H. PEKPINARLI

DISCHARGE ESTIMATIONS WITH REGRESSION ANALYSIS USING BASIN PARAMETERS AND GIS TECHNIQUES

HAKAN PEKPINARLI

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Approval of the Graduate School of Natural and Applied Sciences.

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Prof. Dr. Canan ÖZGEN

Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

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Assist. Prof. Dr. Zuhal AKYÜREK

Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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Assoc. Prof. Dr. Nurünnisa USUL

Supervisor

Examining Committee Members

Prof. Dr. Doğan Altınbilek (METU, CE)	________________________
Assoc. Prof. Dr. Nurünnisa Usul (METU, CE)	________________________
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Name, Last name : Hakan, Pekpınarlı

Signature :

ABSTRACT

DISCHARGE ESTIMATIONS WITH REGRESSION ANALYSIS USING BASIN PARAMETERS AND GIS TECHNIQUES

Pekpınarlı, Hakan

M. S., Geodetic and Geographic Information Technologies

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Discharge estimations at certain cross sections of streams are very important for hydrologic studies especially for designs. In this study, it is aimed to determine regional mathematical equations that represent annual and monthly average discharges at desired locations using basin characteristics obtained with Geographical Information Systems (GIS) techniques and regression analysis.

Study area covers three river basins, which are Gediz, Küçük Menderes and Büyük Menderes. The data used are Digital Elevation Model (DEM), monthly average discharges observed at stream gauging stations and monthly total precipitation data from the precipitation observation stations in the study area. Stream networks are delineated from DEM using a GIS software. The basin parameters obtained from DEM are drainage area, total river length, main channel slope, main channel length and mean basin slope. Precipitation amount is also included in the analyses as the sixth parameter to improve the results. Using these parameters annual and monthly average discharge equations are determined and the best equation for each month is found based on the adjusted coefficient of determination values and stepwise regression analysis. Three models, each representing a different basin and a general model that represents the whole study area are developed. The verification of the models is made using the discharges at the additionally chosen stations that are not included in the model development. An interface that acquires the drainage area for a certain cross section and estimates the discharge according to the desired regression equation is written using arc objects and visual basic programming language. At the end, regression analysis results of the models are assessed and interpreted.

Keywords: Discharge Estimation, GIS, Regression Analysis, Western Anatolia

ÖZ

GIS TEKNİKLERİ VE HAVZA PARAMETRELERİ KULLANILARAK REGRESYON ANALİZİ İLE AKIM HESAPLAMALARI

Pekpınarlı, Hakan

Yüksek Lisans, Jeodezi ve Coğrafi Bilgi Teknolojileri

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Nehirlerin belli kesitlerindeki akım hesaplamaları hidrolojik çalışmalarda bilhassa tasarımlar için çok önemlidir. Bu çalışma, istenilen kesitlerde yıllık ve aylık ortalama akımları gösteren bölgesel matematiksel eşitlikleri; Coğrafi Bilgi Sistemleri (CBS) teknikleri ile elde edilen havza karaktersitiklerini ve regresyon analizini kullanarak belirlemeyi amaçlamaktadır.

Çalışma alanı üç nehir havzasını kapsamaktadır, bunlar Gediz, Küçük Menderes ve Büyük Menderes Havzalarıdır. Kullanılan veriler, çalışma alanının Sayısal Yükseklik Modeli (SYM), nehir ölçüm istasyonlarında gözlenen aylık ortalama akımlar ve yağış gözlem istasyonlarının aylık toplam yağış verileridir. Nehir ağları SYM'den, bir CBS programı kullanılarak elde edilmiştir. SYM'den elde edilen havza parametreleri; drenaj alanı, toplam nehir uzunluğu, ana kolun eğimi, ana kolun uzunluğu ve ortalama havza eğimidir. Yağış miktarı altıncı parametre olarak sonuçları iyileştirmek için bunlara ilave edilmiştir. Yıllık ve aylık ortalama akım eşitlikleri regresyon analizleriyle bulunmuş ve herbir ay için en iyi eşitlikler düzeltilmiş belirlilik katsayısı kullanılarak ve aşamalı regresyon analiziyle belirlenmiştir. Farklı havzaları ifade eden üç model ve tüm çalışma alanını ifade eden genel bir model geliştirilmiştir. Modellerin doğrulanması model geliştirmeye dahil edilmeyen istasyonlardan seçilenlerdeki akımlar kullanılarak yapılmıştır. ‘Arc objects’ ve ‘visual basic’ programlama dilini kullanarak istenilen bir kesit için drenaj alanını elde eden ve akımı ilgili regresyon eşitliğine göre hesaplayan bir arayüz yazılmıştır. Son olarak, modellerin regresyon analiz sonuçları değerlendirilip yorumlanmıştır.

Anahtar Kelimeler: Akım Hesaplaması, GIS, Regresyon Analizi, Batı Anadolu

To My Family

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CHAPTER 1

INTRODUCTION

1.1 Importance of the Subject

Water is the source of life and most valuable natural resource that supplies food, electricity and beauty. From the beginning of human life, water had kept its importance and even fights emerged to take control of it. Water is the most important matter on earth; controlling it gives many advantages, but without control, it can be a very destructive power like flood. Controlling of water is a great concern even now, and it requires the understanding of the water behavior. Water is constantly moving within and above the earth in hydrologic cycle. It evaporates, precipitates and remaining part from the infiltration becomes surface waters and forms streams.

Besides their advantages streams may cause damages hence; hydrology and hydraulics of the catchments are very important issues. In order to design dams, channels, culverts or any other hydraulic structures, the hydrology and the hydraulics of the water body in river basin must be studied comprehensively. In these analyses and studies, discharge is the key parameter. Discharge is not only the important parameter for designing hydraulic structures but also the depicter of available water in catchments so it reflects significant information for water supply potential or hydropower. Stream waters can be diverted and/or stored to form ponds or dams for water supply, irrigation, hydroelectric or recreational purposes. Unfortunately, water on our earth is limited; together with increase in population and industrialization, its efficient usage gains more importance day by day.

Annual total precipitation average of Turkey is around 640 mm so it is far below the World average that is around 1000 mm (Web.1, Web.2). In Turkey population and industrialization are increasing, but unfortunately precipitation tends to decrease (Web.3). This situation implies that there might be drought problem in the near future hence water resource management gains more importance. In addition to that, Turkey uses its water resources far below its potential. In Turkey, there are 26 basins; but not all of them are used efficiently. The discharges are obtained from stream gauging stations however; the number of gauges is limited in Turkey because of mainly the operation costs, which is the common problem of developing countries. Therefore, in Turkey and similarly in many other countries most of the basins are poorly gauged basins and flow records are not adequate. These factors make it difficult to work on ungauged locations. In these circumstances, some methods have been developed in hydrology to estimate the discharges at ungauged locations.

1.2 Aim of the Study

In this study, it is aimed to determine regional mathematical equations that represent monthly and annual average discharges to be used at desired locations on streams. In order to do this, basin parameters of the study area are extracted by GIS and used in regression analyses.

In Turkey, all of the streams have irregular regimes so their discharges change very much from one month to the other. Therefore, besides the annual discharges, monthly average discharges were also studied.

Basin is a system that converts precipitation into streamflow. Therefore basin characteristics are the determining factors to produce surface and subsurface flows in the streams. Mean discharges in the basin are mainly affected by morphologic and climatic basin characteristics. Morphologic characteristics are related with the topography of the basin and they are included in the analyses as basin parameters; Drainage Area, Total River Length, Mean Basin Slope, Main Channel Length and Main Channel Slope. In order to determine basin parameters, the only required data are the topographic map or the Digital Elevation Model (DEM) which is a digital form of elevation values in a grid form. The most important climatic characteristics are related with the precipitation and temperature in the basin. In many locations there are no or very limited precipitation data. For that reason, discharges are tried to be estimated using only the parameters found from DEM by GIS techniques. If precipitation data are also available then the models are made to include them to improve the results, since it is the main cause of streamflow.

1.3 Scope of the Study

The study area covers three river basins, which are Gediz, Küçük Menderes and Büyük Menderes Basins. They are at the west side of Turkey and adjacent to each other. The main rivers of the study area are Gediz, Küçük Menderes and Büyük Menderes and they flow to the Aegean Sea. Morphologic and climatic characteristics of the basins are similar. Küçük Menderes Basin is smaller than the other two and it is surrounded by them. Küçük Menderes Basin has very few stream gauging stations, therefore it can also be considered as an ungauged basin.

In this study, GIS techniques are used to obtain the river network from DEM and to extract the important basin parameters that affect the flow. In collaboration with the developing information technology, GIS usage and its offered opportunities have increased in the recent years and similarly they are being used increasingly in hydrological applications. Both lumped and distributed parameter models are adapted to GIS for hydrological analyses and applications.

Regression analyses were used to develop the models using the basin parameters that are extracted by GIS techniques. A general regional model that represents the whole study area and a separate model for each basin were developed. In the general regional model, all three river basins were used with their sub-basin parameters for representing annual and monthly average discharges of 24 stream gauging stations. In the second model, only Gediz Basin with its nine stream gauging stations, in the third model, only Küçük Menderes basin with its three stations and in the fourth model, only Büyük Menderes basin with its 12 stations were used. Stepwise regression analyses were performed for each model to obtain the best equations that have the significant parameters for the annual and monthly average discharges. In order to verify the models, testing was performed. Totally 13 stream gauging stations that were not included in the model developments were used for testing.

In the second chapter, previous studies related with the subject are given and the models used in similar hydrologic applications with this study are presented.

In the third chapter, the data used and the study area are described. Moreover, starting with the stream delineation, how GIS is used step by step to extract basin parameters is explained in detail.

In the fourth chapter, firstly the definitions of the regression analysis are given then the model building with regression analysis is explained. The test results of the models are also presented.

In the fifth chapter, developed models are assessed and the results are interpreted. At the end of this chapter, the results are summarized in discussion of the results part.

In the sixth chapter, conclusion is given and recommendations for the similar or further studies are presented.

1.4 Data and software used in the study

One of the important data needed to perform this study is DEM of the study area. DEM and 1:500.000 scale topographic map were obtained from State Hydraulic Works (DSI). The discharge and the precipitation data in the basins were also obtained from DSI. In addition to that, stream gauging stations data of General Directorate of Electrical Power Resources Survey and Development Administration (EIE) were added to those obtained in DSI for including important river branches to the analyses.

In this study, ArcGIS software of Environmental Systems Research Institute (ESRI) is used as main GIS software. Besides that, ArcGIS Hydro Data Model (ArcHydro) is used for delineation of the river network. Minitab 13.2 Software is used for performing the regression analyses.

CHAPTER 2

LITERATURE REVIEW

2.1 General

Discharge estimation is a very important and difficult subject in hydrology. In order to estimate the discharges many methods have been developed for many decades. The methods of the discharge estimations at ungauged locations can be grouped into mainly three model types. These models are physical models, conceptual models and empirical models. Besides, lumped and distributed parameter models are used to adapt these models to computerized applications with respect to lumped or distributed parameter inputs. In this chapter, previously developed methods related with these models are presented.

Generally, discharge estimations are based on the determination of peak or mean discharges as well as hydrograph determination for a rainfall event. Generally, peak discharges are important in flood prevention studies or designing the hydraulic structures and mean discharges are used for estimating water supply or hydro electrical potentials. Discharge estimation for a rainfall event is a challenging subject in hydrology, especially at ungauged locations. How much rainfall will become runoff, depends on many basin parameters. Rainfall-runoff models have been developed to solve this problem. Synthetic unit hydrograph methods are based on synthetic data generation for rainfall event and widely used for this purpose. These methods use rainfall and watershed characteristics to derive a hydrograph. Mostly used synthetic hydrograph method is developed by US Soil Conservation Service (1975). This method was developed with the analysis of large number of unit hydrographs obtained from observed runoff and rainfall data in the basins at different geographic locations with varying sizes. Dimensionless unit hydrograph is used for constructing synthetic unit hydrograph, and in order to do that two terms, time to peak and peak discharge need to be determined. Time to peak can be computed by adding half of rainfall duration to lag time which can be estimated by the formula including stream length, average watershed slope and curve number (US Soil Conservation Service, 1975). Curve number can be estimated from soil and land use of the catchments. After the determination of time to peak, peak discharge can be computed with drainage area of the basin.

2.2 Lumped and Distributed Parameter Models

The models are used to represent the hydrological events with some approaches and assumptions, and they are aimed to represent discharge or runoff using the parameters related with climatic, morphologic and land use situation of the corresponding basin. According to the inclusion of the input data, the models can be classified into two categories as Lumped Parameter Models and Distributed Parameter Models. Both of them have certain advantages and disadvantages.

Lumped Parameter Models take the averages of the related variables over sub-basin areas and use them to produce the discharge or runoff, like hydrologic process occurs at one point. The discharge in the sub-basin is calculated using these average values of the variables. Sub-basin outlet points can be regarded as the nodes for the hydrologic analysis. The discharges found at each node are added to the ones at the following junctions and this process continues towards the basin outlet point. Tree structure is a simplified form that can be adapted to automated computation. For example Watershed Modeling System (WMS) is a program that converts spatially distributed watershed data into lumped tree structure to be used in hydrologic modeling programs such as TR20 and HEC1. TR20 program computes the synthetic hydrograph with the tree structure using sub-basin area and SCS curve number information stored at the nodes (Web.4).

Lumped parameter models are suitable for the application of empirical models like regression analysis. In this study, sub-basin parameters can be considered as the single numbers stored on the outlet points that are the nodes of stream gauging stations.

Distributed parameter models use spatial variability of the variables and compute the flow from one cell to another. Distributed parameter models are suited to physically based models and conceptual water balance models that define water balance of the hydrologic cycle for each cell. Distributed parameter models are fitted to GIS techniques like spatial analyses and raster operations. When the good quality of spatial data are available for ungauged basins to estimate the discharge, distributed parameter models can be applied. These models require distributed parameters for each cell, hence matrix operations are used. For example, raster operation is the matrix operation that might have large number of rows and columns and if we regard the operations between the several layers, it may take hours depending on the software and hardware used. Distributed parameter models take more computation time than the lumped parameter models. In summary, lumped parameter model has simplified terms so requires less computation time but has lack of spatial variation of information. Suitable model type amongst lumped and distributed parameter models should be selected regarding the available spatially distributed information, quality of distributed information, usages and needs.

2.3 Physical Models

Physically based hydrological models use strong physical bonds to calculate the discharge. For example, Shetran which is improved version of the She/Shesed model, is physically based spatially distributed model for discharge simulation and it uses balance equation including interception, evapotranspiration, transpiration and infiltration (Figueiredo and Bathurst, 2002). In physical models, all terms are calculated from well known formulas. Therefore, extracting necessary information from an ungauged basin to use in these formulas is very difficult, sometimes an impossible task. If available information does not fit the requirements, physically based models can not be applied to ungauged basins. Actually, in practice physically based methods do not seem feasible to be applied at ungauged basins.

2.4 Conceptual Models

Conceptual water balance models are similar to physically based models but include estimation of parameters by empirical methods, which do not use physical rules instead they use mathematical approaches like regression analysis. In addition, conceptual models use simplified definitions to represent the point of interest. Water balance methods are based on the balance of hydrological cycle and mainly include precipitation, infiltration and runoff. If the discharge is estimated from the water balance equation with respect to time base, hydrograph can be simulated.

Xu (1999) applied a six parameter conceptual water balance model to 26 small catchments for simulating river flow. The model was calibrated with observed values. Four catchments were chosen for testing the simulated and observed values. Regression analysis was used for relating the parameters to physical catchment characteristics. Percentages of lake, forest and clayey soil cover were used to find the formulas of six parameters with multiple linear regression.

Croke et al. (2003) used conceptual rainfall-runoff model, IHACRES which consists of non-linear loss module to convert rainfall to effective rainfall and linear routing model to estimate stream flow from effective rainfall. In this model, temperature, soil moisture index and storage coefficient were also included in loss module. In addition, CATCHCROP module which was developed by Perez et. al. (2002) used to create a hydrologic module in order to reflect land cover changes especially forest cover on infiltration and runoff. A simple regionalization was applied on three sub catchments and the parameters were calibrated. Any of the three sub catchments was selected as reference catchment to regionalize parameters for predicting the discharge in the other two sub catchments. It was concluded that being not depending on reference catchment, annual or seasonal streamflow can be predicted; however largest reference catchment seems to be superior on the other catchments for regionalization. In order to assess the quality of the model calibration Nash-Sutcliffe efficiency is used using observed test values which are not included in the model calibration.

Hundecha et al. (2002) used catchment properties as model parameters in a continuous transfer function to estimate similarities between gauged and ungauged catchments. For flow simulations in gauged locations, previously developed conceptual semi distributed model namely HBV-IWS was used. A large basin with 100.000 km^2 area was divided into a number of zones according to elevation, soil type, landuse, size and shape of the catchments. 900 rain gauges were used in external drift krigging for interpolation. In order to test flow more than 60 gauges were used. Similarities between the catchments were derived by distance function which use soil type, landuse and size & shape of the catchments. If the distance between gauged and ungauged catchments were below the limited values, then flow at ungauged locations were estimated from that of the gauged locations. Validation catchments that are not used in the calibration are used to get parameters and these parameters are used in the prediction. These predicted and observed discharges are evaluated by Nash-Sutcliffe efficiency.

2.5 Empirical Models

Empirical models are not related with the physical laws. However, empirical models may include some parameters that are apparently relevant with the subject but these parameters cannot be formularized with the physical definitions. If the discharge estimations are concerned, the rational peak discharge method of Kuichling (1889), synthetic hydrograph methods and regression analysis method can be defined as empirical methods.

For peak flows rational method was introduced by Kuichling (1889). At present, this method is still used for small urban and rural watersheds and it was adapted to some computer programs for automated computations by also using GIS. This method requires estimation of concentration time of drainage area, estimation of runoff coefficient, which can be found using land use and soil maps with runoff coefficient table. After that, return period is selected to find the intensity which is the last parameter to estimate the peak discharge for selected return period in Q=C*I*A equation.

The U.S Soil Conservation Service (1975) developed peak discharge estimation method named as TR-55 in 1975. In this method, graphics and charts are used to compute peak discharges and design discharges can be found from rainfall recurrence times.

Synthetic methods have been used commonly for many years to determine discharges. These equations are developed with observing large number of watersheds and discharges. However they have some disadvantages since they use some generalizations. Success of the synthetic equations changes from site to site and by the methods used. In other words, at some locations one synthetic method gives good results but another synthetic method may not give that much success. Some parameters affect the discharges such as climatic factors, mean elevation of the watershed, forest cover etc. These factors may affect the discharges much in some watersheds where calibration is crucial and if the basin does not have enough flow data, synthetic methods can not be used effectively.

The other method for estimating discharges is the regression analysis, it is based on observed flow values from the stream gauging stations, and these values can be used for the estimates at ungauged locations. Observed flows from the gauging stations represent basin characteristics and depend on these characteristics. Therefore, flows can be estimated using these basin characteristics. In order to determine the basin characteristics and parameters, regression analysis is widely used method in hydrology. In regression analysis the basin parameters that affect the flows are analyzed to find an equation depending on these parameters. Regression analysis is an empirical method that uses statistical relationships to find discharge values with respect to the basin characteristics or parameters.

Today, many statistical computer programs make regression analysis on user-defined parameters. In regression analyses for flow estimations, the most important thing is to find the independent basin parameters that affect the flow. In many early empirical equations, $Q=c*A^m$ form used for determining mean or peak discharge (Federovski and Mezencev, 1998). In the equation A is drainage area, c and m are the constants that are to be determined by the regression analysis. However, together with the drainage area, some additional parameters increase the accuracy of the estimation. Information on land use, geomorphology and climate are the other important characteristics that affect the flows so these must be analyzed for representing the characteristics of the basin and finding important basin parameters based on these characteristics in regression analyses (Tasker, 1980).

Misalis et al. (1999) developed a regression equation for October mean monthly flow at ungauged sites. For mountainous region, discharge was represented only depending on drainage area but in the same study for another mountainous region, the discharge was found depending on drainage area and mean annual precipitation as well. Similarly, Lowham developed regression equation for estimating mean annual flow in mountainous region using drainage area and mean annual precipitation (Brinkman and Lowham, 2001).

Vogel et al. (1999) developed regional regression equation for annual stream flow using geomorphic and climatic characteristics of the basins across the United States. The goal was to investigate the climate effect on annual flow. Firstly, only the Drainage Areas were used and adjusted R^2 values were found about 71,4% however, addition of mean annual temperature and precipitation in regression equation increased R^2 values to 94,5%. Therefore it was shown that climate information is a very important parameter for mean flows. In this study, it was stated that geomorphic, landuse and climate characteristics can be integrated and implemented using GIS for annual flow estimations with regression equation.

Magette et al. (1976) developed multiple linear regression equations to predict the selected parameters, which will be included in Kentucky watershed model (KWM) to simulate stream flow at ungauged sites. Twenty one watersheds which ranked in size from 3,8 to 1236 ha were used in this study and five of them were randomly selected to test the predictive equations. Fifteen easily determinable watershed characteristics were used to represent five independent KWM flow equation components. The results were compared as observed and simulated and it was stated that good and reasonable estimates can be obtained for ungauged watersheds.

Goodrich et al. (1997) examined 29 watersheds using regression analysis which assumes runoff response proportional to watershed drainage area. For mean annual response, they used $Q=a*A^b$ type equation which had been used in many other studies previously. In this equation a and b are the constants that are extracted from regression analysis. The watershed drainage areas range from $1,83*10^3$ m^2 to $1,48*10^8$ m^2 (0,183 – 14800 ha) were used and mean annual values were computed for 11 year period (1969-1979). With analyzing regression curves of different basins, it was concluded that below $6*10^5$ m^2 (60 ha) watershed area, the annual runoff response is nearly linear ($Q=0,03*1A^{0,97}$ $R^2=0,99$), but above this transition point, runoff response becomes non-linear ($Q=0,12*1A^{0,82}$ with $R^2=0,95$). This tendency was also stated by Huang and Willgoose (1993). According to them, larger watersheds have the streams with relatively large water contact surface, so increasing the drainage area will increase transmission losses and this will show a decreasing tendency of runoff while increasing the drainage area. On the contrary, in a number of other studies, it was concluded that runoff response becomes more linear with increasing basin scale (Gupta and Waymire 1986, Beven et al., 1988, Wang et al., 1981).

Federovski and Mezencev (1998) predicted daily and monthly flows for ungauged basins which have no rain gauges. They used two techniques for this prediction, first one was interpolating the rainfall from nearby catchments and the other one was transferring the amounts of storm rainfall into daily streamflow. For transferring rainfall to streamflow, Generalized Flood Pattern Method (GFPM) proposed by Mezencev (1979) was used. This method is similar to the unit hydrograph (UH) methods. However, GFPM uses complex floods with 1 to 5 days rainfall, while UH method uses isolated storms with near unit duration. For evaluating the flow pattern 4 years of input data between 1977 to 1980 years were used. Unit floods (UF) were predicted from daily runoff records and grouped into four categories with 11 types (patterns). Total flood volumes were derived from empirical relationships from total rainfall depths. In order to test the model, monthly average discharges were computed and compared with observed values. The correction coefficients were about 0.90. It was concluded that this model can be capable to predict daily and monthly flow patterns at ungauged locations.

Tasker (1980) compared Ordinary Least Squares (OLS) regression with Weighted Least Squares (WLS) regression for the 50 year peak discharge Q_{50} in the form $Q_{50}= c*A^m$. In this equation A is drainage area, c and m are the coefficients which will be determined by regression analysis with observed gauged flows. For weighted regression equation, it was stated that WLS had not been used in practice in regional hydrologic regression and the reason for that is the difficulty for obtaining specific information for weighting functions. Ordinary Least Squares assume all observations as equally weighted, however Weighed Least Squares take into account dependent conditions on observations. These dependent conditions were specified as the length of record at gauging stations and the conditions of the measurements. The weighted functions which use the length of record for the observations were used for WLS in this study. It was concluded that the results of WLS have very small root mean square errors and also smaller errors than those of OLS regression model.

Stedinger and Tasker (1985) made regional regression analyses on Ordinary Least Squares, Weighted Least Squares and Generalized Least Squares (GLS). They concluded that WLS and GLS have remarkable improvements on OLS for estimations especially when the lengths of records vary widely from one site to another.

Ludwig et al. (2004) investigated hydroclimatic patterns in a typical Mediterranean basin in order to verify that increasing temperature results in greater risk of floods. Mean annual flow was also studied but there is not found clear trend with increasing temperature and precipitation. They used 10 discharge stations, 48 precipitation stations and 25 temperature stations and those were converted to seasonal and annual data from daily and monthly averages. When there were some missing values in discharge, precipitation or temperature time series, then these values were completed by finding linear relationship from neighboring stations. Annual precipitation data in 20 years was spatially distributed by applying triangular interpolation method. For temperature, a different path was followed; since elevation strongly influence the temperature to find the grid point climatology, linear regression was performed on elevation and latitude information. For years between 1980 and 2000, observed temperature values were available. The observed ones were also spatially distributed over basin by triangular interpolation method. Combining these two, theoretical and observed temperature information for each cell, the more realistic temperature values obtained especially at the locations where morphological variations occur between stations.

Abdulla and Lettenmaier (1997) used a land surface hydrologic model named Variable Infiltration Capacity (VIC-2L) for estimating stream flow in six unregulated catchments using regionalized equations of 34 unregulated catchments. Two methods were applied for extracting the necessary information in these catchments. First one was direct estimation of saturated hydraulic conductivity and pore size distribution index from U.S Soil Conservation Service State Soil Geographic Database (STATSGO). The second one was estimating the other seven necessary parameters using regression analysis which minimize sum of square distances between observed and predicted stream flows. It was stated that multiple regression is widely used in hydrology especially for transferring stream flow from gauged to ungauged sites. In this study, five different multiple regression equations were investigated. Regional equations were developed to relate model parameters to measurable physical quantities including STATSGO and climatological data. These parameters were used to simulate the model that is constituted with 34 catchments and the model was tested with six catchments. The results were quite good in humid and semi humid catchments. However, regional regression equations did not give that much successful results in arid and semi arid regions.

Yokoo et al. (2001) used regionalization of lumped water balance model parameters based on multiple regressions. Tank model which illustrates runoff process with inflow and outflows of the tank and it uses 12 model coefficients for water balance. 16 basin characteristics were derived from topography, soil type, geology and landuse. Dependent and independent variables were determined, then these dependent parameters were related with 12 model parameters using multiple linear regression equations. The resultant equations were optimized parameters in tank model and these gave good results for runoff simulation.

Pandey and Nguyen (1999) compared nine methods for estimating parameters of the exponential form of regression equation to represent flood flows at ungauged locations. Regionalization of regression equations were also used to lengthen flow statistics for the sites with short record lengths. Each basin is sequentially removed from regression analysis and then checked to test the model. It was stated that nonlinear regression techniques give better results at ungauged basins than linear regression methods. In many situations, Ordinary Least Square regression technique gave slightly better results than Weighted Linear Square regression and Generalized Linear Square regression techniques among linear regression methods, in addition it was stated that the suitable method can vary with discharge range and return period. When drainage area of the basin gets smaller, the results improved and also difference between the most and the least suitable method results were reduced.

Eagleson (1978) developed average annual soil moisture equation to be used in average annual precipitation yield estimation. For soil moisture balance, storm soil moisture and climatic statistics were used. The average annual precipitation yield was transformed into cumulative distribution function of annual yield. Obtained yield frequency function was found sensitive to soil and vegetation properties. Moreover, it was shown that natural catchment yields reduce with absence of vegetation that is related with reduction of average soil moisture.

