ESTIMATION OF SPECIFIC FLOW DURATION CURVES USING BASIN CHARACTERISTICS OF RIVERS IN EASTERN BLACKSEA BASIN

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ABSTRACT

ESTIMATION OF SPECIFIC FLOW DURATION CURVES USING BASIN CHARACTERISTICS OF RIVERS IN EASTERN BLACKSEA BASIN

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New and renewable energy resources are important in view of reduction of greenhouse gasses causing climate change and in eliminating of dependence on foreign sources in energy respects. Within this context, hydraulic energy is evaluated as one of the prior energy resources that should be utilized. Turkey has 26 basins and Eastern Black Sea Basin is one of the most feasible basins with a lot of small hydroelectric power plants. In the other hand, there is not enough number of discharge gauging stations in the basin. For that reason, up to now generally area ratio method has been used to estimate the project discharges of small hydroelectric power plants. Objective of this study is to estimate "the project discharge" which is corresponding to 5 flow percentiles (5%, 10%, 15%, 20%, 25%) depending on topographical, meteorological, hydrologic and soil-land cover parameters through developing a multilinear statistical model for İyidere Basin as a part of Eastern Black Sea Basin. Perimeter of the basin, the ratio of the basin perimeter to the main stream length of the same basin, the drainage frequency, the mean slope of basin, the mean annual precipitation and the curve number are the parameters that have been analysed for the multilinear statistical model. Principal Component Analysis, Multiple Regression Analysis and Stepwise Regression Analysis have been run for the data sets. For the computed discharges validation has been done. As a result of validation, it has been seen that the stepwise regression gives much closer discharge values to the observed values than the multiple regression results.

Keywords: Ungauged Basin, Small HEPP, Statistical Model, Eastern Black Sea Basin, İyidere Havzası

ÖZ

HAVZA KARAKTERİSTİKLERİ KULLANILARAK DOĞU KARADENİZ HAVZASINDAKİ NEHİRLERİN ÖZGÜL DEBİ SÜREKLİLİK EĞRİLERİNİN HESAPLANMASI

YILMAZ, Deniz

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Yeni ve yenilenebilir enerji kaynakları, iklim değişimine neden olan sera gazlarının ve enerji alanında dışa bağımlılığın azaltılması bakımından önemlidir. Bu kapsamda hidrolik enerji, enerji kaynakları içerisinde yararlanılması gereken öncelikli kaynaklardan biri olarak değerlendirilmektedir. Türkiye' de 26 havza mevcuttur ve bu havzalar içinde en önemlilerden biri üzerinde çok sayıda küçük Hidro Elektrik Santral Projesi bulunan Doğu Karadeniz Havzasıdır. Öte yandan havza üzerinde yeterli sayıda akım gözlem istasyonu bulunmamaktadır. Bu sebeple küçük hidroelektrik santrallerin proje debileri hesaplanırken şimdiye kadar genellikle alan oranı metodu kullanılmıştır. Bu çalışma; Doğu Karadeniz Havzası'nın bir parçası olan İyidere Havzası'nda kurulacak küçük hidroelektrik santraller için proje debisini 5 farklı akış yüzdesinde (5%, 10%, 15%, 20%, 25%) topoğrafik, meteorolojik, hidrolojik ve toprak-arazi kullanımı parametrelerle ilişkilendiren çok değişkenli lineer bir istatiksel model geliştirmeyi hedeflemektedir. Bu çok değişkenli lineer istatiksel model geliştirilirken havza çevresi, havza çevresinin ana nehir uzunluğuna oranı, drenaj frekansı, ortalama havza eğimi, yıllık ortalama yağış miktarı ve yüzey akış eğri numarası parametre olarak kullanılmıştır. Model veri setleri için Temel Bileşen Analizi, Çoklu Regresyon Analizi ve Adımsal Regresyon Analizi yapılmıştır. Model sonucunda bulunan debiler için validasyon yapılmıştır. Validasyon sonucunda Adımsal Regresyon' la Çoklu Regresyon' a kıyasla, gözlemlenen debi değerlerine daha yakın değerler bulunduğu görülmüştür.

Anahtar Kelimeler: Ölçüm İstasyonu Olmayan Havza, Küçük Hidroelektrik, İstatistiki Model, Doğu Karadeniz Havzası, İyidere Havzası

To My Dear Husband..

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CHAPTER 1

INTRODUCTION

Hydropower continues to be the most efficient way to generate electricity. Modern hydro turbines can convert as much as 90% of the available energy into electricity. However, the best fossil fuel plants are only about 50% efficient. Hydro resources are also widely distributed compared with fossil and nuclear fuels and can help provide energy independence for countries without fossil fuel resources (Yüksel, 2007).

Turkey is situated at the meeting point of three continents (Asia, Europe and Africa) and stands as a bridge between Asia and Europe. Turkey's geographic location has several advantages for extensive use of most of the renewable energy sources. It is on the humid and warm climatic belt, which includes most of Europe, the near East and western Asia (Yüksek, 2006).

The increases in the imported fuel costs have increased the unit price of electricity produced in thermal power plants above the critical level increasing the economical hydropower potential level for Turkey. This is making especially smaller hydropower plants more preferable since their design, construction and maintenance are less complex and more economical (Günyaktı and Özdemir, 2008).

Turkey has a gross hydropower potential estimated between 430 and 450 TWh/year. In many references the technically feasible hydroelectric potential of Turkey is given as 215-225 TWh/year, which is one half of the gross hydroelectric potential. When the economic feasibility is concerned besides the technical feasibility, this figure comes out as 125-130 TWh/year, which is equivalent to 36-36.3 GW installed capacity and corresponding to 546-678 hydroelectric power plants including small ones (Kaygusuz, 1999; Sorensen, 2004; Özdemir, 2007).

The flow duration curve (FDC) represents the relationship between the magnitude and the frequency of daily, weekly, monthly (or some other time interval of) stream flows for a particular river basin, providing an estimate of the percentage of time the stream flow was equalled or exceeded over a historical period. Although the FDC is widely used in water resources engineering, the number of the studies related to estimating FDCs is small compared with its importance. The majority of the studies are about the utilization domains of duration curves in water resources engineering and some of them cover the determination of the regional flow duration curves (Cigizoglu and Bayazit, 2000).

Cigizoglu and Bayazit (2000) developed a model to determine a flow duration curve for a process in which stream flow is defined as a product of two variables, representing the periodic and the stochastic components, respectively. A method based on the convolution theorem for the product of two variables was presented to obtain the flow duration curve. The cumulative frequency distribution was obtained using some integration procedures and is transformed to a form usable for the discrete variables.

Shao et al. (2009) developed a model which is a four-parameter double power form as a function of the FDC, where the two hydrological parameters represent the mean annual flow (Q) and the cease-to-flow point (τ expressed as a percentage), while the other two parameters (α and β) determine the shape of the FDC. The shape parameters were defined by two statistical parameters closely related to the catchment physiographic characteristics and the associated rainfall pattern in the region.

Karaaslan (2011) introduced a statistical model in linear and non linear form using the topographical parameters and hydro-meteorological variables to estimate the project discharge of potential small hydro-power locations for the selected study areas in Eastern Black Sea Region namely Solaklı and Karadere basins. Annual and seasonal regression models using the annual values of hydro-meteorological parameters and the mean annual air temperature variable in addition to basin parameters were developed separately (Karaaslan, 2011).

Daamen (2003) developed a modelling approach to estimate the effects of land cover change on stream flow and groundwater resources for south-western Victoria and south-eastern South Australia. Two requirements of the approach were: (1) consistency with existing data sets and modelling methods; and (2) the ability to distinguish between land cover types in terms of their water balance. The approach used an empirical model of the effects of forestry on stream flow, ForestImpact for requirement 1 and the SoilFlux model as one dimensional model of soil water and solute movement for requirement 2. The methodology was used to estimate the effects of future land cover change scenarios on water resources within the study area.

Among 26 hydrological basins in Turkey, the Eastern Black Sea Basin has great advantages from the view point of small hydroelectric power potential. Because, the annual average precipitation is the highest in the country going up to 2329 mm in Rize Province (Yuksek, 2006).

İyidere Watershed covers İkizdere, Kalkandere and İyidere counties of Rize. Total rainfall area is 1074 km^2, mean annual water potential is 1130 hm^3. According to the water potential, İyidere Basin is the third biggest subbasin of the Eastern Black Sea Region. Because of its water potential and steepness, İyidere Basin is very feasible to build hydroelectric power plants. Here are the numbers of HEPP projects in İyidere Basin: 2 operating, 7 having license, 5 waiting for license, 7 doing feasibility study. Total installed power of those 21 projects is 674 MW, energy production is 2509 GWh/year (DSI, 2010).

Objective of this study is to estimate “the project discharge” depending on topographical, meteorological, hydrologic and the other (soil and land cover) parameters through developing a multilinear statistical model for İyidere Basin as a part of Eastern Black Sea Basin.

Linear, shape, morphological and slope measures as topographical parameters have been computed via Geographic Information System (GIS) technologies. Mean annual precipitation and curve number are the hydro-meteorological and the soil-land cover parameters, respectively.

There are 5 chapters in this study. First Chapter is “Introduction”, Second Chapter is “Data Collection” which includes information about the data used in the study, Third Chapter is “Data Analysis and Results” which includes the results of data analyses, Fourth Chapter is “Model Development” which includes the model parameters and the multilineer equations, the last one is “Chapter 5-Conclusions and Recommendations”.

CHAPTER 2

DATA COLLECTION

2.1 Topographic Data

The use of computers in hydrologic analyses has become so widespread that it provides the primary source of data for decision making for many of hydrologic engineers. Since so much of hydrology is linked to processes at the earth's surface, the connection to the topographic, computer-based methodology known as the Geographic Information System (GIS) is a predictable step in the evolution of hydrologic engineering (web 1). One of the capabilities of a GIS most important to hydrologic applications is the description of the topography of a region. Techniques used in the computer description of topography are called Digital Elevation Models (web 1).

The digital elevation model (DEM) used in this study has been produced by a private sector company for DSI. This DEM has been digitalized from 1/25000 scaled map sheets by 10x10 m resolution. DEM of the study area is shown in Figure 2.1.

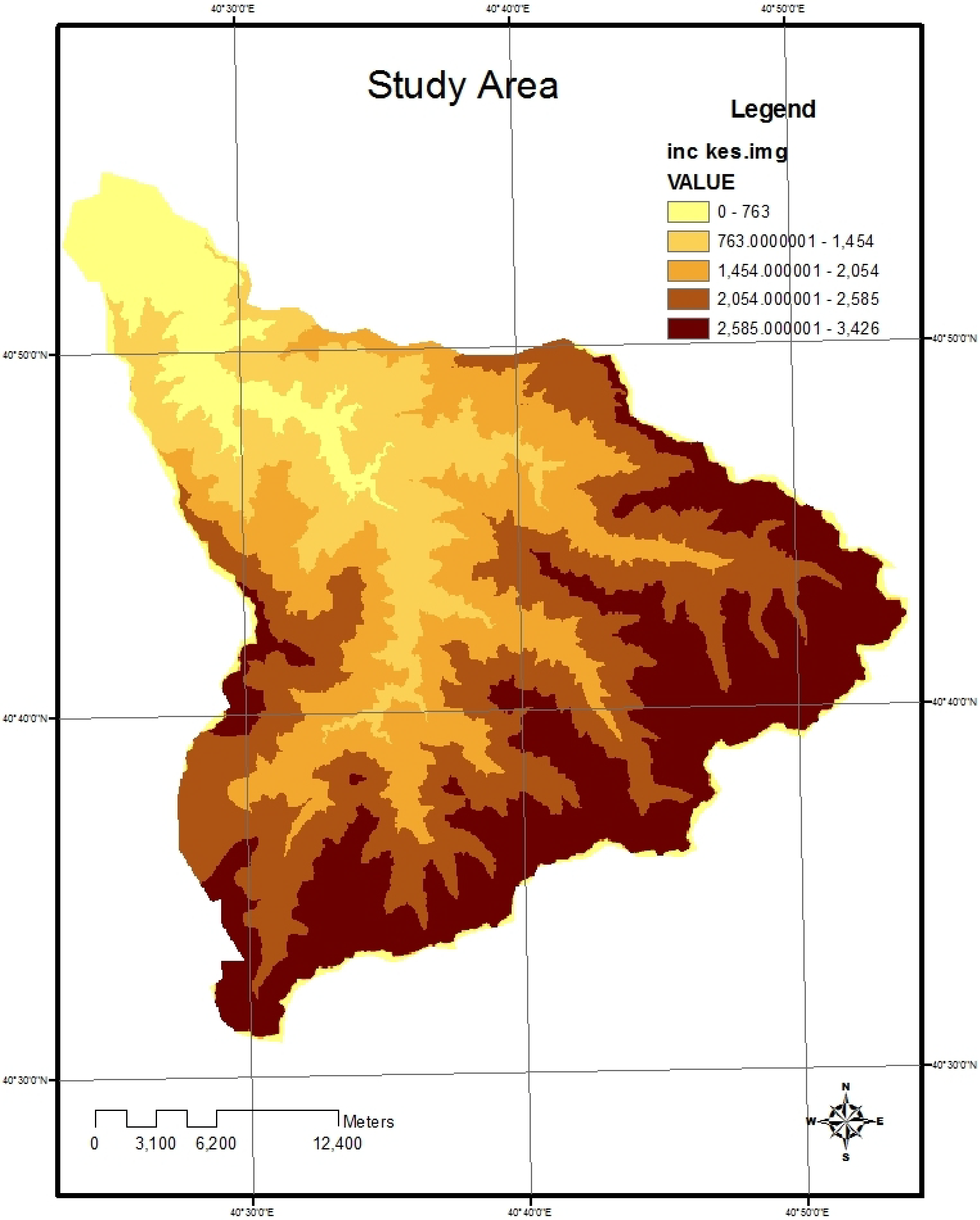

Figure 2.1 DEM of the Study Area

2.2 Hydrologic Data

The first step of hydrologic modeling is to collect data by making observations. Because natural conditions are not similar to laboratory conditions, hydrologists must work at rural area to discover hydrologic events. To discover hydrologic events, many gage stations that have sensible instruments should be built (limnigraph, etc) and observation network at gauging stations should be set up. Furthermore, at these observation networks that include many gauging stations, hydrometric measurements should be done carefully. Because hydrologic data change not only in time but also in location, measurements should be done regularly at closer points (Karaman, 2010). There are two public organizations in Turkey which are responsible for hydrologic observation and measurements: State Hydraulic Works (DSI) and Electrical Power Resources Survey and Development Administration (EIEI).

In this study, mean daily discharges gathered from 5 streamflow gauging stations in İyidere basin are used as hydrologic data. 22-77, 22-96 and 22-78 stations are operated by DSI while 2215, 2218 and 2233 stations are operated by EIEI. 22-77 streamflow gauging station was operated between 1965-1996 and closed in 1996. In 1999, 22-96 streamflow gauging station started to be operated instead of 22-77. Because of that reason, 22-77 and 22-96 streamflow gauging stations are accepted as same stations. In Table 3.1, some properties of the stations are given. In Figure 2.2, the network of the streamflow gauging stations are given.

Table 2.1 Some Characteristics of the Streamflow Gauging Stations in İyidere Basin

Station No	Coordinates		Drainage Area	Observation Period
	X (m)	Y (m)	(km^2)	
2215	634947	4510034	445	1965-2007
2218	625857	4519524	835	1955-2007
2233	633449	4503008	249	1965-2007
22-78	635313	4505006	288	1985-2007
22-96	641707	4514296	156	1982-2007

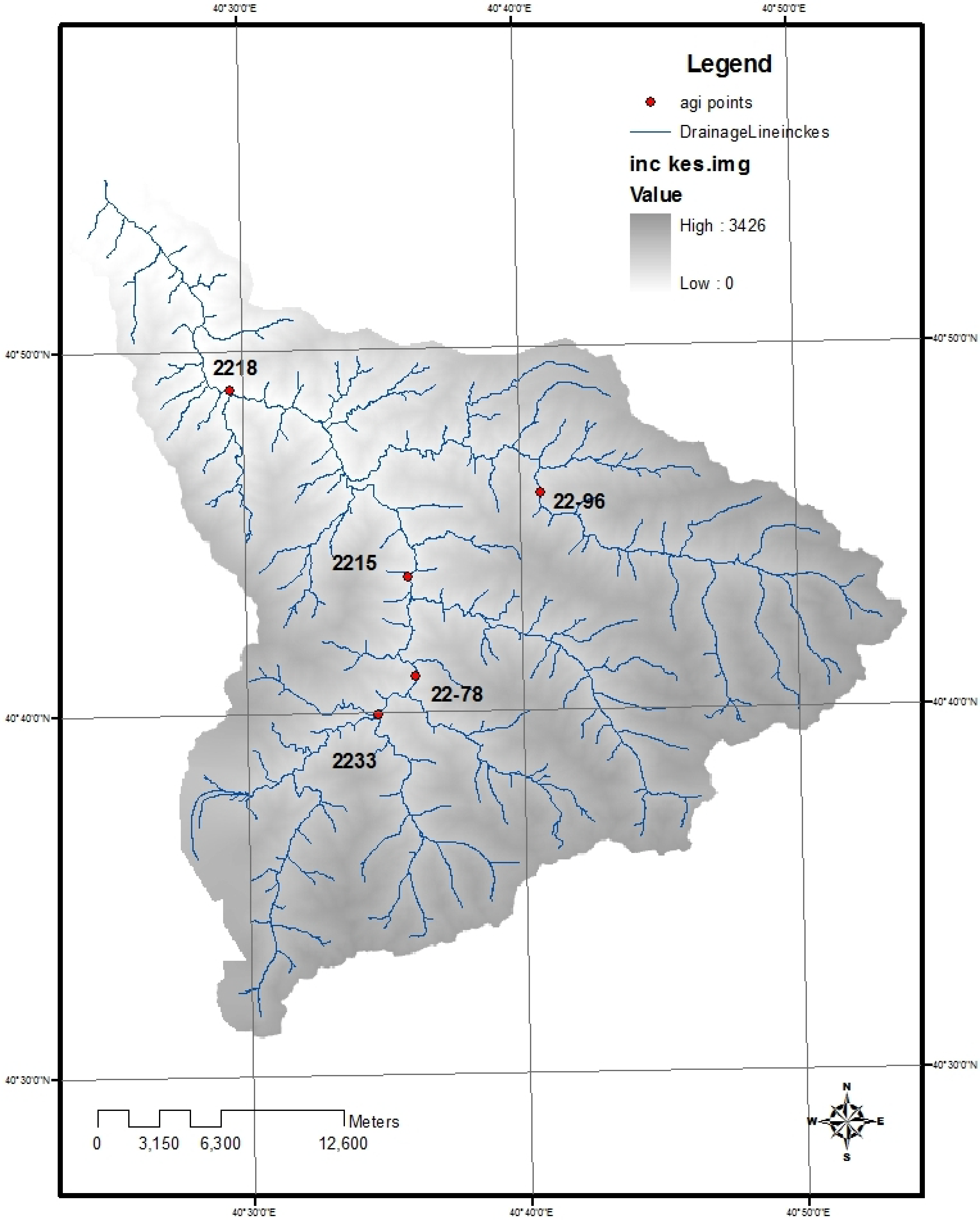

Figure 2.2 Network of the Streamflow Gauging Stations in İyidere Basin

2.3 Meteorological Data

Some properties of rainfall like duration, intensity, changing by time or location must be known to do planning in water resources, agriculture, urbinatization, drainage, flood control and transportation. Moreover rainfall properties are needed to design/operate safe and economical engineering structers (Karahan, 2010).

In this study, daily rainfall measurements gathered from 3 meteorological stations which are operated by Turkish State Meteorological Service are used. Only one of them, İkizdere DMI, is within the boundries of İyidere Watershed. It is a small climate station which has measurements between 1975-1996 years. The other stations are Uzungöl DMI and Rize DMI, which are a small climate station in Solaklı Watershed and a big climate station in Büyükdere Watershed, respectively.

There are not sufficient numbers of meteorological stations in İyidere Watershed. Only station in the basin is İkizdere DMI and it is not being operated since 1996. Because of that reason it is very hard to find reliable areal mean precipitation values. The other stations are being operated since 1975 but their measurements, especially for Uzungöl DMI, have some discontinuity. The locations of the meteorological stations in İyidere basin and neighbour watersheds can be seen in Figure 2.2. In Table 2.2, some properties of the meteorological stations can be seen.

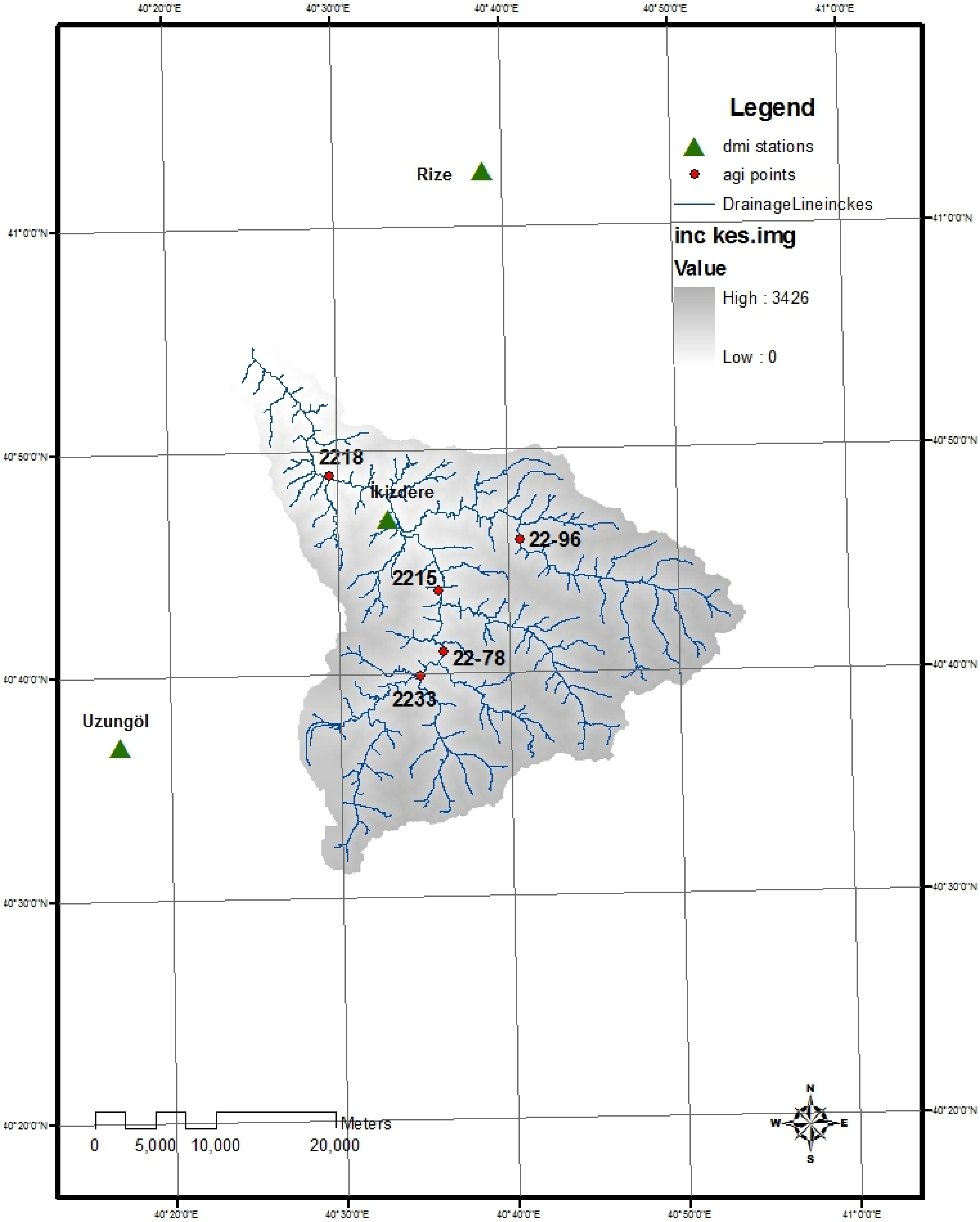

Figure 2.3 Meteorological Stations in İyidere Basin and in Neighbour Basins

Table 2.2 Some Properties of the Meteorological Stations in İyidere Basin and Neighbour Basins

Station No	Station Name	Station Type	Coordinates		Elevation	Mean Annual Rainfall	Observation Period
			X (m)	Y (m)	(m)	(mm)	
1803	İkizdere	Small Climate	630685	4515821	800	1083.35	1975-1996
1962	Uzungöl	Small Climate	608482	4496916	1450	1133.50	1991-2007
17040	Rize	Big Climate	638525	4544838	8.6	2248.35	1975-2007

2.4 Soil and Land Cover Data

Lithology, bedrock structure, landforms, climate (including rainfall, seasonality, evaporation) and vegetation all influence, to greater or lesser degrees, the recharge, transmission, storage and discharge characteristics of a particular hydrological system (web 2). Geographic Information Systems can be used to link land cover data to topographic data and to other information concerning processes and properties releated to geographic location. When applied to hydrologic systems, nontopographic information can include description of soils, land cover, ground cover, ground water conditions, as well as man made systems and their characteristics on or below the land surface (web 1).

In this study, soil data layers are gathered from 1/25000 Scaled National Soil Database of General Directorate of Rural Services. In those layers; soil groups, soil depths, the other soil characteristics, erosion degrees and slope values are available. On the other hand, landcover data layers are gathered from the results of Coordination of Information on the Environment (CORINE) Land Cover 2006 study. In those layers; polygons for 5 land cover groups (1.Artificial Surfaces, 2.Agricultural Areas, 3.Forest and Semi-Natural Areas, 4.Wetlands, 5.Water Bodies) are available.

2.5 Characteristics of the Project Sites

İyidere Basin is very important because of its water potential. It is very feasible to build HEPPs. Here are the numbers of HEPP projects in İyidere Basin: 2 operating, 7 having license, 5 waiting for license, 7 doing feasibility study. Total number is 21 (DSI, 2010).

In İyidere Basin, there is not enough number of stations to do this study. For that reason six projects have been chosen in addition to stations. 6 projects and their characteristics can be seen in Table 2.3. The map of the project sites are given in Figure 2.4.

