ESTIMATION OF SPECIFIC FLOW DURATION CURVES USING BASIN CHARACTERISTICS OF RIVERS IN SOLAKLI AND KARADERE BASINS

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ABSTRACT

ESTIMATION OF SPECIFIC FLOW DURATION CURVES USING BASIN CHARACTERISTICS OF RIVERS IN SOLAKLI AND KARADERE BASINS

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Demand for energy is constantly growing both in the world and in Turkey. Sustainable development being an important concept, development of small hydro power projects has been popular in recent years. Eastern Black Sea Basin in Turkey has a lot of small hydro power potential because of high amount of precipitation and existence of steep slopes. Since the amount of river runoff is the only parameter that is variable in order to determine the power potential, it is vital to estimate the project discharge in ungauged basins accurately that have hydro power potential. Projects discharges of hydro-power plants in ungauged basins have been calculated using conventional methods up to now. This study aims to introduce a statistical model in linear and multi-variate form using the topographical and morphological parameters derived from GIS and hydro-meteorological variables to estimate the specific flow duration curves of potential small hydro-power locations for the selected study areas in Eastern Black Sea Region namely Solaklı and Karadere basins. As well as developing an annual regression model using the annual values of hydro-meteorological parameters; seasonal regression model (spring season) has also been developed by including the mean seasonal (spring) air temperature variable instead of snow covered area (SCA) in addition to basin parameters. By studying the spring model, effect of different variables from the annual model were tested and discussed with some recommendations for the future studies.

Keywords: Ungauged Basin, Small Hydro-Power, Statistical Model, GIS, Eastern Black Sea Basin

ÖZ

SOLAKLI VE KARADERE HAVZALARINDAKİ AKARSULARIN HAVZA KARAKTERISTİKLERİNİ KULLANARAK ÖZGÜL DEBİ SÜREKLİLİK EĞRİLERİNİN TAHMİN EDİLMESİ

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Dünyada ve Türkiye'de enerjiye olan talep gittikçe artmaktadır. Sürdürülebilir kalkınma konseptinin önemiyle beraber, küçük hidroelektrik santrallerin geliştirilmesi son yıllarda önem kazanmıştır. Bu bağlamda yüksek yağış oranı ve yüksek eğimlerin varlığı sebebiyle Türkiye'deki Doğu Karadeniz Bölgesi'nin ciddi bir hidroelektrik potansiyeli mevcuttur. Hidroelektrik potansiyel belirlenmesinde nehir akımları tek değişken olduğundan ötürü, hidroelektrik potansiyeli olan ve ölçüm istasyonu olmayan havzalardaki akım miktarını en iyi şekilde belirlemek çok önemlidir. Şimdiye dek; ölçüm istasyonu olmayan hidroelektrik santrallerinin havzalarının hesapları geleneksel metotlatla yapılagelmiştir. Bu çalışmada; Doğu Karadeniz Bölgesi'nde seçilmiş Karadere ve Solaklı havzalarındaki potansiyel küçük hidroelektrik santrallerinin özgül debi süreklilik eğrilerinin tahmin edilmesi için CBS yöntemleri kullanılarak çıkarılan topografik, morfolojik ve hidro-meteorolojik parametrelerle kurulan lineer ve çoklu değişkenli istatistiki modellemelerin geliştirilmesi amaçlamaktadır. Yıllık bazda hidro-meteorolojik parametrelerin yıllık değerleri kullanılarak bir regresyon modeli geliştirildiği gibi; mevsimsel (ilkbahar) ortalama hava sıcaklığını karla kaplı alan parametresi yerine kullanarak, diğer havza parametrelerine ilaveten mevsimel (ilkbahar) model de geliştirilmiştir. İlkbahar modelini kurarak, farklı parametrelerin etkisi test edilmiş ve gelecekteki çalışmalar için önerilerde bulunulup sonuçlar tartışılmıştır.

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

To the Meaning of My Life…

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CHAPTER 1

INTRODUCTION

1.1 Definition of the Problem

Demand for energy is constantly growing both in Turkey and in the world as long as the population goes on increasing and industries of nations keep growing. Supplying the necessary demand has not been sufficient since the term sustainable development was coined. This means that while meeting the demands of humanity, the future generations should also be able to benefit from the world's resources. Concordantly, the concept called "renewable energy" has been a very important issue. Sunlight, tides, wind, rain and water are some of the most important renewable energy sources that are being used in energy supply. The share of hydroelectricity in electricity generation is 15 %, the rest of renewable sources contributing only 3 % (Web 1). In this context, hydropower remains very important and has been gaining much importance in growing countries like Turkey in recent years.

The use of hydropower has always been important for the advance of civilization and it dates back to ancient ages. With the triggering effect of the industrial revolution, hydropower has significantly contributed to power generation. In 1881, Cragside House became the first house in the world to be lit using hydroelectric power. In 1882, world's first hydroelectric power plant began operation on the Fox River in Appleton, Wisconsin. In the following years, hydropower generation continued to be essential for development.

In Turkey, during 1950s, the total amount of hydroelectricity used to consist of only 4.4 % of Turkey's whole electricity generation. By 2008, this ratio has risen to 17 %. Currently being only 35 % of the economically feasible hydropower is under operation, development of hydropower projects still remain important (Yuksel et al., 2008).

To generate electricity from hydro power, it was popular to construct large dams. Dams not only provide a reliable and a large amount of power supply; but also they are used for irrigation, water supply, flood control, recreational, etc. purposes. In recent years; the damages and negative impacts of dams like social, environmental and economical impacts have come up. A lot of people may be forced to leave their hometowns and a large amount of lands may be flooded. Furthermore, operation of dams goes on until the dead volume of the reservoir is filled with sediment. These problems have brought a new concept called "small hydro power".

Small hydro power is a development of hydro power on a small scale. Having a large amount of small hydropower potential in Turkey, investors have lately been interested in electricity generation from small hydro electric power plants. Eastern Black Sea Basin is the most important basin regarding with the small hydro power potential according to Yuksel et al. (2008).

Installed power capacity of a hydro power plant is a function of height difference between the source and outflow of water (head) and discharge. Since head is accepted to be constant, the only variable in power function is discharge. Conventional methods have been used to estimate project discharge and a fresh method has to be offered to estimate project discharges of small hydro electric power plants in the basins that are commercially popular.

In order to determine a project discharge of a certain project, the flow duration curve for annual period is used. However, flows in Turkey are not regular and the snowmelt contribution to the runoff is significant especially in Eastern Black Sea Region. Snowmelt season is the spring season and it is important to study not only annual flow duration curves, but also seasonal flow duration curves for the spring season. Therefore, to determine an extra installed capacity for the spring season is beneficiary for the investors which allow them to make use of high flows in the spring season resulting from snowmelt.

1.2 Aim of the Study

The aim of this study is to estimate seasonal and annual flow duration curves for the range of probabilities between 5% and 40% by developing statistical models for the ungauged basins within Solaklı and Karadere watersheds (located in Eastern Black Sea Basin) in order to determine the project discharge values of potential hydropower locations.

The model parameters are both topographic and hydro-meteorological data where the topographic and morphological parameters are extracted by using Geographic Information System (GIS). Linear, relief, morphological and shape measures are the categories of topographic parameters. Furthermore, the snow covered area (SCA) data from satellite images of the selected basins are associated in the model by seeking a relationship with mean daily temperature values of the related meteorological stations. By setting up regression models using several statistical methods; the dominant parameters are defined and the flow values corresponding to 8 percentiles of flow duration curve (5%, 10%, 15%, 20%, 25%, 20%, 30%, 35% and 40%) are determined for both annual and seasonal models. The season here, refers to the spring season. Then the model is validated by comparing the results with the values of a selected flow gauging station.

1.3 Organization of the Thesis

This study is composed of 6 chapters. This chapter being the "Introduction" chapter, the other chapters are given as:

In Chapter 2, a brief literature review related with the scope of this thesis was provided.

In Chapter 3, the description of the study areas and also the information about the collected data as hydro-meteorological, topographic and snow covered area (SCA) data are given.

In Chapter 4, the analyses and processing of the collected data are explained. Completion of missing hydro-meteorological data, deriving the seasonal and annual flow duration curves of the stream flow gauging stations and the project sites, developing the Digital Elevation Model (DEM) of the basins within Solaklı and Karadere watersheds, delineation of the basins and deriving the topographic parameters and studying the relationship between SCA and mean daily temperature of the selected stations are given.

In Chapter 5, the development of multi-linear and multi-variate regression models, fitting the appropriate functions for FDCs and validation of the results are given.

Chapter 6 is the last chapter of thesis and final discussions, conclusions and recommendations are listed.

CHAPTER 2

LITERATURE REVIEW

Small hydroelectric power plants (Small HEPPs) are widely accepted to be the power plants that have less capacity than 10 MW (Paish, 2002). They have been popular in Turkey in recent years after the liberation of the energy market in 2001. Also small hydropower potential of Turkey is high because of being a mountainous country (Yuksel et al., 2008). Günyaktı et al. (2008) state that without expensive civil works, it is possible to develop high heads with relatively small discharges which can produce desired amount of energy. According to the study of Yuksel et al. (2008); 30.34 % of the hydropower energy will be generated from small HEPPs when the projects under design stage will be completed. Particularly, the result of a study show that 52.18 % of annual energy of all projects is in Eastern Black Sea Basin (Yuksel et al., 2008). According to Yuksel et al. (2008); the reasons behind high small hydropower potential in Eastern Black Sea Basin are being the wettest basin of Turkey as the annual total amount of precipitation in Rize goes up to 2329 mm and being covered with sharp valleys with steep slopes thus providing considerable heads and discharges.

Yanık et al. (2005) offer a method to obtain regional flow duration curves to determine the design discharge values of the regional hydroelectric potential in ungauged basins. Conventional methods like drainage area ratio methods to determine the flow duration curves (FDC) of the ungauged basins do not seem to be sufficient in large spatial scales. Eastern Black Sea Basin where Solaklı and Karadere basins are located is selected for the case study. Considering the specific flow duration curves and the probability of exceedance interval between 30 % and 100 % (the required interval for project discharges) and also using the cluster analysis methods, Solaklı and Karadere basins came up to be in the same homogeneous region. Moreover, an analytical function is fitted to calculate the specific discharge corresponding to a given exceedance probability within the range of 30 % and 100 %. The equation is given below and it is valid for the basins within region A that results from study of Yanık et al. (2005).

$$Q_t = 0.0668 - 0.002174t + 0.0002843t^2 - 0.0000001317t^3 \quad (2.1)$$

Where t is the flow percentile that is desired (%) and Q_t is the specific discharge corresponding to desired flow percentile ($m^3/s/km^2$).

Estimation of river runoff is one of the key works in the water resources applications. Mohamoud, (2008) in his study predicted flow duration curves and streamflow time series for ungauged catchment in the Mid-Atlantic Region, USA. Step-wise regression analysis is performed and the dominant climatic and landscape parameters are identified. The regional flow duration curves are also developed. Climate, geomorphologic and soil descriptors come out to be the dominant parameters that influence the hydrology of the selected regions. The constructed flow duration curves are then compared with the sites that are not included in the model for verification purpose. Furthermore, the streamflow time series that are predicted are compared with the catchments calculated by drainage area ratio methods.

Feasibility of the projects is based on head and discharge. Uncertainty in discharge estimation in ungauged catchments directly affects the feasibility. Therefore, setting a runoff model especially in poorly gauged basins has been attracting attention. Algancı et al., (2008); develop a regression model for Solaklı Basin which is one of the basins studied in this thesis. They use remote sensing (RS) and geographical information systems (GIS) to derive a digital elevation model (DEM). With the combination of hydro-meteorological data; they set up a regression model using GIS environment and verified the results using a sub-basin within Solaklı Basin. Both linear and logarithmic regression models are used and it is seen that logarithmic models provide better results compared to linear models. The parameters involved in these equations are mean basin elevation, basin area and rainfall values.

Snowmelt runoff is an important input for runoff in mountainous regions. Snowmelt runoff in mountainous eastern part of Turkey constitutes 60-70 % of total runoff during spring and early summer seasons where temperatures start to rise (Şorman A. A., 2005). In the study area where Solaklı and Karadere basins lie, snowmelt is an important input for the model since the mean altitude of the region is relatively high. In the literature, Zaherpour et al. (in press) include snow water equivalent (SWE) in long-term forecasting of riverflow and find out that snowmelt is a significant parameter in Dez Basin in Iran. They use both SWE and snow covered area (SCA) data and the results show that substituting SCA for SWE depths are acceptable. Besides, after determining all the parameters including temperature, rainfall, SWE and input flow, riverflow forecasting model is developed in one to six-month time steps (Zaherpour et al., in press). The forecasting is made for 1971-1977 period. On the other hand, for the 1990-1997 period where satellite images are available; the SCA data is used instead of SWE depths data in developing the forecasting model.

Precipitations are extremely variable, both spatially and temporally, and the knowledge of its areal mean is a prerequisite to any serious water balance computations (Valery et al., 2009). It is not possible to observe the mean areal precipitation. There is not a perfect areal estimation even in densely gauged experimental catchments and it is obviously worse in data-sparse mountainous regions (Valery et al., 2009). In the study of Valery et al. (2009), they present an attempt to "invert" the hydrological cycle and to use streamflow measurements to improve the knowledge of precipitation input in data-sparse mountainous regions. In other words, they utilize streamflow measurements in order to guess how much rain falls at higher elevations where no observations are made. In this paper, two data sets of 31 Swiss and 94 Swedish catchments and three simple long-term water balance formulas are used. A simple two-parameter correcting model to regionalize precipitation from the too sparse precipitation gauging network; the first parameter (α) aims to correct snow undercatch by precipitation gauges while the second one (β) targets the precipitation-elevation relationship (Valery et al., 2009). According to the results of this study; identification of precipitation-elevation (β) relationship is easier than that of snow undercatch (α).

Predicting streamflow time series or some hydrological indices (like specific percentiles of flow duration curves, mean annual flows, etc.) of ungauged or poorly gauged basins have always attracted attentions of scientists. In the study of Masih et al. (2010); a conceptual rainfall-runoff model (HBV) is used for streamflow simulations in a basin in Iran. There are four measures which are defined for hydrologic similarity between a catchment simulated by HBV model and a selected ungauged or poorly gauged catchment. These are; drainage area, spatial proximity, catchment characteristics and flow duration curve (FDC). FDCs could be established from some regionalization methods available in the literature (Masih et al., 2010). The aim of this paper is to check whether the parameters of a conceptual model of a gauged catchment could be transferred for simulating streamflows of an ungauged or poorly gauged basin or not. The results of this study show that the similarity measures which are drainage area, spatial proximity and catchment characteristics do not give satisfactory results. However, FDC provides the best results among all. By using a statistical criterion called relative root mean square error (RRMSE), the similarities of catchments can be analysed. Thus, catchment similarity based on FDCs provides a sound basis for transferring model parameters from gauged catchments to data limited catchments in the study area (Masih et al., 2010).

In the study of Li et al. (2010), a new regionalization approach called the “index model” and its application to predict flow duration curves in ungauged basins are presented. Each parameter in a hydrological predictive tool in ungauged catchments is estimated from a set of catchment characteristics and climatic variables by the index model. This model could also easily be interpreted for FDCs. In the selected catchments located in south east

Australia; climatic factors and some catchment characteristics like leaf area index, elevation and fraction of total native woody generation come out to be significant parameters. Furthermore, index model provides the most accurate predictions followed by linear regression among nearest neighbour and hydrological similarity techniques.

Post (2004), presents a different method for estimating flow duration curve (FDC) using logarithmic transformation. In this study FDC is defined using two parameters; the “cease to flow” point and the slope of FDC. This method is applied in a region in Australia (Burdekin catchment) and parameters are related to area, mean annual precipitation, drainage density and total stream length of the catchments. By this way, a regionalisation procedure is developed where FDC of an ungauged catchment could be estimated based on characteristics of the related catchment.

CHAPTER 3

DESCRIPTION OF THE STUDY AREA AND DATA COLLECTION

3.1 Description of the Study Area

The study region which is composed of the watersheds of Solaklı and Karadere streams locates in the Eastern Black Sea Region. These two watersheds are named according to their main streams. Karadere Watershed lies between the coordinates; 40° 48’- 40° 95’ north latitudes and 39° 72’ - 40° 10’ east longitudes. Solaklı Watershed lies between the coordinates 40° 18’ - 40° 95’ north latitudes and 40° 10’ - 40° 48’ east longitudes. Both lie within the province of Trabzon. Solaklı and Karadere watersheds are adjacent and the locations of Solaklı and Karadere watersheds in Turkey are shown in Figure 3.1.

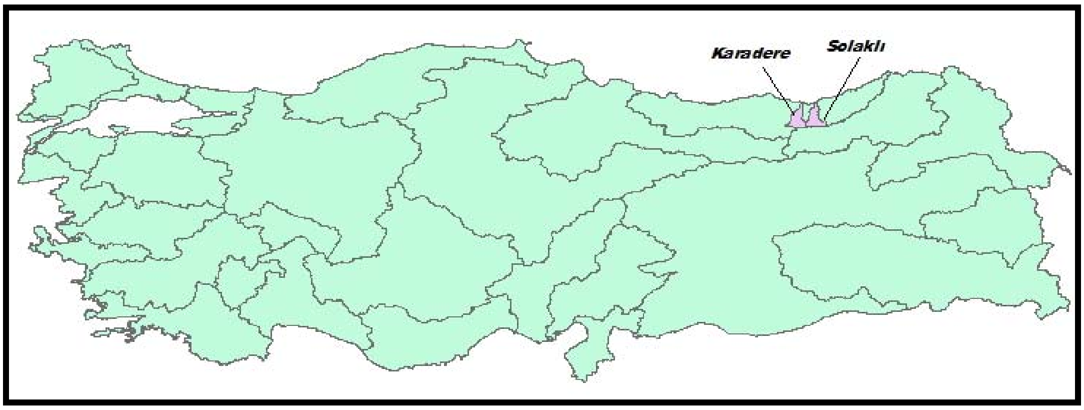

Figure 3.1 The locations of Karadere and Solaklı basins in Turkey

Karadere and Solaklı streams rise in the Horos Soğanlı and Haldizen mountains from about 2850 m and 3350 m respectively and flow into the Black Sea. The Kara Stream rises at the southeastern region of the basin and joins Alçak Stream at about 1600 m. Then the stream joins Karadere Stream at about 1410 m. For Solaklı Watershed; Haldizen Stream rises at southeastern region of the watershed and joins Solaklı Stream at about 300 m. The watershed boundaries and stream network are shown in Figure 3.2.

The areas of Karadere and Solaklı watersheds are 729.26 km^2 and 758.44 km^2 respectively. Solaklı Watershed is covered by 23% of coniferous forest, 20% of deciduous forest, 16% of bare land, 14% of pasture, 12% of rocky land and 12% of agricultural area (Alganci et al., 2010). Since the Karadere Watershed is adjacent to Solaklı Watershed; the land use distribution is expected to be almost same with that of Solaklı.

The main reason behind the selection of this project site is that there is a large amount of hydro-power potential and planned small HEPPs. Small HEPPs are going to contribute about 5% of all hydro-power energy when the small HEPPs under design stage are in operation. Furthermore, about more than 50 % of the small hydro-power energy potential is in the Eastern Black Sea region (Yüksel et al., 2008). Particularly, Solaklı and Karadere watersheds are two of the important streams in the region and are found to be in the same homogeneous region which is obtained as a result of the study of Yanık, et al. 2005.

3.2 Data Collection

3.2.1 Introduction

Hydrologic data are so important for hydrologic practices and science. These data are critical for performing risk assessment and economic analysis and also evaluating the impact of the water projects on public. Therefore, good, consistent historical data are essential for modeling to make accurate predictions (Web 2). The quality of data has a lot of importance also in scientific researches. Collection, arrangement and analysis of the hydrologic data are among the most time consuming activities in overall hydrologic studies (Zaherpour et al., in press). For collection, storage and analysis, most countries have one or more agencies responsible for the management of hydrologic data. In Turkey, State Meteorological Organization (DMI), State Hydraulic Works (DSI), Electrical Power Resources Survey and Development Administration (EIEI) and General Directorate of Rural Services (KHGM) collect and also analyze hydrologic and meteorologic data (Usul, 2001).

There are several types of data that are used in this study including hydro-meteorological data such as daily rainfall, daily temperature and mean daily discharges; topographic data such as digital topographic map and snow covered area (SCA) of the study area. The rainfall and temperature data are gathered from DMI, the discharge data are gathered both from DSI and EIEI. Also the snow covered area maps are obtained through the result of SEVIRI image files (Surer, 2008). The input for the digital elevation model is gathered from DSI.

3.2.2 Hydro-Meteorological Data

The meteorological stations in Turkey are set up and operated by DMI and DSI. There are two meteorological stations in Karadere and three meteorological stations in Solaklı watersheds. All of the stations in both basins are operated by DMI. These stations measure daily rainfall and temperature. The ones in Karadere Watershed are Dağbaşı DMI and Kayaiçi DMI which are both closed among which Kayaiçi DMI does not have any records. In Solaklı Watershed, there are Çaykara DMI, Köknar DMI and Uzungöl DMI among which only Uzungöl DMI is under operation. Also Köknar DMI has no records. Only Uzungöl DMI, Dağbaşı DMI and Çaykara DMI stations are used for the analysis and processing of meteorological data. Trabzon DMI, Trabzon Meydan DMI and Rize DMI are the stations that are outside the study area. Trabzon DMI was closed in 2005 and then Trabzon Meydan DMI was put into operation.

Mean annual rainfall values and seasonal rainfall values for the spring month of Uzungöl DMI, Dağbaşı DMI and Çaykara DMI are transferred to the median elevation of the basins in order to acquire a representative mean areal rainfall value for the related watersheds. Mean daily temperature values of the same stations used for rainfall analysis are also used to get a significant relationship with the daily snow covered area data of each basin which are explained later in Chapter 3.2.4.

The networks in two watersheds are insufficient in order to have an idea about the areal mean precipitation values. Only in three stations there are some records of precipitation and the network density is about 500km^2/station. According to World Meteorological Organization (WMO), the mountainous regions of temperate zones should have at least 200 km^2/station (Usul, 2001). Also the observation periods of the related stations do not seem to be sufficient since Dağbaşı DMI and Çaykara DMI have relatively shorter measured periods and both have discontinuous measurements as well as Uzungöl DMI. The locations of the meteorological stations within the watersheds of Solaklı and Karadere are seen in Figure 3.2. In Table 3.1, there are some properties of the stations which are within the basin. In this table, the coordinate information of Uzungöl DMI and the other big climate stations are taken from the website of DMI. The coordinate information of Çaykara DMI and Dağbaşı DMI are gathered from Meteorological Bulletin of DMI published in 1995.

Table 3.1 Some Properties of the Meteorological Stations within Solaklı and Karadere Watersheds

Station No	Station Name	Station Type	Coordinates		Elevation (m)	Mean Annual Temperature (°C)	Mean Annual Rainfall (mm)	Observation Period
			X (m)	Y (m)				
1962	Uzungöl DMI	Small Climate	608526	4497033	1355.0	8.4	1116.85	1983-2009
1801	Çaykara DMI	Small Climate	611181	4511840	400.0	12.4	998.51	1989-1998
1787	Dağbaşı DMI	Small Climate	577432	4509523	545.0	12.4	646.38	1989-1998
17037	Trabzon DMI	Big Climate	564004	4538814	30.0	14.6	833.94	1975-2005
17038	Trabzon Meydan DMI	Big Climate	564004	4538814	38.8			2005-2008
17040	Rize DMI	Big Climate	626164	4544172	8.6	14.1	2246.32	1975-2008

The discharge measurements in the streams in Turkey are made by EIEI and DSI. There are also some separate individual flow gauging stations within the project area, operated by private sector institutions. Average daily discharge measurements are collected from the stations. There are four streamflow gauging stations in Solaklı Watershed and six in Karadere Watershed. 2202, 2240 and 2234, operated by EIEI, 22-44, operated by DSI and 22-222 and 22-208 operated by private sector are the stations that are present in Karadere Watershed. 2203, operated by EIEI, 22-52, 22-57 and 22-07, operated by EIEI, are the streamflow gauging stations that are present in Solaklı Watershed. 2240 namely Karadere-Pervane Köprü streamflow gauging station was in operation just for two years between the years 1965-1966 and 2203 namely Of Deresi-Dernekpazar streamflow gauging station was in operation between 1943 and 1949 and then it was closed. So these two stations stated above are not used because their observation period is considered to be very short. In Table 3.2 some properties of the stations are seen. Also in Figure 3.2, the network of the streamflow gauging stations is demonstrated.

Table 3.2 Some Characteristics of the Streamflow Gauging Stations within Solaklı and Karadere Watersheds

Flow Gauging Stations	Elevation (m)	Catchment Area (km^2)	Coordinates (X) (m)	Coordinates (Y) (m)	Evaluated Years
2202 Karadere - Ağnas	105	633.2	584351	4520932	1943–1950, 1953–1958, 1967–2010
22-44 Karadere - Aytaş	527	426.8	576137	4503949	1978–1983, 1987–1988, 1992, 1995–1996, 1999–2010
2234 Karadere - Erikli	1362	204.3	580574	4495249	1965–1974
22-52 Solaklı Stream- Ulucami	295	560.1	605175	4511794	1979–1997, 1999–2010
22-57 Ögene Stream - Alçakköprü	675	240.1	602665	4502811	1979–1983, 1985, 1987–1989, 1991–1992, 1994–1996, 2000–2005
22-007 Haldizen Stream - Serah	1114	149.2	609610	4497257	1966–1967, 1972–1977, 1979–1981, 1983–1994, 1996–1997, 1999–2007
22-208 Ortacag	870	38.7	579795	4508077	2007–2010
22-222 Canak-II	1880	9.2	583751	4504789	2007–2010

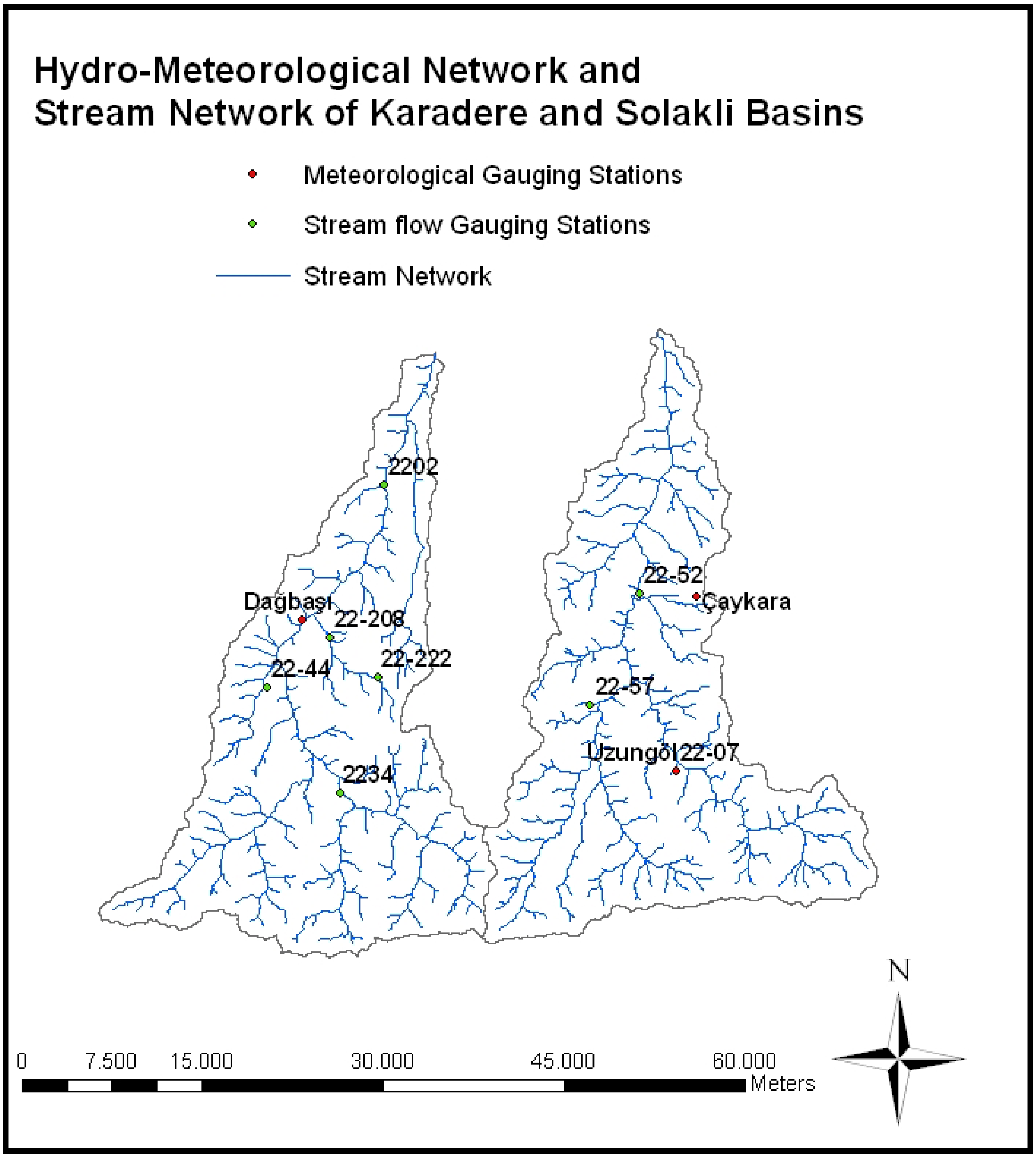

Figure 3.2 Hydro-Meteorological Network and Stream of Karadere and Solaklı Basins

3.2.3 Topographic Data

Topographic map is important to obtain the parameters like linear measures, relief or slope parameters, shape and morphological parameters which influence the surface runoff. The digital elevation models (DEM) of the Karadere and Solaklı basins are shown in Figure 3.3 and Figure 3.4 respectively. These models are acquired from ASTER DEM products which are in 30x30m resolution obtained from internet (Web 3). In Figure 3.3 and Figure 3.4 the outlet points of the basins are the most downstream points that are necessary for this study, in other words the last gauging station or facility site, since more downstream of these points are not used in the modeling studies.

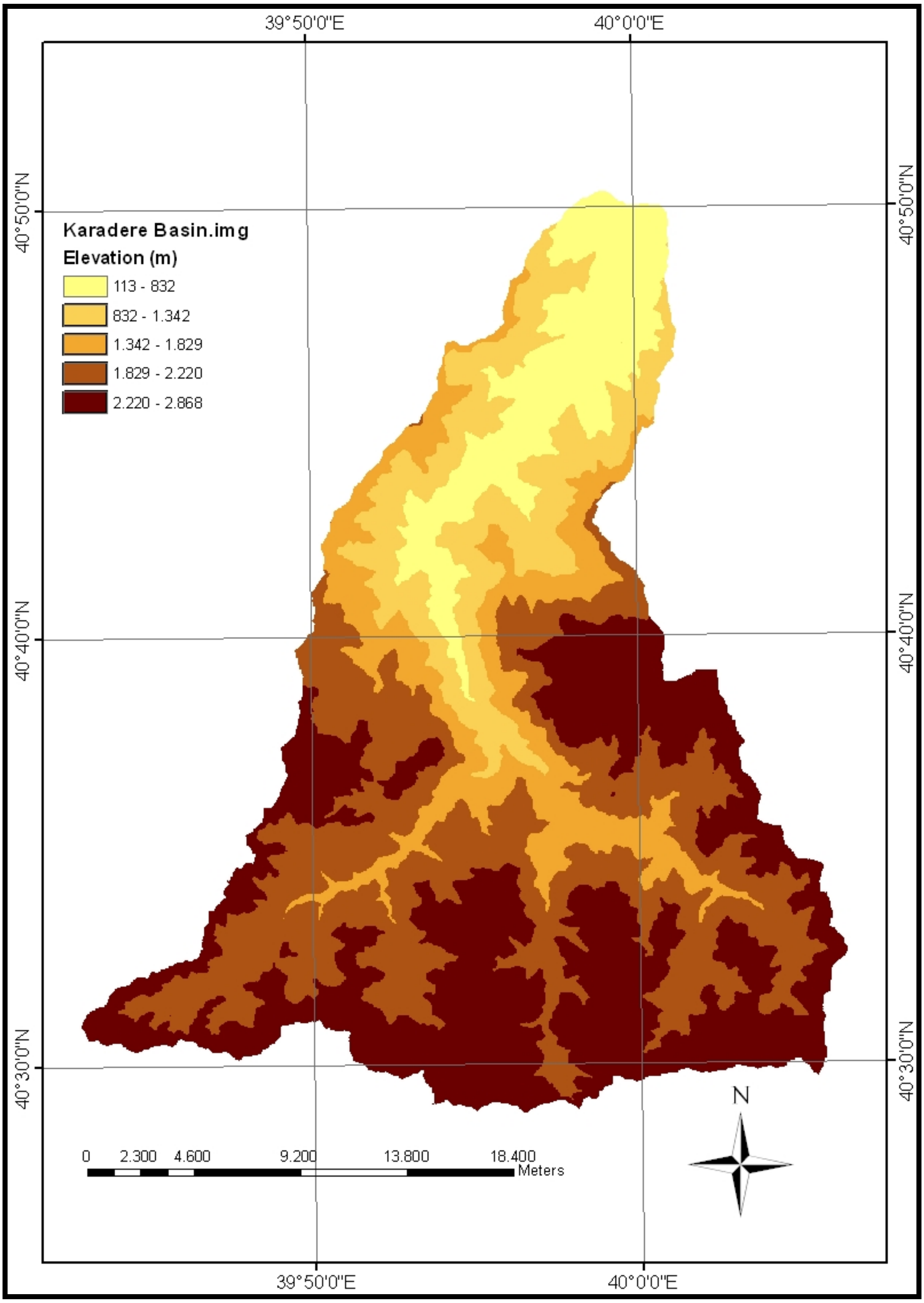

Figure 3.3 DEM of Karadere Basin

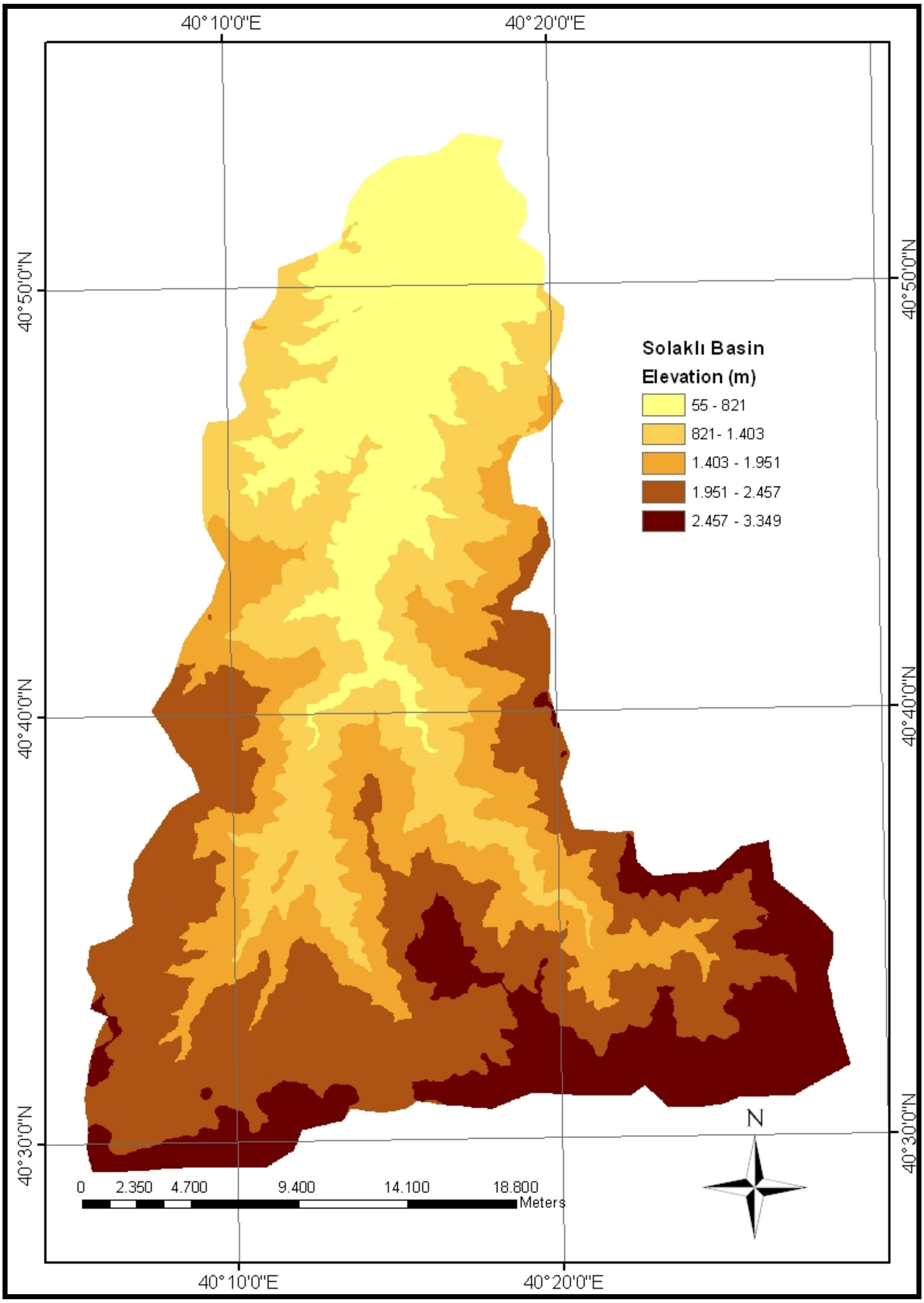

Figure 3.4 DEM of Solaklı Basin

3.2.4 Snow Covered Area Data

In the regions where the altitude is relatively high, snow is the main source of streamflow. According to Usul, 2001; especially in the mountainous regions of Eastern Anatolia, 70% of river flow is due to snowmelt and the snowmelt season in Turkey generally begins in the spring and lasts till early summer season which is a long season. Being a relatively mountainous region, the snowmelt in Eastern Black Sea Basin contributes to the streamflow significantly. Therefore, investigating the effect of snowmelt on streamflow generation, especially in spring months, is important in this study.

In this context; monitoring, modeling and quantification of the snow covered area data (SCA) are critical. In recent years there have been a lot of technological and scientific developments on mapping snow covered areas using remote sensing techniques. MSG SEVIRI is one of the recent satellites that is powerful in mapping snow covered areas (Surer, 2008).

The snow covered area data are gathered from the SEVIRI SR (Snow Recognition) products of the months between January and May of the years 2008 and 2009. A pixel value based algorithm is developed for SR over mountainous areas of Europe. This method is using the satellite images acquired every 15 minutes from a geostationary satellite; Meteosat Second Generations (MSG) instrument Spinning Enhanced Visible and Infra-Red Imager (SEVIRI). Cloud can be distinguished from snow by the algorithms used to produce the SEVIRI SR products (Surer, 2008).

In Figure 3.5, a picture of a SEVIRI SR product is seen. In this figure, snow is shown in white color, clouds are shown in cyan color, water is shown in blue color and land is shown in green color.

The SEVIRI SR products are used indirectly in the seasonal model. With the help of GIS, snow covered area values are represented as a percentage of snow cover to the total area of the related basin. After determining the snow covered areas as percentage, the relationship between mean daily temperature of each basin for the snowmelt season and snow covered area of each basin is studied since mean daily temperature is found to be significant in previous studies (Zaherpour et al., in press).