Berger and Entekhabi (2001) studied long term hydrologic response of a basin using actual evaporation ratio with potential evaporation (E/E_p) and precipitation runoff loss ratio (R/P). These ratios were predicted by physiographic and climatic features of 10 basins that have diverse climates and terrains. A surface water balance and groundwater interaction model was used to represent long term hydrologic response. Six variables; median slope, relief ratio, drainage density, wetness ratio, infiltration capacity and saturated zone efficiency index, were selected as basin descriptors. Stepwise regression analysis was used to identify strong relationship between these variables with hydrologic response ratios. When regression analysis was applied individually one by one, wetness ratio was found to have the strongest relationship with R/P (R^2=0,70) and sequentially adding the other five variables increased R^2 values gradually to 0,90.

There is another method named as flow duration curve method which is also used to estimate flow characteristics at ungauged locations. Two possible methods can be applied to ungauged locations. First one uses the records of nearby gauging station within the same drainage basin and the second one uses regionalized flow duration curve. Mean discharges or peak discharges with relevant return period can be used to normalize a flow duration curve at ungauged locations then they can be estimated from regionalized regression equation (USGS, 1993). For example, the regionalized regression equation for the peak discharge that has the two years return period was developed by USGS (1993) on the basis of regression analysis using drainage area, channel slope and slope length.

CHAPTER 3

STUDY AREA

3.1 General

The study area is the western part of Turkey in the Aegean Region. It covers three river basins, which are Gediz, Küçük Menderes, and Büyük Menderes river basins. These basins are numbered respectively as 5^{th}, 6^{th} and 7^{th} basins among the 26 basins in Turkey. Total study area is around 5 million hectares. Figure 3.1 shows general overview of the study area. There are some reasons for the selection of this region as the study area. First of all, three basins are adjacent and have similar climates so that a regional model can be derived. Another reason is the suitable climatic condition that does not require taking into account snow melting effect in the analyses. In addition, because of the fact that Küçük Menderes Basin is in between Gediz and Büyük Menderes Basins and it does not have many stream gauging stations like the other two basins. Therefore, regional equations can be applied and checked for Küçük Menderes Basin as an ungauged basin.

3.1.1 Gediz Basin

Gediz Basin is in between Susurluk Basin and Küçük Menderes Basin and it has geographical coordinates between 38°04' - 39°13' North Latitudes and 26°42' - 29°45' East Longitudes. It covers 1.7 million ha area that is around 2,2% of the area of Turkey. It has generally mountainous topography. The mountains lay east-west direction especially at the north and south of the basin and their elevations reduce towards the sea. Valleys between the mountains are narrow at the north but quite wide at the center and south. The elevations of these valleys change between 400 m and 600 m. Towards the west, after Salihli valley in the middle of the basin that has 100 m lowest elevation, elevations reduce to 2,5 m at Menemen valley and then reach to the sea level (Topraksu, 1974a).

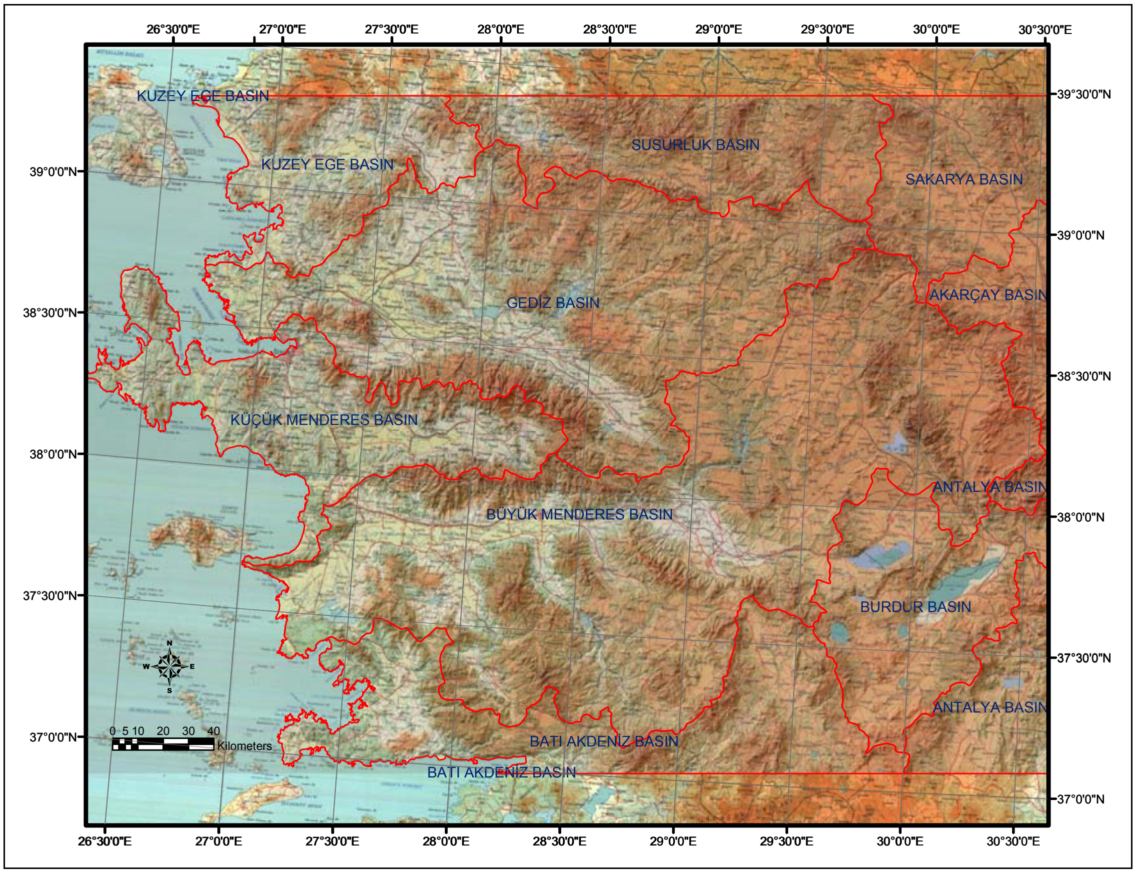

Figure 3.1 General Overview Map of the Study Area.

Gediz Basin has a typical Mediterranean climate; summers are hot and dry, winters are cool and rainy. The precipitation distribution in seasons is; 43,5% in winter, 36,9% in autumn, 16,1% in spring and 3,5% in summer. Precipitation is high at mountains and low in valleys. Annual total precipitation changes between 330 mm and 1060 mm in the recording period of the precipitation gauges. When excessive rainfall occurs, irregular topography and the water coming from the mountains cause floods in some valleys. Vegetation cover is generally forest and maquis. Above 1000 m elevation maquis are replaced with forest trees (Topraksu, 1974a).

The main river of the basin is Gediz River that springs at the 26 km east of the Gediz town and takes the waters of the highest mountain in the basin, Murat Mountain, which is at the boundary of Gediz and Sakarya Basins. Gediz River is fed by several stream branches. The regimes of Gediz River and its branches are not very regular; in summers, some of the branches may disappear and in spring, some of them change their beds. The discharge in Gediz River can be affected and reduced by mainly Demirköprü Dam and Marmara Lake Regulator.

3.1.2 Küçük Menderes Basin

Küçük Menderes Basin is between 38° 41' - 37° 53' North Latitudes and 28° 24' - 26° 11' East Longitudes. The basin is surrounded by Gediz Basin at the northeast and Büyük Menderes at the south, and it covers around 0,7 million ha area that includes İzmir province and its districts. Vegetation cover includes grasses, bushes and forests (Topraksu, 1974b).

Küçük Menderes River, which is the main and the longest river in the basin, springs at the east side of the basin from the south foot of the Bozdağ Mountain. Küçük Menderes River has many river branches. Out of the west boundary of the basin at Karaburun Peninsula, there are some other small rivers that are separately discharge to the Aegean Sea. Küçük Menderes River is not fed by high amount of waters; the mountains around the basin do not have snow so the only source of river flow is the rainfall. When rainfall occurs above the infiltration rate that is generally the case except summer, discharge is high because of the high slope of the mountains, thin soil layer and weak vegetation cover in the area. The regimes of the Küçük Menderes River and its branches are not regular because of instantaneous heavy rainfalls. Sometimes this causes flood in some valleys, however in summers some minor branches can disappear as in the case of Gediz branches.

The basin has Mediterranean climate similar to Gediz Basin. Precipitation occurs especially in winters (54%) then this followed by spring (23%) and autumn (21%), in summer there is very little precipitation (2%). Average annual precipitation is around 700 mm in the basin. The precipitation is high in the basin boundaries where mountains are present and low at the west and in the middle of the basin. At the mountainous topography, dominant vegetation cover is bush and partially forest.

3.1.3 Büyük Menderes Basin

Büyük Menderes Basin is in between 37° 7' – 38° 55' North Latitudes and 27° 0' - 30 35' East Longitudes. Büyük Menderes River is the main river (584 km) that has a drainage area of about 2,6 million ha. From the north, Aydın Mountain is the boundary between Küçük Menderes and Büyük Menderes basins. The basin is surrounded by many basins Gediz from the north, Sakarya from the northeast, Akarçay and Antalya from the east, Burdur Basin from the southeast and Batı Akdeniz from the south.

The name of the Büyük Menderes River has a meaning as Meander River because of its route that includes many loops and s shapes. This situation can also be seen in Gediz and Küçük Menderes Rivers so they are also regarded as the Meander Rivers. Büyük Menderes River results from the combination of mainly two stream branches which are Banaz stream (170 km long) and the stream that springs by the waters of Kumalar Mountain in Sandıklı Valley. Banaz River springs from the south foot of the Murat Mountain that is also the origin of the Gediz River. The other big branches of Büyük Menderes are Akçay (291 km) and Çine (99 km). Işıklı Lake regulates the flows that come from Sandıklı Valley and there are also Keban and Adıgüzel Dams on the river. During spring, Büyük Menderes River has high flow that sometimes cause floods on plains but very low flow during the summers. Similar to Gediz and Küçük Menderes Rivers, its regime is also not regular. During the summer some of its branches may dry and disappear. This river has changed its bed at some flat terrains in the course of time. Since its discharges are high in some months, it carries sediments through its way to the sea and forms deltas. By the centuries, these deltas have filled the sea formed lands and they continue to expand (Web.5).

3.2 The Data Used for the Study

1:500.000 scaled topographical map and Digital Elevation Model (DEM) of the study area are obtained from State Hydraulic Works (DSI). DEM of the study area can be seen in Figure 3.2. DEM may store the elevation values in different formats such as ASCII, Geotiff or Digital Terrain Elevation Data (DTED). The DEM that is obtained from DSI, is originated from DTED of Shuttle Radar Topography Mission (SRTM). SRTM is the project mainly supported by National Aeronautics and Space Administration of

United States (NASA) and National Geospatial-Intelligence Agency of United States (NGA) to obtain DTED covering almost the whole earth by radar interferometry (Web.6).

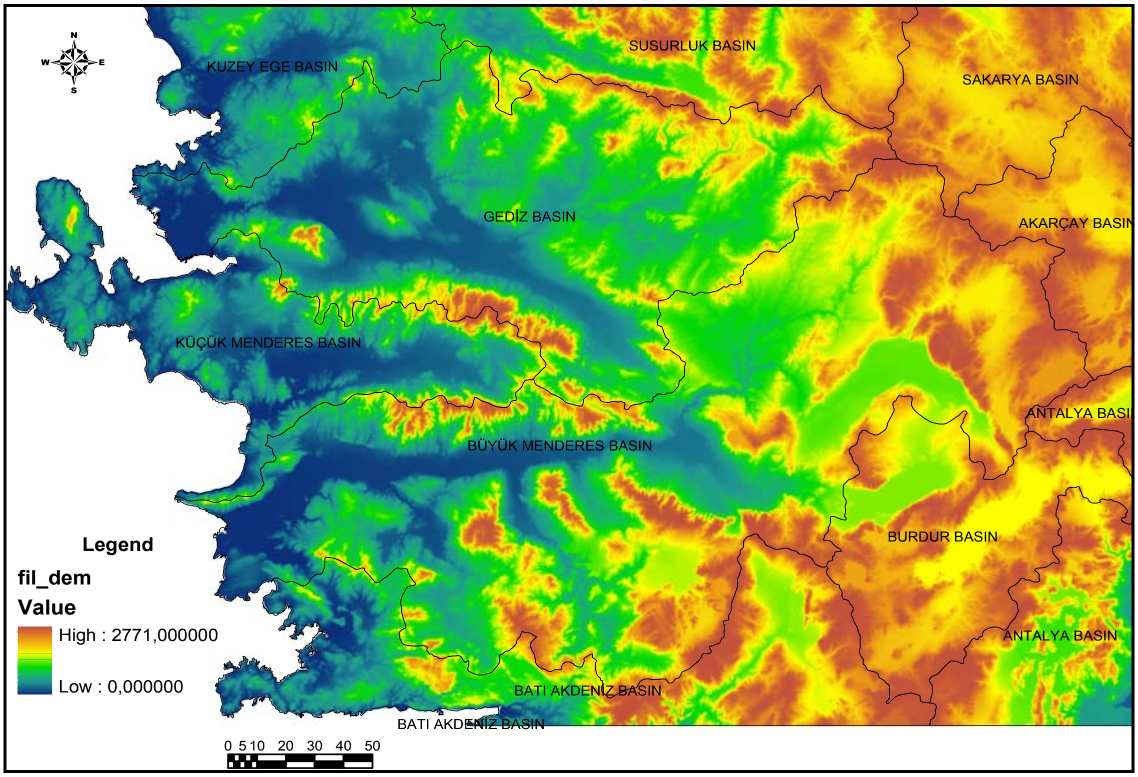

Figure 3.2 SRTM-3arc (90 m resolution) DEM with basin boundaries.

DEM used in this study has approximately 90 m resolution and this implies around 1:250.000 scale that results from SRTM-3 data that are sampled at three arc seconds. SRTM-3 data have 20 m absolute horizontal and 16 m vertical accuracy (Web.7). SRTM-3 data can be downloaded freely from the internet by following the download link in the USGS web site (Web.8). This free data include no data values because of the water bodies and mountain shadows that prevent quantification of elevation. These no data spaces can be removed by making vector contours and converting back via re-interpolation to the raster DEM (Web.9). The SRTM DEM obtained from DSI was corrected version for no data spaces. Two Maps in 1:800.000 scale, one of them showing the Stream Gauging Station locations and the other showing Precipitation Observation Stations are also obtained from DSI. General network of stream branches are also shown in these maps. Moreover, monthly discharges in the recording period and similarly monthly precipitation values are obtained in excel sheets with their location information from DSI. Additional flow data are obtained from General Directorate of Electrical Power Resources Survey and Development Administration (EIE) as excel sheets that include monthly average discharges for corresponding record periods and location information.

3.2.1 Stream Gauging Stations

The data obtained from the stream gauging stations are the key elements used in both constituting the model and its testing. These data obtained from DSI and EIE include monthly average discharges throughout the record period and other information related with the location and the contributing drainage areas. In order to select the stream gauging stations that are to be used in this study a 1:800.000 scale map, which shows all DSİ and EİE stations, as well as meteorological stations, is obtained from DSİ. This 1:800.000 scale map is scanned and georeferenced over 1:500.000 scale topographical map using river branch intersections and shore lines as references and adjusting the scale to the topographical map scale.

Selection of the gauges is made based on some criteria. Long record period is preferred for the selection and monthly average discharges (m^3/s) are found by taking averages on record periods. Another important factor is selecting the stream gauging stations strategically so that they cover and reflect the whole area. On every major branch, it is tried to take a stream gauging station for the model development. Besides, drainage areas are selected in different sizes to have wide range of flow values and the gauges are selected in a way that they are not close to each other. However, between two close gauges one is selected for model building, the other is selected for testing.

24 stream gauging stations are selected in three basins; nine from Gediz River, three from Küçük Menderes River and 12 from Büyük Menderes River. In Figure 3.3, stream gauging stations used for model building are given with their sub-basin boundaries. Test stream gauging stations are shown in Figure 4.1. There are very few gauges on Küçük Menderes River so three of them are used in the model development and two of them are used for testing the model. For testing the model, totally 13 gauges are used, five from Gediz Basin, two from Küçük Menderes Basin and six from Büyük Menderes Basin. Stream gauging stations are digitized manually on the streamlines that are

drawn automatically by the software from the DEM using the river map, which shows stream gauging stations, as a base map. While digitizing the gauges it is important to use all of available knowledge about the location because if the gauges are digitized on different river branches then all computations will be wrong. 1:500.000 scale topographical map and 1:800.000 scale river network map are used at the same time with drainage areas and elevation information of the gauges for digitization. Database is formed including the stream gauging station names, their id numbers and respectively monthly average discharges. Id numbers are taken as stream gauging station numbers but basin number is added before their numbers and for EIE stations “0” is added at the end of the number so that they will be different from DSI numbers and every id number has a unique value. DSI and EIE stream gauging stations are checked whether they intersect with the stream lines using ArcGIS selection tool that allow selection of the stream gauging station locations that intersect with stream lines and digitized on the stream lines.

3.2.2 Precipitation Observation Stations

The data of the precipitation observation stations are obtained from DSI. The data include 1:800.000 scale map that shows precipitation station locations and excel sheets that show monthly total precipitations of stations in their recording periods. Monthly total precipitation values of 46 meteorological stations, which are available in the study area, are used to obtain monthly average total precipitations in the sub-basin areas. 1:800.000 scale map is georeferenced over 1:500.000 scale topographical map by adjusting the scale and taking stream branch intersections and precipitation station towns as reference points. Precipitation stations are digitized over 1:800.000 scale map and for this purpose, the location information is checked on the 1:500.000 topographical map using the information about precipitation station locations. Monthly total precipitation values are inserted to a database under twelve attributes, which represent different months. Thus, precipitation values are distributed over the study area for every month. In Figure 3.3, precipitation gauging stations are shown with sub-basin boundaries of the stream gauging stations.

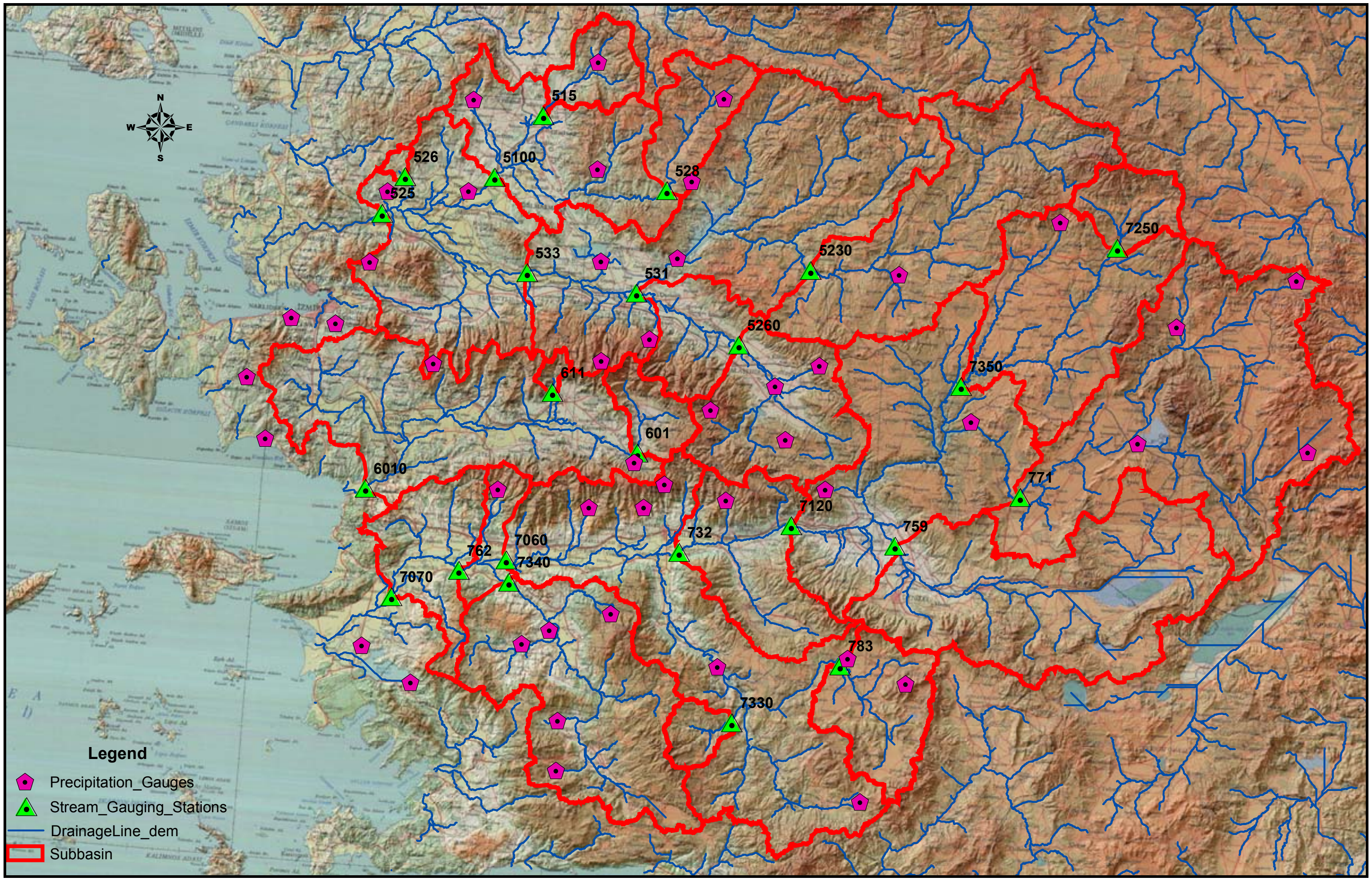

Figure 3.3 Gauging Stations of the study area with the sub-basin boundaries.

There are several methods to distribute the point information to the area. These methods are surface interpolation methods like krigging and thiessen polygons method. Krigging method concerns the statistical distribution and makes smooth transitions and thiessen polygons method use the point value inside the polygon that is produced by taking half distance between points. Surface interpolation methods give more reasonable results but take more computation time. After krigging operation like the other surface interpolation methods the resultant grid values include plenty of distinct values that have decimal parts. This makes very difficult, sometimes impossible to find the average values in the polygon areas. Firstly, elaborating the precipitation over the area and then averaging these values in the sub-basin polygons is not an appropriate way. Since precipitation values do not differ much from one station and region to another, therefore the thiessen polygon method is selected and used. The advantages to use the thiessen polygons method are short computation time and simple results for the generalization into the polygons. Create Thiessen Polygon Methods 3.0 tool which is a small script for ArcGIS downloaded from ESRI web site and used to obtain thiessen polygons from the point precipitation values (Web.10). Once thiessen polygons are created in a shape file as vectors, it is necessary to convert these to raster file with 90 m DEM resolution, which is necessary while having raster operations with DEM.

All precipitation stations of DSI in the study area are used because using more stations for the interpolation increases the accuracy. Due to the oral information obtained from DSI, the climate and consequently the precipitation differ much behind the mountains surrounding the region, therefore the gauges that are outside of the study area are not used. ArcGIS zonal statistics tool, which calculates cell statistics such as mean (average), maximum, minimum, sum, range and standard deviation based on attributes of raster in defined polygon areas, is used to average precipitations over the sub-basin areas. Determination of the sub-basin polygons are explained under the sub-basins part in this chapter. After these processes, sub-basin precipitations with other basin parameters are used in the regression analyses. In Figure 3.4 thiessen polygons for precipitation values can be seen. An example for areal precipitation distribution is given in Figure 3.5 for January.

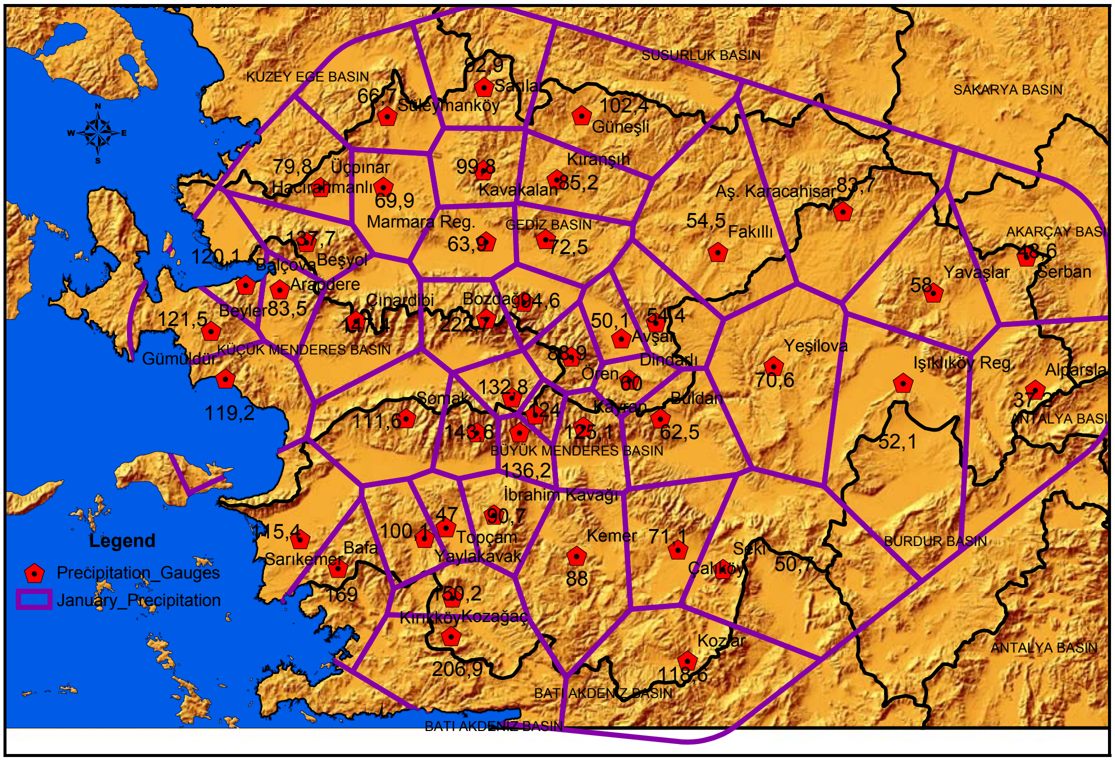

Figure 3.4 Thiessen polygons of the precipitation observation stations in the study area.

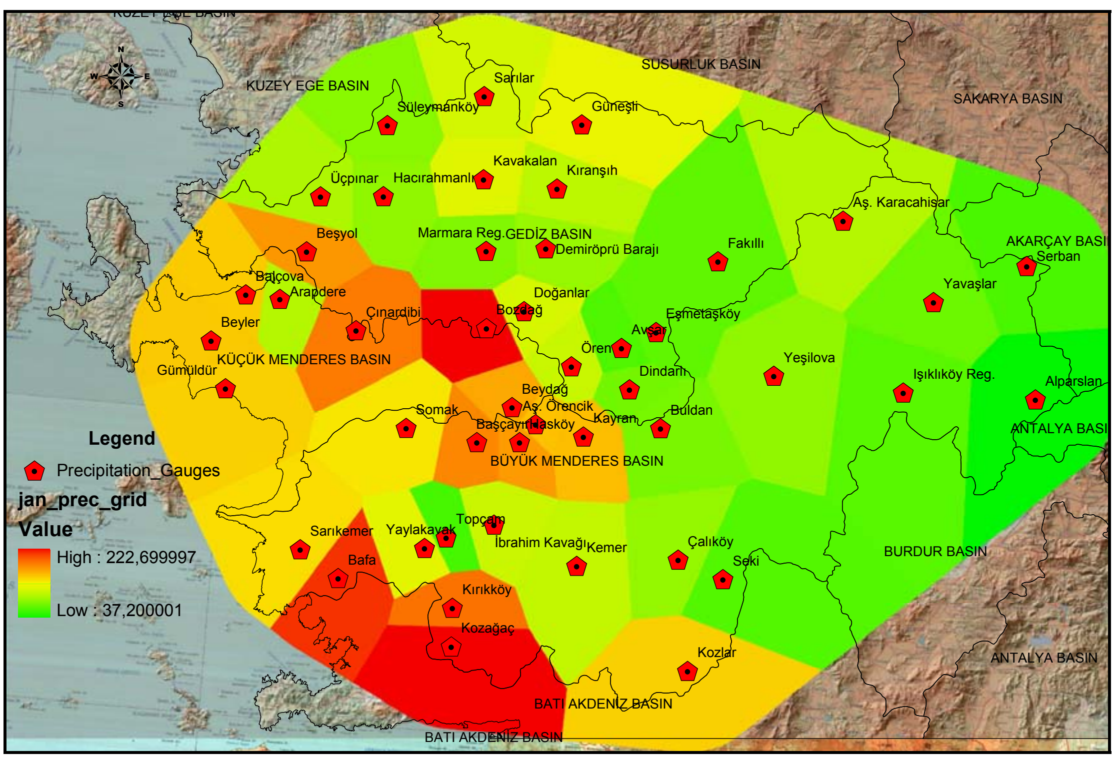

Figure 3.5 Sample of Precipitation distribution with thiessen polygons in January.