Table 2.3 Chosen Projects in İyidere Basin

Name of the Facility	**Coordinates of the Diversion Weir (m)**		**Installed Capacity (MW)**	**Project Discharge (m^3/s)**	**Percentage Corresponding to Project Discharge (%)**	**Period of Discharge Measurement**	**Drainage Area of the Diversion Weir (km^2)**
	X	**Y**					
İncirli HEPP	619450	4529900	25.20	62	10	1963-2004	895
Selin 1 HEPP	638355	4516000	18.65	13	15	1965-2007	215.1
Selin 2 HEPP	634755	4516420	18.10	14.5	18	1965-2007	243
Rüzgarlı 1 HEPP	631750	4512950	4.76	2.5	10	1965-2000	30.11
Rüzgarlı 2 HEPP	630800	4511650	5.36	1.85	8	1965-2000	23.12
Arı 2 HEPP	648350	4511200	16.60	7.5	16	1965-2003	124

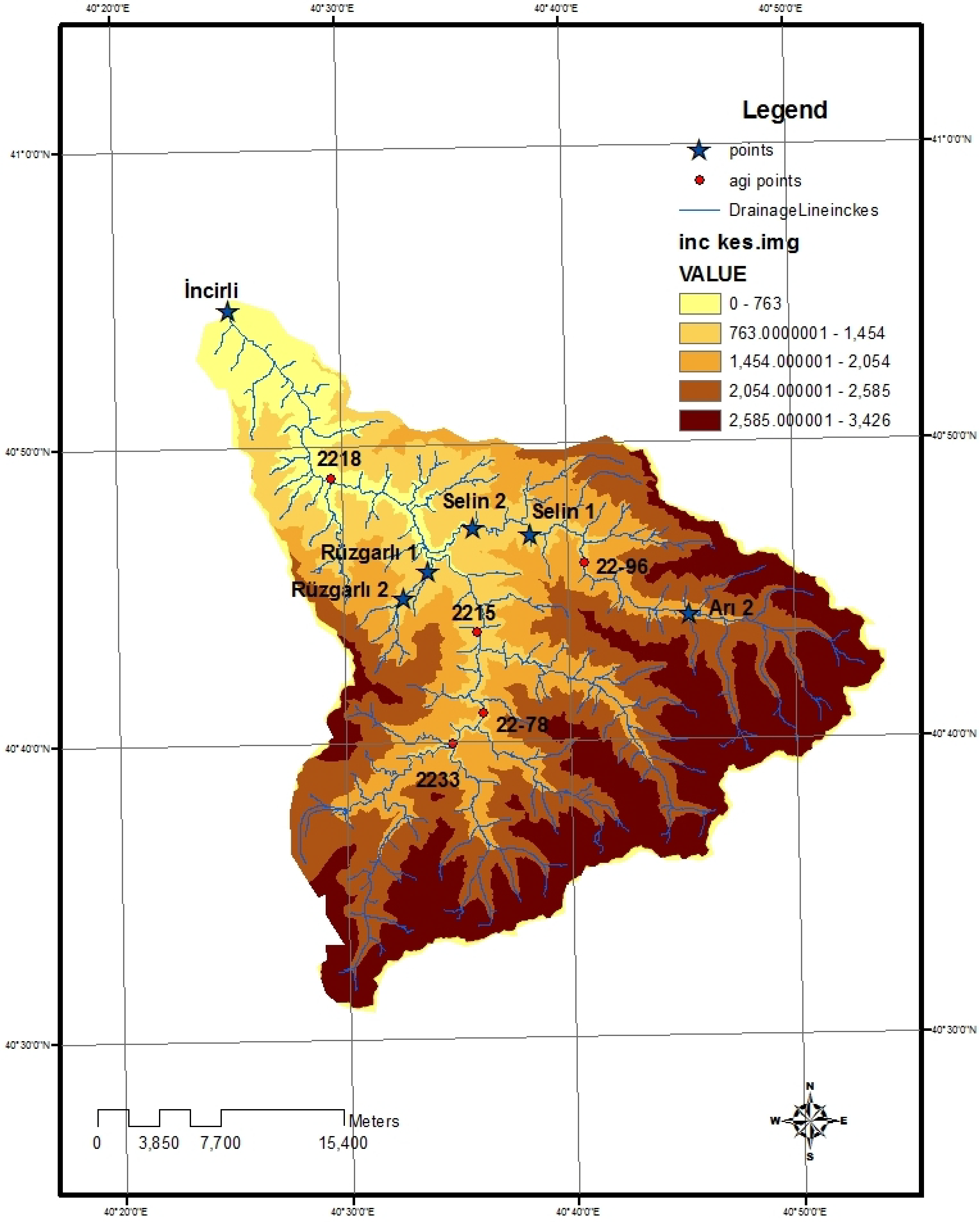

Figure 2.4 The Map of Chosen Projects in İyidere Basin

CHAPTER 3

DATA ANALYSIS AND RESULTS

3.1 Topographic Data

10x10 m digital elevation model has been used to derive the basin characteristics which are needed for the statistical model. While deriving those characteristics, Arc Hydro as extension of Arc GIS has been used. Arc Hydro is an ArcGIS-based system geared to support water resources applications. It consists of two key components: Arc Hydro Data Model and Arc Hydro Tools. These two components, together with the generic programming framework, provide basic database design and set of tools that facilitate analyses often performed in the water resources area. The Arc Hydro tools are used to derive several data sets that collectively describe the drainage patterns of a catchment. Raster analysis is performed to generate data on flow direction, flow accumulation, stream definition, stream segmentation and watershed delineation. These data are then used to develop a vector representation of catchments and drainage lines. Using this information, a geometric network is constructed (Arc Hydro Tools Tutorial, 2007).

It is started to identify the surface drainage pattern by Terrain Preprocessing. Once preprocessed, the DEM and its derivatives can be used for efficient watershed delineation and stream network generation. The flowchart of terrain preprocessing is given in Figure 3.1.

After Terrain Preprocessing, Watershed Delination is done. The coordinates of 5 stations in İyidere basin and the diversion weirs of 6 HEPPs have been used as the outlet points.

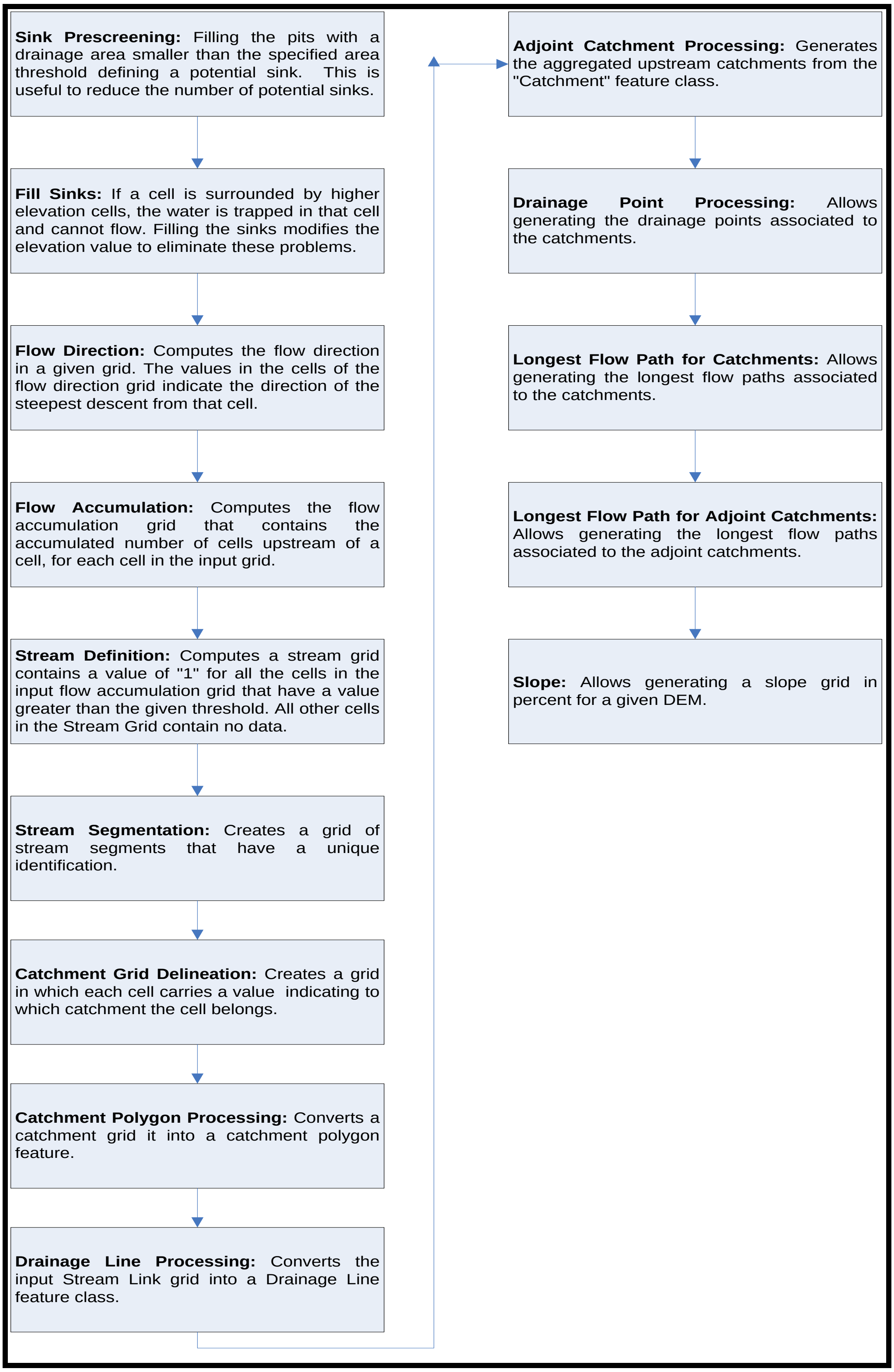

Figure 3.1 Flowchart of Terrain Preprocessing

3.2 Hydro-Meteorological Data Analysis

3.2.1 Rainfall Data

3 meteorological stations which are operated by Turkish State Meteorological Service are used for rainfall data. Only one of them, İkizdere DMI, is within the boundries of İyidere Watershed. It is a small climate station which has measurements between 1975-1996 years. The other stations are Uzungöl DMI and Rize DMI, which are a small climate station in Solaklı Watershed and a big climate station in Büyükdere Watershed, respectively.

There are not sufficient numbers of meteorological stations in Iyidere Watershed. Only station in the basin is İkizdere DMI and it is not being operated since 1996. Because of that reason it is very hard to find reliable areal mean precipitation values. The other stations are being operated since 1975 but their measurements, especially for Uzungöl DMI, have some discontinuity.

Long term data are very important to determine the serial dependency and the long term trend of the climatic components. Preparing the meteorological data, which their missing part is completed by a proper method, are quiet important to determine the climatic changes and the analyses need similar long term data (Yozgatlıgil, 2010).

Because of the insufficient number of meteorological stations in İyidere Basin, the missing records are estimated by regression in this study. 1991-1996 observation periods of the meteorological stations in the adjecent basins are used to develop regression equations. In those equations, dependent variable is İkizdere DMI and independent variables are Rize DMI and Uzungöl DMI.

3.2.1.1 Meteorological Station, İkizdere

İkizdere DMI was operated between 1975-1996 years and it was closed in 1996. April month of 1976 and November month of 1996 are missing data. Some regression analyses have been done for the missing data: first by Uzungöl DMI, second by Rize DMI and finally by both Uzungöl and Rize DMIs.

The independent variable for the first analysis is Uzungöl DMI, for the second analysis is Rize DMI, for the final analysis both Uzungöl and Rize DMIs. Regression equations are given in Table 3.1.

Table 3.1 The Regression Equations

Equation 1	$y = 0.0002x_1^2 + 0.0094x_1 + 3.7848$	**R^2 = 0.4359**
Equation 2	$y = 0.307x_2 + 2.9879$	**R^2 = 0.2984**
Equation 3	$y= 0.7608x_1 + 0.093528x_2 - 0.000221$	**R^2 = 0.7058**

Here, x_1 is the precipitation value of Uzungöl DMI in mm; x_2 is the precipitation value of Rize DMI in mm; y is the precipitation value of İkizdere DMI in mm.

Because R^2 is the biggest in the third regression analysis, the missing values of İkizdere DMI have been completed by regression equation $y = 0.7608x_1 + 0.093528x_2 - 0.000221$. The mean monthly rainfall values of İkizdere DMI can be seen in Table 4.2. Between 1997 and 2007 the values are completed by the above equation.

Table 3.2 Mean Monthly Rainfall Values of İkizdere DMI, mm

Years	Months												Annual Precipitation (mm)
	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	
1975	45.40	133.60	73.60	59.50	84.30	79.00	42.90	31.90	71.00	156.00	84.50	139.60	**1001.30**
1976	173.20	102.10	37.30	76.73	102.40	2.60	82.90	30.20	71.40	308.30	30.30	62.30	**1079.73**
1977	155.90	27.50	92.40	60.30	94.60	98.00	180.60	115.60	45.70	197.40	90.50	141.10	**1299.60**
1978	80.60	76.30	37.30	185.60	57.90	193.90	26.70	40.60	48.20	60.80	235.40	173.20	**1216.50**
1979	70.50	91.80	68.40	68.50	72.70	72.90	67.00	16.20	20.80	146.50	109.50	147.00	**951.80**
1980	132.00	47.30	60.50	97.40	56.30	15.70	6.30	62.60	97.80	91.20	233.90	124.60	**1025.60**
1981	64.20	83.80	107.00	58.00	106.80	55.60	42.40	74.60	70.70	71.80	225.20	84.00	**1044.10**
1982	132.80	137.00	83.70	80.20	41.30	40.40	67.00	30.20	46.80	141.70	112.40	73.40	**986.90**
1983	100.10	55.00	57.10	34.20	94.80	98.80	86.00	36.70	100.90	145.60	93.90	109.10	**1012.20**
1984	60.30	20.30	49.80	76.60	158.30	58.80	42.00	106.70	11.80	149.00	16.50	65.30	**815.40**
1985	94.50	142.40	49.40	62.50	106.90	67.70	28.70	22.80	89.10	163.00	16.50	224.30	**1067.80**
1986	113.60	105.60	11.00	40.70	151.70	148.90	15.20	16.00	149.70	74.30	177.10	107.50	**1111.30**
1987	70.20	58.00	60.20	110.20	28.80	82.50	105.30	130.20	75.40	93.00	107.00	145.90	**1066.70**
1988	102.20	67.50	106.60	56.90	109.90	151.50	178.50	156.60	55.60	158.20	222.80	103.70	**1470.00**
1989	141.20	75.80	90.80	44.30	102.30	76.80	36.60	8.50	146.60	131.30	119.80	92.10	**1066.10**
1990	122.20	84.40	61.90	164.40	125.10	93.70	69.70	39.10	82.60	146.60	107.50	141.00	**1238.20**
1991	105.30	51.30	80.30	29.80	195.50	76.80	46.80	63.20	21.20	93.20	32.80	129.00	**925.20**
1992	134.30	125.50	70.70	65.70	55.40	95.80	149.80	53.40	78.90	138.20	239.40	86.70	**1293.80**
1993	189.10	74.20	61.30	81.40	79.90	121.40	36.90	57.00	58.40	58.30	181.40	92.80	**1092.10**
1994	68.70	124.30	63.00	39.50	51.10	97.70	57.80	30.10	48.20	161.80	150.30	128.90	**1021.40**
1995	60.90	19.20	52.00	111.40	69.60	149.90	112.00	61.70	139.20	144.30	139.80	79.70	**1139.70**
1996	23.70	27.10	28.20	84.30	62.60	80.50	32.50	117.60	104.20	126.80	129.83	90.90	**908.23**
1997	113.64	92.47	119.03	70.45	80.21	83.79	115.12	49.88	107.90	107.12	35.73	88.13	**1063.47**
1998	119.01	110.96	132.58	75.27	115.34	79.70	50.08	76.10	66.93	79.06	81.99	99.33	**1086.35**
1999	36.32	59.61	95.29	108.38	142.33	71.40	67.58	66.29	83.07	111.84	96.02	31.04	**969.17**
2000	169.97	101.64	99.29	59.42	62.21	102.80	32.42	119.25	97.58	140.74	15.60	115.70	**1116.61**
2001	19.71	82.99	84.48	114.00	129.60	95.35	65.27	75.47	53.43	111.34	164.88	111.10	**1107.63**
2002	111.81	43.40	85.05	98.55	48.37	130.50	71.62	77.07	86.22	99.65	86.87	121.69	**1060.81**
2003	48.41	82.27	102.17	75.27	32.16	46.80	65.46	47.82	116.86	160.54	103.13	74.14	**955.03**
2004	78.03	153.00	115.86	96.96	144.78	122.49	43.72	77.87	45.28	78.74	202.00	84.41	**1243.14**
2005	76.52	64.37	111.22	103.94	83.82	128.51	27.26	89.44	72.77	221.60	148.42	69.20	**1197.08**
2006	95.92	83.94	91.16	117.24	99.82	54.39	119.25	13.56	80.13	128.06	176.98	119.12	**1179.59**
2007	88.16	50.70	105.42	100.75	41.71	54.99	93.15	110.47	48.22	82.12	148.55	89.69	**1013.96**
Average	**96.92**	**80.47**	**77.09**	**82.07**	**90.56**	**88.78**	**68.62**	**63.78**	**75.53**	**129.64**	**124.74**	**107.44**	1085.65

İkizdere DMI has 1085.65 mm rainfall depth as mean annual.

3.2.1.2 Meteorological Station, Rize

Rize DMI has been operating since 1975 and its data do not need to be completed. The mean monthly rainfall values of Rize DMI can be seen in Table 3.3.

Table 3.3 Mean Monthly Rainfall Values of Rize DMI, mm

Years	Months												Annual Precipitation (mm)
	Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	
1975	144.90	340.70	82.70	76.50	74.80	130.40	190.40	148.20	349.30	246.10	321.00	297.50	**2402.50**
1976	298.50	223.30	74.30	62.50	132.10	127.30	91.30	208.60	224.40	272.20	103.60	140.80	**1958.90**
1977	193.40	54.00	149.90	112.10	74.30	102.80	124.40	218.50	295.00	287.40	118.90	248.40	**1979.10**
1978	210.30	133.60	78.90	213.20	66.70	250.50	136.20	141.50	136.00	176.10	328.10	321.30	**2192.40**
1979	194.80	210.50	96.80	117.30	189.80	92.90	193.00	134.60	203.50	398.60	202.90	163.40	**2198.10**
1980	435.40	89.60	162.50	98.30	63.30	78.10	32.80	329.20	293.40	149.20	317.90	196.40	**2246.10**
1981	130.20	172.50	195.90	67.20	188.00	65.10	84.50	298.90	131.50	180.60	406.80	136.30	**2057.50**
1982	231.90	238.80	134.60	115.90	28.90	96.00	162.70	102.60	170.80	322.50	250.00	175.10	**2029.80**
1983	202.50	135.80	222.60	26.00	94.00	183.50	167.50	97.20	227.70	310.30	311.50	184.90	**2163.50**
1984	140.80	51.40	134.60	108.70	92.60	40.80	144.20	194.20	52.40	373.00	198.20	163.10	**1694.00**
1985	126.60	476.30	150.30	67.80	135.70	167.40	232.20	100.90	208.70	404.90	135.10	332.50	**2538.40**
1986	222.00	254.70	110.60	57.10	118.90	125.00	152.90	53.20	237.50	272.80	248.40	196.30	**2049.40**
1987	260.50	180.60	163.40	137.60	23.60	87.90	123.90	421.40	169.50	251.40	148.60	319.90	**2288.30**
1988	249.70	173.90	213.00	51.30	132.00	167.00	120.50	332.70	179.00	383.90	502.00	192.90	**2697.90**
1989	185.70	124.10	106.90	50.20	126.10	101.90	71.10	116.70	247.90	516.60	229.70	286.60	**2163.50**
1990	248.90	124.10	85.70	163.90	132.30	172.30	57.80	129.80	355.10	297.60	198.60	222.50	**2188.60**
1991	212.70	192.90	226.00	34.30	169.40	242.10	74.30	180.70	175.40	340.80	121.80	353.80	**2324.20**
1992	279.40	296.00	91.20	116.40	70.30	161.30	184.60	12.50	281.60	193.20	424.00	244.70	**2355.20**
1993	266.30	103.80	91.20	120.50	54.90	145.30	157.40	255.90	193.70	149.30	259.90	169.70	**1967.90**
1994	169.10	257.40	139.40	30.40	54.90	86.90	128.00	111.30	86.60	294.70	371.50	506.00	**2236.20**
1995	183.90	57.10	150.20	103.10	67.60	221.80	82.70	199.00	249.50	207.80	290.90	208.30	**2021.90**
1996	137.80	106.90	106.50	83.50	68.20	164.00	113.10	160.60	427.70	511.70	40.30	274.20	**2194.50**
1997	333.30	223.20	195.70	91.90	66.10	227.20	397.90	103.00	294.70	345.70	148.60	277.70	**2705.00**
1998	202.80	219.20	169.70	41.00	150.50	94.80	111.70	101.90	186.90	271.00	195.00	384.40	**2128.90**
1999	128.80	153.30	137.90	77.70	191.00	89.90	167.80	215.00	296.80	409.20	277.50	52.90	**2197.80**
2000	419.00	214.70	155.40	56.10	97.40	149.90	36.70	296.40	317.70	249.60	67.60	208.10	**2268.60**
2001	94.40	173.10	171.20	127.20	126.50	136.10	92.70	240.80	281.70	314.40	507.80	344.30	**2610.20**
2002	172.20	118.30	88.60	97.10	24.20	151.60	202.90	125.30	249.10	345.60	143.00	354.30	**2072.20**
2003	108.40	172.80	139.00	85.70	30.70	57.90	203.70	76.90	404.30	448.30	196.50	284.30	**2208.50**
2004	138.80	244.10	184.60	128.90	148.00	177.30	116.00	255.00	166.10	302.60	386.50	321.70	**2569.60**
2005	134.00	139.20	253.70	132.80	60.80	218.90	43.40	210.40	319.30	500.00	397.70	189.20	**2599.40**
2006	304.10	196.30	122.20	118.80	100.10	113.80	181.80	23.00	319.90	302.80	380.10	233.20	**2396.10**
2007	185.30	155.70	154.30	119.80	42.50	80.40	216.70	403.50	200.80	268.80	418.60	244.80	**2491.20**
Average	**210.50**	**182.06**	**143.62**	**93.66**	**96.85**	**136.61**	**139.30**	**181.80**	**240.41**	**312.08**	**262.08**	**249.38**	**2248.35**

The mean annual rainfall depth is 2248.35 mm for Rize DMI.

3.2.1.3 Meteorological Station, Uzungöl

“November month of 1996 in Uzungöl DMI is missing and the mean monthly rainfall value of November month, 119.36 mm, is accepted as the missing value. Also the period for the analyses of rainfall data of Uzungöl DMI is accepted to be between 1991 and 2007 although the measurements started in 1983. The reason behind this is the discontinuity of Uzungöl DMI rainfall data before the year 1991” (Karaaslan, 2011). The mean monthly rainfall values of Uzungöl DMI can be seen Table 3.4.

Table 3.4 Mean Monthly Rainfall Values of Uzungöl DMI, mm

Years	**Months**												**Annual Precipitation (mm)**
	Jan	**Feb**	**March**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	
1991	73.40	76.90	96.70	77.50	163.10	106.90	43.80	91.70	40.10	111.40	47.50	98.50	**1027.50**
1992	153.10	194.50	64.40	79.30	107.30	106.50	127.20	50.20	125.50	105.70	197.40	60.50	**1371.60**
1993	174.60	69.60	69.90	115.70	72.40	136.00	65.10	59.80	34.90	38.80	181.00	56.30	**1074.10**
1994	47.20	122.30	63.10	52.20	82.20	148.30	79.70	49.60	46.40	95.90	118.70	126.20	**1031.80**
1995	66.30	35.80	78.30	118.60	109.90	150.80	73.20	68.00	99.30	152.10	161.10	59.20	**1172.60**
1996	26.20	52.70	35.40	122.10	40.40	92.10	74.10	115.70	109.20	188.10	119.40	79.70	**1055.10**
1997	108.40	94.10	132.40	81.30	97.30	82.20	102.40	52.90	105.60	98.30	28.70	81.70	**1065.30**
1998	131.50	118.90	153.40	93.90	133.10	93.10	52.10	87.50	65.00	70.60	83.80	83.30	**1166.20**
1999	31.90	59.50	108.30	132.90	163.60	82.80	68.20	60.70	72.70	96.70	92.10	34.30	**1003.70**
2000	171.90	107.20	111.40	71.20	69.80	116.70	38.10	120.30	89.20	154.30	12.20	126.50	**1188.80**
2001	14.30	87.80	90.00	134.20	154.80	108.60	74.40	69.60	35.60	107.70	154.30	103.70	**1135.00**
2002	125.80	42.50	100.90	117.60	60.60	152.90	69.20	85.90	82.70	88.50	96.60	116.40	**1139.60**
2003	50.30	86.90	117.20	88.40	38.50	54.40	61.00	53.40	103.90	155.90	111.40	62.50	**983.80**
2004	85.50	171.10	129.60	111.60	172.10	139.20	43.20	71.00	39.10	66.30	218.00	71.40	**1318.10**
2005	84.10	67.50	115.00	120.30	102.70	142.00	30.50	91.70	56.40	229.80	146.20	67.70	**1253.90**
2006	88.70	86.20	104.80	139.50	118.90	57.50	134.40	15.00	66.00	131.10	185.90	127.90	**1255.90**
2007	93.10	47.50	119.60	117.70	49.60	62.40	95.80	95.60	38.70	74.90	143.80	87.80	**1026.50**
Average	**89.78**	**89.47**	**99.44**	**104.35**	**102.14**	**107.79**	**72.49**	**72.86**	**71.19**	**115.65**	**123.42**	**84.92**	**1133.50**

Uzungöl DMI has 1133.50 mm rainfall depth as mean annual.

3.2.1.4 Point Rainfall Estimation

Because rainfall is the most effective force of the water cycle, correct estimation of its distribution by time and by location is quiet important for the watershed based hydrological modeling. Generally, the point rainfall data gathered from meteorological stations are used as hydrological model input. While areal estimation of rainfall is being computed from point rainfall measurements, some methods like Thiessen Polygon, Krigging, Inverse Distance Weighting can be used (Hoblit and Curtis, 2002).

Increase of precipitation by the elevation is used to find the point estimation of precipitation because of the insufficient number of the meteorological stations in İyidere Basin. After the median altitudes have been found by plotting hypsometric curves for the drainage areas of 5 stream flow gauging stations and 6 planned HEPP projects, the precipitation is carried from İkizdere DMI to the median altitude of each drainage area. The median altitudes of total 11 drainage areas can be seen in Table 3.5.

Table 3.5 Median Altitudes of 11 Drainage Areas

	Gauging Stations					Projects					
	2218	2215	22-78	2233	22-96	İncirli	Selin 1	Selin 2	Rüzgarlı 1	Rüzgarlı 2	Arı 2
Median Altitudes (m)	2459.00	2517.50	2543.50	2538.70	2727.00	2436.00	2631.00	2577.00	2000.00	2116.00	2822.50

The formula used in this study is given by (web 3):

$$P_h = P_{ref_1}(1 + (\frac{h_{ref} - h}{100})p_{cor}) \quad (3.1)$$

P_h is corrected precipitation, P_{ref1} is the corrected precipitation at the observation station, h is the corrected precipitation height, h_{ref} is the observation station height and p_{cor} is the correction factor.

$$P_{ref_1} = P_{ref} \times p_{catch} \quad (3.2)$$

Here P_{ref} is the precipitation at the observation station, p_{catch} is the catchment deficiency and p_{catch} and p_{cor} are assumed to be 0.2 % and 5 %

respectively. These correction factors have been gathered by personal communication with Assoc. Prof. Dr. Arda Şorman.

3.2.2 Discharge Data

In this part of the study, correlation and regression studies for the discharge data, calculating mean monthly and yearly discharges, plotting the flow duration curves for both gauging stations' and planned projects' areas have been done.

For 2215, 2218, 2233 stations, the measurement periods are between 1965-2007. For 22-78 and 22-96 stations, it is between 1985-2007 and 1982-2007, respectively. In addition, 1989, 1993, 1997, 1998 years' data are missing for 22-78 station. 1988-1993, 1997-1999 years' data are also missing for 22-96 station. In this case, the period between 1982 and 2007 has been selected to be used for all discharge data studies.

Stations 2215 and 2233 have been used to complete the missing values of station 22-78 by regression equation which has been obtained by stepwise regression analysis. The missing data of station 22-96 has been completed by another regression equation which stations 2215 and 2218 have been used. The regression equations and their determination coefficients for stations 22-78 and 22-96 can be seen in Table 3.6.

Table 3.6 Regression Equations and R^2's for Stations 22-78 and 22-96

For 22-78	$y_1 = -0.95765 + 0.40282x_1 + 0.553543x_2$	**R^2 = 0.9761**
For 22-96	$y_2 = 2.6046 + 0.0227x_3^2 - 0.1973x_3$	**R^2 = 0.7346**

Here, x_1 is the discharge value of station 2215 in m^3/s; x_2 is the discharge value of station 2233 in m^3/s; x_3 is the difference between discharge values of station 2218 and station 2215 in m^3/s; y_1 is the discharge value of station 22-78 in m^3/s; y_2 is the discharge value of station 22-96 in m^3/s.