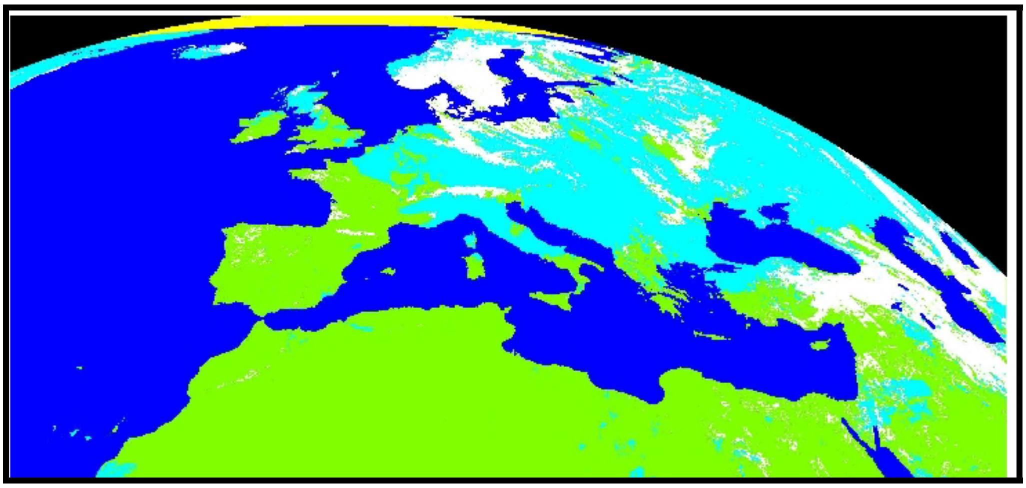

Figure 3.5 An image file from a SEVIRI SR product

3.2.5 Characteristics of the Facility Sites

The Eastern Black Sea Basin is the basin with the largest potential for small HEPPs (Yuksel et al, 2008). Solaklı and Karadere basins are the two basins which are very popular in this case. To increase the sample size in the study area, the basins of each project are also delineated besides flow gauging stations.

There are several HEPP projects in both Solaklı and Karadere basins. For Karadere basin, four projects are selected and seven projects are selected for Solaklı watershed. All of these projects are the projects of private companies. Some important properties of these projects were gathered from DSI IV. Planning Directorate. The lists of the projects and their related properties are given below in Table 3.3 and Table 3.4. In Figures 3.6 and 3.7, the locations of the diversion weirs and their related HEPPs can be seen.

Table 3.3 Some Properties of the HEPPs and Diversion Weirs Located within Karadere Watershed

NAME OF THE FACILITY	COORDINATES OF THE DIVERSION WEIR (X, Y) (m) (UTM)	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
Çanak-I REG	4503635, 579975	10.0	1.4	13	1967-2003	5.60
Bangal REG	4495540, 575090	17.0	5.8	13	1967-2003	135.50
Erikli REG	4495600, 580500	78.0	12.3	13	1967-2001	209.00
Akkocak REG-HEPP	4496300, 577425					349.00

Table 3.4 Some Properties of the HEPPs and Diversion Weirs Located within Solaklı Watershed

NAME OF THE FACILITY	COORDINATES OF THE DIVERSION WEIR (X, Y) (m) (UTM)	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
Uzungöl-I HEPP	4498674, 608432	28.2	12.0	8.5	1966-2005	170.80
Arca HEPP	4526774, 607931	16.4	39.0	12.5	1979-2003	734.60
Güneşli-II HEPP	4518660, 606340	12.6	31.0	16.0	1971-2003	653.00
Çaykara HEPP	4512338, 605451	27.0	23.8	18.0	1979-2004	568.00
Ballıca HEPP	4522577, 608148	13.8	39.0	12.0	1979-2006	703.20
Irmak REG (Esentepe HEPP)	4496639, 602194	16.2	10.0	12.0	1968-2003	119.18
Oğlaklı REG (Esentepe HEPP)	4497200, 601208					88.25

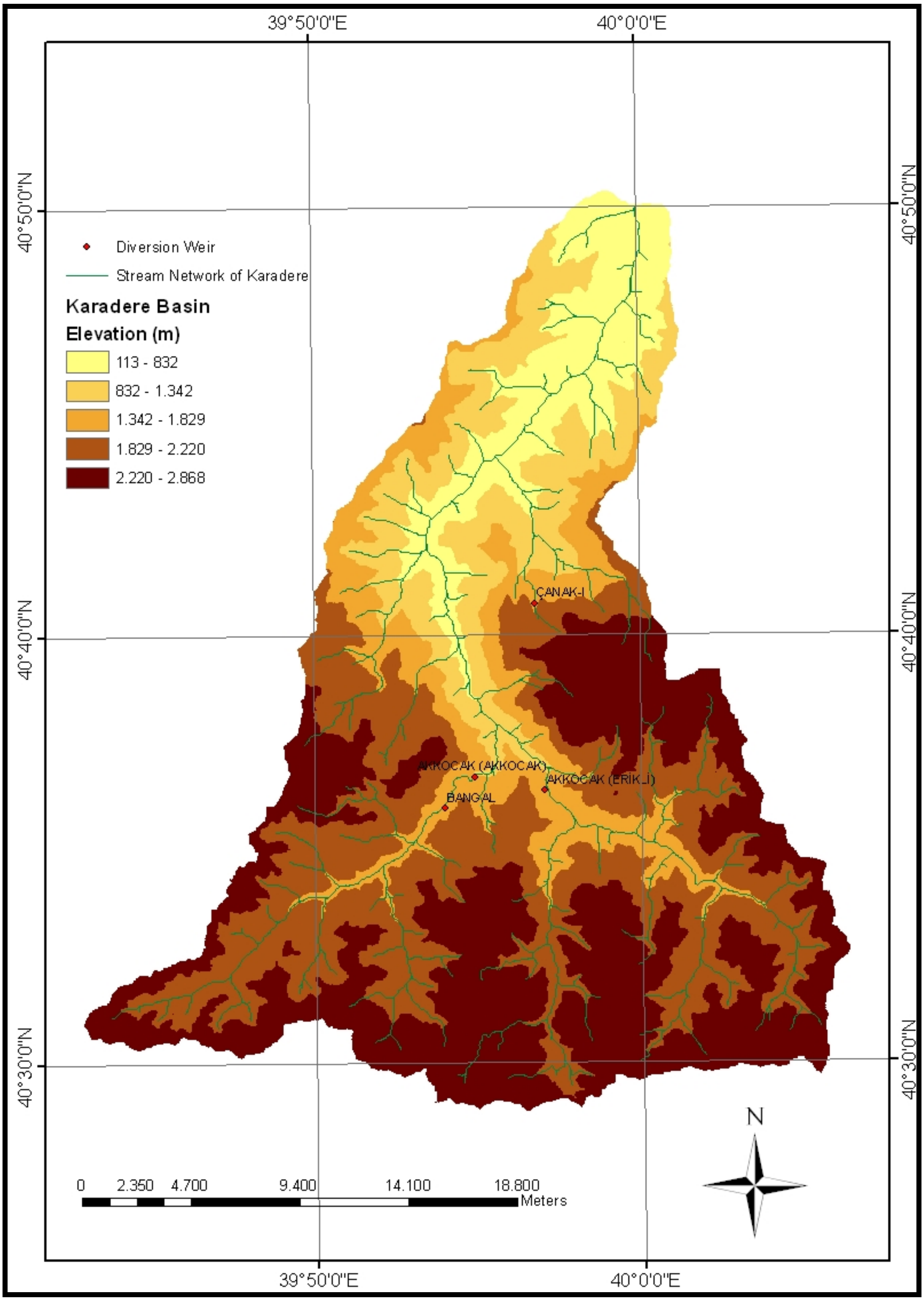

Figure 3.6 The Locations of the Planned Projects within Karadere Basin

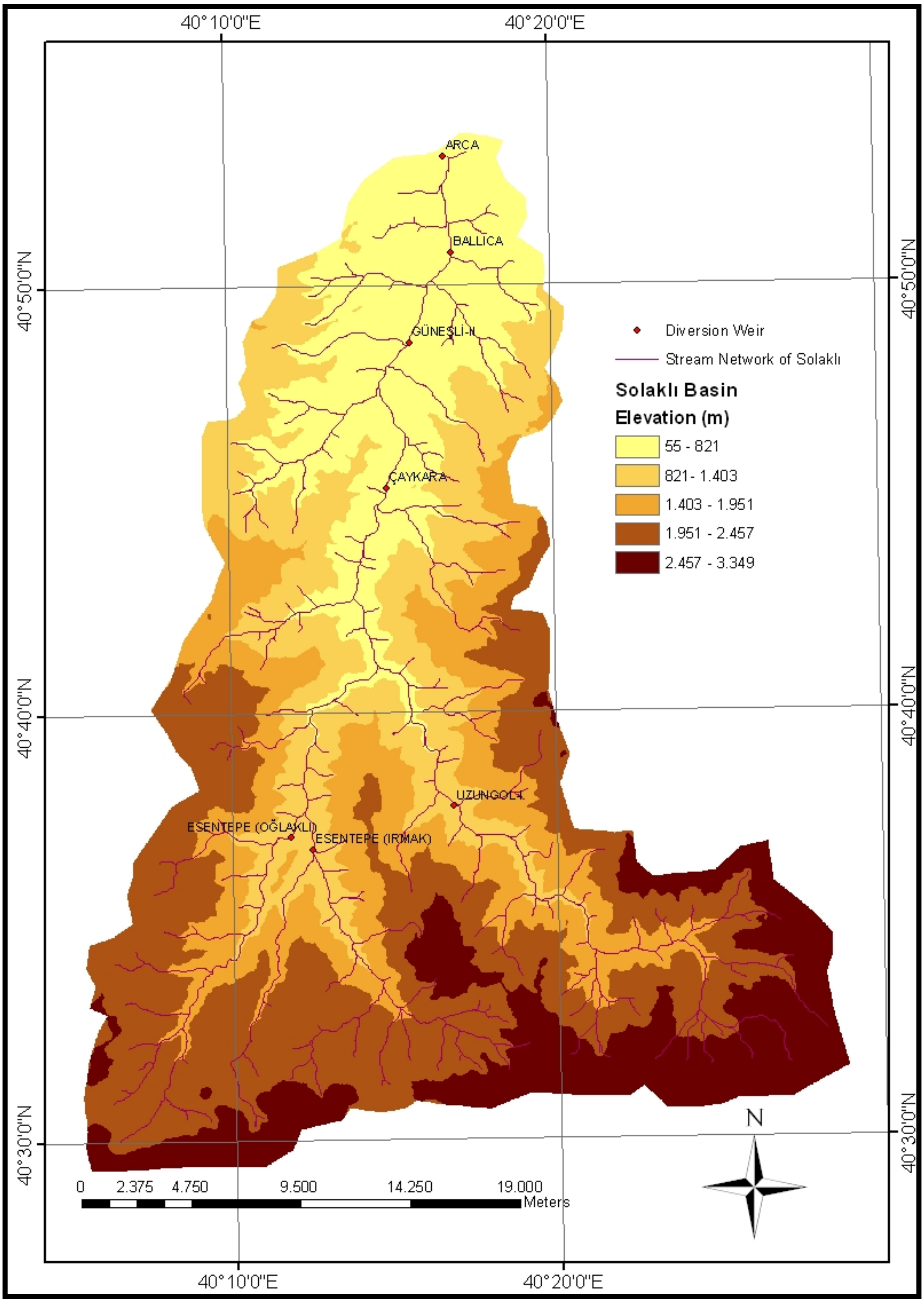

Figure 3.7 The Locations of the Planned Projects within Solaklı Basin

CHAPTER 4

PROCESSING AND ANALYSIS OF DATA

4.1 Rainfall Data

In this study, rainfall data are collected from meteorological stations which are point observations. As stated in Chapter 3.2.2, Dağbaşı DMI is the only meteorological station within Karadere Watershed; Çaykara DMI and Uzungöl DMI are the two stations in Solaklı Watershed that are used as valid rainfall measuring stations. Outside the study area, there are Trabzon DMI and Rize DMI stations. The necessary information about the stations like the periods of observation, coordinates and elevations are given in Table 3.1.

Firstly, the rainfall values of each meteorological station are analyzed. It is seen that there are some missing values and discontinuities in the stations. There are several methods to estimate missing records of a station using the surrounding stations like station average method, normal ratio method, inverse distance weighting method and regression (Dingman, 2002). In this study, the regression method is used since the other methods are not appropriate to be used. The other methods could be used whenever the number of stations is more than one, but for this study only Uzungöl DMI is the appropriate meteorological station that is used for regression analyses since Trabzon Meydan (Trabzon) DMI and Rize DMI are not found to be suitable to be used to complete the missing values because of low determination coefficient value which is explained in the following paragraph.

Trabzon Meydan DMI is accepted to be the continuation of the closed station Trabzon DMI because their locations are very close. This assumption is accepted also by DMI. So Trabzon Meydan (Trabzon) DMI is the true denotation for these stations.

It is obvious that there is no relationship between the values of Trabzon Meydan (Trabzon) DMI and the values of other stations as the highest value of coefficient of determination (R^2) is 0.45 which is between Trabzon Meydan (Trabzon) DMI and Çaykara DMI. Besides, the same situation as Trabzon Meydan (Trabzon) DMI is valid for Rize DMI since the highest R^2 value is 0.22 which is not sufficient. Therefore, Trabzon Meydan (Trabzon) DMI and Rize DMI are not used to complete the missing values. The reasons behind the low values of coefficient of determination values of the relationships stated above, the distance and the elevation difference between the meteorological stations Trabzon Meydan (Trabzon) DMI, Rize DMI and the stations inside the selected study area are very big.

November month of 1996 in Uzungöl DMI is missing and since there are no other stations for Uzungöl DMI to complete; the mean monthly rainfall value of November month, 119.36 mm, is accepted to be the missing value of 1996 November of Uzungöl DMI. Also the period for the analyses of rainfall data of Uzungöl DMI is accepted to be between 1991 and 2009 although the measurements started in 1983. The reason behind this is the discontinuity of Uzungöl DMI rainfall data before the year 1991.

4.1.1 Dağbaşı DMI

Dağbaşı DMI started to measure rainfall depths in 1989 and it was closed ain1998. There are discontinuities in the measurements of Dağbaşı DMI. There are not any measured data in 1992 and 1996 whereas some months of 1997 and 1998 are lacking. Furthermore, the data in 1989 are not taken into account because in that year there are not any data in Uzungöl DMI. Three kinds of regression analyses are performed by considering different periods of the year to complete the missing values of Dağbaşı DMI. The independent variable in this model is Uzungöl DMI.

First regression analysis is performed by taking account of whole year data. The second analysis is performed by dividing the year into two halves whereas half years are fall-winter (starting from the beginning of September till the end of February) and spring-summer (starting from the beginning of March till the end of August) periods. The last one is considering each season as winter, spring, summer and fall according to calendar year. The list of the equations and coefficient of determination values are given in Table 4.1.

Table 4.1 The List of Equations and R^2 Values Depending on Different Regression Analyses Between Dağbaşı DMI – Uzungöl DMI

	Fall	Winter	Spring	Summer
Annual	$y = 0.523x + 3.971$, $R^2 = 0.62$.			
Half-Annual	$y = 0,434x + 10,473$, $R^2 = 0,58$		$y = 0,682x - 7,299$, $R^2 = 0,71$	
Seasonal	$y = 0,499x + 8,558$ $R^2 = 0,71$	$y = 0,333x + 14,777$ $R^2 = 0,45$	$y = 0,740x - 15,656$ $R^2 = 0,67$	$y = 0,749x - 9,611$ $R^2 = 0,55$

The mean annual rainfall values of Dağbaşı DMI were calculated considering the regression equations shown above. The results with the relative errors are given in Table 4.2.

Table 4.2 Mean Annual Rainfall Values, Seasonal Variations and Relative Errors of Dağbaşı DMI for Various Regression Analyses, mm

		Fall	Winter	Spring	Summer
Annual	By Equation	638			
	Observed	634			
	Relative Error (%)	1			
Half-Annual	By Equation	319		320	
	Observed	311		323	
	Relative Error (%)	3		1	
Seasonal	By Equation	187	133	164	157
	Observed	182	129	173	150
	Relative Error (%)	3	3	5	5

When both the regression equations with determination coefficients and the relative errors are examined; it is seen that the variation of R^2 values and relative errors between seasons are not low and it is decided to complete the missing values of Dağbaşı DMI by annual regression equation y = 0.523x + 3.971, R^2=0.62. The mean monthly rainfall values of Dağbaşı DMI are given below in Table 4.3. Please note that bold values are the values that are completed from Uzungöl DMI by the related equation provided above. The scatter diagram with the accepted regression equation and R^2 value is also given in Figure 4.1.

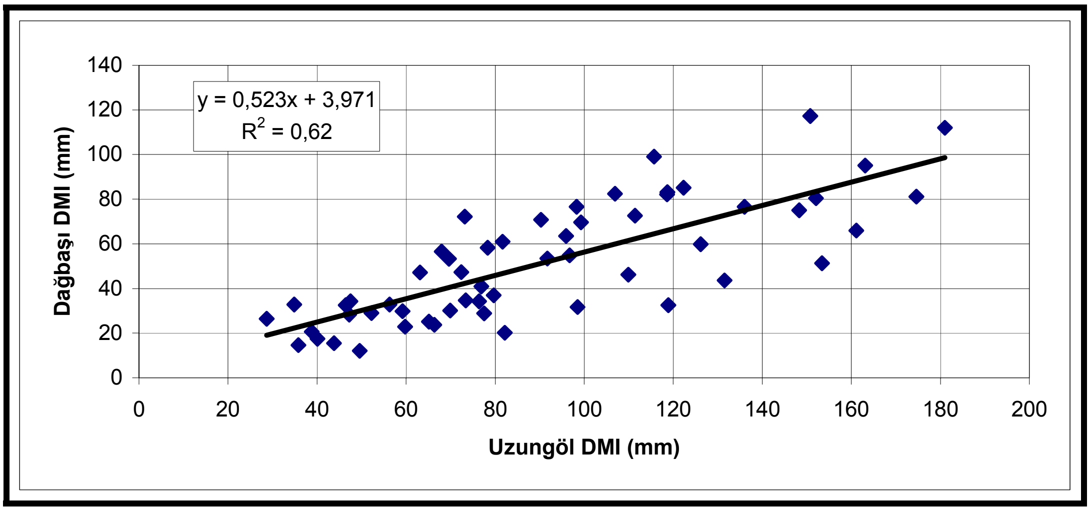

Figure 4.1 Regression Equation of Uzungöl DMI and Dağbaşı DMI

Table 4.3 Mean Monthly Rainfall Values of Dağbaşı DMI, mm

Years	Months												
	January	February	March	April	May	June	July	August	September	October	November	December	Yearly Total
1990	46,2	47,1	33,3	114,1	80,1	76,1	18,3	11,2	62,9	90,1	70,8	34,2	684,4
1991	34,7	41,0	54,9	28,8	95,1	82,5	15,5	53,4	17,5	72,7	34,2	31,7	562,0
1992	**84,0**	**105,7**	**37,7**	**45,4**	**60,1**	**59,7**	**70,5**	**30,2**	**69,6**	**59,3**	**107,2**	**35,6**	765,0
1993	81,1	53,3	30,1	99,0	47,3	76,6	25,2	22,9	32,8	20,6	112,0	32,9	633,8
1994	28,3	85,2	47,2	29,0	20,2	75,1	37,0	12,1	32,5	63,5	83,1	59,8	573,0
1995	23,7	14,7	58,3	82,1	46,2	117,2	72,2	56,6	69,6	80,4	65,9	29,8	716,7
1996	**17,7**	**31,5**	**22,5**	**67,8**	**25,1**	**52,1**	**42,7**	**64,5**	**61,1**	**102,3**	**66,4**	**45,7**	599,4
1997	**60,7**	**53,2**	**73,2**	**46,5**	**54,9**	**47,0**	**57,5**	**31,6**	**59,2**	76,6	26,4	61,0	647,7
1998	43,7	32,5	51,3	**53,1**	**73,6**	**52,7**	**31,2**	**49,7**	**38,0**	**40,9**	**47,8**	**47,5**	562,0
Average	46,7	51,6	45,4	62,9	55,8	71,0	41,1	36,9	49,2	67,4	68,2	42,0	638,2

The mean annual rainfall depth is 638.2 mm for Dağbaşı DMI.

4.1.2 Çaykara DMI

Çaykara DMI started to measure rainfall depths in 1989 as the same as Dağbaşı DMI. There are also missing data for this station where in 1996 has no ever data; in 1997 and 1998 there are missing data in some months. The period for the analyses starts also at 1990. The same methodology that is explained in Chapter 4.1.1.1 for completion of missing values of Dağbaşı DMI is applied for Çaykara DMI. The list of the equations and related R^2 values are given in Table 4.4.

Table 4.4 The List of Equations and R^2 Values Depending on Different Regression Analyses between Çaykara DMI – Uzungöl DMI

	Fall	Winter	Spring	Summer
Annual	$y = 0{,}804x + 6{,}582$, $R^2 = 0{,}65$			
Half-Annual	$y = 0{,}779x + 13{,}736$, $R^2 = 0{,}74$		$y = 0{,}810x + 1{,}132$, $R^2 = 0{,}53$	
Seasonal	$y = 0{,}901x + 6{,}646$, $R^2 = 0{,}84$	$y = 0{,}628x + 23{,}626$, $R^2 = 0{,}64$	$y = 1{,}054x - 36{,}840$, $R^2 = 0{,}77$	$y = 1{,}062x - 3{,}342$, $R^2 = 0{,}63$

The mean annual rainfall values of Çaykara DMI are calculated considering the regression equations shown above. The results with the relative errors are given in Table 4.5.

Table 4.5 Mean Annual Rainfall Values and Relative Errors of Çaykara DMI for Various Regression Analyses

		Fall	Winter	Spring	Summer
Annual	By Equation	994			
	Observed	1014			
	Relative Error (%)	2			
Half-Annual	By Equation	552		440	
	Observed	567		447	
	Relative Error (%)	3		2	
Seasonal	By Equation	312	244	200	245
	Observed	245	322	206	241
	Relative Error (%)	27	24	3	2

If the determination coefficients and relative errors are compared between three different periods, the error variation and the values of R^2 between the seasons can easily be seen. This variation is much higher than that of Dağbaşı DMI. Therefore, the annual regression equation y = 0.804x + 6.582, R^2=0.65 is accepted for completion of missing values of Çaykara DMI. The scatter diagram and the accepted regression equation with its R^2 value are given in Figure 4.2. Also the mean monthly rainfall values of Çaykara DMI are given in Table 4.6. Bold values are the values that are completed from Uzungöl DMI.

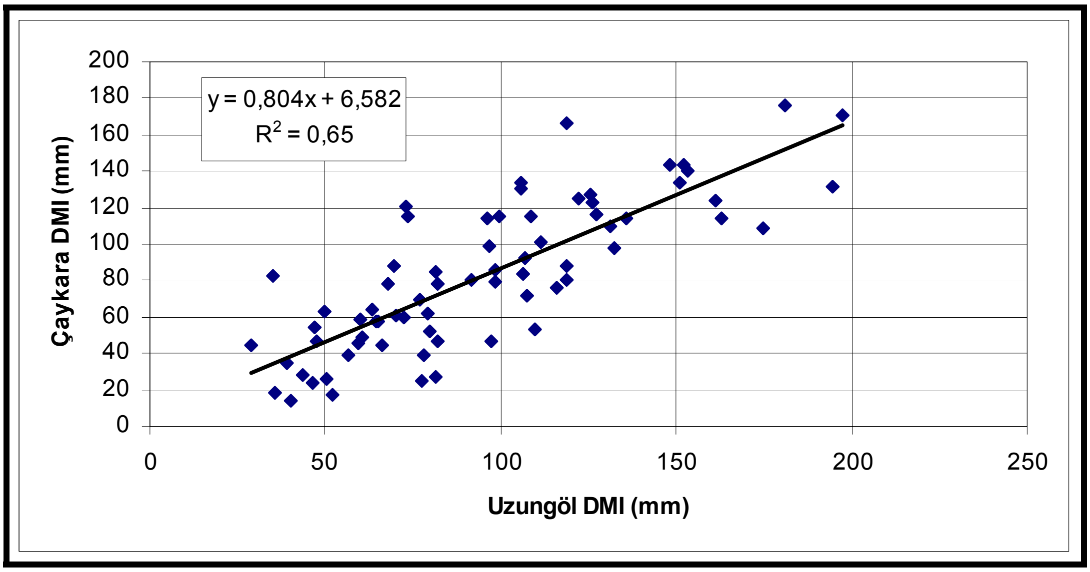

Figure 4.2 Regression Equation of Uzungöl DMI and Çaykara DMI

Table 4.6 Mean Monthly Rainfall Values of Çaykara DMI, mm

Years	Months												
	January	February	March	April	May	June	July	August	September	October	November	December	Yearly Total
1990	88,6	66,4	39,2	158,6	112,6	114,4	32,8	48,0	86,4	161,8	114,6	77,4	1100,8
1991	115,2	69,4	99,4	24,8	114,6	92,8	28,0	80,4	14,4	101,0	46,2	86,2	872,4
1992	140,6	131,2	57,4	62,2	71,8	83,8	116,2	26,4	127,1	130,4	170,5	48,6	1166,2
1993	109,1	88,3	60,8	76,2	59,5	114,0	57,9	58,9	82,2	34,6	175,7	39,2	956,4
1994	54,4	124,9	64,2	17,0	46,7	144,0	51,8	62,7	23,8	113,8	166,5	122,6	992,4
1995	44,5	18,5	39,4	80,7	52,9	134,0	121,1	78,1	115,3	143,0	124,1	46,1	997,7
1996	**27,6**	**49,0**	**35,0**	**104,8**	**39,1**	**80,6**	**66,2**	**99,6**	**94,4**	**157,8**	**102,5**	**70,7**	927,3
1997	115,4	**82,2**	97,9	26,9	46,3	78,7	**88,9**	**49,1**	134,2	79,8	44,8	84,8	929,1
1998	110,2	87,6	**129,9**	**82,1**	**113,6**	**81,4**	**48,5**	**76,9**	**58,8**	**63,3**	**74,0**	**73,6**	999,9
Average	89,5	79,7	69,3	70,4	73,0	102,6	67,9	64,5	81,8	109,5	113,2	72,1	993,6

The mean annual rainfall depth is 993.6 mm for Çaykara DMI.

4.1.3 Uzungöl DMI

The mean monthly rainfall values of Uzungöl DMI are also given in Table 4.7. The bold value that is the November month of 1996 is completed by accepting the mean November rainfall depth as for 1996 November month as explained before.

Table 4.7 Mean Monthly Rainfall Values of Uzungöl DMI, mm

Years	Months												
	January	February	March	April	May	June	July	August	September	October	November	December	Yearly Total
1991	73,4	76,9	96,7	77,5	163,1	106,9	43,8	91,7	40,1	111,4	47,5	98,5	1027,5
1992	153,1	194,5	64,4	79,3	107,3	106,5	127,2	50,2	125,5	105,7	197,4	60,5	1371,6
1993	174,6	69,6	69,9	115,7	72,4	136,0	65,1	59,8	34,9	38,8	181,0	56,3	1074,1
1994	47,2	122,3	63,1	52,2	82,2	148,3	79,7	49,6	46,4	95,9	118,7	126,2	1031,8
1995	66,3	35,8	78,3	118,6	109,9	150,8	73,2	68,0	99,3	152,1	161,1	59,2	1172,6
1996	26,2	52,7	35,4	122,1	40,4	92,1	74,1	115,7	109,2	188,1	**119,4**	79,7	1055,1
1997	108,4	94,1	132,4	81,3	97,3	82,2	102,4	52,9	105,6	98,3	28,7	81,7	1065,3
1998	131,5	118,9	153,4	93,9	133,1	93,1	52,1	87,5	65,0	70,6	83,8	83,3	1166,2
1999	31,9	59,5	108,3	132,9	163,6	82,8	68,2	60,7	72,7	96,7	92,1	34,3	1003,7
2000	171,9	107,2	111,4	71,2	69,8	116,7	38,1	120,3	89,2	154,3	12,2	126,5	1188,8
2001	14,3	87,8	90,0	134,2	154,8	108,6	74,4	69,6	35,6	107,7	154,3	103,7	1135,0
2002	125,8	42,5	100,9	117,6	60,6	152,9	69,2	85,9	82,7	88,5	96,6	116,4	1139,6
2003	50,3	86,9	117,2	88,4	38,5	54,4	61,0	53,4	103,9	155,9	111,4	62,5	983,8
2004	85,5	171,1	129,6	111,6	172,1	139,2	43,2	71,0	39,1	66,3	218,0	71,4	1318,1
2005	84,1	67,5	115,0	120,3	102,7	142,0	30,5	91,7	56,4	229,8	146,2	67,7	1253,9
2006	88,7	86,2	104,8	139,5	118,9	57,5	134,4	15,0	66,0	131,1	185,9	127,9	1255,9
2007	93,1	47,5	119,6	117,7	49,6	62,4	95,8	95,6	38,7	74,9	143,8	87,8	1026,5
2008	123,2	62,0	40,5	75,5	114,2	111,8	76,8	67,6	85,3	105,8	22,8	72,6	958,1
2009	0,0	123,9	140,7	65,6	96,5	79,9	100,9	37,8	122,7	49,6	246,9	76,4	1140,9
Average	86,8	89,8	98,5	100,8	102,5	106,5	74,2	70,7	74,6	111,7	124,6	83,8	1124,7

Mean annual rainfall value for Uzungöl DMI is 1124.7 mm.

4.1.4 Areal Estimation of Rainfall

For many applications in hydrology, areal precipitation values are input to hydrologic models. For the model in this study, mean areal rainfall values that are representative for each basin are determined for the model. There are several techniques used to estimate mean areal rainfall values of a particular region, generally a drainage basin. There are principally two methods: first one is direct weighted averages and the second one is surface fitting methods. The first method includes: arithmetic average, thiessen polygons and two-axis method. The second one includes isohyetal method, kriging, conventional hypsometric method and algorithmic hypsometric methods. The techniques to be used depend on several factors such as the number of stations, objective of study and the nature of the region (Dingman, 2002).

In this study a different technique which belongs to the direct weighted averages method is used to estimate areal rainfall. In this technique the orographic effect on rainfall is considered. This means that precipitation increases with the elevation. The formula is given by (Web 4):

$$P_h = P_{ref}\,(1 + (\frac{h}{h_{ref}})p_{cor}) \tag{4.1}$$

where P_{ref} is the precipitation at the observation station, P_h is corrected precipitation, h is the height to which the precipitation is corrected, h_{ref} is the height of observation station and p_{cor} is the correction factor. p_{cor} is assumed to be 5% (A.A. Şorman, personal communication, June 25 2010). However this formula is wrong since the precipitation amount at the target point becomes always greater than the precipitation amount in reference station. So this formula is corrected as:

$$P_h = P_{ref}(1+(\frac{h_{ref}-h}{100})p_{cor}) \quad (4.2)$$

is the modified formula after the precipitation amount in the observation station is corrected by catch deficiency by the formula given:

$$P_{ref} = P \times p_{catch} \quad (4.3)$$

Here the p_{catch} is assumed to be 0.3 %. This correction factor is also gathered by personal communication.

The formula mentioned in Equation 4.2 is used to calculate the rainfall amount at the median elevation of each basin. Median elevation of each basin is assumed to represent mean areal rainfall of the basin.

4.2 Temperature Data

Temperature records are also collected from Çaykara DMI, Dağbaşı DMI, Trabzon Meydan (Trabzon) DMI, Rize DMI and Uzungöl DMI. The main purpose to collect temperature records of the related meteorological stations is to determine mean daily temperature values of each basin for certain periods of 2008 and 2009 years to look for a relationship with snow covered areas (SCA) for Solaklı and Karadere basins in order to replace mean annual or seasonal temperature values instead of SCA values in the final regression model. The station used for the analysis is Uzungöl DMI since Dağbaşı DMI and Çaykara DMI were closed at 1998. In addition, Trabzon Meydan (Trabzon) DMI and Rize DMI are not used in calculations because they locate outside the study areas.

To estimate the missing data of Dağbaşı DMI and Çaykara DMI, seasonal regression analyses are performed and the results are given in Figure 4.3 and 4.4.

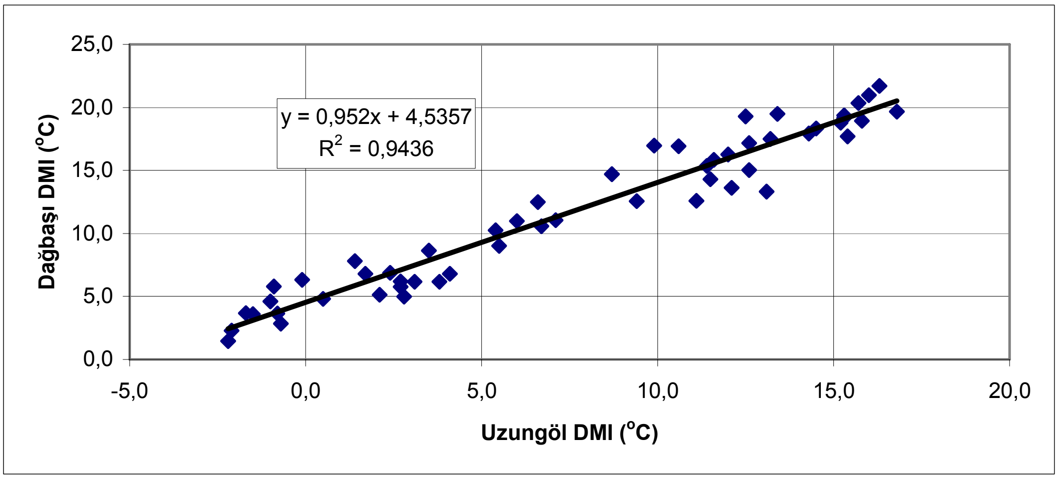

Figure 4.3 Regression Equation of Uzungöl DMI and Dağbaşı DMI

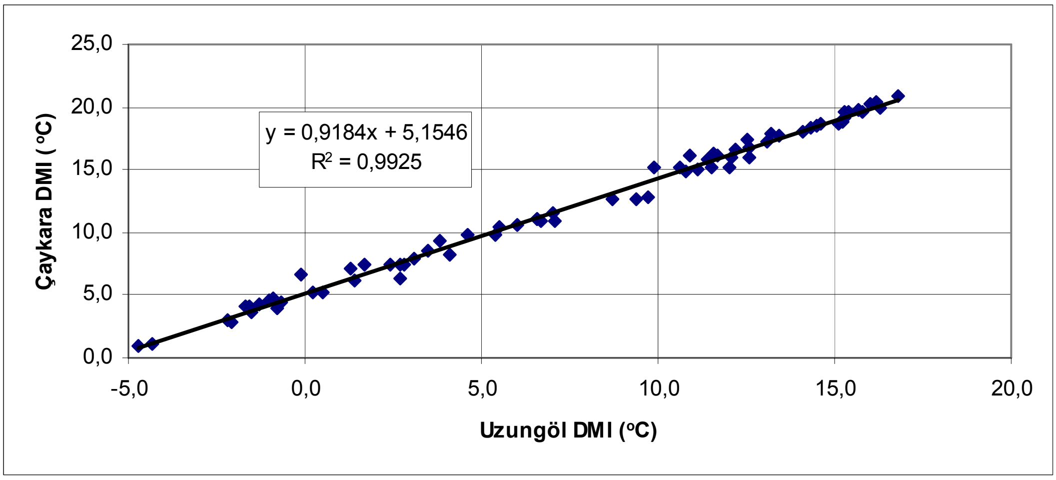

Figure 4.4 Regression Equation of Uzungöl DMI and Çaykara DMI

The mean monthly temperature values of Uzungöl DMI are given below in Table 4.8. Although temperature recording of Uzungöl DMI started in 1983, the beginning year of records of Uzungöl DMI is accepted to be 1991 since the data before are not continuous.

The mean daily temperature values of Uzungöl DMI for the years 2008 and 2009 are available and these data are ready to be used to make a correlation analysis with SCA data of the related basins.

Table 4.8 Mean Monthly Temperature Values of Uzungöl DMI, °C

Years	Months												
	January	February	March	April	May	June	July	August	September	October	November	December	Mean Annual
1991	-1,7	-1,5	2,7	9,4	10,6	14,3	16,8	15,8	12,6	11,6	5,5	0,5	8,1
1992	-4,7	-4,3	1,3	6,6	9,7	14,6	15,1	16,2	11,7	10,9	4,6	-1,3	6,7
1993	-2,2	-2,1	2,4	6,6	11,5	13,2	14,5	16,0	12,5	9,9	1,4	3,8	7,3
1994	3,1	-0,7	2,8	11,1	12,1	13,1	15,4	15,3	16,3	12,6	4,1	-0,8	8,7
1995	2,7	1,7	6,0	7,1	12,0	15,2	15,3	15,7	13,4	8,7	5,4	-0,1	8,6
1996	1,0	2,8	1,8	5,9	14,3	12,5	17,2	16,4	13,5	9,7	**5,4**	6,3	8,9
1997	0,2	-2,4	-1,6	7,0	12,2	14,1	15,3	15,8	10,8	11,4	6,7	3,5	7,8
1998	-0,9	-1,0	2,1	10,6	12,6	14,7	16,9	17,3	14,5	11,7	8,0	3,7	9,2
1999	2,5	2,8	4,2	7,7	10,2	14,5	17,6	17,3	13,9	10,2	4,8	4,4	9,2
2000	-2,7	-1,1	1,2	11,2	10,1	13,2	17,8	16,5	13,6	9,4	6,3	2,0	8,1
2001	1,6	2,5	7,7	9,4	9,9	14,5	17,7	18,0	15,2	8,9	5,7	3,3	9,5
2002	-3,0	3,1	5,3	6,3	10,8	14,2	18,0	16,3	15,4	11,8	7,9	-1,7	8,7
2003	3,1	-1,5	-0,9	6,4	13,1	13,3	16,0	16,2	13,0	11,2	4,8	2,7	8,1
2004	2,6	0,3	3,4	7,1	10,3	13,5	15,5	16,8	13,7	11,5	5,7	0,2	8,4
2005	1,1	1,0	2,1	8,5	11,7	12,9	17,4	17,7	13,9	8,0	5,3	3,8	8,6
2006	-2,0	2,1	5,2	8,2	11,0	15,5	15,0	19,7	14,0	11,2	4,2	-2,1	8,5
2007	0,2	0,2	2,7	3,6	15,7	15,6	17,1	18,1	15,0	12,3	4,9	0,3	8,8
2008	-4,5	-2,8	7,8	10,3	9,2	13,6	16,4	17,6	14,4	10,3	7,1	1,3	8,4
2009	2,2	4,1	3,5	5,8	10,4	15,6	16,8	14,3	13,0	12,7	5,5	5,5	9,1
Average	-0,1	0,2	3,1	7,8	11,4	14,1	16,4	16,7	13,7	10,7	5,4	1,9	8,5

4.2.1 Areal Estimation of Temperature

Areal seasonal estimation of mean temperature is done after finding a relationship between snow covered area (%) of the basins and mean daily temperature values of Uzungöl DMI.

In this study, areal temperature amount of each basin is determined by the saturated adiabatic lapse rate technique. In this technique, the saturated air temperature decreases 0.5°C every 100m. It means that the lapse rate is 0.5°C/100m. Here, the mean areal temperature of the basin is calculated as transferring the mean seasonal (spring) temperature of Uzungöl DMI to the median basin elevations of each basin. Since mean areal temperature values are only used for seasonal (spring) models, the mean seasonal temperature values are considered. Also, the temperature values at median elevations of each basin are assumed to represent areal temperature value of each basin. Median basin elevation is determined by deriving the hypsometric curve of each basin and extracting the elevation corresponding to 50% of cumulative area. The equation to estimate the areal temperature value of the basin is given by:

$$T_h = T_{ref} + \left(\frac{(href - h)}{100}\right) \times 0.5 \tag{4.4}$$

where T_{ref} is the mean seasonal temperature value for the observation station, T_h is mean seasonal temperature value of the basin, h is the height to which the temperature is transferred, h_{ref} is the height of observation station.

4.3 Discharge Data

There are five stream flow gauging stations in Karadere Basin and three in Solaklı Basin as stated in Chapter 3.2.2. Discharge records of the stations are carefully observed and analyzed and some corrections are made. In this chapter, the analyses of discharge data are given in two parts. In the first part; the stream flow gauging stations in Karadere Basin and in the second part the ones in Solaklı Basin are analyzed.

