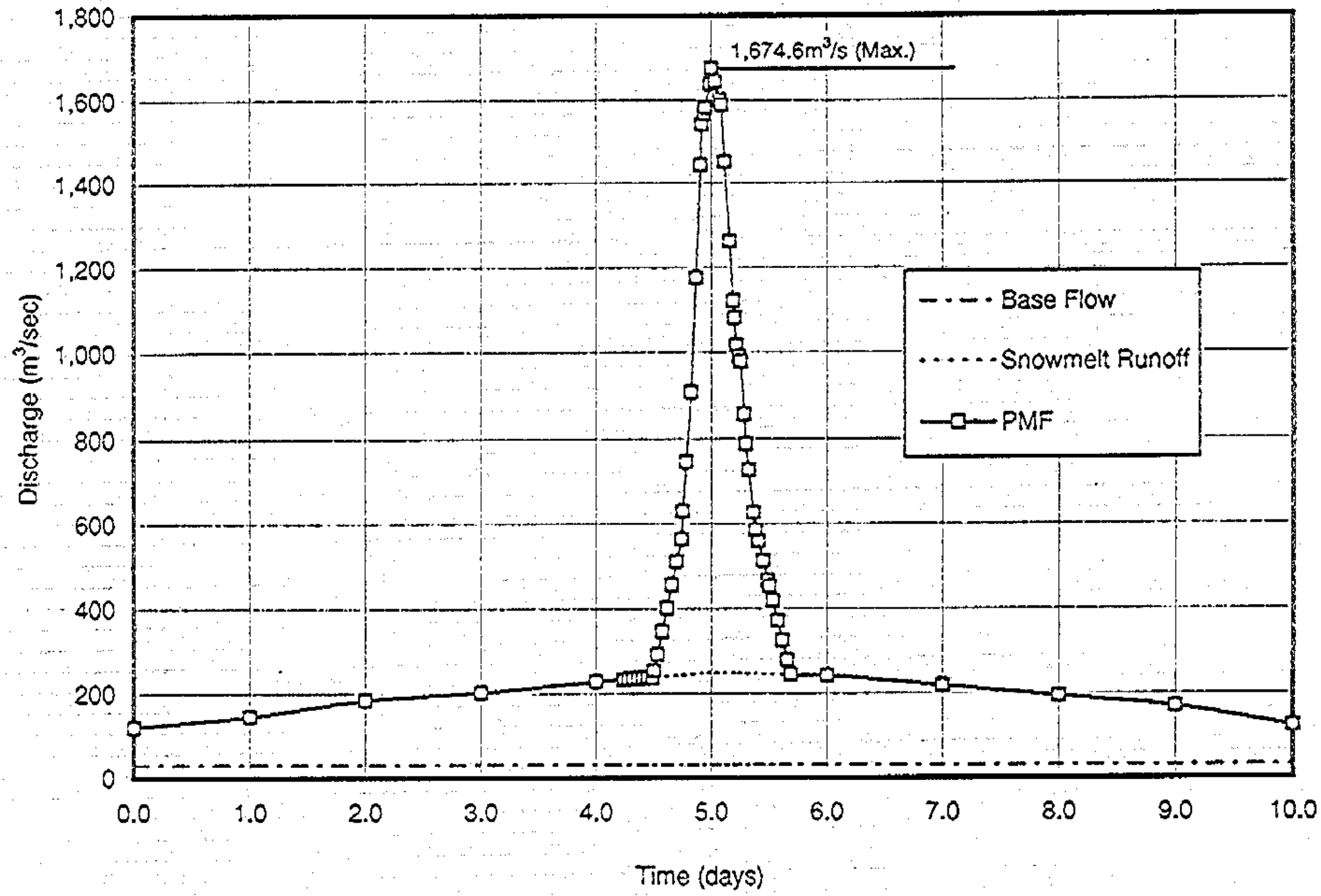
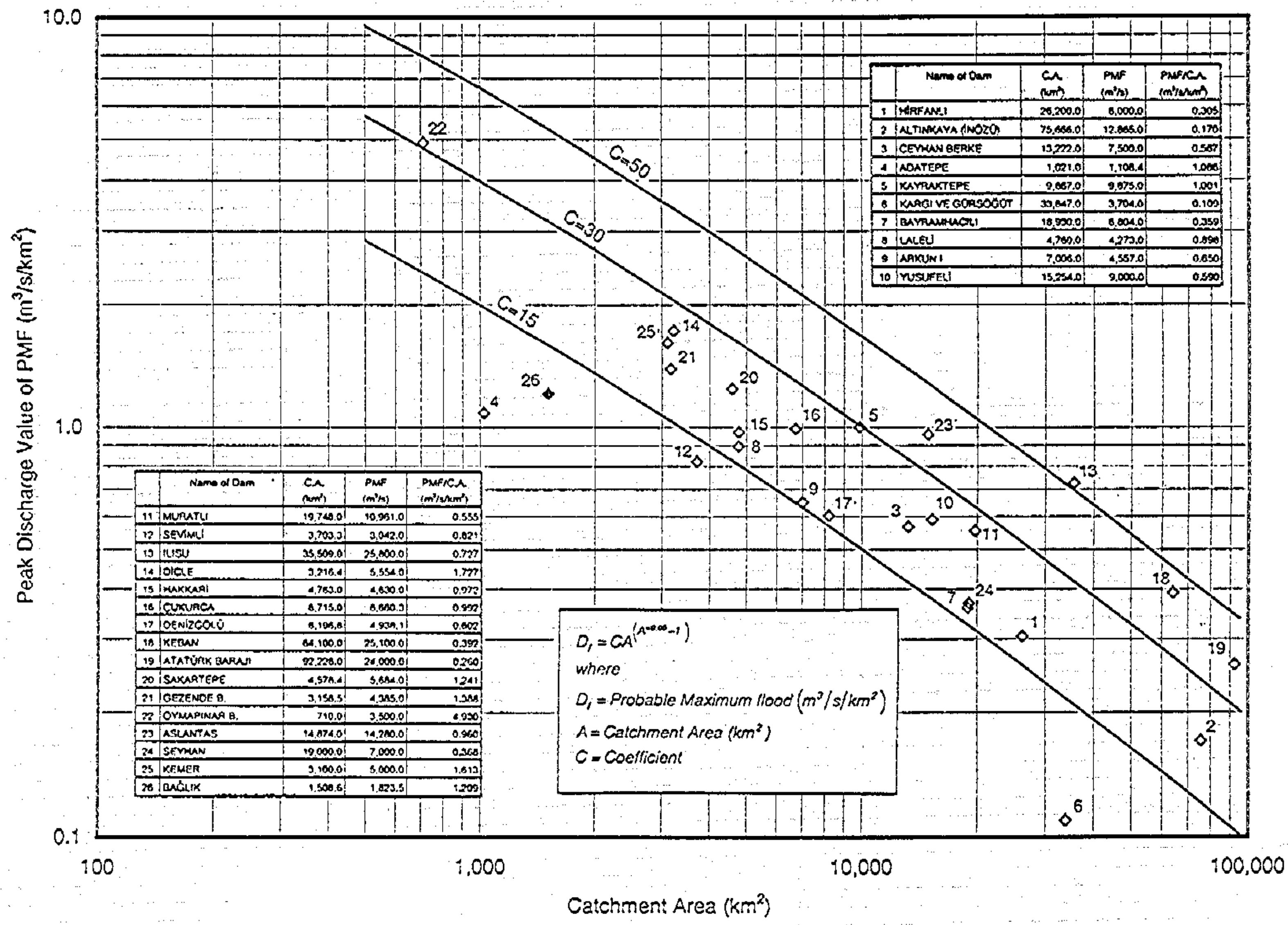