The mean monthly discharge values of stations 2215, 2218, 2233, 22-78 and 22-96 are given below in between Table 3.7-3.11. The mean monthly values of stations 2215, 2218, 2233, 22-78 and 22-96 for each year are demonstrated in Figure 3.2, 3.3, 3.4, 3.5 and 3.6. The mean annual flows of stations 2215, 2218, 2233, 22-78 and 22-96 can be seen in between Figure 3.7-3.11.

Table 3.7 Mean Monthly Discharge Values of 2215

Years	Months												Mean Annual (m^3/s)
	10	11	12	1	2	3	4	5	6	7	8	9	
1982	4.96	5.45	4.70	3.74	3.27	4.69	24.05	41.84	30.38	18.02	7.60	4.36	12.75
1983	4.79	4.78	4.37	3.86	4.02	6.99	18.04	40.18	29.51	12.70	7.18	7.11	11.96
1984	7.12	9.64	6.59	5.00	4.36	6.96	13.04	27.08	34.54	23.96	12.49	8.23	13.25
1985	4.43	3.40	3.91	4.11	4.33	5.84	20.88	42.57	26.39	11.36	5.30	4.31	11.40
1986	7.55	5.48	5.76	5.52	5.22	6.84	22.10	27.98	40.42	23.78	7.25	4.92	13.57
1987	6.61	6.70	5.26	4.21	5.10	5.24	9.79	34.91	31.04	17.67	8.49	5.46	11.71
1988	5.53	6.69	6.57	6.37	5.74	6.30	16.90	30.81	41.70	29.25	14.71	7.41	14.83
1989	11.83	12.66	8.02	4.50	4.11	9.81	31.04	36.76	30.81	13.07	5.37	4.71	14.39
1990	7.55	5.07	5.14	4.59	4.54	6.00	17.77	38.65	44.73	17.92	6.71	5.02	13.64
1991	7.27	9.22	7.10	5.18	4.89	8.53	18.78	29.58	26.07	10.68	5.83	4.30	11.45
1992	3.79	4.00	3.50	3.95	3.32	6.09	18.87	35.09	56.92	22.56	8.83	4.60	14.29
1993	10.15	9.50	6.38	4.64	4.59	9.23	22.61	39.41	43.47	29.44	12.71	6.33	16.54
1994	4.26	5.06	4.72	3.61	3.75	5.31	28.20	30.78	21.08	11.45	8.43	3.85	10.88
1995	4.98	8.30	6.83	6.14	4.65	5.92	11.76	42.28	35.91	14.49	7.51	5.71	12.87
1996	14.54	13.20	8.86	5.78	5.57	4.70	13.08	48.14	28.94	15.87	7.42	5.81	14.33
1997	6.94	6.06	4.12	4.14	3.62	4.17	21.21	42.12	36.26	17.64	7.96	5.67	13.33
1998	14.60	7.14	3.71	3.34	3.69	8.65	33.70	43.81	33.18	12.61	7.18	5.90	14.79
1999	6.70	5.24	6.49	4.60	4.78	6.20	17.03	38.24	33.77	18.43	8.87	7.05	13.12
2000	6.11	6.97	6.41	5.52	5.27	6.98	28.43	30.15	27.83	9.96	5.43	5.96	12.08
2001	9.39	5.75	5.06	3.91	3.27	8.16	18.25	28.62	31.73	11.89	5.04	3.33	11.20
2002	3.58	6.07	5.46	4.56	4.51	8.72	15.30	31.35	48.44	29.31	10.58	7.02	14.58
2003	6.44	5.44	3.91	3.66	3.60	3.66	21.43	31.49	20.37	9.57	5.55	6.47	10.13
2004	8.40	12.53	6.42	5.33	5.84	16.24	19.15	45.05	48.93	18.96	8.87	7.49	16.94
2005	5.48	5.44	5.44	5.65	5.96	7.97	32.76	51.78	46.29	23.54	9.63	6.91	17.24
2006	13.94	12.70	8.15	4.60	5.88	8.07	23.23	42.66	33.09	16.33	7.78	5.79	15.18
2007	7.54	10.46	5.31	4.62	4.24	6.10	7.66	64.43	39.46	17.55	8.55	4.65	15.05
Average	7.48	7.42	5.70	4.66	4.54	7.05	20.19	38.30	35.43	17.62	8.13	5.71	**13.52**

Table 3.8 Mean Monthly Discharge Values of 2218

Years	Months												Mean Annual (m^3/s)
	10	11	12	1	2	3	4	5	6	7	8	9	
1982	13.39	21.41	14.51	12.84	10.18	14.55	64.76	72.08	59.20	34.22	16.86	12.00	28.83
1983	15.10	15.93	13.68	11.84	12.08	19.35	35.10	62.48	56.44	30.03	16.49	17.36	25.49
1984	22.61	23.82	13.92	11.49	10.81	17.24	26.60	51.14	57.78	37.36	24.30	14.60	25.97
1985	14.67	12.37	9.93	10.82	11.81	15.87	50.34	74.98	47.64	20.30	11.37	10.53	24.22
1986	20.05	13.25	17.16	13.44	14.96	15.98	42.11	50.32	72.40	44.52	17.39	18.11	28.31
1987	19.00	13.70	14.02	13.11	12.34	13.23	28.46	60.28	53.26	30.84	21.63	14.09	24.50
1988	13.97	17.41	12.25	11.04	11.18	16.60	34.96	49.05	55.19	54.04	35.35	24.98	28.00
1989	31.15	28.29	22.96	13.59	15.07	41.85	85.37	81.76	70.47	35.20	10.65	11.55	37.32
1990	19.90	11.01	14.09	10.37	13.13	24.41	43.73	73.87	81.80	46.08	17.15	14.33	30.82
1991	23.81	23.89	15.93	11.69	13.11	24.64	43.53	60.68	64.28	34.57	16.49	11.55	28.68
1992	11.46	11.55	8.70	7.50	9.74	22.91	51.90	67.13	95.25	47.62	24.80	14.08	31.05
1993	23.26	24.34	18.05	12.86	11.62	21.69	48.77	86.21	92.53	53.34	22.92	15.88	35.96
1994	12.10	20.27	18.04	12.49	13.36	20.50	52.23	47.79	38.85	21.51	13.41	10.37	23.41
1995	14.35	15.96	14.51	15.56	10.97	18.03	28.01	67.54	59.16	30.96	17.92	19.73	26.06
1996	29.25	24.21	15.70	12.44	11.81	10.55	21.62	70.91	49.09	27.70	18.25	17.28	25.73
1997	24.07	14.77	13.72	13.32	11.64	13.46	40.41	86.51	69.18	36.60	18.25	21.55	30.29
1998	24.10	17.24	10.14	11.56	14.48	21.70	75.68	87.27	63.82	25.08	15.00	14.45	31.71
1999	16.04	13.29	13.39	9.16	10.17	11.92	29.38	67.40	57.18	34.39	16.95	17.88	24.76
2000	15.69	18.75	18.27	12.45	13.17	16.69	63.82	58.08	50.02	22.42	16.59	12.94	26.57
2001	19.79	12.50	13.50	9.78	9.19	20.06	32.31	45.99	50.65	22.80	12.83	9.75	21.60
2002	10.91	25.60	15.35	10.34	12.05	18.70	31.18	52.67	80.83	50.18	19.09	16.27	28.60
2003	14.79	12.36	10.65	12.54	9.66	11.21	36.06	49.66	33.42	16.95	11.79	15.51	19.55
2004	19.10	30.01	14.42	12.58	15.50	31.20	38.60	71.84	80.53	37.68	18.71	16.61	32.23
2005	13.80	14.20	16.11	13.78	13.54	18.20	56.90	73.72	65.36	35.44	17.22	15.57	29.49
2006	29.37	29.18	15.77	10.76	13.71	19.42	39.67	60.64	51.01	31.38	11.46	9.59	26.83
2007	13.70	22.12	13.74	12.93	11.38	18.77	29.60	113.23	64.20	36.23	16.96	10.33	30.27
Average	18.67	18.75	14.56	11.93	12.18	19.18	43.50	67.05	62.29	34.52	17.69	14.88	**27.93**

Table 3.9 Mean Monthly Discharge Values of 2233

Years	Months												Mean Annual (m^3/s)
	10	11	12	1	2	3	4	5	6	7	8	9	
1982	1.79	2.21	1.73	1.51	1.39	1.84	12.87	21.01	15.69	8.30	3.79	1.83	6.16
1983	2.18	1.94	1.57	1.53	1.45	2.98	7.24	23.31	17.71	6.20	2.46	2.02	5.88
1984	2.51	3.51	1.76	1.45	1.33	2.12	4.77	16.14	19.66	10.85	4.25	2.94	5.94
1985	1.77	1.63	1.42	1.21	1.26	1.70	7.20	19.25	13.01	4.81	2.07	1.77	4.76
1986	2.75	2.87	2.08	1.77	1.94	2.95	10.30	15.30	25.05	11.76	3.79	1.89	6.87
1987	2.35	2.49	1.57	1.50	1.63	1.44	4.77	18.89	18.80	9.47	4.27	2.67	5.82
1988	2.24	2.72	2.01	1.49	1.49	2.08	7.94	19.92	25.48	16.91	5.85	3.10	7.60
1989	4.86	5.05	3.09	1.85	1.65	4.64	18.90	20.35	18.33	8.01	3.37	2.62	7.73
1990	4.61	2.35	2.22	2.18	1.84	3.57	8.31	21.62	19.65	8.59	3.05	2.18	6.68
1991	2.16	3.71	2.87	2.08	1.62	3.66	11.97	20.06	18.36	7.53	2.69	1.73	6.54
1992	1.74	1.91	1.54	1.55	1.28	2.19	7.71	19.33	28.94	12.92	5.03	2.45	7.22
1993	3.93	3.56	2.55	2.05	1.69	2.90	8.92	23.52	29.03	14.70	5.04	2.34	8.35
1994	1.78	2.55	2.20	1.53	1.44	2.52	12.23	13.94	9.80	6.05	3.05	1.69	4.90
1995	2.32	2.42	1.74	1.88	1.65	2.41	5.56	23.92	17.44	7.15	3.52	2.40	6.03
1996	5.41	5.93	2.93	1.45	1.62	1.55	3.55	21.64	14.12	8.18	2.82	2.57	5.98
1997	4.57	3.09	2.38	1.72	1.66	1.91	12.06	25.47	20.66	8.05	3.25	2.82	7.30
1998	6.66	3.50	1.78	1.56	1.67	2.51	16.35	27.84	19.20	5.44	2.94	1.75	7.60
1999	2.37	2.28	2.61	1.37	1.36	2.00	7.11	24.65	20.47	9.72	4.05	3.42	6.78
2000	2.25	2.62	2.50	1.83	1.76	2.40	17.80	18.84	15.78	5.02	2.89	2.23	6.33
2001	2.79	2.28	1.51	1.62	1.32	4.41	10.73	14.20	14.34	5.65	2.22	1.68	5.23
2002	1.44	1.88	2.04	1.81	1.83	3.61	9.70	20.88	26.09	13.79	4.91	2.82	7.57
2003	3.04	2.89	2.15	2.08	1.76	1.72	13.06	20.98	12.19	4.54	2.85	1.68	5.75
2004	2.41	5.40	3.09	2.26	2.44	7.16	10.91	26.01	27.88	10.35	3.15	2.48	8.63
2005	2.80	2.19	2.16	2.42	2.63	3.23	15.26	27.18	23.79	11.85	4.76	2.87	8.43
2006	6.11	5.47	4.06	2.10	2.42	4.03	13.85	24.03	18.47	7.69	3.00	2.16	7.78
2007	3.58	4.99	2.50	2.00	2.22	3.40	4.42	34.77	22.16	6.22	3.51	2.12	7.66
Average	3.09	3.13	2.23	1.76	1.71	2.88	10.13	21.65	19.70	8.84	3.56	2.32	**6.75**

Table 3.10 Mean Monthly Discharge Values of 22-78

Years	Months												Mean Annual (m^3/s)
	10	11	12	1	2	3	4	5	6	7	8	9	
1982	2.03	2.46	1.89	1.38	1.13	1.95	15.86	27.52	19.96	10.90	4.20	1.81	7.59
1983	2.18	2.04	1.67	1.44	1.47	3.51	10.32	28.13	20.73	7.59	3.29	3.03	7.12
1984	3.30	4.87	2.67	1.86	1.53	3.02	6.93	18.88	23.84	14.70	6.43	3.98	7.67
1985	1.80	1.31	1.40	1.37	1.49	2.34	11.44	26.84	16.87	6.28	2.33	1.76	6.27
1986	2.87	2.88	1.81	1.44	1.73	3.20	13.17	18.31	40.30	17.18	3.93	2.16	9.08
1987	2.85	3.21	1.95	1.92	2.10	1.89	6.83	32.23	26.58	11.24	4.25	2.34	8.11
1988	1.88	3.20	2.10	1.52	1.54	2.38	10.40	33.90	44.50	25.19	8.21	4.66	11.62
1989	6.50	6.94	3.98	1.88	1.61	5.56	22.01	25.12	21.60	8.74	3.07	2.39	9.12
1990	5.74	3.07	2.95	2.52	2.42	5.35	14.36	36.68	32.69	12.80	4.15	2.37	10.42
1991	3.00	6.49	3.07	2.15	1.65	5.19	16.58	28.14	31.17	12.06	3.67	1.76	9.58
1992	1.71	1.95	1.12	1.23	1.03	2.18	9.63	27.09	40.66	16.34	7.40	3.33	9.47
1993	5.31	4.84	3.02	2.05	1.82	4.36	13.09	27.94	32.62	19.04	6.95	2.89	10.33
1994	2.31	3.06	2.65	2.17	2.08	4.02	18.72	24.45	15.86	7.19	4.11	2.31	7.41
1995	3.35	3.39	2.36	2.81	2.60	4.02	8.74	38.62	25.26	8.82	3.56	2.30	8.82
1996	5.35	6.60	3.15	2.10	1.98	2.16	3.88	24.27	15.13	8.25	2.16	1.93	6.41
1997	4.37	3.19	2.02	1.66	1.42	1.78	14.27	30.11	25.09	10.60	4.05	2.89	8.45
1998	8.61	3.85	1.52	1.25	1.45	3.92	21.67	32.10	23.04	7.13	3.56	2.39	9.21
1999	3.13	3.05	4.08	2.21	2.23	3.32	11.32	23.61	19.34	11.83	5.43	3.03	7.71
2000	2.31	2.47	2.27	1.99	1.70	3.16	26.41	17.41	22.23	6.79	3.36	2.56	7.72
2001	4.05	3.01	2.35	2.06	1.72	4.40	12.16	21.60	37.24	13.86	3.90	1.89	9.02
2002	1.70	3.27	2.45	2.71	2.48	3.91	6.60	22.60	40.18	19.38	4.63	3.51	9.45
2003	4.11	3.41	2.67	2.39	2.04	1.89	17.08	33.78	12.66	6.31	4.10	3.37	7.82
2004	3.27	6.00	3.56	2.56	2.25	12.04	11.68	38.54	42.81	23.14	6.74	2.70	12.94
2005	2.18	1.97	1.98	1.93	2.06	3.50	17.38	22.46	22.27	12.69	2.78	2.23	7.78
2006	8.07	7.67	4.03	1.85	1.39	2.95	17.73	34.39	38.26	24.41	3.55	1.28	12.13
2007	4.06	6.02	2.57	2.01	1.98	3.38	4.58	44.25	27.21	9.56	4.43	2.09	9.34
Average	3.69	3.85	2.51	1.94	1.80	3.67	13.18	28.42	27.62	12.77	4.39	2.58	**8.87**

Table 3.11 Mean Monthly Discharge Values of 22-96

Years	Months												Mean Annual (m^3/s)
	10	11	12	1	2	3	4	5	6	7	8	9	
1982	1.93	1.92	1.72	1.79	1.41	1.30	4.69	9.18	9.14	5.68	3.02	2.06	3.65
1983	1.92	1.79	1.55	1.35	1.96	3.69	4.98	10.39	9.34	5.03	2.43	1.85	3.86
1984	1.64	2.17	3.76	4.03	2.83	2.88	4.30	8.04	11.80	6.36	2.30	1.71	4.32
1985	1.61	1.47	1.60	1.60	1.55	2.46	5.03	13.80	10.42	4.14	2.37	1.70	3.98
1986	2.28	2.14	1.88	1.88	1.83	3.83	7.69	8.39	17.45	9.07	2.84	1.93	5.10
1987	2.15	2.00	1.90	1.35	1.19	1.12	2.21	12.17	11.83	6.19	2.73	1.81	3.89
1988	2.91	3.43	2.44	2.44	2.45	3.10	7.03	6.76	5.88	14.80	9.35	6.26	5.57
1989	7.79	5.09	5.02	2.73	3.88	20.99	62.56	42.58	32.42	10.62	2.42	3.54	16.64
1990	5.24	3.27	3.00	2.43	2.82	8.10	15.55	31.37	29.03	16.78	3.23	3.92	10.39
1991	6.49	5.61	2.72	2.45	2.94	8.51	13.04	20.43	29.58	11.55	3.15	2.46	9.08
1992	2.66	2.58	2.41	2.39	2.44	7.65	26.21	21.61	31.01	14.17	6.35	3.13	10.22
1993	5.28	4.76	3.48	2.70	2.88	4.84	14.11	45.72	49.65	12.13	3.15	3.13	12.65
1994	2.73	3.82	2.19	1.70	1.52	1.69	8.78	9.96	10.30	5.22	3.13	2.36	4.45
1995	2.76	2.88	2.44	1.68	1.02	1.56	3.31	10.94	13.29	7.42	4.36	3.30	4.58
1996	3.23	3.54	2.98	2.85	2.61	2.52	3.50	8.38	8.60	5.74	2.00	1.09	3.92
1997	6.84	2.69	3.01	2.77	2.72	2.84	11.28	44.05	21.56	7.72	3.06	6.86	9.62
1998	3.67	3.32	2.39	2.55	3.30	5.11	38.95	39.76	19.98	4.12	2.65	9.24	11.25
1999	5.37	2.71	2.60	2.34	2.35	2.39	4.40	17.22	10.88	5.71	2.68	3.66	5.19
2000	2.61	2.93	2.13	1.32	0.86	1.09	13.90	17.13	16.68	6.22	2.54	1.73	5.76
2001	3.60	1.87	1.44	1.26	1.03	3.13	7.50	10.95	16.64	7.20	3.13	1.91	4.97
2002	1.76	2.40	1.28	0.89	0.63	0.98	7.87	18.24	25.44	20.20	6.70	2.46	7.40
2003	2.31	1.29	1.22	1.27	0.87	0.44	5.13	15.27	9.96	3.37	1.43	2.25	3.73
2004	5.83	6.46	2.21	0.99	0.72	2.62	6.47	27.54	26.78	13.38	3.77	2.11	8.24
2005	2.38	2.19	1.88	1.70	1.81	2.32	11.68	18.93	18.65	11.00	3.74	3.07	6.61
2006	4.74	3.79	2.53	1.44	1.26	2.15	10.09	18.96	19.62	8.78	2.82	2.13	6.53
2007	2.52	5.20	2.68	2.75	2.43	4.41	9.60	52.45	19.83	9.47	2.81	2.56	9.73
Average	3.55	3.13	2.40	2.03	1.97	3.91	11.92	20.78	18.68	8.93	3.39	3.01	**6.97**