For the analyses of discharge data of stream flow gauging stations, a macro program called “Su Temini”, developed by Beray Engineering, is used. The correlation and regression studies between the stations, calculating mean monthly and yearly discharge data and deriving the flow duration curves for the related basins are performed by this macro. This macro is one of the most practical and useful tools in deriving flow duration curves of the basins which are very important in this study.

4.3.1 Karadere Basin

2202 Ağnas stream flow gauging station is the station in the most downstream. 22-44 Aytaş and 2234 Erikli are the stations that are in the upstream part of the basin. Besides these; 22-208 and 22-222 are the stations operated by private companies that are present on the tributaries of Karadere.

Firstly, the stream flow periods of the stations used to obtain flow duration curves are determined.

In Karadere Basin; for 2202 Ağnas; the period between 1967 and 2009 is selected since 43 years of measured discharge data seem to be sufficient and the years before 1967 are not continuous (See Table 3.2). Measurements for

22-44 Aytaş started in 1978 and there are measurements till 2009. Measurements in 22-44 Aytaş are not continuous but they are completed by regression equation with 2202 Ağnas being the independent variable. Also for 2234 Erikli, the measurements start in 1965 and ended in 1974. The stream flow period of 2234 Erikli is extended till 2009 by completing the missing values from 2202 Ağnas. Also the stream flow period this station is accepted to start in 1967 to be consistent with the beginning year of other stations in Karadere Basin.

When the discharge records in both 22-44 Aytaş and 2202 Ağnas are observed; it is seen that some of the records of 22-44 Aytaş is higher than that of 2202 Ağnas. This is physically impossible since 2202 Ağnas locates more downstream of 22-44 Aytaş (See Figure 3.2). This issue may be because of some measurement errors in one of the stations. To correct these errors; 2202 Ağnas which is the more downstream station is accepted to be more reliable and the discharge values of 22-44 Aytaş which are greater than 2202 Ağnas are corrected by carrying the discharge values of 2202 Ağnas of the day that the discharge values of 22-44 are greater, to 22-44 Aytaş by the drainage are ratio method which is given below. There are not any values in 2234 Erikli that are greater than 2202 Ağnas.

$$Q_{22-44\mathrm{Aytas}} = Q_{2202\mathrm{Agnas}}\left(\frac{A_{22-44Aytas}}{A_{2202\mathrm{Agnas}}}\right) \tag{4.5}$$

Secondly, the missing data of 22-44 Aytaş is completed by using the values of 2202 Ağnas via regression equation. The equation is given below in Figure 4.5.

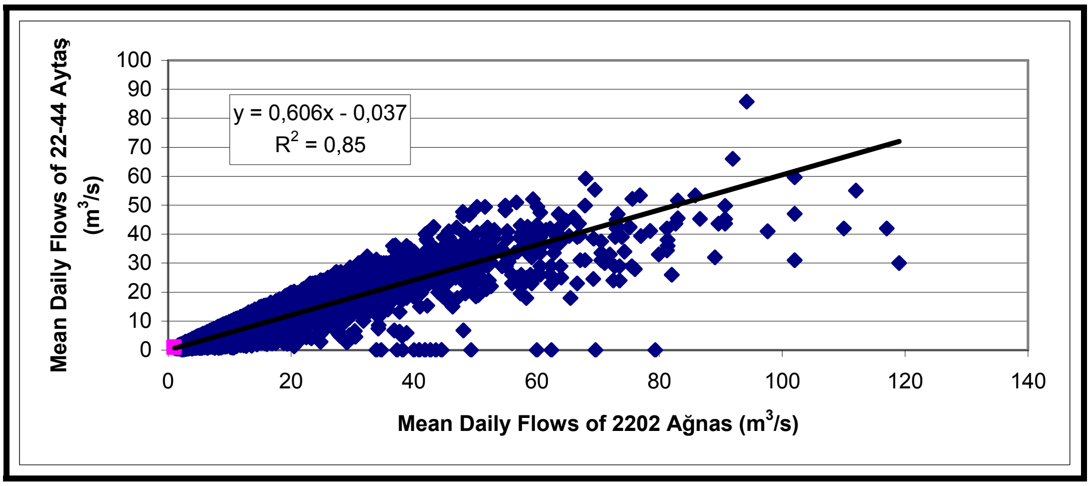

Figure 4.5 Regression Equation of 2202 Ağnas and 22-44 Aytaş

The regression equation between 2202 Ağnas and 2234 Erikli is also given below in Figure 4.6. The missing values of 2234 Erikli between the years 1968 and 2009 are completed from 2202 Ağnas.

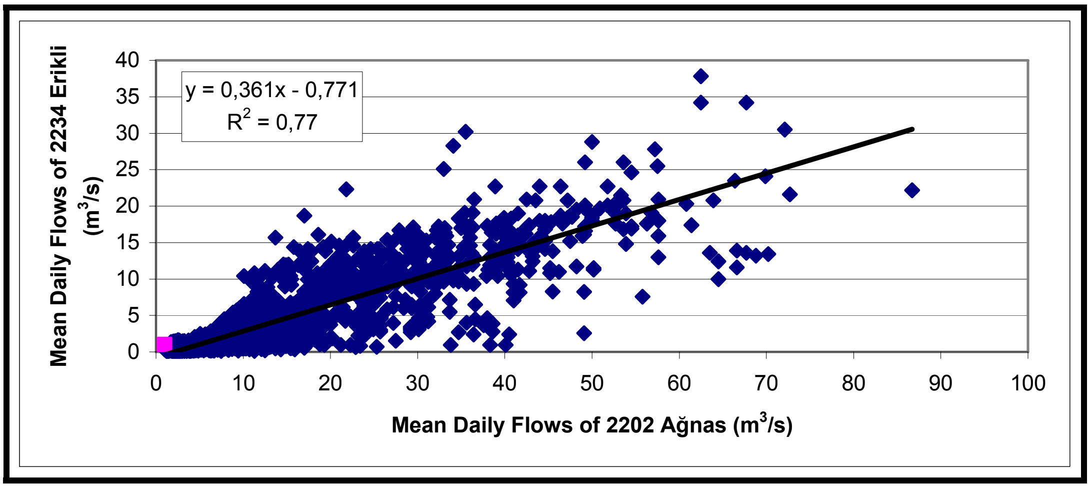

Figure 4.6 Regression Equation of 2202 Ağnas and 2234 Erikli

The mean monthly discharge values of 2202 Ağnas, 22-44 Aytaş, 2234 Erikli , 22-208 and 22-222 are given below in Table 4.9, 4.10, 4.11, 4.12 and 4.13 respectively. Please note that in Table 4.10 and 4.11 the bold values in are the values that are completed from 2202 Ağnas by using the daily flows. The mean monthly values of 2202 Ağnas, 22-44 Aytaş, 2234 Erikli, 22-208 and 22-222 for each year are demonstrated in Figure 4.7, 4.8 and 4.9, 4.10 and 4.11 respectively. The mean annual flows of 2202 Ağnas, 22-44 Aytaş, 2234 Erikli, 22-208 and 22-222 for each year are given in Figure 4.12, 4.13, 4.14, 4.15 and 4.16 respectively.

Table 4.9 Mean Monthly Discharge Values of 2202 Ağnas, m^3/s

Years	Months												Mean Annual
	10	11	12	1	2	3	4	5	6	7	8	9	
1967	2.67	1.42	1.70	2.96	5.20	8.51	27.41	49.28	19.26	15.56	11.97	4.85	12.57
1968	4.56	4.43	7.80	5.18	5.72	9.05	42.35	40.48	18.15	6.00	4.93	3.43	12.67
1969	7.42	7.55	3.61	2.24	3.70	7.78	22.31	30.04	7.64	4.42	2.87	1.74	8.44
1970	6.43	5.04	3.85	3.96	5.40	12.51	26.10	22.85	8.18	2.77	6.69	7.52	9.28
1971	12.77	7.99	6.73	3.59	3.17	10.88	19.95	31.95	20.39	7.37	4.27	5.64	11.22
1972	7.90	5.89	5.70	2.42	3.41	6.12	41.15	35.68	22.75	7.53	4.18	4.30	12.25
1973	5.73	4.49	2.32	3.73	5.89	7.40	20.51	25.78	21.81	6.69	5.15	4.66	9.51
1974	3.99	9.87	8.31	4.27	4.85	12.29	22.16	29.50	11.96	4.01	4.30	5.53	10.09
1975	1.83	1.99	3.52	2.83	4.98	10.81	35.95	30.79	10.23	6.30	3.76	2.42	9.62
1976	7.67	2.91	4.38	5.85	4.78	9.37	27.00	42.32	16.50	6.38	5.44	5.44	11.50
1977	8.68	4.27	3.44	3.22	4.68	9.39	23.78	34.44	20.18	11.06	5.47	5.55	11.18
1978	9.27	8.11	6.51	4.67	8.28	13.82	38.98	51.19	27.76	8.82	6.09	5.39	15.74
1979	3.07	4.43	6.32	5.17	5.57	10.75	35.42	41.40	15.61	11.33	4.67	3.76	12.29
1980	7.81	11.97	7.20	5.88	6.19	15.37	26.07	30.74	8.95	2.98	3.11	2.74	10.75
1981	3.17	4.71	5.31	3.43	3.12	8.29	20.39	38.17	22.60	9.82	5.13	6.22	10.86
1982	3.89	6.28	4.12	4.15	4.99	7.34	42.45	31.95	12.10	7.90	3.94	4.01	11.09
1983	5.35	4.88	3.52	3.95	4.92	14.90	21.37	32.16	18.10	4.64	3.90	4.64	10.20
1984	8.72	16.26	5.36	2.54	2.62	6.91	26.32	35.45	14.30	7.70	6.94	4.04	11.43
1985	3.24	3.03	2.19	2.61	4.19	7.46	31.09	31.91	19.05	7.17	2.47	2.23	9.72
1986	9.51	6.93	6.40	5.84	7.13	9.14	21.30	28.43	19.99	5.92	3.34	3.22	10.60
1987	7.65	9.65	6.11	7.72	7.11	8.21	28.60	48.06	18.23	8.89	9.70	4.45	13.70
1988	5.88	9.76	6.45	5.97	6.82	9.71	33.14	48.37	27.28	10.32	6.38	4.63	14.56
1989	14.12	14.17	5.95	4.52	6.27	10.43	33.84	17.43	10.47	4.08	2.97	5.55	10.82
1990	7.75	4.84	8.19	4.57	4.41	9.97	41.88	31.22	16.61	5.85	4.71	3.95	12.00
1991	12.03	15.70	3.26	1.60	8.20	10.95	28.68	22.12	10.29	4.16	5.73	3.29	10.50
1992	2.09	6.25	3.01	3.13	7.50	15.46	33.11	31.96	23.79	7.83	4.28	4.31	11.89
1993	7.71	10.11	10.02	6.75	5.16	13.23	32.86	49.65	40.68	6.20	5.18	3.10	15.89
1994	1.92	4.37	5.39	2.88	5.97	10.40	19.76	14.15	6.38	4.30	3.31	1.96	6.73
1995	3.80	3.91	5.79	4.58	3.99	7.53	21.05	27.86	18.04	12.36	4.91	6.32	10.01
1996	13.47	16.61	7.68	4.39	3.77	5.43	17.63	31.11	12.46	4.55	6.01	5.01	10.68
1997	6.45	4.79	5.97	5.79	5.54	7.46	24.77	24.08	10.62	5.90	4.59	6.96	9.41
1998	9.55	7.33	2.90	4.36	6.74	10.12	23.36	28.94	13.83	4.40	6.13	2.69	10.03
1999	2.90	4.80	8.28	2.73	3.33	8.44	28.62	44.98	16.71	7.19	4.11	7.12	11.60
2000	5.61	7.01	5.74	5.01	7.54	12.23	33.77	20.11	14.63	3.58	2.63	5.53	10.28
2001	8.45	5.82	3.31	2.33	3.98	11.77	21.90	21.79	8.92	3.75	2.93	1.71	8.06
2002	2.58	6.03	4.90	5.54	5.50	10.15	27.35	25.12	16.19	5.50	4.10	6.67	9.97
2003	4.44	4.06	4.47	4.61	3.66	6.15	34.06	21.36	7.97	3.78	3.45	5.33	8.61
2004	5.40	8.90	4.64	5.26	9.08	26.16	30.94	41.87	28.14	6.20	4.86	4.88	14.69
2005	3.19	3.31	4.74	4.55	5.82	12.01	42.96	36.67	15.09	5.39	4.60	3.30	11.80
2006	14.18	15.86	8.90	5.01	8.01	10.46	44.53	39.92	10.21	9.47	2.57	2.93	14.34
2007	7.74	14.89	5.88	6.08	6.54	13.61	17.97	60.73	8.19	3.79	2.61	2.66	12.56
2008	3.96	8.47	5.36	3.11	5.91	25.58	27.70	18.67	12.03	5.64	5.02	4.89	10.53
2009	6.33	2.97	2.91	3.12	4.73	11.83	18.70	40.58	17.59	12.19	4.82	6.73	11.04
Average	6.53	7.26	5.31	4.23	5.45	10.82	28.82	33.52	16.28	6.74	4.75	4.45	11.18

Table 4.10 Mean Monthly Discharge Values of 22-44 Aytaş, m^3/s

Years	Months												Mean Annual
	10	11	12	1	2	3	4	5	6	7	8	9	
1967	**1.58**	**0.82**	**0.99**	**1.76**	**3.12**	**5.12**	**16.57**	**29.82**	**11.63**	**9.39**	**7.21**	**2.90**	7.58
1968	**2.72**	**2.65**	**4.69**	**3.10**	**3.43**	**5.45**	**25.62**	**24.49**	**10.96**	**3.60**	**2.95**	**2.04**	7.64
1969	**4.46**	**4.54**	**2.15**	**1.32**	**2.20**	**4.67**	**13.48**	**18.16**	**4.59**	**2.64**	**1.70**	**1.02**	5.08
1970	**3.86**	**3.02**	**2.29**	**2.36**	**3.24**	**7.54**	**15.77**	**13.80**	**4.92**	**1.64**	**4.02**	**4.52**	5.58
1971	**7.70**	**4.80**	**4.04**	**2.14**	**1.88**	**6.55**	**12.05**	**19.32**	**12.31**	**4.43**	**2.55**	**3.38**	6.76
1972	**4.75**	**3.53**	**3.42**	**1.43**	**2.03**	**3.67**	**24.89**	**21.58**	**13.75**	**4.52**	**2.50**	**2.57**	7.39
1973	**3.44**	**2.68**	**1.37**	**2.22**	**3.53**	**4.45**	**12.39**	**15.58**	**13.17**	**4.02**	**3.09**	**2.79**	5.73
1974	**2.38**	**5.94**	**5.00**	**2.55**	**2.90**	**7.41**	**13.39**	**17.83**	**7.21**	**2.39**	**2.57**	**3.32**	6.07
1975	**1.07**	**1.17**	**2.09**	**1.67**	**2.98**	**6.51**	**21.74**	**18.62**	**6.16**	**3.78**	**2.24**	**1.43**	5.79
1976	**4.61**	**1.73**	**2.62**	**3.51**	**2.86**	**5.64**	**16.32**	**25.60**	**9.96**	**3.83**	**3.26**	**3.26**	6.93
1977	**5.22**	**2.55**	**2.04**	**1.92**	**2.80**	**5.65**	**14.37**	**20.83**	**12.19**	**6.66**	**3.28**	**3.32**	6.74
1978	4.36	4.94	3.43	2.56	4.80	8.88	20.21	23.68	14.65	5.29	2.32	1.66	8.07
1979	1.85	1.92	2.80	2.98	3.63	7.61	18.33	22.53	11.32	5.65	2.43	0.86	6.83
1980	2.04	6.84	3.11	2.09	2.22	7.36	16.33	18.19	5.33	0.75	1.87	1.85	5.67
1981	2.14	3.17	3.99	2.49	2.46	6.26	15.92	25.68	18.12	6.96	3.28	4.20	7.89
1982	2.75	4.60	2.81	3.20	3.40	5.49	28.11	24.59	8.40	5.26	2.66	2.76	7.84
1983	3.50	3.31	2.37	2.74	3.66	10.69	16.30	24.80	11.64	3.13	2.63	3.26	7.34
1984	**5.25**	**9.81**	**3.21**	**1.50**	**1.55**	**4.15**	**15.91**	**21.44**	**8.63**	**4.63**	**4.17**	**2.41**	6.89
1985	**1.92**	**1.80**	**1.29**	**1.55**	**2.50**	**4.48**	**18.80**	**19.29**	**11.51**	**4.31**	**1.46**	**1.31**	5.85
1986	**5.72**	**4.16**	**3.84**	**3.50**	**4.28**	**5.50**	**12.86**	**17.19**	**12.07**	**3.55**	**1.99**	**1.91**	6.38
1987	5.21	6.07	4.54	5.83	4.79	6.25	18.86	30.85	12.86	5.73	4.07	1.98	8.92
1988	1.59	5.60	3.45	2.57	2.73	4.93	17.77	24.00	18.79	7.11	**3.83**	**2.77**	7.93
1989	**8.52**	**8.55**	**3.57**	**2.70**	**3.76**	**6.28**	**20.47**	**10.52**	**6.30**	**2.43**	**1.76**	**3.32**	6.52
1990	**4.66**	**2.89**	**4.92**	**2.73**	**2.63**	**6.00**	**25.34**	**18.88**	**10.03**	**3.51**	**2.82**	**2.36**	7.23
1991	**7.25**	**9.47**	**1.94**	**0.93**	**4.93**	**6.60**	**17.34**	**13.36**	**6.20**	**2.48**	**3.43**	**1.96**	6.32
1992	1.50	4.51	1.76	1.55	1.95	8.21	22.34	23.87	20.42	4.45	2.35	2.91	7.98
1993	4.63	6.09	6.03	4.05	3.09	7.98	19.87	30.04	24.61	3.72	3.10	1.84	9.59
1994	1.12	2.61	3.23	1.71	3.58	6.26	11.93	8.54	3.83	2.57	1.97	1.15	4.04
1995	0.94	1.43	1.50	2.05	1.98	4.12	16.11	19.23	13.48	4.89	2.45	2.15	5.86
1996	5.83	9.94	4.37	2.48	1.95	3.63	12.98	23.20	9.30	2.54	2.78	3.60	6.88
1997	**3.87**	**2.86**	**3.58**	**3.47**	**3.32**	**4.48**	**14.97**	**14.55**	**6.40**	**3.54**	**2.74**	**4.18**	5.66
1998	**5.75**	**4.40**	**1.72**	**2.60**	**4.05**	**6.09**	**14.12**	**17.49**	**8.34**	**2.63**	**3.68**	**1.59**	6.04
1999	1.10	2.31	5.74	1.30	1.35	4.47	22.84	29.41	12.21	4.14	1.82	2.85	7.46
2000	2.76	3.61	2.69	1.60	2.11	4.82	24.38	14.71	8.00	1.68	1.07	1.17	5.72
2001	3.42	3.57	1.30	1.08	0.82	8.25	16.81	17.39	6.91	2.17	1.26	0.81	5.32
2002	0.99	1.68	1.59	1.65	2.73	7.83	20.27	21.51	11.88	3.27	1.68	1.72	6.40
2003	1.92	1.43	1.18	1.48	1.20	1.82	21.69	18.60	5.83	1.42	0.97	1.24	4.90
2004	1.30	3.98	1.66	1.40	2.21	16.08	22.01	29.96	18.34	3.61	1.71	1.54	8.65
2005	1.13	1.08	1.04	1.01	1.48	5.72	31.39	29.10	11.95	3.85	1.89	1.40	7.59
2006	6.17	9.93	5.03	1.70	2.06	7.04	27.28	27.74	6.95	4.06	1.66	1.22	8.40
2007	2.51	8.95	3.03	2.43	2.74	7.64	13.12	36.88	5.95	2.96	1.64	1.24	7.42
2008	1.38	2.63	2.22	1.77	3.01	17.73	20.93	13.73	7.75	2.46	2.49	1.48	6.47
2009	2.07	1.42	1.27	1.34	1.96	**7.13**	**11.29**	3.31	12.10	4.87	2.29	2.81	4.32
Average	3.42	4.16	2.90	2.23	2.79	6.57	18.45	20.93	10.63	3.87	2.60	2.28	6.74

Table 4.11 Mean Monthly Discharge Values of 2234 Erikli, m^3/s

Years	Months												Mean Annual
	10	11	12	1	2	3	4	5	6	7	8	9	
1967	0.49	0.36	0.43	0.41	0.57	0.98	3.20	17.84	5.37	3.34	1.48	0.68	2.93
1968	0.72	0.93	1.31	0.93	0.82	1.84	13.97	12.98	5.76	1.69	0.57	0.38	3.49
1969	0.71	1.48	1.10	0.53	0.45	1.45	7.39	12.22	1.89	0.98	0.52	0.34	2.42
1970	0.56	0.40	0.18	0.20	0.48	3.26	9.21	11.77	3.51	0.69	0.51	0.50	2.61
1971	1.26	0.75	1.47	0.52	0.19	1.56	6.67	12.70	7.58	1.34	0.83	0.39	2.94
1972	0.77	0.67	1.01	0.62	0.68	1.83	16.02	13.93	11.87	3.28	0.75	0.62	4.34
1973	0.71	0.69	0.82	0.55	1.10	1.20	8.63	13.48	8.33	1.99	0.57	0.45	3.21
1974	0.48	1.38	0.67	0.59	0.64	2.77	5.86	15.84	5.27	0.92	0.43	0.37	2.94
1975	0.03	0.06	0.50	0.27	1.03	3.13	12.21	10.34	2.92	1.50	0.61	0.19	2.73
1976	2.00	0.28	0.81	1.34	0.96	2.61	8.98	14.51	5.19	1.53	1.19	1.19	3.38
1977	2.36	0.77	0.47	0.39	0.92	2.62	7.81	11.66	6.51	3.22	1.22	1.25	3.27
1978	2.58	2.16	1.58	0.92	2.22	4.22	13.30	17.71	9.25	2.41	1.43	1.17	4.91
1979	0.37	0.83	1.51	1.10	1.24	3.11	12.02	14.17	4.86	3.32	0.91	0.59	3.67
1980	2.05	3.55	1.83	1.35	1.46	4.78	8.64	10.33	2.46	0.31	0.36	0.23	3.11
1981	0.40	0.94	1.15	0.47	0.35	2.22	6.59	13.01	7.39	2.77	1.08	1.47	3.15
1982	0.63	1.49	0.71	0.73	1.03	1.88	14.55	10.76	3.60	2.08	0.66	0.68	3.23
1983	1.16	0.99	0.50	0.66	1.01	4.61	6.94	10.84	5.76	0.90	0.64	0.90	2.91
1984	2.38	5.10	1.17	0.16	0.21	1.72	8.73	12.03	4.39	2.01	1.73	0.69	3.36
1985	0.47	0.32	0.05	0.24	0.74	1.92	10.45	10.75	6.11	1.82	0.16	0.12	2.76
1986	2.67	1.73	1.54	1.34	1.80	2.53	6.92	9.49	6.45	1.37	0.46	0.44	3.06
1987	1.99	2.71	1.44	2.02	1.80	2.19	9.55	16.58	5.81	2.44	2.73	0.83	4.17
1988	1.43	2.75	1.56	1.38	1.69	2.74	11.19	16.69	9.08	2.95	1.53	0.90	4.49
1989	4.33	4.35	1.38	0.86	1.49	2.99	11.45	5.52	3.01	0.70	0.35	1.30	3.14
1990	2.03	0.97	2.18	0.88	0.82	2.83	14.35	10.50	5.23	1.34	0.93	0.65	3.56
1991	3.57	4.90	0.42	0.01	2.19	3.18	9.58	7.21	2.95	0.73	1.30	0.42	3.04
1992	0.13	1.49	0.33	0.36	1.94	4.81	11.18	10.77	7.82	2.06	0.77	0.79	3.54
1993	2.01	2.88	2.85	1.66	1.09	4.00	11.09	17.15	13.92	1.47	1.10	0.35	4.96
1994	0.04	0.81	1.17	0.28	1.38	2.98	6.36	4.34	1.53	0.78	0.46	0.11	1.69
1995	0.70	0.64	1.32	0.88	0.67	1.95	6.83	9.29	5.74	3.69	1.00	1.51	2.85
1996	4.09	5.22	2.00	0.81	0.59	1.19	5.59	10.46	3.73	0.87	1.40	1.04	3.08
1997	1.56	0.96	1.38	1.32	1.23	1.92	8.17	7.92	3.06	1.36	0.89	1.74	2.63
1998	2.68	1.88	0.28	0.80	1.66	2.88	7.66	9.67	4.22	0.82	1.44	0.21	2.85
1999	0.28	0.96	2.22	0.21	0.43	2.28	9.56	15.47	5.26	1.82	0.71	1.80	3.42
2000	1.25	1.76	1.30	1.04	1.95	3.64	11.42	6.49	4.51	0.54	0.22	1.24	2.95
2001	2.28	1.33	0.43	0.08	0.67	3.48	7.14	7.10	2.45	0.58	0.30	0.01	2.15
2002	0.29	1.41	1.00	1.23	1.22	2.89	9.10	8.30	5.07	1.22	0.71	1.64	2.84
2003	0.83	0.70	0.84	0.89	0.55	1.45	11.53	6.94	2.11	0.59	0.47	1.16	2.34
2004	1.18	2.44	0.90	1.13	2.51	8.67	10.40	14.34	9.39	1.47	0.98	0.99	4.53
2005	0.38	0.42	0.94	0.87	1.33	3.56	14.74	12.47	4.68	1.18	0.89	0.42	3.49
2006	4.35	4.96	2.44	1.04	2.12	3.00	15.31	13.64	2.92	2.65	0.17	0.30	4.41
2007	2.02	4.60	1.35	1.42	1.59	4.14	5.71	21.15	2.19	0.60	0.18	0.24	3.77
2008	0.77	2.29	1.17	0.35	1.36	8.46	9.23	5.97	3.57	1.27	1.04	0.99	3.04
2009	1.51	0.30	0.28	0.36	0.94	3.50	5.98	13.88	5.58	3.63	0.97	1.66	3.22
Average	1.45	1.76	1.12	0.77	1.14	3.00	9.56	11.82	5.31	1.68	0.85	0.77	3.27

Table 4.12 Mean Monthly Discharge Values of 22-208 Station, m^3/s

Years	Months												Mean Annual
	10	11	12	1	2	3	4	5	6	7	8	9	
2007		1.28	0.56	0.53	0.44	1.15	2.24	3.37	1.36	0.77	0.35	0.33	1.13
2008	0.76	0.90	0.49	0.33	0.37	1.46	1.38	0.59	0.77	0.40	0.43	0.44	0.69
2009	0.94	0.45	0.27	0.40	0.48	1.57	2.07	3.04	2.77	2.99	0.89	1.06	1.41
Average	**0.76**	**1.09**	**0.53**	**0.43**	**0.41**	**1.30**	**1.81**	**1.98**	**1.06**	**0.59**	**0.39**	**0.38**	**1.08**

Table 4.13 Mean Monthly Discharge Values of 22-222 Station, m^3/s

Years	Months												Mean Annual
	10	11	12	1	2	3	4	5	6	7	8	9	
2007										0.35	0.09	0.04	0.16
2008	0.09	0.12	0.04	0.04	0.03	0.17	1.59	0.83	0.47	0.25	0.11	0.15	0.33
2009	0.22	0.07	0.05	0.04	0.03	0.06	0.22	3.62	2.73	0.79	0.29	0.32	0.70
Average	**0.16**	**0.10**	**0.05**	**0.04**	**0.03**	**0.11**	**0.91**	**2.22**	**1.60**	**0.47**	**0.16**	**0.17**	**0.40**