3.3 Use of GIS for Determining Basin Characteristics

For visual understanding, contour map of the study area is obtained from DEM (Figure 3.6). As can be seen from the figure, the areas around the streams have very flat terrains. This is the evidence for that some stream branches may change their beds in different seasons and disappear in summers. Mountains surround the large flat areas and their elevations rapidly increase, that results from the sudden floods in the valleys when heavy rainfall occurs.

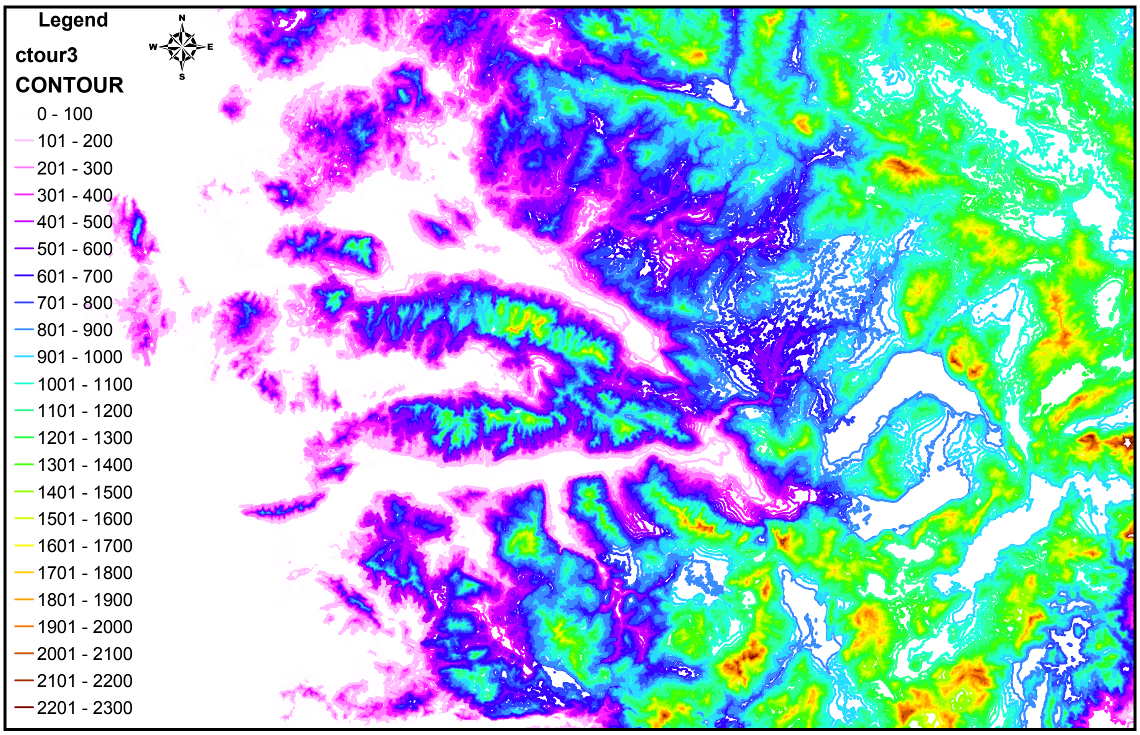

Figure 3.6 Contour Map obtained from the DEM.

Furthermore, slope map of the study area is obtained (Figure 3.7). The slope map shows the slope of each cell in degrees using the DEM elevation differences and cell size of 90 m. 1:500.000 scale topographic map is scanned and Gediz, Küçük Menderes and Büyük Menderes Rivers are digitized manually on this scanned image by visual interpretation. Rivers are also delineated automatically from the DEM by ArcGIS Hydro Data Model (Arc Hydro). Manually and automatically digitized stream lines can be seen in Figure 3.8.

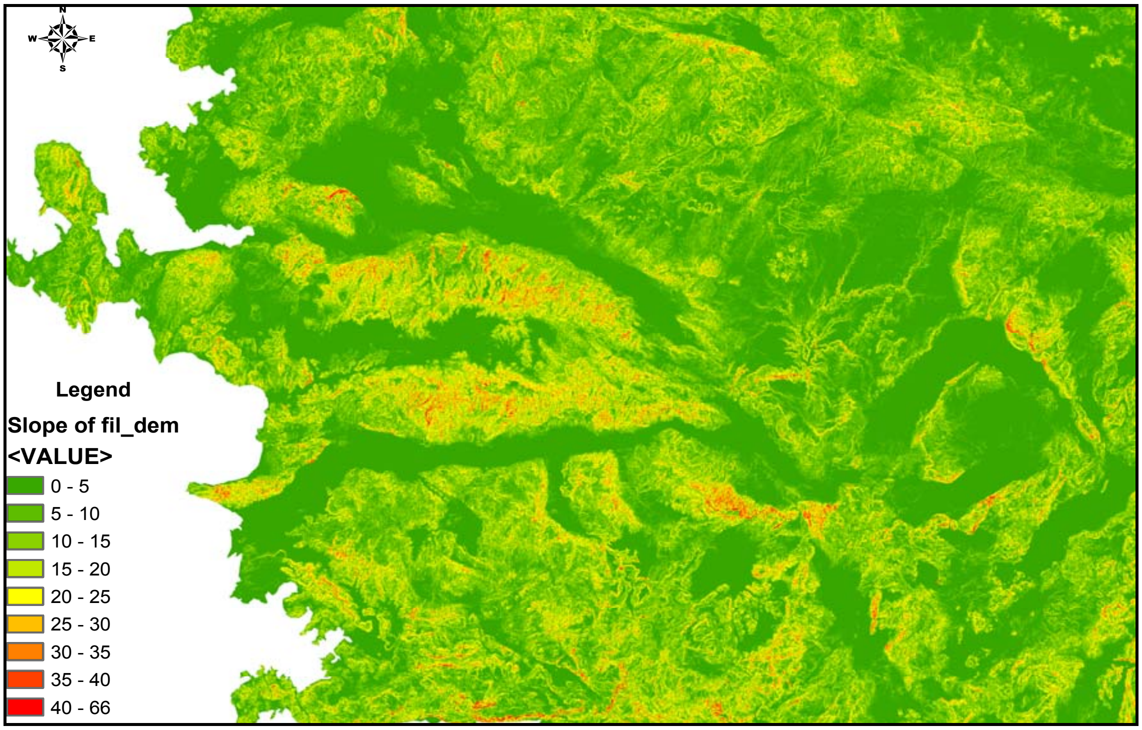

Figure 3.7 Slope map (%) of the study area.

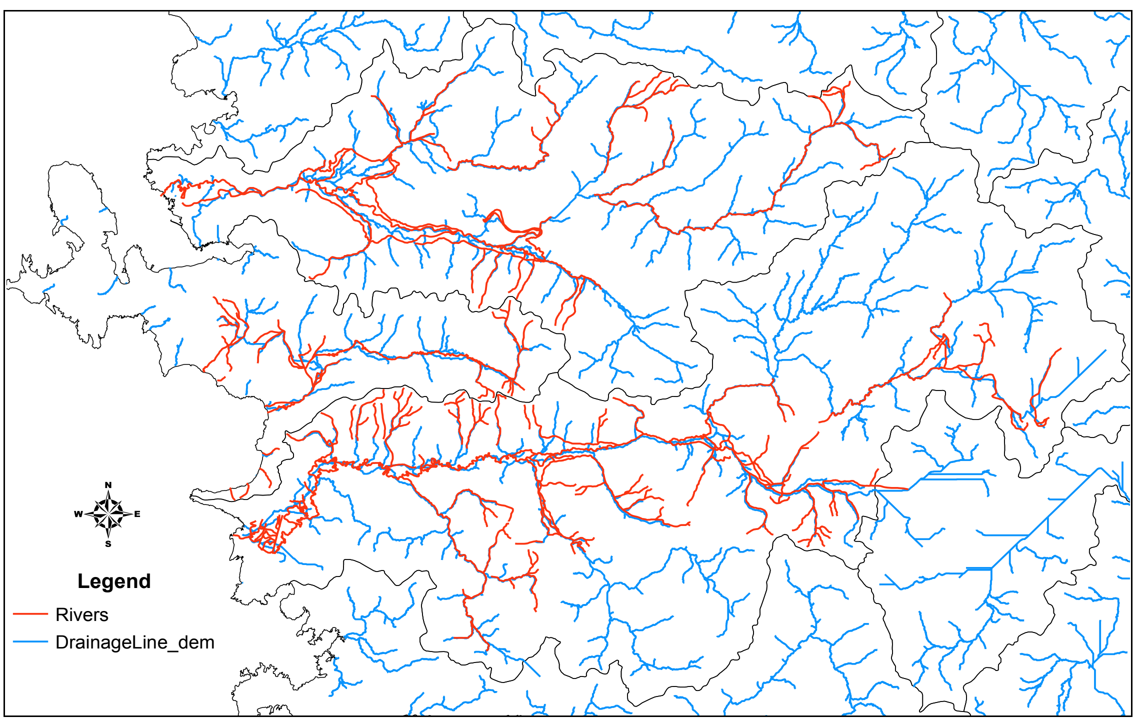

Figure 3.8 Difference between manually digitized (red color) and automatically delineated (blue color) stream network.

Arc Hydro uses an algorithm that follows filling pits, flow direction, flow accumulation, stream definition and catchment determination processes sequentially using DEM to shape the stream lines and corresponding catchments (Web.11).

3.3.1 Flow Direction

Flow direction grid shows the directions of the flow from one cell to another using the DEM. Many approaches were developed to find the flow directions that most likely occur in reality. Arc Hydro uses 8 directional-flow direction (D8) model, introduced by O'Callaghan and Mark (1984). This method uses elevation values from DEM and compares these values within eight neighboring cells. As it is obvious, water flows from higher elevation to lower elevation so the model uses same principle to define the direction of flow by searching the lowest elevation around the center cell. This procedure is (3x3) matrix operation over DEM layer, after applying this operation each cell returns to a value that represents flow directions. In order to apply flow direction algorithm, DEM should not include the cells that all surrounding cell elevations are higher than that center cells. In this case, these cells break the continuity of the flow direction and behave like sinks (pits), hence these cells should be raised up in order not to cut flows. After filling pits operation, which includes searching and raising these cell elevation values, flow direction grid can be obtained without error spots. Flow direction grid of the study area is given in Figure 3.9. The pixel size of each cell in the flow direction grid is the same as DEM pixel size. While dealing with large images with small cell sizes the simplicity of the algorithm reduces the computation time.

There are also other algorithms that permit more than 8 possible directions and/or multiple flow directions from one center cell. Although the multiple flow direction algorithm seems to give reasonable results in the flat areas, a single flow-direction algorithm seems more appropriate in the large areas with the zones of well-defined valleys (Martz and Garbrecht, 1992). Tarboton (1997) introduced a new model as infinite directional flow model ($D\infty$). Similar to D8 model, $D\infty$ model uses 3x3 matrix to determine the flow direction but in this model, steepest descent slope is found using 8 triangular facets. Slope is kept at the center cell as degree between 0 and 2π. This model gives smooth stream lines in the flat terrains but requires more computation time than D8 method. For the small areas in large scales, $D\infty$ method can be used. Girgin (2003) used D8 method to determine the stream network of Turkey and found this method consistent with the actual network. Similarly, in this study D8 model is tested and found applicable after completed automated stream line definition and compared with the real situation via topographical map and river map that is obtained from DSİ.

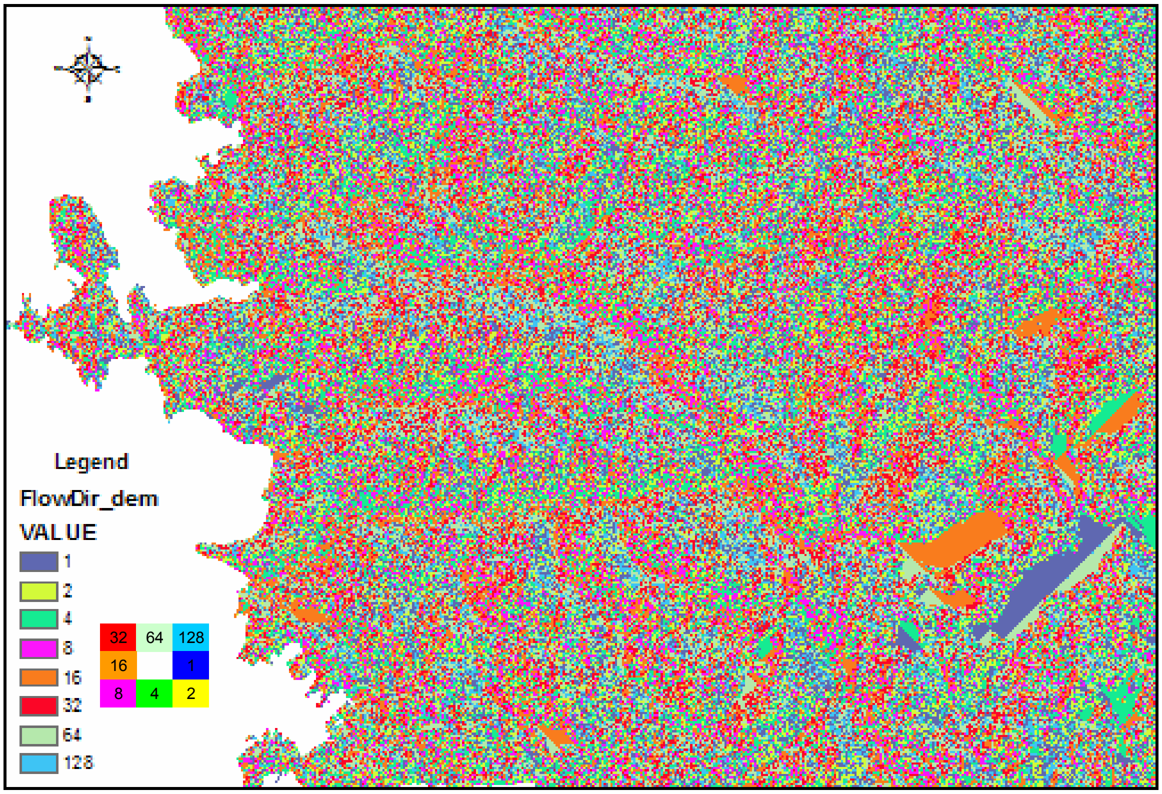

Figure 3.9 Flow Direction Grid of the Study Area.

3.3.2 Flow Accumulation

Starting from the flow direction grid, its implied network are formed and if the number of cells are added throughout the network lines, flow accumulation values are found for each cell. Flow accumulation values reflect important information to define the streamlines since it gives number of accumulated flows from upstream cells.

Minor branches have small flow accumulation values but these values will be added when two branches join and form bigger branches. Similarly maximum flow accumulation values are much higher in large streams than the small streams. Flow accumulation grid that is colored depending on the flow accumulation values can be seen in Figure 3.10.

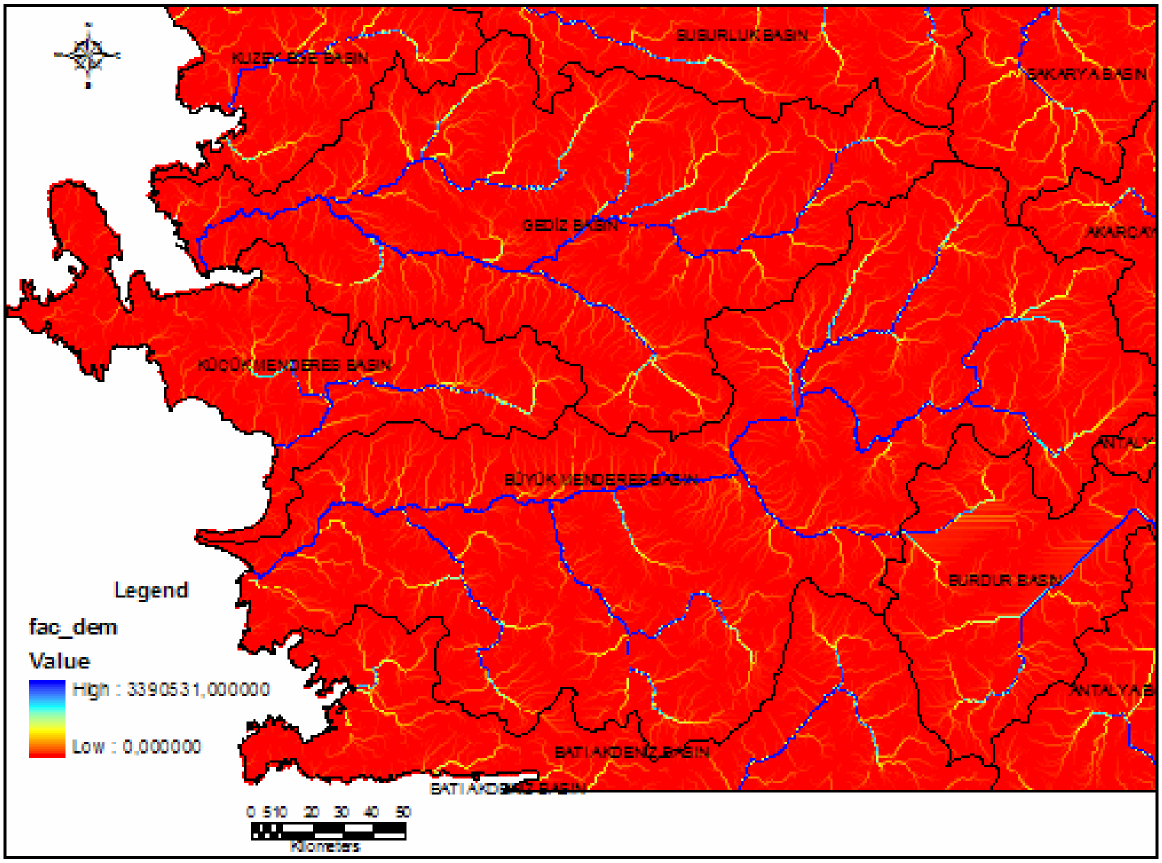

Figure 3.10 Flow Accumulation Grid of the Study Area.

3.3.3 Stream Network Definition

Flow accumulation network shows the drainage lines that can be defined as stream. The streamlines are determined by giving a threshold value to the flow accumulation values. In this study, a threshold value of 5000 is used to define the streams since stream lines fit the actual stream network map obtained from DSI and also with manually digitized stream lines. If a lower threshold value is assigned, then a very detailed stream network, mostly dry beds will be obtained.

3.3.4 Sub-basins

In this study, as mentioned before three river basins are studied, Gediz, Küçük Menderes and Büyük Menderes. These river basins, used in the study, are divided into sub-basins. Sub-basin can be defined as an area that feeds the river branch with its surface waters passing through a specified outlet point on the river. If the ridges around the channel encircles, this line will be the boundary between two sub-basins, which take their waters from different sides of the hills. Sub-basin boundaries can be determined easily using topographical maps or DEMs. Nowadays, GIS softwares such as Arc Hydro can determine sub-basins from DEM with an outlet point on the river that can also be defined using DEM. In the study area, using Arc Hydro software, small catchments covering the region and their outlet points are automatically determined from the streamline and DEM. Using these catchments as reference and with visual interpretations sub-basins of the stream gauging stations are digitized manually. In this operation, stream gauging stations are taken as outlet points and their basins are determined as contributing drainage areas to those gauges.

Sub-basin boundaries are also checked by the batch watershed delineation tool of Arc Hydro and found fit with the manually digitized boundaries. When the outlet point marked on the map the program uses flow direction grid and encircles the area where the direction of flow would be towards that outlet point.

Basin boundaries in the study area that are obtained from DSI are checked with delineated stream lines and digitized sub-basin polygons. DSI's basin boundaries fitted almost everywhere with the automatically determined catchments except the boundary between Büyük Menderes and Burdur Basins. At Büyük Menderes basin boundary, it is observed that Arc Hydro program automatically extends stream lines to Acıgöl Lake that is in the Burdur Basin according to the information obtained from DSI. Girgin (2003) identified the same situation at the Burdur basin boundary and by removing the flat area between the mountains as no data value from the DEM solved this problem. He also determined 26 national basin boundaries of Turkey using raster based analysis method and identified basin boundary discrepancies between the boundaries determined by the DSI and obtained from DEM. Water bodies, behave like sinks and before applying D8 algorithm, if they are removed as no data values, the resultant stream lines and basin boundaries will be more consistent with the actual situation. Since the aim of this thesis is to estimate discharges using GIS techniques; automatically determined streamlines from DEM using Arc Hydro and their corresponding catchments are accepted and used in the study. After digitization, sub-basin polygons are used to extract necessary information from either DEM or other spatial data. Sub-basin areas are the drainage areas of the stream gauging stations and can be easily determined as polygon areas from any GIS software. Sub-basins of the stream gauging stations are shown in Figure 3.3.

3.3.5 Drainage Area

Drainage area is the most important basin parameter that affects the discharge. There is very close relationship between the size of the basin and the discharge. In this respect, many studies (Vogel et. al., 1999, Goodrich et. al., 1997) have been performed for many decades for estimating the discharge with only the drainage area of the basin (Federovski and Mezencev, 1998). For example, the drainage area is used in the design of storm water systems and using rational formula the discharge coming from the basin is estimated from the contributing area. The drainage area of the basin or contributing drainage area to stream gauging station can be found easily using a topographical map and once sub-basins are defined, drainage areas will be the areas of the sub-basins. Drainage area is calculated by GIS software as a polygon area of the sub-basin.

3.3.6 Total River Length

Total river length is an important parameter like drainage area because it is related with the basin area as well as the water potential. Total river lengths are found with selecting river branches and finding their total lengths in corresponding sub-basins. Since, streamlines are obtained automatically from the DEM as polylines, they have the segments divided from the intersections. At the stream gauging stations, the lines are split into two portions so that above this point, a line can be selected. After selecting the lines above gauging stations for each sub-basins sequentially, total river lengths are calculated via taking the sums of selected line lengths from the database.

3.3.7 Main Channel Length

Main channel is defined as the longest stream branch in the sub-basin. After defining the main channels for each sub-basin, their lengths are calculated like in the total river lengths. Stream definition can be made according to flow accumulation criteria with high flow accumulation threshold. One of the advantages of using a GIS program is to define the main channel and its length very easily. Some small river branches can disappear or changes their paths especially in summers like some branches in the study area but the main channel is not expected to change much.

3.3.8 Main Channel Slope

Main channel slope can be calculated in two ways. The slope is calculated from the starting point of the river to the outlet point. By the second method, main channel length is deducted 10% from at each end and the slope is calculated according to remaining part. In this study, main channel slope is calculated from the upstream to the outlet gauge point as follows. Upstream elevation is taken at the water head where the main channel is starting from. Elevation grid cell is selected at the water head so that elevation value is obtained. Similarly, stream gauging station elevations are found from info tool that shows elevation value while selecting the cell in the DEM.

There is also another method to obtain stream gauging station elevations. GIS tools give regional statistics of any raster value in the selected polygon layer. If sub-basin areas of the concerned gauges are taken as polygon layer and DEM is selected as raster, all statistical values of the elevations in the sub-basin polygons are determined. Thus, maximum, minimum and mean elevations as well as sub-basin areas are determined. Minimum value represents the minimum downstream elevations consequently in general, the stream gauging station elevations.

Using water head and stream gauging station elevations, the height difference between them are found and this value is divided by main channel length thus the value obtained from this operation will be the main channel slope of the sub-basin. However, to ease the calculations, the main channel slope parameter is taken as 1000 times the actual main channel slope. While using the main channel length as kilometers and the difference between the upstream elevation and the downstream elevation is taken as meters, same main channel parameter is obtained.

3.3.9 Sub-basin Slope

Sub-basin slope is another important parameter affecting the flow. It is calculated by taking averages of all individual cell slopes in the sub-basin. If the slope of the basin is high then the rainfall becomes runoff quickly and the infiltration will be low, therefore larger surface water amounts will occur. The main channel slope relevant to the flow in and around the channel hence play important role for the large sub-basin areas. In this case, sub-basin slope will determine the amount of surface flow to the stream and will be more important than the main channel slope for the discharge. GIS tools gives automatically the average slope values for sub-basins in degrees and in percentages (Web.12). In this study, sub-basin slope is used as percentage in the regression analyses.

Extracted parameters using GIS techniques from every sub-basins of the stream gauging stations that are used for the model development are presented in Table 3.1 with the discharge data. Similarly, the parameters that are obtained for the gauges in testing the models can be seen in Table 3.2.

Table 3.1 Collected and determined parameters for the sub-basins used for model building.