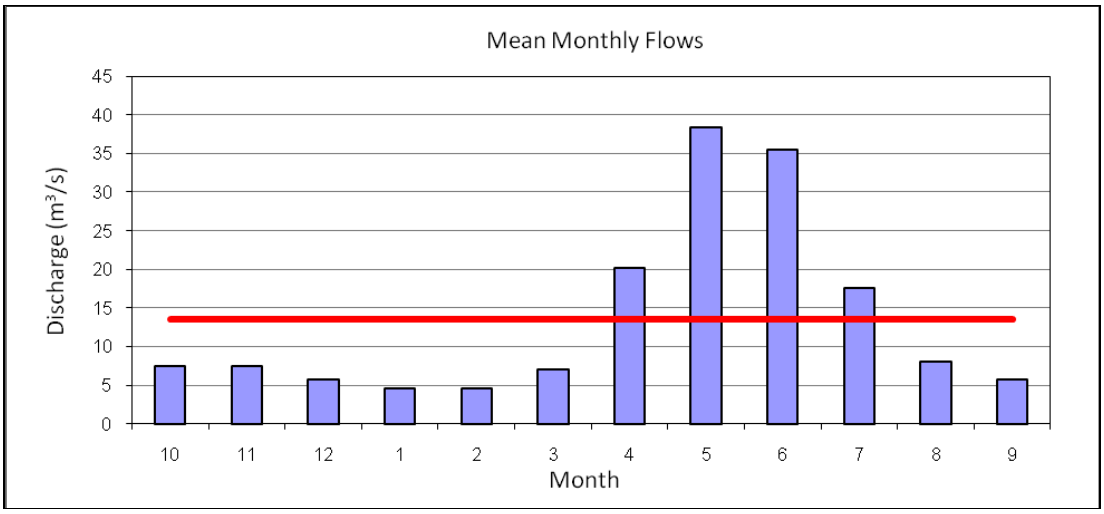

Figure 3.2 Mean Monthly Discharge Values of 2215

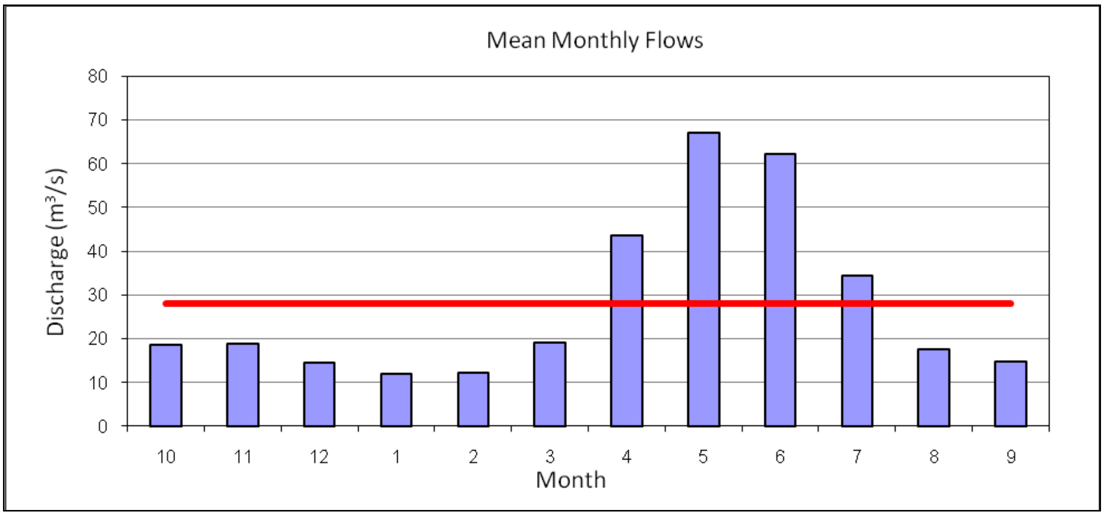

Figure 3.3 Mean Monthly Discharge Values of 2218

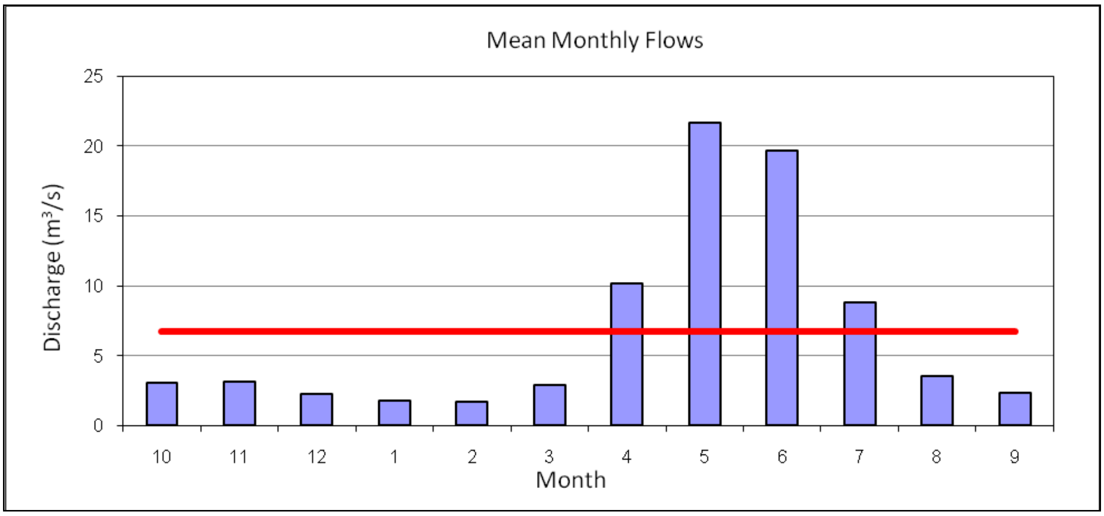

Figure 3.4 Mean Monthly Discharge Values of 2233

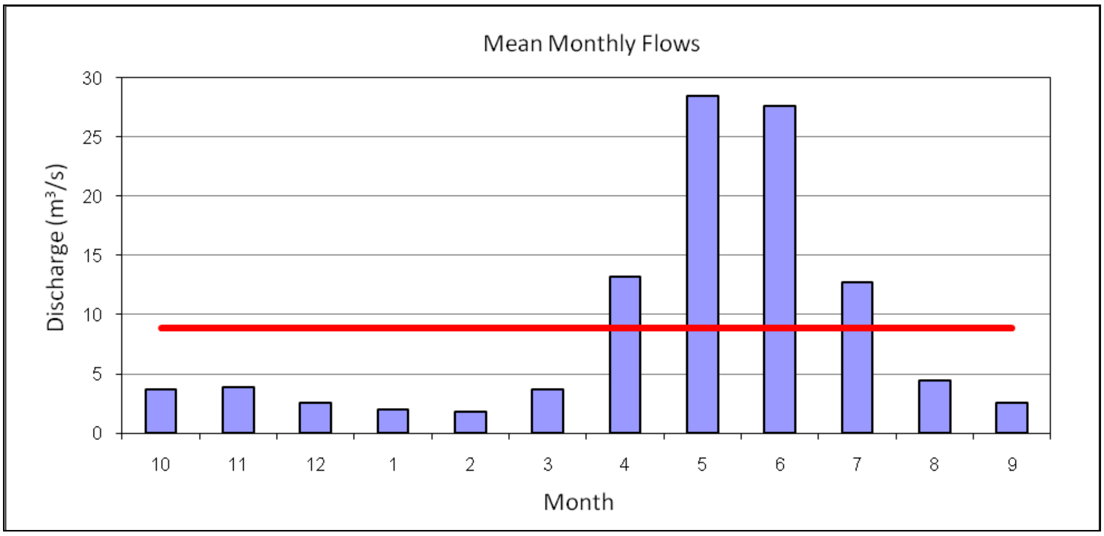

Figure 3.5 Mean Monthly Discharge Values of 22-78

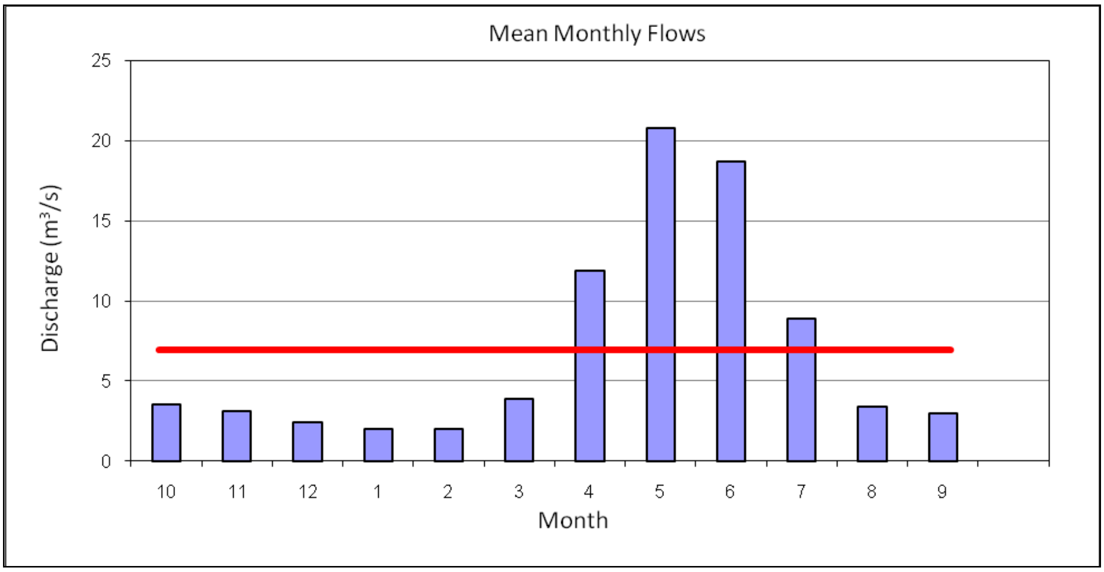

Figure 3.6 Mean Monthly Discharge Values of 22-96

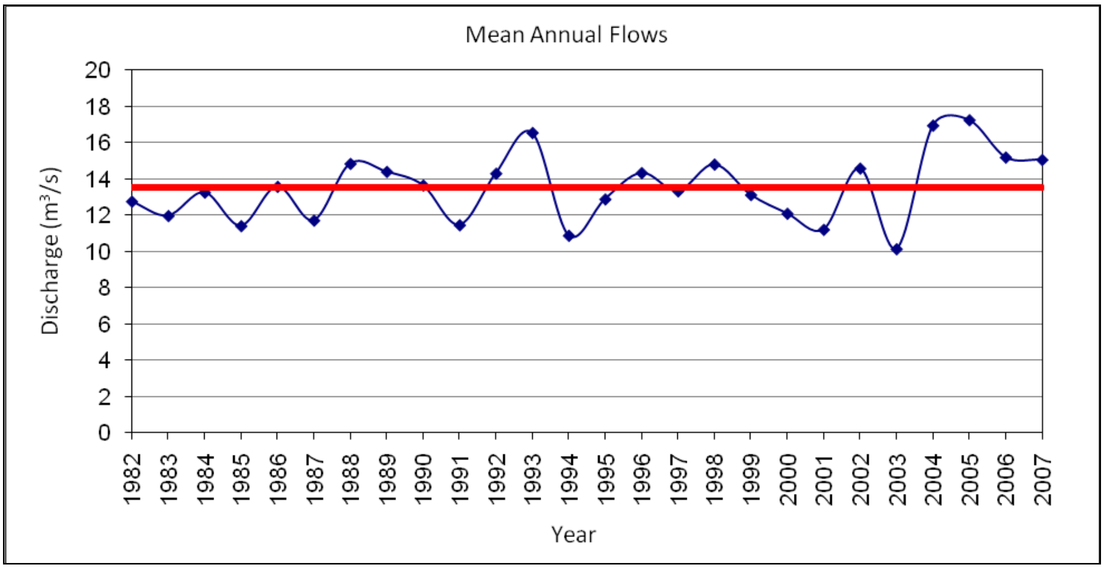

Figure 3.7 Mean Annual Discharge Values of 2215

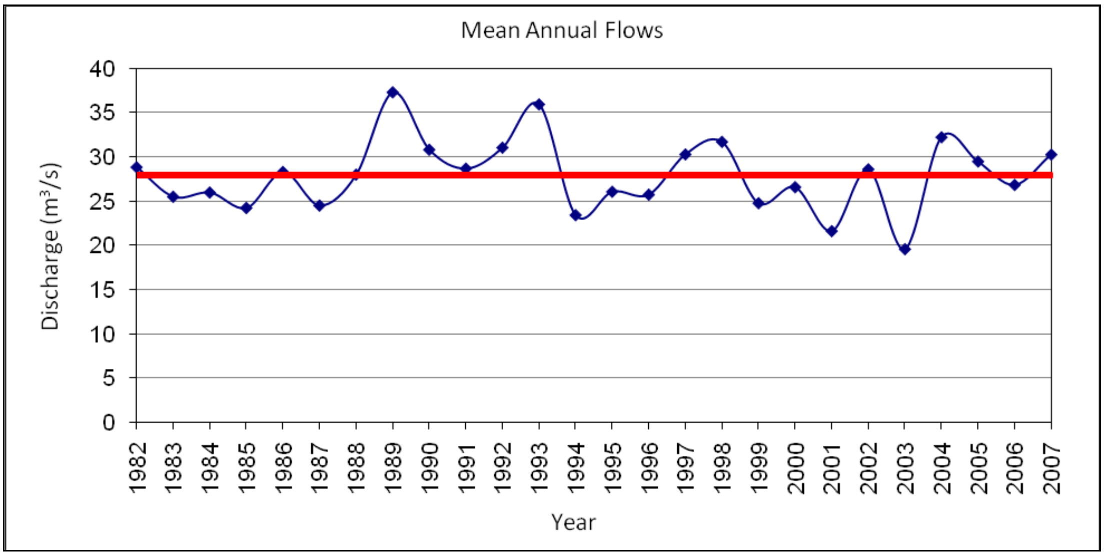

Figure 3.8 Mean Annual Discharge Values of 2218

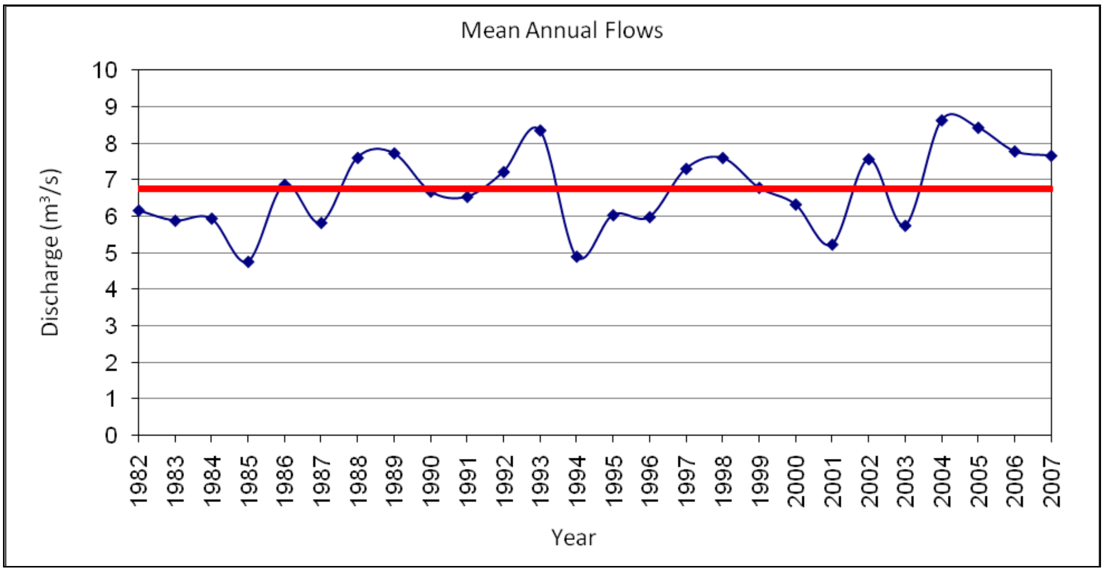

Figure 3.9 Mean Annual Discharge Values of 2233

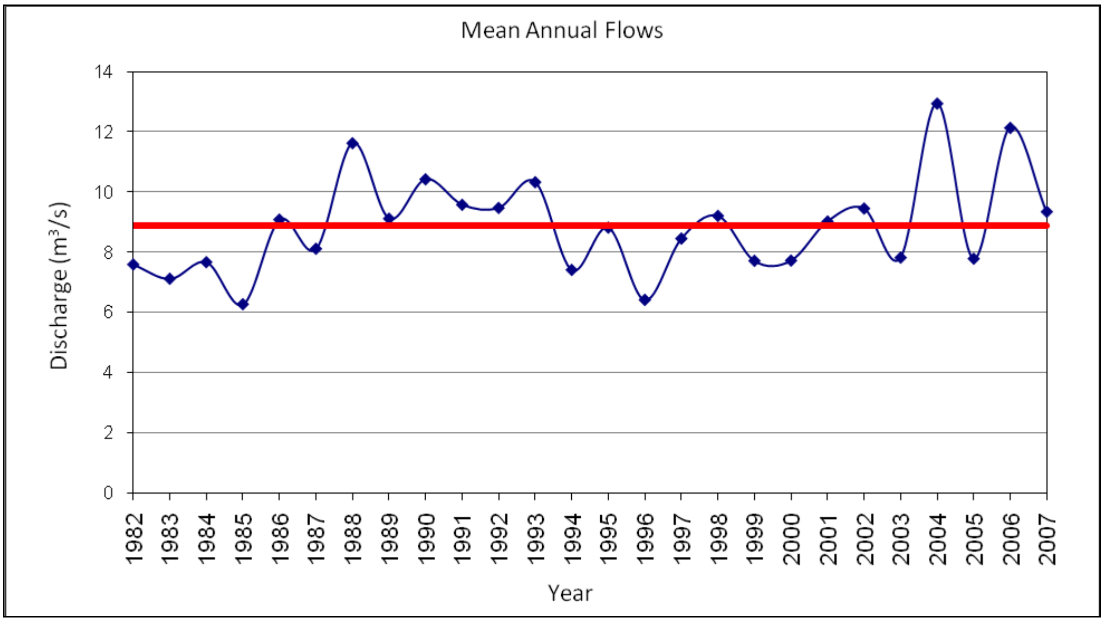

Figure 3.10 Mean Annual Discharge Values of 22-78

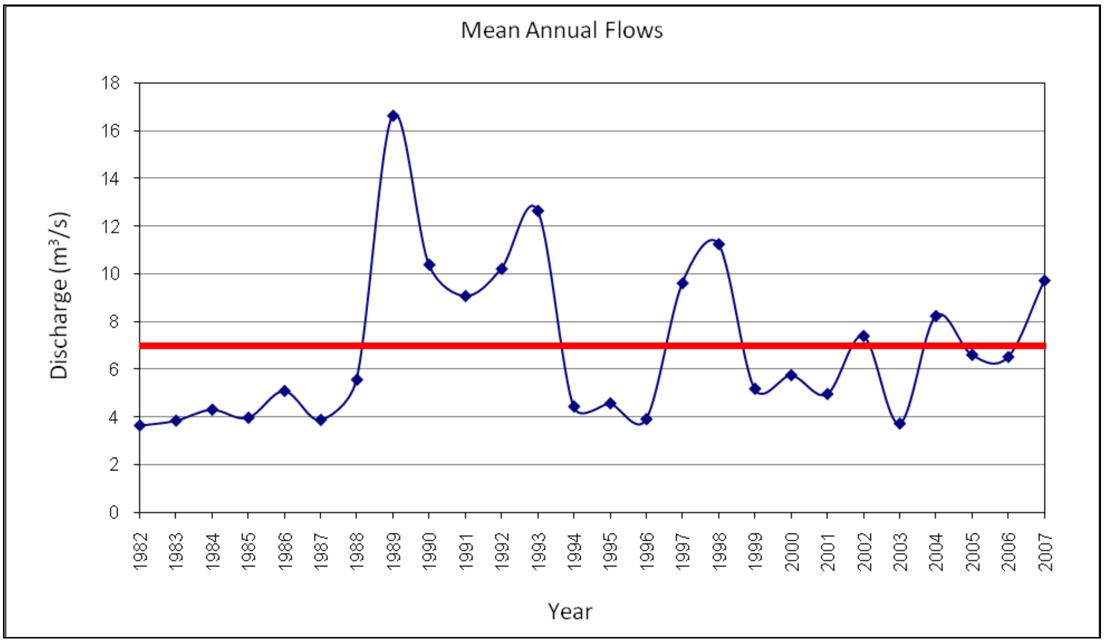

Figure 3.11 Mean Annual Discharge Values of 22-96

Mean annual discharge values, drainage areas and record numbers of stations 2215, 2218, 2233, 22-78 and 22-96 can be seen in Table 3.12.

Table 3.12 Mean Annual Discharge Values, Drainage Areas and Record Numbers of Stations 2215, 2218, 2233, 22-78 and 22-96

Station No	Mean Annual Discharge (m^3/s)	Drainage Area (km^2)	Record Number (Year)
2215	13.52	445	42
2218	27.93	835	52
2233	6.75	249	42
22-78	8.87	288	22
22-96	6.97	156	25

3.2.2.1 Flow Duration Curves

The FDC characterizes the relationship between the magnitude and frequency and hence provides the complete range of streamflow over time (Shao et al., 2009). The flow duration curve (FDC) represents the relationship between the magnitude and the frequency of daily, weekly, monthly (or some other time interval of) stream flows for a particular river basin, providing an estimate of the percentage of time the stream flow was equalled or exceeded over a historical period (Cigizoglu and Bayazit, 2000).

The annual flow duration curves of stations 2215, 2218, 2233, 22-78 and 22-96 used in this study can be seen in between Figure 3.12 and 3.16:

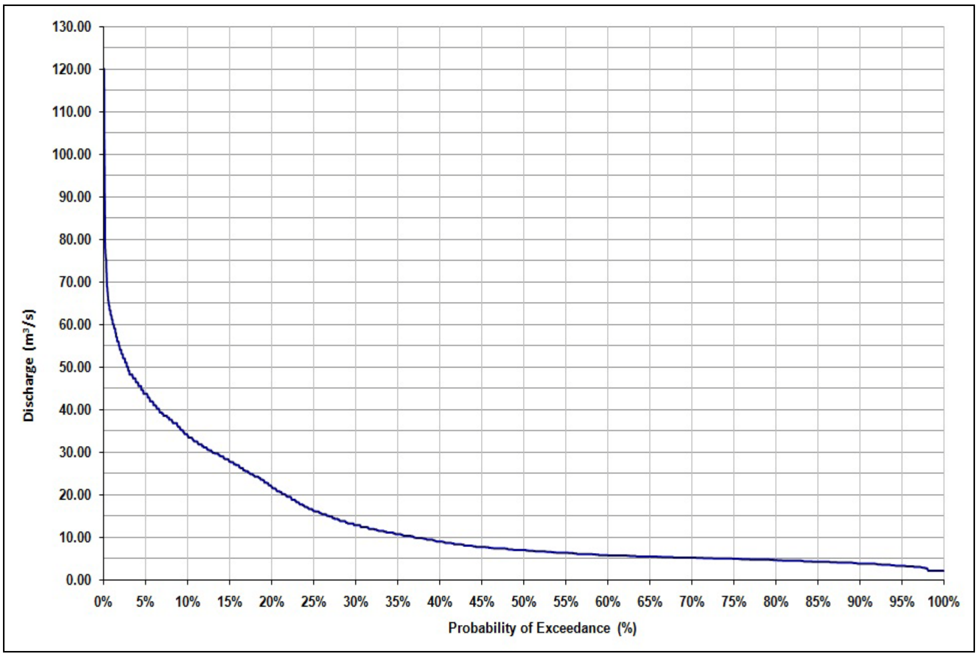

Figure 3.12 Annual Flow Duration Curve of 2215

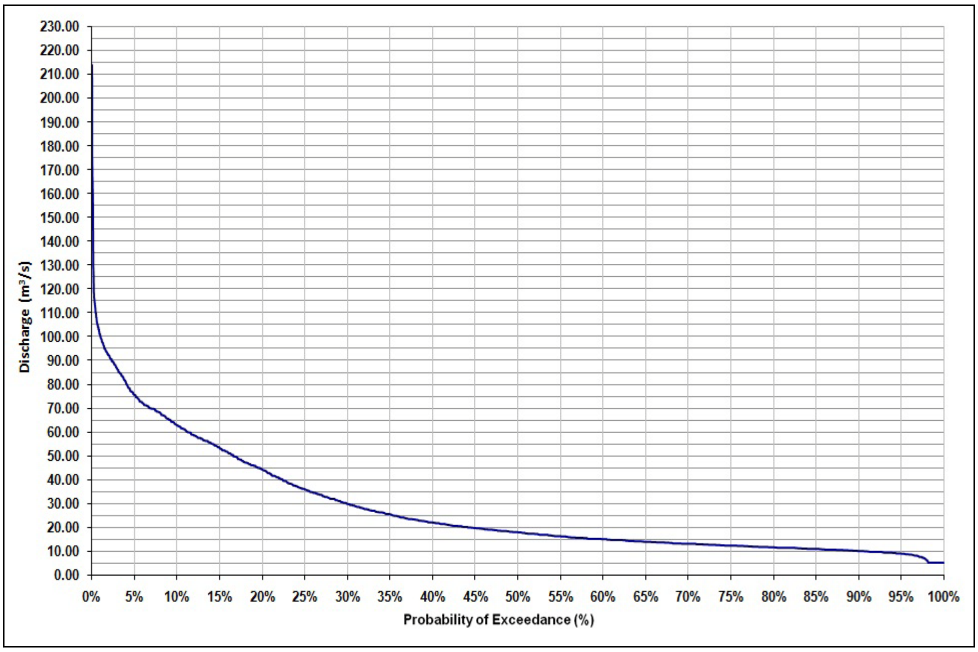

Figure 3.13 Annual Flow Duration Curve of 2218

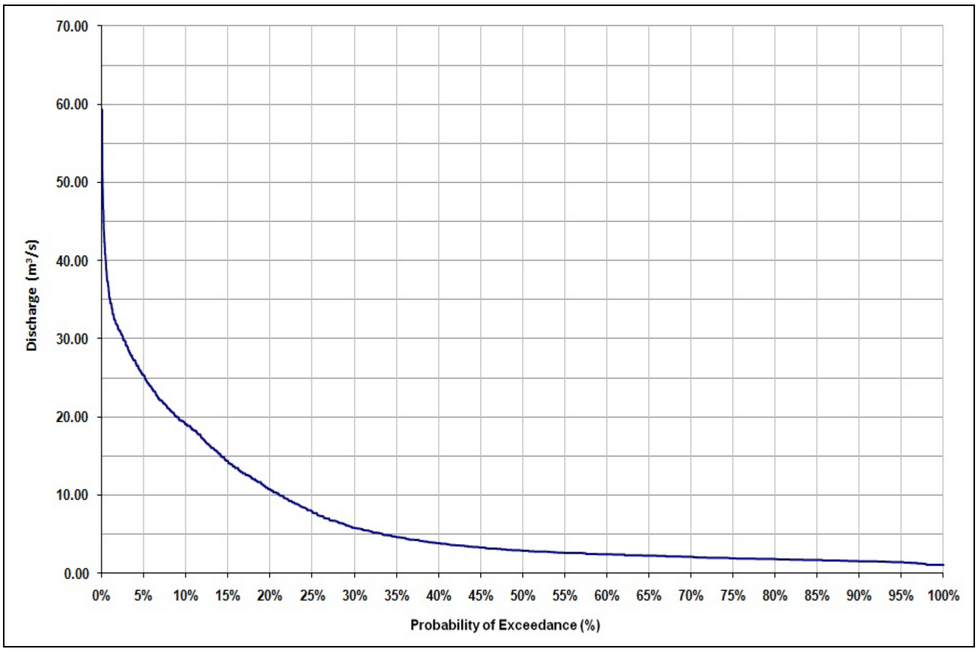

Figure 3.14 Annual Flow Duration Curve of 2233

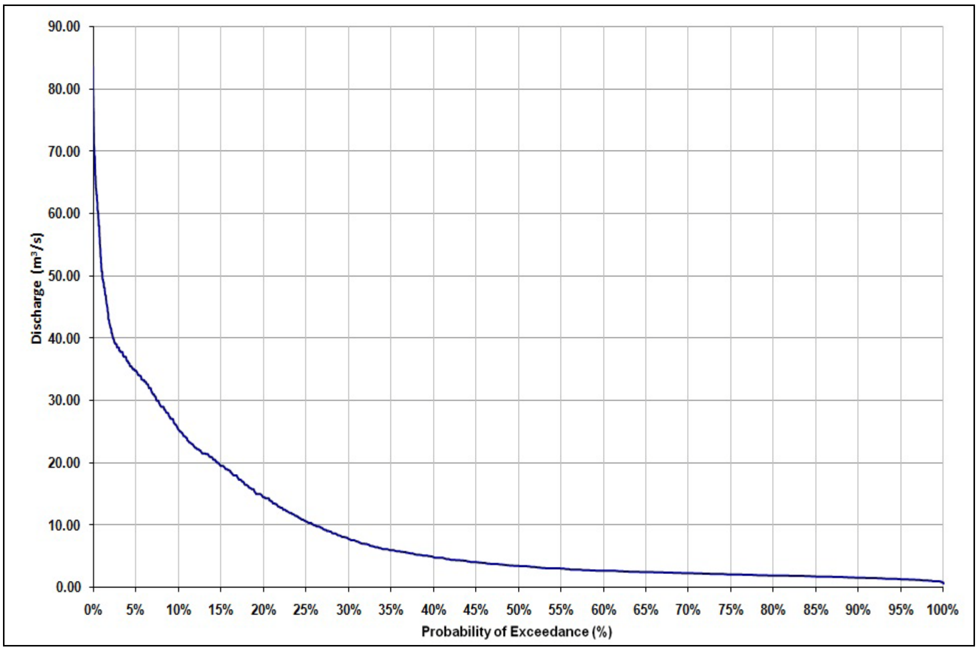

Figure 3.15 Annual Flow Duration Curve of 22-78

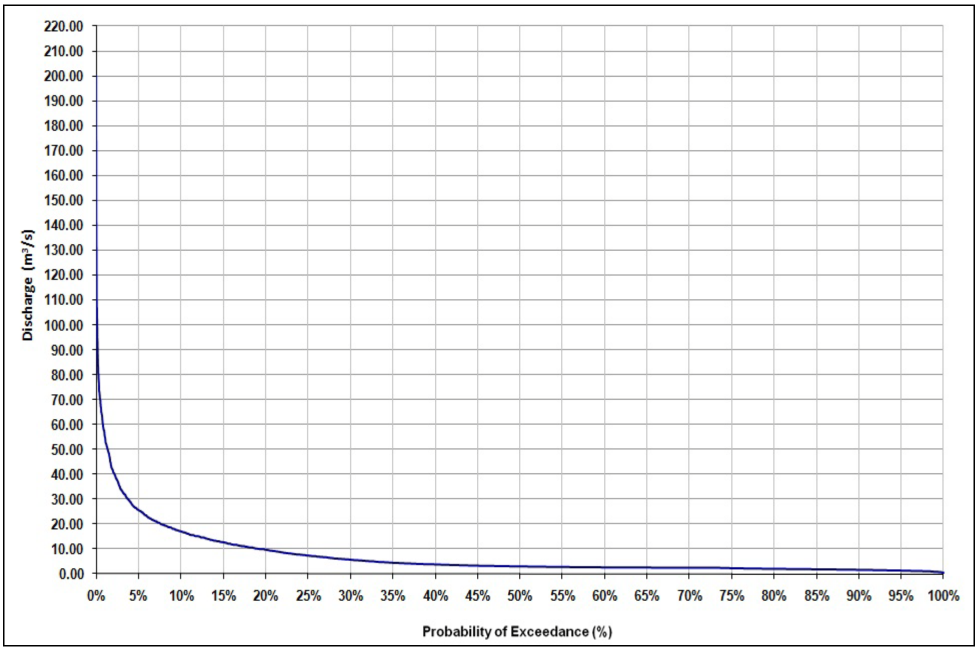

Figure 3.16 Annual Flow Duration Curve of 22-96

3.2.2.2 Estimation of Flow Duration Curves (FDC) of Project Sites

In İyidere Basin, there are only 5 stream flow gauging stations but much more stations are needed to set up a reliable statistical model. To increase the sample number for the model, 6 planned small HEPP projects in İyidere basin have been used.

In the literature, there are several methods to find the annual FDCs for ungauged basins:

Cigizoglu and Bayazit (2000) developed a model to determine a flow duration curve for a process in which stream flow is defined as a product of two variables, representing the periodic and the stochastic components, respectively.

Shao et al. (2009) developed a model which is a four-parameter double power form as a function of the FDC, where the two hydrological parameters represent the mean annual flow (Q) and the cease-to-flow point (τ expressed as a percentage), while the other two parameters (α and β) determine the shape of the FDC.

Post (2004) represented a logarithmic transformation method of defining the flow duration curve which requires just two parameters.

Karaaslan (2011) introduced a statistical model in linear and non linear form using the topographical parameters and hydro-meteorological variables to estimate the project discharge of potential small hydro-power locations for the selected study areas in Eastern Black Sea Region namely Solaklı and Karadere basins. He used 11 planned HEPPs' drainage areas in addition to 6 stream flow gauging stations' drainage areas. While estimating the FDCs of project sites, he divided the FDCs into 8 parts from 5% to 40%. He found 8 different equations for each annual and seasonal period. Those equations can be seen in Table 3.13.

Table 3.13 The Equations Used in Karaaslan (2011) for FDC Estimations of HEPPs in Solaklı and Karadere Basins

	Annual Relationship	Seasonal Relationship
Relationship for 5% of FDC	$y=0.2573x^{0.8038}$; $R^2=0.73$	$y=0.5279x^{0.7337}$; $R^2=0.72$
Relationship for 10% of FDC	$y=-0.1336x^{0.8647}$; $R^2=0.75$	$y=0.2744x^{0.8104}$; $R^2=0.79$
Relationship for 15% of FDC	$y=-0.0769x^{0.9183}$; $R^2=0.76$	$y=0.1748x^{0.8611}$; $R^2=0.83$
Relationship for 20% of FDC	$y=0.0492x^{0.9540}$; $R^2=0.76$	$y=0.1300x^{0.8923}$; $R^2=0.85$
Relationship for 25% of FDC	$y=0.0328x^{0.9828}$; $R^2=0.77$	$y=0.1030x^{0.9136}$; $R^2=0.87$
Relationship for 30% of FDC	$y=0.0216x^{1.0162}$; $R^2=0.78$	$y=0.0790x^{0.9419}$; $R^2=0.89$
Relationship for 35% of FDC	$y=0.0150x^{1.0667}$; $R^2=0.78$	$y=0.0582x^{0.9765}$; $R^2=0.91$
Relationship for 40% of FDC	$y=0.0111x^{1.0675}$; $R^2=0.77$	$y=0.0464x^{0.9972}$; $R^2=0.92$

Here y is discharge value (m^3/s), x is drainage area (km^2).

Gulliver and Arndt (1991) showed that the discharges of a stream flow gauging station could be carried to the ungauged HEPP area by Equation (3.3) depending on the drainage areas of gauging station and the ungauged HEPP area.

$$Q_p = \left(\frac{A_p}{A_{st}} \right)^C Q_{st} \tag{3.3}$$

Here, C is a coefficient between 0.6 and 1.2; A_p is the drainage area of HEPP in km^2; A_{st} is the drainage area of the gauging station in km^2; Q_p is the discharge value of the HEPP area in m^3/s; Q_{st} is the discharge value of the gauging station in m^3/s.

In this study, the FDCs have been divided into 5 parts (%5 to 25%) and each part has beeen modeled separately. For the project sites, to determine the flow values for each percentile; 5 separate relationships have been derived for the model. The reason behind selecting the range from %5 to 25% of the each basin's FDC is that the range of project discharges of energy production purpose facilities.