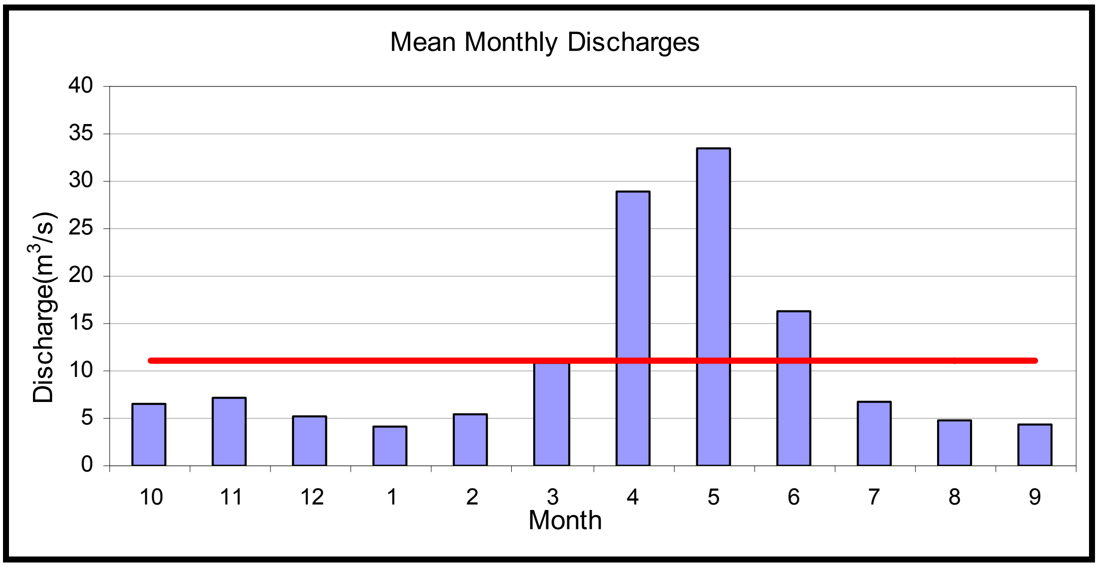

Figure 4.7 Mean Monthly Discharge Values of 2202 Ağnas

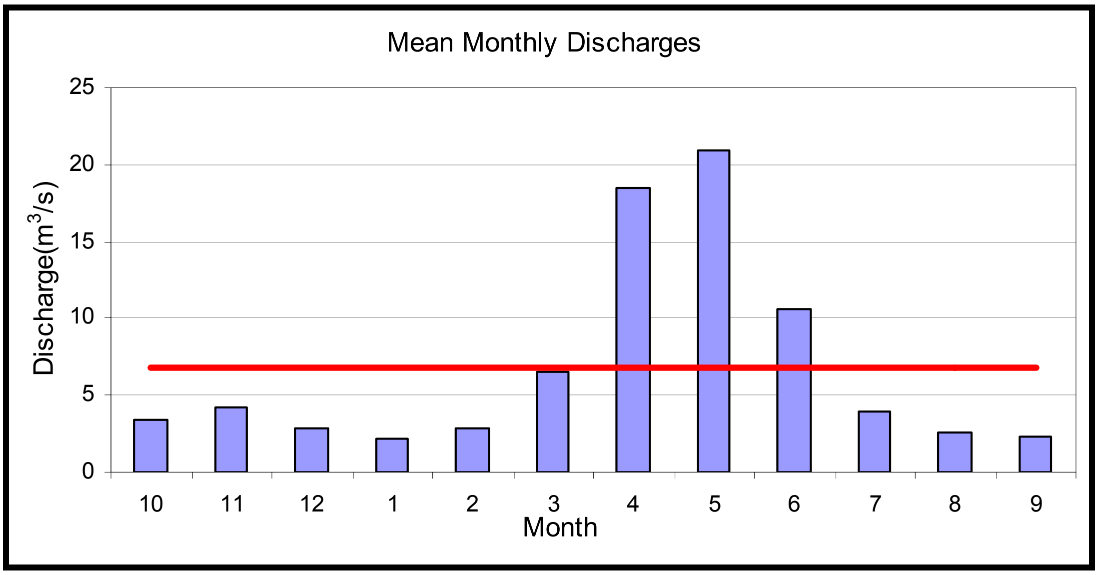

Figure 4.8 Mean Monthly Discharge Values of 22-44 Aytaş

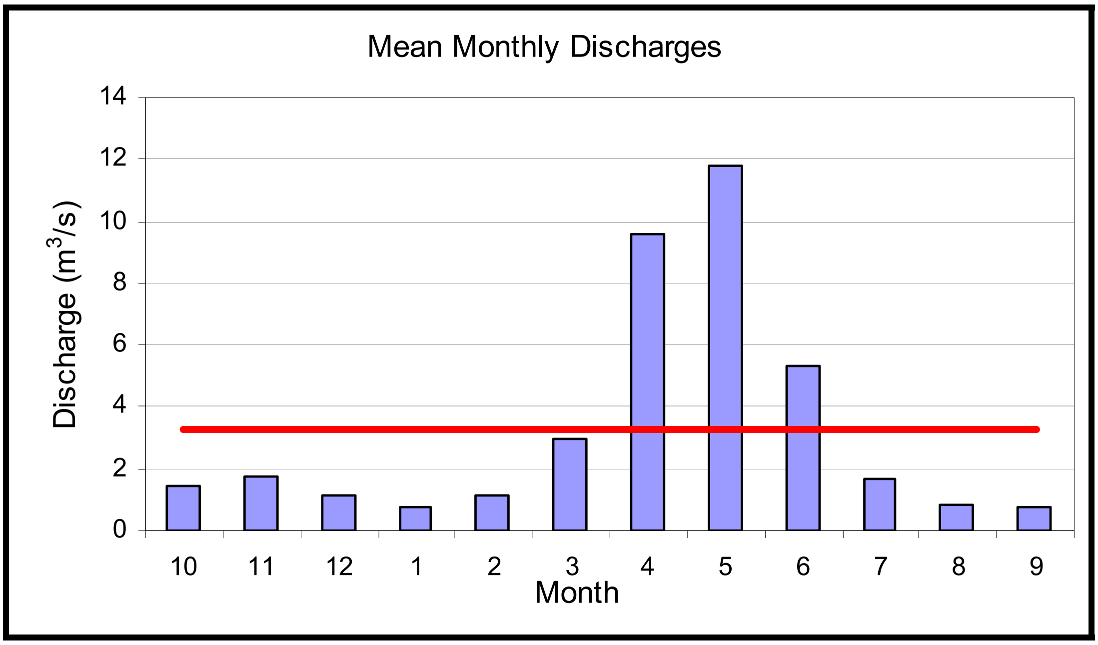

Figure 4.9 Mean Monthly Discharge Values of 2234 Erikli

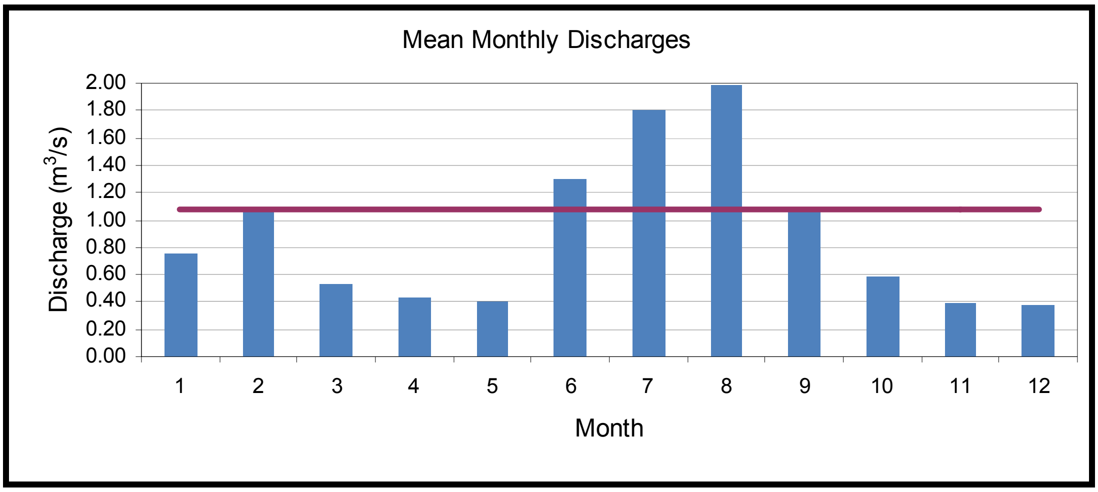

Figure 4.10 Mean Monthly Discharge Values of Station 22-208

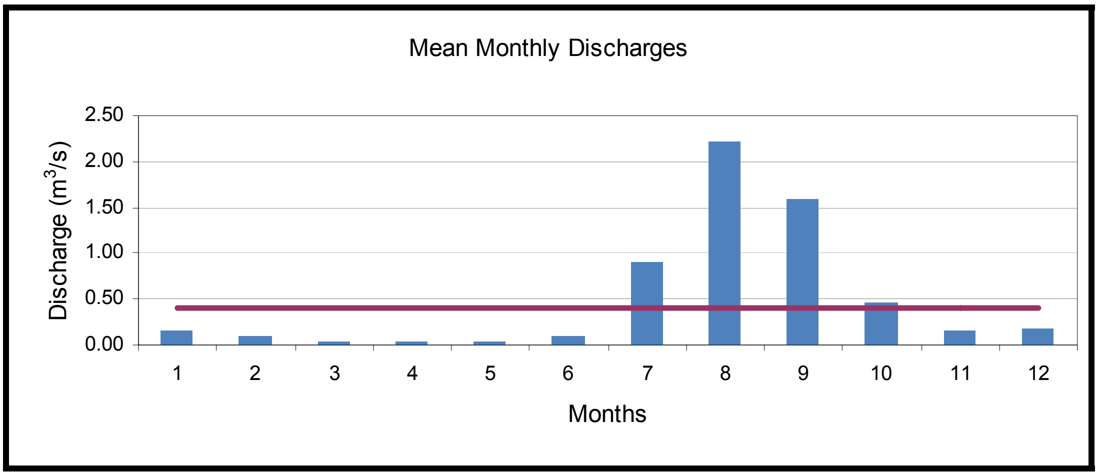

Figure 4.11 Mean Monthly Discharge Values of Station 22-222

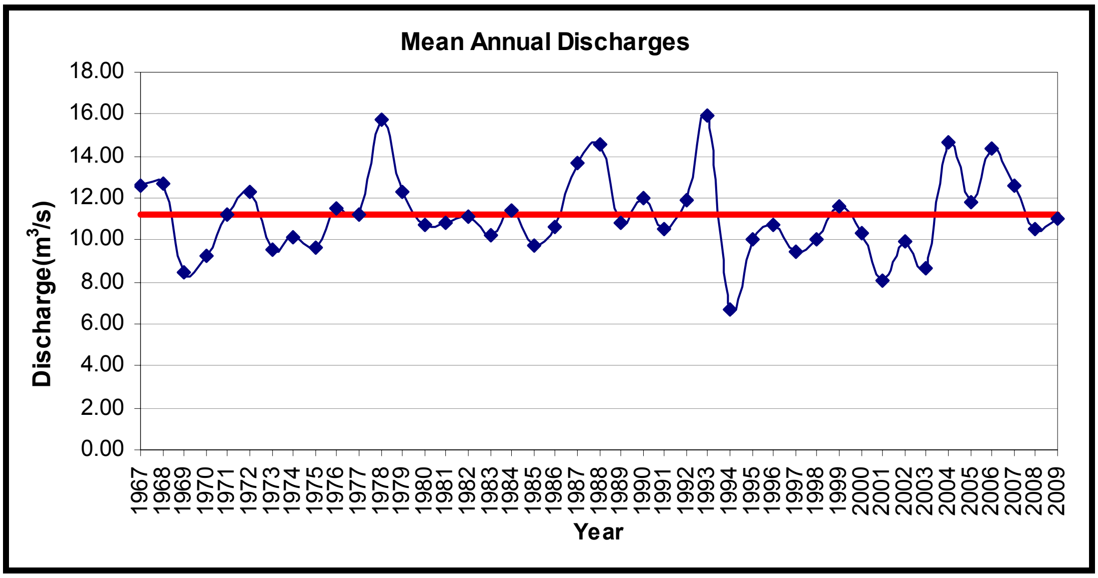

Figure 4.12 Mean Annual Discharge Values of 2202 Ağnas

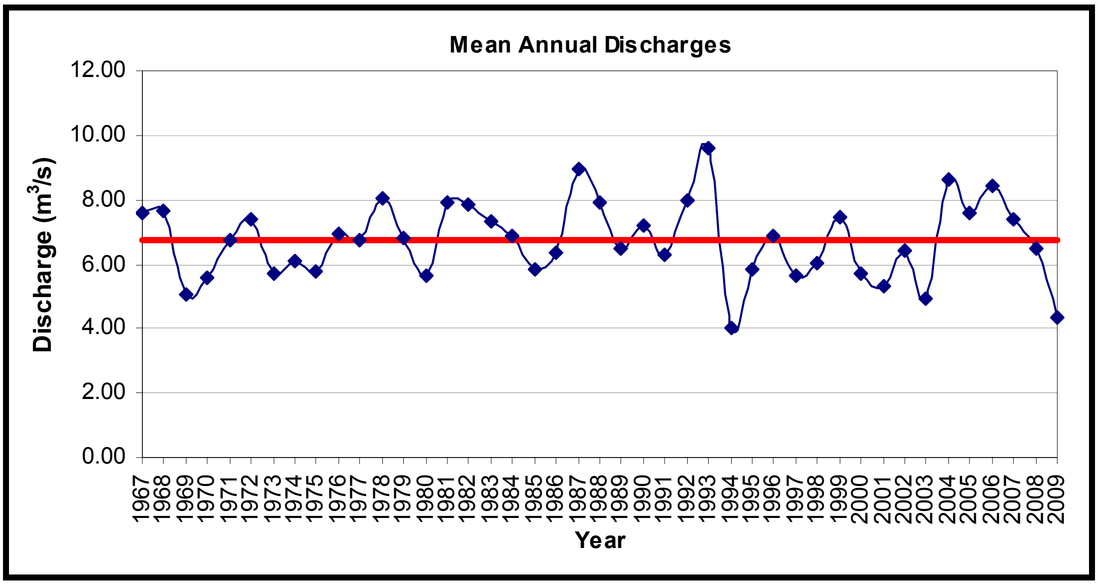

Figure 4.13 Mean Annual Discharge Values of 22-44 Aytaş

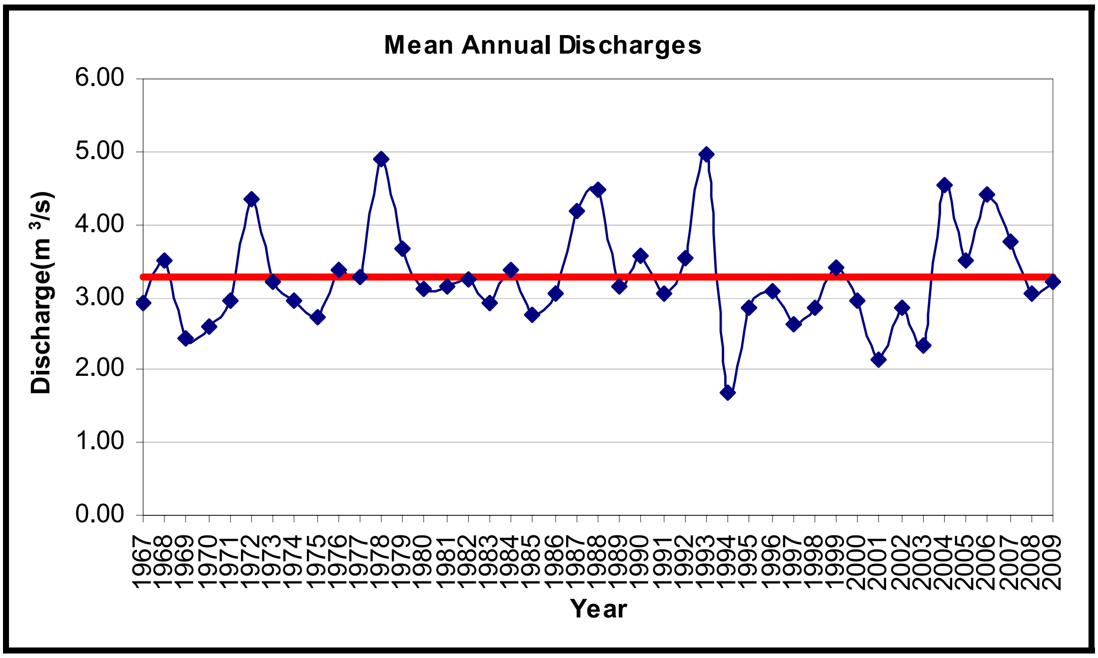

Figure 4.14 Mean Annual Discharge Values of 2234 Erikli

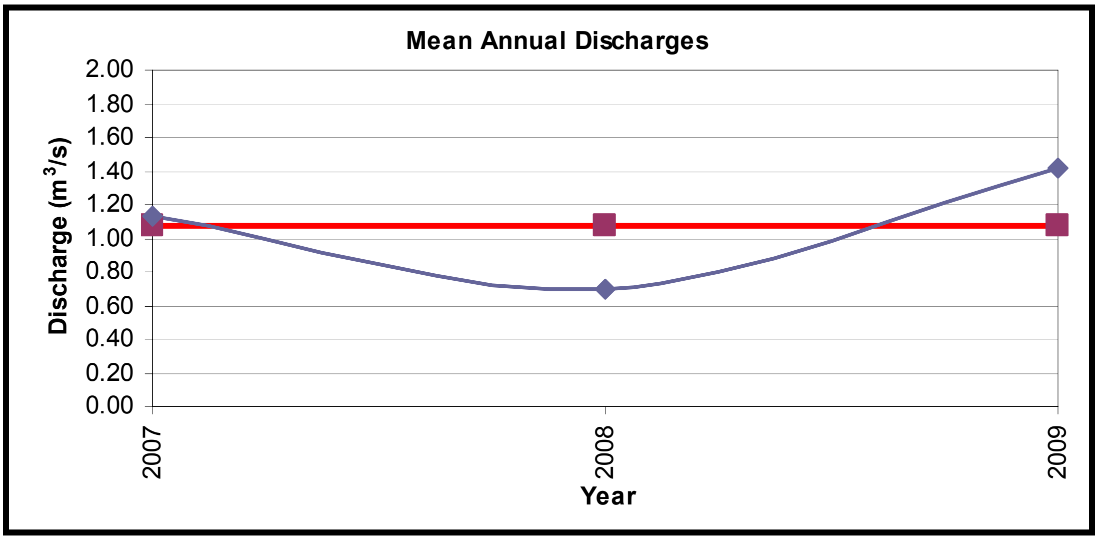

Figure 4.15 Mean Annual Discharge Values of Station 22-208

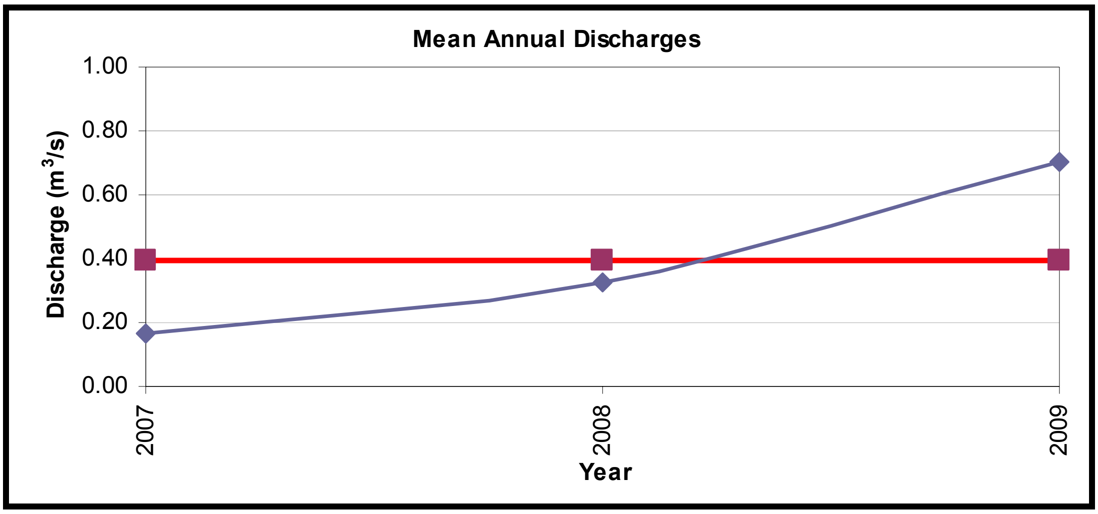

Figure 4.16 Mean Annual Discharge Values of Station 22-222

4.3.2 Solaklı Basin

22-52 Ulucami is the station that is the most downstream one; 22-57 Alçakköprü and 22-07 Serah are the stations that are in the upstream part.

Firstly, the stream flow periods of the stations used to obtain flow duration curves are determined.

In Solaklı Basin; for 22-52 Ulucami; the period between 1979 and 2009 is selected. There are not any data in the year 1998. Since there are not also any data within the stations in the basin; the station 2202 Ağnas which is the only station among all stations that has data in 1998 is used to complete the missing values of 22-52 Ulucami. Measurements for 22-57 Alçakköprü started in 1979 and there are measurements till 2005. Measurements in 22-57

Alçakköprü are not continuous but they are completed by regression equation with 22-52 Ulucami being the independent variable. The last station 22-07 Serah started measuring discharge at 1966 till 2007 but it is also a discontinuous station. Its missing data are also completed from 22-52 Ulucami. In addition, for 22-07 Serah the data before 1979 are disregarded.

Before completing the missing values of 22-57 Alçakköprü and 22-07 Serah; the discharge records in all stations are observed; it is seen that some of the records of the sum of 22-57 Alçakköprü and 22-07 Serah are higher than that of 22-52 Ulucami. This is physically impossible since 22-52 Ulucami locates more downstream of 22-57 Alçakköprü and 22-07 Serah (See Figure 3.2). To correct these errors; the values of 22-52 Ulucami which is in the most downstream are accepted to be more reliable.

Firstly, the discharge values of 22-52 Ulucami and the sum of discharge values of 22-57 Alçakköprü and 22-07 Serah are compared and the values of 22-57 Alçakköprü and 22-07 Serah are corrected if the sums of their values are greater. The following equations were used to correct the values:

$$Q_{22-57\,Alcakkopru} = Q_{22-52Ulucami}\left(\frac{A_{22-57Alcakkopru}}{A_{22-52Ulucami}}\right) \tag{4.6}$$

$$Q_{22-07\,Serah} = Q_{22-52Ulucami}\left(\frac{A_{22-07Serah}}{A_{22-52Ulucami}}\right) \tag{4.7}$$

Missing values in 1998 for 22-52 Ulucami is completed from 2202 Ağnas. The regression equation and its determination coefficient are given in Figure 4.17. Also missing values of 22-57 Alçakköprü and 22-07 Serah are completed by using the values of 22-52 Ulucami via regression equation. The equations for 22-52 Ulucami-22-57 Alçakköprü and 22-52 Ulucami – 22-07 Serah are given below in Figure 4.18 and 4.19 respectively.

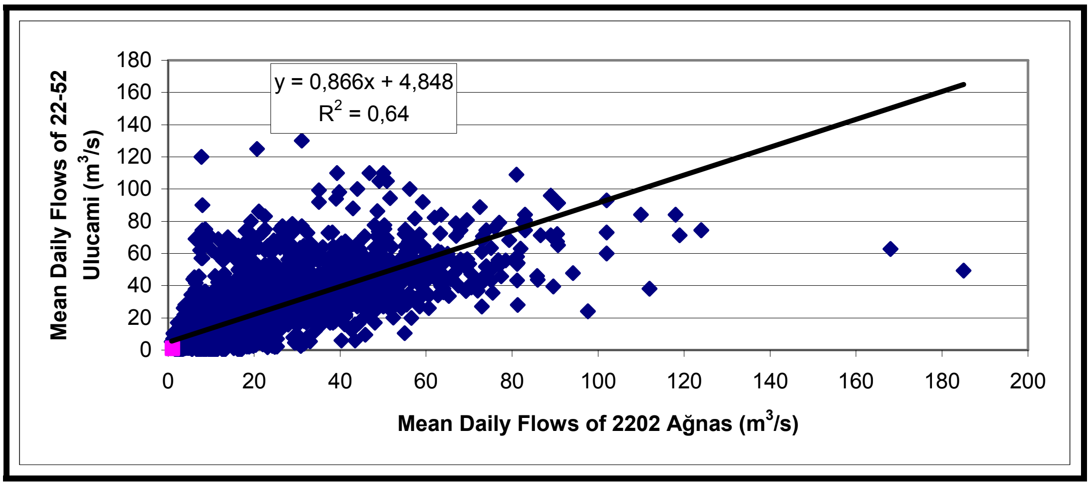

Figure 4.17 Regression Equation of 2202 Ağnas and 22-52 Ulucami

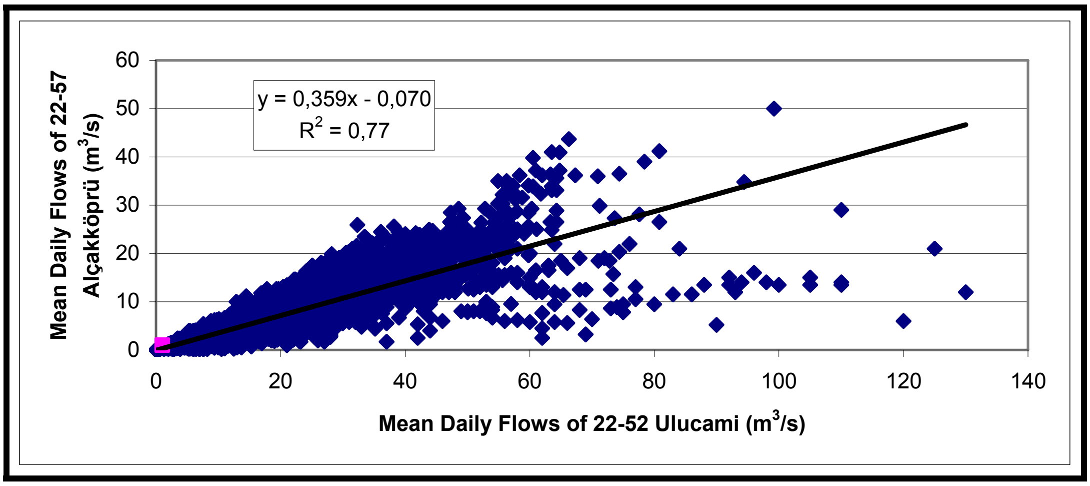

Figure 4.18 Regression Equation of 22-52 Ulucami and 22-57 Alçakköprü

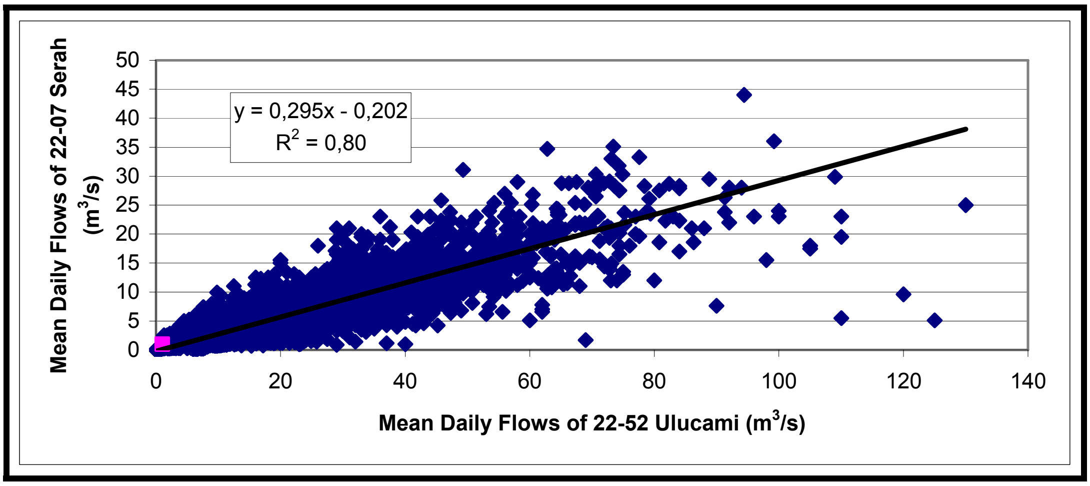

Figure 4.19 Regression Equation of 22-52 Ulucami and 22-07 Serah

The mean monthly discharge values of 22-52 Ulucami, 22-57 Alçakköprü and 22-07 Serah are given below in Table 4.14, 4.15 and 4.16 respectively. Please note that in Table 4.14 the bold values are completed from 2202 Ağnas. Also in 4.15 and 4.16 the bold values are the values that are completed from 22-52 Ulucami by using the daily flows. The mean monthly values of 22-52

Ulucami, 22-57 Alçakköprü and 22-07 Serah for each year are demonstrated in Figure 4.20, 4.21 and 4.22 respectively. The mean annual flows of 22-52 Ulucami, 22-57 Alçakköprü and 22-07 Serah for each year are given in Figure 4.23, 4.24 and 4.25 respectively.

Table 4.14 Mean Monthly Discharge Values of 22-52 Ulucami, m^3/s

Years	Months												Mean Annual
	10	11	12	1	2	3	4	5	6	7	8	9	
1979	4.70	8.33	8.73	7.19	7.39	11.06	32.87	45.42	27.40	18.65	7.43	5.62	15.40
1980	9.03	18.09	9.88	5.93	5.74	16.67	37.08	40.06	15.82	3.75	1.29	1.05	13.70
1981	1.64	6.45	4.00	1.62	1.25	5.23	17.11	34.60	45.57	27.53	13.48	11.74	14.18
1982	8.53	16.82	11.69	8.42	7.06	12.55	41.50	39.61	20.90	11.61	5.10	2.39	15.51
1983	3.06	4.21	2.50	1.91	2.89	11.43	22.28	37.45	24.40	11.63	7.09	7.73	11.38
1984	13.97	21.63	8.51	4.20	3.30	8.10	7.21	26.42	25.57	17.02	15.06	5.46	13.04
1985	3.65	2.66	1.71	2.16	2.65	6.70	25.02	34.16	20.35	11.62	3.33	2.56	9.71
1986	10.46	7.82	8.27	5.68	7.71	9.31	24.00	32.74	31.32	12.26	6.06	5.99	13.47
1987	6.57	8.69	7.67	7.61	7.14	6.84	20.31	34.77	24.15	15.67	12.17	7.84	13.29
1988	7.26	10.76	6.81	6.95	7.39	8.61	26.81	48.58	71.53	37.74	34.76	16.33	23.63
1989	17.07	23.04	11.22	4.98	5.62	20.87	52.22	36.38	30.67	12.07	6.53	6.15	18.90
1990	15.07	7.97	11.01	4.13	6.00	16.93	37.09	65.93	35.53	15.49	7.86	6.66	19.14
1991	11.85	17.79	8.39	5.75	7.60	15.65	31.49	41.00	31.36	13.95	8.50	5.53	16.57
1992	5.26	6.45	4.19	3.53	5.39	14.04	32.09	54.15	43.69	19.24	10.98	8.26	17.27
1993	12.80	11.92	10.84	7.65	6.55	13.26	32.04	51.79	38.40	11.88	6.46	6.87	17.54
1994	2.98	4.62	5.63	6.29	6.11	8.87	30.31	27.64	18.93	10.03	7.66	6.98	11.34
1995	4.68	7.52	7.00	7.76	6.11	7.15	20.33	45.25	28.26	15.87	8.97	8.38	13.94
1996	17.24	16.91	9.62	6.12	6.09	5.79	14.19	37.45	19.15	10.12	8.19	9.91	13.40
1997	16.91	8.85	6.29	5.22	6.10	6.83	36.11	43.79	22.82	11.22	7.16	9.38	15.06
1998	**13.12**	**11.19**	**7.36**	**8.62**	**10.68**	**13.61**	**25.07**	**29.90**	**16.82**	**8.66**	**10.15**	**7.17**	13.53
1999	12.21	11.38	11.01	5.56	5.86	8.44	19.71	38.85	25.16	14.68	8.52	7.90	14.11
2000	5.62	5.81	5.83	4.67	6.48	12.14	36.92	23.65	18.60	6.81	5.90	7.07	11.62
2001	12.14	7.80	5.33	4.13	4.44	12.30	24.29	28.43	22.44	10.71	5.81	3.54	11.78
2002	4.00	10.50	10.50	6.66	6.15	9.83	22.98	28.49	34.45	14.58	11.41	8.93	14.04
2003	6.76	5.55	4.81	5.95	3.90	4.92	27.37	29.12	14.01	7.37	5.68	7.55	10.25
2004	7.51	13.36	7.47	6.47	9.70	24.23	27.83	45.62	37.37	15.19	9.15	8.01	17.66
2005	5.46	6.01	7.59	6.78	7.28	10.87	30.94	35.66	24.07	13.51	6.66	6.94	13.48
2006	13.07	18.52	9.71	6.12	7.07	13.16	30.76	38.51	20.40	14.14	8.07	6.66	15.52
2007	8.15	15.31	7.44	6.80	6.43	13.57	22.77	65.41	19.68	11.88	7.07	4.42	15.74
2008	4.18	8.73	6.54	4.23	5.36	22.58	28.29	23.71	20.78	11.37	8.24	6.44	12.54
2009	10.43	5.83	4.42	4.90	5.65	12.64	17.45	38.89	25.59	14.82	7.45	9.96	13.17
Average	8.88	10.66	7.48	5.61	6.03	11.75	27.56	38.82	27.59	13.91	8.78	7.08	14.51

Table 4.15 Mean Monthly Discharge Values of 22-57 Alçakköprü, m^3/s

Years	Months											Mean Annual
	10	11	12	1	2	3	4	5	6	7	8	9	
1979	1.38	2.24	2.61	2.66	2.26	3.80	10.39	17.29	10.00	7.69	3.04	1.52	5.41
1980	2.47	7.27	3.57	2.30	2.48	5.57	13.26	15.89	6.82	1.61	0.55	0.45	5.19
1981	0.74	3.06	1.72	0.70	0.54	2.18	7.38	14.28	15.23	5.50	2.09	1.23	4.55
1982	1.30	3.21	2.43	1.73	1.46	3.19	14.29	12.71	6.84	3.03	1.25	0.64	4.34
1983	0.77	0.69	0.56	0.59	0.58	2.82	6.65	11.16	5.86	1.10	2.26	1.94	2.91
1984	**4.95**	**7.70**	**2.98**	**1.44**	**1.12**	**2.84**	**2.52**	**9.41**	**9.11**	**6.04**	**5.34**	**1.89**	4.61
1985	1.43	1.13	0.73	0.90	0.88	2.38	8.44	12.44	6.41	2.36	1.53	1.07	3.31
1986	**3.69**	**2.74**	**2.90**	**1.97**	**2.70**	**3.27**	**8.55**	**11.68**	**11.17**	**4.33**	**2.11**	**2.08**	4.77
1987	1.72	2.66	2.17	1.81	2.05	2.07	8.31	14.65	10.82	6.58	2.54	1.65	4.75
1988	1.26	4.08	2.75	2.19	1.81	1.94	8.52	12.27	10.76	4.51	3.50	3.14	4.73
1989	7.36	11.26	4.18	1.88	1.98	7.16	27.83	19.01	9.82	3.27	1.62	1.34	8.06
1990	**5.34**	**2.79**	**3.88**	**1.41**	**2.08**	**6.01**	**13.25**	**23.60**	**12.69**	**5.49**	**2.75**	**2.32**	6.80
1991	3.65	6.17	2.73	1.36	1.68	5.24	14.57	17.49	10.00	3.58	2.12	1.74	5.86
1992	1.71	3.17	1.88	1.55	1.66	3.71	12.70	25.23	15.24	5.10	2.52	2.57	6.42
1993	**4.52**	**4.21**	**3.82**	**2.68**	**2.28**	**4.69**	**11.43**	**18.52**	**13.71**	**4.19**	**2.25**	**2.40**	6.23
1994	1.38	1.86	2.55	1.58	1.77	3.47	13.93	12.72	6.59	2.76	1.84	1.49	4.33
1995	2.02	3.21	2.91	3.14	2.76	3.80	10.29	26.53	11.86	3.48	2.05	2.01	6.17
1996	5.49	6.35	3.20	1.92	1.74	1.75	5.81	17.13	7.90	3.42	2.62	3.06	5.03
1997	**6.00**	**3.11**	**2.19**	**1.80**	**2.12**	**2.38**	**12.89**	**15.65**	**8.12**	**3.96**	**2.50**	**3.30**	5.34
1998	**4.64**	**3.95**	**2.57**	**3.03**	**3.76**	**4.82**	**8.93**	**10.66**	**5.97**	**3.04**	**3.58**	**2.51**	4.79
1999	1.69	2.95	4.82	1.67	1.28	2.73	11.52	19.85	11.49	5.10	2.43	2.32	5.65
2000	1.75	2.14	2.20	1.30	2.41	3.85	19.26	13.80	9.71	2.94	1.17	1.40	5.16
2001	4.95	4.06	1.66	1.15	1.07	4.89	11.97	13.87	8.40	2.53	1.19	0.58	4.69
2002	0.65	2.23	1.33	1.07	2.08	4.44	9.14	12.90	11.01	4.24	2.18	2.27	4.46
2003	2.21	2.40	2.08	2.17	1.39	1.80	11.57	12.14	4.99	1.82	1.15	1.28	3.75
2004	1.53	4.98	2.39	1.74	2.24	9.22	11.24	19.53	16.44	5.68	2.40	2.09	6.62
2005	1.36	1.62	1.97	1.80	1.83	4.10	14.36	15.91	10.23	5.62	2.41	2.16	5.28
2006	**4.62**	**6.58**	**3.41**	**2.13**	**2.47**	**4.65**	**10.97**	**13.75**	**7.25**	**5.01**	**2.83**	**2.32**	5.50
2007	**2.86**	**5.42**	**2.60**	**2.37**	**2.24**	**4.80**	**8.11**	**23.41**	**7.00**	**4.20**	**2.47**	**1.52**	5.58
2008	**1.43**	**3.06**	**2.28**	**1.45**	**1.85**	**8.04**	**10.09**	**8.44**	**7.39**	**4.01**	**2.89**	**2.24**	4.43
2009	**3.68**	**2.02**	**1.52**	**1.69**	**1.96**	**4.47**	**6.19**	**13.89**	**9.12**	**5.25**	**2.61**	**3.51**	4.66
Average	2.86	3.82	2.54	1.78	1.89	4.07	11.11	15.67	9.61	4.11	2.32	1.94	5.14

Table 4.16 Mean Monthly Discharge Values of 22-07 Serah, m^3/s

Years	Months												Mean Annual
	10	11	12	1	2	3	4	5	6	7	8	9	
1979	1.76	1.91	1.82	1.22	1.33	1.97	6.09	13.25	11.36	6.93	2.31	1.52	4.29
1980	1.91	3.73	2.40	1.44	1.87	3.97	8.56	14.36	5.02	1.00	0.34	0.28	3.74
1981	0.44	1.43	1.06	0.43	0.33	1.43	5.24	10.32	16.78	8.45	3.08	1.97	4.25
1982	**2.31**	**4.76**	**3.25**	**2.28**	**1.88**	**3.50**	**12.04**	**11.48**	**5.96**	**3.22**	**1.30**	**0.50**	4.37
1983	0.94	1.69	1.22	0.62	0.97	1.37	8.15	11.05	8.56	4.24	1.79	1.38	3.50
1984	2.43	3.61	1.52	0.79	0.36	1.18	3.23	10.66	9.80	5.58	2.44	1.78	3.61
1985	0.70	0.65	0.46	0.54	0.43	1.04	5.33	11.53	7.19	2.47	1.05	0.70	2.67
1986	2.38	2.00	1.59	1.24	1.36	1.98	5.92	9.23	15.48	6.65	2.01	1.25	4.26
1987	1.65	2.03	1.55	1.57	1.75	1.50	4.52	11.51	8.96	5.78	3.49	1.76	3.84
1988	1.64	2.51	1.56	1.31	1.46	1.09	6.38	13.25	17.60	11.47	5.50	3.05	5.57
1989	4.51	4.29	2.73	1.38	1.49	4.75	14.10	12.15	12.33	5.70	2.24	1.28	5.58
1990	3.28	1.94	1.94	1.10	1.16	2.91	8.99	17.73	13.69	6.64	2.37	1.38	5.26
1991	1.96	3.32	1.63	1.09	1.11	3.23	7.95	12.39	12.30	5.55	2.28	1.18	4.50
1992	1.70	2.11	1.28	1.01	0.97	2.05	6.89	14.85	17.49	7.31	3.30	2.09	5.09
1993	3.53	2.71	1.90	1.37	1.32	2.47	8.35	17.48	17.19	7.77	3.15	1.44	5.72
1994	0.80	1.28	1.40	1.03	1.00	1.98	9.14	10.34	6.52	4.34	2.14	1.29	3.44
1995	**1.18**	**2.02**	**1.86**	**2.09**	**1.60**	**1.91**	**5.80**	**13.15**	**8.14**	**4.48**	**2.45**	**2.27**	3.91
1996	4.14	4.48	2.28	1.57	1.20	1.20	3.41	12.24	7.80	4.81	2.21	2.05	3.95
1997	4.32	2.58	1.77	1.48	1.35	1.55	7.86	13.83	9.82	5.21	2.15	2.22	4.51
1998	**3.67**	**3.10**	**1.97**	**2.34**	**2.95**	**3.81**	**7.19**	**8.62**	**4.76**	**2.35**	**2.79**	**1.91**	3.79
1999	1.31	1.41	2.08	0.83	0.81	1.45	4.60	11.69	9.72	5.03	2.02	1.43	3.53
2000	0.91	1.35	1.47	0.96	0.99	1.60	7.73	6.17	6.26	2.19	1.34	1.10	2.67
2001	2.82	1.57	0.97	0.87	0.88	3.13	5.75	8.32	8.84	3.67	1.26	0.94	3.25
2002	1.24	1.35	0.89	0.85	1.34	2.18	5.37	9.08	14.13	6.04	2.06	2.08	3.88
2003	2.06	1.58	1.12	1.20	0.89	0.91	6.73	10.24	6.88	3.09	2.61	2.93	3.35
2004	2.10	3.24	1.61	1.15	1.30	4.44	5.43	12.68	12.58	5.17	2.18	1.45	4.44
2005	1.36	1.29	1.26	1.30	0.98	1.90	7.19	9.89	6.40	4.48	2.70	2.51	3.44
2006	5.16	4.92	2.63	1.11	1.17	2.65	6.83	11.86	8.27	4.57	1.11	0.26	4.21
2007	1.85	4.25	0.93	0.96	1.20	3.48	2.25	23.34	9.43	3.73	1.49	1.39	4.53
2008	**1.03**	**2.37**	**1.73**	**1.05**	**1.38**	**6.46**	**8.14**	**6.79**	**5.93**	**3.15**	**2.23**	**1.70**	3.50
2009	**2.88**	**1.52**	**1.10**	**1.24**	**1.47**	**3.53**	**4.95**	**11.27**	**7.35**	**4.17**	**2.00**	**2.74**	3.68
Average	2.19	2.48	1.64	1.21	1.24	2.47	6.78	11.96	10.08	5.01	2.24	1.61	4.08

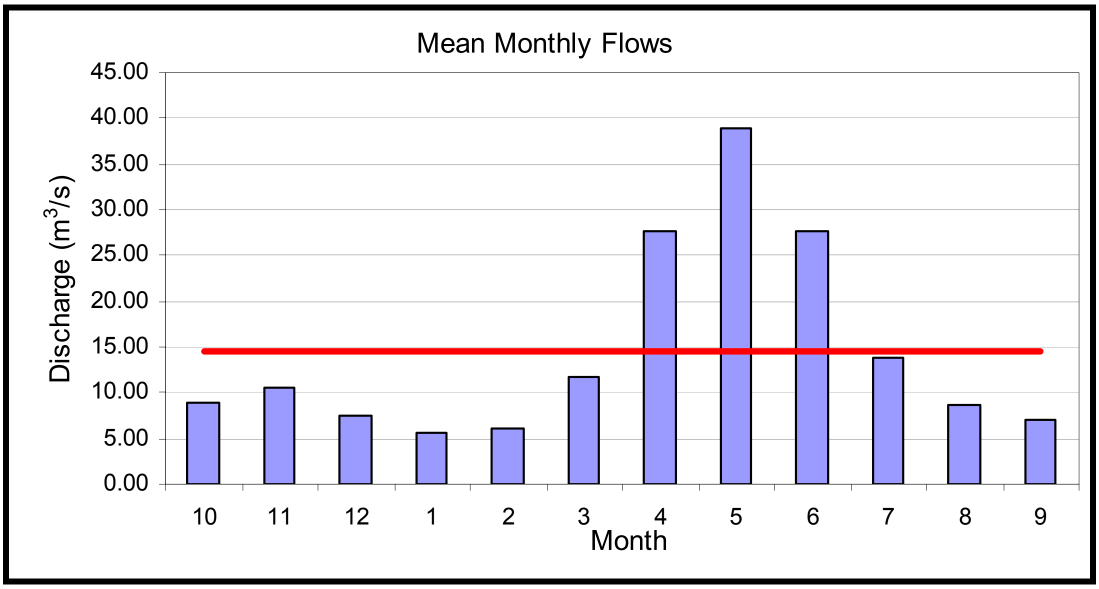

Figure 4.20 Mean Monthly Discharge Values of 22-52 Ulucami

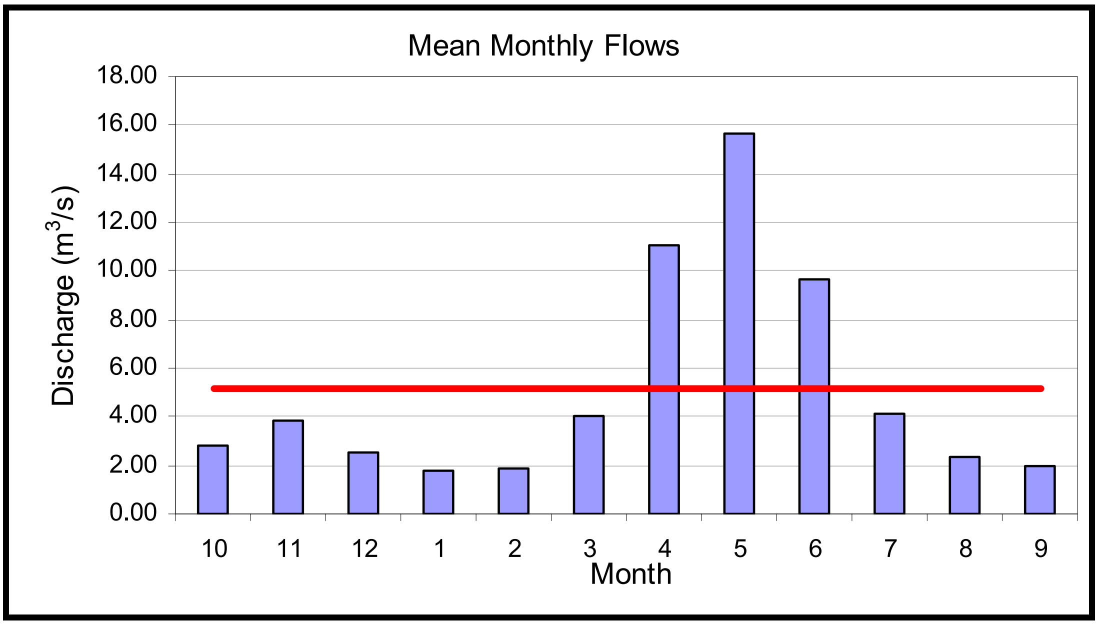

Figure 4.21 Mean Monthly Discharge Values of 22-57 Alçakköprü

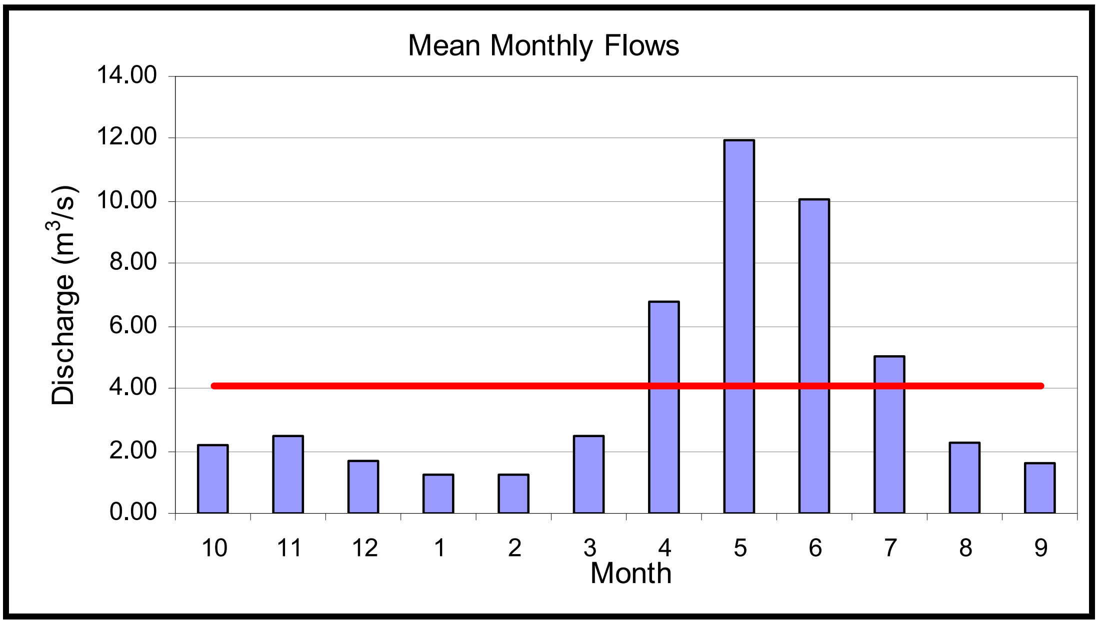

Figure 4.22 Mean Annual Discharge Values of 22-07 Serah

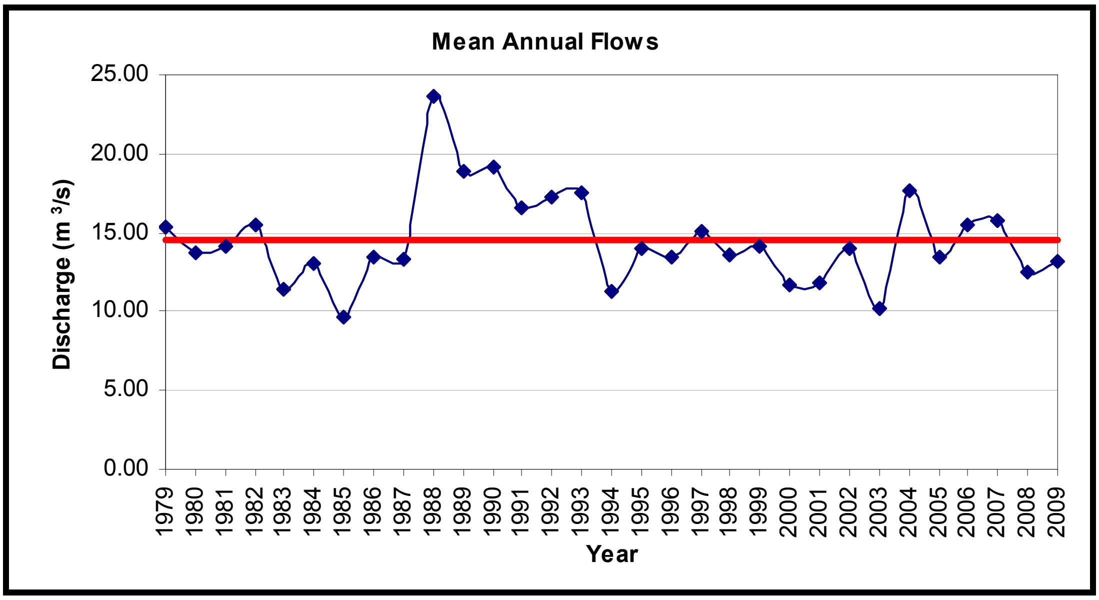

Figure 4.23 Mean Annual Discharge Values of 22-52 Ulucami

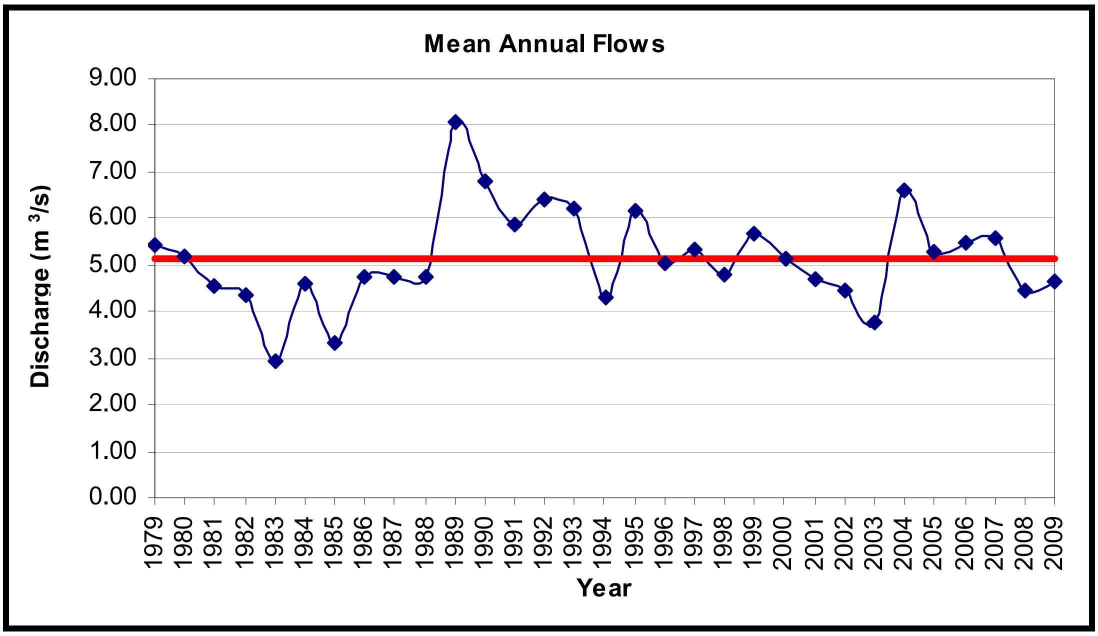

Figure 4.24 Mean Annual Discharge Values of 22-57 Alçakköprü

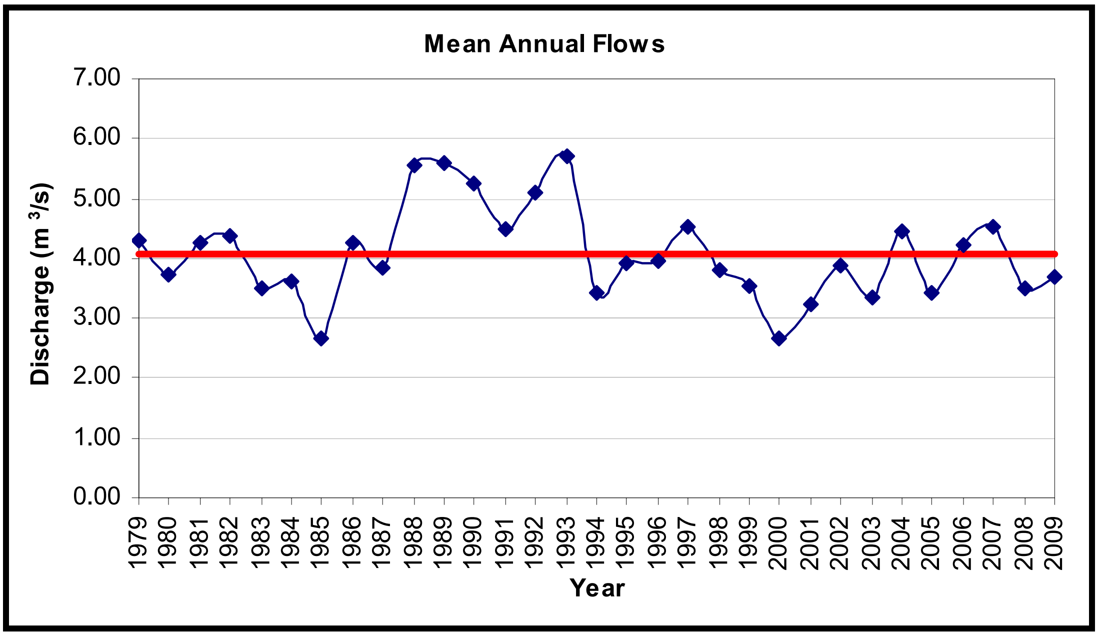

Figure 4.25 Mean Annual Discharge Values of 22-07 Serah

The mean annual discharge values of the flow gauging stations in Solaklı and Karadere basins are given in Table 4.17.

