ABSTRACT

In this study, 10 main ephemeral rivers of Northern part of Cyprus has been modelled and analyzed. The basin areas of these rivers are drained from the Troodos Mountains, who receives the maximum precipitation rates all over the Cyprus. Since the upstream of all these rivers are drained from the same or similar sources, the correlation between these rivers is investigated by Kendall, Sperman and Pearson correlation methods. The results support the good correlation between the rivers, with decreasing trend as the distance between them increases. The monitored flow data from 1965's to 2000, for each river, has been analysed by stochastic modelling techniques such as autoregressive models in the first, second and third orders. The results were than used to predict the future flow estimates for these rivers. The prediction of future flows were modelled by AR (10), AR (12), AR (14), AR (15) autoregressive models, in which data prediction for 2030 has been obtained. The results show that in between 2009-2012 and 2018-2021 the peak flows will probable to occur in the northern drainage areas of Troodos Mountains.

The importance of the stochastic modelling of these rivers is believed to be a helpful study for the future development, planning and management of water resources of the area.

Key words: Autoregressive model, Cyprus, river, stochastic modelling, Troodos

Öz

Bu çalışmada Troodos dağlarından mevsimsel akış gösteren 10 dere modellenip incelendi. Bu dereler tüm Kıbrısta maksimum yağış alan yerler olup, havza alanları Troodos dağlarında bulunur. Bu dereler aynı veya benzeri kaynaktan aktıkları için, dereler arasındaki ilişki Kendall, Sperman, Pearson korelasyon metodları kullanılarak incelendi. Dereler arasında iyi bir ilişki olduğu sonucuna varıldı ve dereler arasındaki mesafe arttıkça ilişkinin azaldığı gözlendi. 1965-2000 yılları arasındaki gözlenmiş akımlar her bir dere için stokastik modelleme tekniklerinden birinci, ikinci ve üçüncü otoregresif modellerle elde edildi. Daha sonra sonuçlar derelerdeki gelecek akımların tahmininde kullanıldı. AR (10), AR (12), AR (14), AR (15) otoregresif modelleri gelecek akım verilerin bulunmasında kullanıldı. 2030 yılının akım verisi elde edildi. Sonuçlar Trodos dağlarının kuzey drenaj alanında 2009-2012 ve 2018-2021 yılları arasında pik akış değerlerinin oluşacağını gösteriyor.

Bu derelerin stokastik modellemesinin önemi, su kaynakları alanının geleceğinin gelişmesi, planlanması ve işletilmesinde yardımcı bir kaynak olduğuna inanılmaktadır.

Anahtar sözcükler: Akarsu, Kıbrıs, otoregresif modelleme, stokastik modelleme, Trodos

This thesis is dedicated to my parents.

For their endless love, support and encouragement.

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ABBREVIATIONS

AR (*p*)	Autoregressive Markov Models
ARMA (*p, q*)	Autoregressive Moving Average
a.m.s.l.	above M.S.L.
ARIMA	Autoregressive Integrated Moving Average
SARIMA	Seasonal Autoregressive Integrated Moving Average
ANN	Artificial Neural Network
KNN	K-Nearest Neighbours
SVM	Support Vector Machine
PSR	Phase Space Reconstruction

LIST OF SYMBOLS

μ	The Mean
$P_{0.50}$	The Median
X_i	Sum of all data pairs
n	Sample size
σ	Sample standard deviation
σ^2	Sample variance
g	Measure of skewness
min.	Minimum value
max.	Maximum value
N	Number of data
ρ	Measure of correlation
$\rho_{Kendall}$	Kendall's correlation coefficient
$\rho_{Sperman}$	Sperman's correlation coefficient
$\rho_{Pearson}$	Pearson's correlation coefficient
α	Confidence level
H_0, H_1	The significance of the acceptable error rate α
p	Probability of obtaining computed test statistic
x	Data pairs
y	Data pairs
μ_x	The mean of *x* data pairs
μ_y	The mean of *y* data pairs
σ_x	The standard deviation of *x* data pairs
σ_y	The standard deviation of *y* data pairs

S	The monotonic dependence of y on x
μ_s	The mean of monotonic dependence of y on x
σ_s	The standard deviation of monotonic dependence of y on x
M	Number of discordant pairs
P	Number of concordant pairs
Z_S	The standard normal variable which passes S probability
$Z_{Critical}$	The standard normal variable which passes critical probability
Rx_i	Ranks of x data pairs
Ry_i	Ranks of y data pairs
t	The test statistics
X_i	Sequence of flow observations (mcm)
r_k	The autocorrelation coefficient;
k	The interval number of the autocorrelations
σ_{rk}	The standard deviation of the r_k
y_i	Standardized X_i flows (mcm)
σ_y	The standard deviation of standardized X_i flows
μ_y	The mean of standardized X_i flows
y_i'	Non standardized X_i flows (mcm)
ϕ_p	Autoregressive coefficients for AR model
θ_q	Autoregressive coefficients for MA model
ε_i	Residuals
σ_ε	The standard deviation of residuals ε_i
μ_ε	The mean of residuals
p	Order of AR model

q	Order of MA model
AIC	Akaike Information Criterion
Δt	Discrete time interval
λ	A value which effects skewness
T	Time period
$\sigma_{\varepsilon}{}^{2}$	The maximum likelihood estimate of the residual variance
m	Maximum lag between 0.1*n*-0.3*n* for the Box Pierce Port Manteau test
$r_{k\varepsilon}$	The autocorrelation numbers of residuals
Q	The formulation of the Box Pierce Port Manteau test
η_i	Uniform random number between (0-1)
$Z_{1i,} Z_{2i}$	Standard Normal random numbers
ψ_p	The predicting error parameters of flows;
$e_i(l)$	The prediction error of the l^{th} year flow
$Var[e_i(1)]$	The variance of prediction error of the l^{th} year flow
$Z_{\alpha/2}$	The standard normal variable which passes $\alpha/2$ probability.
$y_i(l)$	The predicted flow of the l^{th} year (mcm)
mcm	Million cubic meter
R^2	The degree of fit of the regression
P	The annual precipitation
SR	The annual surface runoff
σ_p	The standard deviation of the synthetic data
σ_M	The standard deviation of the measured time series
γ	The efficiency index

CHAPTER 1

INTRODUCTION

The objective of this study is to identify the most appropriate type of model of the yearly flows draining from Troodos Mountains for the particular case, estimating the future yearly flows to take precautions from any flood disasters and to investigate potential capacities of dam construction at the downstream of Troodos Mountains. This will be achieved via autoregressive models, working in different orders.

In recent years, there has been considerable interest in building models which preserve the autocorrelation structure of the observations. Systematic study of the autocorrelation function has led to the specification of stochastic models which can be used for prediction and generation of hydrologic sequences. Several types of stochastic models have been proposed during the last two decades for the stochastic modelling of hydrologic time series in general, and stream flow time series in particular.

Hence, an important problem in stochastic hydrology is to select or identify the type of model for representing the hydrologic time series. In common practice such model identification is usually done by judgment, experience, or personal preference. In some cases, though, the statistical properties of the various alternative models as well as the statistical characteristics of the sample time series are used for identifying the most appropriate type of model for the particular case. It is, of course desirable that in addition to the above factors, physical considerations must be used for aiding in the identification of the model type (Salas & Smith, 1981).

Actually the exact mathematical models of a hydrologic time series are never known. The suitable model is only estimation. The exact model parameters are also never known in hydrology; they must be estimated from limited data. Identification of models and estimation of their parameters from available data are often referred in the literature as time series modelling or stochastic modelling of hydrologic series (Salas *et al.*, 1981).

Almost all hydrologic time series of daily, weekly and monthly values have deterministic components occurring due to astronomic cycle and therefore they are periodic-stochastic series in nature; on the other hand none of the hydrologic time series are purely deterministic or periodic. The deterministic components in time series can be mainly classified as transient components (trends and jumps) and periodic components. If the yearly flow series haven’t transient components, they are assumed as stationary. If the time interval get closer (season, month, week, day), than there will be a periodic component and the flow series will not be stationary (Bayazıt, 1996).

Future prediction of the purpose of constructing the stochastic models is to generate synthetic processes. With the use of generated processes, it can be possible for the investigations of planning and management of water resources to consider for flows not only the observed sample but also the other samples which come from the same population. So, the system behaviour can be investigated not only according to the available sample but also with aid of synthetic series (Bayazıt, 1981).

The first chapter contains information for the reader to follow the content of the thesis. The second chapter gives information about the model used in the thesis. The new technologies and investigations which has been done gives knowledge about new modelling systems and compare different models by each model to get advantage or disadvantage of a model. The third chapter is about Troodos Mountains drainage area characteristics such as surface water, climate, geology and soil. The fourth chapter explains correlation and types of correlation. How to use hypothesis test with correlation? The fifth chapter is the main subject and gives information and knowledge about time series modelling. The sixth chapter explains the relation between ten rivers draining from Troodos Mountains. The regression model used in this study is a set of simple exponential regression equations that can appropriately defines a relationship of Rainfall-Runoff event. Secondly explains the relation between synthetic sequences and surface runoff of ten rivers lastly gives the results of synthetic sequences and predicted synthetic sequences which are obtained from annual surface runoff of ten rivers.

CHAPTER 2

LITERATURE REVIEW

Linear stochastic methods of time series analysis, modelling and forecasting, such as the autoregressive (AR), autoregressive moving average (ARMA) and autoregressive integrated moving average (ARIMA) have been widely used in hydrologic time-series data analysis and forecasting (Abrahant & See, 2000; Mishra *et al*., 2004; Wang *et al*., 2005). Tools such as stochastic models, engineering fuzzy set theory models, artificial neural networks, k-nearest neighbours, neural fuzzy networks, chaotic theory models, support vector machine models or hybrid models, appear too complex or too demanding in terms of data and resources for widespread practical applications (Jakeman, 1993). Thus, simpler approaches, offered by the most important and widely used ARMA family models, appear to demonstrate a good ability in explaining the short and medium-term stochastic processes of hydrologic time series in comparison to the above models (Abrahant & See, 2000; Hwang, 2001; Chen & Wu, 2003).

Many data driven models, including linear, nonparametric or non-linear approaches, are developed for hydrologic discharge time series prediction in the past decades (Marques *et al*., 2006). Generally there are two basic assumptions while modelling with different techniques. The first assumption suggests that a time series is originated from a stochastic process with an infinite number of degree of freedom. Under this assumption, linear models such as autoregressive (AR), autoregressive moving average (ARMA), autoregressive integrated moving average (ARIMA), and seasonal ARIMA (SARIMA) had made a great success in river flow prediction (Carlson *et al*., 1970; Salas *et al*., 1985; Haltiner & Salas, 1988; Yu & Tseng, 1996; Kothyari & Singh, 1999; Huang *et al*., 2004; Maria *et al*., 2004). The second assumption suggests that a random looking hydrologic time series is derived from a deterministic dynamic system such as chaos. In the past two decades, chaos based stream flow prediction techniques have been increasingly obtaining interests of the hydrology community (Jayawardena & Lai, 1994; Jayawerdana & Gurung, 2000; Elshorbagy *et al*., 2002; Wang *et al*., 2006b). On the other hand, still there are some doubts that have been raised in literature in terms of the existence of chaos in hydrologic data (Ghilardi & Rosso, 1990; Koutsoyiannis & Pachakis, 1996; Pasternack, 1999; Schertzer *et al*., 2002; Wang *et al*., 2006a). Generally, the prediction techniques for a dynamic system can be roughly divided into two approaches; local and global. Local approach uses only nearby states to make predictions where as global approach involves all the states. Engineering fuzzy set theory models, artificial neural networks, k-nearest neighbours, neural fuzzy networks, chaotic theory models, support vector machine models or hybrid models are some typical forecast methods for dynamic systems (Wang *et al*., 2006b; Sivapragasam *et al*., 2001; Laio *et al*., 2003). Phase space reconstruction (PSR) is a precondition before performing any predictions of the dynamic system. Typical methods involved in PSR are correlation integral, singular value decomposition of the sample covariance matrix, false nearest neighbours (FNN) and true vector fields (Grassberger & Procaccia, 1983; Abarbanel *et al*., 1993).

In long or short-term river operation studies, river flow data estimation and monitoring is an important parameter. One of the common methods employed is based on using past observed data and forecasting river discharge in the future or using time series analysis. For more than half century, Box Jenkins methodology using ARMA linear models have dominated many areas of time series forecasting. Box and Jenkins (1970) made ARMA models popular by proposing a model building methodology involving an iterative three stage process of model selection, parameter estimation and model checking. Recent explanations of the process often add a preliminary stage of data preparation and final stage of model application (or forecasting) (Makridakis *et al*., 1998).

The problem of estimating the order and the parameters of a model such as ARMA is an active area of research (Chan, 1999; Souza & Neto, 1996; Tsay & Tiao, 1984). When modelling linear and stationary time series, one frequently chooses the class of ARMA models because of its high performance and robustness.

In recent years, artificial neural networks have been investigated to substitute the ARMA models in estimating time series data. Abrahart and See (2000) compared ARMA models to artificial neural network (ANN) for forecasting river flow data for two contrasting catchments. The relative performance between the ANN and ARMA forecasts were quite similar at each station using common data inputs. Applications of ARMA models in short term rainfall prediction for real-time flood forecasting was investigated by Toth *et al*. (2000). They used three models including ARMA, ANN's and nearest-neighbour approaches. Hwarng (2001) compared an ARMA (p, q) model with an ANN to forecast time series. He presented a summary of other researcher's work and concluded that ANN’S are not better than traditional ARMA models in performance if there is no non-linearity in the data. It is important to note that in the literature of time series forecasting with artificial neural network (ANN), the ARMA model is used as a benchmark to test the effectiveness of the proposed methodology (Hwang, 2001; Tseng *et al*., 2002). Chenoweth *et al*. (2000) showed that an ANN is not able to estimate the order of ARMA models accurately when the number of data points is less than 100. Rojas *et al*. (2008) investigate a hybrid methodology that combines ANN and ARMA models and resolve one of the most important problems in time series using ARMA structure and Box-Jenkins methodology: the identification of the model.

Comparative studies on the above prediction techniques have been further carried out by many researchers. Sivakumar *et al*. (2002) found that the performance of the KNN approach was consistently better than ANN in short term river flow prediction. Laio *et al*. (2003) carried out a comparison of KNN and ANN for flood predictions and found that KNN performed slightly better at short forecast time while the situation was reversed for longer time. Similarly Yu *et al*. (2004) proposed that KNN performed worse than ARIMA on the basis of daily stream flow prediction. Wu and Chau (2010) compare four forecast models, ARMA, ANN, KNN and ANN-PSR and develop an optimal model for monthly stream flow prediction. The conclusions in literature are very inconsistent. It is difficult to justify which modelling technique is more suitable for a stream flow forecast.

CHAPTER 3

NORTHERN PART OF CYPRUS, TROODOS MOUNTAINS DRAINAGE AREA CHARACTERISTICS

3.1 Overview of surface water

Cyprus is an island with a long history dating back several thousands of years before Christ. Its civilization, examples of which are abundantly manifest throughout the island, has been one of the world’s most dominant for hundreds of years .Water has ever since been utilized both for domestic and irrigation purposes and there are cases of lengthy conveyors made up of canals and aqueducts conveying water from distant springs to cities, such as the case of the ancient city of Salamis which was supplied with water from the Kythrea Spring, lying at a distance of about 35 km (Kontetis, 1974).

Unfortunately, Cyprus has no rivers of perennial flow. Most rivers flow only during the winter and spring months, so that no dependable supplies can be obtained from them without storage. In the case of groundwater, it is found in most parts of the island, usually polluted due to anthropogenic and geologic means. With these problems in the ground and surface water development, the possibility for surface water development through the construction of storage reservoirs presents many technical and economic problems such as poor topography and geology. Consequently, the construction of dams in days before the development of modern machinery and dam techniques was a tough proposition. Although in other countries of similar or even less civilization favourable topographic and geologic conditions made possible the construction of dams very early in history, in Cyprus, for the reasons mentioned, this had not become possible until recent years (Konteatis, 1974).

On the other hand, the disadvantages pointed out for the perennial characteristics of rivers were unreliable runoff, heavy sediment transport and adverse effects on downstream water rights and on natural groundwater recharge through river beds. Therefore, important irrigation works the construction of dams were instead carried over via aquifer pumping works producing water at least three times cheaper than surface water storage facilities, dams. However, in the last decade, aquifers have been badly over pumped with a consequential depletion and sea water intrusion in many parts like Famagusta and Morphou aquifers.

In the coming decade the growing demand for irrigation, domestic, industrial and tourism, led the scientist to embark on alternative or integrated water resources plans.

In searching for a new alternative, the limiting conditions such as topography, geology, hydrology, water capacity and requirements should be carefully assessed.

Available surface water resources like river flow must be accurately studied and assess, for the hydrological point of view.

Unfortunately, in Northern part of Cyprus accurate direct measurements of river flows have not been carried since last 40 years. On the other hand, precipitation data for the last 80 years can be achieved from State Meteorological Department.

Therefore, for surface water planning one can rely on hydrological studies and use indirect methods to estimate surface runoff. However, it is vital to rely on real river flow observations while designing water resources structures for irrigation or domestic purposes.

3.2 Overview of Cyprus weather

Cyprus has an intense Mediterranean climate with the typical seasonal rhythm strongly marked with respect to temperature, precipitation and weather in general. Hot dry summers from mid-May to mid-September and rainy, rather changeable, winters from November to mid-March are separated by short autumn and spring seasons of rapid change in weather conditions. The typical annual distribution of the mean monthly precipitation hydrologic years between 1916/1917 to 1999/2000 in Cyprus is shown in Fig 3.1 (Rossel, 2001).

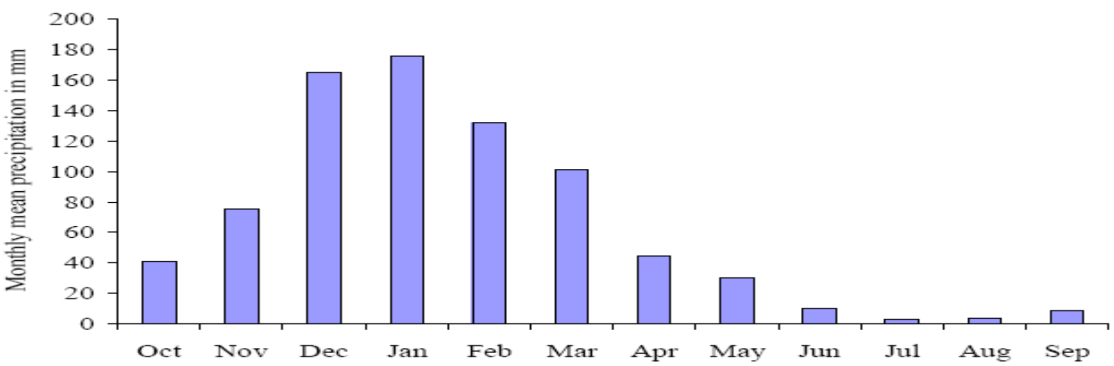

Figure 3.1 The typical annual distribution of the mean monthly precipitation hydrologic years between 1916/17 to 1999/2000 in Cyprus (Station: 110-Ayia) (Rossel, 2001).

The central Troodos massif, raising to 1951 meters a.m.s.l., and to a less extent the long narrow Kyrenia mountain range, with peaks of about 1000 meters a.m.s.l. play an important part in the meteorology of Cyprus. The predominantly clear skies and high sunshine amounts give large seasonal and daily differences between temperatures of the sea and the interior of the island that also causes considerable local effects especially near the coasts.

The average precipitation from December to February being about 60% of the annual total is the main reason of ephemeral river distribution all around the island.

The average precipitation for the year as a whole is about 500 mm but it was as low as 182 mm in 1972/1973 and as high as 759 mm in 1968/1969. The average precipitation refers to the island as a whole and covers the period 1961-1990. Statistical analysis of precipitation in Cyprus reveals a decrease of precipitation amounts in the last 30 years.

The mean annual precipitation increases up on the south-western windward slopes from 450 millimetres to nearly 1100 millimetres at the top of the central massif. On the leeward slopes amounts decrease steadily northwards and eastwards to between 300 and 350 millimetres in the central plain and the flat south eastern parts of the island.

The narrow ridge of the Kyrenia range, stretching 80 kilometres from west to east along the extreme north of the island, produces a relatively small increase of precipitation to nearly 550 millimetres along its ridge at about 1000 metres a.m.s.l.

Precipitation in the warmer months contributes little or nothing to water resources and agriculture. The small amounts that fall are rapidly absorbed by the very dry soil and soon evaporated by high temperatures and low humidity. Autumn and winter precipitation, on which agriculture and water supply generally depend, is somewhat variable. About 60% of annual precipitation is recorded during the winter months (Rossel, 2001).

Statistical analysis of the records available over the period of the hydrological years 1918-2008 shows that the precipitation time series displays a step change around 1970 at Northern part of Cyprus and can be divided into two separate periods. From 1918 to 1970 the increase in precipitation records show positive deviations from mean annual average values, where as after 1970 this deviation has shown that there is a decreasing trend on the precipitation rates of Northern part of Cyprus (Gökçekuş *et al*., 2009).

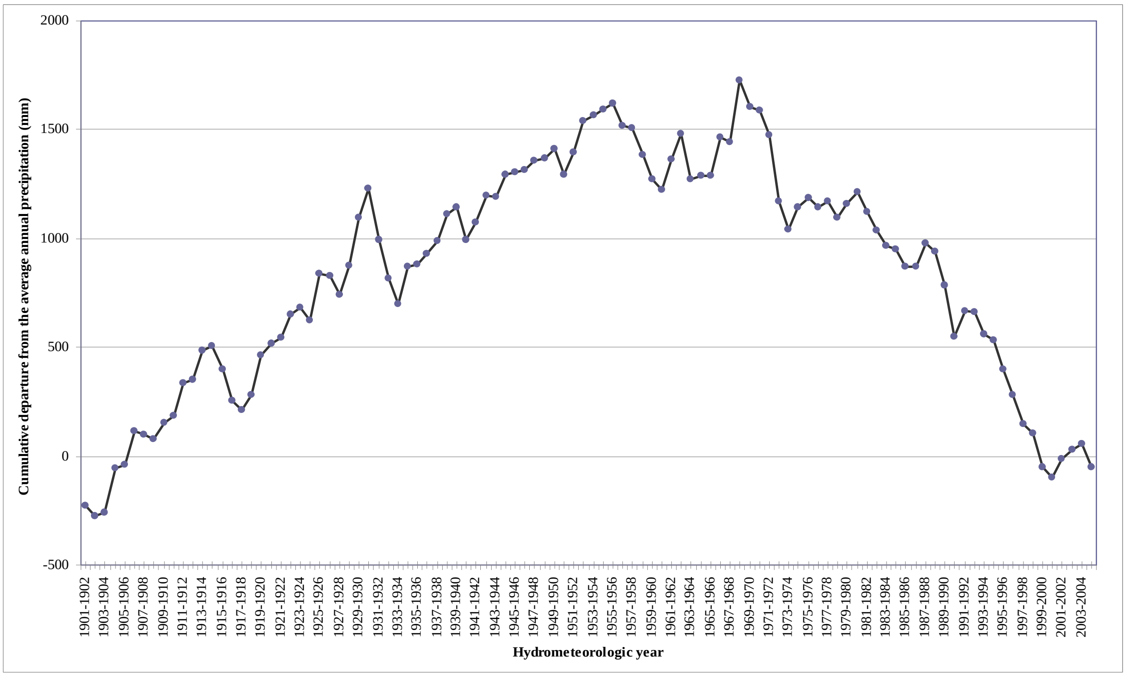

Figure 3.2 Cumulative departures from the average annual precipitation in Northern part of Cyprus. (mm) (Gökçekuş *et al*. 2009).

3.3 Troodos Massif northern drainage area

Eighty percent of surface runoff in Cyprus is generated in the Troodos Mountains. The seasonal distribution of surface runoff follows the seasonal distribution of precipitation, with minimum values during the summer months and maximum values during the winter months. As a result of the eastern Mediterranean climate with long hot summers and a low mean annual precipitation, there are no rivers with perennial flow along their entire length. Most rivers flow 3 to 4 months a year and are dry during the rest of the year. Only parts of some rivers upstream in the Troodos areas have a continuous flow. Most rivers have a rather steep slope except for the rivers in the low land areas (Klohn, 2002).

The flow of the rivers at the Northern part of Cyprus is usually characterized with relatively short term flows due to rains. However, the rivers originating from the Troodos Mountains are more regular and have constant flow due to high precipitation. Ten of the main rivers in the Northern part of Cyprus originating from the Troodos Mountains are carrying an estimated average of 92 mcm of water annually (DSI, 2003).

However, this annual precipitation value is estimated via theoretical calculations such as production of synthetic unit hydrographs. As it is mentioned before real river flow observations must be gathered in order to be able to design, water resources structures on those rivers. Therefore, since most of these rivers are controlled and monitored at their upper reaches, it would be more reliable to use these data and predict future flow rates for those 10 rivers. The estimated flow rates of 10 rivers are given in Table 3.1 (DSI, 2003).

Table 3.1 Ten main rivers originating from Troodos Mountains (DSI, 2003).

River code	River name	Catchment name	Annual average surface runoff (mcm)
1.1	Yeşilırmak (Limnitis)	Yeşilırmak (Limnitis)	10,5
1.3	Yedidalga (Kambos)	Yedidalga (Kambos)	2,7
1.5	Maden (Xeros)	Maden (Xeros)	9,6
1.6	Lefke (Marathasa)	Lefke (Marathasa)	10,0
1.7	Çamlı (Karyotis)	Çamlı (Karyotis)	13,8
1.8	Çakıl (Atsas)	Çakıl (Atsas)	3,5
1.9	Doğancı (Elea)	Doğancı (Elea)	9,5
1.11	Güzelyurt (Serakhis)	Güzelyurt (Serakhis)	16,1
2.1	Kanlı (Pedios)	Kanlı (Pedios)	11,4
2.5	Çakıllı (Yialias)	Çakıllı (Yialias)	5,1
	All 10 rivers		92,2

3.3.1 Data analysis

The study area covers the north-west part of Cyprus. All the rivers are draining from Troodos Mountains. Between 1965-1993 flows observations on these rivers were made on a limited number of times. These data are available on Kypris and Neophytou (1994). However the gaps on these have been completed by the data gathered from the report on surface water resources Rossel (2002). These two data sources are than reviewed and the final data river flow data tables are created, covering river flow data of 10 rivers from 1965 to 1999. Table 3.2 gives the stream gauge stations on these rivers and their identification.

Table 3.2 Table of the stream gauge station identification (DHW, 2006).

Station number	**Station name**	**Drainage area(km^2)**	**Number of years of data**
128301810	Limnitis	90,69	33
131101770	Xeros	94,97	29
132103085	Marathasa	91,91	26
133304195	Karyotis	93,55	34
134204790	Atsas	64,66	34
135407440	Elea	162,51	34
137108550-137311690	Peristerona and Akaki	737,45*	34
161113185	Pedios	867,14	24
165115385	Yialias	598,39	29

* 737.45 km^2 represents the total drainage area of Serakhis River, which covers the watersheds of Peristerona and Akaki Rivers.

3.4 Characteristics of water resources data

Data analyzed by the water resources scientist often have the following characteristics (Helsel & Hirsch, 1991).

1. A lower bound of zero. No negative values are possible.
2. Presence of 'outliers', observations considerably higher or lower than most of the data, which infrequently but regularly occur. Outliers on the high side are more common in water resources.
3. Positive skewness, due to items 1 and 2. An example of a skewed distribution, the log normal distribution, is presented in Fig. 3.3. Values of an observation on the horizontal axis are plotted against the frequency with which that value occurs. These density functions are like histograms of large data sets whose bars become infinitely narrow. Skewness can be expected when outlying values occur in only one direction.
4. Non-normal distribution of data, due to items 1-3 above. Fig. 3.4 shows an important symmetric distribution, the normal. While many statistical tests assume data follow a normal distribution as in Fig. 3.4, water resources data often look more like Fig. 3.3. In addition, symmetry does not guarantee normality. Symmetric data with more observations at both extremes (heavy tails) than occurs for a normal distribution are also non-normal.
5. Data reported only as below or above some threshold (censored data). Examples include concentrations below one or more detection limits, annual flood stages known only to be lower than a level which would have caused a public record of the flood, and hydraulic heads known only to be above the land surface (artesian wells on old maps).
6. Seasonal patterns. Values tend to be higher or lower in certain seasons of the year.
7. Autocorrelation. Consecutive observations tend to be strongly correlated with each other. For the most common kind of autocorrelation in water resources (positive autocorrelation), high values tend to follow high values and low values tend to follow low values.
8. Dependence on other uncontrolled variables. Values strongly cover with water discharge, hydraulic conductivity, sediment grain size, or some other variable.

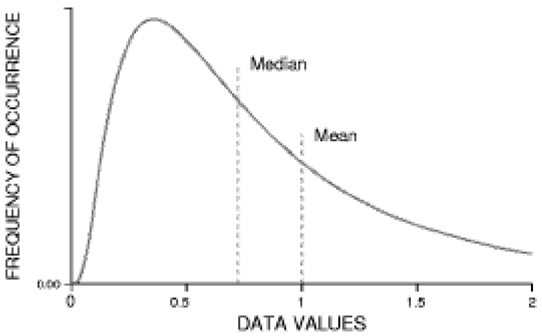

Figure 3.3 Probability density functions for a log normal distribution (Helsel & Hirsch, 1991).

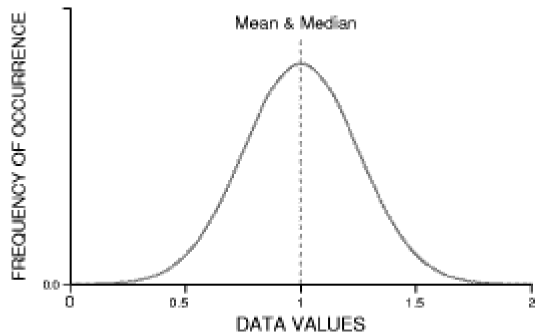

Figure 3.4 Probability density functions for a normal distribution (Helsel & Hirsch, 1991).

3.4.1 Measures of location

The mean and median are the two most commonly-used measures of location.

The mean (μ) is computed as the sum of all data values X_i, divided by the sample size *n*:

$$\mu = \sum_{i=1}^{n} \frac{X_i}{n} \qquad (3\text{-}1)$$

The median, or 50^{th} percentile $P_{0.50}$, is the central value of the distribution when the data are ranked in order of magnitude. For an odd number of observations, the median is the data point which has an equal number of observations both above and below it. For even number observations, it is the average of the two central observations. To compute the median, the observations are arranged from smallest to largest, so that X_i is the smallest observation, up to X_n, the largest observation. Then

$$\text{Median } (P_{0,50}) = \frac{X_{n+1}}{2} \text{ when } n \text{ is odd, and} \tag{3-2}$$

$$\text{Median } (P_{0,50}) = \frac{X_{\frac{n}{2}} + X_{\frac{n}{2}+1}}{2} \text{ when } n \text{ is even} \tag{3-3}$$

The median is only minimally affected by the magnitude of a single observation, being determined solely by the relative order of observations. This resistance to the effect of a change in value or presence of outlying observations is often a desirable property (Helsel & Hirsch, 1991).

3.4.2 Measures of spread

It is just as important to know how variable the data are as it is to know their general center or location. Variability is quantified by measures of spread.

The sample variance, and its square root the sample standard deviation, are the classical measures of spread. Like the mean, they are strongly influenced by outlying values (Helsel & Hirsch, 1991).

$$\sigma^2 = \sum_{i=1}^{n} \frac{(X_i - \mu)^2}{(n-1)} \qquad \text{Sample variance} \tag{3-4}$$

$$\sigma = \sqrt{\sigma^2} \qquad \text{Sample standard deviation} \tag{3-5}$$

3.4.3 Measures of skewness

Hydrologic data are typically skewed, meaning that data sets are not symmetric around the mean or median, with extreme values extending out longer in one direction. The density function for a lognormal distribution shown previously in Fig. 3.3 illustrates this skewness. When extreme values extend the right tail of the distribution, as they do with Fig. 3.3, the data are said to be skewed to the right, or positively skewed. Left skewness, when the tail extends to the left, is called negative skew.