11 flow gauging stations have been used for the drainage area-flow value relationship: 5 flow gauging stations (2215, 2218, 2233, 22-78, 22-96) from İyidere Basin. 3 flow gauging stations (2202, 22-44 and 2234) from Karadere Basin, 3 flow gauging stations (22-52, 22-57 and 22-07) from Solaklı Basin. Karadere and Solaklı basins are not the study areas, but they are adjacent to İyidere basin.

Discharge values have been matched with the drainage areas for each flow percentile. Then, all combinations between the drainage areas and the discharge values for each percentile have been tried to find a regression equation similar to Equation 3.4. The regression analyses have been done and 5 regression equations have been found. The regression equations can be seen in Table 3.14.

Table 3.14 The Regression Equations btw. Drainage Area and Discharge

	Equations	**R^2**
For 5% of FDC	$Q_p = Q_{st}*1.0614(A_p/A_{st})^{0.7149}$	0.7427
For 10% of FDC	$Q_p = Q_{st}*1.0187(A_p/A_{st})^{0.7498}$	0.7031
For 15% of FDC	$Q_p = Q_{st}*1.0171(A_p/A_{st})^{0.8045}$	0.7149
For 20% of FDC	$Q_p = Q_{st}*1.0271(A_p/A_{st})^{0.8505}$	0.7341
For 25% of FDC	$Q_p = Q_{st}*1.0156(A_p/A_{st})^{0.8879}$	0.7336

A_p is the drainage area of HEPP in km^2; A_{st} is the drainage area of the gauging station in km^2; Q_p is the discharge value of the HEPP area in m^3/s; Q_{st} is the discharge value of the gauging station in m^3/s.

The FDCs according to the equations in Table 3.13 for the projects in Solaklı and Karadere basins and the FDCs according to the equations in Table 3.14 for the projects in İyidere basin are showed in Figure 3.17. Here, “dn” means the projects in İyidere basin; “sk” means the projects in Solaklı and Karadere basins. This figure shows that FDCs in İyidere basin have higher specific discharge values than ones in Solaklı-Karadere basins which supports the region groups of Yanık’s study mentioned in Chp.2. Solaklı and Karadere basins are in Region A, İyidere basin is in Region B according to Yanık’ s study.

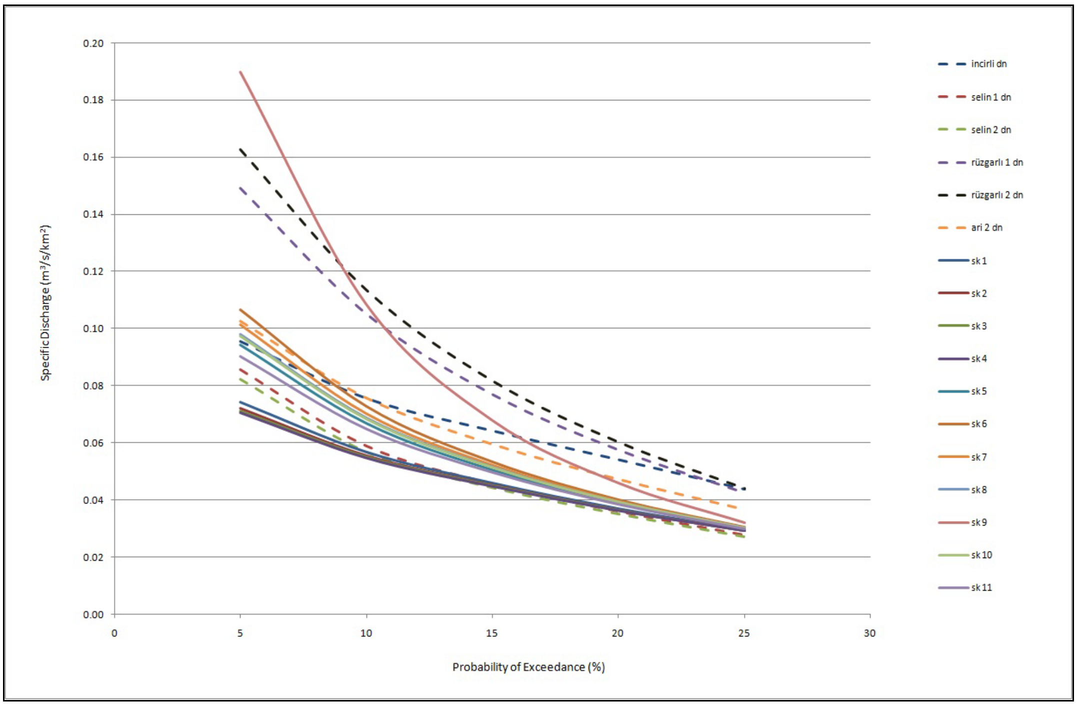

Figure 3.17 The FDCs of the Projects in İyidere and Solaklı-Karadere Basins

The FDCs of 6 planned HEPPs in İyidere basin are given in Figure 3.18-3.23. They are ordered from the biggest drainage area to the smallest drainage area. Here, “hüs denk” means FDCs according to the equations in Table 3.13, “deniz denk” means FDCs according to the equations in Table 3.14 and “area ratio” means FDCs according to the classical area ratio equation which C coefficient in Eq. 3.4 is 1. For İncirli HEPP which has the biggest drainage area, “deniz denk” is above the “area ratio”. For Selin 2, Selin 1 and Arı 2 “deniz denk” is under the “area ratio”. For Rüzgarlı 1 and Rüzgarlı 2 which has the smallest drainage area, “deniz denk” is above the “area ratio”. So it is concluded that the equations in Table 3.14 can be useful for the FDCs when the drainage area is between 50 and 850 km^2.

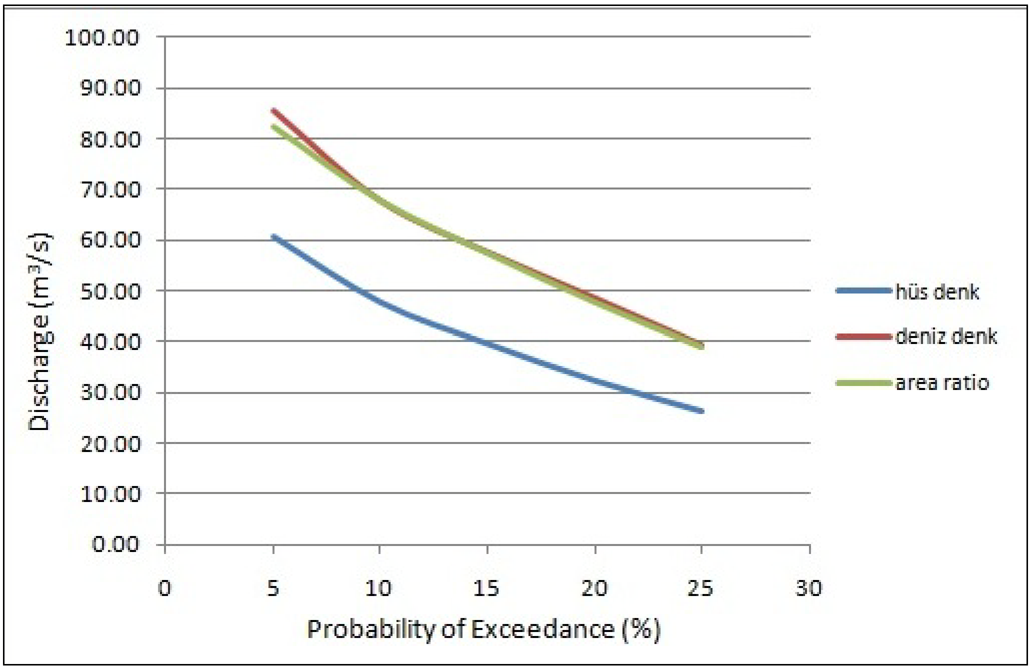

Figure 3.18 The FDC of İncirli HEPP

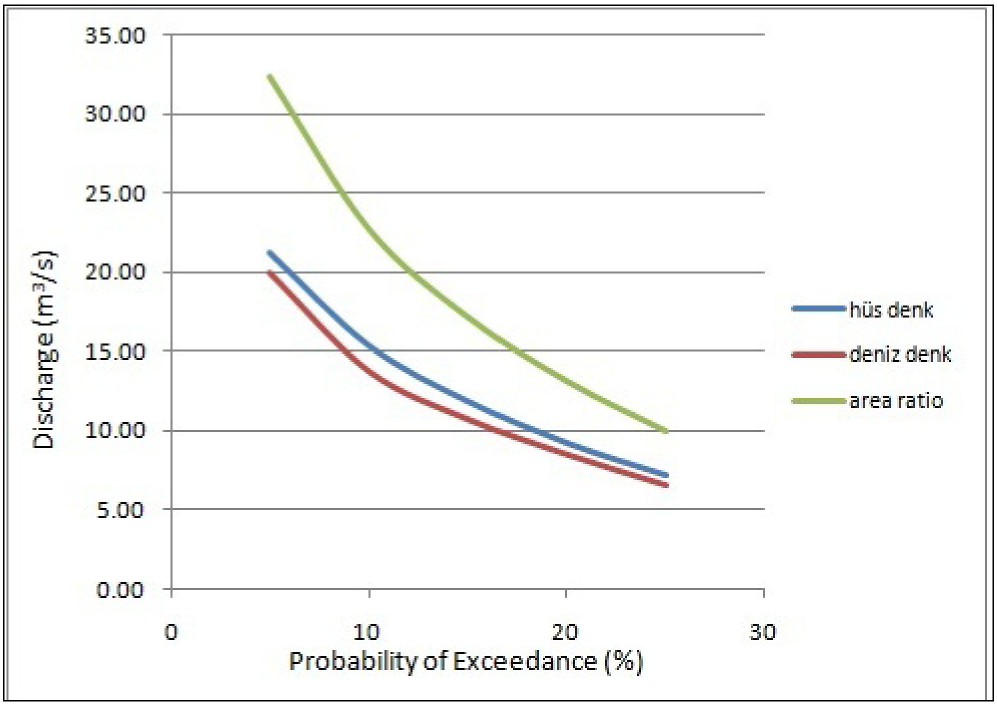

Figure 3.19 The FDC of Selin 2 HEPP

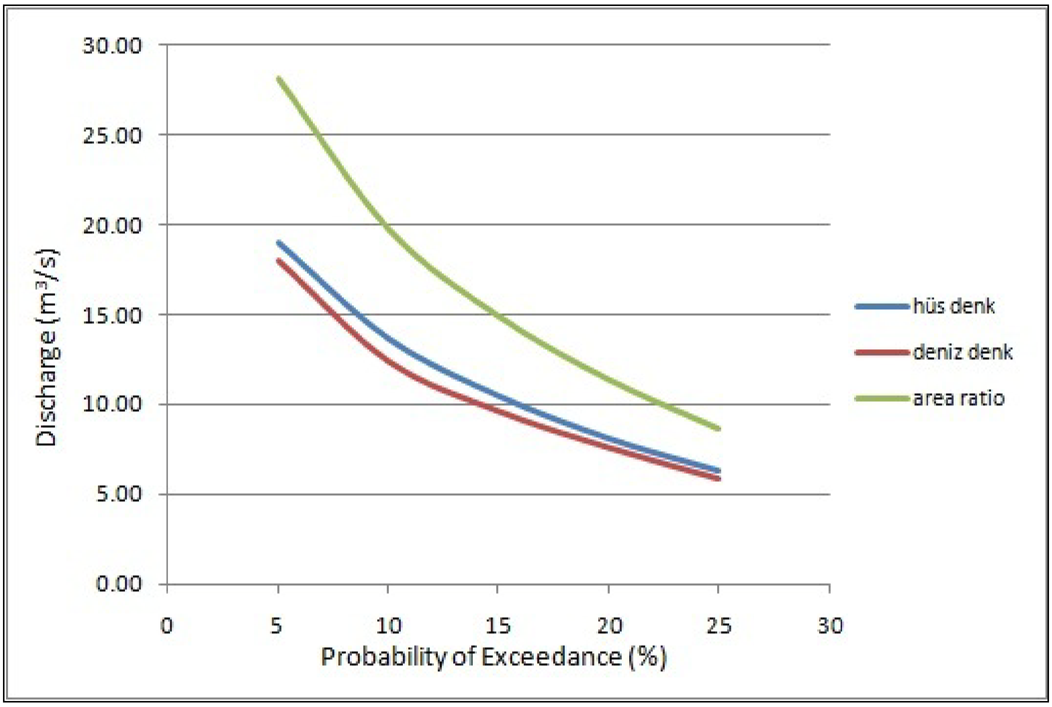

Figure 3.20 The FDC of Selin 1 HEPP

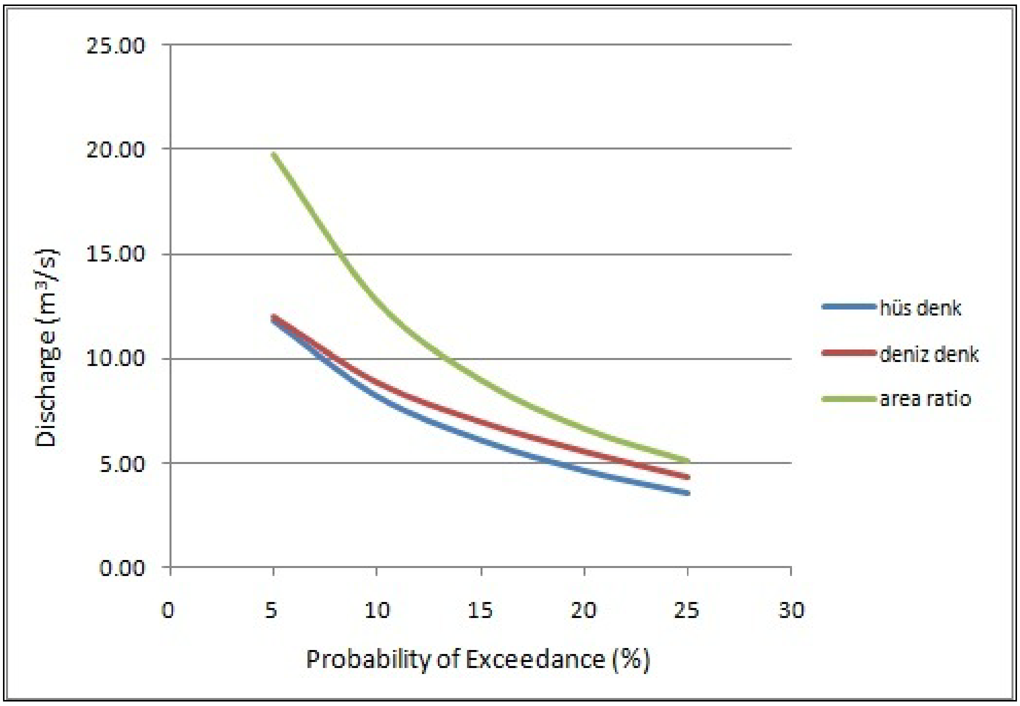

Figure 3.21 The FDC of Arı 2 HEPP

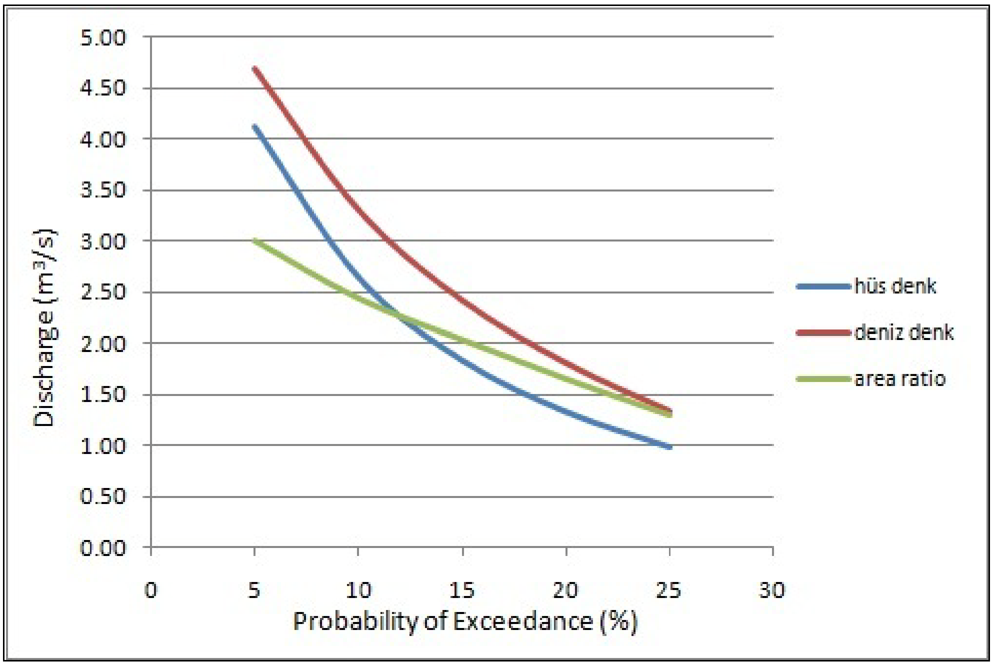

Figure 3.22 The FDC of Rüzgarlı 1 HEPP

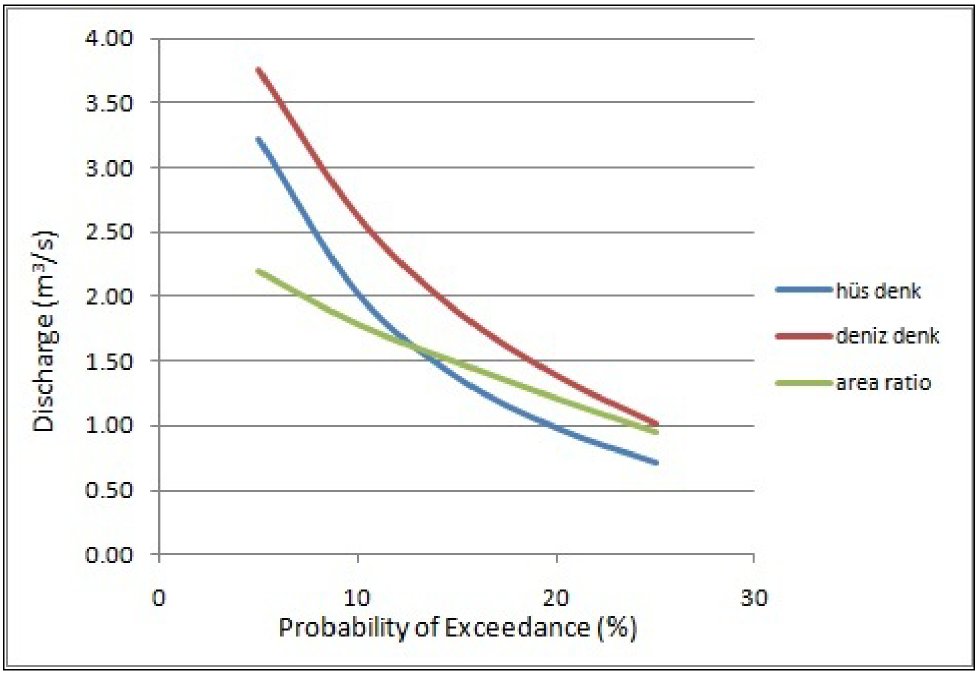

Figure 3.23 The FDC of Rüzgarlı 2 HEPP

3.3 Soil and Land Cover Data

In this study, soil data layers are gathered from 1/25000 Scaled National Soil Database of General Directorate of Rural Services. In those layers; soil groups, soil depths, the other soil characteristics, erosion degrees and slope values are available. On the other hand, landcover data layers are gathered from the results of Coordination of Information on the Environment (CORINE) Land Cover 2006 study. In those layers; polygons for 5 land cover groups (1.Artificial Surfaces, 2.Agricultural Areas, 3.Forest and Semi-Natural Areas, 4.Wetlands, 5.Water Bodies) are available.

First of all, dominant land cover groups for each subbasin have been decided. Dominant land cover groups and their areal percentages can be seen in Table 3.15. The map of dominant land cover groups for subbasin 22-96 is given in Figure 3.24. For each subbasin, soil data and land cover data layers have been overlayed by ArcGIS and the areal percentages of the dominant soil groups for each land cover group have been calculated. In Table 3.16, the areal percentages of the dominant soil groups are given. The map of dominant land soil groups for subbasin 22-96 is given in Figure 3.25. Legend for the soil and land cover groups can be seen in Appendix A.

After calculating the dominant soil group area ratios, hydrologic soil groups and hydrologic classes have been decided by the help of Soil, Fertilizer and Water Resources Research Institute. Hydrologic soil groups and hydrologic classes are given in Table 3.17. The characteristics of hydrologic soil groups can be seen in Table 3.18. Areas for each land use-hydrologic soil group polygon have been determined and a curve number which is an index developed by the Soil Conservation Service (SCS) to represent the potential for storm water runoff within a drainage area, has been assigned to each polygon based on the curve number table which has been published by General Directorate of Rural Services. Finally the curve number for each subbasin has been calculated by area-weighting the land use-hydrologic soil group polygons. The basic equation for curve number calculation is as follows:

$$CN_{aw} = \frac{\sum_{i=1}^{n}(CN_i * A_i)}{\sum_{i=1}^{n} A_i} \quad (3.4)$$

Here, CN_{aw} is the area-weighted curve number for the subbasin, CN_i is the curve number for each land use-hydrologic soil group polygon, A_i is the area for each land use-hydrologic soil group polygon, n is the number of land use-hydrologic soil polygons in each subbasin. Unique and total curve number values for all of the subbasins can be seen in Table 3.19. The map of unique curve numbers for the subbasin 22-96 is given in Figure 3.26.

Table 3.15 Dominant Land Cover Groups and Their Areal Percentages, %

	Dominant Land Cover Groups					
Subbasins	**333**	**321**	**324**	**311**	**313**	**243**
2218	46.32	23.17	7.44	7.43	-	-
2215	58.38	21.57	8.32	-	-	-
22-78	62.06	18.04	-	-	-	-
2233	62.31	17.09	-	-	-	-
22-96	42.05	48.20	-	-	-	-
İncirli	41.02	20.52	-	9.02	-	9.46
Selin 1	35.49	40.35	-	-	13.10	-
Selin 2	32.99	37.68	-	-	14.70	-
Rüzgarlı 1	-	14.20	10.35	14.10	51.62	-
Rüzgarlı 2	-	14.24	10.34	14.00	51.58	-
Arı 2	44.74	51.29	-	-	-	-

In Table 3.15, 333 means “Forest and semi-natural areas,Open spaces with little or no vegetation, Sparsely vegetated”. 321 means “Forest and semi-natural areas, Scrub/herbaceous vegetation”. 324 means “Forest and semi-natural areas,Open spaces with little or no vegetation, Burnt areas”. 311 means “Forest and semi-natural areas, Forests, Broad-leaved”. 313 means “Forest and semi-natural areas, Forests, Mixed”. 243 means “Agricultural areas, Heterogeneous agricultural areas”.

Table 3.16 Dominant Soil Groups and Their Areal Percentages for Each of the Land Cover Group, %

Dominant Land Cover and Soil Group Area Ratios for the Basins of Streamflow Gauging Stations and Planned Projects (%)

CORINE 2006 Dominant Landcover Groups: 333

	2215			2218			2233			2278			2296			arı2			inc			ruz1	ruz2	sel1			sel2		
		Y	66.32		Y	52.39		Y	32.17		Y	55.78		Y	49.5		Y	31.79		Y	29.85				Y	82.13		Y	92.55
		P	17.77		P	0.57		P	0.56		P	7.69		P	0		P	0		P	0				P	0		P	0
333	58.38	K	0	46.32	K	0	62.31	K	0	62.06	K	0	42.05	K	0	44.74	K	0	41.02	K	0			35.49	K	0	32.99	K	0
		A	0.78		A	0.8		A	0.82		A	10.41		A	0		A	0		A	0				A	0		A	0
		G	0		G	0		G	0		G	0		G	0		G	0		G	0				G	0		G	0
		Ç	15.13		Ç	46.24		Ç	66.45		Ç	26.12		Ç	50.5		Ç	68.21		Ç	70.15				Ç	17.87		Ç	7.45

CORINE 2006 Dominant Landcover Groups: 321

	2215			2218			2233			2278			2296			arı2			inc			ruz1			ruz2			sel1			sel2		
		Y	74.23		Y	80.15		Y	87.49		Y	94.37		Y	80.62		Y	86.38		Y	65.89		Y	100		Y	100		Y	95.08		Y	87.60
		P	0.26		P	0.67		P	0.14		P	0.81		P	0		P	0		P	0		P	0		P	0		P	0.73		P	1.47
321	21.57	K	0	23.17	K	0	17.90	K	0	18.04	K		48.20	K	0	51.29	K	0	20.52	K	0	14.24	K	0	14.24	K	0	40.35	K	0	37.68	K	2.97
		A	0.97		A	0		A	0.36		A	0.86		A	0		A	0		A	0.25		A	0		A	0		A	0		A	0
		G	0		G	0		G	0		G			G	0		G	0		G	0		G	0		G	0		G	0		G	0
		Ç	24.54		Ç	19.18		Ç	12.01		Ç	3.96		Ç	19.38		Ç	13.62		Ç	33.86		Ç	0		Ç	0		Ç	4.19		Ç	7.95

CORINE 2006 Dominant Landcover Groups: 324

	2215			2218			ruz1			ruz2		
		Y	49.65		Y	58.54		Y	100		Y	100
		P	28.63		P	24.36		P	0		P	0
324	8.32	K	0	7.44	K	0	10.34	K	0	10.34	K	0
		A	0.37		A	0.36		A	0		A	0
		G	0		G	0		G	0		G	0
		Ç	21.35		Ç	16.74		Ç	0		Ç	0

CORINE 2006 Dominant Landcover Groups: 311

	2218			inc			ruz1			ruz2		
		Y	4.44		Y	0.48		Y	49.58		Y	62.05
		P	93.44		P	98.88		P	50.42		P	37.95
311	7.43	K	0	9.02	K	0	14.00	K	0	14.00	K	0
		A	0		A	0		A	0		A	0
		G	0		G	0		G	0		G	0
		Ç	2.12		Ç	0.64		Ç	0		Ç	0

CORINE 2006 Dominant Landcover Groups: 313

	ruz1			ruz2			sel1			sel2		
		Y	5.68		Y	5.59		Y	0		Y	0
		P	94.32		P	94.41		P	100		P	100
313	51.58	K	0	51.58	K	0	13.10	K	0	14.70	K	0
		A	0		A	0		A	0		A	0
		G	0		G	0		G	0		G	0
		Ç	0		Ç	0		Ç	0		Ç	0

CORINE 2006 Dominant Landcover Groups: 243

	inc		
		Y	0.8
		P	99
243	9.46	K	0.2
		A	0
		G	0
		Ç	0

Table 3.17 Hydrologic Soil Groups and Classes

Main Soil Groups	Hydrologic Classification	Hydrologic Soil Groups
Y	Poor	C
P	Poor-Very Poor	C-D
Ç	Very Poor	D

Table 3.18 Definition of Hydrologic Soil Groups

Hydrologic Soil Groups	Soil Group Characteristics
A	Soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well to excessively-drained sands or gravels. These soils have a high rate of water transmission.
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
D	Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Table 3.19 Unique and Total Curve Numbers for the Subbasins

	Unique Curve Numbers																		Area-Weighted Total Curve Numbers
	333			321			324			311			313			243			
Subbasins	Y	P	Ç	Y	P	Ç	Y	P	Ç	Y	P	Ç	Y	P	Ç	Y	P	Ç	
2218	82.00	86.00	91.00	78.00	82.00	86.00	80.00	84.00	88.00	77.00	81.00	85.00	-	-	-	-	-	-	69.96
2215	82.00	86.00	91.00	78.00	82.00	86.00	80.00	84.00	88.00	-	-	-	-	-	-	-	-	-	71.65
22-78	82.00	86.00	91.00	78.00	82.00	86.00	-	-	-	-	-	-	-	-	-	-	-	-	60.01
2233	82.00	86.00	91.00	78.00	82.00	86.00	-	-	-	-	-	-	-	-	-	-	-	-	67.80
22-96	82.00	86.00	91.00	78.00	82.00	86.00	-	-	-	-	-	-	-	-	-	-	-	-	74.37
İncirli	82.00	86.00	91.00	78.00	82.00	86.00	-	-	-	77.00	81.00	85.00	-	-	-	76.00	80.00	84.00	68.84
Selin 1	82.00	86.00	91.00	78.00	82.00	86.00	-	-	-	-	-	-	76.00	80.00	84.00	-	-	-	71.76
Selin 2	82.00	86.00	91.00	78.00	82.00	86.00	-	-	-	-	-	-	76.00	80.00	84.00	-	-	-	67.94
Rüzgarlı 1	-	-	-	78.00	82.00	86.00	80.00	84.00	88.00	77.00	81.00	85.00	76.00	80.00	84.00	-	-	-	75.89
Rüzgarlı 2	-	-	-	78.00	82.00	86.00	80.00	84.00	88.00	77.00	81.00	85.00	76.00	80.00	84.00	-	-	-	75.73
Arı 2	82.00	86.00	91.00	78.00	82.00	86.00	-	-	-	-	-	-	-	-	-	-	-	-	79.78

Here, Y means “High-level mountain meadow soils”, P means “Red yellow podzolic soils” and Ç means “Bare rocks”.