		MODEL PARAMETERS							PRECIPITATION (Monthly Total) (mm)													DISCHARGE (Monthly Average) (m^3/s)													
MODELS	Gauge ID	UPSTREAM ELEVATION (m)	GAUGE ELEV. (m)	AREA (km^2)	SUB BASIN SLOPE %	TOTAL RIVER LENGTH (km)	MAIN CHANNEL LENGTH (km)	MAIN CHANNEL SLOPE (*1000)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	P (annual avg)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Q (annual avg)	Records (years)
	515	431	107	506	19,4	56	35	9,4	92,8	77,5	66,7	61,1	38,3	12,1	3,6	5,2	17,3	35,4	78,2	112,0	50,0	4,9	4,4	4,5	3,6	1,3	0,3	0,0	0,0	0,1	0,0	0,2	2,8	1,8	31
	525	1.117	19	16.136	15,0	2.009	305	3,6	84,1	74,6	66,0	55,0	40,8	18,6	10,3	6,5	15,0	37,3	73,5	104,3	48,8	69,7	74,2	64,8	48,2	26,5	18,9	22,6	24,7	23,1	22,7	25,3	47,5	39,0	29
	526	281	205	51	14,4	2	2	33,2	79,8	72,5	69,6	45,5	26,8	10,0	4,2	3,1	12,3	36,0	84,4	113,3	46,5	0,7	0,7	0,5	0,3	0,1	0,0	0,0	0,0	0,0	0,0	0,2	0,7	0,3	29
	528	803	375	744	14,6	75	54	8,0	96,4	80,3	69,5	55,9	45,0	20,3	8,3	4,5	14,7	34,5	75,5	116,3	51,8	9,9	7,5	6,4	4,2	2,6	0,6	0,2	0,1	0,1	0,2	0,8	6,2	3,2	18
GEDİZ	531	570	89	2.449	17,9	291	106	4,5	71,7	70,0	63,8	53,0	37,3	16,6	10,4	8,0	12,8	35,4	69,1	95,6	45,3	7,0	8,2	9,1	7,3	2,5	1,3	0,8	0,9	0,8	0,8	2,2	7,9	4,1	15
	533	1.117	51	10.431	15,6	1.269	243	4,4	77,6	70,2	62,8	52,5	40,3	19,3	11,7	7,3	14,6	36,5	68,2	96,5	46,5	19,4	23,5	19,1	14,0	8,2	4,8	12,0	12,5	4,8	9,6	10,4	14,3	12,7	11
	5100	803	53	3.162	14,2	383	129	5,8	88,9	77,6	66,2	60,5	47,4	21,2	9,6	6,6	16,2	38,7	77,3	106,3	51,4	15,9	1,9	13,2	9,5	5,8	2,9	1,2	0,6	1,1	1,6	2,6	8,9	5,4	32
	5230	1.117	382	3.241	14,3	389	128	5,7	67,6	62,9	58,0	52,6	41,2	21,3	15,7	9,3	15,7	36,9	64,7	84,5	44,2	23,4	26,0	20,4	16,5	11,8	5,8	2,4	1,6	1,7	3,7	6,3	14,8	11,2	31
	5260	570	135	1.649	17,9	197	60	7,3	66,0	65,3	60,5	52,6	36,9	16,2	10,8	8,2	12,3	34,9	65,8	89,6	43,3	5,2	4,5	4,3	2,3	0,9	0,7	0,4	0,1	0,3	0,4	0,4	1,9	1,8	19
	601	602	176	438	22,4	43	26	16,5	139,5	127,2	102,9	75,2	51,5	19,4	11,8	7,7	18,0	46,6	111,5	183,6	74,6	2,8	4,1	4,3	4,5	2,7	1,1	0,6	0,5	0,5	0,6	0,9	2,9	2,1	39
KÜÇÜK MEND.	611	225	141	69	29,9	5	5	17,7	222,7	182,4	144,5	104,1	65,6	27,5	10,5	7,1	25,1	61,0	154,5	267,1	106,0	1,1	0,8	1,0	0,7	0,4	0,1	0,1	0,1	0,1	0,0	0,1	0,8	0,4	19
	6010	602	1	3.890	16,8	498	141	4,3	138,2	120,6	99,5	70,6	43,2	15,0	6,7	4,4	18,8	46,9	111,5	173,8	70,8	30,9	35,3	28,7	17,4	9,6	4,3	1,0	0,2	0,7	1,8	4,4	16,6	12,6	37
	732	1.206	59	16.648	13,4	2.008	315	3,6	62,9	58,7	56,3	48,9	40,2	23,2	14,6	11,4	13,6	33,8	57,0	73,1	41,1	67,2	72,3	70,7	55,3	43,4	28,6	20,5	19,9	23,2	30,0	37,8	55,8	43,7	36
	759	892	163	3.768	14,0	462	119	6,1	54,1	54,9	58,0	43,6	38,3	21,9	12,4	9,7	8,8	27,3	48,6	63,3	36,7	14,0	15,1	15,0	10,6	7,1	5,7	1,3	1,0	3,1	7,9	11,1	13,2	8,8	25
	762	1.206	17	25.825	15,3	3.105	396	3,0	79,5	72,2	66,2	49,3	38,0	20,5	12,8	9,8	12,6	34,7	66,1	90,9	46,1	154,2	166,9	149,1	98,0	62,5	45,5	46,0	50,1	42,6	48,0	59,4	105,1	85,6	30
	771	1.206	795	5.026	12,5	588	149	2,8	50,1	46,8	45,1	47,9	44,4	27,0	15,5	14,3	15,7	33,7	50,0	59,1	37,5	5,9	6,9	7,4	10,3	10,5	10,4	20,5	21,3	12,7	7,0	5,7	6,4	10,4	30
	783	1.124	859	1.095	14,1	120	42	6,3	71,9	71,5	70,7	41,6	33,7	17,6	13,3	10,4	7,0	26,6	63,0	88,1	43,0	1,4	1,6	2,0	1,5	1,1	0,7	0,5	0,5	0,5	0,6	0,7	0,9	1,0	17
BÜYÜK MEND.	7060	1.206	23	22.440	14,9	2.700	380	3,1	72,3	65,9	61,1	48,5	38,7	21,3	13,6	10,5	12,6	33,9	62,1	83,2	43,7	115,6	124,7	112,0	80,3	57,9	40,2	35,3	38,2	35,3	41,3	52,0	79,8	67,7	40
	7070	1.206	8	26.899	15,3	3.266	428	2,8	81,0	73,5	67,2	49,8	37,7	20,2	12,4	9,6	12,8	35,1	67,5	92,7	46,6	183,1	192,1	165,8	116,8	77,9	52,7	32,8	30,4	37,2	46,3	64,7	117,8	93,1	32
	7120	1.206	127	15.162	12,7	1.859	275	3,9	59,0	55,8	54,2	48,5	40,6	23,9	15,1	11,9	13,9	33,6	54,6	69,5	40,1	58,1	66,4	64,2	52,7	42,0	31,0	27,5	29,8	28,1	29,5	34,1	45,9	42,4	38
	7250	1.088	896	554	15,8	55	25	7,8	82,5	75,5	67,1	60,9	45,6	23,0	17,1	10,6	17,1	38,9	77,1	105,0	51,7	5,1	6,8	7,3	8,1	4,7	2,0	0,4	0,1	0,1	0,7	1,8	3,5	3,4	19
	7330	709	361	270	21,2	24	16	22,0	88,0	66,9	59,3	31,8	29,0	14,0	7,0	3,9	8,0	32,3	54,4	95,5	40,8	7,2	4,3	5,8	3,1	1,8	1,0	0,7	0,5	0,4	0,7	1,2	3,6	2,5	10
	7340	619	26	3.011	17,8	344	112	5,3	129,6	115,3	100,4	54,2	33,3	15,1	7,8	5,6	12,0	39,3	91,7	144,3	62,4	32,3	3,7	32,6	13,1	5,8	2,4	0,4	0,0	0,1	0,3	5,7	13,3	9,1	7
	7350	1.088	493	2.957	10,9	390	116	5,1	73,3	66,7	61,4	55,3	42,7	24,0	17,8	12,2	17,4	37,7	67,0	90,0	47,1	5,2	5,3	7,0	8,5	6,1	3,9	2,7	2,5	2,7	3,2	4,9	6,3	4,9	4

Table 3.2 Collected and determined parameters for the sub-basins used for testing.

				TEST PARAMETERS					PRECIPITATION (Monthly Total) (mm)												P (annual avg)	DISCHARGE (Monthly Average) (m3/s)												Q (annual avg)	Records (years)
MODELS	Gauge ID	UPSTREAM ELEVATION (m)	GAUGE ELEVATION (m)	AREA (km^2)	SUB BASIN SLOPE %	TOTAL RIVER LENGTH (km)	MAIN CHANNEL LENGTH (km)	MAIN CHANNEL SLOPE (*1000)	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		
GEDİZ	538	1.117	34	763	9,9	80	50	21,8	139,72	115,41	99,98	71,45	43,50	10,99	4,42	1,94	18,57	46,67	116,74	177,23	70,55	4,015	4,818	6,909	5,416	2,256	1,196	0,920	0,895	0,445	1,058	1,742	6,876	3,05	9
	5140	875	383	663	9,9	64	50	9,9	54,70	51,08	48,73	44,02	37,16	20,61	15,31	8,91	15,11	34,93	53,27	65,68	37,46	7,116	7,872	6,202	3,544	2,229	0,859	0,293	0,151	0,227	0,436	1,105	4,775	2,90	29
	5180	1.117	22	15.867	8,8	1.988	169	6,5	83,96	74,63	65,90	55,11	40,96	18,76	10,41	6,60	15,01	37,29	73,21	104,04	48,82	95,770	105,386	91,167	63,679	40,840	24,251	25,145	27,771	27,989	27,973	32,045	60,235	51,85	28
	5220	749	265	756	9,0	78	47	10,3	97,27	80,58	69,67	55,70	45,09	20,24	8,21	4,39	14,61	33,99	75,75	116,98	51,87	9,590	9,576	7,326	4,178	2,193	0,704	0,243	0,147	0,180	0,461	1,687	6,863	3,60	20
	5270	801	108	1.484	7,8	168	105	6,6	95,20	81,71	69,80	63,34	53,69	25,22	11,58	6,49	15,92	41,23	78,89	113,60	54,72	16,573	11,919	10,306	6,091	3,419	1,110	0,298	0,188	0,068	0,458	1,871	13,644	5,50	12
KÜÇÜK MEND.	612	374	250	63	8,4	4	4	28,5	219,19	180,16	142,84	102,89	64,77	26,73	10,23	6,87	24,89	60,64	152,67	263,80	104,64	0,967	0,854	0,870	0,790	0,521	0,279	0,038	0,002	0,002	0,186	0,461	1,079	0,50	16
	613	312	241	56	13,9	3	3	20,7	156,83	140,41	113,36	81,44	50,03	13,07	5,43	2,73	21,25	54,18	120,21	205,17	80,34	1,533	1,068	1,126	0,681	0,420	0,201	0,107	0,093	0,134	0,205	0,537	1,175	0,61	14
BÜYÜK MEND.	703	1.207	835	1.996	14,3	223	77	4,8	52,18	48,55	48,38	50,21	44,19	28,37	18,92	17,40	19,09	35,62	52,16	69,25	40,36	5,216	7,740	8,542	5,629	2,037	0,666	0,016	0,014	0,019	0,073	0,389	2,382	2,73	40
	709	619	30	2.952	14,0	340	109	5,4	130,33	115,73	100,24	54,45	33,66	15,38	7,83	5,68	12,00	39,48	92,13	145,51	62,70	61,647	63,247	45,040	20,711	9,844	5,266	1,315	0,208	0,349	3,639	8,460	37,050	21,40	20
	735	619	152	1.657	12,8	173	63	7,4	163,09	138,13	104,65	59,90	41,59	22,09	8,19	7,60	13,37	48,78	106,16	185,94	74,96	23,594	23,200	18,840	11,347	5,714	3,235	1,685	1,041	1,025	1,692	4,237	14,801	9,20	32
	739	302	120	107	10,2	10	10	19,0	111,60	105,30	90,20	70,90	40,90	17,30	5,20	4,10	20,60	49,80	110,80	135,80	63,54	2,046	1,732	1,590	0,796	0,290	0,092	0,020	0,012	0,019	0,087	0,301	1,416	0,70	30
	7260	1.207	245	10.110	10,7	1.245	215	4,5	60,20	55,32	52,38	50,52	42,71	25,23	16,63	13,07	16,21	36,03	56,38	70,41	41,26	22,214	27,444	26,537	29,925	24,151	19,685	31,289	33,376	21,993	15,584	16,092	19,829	24,01	19
	7310	728	475	182	6,5	17	11	22,8	103,45	87,77	70,40	42,19	32,83	16,91	12,37	8,20	8,96	36,95	71,40	114,64	50,51	6,293	4,732	3,274	1,586	0,882	0,512	0,340	0,259	0,260	0,338	1,297	5,273	2,09	10

CHAPTER 4

MODEL BUILDING WITH REGRESSION ANALYSIS

4.1 General

In this study, an empirical method, regression analysis is used to estimate regional equations for monthly average discharges. In the previous part, brief information and previous studies had been given about the regression analysis. This part begins with the basics of the regression analysis as well as renders detailed information upon the analysis within the scope of this study. Furthermore, the testing and evaluation methods of these analyses and how they are executed are explained in the following parts.

Regression is used for the purpose of obtaining the relation between variables while regression analysis is used in order to represent this relation via mathematical functions. The regression equation is the result of the function defined by the regression analysis. This equation includes the dependent variable (response) and the independent variables (predictors) that define the dependent one. The aim of the analysis is to find out the coefficients of the independent variables that take place within this equation.

The levels of the relations between the dependent variable namely response and independent variables namely predictors are derived from the regression analyses. Relation level is defined as Pearson Correlation Coefficient (r). Equalization of the correlation coefficient to “1” means that dependent variable is completely described with independent variables and if correlation coefficient is “0” then there is no relation between the dependent variable and independent variables. Simple linear regression results from the usage of a dependent and an independent variable in the regression equation for linear relationship. If more than one independent variable is used, multiple linear regression and multiple correlation coefficient (R) have to be taken into account.

In order to see how high the relation between the predictors and the response, the square of the multiple correlation coefficient namely the coefficient of determination (R^2, Eq. 1, 2) is used. Coefficient of determination equals to Explained Sum of Squares (Sum of Squares Regression, SSR) divided by Total Sum of Squares (SST) (Eq. 1). SST is variation of observed values for the average of them and can be formulated as $\sum_{1}^{n} (yi - \bar{y})^2$. SSR is the variation of model values with respect to their average value and can be formulated as $\sum_{1}^{n} (`yi' - `\overline{y}i')^2$ where $`\overline{y}i'$ is the average of the model values. The coefficient of determination (R^2) caan also be found by subtracting the ratio of SSE (Sum of Squares Error or Residual) divided by SST from “1” value (Eq. 2). In this case, SSE is the variation of the model values with respect to the values that are obtained from the model and SSE can be formulated as $\sum_{1}^{n} (`yi' - yi)^2$ (Özdamar, 2002). The equation is determined in a way that the sum of squared errors is minimized.

$$R^2 = \frac{\sum_{1}^{n} (`yi' - `\overline{y}i')^2}{\sum_{1}^{n} (yi - \bar{y})^2} \qquad (1)$$

$$R^2 = 1 - \frac{\sum_{1}^{n} (`yi' - yi)^2}{\sum_{1}^{n} (yi - \bar{y})^2} \qquad (2)$$

In Eq.1 and Eq.2, n is the number of stream gauging stations used for model building. $`yi$ denotes the model result that is obtained by the regression equation. $`\overline{y}i'$ denotes the arithmetic mean of the model values. yi denotes the observed discharge value from the stream gauging station. $\bar{y}$ denotes the arithmetic mean of the observed discharges.

R^2 values change between “0” to “1”, “1” means that regression explain 100% of the response and “0” means that there is not any relation, which is similar to correlation coefficient. If the number of predictors increase then SSR also increases according to the definition, but this is not reasonable for all cases. Therefore, another term Adjusted

Coefficient of determination (R^2(adj), Eq.3) is used and it considers the number of predictors used in the analysis and adjust the ratio accordingly.

$$R^2\,(adj)= 1-(1- R^2)*(n-1)/(n-k-1) \qquad (3)$$

Where n shows number of observations and k shows number of coefficients that are used in the regression and it excludes constant coefficient.

4.2 Regression Analysis Testing Methods

In regression analysis, t-test is used in order to determine the significance of the parameters. In this test, hypothesis H_0 that represents no significant relation between the independent parameter and the dependent parameter is tested. If H_0 is approved the coefficient of the independent parameter is very close to zero then the parameter may not be included in the analysis. If H_0 is rejected then H_1 is accepted that means the independent parameter is significant for the dependent parameter.

t value is found by dividing the coefficient of the parameter to its standard error of the estimate ($t=b/s_b$, $s_b=\sqrt{\mathrm{var}(b)}$) and thereafter this value is compared with the t value in t distribution table using degrees of freedom and significance level (Şıklar, 2000). Significance level (α) is generally taken as “0,05” that shows 95% confidence interval (1-α). Confidence interval represents the distribution range that lies within population of the regression. Degrees of freedom should be selected as (n-2) in which n is the number of samples used in regression. If the t value obtained is bigger than the t value in the table, H_0 is rejected and H_1 is accepted and it can be said that for %95 confidence interval or for “0,05” significance level, the independent parameter shows significant relation for the dependent parameter.

There is another option in t-test for determining the significance of the parameter for the model or response, this is p value test. If p probability value of the t-test is smaller than selected α confidence interval, the parameter is determined as significant. p values of the parameters in the regression analysis can also be compared with each other and this information helps for selecting the parameters that are significant for the response, consequently the statistically significant equations. While adding or taking out the parameters, one parameter can gain importance or lose its importance in the equation so it is important to trace the p values of the parameters.

There is another method, F test to test the significance of the model. F is a function of R^2 and it can be checked with the table value for the significance like in the t-test. P probability value of the F-test is similar to p value of the t-test. If significance level is selected as 5% then the p value of the F-test below this percent implies that the regression model and the regression equation are significant. k shows the degree of freedom of the regression and (n-k-1) shows the degree of freedom of the residuals. F value can be found from Eq. (4).

$$F = [R^2/k]/[(1 - R^2)/(n - k - 1)] \quad (4)$$

4.3 Use of Regression Analysis for the Study

In this study, monthly average discharges obtained from the stream gauging stations are used as dependent variables. Since these discharges depend on some basin parameters such as drainage area, mean basin slope, total river length, main channel length, main channel slope, these parameters are used as predictors in the analyses. First priority is given to the basin parameters that can be determined using GIS techniques from only DEM, in case there exist precipitation data for the basin where the discharge estimations will be made, it is also considered in the analysis. Average precipitations over the sub-basins are also added as predictors to take into account the climatic characteristics of the sub-basins. All these predictors can be defined as independent variables since there are no apparent relations between them.

Before starting the regression analysis, relation in the model should be considered and selected so that model can be built up on this. It is necessary to investigate firstly which kind of relation is there between the dependent and independent parameters. Relationship between the response and predictors can be linear or non-linear like exponential equation.

As it is investigated in this study and it was determined from the previous studies that there is an exponential relation between the discharge and basin parameters especially the drainage area that has been frequently used in the literature. Exponential non-linear equation (Eq.5) has a specialty because it can be converted to a linear form by taking logarithms on both sides. In this case, Logarithmic Regression Equation (Eq.6) turns to Linear Regression Equation (Eq.7) so the coefficients of the predictors are determined using Linear Regression rules, then the coefficients are converted back by taking exponents of these coefficients.

$$Y=b*X^n \tag{5}$$

$$\text{Log } Y= \text{Log } b + n* \text{Log } X \tag{6}$$

$$Y_a = b_a + n*X_a \tag{7}$$

In regression analysis part of the study, Minitab 13.2 software is used, in which it is possible to have different types of relationships and number of variables (Özdamar, 2002).

Starting from the Drainage Areas of the sub-basins, the other important basin parameters are included in the Logarithmic Regression Analyses with different combinations. Four models are developed for each monthy average and annual discharge. The first three models are based on the sub-basins of Gediz, Küçük Menderes and Büyük Menderes Basins. The forth model is the General Model that includes the parameters of the area covering all three basins.

Same software makes their tests also as t-test and F-test. t-test and F-test results and their p probability values represent the significance levels hence, it can be understood that the parameters should be included in the model or not. The test results are considered with R^2 values in order to find strong relationships between the discharges and the basin parameters. The program also shows outputs of the results and their graphs in a suitable way that interpretation and assessments can easily be made. Results are presented and assessed in Chapter 5. Table 4.1 shows an example of one of the outputs from the regression analysis.

Table 4.1 Sample Output of the Regression Analysis Result from Minitab 13.2 software.

Regression Analysis: Log_Qjan versus logA; Log_slope; LOG_MCSlope

```
The regression equation is
Log_Qjan = - 5,58 + 1,24 logA + 1,36 Log_slope + 1,08 LOG_MCSlope
(1)              (2)          (3)          (4)      (5)
Predictor        Coef       SE Coef          T        P
Constant       -5,584        1,413      -3,95    0,001
logA           1,2433       0,2043       6,09    0,000
Log_slop       1,3598       0,7357       1,85    0,079
LOG_MCSl       1,0813       0,5454       1,98    0,061
(6)              (7)              (8)
S = 0,2714      R-Sq = 85,7%     R-Sq(adj) = 83,6%

Analysis of Variance
(9)               (10)        (11)        (12)       (13)      (14)
Source             DF          SS          MS          F         P
Regression          3      8,8283      2,9428     39,96    0,000
Residual Error     20      1,4728      0,0736
Total              23     10,3011
(15)
Unusual Observations
Obs       logA   Log_Qjan         Fit      SE Fit    Residual    St Resid
  3       1,71    -0,1308     -0,2418      0,1982      0,1110        0,60 X

X denotes an observation whose X value gives it large influence.
```

In this example, logarithms of drainage area, slope and main channel slope parameters are used to represent logarithm of January average discharge in General Model. In this output, the resultant regression equation can be seen at the top. Below the equation, all terms included in the analyses and their t-test values and t-test probability values can be seen. In Table 4.1, the terms are numbered from (1) to (15) and explained as follows.

(1) the predictors that are used in the analysis and includes also the constant value.

(2) the coefficients of the predictors that are obtained from the regression analysis.

(3) the standard error of each coefficient.

(4) the t-test value that is obtained via dividing the coefficient of each parameter by its standard error ((2)/(3)).

(5) as the p value, is the probability of the t-test value.

(6) the standard error of estimate of the equation.

(7) R^2 value of the regression equation.

(8) R^2 (adj) value of the equation.

(9) the general terms of the model.

(10) degree of freedom of each term, for regression it equals to the number of the parameters in the equation. The degree of freedom for the total is “23” this value can be found from the (n-1) formula where n shows the units or the data points used in the analysis, as can be understood that n is 24 for the general model. Degree of freedom of the residual error can be found as (n-1-k).

(11) sum of the square values of the regression, error and total respectively as SSR, SSE and SST.

(12) the mean of squares (MS) for regression and error. Mean square of the regression (MSR) can be obtained from dividing SSR by its degree of freedom and similarly mean square of the error (MSE) can be obtained from dividing the SSE by its degree of freedom ((11)/(10)).

(13) the F value of the model that can be calculated by dividing the mean square of the regression (MSR) to the mean square of error (MSE).

(14) the p value that is the probability value of the F value.

(15) the unusual observations and if the unusual observation is because of the high standardized residual that is shown with R letter in the output when it is above “2” value then the observation can be checked for the error.

p value shows t-test probabilities, for example LogA parameters p value is “0” that means that LogA parameter is significant for LogQ response. For the LogSlope parameter p value is “0,079” and this value is smaller than “0,1” significant level so it falls within the 90% confidence interval. The smaller the p value is, the the greater influence the parameter has on the response. Coefficient of determination (R^2 or R-Sq) equals to “85,7” and adjusted coefficient of determination (R-Sq(adj)) equals to “83,6”. In the output table, DF represents degrees of freedom, for each individual parameter DF equals to “1” hence, DF of the regression equals to number of the parameters in the analysis. SS is the sum squares and MS is the mean squares. F test value is calculated using SS Regression (SSR) and SS Residual Error (SSE) and P value shows the probability of the F-test. If the p value of the F-test is close to “0” then the regression equation and the model are significant. In this case, all p values of the t-test is small and P values of the F-test is close to “0” hence, the regression parameters should be included in the analysis and the regression equation is significant. In Appendix B, sample regression analysis outputs of Minitab 13.2 software can be seen.

4.4 Stepwise Regression Analysis

In this study, in order to decide the regression equation, which represents the discharge in a certain confidence level, stepwise regression is applied. The regression equation is determined in a way that the p value of the parameters included in the equation is smaller than the desired confidence level. Stepwise regression analysis is performed in order to find the regression equations that have the significant parameters for the response with the highest coefficient of determination. 0,15 confidence interval (α) was selected to perform stepwise regression analysis and it is also default value in Minitab 13.2. In this case, significant level for each parameter included in the analysis will be higher than 0,85 significance level. Since in the output of the stepwise regression, the maximum p value of the selected parameters needs to fall within desired confidence interval; the equations that have less confidence interval can also be selected by regarding the p values of the parameters. For example, if 0,05 confidence interval i.e. 0,95 significance level is desired, the equation that has the parameters whose maximum p value is less than 0,05 must be selected.

Table 4.2 represents stepwise regression output of the General Model for January. Starting from the most significant parameter, the other parameters are added automatically by the software. In this analysis, drainage area is the most significant parameter that has the 78,62% R^2(adj) value. Best equations obtained from stepwise regression can be seen in blue color in Table 5.9.

As can be seen in Table 4.2, when the precipitation parameter is included in the analysis, significance of the drainage parameter increases since the t value increases. In this case p value of the precipitation parameter is 0,031 that is lower than the 0,15 confidence interval. For this equation, R^2(adj) equals to 82,14%.

When the main channel slope parameter is added to drainage area and the precipitation parameters, R^2(adj) value increases to 85,46%. Significant level for the main channel slope is 0,974 (1 - 0,026(p value)).

Table 4.2 Sample Stepwise Regression Analysis Output from Minitab 13.2.

Stepwise Regression: Log_Qjan versus logA; Log_slope; ...

```
 Alpha-to-Enter: 0,15  Alpha-to-Remove: 0,15

 Response is Log_Qjan on 6 predictors, with N =   24


    Step         1       2       3       4
Constant    -1,507  -3,891  -6,301  -7,432

logA         0,774   0,871   1,300   1,533
T-Value       9,25    9,99    6,68    7,28
P-Value      0,000   0,000   0,000   0,000

Log_Pjan              1,07    1,07    1,32
T-Value               2,31    2,55    3,26
P-Value              0,031   0,019   0,004

LOG_MCSl                      1,22    1,51
T-Value                       2,41    3,10
P-Value                      0,026   0,006

LOG_MCLe                            -0,182
T-Value                              -2,12
P-Value                              0,047

S            0,309   0,283   0,255   0,235
R-Sq         79,55   83,69   87,36   89,78
R-Sq(adj)    78,62   82,14   85,46   87,63
C-p           14,4     9,5     5,3     3,2
```

When the main channel length parameter is added to those, R^2(adj) increases to 87,63%. For this equation, significance level of the drainage area, precipitation and main channel slope parameters are higher than 99%. In Appendix C, sample stepwise regression outputs of Minitab 13.2 software can be seen. In Figure 4.1, stream gauging stations used for model building and testing is given.