The coefficient of skewness (*g*) is the skewness measure used most often. It is the adjusted third moment divided by the cube of the standard deviation (Helsel & Hirsch, 1991).

$$g = \frac{n}{(n-1)(n-2)} \sum_{i=1}^{n} \frac{(X_i - \mu)^3}{\sigma^3} \qquad (3\text{-}6)$$

3.5 Summarizing measured data

One of the most frequent tasks when analysing data is to describe and summarize those data in forms which convey their important characteristics "What is the flow rate of a river?" ,"How variable is sediment transport?" ,"What is the 100 year flood?" Estimation of these and similar summary statistics are basic to understanding sample data. Statistics computed from the sample data are only inferences or estimates about characteristics of the data, such as location, spread and skewness. Measure of location is usually the sample mean and sample median. Measures of spread include the sample standard deviation. The characteristics of data often describe selection of appropriate data analysis procedures of the sample. In this study all these measures are calculated for the 10 rivers under the consideration. Table 3.3 summarizes the results of these measuring studies.

Table 3.3 Surface runoff statistics of 10 rivers.

Limnitis (Station: 128301810)		**Xeros(Station: 131101770)**	
Number of datas (*N*)	33	Number of datas (*N*)	29
Mean (μ)	10,60 mcm	Mean (μ)	5,15 mcm
Median ($P_{0,50}$)	8,67 mcm	Median ($P_{0,50}$)	5,00 mcm
Standard Deviation (σ)	6,56 mcm	Standard Deviation (σ)	2,67 mcm
Variance (σ^2)	43,04 mcm	Variance (σ^2)	7,12 mcm
Skewness (*g*)	0,54	Skewness (*g*)	0,30
Minimum (*min*)	1,50 mcm	Minimum (*min*)	0,74 mcm
Maximum (*max*)	25,55 mcm	Maximum (*max*)	10,75 mcm

Marathasa (Station: 132103085)		**Karyotis (Station: 133304195)**	
Number of datas (*N*)	26	Number of datas (*N*)	34
Mean (μ)	6,19 mcm	Mean (μ)	10,92 mcm
Median ($P_{0,50}$)	6,11 mcm	Median ($P_{0,50}$)	9,39 mcm
Standard Deviation (σ)	3,40 mcm	Standard Deviation (σ)	6,73 mcm
Variance (σ^2)	11,56 mcm	Variance (σ^2)	45,30 mcm
Skewness (*g*)	1,30	Skewness (*g*)	1,62
Minimum (*min*)	1,14 mcm	Minimum (*min*)	2,04 mcm
Maximum (*max*)	17,48 mcm	Maximum (*max*)	35,93 mcm

Table 3.3 (Continuous) Surface runoff statistics of 10 rivers.

Atsas (Station: 134204790)		**Elea (Station: 135407440)**	
Number of datas (*N*)	34	Number of datas (*N*)	34
Mean (μ)	1,62 mcm	Mean (μ)	5,53 mcm
Median ($P_{0,50}$)	0,99 mcm	Median ($P_{0,50}$)	4,55 mcm
Standard Deviation (σ)	2,22 mcm	Standard Deviation (σ)	5,46 mcm
Variance (σ^2)	4,93 mcm	Variance (σ^2)	29,78 mcm
Skewness (*g*)	2,54	Skewness (*g*)	2,10
Minimum (*min*)	0,01 mcm	Minimum (*min*)	0,11 mcm
Maximum (*max*)	9,54 mcm	Maximum (*max*)	27,23 mcm

Peristerona (Station: 137108550)		**Akaki (Station: 137311690)**	
Number of datas (*N*)	34	Number of datas (*N*)	34
Mean (μ)	12,91 mcm	Mean (μ)	10,46 mcm
Median ($P_{0,50}$)	11,59 mcm	Median ($P_{0,50}$)	9,75 mcm
Standard Deviation (σ)	7,89 mcm	Standard Deviation (σ)	8,59 mcm
Variance (σ^2)	62,29 mcm	Variance (σ^2)	73,84 mcm
Skewness (*g*)	1,13	Skewness (*g*)	2,10
Minimum (*min*)	1,67 mcm	Minimum (*min*)	0,76 mcm
Maximum (*max*)	38,97 mcm	Maximum (*max*)	45,02 mcm

Pedios (Station: 161113185)		**Yialias (Station: 165115385)**	
Number of datas (*N*)	24	Number of datas (*N*)	29
Mean (μ)	4,42 mcm	Mean (μ)	4,04 mcm
Median ($P_{0,50}$)	3,75 mcm	Median ($P_{0,50}$)	2,82 mcm
Standard Deviation (σ)	2,82 mcm	Standard Deviation (σ)	3,45 mcm
Variance (σ^2)	7,92 mcm	Variance (σ^2)	11,89 mcm
Skewness (*g*)	1,26	Skewness (*g*)	1,17
Minimum (*min*)	0,93 mcm	Minimum (*min*)	0,48 mcm
Maximum (*max*)	12,88 mcm	Maximum (*max*)	13,14 mcm

CHAPTER 4
CORRELATION

Correlation is the measure of the strength of association between the two continuous variables. Of interest is whether one variable generally increases as the second increases, whether it decreases as the second increases, or whether their patterns of variation are totally unrelated. Correlation measures observed co-variation. It does not provide evidence for causal relationship between the two variables. One may cause the other, as precipitation causes runoff. They may also be correlated because both share the same cause, such as two solutes measured at a variety of times or a variety of location. Evidence for causation must come from outside the statistical analysis from the knowledge of the processes involved (Helsel & Hirsch, 1991).

"ρ" is a measure of correlation which depends on data values of the population, the mean and the standard deviation of the population, rank values of the population and the monotic dependence of one population on other, such as Kendall's correlation method, Sperman's correlation method and Pearson's correlation method. Measures of correlation have the characteristic of being dimensionless and scaled in the range $1 \leq \rho \leq -1$. When there is no correlation between two variables, $\rho = 0$. When one variable increases as the second increases, ρ is positive. When they vary in opposite directions, ρ is negative. The significance of the correlation is evaluated using a hypothesis test.

H_0: $\rho = 0$ versus H_1: $\rho \neq 0$

When one variable is a measure of time or location, correlation becomes a test for temporal or spatial trend (Helsel & Hirsch, 1991).

4.1 Hypothesis test

Hypothesis tests which assume that the data have a particular distribution (usually a normal distribution, as in Fig. 3.4) are called parametric tests. Since the information contained in the data is summarized by parameters, usually the mean and standard deviation, and the test statistic are computed using these parameters.

Hypothesis tests not requiring the assumption that data follow a particular distribution are called distribution-free or non-parametric tests. Information is extracted from the data by comparing each value with all others rather than by computing parameters (Helsel & Hirsch, 1991).

4.1.1 Prediction intervals

The question is often asked whether one new observation is likely to have come from the same distribution as previously collected data, or alternatively from a different distribution. This can be evaluated by determining whether the new observation is outside the prediction interval computed from existing data. Prediction intervals contain 100*(1-α) percent of the data distribution, while 100*α percent are outside of the interval. If a new observation comes from the same distribution as previously measured data, there is a 100*α percent chance that it will lie outside of the prediction interval.

4.1.2 One-sided prediction intervals

One sided prediction intervals are appropriate if the interest is in whether a new observation is larger than existing data, or smaller than existing data but not both. The decision to use a one-sided interval must be based entirely on the question of interest. It should not be determined after looking at the data and deciding that the new observation is likely to be only larger, or only smaller, than existing information. One sided intervals use α rather than α/2 as the error risk, placing all the risk on one side of the interval (Fig. 4.1) (Helsel & Hirsch, 1991).

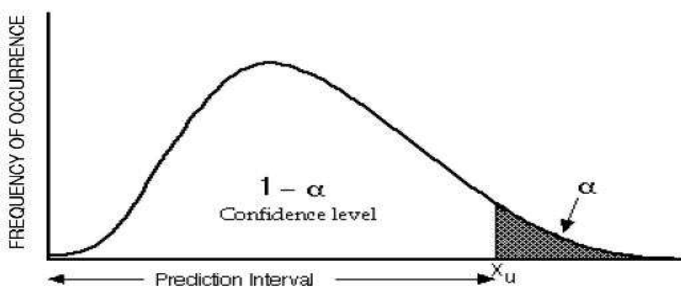

Figure 4.1 One-sided prediction intervals (Helsel & Hirsch, 1991).

4.1.3 Two-sided prediction intervals

The prediction interval of confidence level α is simply the interval between the α/2 and 1-(α/2) percentiles of the distribution (Fig 4.2). This interval contains 100*(1-α) percent of the data, while 100*α percent lies outside of the interval. Therefore if the new additional data point comes from the same distribution as the previously measured data, there is a 100*α percent chance that it will lie outside of the prediction interval (Helsel & Hirsch, 1991).

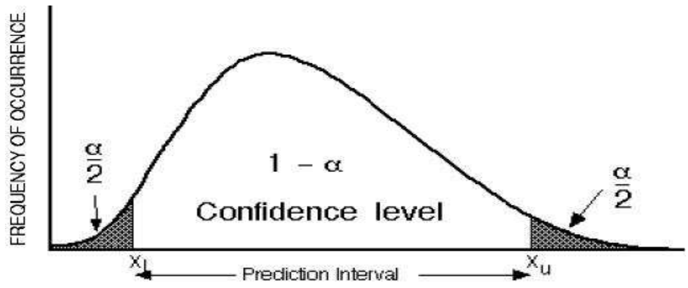

Figure 4.2 Two-sided prediction intervals (Helsel & Hirsch, 1991).

4.1.4 Decide on an acceptable error rate α

The α values, or significance level, is the probability of incorrectly rejecting the null hypothesis (rejecting H_0 when it is in fact true, called a "*Type I* error"). Fig. 4.3 shows that this is one of four possible outcomes of a hypothesis test. The significance level is the risk of a *Type I* error deemed acceptable by the decision maker. It is a "management tool" dependent not on the data, but on the objectives of the study. Statistical tradition uses a default of 5% for α, but there is no reason why other values should not be used. Let's suppose that an expensive cleanup process will be mandated if the null hypothesis of "no contamination" is rejected, for example. The α-level for this test might be set very small (such as 1%) in order to minimize the chance of needless cleanup costs. On the other hand, suppose the test was simply a first cut at classifying sites into "high" and "low" values prior to further analysis of the "high" sites. In this case the α-level might be set to 0.10 or 0.20 (Helsel & Hirsch, 1991).

Since α represents one type of error, why not keep it as small as possible? One way to do this would be to never reject $H_{0,}$ α would than equal zero. Unfortunately this would lead to large errors of a second type, failing to reject H_0 when it was in fact false. This second type of error is called a *Type II* error, or lack of power (Fig 4.3). Both errors are of concern to practitioners, and both will have some finite probability of occurrence unless decision to “always reject” or “never reject” are made. Once a decision is made as to an acceptable *Type I* risk α, two steps can be taken to concurrently reduce the risk of *Type II* error β.

1. The sample size *n* increases.

2. The test procedure with the greatest power for the type of data being analyzed.

For water quality applications, null hypotheses are usually of “no contamination” situations with low power that actual contamination may not be detected. This happens with simplistic formulas for determining sample sizes. Instead, probabilities of *Type II* errors should be considered when setting sample size. Power is also sacrificed when data having the characteristics outlined are analyzed with tests requiring a normal distribution. Power loss increases as skewness and the number of outliers increase (Helsel & Hirsch, 1991).

		Unknown True Situation	
		H_0 is true	H_0 is false
Decision	Fail to Reject H_0	Correct decision Prob (correct decision)=1-α	Type II error Prob (Type II error)=β
	Reject H_0	Type I error Prob (Type I error)=α **Significance level**	Correct decision Prob (correct decision)=1-β **Power**

Figure 4.3 Four possible results of hypothesis testing (Helsel & Hirsch, 1991).

4.1.5 Compute the test statistics from the data

Test statistics summarize the information contained in the data. If the test statistic is not unusually different from what is expected to occur if the null hypothesis is true, the null hypothesis is not rejected. However, if the test statistic is a value unlikely to occur when H_0 is true, the null hypothesis is rejected. The *p*-value measures how unlikely the test statistic is when H_0 is true (Helsel & Hirsch, 1991).

4.1.6 Compute the *p* value

The *p*-value is the probability of obtaining the computed test statistic, or one even less likely, when the null hypothesis is true. It is derived from the data, concisely expressing the evidence against the null hypothesis contained in the data. It measures the "believability" of the null hypothesis .The smaller the *p*-value, the less likely is the observed test statistic when H_0 is true, and the stronger the evidence for rejection of the null hypothesis. The *p*-value provides more information the strength of the scientific evidence (Helsel & Hirsch, 1991).

4.2 Kendall's correlation method

Kendall's correlation method (Kendall, 1938 and Kendall, 1975) measures the strength of the monotonic relationship between *x* and *y*. The model is a rank based procedure and is therefore resistant to the effect of a small number of unusual values. It is well suited for variables which exhibit skewness around the general relationship. Since the correlation coefficient of Kendall's correlation method depends only on the ranks of the data and not the values themselves. It can be implemented even in cases where some of the data are censored, such as concentrations known only as less than the reporting limit (Helsel & Hirsch, 1991).

Kendall' correlation coefficient generally is lower than values of the traditional Pearson's correlation coefficient for linear associations of the same strength. "Strong" linear correlations of 0.9 or above correspond to Kendall's correlation coefficient values of about 0.7 or above. These lower values do not mean that Kendall's correlation coefficient is less sensitive than Pearson's correlation coefficient, but simply that a different scale of correlation is being used. Kendall correlation coefficient is easy to compute by hand, resistant to outliers, and measures all monotonic correlations (linear and nonlinear). Its large sample approximation produces *p* values very near exact values, even for small sample sizes. As it is a rank correlation method, is invariant to monotonic power transformations of one or both variables. For example, Kendall's correlation coefficient of log(*y*) versus log(*x*) will be identical to that of *y* versus log(*x*), and of *y* versus *x* (Helsel & Hirsch, 1991).

4.2.1 Computation

Kendall's correlation coefficient is most easily computed by first ordering all data pairs by increasing *x*. If a positive correlation exists, the *y*'s will increase more often than decrease as *x* increases. For a negative correlation, the *y*'s will decrease more often than increase. If no correlation exists, the *y*'s will increase and decrease about the same number of times.

A two-sided test for correlation will evaluate the following equivalent statements for the null hypothesis H_0, as compared to the alternate hypothesis H_1:

H_0: ***a.*** No correlation exists between *x* and *y* ($\rho_{Kendall}$ =0), or

b. *x* and *y* are independent, or

c. The distribution of *y* does not depend on *x*, or

d. Probability ($y_i < y_j$ for $i<j$) =1/2

H_1: ***a.*** *x* and *y* are correlated ($\rho_{Kendall} \neq 0$), or

b. *x* and *y* are dependent, or

c. The distribution of y (percentiles, etc.) depends on *x*, or

d. Probability ($y_i < y_j$ for $i<j$) $\neq 1/2$

The test statistics *S*; measures the monotonic dependence of *y* on *x*. Kendall's *S* is calculated by subtracting the number of "discordant pairs" *M*, the number of (*x*, *y*) pairs where *y* decreases as *x* increases, from the number of "concordant pairs" *P*, the number of (*x*, *y*) pairs where *y* increases with increasing *x*:

$$S = P - M \qquad (4\text{-}1)$$

Where;

P="number of pluses", the number of times the *y*'s increase as the *x*'s increase, or the number of, $y_i < y_j$ for all $i<j$

M="number of minuses," the number of times the *y*'s decrease as the *x*'s increase, or the number of $y_i > y_j$ for all $i<j$,

For all i=1,… (n-1) and j= (i+1),…n

There are $n(n-1)/2$ possible comparisons to be made among the *n* data pairs. If all *y* values increased along with the *x* values, $S=n(n-1)/2$. In this situation, the correlation coefficient $\rho_{Kendall}$ should equal +1. When all *y* values decrease with increasing *x*, $S=-n(n-1)/2$ and $\rho_{Kendall}$ should equal -1. Therefore dividing *S* by $n(n-1)/2$ will give a value always falling between -1 and +1. This then is the definition of $\rho_{Kendall}$ measuring the strength of the monotonic association between two variables:

Kendall's correlation coefficient;

$$\rho_{Kendall} = \frac{S}{\frac{n(n-1)}{2}} \tag{4-2}$$

To test for significance of Kendall's correlation coefficient, *S* is compared to what would be expected when the null hypothesis is true. If it further from 0 than expected, H_0 is rejected. For $n \leq 10$ the table of *p* values for Kendall's *S* statistics and Kendall's correlation coefficient is found in appendix 5.4. For $n \geq 10$ the test statistic can be modified to be closely approximated by a normal distribution (Helsel & Hirsch, 1991).

$$\mu_S = 0 \tag{4-3}$$

$$\sigma_S = \sqrt{\frac{n(n-1)(2n+5)}{18}} \tag{4-4}$$

$$Z_S = \begin{cases} \frac{S-1}{\sqrt{\sigma_S}} & \text{If S>0} \\ 0 & \text{If S=0} \\ \frac{S+1}{\sqrt{\sigma_S}} & \text{If S<0} \end{cases} \tag{4-5}$$

The null hypothesis is rejected at significance level α if $Z_S > Z_{critical}$ is the value of the standard normal distribution with a probability of exceed of α/2 (Helsel & Hirsch, 1991).

Example 1: (Helsel & Hirsch, 1991) 10 pairs of *x* and *y* are given below, ordered by increasing *x.*

y	1,22	2,20	4,8	1,28	1,97	1,46	2,64	2,34	4,84	2,96
x	2	24	99	197	377	544	632	3452	6587	53,17

To compute S, first compare y_1=1.22 with all subsequent y’s (y_j, ,j>1),

2.20 >1.22, so score a+

4.80>1.22, score a+

1.28>1.22, score a+

1.97>1.22, score a+ etc.

All subsequent y’s are larger, so there are 9+’s for i=1.

For i=2, and compare y_2=2.20 to all subsequent y’s.

4.80>2.20, so score a+

1.28<2.20, score a-

1.97<2.20, score a-

1.46<2.20, score a-

There are 5+’s and 3-‘s for i=2.Continue in this way, until the final comparison of y_{n-1}=4.84 to y_{n}.. It is convenient to write all +’s and -‘s below their respective y_i ,as below:

y_i	1,22	2,20	4,80	1,28	1,97	1,46	2,64	2,34	4,84	2,96
	+	+	-	+	-	+	-	+	-	
	+	-	-	+	+	+	+	+		
	+	-	-	+	+	+	+			
	+	-	-	+	+	+				
	+	+	-	+	+					
	+	+	+	+						
	+	+	-							
	+	+								
	+									

In total there are 33+’s (P=33) and 12-‘s (M=12).

Therefore S=33-12=21 (4-6)

There are10*9/2=45 possible comparisons, so;

$\rho_{Kendall}$ =21/45=21/45=0.47 (4-7)

Turning to exact critical value table,

For n=10 and S=21, the exact p value is 2*0.036 = 0.072

The large sample approximation is;

$$Z_S = (21-1)/\sqrt{(10/18)*(10-1)*(20+5)} = 20/11.18 = 1.79 \qquad (4\text{-}8)$$

from a table of the standard normal distribution, for 1.79 is 0.0367 So that
$p \approx 2*0.0367 = 0.074$;

0.074 and larger than 0.074 significance, ρ =0 Hypothesis decision rejected Both populations are 0.10 significance level dependent.

4.3 Sperman's correlation method

Sperman's correlation method is an alternative rank correlation coefficient to Kendall's correlation method. Sperman's correlation method is easiest to understand as the linear correlation coefficient computed on the ranks of the data. The model can be computed as a rank transform method. Sperman's correlation coefficient and Kendall's correlation coefficient use different scales to measure the same correlation. Though Kendall's correlation coefficient is generally lower than Sperman's correlation coefficient in magnitude, their *p*-values for significance should be quite similar when computed on the same data (Helsel & Hirsch, 1991).

To compute Sperman's correlation coefficient, the data for the two variables are ranked independently among themselves. For the ranks of *x*, (Rx_i) and ranks of *y*, (Ry_i) Sperman's correlation coefficient can be computed from the equation:

$$\rho_{Sperman} = \frac{\sum_{i=1}^{n}(Rx_i Ry_i) - n\left(\frac{n+1}{2}\right)^2}{\frac{n(n^2-1)}{12}} \qquad (4\text{-}9)$$

Where $(n+1)/2$ is the mean rank of both *x* and *y*. If there is a positive correlation, the higher ranks of *x* will be paired with the higher ranks of *y*, and their product will be large. For a negative correlation the higher ranks of *x* will be related to lower ranks of *y*, and their product will be small. When there is no correlation, there will be nothing other than a random pattern in the association between *x* and *y* ranks, and their product will be similar to the product of their average rank, the second term in the numerator of equation (4.9). Thus Sperman's correlation coefficient will be close to zero (Helsel & Hirsch, 1991).

It is important to note that the Sperman's correlation method do not fit the distribution of the test statistic well for small sample sizes (n<20), in contrast to

Kendall's correlation method. This is one reason Kendall's correlation method is often preferred over Sperman's correlation method (Helsel & Hirsch, 1991).

The significance of Sperman's correlation coefficient can be tested by determining whether $\rho_{Sperman}$ differs from zero. The test statistic t is computed by equation (4-10), and compared to a table of the t distribution with n-2 degree of freedom (Helsel & Hirsch, 1991).

$$t = \frac{\rho_{Sperman}\sqrt{n-2}}{\sqrt{1-\rho_{Sperman}{}^{2}}} \tag{4-10}$$

4.4 Pearson's correlation method

The most commonly used method is Pearson's correlation method. It is also called the linear correlation coefficient because Pearson's correlation coefficient measures the linear association between two variables (Helsel & Hirsch, 1991).

Pearson's correlation method is not as resistant to outliers as was Kendall's correlation method and Sperman's correlation method because it is computed using non-resistant measures, means and standard deviations. It assumes that the data follow a bivariate normal distribution. With this distribution, not only do the individual variables x and y follow a normal distribution, but their joint variation also follows a specified pattern. This assumption rules out the use of Pearson's correlation method when the data have increasing variance. Skewed variables often demonstrate outliers and increasing variance. Thus the method is not useful for describing the correlation between untransformed hydrological variables (Helsel & Hirsch, 1991).

Pearson's correlation coefficient is invariant to scale changes, as in converting stream flows in cubic feet per second into cubic meter per second, etc. This dimensionless property is obtained by standardizing, dividing the distance from the mean by the sample standard deviation, as shown in the formula

$$\rho_{Pearson} = \frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{x_i-\mu_x}{\sigma_x}\right)\left(\frac{y_i-\mu_y}{\sigma_y}\right) \tag{4-11}$$

The significance of Pearson's correlation coefficient can be tested by determining whether $\rho_{Pearson}$ differs from zero. The test statistic *t* is computed by equation (4-12), and compared to a table of the *t* distribution with *n*-2 degree of freedom (Helsel & Hirsch, 1991).

$$t = \frac{\rho_{Pearson}\sqrt{n-2}}{\sqrt{1-\rho_{Pearson}{}^{2}}} \qquad (4\text{-}12)$$

CHAPTER 5

TIME SERIES MODELLING

5.1 Time series

A time series is a sequence of observations *(X_1, X_2,...X_i)* ordered in discrete time (Δt) intervals. If there is a statistical relationship between X_i and X_{i+1}, X_i produces a stochastic process (Bayazıt, 1996).

Since the probability density function and parameters are not enough to determine the sample of time series with stochastic process, internal dependencies between sequences must also investigated (Bayazıt, 1996).

These internal dependencies between sequences of observations are measured by autocorrelation coefficients. The autocorrelation coefficient can be used to detect non-randomness in data and to identify an appropriate time series model if the data are not random. The autocorrelation function can be defined as:

$$r_k = \frac{\sum_{i=1}^{n-k}(X_i - \mu)(X_{i+k} - \mu)}{\sum_{i=1}^{n}(X_i - \mu)^2} \qquad (5\text{-}1)$$

In which, r_k is the autocorrelation coefficient; k is the interval number of the autocorrelations; n is the total number of the data; μ is the mean of the data; X_i is the i^{th} period of the data (Bayazıt, 1996).

The standard deviation of σ_{rk} sampling distribution;

$$\sigma_{rk} = \frac{(n-k-1)^{1/2}}{n-k} = \frac{1}{\sqrt{n}} \qquad (5\text{-}2)$$

The main importance of the stochastic process is the stationary of the sequences. The autocorrelation coefficients are also dependent from time like, probability density function and parameters (Bayazıt, 1996).

An important step in analyzing time series data is to consider the types of data patterns, so that the models most appropriate to those patterns can be utilized. Four types of time series components can be distinguished. They are;

i. **Trend and Jump:** Trend occurs when there is long term decrease or increase in the data, whereas jump occurs at sudden decrease or sudden increase in the data.

ii. **Periodic component:** When the data changes according to particular time period, T, the data can be explained by the help of Fourier expansion.

iii. **Internal dependent component:** Statistical internal dependencies between X_i with $X_{i-1}, X_{i-2...}$

iv. **Irregular component:** Remaining component that the above components separated from time series (Bayazıt, 1996).

5.2 The modelling of time series

5.2.1 Model identification

At the first stage of the iterative approach to model building, the identification (specification) stage one uses the data and the knowledge of the system to suggest an appropriate parsimonious sub class of models which may be tentatively entertained (Ledolter,1976).

5.2.2 Model estimation

At this stage efficient use of the data is made by making inferences about the parameters conditionally on the adequacy of the entertained model (Ledolter, 1976).

5.2.3 Diagnostic checking

After fitting the tentatively entertained models to the observed data one has to check the fitted model in its relation to the observed data with intent to reveal model inadequacies and to achieve improvement (Ledolter, 1976).

5.2.4 Model using

After selecting the suitable model synthetic series derived. These series can be use in simulation projects and other suitable using area of flow models to predict the future flows (Ledolter, 1976).

5.3 Yearly flow modelling

Yearly flows are assumed as stationary. During setting up of a model it is necessary to simplify the X_i flows standardized with the above equation (Bayazıt, 1996);

$$y_i = \frac{X_i - \mu_x}{\sigma_x} \tag{5-3}$$

After standardization the mean of the y_i variable will be zero, standard deviation will be one. By inverse transformation can be reach to X_i values. Yearly flow modeling time series can be divided into three model;

- ***i.*** Autoregressive models (Markov models), AR (p)
- ***ii.*** Autoregressive moving average models, ARMA (p, q)
- ***iii.*** Moving average models MA (q)

5.3.1 Autoregressive models (Markov models); AR (*p*)

General expression of Markov models can be defined as:

$$y_i = \sum_{j=1}^{p} \phi_1 y_{i-j} + \varepsilon_i \tag{5-4}$$

$$y_i = \phi_1 y_{i-1} + \phi_2 y_{i-2} + ... + \phi_p y_{i-p} + \varepsilon_i \tag{5-5}$$

In which, y_i is the flow of the i^{th} year; ϕ_p is the autoregressive coefficients for autoregressive models; ε_i is the residuals; p is the order of model, p^{th} order Markov model defines the flow of any year which depend on previous p year flow (Bayazıt, 1981).

Autoregressive coefficients ϕ_p can be computed with below matrix form. r_p is the autocorrelation coefficients.

$$\begin{pmatrix} 1 & r_1 & r_2 & r_3 & r_4 & \cdots & r_{p-1} \\ r_1 & 1 & r_1 & r_2 & r_3 & \cdots & r_{p-2} \\ r_2 & r_1 & 1 & r_1 & r_2 & \cdots & r_{p-3} \\ \cdot & \cdot & \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & & \cdot \\ r_{p-1} & r_{p-2} & r_{p-3} & r_{p-4} & r_{p-5} & \cdots & 1 \end{pmatrix} \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \cdot \\ \cdot \\ \cdot \\ \phi_p \end{pmatrix} = \begin{pmatrix} r_1 \\ r_2 \\ r_3 \\ \\ \\ \\ r_p \end{pmatrix}$$

The distribution of data sample with respect to the time usually attains the order of the Markov model. If the data is linearly changing with time, then the linear distribution will be modeled by first order Markov model. Second order Markov model will give satisfactory result when the data follows parabolic distribution. The polynomial distribution, depending on the fitness of data can be described by *3^rd^* to *n*th order Markov models. Table 5.1 summarizes the definition of the different order Markov models.

Table 5.1 The definition of the different order Markov models.

1st order Markov model flow equation (y_i) $y_i = \phi_1 y_{i-1} + \varepsilon_i$
1st order Markov model autoregressive coefficient (ϕ_p) $\phi_1 = r_1$
2nd order Markov model flow equation (y_i) $y_i = \phi_1 y_{i-1} + \phi_2 y_{i-2} + \varepsilon_i$
2nd order Markov model autoregressive coefficients (ϕ_p) $\phi_1 = (r_1 - r_1 r_2)/(1 - r_1^2)$ $\phi_2 = (r_2 - r_1^2)/(1 - r_1^2)$
3rd order Markov model flow equation (y_i) $y_i = \phi_1 y_{i-1} + \phi_2 y_{i-2} + \phi_3 y_{i-3} + \varepsilon_i$
3rd order Markov model autoregressive coefficients (ϕ_p) $\phi_1 = (1 - r_1^2)(r_1 - r_3) - (1 - r_2)(r_1 r_2 - r_3)/(1 - r_2)(1 - 2r_1^2 + r_2)$ $\phi_2 = (r_2 + r_2^2 - r_1^2 - r_1 r_3)/(1 - 2r_1^2 + r_2)$ $\phi_3 = ((r_1 - r_3)(r_1^2 - r_2) - (1 - r_2)(r_1 r_2 - r_3))/((1 - r_2)(1 - 2r_1^2 + r_2))$

5.3.2 Autoregressive moving average models; ARMA (*p, q*)

Autoregressive moving average model ARMA (*p, q*) is the most widely used periodic and hydrologic time series model. The ARMA models have physical justification in hydrology. The low flows in a river mainly result from groundwater and the flow at a particular time is a fraction of previous flows during the recession period, which may be represented by an autoregressive dependence structure. The high flows during the wet season are formed mainly by heavy rainfall or snowmelts or both, and therefore, may be represented by moving average scheme (Salas. *et. al.*, 1985).

$$y_i = \phi_1 y_{i-1} + \phi_2 y_{i-2} + ... + \phi_p y_{i-p} + \varepsilon_i - \theta_1 \varepsilon_{i-1} - \theta_2 \varepsilon_{i-2} - ... - \theta_q \varepsilon_{i-q} \quad (5\text{-}6)$$

In which, y_i is the flow of the i^{th} year; ϕ_p is the autoregressive coefficients for autoregressive models; θ_q autoregressive coefficients for moving average models; ε_i is the residuals; *p* is the order of model, p^{th} order Markov model defines the flow of any year which depend on previous *p* year flow; *q* is the order of model, q^{th} order Markov model means which the flow of any year is depend on previous *q* year flow (Bayazıt, 1981).

5.3.2.1 First order autoregressive-moving average models; ARMA (1, 1)

$$y_i = \phi_1 y_{i-1} + \varepsilon_i - \theta_1 \varepsilon_{i-1} \quad (5\text{-}7)$$

$$r_1 = \frac{(1-\phi_1\theta_1)(\phi_1-\theta_1)}{1+\theta_1^{\,2} - 2\phi_1\theta_{1''}} \quad (5\text{-}8)$$

$$r_2 = \phi_1 r_1 \quad (5\text{-}9)$$

In which, y_i flow of the i^{th} year; ϕ_1 is the first autoregressive coefficients for autoregressive model; θ_1 is the first autoregressive coefficients for moving average model; r_1 is the first autocorrelation number; r_2 is the second autocorrelation number; ε_i is the residuals.

5.3.3 Moving average models; MA (*q*)

Sometimes autoregressive coefficients of autoregressive moving cases, the ARMA (*p*, *q*) model should be rejected and replaced with moving average models. General expression of moving average models can be defined as:

$$y_i = \varepsilon_i - \sum_{j=1}^{q} \theta_j \varepsilon_{i-j} - \varepsilon_i - \theta_1 \varepsilon_{i-1} - \ldots - \theta_q \varepsilon_{i-q} \qquad (5\text{-}10)$$

In which, y_i is the flow of the i^{th} year; θ_q is the autoregressive coefficients for the moving average model; ε_i is the residuals; q is the order of model, q^{th} order moving average model means which the flow of any year is depend on previous q year flow (Bayazıt,1981).