As a result, it can be seen that dominant main soil groups are Y-High-level mountain meadow soils, P-Red yellow podzolic soils and Ç-Bare rocks. Hydrologic groups of those soils support that high inflow values are understandable in the study area.

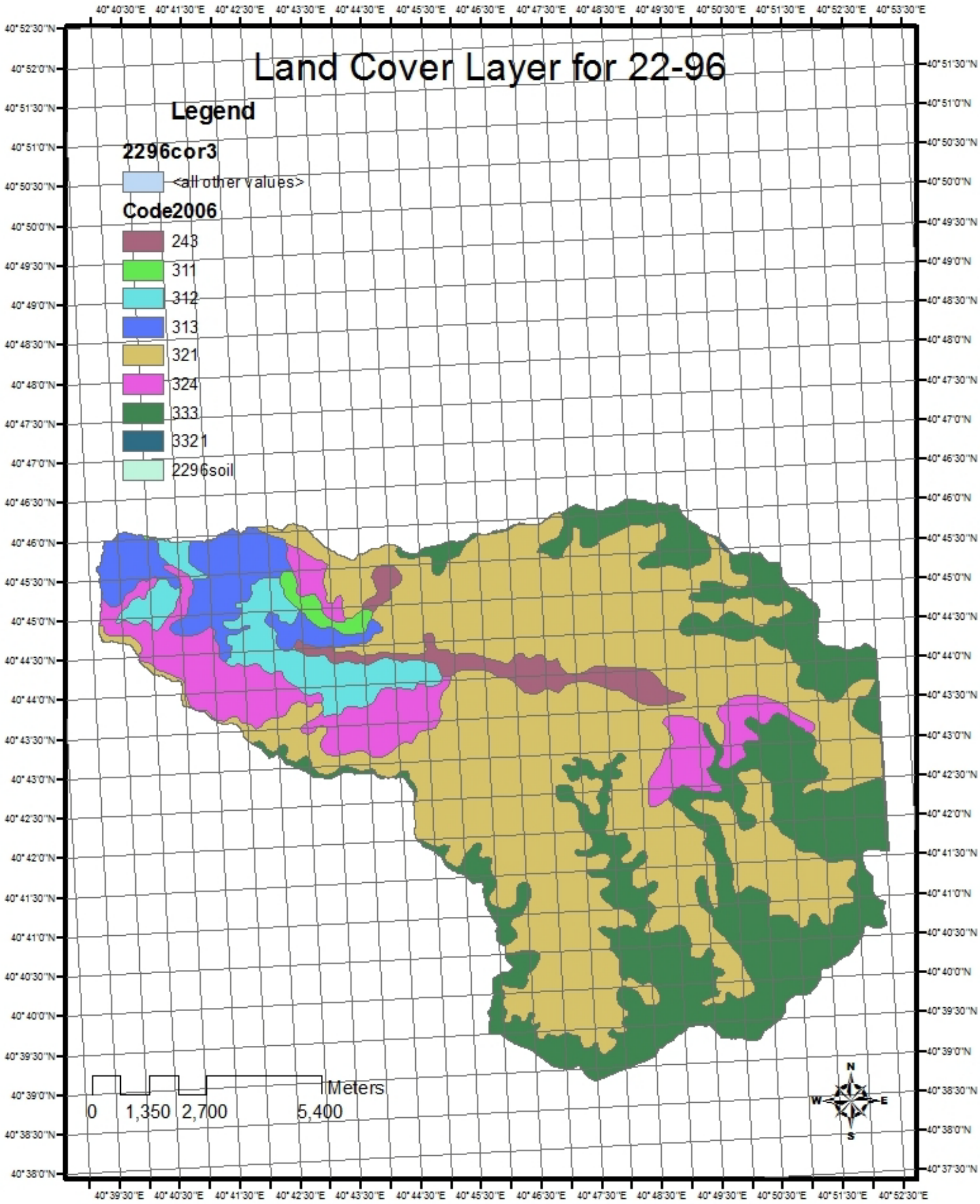

Figure 3.24 Land Cover Group Layer for Subbasin 22-96

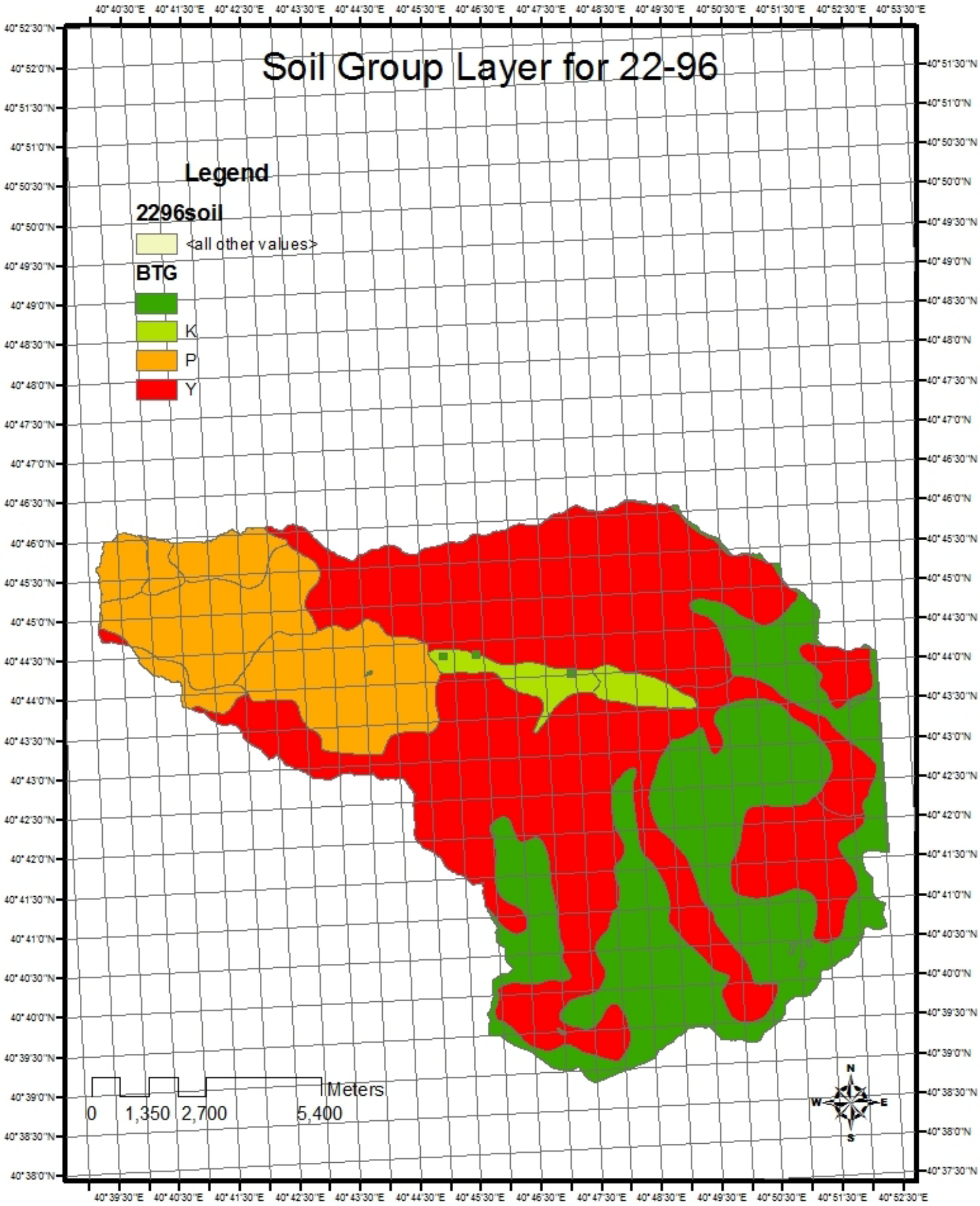

Figure 3.25 Soil Group Layer for Subbasin 22-96

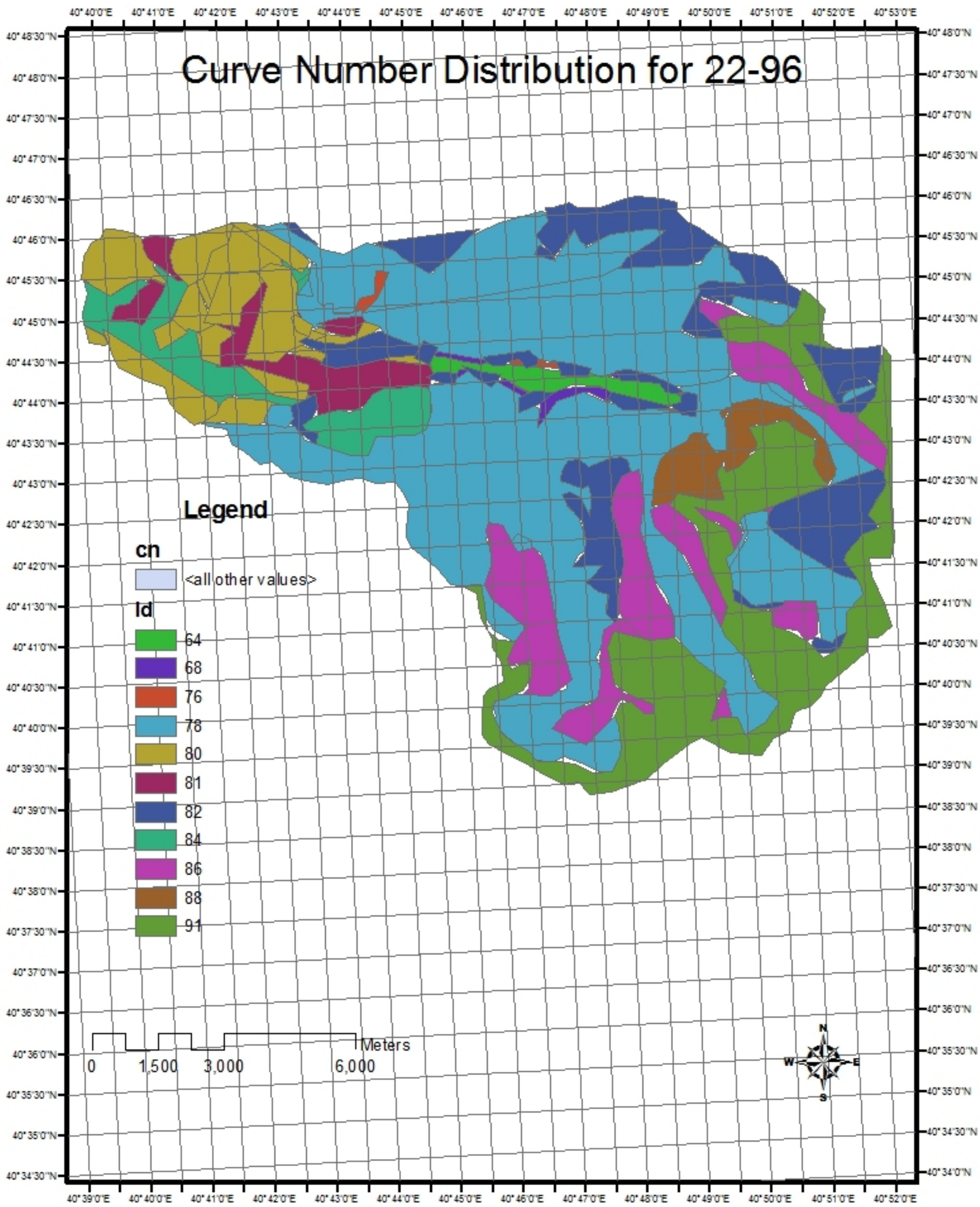

Figure 3.26 Unique Curve Numbers for Subbasin 22-96

CHAPTER 4

MODEL DEVELOPMENT

In this chapter, models have been developed to estimate specific FDCs for 5 flow percentiles (5%, 10%, 15%, 20%, 25%) in İyidere basin. 5 flow gauging stations and 5 HEPP facilities have been used as samples. Some of the parameters from linear, shape, morphological, slope, meteorological, soil-land cover categories have been used as independent variables. As dependent hydrologic variable, specific runoff ($m^3/s/km^2$) has been used. 2218 flow gauging station has been selected for the validation.

4.1 Categories of Parameters

Parameters for both the flow gauging stations' basins and the HEPP facilities' drainage areas have been grouped in 6 categories which are linear, shape, morphological, slope, aspect, meteorological and soil-land cover parameters.

The perimeter of the basin (P); in km is linear, the ratio of the perimeter of the basin to the main stream length of the same basin (P/L); dimensionless is shape, the drainage frequency (Df); km^{-2} is morphological parameter.

While computing the drainage frequency for the study area, it has been realized that the drainage frequency changes by "stream definition threshold" in ArcHydro. In Table 4.1, the results for different thresholds can be seen.

Table 4.1 Drainage Frequency Values for Different Thresholds

		Drainage Frequency (km^{-2})		
		threshold = 1	**threshold = 0.75**	**threshold = 0.50**
Gauging Stations	**2218**	1.00	0.78	0.54
	2215	0.99	0.77	0.55
	22-78	1.04	0.79	0.55
	2233	1.06	0.81	0.52
	22-96	0.97	0.69	0.42
Projects	**İncirli**	1.00	0.76	0.53
	Selin 1	1.00	0.75	0.47
	Selin 2	1.02	0.76	0.48
	Rüzgarlı 1	1.05	0.79	0.54
	Rüzgarlı 2	0.91	0.74	0.56
	Arı 2	0.92	0.72	0.37

As slope/aspect parameter, the mean slope and the aspect of basin have been used. The basin slope in percentage and the basin aspect in degrees have been calculated for all of the basins using ArcGIS. While computing the basin aspect for the study area, it has been realized that the aspects for all subbasins are nearly the same. Because of those small differences, basin aspect has not been used as a model parameter. The percentages for 4 directions can be seen in Table 4.2. In addition, raster maps which show the aspect of all subbasins are in Figure 4.1.

Table 4.2 Percentages corresponding to 4 Directions for the Subbasins

	Percentages corresponding to 4 Directions (%)			
Subbasins	**North (315°-45°)**	**East (45°-135°)**	**South (135°-225°)**	**West (225°-315°)**
2218	17.75	14.83	**38.04**	29.38
2215	24.37	21.63	**29.10**	24.90
22-78	21.23	22.52	**35.09**	21.16
2233	28.08	24.70	**28.31**	18.90
22-96	29.14	17.11	**29.57**	24.18
İncirli	26.39	20.29	**26.98**	26.33
Selin 1	22.02	11.83	**35.62**	30.53
Selin 2	22.23	11.24	**35.80**	30.73
Rüzgarlı 1	34.83	**37.68**	6.21	21.28
Rüzgarlı 2	34.89	**40.92**	6.97	17.23
Arı 2	25.98	20.32	23.32	**30.38**

As hydro-meteorological parameter, the mean annual precipitation in mm has been used. It has been calculated as stated in Chapter 3.

As soil-land cover parameter, curve number (CN) which is dimensionless, is used. After it has been calculated for the main soil groups as stated in Chapter 3, for each subbasin weighted average of the CN according to the main soil group area percentages have been calculated.

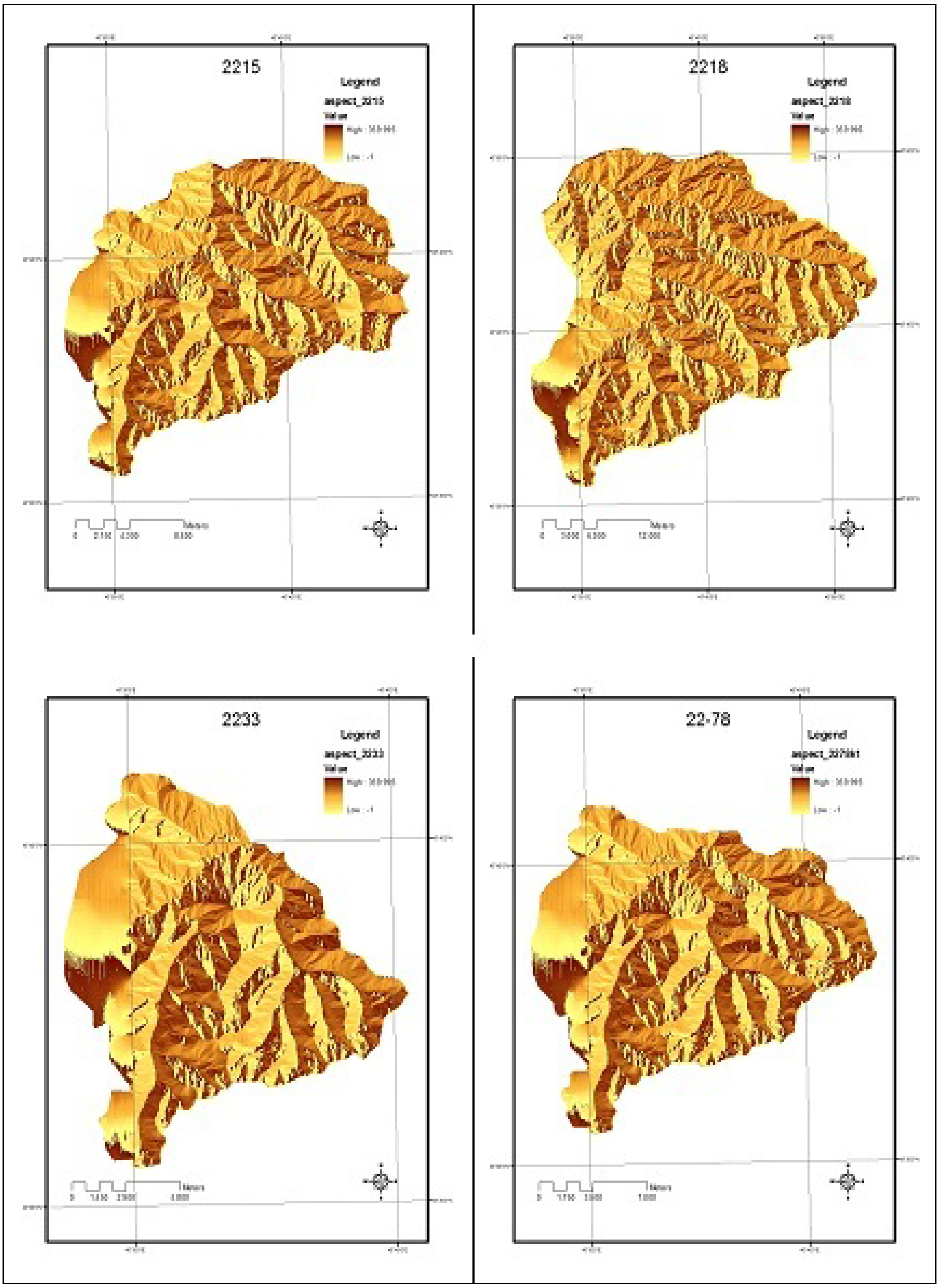

Figure 4.1 Raster Maps for the Subbasin Aspects

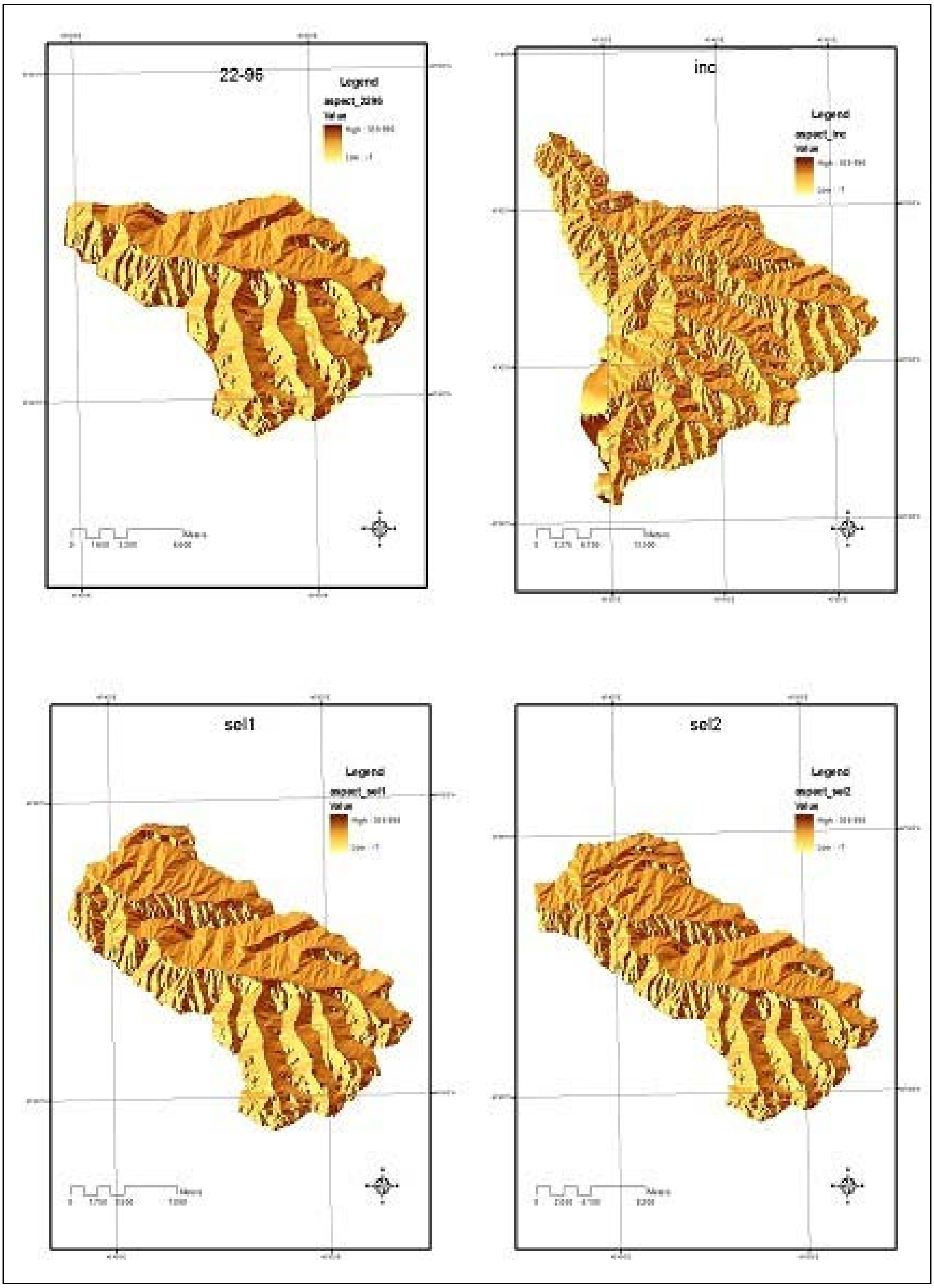

Figure 4.1 (Continued)

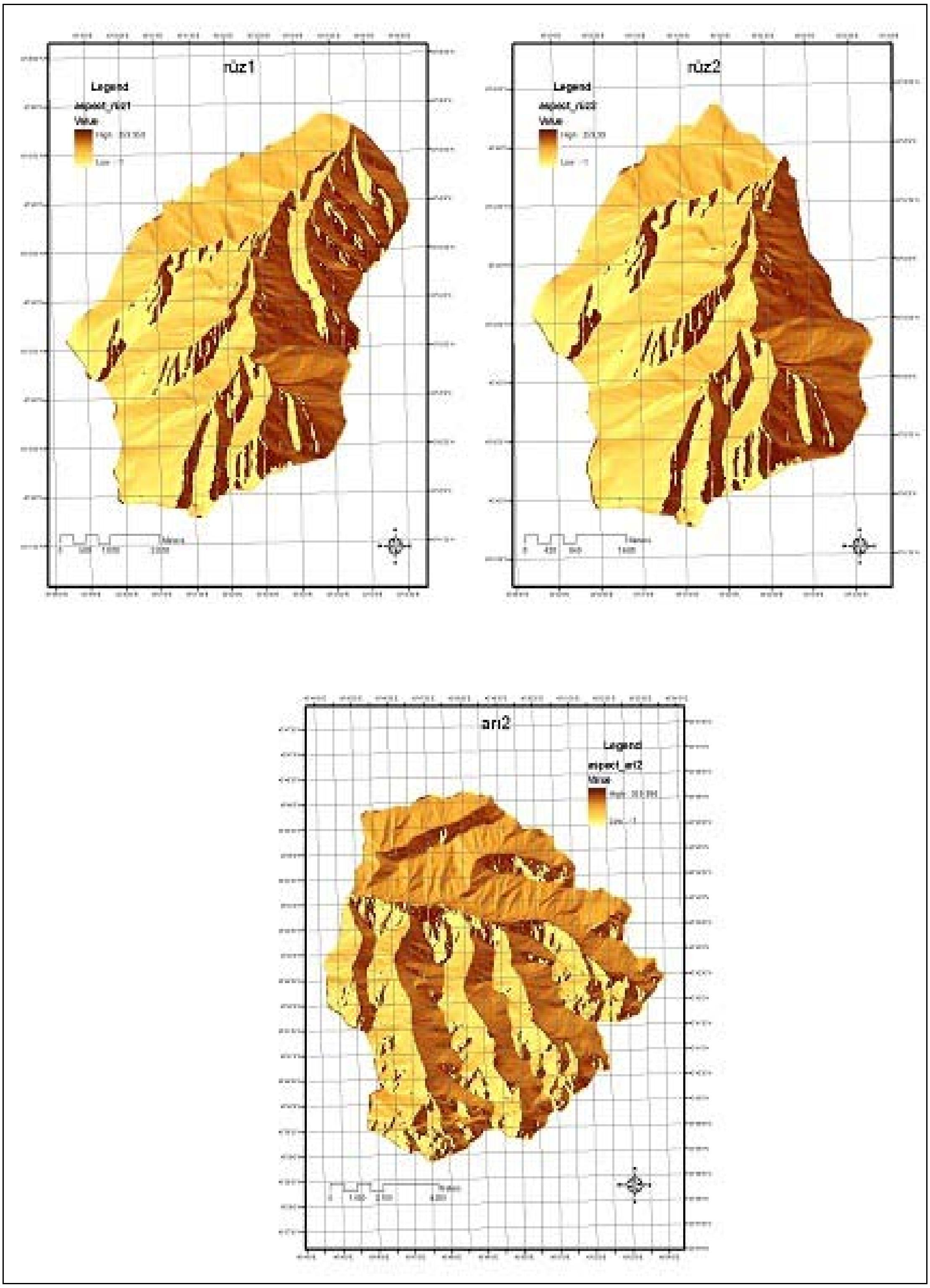

Figure 4.1 (Continued)

The independent model parameters for each basin are given in Table 4.3 and the dependent model parameters for each basin can be seen in Table 4.4.