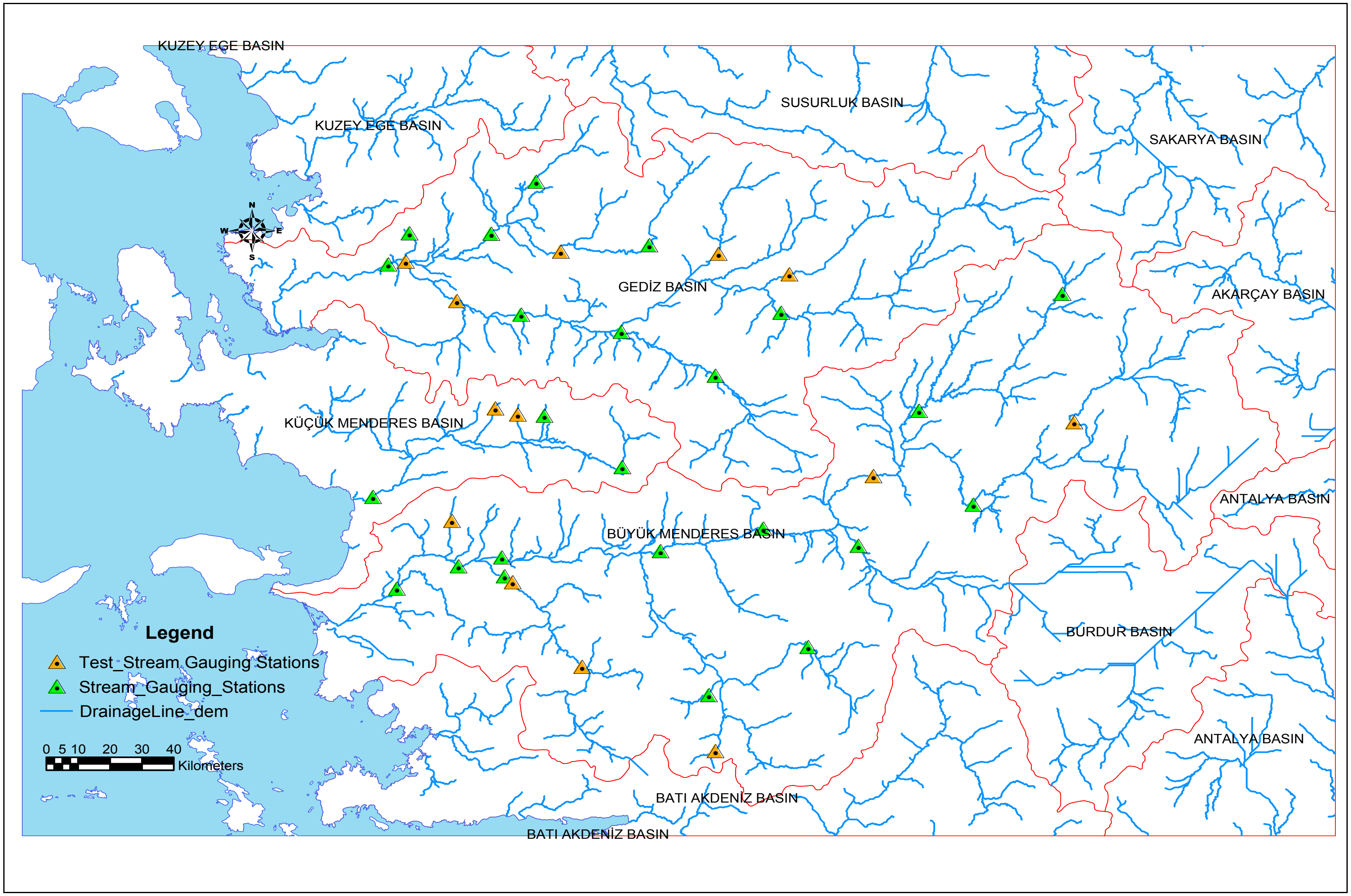

Figure 4.1 Stream Gauging Stations used for model building (green color) and testing (orange color)

CHAPTER 5

EVALUATION OF THE RESULTS

5.1 General

As mentioned before, three models are developed for each study basin. Furthermore, a general model that covers the whole study area is developed using all the parameters of three basins and their observed discharges. Henceforth these four models are named as General Model, Gediz Model, Küçük Menderes Model and Büyük Menderes Model. A total of 24 stream gauging stations and their corresponding sub-basins are used in the general model development. As stated before, nine stations from Gediz Basin, three from Küçük Menderes Basin and 12 from Büyük Menderes Basin are used for the model developments of the concerned basin models. Several sub-basins in each basin that are not included in the model development are used to test the models. 13 sub-basins with their discharges at their outlet gauging stations are used for the testing, five from Gediz Basin, two from Küçük Menderes Basin and six from Büyük Menderes Basin. In Figure 4.1, the locations of the stream gauging stations used for model building and testing can be seen. It should be noted that for Küçük Menderes Model, only three sub-basins and the data of their stream gauging stations are used to develop the model hence this small number is not sufficient to obtain appropriate results. This point is elaborated in the Model Assessments part.

In order to select the model and its equations for the region, adjusted coefficient of determination (R^2(adj)) results are utilized with the stepwise regression analyses and the regression analysis tests are considered. In this chapter, regression analyses results are presented and evaluated. Firstly, the importance of each parameter for the models is discussed with the regression analysis results, and then each model is evaluated. Since the main aim of this study is to represent the discharge using the basin parameters that are obtained by GIS techniques, firstly it is tried to obtain best results while increasing the number of basin parameters in the equation. Afterwards, precipitation parameter is also included in the equations for the improvement of the results. The results are evaluated using R^2 (adj) values of the best parameter combinations. Besides that stepwise regression analysis is performed for highlighting the best equations that have significant parameters. For all the models, obtained R^2 (adj) values of the equations that have one, two and three parameters can be seen respectively in Tables 5.1a-b-c.

5.2 Evaluation of the Individual Parameters in Regression Analyses

5.2.1 Drainage Area

If only the drainage area is used in the General Model, the coefficient of determinations (R^2) are found between 70,9% and 89,0% and the adjusted coefficient of determinations (R^2(adj)) are found between 69,6% and 88,5% respectively for monthly average discharges. The minimum R^2(adj) value is obtained in August and the maximum value is obtained in June.

For the annual average discharge R^2(adj) is 89,1% that is higher than the maximum R^2(adj) obtained for the monthly average discharges. R^2(adj) percentages for the months; January, February, August, September are below 80% but except these months, the values are above this value. This tendency can also be seen if Büyük Menderes Model is taken into consideration. Although the percentages are higher in Gediz Model regarding the drainage area, in February and August the percentages are not so high similarly.

For annual average discharge, Büyük Menderes Model gives R^2 (adj) as 84,4% and Gediz Model gives 91,9%. This difference most probably results from the basin areas. Gediz Basin is smaller than Büyük Menderes Basin and Gediz group drainage areas varies between 51 km^2 to 16.136 km^2 and the average area of them is 4.263 km^2, however Büyük Menderes subbasins drainage areas varies between 270 km^2 to 26.899 km^2 and the average of them 10.305 km^2.

If Küçük Menderes model is taken into account, the drainage area parameter give less than 25% R^2(adj) in consecutive months August, September, October and November.

Table 5.1a R^2(adj) values of the regression analyses with single parameter (%).

GENERAL	A	TR L	MC S	MC L	S	P
JAN	78,6	76,5	56,2	22,1	7,0	1,9
FEB	74,5	72,0	54,1	25,7	8,5	7,9
MAR	84,1	82,5	63,1	29,6	8,6	4,2
APR	86,6	85,5	69,5	36,0	12,7	0,0
MAY	85,6	85,0	70,5	37,7	16,3	0,0
JUN	88,5	87,9	73,3	35,8	18,1	25,3
JUL	83,0	80,9	66,6	32,9	17,5	40,3
AUG	69,6	66,9	52,1	28,6	17,0	38,9
SEP	78,4	76,0	58,9	31,7	19,5	0,0
OCT	84,5	82,2	62,3	31,7	27,8	9,3
NOV	85,5	82,3	63,8	27,2	24,0	20,1
DEC	82,4	79,7	60,1	27,8	12,2	11,7
ANNUAL	89,1	87,0	69,7	31,2	15,4	8,8
GEDİZ	**A**	**TR L**	**MC S**	**MC L**	**S**	**P**
JAN	89,9	89,3	84,5	10,7	30,2	10,9
FEB	75,8	74,5	68,4	15,1	16,1	8,1
MAR	92,3	92,1	85,0	21,1	21,7	12,4
APR	88,9	89,2	80,7	28,7	15,9	0,0
MAY	83,8	84,2	74,6	31,4	13,8	0,0
JUN	89,3	89,1	77,8	30,1	11,3	16,4
JUL	84,2	81,5	66,2	26,4	7,9	48,1
AUG	74,0	70,2	53,9	24,4	6,0	40,2
SEP	83,4	80,4	63,0	26,9	9,4	0,0
OCT	88,4	84,6	66,3	25,8	25,2	2,6
NOV	82,8	78,3	65,3	16,7	29,0	19,6
DEC	87,2	85,2	78,6	16,3	29,5	19,1
ANNUAL	91,9	90,6	81,2	20,9	23,8	8,3
KÜÇÜK MEN.	**A**	**TR L**	**MC S**	**MC L**	**S**	**P**
JAN	59,5	57,1	62,6	0,0	0,0	30,2
FEB	81,0	79,4	68,9	0,0	0,0	55,6
MAR	78,4	76,8	66,1	0,0	0,0	54,3
APR	82,8	82,2	54,6	6,7	0,0	59,1
MAY	72,1	71,5	41,3	5,1	0,0	57,4
JUN	65,2	64,5	36,5	0,0	0,0	6,2
JUL	67,5	66,3	46,8	26,9	0,0	0,0
AUG	0,0	0,0	0,0	14,2	12,6	0,0
SEP	19,2	17,8	21,5	10,2	0,0	66,7
OCT	15,3	14,3	0,0	0,0	7,9	29,1
NOV	20,1	18,5	7,5	0,0	8,8	24,4
DEC	53,3	51,5	41,5	0,0	0,0	42,8
ANNUAL	71,3	69,7	56,0	0,0	0,0	53,9
BÜYÜK MEN.	**A**	**TR L**	**MC S**	**MC L**	**S**	**P**
JAN	66,7	63,8	24,8	62,8	0,0	0,0
FEB	72,5	69,6	32,9	65,1	0,0	0,0
MAR	72,4	69,7	32,3	68,4	0,0	0,0
APR	80,7	78,5	47,0	76,6	0,0	5,7
MAY	85,4	83,4	54,6	81,2	0,0	6,1
JUN	88,2	86,5	58,8	84,2	0,7	18,3
JUL	77,3	75,8	55,9	73,4	6,5	4,1
AUG	59,5	58,5	39,0	55,2	12,2	21,1
SEP	69,9	69,0	44,1	65,8	12,1	0,0
OCT	75,9	74,8	44,3	70,8	7,0	0,0
NOV	89,1	87,8	50,3	86,7	0,0	0,0
DEC	78,0	75,7	35,7	74,8	0,0	0,0
ANNUAL	84,4	82,0	48,0	80,7	0,0	0,0

Table 5.1b R^2(adj) values of the regression analyses with two parameters (%).

GENERAL	A,S	A,TRL	A,MCL	A,MCS	A,P
JAN	81,3	79,3	77,7	81,7	82,1
FEB	75,6	76,2	73,4	76,6	73,6
MAR	86,7	84,1	83,4	85,8	85,7
APR	87,5	86,1	86,7	86,6	86,6
MAY	85,5	84,9	86,1	85,2	86,9
JUN	88,3	87,9	88,5	88,2	91,5
JUL	82,4	83,7	82,6	82,8	87,7
AUG	68,1	71,9	68,7	70,1	72,9
SEP	77,3	79,7	77,9	79,5	77,3
OCT	84,2	85,8	84,0	86,9	84,1
NOV	84,8	89,2	84,8	87,5	84,8
DEC	83,0	84,6	81,6	85,1	83,2
ANNUAL	89,5	90,0	88,6	89,9	89,1
GEDİZ	**A,S**	**A,TRL**	**A,MCL**	**A,MCS**	**A,P**
JAN	89,6	88,9	89,2	89,3	89,8
FEB	73,4	73,8	73,6	73,4	74,0
MAR	91,5	91,6	91,9	91,7	93,0
APR	88,2	88,1	90,0	87,8	90,3
MAY	82,8	82,6	85,8	82,2	88,6
JUN	89,9	88,3	90,8	88,4	93,6
JUL	85,3	85,1	84,6	85,7	92,3
AUG	73,8	78,2	73,8	77,9	78,7
SEP	83,6	85,2	83,9	86,9	82,9
OCT	87,4	92,6	88,7	93,3	88,2
NOV	82,1	90,3	81,3	84,1	81,8
DEC	86,7	87,0	85,9	85,9	86,4
ANNUAL	91,1	91,3	91,4	91,1	92,3
KÜÇÜK MEN.	**A,S**	**A,TRL**	**A,MCL**	**A,MCS**	**A,P**
JAN	70,7	80,5	65,3	47,1	42,8
FEB	90,6	85,4	77,5	71,9	76,1
MAR	88,7	83,3	73,3	67,9	73,4
APR	95,0	76,1	74,3	78,6	79,6
MAY	91,5	60,2	58,2	67,0	67,5
JUN	93,8	51,0	48,2	56,0	56,6
JUL	51,4	59,9	58,7	52,7	63,1
AUG	0,0	0,0	0,0	0,0	0,0
SEP	7,9	2,2	0,0	0,0	50,4
OCT	65,2	0,0	0,0	0,0	0,0
NOV	75,5	13,0	0,0	0,0	0,0
DEC	85,4	54,6	42,0	29,9	37,6
ANNUAL	88,2	73,0	62,0	57,0	66,3
BÜYÜK MEN.	**A,S**	**A,TRL**	**A,MCL**	**A,MCS**	**A,P**
JAN	90,8	80,0	66,5	81,0	77,2
FEB	77,9	83,7	84,0	81,0	69,6
MAR	90,2	82,5	72,7	81,7	74,6
APR	85,6	86,2	81,6	82,7	79,3
MAY	86,4	89,4	86,7	85,7	84,5
JUN	87,7	90,7	89,4	88,1	87,9
JUL	74,9	78,7	77,7	74,9	75,7
AUG	57,3	56,7	60,0	55,7	58,2
SEP	68,0	67,5	70,2	68,1	66,7
OCT	73,4	75,1	79,1	77,0	75,7
NOV	91,2	90,1	88,4	93,7	87,9
DEC	88,1	83,7	77,0	87,9	78,7
ANNUAL	91,0	91,5	85,0	87,8	83,1

Table 5.1c R^2(adj) values of the regression analyses with three parameters (%).

GENERAL	A,S,TRL	A,S,MCL	A,S,MCS	A,TRL,MCL	A,TRL,MCS	A,MCL,MCS
JAN	82,7	81,2	83,6	78,3	81,1	81,7
FEB	77,9	74,4	77,0	75,5	76,6	75,4
MAR	87,2	86,1	87,9	83,6	85,2	85,1
APR	87,2	87,2	87,4	86,4	86,0	86,4
MAY	84,8	85,6	85,0	85,5	84,5	85,5
JUN	87,7	88,1	87,9	88,0	87,6	88,0
JUL	83,3	81,9	82,1	84,0	83,0	82,2
AUG	70,5	67,2	68,7	72,3	71,0	68,8
SEP	78,7	76,8	78,5	80,0	79,6	78,7
OCT	85,4	84,0	87,2	85,9	86,9	86,2
NOV	88,7	84,1	87,1	88,9	89,5	87,1
DEC	85,8	82,2	85,2	84,2	85,6	84,5
ANNUAL	90,8	89,0	90,1	89,8	90,1	89,4
GEDİZ	**A,S,TRL**	**A,S,MCL**	**A,S,MCS**	**A,TRL,MCL**	**A,TRL,MCS**	**A,MCL,MCS**
JAN	88,7	88,6	89,6	88,0	88,4	88,3
FEB	71,3	70,6	70,5	71,4	71,2	70,7
MAR	90,6	91,0	90,7	91,0	90,7	91,5
APR	87,0	88,9	86,9	88,9	86,8	89,8
MAY	81,0	84,3	81,0	84,3	81,0	85,0
JUN	89,1	90,5	89,6	89,9	87,5	89,9
JUL	92,4	84,5	89,9	88,0	84,7	84,7
AUG	88,2	72,2	82,0	82,8	77,8	75,7
SEP	91,8	83,1	90,7	89,0	86,1	85,8
OCT	92,7	88,3	92,7	96,6	94,0	92,6
NOV	89,6	80,8	82,6	91,5	89,2	82,4
DEC	85,8	85,6	85,4	86,0	86,3	84,4
ANNUAL	90,4	90,6	90,1	91,1	90,4	90,4
KÜÇÜK MEN.	**A,S,TRL**	**A,S,MCL**	**A,S,MCS**	**A,TRL,MCL**	**A,TRL,MCS**	**A,MCL,MCS**
JAN	100,0	66,1	82,3	63,8	75,2	38,6
FEB	98,2	83,7	88,2	70,8	89,3	64,4
MAR	96,7	79,3	84,2	66,8	89,9	56,7
APR	90,4	93,9	91,5	54,4	91,4	73,4
MAY	83,2	91,6	87,1	24,4	86,5	59,4
JUN	88,1	92,9	89,8	3,1	73,6	55,4
JUL	19,8	21,0	5,4	96,2	66,8	22,2
AUG	0,0	0,0	0,0	36,0	0,0	25,8
SEP	0,0	0,0	0,0	60,4	0,0	15,6
OCT	37,3	50,0	35,6	0,0	73,8	0,0
NOV	80,9	51,1	55,3	0,0	50,2	0,0
DEC	96,2	73,8	80,2	9,5	62,7	23,7
ANNUAL	93,9	77,0	80,6	46,5	84,9	44,0
BÜYÜK MEN.	**A,S,TRL**	**A,S,MCL**	**A,S,MCS**	**A,TRL,MCL**	**A,TRL,MCS**	**A,MCL,MCS**
JAN	89,7	89,7	92,5	81,0	86,8	79,4
FEB	81,7	84,8	80,4	84,2	86,7	89,1
MAR	89,0	89,0	90,6	82,1	86,2	80,4
APR	85,0	84,5	84,3	84,7	85,7	82,4
MAY	88,4	86,3	85,1	88,1	88,4	86,2
JUN	91,2	88,1	86,8	89,6	89,7	88,6
JUL	87,3	76,1	72,2	76,1	76,2	74,9
AUG	72,6	62,5	56,7	55,3	51,4	55,1
SEP	76,8	71,6	70,2	66,9	64,5	67,2
OCT	79,3	78,8	77,6	76,9	74,6	78,6
NOV	90,1	90,1	93,2	89,3	93,3	92,9
DEC	86,6	86,6	90,6	83,6	89,4	86,6
ANNUAL	91,2	90,1	90,6	91,5	92,1	87,4

Table 5.1c (Contd.) R^2(adj) values of the regression analyses with three parameters (%).

GENERAL	A,S,P	A,TRL,P	A,MCL,P	A,MCS,P
JAN	81,6	83,3	82,3	85,5
FEB	74,8	75,4	72,3	75,8
MAR	86,3	85,7	85,0	87,7
APR	87,0	86,3	86,4	87,4
MAY	86,3	86,6	86,7	87,5
JUN	91,5	91,3	91,4	92,5
JUL	87,9	89,9	87,2	89,0
AUG	71,8	78,0	71,9	77,9
SEP	76,2	78,6	76,8	78,7
OCT	83,5	85,4	83,8	86,4
NOV	84,1	88,8	84,1	86,9
DEC	82,6	85,7	82,4	86,1
ANNUAL	89,0	90,2	88,6	90,2
GEDİZ	**A,S,P**	**A,TRL,P**	**A,MCL,P**	**A,MCS,P**
JAN	93,7	88,8	89,6	88,9
FEB	71,5	72,0	71,2	71,1
MAR	93,7	92,2	92,3	92,3
APR	90,8	89,3	90,5	89,4
MAY	89,8	87,7	88,7	88,1
JUN	92,9	92,9	94,5	93,4
JUL	91,9	94,4	91,7	93,5
AUG	76,3	88,7	76,9	82,9
SEP	81,9	88,0	82,9	89,3
OCT	90,0	94,1	88,0	94,8
NOV	84,8	91,7	79,8	83,8
DEC	89,3	86,8	84,9	84,9
ANNUAL	93,6	92,2	91,5	91,7
KÜÇÜK MEN.	**A,S,P**	**A,TRL,P**	**A,MCL,P**	**A,MCS,P**
JAN	48,7	61,4	75,7	6,9
FEB	89,7	71,8	78,8	54,1
MAR	88,7	68,5	76,3	48,7
APR	99,3	59,5	61,4	65,6
MAY	91,8	39,0	35,1	61,1
JUN	94,1	15,6	13,3	41,9
JUL	27,2	50,1	99,7	63,5
AUG	0,0	0,0	1,2	0,0
SEP	42,0	38,3	25,6	89,6
OCT	95,6	0,0	0,0	0,0
NOV	88,1	0,0	0,0	0,0
DEC	85,2	10,9	28,4	0,0
ANNUAL	93,1	50,1	59,5	32,8
BÜYÜK MEN.	**A,S,P**	**A,TRL,P**	**A,MCL,P**	**A,MCS,P**
JAN	90,1	86,3	79,5	88,4
FEB	80,6	82,4	82,0	79,1
MAR	89,1	86,0	76,6	84,4
APR	88,3	89,3	81,3	88,2
MAY	93,5	92,4	86,3	89,9
JUN	95,5	94,4	89,6	91,1
JUL	73,6	80,9	75,8	74,1
AUG	52,9	60,5	58,9	63,8
SEP	65,1	63,5	66,5	64,2
OCT	72,7	75,1	77,7	76,0
NOV	90,5	88,9	87,0	93,0
DEC	86,6	83,5	78,1	88,8
ANNUAL	90,0	90,8	84,1	87,3

In Küçük menderes Model, good results are obtained for February, March and April; these are higher than 75%. It should be noted that for August, there is not any relation found between the drainage area and the discharge because R^2(adj) equals to “0”. For this model, R^2 values are generally lower than the other models regarding the drainage areas. It can be concluded that it is difficult to estimate the discharge in August with only the drainage area for all the models.

5.2.2 Total River Length

As determined form the regression analyses results, total river length parameter is an important parameter like the drainage area for the discharge. If just the total river length parameter is used in the regression analyses, following results are obtained. In general model, R^2 (adj) values are between 66,9% and 87,9% for monthly discharges. The lowest values are obtained in August for all the models and these values are 70,2% for the Gediz Model, 0% for the Küçük Menderes Model and 58,5% for the Büyük Menderes Model. R^2 (adj) values for the annual average discharges for the General, Gediz, Küçük Menderes and Büyük Menderes respectively as 87%, 90,6%, 69,7% and 82%. In Gediz Model R^2 (adj) values are generally higher than the other models.

5.2.3 Main Channel Slope

If only the main channel slope parameter is used in the regression analyses, R^2 (adj) values for the annual average discharges for General Model, Gediz Model, Küçük Menderes Model and Büyük Menderes Model are respectively 69,7%, 81,2%, 56% and 48%. Generally the lowest R^2 (adj) values are obtained in August with main channel slope. For all the models, it gives higher R^2 (adj) values than the mean basin slope parameter for the equation with one parameter. Similarly, the mean basin slope parameter gives higher R^2 (adj) values than the main channel length parameter except the Büyük Menderes Model.

5.2.4 Main Channel Length

If only the main channel length parameter is used in the regression analyses, R^2 (adj) values change between 22,10% and 37,7% in General Model, 10,7% and 31,4% in

Gediz Model, 0% and 26,9% in Küçük Menderes Model, 62,8% and 86,7% in Büyük Menderes Model. In every model, the lowest R^2 (adj) values are obtained for January.

5.2.5 Mean Basin Slope

Mean basin slope as a single parameter does not give successful results to represent monthly discharges. In the General Model, basin slope gives R^2 values between 7% and 27,8%. For annual average discharges, R^2 (adj) values are 15,4% for General Model, 23,8% for Gediz Model, 0% for Küçük Menderes and 0% for Büyük Menderes Models. In September, October and November R^2 values are higher than the other months. In January, February and March R^2 values are lower than 10%. In Gediz Model, obtained R^2(adj) values for October, November, December and January are higher than 25 % and R^2 (adj) values are generally higher than the other model values for the mean basin slope similarly for the main channel slope parameter. In Küçük Menderes and Büyük Menderes Models, it is determined that the mean basin slope is not very important parameter that affects the discharge. However, maximum R^2(adj) values are obtained for August in both models as 12,6% and 12,2% respectively.

5.2.6 Precipitation

As explained before, total monthly precipitation values are distributed and averaged over the sub-basin polygons and these values are used in the regression analyses. When only the precipitation is used in the analysis, as it is obvious that good approximations can not be achieved but when it is used with the other parameters, it is expected to improve the results. Precipitation parameter is additionally considered in the analysis with the basin parameters.

If just the precipitation parameter is used in the General Model, it gives highest R^2 (adj) values in summer months; in June as 25,3%, in July as 40,3% and in August as 38,9%. In April and May it gives the lowest R^2 (adj) values as 0%. This tendency can also be seen in Gediz and Büyük Menderes Models. However, in Küçük Menderes Model the highest R^2 (adj) value is obtained in September as 66,7% and the lowest values in July and August as 0%. Although, precipitation parameter alone does not give high R^2

values; together with the drainage area parameter, it definitely increases the R^2 values so does the accuracy of the discharge estimations.

5.3 Model Assessments

5.3.1 General Model

In General Model whole study area that includes Gediz, Küçük Menderes and Büyük Menderes Basins is used to derive regional equations. Drainage area is determined as the most important basin parameter that affects the discharge since it gives highest R^2 value amongst the other basin parameters for almost every month.

Total river length is determined as the second important basin parameter similarly regarding the R^2 values. R^2 values for annual average discharge also reflects the same situation for all the models.

Main channel slope is another important parameter for this model since its R^2 (adj) value is 69,7% for the annual average discharge. Besides, R^2 (adj) values for the annual average discharge are 31,2% for the main channel length and 15,4% for the mean basin slope.

All combinations using two, three and four parameters with the drainage area parameter were applied. R^2 (adj) values obtained from the General Model can be seen in Tables 5.1a-b-c. In Table 5.2 the best basin parameter combinations of the equations without the precipitation parameter can be seen with their R^2 and R^2 (adj) values. The test results of the General Model are given with the R^2 (adj) values in Table 5.3 for obtained best equations.

As seen in Table 5.3, for annual average discharge the drainage area parameter alone gives 89,1% R^2 (adj) value. Total river length with the drainage area gives 90%. When the mean basin slope, total river length and the drainage area parameters are used together, 90,8% R^2 (adj) value in Table 5.2, is obtained.

Table 5.2 Best results (R^2 and R^2 (adj) %) of basin parameters without the precipitation in the General Model.

GENERAL MODEL		A	A,S	A,TRL	A,MCL	A,MCS	A,S, TRL	A,S, MCL	A,S, MCS	A,TRL, MCL	A,TRL, MCS
JAN	R^2	79,6				83,3			85,7		
	R^2 (adj)	78,6				81,7			83,6		
FEB	R^2	75,6				78,6	80,8				
	R^2 (adj)	74,5				76,6	77,9				
MAR	R^2	84,8	87,9						89,5		
	R^2 (adj)	84,1	86,7						87,9		
APR	R^2	87,1	88,6						89		
	R^2 (adj)	86,6	87,5						87,4		
MAY	R^2	86,2			87,3			87,5			
	R^2 (adj)	85,6			86,1			85,6			
JUN	R^2	89			89,5			89,7			
	R^2 (adj)	88,5			88,5			88,1			
JUL	R^2	83,7		85,1						86,1	
	R^2 (adj)	83		83,7						84	
AUG	R^2	70,9		74,3						75,9	
	R^2 (adj)	69,6		71,9						72,3	
SEP	R^2	79,3		81,4						82,6	
	R^2 (adj)	78,4		79,7						80	
OCT	R^2	85,2				88			88,8		
	R^2 (adj)	84,5				86,9			87,2		
NOV	R^2	86,1		90,2							90,9
	R^2 (adj)	85,5		89,2							89,5
DEC	R^2	83,2				86,4	87,6				
	R^2 (adj)	82,4				85,1	85,8				
ANN	R^2	89,6		90,9			92				
	R^2 (adj)	89,1		90			90,8				

Table 5.3 Best results (R^2(adj) %) of the General Model with testing (Nash-Sutcliffe efficiency %).

GENERAL MODEL		A	A,TRL	A,P	A,S	A,TRL, P	A,TRL, S	A,TRL, MCL	A,TRL, MCS	A,S, MCS	A,MCS, P	A,TRL, P,S
JAN	R^2 (Adj)	78,6		82,1							85,5	
	TEST	53,0		74,6							30,0	
FEB	R^2 (Adj)	74,5	76,2				77,9					
	TEST	47,4	53,9				18,1					
MAR	R^2 (Adj)	84,1		85,7						87,9		
	TEST	70,2		80,7						67,3		
APR	R^2 (Adj)	86,6			87,5							
	TEST	86,5			59,6							
MAY	R^2 (Adj)	85,6		86,9							87,5	
	TEST	90,8		92,8							82,7	
JUN	R^2 (Adj)	88,5		91,5							92,5	
	TEST	91,5		89,8							86,8	
JUL	R^2 (Adj)	83,0		87,7								90,7
	TEST	54,0		79,7								38,3
AUG	R^2 (Adj)	69,6		72,9		78,0						
	TEST	34,5		39,6		72,6						
SEP	R^2 (Adj)	78,4	79,7					80,0				
	TEST	54,5	64,8					62,9				
OCT	R^2 (Adj)	84,5	85,8							87,2		
	TEST	86,5	90,2							<0		
NOV	R^2 (Adj)	85,5	89,2						89,5			
	TEST	90,0	95,1						84,6			
DEC	R^2 (Adj)	82,4	84,6								86,1	
	TEST	61,3	65,7								30,7	
ANN	R^2 (Adj)	89,1	90,0				90,8					
	TEST	79,7	83,8				58,3					

When the total river length parameter is used with the drainage area parameter, they give the highest R^2 (adj) values for the two basin parameters equation in five months. These months are February, July, August, September and November. If precipitation parameter is used with the drainage area parameter, they give the highest R^2 (adj) values in six months; January, March, April, May, June and July. In the Table 5.9a, the best equations obtained for the General Model either regarding the highest R^2 (adj) values and obtained from the stepwise regression analyses can be seen.