5.3.3.1 First order moving average models; MA (1)

$$y_i = \varepsilon_i - \theta_1 \varepsilon_{i-1} \qquad (5\text{-}11)$$

$$\theta_1^{\,2} + \frac{\theta_1}{r_1} + 1 = 0 \qquad (5\text{-}12)$$

In which, y_i is the flow of the i^{th} year; θ_1 is the first autoregressive coefficients for moving average model; r_1 is the first autocorrelation number; ε_i is the residuals.

5.4 Akaike information criterion

Before deciding on which method is suitable for modelling, it is important to implement checks such as Akaike information criteria. Akaike recommends the following relationship.

$$AIC(p,q) = \min(n \ln \sigma_\varepsilon^{\,2} + 2(p+q)) \qquad (5\text{-}13)$$

Where; n is the sample size; $\sigma_\varepsilon^{\,2}$ is the maximum likelihood estimate of the residual variance; p is the order of autoregressive model; q is the order of moving average model.

The model, which gives the minimum *AIC* number, is the one to be selected.

5.5 Box-Cox transformation

In order to implement the ARMA or AR methods, it is necessary to convert the data distribution into normal distribution. Sometimes the data itself is following normal distribution which shows that there is no need for the Box-Cox transformation. Therefore the skewed distribution data should be transformed into normal distribution (*g*=0) before the implementation of ARMA or AR models. As a result the Box-Cox transformation is used to change the shape of a distribution efficiently and objectively and to achieve parity for the observations.

$$y = \left(\frac{X^{\lambda} - 1}{\lambda} \right) \text{ For } \quad \lambda \neq 0 \tag{5-14}$$

$$y = \log(x) \quad \text{For} \quad \lambda = 0 \tag{5-15}$$

5.6 The Box Pierce Porte Manteau test

The Box-Pierce Porte Manteau test used, to check the residuals ε_i, whether they are independent and normal. This test is used by statistical formulation of *Q*.

$$Q = n \sum_{k=1}^{m} r_{k\varepsilon}{}^{2} \tag{5-16}$$

Where; $r_{k\varepsilon}$ is the autocorrelation numbers of residuals; *n* is the sample size; *m* is the maximum lag (between 0.1*n*-0.3*n*). If the value got from X^2 distribution table 0.05 significance level bigger than the calculated *Q*, the residuals are independent and normal. To read the value from X^2 distribution table needed the significance level and (*m*-*p*-*q*) value. *p* is the order of the autoregressive model; *q* is the order of the moving average model.

5.7 The derivation of synthetic sequence

After determining the suitable model from Akaike information criteria for the derivation of synthetic sequences, the second step is to determine the values of normal and independent residuals ε_i. The residuals can be defined as;

$$\varepsilon_i = \mu_\varepsilon + \sigma_\varepsilon Z_i \tag{5-17}$$

Where; μ_ε is the mean of residuals; σ_ε is the standard deviation of residuals; $Z_{1i,} Z_{2i}$ represents the standard normal random numbers which must be calculated by using uniform random numbers; η_i is the uniform random numbers between 0 and 1 (0< η_i <1). The standard normal random numbers are defined by;

$$Z_{1i} = (-2 \ln \eta_{1i})^{1/2} \cos(2\pi\eta_{2i}) \tag{5-18}$$

$$Z_{2i} = (-2 \ln \eta_{1i})^{1/2} \sin(2\pi\eta_{2i}) \tag{5-19}$$

Synthetic sequences are then derived after inserting residual ε_i into model equation. The values read from synthetic sequences are the standardized values. The mean of standardized values is always zero, where as the standard deviation is one. Converting the standardized values into non-standardized form will help to find non-standardized X_i flow values.

5.8 Predicting the future flows by synthetic sequence

After determining the suitable model for synthetic sequences, the second step is to deriving of the future predicting synthetic sequences. Normal and independent residuals ε_i, is not required during future flow predictions. This is the residuals of previous years demolishes when predicting for future. After determining the values got from predicting synthetic sequences are the standardized values. Converting the standardized values into non-standardized form and by inverse transformation, one can easily reach to predicting X_i flow values.

5.8.1 Predicting the error parameters of the synthetic sequences

As it was given in section (5.3) the AR (*p*) model and ARMA (*p*, *q*) model can be used to derive the predicting error parameters.

In AR (*p*) model, the defining equation is;

$$y_i = \phi_1 y_{i-1} + \phi_2 y_{i-2} + ... \phi_p y_{i-p} + \varepsilon_i \tag{5-20}$$

and for ARMA(*p*, *q*) model, the defining equation is;

$$y_i = \phi_1 y_{i-1} + \phi_2 y_{i-2} + ... + \phi_p y_{i-p} + \varepsilon_i - \theta_1 \varepsilon_{i-1} - \theta_2 \varepsilon_{i-2} - ... - \theta_q \varepsilon_{i-q} \quad (5\text{-}21)$$

To predict the error parameters for the flow, equation (5-20) and (5-21) are converted;

$$y_i = \psi_1 \varepsilon_{i-1} + \psi_2 \varepsilon_{i-2} + ... \psi_p \varepsilon_{i-p} + \varepsilon_i \quad (5\text{-}22)$$

$$y_i = \varepsilon_i + \psi_1 \varepsilon_{i-1} + \psi_2 \varepsilon_{i-2} + ... \psi_p \varepsilon_{i-p} \quad (5\text{-}23)$$

Where; y_i is the flow of the i^{th} year; ψ_p is the predicting error parameter; ε_i is the residuals.

For predicting the next year error parameters for AR (p) model;

$$y_{i+1} = \psi_1 \varepsilon_{i+1-1} + \psi_2 \varepsilon_{i+1-2} + ... \psi_p \varepsilon_{i+1-p} + \varepsilon_{i+1} \quad (5\text{-}24)$$

For predicting the next year error parameters for ARMA (p, q) model;

$$y_{i+1} = \varepsilon_{i+1} + \psi_1 \varepsilon_{i+1-1} + \psi_2 \varepsilon_{i+1-2} + ... \psi_p \varepsilon_{i+1-p} \quad (5\text{-}25)$$

Writing the equation (5-24) and (5-25) in the form;

$$e_i(l) = \sum_{p=0}^{l-1} \psi_p \varepsilon_{i+1-p} \quad (5\text{-}26)$$

Where; $e_i(l)$ is the prediction error of the l^{th} year; ψ_p is the predicting error parameters; ε_i is the residuals;

The prediction value of ε_i residual is zero. That’s why the prediction of error parameter is also zero. The prediction is objective. ($\psi_0 = 1$)

The variance of prediction error computed by;

$$Var[e_i(l)] = \sum_{p=0}^{l-1} \psi_p^{\,2} \sigma_\varepsilon^{\,2} \quad (5\text{-}27)$$

The confidence interval between i^{th} and $i+1^{th}$ year, acceptance level of 100*(1-α) is;

$$y_i(l) \pm Z_{\alpha/2}\left[\sum_{p=0}^{l-1} \psi_p{}^2\right]^{1/2} \sigma_\varepsilon \tag{5-28}$$

Where; $Z_{\alpha/2}$ is a standard normal variable which passes $\alpha/2$ probability; σ_ε is the standard deviation of residuals; ψ_p is the predicting error parameters; $y_i(l)$ is the predicted flow of the l^{th} year.

For AR (*p*) model to calculate the ψ_p prediction error parameter, substitute equation (5-22) into equation (5-20).

For p=1 $\psi_1 = \phi_1$

For p=2 $\psi_2 = \phi_1{}^2 + \phi_2$ (5-29)

For p=3 $\psi_3 = \phi_1\psi_2 + \phi_2\psi_1 + \phi_3$

For p=n $\psi_n = \phi_1\psi_{n-1} + \phi_2\psi_{n-2} + \phi_3\psi_{n-3} + \ldots\phi_q\psi_0$

For ARMA (*p*, *q*) model to calculate the ψ_p prediction error parameter, substitute equation (5-23) into equation (5-21).

For p=1 $\psi_1 = \phi_1 - \theta_1$

For p=2 $\psi_2 = \phi_1\psi_1 + \phi_2 - \theta_2$ (5-30)

For p=3 $\psi_3 = \phi_1\psi_2 + \phi_2\psi_1 + \phi_3 - \theta_3$

For p=n $\psi_n = \phi_1\psi_{n-1} + \phi_2\psi_{n-2} + \phi_3\psi_{n-3} + \ldots\phi_q\psi_0 - \theta_n$

CHAPTER 6

RESULTS AND DISCUSSIONS

6.1 Introduction

Water experts and politicians agree that there is an acute water shortage problem in Mediterranean and the Middle East region. They also agree that the problem must be addressed immediately in a regional context; it is an issue “which cannot wait” (Angelakis *et al.*, 1999). Cyprus, located at eastern Mediterranean, is a semi-arid country having an area of 9215 km^2 of which average annual rainfall was approximately 500 mm ranging from 300 mm from the flat and coastal areas to 1100 mm at the mountainous areas (Charalambous, 2001).

The statistical analysis of the records available over the period of hydrological years 1916/1917-1999/2000 demonstrates that the precipitation time series display a step change or shift at 1970-1971 period. The meteorological data has shown that from the beginning of the century (1900’s) the annual mean average of the precipitation data was always greater than the long term average of the century. However, after 1970-1971 period this trend has changed and the annual mean average, fall below the long term averages of the century (Fig 3.2). This result is also confirmed by Klohn in 2002 who has mentioned that after 1970 the precipitation data demonstrate a slight decrease from mean average.

This drop in the trend of precipitation is generally attributed to the global warming and climate change effects which is accepted as a cause of global environmental changes and pollution.

6.2 Discussions

Hence, an important problem in stochastic hydrology is to select or identify the type of model for representing the hydrologic time series. In common practice, such model identification is usually done by judgement, experience, or personal preference. In some cases, though, the statistical properties of the various alternative models as well as the statistical characteristics of the sample time series are used for identifying the most appropriate type of model for the particular case. It is, of course desirable that in addition to the above factors, physical considerations must be used for aiding in the identification of the model type (Salas & Smith, 1981).

In fact the actual mathematical models of a hydrologic time series are never known. The inferred population model is only an approximation. The exact model parameters are also never known in hydrology; they must be estimated from limited data.

The purpose of constructing the models of stochastic processes is to generate synthetic processes for the considered variable with the aid of these models. With the use of generated processes, it can be possible for the investigations of planning and management of water resources to consider for flows not only the observed sample but also the other samples which come from the same population. So, the system behaviour can be investigated not only according to the available sample but also with aid of synthetic series (Bayazıt, 1981).

The other using part of the synthetic sequences is predicting the future flows. While going forward, predicting errors of the flows increases. That's why synthetic sequences; predict flows, in the near future.

For synthetic sequences AR (1), AR (2), AR (3), ARMA (1, 1) models which are mostly used in hydrology are investigated. AR (10), AR (12), AR (14), AR (15) models are used for predicted synthetic sequence.

6.3 Correlation between rivers on study area

The key missing connection for considered rivers is to understand if there exists a linkage between them in terms of surface runoff and precipitation values. For sure, the magnitude of the stream response will differ from each other depending on the magnitude of the rain event, the geology in a catchment and the water content in the surface soils. These altered conditions in terms of factors influencing the discharge of rivers, such as river slopes and drainage areas, increases the intention to demonstrate the level of linkage between the rivers to better manage flows in rivers and their responses to precipitation.

The significance of the correlation of the rivers is all tested via hypothesis test. The hypothesis was constructed under the idea of there is no relationship between the rivers with a significance level of 90%. The results are all rejected when all the methods are tested. (Kendall correlation, Sperman correlation, and Pearson correlation).The results of the hypothesis tests are given in Appendix 3 and prove that the river flows are dependent on each other. The results of all these methods are shown from Fig.6.1 to Fig.6.10.

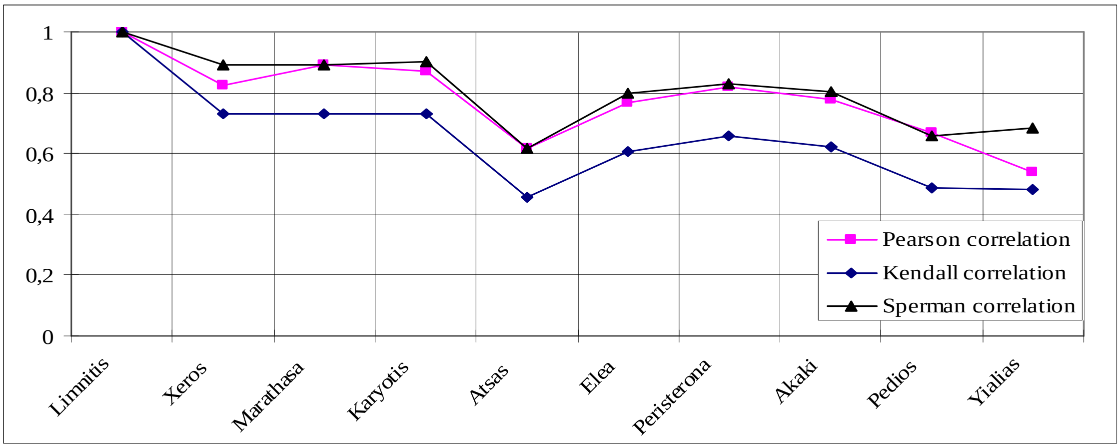

Figure 6.1 Correlation between the Limnitis River with other rivers.

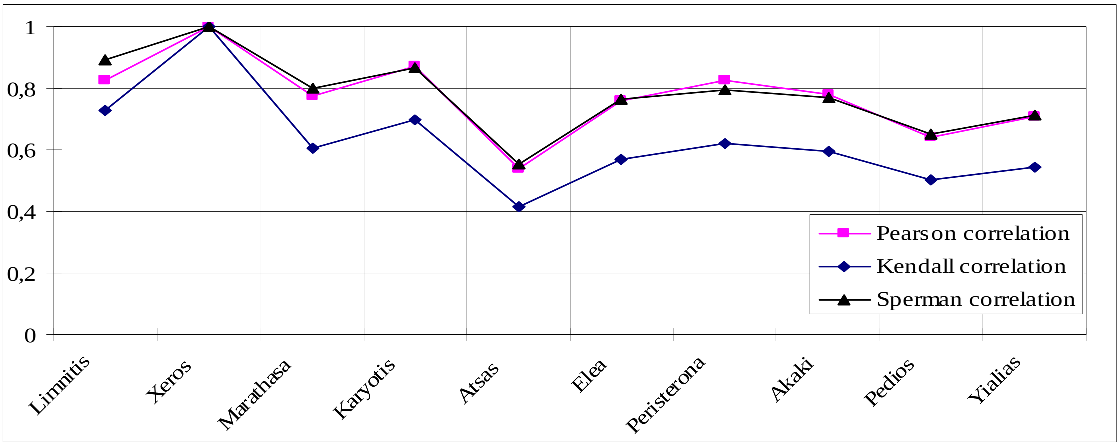

Figure 6.2 Correlation between the Xeros River with other rivers.

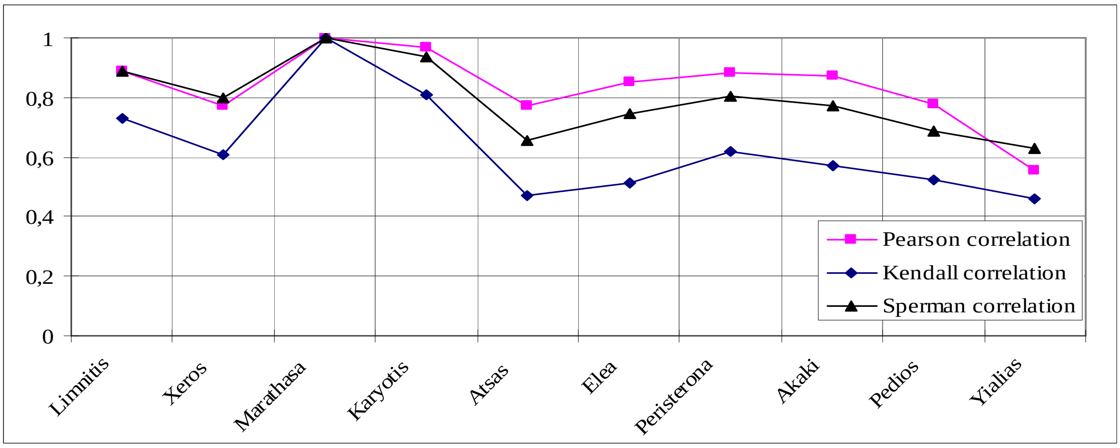

Figure 6.3 Correlation between the Marathasa River with other rivers.

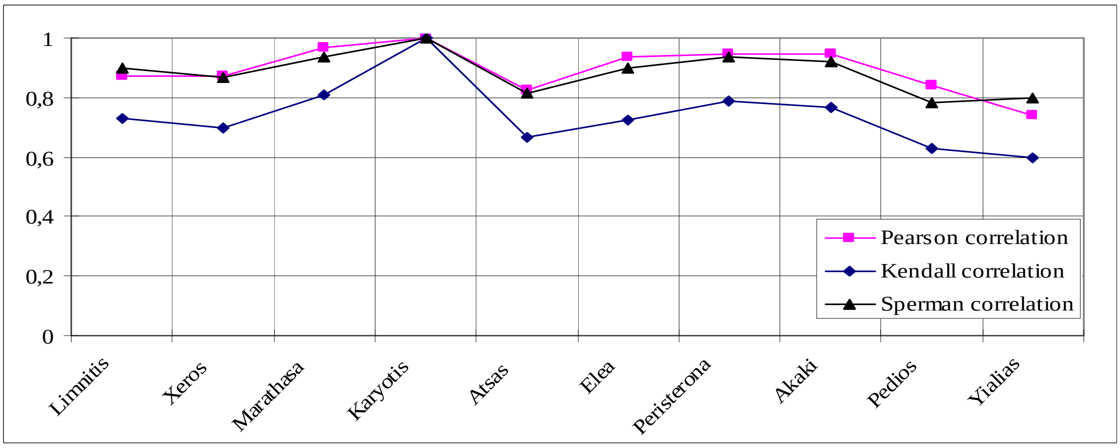

Figure 6.4 Correlation between the Karyotis River with other rivers.

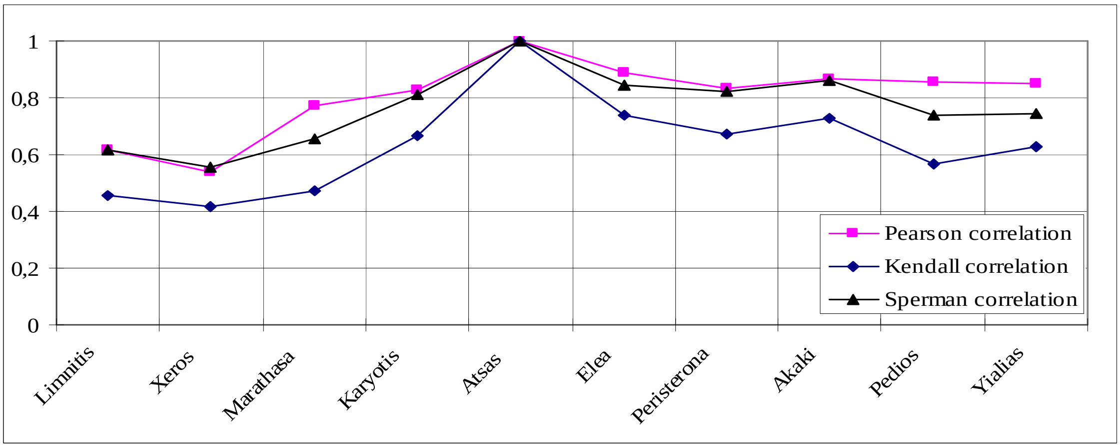

Figure 6.5 Correlation between the Atsas River with other rivers.

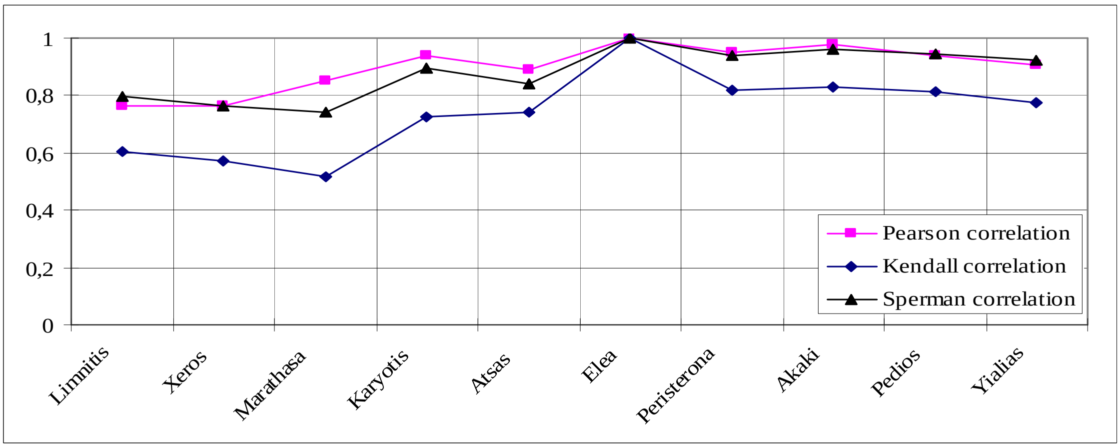

Figure 6.6 Correlation between the Elea River with other rivers.

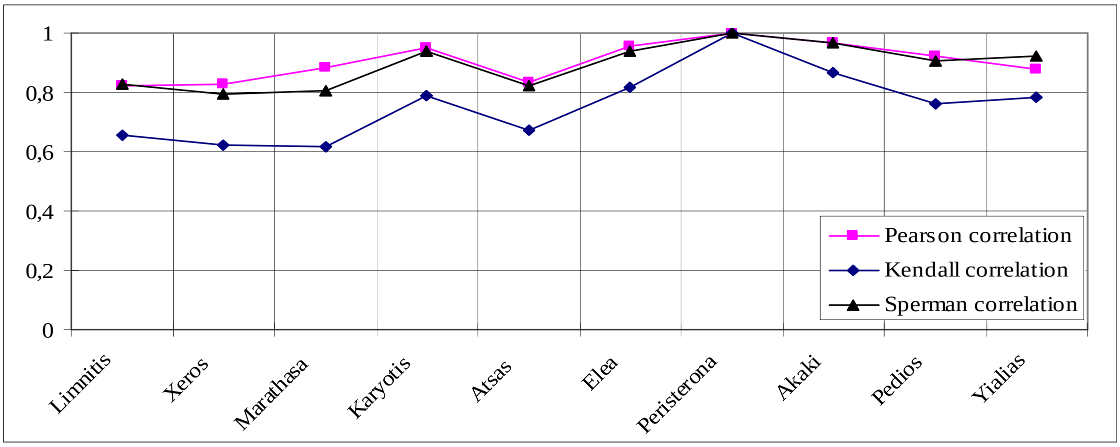

Figure 6.7 Correlation between the Peristerona River with other rivers.

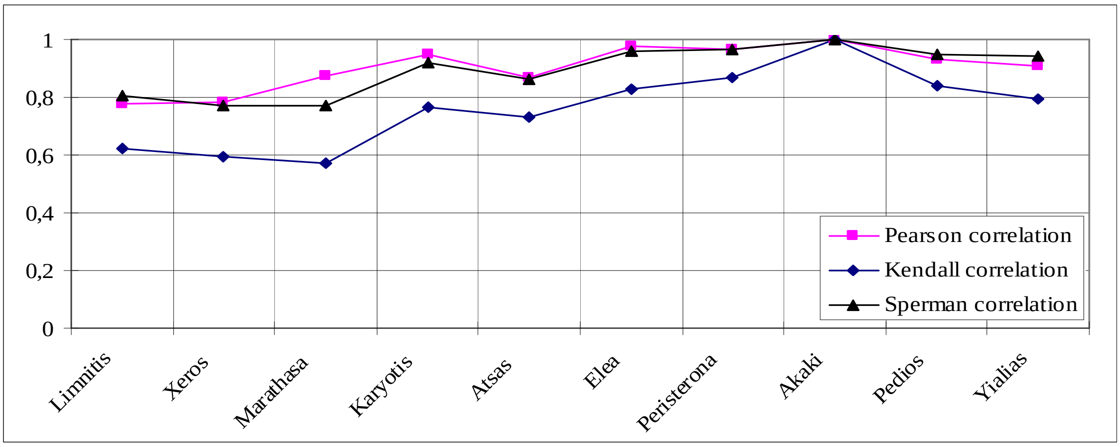

Figure 6.8 Correlation between the Akaki River with other rivers.

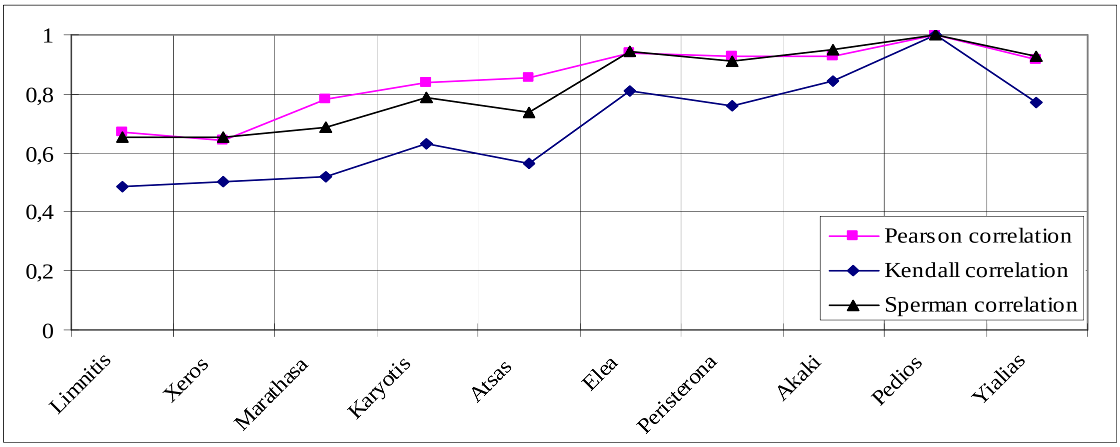

Figure 6.9 Correlation between the Pedios River with other rivers.

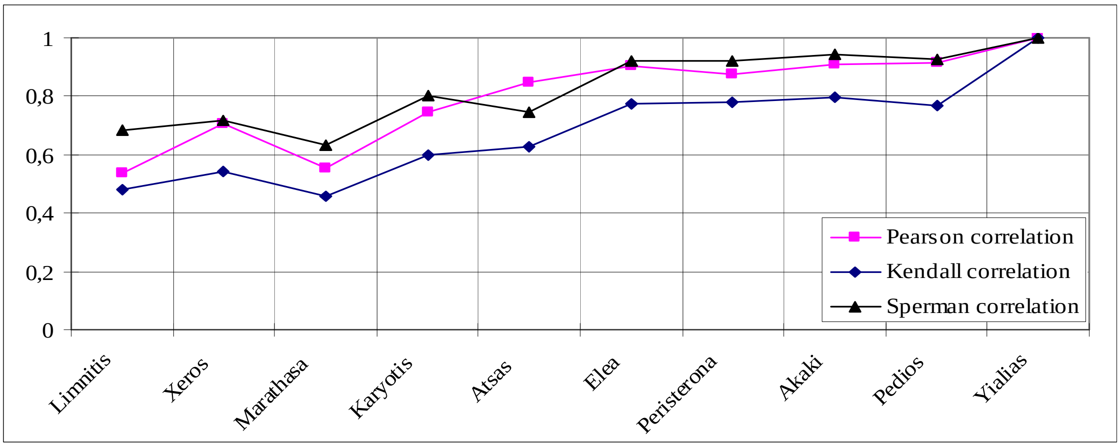

Figure 6.10 Correlation between the Yialias River with other rivers.

The Figures has shown that the Sperman correlation and Pearson correlation methods have similar results but Kendall correlation method produced same trend with lower correlations between each river. The deviations on results of Kendall correlation method does not mean that Kendall's correlation method results are less sensitive or correlation between variables are not strong. The reason is due to the usage of different scale of correlation.

Not surprisingly, the yearly averages of river flows are all positively correlated since the climatic factors are same for all the rivers at the same time and same spatial distribution. The correlation coefficient over complete record was "very strong" and "strong", showing spatial homogeneity between the rivers.

The results of correlation matrix for stream flow between the rivers in the order of west to east are given in Table 6.1. High correlation coefficients are bolded, showing a strong relation between stations.

Table 6.1 The Pearson's correlation matrix values for yearly discharges in rivers.

	Limnitis	Xeros	Marathasa	Karyotis	Atsas	Elea	Peristerona	Akaki	Pedios	Yialias
Limnitis	1									
Xeros	**0,83**	1								
Marathasa	**0,89**	0,77	1							
Karyotis	**0,87**	**0,87**	**0,97**	1						
Atsas	0,62	0,54	0,77	**0,83**	1					
Elea	0,77	0,76	**0,85**	**0,94**	**0,89**	1				
Peristerona	**0,82**	**0,83**	**0,88**	**0,95**	**0,83**	**0,95**	1			
Akaki	0,78	0,78	**0,87**	**0,95**	**0,87**	**0,98**	**0,97**	1		
Pedios	0,67	0,64	0,78	**0,84**	**0,85**	**0,94**	**0,93**	**0,93**	1	
Yialias	0,54	0,71	0,55	0,74	**0,85**	**0,91**	**0,88**	**0,91**	**0,92**	1

Even though the overall results show that there is a relation between the stream flows of rivers, it is clear that the western part rivers: Limnitis, Xeros and Marathasa are not following a strong relationship with others, whereas Karyotis is behaving like a transition river which has strong relationship with nearly all the rivers. On the other hand, Limnitis, Xeros and Marathasa have a strong relationship with each other. The difference between these rivers and the others is the spatial coverage of their drainage areas. Their drainage areas are extending up to the peaks of Troodos Mountains in which the natural ecological pattern is not affected by anthropogenic activities. On the other hand, the upper drainage area of other rivers has been changed due to urbanization activities and ecological disturbances.

6.4 Rainfall-Runoff relationships between rivers on study area

Rainfall in arid and semi-arid climate regions is typically meagre, irregular and highly variable (Sharon, 1972; Goodrich *et. al*., 1995; Ahrens, 2003). Runoff generation in these regions is dominated by an infiltration excess mechanism with a short time to final infiltration rates and a fast response due to steep hill slopes with shallow soils, exposed rocks and lack of vegetation (Wheather, 2002; Greenbaum *et. al*., 2006). Some of arid and semi-arid catchments have alluvial channel beds through which flood water infiltrates during flow and flood peaks and thus volumes are reduced (Wheather, 2002). For catchments with rocky channel beds, this process is not significant. Rainfall-Runoff modelling in arid and semi-arid catchments is a challenging task for several reasons.

Runoff data is the important information for the design and planning of many water resources engineering projects. Many hydrologists devote themselves to develop Rainfall-Runoff models to estimate runoff. The Rainfall-Runoff process, which involves many mechanisms, is known as a highly complicated and nonlinear phenomenon. Although difficulties exist in the modelling of the Rainfall-Runoff processes, the regression model used in this study is a set of simple exponential regression equations that can appropriately defines a relationship of Rainfall-Runoff event. The regression model simply requires only rainfall and stream flow records. Regression analysis is the mathematical process of using observations to find the line of best fit through the data in order to make estimates and predictions about the behaviour of the variables (Bayazıt, 1996).

The following figures describe the relationship of annual precipitation and annual surface runoff of 10 streams. These rivers followed exponential relationship. These surface runoff and precipitation values are obtained from Kypris and Neophytou (1994).

The R squared for the regression which by construction is always between 0 and 1 inclusive, indicates the degree of fit of the regression. A value of 0 indicates that the regression is perfectly useless in explaining the dependent variable and a value of 1 signifies a perfect fit between the dependent variable and the linear combination of the explanatory variables. The goal is frequently, but not always to get a high R^2.

During the selection criteria of data, involved in defining Rainfall-Runoff relationship, some of the monitored values were taken as outliers. The outliers were minimizing the quality of data fit on the regression analyses.

Table 6.2 The outlier data values of 10 rivers originating from Troodos Mountains.