Table 4.3 Model Parameters

		Categories of Parameters					
		Linear	Shape	Morphological	Slope	Hydro-Meteorological	Soil-Land Cover
		Basin Perimeter (km)	Perimeter/Main Stream Length	Drainage Frequency (km^{-2})	Mean Slope of Basin (%)	Mean Annual Precipitation (mm)	CN
Gauging Stations	2218	184.78	3.36	0.54	49.03	1785.30	69.96
	2215	126.92	3.43	0.55	47.40	1848.33	71.65
	22-78	100.76	3.32	0.55	44.57	1876.34	60.01
	2233	90.02	3.38	0.52	43.61	1871.17	67.80
	22-96	80.36	3.20	0.42	48.96	2074.05	74.37
Projects	İncirli	215.96	3.07	0.53	50.74	1760.52	68.84
	Selin 1	93.6	2.98	0.47	50.22	1970.62	71.76
	Selin 2	106.16	2.88	0.48	50.57	1912.44	67.94
	Rüzgarlı 1	31.4	3.03	0.54	54.31	1290.76	75.89
	Rüzgarlı 2	26.36	3.43	0.56	51.16	1415.74	75.73
	Arı 2	61.42	3.91	0.37	48.09	2176.95	79.78

Table 4.4 Specific Discharge Values btw. 5%-25% Flow Percentiles

	Specific Discharge Values ($m^3/s/km^2$)				
Subbasins	**5%**	**10%**	**15%**	**20%**	**25%**
2218	0.094	0.077	0.066	0.055	0.045
2215	0.107	0.086	0.071	0.056	0.042
22-78	0.084	0.051	0.042	0.036	0.031
2233	0.119	0.092	0.071	0.054	0.039
22-96	0.171	0.110	0.078	0.058	0.044
İncirli	0.095	0.076	0.064	0.054	0.044
Selin 1	0.086	0.059	0.046	0.036	0.028
Selin 2	0.082	0.057	0.044	0.035	0.027
Rüzgarlı 1	0.149	0.105	0.077	0.058	0.043
Rüzgarlı 2	0.163	0.114	0.082	0.060	0.044
Arı 2	0.103	0.076	0.060	0.047	0.037

4.2 Model Development

4.2.1 Principal Component Analysis

The central idea of principal component analysis (PCA) is to reduce the dimensionality of a data set consisting of a large number of interrelated variables, while retaining as much as possible of the variation present in the data set. This is achieved by transforming to a new set of variables, the principal components (PCs), which are uncorrelated, and which are ordered so that the first few retain most of the variation present in all of the original variables (Jolliffe, 2002).

PCA has been run for the 5 data sets and specific flow values as criterion variable are different in every data set. The output for 10% data set is given in Appendix-B. PCA results for each data set have been reviewed and the parameters have been selected for multiple regression analysis. The selected parameters can be seen in Table 4.5.

Table 4.5 The Selected Parameters after PCA

	Parameters					
	Basin Perimeter (km)	**Perimeter/Main Stream Length**	**Drainage Frequency (km^{-2})**	**Mean Slope of Basin (%)**	**Mean Annual Precipitation (mm)**	**CN**
Model 5%	√		√		√	
Model 10%	√		√		√	
Model 15%			√		√	√
Model 20%			√		√	√
Model 25%			√		√	√

For all of the models, 3 eigenvalues have been greater than 1 and the first three vectors of communalities have values below 0.6 which suggests that 3 principal components have been needed. From the eigen-vector matrix, the variables that correspond to the row with large absolute values in any column have been associated with that eigenvector. The correlation matrix has been also used in similar eigen values.

4.2.2 Multiple Regression Analysis

"The objective of multiple regression analysis is to develop a prediction equation relating a criterion variable to p predictor variables. It is an alternative to stepwise regression method. Stepwise regression method differs from it with the partial F test" (McCuen, 1993).

In this study, each model's parameters selected after PCA have been used to run Multiple Regression Analysis. For the 5% and 10% models; basin perimeter, drainage frequency and mean annual precipitation have been used as the predictor variables. For the 15%, 20% and 25% models; drainage frequency, mean annual precipitation and curve number have been used as the predictor variables. The output for 10% model is given in Appendix-C. The summary table of multiple regression analysis is given in Table 4.6.

Table 4.6 Summary Table of Multiple Regression Analysis

	Coefficients						t						Intercept	Multiple	S_e/S_y
	Perimeter	P/L	D_f	Mean Slope	Precipitation	CN	Perimeter	P/L	D_f	Mean Slope	Precipitation	CN	Coefficient	R^2	
5%	-0.00020		-0.19037		-0.00007		-0.36429		-0.35917		-0.58387		0.36263	0.45186	0.88491
10%	-0.00007		-0.13636		-0.00006		-0.18034		-0.38670		-0.70965		0.26443	0.37433	0.94542
15%			0.18178		0.00001	0.00259			0.78451		0.19427	0.96708	-0.23128	0.60272	0.75335
20%			0.15151		0.00001	0.00180			0.95364		0.32946	0.97972	-0.17671	0.56175	0.79124
25%			0.10330		0.00001	0.00113			0.92618		0.35243	0.87708	-0.11069	0.43682	0.89696

In Table 4.6, the signs of mean annual precipitation are negative for the 5% and 10% models while for the 15%, 20% and 25% models they are positive. This is not rational because when the mean annual precipitation increases, the discharge value must increase, too. To solve that problem, the correlation between the precipitation and the specific discharge has been analysed. It has been realized that the relationship between the mean annual precipitation and the specific discharge for Rüzgarlı 1 and Rüzgarlı 2 subbasins is not meaningful. Their precipitation values are low but discharge values are high while for the other subbasins it is reverse. The correlation analysis after Rüzgarlı 1 and Rüzgarlı 2 subbasins have been removed is given in Figure 4.2.

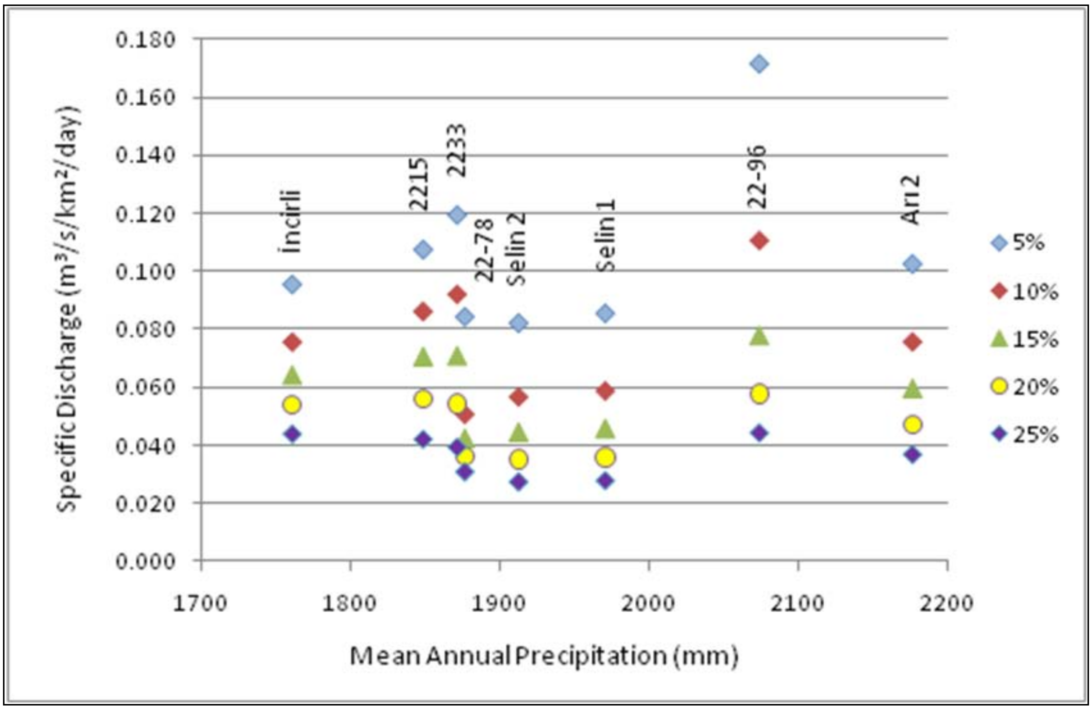

Figure 4.2 The Correlation between the Precipitation and the Specific Discharge

As it can be seen in the Figure 4.2, there are 2 different trend groups in the data sets between 5%-20% models. The subbasins of İncirli, 2215, 2233 and 22-96 are the first group which has a rapid increasement in specific discharge values by the precipitation increase. Second group is the subbasins of 22-78, Selin 2, Selin 1 and Arı 2. Their specific discharge values change much more slightly than the first group's. For the first group, the drainage area changes from 150 km^2 to 900 km^2 and for the second group it changes from 100 km^2 to 300 km^2. To combine those 2 trend groups, trend analysis studies have been done and the correction factors corresponding to the FDCs of Selin 2, Selin 1 and Arı 2 subbasins have been found. In the first trend analysis, the slopes of the 2 groups have been equated. In Table 4.7, the correction factors found by the first trend analysis and the new specific discharge values of Selin 2, Selin 1 and Arı 2 subbasins can be seen. The new correlation between the mean annual precipitation and the specific discharge is given in Figure 4.3. In the second trend analysis, all discharge values have been tried to be put in the same line. In Table 4.8, the correction factors found by the second trend analysis and the new specific discharge values of Selin 2, Selin 1 and Arı 2 subbasins can be seen. The new correlation between the mean annual precipitation and the specific discharge is given in Figure 4.4.

Table 4.7 The Correction Factors and the Corrected Discharge Values After the First Trend Analysis

		Corrected Specific Discharges ($m^3/s/km^2$)		
Data Set	**Correction Factor**	**Selin 1**	**Selin 2**	**Arı 2**
5%	3.75	0.3208	0.3083	0.3845
10%	1.43	0.0840	0.0812	0.1081
15%	0.67	0.0304	0.0296	0.0397
20%	0.25	0.0090	0.0088	0.0118

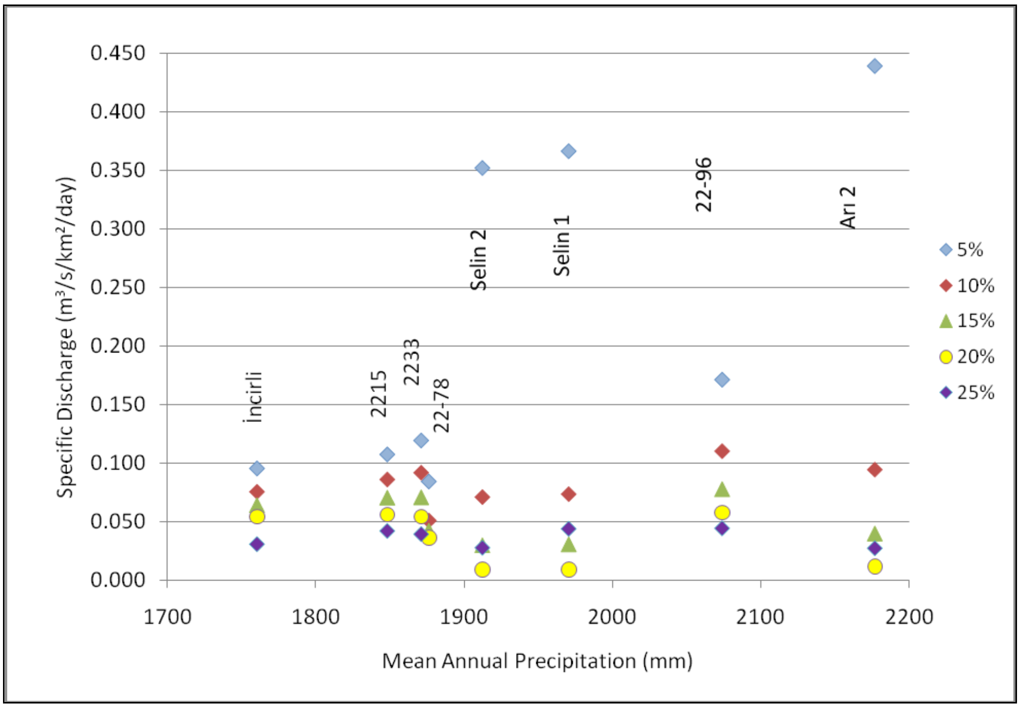

Figure 4.3 The New Correlation between the Precipitation and the Specific Discharge After the First Trend Analysis

Table 4.8 The Correction Factors and the Corrected Discharge Values After the Second Trend Analysis

		Corrected Specific Discharges ($m^3/s/km^2$)		
Data Set	**Correction Factor**	**Selin 1**	**Selin 2**	**Arı 2**
5%	1.70	0.1454	0.1397	0.1743
10%	1.66	0.0977	0.0943	0.1256
15%	1.60	0.0730	0.0710	0.0952
20%	1.55	0.0557	0.0545	0.0733

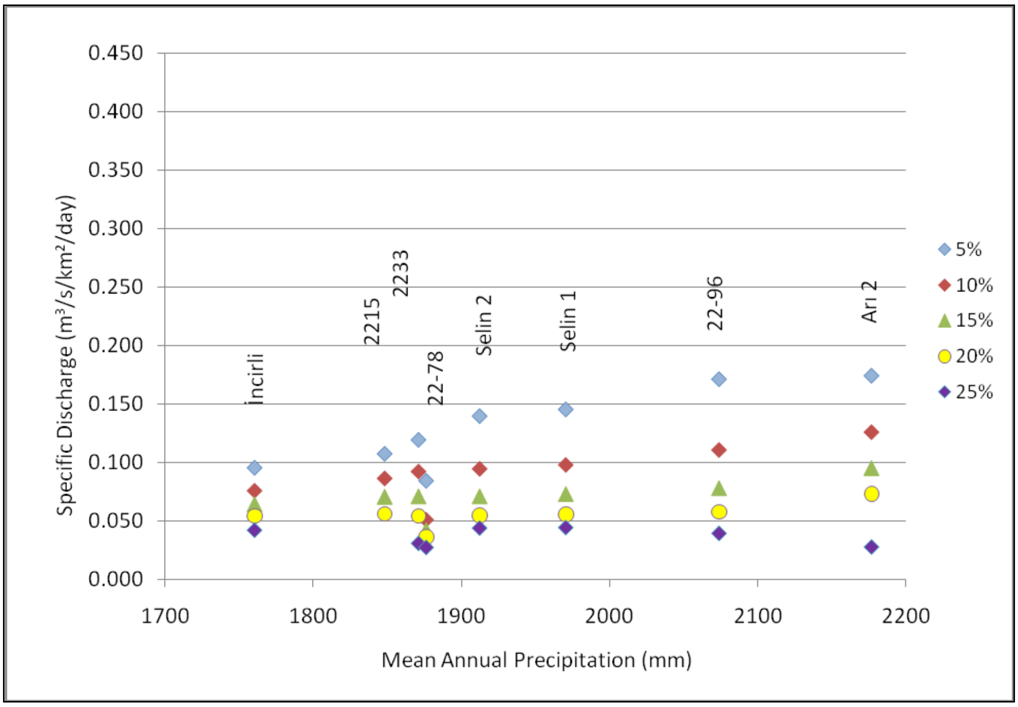

Figure 4.4 The New Correlation between the Precipitation and the Specific Discharge After the Second Trend Analysis

After stepwise analysis has been done for the results of 2 trend analyses, it has been realized that the coefficient of precipitation's sign has been found as negative by the second trend analysis. Because of that reason, the results of the first trend analysis have been used for the model development. The new data sets for 8 subbasins with the corrected specific discharge values have been run into the PCA. The new results for PCA are given in Table 4.9. The output for 10% annual model is provided in Appendix-D.

Table 4.9 The New Selected Parameters after PCA

	Parameters					
	Basin Perimeter (km)	Perimeter/Main Stream Length	Drainage Frequency (km^{-2})	Mean Slope of Basin (%)	Mean Annual Precipitation (mm)	CN
Model 5%		√			√	√
Model 10%		√	√			√
Model 15%		√			√	√
Model 20%				√	√	√
Model 25%	√	√				√

"The selected parameters after PCA are given in Table 4.10. Here, mean slope of the basin (S), P/L, D_f and mean annual precipitation of the basin (MAP) are the selected parameters" (Karaaslan, 2011).

Table 4.10 The Selected Parameters after PCA in Karaaslan (2011)

MODEL	Basin Perimeter P (km)	Average Slope of the Basin S (%)	Maximum Basin relief ΔH (m)	Basin perimeter/main stream lenght P/L	Drainage Density D_d (km^{-1})	Drainage Frequency D_f (km^{-2})	Mean Annual Precipitation of the Basin MAP (mm)
Annual Model 1 (5%)		x		x		x	x
Annual Model 2 (10%)		x		x		x	x
Annual Model 3 (15%)		x		x		x	x
Annual Model 4 (20%)		x		x		x	x
Annual Model 5 (25%)		x		x		x	x
Annual Model 6 (30%)		x		x		x	x
Annual Model 7 (35%)		x		x		x	x
Annual Model 8 (40%)		x		x		x	x

The new summary table of multiple regression analysis is given in Table 4.11. The output for 10% annual model is provided in Appendix-E. It is seen that the sign of mean basin slope of the basin is negative in 15% and 20% models. Mean annual precipitation and perimeter have been selected only for 5% and 25% models and their signs are positive. The sign of curve number is positive for all models except 5% model. The sign of drainage frequency is negative for the 10% model and positive for the rest. The sign of P/L is negative for 5% model and positive for 10% model.

Table 4.11 New Summary of Multiple Regression Analysis

	Coefficients						t						Intercept	Multiple	S_e/S_y
	Perimeter	P/L	D_f	Mean Slope	Precipitation	CN	Perimeter	P/L	D_f	Mean Slope	Precipitation	CN	Coefficient	R^2	
5%		-0.04039			0.00113	-0.01526		-0.08631			1.07181	-0.57556	-0.73336	0.61882	0.78095
10%		0.00569	-0.02097			0.00152		0.12100	-0.09223			0.57037	-0.03225	0.50180	0.89281
15%			0.30753	-0.00218		0.00414			0.93548	-0.26920		1.07518	-0.28429	0.45833	0.93095
20%			0.40963	-0.00159		0.00451			1.06796	-0.16893		1.00486	-0.40688	0.48232	0.91011
25%	0.00006		0.05517			0.00104	0.40118		0.48661			0.78265	-0.06935	0.48223	0.91018

CN is generally the most important parameter for the models according to the t_i values. Model quality is decreasing from the lowest to the highest flow percentile according to the R^2 values.

Multiple regression analysis results for Karaaslan (2011) the annual models are given in Table 4.12.

Table 4.12 Multiple Regression Analysis Results Given in Karaaslan (2011)

MODELS	Annual Model 1 (5%)	Annual Model 2 (10%)	Annual Model 3 (15%)	Annual Model 4 (20%)	Annual Model 5 (25%)	Annual Model 6 (30%)	Annual Model 7 (35%)	Annual Model 8 (40%)
Coefficient of S	-5.78E-03	-2.90E-03	-1.59E-03	-9.28E-04	-5.70E-04	-2.92E-04	-1.44E-04	-5.36E-05
t_S	-1.07	-1.07	-1.01	-0.86	-0.71	-0.47	-0.27	-0.11
Coefficient of P/L	-4.38E-02	-2.23E-02	-1.24E-02	-7.77E-03	-4.87E-03	-2.91E-03	-1.87E-03	-1.26E-03
$t_{P/L}$	-0.58	-0.59	-0.56	-0.52	-0.44	-0.33	-0.25	-0.19
Coefficient of D_f	3.87E-02	-3.96E-04	-2.05E-02	-2.38E-02	-2.41E-02	-2.16E-02	-1.99E-02	-1.76E-02
t_{Df}	0.56	0.00	-0.10	-0.17	-0.23	-0.27	-0.29	-0.29
Coefficient of MAP	5.35E-05	3.37E-05	2.54E-05	1.91E-05	1.52E-05	1.14E-05	9.10E-06	7.40E-06
t_{MAP}	0.46	0.57	0.74	0.82	0.87	0.84	0.79	0.72
Intercept coefficient	0.37	0.21	0.13	0.09	0.06	0.04	0.03	0.02
Multiple R^2	0.88	0.83	0.73	0.65	0.61	0.59	0.61	0.63
S_e/S_y	0.40	0.48	0.61	0.69	0.72	0.74	0.73	0.71

4.2.3 Stepwise Regression Analysis

Stepwise regression is an automatic regression algorithm that enters X variables into the regression model, one X variable at a time. The X variables are entered based on statistical criteria, usually partial F ratios and their corresponding p values (Schmee, 2010).

Results of stepwise regression analyses can be seen in Table 4.13. Also the output for 10% annual model is in Appendix-F.

In Table 4.13, the mean annual precipitation has been selected only for 5% model and its sign is positive. The signs of mean basin slope of the basin and P/L are negative for all models except 5% model. The sign of CN is positive for all of the models except 5% model. The sign of perimeter is positive for the whole models.

CN and mean basin slope have the biggest t_i values. Model quality is increasing from the 20% flow to the 5% flow percentile according to the R^2 values.

When the stepwise and the multiple regression results are compared, stepwise regression analysis gives better results than the multiple regression analysis.

Table 4.13 Summary of Stepwise Regression Analysis

Models	Coefficients						t						Intercept Coefficient	Multiple R^2	S_e/S_y
	Perimeter	P/L	D_f	Mean Slope	Precipitation	CN	Perimeter	P/L	D_f	Mean Slope	Precipitation	CN			
5%				0.019337	0.001265	-0.02222				0.348	1.199	-0.8384	-1.56400	0.7042	0.68798
10%		-0.0281		-0.004908		0.00353		-0.590		-0.866		1.3066	0.16333	0.7349	0.65122
15%	0.000436	-0.0698		-0.013196		0.00637	1.072	-1.030		-1.636		1.6576	0.41874	0.7679	0.68136
20%	0.000562	-0.0802		-0.014968		0.00686	1.181	-1.012		-1.587		1.5256	0.47116	0.8037	0.62652
25%	0.000151	-0.0082		-0.002926		0.00155	1.074	-0.350		-1.049		1.1669	0.07847	0.7569	0.69723

The results of Karaaslan (2011) for stepwise regression analysis are shown in Table 4.14.

Table 4.14 The Results of Stepwise Regression Analysis in Karaaslan (2011)

MODELS	Annual Model 1 (5%)	Annual Model 2 (10%)	Annual Model 3 (15%)	Annual Model 4 (20%)	Annual Model 5 (25%)	Annual Model 6 (30%)	Annual Model 7 (35%)	Annual Model 8 (40%)
Coefficient of P	-1.73E-04	-1.09E-04	-7.10E-05	7.30E-05	6.90E-05	6.20E-05		
t_P	-0.31	-0.39	-0.43	0.66	0.84	0.96		
Coefficient of S	-4.00E-03	-2.10E-03	-9.80E-04				-3.70E-04	
t_S	-0.74	-0.78	-0.62				-0.69	
Coefficient of P/L	-3.30E-02	-1.92E-02	-1.06E-02	-7.49E-03	-5.12E-03	-4.55E-03	-4.56E-03	-1.27E-03
$t_{P/L}$	-0.44	-0.51	-0.49	-0.50	-0.46	-0.52	-0.61	-0.19
Coefficient of ΔH				-1.40E-05	-1.10E-05	-9.00E-06		
$t_{\Delta H}$				-1.69	-1.77	-1.81		
Coefficient of Dd	-8.18E-02					1.91E-02	3.75E-02	
t_{Dd}	-0.15					0.31	0.72	
Coefficient of D_f								-1.56E-02
t_{Df}								-0.26
Coefficient of MAP	4.90E-05	3.00E-05	2.20E-05	2.70E-05	2.30E-05	1.70E-05	8.00E-06	7.00E-06
t_{MAP}	0.42	0.51	0.64	1.16	1.32	1.27	0.71	0.64
Intercept coefficient	0.36	0.18	0.10	0.05	0.03	0.01	0.01	0.02
Multiple R^2	0.93	0.92	0.83	0.78	0.75	0.75	0.70	0.62
S_e/S_y	0.31	0.34	0.48	0.55	0.58	0.61	0.64	0.69

4.3 Validation of Results

To check the quality of the model results given above, discharge values found by the multiple and stepwise regressions are compared with the station 2218's data which has been selected for the validation.

The validation results can be seen in Table 4.15 and the FDCs found by the regression analyses and for the observed discharge values are given in Figure 4.5.

As it can be seen in Figure 4.5, stepwise regression results are much closer to the observed values than the multiple regression results. There are irrationalities in model 5% and 10% results for multiple regression analysis.

Table 4.15 Validation Results

	Multiple Regression		**Stepwise Regression**		**Observed Values**	
	Specific Discharge ($m^3/s/km^2$)	**Discharge (m^3/s)**	**Specific Discharge ($m^3/s/km^2$)**	**Discharge (m^3/s)**	**Specific Discharge ($m^3/s/km^2$)**	**Discharge (m^3/s)**
Model 5%	0.083	**67.632**	0.088	**71.670**	0.094	**76.700**
Model 10%	0.082	**66.707**	0.075	**61.164**	0.077	**63.100**
Model 15%	0.063	**51.565**	0.063	**51.383**	0.066	**53.500**
Model 20%	0.050	**40.846**	0.051	**41.572**	0.055	**44.500**
Model 25%	0.043	**35.286**	0.044	**35.670**	0.045	**36.300**

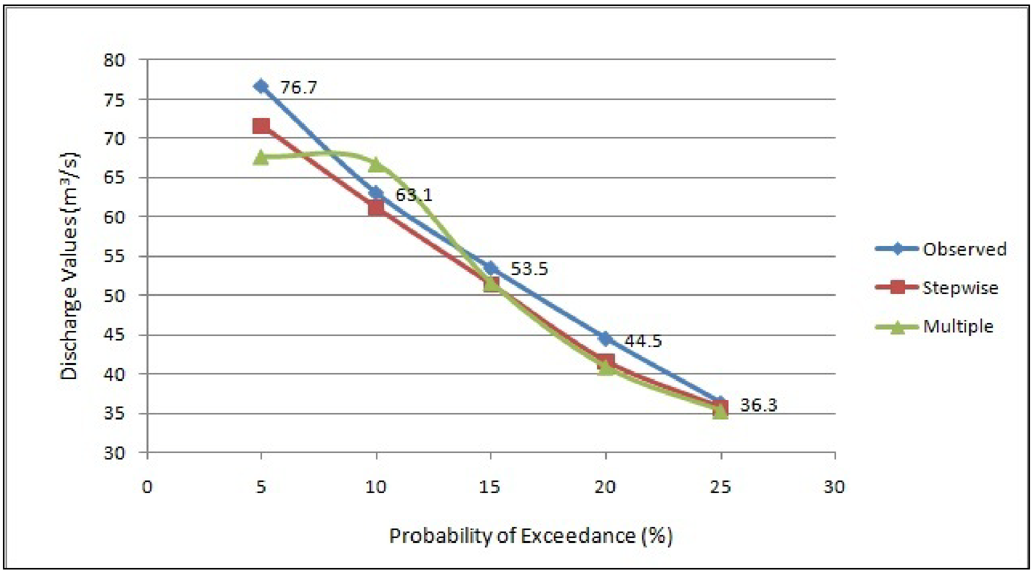

Figure 4.5 FDCs for Multiple Regression Results, Stepwise Regression Results and Observed Discharges

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

In this study, a multilinear statistical model has been developed to estimate "the project discharge" depending on topographical, meteorological, hydrologic and soil-land cover parameters. İyidere Basin, a part of Eastern Black Sea Basin, has been selected as the study area. Topographic and morphological parameters have been extracted from Geographic Information System (GIS) technologies. Mean daily discharges gathered from 5 streamflow gauging stations in İyidere basin have been used as hydrologic data. Daily rainfall measurements gathered from 3 meteorological stations which are operated by Turkish State Meteorological Service have been used.