5.3.2 Gediz Model

In Gediz Model, discharge data from nine stream gauging stations and their corresponding sub-basin characteristics are used to develop the model. In this model as expected, drainage area is found to be the most important basin parameter like in the General Model. Total river length and the main channel slope are the next two significant parameters for this model. In this model, mean basin slope parameter is more significant than in case of Küçük Menderes, Büyük Menderes and General Models.

In Table 5.4 the best basin parameter combinations of the equations without the precipitation parameter can be seen with their R^2 and R^2 (adj) values. In Table 5.5 for obtained best equations, the test results of the Gediz Model is given with the R^2 (adj) values of the equations.

As seen in Table 5.4, for annual average discharge, using the drainage area parameter alone in the analysis gives 91,9% R^2 (adj). Adding a second basin parameter does not increase R^2 (adj). When the precipitation parameter is used with the drainage area parameter, R^2 (adj) becomes 92,3% (Table 5.5) and when the mean basin slope parameter is added to them as the third parameter, R^2 (adj) becomes 93,6% (Table 5.5) that is the highest percentage for the annual average discharge. As can be seen in Table 5.1a, using the drainage area alone in the analysis, gives higher R^2 (adj) values in this model than the other models.

Table 5.4 Best results (R^2 and R^2 (adj) %) of basin parameters without the precipitation in the Gediz Model.

GEDİZ MODEL		A	A,TRL	A,MCL	A,MCS	A,S, TRL	A,S, MCS	A,TRL, MCL	A,MCL, MCS
JAN	R^2	90,7					92,2		
	R^2 (adj)	89,9					89,6		
FEB	R^2	77,8	78,2					78,5	
	R^2 (adj)	75,8	73,8					71,4	
MAR	R^2	92,9		93,2					93,7
	R^2 (adj)	92,3		91,9					91,5
APR	R^2	90,1		91,6					92,3
	R^2 (adj)	89,2		90					89,8
MAY	R^2	85,5		88,2					88,7
	R^2 (adj)	84,2		85,8					85
JUN	R^2	90,2		92,3				92,9	
	R^2 (adj)	89,3		90,8				90,5	
JUL	R^2	85,5			88,1	94,3			
	R^2 (adj)	84,2			85,7	92,4			
AUG	R^2	76,2	81,8			91,2			
	R^2 (adj)	74	78,2			88,2			
SEP	R^2	84,8			89,1	93,8			
	R^2 (adj)	83,4			86,9	91,8			
OCT	R^2	89,4			94,4			97,4	
	R^2 (adj)	88,4			93,3			96,6	
NOV	R^2	84,3	91,9					93,6	
	R^2 (adj)	82,8	90,3					91,5	
DEC	R^2	88,3	89,2						
	R^2 (adj)	87,2	87						
ANN	R^2	92,5		92,8				93,3	
	R^2 (adj)	91,9		91,4				91,1	

Table 5.5 Best results (R^2(adj) %) of the Gediz Model with testing (Nash-Sutcliffe efficiency %).

GEDİZ MODEL		A	TRL	A,TRL	A,P	A,TRL, P	A,TRL, S	A,TRL, MCL	A,S,P	A,MCL, P	P,S, TRL, MCL	A,TRL, P,S
JAN	R^2 (Adj)	89,9			89,8							
	TEST	65,4			70,1							
FEB	R^2 (Adj)	75,8										
	TEST	60,1										
MAR	R^2 (Adj)	92,3			93,0							
	TEST	71,1			74,5							
APR	R^2 (Adj)		89,2		90,3				90,8		91,0	
	TEST		69,0		78,9				59,4		12,8	
MAY	R^2 (Adj)		84,2		88,6				89,8		89,9	
	TEST		68,3		74,2				21,1		<0	
JUN	R^2 (Adj)	89,3			93,6					94,5		
	TEST	79,4			95,8					67,7		
JUL	R^2 (Adj)	84,2			92,3	94,4						97,5
	TEST	57,4			42,6	62,7						15,7
AUG	R^2 (Adj)	74,0			78,7	88,7						92,0
	TEST	32,1			11,9	40,5						<0
SEP	R^2 (Adj)	83,4		85,2			91,8					
	TEST	37,5		54,5			<0					
OCT	R^2 (Adj)	88,4		92,6				96,6				
	TEST	64,7		90,1				85,4				
NOV	R^2 (Adj)	82,8		90,3		91,7						
	TEST	62,8		95,0		99,2						
DEC	R^2 (Adj)	87,2							89,3			
	TEST	65,0							1,3			
ANN	R^2 (Adj)	91,9			92,3				93,6			
	TEST	67,4			72,4				76,3			

5.3.3 Küçük Menderes Model

As indicated before, three stream gauging stations and their corresponding sub-basin parameters are used to develop the Küçük Menderes model. Since the number of stations is very small, the results are not dependable for this basin when only its stations are used.

The drainage area, the total river length and the main channel slope parameters are the significant basin parameters for this model. Precipitation is the forth important parameter for this model. Since the mean basin slope and the main channel length parameters give an R^2 (adj) of almost zero for the annual discharge, these are not significant parameters. R^2 (adj) values obtained from the Küçük Menderes Model for the equations including different number of parameters can be seen in Tables 5.1a-b-c.

For the annual average discharge, the drainage area parameter alone gives 71,3% R^2 (adj) and the total river length parameter gives 69,7%. When the mean basin slope and the main channel length parameters are used alone in the analysis, they give 0% R^2 (adj) (Table 5.1a). When the drainage area and the mean basin slope parameters are used together, R^2 (adj) becomes 88,2% (Table 5.1b). When the drainage area, the mean basin slope and the total river length parameters are used together, R^2 (adj) becomes 93,9% (Table 5.1c).

In this model there are so many zero R^2 (adj) values for the individual parameters and for their combinations. Although, there are R^2 (adj) values more than 90%, this is most probably because of the small number of observations that are used to develop the model. In the light of the above mentioned analysis results, Küçük Menderes Model is not a complete model.

5.3.4 Büyük Menderes Model

As noted before, 12 stream gauging stations and their corresponding sub-basin parameters are used to develop the Büyük Menderes Model. For this model, the drainage area, the total river length and the main channel length parameters are found to be significant since their R^2 (adj) values for one parameter equations are higher almost for every month. However, the mean basin slope and unexpectedly the precipitation are not significant parameters for this model. The precipitation value used does not seem as the representative of the basin. The precipitation might change much in the basin because of the large area and alignment of the basin that take places between the Southwest and the Middle Anatolia. In the area, there exist precipitation stations that belong to DMI (State Meteorological Institute). However, in this study only the stations of DSI are used, because they are free of charge. R^2 (adj) values obtained from the Büyük Menderes Model for the equations including different number of parameters can be seen in Tables 5.1a-b-c.

For the annual average discharge, when the drainage area parameter is used alone in the analysis, R^2 (adj) equals to 84,4% (Table 5.1a). When the total river length is used with the drainage area, R^2 (adj) becomes 91,5% and when the main channel slope is added to them as the third basin parameter, R^2 (adj) becomes 92,1%. In Table 5.6 the best basin parameter combinations of the equations without the precipitation parameter are given with their R^2 and R^2 (adj) values. In Table 5.7 for obtained best equations, the test results of the Büyük Menderes Model is given with the R^2 (adj) values of the equations.

Table 5.6 Best results (R^2 and R^2 (adj) %) of basin parameters without the precipitation in the Büyük Menderes Model.

BÜYÜK MENDERES		A	A,S	A,TRL	A,MCL	A,MCS	A,S, TRL	A,S, MCS	A,TRL, MCS	A,MCL, MCS
JAN	R^2	69,7						94,6		
	R^2 (adj)	66,7						92,5		
FEB	R^2	75			86,9					92,1
	R^2 (adj)	72,5			84					89,1
MAR	R^2	74,9	92					93,2		
	R^2 (adj)	72,4	90,2					90,6		
APR	R^2	82,5		88,7					89,6	
	R^2 (adj)	80,7		86,2					85,7	
MAY	R^2	86,7		91,3					91,6	
	R^2 (adj)	85,4		89,4					88,4	
JUN	R^2	89,3		92,4			93,6			
	R^2 (adj)	88,2		90,7			91,2			
JUL	R^2	79,4		82,5			90,7			
	R^2 (adj)	77,3		78,7			87,3			
AUG	R^2	63,1			67,3		80			
	R^2 (adj)	59,5			60		72,6			
SEP	R^2	72,6					83,1			
	R^2 (adj)	69,9					76,8			
OCT	R^2	78,1			82,9					
	R^2 (adj)	75,9			79,1					
NOV	R^2	90,1				94,8			95,1	
	R^2 (adj)	89,1				93,7			93,3	
DEC	R^2	80	90,2					93,1		
	R^2 (adj)	78	88,1					90,6		
ANN	R^2	85,9		93					94,2	
	R^2 (adj)	84,4		91,5					92,1	

Table 5.7 Best results (R^2(adj) %) of the Büyük Menderes Model with testing (Nash-Sutcliffe efficiency %).

BÜYÜK MENDERES		A	A,TRL	A,S	A,MCL	A,MCS	A,TRL, P	A,TRL, S	A,TRL, MCS	A,S,P	A,S, MCS	A,MCL ,MCS	A,TRL,P ,S	P,S, TRL, MCS
JAN	R^2 (Adj)	66,7		90,8							92,5			
	TEST	<0		<0							<0			
FEB	R^2 (Adj)	72,5			84,0							89,1		
	TEST	<0			<0							<0		
MAR	R^2 (Adj)	72,4		90,2							90,6			
	TEST	9,6		0,3							9,0			
APR	R^2 (Adj)	80,7	86,2				89,3							89,8
	TEST	83,3	82,3				83,6							93,7
MAY	R^2 (Adj)	85,4	89,4							93,5				96,9
	TEST	95,7	92,7							43,7				71,6
JUN	R^2 (Adj)	88,2	90,7							95,5				97,3
	TEST	93,6	90,6							11,4				30,1
JUL	R^2 (Adj)	77,3	78,7					87,3					87,9	
	TEST	46,0	41,5					<0					<0	
AUG	R^2 (Adj)	59,5			60,0			72,6					76,6	
	TEST	33,7			41,6			<0					<0	
SEP	R^2 (Adj)	69,9			70,2			76,8					77,0	
	TEST	64,4			68,5			<0					<0	
OCT	R^2 (Adj)	75,9			79,1			79,3						
	TEST	94,0			96,8			<0						
NOV	R^2 (Adj)	89,1				93,7								
	TEST	78,3				39,7								
DEC	R^2 (Adj)	78,0		88,1							90,6			
	TEST	<0		<0							<0			
ANN	R^2 (Adj)	84,4	91,5						92,1					
	TEST	63,0	58,8						60,0					

5.4 Testing of the Models

As mentioned before, in order to test the models 13 stream gauging stations and their corresponding sub-basin parameters are selected. Five of them are from Gediz, two of them from Küçük Menderes and six of them are from Büyük Menderes Basin. In Figure 4.1, the stream gauging stations used for testing are shown. Testing is made based on the Nash-Sutcliffe efficiency (Eq.8).

$$\text{Nash-Sutcliffe efficiency} = 1 - \frac{\sum_{1}^{n} (y'i' - yi)^2}{\sum_{1}^{n} (yi - \bar{y})^2} \qquad (8)$$

In Eq.8, n is the number of stream gauging stations used for testing. $y'i$ denotes the model result that is obtained using the test sub-basin parameters in the model equation. yi denotes the observed discharge from the test stream gauging station. $\bar{y}$ denotes the arithmetic mean of the observed discharges of the test stream gauging stations.

In this formula, if the difference between the discharge values obtained from the model and observed ones from the stream gauging stations decrease, the nominator value will also decrease in the fraction and the efficiency will come close to “1”. The denominator is calculated same as in the R^2 formula in Eq.2. For Nash-Sutcliffe efficiency, “1” value represents the best fit and “0” value represents the worst fit between the model and observed values.

This efficiency is determined in similar way to the R^2, so that the test and the model results can be compared. For the calculation of R^2, the model results and the observed values are compared, but in Nash-Sutcliffe efficiency, the model discharges that are obtained using the test sub-basin parameters and the observed discharges from corresponding stream gauging stations are compared.

R^2 (adj) values and their corresponding test values of the best combinations for the General, Gediz and Büyük Menderes Models are evaluated and the related tables are presented in this part. Model testing results are found for the equations that have the different number of parameters giving the highest R^2 (adj) values.

Testing results of the best combinations of parameters including the precipitation parameter are given with the Nash-Sutcliffe efficiency percentages for the General Model in Table 5.3. In the following paragraphs the values of this table are used.

In General Model, if the equation that includes only the drainage area parameter is used for the testing, the lowest Nash-Sutcliffe efficiency is obtained for August as 34,5% similarly its corresponding 69,6% R^2 (adj) value is also the lowest value for this month. The maximum test value is obtained for June as 91,5% and its corresponding R^2 (adj) value is 88,5%.

If the drainage area and the total river length parameters are used for testing, amongst the selected results of the General Model. The lowest test value and its corresponding R^2 (adj) value are obtained in February. The highest test value and its corresponding R^2 (adj) value are obtained for November respectively as 95,1% and 89,2%.

If the drainage area and the precipitation parameters are used for testing the General Model, the lowest test value and its related R^2 (adj) value are obtained in August. The test values are 89,0% for April, 92,8% for May, 89,8% for June, 79,7% for July and their corresponding R^2 (adj) values are respectively 86,6%, 86,9%, 91,5%, 87,7%.

When the drainage area, the total river length and the precipitation parameters are used together, the lowest test value is obtained for February as 57,2%. In February R^2 (adj) value is 72% that is also the lowest value obtained for this combination in this month. Highest test values are obtained in October as 94,8% and November as 95,3%. In this case, R^2 (adj) values of the model are 94,1% for October and 91,7% for November.

It should be noted that, when the drainage area, the total river length and the mean basin slope parameters are used together in February, the test value obtained is 18,1%. On contrary to smaller R^2 (adj) value, the test value obtained while using the drainage area, the total river length and the precipitation parameters gives the better test result as 57,2%.

For the annual average discharge, when only the drainage area parameter is used in the analysis, the test result is 79,7%. When the total river length is used with the drainage area parameter, test result is 83,8% and when the precipitation parameter is added to them, the test result becomes 77,0%. Testing results of the General Model are found quite consistent with R^2 (adj) values of the model.

For Gediz Model, the testing results (Nash-Sutcliffe efficiency %) of the best equations that include all parameters are presented in Table 5.5.

If the drainage area parameter is concerned, the minimum test result is obtained in August as 32,1% and its corresponding R^2 (adj) value is 74,0%. The highest test value is obtained in June as 79,4% and R^2 (adj) value is 89,3% for this month (Table 5.5).

In this model some of the testing results are below zero; the reason for that is the big difference between the test discharge and the discharge obtained from the model. As can be understood from the Nash-Sutcliffe efficiency formula, even if the one discharge obtained from the model equation is unexpectedly high, this results from the negative test result. In most of the cases, one spike discharge obtained from the model equation causes the negative test result. The test result values of the Gediz Model are generally lower than the test results obtained for the General Model.

Testing is not applied for the Küçük Menderes Model. There are some difficulties to obtain appropriate testing results for this model. For Küçük Menderes Model 2 discharge data from stream gauging stations are selected for the testing. Since the available number of stream gauging stations is 5 in Küçük Menderes Basin and 3 of them is used for the model development, it is necessity to select 2 stream gauging station that have the similar characteristics for testing. Because, the discharges of the selected stream gauging stations are very low; it is very difficult to obtain high Nash-Sutcliffe efficiency percentages. Since 2 data points are selected for testing, the discharges from the test stream gauging stations are compared with the model results directly without need to regard the testing.

For Büyük Menderes Model, the precipitation parameter is also considered for the highest R^2 (adj) values of the equations with the testing results and these are given in Table 5.7. In the following paragraphs this table values are used.

In Büyük Menderes Model, when the equation that includes only the drainage area parameter is concerned, the test results are very high for certain months such as May, June and October respectively as 95,7%, 93,6% and 94,0%. However, for certain months such as December, January and February, the testing results are below zero. This means that there are no relation found between the model and the observed discharges of the stream gauging stations used for testing (Table 5.7).

When the equation that includes the drainage area and the total river length parameters are taken into account, in April, May and June, the test results are respectively, 82,3%, 92,7% and 90,6%.

When the equation including the drainage area, the total river length and the mean basin slope parameters are concerned, testing results are far lower than zero. Same situation is seen when the precipitation parameter is added to the other parameters in the equation. Therefore, the equation that include these parameter combinations cannot be selected as applicable equations for ungauged locations.

For annual average discharge, when the drainage area parameter is concerned, test result is 63,0%, when the total river length is considered with the drainage area parameter test value is 58,8% and when the main channel slope is added to them, test value becomes 60,0%.

In addition to the above mentioned tests, the discharges from the test stream gauging stations of Gediz and Büyük Menderes Basins are compared with the General Model results using Nash-Sutcliffe efficiency in Table 5.8. As can be seen in the table, for different months and parameter combinations, different models may give the highest test results. For the selection of the best equation, either highest R^2 (adj) value or stepwise regression results must be considered.

Table 5.8 Testing results of the models due to best basin parameter combinations of the General Model.

	MODELS	A	A,S	A,TRL	A,MCL	A,MCS	A,S, TRL	A,S, MCL	A,S, MCS	A,TRL, MCL	A,TRL, MCS
	GENERAL	53				45			54		
JAN	GEDİZ	71				67			76		
	BÜYÜK M.	<0				<0			<0		
	GENERAL	47				70	17				
FEB	GEDİZ	66				96	16				
	BÜYÜK M.	<0				<0	<0				
	GENERAL	70	33						67		
MAR	GEDİZ	80	28						76		
	BÜYÜK M.	15	14						13		
	GENERAL	87	60						74		
APR	GEDİZ	86	52						71		
	BÜYÜK M.	83	70						71		
	GENERAL	91			87			76			
MAY	GEDİZ	90			85			72			
	BÜYÜK M.	91			90			82			
	GENERAL	92			90			82			
JUN	GEDİZ	97			95			86			
	BÜYÜK M.	82			81			74			
	GENERAL	54		56						55	
JUL	GEDİZ	79		83						79	
	BÜYÜK M.	35		36						36	
	GENERAL	35		42						39	
AUG	GEDİZ	53		66						59	
	BÜYÜK M.	18		22						22	
	GENERAL	55		65						63	
SEP	GEDİZ	59		72						68	
	BÜYÜK M.	42		49						50	
	GENERAL	87				<0			<0		
OCT	GEDİZ	86				<0			<0		
	BÜYÜK M.	86				98			88		
	GENERAL	90		95							85
NOV	GEDİZ	90		97							83
	BÜYÜK M.	86		85							84
	GENERAL	61				48	35				
DEC	GEDİZ	77				63	38				
	BÜYÜK M.	7				<0	0				
	GENERAL	80		84			58				
ANN	GEDİZ	83		88			56				
	BÜYÜK M.	61		60			47				

For December, January and February none of the models gives good testing results using the test sub-basins of Büyük Menderes Basin. In March and November, General Model gives better test results than the Büyük Menderes Model itself. In May, June and October, Büyük Menderes Model gives better results than the General Model. The best equations that have the highest R^2 (adj) values are presented with the stepwise regression analysis results in blue color in Tables 5.9 a-b-c.

Table 5.9a Best Equations of the General Model due to R^2(adj) and Stepwise Regression Results (Blue color).

GENERAL MODEL	A	A,TRL	A,P	A,S	A,MCS	A,TRL,S	A,TRL,MCL
JAN	$Q=0,031A^{0,774}$		$Q=0,00013A^{0,871}P^{1,07}$				
FEB	$Q=0,022A^{0,798}$	$Q=0,00008A^{2,87}TRL^{-1,87}$	$Q=0,00457A^{0,823}P^{0,323}$		$Q=1*10^{-4}A^{1,21}MCS^{1,16}$	$Q=4*10^{-7}A^{3,16}S^{1,46}TRL^{2,05}$	
MAR	$Q=0,028A^{0,788}$		$Q=0,00025A^{0,852}P^{1,00}$				
APR	$Q=0,019A^{0,800}$		$Q=0,00166A^{0,819}P^{0,576}$	$Q=6*10^{-4}A^{0,868}S^{1,03}$			
MAY	$Q=0,005A^{0,894}$		$Q=5*10^{-6}A^{0,897}P^{1,28}$				
JUN	$Q=0,001A^{1,03}$		$Q=0,00002A^{0,946}P^{1,56}$				
JUL	$Q=0,00015A^{1,19}$		$Q=0,00002A^{1,02}P^{1,48}$				
AUG	$Q=0,00004A^{1,29}$		$Q=0,00001A^{1,08}P^{1,73}$				
SEP	$Q=0,0001A^{1,21}$	$Q=1*10^{-7}A^{3,98}TRL^{-2,5}$					$Q=2*10^{-9}A^{67608,3}TRL^{0,0004}MCL^{1,8}$
OCT	$Q=0,00015A^{1,21}$	$Q=2*10^{-7}A^{3,67}TRL^{-2,23}$			$Q=1*10^{-7}A^{7,78}MCS^{1,62}$		
NOV	$Q=0,0017A^{0,986}$	$Q=5*10^{-7}A^{3,96}TRL^{-2,69}$					
DEC	$Q=0,02138A^{0,777}$	$Q=0,00010A^{2,74}TRL^{-1,77}$					
ANNUAL	$Q=0,00912A^{0,850}$	$Q=0,00018A^{2,98}TRL^{-1,29}$				$Q=6*10^{-6}A^{2,47}S^{0,934}TRL^{-1,41}$	

GENERAL MODEL	A,TRL,MCS	A,S,MCS	A,TRL,P	A,MCS,P	A,TRL,P,S	A,P,MCS,MCL	A,P,TRL,MCS
JAN				$Q=5*10^{-7}A^{1,30}MCS^{1,27}P^{1,02}$		$Q=3,7*10^{-8}A^{1,533}P^{1,32}MCS^{1,51}MCL^{-0,182}$	
FEB							
MAR		$Q=9*10^{-6}A^{1,16}S^{1,33}MCS^{0,803}$					
APR							
MAY				$Q=3*10^{-7}A^{1,18}MCS^{0,802}P^{1,66}$			
JUN				$Q=1*10^{-7}A^{1,26}MCS^{0,94}P^{1,88}$			
JUL					$Q=3*10^{-11}A^{4,19}TRL^{-2,82}S^{1,36}P^{1,77}$		$Q=3,45*10^{-15}A^{5,6}P^{2,65}TRL^{-3,5}MCS^{2,1}$
AUG			$Q=3*10^{-13}A^{6,65}TRL^{-5,04}P^{2,73}$				
SEP							
OCT		$Q=2*10^{-10}A^{138}S^{2,6}MCS^{407,4}$					
NOV	$Q=1*10^{-7}A^{4786,3}TRL^{0,007}MCS^{5,3}$						
DEC				$Q=4*10^{-6}A^{1,24}MCS^{1,12}P^{0,653}$			
ANNUAL							

Table 5.9b Best Equations of the Gediz Model due to R^2 (adj) and Stepwise Regression Results (Blue color).

GEDİZ MODEL	A	TRL	A,TRL	A,P	A,TRL,S	A,TRL,MCL	A,TRL,P
JAN	$Q=0,04365A^{0,730}$			$Q=0,00525A^{0,772}P^{0,401}$			
FEB	$Q=0,03890A^{0,730}$						
MAR	$Q=0,03548A^{0,752}$			$Q=0,00107A^{0,811}P^{0,711}$			
APR	$Q=0,02291A^{0,764}$	$Q=0,21038TRL^{0,671}$		$Q=0,00018A^{0,817}P^{1,10}$			
MAY	$Q=0,00575A^{0,861}$	$Q=0,06918TRL^{0,756}$		$Q=0,000003A^{0,874}P^{1,96}$			
JUN	$Q=0,00093A^{1,000}$			$Q=0,00002A^{0,932}P^{1,61}$			
JUL	$Q=0,0016A^{1,15}$			$Q=0,00002A^{0,937}P^{1,77}$			$Q=1*10^{-8}A^{3,40}TRL^{-2,16}P^{1,78}$
AUG	$Q=0,0008A^{1,19}$			$Q=0,00001A^{0,980}P^{2,10}$			$Q=3*10^{-13}A^{6,65}TRL^{-5,04}P^{2,73}$
SEP	$Q=0,0018A^{1,11}$		$Q=1*10^{-7}A^{3,87}TRL^{-2,43}$		$Q=1*10^{-15}A^{6,47}S^{3,46}TRL^{-4,51}$		
OCT	$Q=0,0013A^{1,19}$		$Q=5*10^{-9}A^{4,76}TRL^{-3,14}$			$Q=2*10^{-10}A^{5,71}TRL^{-4,10}MCL^{0,242}$	
NOV	$Q=0,00224A^{0,914}$		$Q=5*10^{-7}A^{4,61}TRL^{-3,24}$				$Q=4*10^{-11}A^{5,11}TRL^{-3,59}P^{1,21}$
DEC	$Q=0,03715A^{0,704}$						
ANNUAL	$Q=0,01288A^{0,792}$			$Q=0,00068A^{0,841}P^{0,654}$			

GEDİZ MODEL	A,S,P	A,MCL,P	TRL,S,P	A,MCS,S,TRL	A,TRL,P,S	A,P,TRL,MCL	A,P,TRL,S,MCL
JAN			$Q=0,93111TRL^{0,618}S^{-2,39}P^{1,31}$				
FEB							
MAR			$Q=0,03162TRL^{0,678}S^{-1,64}P^{1,59}$				
APR	$Q=0,00015A^{0,768}S^{-1,56}P^{2,31}$						
MAY	$Q=0,00002A^{0,759}S^{-1,81}P^{3,14}$		$Q=4*10^{-4}TRL^{0,648}S^{-2,065}P^{3,07}$				
JUN		$Q=0,00002A^{0,870}MCL^{0,115}P^{1,45}$					
JUL					$Q=4*10^{-14}A^{5,34}TRL^{-3,67}P^{1,36}S^{2,52}$		$Q=2,1*10^{-14}A^{5,67}P^{1,2}TRL^{-4,01}S^{2,4}MCL^{0,106}$
AUG					$Q=1*10^{-19}A^{8,71}TRL^{-6,58}P^{1,87}S^{3,20}$		$Q=6,03*10^{-20}A^{9,16}P^{1,65}TRL^{-7,1}S^{2,9}MCL^{0,2}$
SEP				$Q=8,57*10^{-18}A^{5,65}MCS^{1,84}S^{3,5}TRL^{-3,2}$			
OCT						$Q=2,88*10^{-13}A^{5,98}P^{1,5}TRL^{-4,27}MCL^{0,217}$	
NOV							
DEC	$Q=0,02692A^{0,711}S^{-1,91}P^{1,19}$						
ANNUAL	$Q=0,00191A^{0,802}S^{-1,60}P^{1,60}$						

Table 5.9c Best Equations of the Büyük Menderes Model due to R^2 (adj) and Stepwise Regression Results (Blue color).