Table 4.17 Mean Annual Discharge/Specific Discharge Values of the Streamflow Gauging Stations within Karadere and Solaklı Basins

Station No	Mean Annual Discharge Values (m^3/s)	Drainage Area (km^2)	Number of Records (Year)
2202	11.18	634.77	43
22-44	6.74	425.90	43
2234	3.27	206.79	43
22-52	14.51	563.22	31
22-57	5.14	240.76	31
22-007	4.08	148.72	31
22-208	1.08	38.73	3
22-222	0.4	9.22	3

4.3.3 Flow Duration Curves

According to Cigizoglu et al. (2000); flow duration curve (FDC) is a representation of the relationship between the magnitude and the frequency of either daily, monthly, weekly 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. FDCs are generally used in water resources applications and recently they have been used in validating the outputs of hydrologic models and/or compare observed and modeled hydrologic response (Post, 2004).

In this study both annual and seasonal flow duration curves of the related stream flow gauging stations are derived. In the first part, annual and in the second part seasonal (spring) flow duration curves are presented.

The flow duration curves are necessary to determine the flow values corresponding to 8 selected flow percentiles varying from 5% to 40% with a 5% increment. The effect of the parameters to each flow percentile are going to be investigated and 8 different models seasonally and annually are going to be set up. The necessary information about the models is presented in Chapter 5.

In the following sections; the annual and seasonal FDCs of each flow gauging stations are given. These flow duration curves are obtained by running the macro program "Su Temini". The FDCs of 22-208 and 22-222 which are individual gauging stations operated by private companies are not given since their period of observation is very short (2 years).

4.3.3.1 Annual Flow Duration Curves

The annual flow duration curves of 2202 Ağnas, 22-44 Aytaş, 2234 Erikli, 22-52 Ulucami, 22-57 Alçakköprü and 22-07 Serah are given below in between Figure 4.26 and 4.31:

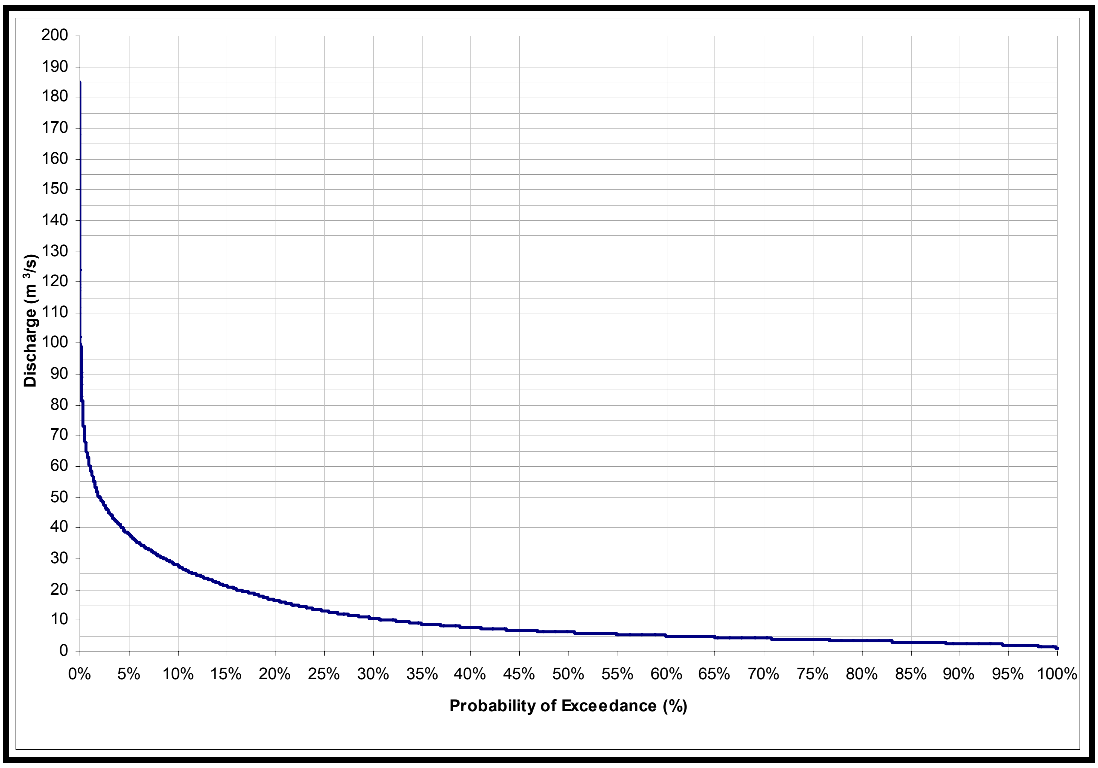

Figure 4.26 Annual Flow Duration Curve of 2202 Ağnas

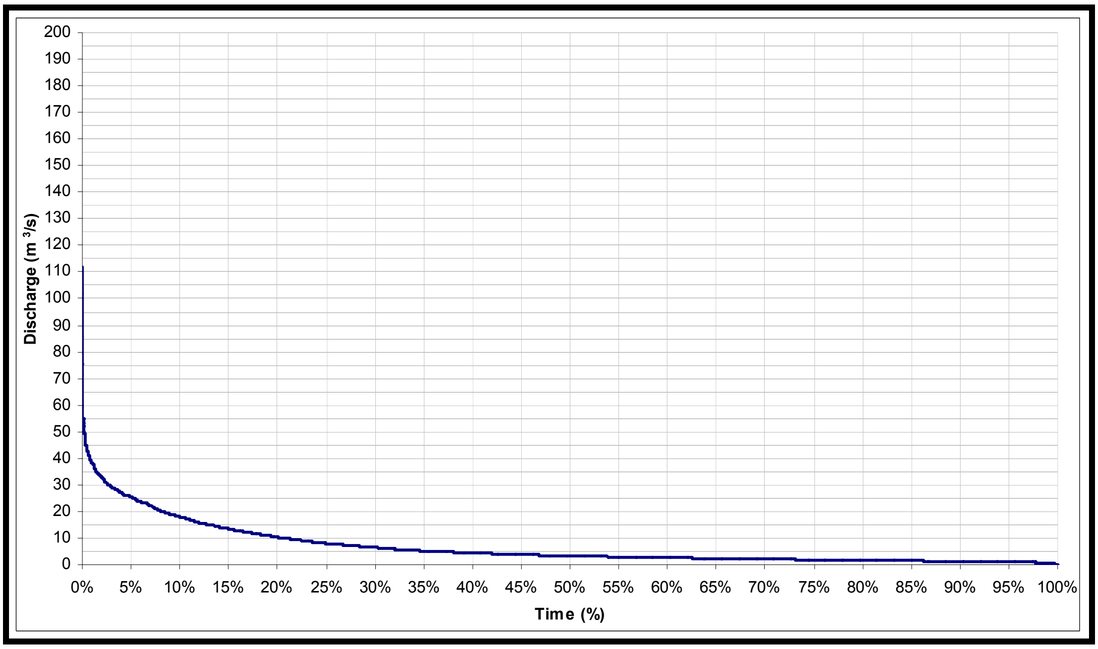

Figure 4.27 Annual Flow Duration Curve of 22-44 Aytaş

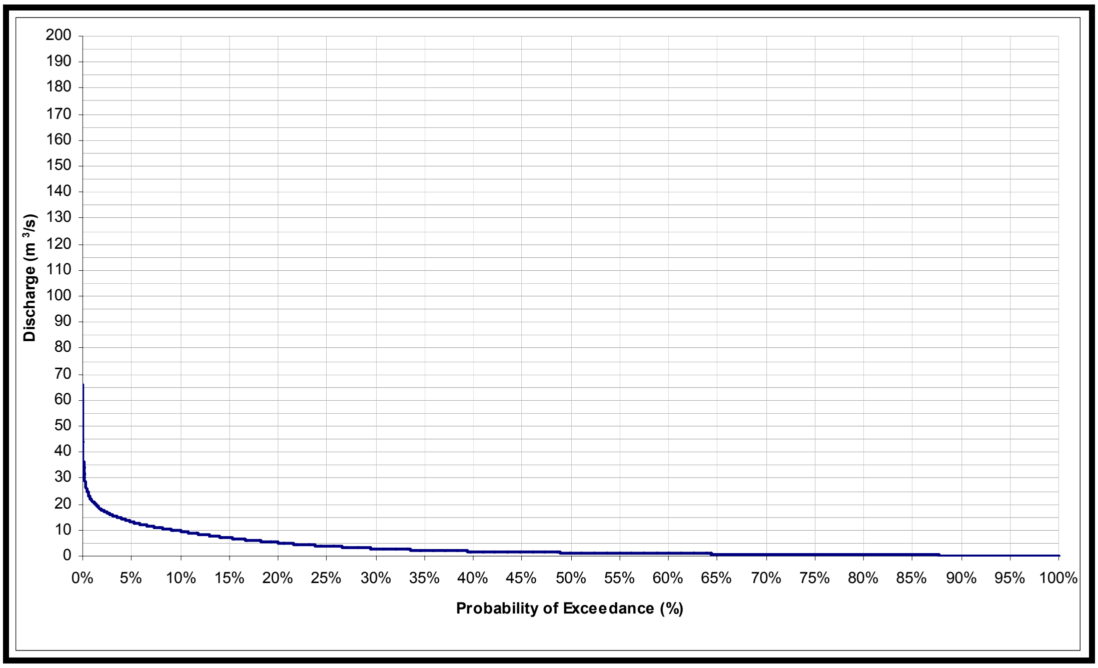

Figure 4.28 Annual Flow Duration Curve of 2234 Erikli

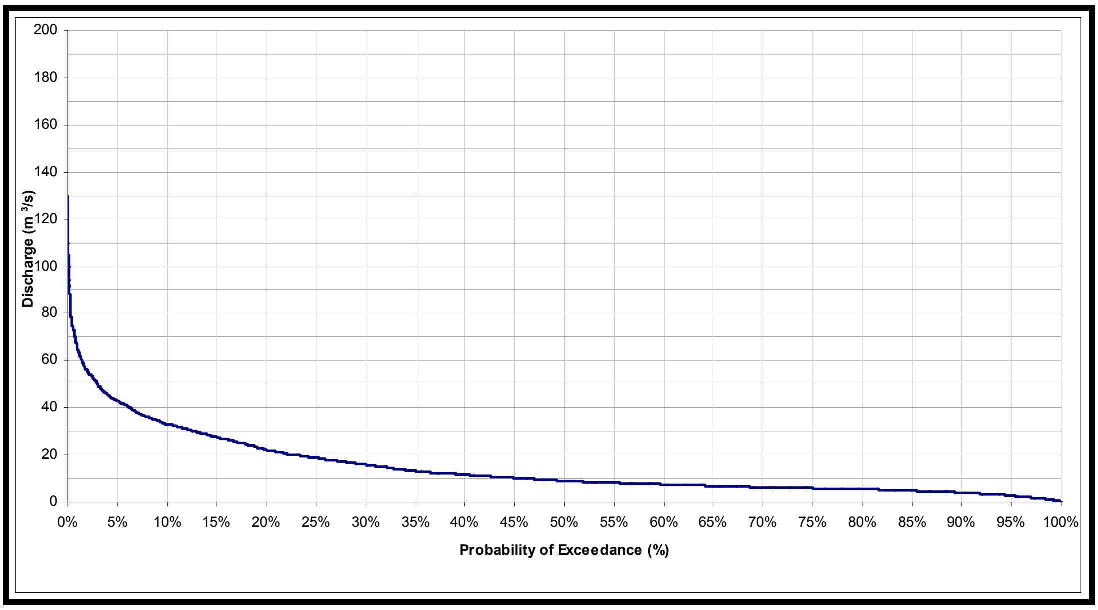

Figure 4.29 Annual Flow Duration Curve of 22-52 Ulucami

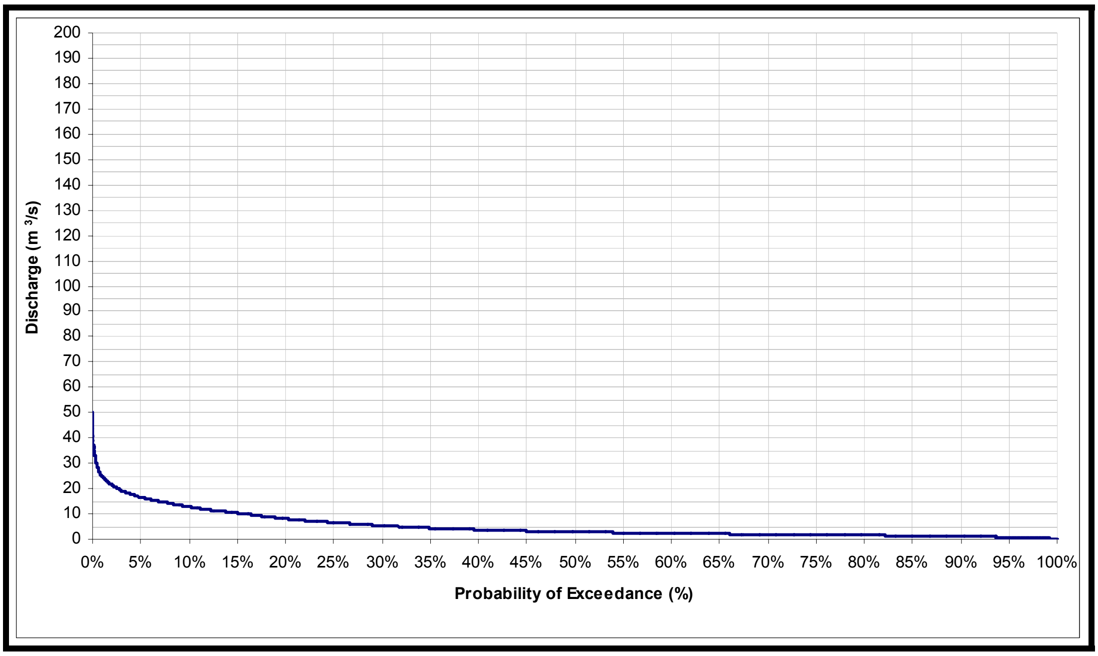

Figure 4.30 Annual Flow Duration Curve of 22-57 Alçakköprü

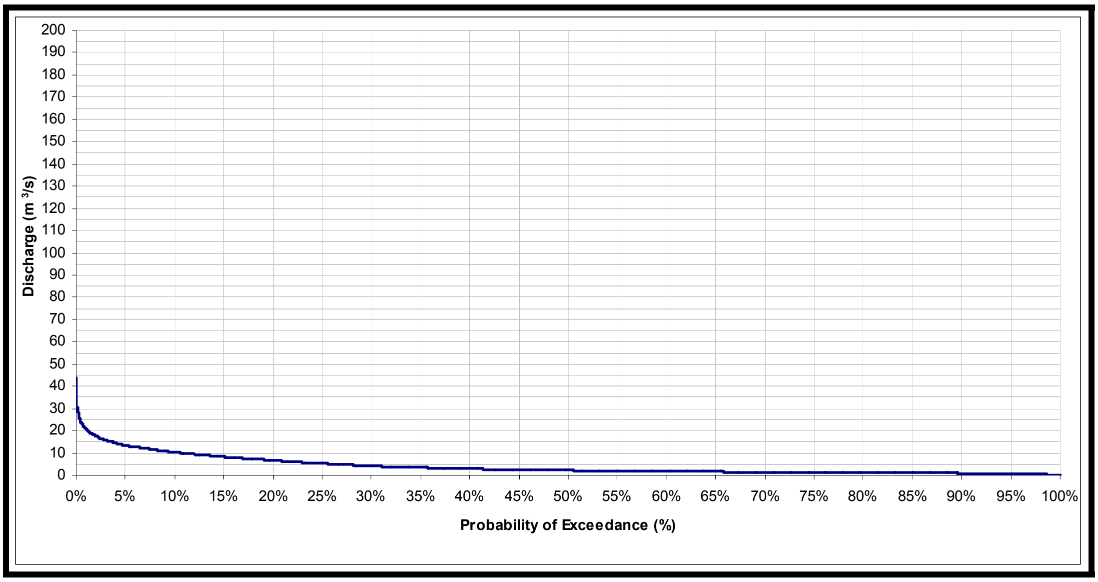

Figure 4.31 Annual Flow Duration Curve of 22-07 Serah

4.3.3.2 Seasonal Flow Duration Curves

Seasonal flow duration curves are required in order to set up spring season model. These curves are derived by considering only the spring season (march, april and may months) of the year by disregarding the rest of the year. Using the same macro program, the seasonal flow duration curves are obtained. The seasonal flow duration curves of 2202 Ağnas, 22-44 Aytaş, 2234 Erikli, 22-52 Ulucami, 22-57 Alçakköprü and 22-07 Serah are given below in between Figure 4.32 and 4.37:

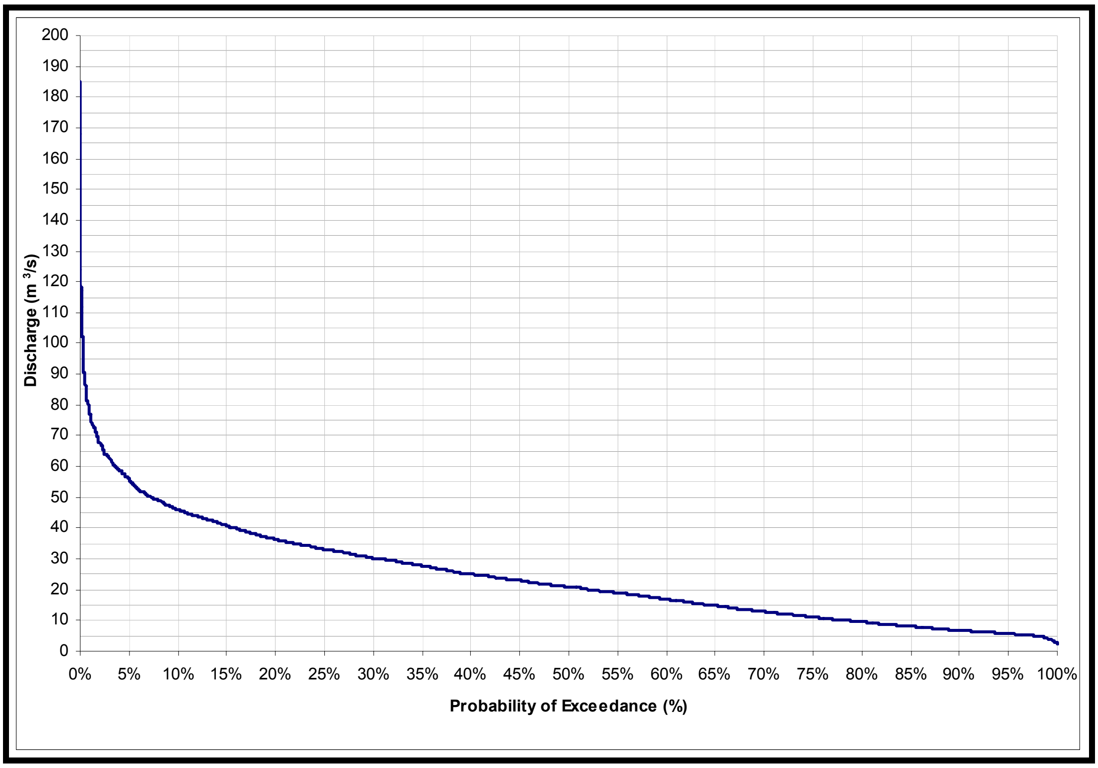

Figure 4.32 Seasonal Flow Duration Curve of 2202 Ağnas

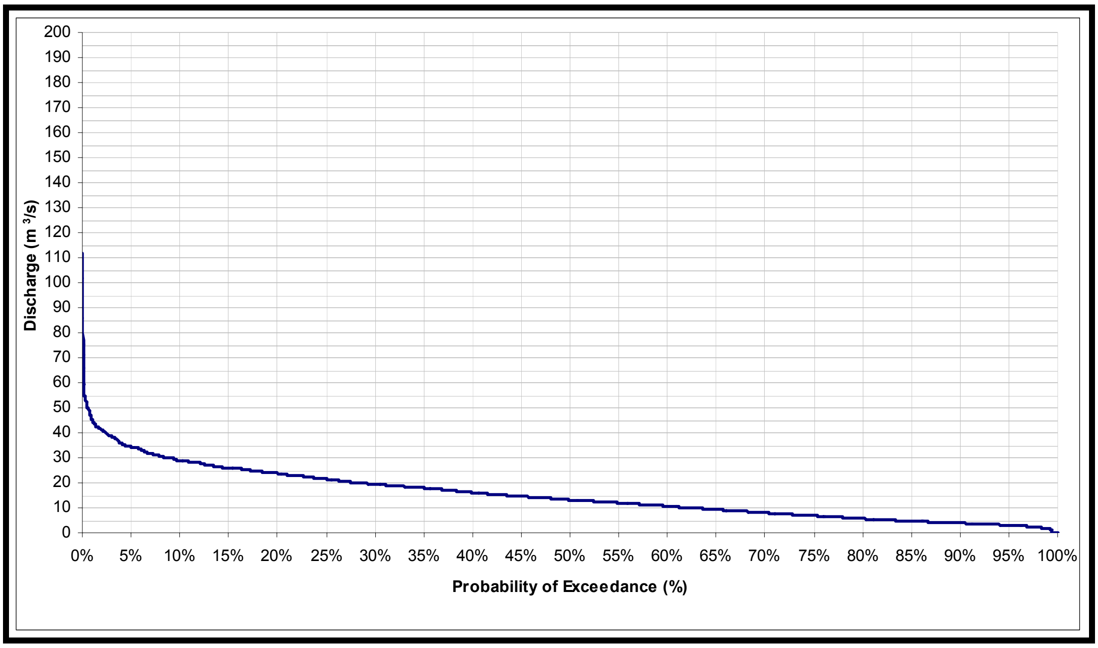

Figure 4.33 Seasonal Flow Duration Curve of 22-44 Aytaş

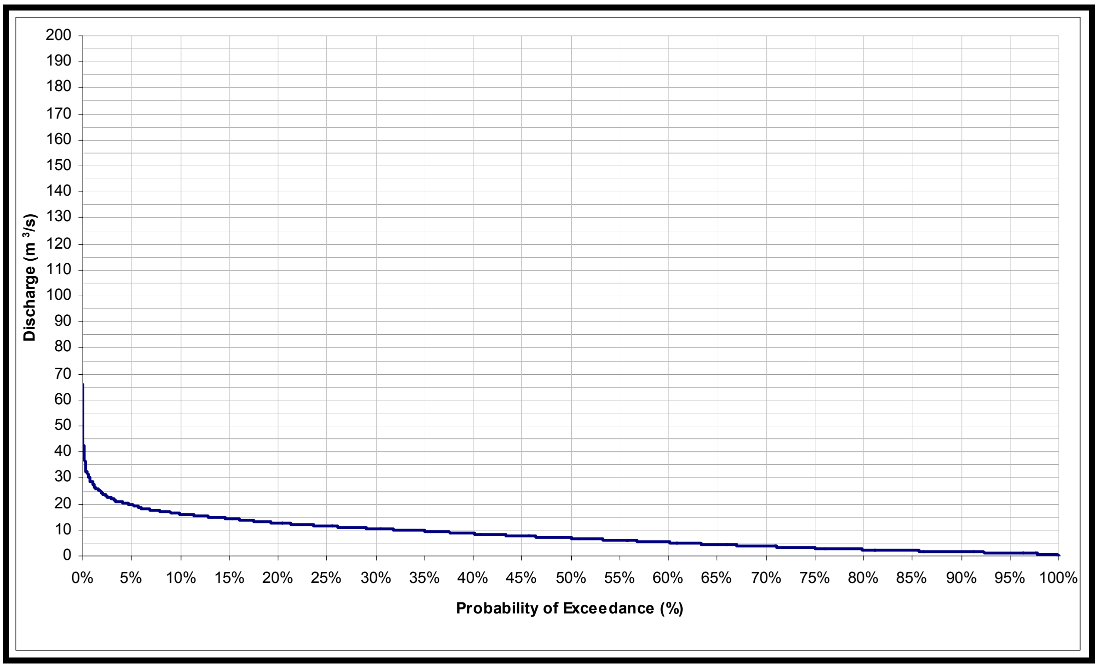

Figure 4.34 Seasonal Flow Duration Curve of 2234 Erikli

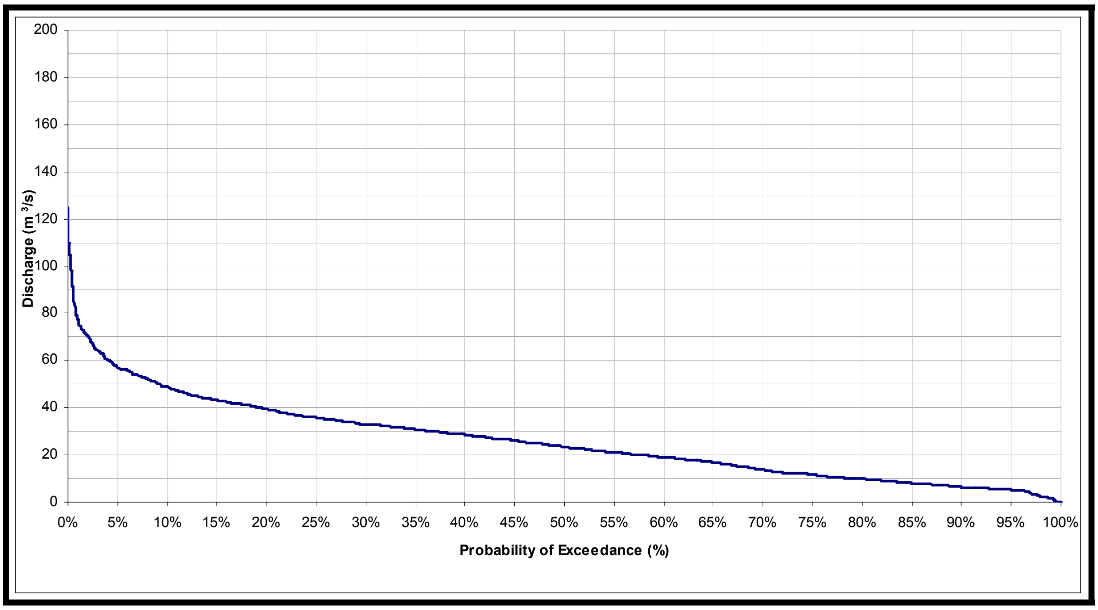

Figure 4.35 Seasonal Flow Duration Curve of 22-52 Ulucami

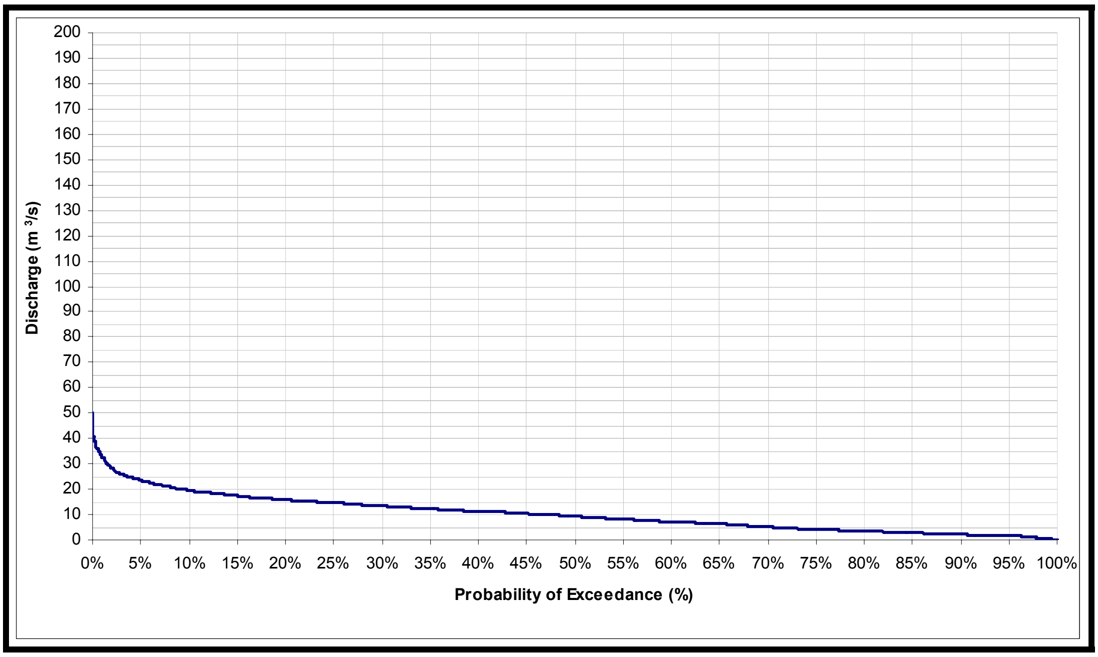

Figure 4.36 Seasonal Flow Duration Curve of 22-57 Alçakköprü

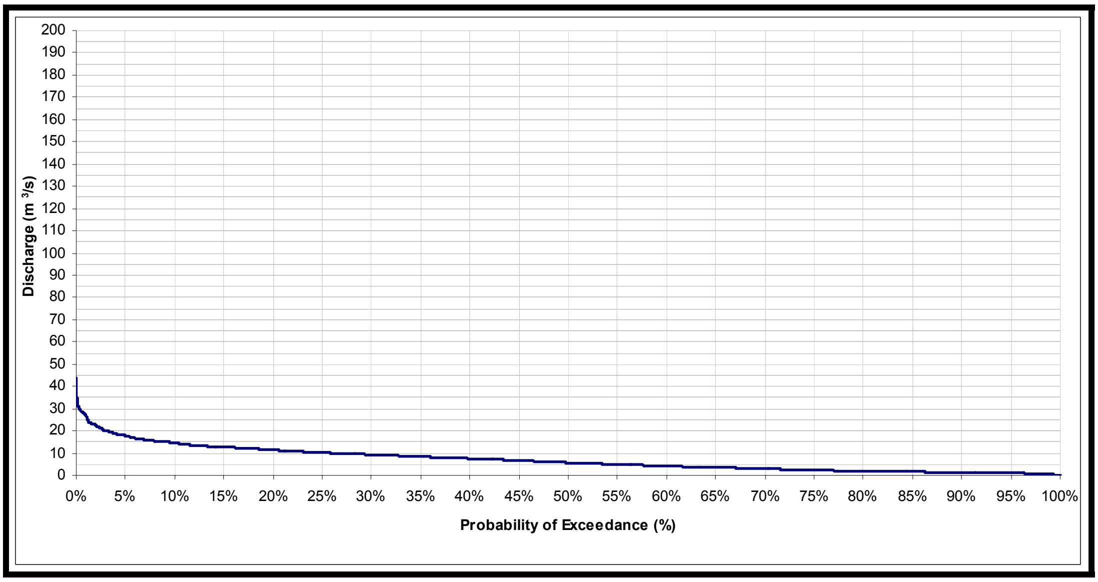

Figure 4.37 Seasonal Flow Duration Curve of 22-07 Serah

4.3.4 Estimation of Project Runoffs at Project Sites

Since there are only 6 stream flow gauging stations available for the model and this number is not enough to set up a statistical model, more basins are needed to increase the number of degrees of freedom in the model. For this reason, the locations and some other properties of some planned small HEPP projects within Solaklı and Karadere basins (see Table 3.3 and 3.4) are gathered and the parameters of these basins are extracted. To find out the daily stream flow series of these basins, there are some methods to transfer stream flow from gauged basins to ungauged basins.

Although in literature there are methods on drainage area ratio methods; a different regional approach specifically for the study area is applied in order to look for a relationship between drainage areas and flow values corresponding to different percentiles. The regional relationship between drainage area and flow value is more advantageous than conventional drainage area ratio methods as the predicted flow values bring less intercorrelation between variables in the statistical models that are going to be explained in Chapter 5. Besides this, being a regional method; in other words; the relationships for each percentile are specific for the study area, the predicted flow values would be more realistic.

As stated in Chapter 4.1.3.3, the FDCs are divided into 8 parts and each part is modeled separately. To determine the flow values for each percentile for the project sites; 8 separate relationships are derived for the annual model. Also, 8 relationships are derived for the seasonal (spring) models.

In order to derive the relationships between drainage area and flow values, 11 flow gauging stations are used. 3 flow gauging stations are located in Karadere basin which are 2202, 22-44 and 2234. 3 flow gauging stations locate in Solaklı Basin which are 22-52, 22-57 and 22-07, and 5 flow gauging stations are in İyidere Basin which is not in the study area but adjacent to Solaklı Basin. The IDs of flow gauging stations in İyidere Basin are 2218, 2233, 22-78, 2296 and 2215. The information about the gauging stations in İyidere Basin is gathered from an ongoing research.

For a flow value of a gauging station corresponding to a certain exceedance probability, the drainage area of that gauging station is determined. Then, the points are plotted and a relationship is derived for a certain flow percentile. The regression analyses are performed for each flow percentile and 8 regression equations are formed. The equations and their respective determination coefficients are given below in Table 4.18. Here y stands for discharge value (m^3/s) corresponding to the related percentile, whereas x stands for drainage area (km^2). Also in Figure 4.38 and 4.39, relationships for annual and seasonal (spring) flows could be seen.