In İyidere Basin, there is not enough number of stations to do this study. For that reason six projects have been chosen in addition to stations. Flow values have been divided into 5 percentiles from 5% to 25%.

The FDCs of planned project sites found by these equations, the equation used in Karaaslan (2011) and the classical area ratio equation which C coefficient is 1 have been compared. It is concluded that FDCs in İyidere basin have higher specific discharge values than ones in Solaklı-Karadere basins and that supports the region groups of Yanık (2005) mentioned in Chp.1. “Solaklı and Karadere basins are in Region A, İyidere basin is in Region B” (Yanık, 2005).

The FDC equations of 6 planned HEPPs in İyidere basin computed as in Table 3.13, Table 3.14 and the results of classical area ratio have been compared for each HEPP. It is concluded that the equations in Table 3.14 can be useful for the FDCs when the drainage area is between 50 and 850 km^2.

After calculating the all parameters, PCA, Multiple Regression Analysis and Stepwise Regression Analysis have been run for the 5 data sets.

In the Multiple Regression Analysis; drainage frequency is generally the most important variable while in the Stepwise Analysis; perimeter is generally the most important variable.

To check the quality of the model results, discharge values found by the multiple and stepwise regressions have been compared with the station 2218’s data which has been selected for the validation. The stepwise regression results have been much closer to the observed values than the multiple regression results. There are irrationalities in model 5% and 10% results for multiple regression analysis.

The model parameters and model equations found in this study can be applied in basins which are hydrologically similar to İyidere Basin.

5.2 Recommendations

Here are the recommendations:

- The number of streamflow gauging stations should be increased.

- The number of meteorological stations should be increased and they should be built at upper elevations, too.

- Some parameters related to how fast snow melts should be included because İyidere basin is a snow dominated basin. For example, basin aspect percentages should be included as a parameter by being associated with the basin areas.

- Model developments mentioned in this study should be done for the adjacent basins, too. And then regionalization studies for the FDCs should be tried.

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APPENDIX A

LEGENDS FOR SOIL-LANDCOVER DATA

Table A.1 Soil Data Legend 1

Symbol	BTG - Main Soil Groups
P	Red yellow podzolic soils
G	Gray brown podzolic soils
M	Brown forest soils
N	Brown forest soils without lime
CE	Chestnut (maron) color soils
D	Reddish maron soils
T	Red Mediterranien soils
E	Red brown Mediterranien soils
B	Brown soils
U	Brown soils without lime
F	Reddish brown soils
R	Rendzinas
V	Vertisoils
Z	Cherzolerma
L	Regosoils
X	Basaltic soils
Y	High-level mountain meadow soils
A	Aluvial soils
H	Hydromorphic soils
S	Aluvial shore soils
K	Kolivual soils
C	Salty-alcali (and the mixture) soils
O	Organic soils

Table A.2 Soil Data Legend 2

<table>
<tr><th colspan="9">Combination of BTG and TOK</th></tr>
<tr><th colspan="2">Main Soil Group (BTG)</th><th colspan="7">Soil – Deepness Combination (EDK)</th></tr>
<tr><th rowspan="2">Symbol</th><th rowspan="2">Meaning</th><th rowspan="2">Slope %</th><th colspan="5">Deepness (cm)</th></tr>
<tr><th>Depth 90+</th><th>Middle Deep 90-50</th><th>Thin 50-20</th><th>Very thin 20-0</th><th>Litozolic</th></tr>
<tr><td rowspan="6">P
G
M
N

CE
D
T
E

B
U
F
R
V
Z
L
X
Y</td><td rowspan="6">Red yellow podzolic soils
gray brown podzolic soils
brown forest soils
brown forest soils without lime
chestnut (maron) color soils
reddish maron soils
red Mediterranien soils
red brown Mediterranien soils
brown soils
brown soils without lime
reddish brown soils
Rendzinas
Vertisoils
cherzolerma
regosoils
basaltic soils
High-level mountain meadow soils</td><td>A
0 – 2</td><td>1</td><td>2</td><td>3</td><td>4</td><td>25</td></tr>
<tr><td>B
2 – 6</td><td>5</td><td>6</td><td>7</td><td>8</td><td>26</td></tr>
<tr><td>C
6 – 12</td><td>9</td><td>10</td><td>11</td><td>12</td><td>27</td></tr>
<tr><td>D
12 – 20</td><td>13</td><td>14</td><td>15</td><td>16</td><td>28</td></tr>
<tr><td>E
20 – 30</td><td>17</td><td>18</td><td>19</td><td>20</td><td>29</td></tr>
<tr><td>F
30 +</td><td>21</td><td>22</td><td>23</td><td>24</td><td>30</td></tr>
</table>

Table A.3 Soil Data Legend 3

Other Soil Characteristics (DTO)	
Symbol	Meaning
h	Slightly salty
s	Salty
a	Alcali
k	Slightly salty-alcali
v	Salty-alcali
t	Stony
r	Rocky
y	Not sufficiently drained
f	Badly drained

Table A.4 Soil Data Legend 4

Erosion Level Sensibility (ERZ)			
Water Erosion		Wind Erosion	
1	Non or very low	R1	Slightly
2	Medium	R2	Medium
3	Highly	R3	Highly
4	Very high		

Table A.5 Landcover Data Legend

GRID_CODE,CLC_CODE,LABEL1,LABEL2,LABEL3,RGB
1,111,Artificial surfaces,Urban fabric,Continuous urban fabric,230-000-077
2,112,Artificial surfaces,Urban fabric,Discontinuous urban fabric,255-000-000
3,121,Artificial surfaces,"Industrial, commercial and transport units",Industrial or commercial units,204-077-242
4,122,Artificial surfaces,"Industrial, commercial and transport units",Road and rail networks and associated land,204-000-000
5,123,Artificial surfaces,"Industrial, commercial and transport units",Port areas,230-204-204
6,124,Artificial surfaces,"Industrial, commercial and transport units",Airports,230-204-230
7,131,Artificial surfaces,"Mine, dump and construction sites",Mineral extraction sites,166-000-204
8,132,Artificial surfaces,"Mine, dump and construction sites",Dump sites,166-077-000
9,133,Artificial surfaces,"Mine, dump and construction sites",Construction sites,255-077-255
10,141,Artificial surfaces,"Artificial, non-agricultural vegetated areas",Green urban areas,255-166-255
11,142,Artificial surfaces,"Artificial, non-agricultural vegetated areas",Sport and leisure facilities,255-230-255
12,211,Agricultural areas,Arable land,Non-irrigated arable land,255-255-168
13,212,Agricultural areas,Arable land,Permanently irrigated land,255-255-000
14,213,Agricultural areas,Arable land,Rice fields,230-230-000
15,221,Agricultural areas,Permanent crops,Vineyards,230-128-000
16,222,Agricultural areas,Permanent crops,Fruit trees and berry plantations,242-166-077
17,223,Agricultural areas,Permanent crops,Olive groves,230-166-000
18,231,Agricultural areas,Pastures,Pastures,230-230-077
19,241,Agricultural areas,Heterogeneous agricultural areas,Annual crops associated with permanent crops,255-230-166
20,242,Agricultural areas,Heterogeneous agricultural areas,Complex cultivation patterns,255-230-077
21,243,Agricultural areas,Heterogeneous agricultural areas,"Land principally occupied by agriculture, with significant areas of natural vegetation",230-204-077
22,244,Agricultural areas,Heterogeneous agricultural areas,Agro-forestry areas,242-204-166
23,311,Forest and semi natural areas,Forests,Broad-leaved forest,128-255-000
24,312,Forest and semi natural areas,Forests,Coniferous forest,000-166-000
25,313,Forest and semi natural areas,Forests,Mixed forest,077-255-000
26,321,Forest and semi natural areas,Scrub and/or herbaceous vegetation associations,Natural grasslands,204-242-077
27,322,Forest and semi natural areas,Scrub and/or herbaceous vegetation associations,Moors and heathland,166-255-128
28,323,Forest and semi natural areas,Scrub and/or herbaceous vegetation associations,Sclerophyllous vegetation,166-230-077
29,324,Forest and semi natural areas,Scrub and/or herbaceous vegetation associations,Transitional woodland-shrub,166-242-000
30,331,Forest and semi natural areas,Open spaces with little or no vegetation,"Beaches, dunes, sands",230-230-230
31,332,Forest and semi natural areas,Open spaces with little or no vegetation,Bare rocks,204-204-204
32,333,Forest and semi natural areas,Open spaces with little or no vegetation,Sparsely vegetated areas,204-255-204
33,334,Forest and semi natural areas,Open spaces with little or no vegetation,Burnt areas,000-000-000
34,335,Forest and semi natural areas,Open spaces with little or no vegetation,Glaciers and perpetual snow,166-230-204
35,411,Wetlands,Inland wetlands,Inland marshes,166-166-255
36,412,Wetlands,Inland wetlands,Peat bogs,077-077-255
37,421,Wetlands,Maritime wetlands,Salt marshes,204-204-255
38,422,Wetlands,Maritime wetlands,Salines,230-230-255
39,423,Wetlands,Maritime wetlands,Intertidal flats,166-166-230
40,511,Water bodies,Inland waters,Water courses,000-204-242
41,512,Water bodies,Inland waters,Water bodies,128-242-230
42,521,Water bodies,Marine waters,Coastal lagoons,000-255-166
43,522,Water bodies,Marine waters,Estuaries,166-255-230
44,523,Water bodies,Marine waters,Sea and ocean,230-242-255

APPENDIX B

PCA OUTPUT FOR 10% MODEL

```
PRINCIPAL COMPONENTS ANALYSIS
-----------------------------
Version 91.4

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```

STATISTICS FOR UNTRANSFORMED DATA

VAR	MEAN	ST DEV	COEFF of VAR
1	101.6127000	57.8899700	.5697117
2	3.2728180	.2866126	.0875736
3	.5028182	.0612500	.1218134
4	48.9691800	3.0321250	.0619191
5	1816.5670000	260.3672000	.1433293
6	71.2485400	5.3037940	.0744407
7	.0820909	.0215984	.2631035

****
*****

CORRELATION MATRIX

var	1	2	3	4	5	6	7
1	1.000	-.191	.194	-.156	.248	-.461	-.432
2	-.191	1.000	-.307	-.443	.291	.364	.178
3	.194	-.307	1.000	.022	-.732	-.480	.098
4	-.156	-.443	.022	1.000	-.553	.531	.298

5	.248	.291	-.732	-.553	1.000	-.092	-.471
6	-.461	.364	-.480	.531	-.092	1.000	.606
7	-.432	.178	.098	.298	-.471	.606	1.000

Determinant of R = .0015028

Total Sphericity Test of R = I
Computed Chi square = 44.42
degrees of freedom = 21

****

Prin. Comp.	Eigen- value	Percent trace	Cumulative percent	Chi Square for partial sphericity test	df
1	2.5603	36.58	36.58	44.42	21
2	2.2084	31.55	68.13	34.74	15
3	1.1437	16.34	84.46	23.09	10
4	.6478	9.25	93.72	15.26	6
5	.3692	5.27	98.99	9.05	3
6	.0518	.74	99.73	.87	1
7	.0188	.27	100.00	.00	0

****

EIGENVECTOR MATRIX
==================

Var: Standardized Eigenvector (e ** 2 / lambda)

Var	1	2	3	4	5	6	7
1	.618	-.322	.206	-.684	-.054	-.019	-.023
2	-.007	.716	-.564	-.258	.312	-.058	.033
3	-.062	-.861	-.471	-.088	.082	.127	.048
4	-.709	-.279	.603	-.115	.184	-.051	.074
5	.666	.676	.231	-.001	-.179	.083	.081
6	-.759	.554	.195	-.222	.080	.143	-.047
7	-.807	.096	-.324	-.206	-.435	-.045	.025

****

Communalities for Eigenvector 1 to
----

var 1 2 3 4 5 6 7

1	.382	.485	.528	.996	.999	.999	1.000
2	.000	.513	.831	.898	.996	.999	1.000
3	.004	.745	.967	.975	.981	.998	1.000
4	.503	.581	.945	.958	.992	.995	1.000
5	.444	.901	.954	.954	.986	.993	1.000
6	.577	.884	.922	.971	.977	.998	1.000
7	.651	.660	.766	.808	.997	.999	1.000

APPENDIX C

MULTIPLE REGRESSION ANALYSIS OUTPUT FOR 10% MODEL

```
 MULTIPLE REGRESSION ANALYSIS
 ============================
 Version 91.4

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*****************************************************************
***

            STATISTICS FOR UNTRANSFORMED DATA
            =================================
                        Standard     Coefficient
  Var       Mean        Deviation    of Variation      Minimum
Maximum
  ---   ------------   -----------   ------------    -----------
-----------

    1    101.6127000     57.8899700       .5697117     26.3600000
215.9600000
    2       .5028182       .0612500       .1218134       .3680000
.5620000
    3   1816.5670000    260.3672000       .1433293   1290.7610000
2176.9470000
    4       .0820909       .0215984       .2631035       .0510000
.1140000


*****************************************************************
***

           CORRELATION MATRIX
```

=================

ROW	1	2	3	4
1	1.000	.194	.248	-.432
2	.194	1.000	-.732	.098
3	.248	-.732	1.000	-.471
4	-.432	.098	-.471	1.000

.2937483 = Determinant of intercorrelation matrix

****

Var	b	t	R	R**2	t*R
1	-.0000673	-.18034	-.43160	.18628	.07784
2	-.1363593	-.38670	.09805	.00961	-.03792
3	-.0000589	-.70965	-.47123	.22206	.33441

.2644295 = Intercept

****

ANALYSIS OF RESIDUALS
=====================

OBS NO.	PREDICTED YP	OBSERVED Y	RESIDUAL e = YP - Y	REL ERROR e / Y
1	.0739473	.0770000	-.0030527	-.03965
2	.0718118	.0860000	-.0141882	-.16498
3	.0727411	.0510000	.0217411	.42630
4	.0767680	.0920000	-.0152320	-.16557
5	.0793835	.1100000	-.0306165	-.27833
6	.0741264	.0760000	-.0018736	-.02465
7	.0780363	.0590000	.0190363	.32265
8	.0788436	.0570000	.0218436	.38322
9	.1126981	.1050000	.0076981	.07332
10	.1026799	.1140000	-.0113201	-.09930
11	.0819640	.0760000	.0059640	.07847

****

GOODNESS-OF-FIT STATISTICS

.3743301 = MULTIPLE R SQUARE

```
 .6118252 = MULTIPLE R

 .0204195 = STANDARD ERROR OF ESTIMATE (Se)
 .0215984 = STANDARD DEVIATION (Sy)

 .9454175 = Se/Sy


 .1869481 = MEAN RELATIVE ERROR
 .1427988 = STANDARD DEVIATION OF RELATIVE ERRORS


1.396 = F FOR ANALYSIS OF VARIANCE ON R
                N.D.F.1 =  3.   N.D.F.2 =   7.


*****************************************************************
************

     DISTRIBUTION OF RESIDUALS FOR NORMALITY CHECK

 CELL STANDARDIZED
       VARIATE      FREQUENCY


   1                     .0
    -.200000E+01
   2                     .0
    -.150000E+01
   3                    1.0
    -.100000E+01
   4                    3.0
    -.500000E+00
   5                    2.0
     .000000E+00
   6                    2.0
     .500000E+00
   7                    1.0
     .100000E+01
   8                    2.0
     .150000E+01
   9                     .0
     .200000E+01
  10                     .0
```

APPENDIX D

PCA OUTPUT FOR 10% MODEL

PRINCIPAL COMPONENTS ANALYSIS

Version 91.4

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STATISTICS FOR UNTRANSFORMED DATA

VAR	MEAN	ST DEV	COEFF of VAR
1	117.7756000	50.7057100	.4305283
2	3.2822220	.3041105	.0926538
3	.4921111	.0628479	.1277108
4	48.1321100	2.5568250	.0531210
5	1919.5250000	134.8031000	.0702273
6	70.2338900	5.3657220	.0763979
7	.0827778	.0142897	.1726268

****
*****

CORRELATION MATRIX
----

var	1	2	3	4	5	6	7
1	1.000	-.310	.608	.374	-.816	-.277	-.400
2	-.310	1.000	-.349	-.457	.441	.463	.417
3	.608	-.349	1.000	-.286	-.938	-.776	-.577
4	.374	-.457	-.286	1.000	.035	.393	-.085

5	-.816	.441	-.938	.035	1.000	.675	.583
6	-.277	.463	-.776	.393	.675	1.000	.698
7	-.400	.417	-.577	-.085	.583	.698	1.000

Determinant of R = .0000313

Total Sphericity Test of R = I
Computed Chi square = 50.14
degrees of freedom = 21

****

Prin. Comp.	Eigen- value	Percent trace	Cumulative percent	Chi Square for partial sphericity test	df
1	3.8529	55.04	55.04	50.14	21
2	1.6195	23.14	78.18	32.71	15
3	.9001	12.86	91.04	21.97	10
4	.4894	6.99	98.03	13.29	6
5	.1087	1.55	99.58	4.66	3
6	.0253	.36	99.94	1.09	1
7	.0041	.06	100.00	.00	0

****

EIGENVECTOR MATRIX
==================

Var — Standardized Eigenvector (e ** 2 / lambda)

Var	1	2	3	4	5	6	7
1	-.716	.405	-.542	-.046	.163	-.018	.027
2	.581	-.491	-.527	-.375	.018	.047	-.018
3	-.915	-.272	-.182	.124	-.180	.084	.019
4	.008	.990	.038	-.109	-.023	.080	-.022
5	.947	.003	.285	-.105	.064	.064	.043
6	.825	.401	-.334	-.031	-.203	-.063	.016
7	.766	-.020	-.318	.554	.063	.036	-.009

****

Communalities for Eigenvector 1 to
----

var	1	2	3	4	5	6	7
1	.512	.676	.970	.972	.999	.999	1.000
2	.337	.578	.856	.997	.997	1.000	1.000
3	.838	.912	.945	.960	.993	1.000	1.000
4	.000	.979	.981	.993	.993	1.000	1.000
5	.898	.898	.979	.990	.994	.998	1.000
6	.681	.842	.954	.955	.996	1.000	1.000
7	.586	.587	.688	.995	.999	1.000	1.000

APPENDIX E

MULTIPLE REGRESSION ANALYSIS OUTPUT FOR 10% MODEL

```
MULTIPLE REGRESSION ANALYSIS
 ============================
 Version 91.4

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*****************************************************************
***

             STATISTICS FOR UNTRANSFORMED DATA
             =================================
                         Standard     Coefficient
  Var       Mean         Deviation    of Variation       Minimum
Maximum
  ---   ------------    -----------   ------------    -----------
-----------

    1      3.2822220       .3041105       .0926538      2.8800000
3.9150000
    2       .4921111       .0628479       .1277108       .3680000
.5520000
    3     70.2338900      5.3657220       .0763979     60.0060000
79.7780000
    4       .0827778       .0142897       .1726268       .0640000
.1100000


*****************************************************************
***

            CORRELATION MATRIX
            ==================
```

ROW	1	2	3	4
1	1.000	-.349	.463	.417
2	-.349	1.000	-.776	-.577
3	.463	-.776	1.000	.698
4	.417	-.577	.698	1.000

.3121783 = Determinant of intercorrelation matrix

****

Var	b	t	R	R**2	t*R
1	.0056857	.12100	.41712	.17399	.05047
2	-.0209694	-.09223	-.57718	.33313	.05323
3	.0015190	.57037	.69796	.48715	.39810

-.0322473 = Intercept

****

ANALYSIS OF RESIDUALS

OBS NO.	PREDICTED YP	OBSERVED Y	RESIDUAL e = YP - Y	REL ERROR e / Y
1	.0819145	.0770000	.0049145	.06382
2	.0845121	.0860000	-.0014879	-.01730
3	.0663325	.0640000	.0023325	.03644
4	.0789426	.0920000	-.0130574	-.14193
5	.0900801	.1100000	-.0199199	-.18109
6	.0786803	.0760000	.0026803	.03527
7	.0838635	.0740000	.0098635	.13329
8	.0771991	.0710000	.0061991	.08731
9	.1034752	.0950000	.0084752	.08921

****

GOODNESS-OF-FIT STATISTICS

.5018018 = MULTIPLE R SQUARE
.7083797 = MULTIPLE R

.0127580 = STANDARD ERROR OF ESTIMATE (Se)
.0142897 = STANDARD DEVIATION (Sy)

```
       .8928141 = Se/Sy


       .0872968 = MEAN RELATIVE ERROR
       .0555023 = STANDARD DEVIATION OF RELATIVE ERRORS

*****************************************************************
************

     1.679 = F FOR ANALYSIS OF VARIANCE ON R
                     N.D.F.1 =  3.   N.D.F.2 =   5.


*****************************************************************
************

     DISTRIBUTION OF RESIDUALS FOR NORMALITY CHECK

 CELL STANDARDIZED
       VARIATE      FREQUENCY


    1                       .0
     -.200000E+01
    2                      1.0
     -.150000E+01
    3                      1.0
     -.100000E+01
    4                       .0
     -.500000E+00
    5                      1.0
      .000000E+00
    6                      4.0
      .500000E+00
    7                      2.0
      .100000E+01
    8                       .0
      .150000E+01
    9                       .0
      .200000E+01
   10                       .0
```

APPENDIX F

STEPWISE REGRESSION ANALYSIS OUTPUT FOR 10% MODEL

```
STEPWISE (FORWARD) REGRESSION ANALYSIS
 ======================================

 Version 91.4

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```

CHARACTERISTICS OF DATA

===
===

Var	Mean	Standard deviation	Coeff. of variation	Minimum	Maximum
1	117.775600	50.705710	.430528	61.420000	215.960000
2	3.282169	.304064	.092641	2.880087	3.914595
3	.492144	.062823	.127652	.367891	.552108
4	48.132040	2.556862	.053122	43.610190	50.737260
5	1919.525000	134.803200	.070227	1760.521000	2176.947000
6	70.233920	5.365839	.076400	60.006000	79.778400

```
    7      .082700      .014492      .175235      .063500
.110500

*****************************************************************
***************



CORRELATION MATRIX
 ------------------

 Var     1     2     3     4     5     6     7
  1    1.000 -.310  .609  .374 -.816 -.277 -.391
  2    -.310 1.000 -.349 -.457  .441  .462  .411
  3     .609 -.349 1.000 -.284 -.939 -.776 -.567
  4     .374 -.457 -.284 1.000  .035  .393 -.082
  5    -.816  .441 -.939  .035 1.000  .675  .572
  6    -.277  .462 -.776  .393  .675 1.000  .693
  7    -.391  .411 -.567 -.082  .572  .693 1.000


=================================================================
==============

 Step number =  1     Enter predictor variable  6

*****************************************************************
***************

 STATISTICAL CHARACTERISTICS
   FOR VARIABLE SELECTION
 ---------------------------
       Partial R   Partial F
 Var   to  enter   to  enter
 ---   ---------   ---------

   1      -.3910       1.263
   2       .4108       1.421
   3      -.5673       3.323
   4      -.0823        .048
   5       .5718       3.400
   6       .6933       6.480

*****************************************************************
***************

  1.0000 = Determinant of Intercorrelation Matrix

*****************************************************************
***************

         GOODNESS-OF-FIT STATISTICS
         --------------------------
          .4807 = Increase in R**2 Due to Variable Added
```

```
          .4807 = Multiple R**2
          .6933 = Multiple R

       .0111643 = Standard error of estimate (Se)
       .0144919 = Standard deviation of Y    (Sy)

       .7703826 = Se/Sy

       .0880776 = Mean of Absolute Relative Errors
       .0659512 = Std. dev. of Absolute Relative Errors
          6.480 = Total F for the Analysis of Variance on R
                    df 1 =  1.     df 2 =   7.

          6.480 = Partial F to Enter
                    df 1 =   1     df 2 =   7.

*****************************************************************
***************

 Var       b        t        r      r**2    t*r     Se(bi)
Se(bi)/bi
 ---    ---------  ------   -----   -----   -----   --------   --
-------

   6      .001873   .6933   .6933   .4807   .4807      .0007
.39284

         -.048814 = Intercept


=================================================================
==============

 Step number =  2     Enter predictor variable  4

*****************************************************************
***************

 STATISTICAL CHARACTERISTICS
   FOR VARIABLE SELECTION
 ---------------------------
       Partial R   Partial F
 Var   to  enter   to  enter
 ---   ---------   ---------

   1      -.2870        .539
   2       .1410        .122
   3      -.0647        .025
   4      -.5359       2.417
   5       .1950        .237

*****************************************************************
***************
```

```
   .8453 = Determinant of Intercorrelation Matrix

*****************************************************************
***************


 GOODNESS-OF-FIT STATISTICS
          --------------------------
           .1491 = Increase in R**2 Due to Variable Added
           .6298 = Multiple R**2
           .7936 = Multiple R

        .0101817 = Standard error of estimate (Se)
        .0144919 = Standard deviation of Y    (Sy)

        .7025796 = Se/Sy

        .0660728 = Mean of Absolute Relative Errors
        .0564234 = Std. dev. of Absolute Relative Errors

*****************************************************************
***************

           5.103 = Total F for the Analysis of Variance on R
                     df 1 =  2.     df 2 =   6.

           2.416 = Partial F to Enter
                     df 1 =   1     df 2 =   6.

*****************************************************************
***************

 Var        b        t        r      r**2    t*r     Se(bi)
Se(bi)/bi
 ---    ---------  ------   -----   -----   -----   --------   --
-------

   6      .002319   .8585   .6933   .4807   .5952      .0007
.31469
   4     -.002381  -.4200  -.0823   .0068   .0346      .0015
.64327

           .034431 = Intercept


=================================================================
==============

 Step number =  3     Enter predictor variable  2

*****************************************************************
***************

STATISTICAL CHARACTERISTICS
```

```
   FOR VARIABLE SELECTION
 ---------------------------
       Partial R   Partial F
 Var   to  enter   to  enter
 ---   ---------   ---------

   1       .0083        .000
   2      -.5331       1.985
   3      -.0532        .014
   5       .0166        .001

*****************************************************************
***************

   .2558 = Determinant of Intercorrelation Matrix

*****************************************************************
***************

         GOODNESS-OF-FIT STATISTICS
         --------------------------
          .1052 = Increase in R**2 Due to Variable Added
          .7349 = Multiple R**2
          .8573 = Multiple R

       .0094375 = Standard error of estimate (Se)
       .0144919 = Standard deviation of Y    (Sy)

       .6512232 = Se/Sy

       .0584322 = Mean of Absolute Relative Errors
       .0575869 = Std. dev. of Absolute Relative Errors

*****************************************************************
***************

          4.621 = Total F for the Analysis of Variance on R
                    df 1 =  3.     df 2 =   5.

          1.984 = Partial F to Enter
                    df 1 =   1     df 2 =   5.

*****************************************************************
***************

 Var        b         t        r       r**2    t*r     Se(bi)
Se(bi)/bi
 ---    ---------  ------   -----   -----   -----   --------   --
-------

   6      .003529  1.3066   .6933   .4807   .9059      .0011
.30984
   4     -.004908  -.8660  -.0823   .0068   .0713      .0023
.46613
```

```
   2      -.028103  -.5897   .4108   .1687  -.2422       .0199
.70986

          .163330 = Intercept
```