BÜYÜK M. MODEL	A	A,TRL	A,S	A,MCL	A,MCS	A,TRL,S	A,TRL,MCS
JAN	$Q=0,01445*A^{0,863}$		$Q=1*10^{-8}*A^{1,08}*S^{4,84}$				
FEB	$Q=0,00661*A^{0,941}$			$Q=2*10^{-5}*A^{4,63}MCL^{-5,18}$			
MAR	$Q=0,02089*A^{0,829}$		$Q=1*10^{-7}*A^{1,01}*S^{3,89}$				
APR	$Q=0,01660*A^{0,827}$	$Q=2*10^{-7}*A^{6,32}*TRL^{-5,22}$					
MAY	$Q=0,00741*A^{0,876}$	$Q=4*10^{-7}*A^{5,76}*TRL^{-4,64}$					
JUN	$Q=0,00263*A^{0,949}$	$Q=6*10^{-7}*A^{5,25}*TRL^{-4,08}$					
JUL	$Q=0,00032*A^{1,13}$	$Q=4*10^{-10}*A^{6,59}*TRL^{-5,18}$				$Q=6*10^{-15}A^{18,3}S^{-6,05}TRL^{16,6}$	
AUG	$Q=0,00002*A^{1,39}$			$Q=8*10^{-8}*A^{4,87}*MCL^{-4,89}$		$Q=1*10^{-19}A^{28,5}S^{-11,4}TRL^{-26,2}$	
SEP	$Q=0,00006*A^{1,31}$			$Q=8*10^{-7}*A^{3,93}*MCL^{-3,69}$		$Q=6*10^{-15}A^{20,0}S^{-7,93}TRL^{-18,1}$	
OCT	$Q=0,00047*A^{1,11}$			$Q=6*10^{-6}*A^{3,81}*MCL^{-3,79}$		$Q=6*10^{-12}A^{14,2}S^{-4,80}TRL^{-12,6}$	
NOV	$Q=0,00245*A^{0,980}$				$Q=0,000009A^{1,41}MCS^{1,28}$		
DEC	$Q=0,00724*A^{0,907}$		$Q=4*10^{-7}*A^{1,05}*S^{3,20}$				
ANNUAL	$Q=0,00646*A^{0,905}$	$Q=1*10^{-9}*A^{7,23}*TRL^{-6,01}$					$Q=1*10^{-9}A^{6,37}TRL^{-4,98}MCS^{0,666}$

BÜYÜK M. MODEL	A,MCL,MCS	A,S,MCS	A,TRL,P	A,S,P	A,TRL,P,S	A,P,MCS,S	A,P,TRL,MCS
JAN		$Q=1*10^{-9}A^{1,38}S^{3,88}MCS^{1,02}$					
FEB	$Q=1*10^{-7}A^{4,48}MCL^{-4,29}MCS^{1,46}$						
MAR		$Q=5*10^{-8}A^{1,21}S^{3,23}MCS^{0,702}$					
APR			$Q=4*10^{-13}A^{7,96}TRL^{-6,83}P^{1,86}$				$Q=3,7*10^{-17}A^{7,26}P^{3,35}TRL^{-5,7}MCS^{1,55}$
MAY				$Q=1*10^{-13}A^{0,925}S^{3,64}P^{4,26}$		$Q=5,83*10^{-18}A^{1,29}P^{5,68}MCS^{1,28}S^{3,18}$	
JUN				$Q=3*10^{-13}A^{0,920}S^{4,23}P^{3,91}$		$Q=5,02*10^{-15}A^{1,19}P^{4,41}MCS^{0,95}S^{3,77}$	
JUL					$Q=3*10^{-12}A^{23,4}TRL^{-21,5}P^{-2,12}S^{-10,8}$		
AUG					$Q=1*10^{-13}A^{42,6}TRL^{-39,6}P^{-5,34}S^{-25,3}$		
SEP					$Q=1*10^{-13}A^{21,9}TRL^{-19,9}P^{-1,44}S^{-9,53}$		
OCT							
NOV							
DEC		$Q=7*10^{-8}A^{1,40}S^{2,08}MCS^{1,18}$					
ANNUAL							

5.5 Automated Discharge Estimation

In this study, as explained before when only the drainage area parameter is used in the regression analyses the coefficient of determination values are generally between 80 % and 90 %. These results are quite good although one parameter is used in regression equation. Therefore, in order to estimate the discharge at certain cross sections on the rivers in the study area, a visual basic program that automatically computes the discharge using the drainage area parameter in the regression equation was written.

The program uses flow accumulation grid to find the drainage area. As described before, flow accumulation grid represents the number of upstream cells whose waters would accumulate and pass the selected outlet point. If the number of upstream cells (flow accumulation values) is multiplied by the actual cell area, which is 8100 m^2, the drainage area of the selected outlet cell is obtained.

The program was written in visual basic language that uses arc objects to get the cell value of the flow accumulation grid when the mouse button is clicked at a point on the river in the map. Then the algorithm is followed finding the drainage area and using it in the regression equations that are obtained in General, Gediz and Büyük Menderes Models to find the monthly and annual average discharges. In Figure 5.1, flow accumulation grid, which is used for the application of the program, is given.

As can be seen in Figure 5.2, one of the three models can be selected in the check boxes and monthly or annual average discharge can be selected in the listbox. When these are selected, the corresponding discharge equation can be seen and when the cell on the map is clicked with the mouse button, the drainage area is acquired and the discharge is calculated using corresponding regression equation.

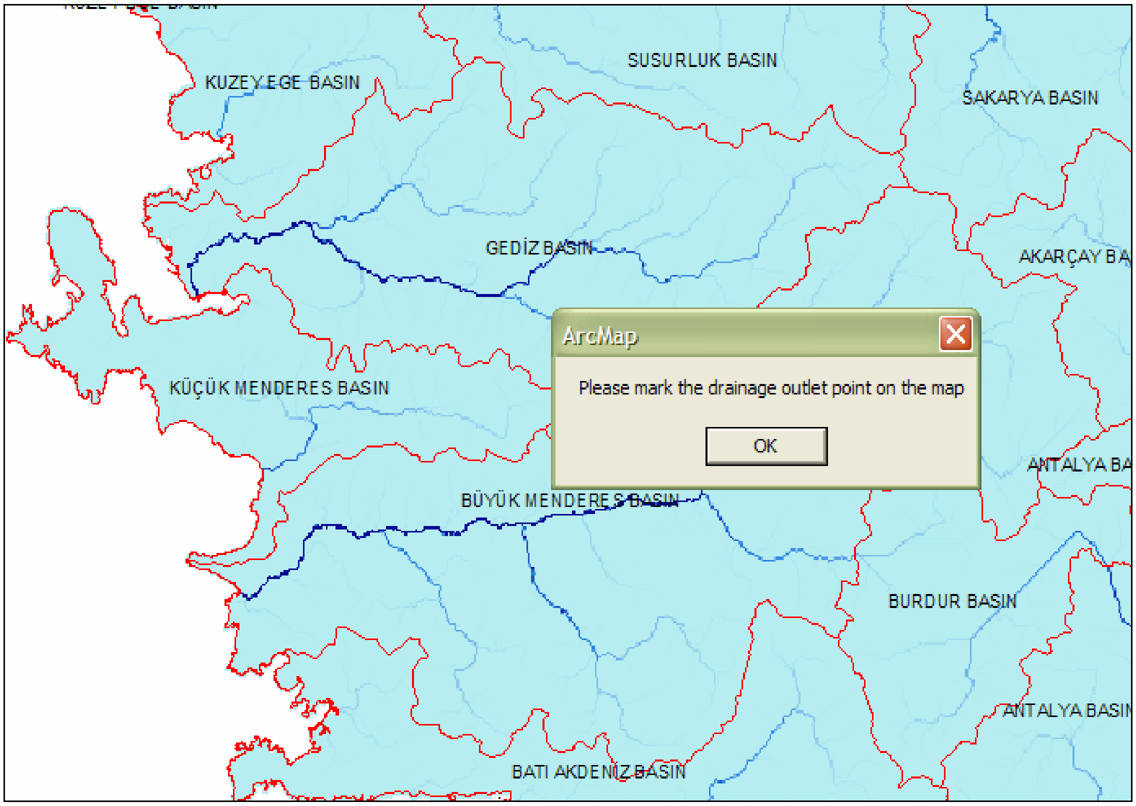

Figure 5.1 Flow Accumulation Map used for the automated discharge computation.

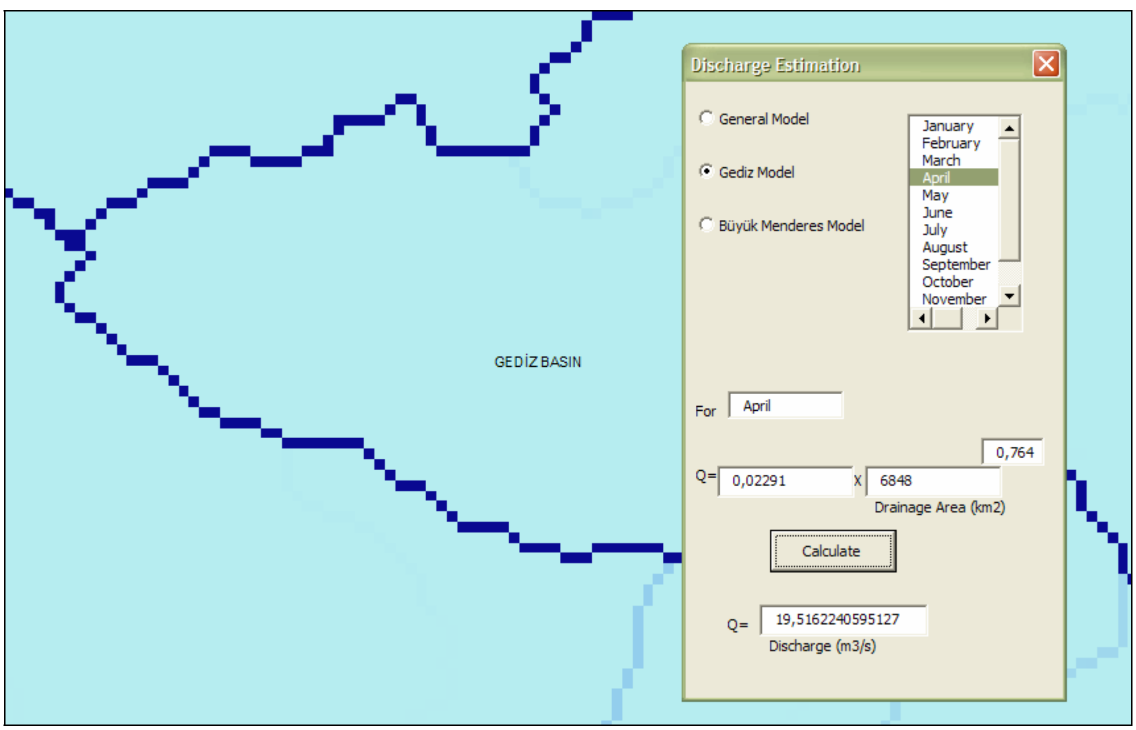

Figure 5.2 Visual Basic Program interface.

The program can also be used with topographic base map that allows selecting the desired location. In Figure 5.3, screenshot of the application using topographic base map is given. In the figure, it can be seen that the flow accumulation raster obtained from DEM fits the topographic map well.

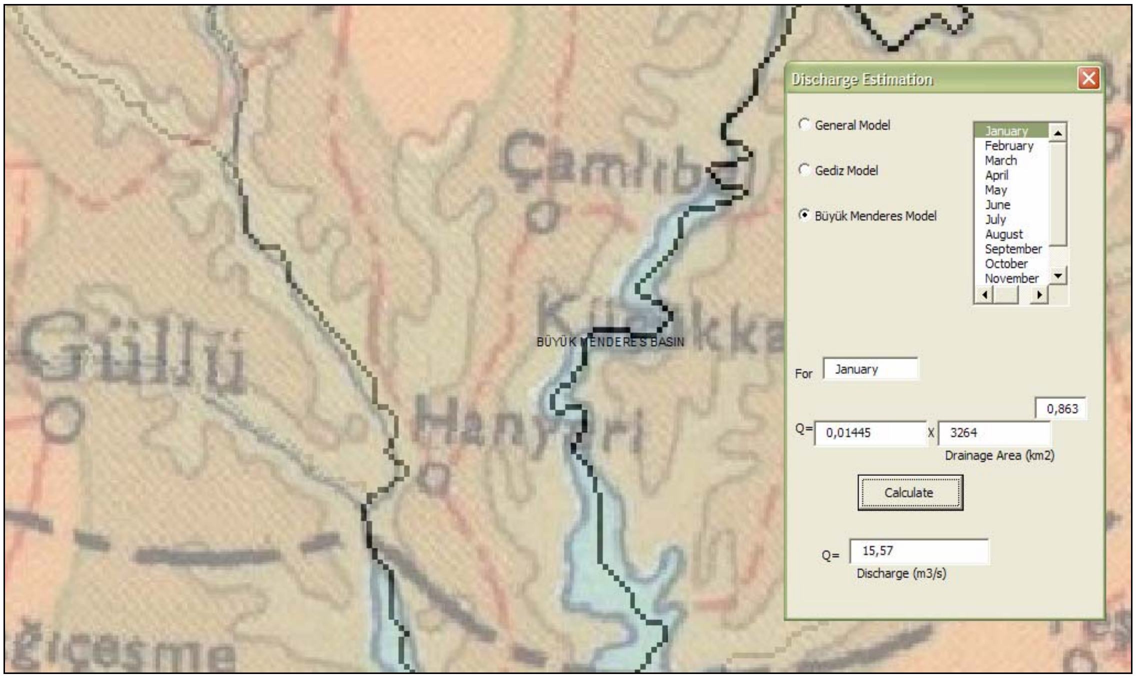

Figure 5.3 Visual Basic Program interface with topographic base map.

When the mouse button is clicked anywhere on the map, the program also shows x and y coordinates as well as the flow accumulation value at that point in the status bar at the lower left corner of ArcGIS.

This algorithm allows estimating the discharge also on the nearby basins. Since the morphology and the climate are important for the basin characteristics, similar basins are most likely be nearby basins. In this respect, Gediz Model can be selected for the discharge estimations in Kuzey Ege, Susurluk and Sakarya Basins, Büyük Menderes Model can be selected for Sakarya, Afyon, Batı Akdeniz, Burdur, Antalya and Akarçay Basins. If a location in Küçük Menderes Basin is selected for the discharge estimation, either General Model or the model of the closest basin should be chosen. In Figure 5.4, basins around the study area are shown. General Model can be applied to all basins in Western Anatolia. Furthermore, General Model and Büyük Menderes Models can be applied to Orta Akdeniz and Doğu Akdeniz Basins since they have similar climate with the study area. However, outside of the study area, the success of the estimation can not be guaranteed.

Figure 5.4 Basins of Western and Middle Anatolia.

In Appendix A, visual basic program code is given with the explanations to use.

5.6 Discussion of the Results

In this study, important basin parameters; the drainage area, the total river length, the main channel length and the mean basin slope parameters were extracted successfully from the DEM using GIS techniques.

Regression analyses were performed to determine discharge in terms of basin parameters and also precipitation for each basin and three models were developed for Gediz, Küçük Menderes and Büyük Menderes Basins. In order to represent the whole study area, a General Model was developed using these three basins together. Best equations that represent monthly and annual discharges are determined either regarding the highest R^2 (adj) values or using stepwise regression analysis, which defines statistically significant equations.

Vogel et. al. (1999) used hydrologic, geomorphic and climatic basin characteristics of 1553 watershed across the United States to develop regression models for the annual discharge. Based on only the drainage area parameter, they found R^2 (adj) values between 27,3% and 99,1% for annual discharge. When the precipitation and the temperature parameters are added, they obtained R^2 (adj) values between 85,2% and 99,7%. Their success results from huge number of stream gauging stations used for the study and long record periods of the stations. However in this study in order to develop the General Model, 24 stream gauging stations and their corresponding sub-basins are used. This is because of the lack of stream gauging stations in the area. If the number of sub-basins included in the analyses increase R^2 (adj) values will also increase. It is important to note that if only the drainage area parameter is used in regression analysis, R^2 values are found between 63,1% and 92,9% and most of them are above 80% for all the models except Küçük Menderes. In this study, when the precipitation is also included in the analyses R^2(adj) values of the annual average discharge are reached to 90,8%, 93,6% and 92,1% respectively for the General, Gediz and Büyük Menderes Models. As found in the similar studies and also from this study, when the precipitation parameter is added to the analyses, the results are improved.

Yokoo et. al. (2001) used multiple regression for the parameters of lumped water balance model. They used 16 characteristics of the basin related with topography, soil type, geology and land-use to find the parameters for the rainfall-runoff simulation program. They found that R^2 (adj) values of the parameters change between 11,5% and 77,5%. Berger and Entekhabi (2001) used six basin parameters for the variables of the equilibrium of surface water and ground water interaction model. These parameters are median slope, relief ratio, drainage density, wetness ratio, infiltration capacity and saturation zone efficiency index. They performed stepwise regression and found out that R^2 (adj) values increase from 70% to 90% while increasing number of parameters in the model. In their study, R^2 (adj) value is found as 79% for the statistically significant model.

In this study, since the General Model that includes the whole study area generally gives better test results than the Gediz Model. The General Model seems to supersede the Gediz Model for the discharge estimations in Gediz Basin.

As explained before, only three stream gauging stations are used for the development of Küçük Menderes Model. These stream gauging stations and their corresponding sub-basins are also included in the development of General Model. In order to verify the General Model, two stream gauging stations of Küçük Menderes Basin are also used for testing.

General Model can also be applied to Büyük Menderes Basin since 12 stream gauging stations of Büyük Menderes Basin are also included in the model development of the General Model. As indicated before, for several months Büyük Menderes Model gives better results than the General Model so it seems superior to the General Model for these months.

In this study, stepwise regression analysis results for all the models except Küçük Menderes, indicate R^2 (adj) values of the statistically significant equations change between 60-98% and most of them are higher than 85%. Similarly, the best equations of the General Model have R^2 (adj) values between 85% and 90%. Generally the lowest R^2 values were obtained in August for all the models.

The models were tested for the verification by using the observed discharges from the stream gauging stations, which are not included in the model development part. Nash-Sutcliffe efficiency was used for this purpose. Test results were found close to the related R^2 (adj) values especially for the General Model. Although some testing results seem to differ more for the other models, these are generally results from one unexpected high value obtained from the equation. The more number of stream gauging stations used for testing, the closer results with the model values can be expected. For the General Model, the testing was applied with the sufficient number of stations so the results are found close to the model values.

Since the General Model testing results were found high and very close to the related R^2 (adj) values, it can be concluded that General Model that represents the whole study area was successfully constituted. Gediz and Büyük Menderes Models gave high R^2 (adj) values and good testing results for certain months while using various combinations of the parameters. Küçük Menderes Model was developed using the discharges of only three stream gauging stations so the accomplishment of this model is limited. In this respect, General Model can be applied to Küçük Menderes Basin instead of Küçük Menderes Model itself. General Model can also be applied to the ungauged basins that have similar climatic and morphologic conditions, for example Aegean coast basins. Moreover, Gediz and Büyük Menderes Models can be applied to the nearby catchments.

In this study, although the models gave good discharge estimations as compared to the similar studies, some factors make it difficult to have better estimations. The regimes of the three main streams in the study area are not regular and there exist some hydraulic structures that affect the discharges such as dams or regulators. Therefore the variability of streamflow used in this study is not homogeneous; this is because of the limited number of stream gauging stations in the area. If the homogeneity is achieved by selecting the stream gauging stations that are not affected by the hydraulic structures, better results can be obtained.

The basins generally have very flat areas that cause the streams change their beds and some branches disappear in summer. As mentioned before, Büyük Menderes Stream as its name in Turkish implies shows many loops and meanders that may merge or separate, so these factors make it difficult to have better discharge estimations. For these areas, $D\infty$ method for the flow direction may give more realistic stream lines than D8 method. If SRTM-1 DEM (30 m resolution) is used instead of SRTM-3 (90 m resolution); the results will be more accurate. However unlike SRTM-3, SRTM-1 is not distributed via internet outside of United States free of charge. For the studies that cover small areas like Küçük Menderes Basin, using high resolution DEM will be more suitable.

Since the drainage area parameter alone gives generally R^2 (adj) values higher than 80% for the General, Gediz and Büyük Menderes Models; a visual basic program that automatically computes the discharges according to the derived models that include the drainage area parameter were written using Arc objects. GIS environment, enables to make automated computations with user interface that uses spatial information.

As in the lumped parameter models, the basin parameters were appointed on the stream gauging station nodes hence regression analyses were applied using the discharges at the nodes. However, visual basic program uses flow accumulation cell values that are stored in each cell of the raster and compute the drainage areas accordingly. Raster operation is easier and more useful way than the vector operation for the drainage area determination and it also enables complicated calculations between the raster layers.

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In this study, it is aimed to find regional equations to be used for the determination of the discharge at certain locations on streams. For this purpose, observed discharge values from the stream gauging stations are used to develop models using the important basin characteristics as the parameters in regression analysis.

Automated stream network formation that uses 8-directional flow algorithm is feasible for the studies that have large areas and valley shape river beds. Automated stream delineation gives more reasonable stream network shape than the manually digitized stream network since manually digitized streamlines might not have suitable connections or some stream branches might not be identified on the base map. It is also important to note that, automated stream delineation process required much less time than the manually digitization of the streams. Once the stream network and the sub-basin polygons are digitized, GIS gives an opportunity to make overlay operations with the DEM and the other spatial information thus to determine plenty of parameters.

Regression analysis is a suitable method for monthly and annual discharge estimations however it can not be used for the daily discharge estimations. Other rainfall-runoff models should be used for the daily discharges. In these models, regression analysis can be applied to determine the parameters to be used in the model.

Stepwise regression provides best equations within confidence interval and can be used in reliance whenever necessary parameters exist. The drainage area parameter is the most important parameter so it will be needed first.

This study is mainly based on the readily available data from DSI and EIE and showed that these data can also be used for the similar or further studies in reliance. Since R^2 values are found high from the results of the regression analyses, similar procedures can be applied to find the discharge equations for the other basins in Turkey. These studies will provide information about water potential for water supply and also for determination of energy potential by taking into account the elevation difference between the water head and desired outlet point of the sub-basin.

As conclusion, GIS provides many tools that facilitate the stream network delineation and basin parameter determinations. It also enables many operations between different kinds of spatial information and shortens the computation time for extracting the necessary information. The basin parameters that are extracted from DEM using GIS techniques provide good input data for the regression analysis to represent the discharges at desired points on the streams. Regression analysis is a suitable method for the discharge estimations at ungauged locations.

6.2 Recommendations

Following recommendations can be useful for similar or further studies.

- The discharge data from the stream gauging stations of DSI and EIE can be found easily from the annual discharge data books. However, the discharge as well as the precipitation data can be found in excel sheets from DSI. The discharge data of the stream gauging stations belonging to EIE can be transferred to soft copies and these digital data can be used to save time for similar studies.

- It is seen in this study that SRTM-3 DEM fits the topographical map well. For the large areas like the study area of the thesis, SRTM-3 (90 m resolution) DEM can be used in reliance. However, for detailed studies on small basins SRTM-1 (30 m resolution) DEM will be more useful.

- In this study, it is tried to digitize the streamlines manually on the 1:500.000 scale topographical map. This process is very time consuming and hard work for identifying small branches and their networks. However, stream network can be delineated in appropriate quality using Arc Hydro program from DEM. 8 directional flow algorithm of Arc Hydro can be applied for the similar scale basins. On valley shape riverbeds, the program can determine the streamlines that exactly show the real network pattern. However, for flat topographies higher resolution DEM would provide better results.

- Similar to the program written in this study for automated discharge estimation by drainage area, the programs or scripts that use other basin parameters can also be written. These programs can use the sub-basin polygons, streamlines, DEM and stream gauging station locations to determine important basin parameters.

- Other parameters such as mean basin elevation, forest cover, and average temperature of the month can also be tried with the basin parameters used in this study to express the discharge.

- Mean basin elevation can easily be obtained as the elevation averages in sub-basin polygons by GIS techniques, and can be included in the regression equation.

- Forest cover data can be obtained from General Directorate of Environment and Forestry. Forest cover data are available in digital form by the forest densities numbered respectively “0” to “3” by polygons. “0” represents no forest cover and “3” represents dense forest. These data could be used for spatially distributed models to obtain better results.

- Monthly temperature data from the observation stations of both DSI and DMI can be obtained and more realistic relationships can be reached.

- For the other river basins all over Turkey, similar studies can be performed for mean flows and regionalization can be applied for the region that covers several small basins to find a general model.

- For further studies, in order to select the models that are built in this study for the discharge estimation in any basin, the similarity functions can be constituted and checked using the morphology and the climate of the basins.

- For further or advanced studies, peak discharges can be studied using a similar procedure with important basin parameters and precipitation parameter but in this case, other factors that are related with the infiltration should be included in the analysis. Therefore, land use and soil cover data should also be collected and considered.

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Appendix A: Visual Basic Program Code for Automated Discharge Estimation Using the Drainage Area

Explanations for Using the Program

The program was written in visual basic language that uses arc objects to get the cell value of the flow accumulation grid when the mouse button is clicked on the map. Thereafter, the drainage area is calculated by multiplying the flow accumulation value with the raster cell size (DEM resolution is 90 m in this study). The discharge will be calculated according to the selected model and month from the interface using drainage area value in the corresponding regression equation.

In order to use this program in ArcMap, the codes should be inserted to visual basic editor that can be reached under the Tools menu > Macros > Visual Basic Editor. Firstly, user form should be created including OptionButton1-2-3, TextBox1-2-3-4-5, ListBox1 and CommandButton1.

The code in Table A1 should be copied to This Document tab below the ArcMap Objects and the code in Table A2 should be copied inside the Forms tab in Visual Basic Editor.

The path of the flow accumulation raster should be changed in the following code: m_pRasterLayer.CreateFromFilePath "F:\Tez veri\DSI\Layers\fac_dem"

The raster cell size is 90 m in this case so 90x90=8100m2 is converted to km2 for the calculation of the drainage area as 0,0081. If different cell size is used for the flow accumulation raster this value should be changed accordingly in following code: UserForm.TextBox3 = CStr(CLng(pRasIdentify.MapTip * 0.0081))

It should be noted that the code under UIToolControl1, can be put in ArcMap as a command button. In order to do this, in the extension selection list Customize option should be selected and Project.UIToolControl1 button should be dragged to the menu bar. If the project is saved as ProjectName.mxd, the command button and the necessary files will be automatically loaded for the next usage without applying the same procedure.