Figure 6-34 Hydrograph of PMF at Kaledüzu Dam Site



	Name of Dam	C.A. (km²)	PMF (m³/s)	PMF/C.A. (m³/s/km²)
1	HİRFANLI	26,200.0	8,000.0	0.305
2	ALTINKAYA (İNÖZÜ)	75,666.0	12,865.0	0.170
3	CEYHAN BERKE	13,222.0	7,500.0	0.567
4	ADATEPE	1,021.0	1,108.4	1.086
5	KAYRAKTEPE	9,867.0	9,875.0	1.001
6	KARGI VE GÜRSÖĞÜT	33,847.0	3,704.0	0.109
7	BAYRAMHACILI	18,930.0	6,804.0	0.359
8	LALELİ	4,760.0	4,273.0	0.898
9	ARKUN I	7,006.0	4,557.0	0.650
10	YUSUFELİ	15,254.0	9,000.0	0.590

	Name of Dam	C.A. (km²)	PMF (m³/s)	PMF/C.A. (m³/s/km²)
11	MURATLI	19,748.0	10,961.0	0.555
12	SEVİMLİ	3,703.0	3,042.0	0.821
13	ILISU	35,509.0	25,800.0	0.727
14	DİCLE	3,216.4	5,554.0	1.727
15	HAKKARİ	4,763.0	4,630.0	0.972
16	ÇUKURCA	6,715.0	6,660.3	0.992
17	DENİZGÖLÜ	8,196.8	4,939.1	0.602
18	KEBAN	64,100.0	25,100.0	0.392
19	ATATÜRK BARAJI	92,226.0	24,000.0	0.260
20	SAKARTEPE	4,576.4	5,684.0	1.241
21	GEZENDE B.	3,158.5	4,385.0	1.388
22	OYMAPINAR B.	710.0	3,500.0	4.930
23	ASLANTAŞ	14,874.0	14,280.0	0.960
24	SEYHAN	19,000.0	7,000.0	0.368
25	KEMER	3,100.0	5,000.0	1.613
26	BAĞLIK	1,508.6	1,823.5	1.209