River name	Outlier data value		
	Hydrologic year (1 Oct.-30 Sep.)	Annual precipitation (mm)	Annual surface runoff (mcm)
Limnitis (Station: 128301810)	1966-1967	1195	20,34
	1970-1971	764	7,33
Marathasa (Station:132103085)	1986-1987	1095	7,74
	1991-1992	1056	7,38
Karyotis (Station: 133304195)	1985-1986	594	3,38
	1988-1989	733	14,36
Atsas (Station:134204790)	1988-1989	524	3,32
Elea (Station: 135407440)	1965-1966	489	4,70
	1969-1970	395	2,91
	1973-1974	443	5,08
	1988-1989	547	9,81
Peristerona (Station: 137108550)	1968-1969	1032	38,97
	1973-1974	533	11,03
	1988- 1989	625	19,99
Akaki (Station: 137311690)	1979-1980	582	17,34
	1980-1981	574	16,84
	1988-1989	533	17,78
	1991-1992	777	19,58
Pedios (Station:161113185)	1969-1970	462	1,11
	1981-1982	512	1,59
	1988-1989	542	7,25
Yialias (Station: 165115385)	1979-1980	530	8,64
	1980-1981	513	6,99
	1985-1986	483	1,05
	1990-1991	285	0,48

Table 6.3 Annual precipitation and annual surface runoff values of the Limnitis River (Station: 128301810).

Hydrologic year (1 Oct.-30 Sep.)	Annual precipitation (mm)	Annual surface runoff (mcm)
1966-1967	1195	20,34
1967-1968	854	15,91
1968-1969	1086	25,55
1969-1970	590	4,19
1970-1971	764	7,33
1971-1972	609	3,45
1974-1975	845	15,62
1975-1976	844	16,82
1976-1977	666	12,79
1977-1978	917	23,37
1978-1979	691	7,81
1979-1980	753	16,07
1980-1981	778	18,14
1981-1982	570	6,01
1982-1983	713	11,70
1983-1984	680	8,51
1984-1985	627	8,67
1985-1986	534	3,59
1986-1987	905	17,46
1987-1988	919	18,36
1988-1989	646	11,95
1989-1990	512	4,24
1990-1991	393	1,50
1991-1992	917	15,65
1992-1993	742	12,53

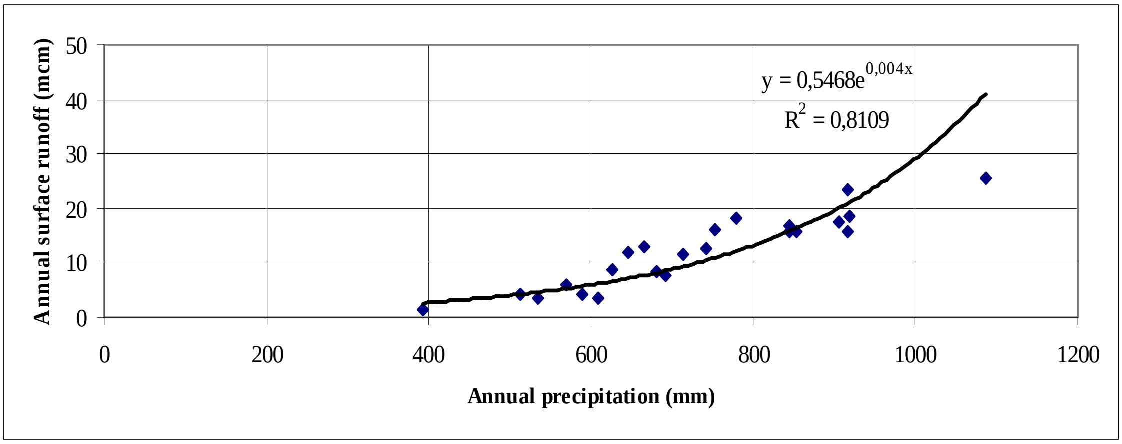

Figure 6.11 Relation between annual surface runoff and annual precipitation of the Limnitis River (Station: 128301810).

Table 6.4 Annual precipitation and annual surface runoff values of the Xeros River (Station: 131101770).

Hydrologic year (1 Oct.-30 Sep.)	Annual precipitation (mm)	Annual surface runoff (mcm)
1990-1991	340	0,74
1991-1992	918	10,75
1992-1993	791	8,52

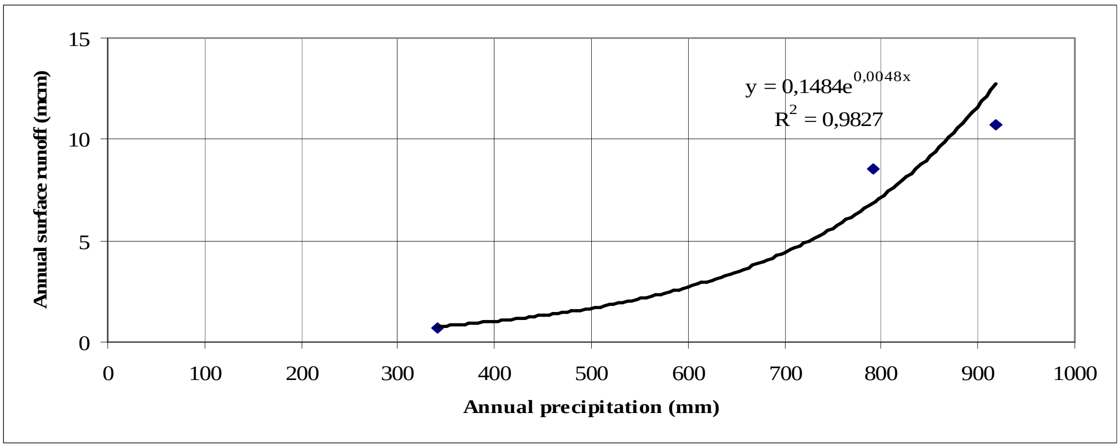

Figure 6.12 Relation between annual surface runoff and annual precipitation of the Xeros River (Station: 131101770).

Even though the relationship between the surface runoff and precipitation of the Xeros River is given; it is clear that the resultant relationship is produced by only three samples. Therefore, the resultant equation of the Xeros River is not reliable for real estimates.

Table 6.5 Annual precipitation and annual surface runoff values of the Marathasa River (Station: 132103085).

Hydrologic year (1 Oct.-30 Sep.)	**Annual precipitation (mm)**	**Annual surface runoff (mcm)**
1967-1968	924	9,78
1968-1969	1253	17,48
1969-1970	620	3,70
1970-1971	859	5,40
1971-1972	569	3,44
1972-1973	334	1,14
1973-1974	628	2,41
1974-1975	1019	8,80
1975-1976	887	6,35
1976-1977	812	5,87
1977-1978	960	9,97
1978-1979	773	3,83
1979-1980	915	6,85
1980-1981	1009	8,11
1981-1982	795	4,94
1982-1983	791	6,38
1983-1984	793	5,57
1984-1985	773	4,80
1985-1986	594	2,41
1986-1987	1095	7,74
1987-1988	1051	8,76
1988-1989	920	7,85
1989-1990	534	2,86
1990-1991	444	1,76
1991-1992	1056	7,38
1992-1993	813	7,35

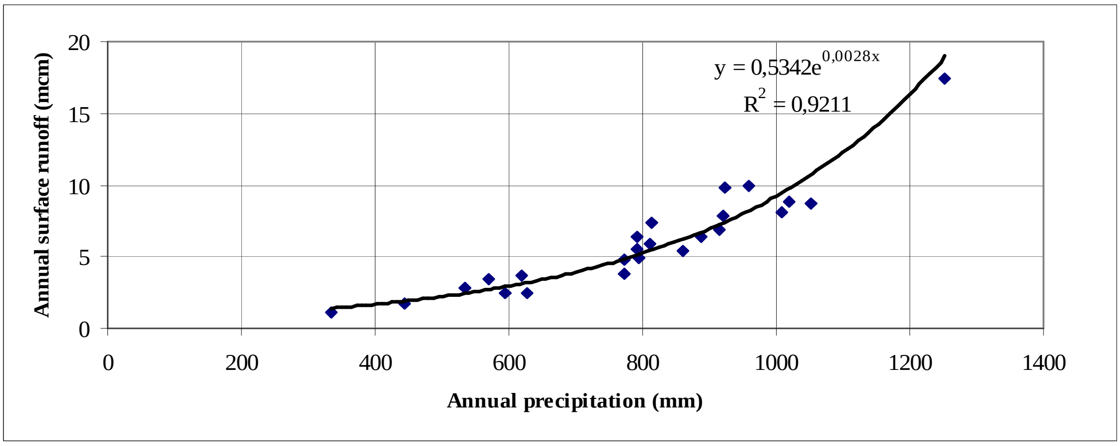

Figure 6.13 Relation between annual surface runoff and annual precipitation of the Marathasa River (Station: 132103085).

Table 6.6 Annual precipitation and annual surface runoff values of the Karyotis River (Station: 133304195).

Hydrologic year (1 Oct.-30 Sep.)	**Annual precipitation (mm)**	**Annual surface runoff (mcm)**
1965-1966	769	11,51
1966-1967	1071	22,72
1967-1968	885	19,17
1968-1969	1251	35,93
1969-1970	591	7,38
1970-1971	880	11,94
1971-1972	721	8,63
1972-1973	282	3,23
1973-1974	605	6,18
1974-1975	890	13,80
1975-1976	834	12,69
1976-1977	724	8,81
1977-1978	841	14,89
1978-1979	660	7,50
1979-1980	841	12,99
1980-1981	910	16,20
1981-1982	716	9,04
1982-1983	722	10,81
1983-1984	637	7,45
1984-1985	753	9,57
1985-1986	594	3,38
1986-1987	907	14,50
1987-1988	920	16,99
1988-1989	733	14,36
1989-1990	502	4,08
1990-1991	401	2,04
1991-1992	1015	15,79
1992-1993	818	15,16

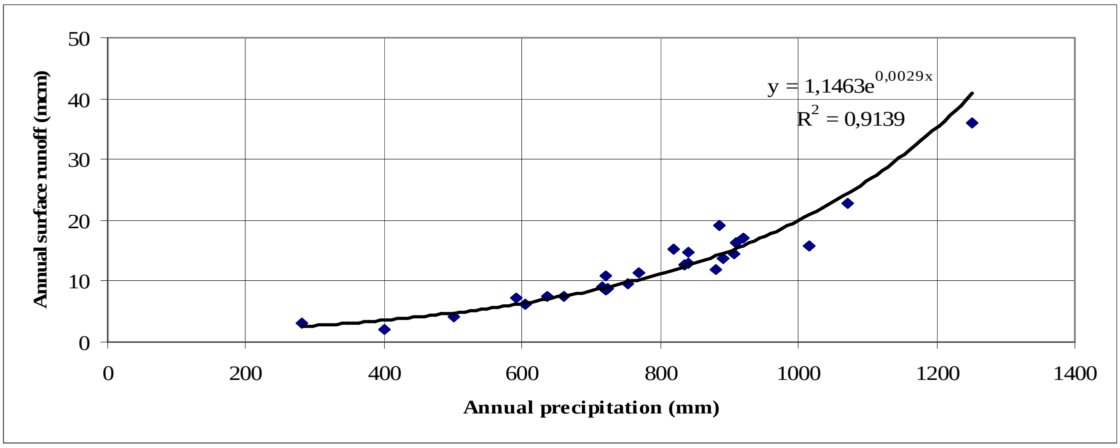

Figure 6.14 Relation between annual surface runoff and annual precipitation of the Karyotis River (Station: 133304195).

Table 6.7 Annual precipitation and annual surface runoff values of the Atsas River (Station: 134204790).

Hydrologic year (1 Oct.-30 Sep.)	Annual precipitation (mm)	Annual surface runoff (mcm)
1965-1966	505	1,32
1966-1967	745	9,54
1967-1968	581	2,63
1968-1969	828	8,67
1969-1970	380	0,57
1970-1971	605	1,60
1971-1972	525	1,30
1972-1973	168	0,12
1973-1974	416	0,36
1974-1975	605	1,23
1975-1976	587	1,18
1976-1977	468	0,40
1977-1978	542	1,42
1978-1979	456	0,41
1979-1980	562	1,29
1980-1981	621	2,69
1981-1982	491	0,52
1982-1983	510	0,46
1983-1984	407	0,27
1984-1985	532	0,74
1986-1987	550	0,68
1987-1988	603	1,55
1988-1989	524	3,32
1989-1990	374	0,21
1991-1992	697	3,47
1992-1993	578	5,11

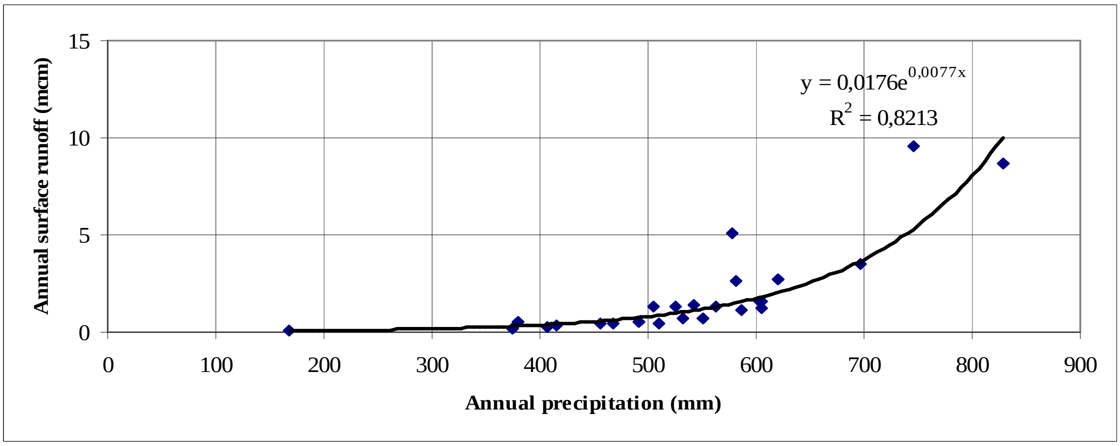

Figure 6.15 Relation between annual surface runoff and annual precipitation of the Atsas River (Station: 134204790).

Table 6.8 Annual precipitation and annual surface runoff values of the Elea River (Station: 135407440).

Hydrologic year (1 Oct.-30 Sep.)	Annual precipitation (mm)	Annual surface runoff (mcm)
1965-1966	489	4,70
1966-1967	829	15,22
1967-1968	534	6,71
1968-1969	956	27,23
1969-1970	395	2,91
1970-1971	662	7,60
1971-1972	566	5,45
1972-1973	182	0,54
1973-1974	443	5,08
1974-1975	662	8,13
1975-1976	632	7,19
1976-1977	530	4,41
1977-1978	527	6,27
1978-1979	476	2,40
1979-1980	581	6,81
1980-1981	588	10,20
1981-1982	474	3,01
1982-1983	505	1,65
1983-1984	452	1,81
1984-1985	543	4,91
1985-1986	404	0,19
1986-1987	569	4,27
1987-1988	614	8,22
1988-1989	547	9,81
1989-1990	400	0,97
1990-1991	260	0,11
1991-1992	716	10,86
1992-1993	614	12,73

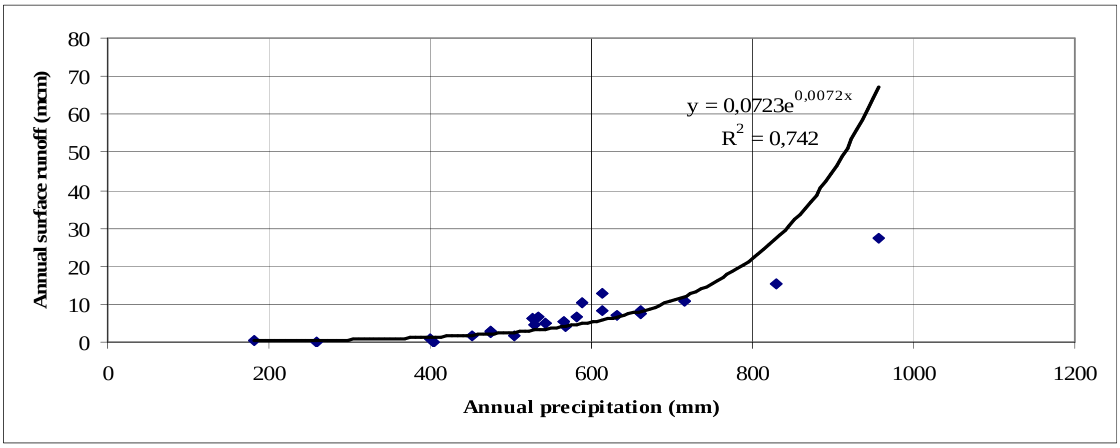

Figure 6.16 Relation between annual surface runoff and annual precipitation of the Elea River (Station: 135407440).

Table 6.9 Annual precipitation and annual surface runoff values of the Peristerona River (Station: 137108550).

Hydrologic year (1 Oct.-30 Sep.)	**Annual precipitation (mm)**	**Annual surface runoff (mcm)**
1965-1966	572	11,30
1966-1967	805	26,29
1967-1968	692	16,39
1968-1969	1032	38,97
1969-1970	468	5,91
1970-1971	722	14,78
1971-1972	619	11,88
1972-1973	252	1,67
1973-1974	533	11,03
1974-1975	729	16,86
1975-1976	679	13,12
1976-1977	577	8,79
1977-1978	606	13,03
1978-1979	600	8,61
1979-1980	704	18,42
1980-1981	730	20,30
1981-1982	551	7,98
1982-1983	585	10,43
1983-1984	515	8,56
1984-1985	615	14,85
1985-1986	516	5,52
1986-1987	670	17,30
1987-1988	760	21,41
1988- 1989	625	19,99
1989-1990	433	5,56
1990-1991	350	2,80
1991-1992	848	22,39
1992-1993	714	22,23

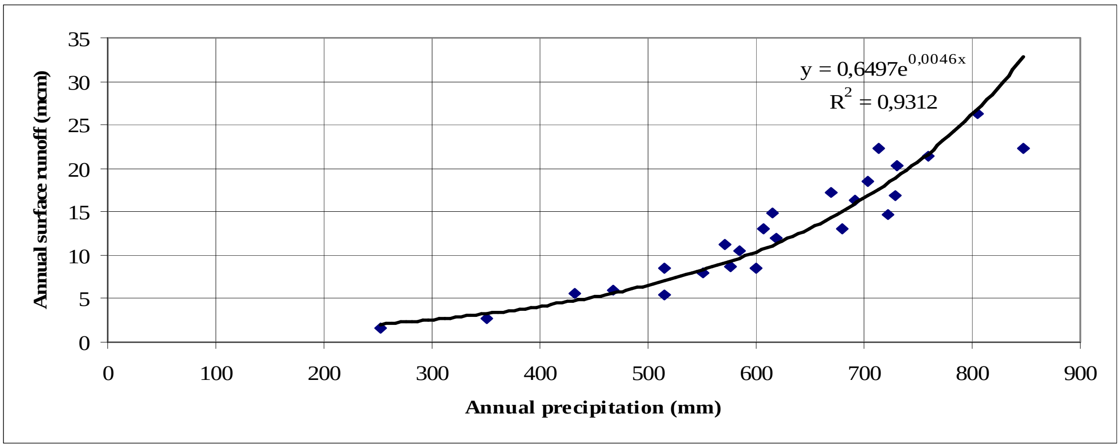

Figure 6.17 Relation between annual surface runoff and annual precipitation of the Peristerona River (Station: 137108550).

Table 6.10 Annual precipitation and annual surface runoff values of the Akaki River (Station: 137311690).

Hydrologic year (1 Oct.-30 Sep.)	**Annual precipitation (mm)**	**Annual surface runoff (mcm)**
1965-1966	489	10,11
1966-1967	757	25,07
1967-1968	562	13,92
1968-1969	927	45,02
1969-1970	395	3,82
1970-1971	637	12,28
1971-1972	525	10,51
1972-1973	194	0,76
1973-1974	437	6,92
1974-1975	570	11,59
1975-1976	592	12,58
1976-1977	481	8,13
1977-1978	449	10,55
1978-1979	502	6,74
1979-1980	582	17,34
1980-1981	574	16,84
1981-1982	465	4,75
1982-1983	458	6,06
1983-1984	415	4,60
1984-1985	523	9,78
1985-1986	474	3,50
1986-1987	484	9,72
1987-1988	577	15,80
1988-1989	533	17,78
1989-1990	418	4,73
1990-1991	307	1,53
1991-1992	777	19,58
1992-1993	623	17,81

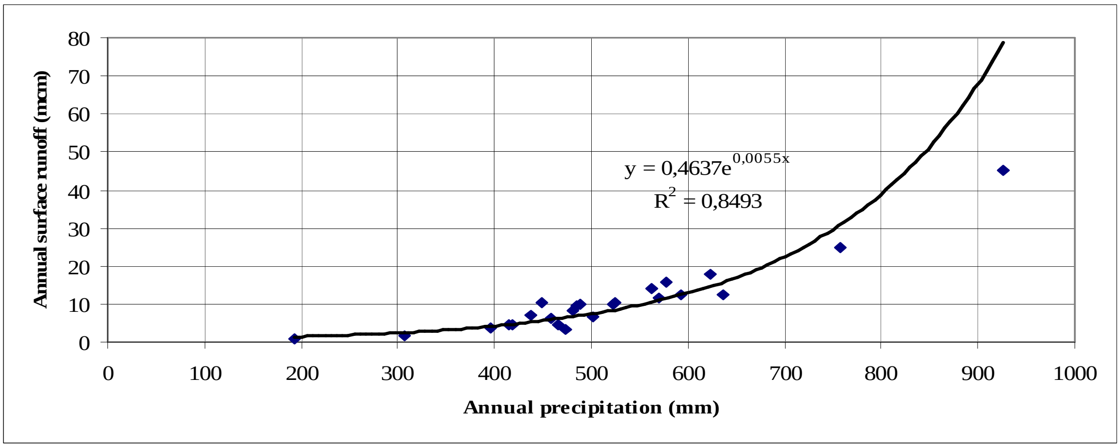

Figure 6.18 Relation between annual surface runoff and annual precipitation of the Akaki River (Station: 137311690).

Table 6.11 Annual precipitation and annual surface runoff values of the Pedios River (Station: 161113185).

Hydrologic year (1 Oct.-30 Sep.)	Annual precipitation (mm)	Annual surface runoff (mcm)
1967-1968	496	3,55
1968-1969	924	12,88
1969-1970	462	1,11
1970-1971	684	5,02
1971-1972	573	4,44
1974-1975	690	7,08
1975-1976	655	6,01
1976-1977	532	2,83
1977-1978	512	3,90
1978-1979	570	2,61
1979-1980	576	5,09
1980-1981	601	5,20
1981-1982	512	1,59
1982-1983	467	2,42
1983-1984	445	1,81
1984-1985	533	3,60
1985-1986	528	1,71
1986-1987	496	3,27
1987-1988	588	5,48
1988-1989	542	7,25
1989-1990	423	2,29
1990-1991	318	0,93
1991-1992	762	8,84
1992-1993	639	7,30

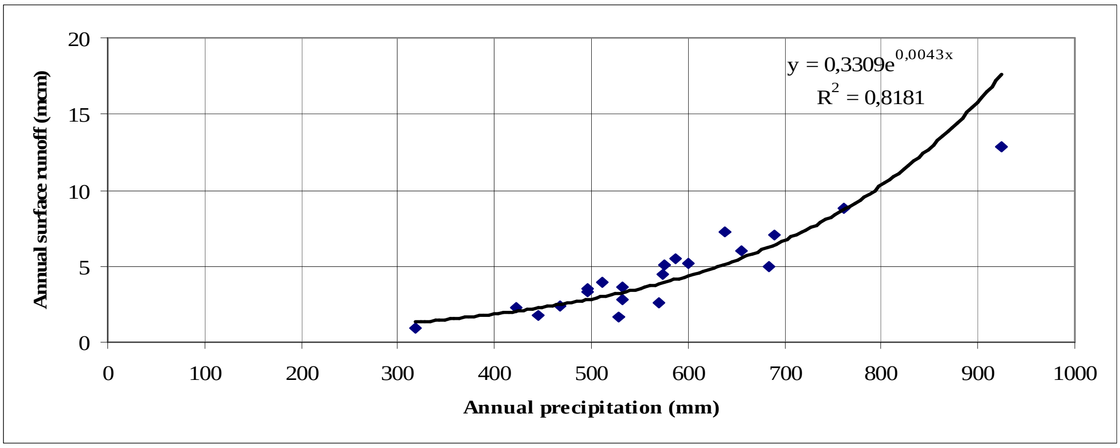

Figure 6.19 Relation between annual surface runoff and annual precipitation of the Pedios River (Station: 161113185).

Table 6.12 Annual precipitation and annual surface runoff values of the Yialias River (Station: 165115385).

Hydrologic year (1 Oct.-30 Sep.)	Annual precipitation (mm)	Annual surface runoff (mcm)
1976-1977	464	2,82
1977-1978	373	2,75
1978-1979	484	3,27
1979-1980	530	8,64
1980-1981	513	6,99
1981-1982	373	1,52
1982-1983	357	1,41
1983-1984	419	1,89
1984-1985	520	4,59
1985-1986	483	1,05
1986-1987	397	2,12
1987-1988	540	6,03
1988-1989	514	9,25
1989-1990	373	1,60
1990-1991	285	0,48
1991-1992	774	13,14
1992-1993	637	11,95

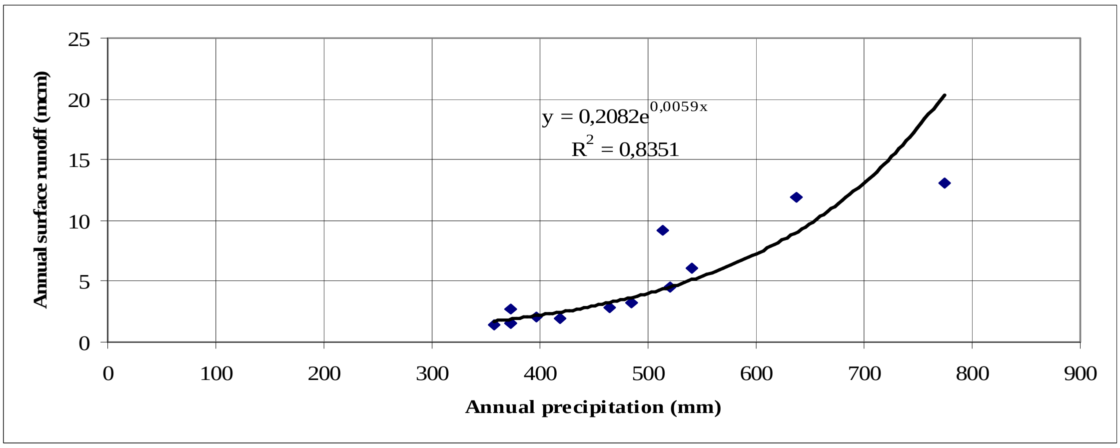

Figure 6.20 Relation between annual surface runoff and annual precipitation of the Yialias River (Station: 165115385).

Graphs of yearly rainfall versus annual stream flow are assessed for each year of the rivers separately in Fig. 6.11 to Fig 6.20. Visual examination identified two distinct relationships for data points, which correlated to data representing the “none or negligible” surface runoff and opposed to this excess water conditions. The “none or negligible” condition is assumed when the sum of the seasonal precipitation is greater than 250 mm. Therefore, the excess water requirement has lower limit, around 300 mm, in which a considerable runoff values can be obtained within a season.

During the analysis, the data plots are examined and obvious outliers were moved from the data group prior to determining the exponential regression equations that are used to represent Rainfall-Runoff relationship. Within these analyses, the runoff characteristics include only the stream flow characteristics of the rivers. However, runoff characteristics can be affected by numerous physical variables such as topography, land cover, soil condition, and drainage area, all of which are related with geologic conditions. In the study area, the land cover and soil conditions can be accepted as rather constant since the dense vegetal cover and Troodos Volcanic massif structure is uniformly distributed along the study area.

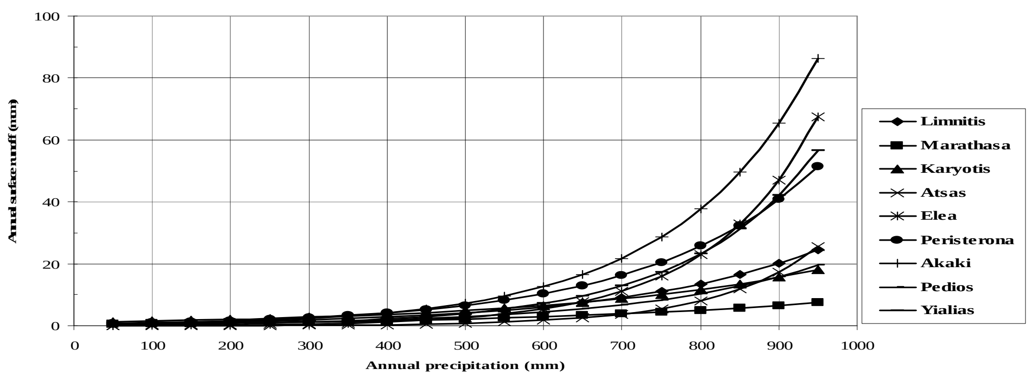

Figure 6.21 Rainfall-Runoff relationships of all the river basins in the study area without considering the drainage area and slope of the drainage area of the gauge stations of rivers.

On the other hand, the drainage area and its slope due to topographic conditions are varying between each river basin. These lacks of involvement of these parameters are effective on differences between the Rainfall-Runoff relationships of each river basin.

Table 6.13 The surface area and the slope of the drainage area of gauge stations of rivers.

Station number	Station name	Surface area(km^2)	Slope (%)
128301810	Limnitis	48	4,2
131101770	Xeros	24	6,6
132103085	Marathasa	23	13
133304195	Karyotis	63	7,3
134204790	Atsas	33	4,8
135407440	Elea	81	5,1
137108550	Peristerona	77	3,4
137311690	Akaki	90	2,7
161113185	Pedios	29	3,8
165115385	Yialias	73	2,6

In order to increase the relationship, both the drainage area and slope of basins are related with the exponential regression relationship of all the rivers.

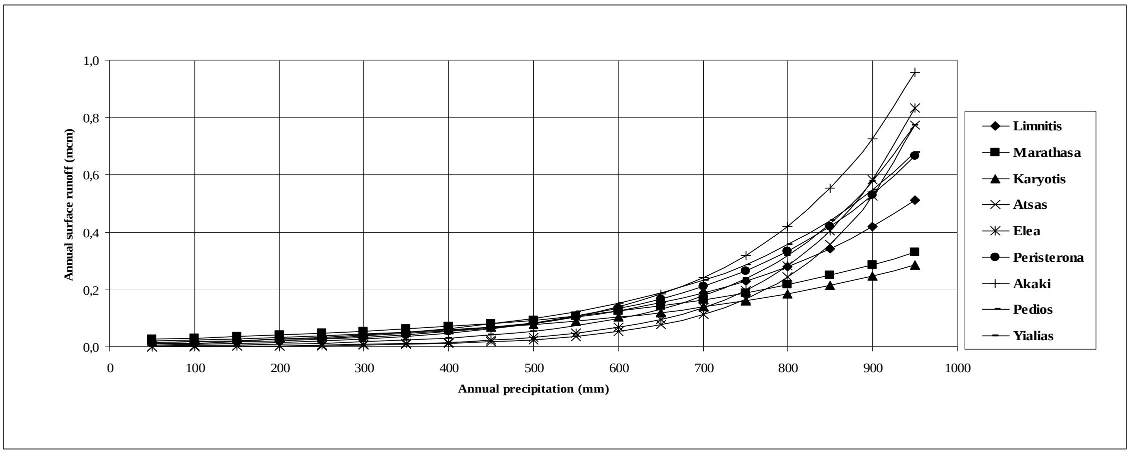

Figure 6.22 Rainfall-Runoff relationships of all the river basins in the study area considering the drainage area of the gauge stations of rivers.