Table 4.18 The Relationships between Drainage Area and Related Discharges

	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	$y=0.0111x^{1.0675}$; $R^2=0.77$	$y=0.0464x^{0.9972}$; $R^2=0.92$

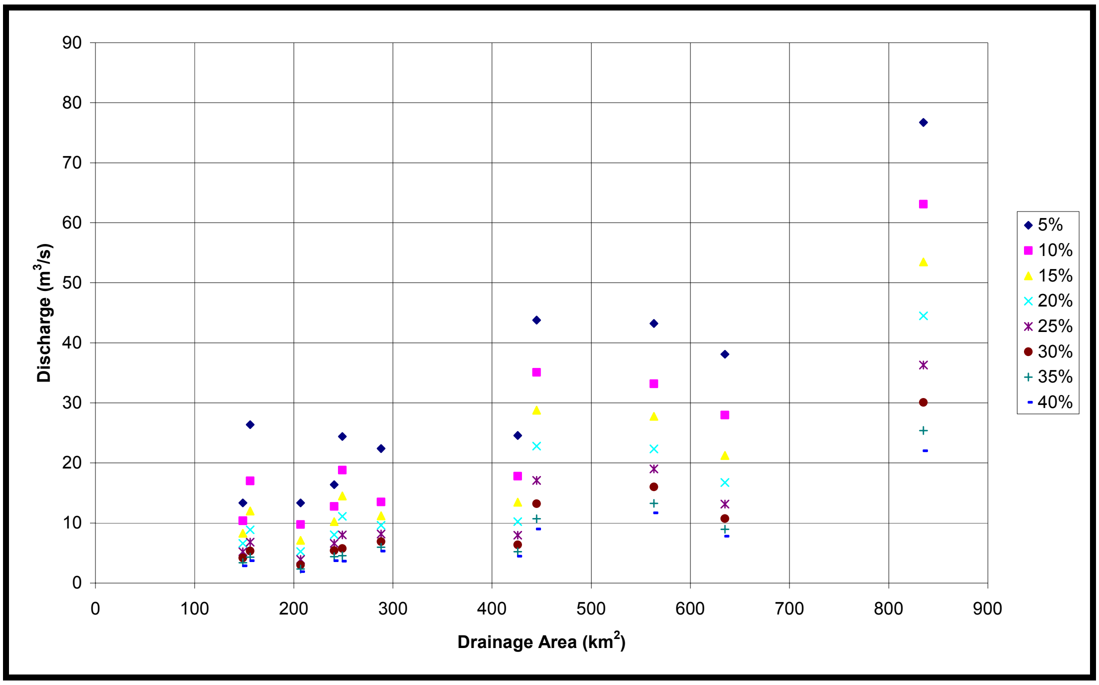

Figure 4.38 Regional Relationship of Flow Gauging Stations for Annual Flows

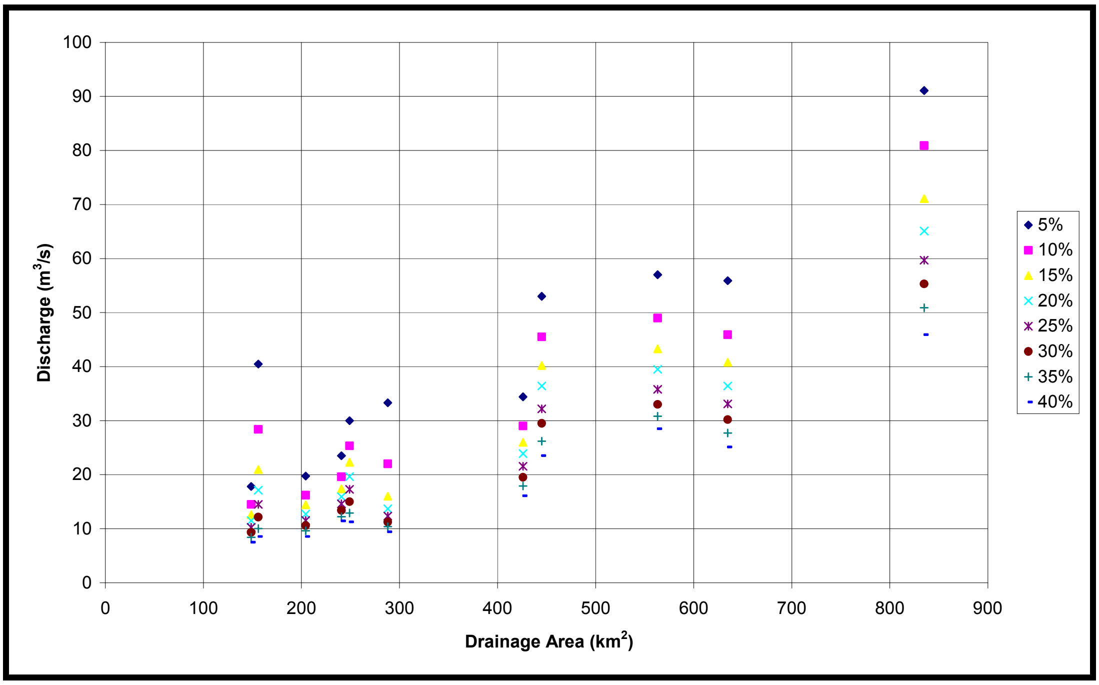

Figure 4.39 Regional Relationship of Flow Gauging Stations for Seasonal Flows

In Figure 4.38 and 4.39 and in Table 4.18; it can be concluded that the relationships between 11 flow gauging stations are good. The ranges for determination coefficients vary from 0.70 to 0.93.

The flow values of facility sites corresponding to each selected exceedance probability could be calculated depending on drainage areas of the facility sites.

4.4 Topographic Data

ASTER DEM products are used in a resolution of 30x30 m as stated in Chapter 3.2.3. By using the Arc Hydro extension of Arc GIS, some basin characteristics are derived after obtaining the digital elevation models. 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.

The whole steps in delineating the watershed are described in the flowchart given in Figure 4.40.

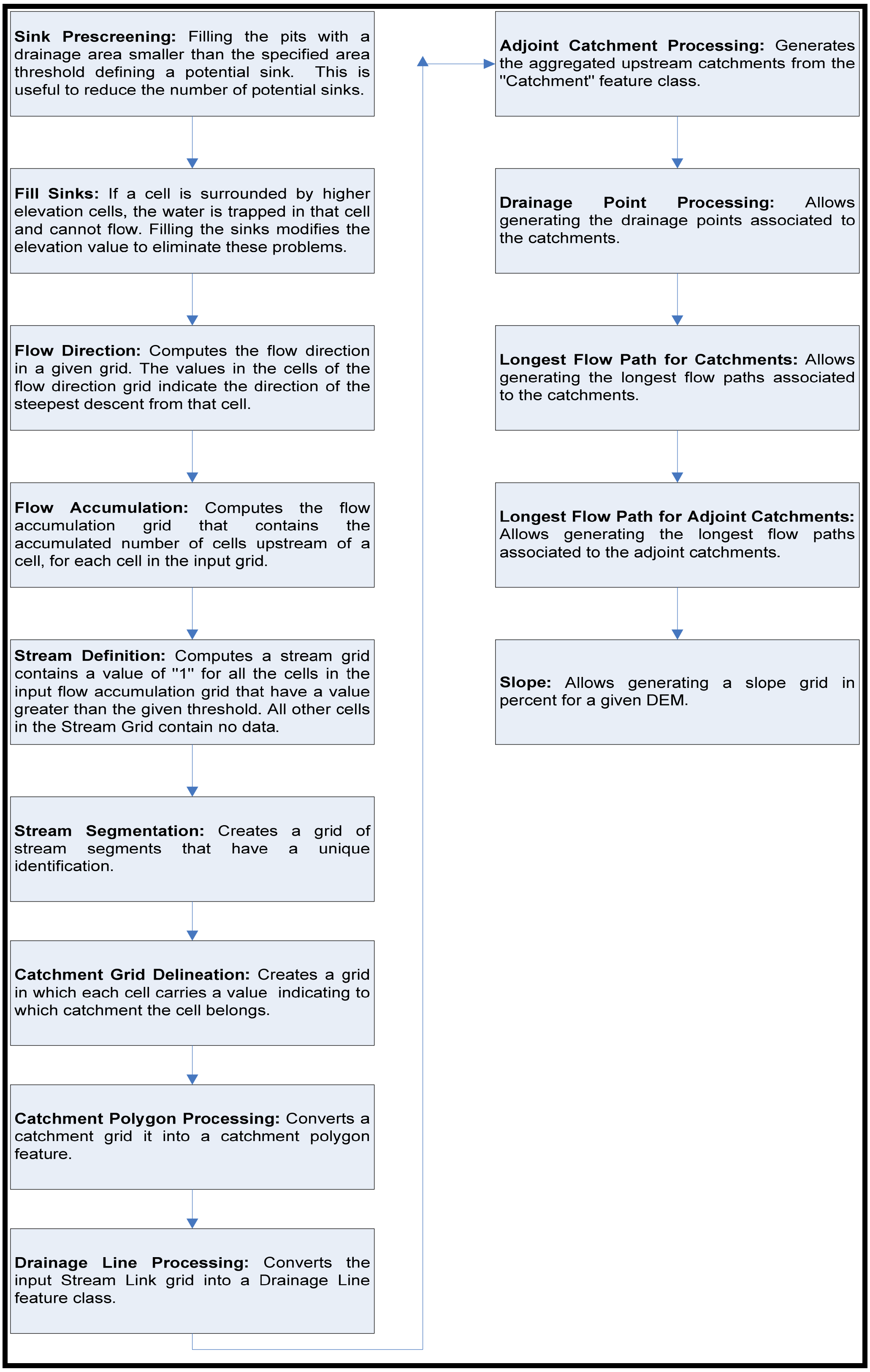

Figure 4.40 Flowchart of Terrain Processing

The terrain preprocessing is the stage just before delineating the watershed. It uses DEM to identify the surface drainage pattern. The steps in this stage are performed sequentially. The steps after terrain processing are under the watershed processing stage which is described below:

Firstly, the outlet points for the watersheds are determined in order to get the characteristics of the watershed. The watersheds of the stream gauging stations within Karadere and Solaklı watersheds together with the watersheds of the diversion weirs of hydro-power facilities are delineated. The coordinate information for the gauging stations is gathered from DSI and EIEI; some important properties of the diversion weirs of the HEPPs are gathered from DSI by personal communication as explained in Chapter 3.2.5. Also the subwatershed delineation is performed accordingly. After then, drainage area centroids and longest flow paths of the related watersheds are determined.

4.5 Snow Covered Area Data

SEVIRI SR product images for the months of January-May in 2008 and 2009 are obtained (S.Surer, personal communication, May 16 2010). as well as the mean daily temperature values of Uzungöl DMI. In this part; the aim is to look for a relationship between mean daily temperature values of Uzungöl DMI and snow covered area data of each basin.

The snow covered area data of Solaklı and Karadere basins are determined by using the “raster calculator” tool. Multiplying the related watershed polygon with the raster of SEVIRI image file of a particular day, a new map is obtained representing the snow covered area of the related basin. Some portions of the basin can either be covered with snow or/and clouds. This means that the rest of the basin is not covered with clouds or snow. The total area of the snow is calculated by counting the number of pixels that are under snow and multiplying it with the spatial resolution. Knowing the total area of the basin, the ratio of snow area to the total basin area yields snow covered area as percentage. This procedure is performed for each day that are available. One should note that the maps containing more than 25% of clouds are disregarded and the rest of the maps are considered for the analyses. Totally, 35 days from 2009 and 21 days from 2008 year are studied. January month is not used in these analyses because the snowmelt did not start in January month.

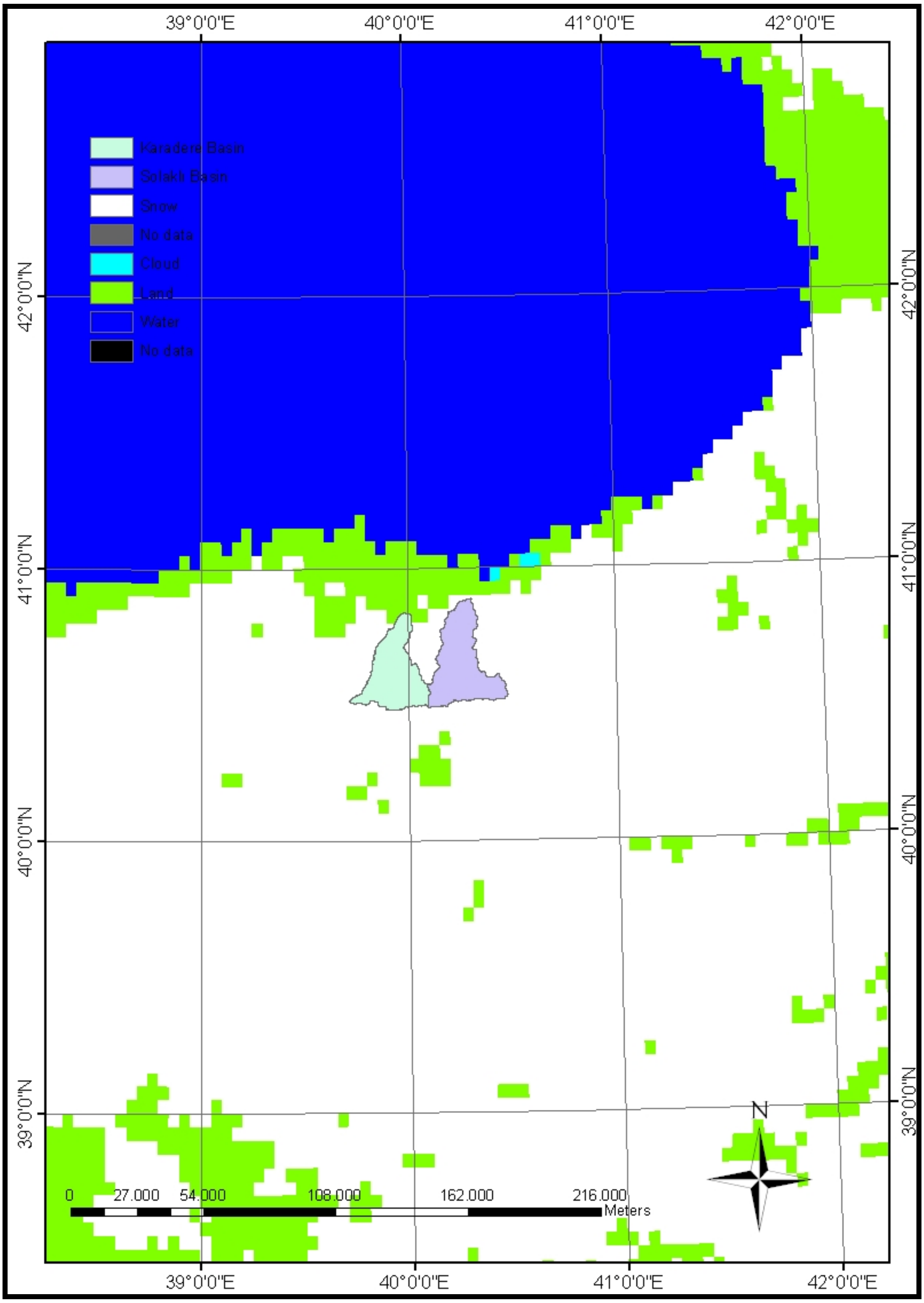

Figure 4.41 Karadere and Solaklı Basins on 14 January 2008

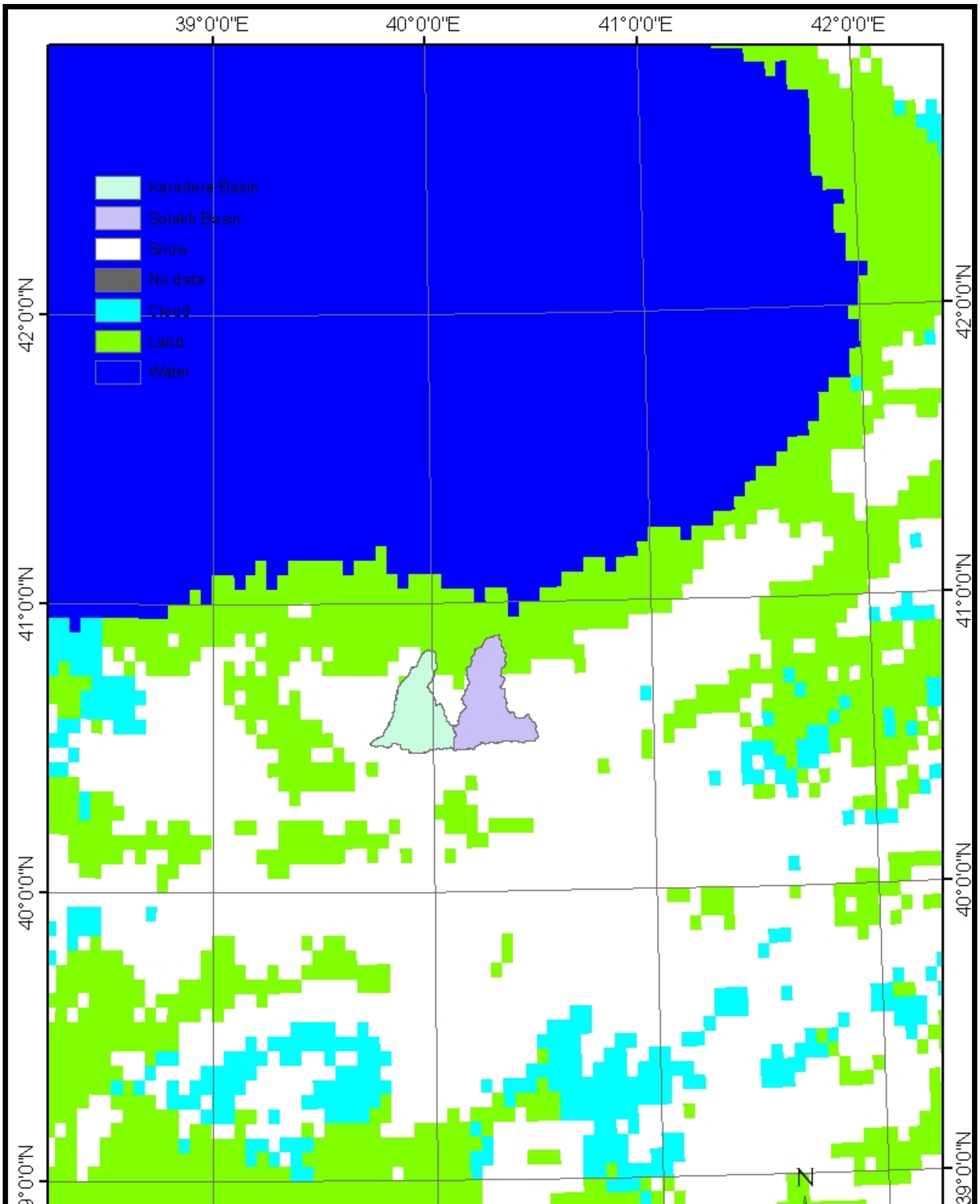

Figure 4.42 Karadere and Solaklı Basins on 12 March 2008

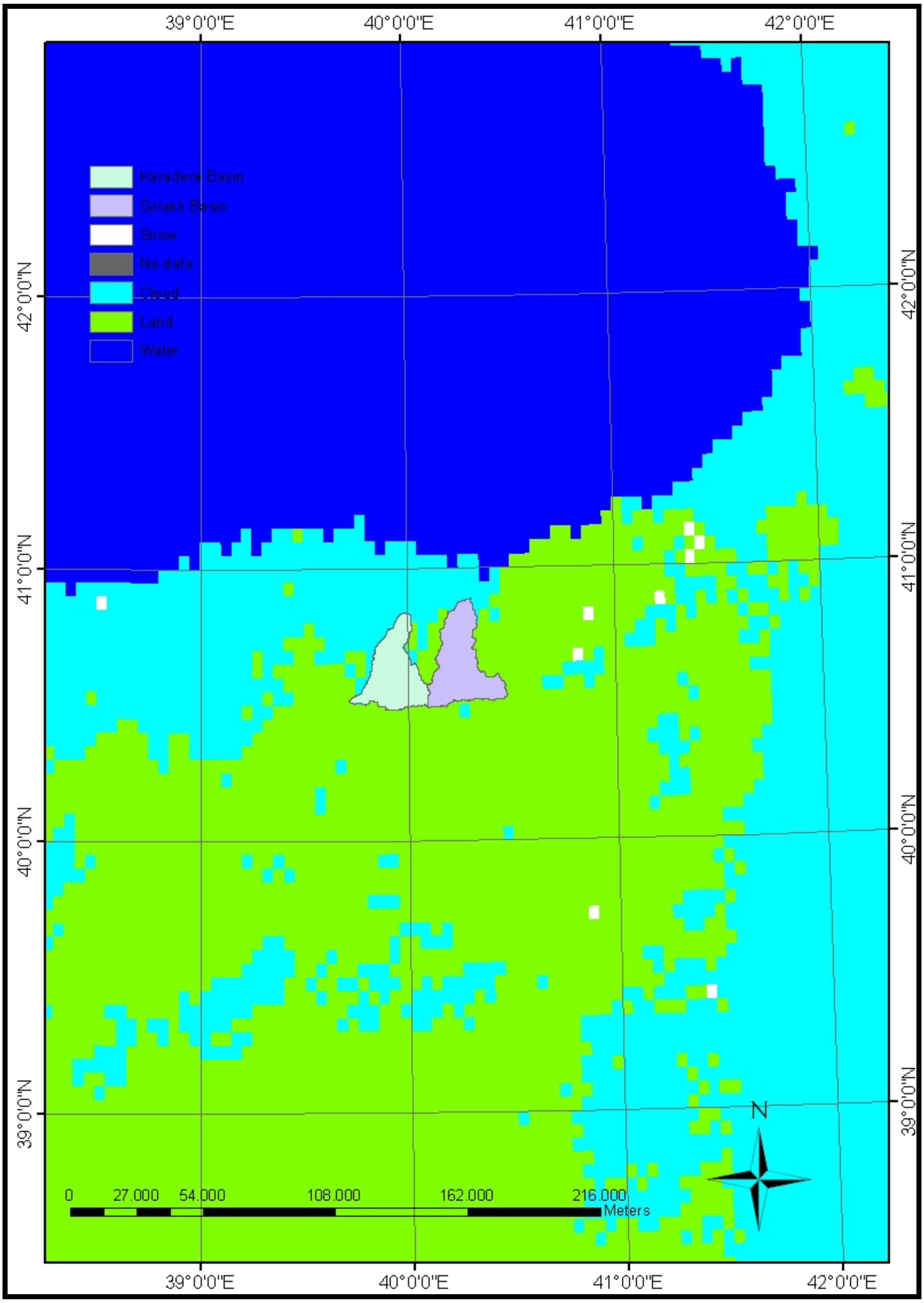

Figure 4.43 Karadere and Solaklı Basins on 29 April 2008

In Figures between 4.41-4.43, the situations of the basins on 14 January 2008, 12 March 2008 and 29 April 2008 can be seen respectively. If one can compare Figure 4.41 and 4.42 one can see the melting of snow in the region in one month. In Figure 4.43 a picture from a cloudy day can be seen.

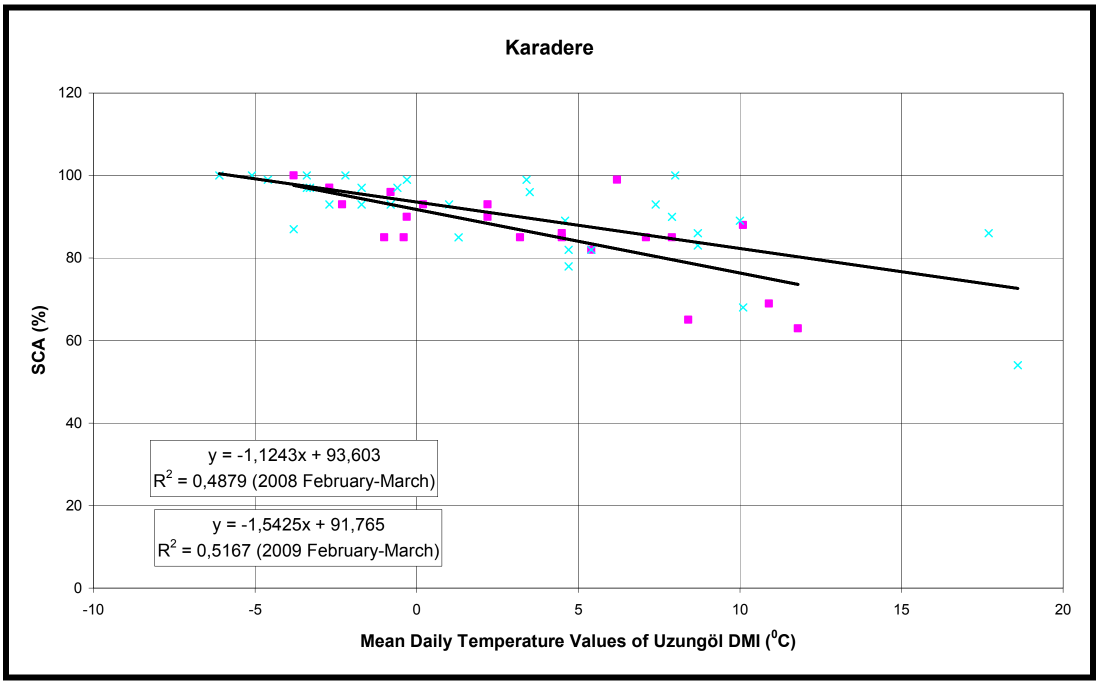

Figure 4.44 SCA-Mean Daily Temperature Values of Uzungöl DMI Relationship for Karadere Basin

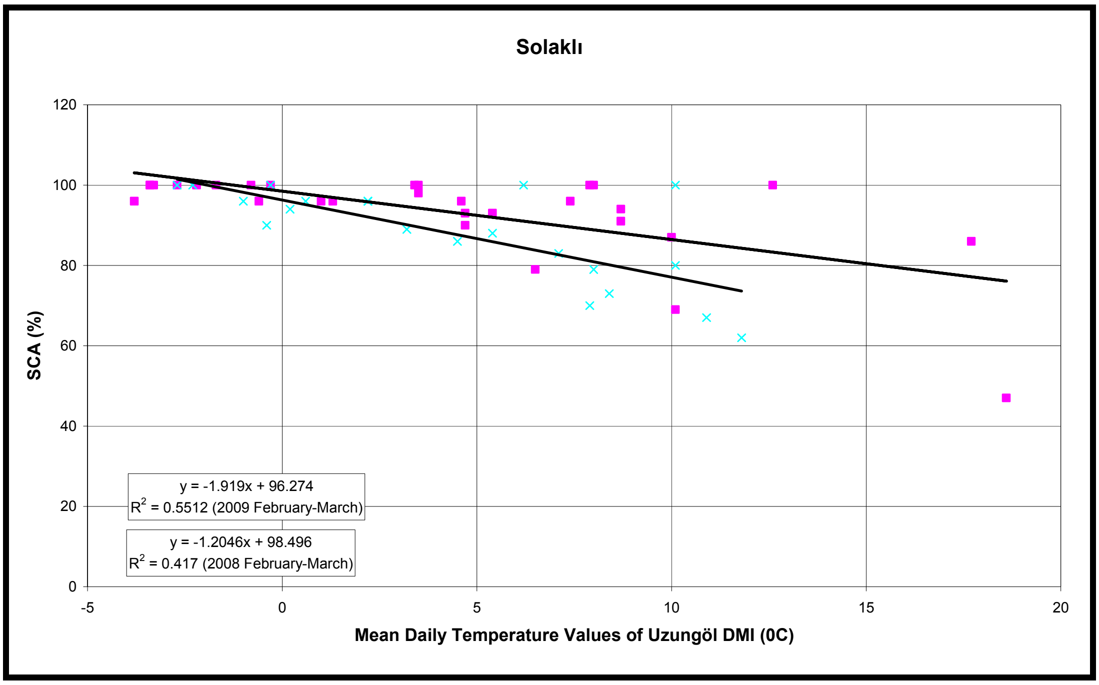

Figure 4.45 SCA-Mean Daily Temperature Values of Uzungöl DMI Relationship for Solaklı Basin

Table 4.19 Summary Table of Correlation Analyses for SCA-Mean Daily Temperature Values of Uzungöl DMI

	2008 (February-March)	2009 (February-March)
Karadere	$y = -1.12x + 93.60$, $R^2=0.49$	$y = -1.54x + 91.78$, $R^2=0.52$
Solaklı	$y = -1.21x + 98.50$, $R^2=0.42$	$y = -1.92x + 96.27$, $R^2=0.55$

In Table 4.19 above, the relationship between mean daily temperature values of Uzungöl DMI, in °C, and snow covered area values, in %, can be seen. The dependent variable, y, stands for snow covered area value of the related basin; whereas the independent variable, x, stands for mean daily temperature value of Uzungöl DMI.

As can be seen from Figure 4.36, 4.37 and Table 4.19; the snowmelt rates in both basins are relatively similar. Furthermore, in 2009 the rate of snowmelt is faster compared to 2008. Furthermore, the snow covered area and mean daily temperature is inversely proportional to each other which is physically rational.

As a result; mean daily temperature values of Uzungöl DMI is accepted to represent snow covered area values of Solaklı and Karadere basins. In this case; mean temperature value of the spring season for each basin can be representative of effect of snowmelting within the seasonal models.

CHAPTER 5

MODEL DEVELOPMENT AND DISCUSSION OF RESULTS

5.1 Introduction

The main objective of this chapter is to set up regional prediction models for FDCs both annually and seasonally (spring season) that are corresponding to 8 flow percentiles (5%, 10%, 15%, 20%, 25%, 30%, 35% and 40%) using some of the parameters from each category which are described in the preceding sections and also the dependent hydrologic variable, specific runoff. Specific runoff values ($m^3/s/km^2$) are used instead of flow values (m^3/s) by dividing the flow values to drainage area of the basin concerned.

The range from 5% to 40% of the flow duration curves of each basin are selected because the project discharges of facilities those operate for energy production purpose lies in this range. Since flow values for different percentiles of FDCs are affected by different parameters and/or in different degrees, it is decided to model each flow percentile separately.

Besides the annual models; the spring seasonal models are also selected. The reason why spring season is selected for the modeling is to look for the influence of the snowmelt to the flow percentiles of the FDCs of spring season which are usually higher than the other seasons.

The sample size is 16 with 5 of them being flow gauging stations and 11 of them being the HEPP facilities within the project sites. DSI 22-52 Ulucami flow gauging station is used for validation.

5.2 Topographic Parameters

All the basins required for the models are delineated and related parameters are extracted and these parameters are grouped in four categories which are linear measures, relief or slope parameters, shape parameters, morphological parameters and hydrological parameters.

The only linear measure is the perimeter of the basin (P); in km; whereas the shape measure is the ratio of the perimeter of the basin to the main stream length of the same basin (P/L) which is a dimensionless unit. This unit is an indicator of the shape of the basin. The smaller P/L values indicate relatively narrower and rectangular basins; on the other hand the bigger P/L values indicate a wider and circular basin shape.

The morphological measures are the drainage density and drainage frequency parameters.

Drainage density, D_d, of a basin is the total length of all the branches of a river per unit area and it shows how the basin is drained (Usul, 2001). The formula for the drainage density is given below in Equation 5.1:

$$D_d = \frac{\sum L_u}{A} \tag{5.1}$$

Where D_d is the drainage density in m/km^2, ΣL_U is the total length of the stream branches of all orders in m, and A is the basin area in km^2.

A similar term, drainage frequency, D_f, gives the same information with the number of branches. It is equal to the total number of branches from all orders per unit area. The formula for the drainage frequency is given below in Equation 5.2:

$$D_f = \frac{\sum N_u}{A} \tag{5.2}$$

Precipitation and discharge parameters are calculated as they are stated in Chapter 4. For the seasonal model mean seasonal temperature of the basin (T) is also used in $^{\circ}$C. Here the season is selected as spring. Furthermore; for the seasonal model, mean precipitation of the basin for the spring season (MSP) is used instead of annual mean precipitation (MAP).

The parameters for each basin are given in Table 5.1. In Table 5.2 and 5.3; the specific discharge values for annual and seasonal FDCs can be seen respectively.

Table 5.1 The Parameter List of the Basins
Used in the Model

CATEGORIES OF PARAMETERS		Linear	Relief/Slope	Relief/Slope	Shape	Morphological	Morphological	Hydro-Meteorological	Hydro-Meteorological	Hydro-Meteorological
NAME OF THE BASIN	PROJECT OR STATION NAME	Basin Perimeter (km)	Mean Slope of Basin (%)	Maximum Basin Relief (m)	Perimeter/Main Stream Lenght	Drainage Frequency (km^{-2})	Drainage Density (km^{-1})	Mean Annual Precipitation (mm)	Mean Spring Precipitation (mm)	Mean Spring Temperature (°C)
PROJECTS IN SOLAKLI	Çaykara	161.5	44.85	3077	3.61	0.55	0.64	1816.1	388.6	4.1
	Güneşli-II	179.9	45.43	3191	3.43	0.54	0.64	1746.2	373.6	4.8
	Ballıca	194.0	44.94	3263	3.39	0.54	0.64	1703.2	364.4	5.2
	Arca	202.3	44.75	3294	3.28	0.55	0.64	1676.3	358.7	5.5
	Uzungöl	83.6	47.96	2373	3.09	0.55	0.64	1659.1	445.2	2.8
	Oğlaklı	61.6	41.79	1845	3.10	0.46	0.63	1580.3	424.1	3.5
	Irmak	67.4	36.91	2105	3.97	0.60	0.67	1639.1	439.8	3.0
PROJECTS IN KARADERE	Bangal	74.5	35.08	1186	3.58	0.50	0.63	1168.4	300.4	3.3
	Çanak-I	13.3	25.74	964	2.86	0.64	0.41	1169.7	300.8	3.3
	Akkocak	79.5	35.49	1418	3.39	0.50	0.62	1166.1	299.8	3.3
	Erikli	89.1	36.77	1500	4.06	0.56	0.63	1190.1	306.0	3.0
GAUGING STATIONS IN SOLAKLI	22-57	100.3	40.27	2379	3.74	0.54	0.65	1585.3	425.4	3.4
	22--07	72.4	47.59	2240	2.85	0.56	0.64	1693.4	454.4	2.5
GAUGING STATIONS IN KARADERE	2202	178.6	41.56	2755	3.20	0.54	0.63	1122.5	288.6	4.0
	22-44	134.2	38.75	2322	4.03	0.54	0.62	1168.4	300.4	3.3
	2234	88.8	36.65	1503	4.12	0.57	0.63	1190.4	306.1	3.0
STATIONS USED FOR VALIDATION	22-52	159.5	44.93	3053	3.62	0.55	0.64	1815.7	388.5	4.1
	22-208	34.6	37.08	2150	2.77	0.54	0.65	1086.7	279.4	4.6

Table 5.2 Specific Discharge Values of Each Basin Corresponding to Each Exceedance Probability for Annual FDCs

Flow	Specific Flow Values Corresponding to Each Percentile ($m^3/s/km^2$)															
Percentile	Çaykara	Güneşli-2	Ballıca	Arca	Uzungol	Oğlaklı	Irmak	Bangal	Çanak-1	Akkocak	Erikli	22-57	22-007	2202	22-44	2234
5%	0.0742	0.0722	0.0710	0.0705	0.0943	0.1067	0.1013	0.0980	0.1897	0.0973	0.0903	0.0685	0.0901	0.0599	0.0594	0.0638
10%	0.0567	0.0556	0.0550	0.0547	0.0669	0.0728	0.0702	0.0687	0.1083	0.0683	0.0649	0.0534	0.0699	0.0440	0.0424	0.0466
15%	0.0458	0.0453	0.0450	0.0448	0.0506	0.0533	0.0522	0.0515	0.0677	0.0513	0.0497	0.0428	0.0558	0.0334	0.0317	0.0340
20%	0.0368	0.0365	0.0364	0.0363	0.0389	0.0400	0.0395	0.0392	0.0458	0.0392	0.0385	0.0336	0.0444	0.0263	0.0244	0.0251
25%	0.0294	0.0293	0.0293	0.0293	0.0300	0.0304	0.0302	0.0301	0.0319	0.0301	0.0299	0.0276	0.0352	0.0206	0.0188	0.0188
30%	0.0239	0.0240	0.0240	0.0240	0.0235	0.0232	0.0233	0.0234	0.0222	0.0234	0.0236	0.0225	0.0282	0.0169	0.0151	0.0144
35%	0.0199	0.0200	0.0201	0.0201	0.0189	0.0183	0.0185	0.0187	0.0161	0.0187	0.0190	0.0184	0.0229	0.0141	0.0122	0.0111
40%	0.0170	0.0172	0.0173	0.0173	0.0157	0.0150	0.0153	0.0155	0.0123	0.0155	0.0159	0.0156	0.0194	0.0122	0.0103	0.0090

Table 5.3 Specific Discharge Values of Each Basin Corresponding to Each Exceedance Probability for Seasonal FDCs

Flow	Specific Flow Values Corresponding to Each Percentile ($m^3/s/km^2$)														
Percentile	Çaykara	Güneşli-2	Ballıca	Arca	Uzungol	Oğlaklı	Irmak	Bangal	Çanak-1	Akkocak	Erikli	22-57	22-007	2202	22-44	2234
5%	0.0976	0.0940	0.0919	0.0910	0.1352	0.1599	0.1489	0.1425	0.3492	0.1410	0.1275	0.0976	0.1197	0.0881	0.0808	0.0966
10%	0.0825	0.0803	0.0790	0.0785	0.1040	0.1172	0.1115	0.1080	0.2044	0.1072	0.0998	0.0814	0.0975	0.0723	0.0681	0.0793
15%	0.0725	0.0711	0.0702	0.0699	0.0859	0.0937	0.0903	0.0883	0.1409	0.0878	0.0833	0.0723	0.0847	0.0643	0.0610	0.0706
20%	0.0657	0.0647	0.0641	0.0639	0.0749	0.0802	0.0779	0.0765	0.1100	0.0762	0.0732	0.0660	0.0773	0.0573	0.0561	0.0621
25%	0.0596	0.0588	0.0584	0.0582	0.0662	0.0699	0.0683	0.0673	0.0901	0.0671	0.0650	0.0606	0.0689	0.0521	0.0506	0.0564
30%	0.0547	0.0542	0.0540	0.0538	0.0587	0.0609	0.0599	0.0594	0.0722	0.0592	0.0579	0.0557	0.0627	0.0476	0.0458	0.0517
35%	0.0501	0.0500	0.0499	0.0498	0.0516	0.0524	0.0521	0.0518	0.0561	0.0518	0.0513	0.0507	0.0565	0.0436	0.0420	0.0471
40%	0.0456	0.0456	0.0456	0.0456	0.0457	0.0458	0.0458	0.0458	0.0462	0.0458	0.0457	0.0474	0.0504	0.0395	0.0378	0.0418

5.3 Annual Model Development

5.3.1 Parameter Selection Using Principal Component Analysis

Principal Components Analysis (PCA) is an alternative method for selecting a subset of variables for use in developing a model. It is based on an orthogonal rotation of the correlation matrix. The objective of PCA is to select a subset of variables that are important but relatively uncorrelated (McCuen, 1993).

PCA does not provide a prediction equation; this method only provides the user with the information needed to select a subset of variables. There is also some subjectivity and the selection of parameters depends on the user's personal knowledge of the system and experience (McCuen, 1993).

The data set (7 predictors and a criterion variable) is input to the program PCA for 8 models. Every model differs from each other by different specific flow values corresponding to various exceedance probabilities as indicated before. The output for 15% annual model is provided in Appendix-A.

Predictor variables which are used in model formulation are listed in Table 5.4.

The accepted parameters to be used in the multiple regression models. They are given in Table 5.5.

Table 5.4 Predictor Variables

Predictor Variables (x's)	Type of Data (Category)
X_1: Perimeter (P) km	Linear measure parameter
X_2: Mean Slope of the Basin (S) % X_3: Maximum Basin Relief (ΔH) m	Relief or slope parameter
X_4: Perimeter/Main Stream Length (P/L)	Shape parameter
X_5: Drainage Density (D_d) km^{-1} X_6: Drainage Frequency (D_f) km^{-2}	Morphology parameter
X_7: Mean Annual Depth of Precipitation (MAP) mm	Hydro-Meteorological parameter

Table 5.5 The Selected Parameters after PCA

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

As seen from Table 5.5 that for each flow percentile; the selected parameters are the same. For each model, 4 parameters are selected which mean that 4 eigen values, principal components of the system, totally describe almost 95% of the variation. After selecting the number of variables; identification of dominant variables associated with each principal component are performed. For this identification the eigen-vector matrix is scanned and the values that have relatively large absolute values are selected. If the values in the eigen-vector matrix are almost similar; the correlation matrix are used to help select variables for each principal component.

Mean slope of the basin (S), P/L, D_f and mean annual precipitation of the basin (MAP) are the selected parameters. These parameters are the input variables for multiple regression analysis. Each variable is selected that each one belongs to a different category as S is a relief measure, P/L is a shape measure, D_f is a morphological measure and MAP is a hydro-meteorological measure. This categorization is essential for reducing intercorrelations.

5.3.2 Model Development and Discussion of Results Using Multiple Regression Analysis

The objective of multiple regression analysis (MRA) is to develop a prediction equation relating a criterion variable to predictor variables. MRA can lead to significant increases in prediction accuracy and the ability to measure the effect of each independent variable on the dependent variable (McCuen, 1993).

Totally, eight models are tested by using multiple regression analysis method. Each model differs from each other as the dependent hydrologic variable, specific runoff, corresponding to different flow percentiles. Starting from the first model to eigth model; exceedance probabilities are 5%, 10%, 15%, 20%,25%, 30%, 35% and 40%.

The independent variables are the same for all models which are outputs of PCA as they are described in Chapter 5.3.

The variables for each model are input to the program MULTREG. The summary table for every model is given in Table 5.6. The output for 15% annual model is provided in Appendix-B.

Table 5.6 Multiple Regression Summary for the Annual Models

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

If Table 5.6 is examined carefully; it is seen that the signs of mean basin slope of the basin and P/L are negative for all models. The sign of mean annual precipitation is positive for all models which is physically rational. However; the sign of drainage frequency is positive for the first annual model and negative for the rest. Irrationalities for variables may occur because of intercorrelations between parameters.