Figure 6-35 Peak Discharge Values of Computed Probable Maximum Floods in Turkey

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CHAPTER 7 GEOLOGY AND MATERIALS

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7. GEOLOGY AND MATERIALS

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GEOLOGY AND MATERIALS

7.1 Regional Geology

7.1.1 Topography

The Berta river is one of major tributaries of the Çoruh river of total length approximately 410 km which runs through the northeastern part of the Republic of Turkey. This river is the northernmost (downstreammost) of the tributaries which flow into the Çoruh river from the right-bank side inside Turkey. The mouth of the Çoruh river at the downstreammost part is not inside Turkey, but in the Republic of Georgia, the distance from the mouth to the border being approximately 35 km.

The Berta river is located in the northeastern part of the basin of the Çoruh river which is the mainstream, the catchment area being 1,159 km^2 for the upstream Bayram Project and 1,509 km^2 for the downstream Bağlık Project.

The Berta river consists of a mainstream which is also called the Okçular river or the Bulanık river, and three major tributaries, namely, from the downstream side, the Ardanuç river (Ferhatlı river), the Meydancık river, and the Şavşat river. Topographically, the vicinities of confluences between the mainstream and tributaries are generally of broad widths with thick alluvial deposits and gentle gradients, but at other parts the river widths are narrow, deposits are thin, and the river gradients are steep.

This region is bounded by the Karçal and Yalnızçam mountains which have many high peaks from 2,000 to 3,000 m in elevation, the northern side of the catchment being at the border with the Republic of Georgia. Other than the mountain groups bounding the project catchment, there are steep mountains of elevations of 1,000 to 2,000-m class found inside the basin. Particularly, the southwestern part of the catchment area, in the downstream mountainside of the Bayram dam site, there is a continuation of mountains which have little vegetation, where basement rocks are directly exposed. On the other hand, in the northeastern part of the basin, the mountainside along the Meydancık and Şavşat rivers of the catchment area has much vegetation, with the gently sloped parts of the mountainland upstream of Şavşat village covered widely by cultivated fields and grasslands.

7.1.2 Geology

(1) Outline

The Berta river basin is a region which has been influenced by the Hercynian Orogeny in Carboniferrous time of the Paleozoic and the Alpine Orogeny from the Mesozoic to the Cenozoic.

The geology in this region, as shown in the geological map and the geologic sequence of Figure 7-1 and Table 7-1, consists of the Yusufeli Formation of Jurassic age and the Berta Formation of Cretaceous age, both of the Mesozoic, the İkizdere granitic rocks intruded in both the Berta and Yusufeli formations, and Quaternary deposits overlying these strata.

The relation between these Yusufeli and Berta formations excepting the Quaternary Period deposits is unconformable.

(2) Description of Each Formation

(a) Yusufeli Formation

The Yusufeli Formation belongs to Lower to Middle Jurassic period in the Mesozoic. Typical outcrops of the formation are distributed in an area downstream of Yusufeli village located in the midstream area of the Çoruh river, while along the Berta river there are two places where outcrops in comparatively narrow bands are distributed.

One of the places in the Bağlık dam site where the İkizdere granitic rocks are contacted, upstream of which a band-like distribution of width approximately 800 m extends from north-northeast to south-southwest from the right bank of the Berta river to the left bank, while the other is a distribution extending from north-northeast to south-southwest from the Bağlık powerhouse site to the end of the tailrace tunnel route.

This formation is composed of ophiolite, sandstone, slate, basic tuff, and diabase, and since all are extremely hard. The topography where this formation exposed is featured by exceedingly rugged mountain terrain. Folds and faults are also developed in a complex manner depending on the location, while further, intrusions of the İkizdere granitic rocks can be seen, so that the relations between the rocks in this formation are complicated. This formation was partially metamorphosed by the İkizdere granitic rocks. Metamorphic rocks mainly consist of hornfels.

(b) Berta Formation

The Berta Formation belongs to Upper Cretaceous period. Typical outcrops of this formation are distributed widely from the vicinity of Yusufeli Village on the Çoruh river upstream to the midstream area of the Çoruh river. Along the Berta river, it is widely distributed at the upstream area east of the Yusufeli Formation distributed at the Bağlık dam site.

This formation is composed of tuff, tuff breccia, volcanic breccia, basic or acidic volcanic rocks (basalt, dacite, etc.), interbedded strata of thin limestone and marl, and calcareous sandstone. Calcareous strata are seen at upper parts of this formation, and generally are distributed at higher than EL. 1,000 m. Although irregularities in deposits may be seen in this formation due to local minor faults and lava flows, as a whole these are gentle folds or roughly horizontal sedimentary structures continuous over a wide range. The rocks are adequately hard and form steep slopes and sheer cliffs at many places.