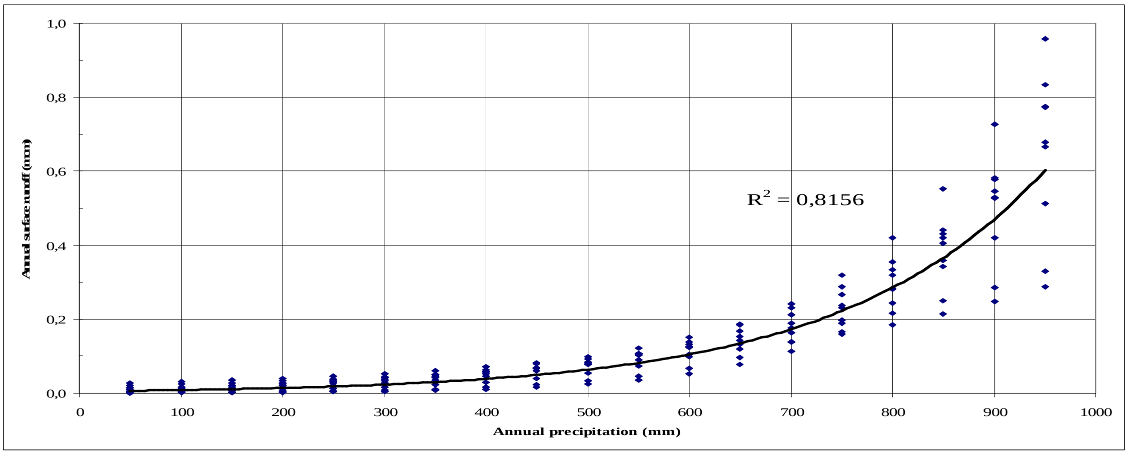

Figure 6.23 The unique exponential regression equation for Rainfall-Runoff relationships of all the river basins in the study area considering the drainage area of the gauge stations of rivers.

Fig.6.23 shows the resultant graph, representing the unique exponential regression equation for defining Rainfall-Runoff relationship of all the river basins in the study area. The regression equation is derived by only considering the drainage area of the individual basins. The final equation derived is given as:

$$SR = 0{,}0053e^{0{,}005P} \quad (6\text{-}1)$$

Where; *SR* is the annual surface runoff and *P* is the annual precipitation. In which the R^2 of the equation proves strong relationship with the data and the derived equation.

The following Figure however, defines the same relationship in which both the slope and the drainage area of the basins are considered.

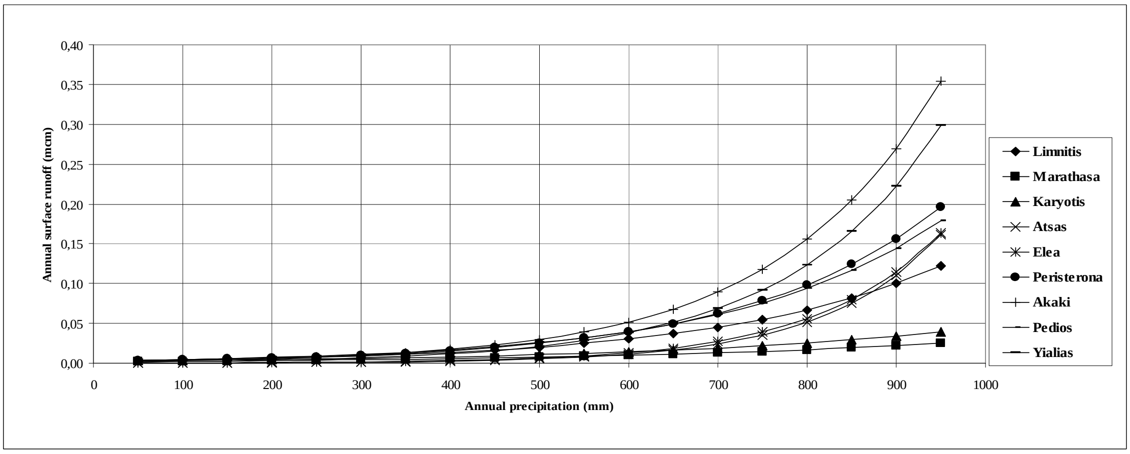

Figure 6.24 Rainfall-Runoff relationships of all the river basins in the study area considering the drainage area and slope of the drainage area of the gauge stations of rivers.

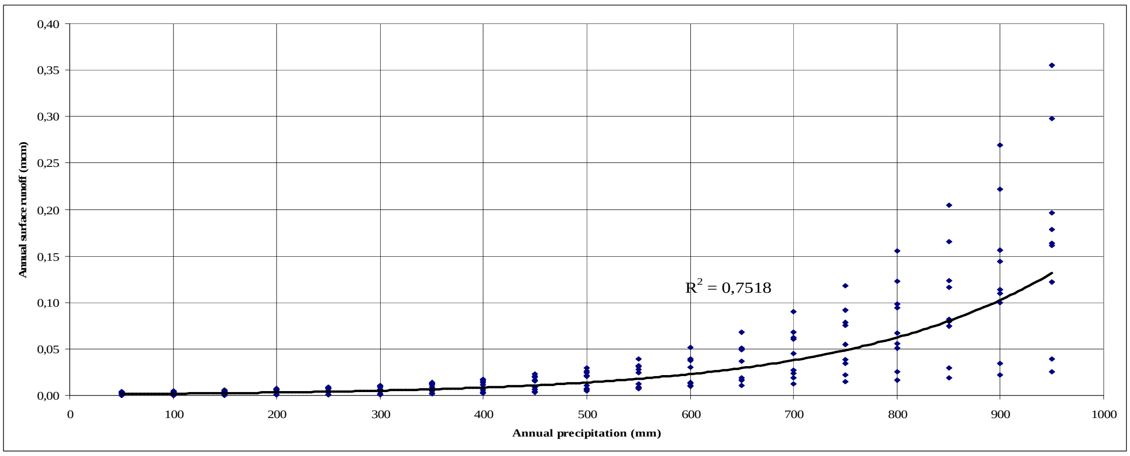

Figure 6.25 The unique exponential regression equation for Rainfall-Runoff relationships of all the river basins in the study area considering the drainage area and slope of the drainage area of the gauge stations of rivers.

$$SR = 0,0012e^{0,005P} \qquad (6\text{-}2)$$

Where; *SR* is the annual surface runoff and *P* is the annual precipitation. Even though the two main parameters are involved in equation (6-2), the relationship between the data and the derived regression equation is not as accurate as the one as shown in equation (6-1).

6.5 The synthetic sequence of river flows

The values of the excess rainfall in terms of river discharge were plotted by data obtained from studies of Kypris and Neophytou (1994) and Rossel (2002), which are the only available data representing the monthly and annual flow rates of considered rivers. The synthetic data was then produced from observed data by the help of autoregressive models such as AR (1), AR (2) and AR (3). Following Figures and Tables are the results of the autoregressive analysis.

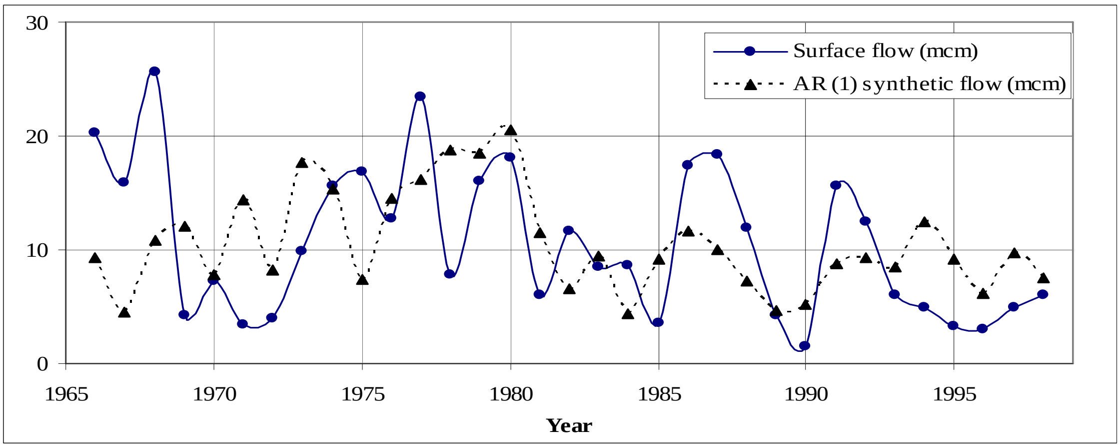

Figure 6.26 Limnitis River (Station: 128301810) synthetic sequences with first order Markov model AR (1).

Table 6.14 Table of the hydrologic annual surface runoff volume and AR (1) synthetic flow of the Limnitis River (Station: 128301810).

Hydrologic year (1 Oct.-30 Sep.)	Surface runoff volume (mcm)	AR (1) synthetic flow (mcm)
1966-1967	20,34	9,31
1967-1968	15,91	4,53
1968-1969	25,55	10,86
1969-1970	4,19	12,01
1970-1971	7,33	7,74
1971-1972	3,45	14,34
1972-1973	4,00	8,18
1973-1974	9,80	17,61
1974-1975	15,62	15,40
1975-1976	16,82	7,33
1976-1977	12,79	14,55
1977-1978	23,37	16,22
1978-1979	7,81	18,76
1979-1980	16,07	18,45
1980-1981	18,14	20,52
1981-1982	6,01	11,55
1982-1983	11,70	6,56
1983-1984	8,51	9,42
1984-1985	8,67	4,38
1985-1986	3,59	9,13
1986-1987	17,46	11,65
1987-1988	18,36	9,97
1988-1989	11,95	7,21
1989-1990	4,24	4,60
1990-1991	1,50	5,17
1991-1992	15,65	8,79
1992-1993	12,53	9,37
1993-1994	6,00	8,53
1994-1995	5,00	12,47
1995-1996	3,30	9,23
1996-1997	3,00	6,18
1997-1998	5,00	9,74
1998-1999	6,00	7,53

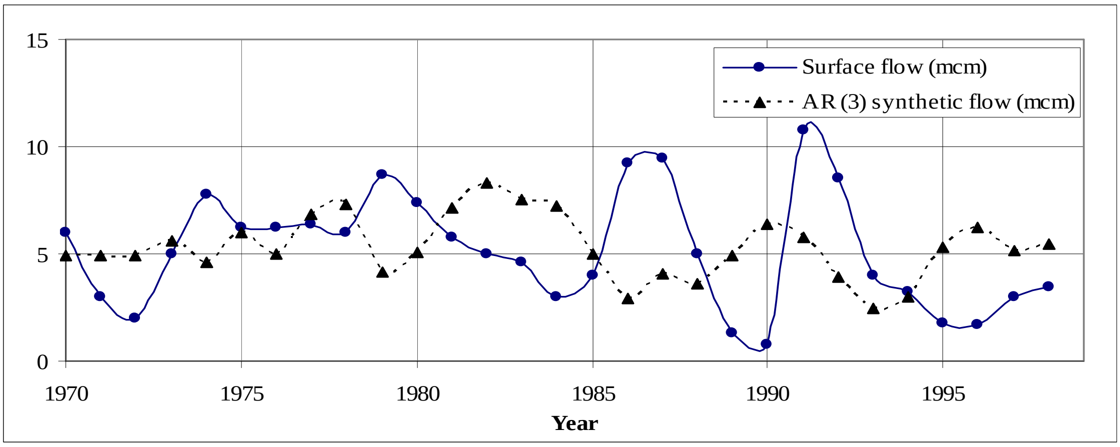

Figure 6.27 Xeros River (Station: 131101770) synthetic sequences with third order Markov model AR (3).

Table 6.15 Table of the hydrologic annual surface runoff volume and AR (3) synthetic flow of the Xeros River (Station: 131101770).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**	**AR (3)synthetic flow (mcm)**
1970-1971	6,00	4,94
1971-1972	3,00	4,94
1972-1973	2,00	4,94
1973-1974	5,00	5,62
1974-1975	7,80	4,58
1975-1976	6,20	5,97
1976-1977	6,25	5,01
1977-1978	6,40	6,81
1978-1979	6,00	7,27
1979-1980	8,70	4,19
1980-1981	7,40	5,08
1981-1982	5,80	7,16
1982-1983	5,00	8,27
1983-1984	4,60	7,57
1984-1985	3,00	7,20
1985-1986	4,00	5,03
1986-1987	9,20	2,95
1987-1988	9,50	4,06
1988-1989	5,00	3,58
1989-1990	1,30	4,92
1990-1991	0,74	6,42
1991-1992	10,75	5,77
1992-1993	8,52	3,91
1993-1994	4,00	2,49
1994-1995	3,20	2,98
1995-1996	1,80	5,30
1996-1997	1,70	6,22
1997-1998	3,00	5,12
1998-1999	3,45	5,44

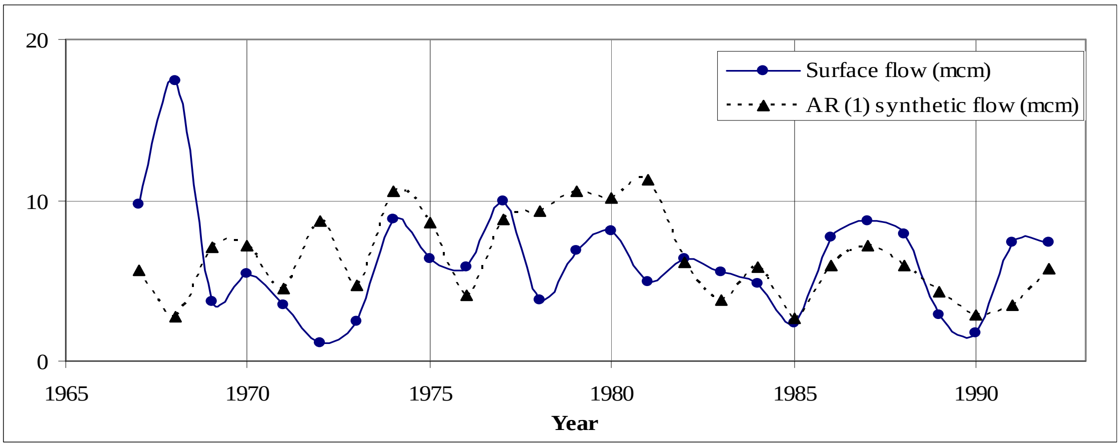

Figure 6.28 Marathasa River (Station: 132103085) synthetic sequences with first order Markov model AR (1).

Table 6.16 Table of the hydrologic annual surface runoff volume and AR (1) synthetic flow of the Marathasa River (Station: 132103085).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**	**AR (1) synthetic flow (mcm)**
1967-1968	9,78	5,65
1968-1969	17,48	2,78
1969-1970	3,70	7,03
1970-1971	5,40	7,23
1971-1972	3,44	4,55
1972-1973	1,14	8,74
1973-1974	2,41	4,71
1974-1975	8,80	10,61
1975-1976	6,35	8,65
1976-1977	5,87	4,08
1977-1978	9,97	8,84
1978-1979	3,83	9,32
1979-1980	6,85	10,55
1980-1981	8,11	10,15
1981-1982	4,94	11,29
1982-1983	6,38	6,19
1983-1984	5,57	3,77
1984-1985	4,80	5,88
1985-1986	2,41	2,71
1986-1987	7,74	5,98
1987-1988	8,76	7,15
1988-1989	7,85	5,90
1989-1990	2,86	4,33
1990-1991	1,76	2,92
1991-1992	7,38	3,48
1992-1993	7,35	5,76

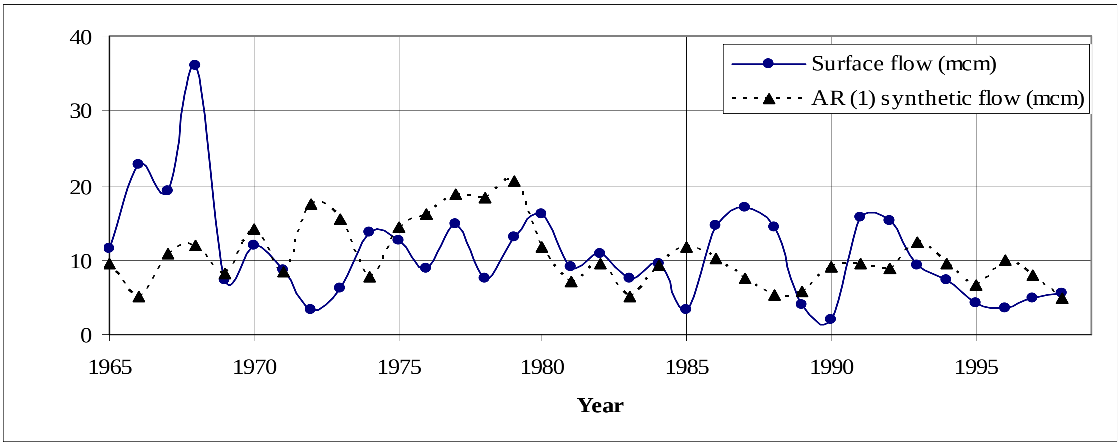

Figure 6.29 Karyotis River (Station: 133304195) synthetic sequences with first order Markov model AR (1).

Table 6.17 Table of the hydrologic annual surface runoff volume and AR (1) synthetic flow of the Karyotis River (Station: 133304195).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**	**AR (1) synthetic flow (mcm)**
1965-1966	11,51	9,51
1966-1967	22,72	5,17
1967-1968	19,17	10,90
1968-1969	35,93	12,03
1969-1970	7,38	8,08
1970-1971	11,94	14,25
1971-1972	8,63	8,49
1972-1973	3,23	17,49
1973-1974	6,18	15,38
1974-1975	13,80	7,74
1975-1976	12,69	14,47
1976-1977	8,81	16,16
1977-1978	14,89	18,74
1978-1979	7,50	18,45
1979-1980	12,99	20,58
1980-1981	16,20	11,70
1981-1982	9,04	7,03
1982-1983	10,81	9,60
1983-1984	7,48	5,04
1984-1985	9,57	9,29
1985-1986	3,38	11,67
1986-1987	14,50	10,13
1987-1988	16,99	7,59
1988-1989	14,36	5,22
1989-1990	4,08	5,72
1990-1991	2,04	8,98
1991-1992	15,79	9,54
1992-1993	15,16	8,78
1993-1994	9,20	12,46
1994-1995	7,20	9,45
1995-1996	4,10	6,66
1996-1997	3,60	9,88
1997-1998	4,80	7,87
1998-1999	5,60	4,79

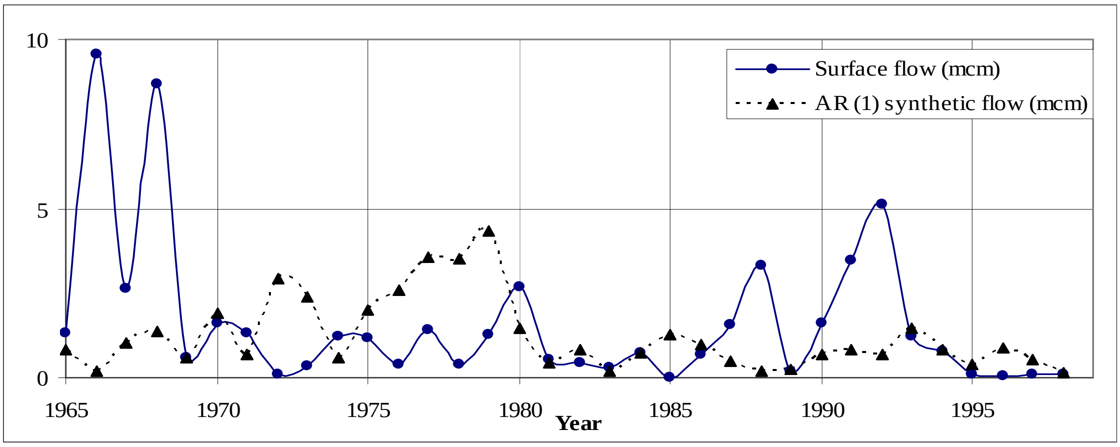

Figure 6.30 Atsas River (Station: 134204790) synthetic sequences with first order Markov model AR (1).

Table 6.18 Table of the hydrologic annual surface runoff volume and AR (1) synthetic flow of the Atsas River (Station: 134204790).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**	**AR (1) synthetic flow (mcm)**
1965-1966	1,32	0,83
1966-1967	9,54	0,21
1967-1968	2,63	1,05
1968-1969	8,67	1,36
1969-1970	0,57	0,59
1970-1971	1,60	1,92
1971-1972	1,30	0,68
1972-1973	0,12	2,92
1973-1974	0,36	2,39
1974-1975	1,23	0,57
1975-1976	1,18	2,01
1976-1977	0,40	2,59
1977-1978	1,42	3,54
1978-1979	0,41	3,51
1979-1980	1,29	4,36
1980-1981	2,69	1,45
1981-1982	0,52	0,46
1982-1983	0,46	0,84
1983-1984	0,27	0,19
1984-1985	0,74	0,74
1985-1986	0,01	1,25
1986-1987	0,68	0,96
1987-1988	1,55	0,51
1988-1989	3,32	0,21
1989-1990	0,21	0,24
1990-1991	1,60	0,68
1991-1992	3,47	0,81
1992-1993	5,11	0,69
1993-1994	1,20	1,45
1994-1995	0,80	0,84
1995-1996	0,08	0,38
1996-1997	0,04	0,87
1997-1998	0,08	0,54
1998-1999	0,08	0,17

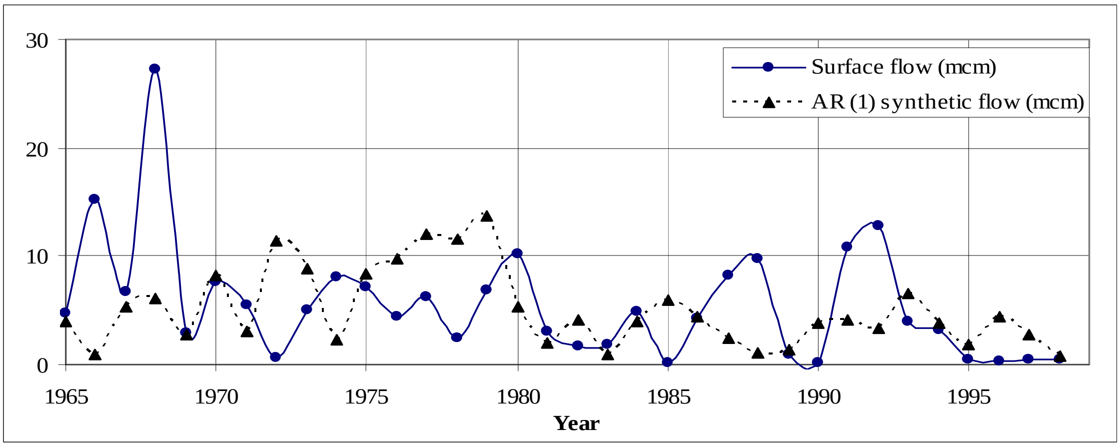

Figure 6.31 Elea River (Station: 135407440) synthetic sequences with first order Markov model AR (1).

Table 6.19 Table of the hydrologic annual surface runoff volume and AR (1) synthetic flow of the Elea River (Station: 135407440).

Hydrologic year (1 Oct.-30 Sep.)	Surface runoff (mcm)	AR (1) synthetic flow (mcm)
1965-1966	4,70	3,93
1966-1967	15,22	0,94
1967-1968	6,71	5,39
1968-1969	27,23	6,12
1969-1970	2,91	2,74
1970-1971	7,60	8,26
1971-1972	5,45	2,99
1972-1973	0,54	11,40
1973-1974	5,08	8,82
1974-1975	8,13	2,35
1975-1976	7,19	8,41
1976-1977	4,41	9,73
1977-1978	6,27	12,08
1978-1979	2,40	11,60
1979-1980	6,81	13,68
1980-1981	10,20	5,25
1981-1982	3,01	1,93
1982-1983	1,65	4,07
1983-1984	1,81	0,87
1984-1985	4,91	4,00
1985-1986	0,19	5,89
1986-1987	4,27	4,38
1987-1988	8,22	2,42
1988-1989	9,81	1,00
1989-1990	0,97	1,36
1990-1991	0,11	3,76
1991-1992	10,86	4,05
1992-1993	12,73	3,37
1993-1994	4,00	6,56
1994-1995	3,20	3,78
1995-1996	0,50	1,80
1996-1997	0,30	4,38
1997-1998	0,40	2,68
1998-1999	0,40	0,78

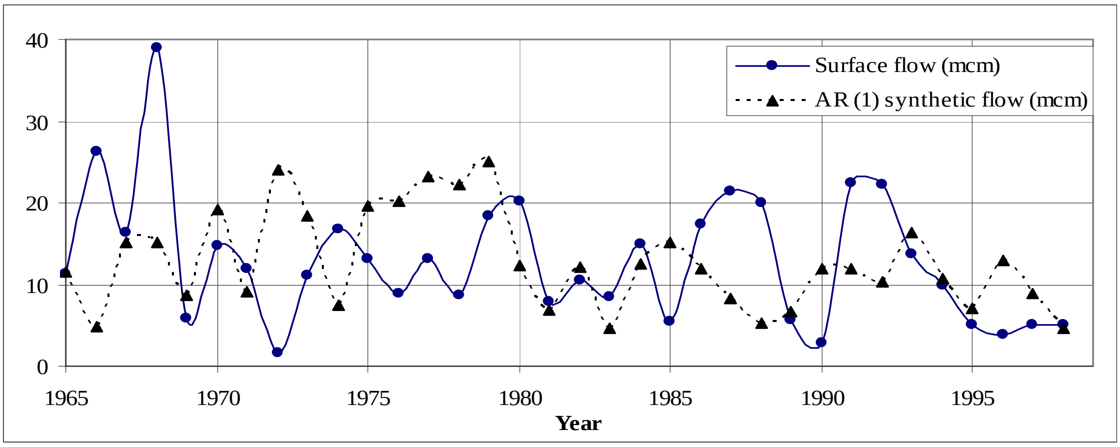

Figure 6.32 Peristerona River (Station: 137108550) synthetic sequences with first order Markov model AR (1).

Table 6.20 Table of the hydrologic annual surface runoff volume and AR (1) synthetic flow of the Peristerona River (Station: 137108550).

Hydrologic year (1 Oct.-30 Sep.)	Surface runoff (mcm)	AR (1) synthetic flow (mcm)
1965-1966	11,30	11,45
1966-1967	26,29	4,85
1967-1968	16,39	15,20
1968-1969	38,97	15,23
1969-1970	5,91	8,73
1970-1971	14,78	19,24
1971-1972	11,88	9,01
1972-1973	1,67	24,02
1973-1974	11,03	18,40
1974-1975	16,86	7,53
1975-1976	13,12	19,53
1976-1977	8,79	20,28
1977-1978	13,03	23,29
1978-1979	8,61	22,14
1979-1980	18,42	25,06
1980-1981	20,30	12,26
1981-1982	7,98	6,97
1982-1983	10,43	12,17
1983-1984	8,56	4,69
1984-1985	14,85	12,58
1985-1986	5,52	15,16
1986-1987	17,30	11,94
1987-1988	21,41	8,30
1988-1989	19,99	5,22
1989-1990	5,56	6,62
1990-1991	2,80	12,00
1991-1992	22,39	11,86
1992-1993	22,23	10,37
1993-1994	13,75	16,29
1994-1995	10,00	10,73
1995-1996	5,00	7,00
1996-1997	3,75	12,89
1997-1998	5,00	8,95
1998-1999	5,00	4,55

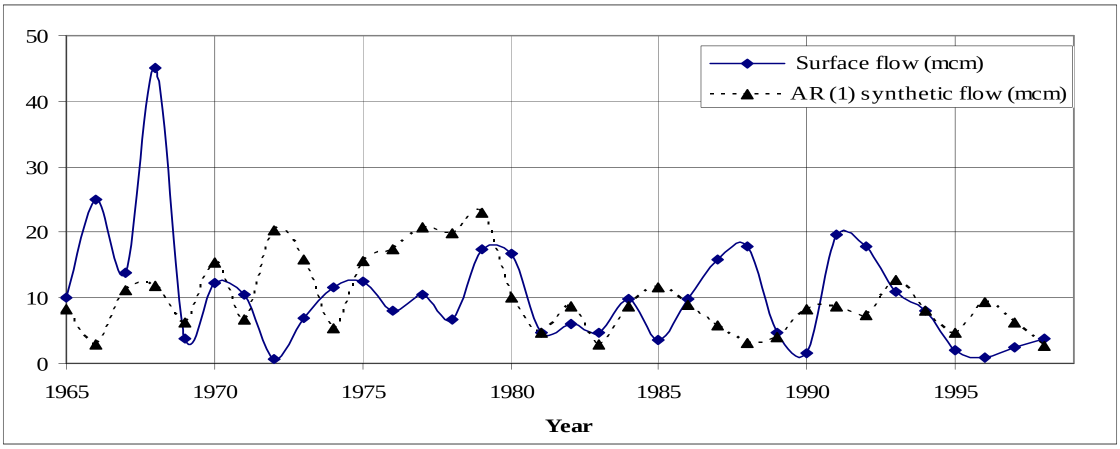

Figure 6.33 Akaki River (Station: 137311690) synthetic sequences with first order Markov model AR (1).

Table 6.21 Table of the hydrologic annual surface runoff volume and AR (1) synthetic flow of the Akaki River (Station: 137311690).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**	**AR (1) synthetic flow (mcm)**
1965-1966	10,11	8,36
1966-1967	25,07	2,98
1967-1968	13,92	11,07
1968-1969	45,02	11,92
1969-1970	3,82	6,23
1970-1971	12,28	15,43
1971-1972	10,51	6,60
1972-1973	0,76	20,32
1973-1974	6,92	15,80
1974-1975	11,59	5,45
1975-1976	12,58	15,66
1976-1977	8,13	17,36
1977-1978	10,55	20,81
1978-1979	6,74	19,90
1979-1980	17,34	23,04
1980-1981	16,84	10,04
1981-1982	4,75	4,77
1982-1983	6,06	8,70
1983-1984	4,60	2,86
1984-1985	9,78	8,75
1985-1986	3,50	11,65
1986-1987	9,72	9,01
1987-1988	15,80	5,74
1988-1989	17,78	3,14
1989-1990	4,73	3,97
1990-1991	1,53	8,33
1991-1992	19,58	8,63
1992-1993	17,81	7,42
1993-1994	11,00	12,70
1994-1995	8,00	7,99
1995-1996	1,90	4,63
1996-1997	0,90	9,27
1997-1998	2,40	6,23
1998-1999	3,70	2,68

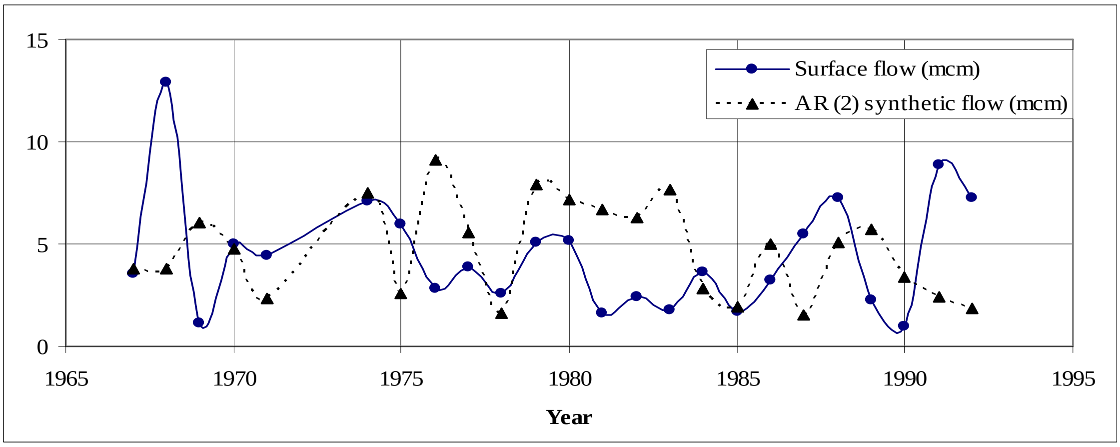

Figure 6.34 Pedios River (Station: 161113185) synthetic sequences with second order Markov model AR (2).