Standardized partial regression coefficient (t_i) is an indicator of the relative importance of the variable concerned. t_i values are a function of both the intercorrelations and predictor-criterion correlation coefficients (McCuen, 1993). The larger t_i value means the more important the variable. Therefore, ti values are good indicators for evaluating the importance of the parameters since it both takes notice of intercorrelations and predictor-criterion coefficient. Coefficient of multiple determination (R^2) is the fraction of the variation in the criterion variable that is explained by the regression equation (McCuen, 1993). In other words, it is the ratio of the explained variation to the total variation showing the ability of regression equation to explain the reality.

When t_i values are compared, it can be concluded that MAP and S variables are generally most important parameters. However, absolute value of t_i being more than 1 meaning that there are some intercorrelations between variables.

Furthermore, when the multiple R^2 values are investigated, it is seen that the value is decreasing from the first model to the last model. Also the value S_e/S_y (the ratio of standard error of estimate (S_e) to the standard deviation (S_y)) also increases showing that model quality decreases when the flow percentile increases. The reasons why the quality of model decreases towards 40% are the effect of baseflow on low flows which is especially significant in Eastern Black Sea Basin and the lack of other parameters which is not included in the model.

5.3.3 Model Development and Discussion of Results Using Stepwise Regression Analysis

The objective of stepwise regression is to develop a prediction equation relating a criterion variable to p predictor variables. Although it is a type of multiple regression analysis it differs from the commonly used multiple regression technique in that stepwise regression, in addition to calibrating a predicting equation, introduces predictor variables sequentially based on a partial-F statistic; thus stepwise regression analysis yields p prediction equations from which one must be selected as the best model. Unlike the multiple regression technique, stepwise regression usually avoids the irrational coefficients because the final model can be selected so that only predictor variables with low intercorrelation are included (McCuen, 1993).

Eight models are tested as the same as multiple regression analyses. The data set (7 predictors and a criterion variable) is input to the program STEPWISE for every model. The parameters here are selected step by step automatically according to partial F test. The most important significant variable which has the highest partial F value enters the equation first. Insertion of parameters goes on until the model becomes significant. The significance of the entire prediction model is tested according to total F test. If total F value is less than the critical value, the model is accepted to be the final model. Stepwise regression summary is given in Table 5.7. The output for 15% annual model is provided in Appendix-C.

Table 5.7 Summary Table for Annual Stepwise Models

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

If Table 5.7 is examined carefully; it is seen that the signs of mean basin slope of the basin and P/L are negative for all models. The sign of mean annual precipitation is positive for all models. However; the signs of drainage density and basin perimeter change among models. The multiple determination of coefficients (R^2), the standard error ratio (S_e/S_y) and the standardized partial regression coefficients (t_i) are the other indicators of model quality.

t_i values indicate that S, MAP and P are the variables that are most important. The absolute values of t_i for ΔH are greater than 1 meaning that it has an intercorrelation resulting an irrationality with other predictor variables.

In addition; when the multiple R^2 values are investigated, it is seen that the value is decreasing from the first model to the last model. Also the value S_e/S_y (the ratio of standard error of estimate (S_e) to the standard deviation (S_y)) also increases showing that model quality decreases when the flow percentile increases. The same reasons discussed in Chapter 5.3.2 also explain this decrease in model quality. Nevertheless; the indicators about model quality shows that stepwise models are better than multiple regression models.

5.4 Seasonal Model Development

For the seasonal models; an additional parameter, mean seasonal temperature value of the basin (T), is included. Besides this, instead of using mean annual precipitation value of the basin, mean seasonal (spring) precipitation value of the basin (MSP) is used.

5.4.1 Parameter Selection Using Principal Component Analysis

The data set (8 predictors and a criterion variable) for each model is input to the program PCA. The output for 15% annual model is provided in Appendix-D.

Predictor variables which are used in model formulation are listed in Table 5.8.

Table 5.8 Predictor Variables

Predictor Variables (x's)	Type of Data (Category)
X_1: Perimeter (P) km	Linear measure parameter
X_2: Mean Slope of the Basin (S) % X_3: Maximum Basin Relief (ΔH) m	Relief or slope parameter
X_4: Perimeter/Main Stream Length (P/L)	Shape parameter
X_5: Drainage Density (D_d) km^{-1} X_6: Drainage Frequency (D_f) km^{-2}	Morphology parameter
X_7: Mean Seasonal Temperature of the Basin (T) °C X_8: Mean Seasonal Depth of Precipitation (MSP) mm	Hydro-Meteorological parameter

In Table 5.9, one can see the selected parameters to be used in multiple regression analysis (MRA).

Table 5.9 The Selected Parameters after PCA

MODEL	Basin Perimeter P (m)	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 Seasonal Basin Temperature T (°C)	Mean Seasonal Precipitation of the Basin MSP (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

For each model, 4 parameters are selected according to the values of each eigen value representing a different principal component, in total describing almost 95% of the variation. After determining that there are 4 eigen values, in other words 4 variables representing the system, each variable is selected according to the same procedure applied in annual PCA.

Perimeter of the basin (P), P/L, D_f and mean seasonal temperature of the basin (T) are the selected parameters for the first five models as seen in Table 5.9. For the last three models, mean seasonal precipitation (MSP) of the basin was selected instead of T. These parameters are the input variables for multiple regression analysis. Please note that each variable belongs to a different category meaning that selection was done considering reducing intercorrelations.

5.4.2 Model Development and Discussion of Results Using Multiple Regression Analysis

Totally, eight models are tried by using multiple regression analysis method. Each model differs from each other as the dependent hydrologic variable, specific runoff, corresponding to different flow percentiles. Starting from the first model to eigth model; flow percentiles are 5%, 10%, 15%, 20%,25%, 30%, 35% and 40%.

The independent variables are the same for all models which are outputs of PCA as they are described in Chapter 5.6. Each variable for the models are input to the program MULTREG. The summary table for every model is given in Table 5.10. The output for 15% annual model is provided in Appendix-E.

Table 5.10 Multiple Regression Summary for the Models

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	-1.43E-03	-7.40E-04	-4.31E-04	-2.89E-04	-2.09E-04	-7.20E-05	-3.30E-05	-1.30E-05
t_P	-1.25	-1.29	-1.29	-1.27	-1.26	-0.65	-0.49	-0.24
Coefficient of P/L	-3.56E-02	-1.85E-02	-1.14E-02	-8.74E-03	-6.51E-03	-6.48E-03	-3.45E-03	-1.92E-03
$t_{P/L}$	-0.23	-0.24	-0.25	-0.28	-0.29	-0.44	-0.38	-0.27
Coefficient of D_f	5.34E-01	2.34E-01	1.23E-01	7.57E-02	5.02E-02	3.12E-02	1.18E-02	2.12E-03
t_{Df}	0.34	0.29	0.27	0.24	0.22	0.20	0.13	0.03
Coefficient of T	5.59E-02	2.80E-02	1.56E-02	1.01E-02	7.21E-03			
t_T	0.76	0.76	0.73	0.69	0.68			
Coefficient of MAP						7.00E-06	1.90E-05	2.50E-05
t_{MAP}						0.07	0.31	0.51
Intercept coefficient	-0.08	0.02	0.05	0.06	0.06	0.07	0.05	0.04
Multiple R^2	0.91	0.93	0.95	0.95	0.95	0.78	0.64	0.50
S_e/S_y	0.35	0.30	0.26	0.26	0.27	0.54	0.70	0.83

If Table 5.10 is examined carefully; it is seen that the signs of basin perimeter and P/L are negative for all models. The signs of mean seasonal precipitation and temperature and also drainage frequency are positive for all models. This is an indication of physically rationality. No ever parameter changes sign so all the models are consistent in this manner.

Furthermore, when the multiple R^2 values are investigated, it is seen that the value is decreasing from the first model to the last model. Also the value S_e/S_y which indicates the standard error of estimate also increases showing that model quality decreases when the flow percentile increases. The effect of baseflow and lack of some significant parameters again influence the model quality in spring model. Moreover, the decrease in model quality is more striking.

When the absolute values of t_i are examined, it can be concluded that T variable which indicates the mean seasonal temperature value is important in this manner.

5.4.3 Model Development and Discussion of Results Using Stepwise Regression Analysis

Eight models are tested as the same as multiple regression analyses.

The data set (8 predictors and a criterion variable) is input to the program STEPWISE. Stepwise regression summary is given in Table 5.7. The output for 15% annual model is provided in Appendix-F.

Table 5.11 Summary Table for Stepwise Models

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	-9.29E-04	-6.66E-04	-3.41E-04	-2.88E-04	-2.09E-04	-1.32E-04	-6.90E-05	
t_P	-0.81	-1.16	-1.02	-1.27	-1.26	-1.20	-1.04	
Coefficient of P/L			-7.13E-03	-8.74E-03	-6.51E-03	-4.86E-03	-2.13E-03	
$t_{P/L}$			-0.16	-0.29	-0.29	-0.33	-0.24	
Coefficient of ΔH		1.10E-05						-4.00E-06
$t_{\Delta H}$		0.26						-0.94
Coefficient of D_f				7.57E-02	5.02E-02	2.75E-02		
t_{Df}				0.24	0.22	0.18		
Coefficient of D_d	-6.28E-02	-2.79E-01	-1.08E-01					
t_{Dd}	-0.57	-0.50	-0.34					
Coefficient of T	3.23E-02	1.87E-02	1.11E-02	1.01E-02	7.21E-03	4.46E-03	2.66E-03	2.41E-03
t_T	0.44	0.50	0.52	0.69	0.68	0.63	0.62	0.70
Coefficient of MAP							2.20E-05	4.90E-05
t_{MAP}							0.37	1.02
Intercept coefficient	0.51	0.25	0.17	0.06	0.06	0.06	0.05	0.03
Multiple R^2	0.95	0.95	0.94	0.95	0.95	0.89	0.73	0.60
S_e/S_y	0.25	0.27	0.28	0.26	0.27	0.40	0.61	0.70

If Table 5.11 is examined carefully; it is seen that the signs of basin perimeter, P/L and drainage density are negative for all models. The signs of mean seasonal precipitation and temperature and also drainage frequency are positive for all models. Only maximum basin relief parameter changes sign showing inconsistency.

Furthermore, when the multiple R^2 values are investigated, it is seen that the value is decreasing from the first model to the last model. Also the value S_e/S_y which indicates the standard error of estimate also increases showing that model quality decreases when the flow percentile increases. The same reasons as discussed in Chapter 5.4.2 are valid for explaining the decrease in model quality. Nevertheless; the indicators about model quality shows that stepwise models are better than multiple regression models.

When the absolute values of t_i are examined, it can be concluded that T variable which indicates the mean seasonal temperature value is important in this manner.

When the absolute values of t_i are examined, it can be concluded that T variable is important as the same as MRA results.

5.5 Validation of Results

The results of the statistical models set up above are compared with the selected flow gauging station; 22-52. The results of drainage area ratio method are also compared. 22-52 is treated as an ungauged basin and flow values of the flow gauging stations 22-52 are derived from the sum of the flow values of 22-07 and 22-57 gauging stations upstream of 22-52.

22-52 is a station operated by DSI and its flow records are from 1979 till 2009. It is located in the Solaklı Basin and has a drainage area of 563.22 km^2.

The validation results for each annual and seasonal models are given below in Table 5.12 and 5.13 respectively. In Figure 5.1 and 5.2 one can see the graphical comparisons.

In Table 5.12 and Figure 5.1, it can be concluded that multiple regression models provide better estimations compared to stepwise models. Stepwise regression model is better than multiple regression model; only for the model corresponding to 40% exceedance probability. Up to 25%, drainage area ratio method is better; but then the results of MRA and stepwise regression provide either better or same estimations. However, when Table 5.13 and Figure 5.2 is examined, models corresponding to percentiles ranging from 5% to 15% provide better estimations for stepwise models, but after 20% to 40%, either multiple regression models are better or they are equally well estimated and also the results of drainage area ratio method are almost perfect and much better than that of MRA and stepwise regression results.

When Table 5.12 is examined, the relative error values for MRA and Stepwise models are increasing towards 40% exceedance probabilities which are consistent with the R^2 and S_e/S_y values. In Table 5.13, it is seen that relative errors for both methods are not increasing as much as in annual models but they could still be accepted to be consistent with the model quality indicators of MRA and Stepwise models as discussed in Chapter 5.3 and 5.4.

One of the reasons of the decrease in the model quality towards 40% is the baseflow is not considered as mentioned before. Besides, absence of some other parameters related with the basin such as; geologic/soil data, land use and land cover data may have increased the error in the models. Intercorrelations between the parameters (especially between specific flow values some of which are derived from flow gauging stations that are present in the calibration) and lack of meteorological stations with poor quality and discontinuous data resulting poor areal rainfall values also affect the model quality. The degrees of freedom are so low that specific flow values of ungauged basins had to be estimated which caused intercorrelations which decrease model quality.

The results of the drainage area ratio method are seemed to be better than the other methods up to 30% exceedance probability for the annual models. After that, they are either equal or worse than the results of MRA and stepwise regression. However for the seasonal models the results of drainage area ratio method are much better. Because some of the values of 22-57 and 22-07, the upstream stations that are used to derive flows of 22-52, are completed from 22-52; drainage area ratio method provided better estimations. Some of the flows of 22-57 and 22-07 are also corrected as stated in Chapter 4.1.3.2 which also results better estimation. Since these corrections are present in spring season; the observed values and the values resulting from drainage area ratio method almost match for the spring model.

Table 5.12 Validation Results for Annual Models

Flow percentile (%)	Specific Discharge Values for MRA ($m^3/s/km^2$)	Discharge Values for MRA (m^3/s)	Specific Discharge Values for Stepwise ($m^3/s/km^2$)	Discharge Values for Stepwise (m^3/s)	Observed values of 22-52 (m^3/s)	Relative error for MRA (%)	Relative error for Stepwise (%)	Discharge Values for Drainage Area Ratio Method (m^3/s)	Relative error for Drainage area ratio method (%)
5	0,0753	42,4146	0,0718	40,4460	43,0000	1,3615	5,9395	42,81	0,4419
10	0,0585	32,9411	0,0553	31,1626	33,0000	0,1785	5,5679	33,53	1,6061
15	0,0465	26,1822	0,0459	25,8501	27,6000	5,1371	6,3403	26,81	2,8623
20	0,0377	21,2210	0,0363	20,4650	22,2000	4,4099	7,8152	21,44	3,4234
25	0,0300	16,8889	0,0295	16,6002	18,9000	10,6407	12,1684	17,02	9,9471
30	0,0238	13,4233	0,0224	12,6108	15,9000	15,5767	20,6868	13,98	12,0755
35	0,0201	11,3263	0,0189	10,6635	13,2000	14,1950	19,2161	11,5	12,8788
40	0,0165	9,3140	0,0180	10,1364	11,6000	19,7065	12,6170	9,73	16,1207

Table 5.13 Validation Results for Seasonal Models

Flow percentile (%)	Specific Discharge Values for MRA ($m^3/s/km^2$)	Discharge Values for MRA (m^3/s)	Specific Discharge Values for Stepwise ($m^3/s/km^2$)	Discharge Values for Stepwise (m^3/s)	Observed values of 22-52 (m^3/s)	Relative error for MRA (%)	Relative error for Stepwise (%)	Discharge Values for Drainage Area Ratio Method (m^3/s)	Relative error for Drainage area ratio method (%)
5	0,1194	28,7538	0,1145	27,5667	57,0000	49,5547	51,6374	57,3	0,5263
10	0,0937	22,5669	0,0956	23,0149	49,0000	53,9451	53,0308	47,69	2,6735
15	0,0791	19,0531	0,0782	18,8155	43,3000	55,9976	56,5463	42,99	0,7159
20	0,0698	16,7949	0,0699	16,8189	39,5000	57,4813	57,4205	39,57	0,1772
25	0,0622	14,9831	0,0622	14,9830	35,8000	58,1479	58,1482	36,25	1,2570
30	0,0560	13,4906	0,0558	13,4366	33,0000	59,1193	59,2831	33,13	0,3939
35	0,0511	12,3135	0,0514	12,3720	30,8000	60,0211	59,8312	30,29	1,6558
40	0,0464	11,1653	0,0461	11,1065	28,5000	60,8234	61,0298	27,56	3,2982

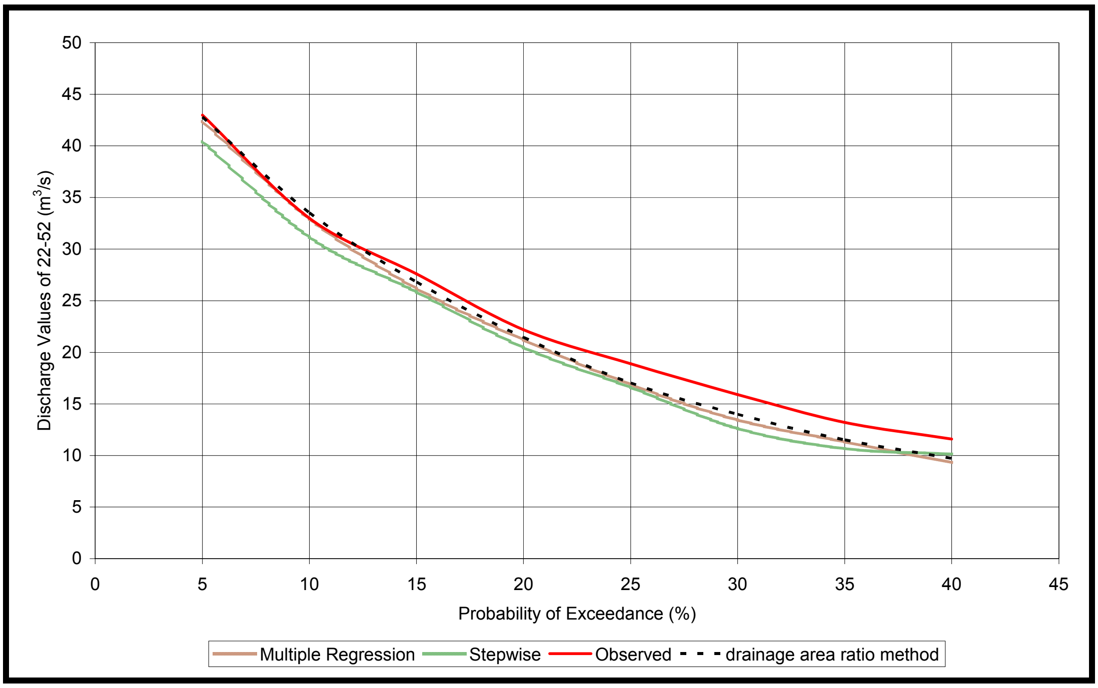

Figure 5.1 Comparison of Annual Multiple and Stepwise Models with Observed FDC and Drainage Area Ratio Method

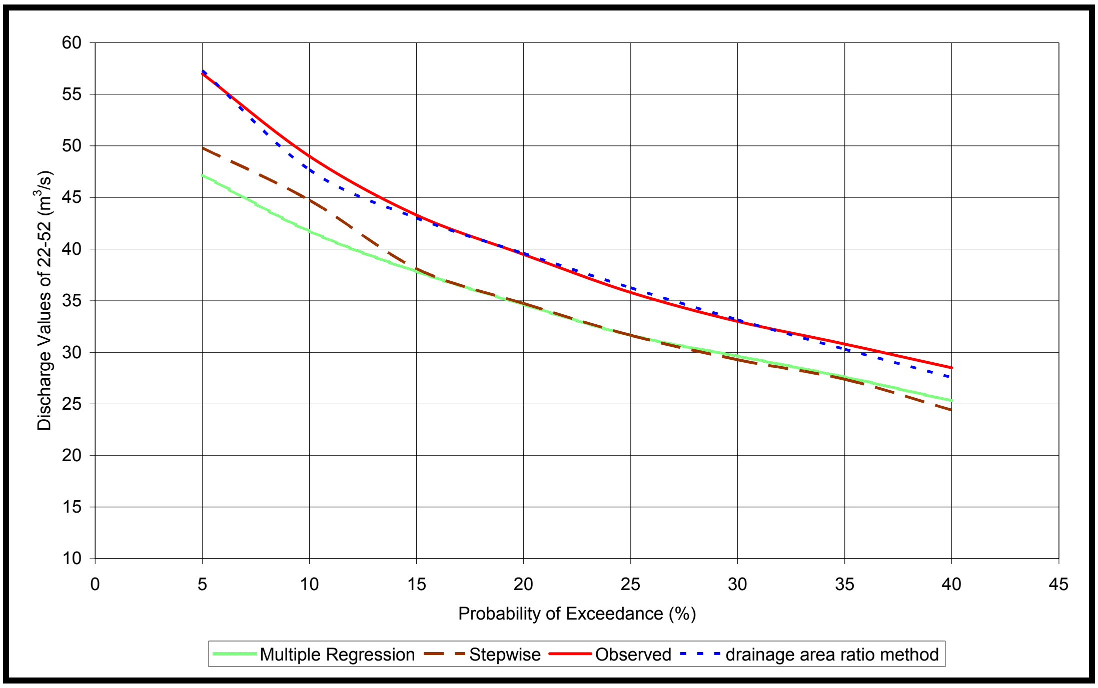

Figure 5.2 Comparison of Seasonal Multiple and Stepwise Models with Observed FDC and Drainage Area Ratio Method

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Estimation of specific flow values corresponding to various exceedance probabilities of the flow duration curves (5% to 40%) by statistical approach was done in this study. In order to realise this objective; flow duration curves were estimated by developing multiple regression and stepwise analyses using the specific runoff values, basin topographic characteristics, morphological and meteorological variables. Furthermore; this study examines the application of statistical models for simulation of the flow duration curve with limited data and smaller amount of gauged basins. It can be concluded that regional specific flow duration curves can be derived by using some of the variables from each category being shape, morphological, hydro-meteorological, relief/slope measures.

Seasonal specific FDCs are also derived using the same parameters for annual models in addition to mean seasonal temperature value of the median elevation of basin. Mean seasonal (spring) temperature values become significant in the models meaning that this variable affects the specific flow values for each percentile of the basins located in Solaklı and Karadere basins. Since temperature values are related with snow covered areas of each basin, it can be concluded that in spring season amount of snowmelt affect specific runoff of the basins in Solaklı and Karadere.

The main conclusions are as follows:

Both stepwise regression analysis and MRA provide an underestimation of discharges for the seasonal and annual models; but annual model results are much better than seasonal model results.

Annual model results of multiple regression analysis corresponding to exceedance probabilities from 5% to 10% almost match with the observed values of 22-52 station which is the station used for validation and better than the results of stepwise regression model. From 10% to 20%; the results of MRA are still applicable, but from 25% to 40%; the model quality decreases significantly; but the results of MRA are still better than or same as the results of stepwise model.

In the annual models of MRA, the most sensitive and important variables are mainly MAP and S variables meaning that the meteorological and slope/relief measures are dominant for the basins concerned. These results are almost consistent with the results of stepwise regression results.

Seasonal model results of both multiple regression analysis and stepwise regression analysis did not provide good results. Stepwise regression results are better than MRA results for the flow values corresponding to the exceedance probabilities from 5% to 15%. However, from 15% to 40% MRA results are either better than or as the same as the results of stepwise regression.

For the seasonal models of MRA, the most sensitive and important variable is the T variable which represents mean seasonal temperature value meaning that the effect of snowmelt is the most important process for the surface runoff in this region. These results are almost consistent with the results of stepwise regression results.

It can be reached a conclusion that MRA provides better estimations of flow duration curves than stepwise regression analysis for annual models and annual model estimation is better than seasonal model estimation. Although the results of drainage area ratio method provide the best results, the similarities between flows of 22-52 and other upstream stations, because of some corrections and extrapolations, must have caused perfect match between the observed values and drainage area method.

The final model parameters and related equations are only valid in Solaklı and Karadere basins. These models can also be applied in similar basins according to hydrological similarity techniques and spatial proximity criteria offered by Li et al. (2010) or the same hydrological region (Region A) offered by Yanık et al. (2005).

Since the exceedance probabilities of project discharges of small HEPPs lie between the range of 5% and 25% of the FDCs; the results of this study can be used in estimation of project discharges in ungauged basins within Solaklı and Karadere basins and similar basins where small HEPPs are planned/designed.

6.2 Recommendations

There are also some recommendations which can be listed as follows:

- The network for streamflow gauging stations should be broadened and it should be controlled in terms of quality and quantity.

- The meteorological and climatological stations should be located also at upper elevations of the pilot areas by governmental and private organizatons and the reliable data should be collected continuously in a daily basis for long term period.

- Simulation studies for the ungauged basins could be performed by using similarity indices such as spatial proximity, neighborhood indices, etc (Masih, et al., 2010).

- In order to form more accurate regressional models; land use data, soil data, geology data should also be obtained other than topographical and hydro-meteorological data.

- Relevant geostatistical techniques should be used in order to estimate mean daily areal values of important hydro-meteorological parameters such as rainfall, snow and temperature. Furthermore, the correction factors, such as lapse rate, used for rainfall and snow measurements should be established based on correlation analyses.

- Usage of snow depletion line instead of median basin elevation to transfer the representative temperature values within the snow covered area may increase the model accuracy and quality.

- Evaluation of model performance should be satisfied with more statistical methods like; Nash-Sutcliffe Efficiency (NSE) and volume balance.

- The flow duration curves should be regionalized by using appropriate statistical distribution functions with 2 or 3 parameters and using more stream flow gauging stations.

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APPENDIX A: PCA OUTPUT FOR 15% ANNUAL MODEL

Data Matrix

161.500000 44.850000 3077.000000 3.610000 .640000
.550000

1816.110000 .045800

179.900000 45.430000 3191.000000 3.430000 .640000
.540000

1746.170000 .045300

194.000000 44.940000 3263.000000 3.390000 .640000
.540000

1703.170000 .045000

202.300000 44.750000 3294.000000 3.280000 .640000
.550000

1676.340000 .044800

83.600000 47.960000 2373.000000 3.090000 .640000
.550000

1659.080000 .050600

61.600000 41.790000 1845.000000 3.100000 .630000
.460000

1580.310000 .053300

```
  67.400000     36.910000  2105.000000       3.970000          .670000
.600000
       1639.060000      .052200

  74.500000     35.080000  1186.000000       3.580000          .630000
.500000
       1168.390000      .051500

  13.300000     25.740000   964.000000       2.860000          .410000
.640000
       1169.750000      .067700

  79.500000     35.490000  1418.000000       3.390000          .620000
.500000
       1166.070000      .051300

  89.100000     36.770000  1500.000000       4.060000          .630000
.560000
       1190.070000      .049700

 100.300000     40.270000  2379.000000       3.740000          .650000
.540000
       1585.290000      .042800

  72.400000     47.590000  2240.000000       2.850000          .640000
.560000
       1693.430000      .055800

 178.600000     41.560000  2755.000000       3.200000          .630000
.540000
       1122.460000      .033400
```

134.200000 38.750000 2322.000000 4.030000 .620000
.540000

1168.430000 .031700

88.800000 36.650000 1503.000000 4.120000 .570000
.630000

1190.400000 .034000

****
**

STATISTICS FOR UNTRANSFORMED DATA

VAR	MEAN	ST DEV	COEFF of VAR
1	111.3125000	56.0757600	.5037687
2	40.2831300	5.8082200	.1441849
3	2213.4380000	763.3208000	.3448576
4	3.4812500	.4161710	.1195464
5	.6187500	.0593155	.0958635
6	.5500000	.0453137	.0823886
7	1454.6580000	267.1718000	.1836664
8	.0471813	.0091287	.1934805

****
**

CORRELATION MATRIX

----

var	1	2	3	4	5	6	7	8
1	1.000	.600	.884	.096	.467	-.205	.350	-.631
2	.600	1.000	.795	-.205	.713	-.370	.735	-.315
3	.884	.795	1.000	-.087	.537	-.165	.699	-.436
4	.096	-.205	-.087	1.000	.287	.174	-.240	-.552
5	.467	.713	.537	.287	1.000	-.553	.462	-.425
6	-.205	-.370	-.165	.174	-.553	1.000	-.115	.090
7	.350	.735	.699	-.240	.462	-.115	1.000	.145
8	-.631	-.315	-.436	-.552	-.425	.090	.145	1.000

Determinant of R = .0001124

Total Sphericity Test of R = I

Computed Chi square = 104.57

degrees of freedom = 28

****

****

Prin. Comp.	Eigen- value	Percent trace	Cumulative percent	Chi Square for partial sphericity test	df

-----	------	-------	----------	--------------	--
1	3.8784	48.48	48.48	104.57	28
2	1.8167	22.71	71.19	73.03	21
3	1.1134	13.92	85.11	53.94	15
4	.7370	9.21	94.32	37.83	10
5	.2770	3.46	97.78	18.98	6
6	.1155	1.44	99.23	8.84	3
7	.0498	.62	99.85	3.43	1
8	.0122	.15	100.00	.00	0

****
****

EIGENVECTOR MATRIX

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

Var	Standardized Eigenvector (e ** 2 / lambda)							
	1	2	3	4	5	6	7	8
1	.827	.230	-.263	.354	.227	.099	.078	-.046
2	.903	-.261	.011	-.066	-.304	-.015	.137	.021
3	.917	-.083	-.337	.114	.114	-.001	-.080	.077
4	.034	.868	.027	-.455	.168	-.061	.076	.026
5	.798	.145	.425	-.331	-.056	.206	-.075	-.016
6	-.422	.155	-.835	-.245	-.159	.123	-.013	-.010
7	.670	-.541	-.223	-.412	.109	-.158	-.033	-.045
8	-.523	-.774	.052	-.218	.228	.139	.077	.027

****

Communalities for Eigenvector 1 to

----

var	1	2	3	4	5	6	7	8
1	.683	.736	.805	.931	.982	.992	.998	1.000
2	.816	.884	.884	.889	.981	.981	1.000	1.000
3	.841	.848	.961	.975	.988	.988	.994	1.000
4	.001	.754	.755	.962	.990	.994	.999	1.000
5	.637	.658	.839	.948	.952	.994	1.000	1.000
6	.178	.202	.899	.959	.985	1.000	1.000	1.000
7	.448	.740	.790	.960	.972	.997	.998	1.000

8	.273	.872	.875	.922	.974	.993	.999	1.000

****
****

APPENDIX B: MULTIPLE REGRESSION ANALYSIS OUTPUT FOR 15% ANNUAL MODEL

DATA MATRIX

===========

44.850000	3.610000	.550000	1816.110000	.045800
45.430000	3.430000	.540000	1746.170000	.045300
44.940000	3.390000	.540000	1703.170000	.045000
44.750000	3.280000	.550000	1676.340000	.044800
47.960000	3.090000	.550000	1659.080000	.050600
41.790000	3.100000	.460000	1580.310000	.053300
36.910000	3.970000	.600000	1639.060000	.052200
35.080000	3.580000	.500000	1168.390000	.051500
25.740000	2.860000	.640000	1169.750000	.067700
35.490000	3.390000	.500000	1166.070000	.051300
36.770000	4.060000	.560000	1190.070000	.049700
40.270000	3.740000	.540000	1585.290000	.042800
47.590000	2.850000	.560000	1693.430000	.055800
41.560000	3.200000	.540000	1122.460000	.033400
38.750000	4.030000	.540000	1168.430000	.031700
36.650000	4.120000	.630000	1190.400000	.034000

****

STATISTICS FOR UNTRANSFORMED DATA

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

Var	Mean	Standard Deviation	Coefficient of Variation	Minimum	Maximum
1	40.2831300	5.8082200	.1441849	25.7400000	47.9600000
2	3.4812500	.4161710	.1195464	2.8500000	4.1200000
3	.5500000	.0453137	.0823886	.4600000	.6400000
4	1454.6580000	267.1718000	.1836664	1122.4600000	1816.1100000
5	.0471813	.0091287	.1934805	.0317000	.0677000

****

CORRELATION MATRIX

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

ROW	1	2	3	4	5
1	1.000	-.205	-.370	.735	-.315
2	-.205	1.000	.174	-.240	-.552
3	-.370	.174	1.000	-.115	.090
4	.735	-.240	-.115	1.000	.145
5	-.315	-.552	.090	.145	1.000

.3429309 = Determinant of intercorrelation matrix

****

Var	b	t	R	R**2	t*R
1	-.0015946	-1.01458	-.31517	.09933	.31977
2	-.0123724	-.56405	-.55229	.30502	.31152
3	-.0205091	-.10181	.09009	.00812	-.00917
4	.0000254	.74331	.14532	.02112	.10802

.1288239 = Intercept

****

ANALYSIS OF RESIDUALS

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

OBS NO.	PREDICTED YP	OBSERVED Y	RESIDUAL e = YP - Y	REL ERROR e / Y
1	.0474858	.0458000	.0016858	.03681
2	.0472168	.0453000	.0019168	.04231
3	.0474010	.0450000	.0024010	.05336
4	.0481784	.0448000	.0033784	.07541
5	.0449722	.0506000	-.0056278	-.11122
6	.0545324	.0533000	.0012324	.02312
7	.0501708	.0522000	-.0020292	-.03887
8	.0480114	.0515000	-.0034886	-.06774
9	.0689763	.0677000	.0012763	.01885
10	.0496495	.0513000	-.0016505	-.03217
11	.0386979	.0497000	-.0110021	-.22137
12	.0475236	.0428000	.0047236	.11036
13	.0491989	.0558000	-.0066011	-.11830
14	.0403932	.0334000	.0069932	.20938
15	.0357723	.0317000	.0040723	.12847
16	.0367196	.0340000	.0027196	.07999

****
****

GOODNESS-OF-FIT STATISTICS

.7301207 = MULTIPLE R SQUARE

.8544710 = MULTIPLE R

.0055378 = STANDARD ERROR OF ESTIMATE (Se)

.0091287 = STANDARD DEVIATION (Sy)

.6066442 = Se/Sy

.0854835 = MEAN RELATIVE ERROR

.0616848 = STANDARD DEVIATION OF RELATIVE ERRORS

****
****

7.440 = F FOR ANALYSIS OF VARIANCE ON R

N.D.F.1 = 4.   N.D.F.2 = 11.

****
****

DISTRIBUTION OF RESIDUALS FOR NORMALITY CHECK

CELL	STANDARDIZED VARIATE	FREQUENCY
1		.0
	-.200000E+01	
2		1.0
	-.150000E+01	
3		2.0
	-.100000E+01	
4		1.0
	-.500000E+00	
5		2.0
	.000000E+00	
6		6.0
	.500000E+00	
7		3.0
	.100000E+01	
8		1.0
	.150000E+01	
9		.0
	.200000E+01	
10		.0

APPENDIX C: STEPWISE REGRESSION ANALYSIS OUTPUT FOR 15% ANNUAL MODEL

```
  DATA MATRIX

      -----------

  161.50000   44.85000 3077.00000    3.61000      .64000      .55000
1816.11000 .04580

  179.90000   45.43000 3191.00000    3.43000      .64000      .54000
1746.17000 .04530

  194.00000   44.94000 3263.00000    3.39000      .64000      .54000
1703.17000  .04500

  202.30000   44.75000 3294.00000    3.28000      .64000      .55000
1676.34000  .04480

   83.60000   47.96000 2373.00000    3.09000      .64000      .55000
1659.08000  .05060

   61.60000   41.79000 1845.00000    3.10000      .63000      .46000
1580.31000  .05330

   67.40000   36.91000 2105.00000    3.97000      .67000      .60000
1639.06000  .05220

   74.50000   35.08000 1186.00000    3.58000      .63000      .50000
1168.39000  .05150
```

```
   13.30000   25.74000  964.00000    2.86000      .41000      .64000
1169.75000  .06770


   79.50000   35.49000 1418.00000    3.39000      .62000      .50000
1166.07000  .05130


   89.10000   36.77000 1500.00000    4.06000      .63000      .56000
1190.07000  .04970


  100.30000   40.27000 2379.00000    3.74000      .65000      .54000
1585.29000  .04280


   72.40000   47.59000 2240.00000    2.85000      .64000      .56000
1693.43000  .05580


  178.60000   41.56000 2755.00000    3.20000      .63000      .54000
1122.46000  .03340


  134.20000   38.75000 2322.00000    4.03000      .62000      .54000
1168.43000  .03170


   88.80000   36.65000 1503.00000    4.12000      .57000      .63000
1190.40000  .03400


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

CHARACTERISTICS OF DATA

==

Var	Mean	Standard deviation	Coeff. of variation	Minimum	Maximum
1	111.312500	56.075760	.503769	13.300000	202.300000
2	40.283130	5.808220	.144185	25.740000	47.960000
3	2213.438000	763.320800	.344858	964.000000	3294.000000
4	3.481250	.416171	.119546	2.850000	4.120000
5	.618750	.059316	.095863	.410000	.670000
6	.550000	.045314	.082389	.460000	.640000
7	1454.658000	267.171800	.183666	1122.460000	1816.110000
8	.047181	.009129	.193480	.031700	.067700

****

CORRELATION MATRIX

Var	1	2	3	4	5	6	7	8
1	1.000	.600	.884	.096	.467	-.205	.350	-.631
2	.600	1.000	.795	-.205	.713	-.370	.735	-.315
3	.884	.795	1.000	-.087	.537	-.165	.699	-.436
4	.096	-.205	-.087	1.000	.287	.174	-.240	-.552
5	.467	.713	.537	.287	1.000	-.553	.462	-.425
6	-.205	-.370	-.165	.174	-.553	1.000	-.115	.090
7	.350	.735	.699	-.240	.462	-.115	1.000	.145
8	-.631	-.315	-.436	-.552	-.425	.090	.145	1.000

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

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

Step number = 1   Enter predictor variable 1

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
1	-.6308	9.254
2	-.3152	1.544
3	-.4360	3.286
4	-.5523	6.145
5	-.4253	3.092
6	.0901	.115
7	.1453	.302

****

1.0000 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.042027	.045800	-.003773	-.0824
2	.040138	.045300	-.005162	-.1140
3	.038690	.045000	-.006310	-.1402
4	.037837	.044800	-.006963	-.1554
5	.050027	.050600	-.000573	-.0113
6	.052286	.053300	-.001014	-.0190
7	.051691	.052200	-.000509	-.0098
8	.050962	.051500	-.000538	-.0105
9	.057246	.067700	-.010454	-.1544
10	.050448	.051300	-.000852	-.0166
11	.049462	.049700	-.000238	-.0048
12	.048312	.042800	.005512	.1288
13	.051177	.055800	-.004623	-.0828
14	.040271	.033400	.006871	.2057
15	.044831	.031700	.013131	.4142
16	.049493	.034000	.015493	.4557

****

```
GOODNESS-OF-FIT STATISTICS
--------------------------
 .3979 = Increase in R**2 Due to Variable Added
 .3979 = Multiple R**2
 .6308 = Multiple R

.0073318 = Standard error of estimate (Se)
.0091287 = Standard deviation of Y    (Sy)

.8031584 = Se/Sy

.1253484 = Mean of Absolute Relative Errors
.1371194 = Std. dev. of Absolute Relative Errors

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

 9.254 = Total F for the Analysis of Variance on R
          df 1 =  1.     df 2 =  14.

 9.254 = Partial F to Enter
          df 1 =   1     df 2 =  14.