Furthermore, this formation contacts the underlying the Yusufeli Formation in unconformity or with thrust faults.

(c) İkizdere Granitic Rocks

The İkizdere granitic rocks comprise batholiths intruded in the above-mentioned Yusufeli and Berta formations and are distributed widely in the Çoruh river basin, particularly, the midstream and downstream areas.

The İkizdere granitic rocks, as a whole, were reported to consist of a granodiorite-tonalite group, an adamellite group, a porphyritic microgranite group, and a granite-gneiss group (according to the EİE study).

(d) Terrace Deposit

As previously mentioned, the project area is featured by a rugged mountain terrain. Consequently, terrace landform and terrace deposit are not very prominently seen. Terraces which are comparatively noticeable in such an environment are those of slightly large scale developed from an elevation of approximately 650 m to around 700 m. These typical outcrops are seen in spots at the right bank of the Berta river midstream. The thicknesses are generally not more than several meters.

(e) Talus Deposit and Colluvial Deposit

These are deposits formed by collapses of slopes seen from midheight down to foots of the steep mountainland. The scales are thicknesses differ depending on the inclination of slopes and geological conditions of the hinterland.

As outcrops of these talus deposits, those of scale several meters in thickness are seen in the vicinity of Bayram village.

(f) Alluvial Deposit

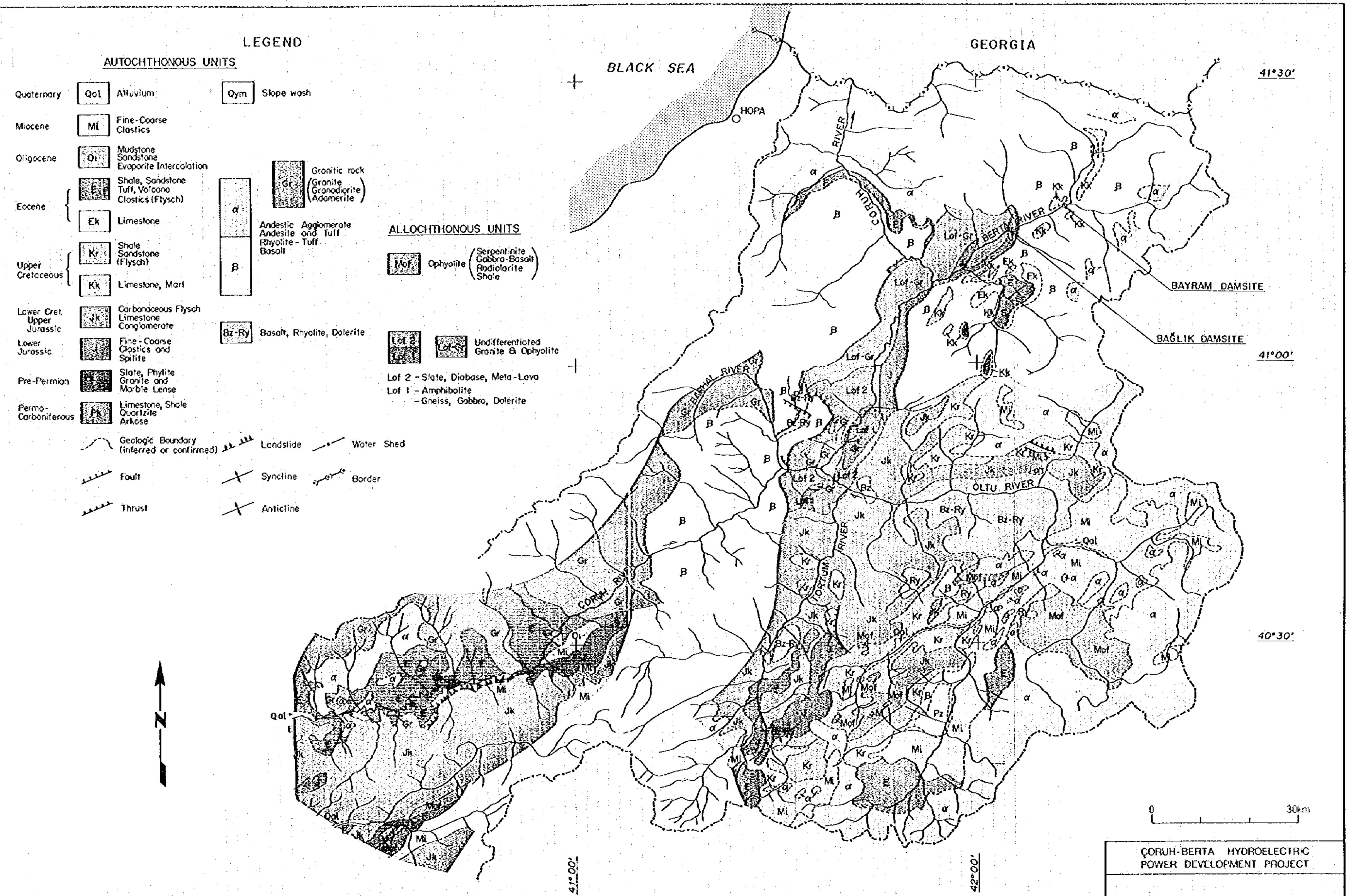
Generally speaking, there is a difference in the thickness of alluvial deposit upstream and downstream of the vicinity of the Bayram dam site. For example, the thickness of sand-gravel at the Bayram dam site is approximately 33 m, whereas it is not more than 6 meters at the Bağlık dam site.