ArcObjects Code

```
Private Sub UIToolControl1_MouseDown(ByVal button As Long, ByVal shift As Long, ByVal x
As Long, ByVal y As Long)
Dim pMxDoc As IMxDocument
Dim m_pApp As IApplication
Dim pActiveView As IActiveView
Dim pPoint As IPoint
Dim pRasRenderer As IRasterRenderer
Dim pIdentify As IIdentify
Dim pArray As IArray
Dim pRasIdentify As IRasterIdentifyObj
Dim pRaster As IRaster
Dim pRasProps As IRasterProps
Set m_pApp = Application
Set pMxDoc = m_pApp.Document
Set pActiveView = pMxDoc.ActiveView
Set pPoint = pActiveView.ScreenDisplay.DisplayTransformation.ToMapPoint(x, y)

Dim m_pRasterLayer As IRasterLayer
Set m_pRasterLayer = New RasterLayer
'Initialize one of the following three methods
m_pRasterLayer.CreateFromFilePath "F:\Tez veri\DSI\Layers\fac_dem"
Set pRaster = m_pRasterLayer.Raster
Set pRasProps = pRaster

YMax = pRasProps.Extent.YMax
XMax = pRasProps.Extent.XMax
XMin = pRasProps.Extent.XMin
YMin = pRasProps.Extent.YMin

If pPoint.x < XMax And pPoint.x > XMin And pPoint.y < YMax And pPoint.y > YMin Then

Set pRasRenderer = m_pRasterLayer.Renderer
Set pIdentify = m_pRasterLayer
Set pArray = pIdentify.Identify(pPoint)

If Not pArray Is Nothing Then
If TypeOf pArray.Element(0) Is IRasterIdentifyObj Then
Set pRasIdentify = pArray.Element(0)
End If
End If

m_pApp.StatusBar.Visible = True
m_pApp.StatusBar.Message(0) = "X: " & Format(pRasIdentify.Location.x, "0.0") + " Y: " &
_Format(pRasIdentify.Location.y, "0.0") + " Flow Accumulation: " &
_Format(pRasIdentify.MapTip, "0.0")
UserForm.TextBox3 = CStr(CLng(pRasIdentify.MapTip * 0.0081))
End If
UserForm.Show
End Sub

Private Sub UIToolControl1_Select()
MsgBox "Please mark the drainage outlet point on the map"
End Sub
```

Visual Basic Form Code

```
Private Sub OptionButton1_Change()

Dim n As Double
Dim m As Double

If OptionButton1.Value = True And ListBox1.Text = "January" Then
n = "0,031" m = "0,774"
ElseIf OptionButton1.Value = True And ListBox1.Text = "February" Then
n = "0,022" m = "0,798"
ElseIf OptionButton1.Value = True And ListBox1.Text = "March" Then
n = "0,028" m = "0,788"
ElseIf OptionButton1.Value = True And ListBox1.Text = "April" Then
n = "0,019" m = "0,800"
ElseIf OptionButton1.Value = True And ListBox1.Text = "May" Then
n = "0,005" m = "0,894"
ElseIf OptionButton1.Value = True And ListBox1.Text = "June" Then
n = "0,001" m = "1,03"
ElseIf OptionButton1.Value = True And ListBox1.Text = "July" Then
n = "0,00015" m = "1,19"
ElseIf OptionButton1.Value = True And ListBox1.Text = "August" Then
n = "0,00004" m = "1,29"
ElseIf OptionButton1.Value = True And ListBox1.Text = "September" Then
n = "0,0001" m = "1,21"
ElseIf OptionButton1.Value = True And ListBox1.Text = "October" Then
n = "0,00015" m = "1,21"
ElseIf OptionButton1.Value = True And ListBox1.Text = "November" Then
n = "0,0017" m = "0,986"
ElseIf OptionButton1.Value = True And ListBox1.Text = "December" Then
n = "0,02138" m = "0,777"
ElseIf OptionButton1.Value = True And ListBox1.Text = "Annual" Then
n = "0,00912" m = "0,850"

ElseIf OptionButton2.Value = True And ListBox1.Text = "January" Then
n = "0,04365" m = "0,730"
ElseIf OptionButton2.Value = True And ListBox1.Text = "February" Then
n = "0,03890" m = "0,730"
ElseIf OptionButton2.Value = True And ListBox1.Text = "March" Then
n = "0,03548" m = "0,752"
ElseIf OptionButton2.Value = True And ListBox1.Text = "April" Then
n = "0,02291" m = "0,764"
ElseIf OptionButton2.Value = True And ListBox1.Text = "May" Then
n = "0,00575" m = "0,861"
ElseIf OptionButton2.Value = True And ListBox1.Text = "June" Then
n = "0,00093" m = "1,0"
ElseIf OptionButton2.Value = True And ListBox1.Text = "July" Then
n = "0,0016" m = "1,15"
ElseIf OptionButton2.Value = True And ListBox1.Text = "August" Then
n = "0,0008" m = "1,19"
ElseIf OptionButton2.Value = True And ListBox1.Text = "September" Then
n = "0,0018" m = "1,11"
ElseIf OptionButton2.Value = True And ListBox1.Text = "October" Then
n = "0,0013" m = "1,19"
ElseIf OptionButton2.Value = True And ListBox1.Text = "November" Then
```

```
n = "0,00224" m = "0,914"
ElseIf OptionButton2.Value = True And ListBox1.Text = "December" Then
n = "0,03715" m = "0,704"
ElseIf OptionButton2.Value = True And ListBox1.Text = "Annual" Then
n = "0,01288" m = "0,792"

ElseIf OptionButton3.Value = True And ListBox1.Text = "January" Then
n = "0,01445" m = "0,863"
ElseIf OptionButton3.Value = True And ListBox1.Text = "February" Then
n = "0,00661" m = "0,941"
ElseIf OptionButton3.Value = True And ListBox1.Text = "March" Then
n = "0,02089" m = "0,829"
ElseIf OptionButton3.Value = True And ListBox1.Text = "April" Then
n = "0,01660" m = "0,827"
ElseIf OptionButton3.Value = True And ListBox1.Text = "May" Then
n = "0,00741" m = "0,876"
ElseIf OptionButton3.Value = True And ListBox1.Text = "June" Then
n = "0,00263" m = "0,949"
ElseIf OptionButton3.Value = True And ListBox1.Text = "July" Then
n = "0,00032" m = "1,13"
ElseIf OptionButton3.Value = True And ListBox1.Text = "August" Then
n = "0,00002" m = "1,39"
ElseIf OptionButton3.Value = True And ListBox1.Text = "September" Then
n = "0,00006" m = "1,31"
ElseIf OptionButton3.Value = True And ListBox1.Text = "October" Then
n = "0,00047" m = "1,11"
ElseIf OptionButton3.Value = True And ListBox1.Text = "November" Then
n = "0,00245" m = "0,980"
ElseIf OptionButton3.Value = True And ListBox1.Text = "December" Then
n = "0,00724" m = "0,907"
ElseIf OptionButton3.Value = True And ListBox1.Text = "Annual" Then
n = "0,00646" m = "0,905"

End If

TextBox1.Text = ListBox1.Text
TextBox4.Text = n
TextBox5.Text = m
TextBox2.Text = ""
End Sub

Private Sub OptionButton2_Change()

Dim n As Double
Dim m As Double

If OptionButton1.Value = True And ListBox1.Text = "January" Then
n = "0,031" m = "0,774"
ElseIf OptionButton1.Value = True And ListBox1.Text = "February" Then
n = "0,022" m = "0,798"
ElseIf OptionButton1.Value = True And ListBox1.Text = "March" Then
n = "0,028" m = "0,788"
ElseIf OptionButton1.Value = True And ListBox1.Text = "April" Then
n = "0,019" m = "0,800"
ElseIf OptionButton1.Value = True And ListBox1.Text = "May" Then
n = "0,005" m = "0,894"
```

```
ElseIf OptionButton1.Value = True And ListBox1.Text = "June" Then
n = "0,001" m = "1,03"
ElseIf OptionButton1.Value = True And ListBox1.Text = "July" Then
n = "0,00015" m = "1,19"
ElseIf OptionButton1.Value = True And ListBox1.Text = "August" Then
n = "0,00004" m = "1,29"
ElseIf OptionButton1.Value = True And ListBox1.Text = "September" Then
n = "0,0001" m = "1,21"
ElseIf OptionButton1.Value = True And ListBox1.Text = "October" Then
n = "0,00015" m = "1,21"
ElseIf OptionButton1.Value = True And ListBox1.Text = "November" Then
n = "0,0017" m = "0,986"
ElseIf OptionButton1.Value = True And ListBox1.Text = "December" Then
n = "0,02138" m = "0,777"
ElseIf OptionButton1.Value = True And ListBox1.Text = "Annual" Then
n = "0,00912" m = "0,850"

ElseIf OptionButton2.Value = True And ListBox1.Text = "January" Then
n = "0,04365" m = "0,730"
ElseIf OptionButton2.Value = True And ListBox1.Text = "February" Then
n = "0,03890" m = "0,730"
ElseIf OptionButton2.Value = True And ListBox1.Text = "March" Then
n = "0,03548" m = "0,752"
ElseIf OptionButton2.Value = True And ListBox1.Text = "April" Then
n = "0,02291" m = "0,764"
ElseIf OptionButton2.Value = True And ListBox1.Text = "May" Then
n = "0,00575" m = "0,861"
ElseIf OptionButton2.Value = True And ListBox1.Text = "June" Then
n = "0,00093" m = "1,0"
ElseIf OptionButton2.Value = True And ListBox1.Text = "July" Then
n = "0,0016" m = "1,15"
ElseIf OptionButton2.Value = True And ListBox1.Text = "August" Then
n = "0,0008" m = "1,19"
ElseIf OptionButton2.Value = True And ListBox1.Text = "September" Then
n = "0,0018" m = "1,11"
ElseIf OptionButton2.Value = True And ListBox1.Text = "October" Then
n = "0,0013" m = "1,19"
ElseIf OptionButton2.Value = True And ListBox1.Text = "November" Then
n = "0,00224" m = "0,914"
ElseIf OptionButton2.Value = True And ListBox1.Text = "December" Then
n = "0,03715" m = "0,704"
ElseIf OptionButton2.Value = True And ListBox1.Text = "Annual" Then
n = "0,01288" m = "0,792"


ElseIf OptionButton3.Value = True And ListBox1.Text = "January" Then
n = "0,01445" m = "0,863"
ElseIf OptionButton3.Value = True And ListBox1.Text = "February" Then
n = "0,00661" m = "0,941"
ElseIf OptionButton3.Value = True And ListBox1.Text = "March" Then
n = "0,02089" m = "0,829"
ElseIf OptionButton3.Value = True And ListBox1.Text = "April" Then
n = "0,01660" m = "0,827"
ElseIf OptionButton3.Value = True And ListBox1.Text = "May" Then
n = "0,00741" m = "0,876"
ElseIf OptionButton3.Value = True And ListBox1.Text = "June" Then
```

```
n = "0,00263" m = "0,949"
ElseIf OptionButton3.Value = True And ListBox1.Text = "July" Then
n = "0,00032" m = "1,13"
ElseIf OptionButton3.Value = True And ListBox1.Text = "August" Then
n = "0,00002" m = "1,39"
ElseIf OptionButton3.Value = True And ListBox1.Text = "September" Then
n = "0,00006" m = "1,31"
ElseIf OptionButton3.Value = True And ListBox1.Text = "October" Then
n = "0,00047" m = "1,11"
ElseIf OptionButton3.Value = True And ListBox1.Text = "November" Then
n = "0,00245" m = "0,980"
ElseIf OptionButton3.Value = True And ListBox1.Text = "December" Then
n = "0,00724" m = "0,907"
ElseIf OptionButton3.Value = True And ListBox1.Text = "Annual" Then
n = "0,00646" m = "0,905"

End If

TextBox1.Text = ListBox1.Text
TextBox4.Text = n
TextBox5.Text = m
TextBox2.Text = ""
End Sub


Private Sub OptionButton3_Change()

Dim n As Double
Dim m As Double

If OptionButton1.Value = True And ListBox1.Text = "January" Then
n = "0,031" m = "0,774"
ElseIf OptionButton1.Value = True And ListBox1.Text = "February" Then
n = "0,022" m = "0,798"
ElseIf OptionButton1.Value = True And ListBox1.Text = "March" Then
n = "0,028" m = "0,788"
ElseIf OptionButton1.Value = True And ListBox1.Text = "April" Then
n = "0,019" m = "0,800"
ElseIf OptionButton1.Value = True And ListBox1.Text = "May" Then
n = "0,005" m = "0,894"
ElseIf OptionButton1.Value = True And ListBox1.Text = "June" Then
n = "0,001" m = "1,03"
ElseIf OptionButton1.Value = True And ListBox1.Text = "July" Then
n = "0,00015" m = "1,19"
ElseIf OptionButton1.Value = True And ListBox1.Text = "August" Then
n = "0,00004" m = "1,29"
ElseIf OptionButton1.Value = True And ListBox1.Text = "September" Then
n = "0,0001" m = "1,21"
ElseIf OptionButton1.Value = True And ListBox1.Text = "October" Then
n = "0,00015" m = "1,21"
ElseIf OptionButton1.Value = True And ListBox1.Text = "November" Then
n = "0,0017" m = "0,986"
ElseIf OptionButton1.Value = True And ListBox1.Text = "December" Then
n = "0,02138" m = "0,777"
ElseIf OptionButton1.Value = True And ListBox1.Text = "Annual" Then
n = "0,00912" m = "0,850"
```

```
ElseIf OptionButton2.Value = True And ListBox1.Text = "January" Then
n = "0,04365" m = "0,730"
ElseIf OptionButton2.Value = True And ListBox1.Text = "February" Then
n = "0,03890" m = "0,730"
ElseIf OptionButton2.Value = True And ListBox1.Text = "March" Then
n = "0,03548" m = "0,752"
ElseIf OptionButton2.Value = True And ListBox1.Text = "April" Then
n = "0,02291" m = "0,764"
ElseIf OptionButton2.Value = True And ListBox1.Text = "May" Then
n = "0,00575" m = "0,861"
ElseIf OptionButton2.Value = True And ListBox1.Text = "June" Then
n = "0,00093" m = "1,0"
ElseIf OptionButton2.Value = True And ListBox1.Text = "July" Then
n = "0,0016" m = "1,15"
ElseIf OptionButton2.Value = True And ListBox1.Text = "August" Then
n = "0,0008" m = "1,19"
ElseIf OptionButton2.Value = True And ListBox1.Text = "September" Then
n = "0,0018" m = "1,11"
ElseIf OptionButton2.Value = True And ListBox1.Text = "October" Then
n = "0,0013" m = "1,19"
ElseIf OptionButton2.Value = True And ListBox1.Text = "November" Then
n = "0,00224" m = "0,914"
ElseIf OptionButton2.Value = True And ListBox1.Text = "December" Then
n = "0,03715" m = "0,704"
ElseIf OptionButton2.Value = True And ListBox1.Text = "Annual" Then
n = "0,01288" m = "0,792"

ElseIf OptionButton3.Value = True And ListBox1.Text = "January" Then
n = "0,01445" m = "0,863"
ElseIf OptionButton3.Value = True And ListBox1.Text = "February" Then
n = "0,00661" m = "0,941"
ElseIf OptionButton3.Value = True And ListBox1.Text = "March" Then
n = "0,02089" m = "0,829"
ElseIf OptionButton3.Value = True And ListBox1.Text = "April" Then
n = "0,01660" m = "0,827"
ElseIf OptionButton3.Value = True And ListBox1.Text = "May" Then
n = "0,00741" m = "0,876"
ElseIf OptionButton3.Value = True And ListBox1.Text = "June" Then
n = "0,00263" m = "0,949"
ElseIf OptionButton3.Value = True And ListBox1.Text = "July" Then
n = "0,00032" m = "1,13"
ElseIf OptionButton3.Value = True And ListBox1.Text = "August" Then
n = "0,00002" m = "1,39"
ElseIf OptionButton3.Value = True And ListBox1.Text = "September" Then
n = "0,00006" m = "1,31"
ElseIf OptionButton3.Value = True And ListBox1.Text = "October" Then
n = "0,00047" m = "1,11"
ElseIf OptionButton3.Value = True And ListBox1.Text = "November" Then
n = "0,00245" m = "0,980"
ElseIf OptionButton3.Value = True And ListBox1.Text = "December" Then
n = "0,00724" m = "0,907"
ElseIf OptionButton3.Value = True And ListBox1.Text = "Annual" Then
n = "0,00646" m = "0,905"

End If
```

```
TextBox1.Text = ListBox1.Text
TextBox4.Text = n
TextBox5.Text = m
TextBox2.Text = ""
End Sub
Private Sub UserForm_Initialize()

ListBox1.AddItem "January"
ListBox1.AddItem "February"
ListBox1.AddItem "March"
ListBox1.AddItem "April"
ListBox1.AddItem "May"
ListBox1.AddItem "June"
ListBox1.AddItem "July"
ListBox1.AddItem "August"
ListBox1.AddItem "September"
ListBox1.AddItem "October"
ListBox1.AddItem "November"
ListBox1.AddItem "December"
ListBox1.AddItem "Annual"

OptionButton1.Value = True

ListBox1.Selected(0) = True
End Sub

Private Sub ListBox1_Change()
Dim n As Double
Dim m As Double
If OptionButton1.Value = True And ListBox1.Text = "January" Then
n = "0,031" m = "0,774"
ElseIf OptionButton1.Value = True And ListBox1.Text = "February" Then
n = "0,022" m = "0,798"
ElseIf OptionButton1.Value = True And ListBox1.Text = "March" Then
n = "0,028" m = "0,788"
ElseIf OptionButton1.Value = True And ListBox1.Text = "April" Then
n = "0,019" m = "0,800"
ElseIf OptionButton1.Value = True And ListBox1.Text = "May" Then
n = "0,005" m = "0,894"
ElseIf OptionButton1.Value = True And ListBox1.Text = "June" Then
n = "0,001" m = "1,03"
ElseIf OptionButton1.Value = True And ListBox1.Text = "July" Then
n = "0,00015" m = "1,19"
ElseIf OptionButton1.Value = True And ListBox1.Text = "August" Then
n = "0,00004" m = "1,29"
ElseIf OptionButton1.Value = True And ListBox1.Text = "September" Then
n = "0,0001" m = "1,21"
ElseIf OptionButton1.Value = True And ListBox1.Text = "October" Then
n = "0,00015" m = "1,21"
ElseIf OptionButton1.Value = True And ListBox1.Text = "November" Then
n = "0,0017" m = "0,986"
ElseIf OptionButton1.Value = True And ListBox1.Text = "December" Then
n = "0,02138" m = "0,777"
ElseIf OptionButton1.Value = True And ListBox1.Text = "Annual" Then
n = "0,00912" m = "0,850"
```

```
ElseIf OptionButton2.Value = True And ListBox1.Text = "January" Then
n = "0,04365" m = "0,730"
ElseIf OptionButton2.Value = True And ListBox1.Text = "February" Then
n = "0,03890" m = "0,730"
ElseIf OptionButton2.Value = True And ListBox1.Text = "March" Then
n = "0,03548" m = "0,752"
ElseIf OptionButton2.Value = True And ListBox1.Text = "April" Then
n = "0,02291" m = "0,764"
ElseIf OptionButton2.Value = True And ListBox1.Text = "May" Then
n = "0,00575" m = "0,861"
ElseIf OptionButton2.Value = True And ListBox1.Text = "June" Then
n = "0,00093" m = "1,0"
ElseIf OptionButton2.Value = True And ListBox1.Text = "July" Then
n = "0,0016" m = "1,15"
ElseIf OptionButton2.Value = True And ListBox1.Text = "August" Then
n = "0,0008" m = "1,19"
ElseIf OptionButton2.Value = True And ListBox1.Text = "September" Then
n = "0,0018" m = "1,11"
ElseIf OptionButton2.Value = True And ListBox1.Text = "October" Then
n = "0,0013" m = "1,19"
ElseIf OptionButton2.Value = True And ListBox1.Text = "November" Then
n = "0,00224" m = "0,914"
ElseIf OptionButton2.Value = True And ListBox1.Text = "December" Then
n = "0,03715" m = "0,704"
ElseIf OptionButton2.Value = True And ListBox1.Text = "Annual" Then
n = "0,01288" m = "0,792"

ElseIf OptionButton3.Value = True And ListBox1.Text = "January" Then
n = "0,01445" m = "0,863"
ElseIf OptionButton3.Value = True And ListBox1.Text = "February" Then
n = "0,00661" m = "0,941"
ElseIf OptionButton3.Value = True And ListBox1.Text = "March" Then
n = "0,02089" m = "0,829"
ElseIf OptionButton3.Value = True And ListBox1.Text = "April" Then
n = "0,01660" m = "0,827"
ElseIf OptionButton3.Value = True And ListBox1.Text = "May" Then
n = "0,00741" m = "0,876"
ElseIf OptionButton3.Value = True And ListBox1.Text = "June" Then
n = "0,00263" m = "0,949"
ElseIf OptionButton3.Value = True And ListBox1.Text = "July" Then
n = "0,00032" m = "1,13"
ElseIf OptionButton3.Value = True And ListBox1.Text = "August" Then
n = "0,00002" m = "1,39"
ElseIf OptionButton3.Value = True And ListBox1.Text = "September" Then
n = "0,00006" m = "1,31"
ElseIf OptionButton3.Value = True And ListBox1.Text = "October" Then
n = "0,00047" m = "1,11"
ElseIf OptionButton3.Value = True And ListBox1.Text = "November" Then
n = "0,00245" m = "0,980"
ElseIf OptionButton3.Value = True And ListBox1.Text = "December" Then
n = "0,00724" m = "0,907"
ElseIf OptionButton3.Value = True And ListBox1.Text = "Annual" Then
n = "0,00646" m = "0,905"

End If
```

```
TextBox1.Text = ListBox1.Text
TextBox4.Text = n
TextBox5.Text = m
TextBox2.Text = ""
End Sub

Private Sub CommandButton1_Click()

Dim n As Double
Dim m As Double

n = TextBox4.Value
m = TextBox5.Value

TextBox2.Value = FormatNumber(n * TextBox3.Value ^ m, 2)
End Sub
```

Appendix B: Sample Regression Analysis Outputs of Minitab 13.2 Software

Sample Regression Analysis output of General Model.

Regression Analysis: Log_Qannual versus logA; LOG_TRlength; Log_Pavrage

```
The regression equation is
Log_Qannual = - 4,91 + 2,38 logA - 1,35 LOG_TRlength + 0,577 Log_Pavrage

Predictor        Coef     SE Coef          T        P
Constant       -4,913       1,402      -3,51    0,002
logA           2,3773      0,8218       2,89    0,009
LOG_TRle      -1,3501      0,7389      -1,83    0,083
Log_Pavr       0,5770      0,4876       1,18    0,251

S = 0,2167      R-Sq = 91,5%     R-Sq(adj) = 90,2%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         3     10,0766      3,3589     71,51    0,000
Residual Error    20      0,9394      0,0470
Total             23     11,0160

Source       DF      Seq SS
logA          1      9,8662
LOG_TRle      1      0,1446
Log_Pavr      1      0,0658

Unusual Observations
Obs       logA   Log_Qave         Fit      SE Fit    Residual    St Resid
  3       1,71    -0,5487     -0,3778      0,1931     -0,1709       -1,74 X
 11       1,84    -0,3554     -0,2867      0,1586     -0,0687       -0,46 X
 17       3,04    -0,0065      0,4481      0,0696     -0,4546       -2,21R
 22       2,43     0,4019     -0,0690      0,0988      0,4709        2,44R

R denotes an observation with a large standardized residual
X denotes an observation whose X value gives it large influence.
```

Sample Regression Analysis output of Gediz Model.

Regression Analysis: Log_Qjan versus logA

```
The regression equation is
Log_Qjan = - 1,36 + 0,730 logA

Predictor        Coef     SE Coef          T        P
Constant      -1,3570      0,2310      -5,87    0,000
logA          0,73040     0,07045      10,37    0,000

S = 0,1973      R-Sq = 90,7%     R-Sq(adj) = 89,9%

Analysis of Variance

Source            DF          SS          MS         F        P
Regression         1      4,1858      4,1858    107,49    0,000
Residual Error    11      0,4283      0,0389
Total             12      4,6142
```

Sample Regression Analysis output of Küçük Menderes Model.

Regression Analysis: Log_Qfeb versus logA; Log_slope

```
The regression equation is
Log_Qfeb = - 0,060 + 0,745 logA - 0,904 Log_slope

Predictor        Coef     SE Coef          T        P
Constant      -0,0599      0,5733      -0,10    0,926
logA           0,7445      0,1181       6,30    0,024
Log_slop      -0,9040      0,4490      -2,01    0,182

S = 0,1850      R-Sq = 95,3%     R-Sq(adj) = 90,6%

Analysis of Variance

Source            DF         SS         MS         F        P
Regression         2    1,38653    0,69327     20,25    0,047
Residual Error     2    0,06849    0,03424
Total              4    1,45502

Source       DF      Seq SS
logA          1     1,24774
Log_slop      1     0,13880
```

Sample Regression Analysis output of Büyük Menderes Model.

Regression Analysis: Log_Qmar versus logA; LOG_MCSlope

```
The regression equation is
Log_Qmar = - 5,00 + 1,41 logA + 1,74 LOG_MCSlope

Predictor        Coef     SE Coef          T        P
Constant       -5,003       1,431      -3,50    0,007
logA           1,4105      0,2669       5,28    0,001
LOG_MCSl       1,7354      0,7063       2,46    0,036

S = 0,2776      R-Sq = 85,0%     R-Sq(adj) = 81,7%

Analysis of Variance

Source            DF         SS         MS         F        P
Regression         2     3,9275     1,9638     25,48    0,000
Residual Error     9     0,6936     0,0771
Total             11     4,6211

Source       DF      Seq SS
logA          1      3,4623
LOG_MCSl      1      0,4653

Unusual Observations
Obs       logA   Log_Qmar         Fit       SE Fit    Residual    St Resid
 10       2,43     0,7606      0,7559       0,2416      0,0046        0,03 X

X denotes an observation whose X value gives it large influence.
```

Appendix C: Sample Stepwise Regression Analysis Outputs of Minitab 13.2 Software

Sample Stepwise Regression Analysis output of General Model.

Stepwise Regression: Log_Qannual versus logA; Log_slope; ...

```
  Alpha-to-Enter: 0,15  Alpha-to-Remove: 0,15

 Response is Log_Qann on  6 predictors, with N =   24


    Step         1        2        3
Constant     -2,035   -3,747   -5,226

logA          0,850    2,281    2,468
T-Value       13,74     2,76     3,08
P-Value       0,000    0,012    0,006

LOG_TRle               -1,29    -1,41
T-Value                -1,74    -1,96
P-Value                0,097    0,064

Log_slop                         0,93
T-Value                          1,65
P-Value                         0,115

S             0,229    0,219    0,210
R-Sq          89,56    90,88    91,97
R-Sq(adj)     89,09    90,01    90,76
C-p             3,2      2,3      1,9
```

Sample Stepwise Regression Analysis output of Gediz Model.

Stepwise Regression: Log_Qjan versus logA; Log_slope; ...

```
  Alpha-to-Enter: 0,15  Alpha-to-Remove: 0,15

 Response is Log_Qjan on  6 predictors, with N =   13


    Step         1
Constant     -1,357

logA          0,730
T-Value       10,37
P-Value       0,000

S             0,197
R-Sq          90,72
R-Sq(adj)     89,87
C-p             5,1
```

Sample Stepwise Regression Analysis output of Küçük Menderes Model.

Stepwise Regression: Log_Qfeb versus logA; Log_slope; ...

```
  Alpha-to-Enter: 0,15  Alpha-to-Remove: 0,15

 Response is Log_Qfeb on  6 predictors, with N =    7


    Step          1
Constant    -0,7202

logA           0,54
T-Value        3,23
P-Value       0,023

S             0,308
R-Sq          67,64
R-Sq(adj)     61,17
```

Sample Stepwise Regression Analysis output of Büyük Menderes Model.

Stepwise Regression: Log_Qmar versus logA; Log_slope; ...

```
  Alpha-to-Enter: 0,15  Alpha-to-Remove: 0,15

 Response is Log_Qmar on  6 predictors, with N =   12


    Step          1        2
Constant     -1,675   -6,857

logA          0,829    1,006
T-Value        5,47    10,17
P-Value       0,000    0,000

Log_slop                3,89
T-Value                 4,39
P-Value                0,002

S             0,340    0,203
R-Sq          74,92    92,01
R-Sq(adj)     72,41    90,23
C-p            13,5      0,8
```