Table 6.22 Table of the hydrologic annual surface runoff volume and AR (2) synthetic flow of the Pedios River (Station: 161113185).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**	**AR (2) synthetic flow (mcm)**
1967-1968	3,55	3,79
1968-1969	12,88	3,79
1969-1970	1,11	6,02
1970-1971	5,02	4,77
1971-1972	4,44	2,30
1974-1975	7,08	7,52
1975-1976	6,01	2,55
1976-1977	2,83	9,10
1977-1978	3,90	5,56
1978-1979	2,61	1,64
1979-1980	5,09	7,88
1980-1981	5,20	7,14
1981-1982	1,59	6,73
1982-1983	2,42	6,26
1983-1984	1,81	7,64
1984-1985	3,60	2,85
1985-1986	1,71	1,90
1986-1987	3,27	5,01
1987-1988	5,48	1,54
1988-1989	7,25	5,09
1989-1990	2,29	5,76
1990-1991	0,93	3,37
1991-1992	8,84	2,42
1992-1993	7,30	1,85

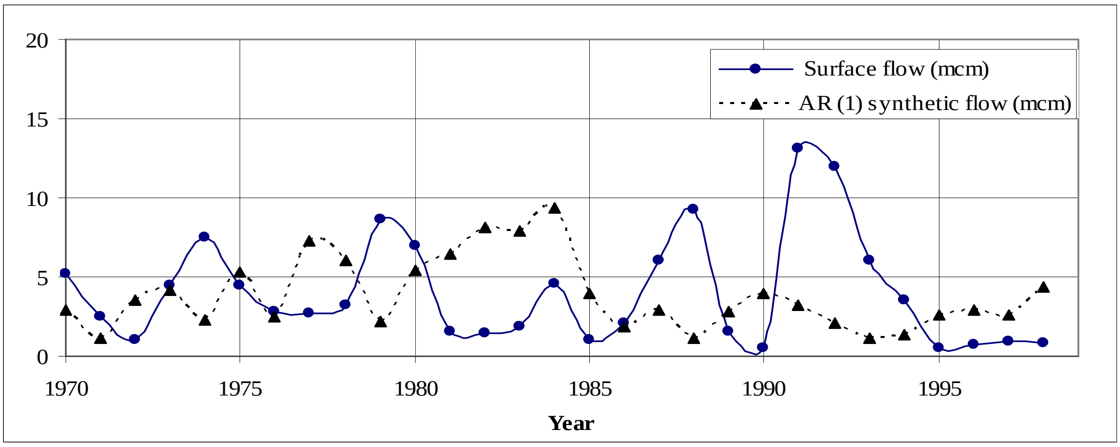

Figure 6.35 Yialias River (Station: 165115385) synthetic sequences with first order Markov model AR (1).

Table 6.23 Table of the hydrologic annual surface runoff volume and AR (1) synthetic flow of the Yialias River (Station: 165115385).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**	**AR (1) synthetic flow (mcm)**
1970-1971	5,25	2,90
1971-1972	2,50	1,17
1972-1973	1,00	3,54
1973-1974	4,50	4,12
1974-1975	7,50	2,28
1975-1976	4,50	5,33
1976-1977	2,82	2,46
1977-1978	2,75	7,28
1978-1979	3,27	6,02
1979-1980	8,64	2,15
1980-1981	6,99	5,46
1981-1982	1,52	6,48
1982-1983	1,41	8,13
1983-1984	1,89	7,96
1984-1985	4,59	9,40
1985-1986	1,05	4,01
1986-1987	2,12	1,86
1987-1988	6,03	2,94
1988-1989	9,25	1,13
1989-1990	1,60	2,78
1990-1991	0,48	3,94
1991-1992	13,14	3,19
1992-1993	11,95	2,07
1993-1994	6,00	1,18
1994-1995	3,50	1,35
1995-1996	0,55	2,64
1996-1997	0,70	2,90
1997-1998	0,90	2,57
1998-1999	0,80	4,35

The results were tested against observed data and synthetic data. The results were evaluated by the efficiency index:

$$\gamma = \left[1 - \left[\frac{\sigma_p}{\sigma_M}\right]^2\right]^{1/2} \qquad (6\text{-}3)$$

Where σ_P is the standard deviation of the synthetic data series and σ_M is the standard deviation of the measured time series.

The efficiency index, γ, gives a very strict criterion for the goodness of the prediction of synthetic sequences (Duckstein *et al.*, 1985): $\gamma \geq 0.86$ indicate a good relationship and $0.6 \leq \gamma \leq 0.86$ is still acceptable (Iritz, 1992).

Table 6.24 shows the results of efficiency index for all rivers. According to limitations of the efficiency index only Atsas River gives good relationship. All the other results are in the acceptable range.

Table 6.24 Table of the efficiency index of the 10 rivers originating from Troodos Mountains.

Stream name	σ_p **(mcm)**	σ_M **(mcm)**	**The efficiency index (** γ **)**
Limnitis	6,56	4,36	0,75
Xeros	2,67	1,44	0,84
Marathasa	3,4	2,62	0,64
Karyotis	6,73	4,22	0,78
Atsas	2,22	1,07	0,88
Elea	5,46	3,54	0,76
Peristerona	7,89	5,89	0,67
Akaki	8,59	5,64	0,75
Pedios	2,82	2,29	0,58
Yialias	3,45	2,27	0,75

6.6 The predicted synthetic sequence of river flows

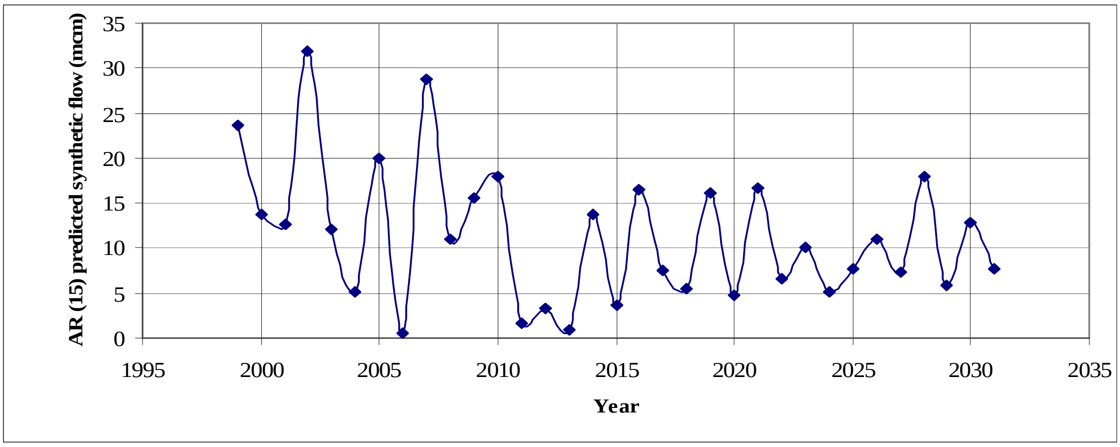

Figure 6.36 Limnitis River (Station: 128301810) predicted synthetic flow with AR (15).

Table 6.25 Table of the annual AR (15) predicted synthetic flow of the Limnitis River (Station: 128301810).

Hydrologic year (1 Oct.-30 Sep.)	**AR (15) predicted synthetic flow (mcm)**
1999-2000	23,69
2000-2001	13,78
2001-2002	12,61
2002-2003	31,85
2003-2004	12,04
2004-2005	5,08
2005-2006	19,89
2006-2007	0,50
2007-2008	28,80
2008-2009	10,93
2009-2010	15,53
2010-2011	17,87
2011-2012	1,58
2012-2013	3,29
2013-2014	0,96
2014-2015	13,78
2015-2016	3,74
2016-2017	16,42
2017-2018	7,54
2018-2019	5,42
2019-2020	16,09
2020-2021	4,81
2021-2022	16,61
2022-2023	6,58
2023-2024	10,16
2024-2025	5,07
2025-2026	7,72
2026-2027	10,97
2027-2028	7,32
2028-2029	17,88
2029-2030	5,88
2030-2031	12,79
2031-2032	7,72

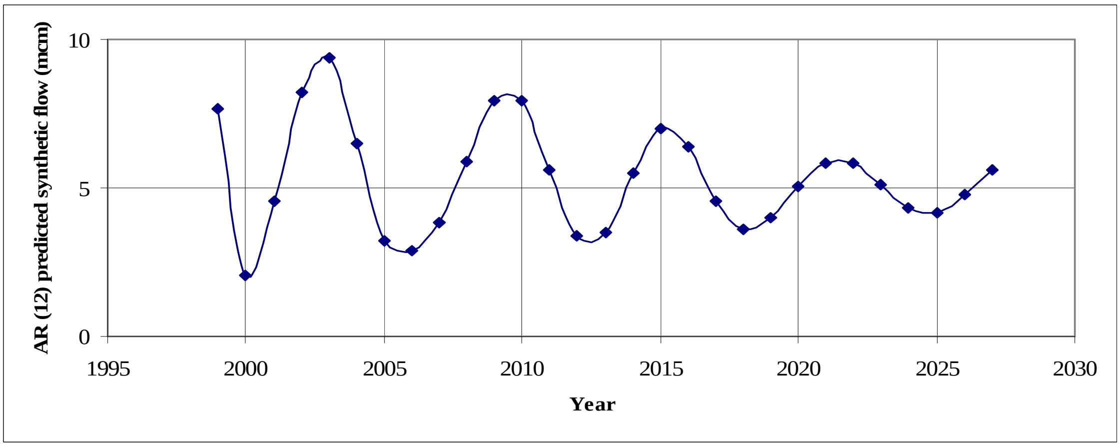

Figure 6.37 Xeros River (Station: 131101770) predicted synthetic flow with AR (12).

Table 6.26 Table of the annual AR (12) predicted synthetic flow of the Xeros River (Station: 131101770).

Hydrologic year (1 Oct.-30 Sep.)	**AR (12) predicted synthetic flow (mcm)**
1999-2000	7,69
2000-2001	2,04
2001-2002	4,55
2002-2003	8,24
2003-2004	9,37
2004-2005	6,48
2005-2006	3,20
2006-2007	2,87
2007-2008	3,83
2008-2009	5,91
2009-2010	7,95
2010-2011	7,96
2011-2012	5,61
2012-2013	3,38
2013-2014	3,49
2014-2015	5,51
2015-2016	7,02
2016-2017	6,38
2017-2018	4,53
2018-2019	3,60
2019-2020	4,02
2020-2021	5,03
2021-2022	5,81
2022-2023	5,82
2023-2024	5,12
2024-2025	4,34
2025-2026	4,16
2026-2027	4,79
2027-2028	5,60

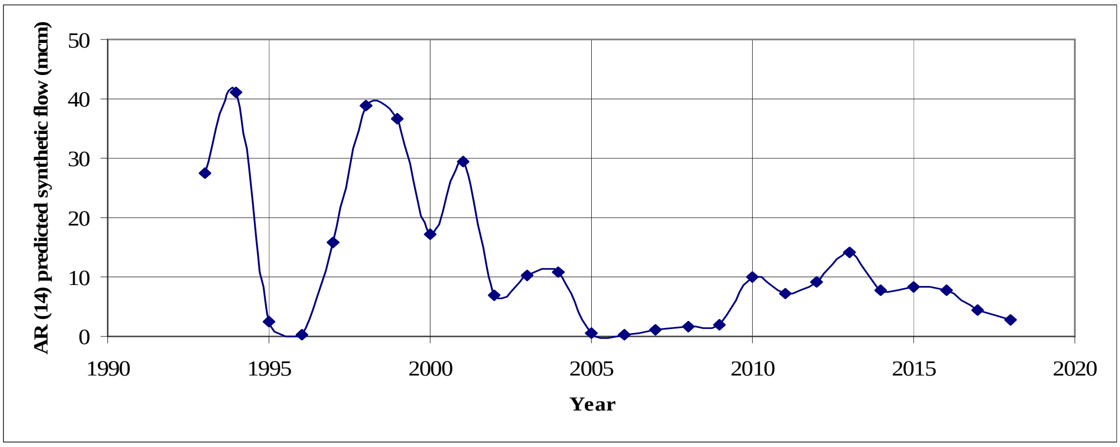

Figure 6.38 Marathasa River (Station: 132103085) predicted synthetic flow with AR (14).

Table 6.27 Table of the annual AR (14) predicted synthetic flow of the Marathasa River (Station: 132103085).

Hydrologic year (1 Oct.-30 Sep.)	**AR (14) predicted synthetic flow (mcm)**
1993-1994	27,54
1994-1995	41,12
1995-1996	2,59
1996-1997	0,31
1997-1998	15,82
1998-1999	38,87
1999-2000	36,62
2000-2001	17,34
2001-2002	29,40
2002-2003	6,92
2003-2004	10,26
2004-2005	10,83
2005-2006	0,55
2006-2007	0,37
2007-2008	1,15
2008-2009	1,68
2009-2010	2,08
2010-2011	9,97
2011-2012	7,27
2012-2013	9,09
2013-2014	14,22
2014-2015	7,65
2015-2016	8,34
2016-2017	7,74
2017-2018	4,48
2018-2019	2,90

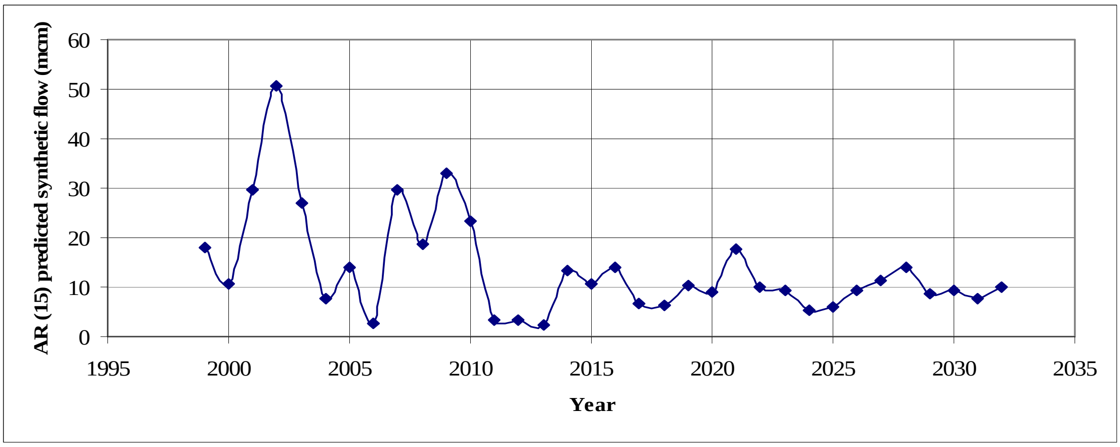

Figure 6.39 Karyotis River (Station: 133304195) predicted synthetic flow with AR (15).

Table 6.28 Table of the annual AR (15) predicted synthetic flow of the Karyotis River (Station: 133304195).

Hydrologic year (1 Oct.-30 Sep.)	AR (15) predicted synthetic flow (mcm)
1999-2000	17,87
2000-2001	10,63
2001-2002	29,56
2002-2003	50,61
2003-2004	26,93
2004-2005	7,82
2005-2006	14,14
2006-2007	2,77
2007-2008	29,57
2008-2009	18,65
2009-2010	33,07
2010-2011	23,23
2011-2012	3,21
2012-2013	3,30
2013-2014	2,48
2014-2015	13,38
2015-2016	10,63
2016-2017	14,16
2017-2018	6,60
2018-2019	6,37
2019-2020	10,43
2020-2021	8,85
2021-2022	17,55
2022-2023	10,06
2023-2024	9,31
2024-2025	5,17
2025-2026	6,11
2026-2027	9,30
2027-2028	11,41
2028-2029	14,02
2029-2030	8,62
2030-2031	9,47
2031-2032	7,53
2032-2033	9,89

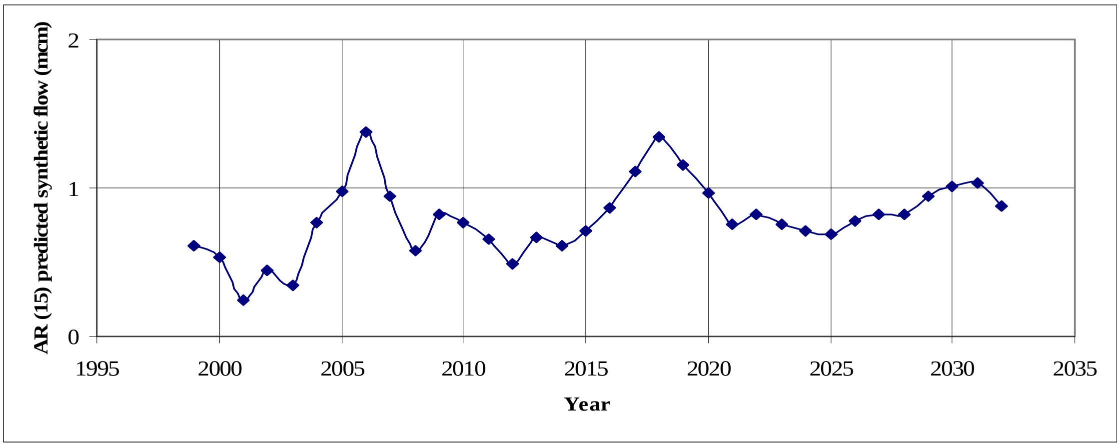

Figure 6.40 Atsas River (Station: 134204790) predicted synthetic flow with AR (15).

Table 6.29 Table of the annual AR (15) predicted synthetic flow of the Atsas River (Station: 134204790).

Hydrologic year (1 Oct.-30 Sep.)	**AR (15) predicted synthetic flow (mcm)**
1999-2000	0,61
2000-2001	0,53
2001-2002	0,24
2002-2003	0,44
2003-2004	0,35
2004-2005	0,76
2005-2006	0,98
2006-2007	1,38
2007-2008	0,95
2008-2009	0,57
2009-2010	0,82
2010-2011	0,77
2011-2012	0,66
2012-2013	0,49
2013-2014	0,67
2014-2015	0,61
2015-2016	0,71
2016-2017	0,86
2017-2018	1,11
2018-2019	1,35
2019-2020	1,16
2020-2021	0,97
2021-2022	0,75
2022-2023	0,82
2023-2024	0,75
2024-2025	0,71
2025-2026	0,69
2026-2027	0,78
2027-2028	0,83
2028-2029	0,82
2029-2030	0,94
2030-2031	1,01
2031-2032	1,03
2032-2033	0,88

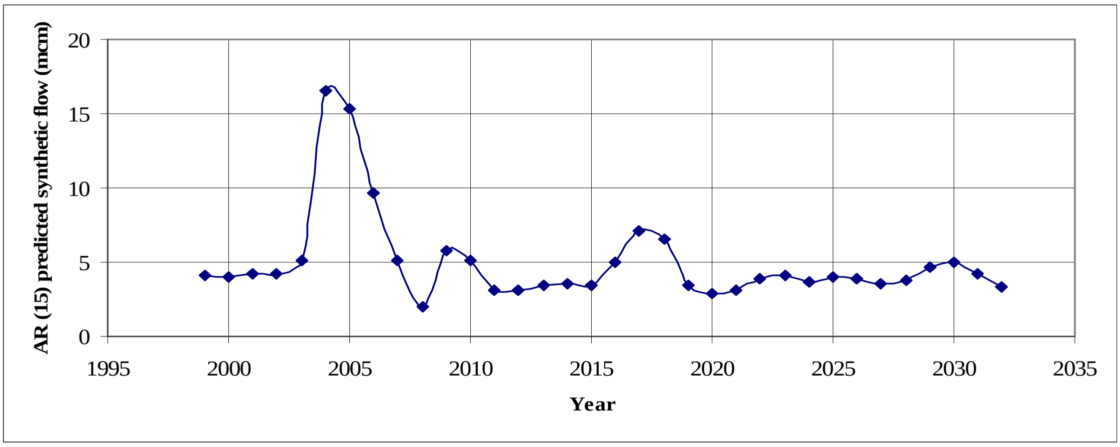

Figure 6.41 Elea River (Station: 135407440) predicted synthetic flow with AR (15).

Table 6.30 Table of the annual AR (15) predicted synthetic flow of the Elea River (Station: 135407440).

Hydrologic year (1 Oct.-30 Sep.)	**AR (15) predicted synthetic flow (mcm)**
1999-2000	4,08
2000-2001	4,00
2001-2002	4,22
2002-2003	4,23
2003-2004	5,13
2004-2005	16,55
2005-2006	15,33
2006-2007	9,63
2007-2008	5,14
2008-2009	2,04
2009-2010	5,83
2010-2011	5,13
2011-2012	3,16
2012-2013	3,07
2013-2014	3,42
2014-2015	3,52
2015-2016	3,47
2016-2017	4,95
2017-2018	7,07
2018-2019	6,56
2019-2020	3,44
2020-2021	2,86
2021-2022	3,14
2022-2023	3,88
2023-2024	4,15
2024-2025	3,65
2025-2026	3,99
2026-2027	3,85
2027-2028	3,60
2028-2029	3,82
2029-2030	4,67
2030-2031	4,99
2031-2032	4,22
2032-2033	3,35

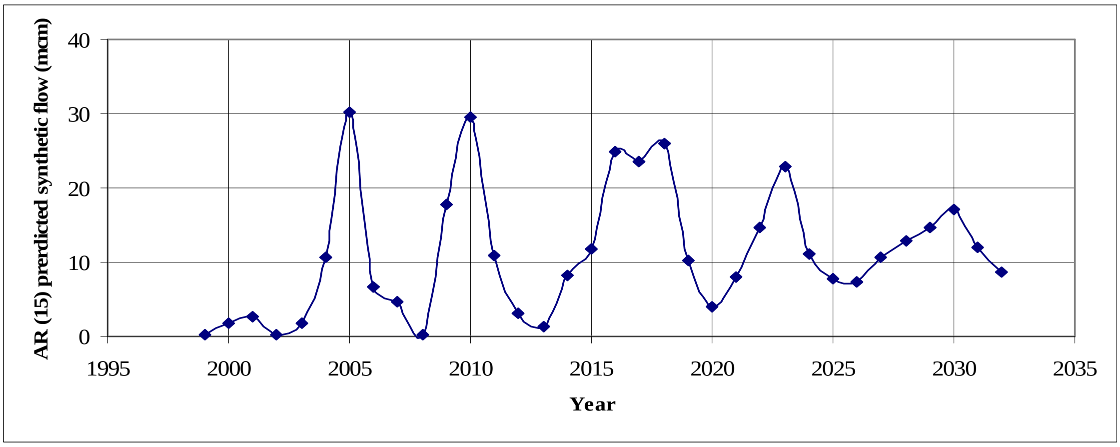

Figure 6.42 Peristerona River (Station: 137108550) predicted synthetic flow with AR (15).

Table 6.31 Table of the annual AR (15) predicted synthetic flow of the Peristerona River (Station: 137108550).

Hydrologic year (1 Oct.-30 Sep.)	**AR (15) predicted synthetic flow (mcm)**
1999-2000	0,11
2000-2001	1,86
2001-2002	2,56
2002-2003	0,16
2003-2004	1,83
2004-2005	10,66
2005-2006	30,29
2006-2007	6,72
2007-2008	4,75
2008-2009	0,23
2009-2010	17,88
2010-2011	29,45
2011-2012	10,91
2012-2013	3,15
2013-2014	1,40
2014-2015	8,29
2015-2016	11,79
2016-2017	24,96
2017-2018	23,48
2018-2019	26,08
2019-2020	10,29
2020-2021	4,07
2021-2022	8,05
2022-2023	14,71
2023-2024	22,95
2024-2025	11,02
2025-2026	7,85
2026-2027	7,31
2027-2028	10,56
2028-2029	12,99
2029-2030	14,69
2030-2031	17,17
2031-2032	12,06
2032-2033	8,66

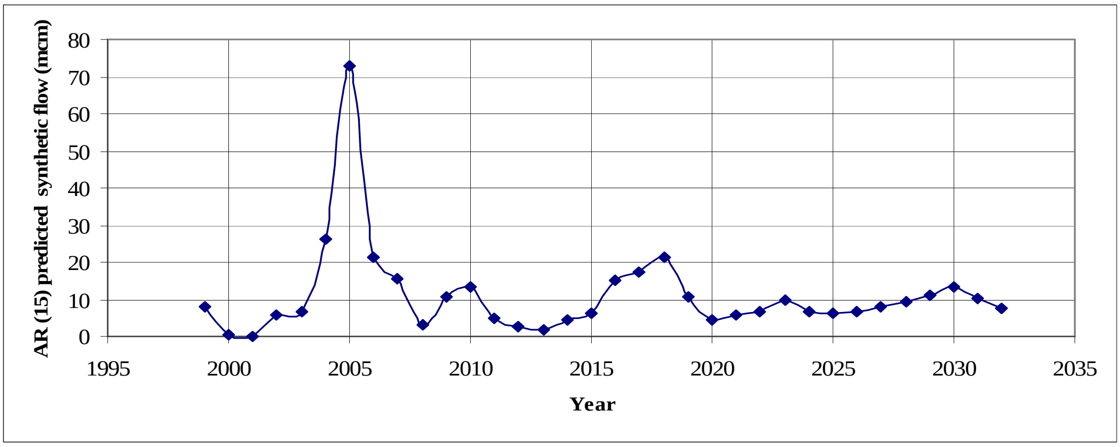

Figure 6.43 Akaki River (Station: 137311690) predicted synthetic flow with AR (15).

Table 6.32 Table of the annual AR (15) predicted synthetic flow of the Akaki River (Station: 137311690).

Hydrologic year (1 Oct.-30 Sep.)	**AR (15) predicted synthetic flow (mcm)**
1999-2000	8,08
2000-2001	0,29
2001-2002	0,12
2002-2003	5,79
2003-2004	6,45
2004-2005	26,11
2005-2006	72,96
2006-2007	21,48
2007-2008	15,54
2008-2009	3,07
2009-2010	10,45
2010-2011	13,53
2011-2012	4,78
2012-2013	2,57
2013-2014	1,80
2014-2015	4,59
2015-2016	6,06
2016-2017	15,06
2017-2018	17,25
2018-2019	21,20
2019-2020	10,87
2020-2021	4,38
2021-2022	5,77
2022-2023	6,64
2023-2024	9,64
2024-2025	6,74
2025-2026	6,38
2026-2027	6,53
2027-2028	7,93
2028-2029	9,52
2029-2030	10,96
2030-2031	13,37
2031-2032	10,02
2032-2033	7,67

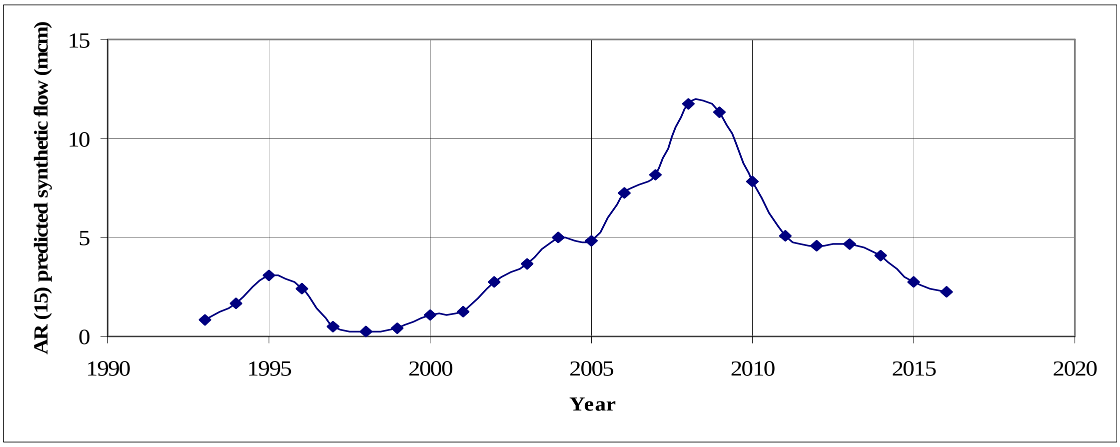

Figure 6.44 Pedios River (Station: 161113185) predicted synthetic flow with AR (15).

Table 6.33 Table of the annual AR (15) predicted synthetic flow of the Pedios River (Station: 161113185).

Hydrologic year (1 Oct.-30 Sep.)	**AR (15) predicted synthetic flow (mcm)**
1993-1994	0,83
1994-1995	1,65
1995-1996	3,07
1996-1997	2,39
1997-1998	0,47
1998-1999	0,25
1999-2000	0,42
2000-2001	1,11
2001-2002	1,29
2002-2003	2,74
2003-2004	3,64
2004-2005	5,01
2005-2006	4,81
2006-2007	7,24
2007-2008	8,19
2008-2009	11,75
2009-2010	11,31
2010-2011	7,87
2011-2012	5,11
2012-2013	4,62
2013-2014	4,71
2014-2015	4,12
2015-2016	2,75
2016-2017	2,24

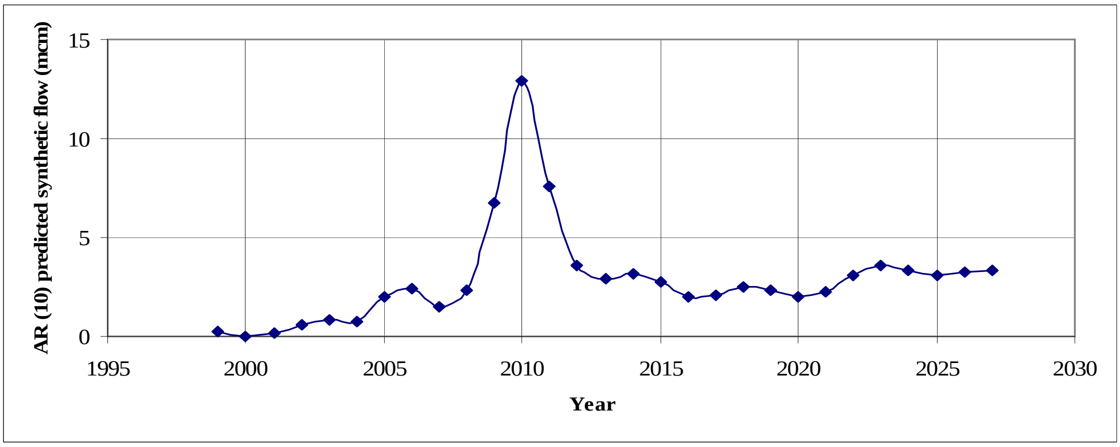

Figure 6.45 Yialias River (Station: 165115385) predicted synthetic flow with AR (10).

Table 6.34 Table of the annual AR (10) predicted synthetic flow of the Yialias River (Station: 165115385).

Hydrologic year (1 Oct.-30 Sep.)	**AR (10) predicted synthetic flow (mcm)**
1999-2000	0,26
2000-2001	0,02
2001-2002	0,19
2002-2003	0,54
2003-2004	0,85
2004-2005	0,77
2005-2006	2,03
2006-2007	2,45
2007-2008	1,51
2008-2009	2,29
2009-2010	6,77
2010-2011	12,90
2011-2012	7,61
2012-2013	3,61
2013-2014	2,96
2014-2015	3,16
2015-2016	2,79
2016-2017	2,02
2017-2018	2,11
2018-2019	2,50
2019-2020	2,34
2020-2021	2,02
2021-2022	2,21
2022-2023	3,06
2023-2024	3,55
2024-2025	3,32
2025-2026	3,11
2026-2027	3,25
2027-2028	3,36

The average of the 35 years of monitored data has shown that the average of 35 years is 72.19 million cubic meters of surface flow per year. The average of predicted 20 years as shown through above Figures and Tables is 78.9 million cubic meters per year. The result shows the reliability of the predicted surface runoff data. Fig.6.46 and Fig. 6.47 shows average annual surface runoff of monitored and predicted data. The surface runoff tables for annual averages are given in Appendix 4.1 and 4.2.

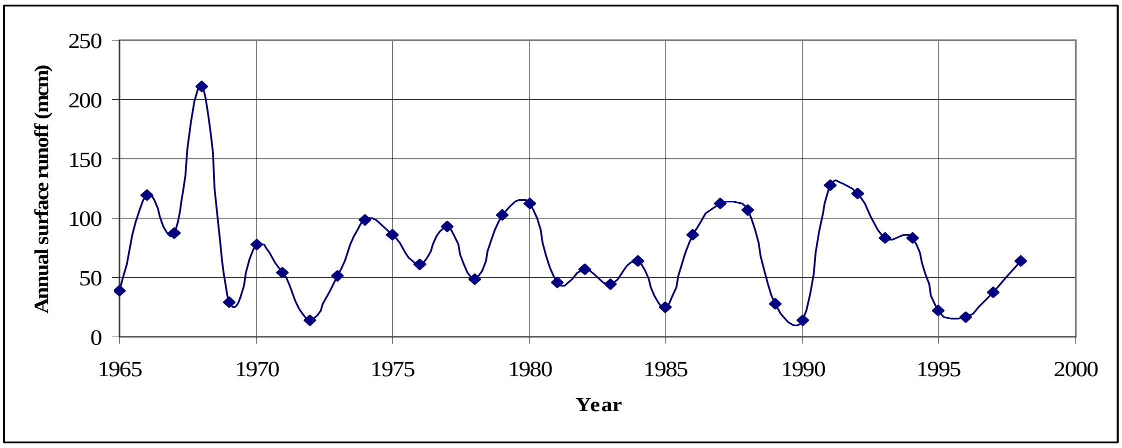

Figure 6.46 Annual surface runoff of the 10 rivers originating from Troodos Mountains.