The deposit are composed of silt, sand, and gravel, with the gravel made up of granite, granodiorite, diabase, limestone, and various volcanic rocks.

Table 7-1 Geologic Sequence

GEOLOGIC TIME			Regional Geology of Çoruh-Berta River (EİE June, 1990)		
Era	Period		Formation	Lithology	Remarks
CENOZOIC	Quaternary		Quaternary System	Alluvial deposit, Terrace deposit Talus deposit Slope wash Colluvial deposit Landslide deposit	
	—1.7Ma—				
	Tertiary		Borçka F. (Tb) Oltu F. (To)	Basic and andecitic lava, Volcanoclastics, Tuff, Agglomerate, Marl, Impure Limestone, Claystone, Sandstone	
	65Ma				
MESOZOIC	Cretaceous	Late	Berta F. (Kb)	Mudstone Marl Limestone Sandstone, Conglomerate Alternation of Basalt, Rhyolite & Dacite Volcanoclastic rock İkizdere Granitic Rocks intruded (Ti)	Bayram dam site
		Early	Pügey F. (J-Kp)	Up : Alternation of Limestone & Marl with Silexite Low : Basal conglomerate, Alternation of Sandstone & Marl	
	143Ma				
	Jurassic	Late (Malm)			
		Mid (Dogger)	Ayvalı Volcanics (Ja)	Rhyolite, Acidic and Basic lava, Volcanoclastic rock, Tuff, Aglomerate, Granite	
		Early (Lias)	Yusufeli F. (Jy)	Up : Greywocke, Slate, Phyllite Mid : Spilite (pillow lava), Metalava, Green Schist Low : Gabbro, Amphibolite : Hornfels	Bağlık dam site
	212Ma 247Ma				
PALEOZOIC	Permo-Carboniferous Pre-Permian			İkizdere Granitic Rocks intruded (Ti)	