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

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

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
1	-.000103	-.6308	-.6308	.3979	.3979	.0000	.32873

.058612 = Intercept

===

===

Step number = 2 Enter predictor variable 4

****

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
2	.1017	.136
3	.3357	1.651
4	-.6365	8.853
5	-.1908	.491
6	-.0520	.035
7	.5038	4.422

****

.9907 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.041016	.045800	-.004784	-.1044
2	.041229	.045300	-.004071	-.0899
3	.040326	.045000	-.004674	-.1039
4	.040735	.044800	-.004065	-.0907
5	.054070	.050600	.003470	.0686
6	.056049	.053300	.002749	.0516
7	.046030	.052200	-.006170	-.1182
8	.049601	.051500	-.001899	-.0369
9	.063246	.067700	-.004454	-.0658
10	.051194	.051300	-.000106	-.0021
11	.042991	.049700	-.006709	-.1350
12	.045410	.042800	.002610	.0610
13	.057745	.055800	.001945	.0349
14	.043855	.033400	.010455	.3130
15	.039037	.031700	.007337	.2314
16	.042366	.034000	.008366	.2461

****

```
GOODNESS-OF-FIT STATISTICS
--------------------------
  .2439 = Increase in R**2 Due to Variable Added
  .6418 = Multiple R**2
  .8011 = Multiple R

.0058684 = Standard error of estimate (Se)
.0091287 = Standard deviation of Y    (Sy)

.6428574 = Se/Sy

.1095873 = Mean of Absolute Relative Errors
.0849105 = Std. dev. of Absolute Relative Errors

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

 11.648 = Total F for the Analysis of Variance on R
            df 1 =  2.     df 2 =  13.

  8.852 = Partial F to Enter
            df 1 =   1     df 2 =  13.

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

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
1	-.000095	-.5831	-.6308	.3979	.3678	.0000	.28600
4	-.010883	-.4962	-.5523	.3050	.2740	.0037	.33610

.095634 = Intercept

==

==

Step number = 3 Enter predictor variable 7

****

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
2	-.1488	.272
3	.1404	.241
5	-.0216	.006
6	.0987	.118
7	.4296	2.716

****

.7942 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.043903	.045800	-.001897	-.0414
2	.042792	.045300	-.002508	-.0554
3	.041149	.045000	-.003851	-.0856
4	.040957	.044800	-.003843	-.0858
5	.055882	.050600	.005282	.1044
6	.057493	.053300	.004193	.0787
7	.049465	.052200	-.002735	-.0524
8	.047612	.051500	-.003888	-.0755
9	.061094	.067700	-.006606	-.0976
10	.048764	.051300	-.002536	-.0494
11	.041794	.049700	-.007906	-.1591
12	.047337	.042800	.004537	.1060
13	.059673	.055800	.003873	.0694
14	.038921	.033400	.005521	.1653
15	.036781	.031700	.005081	.1603
16	.041283	.034000	.007283	.2142

****

```
GOODNESS-OF-FIT STATISTICS
--------------------------
 .0661 = Increase in R**2 Due to Variable Added
 .7079 = Multiple R**2
 .8414 = Multiple R

.0055156 = Standard error of estimate (Se)
.0091287 = Standard deviation of Y    (Sy)

.6042079 = Se/Sy

.1000237 = Mean of Absolute Relative Errors
.0497575 = Std. dev. of Absolute Relative Errors

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

   9.696 = Total F for the Analysis of Variance on R
           df 1 =  3.     df 2 =  12.

   2.716 = Partial F to Enter
           df 1 =   1     df 2 =  12.

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

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

 ---    ---------  ------   -----   -----   -----   --------   -----
----



   1       -.000113   -.6913   -.6308    .3979    .4361         .0000
.24582

   4       -.009141   -.4167   -.5523    .3050    .2302         .0036
.39349

   7        .000010    .2872    .1453    .0211    .0417         .0000
.60675


          .077256 = Intercept


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

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


 Step number =  4     Enter predictor variable  2


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

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
2	-.6487	7.994
3	-.5491	4.748
5	-.2880	.995
6	.1035	.119

****

.2508 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.045681	.045800	-.000119	-.0026
2	.044201	.045300	-.001099	-.0243
3	.043173	.045000	-.001827	-.0406
4	.043358	.044800	-.001442	-.0322

5	.050235	.050600	-.000365	-.0072
6	.056012	.053300	.002712	.0509
7	.052415	.052200	.000215	.0041
8	.047583	.051500	-.003917	-.0761
9	.068750	.067700	.001050	.0155
10	.048798	.051300	-.002502	-.0488
11	.040262	.049700	-.009438	-.1899
12	.048070	.042800	.005270	.1231
13	.054691	.055800	-.001109	-.0199
14	.036920	.033400	.003520	.1054
15	.034983	.031700	.003283	.1036
16	.039770	.034000	.005770	.1697

****

GOODNESS-OF-FIT STATISTICS

.1229 = Increase in R**2 Due to Variable Added

.8309 = Multiple R**2

.9115 = Multiple R

.0043841 = Standard error of estimate (Se)

.0091287 = Standard deviation of Y (Sy)

.4802573 = Se/Sy

.0633611 = Mean of Absolute Relative Errors

.0590819 = Std. dev. of Absolute Relative Errors

****
****

13.509 = Total F for the Analysis of Variance on R

df 1 = 4. df 2 = 11.

7.994 = Partial F to Enter

df 1 = 1 df 2 = 11.

****
****

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
1	-.000071	-.4337	-.6308	.3979	.2736	.0000	.37569
4	-.010638	-.4850	-.5523	.3050	.2678	.0029	.27332
7	.000022	.6388	.1453	.0211	.0928	.0000	.29139
2	-.000980	-.6238	-.3152	.0993	.1966	.0003	.35369

.099817 = Intercept

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

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

Step number = 5   Enter predictor variable 3

****

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
3	-.5420	4.160
5	.2958	.959
6	-.1968	.403

****

.0102 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

==

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.046327	.045800	.000527	.0115
2	.044963	.045300	-.000337	-.0074
3	.044132	.045000	-.000868	-.0193
4	.044672	.044800	-.000128	-.0029
5	.049092	.050600	-.001508	-.0298
6	.057013	.053300	.003713	.0697
7	.049874	.052200	-.002326	-.0446
8	.051517	.051500	.000017	.0003
9	.067328	.067700	-.000372	-.0055
10	.050546	.051300	-.000754	-.0147
11	.041921	.049700	-.007779	-.1565
12	.046064	.042800	.003264	.0763
13	.054589	.055800	-.001211	-.0217
14	.034062	.033400	.000662	.0198
15	.031528	.031700	-.000172	-.0054
16	.041271	.034000	.007271	.2139

****

```
GOODNESS-OF-FIT STATISTICS
--------------------------
 .0497 = Increase in R**2 Due to Variable Added
 .8806 = Multiple R**2
 .9384 = Multiple R

.0038640 = Standard error of estimate (Se)
.0091287 = Standard deviation of Y    (Sy)

.4232851 = Se/Sy

.0437009 = Mean of Absolute Relative Errors
.0605128 = Std. dev. of Absolute Relative Errors

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

14.744 = Total F for the Analysis of Variance on R
           df 1 =  5.     df 2 =  10.

 4.160 = Partial F to Enter
           df 1 =   1     df 2 =  10.

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

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
1	.000056	.3445	-.6308	.3979	-.2173	.0001	1.18321
4	-.011760	-.5361	-.5523	.3050	.2961	.0026	.22288
7	.000036	1.0565	.1453	.0211	.1535	.0000	.24836
2	-.000835	-.5313	-.3152	.0993	.1675	.0003	.37586
3	-.000013	-1.1028	-.4360	.1901	.4808	.0000	.49028

.092197 = Intercept

===

===

Step number = 6 Enter predictor variable 5

****

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
5	.2729	.724
6	-.0108	.001

****

.0029 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.045760	.045800	-.000040	-.0009
2	.044602	.045300	-.000698	-.0154
3	.043987	.045000	-.001013	-.0225
4	.044774	.044800	-.000026	-.0006
5	.048472	.050600	-.002128	-.0421
6	.057469	.053300	.004169	.0782

7	.051309	.052200	-.000891	-.0171
8	.052541	.051500	.001041	.0202
9	.066163	.067700	-.001537	-.0227
10	.051672	.051300	.000372	.0072
11	.041810	.049700	-.007890	-.1587
12	.046568	.042800	.003768	.0880
13	.054425	.055800	-.001375	-.0246
14	.034795	.033400	.001395	.0418
15	.031100	.031700	-.000600	-.0189
16	.039454	.034000	.005454	.1604

****
****

GOODNESS-OF-FIT STATISTICS

.0089 = Increase in R**2 Due to Variable Added

.8894 = Multiple R**2

.9431 = Multiple R

.0039185 = Standard error of estimate (Se)

.0091287 = Standard deviation of Y (Sy)

.4292519 = Se/Sy

.0449630 = Mean of Absolute Relative Errors

.0509564 = Std. dev. of Absolute Relative Errors

****
****

12.068 = Total F for the Analysis of Variance on R

df 1 = 6. df 2 = 9.

.724 = Partial F to Enter

df 1 = 1 df 2 = 9.

****

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
1	.000052	.3220	-.6308	.3979	-.2032	.0001	1.28634
4	-.013528	-.6167	-.5523	.3050	.3406	.0034	.24939
7	.000036	1.0451	.1453	.0211	.1519	.0000	.25492
2	-.001099	-.6993	-.3152	.0993	.2204	.0004	.40439
3	-.000012	-1.0436	-.4360	.1901	.4550	.0000	.52961
5	.027245	.1770	-.4253	.1809	-.0753	.0320	1.17502

.091535 = Intercept

==

==

```
 Step number =  7     Enter predictor variable  6

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


 STATISTICAL CHARACTERISTICS

   FOR VARIABLE SELECTION

 --------------------------

       Partial R   Partial F

 Var   to  enter   to  enter

 ---   ---------   ---------


   6       .2489        .528

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


   .0011 = Determinant of Intercorrelation Matrix


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

ERROR ANALYSIS

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.045328	.045800	-.000472	-.0103
2	.044342	.045300	-.000958	-.0212
3	.043952	.045000	-.001048	-.0233
4	.045337	.044800	.000537	.0120
5	.048612	.050600	-.001988	-.0393
6	.055743	.053300	.002443	.0458
7	.052438	.052200	.000238	.0046
8	.052528	.051500	.001028	.0200
9	.066230	.067700	-.001470	-.0217
10	.051460	.051300	.000160	.0031
11	.042078	.049700	-.007622	-.1534
12	.046011	.042800	.003211	.0750
13	.055397	.055800	-.000403	-.0072
14	.035387	.033400	.001987	.0595
15	.029886	.031700	-.001814	-.0572
16	.040171	.034000	.006171	.1815

****

```
GOODNESS-OF-FIT STATISTICS
--------------------------
  .0068 = Increase in R**2 Due to Variable Added
  .8963 = Multiple R**2
  .9467 = Multiple R

.0040255 = Standard error of estimate (Se)
.0091287 = Standard deviation of Y    (Sy)

.4409702 = Se/Sy

.0459407 = Mean of Absolute Relative Errors
.0522630 = Std. dev. of Absolute Relative Errors
```

****

```
  9.877 = Total F for the Analysis of Variance on R
            df 1 =  7.     df 2 =   8.

   .528 = Partial F to Enter
            df 1 =   1     df 2 =   8.
```

****

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
1	.000072	.4453	-.6308	.3979	-.2809	.0001	1.02882
4	-.015568	-.7098	-.5523	.3050	.3920	.0045	.28649
7	.000036	1.0639	.1453	.0211	.1546	.0000	.25840
2	-.001151	-.7326	-.3152	.0993	.2309	.0005	.40143
3	-.000014	-1.2025	-.4360	.1901	.5243	.0000	.50598
5	.049502	.3216	-.4253	.1809	-.1368	.0449	.90782
6	.027307	.1355	.0901	.0081	.0122	.0376	1.37598

.073000 = Intercept

APPENDIX D: PCA OUTPUT FOR 15% SEASONAL MODEL

Data Matrix

161.500000 44.850000 3077.000000 3.610000 .640000
.550000 4.100000 388.600000 .072500

179.900000 45.430000 3191.000000 3.430000 .640000
.540000 4.800000 373.600000 .071100

194.000000 44.940000 3263.000000 3.390000 .640000
.540000 5.200000 364.400000 .070200

202.300000 44.750000 3294.000000 3.280000 .640000
.550000 5.500000 358.700000 .069900

83.600000 47.960000 2373.000000 3.090000 .640000
.550000 2.800000 445.200000 .085900

61.600000 41.790000 1845.000000 3.100000 .630000
.460000 3.500000 424.100000 .093700

67.400000 36.910000 2105.000000 3.970000 .670000
.600000 3.000000 439.800000 .090300

74.500000 35.080000 1186.000000 3.580000 .630000
.500000

3.300000 300.400000 .088300

13.300000 25.740000 964.000000 2.860000 .410000
.640000 3.300000 300.800000 .140900

```
   79.500000     35.490000  1418.000000       3.390000          .620000
.500000   3.300000  299.800000     .087800


   89.100000     36.770000  1500.000000       4.060000          .630000
.560000   3.000000  306.000000     .083300


  100.300000     40.270000  2379.000000       3.740000          .650000
.540000   3.400000  425.400000     .072300


   72.400000     47.590000  2240.000000       2.850000          .640000
.560000   2.500000  454.400000     .084700


  178.600000     41.560000  2755.000000       3.200000          .630000
.540000   4.000000  288.600000     .064300


  134.200000     38.750000  2322.000000       4.030000          .620000
.540000   3.300000  300.400000     .061000


   88.800000     36.650000  1503.000000       4.120000          .630000
.570000   3.000000  306.100000     .070600
```

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

STATISTICS FOR UNTRANSFORMED DATA

VAR	MEAN	ST DEV	COEFF of VAR
1	111.3125000	56.0757600	.5037687
2	40.2831300	5.8082200	.1441849
3	2213.4380000	763.3208000	.3448576
4	3.4812500	.4161710	.1195464
5	.6225000	.0579080	.0930248
6	.5462500	.0404763	.0740985
7	3.6250000	.8698660	.2399630
8	361.0188000	61.6895200	.1708762
9	.0816750	.0186974	.2289239

****
**

CORRELATION MATRIX

----

var	1	2	3	4	5	6	7	8	9
1	1.000	.600	.884	.096	.450	-.190	.831	-.090	-.762
2	.600	1.000	.795	-.205	.687	-.353	.326	.601	-.638
3	.884	.795	1.000	-.087	.486	-.093	.724	.355	-.653
4	.096	-.205	-.087	1.000	.400	.043	-.119	-.261	-.453
5	.450	.687	.486	.400	1.000	-.511	.106	.394	-.806
6	-.190	-.353	-.093	.043	-.511	1.000	-.137	-.033	.402
7	.831	.326	.724	-.119	.106	-.137	1.000	-.120	-.352
8	-.090	.601	.355	-.261	.394	-.033	-.120	1.000	-.014
9	-.762	-.638	-.653	-.453	-.806	.402	-.352	-.014	1.000

Determinant of R = .0000002

Total Sphericity Test of R = I

Computed Chi square = 172.81

degrees of freedom = 36

****

****
****

Prin. Comp.	Eigen- value	Percent trace	Cumulative percent	Chi Square for partial sphericity test	df
-----	------	-------	----------	---------------	--
1	4.3084	47.87	47.87	172.81	36
2	1.6645	18.49	66.37	133.00	28
3	1.6228	18.03	84.40	113.85	21
4	.9513	10.57	94.97	84.49	15
5	.3105	3.45	98.42	49.93	10
6	.0795	.88	99.30	26.42	6
7	.0426	.47	99.77	18.57	3
8	.0196	.22	99.99	12.04	1
9	.0008	.01	100.00	-.01	0

****
****

EIGENVECTOR MATRIX

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

Var Standardized Eigenvector (e ** 2 / lambda)

Var	1	2	3	4	5	6	7	8	9
1	.875	.213	.427	-.025	.068	.014	-.006	.038	-.022
2	.855	-.426	-.161	-.023	.191	-.022	.156	-.009	.003
3	.900	-.190	.307	-.210	-.006	-.084	-.065	.071	.014
4	.109	.801	-.384	-.376	-.210	-.091	.068	.018	-.000
5	.772	.111	-.583	-.027	-.062	.214	-.024	.023	.003
6	-.418	-.052	.367	-.814	.127	.089	.005	-.022	.001
7	.620	.078	.699	.118	-.316	.053	.037	-.058	.005
8	.296	-.768	-.409	-.292	-.251	-.059	-.040	-.028	-.009
9	-.865	-.385	.206	.041	-.206	.060	.077	.087	-.002

****

Communalities for Eigenvector 1 to

----

var	1	2	3	4	5	6	7	8	9
1	.765	.810	.993	.993	.998	.998	.998	.999	1.000
2	.730	.912	.938	.939	.975	.976	1.000	1.000	1.000
3	.809	.845	.939	.983	.983	.990	.995	1.000	1.000
4	.012	.654	.801	.943	.987	.995	1.000	1.000	1.000
5	.596	.609	.948	.949	.953	.999	.999	1.000	1.000
6	.175	.178	.312	.975	.992	.999	1.000	1.000	1.000
7	.385	.391	.879	.893	.992	.995	.997	1.000	1.000
8	.088	.678	.846	.931	.994	.998	.999	1.000	1.000
9	.748	.897	.939	.941	.983	.987	.992	1.000	1.000

****

APPENDIX E: MULTIPLE REGRESSION ANALYSIS OUTPUT FOR 15% SEASONAL MODEL

DATA MATRIX

===========

161.500000	3.610000	.550000	4.100000	.072500
179.900000	3.430000	.540000	4.800000	.071100
194.000000	3.390000	.540000	5.200000	.070200
202.300000	3.280000	.550000	5.500000	.069900
83.600000	3.090000	.550000	2.800000	.085900
61.600000	3.100000	.460000	3.500000	.093700
67.400000	3.970000	.600000	3.000000	.090300
74.500000	3.580000	.500000	3.300000	.088300
13.300000	2.860000	.640000	3.300000	.140900
79.500000	3.390000	.500000	3.300000	.087800
89.100000	4.060000	.560000	3.000000	.083300
100.300000	3.740000	.540000	3.400000	.072300
72.400000	2.850000	.560000	2.500000	.084700
178.600000	3.200000	.540000	4.000000	.064300
134.200000	4.030000	.540000	3.300000	.061000
88.800000	4.120000	.570000	3.000000	.070600

****

STATISTICS FOR UNTRANSFORMED DATA

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

Var	Mean	Standard Deviation	Coefficient of Variation	Minimum	Maximum
1	111.3125000	56.0757600	.5037687	13.3000000	202.3000000
2	3.4812500	.4161710	.1195464	2.8500000	4.1200000
3	.5462500	.0404763	.0740985	.4600000	.6400000
4	3.6250000	.8698660	.2399630	2.5000000	5.5000000
5	.0816750	.0186974	.2289239	.0610000	.1409000

****

CORRELATION MATRIX

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

ROW	1	2	3	4	5
1	1.000	.096	-.190	.831	-.762
2	.096	1.000	.043	-.119	-.453
3	-.190	.043	1.000	-.137	.402
4	.831	-.119	-.137	1.000	-.352
5	-.762	-.453	.402	-.352	1.000

.2552212 = Determinant of intercorrelation matrix

****

Var	b	t	R	R**2	t*R
1	-.0004305	-1.29126	-.76217	.58091	.98416
2	-.0113810	-.25332	-.45297	.20518	.11475
3	.1232865	.26690	.40182	.16146	.10725
4	.0156314	.72723	-.35206	.12395	-.25603

.0452111 = Intercept

****

ANALYSIS OF RESIDUALS

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

OBS NO.	PREDICTED YP	OBSERVED Y	RESIDUAL e = YP - Y	REL ERROR e / Y
1	.0664889	.0725000	-.0060111	-.08291
2	.0703245	.0711000	-.0007755	-.01091
3	.0709616	.0702000	.0007616	.01085
4	.0745623	.0699000	.0046623	.06670
5	.0856258	.0859000	-.0002742	-.00319
6	.0948301	.0937000	.0011301	.01206
7	.0918760	.0903000	.0015760	.01745
8	.0856184	.0883000	-.0026816	-.03037
9	.1374222	.1409000	-.0034778	-.02468
10	.0856281	.0878000	-.0021719	-.02474
11	.0765774	.0833000	-.0067226	-.08070
12	.0791840	.0723000	.0068840	.09521
13	.0897227	.0847000	.0050227	.05930
14	.0609968	.0643000	-.0033032	-.05137
15	.0597248	.0610000	-.0012752	-.02090
16	.0772565	.0706000	.0066565	.09429

****
****

GOODNESS-OF-FIT STATISTICS

.9501231 = MULTIPLE R SQUARE

.9747426 = MULTIPLE R

.0048762 = STANDARD ERROR OF ESTIMATE (Se)

.0186974 = STANDARD DEVIATION (Sy)

.2607949 = Se/Sy

.0428526 = MEAN RELATIVE ERROR

.0324993 = STANDARD DEVIATION OF RELATIVE ERRORS

****
****

52.386 = F FOR ANALYSIS OF VARIANCE ON R

N.D.F.1 = 4. N.D.F.2 = 11.

****
****

DISTRIBUTION OF RESIDUALS FOR NORMALITY CHECK

CELL	STANDARDIZED VARIATE	FREQUENCY
1		.0
	-.200000E+01	
2		.0
	-.150000E+01	
3		2.0
	-.100000E+01	
4		3.0
	-.500000E+00	
5		4.0
	.000000E+00	
6		3.0
	.500000E+00	
7		1.0
	.100000E+01	
8		3.0
	.150000E+01	
9		.0
	.200000E+01	
10		.0

APPENDIX F: STEPWISE REGRESSION ANALYSIS OUTPUT FOR 15% SEASONAL MODEL

```
      DATA MATRIX
      -----------

  161.50000   44.85000 3077.00000    3.61000      .64000      .55000
4.10000 388.60000     .07250

  179.90000   45.43000 3191.00000    3.43000      .64000      .54000
4.80000 373.60000     .07110

  194.00000   44.94000 3263.00000    3.39000      .64000      .54000
5.20000 364.40000     .07020

  202.30000   44.75000 3294.00000    3.28000      .64000      .55000
5.50000 358.70000     .06990

   83.60000   47.96000 2373.00000    3.09000      .64000      .55000
2.80000 445.20000     .08590

   61.60000   41.79000 1845.00000    3.10000      .63000      .46000
3.50000 424.10000     .09370

   67.40000   36.91000 2105.00000    3.97000      .67000      .60000
3.00000 439.80000     .09030

   74.50000   35.08000 1186.00000    3.58000      .63000      .50000
3.30000 300.40000     .08830
```

```
   13.30000   25.74000  964.00000    2.86000      .41000      .64000
3.30000 300.80000     .14090


   79.50000   35.49000 1418.00000    3.39000      .62000      .50000
3.30000 299.80000     .08780


   89.10000   36.77000 1500.00000    4.06000      .63000      .56000
3.00000 306.00000     .08330


  100.30000   40.27000 2379.00000    3.74000      .65000      .54000
3.40000 425.40000     .07230


   72.40000   47.59000 2240.00000    2.85000      .64000      .56000
2.50000 454.40000     .08470


  178.60000   41.56000 2755.00000    3.20000      .63000      .54000
4.00000 288.60000     .06430


  134.20000   38.75000 2322.00000    4.03000      .62000      .54000
3.30000 300.40000     .06100


   88.80000   36.65000 1503.00000    4.12000      .63000      .57000
3.00000 306.10000     .07060


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

CHARACTERISTICS OF DATA

==

Var	Mean	Standard deviation	Coeff. of variation	Minimum	Maximum
1	111.312500	56.075760	.503769	13.300000	202.300000
2	40.283130	5.808220	.144185	25.740000	47.960000
3	2213.438000	763.320800	.344858	964.000000	3294.000000
4	3.481250	.416171	.119546	2.850000	4.120000
5	.622500	.057908	.093025	.410000	.670000
6	.546250	.040476	.074099	.460000	.640000
7	3.625000	.869866	.239963	2.500000	5.500000
8	361.018800	61.689520	.170876	288.600000	454.400000
9	.081675	.018697	.228924	.061000	.140900

****

CORRELATION MATRIX

Var	1	2	3	4	5	6	7	8	9
1	1.000	.600	.884	.096	.450	-.190	.831	-.090	-.762
2	.600	1.000	.795	-.205	.687	-.353	.326	.601	-.638
3	.884	.795	1.000	-.087	.486	-.093	.724	.355	-.653
4	.096	-.205	-.087	1.000	.400	.043	-.119	-.261	-.453
5	.450	.687	.486	.400	1.000	-.511	.106	.394	-.806
6	-.190	-.353	-.093	.043	-.511	1.000	-.137	-.033	.402
7	.831	.326	.724	-.119	.106	-.137	1.000	-.120	-.352
8	-.090	.601	.355	-.261	.394	-.033	-.120	1.000	-.014
9	-.762	-.638	-.653	-.453	-.806	.402	-.352	-.014	1.000

==

==

Step number = 1   Enter predictor variable 5

****

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
1	-.7622	19.405
2	-.6383	9.626
3	-.6531	10.412
4	-.4530	3.614
5	-.8056	25.890
6	.4018	2.696
7	-.3521	1.981
8	-.0137	.003

****

1.0000 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.077123	.072500	.004623	.0638
2	.077123	.071100	.006023	.0847
3	.077123	.070200	.006923	.0986
4	.077123	.069900	.007223	.1033
5	.077123	.085900	-.008777	-.1022
6	.079724	.093700	-.013976	-.1492
7	.069319	.090300	-.020981	-.2323
8	.079724	.088300	-.008576	-.0971
9	.136951	.140900	-.003949	-.0280
10	.082325	.087800	-.005475	-.0624
11	.079724	.083300	-.003576	-.0429
12	.074522	.072300	.002222	.0307
13	.077123	.084700	-.007577	-.0895
14	.079724	.064300	.015424	.2399
15	.082325	.061000	.021325	.3496
16	.079724	.070600	.009124	.1292

****

```
GOODNESS-OF-FIT STATISTICS
--------------------------
  .6490 = Increase in R**2 Due to Variable Added
  .6490 = Multiple R**2
  .8056 = Multiple R

.0114657 = Standard error of estimate (Se)
.0186974 = Standard deviation of Y    (Sy)

.6132252 = Se/Sy

.1189643 = Mean of Absolute Relative Errors
.0868839 = Std. dev. of Absolute Relative Errors

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

  25.889 = Total F for the Analysis of Variance on R
             df 1 =  1.     df 2 =  14.

  25.889 = Partial F to Enter
             df 1 =   1     df 2 =  14.

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

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

 ---    ---------  ------   -----   -----   -----   --------   -----
----


   5       -.260122   -.8056   -.8056    .6490    .6490         .0511
.19654


          .243601 = Intercept


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

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


 Step number =  2     Enter predictor variable  1


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

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
1	-.7551	17.241
2	-.1971	.526
3	-.5051	4.452
4	-.2413	.804
6	-.0186	.005
7	-.4528	3.353
8	.5571	5.850

****

.7972 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

==

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.070014	.072500	-.002486	-.0343
2	.066941	.071100	-.004159	-.0585
3	.064585	.070200	-.005615	-.0800
4	.063199	.069900	-.006701	-.0959
5	.083027	.085900	-.002873	-.0334
6	.088574	.093700	-.005126	-.0547
7	.080114	.090300	-.010186	-.1128
8	.086420	.088300	-.001880	-.0213
9	.137845	.140900	-.003055	-.0217
10	.087457	.087800	-.000343	-.0039
11	.083981	.083300	.000681	.0082
12	.078364	.072300	.006064	.0839
13	.084898	.084700	.000198	.0023
14	.069030	.064300	.004730	.0736
15	.078320	.061000	.017320	.2839
16	.084031	.070600	.013431	.1902

****

```
GOODNESS-OF-FIT STATISTICS
--------------------------
 .2001 = Increase in R**2 Due to Variable Added
 .8491 = Multiple R**2
 .9215 = Multiple R

.0078014 = Standard error of estimate (Se)
.0186974 = Standard deviation of Y    (Sy)

.4172458 = Se/Sy

.0724124 = Mean of Absolute Relative Errors
.0745621 = Std. dev. of Absolute Relative Errors

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

 36.580 = Total F for the Analysis of Variance on R
           df 1 =  2.     df 2 =  13.

 17.240 = Partial F to Enter
           df 1 =   1     df 2 =  13.

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

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
5	-.187282	-.5800	-.8056	.6490	.4673	.0390	.20802
1	-.000167	-.5010	-.7622	.5809	.3818	.0000	.24084

.216852 = Intercept

===

===

Step number = 3 Enter predictor variable 7

****

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
2	.2402	.735
3	.4046	2.349
4	-.4883	3.758
6	.0311	.012
7	.6905	10.938
8	.5019	4.041

****

.1749 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.067535	.072500	-.004965	-.0685
2	.069627	.071100	-.001473	-.0207
3	.069550	.070200	-.000650	-.0093
4	.070300	.069900	.000400	.0057
5	.079159	.085900	-.006741	-.0785
6	.096829	.093700	.003129	.0334
7	.083614	.090300	-.006686	-.0740
8	.089792	.088300	.001492	.0169
9	.139008	.140900	-.001892	-.0134
10	.089269	.087800	.001469	.0167
11	.080921	.083300	-.002379	-.0286
12	.079372	.072300	.007072	.0978
13	.079438	.084700	-.005262	-.0621
14	.061490	.064300	-.002810	-.0437
15	.069870	.061000	.008870	.1454
16	.081027	.070600	.010427	.1477

****

```
GOODNESS-OF-FIT STATISTICS
--------------------------
 .0719 = Increase in R**2 Due to Variable Added
 .9211 = Multiple R**2
 .9597 = Multiple R

.0058733 = Standard error of estimate (Se)
.0186974 = Standard deviation of Y    (Sy)

.3141263 = Se/Sy

.0539020 = Mean of Absolute Relative Errors
.0457244 = Std. dev. of Absolute Relative Errors

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

46.671 = Total F for the Analysis of Variance on R
           df 1 =  3.     df 2 =  12.

10.936 = Partial F to Enter
           df 1 =   1     df 2 =  12.

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

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
5	-.125058	-.3873	-.8056	.6490	.3120	.0348	.27864
1	-.000355	-1.0636	-.7622	.5809	.8107	.0001	.18133
7	.012310	.5727	-.3521	.1239	-.2016	.0037	.30239

.154375 = Intercept

===

===

Step number = 4   Enter predictor variable 4

****

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
2	.4346	2.562
3	.4771	3.242
4	-.5062	3.791
6	.3496	1.531
8	.4725	3.161

****

.1404 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.066988	.072500	-.005512	-.0760
2	.069742	.071100	-.001358	-.0191
3	.069644	.070200	-.000556	-.0079
4	.070917	.069900	.001017	.0145
5	.082893	.085900	-.003007	-.0350
6	.099166	.093700	.005466	.0583
7	.081109	.090300	-.009191	-.1018
8	.089125	.088300	.000825	.0093
9	.139000	.140900	-.001900	-.0135
10	.089857	.087800	.002057	.0234
11	.077396	.083300	-.005904	-.0709
12	.078116	.072300	.005816	.0804
13	.085105	.084700	.000405	.0048
14	.064052	.064300	-.000248	-.0039
15	.066621	.061000	.005621	.0921
16	.077070	.070600	.006470	.0916

****

```
GOODNESS-OF-FIT STATISTICS
--------------------------
 .0202 = Increase in R**2 Due to Variable Added
 .9413 = Multiple R**2
 .9702 = Multiple R

.0052904 = Standard error of estimate (Se)
.0186974 = Standard deviation of Y    (Sy)

.2829478 = Se/Sy

.0439224 = Mean of Absolute Relative Errors
.0363166 = Std. dev. of Absolute Relative Errors
```

****

```
44.090 = Total F for the Analysis of Variance on R
           df 1 =  4.     df 2 =  11.

 3.790 = Partial F to Enter
           df 1 =   1     df 2 =  11.
```

****

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
5	-.108406	-.3357	-.8056	.6490	.2705	.0325	.30010
1	-.000341	-1.0237	-.7622	.5809	.7803	.0001	.17087
7	.011073	.5152	-.3521	.1239	-.1814	.0034	.30819
4	-.007132	-.1587	-.4530	.2052	.0719	.0037	.51367

.171842 = Intercept

===

===

Step number = 5 Enter predictor variable 6

****

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
2	.0608	.037
3	.2994	.985
6	.5953	5.489
8	.2727	.803

****

.0865 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.067100	.072500	-.005400	-.0745
2	.070070	.071100	-.001030	-.0145
3	.070330	.070200	.000130	.0018
4	.072964	.069900	.003064	.0438
5	.084272	.085900	-.001628	-.0190
6	.094406	.093700	.000706	.0075
7	.087185	.090300	-.003115	-.0345
8	.085952	.088300	-.002348	-.0266
9	.140742	.140900	-.000158	-.0011
10	.086448	.087800	-.001352	-.0154
11	.077269	.083300	-.006031	-.0724
12	.078294	.072300	.005994	.0829
13	.087660	.084700	.002960	.0349
14	.062970	.064300	-.001330	-.0207
15	.063462	.061000	.002462	.0404
16	.077675	.070600	.007075	.1002

****

```
 GOODNESS-OF-FIT STATISTICS
 --------------------------
  .0208 = Increase in R**2 Due to Variable Added
  .9621 = Multiple R**2
  .9809 = Multiple R

.0044585 = Standard error of estimate (Se)
.0186974 = Standard deviation of Y    (Sy)

.2384570 = Se/Sy

.0368900 = Mean of Absolute Relative Errors
.0304346 = Std. dev. of Absolute Relative Errors

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

 50.760 = Total F for the Analysis of Variance on R
           df 1 =  5.     df 2 =  10.

  5.488 = Partial F to Enter
           df 1 =   1     df 2 =  10.

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

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
5	-.060694	-.1880	-.8056	.6490	.1514	.0342	.56274
1	-.000374	-1.1215	-.7622	.5809	.8548	.0001	.13661
7	.012904	.6003	-.3521	.1239	-.2114	.0030	.23096
4	-.009260	-.2061	-.4530	.2052	.0934	.0032	.34754
6	.084888	.1838	.4018	.1615	.0738	.0362	.42688

.100173 = Intercept

===

===

Step number = 6 Enter predictor variable 8

****

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
2	-.1337	.164
3	-.0895	.073
8	-.1500	.207

****

.0267 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

==

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.066350	.072500	-.006150	-.0848
2	.069814	.071100	-.001286	-.0181
3	.070286	.070200	.000086	.0012
4	.073357	.069900	.003457	.0495
5	.083943	.085900	-.001957	-.0228
6	.093749	.093700	.000049	.0005
7	.087318	.090300	-.002982	-.0330
8	.086727	.088300	-.001573	-.0178
9	.140638	.140900	-.000262	-.0019
10	.087220	.087800	-.000580	-.0066
11	.077600	.083300	-.005700	-.0684
12	.077447	.072300	.005147	.0712
13	.087698	.084700	.002998	.0354
14	.063740	.064300	-.000560	-.0087
15	.062863	.061000	.001863	.0305
16	.078051	.070600	.007451	.1055

****
****

```
GOODNESS-OF-FIT STATISTICS
--------------------------
  .0009 = Increase in R**2 Due to Variable Added
  .9629 = Multiple R**2
  .9813 = Multiple R

.0046466 = Standard error of estimate (Se)
.0186974 = Standard deviation of Y    (Sy)

.2485146 = Se/Sy

.0347506 = Mean of Absolute Relative Errors
.0324285 = Std. dev. of Absolute Relative Errors
```

****
****

```
38.980 = Total F for the Analysis of Variance on R
           df 1 =  6.     df 2 =   9.

  .207 = Partial F to Enter
           df 1 =   1     df 2 =   9.
```

****
****

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
5	-.038455	-.1191	-.8056	.6490	.0959	.0605	1.57239
1	-.000391	-1.1716	-.7622	.5809	.8930	.0001	.16553
7	.013504	.6282	-.3521	.1239	-.2212	.0034	.24988
4	-.010802	-.2404	-.4530	.2052	.1089	.0048	.44143
6	.098371	.2130	.4018	.1615	.0856	.0480	.48799
8	-.000016	-.0525	-.0137	.0002	.0007	.0000	2.19787

.089760 = Intercept

==

==

Step number = 7 Enter predictor variable 3

****

STATISTICAL CHARACTERISTICS

FOR VARIABLE SELECTION

Var	Partial R to enter	Partial F to enter
2	-.0294	.007
3	.2485	.527

****

.0001 = Determinant of Intercorrelation Matrix

****

ERROR ANALYSIS

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.066181	.072500	-.006319	-.0872
2	.070090	.071100	-.001010	-.0142
3	.070021	.070200	-.000179	-.0025
4	.072860	.069900	.002960	.0423
5	.083866	.085900	-.002034	-.0237
6	.094045	.093700	.000345	.0037
7	.089169	.090300	-.001131	-.0125
8	.085873	.088300	-.002427	-.0275
9	.140725	.140900	-.000175	-.0012
10	.088493	.087800	.000693	.0079
11	.076432	.083300	-.006868	-.0825
12	.076662	.072300	.004362	.0603
13	.086902	.084700	.002202	.0260
14	.064505	.064300	.000205	.0032
15	.064010	.061000	.003010	.0493
16	.076965	.070600	.006365	.0902

****

```
GOODNESS-OF-FIT STATISTICS
--------------------------
  .0023 = Increase in R**2 Due to Variable Added
  .9652 = Multiple R**2
  .9825 = Multiple R

.0047742 = Standard error of estimate (Se)
.0186974 = Standard deviation of Y    (Sy)

.2553403 = Se/Sy

.0333893 = Mean of Absolute Relative Errors
.0316204 = Std. dev. of Absolute Relative Errors

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

  31.724 = Total F for the Analysis of Variance on R
              df 1 =  7.     df 2 =   8.

    .525 = Partial F to Enter
              df 1 =   1     df 2 =   8.

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

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
5	.016930	.0524	-.8056	.6490	-.0422	.0984	5.81301
1	-.000651	-1.9510	-.7622	.5809	1.4870	.0004	.55991
7	.015777	.7340	-.3521	.1239	-.2584	.0047	.29617
4	-.011650	-.2593	-.4530	.2052	.1175	.0050	.43234
6	.100144	.2168	.4018	.1615	.0871	.0494	.49312
8	-.000126	-.4167	-.0137	.0002	.0057	.0002	1.23768
3	.000016	.6605	-.6531	.4265	-.4314	.0000	1.37818

.081988 = Intercept

==

==

Step number = 8 Enter predictor variable 2

****

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

   2       .1387        .137

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

   .0000 = Determinant of Intercorrelation Matrix

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

ERROR ANALYSIS

==

Obs. No.	Predicted YP	Measured Y	Error e = YP - Y	Relative error (e/Y)
1	.066055	.072500	-.006445	-.0889
2	.070552	.071100	-.000548	-.0077
3	.070181	.070200	-.000019	-.0003
4	.072975	.069900	.003075	.0440
5	.084663	.085900	-.001237	-.0144
6	.094198	.093700	.000498	.0053
7	.088967	.090300	-.001333	-.0148
8	.085524	.088300	-.002776	-.0314
9	.140621	.140900	-.000279	-.0020
10	.088621	.087800	.000821	.0094
11	.076706	.083300	-.006594	-.0792
12	.075458	.072300	.003158	.0437
13	.086851	.084700	.002151	.0254
14	.063739	.064300	-.000561	-.0087
15	.064272	.061000	.003272	.0536
16	.077417	.070600	.006817	.0966

****

```
GOODNESS-OF-FIT STATISTICS
--------------------------
 .0007 = Increase in R**2 Due to Variable Added
 .9659 = Multiple R**2
 .9828 = Multiple R

.0050550 = Standard error of estimate (Se)
.0186974 = Standard deviation of Y    (Sy)

.2703564 = Se/Sy

.0328279 = Mean of Absolute Relative Errors
.0319179 = Std. dev. of Absolute Relative Errors
```

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

```
24.777 = Total F for the Analysis of Variance on R
           df 1 =  8.     df 2 =   7.

  .136 = Partial F to Enter
           df 1 =   1     df 2 =   7.
```

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

Var	b	t	r	r**2	t*r	Se(bi)	Se(bi)/bi
5	.033604	.1041	-.8056	.6490	-.0838	.1135	3.37805
1	-.000793	-2.3779	-.7622	.5809	1.8123	.0005	.68681
7	.018193	.8464	-.3521	.1239	-.2980	.0082	.45008
4	-.010389	-.2312	-.4530	.2052	.1047	.0063	.60906
6	.109838	.2378	.4018	.1615	.0955	.0585	.53239
8	-.000187	-.6184	-.0137	.0002	.0085	.0002	1.24734
3	.000022	.9044	-.6531	.4265	-.5907	.0000	1.29076
2	.000417	.1296	-.6383	.4074	-.0827	.0011	2.70093

.061049 = Intercept