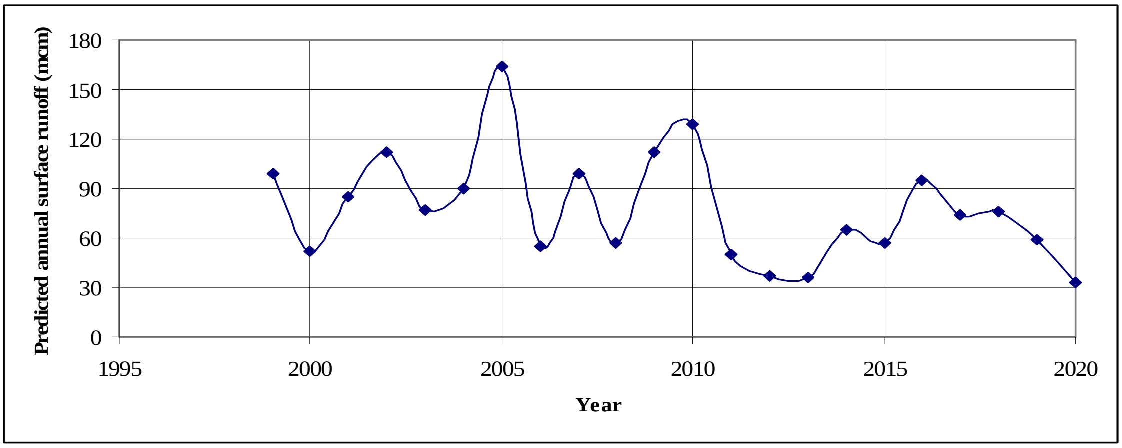

Figure 6.47 Predicted annual surface runoff of the 10 rivers originating from Troodos Mountains.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

The knowledge of river flow characteristics and generation of synthetic river flow data is important in planning, design and operation of water resources systems.

The common procedure in modeling river flow series is to standardize the series and then fit an appropriate stochastic model as time series. Autoregressive model (AR) provides a powerful tool for the modeling of river flow series in particular. The Autoregressive models involve iterative steps of model identification, parameter estimation, model diagnosis and fitting the residuals.

The main purposes of this dissertation were to fit a model to represent a river flow data of 10 rivers at Northern part of Cyprus. The modeling was build on the estimate of parameters, modeling the residuals, generating synthetic river flows and check for goodness of fit to the monitored data. Finally, the findings were used to evaluate the synthetic series for future flow predictions.

The study on available data demonstrated that the (AR) model was an efficient and reliable technique in which, the model identification technique was supplemented by the Akaike's information criterion (AIC) in order to decide the type and the order of the model. The Box-Pierce Porte Manteau test is used to check the dependency of residuals.

We used annual river flow data for the 10 rivers draining from Troodos Mountains in order to illustrate the model implementation. The fitness of good of the results was tested against monitored data by the help of efficiency index. The result shows that the synthetic series are in good relation with the observed river flow discharges.

Secondly, we searched for the connection between 10 rivers in terms of surface runoff and their spatial distribution. The surface runoff magnitudes of the streams were differing from each other depending on the magnitude of the precipitation and the drainage area characteristics of the watershed. The significance of the correlation of the rivers is all tested via hypothesis test with a significance level of 90%. The results of the hypothesis tests prove that the river flows are "strongly" and "very strongly" dependent on each other. The positive correlation is due to the equivalent climatic factors of the region and their homogenous spatial distribution. It is also found that the correlation shifts from "very strong" to "strong" is due to the anthropogenic activities which increases from west to east.

Thirdly, for analysis and design of water resources systems, it is sometimes required to generate a relationship between rainfall and runoff. This was important to be able to identify the transition from "none or negligible" flow condition to surface flow condition. The result has shown that around 250-300mm annual precipitation is considerably enough to initiate surface flow at the ten basins. The regression model is used to model Rainfall-Runoff relationship which gives an exponential relationship between the parameters. During the analysis, the drainage areas and their slopes due to topographic conditions are also considered to generate a unique exponential regression equation for defining Rainfall-Runoff relationship of all the river basins in the study area. The resultant equation was a generalized equation with R^2=0.75.

The methods presented in this research allow us to create future flow predictions for 10 rivers. For this purpose, AR (10), AR (12), AR (14), AR (15) autoregressive models are used to generate expected flows up to 2020. The predicted flows has shown that the mean annual average flows are expected to increase around 9% in the upcoming years rising from 72.19 million cubic meters to 78.9 million cubic meters. These results are approximately 20% less than what is proposed by DSİ (2003).

As part of the future work, it is recommended to generate stochastic modeling for the downstream drainage areas of the 10 rivers in which the surface geology totally changes and surface flow turns to be a subsurface flow due to the gravel and pebbles distributed all around the river beds. Also, the effect of dense vegetal cover on surface flow at the upstream side of the rain gages can be a motivating study to develop the findings in this thesis.

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APPENDIX 1

Appendix 1.1 Table of the hydrologic annual surface runoff volume of the Limnitis River (Station: 128301810).

Hydrologic year (1 Oct.-30 Sep.)	Surface runoff (mcm)
1966-1967	20,34
1967-1968	15,91
1968-1969	25,55
1969 1970	4,19
1970 1971	7,33
1971-1972	3,45
1972-1973	4,00
1973-1974	9,80
1974-1975	15,62
1975-1976	16,82
1976-1977	12,79
1977-1978	23,37
1978-1979	7,81
1979-1980	16,07
1980-1981	18,14
1981-1982	6,01
1982-1983	11,70
1983-1984	8,51
1984-1985	8,67
1985-1986	3,59
1986-1987	17,46
1987-1988	18,36
1988-1989	11,95
1989-1990	4,24
1990-1991	1,50
1991-1992	15,65
1992-1993	12,53
1993-1994	6,00
1994-1995	5,00
1995-1996	3,30
1996-1997	3,00
1997-1998	5,00
1998-1999	6,00

Appendix 1.2 Table of the hydrologic annual surface runoff volume of the Xeros River (Station: 131101770).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**
1970- 1971	6,00
1971-1972	3,00
1972-1973	2,00
1973-1974	5,00
1974-1975	7,80
1975-1976	6,20
1976-1977	6,25
1977-1978	6,40
1978-1979	6,00
1979-1980	8,70
1980-1981	7,40
1981-1982	5,80
1982-1983	5,00
1983-1984	4,60
1984-1985	3,00
1985-1986	4,00
1986-1987	9,20
1987-1988	9,50
1988-1989	5,00
1989-1990	1,30
1990-1991	0,74
1991-1992	10,75
1992-1993	8,52
1993-1994	4,00
1994-1995	3,20
1995-1996	1,80
1996-1997	1,70
1997-1998	3,00
1998-1999	3,45

Appendix 1.3 Table of the hydrologic annual surface runoff volume of the Marathasa River (Station: 132103085).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**
1967-1968	9,78
1968-1969	17,48
1969-1970	3,70
1970-1971	5,40
1971-1972	3,44
1972-1973	1,14
1973-1974	2,41
1974-1975	8,80
1975-1976	6,35
1976-1977	5,87
1977-1978	9,97
1978-1979	3,83
1979-1980	6,85
1980-1981	8,11
1981-1982	4,94
1982-1983	6,38
1983-1984	5,57
1984-1985	4,80
1985-1986	2,41
1986-1987	7,74
1987-1988	8,76
1988-1989	7,85
1989-1990	2,86
1990-1991	1,76
1991-1992	7,38
1992-1993	7,35

Appendix 1.4 Table of the hydrologic annual surface runoff volume of the Karyotis River (Station: 133304195).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**
1965-1966	11,51
1966-1967	22,72
1967-1968	19,17
1968-1969	35,93
1969-1970	7,38
1970-1971	11,94
1971-1972	8,63
1972-1973	3,23
1973-1974	6,18
1974-1975	13,80
1975-1976	12,69
1976-1977	8,81
1977-1978	14,89
1978-1979	7,50
1979-1980	12,99
1980-1981	16,20
1981-1982	9,04
1982-1983	10,81
1983-1984	7,48
1984-1985	9,57
1985-1986	3,38
1986-1987	14,50
1987-1988	16,99
1988-1989	14,36
1989-1990	4,08
1990-1991	2,04
1991-1992	15,79
1992-1993	15,16
1993-1994	9,20
1994-1995	7,20
1995-1996	4,10
1996-1997	3,60
1997-1998	4,80
1998-1999	5,60

Appendix 1.5 Table of the hydrologic annual surface runoff volume of the Atsas River (Station: 134204790).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**
1965-1966	1,32
1966-1967	9,54
1967-1968	2,63
1968-1969	8,67
1969-1970	0,57
1970-1971	1,60
1971-1972	1,30
1972-1973	0,12
1973-1974	0,36
1974-1975	1,23
1975-1976	1,18
1976-1977	0,40
1977-1978	1,42
1978-1979	0,41
1979-1980	1,29
1980-1981	2,69
1981-1982	0,52
1982-1983	0,46
1983-1984	0,27
1984-1985	0,74
1985-1986	0,01
1986-1987	0,68
1987-1988	1,55
1988-1989	3,32
1989-1990	0,21
1990-1991	1,60
1991-1992	3,47
1992-1993	5,11
1993-1994	1,20
1994-1995	0,80
1995-1996	0,08
1996-1997	0,04
1997-1998	0,08
1998-1999	0,08

Appendix 1.6 Table of the hydrologic annual surface runoff volume of the Elea River (Station: 135407440).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**
1965-1966	4,70
1966-1967	15,22
1967-1968	6,71
1968-1969	27,23
1969-1970	2,91
1970-1971	7,60
1971-1972	5,45
1972-1973	0,54
1973-1974	5,08
1974-1975	8,13
1975-1976	7,19
1976-1977	4,41
1977-1978	6,27
1978-1979	2,40
1979-1980	6,81
1980-1981	10,20
1981-1982	3,01
1982-1983	1,65
1983-1984	1,81
1984-1985	4,91
1985-1986	0,19
1986-1987	4,27
1987-1988	8,22
1988-1989	9,81
1989-1990	0,97
1990-1991	0,11
1991-1992	10,86
1992-1993	12,73
1993-1994	4,00
1994-1995	3,20
1995-1996	0,50
1996-1997	0,30
1997-1998	0,40
1998-1999	0,40

Appendix 1.7 Table of the hydrologic annual surface runoff volume of the Peristerona River (Station: 137108550).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**
1965-1966	11,30
1966-1967	26,29
1967-1968	16,39
1968-1969	38,97
1969-1970	5,91
1970-1971	14,78
1971-1972	11,88
1972-1973	1,67
1973-1974	11,03
1974-1975	16,86
1975-1976	13,12
1976-1977	8,79
1977-1978	13,03
1978-1979	8,61
1979-1980	18,42
1980-1981	20,30
1981-1982	7,98
1982-1983	10,43
1983-1984	8,56
1984-1985	14,85
1985-1986	5,52
1986-1987	17,30
1987-1988	21,41
1988-1989	19,99
1989-1990	5,56
1990-1991	2,80
1991-1992	22,39
1992-1993	22,23
1993-1994	13,75
1994-1995	10,00
1995-1996	5,00
1996-1997	3,75
1997-1998	5,00
1998-1999	5,00

Appendix 1.8 Table of the hydrologic annual surface runoff volume of the Akaki River (Station: 137311690).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**
1965-1966	10,11
1966-1967	25,07
1967-1968	13,92
1968-1969	45,02
1969-1970	3,82
1970-1971	12,28
1971-1972	10,51
1972-1973	0,76
1973-1974	6,92
1974-1975	11,59
1975-1976	12,58
1976-1977	8,13
1977-1978	10,55
1978-1979	6,74
1979-1980	17,34
1980-1981	16,84
1981-1982	4,75
1982-1983	6,06
1983-1984	4,60
1984-1985	9,78
1985-1986	3,50
1986-1987	9,72
1987-1988	15,80
1988-1989	17,78
1989-1990	4,73
1990-1991	1,53
1991-1992	19,58
1992-1993	17,81
1993-1994	11,00
1994-1995	8,00
1995-1996	1,90
1996-1997	0,90
1997-1998	2,40
1998-1999	3,70

Appendix 1.9 Table of the hydrologic annual surface runoff volume of the Pedios River (Station: 161113185).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**
1967-1968	3,55
1968-1969	12,88
1969-1970	1,11
1970-1971	5,02
1971-1972	4,44
1974-1975	7,08
1975-1976	6,01
1976-1977	2,83
1977-1978	3,90
1978-1979	2,61
1979-1980	5,09
1980-1981	5,20
1981-1982	1,59
1982-1983	2,42
1983-1984	1,81
1984-1985	3,60
1985-1986	1,71
1986-1987	3,27
1987-1988	5,48
1988-1989	7,25
1989-1990	2,29
1990-1991	0,93
1991-1992	8,84
1992-1993	7,30

Appendix 1.10 Table of the hydrologic annual surface runoff volume of the Yialias River. (Station: 165115385).

Hydrologic year (1 Oct.-30 Sep.)	**Surface runoff (mcm)**
1970-1971	5,25
1971-1972	2,50
1972-1973	1,00
1973-1974	4,50
1974-1975	7,50
1975-1976	4,50
1976-1977	2,82
1977-1978	2,75
1978-1979	3,27
1979-1980	8,64
1980-1981	6,99
1981-1982	1,52
1982-1983	1,41
1983-1984	1,89
1984-1985	4,59
1985-1986	1,05
1986-1987	2,12
1987-1988	6,03
1988-1989	9,25
1989-1990	1,60
1990-1991	0,48
1991-1992	13,14
1992-1993	11,95
1993-1994	6,00
1994-1995	3,50
1995-1996	0,55
1996-1997	0,70
1997-1998	0,90
1998-1999	0,80

APPENDIX 2

Appendix 2.1 Sample study for deriving synthetic sequence

The river flows are skewed distributed. The yearly surface runoff data's are converted to normal distribution with Box-Cox transformation.

Appendix 2.1.1 The difference between flow and transformed flow data of the rivers.

	Flow data (mcm)			Box-Cox transformed data (mcm)		
Stream name	µ (Mean)	g (Skewness)	σ (Standard deviation)	µ (Mean)	g (Skewness)	σ (Standard deviation)
Limnitis	10,60	0,54	6,56	3,51	0,006	1,58
Xeros	5,15	0,30	2,67	3,00	0,004	1,72
Marathasa	6,19	1,30	3,40	2,47	0,011	1,12
Karyotis	10,92	1,62	6,73	2,92	0,013	1,02
Atsas	1,62	2,54	2,22	-0,18	-0,016	1,40
Elea	5,53	2,10	5,46	1,76	0,007	1,84
Peristerona	12,91	1,13	7,89	3,96	0,018	1,59
Akaki	10,46	2,10	8,59	2,97	0,023	1,62
Pedios	4,42	1,26	2,82	1,53	0,013	0,86
Yialias	4,04	1,17	3,45	1,14	0,002	1,08

For sample study Akaki River (Station: 137611390) selected. After converting the skewed distributed surface runoff data's to normal distribution, autocorrelation coefficients are found to obtain the internal dependencies between sequences.

Appendix 2.1.2 Table of the autocorrelation coefficients between skewed distributed surface runoff data.

Lag (*k*)	**Autocorrelation coefficients (r_k)**
1	0,23
2	0,04
3	-0,07
4	-0,17
5	-0,04
6	-0,08
7	0,01
8	-0,03
9	0,04
10	-0,14
11	0,07
12	0,20
13	0,18
14	0,08
15	-0,15
16	-0,10
17	-0,07
18	0,04
19	-0,12
20	0,01
21	0,00
22	-0,12
23	0,09
24	0,12
25	0,13
26	0,10
27	-0,07
28	-0,16
29	-0,18
30	-0,19
31	-0,09
32	-0,05

To use the suitable model and check the linearity of the autocorrelation coefficients, H_0 hypothesis is derived. The Hypothesis (H_0) is the revised normal distribution for autocorrelation coefficient of Box-Cox transformed data.

$$\sigma_{rk} = \frac{1}{\sqrt{n}} = \frac{1}{\sqrt{34}} = 0{,}171 \qquad \text{(A2-1)}$$

The acceptance interval of H_0 hypothesis with the confidence level α=0.05 is $\pm 1{,}96$ from standard normal distribution table.

$$\pm Z_{\alpha/2}\sigma_{rk} = \pm 1{,}96\sigma_{rk} = \pm 0{,}335 \qquad \text{(A2-2)}$$

Since all r_k values are in the interval of $\pm 0{,}335$ the H_0 hypothesis is true.

The first autocorrelation coefficient (r_1) is equal to first autoregressive coefficients (ϕ_1), in first order Markov model AR (1) .The other autoregressive coefficients ($\phi_{i+1}, \phi_{i+2}, \phi_{i+3} \ldots \phi_{i+n}$) find with the above matrix.

$$\begin{pmatrix} 1 & r_1 & r_2 & r_3 & r_4 & \cdots & r_{P-1} \\ r_1 & 1 & r_1 & r_2 & r_3 & \cdots & r_{P-2} \\ r_2 & r_1 & 1 & r_1 & r_2 & \cdots & r_{P-3} \\ \vdots & \vdots & \vdots & \vdots & \vdots & & \vdots \\ r_{P-1} & r_{P-2} & r_{P-3} & r_{P-4} & r_{P-5} & \cdots & 1 \end{pmatrix} \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \vdots \\ \phi_P \end{pmatrix} = \begin{pmatrix} r_1 \\ r_2 \\ r_3 \\ \vdots \\ r_P \end{pmatrix}$$

First order Markov model equation for Akaki River is;

$$y_i = 0{,}232 y_{i-1} + \varepsilon_i \qquad \text{(A2-3)}$$

Second order Markov model equation for Akaki River is;

$$y_i = 0{,}236 y_{i-1} - 0{,}018 y_{i-2} + \varepsilon_i \qquad \text{(A2-4)}$$

Third order Markov model equation for Akaki River is;

$$y_i = 0{,}235 y_{i-1} + 0{,}002 y_{i-2} - 0{,}083 y_{i-3} + \varepsilon_i \qquad \text{(A2-5)}$$

First order autoregressive moving average model equation for Akaki River is;

$$y_i = 0{,}159 y_{i-1} + \varepsilon_i + 0{,}077 \varepsilon_{i-1} \qquad \text{(A2-6)}$$

To find the maximum likelihood estimate of the residual variance of first order Markov model AR (1);

$$y_i = 0{,}232 y_{i-1} + \varepsilon_i \qquad \text{(A2-7)}$$

To take the square of both sides;

$$y_i^{\,2} = \left(0{,}232 y_{i-1} + \varepsilon_i\right)^2 \qquad \text{(A2-8)}$$

$$y_i^{\,2} = 0{,}232^2 * y_{i-1}^{\,2} + 2 * 0{,}232 * y_{i-1} * \sigma_\varepsilon + \sigma_e^{\,2} \qquad \text{(A2-9)}$$

The predicting values are written;

$$1^2 = 0{,}232^2 * 1^2 + 2 * 0{,}232 * 1 * \sigma_\varepsilon + \sigma_\varepsilon^{\,2} \qquad \text{(A2-10)}$$

The result will be two roots $\sigma_{\varepsilon_1} = 0{,}768$ and $\sigma_{\varepsilon_2} = -1{,}231$ (A2-11)

Positive root $\sigma_{\varepsilon_1} = 0{,}768$ will be selected and $\sigma_{\varepsilon_1}^{\,2} = 0{,}590$ (A2-12)

To find the maximum likelihood estimate of the residual variance of second order Markov model AR (2);

$$y_i = 0{,}236 y_{i-1} - 0{,}018 y_{i-2} + \varepsilon_i \qquad \text{(A2-13)}$$

To take the square of both sides;

$$y_i^{\,2} = (0{,}236 y_{i-1} - 0{,}018 y_{i-2} + \varepsilon_i)^2 \qquad \text{(A2-14)}$$

$$y_i^{\,2} = 0{,}236^2 * y_{i-1}^{\,2} + 0{,}018^2 y_{i-2}^{\,2} + \sigma_\varepsilon^{\,2} \qquad \text{(A2-15)}$$

The predicting values are written;

$$1^2 = 0{,}236^2 * 1 + 0{,}018^2 * 1 + \sigma_\varepsilon^{\,2} \qquad \text{(A2-16)}$$

The result will be;

$\sigma_\varepsilon = 0{,}972$ and $\sigma_\varepsilon^{\,2} = 0{,}944$ (A2-17)

To find the maximum likelihood estimate of the residual variance of third order Markov model AR (3);

$$y_i = 0{,}235 y_{i-1} + 0{,}002 y_{i-2} - 0{,}083 y_{i-3} + \varepsilon_i \tag{A2-18}$$

To take the square of both sides;

$$y_i^{\,2} = (0{,}235 y_{i-1} + 0{,}002 y_{i-2} - 0{,}083 y_{i-3} + \varepsilon_i)^2 \tag{A2-19}$$

$$y_i^{\,2} = 0{,}235^2 * y_{i-1}^{\;2} + 0{,}002^2 * y_{i-2}^{\;2} + 0{,}083^2\, y_{i-3}^{\;2} + \sigma_\varepsilon^{\;2} \tag{A2-20}$$

The predicting values are written;

$$1^2 = 0{,}235^2 * 1^2 + 0{,}002^2 * 1^2 + 0{,}083^2 * 1^2 + \sigma_\varepsilon^{\;2} \tag{A2-21}$$

The result will be;

$$\sigma_\varepsilon = 0{,}969 \text{ and } \sigma_\varepsilon^{\;2} = 0{,}938 \tag{A2-22}$$

To find the maximum likelihood estimate of the residual variance of first order autoregressive moving average model ARMA (1, 1);

$$y_i = 0{,}159 y_{i-1} + \varepsilon_i + 0{,}077 \varepsilon_{i-1} \tag{A2-23}$$

To take the square of both sides;

$$y_i^{\,2} = (0{,}159 y_{i-1} + \varepsilon_i + 0{,}077 \varepsilon_{i-1})^2 \tag{A2-24}$$

$$y_i^{\,2} = 0{,}159^2 * y_{i-1}^{\;2} + \sigma_\varepsilon^{\;2} + 0{,}077^2 * \sigma_\varepsilon^{\;2} \tag{A2-25}$$

The result will be;

$$\sigma_\varepsilon = 0{,}985 \text{ and } \sigma_\varepsilon^{\;2} = 0{,}969 \tag{A2-26}$$

The method for testing the model suitability is Akaike information criterion. The model, which gives the minimum *AIC* number, is AR (1) to be selected.

For AR (1) $34\ln 0{,}590 + 2(1) = -15{,}94$ (A2-27)

For AR (2) $34\ln 0{,}944 + 2(2) = 2{,}04$ (A2-28)

For AR (3) $34\ln 0{,}938 + 2(3) = 3{,}82$ (A2-29)

For ARMA (1, 1) $34\ln 0{,}969 + 2(2) = 2{,}93$ (A2-30)

The other *AIC* number results which are used in the models are given in the following table.

Appendix 2.1.3 Table of the Akaike information criteria numbers of models.

Akaike information criteria (*AIC*)				
Stream name	**AR (1)**	**AR (2)**	**AR (3)**	**ARMA (1,1)**
Limnitis	**-22,56***	0,56	1,74	1,14
Xeros	-28	-23	**-31**	-
Marathasa	**-9,24**	0,65	2,89	-
Karyotis	**-24**	-0,89	1,19	0,61
Atsas	**-29,24**	-0,31	1,62	-18,76
Elea	**-19,01**	1,20	3,24	2,58
Peristerona	**-9,55**	2,82	4,54	-5,83
Akaki	**-15,94**	2,04	3,82	2,93
Pedios	6,90	**2,82**	3,99	-
Yialias	**-20,90**	-9,58	-11,39	-

* The bold numbers are the ones chosen for the study

After determining the suitable model and calculating the parameters, the second stage is deriving of the synthetic sequences. First of all to determine values for; normal and independent residuals ε_i;

Appendix 2.1.4 To determine values for; normal and independent residuals ε_i ;

Uniform random numbers between (0-1) (η_i)		$Z_{1i,} Z_{2i}$ Standard normal random numbers $Z_{1i} = (-2\ln\eta_{1i})^{1/2}\cos(2\pi\eta_{2i})$ $Z_{2i} = (-2\ln\eta_{1i})^{1/2}\sin(2\pi\eta_{2i})$		Residuals for AR (1) model equation $\varepsilon_i = \mu_\varepsilon + \sigma_\varepsilon Z_i ; \mu_\varepsilon = 0$	
η_1	0,37	Z_1	0,44	ε_1	0,34
η_2	0,80	Z_2	-1,35	ε_2	-1,04
η_3	0,67	Z_3	0,76	ε_3	0,58
η_4	0,09	Z_4	0,47	ε_4	0,36
η_5	0,46	Z_5	-0,56	ε_5	-0,43
η_6	0,32	Z_6	1,12	ε_6	0,86
η_7	0,22	Z_7	-0,59	ε_7	-0,45
η_8	0,31	Z_8	1,63	ε_8	1,25
η_9	0,54	Z_9	0,71	ε_9	0,54
η_{10}	0,86	Z_{10}	-0,86	ε_{10}	-0,66
η_{11}	0,30	Z_{11}	1,19	ε_{11}	0,92
η_{12}	0,11	Z_{12}	0,99	ε_{12}	0,77
η_{13}	0,22	Z_{13}	1,31	ε_{13}	1,00
η_{14}	0,11	Z_{14}	1,14	ε_{14}	0,87
η_{15}	0,35	Z_{15}	1,45	ε_{15}	1,12
η_{16}	0,99	Z_{16}	-0,13	ε_{16}	-0,10
η_{17}	0,68	Z_{17}	-0,85	ε_{17}	-0,65
η_{18}	0,46	Z_{18}	0,24	ε_{18}	0,19
η_{19}	0,34	Z_{19}	-1,41	ε_{19}	-1,08
η_{20}	0,46	Z_{20}	0,39	ε_{20}	0,30
η_{21}	0,88	Z_{21}	0,52	ε_{21}	0,40
η_{22}	0,99	Z_{22}	-0,01	ε_{22}	-0,01
η_{23}	0,43	Z_{23}	-0,57	ε_{23}	-0,44
η_{24}	0,68	Z_{24}	-1,16	ε_{24}	-0,89
η_{25}	0,75	Z_{25}	-0,72	ε_{25}	-0,55
η_{26}	0,45	Z_{26}	0,23	ε_{26}	0,18
η_{27}	0,98	Z_{27}	0,05	ε_{27}	0,04
η_{28}	0,79	Z_{28}	-0,19	ε_{28}	-0,15
η_{29}	0,75	Z_{29}	0,72	ε_{29}	0,55
η_{30}	0,95	Z_{30}	-0,23	ε_{30}	-0,17
η_{31}	0,68	Z_{31}	-0,81	ε_{31}	-0,62
η_{32}	0,44	Z_{32}	0,35	ε_{32}	0,27
η_{33}	0,35	Z_{33}	-0,47	ε_{33}	-0,36
η_{34}	0,70	Z_{34}	-1,37	ε_{34}	-1,05

Autocorrelation coefficients of the residuals are found to find the internal dependencies between sequences of residuals.

Appendix 2.1.5 Table of the autocorrelation coefficients between residuals for AR (1) model equation.

Lag (*k*)	**Autocorrelation coefficients (r_k)**
1	0,06
2	0,10
3	0,24
4	-0,18
5	0,13
6	0,03
7	0,15
8	0,04
9	0,02
10	-0,13
11	-0,19
12	0,02
13	-0,25
14	0,12
15	0,09
16	-0,19
17	0,10
18	-0,06
19	-0,21
20	-0,11
21	-0,02
22	-0,12
23	-0,02
24	0,03
25	-0,10
26	-0,01
27	-0,06
28	-0,04
29	0,08
30	-0,07
31	-0,01
32	0,07

To check the linearity of the autocorrelation coefficients of the residuals, H_0 hypothesis is derived. The Hypothesis (H_0) is the revised normal distribution for autocorrelation coefficient of residuals.

$$\sigma_{rk} = \frac{1}{\sqrt{n}} = \frac{1}{\sqrt{34}} = 0{,}171 \tag{A2-31}$$

The acceptance interval of H_0 hypothesis with the confidence level α=0.05 is $\pm 1{,}96$ from standard normal distribution table.

$$\pm Z_{\alpha/2}\sigma_{rk} = \pm 1{,}96\sigma_{rk} = \pm 0{,}335 \tag{A2-32}$$

Since all r_k values are in the interval of $\pm 0{,}335$ the H_0 hypothesis is true.

The Box-Pierce Porte Manteau test used for, to check the residuals ε_i, whether they are independent and normal. This test is used by statistical formulation of Q.

$$Q = n\sum_{k=1}^{m} r_{k\varepsilon}^{\ 2} \tag{A2-33}$$

Where; $r_{k\varepsilon}$ is the autocorrelation coefficients of residuals; n is the sample size; m is the maximum lag (between 0.1n-0.3n).

$$Q = 34\sum_{k=1}^{10} 0{,}063^2 + 0{,}104^2 + 0{,}243^2 + 0{,}184^2 + 0{,}132^2 \tag{A2-34}$$

$$Q = 5{,}67 \qquad \text{Degree of freedom=10-1=9} \tag{A2-35}$$

To check the dependency and linearity for the autocorrelation coefficients of residuals, H_0 hypothesis is derived. The Hypothesis (H_0) is the revised normal distribution and independent for autocorrelation coefficient of residuals.

The acceptance interval of H_0 hypothesis with the confidence level α=0.05 and degree of freedom=9 is $16{,}92$ from X^2 distribution table. Since $16{,}92 > 5{,}67$ the H_0 hypothesis is true.