Ma: million years

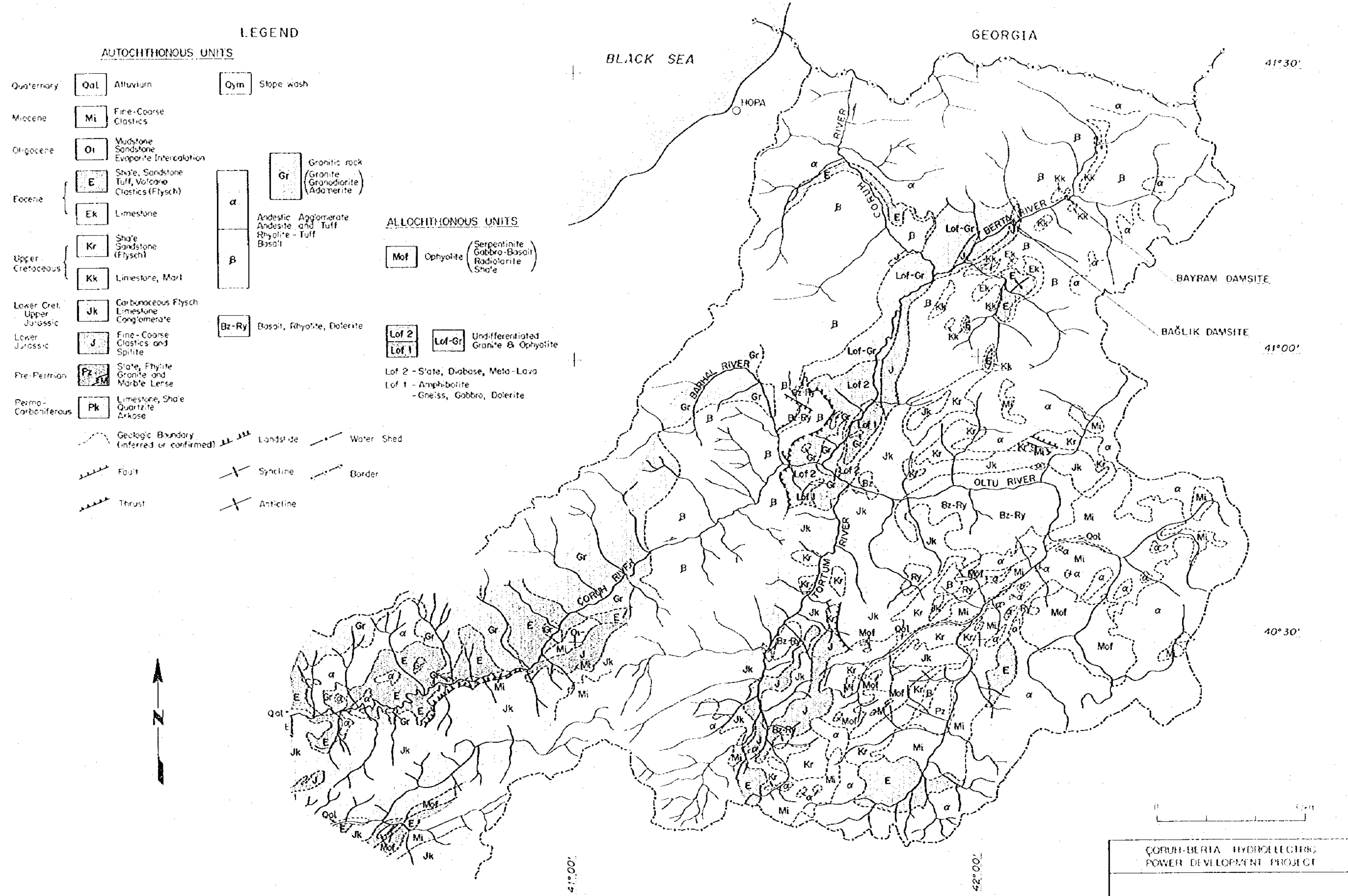


Note : This map is Compiled and Simplified from Geological Map of Çoruh River prepared by JICA in 1986 and Geological Map of Turkey 「Trabzon」, 「Kars」 (1/500,000) prepared by MTA in 1961.

ÇORUH-BERTA HYDROELECTRIC POWER DEVELOPMENT PROJECT

REGIONAL GEOLOGICAL PLAN

Figure 7-1

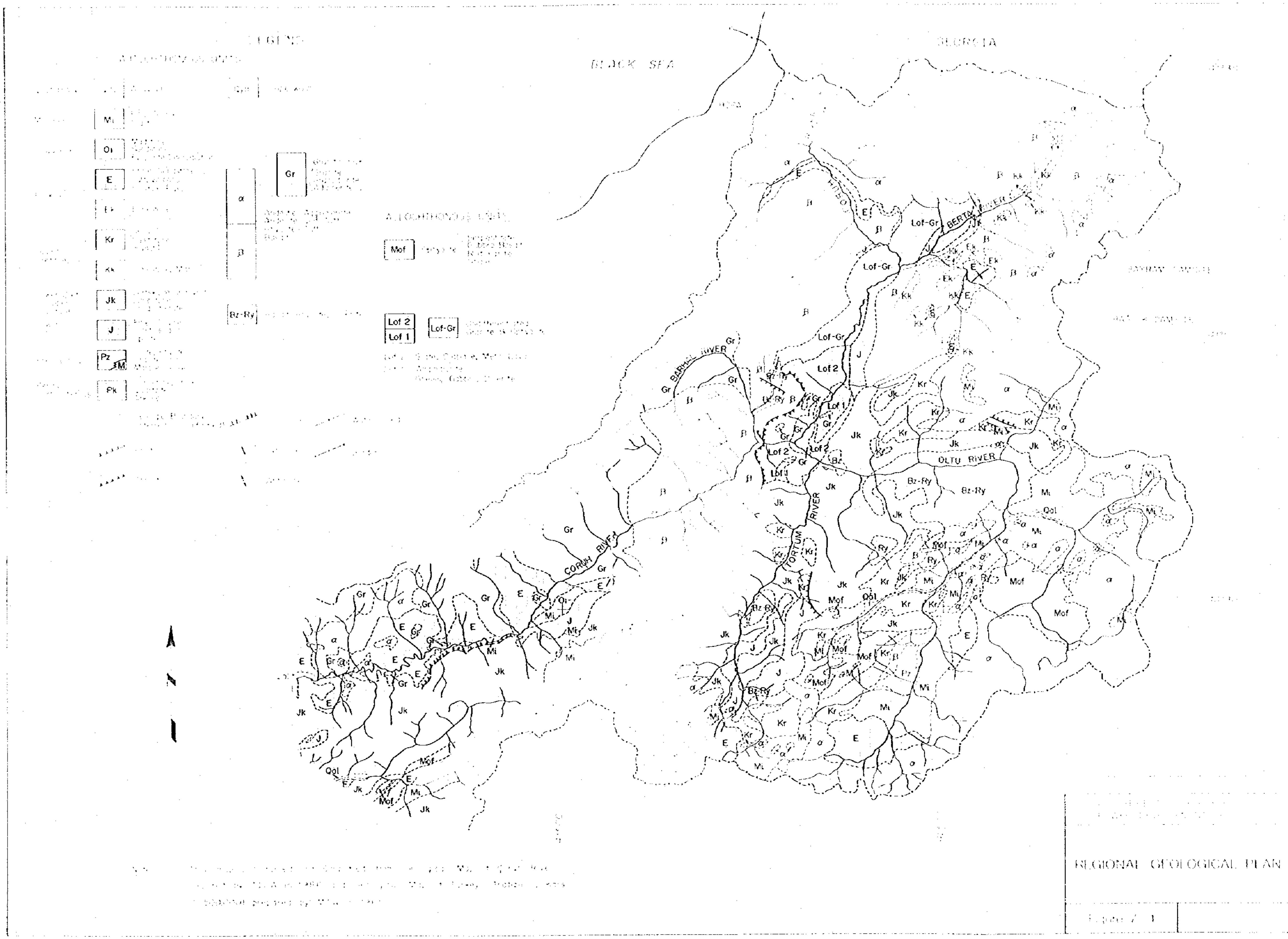


Note : This map is Compiled and Simplified from Geological Map of Çoruh River prepared by JICA in 1986 and Geological Map of Turkey 「Trabzon」,「Kars」 (1/500,000) prepared by MTA in 1961.

ÇORUH-BERTA HYDROELECTRIC POWER DEVELOPMENT PROJECT

REGIONAL GEOLOGICAL PLAN

Figure 7-1


BLACK SEA
GEORGIA
ALLOCHTHONOUS UNITS
CORUH RIVER
OLTU RIVER
TORTUM RIVER
BERTA RIVER
BARHAL RIVER
REGIONAL GEOLOGICAL PLAN

7.2 Outline of Investigation

7.2.1 Existing Data

The existing data referred to in compiling this report are as given in Table 7-2.

7.2.2 Geological Investigation Works

The geological investigation works carried out at the Bayram and Bağlık project sites are as listed below. The details of these works are given in Tables 7-3 to 7-5.

Bayram Project

- Drilling with permeability test		
Dam site	14 holes	Total 1,435.45 m
Powerhouse site	1 hole	Total 100 m
Tailrace tunnel route	1 hole	Total 60 m
- Savail Slope investigation	7 holes	Total 472.5 m
- Impervious materials investigation		Total 23 pits
- Rock materials investigation	2 holes	Total 170 m
- Concrete aggregate investigation		Total 3 pits
- Surface geological survey		
Dam site	Scale 1/1,000	
Dam, tunnel route	Scale 1/5,000	

Bağlık Project

- Drilling with permeability test		
Alternative dam site	14 holes	Total 1,479.2 m
Selected dam site	3 holes	Total 280 m
Alternativepowerhouse site	1 hole	Total 100 m
Selected powerhouse site	1 hole	Total 130 m
- Surface geological survey		
Dam site	Scale 1/1,000	
Dam, tunnel route	Scale 1/5,000	

Table 7-2 Reference Data

No.	Name of Data	Publication
1.	Çoruh River Basin Barhal-Oltu-Berta Creeks Hydroelectric Projects Investigations on Engineering Geology	EİE, 1984
2.	Çoruh-Berta Kolu Bayram ve Bağlık Baraj Yerleri Mühendislik Jeolojisi Raporu (by Turkish)	EİE, 1989
3.	Master Plan Report on Çoruh-Berta River Basin	EİE, 1991
4.	Çoruh-Berta Kolu Enerji Kademeleri Doğal Yapı Gereçleri Raporu (by Turkish)	EİE, 1992
5.	Construction Material Report for Çoruh River Berta Creek Dam and HPP Projects	EİE, 1995
6.	Çoruh-Berta Kolu Bayram Baraj Yeri ve HES Projesi Geçirimsiz Malzeme Deney Sonuçları (by Turkish)	EİE, 1996
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10.	Geological Map of Turkey, KARS, 1:500,000	MTA, 1961
11.	Geological Map of Turkey, VAN, 1:500,000	MTA, 1961

Table 7-3 List of Drill Holes on the Bayram Project

No. of Hole	Location	Length (m)	Direction	Elevation (m)	Remarks
M/S stage					
SK-7	Dam site, right bank	150.00	Vertical	744.62	G.W.L. 94.90m
SK-8	Dam site, right bank	100.30	Vertical	692.74	G.W.L. 57.70m
SK-9	Dam site, riverbed	54.00	Vertical	639.13	
SKE-10	Dam site, left bank	100.00	45°inclined	690.49	
SKE-11	Dam site, right bank	100.00	45°inclined	692.74	
SK-12	Dam site, left bank	150.00	Vertical	754.71	G.W.L. 65.60m
SK-13	Dam site, left bank	100.00	Vertical	690.49	G.W.L. 54.40m
SKE-14	Dam site, left bank	100.00	45°inclined	754.71	
SK-15	Dam site, left bank	100.00	Vertical	660.05	G.W.L. 21.10m
SK-16	Dam site, right bank	104.00	Vertical	661.64	G.W.L. 25.60m
SKE-17	Dam site, right bank	100.00	45°inclined	744.62	
SKE-18	Dam site, left bank	75.00	45°inclined	660.05	
SKE-19	Dam site, right bank	75.00	45°inclined	661.64	
		1308.3			
F/S stage					
SK-7AD	Dam site, right bank & powerhouse site	100.00	Vertical	744.62	Additional drilling of SK-7
SK-101	Dam site, riverbed	127.15	Vertical	–	
BYT-1	Tailrace tunnel	60	Vertical	--	
RQ-1	Quarry site	75	45°inclined	–	
RQ-2	Quarry site	95	Horizontal	--	
H-1(HS-1)	Savail Slope area	55	Vertical	878.74	
H-2(HS-2)	Savail Slope area	85	Vertical	796.66	
H-3(HS-3)	Savail Slope area	74.80	Vertical	750.53	
H-4(HS-4)	Savail Slope area	80	Vertical	837.13	
H-5(HS-5)	Savail Slope area	55.40	Vertical	678.76	
H-6(HS-6)	Savail Slope area	57.90	Vertical	862.03	
H-7(HS-7)	Savail Slope area	64.4	Vertical	670.22	
		929.65			

Remarks: M/S stage; Master plan stage F/S stage; Feasibility study stage

G.W.L.; Depth of ground-water level

Table 7-4 List of Drill holes on the Bağlık Project

No. of Hole	Location	Length (m)	Direction	Elevation (m)	Remarks
M/S stage					
SG-1	EİE Dam site, right bank	230.00	Vertical	601.80	G.W.L. 44.55m
SL-2	EİE Dam site, left bank	200.00	Vertical	589.41	G.W.L. 107.06m
NI-3	EİE Dam site, NEHIR ICI	50.00	Vertical	469.04	
SK-4	EİE Dam site, right bank	12	Vertical	534.65	G.W.L. 70.34m
SK-5	EİE Dam site, left bank	100.00	Vertical	519.79	G.W.L. 49.44m
SK-6	EİE Dam site, NEHIR ICI	28.00	Vertical	–	
SKE-7	EİE Dam site, left bank	100.00	45°inclined	519.78	
SKE-8	EİE Dam site, right bank	101.20	45°inclined	534.65	
SKE-9	EİE Dam site, right bank	100.00	45°inclined	601.80	
SKE-10	EİE Dam site, left bank	100.00	45°inclined	589.41	
SK-11	EİE Dam site, right bank	100.00	Vertical	469.42	G.W.L. 2.45m
SK-12	EİE Dam site, left bank	100.00	Vertical	–	
SKE-13	EİE Dam site, left bank	75.00	45°inclined	–	
SKE-14	EİE Dam site, right bank	75.00	45°inclined	469.43	
		1479.2			
F/S stage					
BGA-1	Proposed dam site, left bank	100	Vertical	543.81	
BGA-2	Proposed dam site, right bank	100	Vertical	539.84	
BGA-3	Proposed dam site, riverbed	80	Vertical	–	
BGA-15	Proposed underground powerhouse site	130	Verticval	–	
BGP-1	Alternative underground powerhouse site	100	Vertical	499.37	
		510			

Remarks: M/S stage; Master plan stage F/S stage; Feasibility study stage

G.W.L.; Depth of ground-water level

Table 7-5 List of Test Pits for Impervious Material at Savail Slope

No. of Line	Location	Depth(m)	Remarks
F/S stage			
MÇ-1	Savail Slope area	1.55	
MÇ-2	Savail Slope area	1.50	
MÇ-3	Savail Slope area	3.30	
MÇ-4	Savail Slope area	3.00	
MÇ-5	Savail Slope area	4.50	
MÇ-6	Savail Slope area	3.50	
YMÇ-7	Savail Slope area	3.00	
YMÇ-8	Savail Slope area	3.00	
YMÇ-9	Savail Slope area	5.00	
		28.35	

Remarks: F/S stage; Feasibility study stage

7.2.3 Seismic Prospecting

The seismic prospecting carried out in connection with materials investigations for the Bayram Project were those listed in Table 7-6.

Table 7-6 List of Seismic Prospecting at Savail Slope

No. of Line	Location	Length(m)	Remarks
F/S stage			
A	Savail Slope area	1,350	
B	Savail Slope area	1,100	
C	Savail Slope area	650	
D	Savail Slope area	450	
E	Savail Slope area	800	
F	Savail Slope area	650	
Total		5,000	

Remarks: F/S stage; Feasibility study stage