Finding the y_i values from AR (1) model equation.

$$y_i = 0{,}232 y_{i-1} + \varepsilon_i \tag{A2-36}$$

Appendix 2.1.6 To determine values for; X_i synthetic flow values for AR (1) model equation.

y_i values for AR (1) model equation		y_i' values for AR (1) model equation. $y_i' = \mu_y + \sigma_y * y_i$		X_i synthetic flow values for AR (1) model equation $(0,3y_i' + 1)^{1/0,3} = X_i$	
y_1	0,00	y_1'	2,97	X_1	8,36
y_2	-1,04	y_2'	1,29	X_2	2,98
y_3	0,34	y_3'	3,52	X_3	11,07
y_4	0,44	y_4'	3,68	X_4	11,92
y_5	-0,33	y_5'	2,44	X_5	6,23
y_6	0,79	y_6'	4,24	X_6	15,43
y_7	-0,27	y_7'	2,54	X_7	6,60
y_8	1,19	y_8'	4,89	X_8	20,32
y_9	0,82	y_9'	4,30	X_9	15,80
y_{10}	-0,47	y_{10}'	2,21	X_{10}	5,45
y_{11}	0,81	y_{11}'	4,28	X_{11}	15,66
y_{12}	0,95	y_{12}'	4,51	X_{12}	17,36
y_{13}	1,23	y_{13}'	4,95	X_{13}	20,81
y_{14}	1,16	y_{14}'	4,84	X_{14}	19,90
y_{15}	1,38	y_{15}'	5,21	X_{15}	23,04
y_{16}	0,22	y_{16}'	3,32	X_{16}	10,04
y_{17}	-0,60	y_{17}'	1,99	X_{17}	4,77
y_{18}	0,05	y_{18}'	3,05	X_{18}	8,70
y_{19}	-1,07	y_{19}'	1,23	X_{19}	2,86
y_{20}	0,05	y_{20}'	3,06	X_{20}	8,75
y_{21}	0,41	y_{21}'	3,63	X_{21}	11,65
y_{22}	0,09	y_{22}'	3,11	X_{22}	9,01
y_{23}	-0,42	y_{23}'	2,30	X_{23}	5,74
y_{24}	-0,99	y_{24}'	1,37	X_{24}	3,14
y_{25}	-0,78	y_{25}'	1,71	X_{25}	3,97
y_{26}	-0,01	y_{26}'	2,96	X_{26}	8,33
y_{27}	0,04	y_{27}'	3,03	X_{27}	8,63
y_{28}	-0,14	y_{28}'	2,75	X_{28}	7,42
y_{29}	0,52	y_{29}'	3,81	X_{29}	12,70
y_{30}	-0,05	y_{30}'	2,88	X_{30}	7,99
y_{31}	-0,63	y_{31}'	1,95	X_{31}	4,63
y_{32}	0,12	y_{32}'	3,17	X_{32}	9,27
y_{33}	-0,33	y_{33}'	2,44	X_{33}	6,23
y_{34}	-1,13	y_{34}'	1,15	X_{34}	2,68

Appendix 2.2 Sample study for deriving predicting synthetic sequence

For sample study Akaki River (Station: 137311690) selected. The degree of synthetic sequence is important in predicting flows. If the degree of the synthetic sequence increases, value suitability increases. That's why AR (15) model selected for synthetic sequences to predict synthetic sequence. By using the same calculation procedure as the above study, fifteenth order autoregressive moving average model equation for Akaki River is;

$$y_i = 0,243 y_{i-1} - 0,011 y_{i-2} + 0,014 y_{i-3} - 0,188 y_{i-4} + 0,068 y_{i-5} - 0,109 y_{i-6} + 0,061 y_{i-7}$$

$$- 0,057 y_{i-8} + 0,127 y_{i-9} - 0,235 y_{i-10} + 0,110 y_{i-11} + 0,112 y_{i-12} + 0,132 y_{i-13} - 0,03 y_{i-14}$$

$$- 0,115 y_{i-15} \tag{A2-37}$$

To find the maximum likelihood estimate of the residual variance of fifteenth order Markov model AR (15), to take the square of both sides;

$$y_i^{\,2} = 0,243^2 y_{i-1}^{\,2} + 0,011^2 y_{i-2}^{\,2} + 0,014^2 y_{i-3}^{\,2} + 0,188^2 y_{i-4}^{\,2} + 0,068^2 y_{i-5}^{\,2} + 0,109^2 y_{i-6}^{\,2}$$

$$+ 0,061^2 y_{i-7}^{\,2} + 0,057^2 y_{i-8}^{\,2} + 0,127^2 y_{i-9}^{\,2} + 0,235^2 y_{i-10}^{\,2} + 0,110^2 y_{i-11}^{\,2} + 0,112^2 y_{i-12}^{\,2}$$

$$+ 0,132^2 y_{i-13}^{\,2} + 0,03^2 y_{i-14}^{\,2} + 0,115^2 y_{i-15}^{\,2} \tag{A2-38}$$

The predicting values are written;

$$1^2 = 0,243^2 * 1^2 + 0,011^2 * 1^2 + 0,014^2 * 1^2 + 0,188^2 * 1^2 + 0,068^2 * 1^2 + 0,109^2 * 1^2 + 0,061^2 * 1^2$$

$$0,057^2 * 1^2 + 0,127^2 * 1^2 + 0,235^2 * 1^2 + 0,110^2 * 1^2 + 0,112^2 * 1^2 + 0,132^2 * 1^2 + 0,03^2 * 1^2$$

$$+ 0,115^2 * 1^2 \tag{A2-39}$$

The result will be;

$$\sigma_\varepsilon = 0{,}868 \text{ and } \sigma_\varepsilon^{\;2} = 0{,}754 \qquad \text{(A2-40)}$$

After determining the suitable model and calculating the parameters, the second stage is deriving of the synthetic sequences. By using the same calculation procedure as the above study, uniform random numbers between (0-1) and standard normal random numbers for normal and independent residuals ε_i are found.

The formula for residual ε_i;

$$\varepsilon_i = \mu_\varepsilon + \sigma_\varepsilon Z_i \qquad \text{(A2-41)}$$

Where; μ_ε is the mean of residual ε_i; ($\mu_\varepsilon = 0$); σ_ε is the standard deviation of residual ε_i.

Appendix 2.2.1 Table of the residuals for AR (15) model equation.

ε_1	ε_2	ε_3	ε_4	ε_5	ε_6	ε_7	ε_8	ε_9	ε_{10}
0,38	-1,17	0,66	0,41	-0,49	0,98	-0,51	1,41	0,61	-0,75

ε_{11}	ε_{12}	ε_{13}	ε_{14}	ε_{15}	ε_{16}	ε_{17}	ε_{18}	ε_{19}	ε_{20}
1,04	0,87	1,14	0,99	1,26	-0,12	-0,74	0,21	-1,23	0,34

ε_{21}	ε_{22}	ε_{23}	ε_{24}	ε_{25}	ε_{26}	ε_{27}	ε_{28}	ε_{29}	ε_{30}
0,45	-0,01	-0,49	-1,01	-0,62	0,20	0,04	-0,16	0,62	-0,20

ε_{31}	ε_{32}	ε_{33}	ε_{34}
-0,70	0,30	-0,41	-1,19

Autocorrelation coefficients of the residuals are found to find the internal dependencies between sequences of residuals.

Appendix 2.2.2 Table of the autocorrelation coefficients between residuals for AR (15) model equation.

Lag (k)	**Autocorrelation coefficients (r_k)**
1	0,06
2	0,10
3	0,24
4	-0,18
5	0,13
6	0,03
7	0,15
8	0,04
9	0,02
10	-0,13
11	-0,19
12	0,02
13	-0,25
14	0,12
15	0,09
16	-0,19
17	0,10
18	-0,06
19	-0,21
20	-0,11
21	-0,02
22	-0,12
23	-0,02
24	0,03
25	-0,10
26	-0,01
27	-0,06
28	-0,04
29	0,08
30	-0,07
31	-0,01
32	0,07

To check the linearity of the autocorrelation coefficients of the residuals, H_0 hypothesis is derived. The Hypothesis (H_0) is the revised normal distribution for autocorrelation coefficient of residuals.

$$\sigma_{rk} = \frac{1}{\sqrt{n}} = \frac{1}{\sqrt{34}} = 0{,}171 \qquad \text{(A2-42)}$$

The acceptance interval of H_0 hypothesis with the confidence level α=0.05 is $\pm 1{,}96$ from standard normal distribution table.

$$\pm \mathrm{Z}_{\alpha/2}\sigma_{rk} = \pm 1{,}96\sigma_{rk} = \pm 0{,}335 \qquad \text{(A2-43)}$$

Since all r_k values are in the interval of $\pm 0{,}335$ the H_0 hypothesis is true.

The Box-Pierce Porte Manteau test used for, to check the residuals ε_i, whether they are independent and normal. This test is used by statistical formulation of Q.

$$Q = n\sum_{k=1}^{m} r_{k\varepsilon}{}^{2} \qquad \text{(A2-44)}$$

Where; $r_{k\varepsilon}$ is the autocorrelation coefficients of residuals; n is the sample size; m is the maximum lag (between 0.1n-0.3n).

$$Q = 34\sum_{k=1}^{10} 0{,}063^2 + 0{,}104^2 + 0{,}243^2 + 0{,}184^2 + 0{,}132^2 \qquad \text{(A2-45)}$$

$Q = 5{,}67$ Degree of freedom=10-1=9 (A2-46)

To check the dependency and linearity for the autocorrelation coefficients of residuals, H_0 hypothesis is derived. The Hypothesis (H_0) is the revised normal distribution and independent for autocorrelation coefficient of residuals.

The acceptance interval of H_0 hypothesis with the confidence level α=0.05 and degree of freedom=9 is 16,92 from X^2 distribution table. Since $16{,}92 > 5{,}67$ the H_0 hypothesis is true.

Finding the y_i values from AR (15) model equation;

$$y_i = 0,243y_{i-1} - 0,011y_{i-2} + 0,014y_{i-3} - 0,188y_{i-4} + 0,068y_{i-5} - 0,109y_{i-6} + 0,061y_{i-7}$$

$$- 0,057y_{i-8} + 0,127y_{i-9} - 0,235y_{i-10} + 0,110y_{i-11} + 0,112y_{i-12} + 0,132y_{i-13} - 0,03y_{i-14}$$

$$- 0,115y_{i-15} \qquad \text{(A2-47)}$$

Appendix 2.2.3 Table of the y_i values for AR (15) model equation.

y_1	y_2	y_3	y_4	y_5	y_6	y_7	y_8	y_9	y_{10}
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

y_{11}	y_{12}	y_{13}	y_{14}	y_{15}	y_{16}	y_{17}	y_{18}	y_{19}	y_{20}
0,00	0,00	0,00	0,00	0,00	-0,12	-0,77	0,03	-1,21	0,06

y_{21}	y_{22}	y_{23}	y_{24}	y_{25}	y_{26}	y_{27}	y_{28}	y_{29}	y_{30}
0,61	0,08	-0,17	-1,18	-0,85	-0,12	0,22	-0,14	0,85	-0,07

y_{31}	y_{32}	y_{33}	y_{34}
-0,97	0,11	-0,51	-0,84

Converting the standardized values into non-standardized form;

$$y_i^{\prime} = \mu_y + \sigma_y * y_i \tag{A2-48}$$

Appendix 2.2.4 Table of the $y_i^{\prime}$ values for AR (15) model equation.

$y_1^{\prime}$	$y_2^{\prime}$	$y_3^{\prime}$	$y_4^{\prime}$	$y_5^{\prime}$	$y_6^{\prime}$	$y_7^{\prime}$	$y_8^{\prime}$	$y_9^{\prime}$	$y_{10}^{\prime}$
2,97	2,97	2,97	2,97	2,97	2,97	2,97	2,97	2,97	2,97

$y_{11}^{\prime}$	$y_{12}^{\prime}$	$y_{13}^{\prime}$	$y_{14}^{\prime}$	$y_{15}^{\prime}$	$y_{16}^{\prime}$	$y_{17}^{\prime}$	$y_{18}^{\prime}$	$y_{19}^{\prime}$	$y_{20}^{\prime}$
2,97	2,97	2,97	2,97	2,97	2,78	1,73	3,01	1,01	3,06

$y_{21}^{\prime}$	$y_{22}^{\prime}$	$y_{23}^{\prime}$	$y_{24}^{\prime}$	$y_{25}^{\prime}$	$y_{26}^{\prime}$	$y_{27}^{\prime}$	$y_{28}^{\prime}$	$y_{29}^{\prime}$	$y_{30}^{\prime}$
3,96	3,10	2,69	1,06	1,59	2,77	3,33	2,74	4,34	2,86

$y_{31}^{\prime}$	$y_{32}^{\prime}$	$y_{33}^{\prime}$	$y_{34}^{\prime}$
1,40	3,15	2,14	1,61

To find the synthetic flow values;

$$(0,3y_i{}' + 1)^{1/0,3} = X_i \tag{A2-49}$$

Appendix 2.2.5 Table of the synthetic flow values for AR (15) model equation.

X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
8,36	8,36	8,36	8,36	8,36	8,36	8,36	8,36	8,36	8,36

X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}
8,36	8,36	8,36	8,36	8,36	7,57	4,02	8,55	2,42	8,78

X_{21}	X_{22}	X_{23}	X_{24}	X_{25}	X_{26}	X_{27}	X_{28}	X_{29}	X_{30}
13,59	8,94	7,18	2,51	3,67	7,51	10,06	7,39	16,12	7,87

X_{31}	X_{32}	X_{33}	X_{34}
3,21	9,19	5,23	3,71

Predicting the synthetic sequences and finding the predicted y_i values using the model equation AR (15);

$$y_i = 0,243y_{i-1} - 0,011y_{i-2} + 0,014y_{i-3} - 0,188y_{i-4} + 0,068y_{i-5} - 0,109y_{i-6} + 0,061y_{i-7}$$

$$- 0,057y_{i-8} + 0,127y_{i-9} - 0,235y_{i-10} + 0,110y_{i-11} + 0,112y_{i-12} + 0,132y_{i-13} - 0,03y_{i-14}$$

$$- 0,115y_{i-15} \tag{A2-50}$$

Appendix 2.2.6 Table of the predicted y_i values for AR (15) model equation.

y_{35}	y_{36}	y_{37}	y_{38}	y_{39}	y_{40}	y_{41}	y_{42}	y_{43}	y_{44}
-0,04	-2,47	-2,80	-0,41	-0,29	1,59	3,57	1,28	0,80	-1,01

y_{45}	y_{46}	y_{47}	y_{48}	y_{49}	y_{50}	y_{51}	y_{52}	y_{53}	y_{54}
0,27	0,61	-0,60	-1,16	-1,44	-0,64	-0,36	0,75	0,95	1,25

y_{55}	y_{56}	y_{57}	y_{58}	y_{59}	y_{60}	y_{61}	y_{62}	y_{63}	y_{64}
0,32	-0,69	-0,41	-0,26	0,17	-0,24	-0,30	-0,28	-0,06	0,16

y_{65}	y_{66}	y_{67}	y_{68}
0,33	0,59	0,22	-0,10

Converting the standardized values into non-standardized form;

$$y_i^{\prime} = \mu_y + \sigma_y * y_i \tag{A2-51}$$

Appendix 2.2.7 Table of the predicted $y_i^{\prime}$ values for AR (15) model equation.

$y_{35}^{\prime}$	$y_{36}^{\prime}$	$y_{37}^{\prime}$	$y_{38}^{\prime}$	$y_{39}^{\prime}$	$y_{40}^{\prime}$	$y_{41}^{\prime}$	$y_{42}^{\prime}$	$y_{43}^{\prime}$	$y_{44}^{\prime}$
2,90	-1,02	-1,56	2,31	2,50	5,54	8,74	5,03	4,26	1,33

$y_{45}^{\prime}$	$y_{46}^{\prime}$	$y_{47}^{\prime}$	$y_{48}^{\prime}$	$y_{49}^{\prime}$	$y_{50}^{\prime}$	$y_{51}^{\prime}$	$y_{52}^{\prime}$	$y_{53}^{\prime}$	$y_{54}^{\prime}$
3,41	3,95	1,99	1,09	0,64	1,93	2,39	4,19	4,50	4,99

$y_{55}^{\prime}$	$y_{56}^{\prime}$	$y_{57}^{\prime}$	$y_{58}^{\prime}$	$y_{59}^{\prime}$	$y_{60}^{\prime}$	$y_{61}^{\prime}$	$y_{62}^{\prime}$	$y_{63}^{\prime}$	$y_{64}^{\prime}$
3,49	1,86	2,31	2,55	3,25	2,58	2,48	2,52	2,87	3,22

$y_{65}^{\prime}$	$y_{66}^{\prime}$	$y_{67}^{\prime}$	$y_{68}^{\prime}$
3,50	3,92	3,32	2,81

To find the synthetic predicting flow values;

$$(0{,}3y_i{}' + 1)^{1/0{,}3} = X_i \qquad \text{(A2-52)}$$

Appendix 2.2.8 Table of the synthetic predicted flow values for AR (15) model equation.

X_{35}	X_{36}	X_{37}	X_{38}	X_{39}	X_{40}	X_{41}	X_{42}	X_{43}	X_{44}
8,08	0,30	0,12	5,79	6,45	26,11	72,96	21,48	15,54	3,07

X_{45}	X_{46}	X_{47}	X_{48}	X_{49}	X_{50}	X_{51}	X_{52}	X_{53}	X_{54}
10,45	13,53	4,78	2,57	1,80	4,59	6,06	15,06	17,25	21,20

X_{55}	X_{56}	X_{57}	X_{58}	X_{59}	X_{60}	X_{61}	X_{62}	X_{63}	X_{64}
10,87	4,39	5,77	6,64	9,64	6,74	6,38	6,53	7,93	9,53

X_{65}	X_{66}	X_{67}	X_{68}
10,96	13,37	10,02	7,67

Finding the predicting errors parameters, the ψ_p coefficients;

For p=1 $\psi_1 = \phi_1$

For p=2 $\psi_2 = \phi_1{}^2 + \phi_2$ (A2-53)

For p=3 $\psi_3 = \phi_1\psi_2 + \phi_2\psi_1 + \phi_3$

For p=n $\psi_n = \phi_1\psi_{n-1} + \phi_2\psi_{n-2} + \phi_3\psi_{n-3} + ...\phi_q\psi_0$

Appendix 2.2.9 Table of the predicted error parameters for AR (15) model equation.

ψ_1	ψ_2	ψ_3	ψ_4	ψ_5	ψ_6	ψ_7	ψ_8	ψ_9	ψ_{10}
0,24	0,05	0,02	-0,18	-0,02	-0,10	0,01	-0,01	0,10	-0,14

ψ_{11}	ψ_{12}	ψ_{13}	ψ_{14}	ψ_{15}	ψ_{16}	ψ_{17}	ψ_{18}	ψ_{19}	ψ_{20}
0,01	0,16	0,15	0,12	-0,13	-0,06	-0,09	-0,04	-0,02	0,03

ψ_{21}	ψ_{22}	ψ_{23}	ψ_{24}	ψ_{25}	ψ_{26}	ψ_{27}	ψ_{28}	ψ_{29}	ψ_{30}
0,06	-0,01	-0,01	-0,03	0,08	0,04	-0,01	-0,04	-0,05	-0,01

ψ_{31}	ψ_{32}	ψ_{33}	ψ_{34}
-0,02	0,03	0,03	0,03

Finding the predicting errors variance;

$$Var[e_i(l)] = \sum_{p=0}^{l-1} \psi_p{}^2 \sigma_\varepsilon{}^2 \qquad \text{(A2-54)}$$

Appendix 2.2.10 Table of the predicted error variance for AR (15) model equation.

$Var[e_i(1)]$	$Var[e_i(2)]$	$Var[e_i(3)]$	$Var[e_i(4)]$	$Var[e_i(5)]$	$Var[e_i(6)]$	$Var[e_i(7)]$
0,75	0,80	0,80	0,80	0,83	0,83	0,83

$Var[e_i(8)]$	$Var[e_i(9)]$	$Var[e_i(10)]$	$Var[e_i(11)]$	$Var[e_i(12)]$	$Var[e_i(13)]$	$Var[e_i(14)]$
0,83	0,83	0,84	0,86	0,86	0,88	0,89

$Var[e_i(15)]$	$Var[e_i(16)]$	$Var[e_i(17)]$	$Var[e_i(18)]$	$Var[e_i(19)]$	$Var[e_i(20)]$	$Var[e_i(21)]$
0,90	0,92	0,92	0,93	0,93	0,93	0,93

$Var[e_i(22)]$	$Var[e_i(23)]$	$Var[e_i(24)]$	$Var[e_i(25)]$	$Var[e_i(26)]$	$Var[e_i(27)]$	$Var[e_i(28)]$
0,93	0,93	0,93	0,93	0,94	0,94	0,94

$Var[e_i(29)]$	$Var[e_i(30)]$	$Var[e_i(31)]$	$Var[e_i(32)]$	$Var[e_i(33)]$	$Var[e_i(34)]$
0,94	0,94	0,94	0,94	0,94	0,94

The acceptance interval of H_0 hypothesis with the confidence level α=0.05 is $\pm 1{,}96$ from standard normal distribution table.

The confidence interval between i^{th} year and $i+1^{th}$ year, acceptance level of 100*(1-α) is;

$$y_i(l) \pm Z_{\alpha/2}\left[\sum_{p=0}^{l-1} \psi_p{}^2\right]^{1/2} \sigma_\varepsilon \qquad \text{(A2-55)}$$

%95 acceptance interval decreasing when you get closer, increasing when you go forward. Predicting errors are increasing when you go forward.

Appendix 2.2.11 %95 acceptance interval of the synthetic predicting flow values.for AR (15) model equation.

$y_i(1)$	1,66	-1,74
$y_i(2)$	-0,72	-4,22
$y_i(3)$	-1,04	-4,55
$y_i(4)$	1,35	-2,16
$y_i(5)$	1,49	-2,07
$y_i(6)$	3,37	-0,19
$y_i(7)$	5,36	1,78
$y_i(8)$	3,06	-0,51
$y_i(9)$	2,59	-0,99
$y_i(10)$	0,78	-2,81
$y_i(11)$	2,08	-1,54
$y_i(12)$	2,42	-1,21
$y_i(13)$	1,23	-2,44
$y_i(14)$	0,69	-3,01
$y_i(15)$	0,42	-3,30
$y_i(16)$	1,23	-2,52
$y_i(17)$	1,52	-2,24
$y_i(18)$	2,64	-1,13
$y_i(19)$	2,83	-0,94
$y_i(20)$	3,14	-0,63
$y_i(21)$	2,21	-1,57
$y_i(22)$	1,20	-2,58
$y_i(23)$	1,48	-2,30
$y_i(24)$	1,63	-2,15
$y_i(25)$	2,06	-1,72
$y_i(26)$	1,65	-2,14
$y_i(27)$	1,59	-2,20
$y_i(28)$	1,62	-2,18
$y_i(29)$	1,84	-1,96
$y_i(30)$	2,06	-1,75
$y_i(31)$	2,23	-1,57
$y_i(32)$	2,49	-1,31
$y_i(33)$	2,12	-1,69
$y_i(34)$	1,80	-2,00

APPENDIX 3

Appendix 3.1 The significance of the relation of the rivers with Kendall correlation method.

LOCATION	Kendall correlation coefficient	*S=P-M*	σ_S	$Z=S-1/\sigma_S$	Probability values from Standard normal distribution table * 2	$\rho=0$ Hyp. decision
Limnitis-Xeros	0,73	296	53,31	5,53	0,00	Reject
Limnitis-Marathasa	0,73	237	45,37	5,20	0,00	Reject
Limnitis-Karyotis	0,73	386	64,54	5,97	0,00	Reject
Limnitis-Atsas	0,46	240	64,54	3,71	0,0002	Reject
Limnitis-Elea	0,61	320	64,54	4,94	0,00	Reject
Limnitis-Peristerona	0,66	347	64,54	5,36	0,00	Reject
Limnitis-Akaki	0,62	328	64,54	5,07	0,00	Reject
Limnitis-Pedios	0,49	134	40,32	3,30	0,001	Reject
Limnitis-Yialias	0,48	196	53,31	3,65	0,0002	Reject
Xerox-Limnitis	0,73	296	53,31	5,53	0,00	Reject
Xerox-Marathasa	0,61	197	45,37	4,33	0,00	Reject
Xerox-Karyotis	0,70	283	53,31	5,29	0,00	Reject
Xerox-Atsas	0,42	169	53,31	3,16	0,0016	Reject
Xerox-Elea	0,57	231	53,31	4,32	0,00	Reject
Xerox-Peristerona	0,62	253	53,31	4,72	0,00	Reject
Xerox-Akaki	0,60	242	53,31	4,53	0,00	Reject
Xerox-Pedios	0,50	139	40,32	3,43	0,0006	Reject
Xerox-Yialias	0,55	221	53,31	4,13	0,00	Reject
Marathasa-Limnitis	0,73	237	45,37	5,20	0,00	Reject
Marathasa-Xeros	0,61	197	45,37	4,33	0,00	Reject
Marathasa-Karyotis	0,81	263	45,37	5,77	0,00	Reject
Marathasa-Atsas	0,47	153	45,37	3,35	0,0008	Reject
Marathasa-Elea	0,51	167	45,37	3,66	0,0002	Reject
Marathasa-Peristerona	0,62	201	45,37	4,41	0,00	Reject
Marathasa-Akaki	0,57	185	45,37	4,05	0,00	Reject
Marathasa-Pedios	0,52	144	40,32	3,55	0,0004	Reject
Marathasa-Yialias	0,46	149	45,37	3,27	0,001	Reject
Karyotis-Limnitis	0,73	386	64,54	5,97	0,00	Reject
Karyotis-Xeros	0,70	283	53,31	5,29	0,00	Reject
Karyotis-Marathasa	0,81	263	45,37	5,77	0,00	Reject
Karyotis-Atsas	0,67	373	67,46	5,52	0,00	Reject
Karyotis-Elea	0,72	406	67,46	6,01	0,00	Reject
Karyotis-Peristerona	0,79	443	67,46	6,56	0,00	Reject
Karyotis-Akaki	0,77	429	67,46	6,35	0,00	Reject
Karyotis-Pedios	0,63	174	40,32	4,29	0,00	Reject
Karyotis-Yialias	0,60	243	53,31	4,54	0,00	Reject
Atsas-Limnitis	0,46	240	64,54	3,71	0,0002	Reject
Atsas-Xeros	0,42	169	53,31	3,16	0,0016	Reject
Atsas-Marathasa	0,47	153	45,37	3,35	0,0008	Reject
Atsas-Karyotis	0,67	373	67,46	5,52	0,00	Reject
Atsas-Elea	0,74	416	67,46	6,15	0,00	Reject
Atsas-Peristerona	0,67	378	67,46	5,59	0,00	Reject
Atsas-Akaki	0,73	409	67,46	6,05	0,00	Reject
Atsas-Pedios	0,57	156	40,32	3,84	0,0002	Reject
Atsas-Yialias	0,63	255	53,31	4,77	0,00	Reject
Elea-Limnitis	0,61	320	64,54	4,94	0,00	Reject
Elea-Xeros	0,57	231	53,31	4,32	0,00	Reject
Elea-Marathasa	0,51	167	45,37	3,66	0,0002	Reject
Elea-Karyotis	0,72	406	67,46	6,01	0,00	Reject

Appendix 3.1 (Continuous) The significance of the relation of the rivers with Kendall correlation method.

LOCATION	**Kendall correlation coefficient**	***S=P-M***	σ_S	$Z=S-1/\sigma_S$	**Probability values from Standard normal distribution table * 2**	$\rho=0$ **Hyp. decision**
Elea-Atsas	0,74	416	67,46	6,15	0,00	Reject
Elea-Peristerona	0,82	458	67,46	6,77	0,00	Reject
Elea-Akaki	0,83	466	67,46	6,90	0,00	Reject
Elea-Pedios	0,81	224	40,32	5,53	0,00	Reject
Elea-Yialias	0,78	315	53,31	5,88	0,00	Reject
Peristerona-Limnitis	0,66	347	64,54	5,36	0,00	Reject
Peristerona-Xeros	0,62	253	53,31	4,72	0,00	Reject
Peristerona-Marathasa	0,62	201	45,37	4,41	0,00	Reject
Peristerona-Karyotis	0,79	443	67,46	6,56	0,00	Reject
Peristerona-Atsas	0,67	378	67,46	5,59	0,00	Reject
Peristerona-Elea	0,82	458	67,46	6,77	0,00	Reject
Peristerona-Akaki	0,87	488	67,46	7,21	0,00	Reject
Peristerona-Pedios	0,76	210	40,32	5,19	0,00	Reject
Peristerona-Yialias	0,78	317	53,31	5,94	0,00	Reject
Akaki-Limnitis	0,62	328	64,54	5,07	0,00	Reject
Akaki-Xeros	0,60	242	53,31	4,53	0,00	Reject
Akaki-Marathasa	0,57	185	45,37	4,05	0,00	Reject
Akaki-Karyotis	0,77	429	67,46	6,35	0,00	Reject
Akaki-Atsas	0,73	409	67,46	6,05	0,00	Reject
Akaki-Elea	0,83	466	67,46	6,90	0,00	Reject
Akaki-Peristerona	0,87	488	67,46	7,21	0,00	Reject
Akaki-Pedios	0,84	232	40,32	5,73	0,00	Reject
Akaki-Yialias	0,80	324	53,31	6,05	0,00	Reject
Pedios-Limnitis	0,49	134	40,32	3,30	0,001	Reject
Pedios-Xeros	0,50	139	40,32	3,43	0,0006	Reject
Pedios-Marathasa	0,52	144	40,32	3,55	0,0004	Reject
Pedios-Karyotis	0,63	174	40,32	4,29	0,00	Reject
Pedios-Atsas	0,57	156	40,32	3,84	0,0002	Reject
Pedios-Elea	0,81	224	40,32	5,53	0,00	Reject
Pedios-Peristerona	0,76	210	40,32	5,19	0,00	Reject
Pedios-Akaki	0,84	232	40,32	5,73	0,00	Reject
Pedios-Yialias	0,77	213	40,32	5,25	0,00	Reject
Yialias-Limnitis	0,48	196	53,31	3,65	0,0002	Reject
Yialias-Xeros	0,55	221	53,31	4,13	0,00	Reject
Yialias-Marathasa	0,46	149	45,37	3,27	0,001	Reject
Yialias-Karyotis	0,60	243	53,31	4,54	0,00	Reject
Yialias-Atsas	0,63	255	53,31	4,77	0,00	Reject
Yialias-Elea	0,78	315	53,31	5,88	0,00	Reject
Yialias-Peristerona	0,78	317	53,31	5,94	0,00	Reject
Yialias-Akaki	0,80	324	53,31	6,05	0,00	Reject
Yialias-Pedios	0,77	213	40,32	5,25	0,00	Reject

Appendix 3.2 The significance of the relation of the rivers with Sperman correlation method.

LOCATION	**Sperman correlation coefficient**	***n-2***	***t* test statistics**	***t* values for 0.05 probability from *t* distribution table**	**ρ =0 Hyp. decision 0.10 significance level**
Limnitis-Xeros	0,89	27	10,31	1,70	10,31 >1,70 Reject
Limnitis-Marathasa	0,89	24	9,61	1,71	9,61>1,71 Reject
Limnitis-Karyotis	0,90	31	11,43	1,70	11,43>1,70 Reject
Limnitis-Atsas	0,62	31	4,37	1,70	4,37>1,70 Reject
Limnitis-Elea	0,80	31	7,32	1,70	7,32>1,70 Reject
Limnitis-Peristerona	0,83	31	8,19	1,70	8,19>1,70 Reject
Limnitis-Akaki	0,80	31	7,53	1,70	7,53>1,70 Reject
Limnitis-Pedios	0,66	22	4,08	1,72	4,08>1,72 Reject
Limnitis-Yialias	0,69	27	4,89	1,70	4,89>1,70 Reject
Xerox-Limnitis	0,89	27	10,31	1,70	10,31>1,70 Reject
Xerox-Marathasa	0,80	24	6,49	1,71	6,49>1,71 Reject
Xerox-Karyotis	0,87	27	9,00	1,70	9,00>1,70 Reject
Xerox-Atsas	0,56	27	3,47	1,70	3,47>1,70 Reject
Xerox-Elea	0,76	27	6,15	1,70	6,15>1,70 Reject
Xerox-Peristerona	0,79	27	6,76	1,70	6,76>1,70 Reject
Xerox-Akaki	0,77	27	6,25	1,70	6,25>1,70 Reject
Xerox-Pedios	0,65	22	4,02	1,72	4,02>1,72 Reject
Xerox-Yialias	0,72	27	5,31	1,70	5,31>1,70 Reject
Marathasa-Limnitis	0,89	24	9,61	1,71	9,61>1,71 Reject
Marathasa-Xeros	0,80	24	6,49	1,71	6,49>1,71 Reject
Marathasa-Karyotis	0,94	24	13,38	1,71	13,38>1,71 Reject
Marathasa-Atsas	0,66	24	4,25	1,71	4,25>1,71 Reject
Marathasa-Elea	0,74	24	5,45	1,71	5,45>1,71 Reject
Marathasa-Peristerona	0,80	24	6,62	1,71	6,62>1,71 Reject
Marathasa-Akaki	0,77	24	5,99	1,71	5,99>1,71 Reject
Marathasa-Pedios	0,69	22	4,46	1,72	4,46>1,72 Reject
Marathasa-Yialias	0,63	24	4,00	1,71	4,00>1,71 Reject
Karyotis-Limnitis	0,90	31	11,43	1,70	11,43>1,70 Reject
Karyotis-Xeros	0,87	27	9,00	1,70	9,00>1,70 Reject
Karyotis-Marathasa	0,94	24	13,38	1,71	13,38>1,71 Reject
Karyotis-Atsas	0,81	32	7,90	1,69	7,90>1,69 Reject
Karyotis-Elea	0,90	32	11,55	1,69	11,55>1,69 Reject
Karyotis-Peristerona	0,94	32	15,17	1,69	15,17>1,69 Reject
Karyotis-Akaki	0,92	32	13,19	1,69	13,19>1,69 Reject
Karyotis-Pedios	0,79	22	5,94	1,72	5,94>1,72 Reject
Karyotis-Yialias	0,80	27	6,93	1,70	6,93>1,70 Reject
Atsas-Limnitis	0,62	31	4,37	1,70	4,37>1,70 Reject
Atsas-Xeros	0,56	27	3,47	1,70	3,47>1,70 Reject
Atsas-Marathasa	0,66	24	4,25	1,71	4,25>1,71 Reject
Atsas-Karyotis	0,81	32	7,90	1,69	7,90>1,69 Reject
Atsas-Elea	0,84	32	8,83	1,69	8,83>1,69 Reject
Atsas-Peristerona	0,82	32	8,23	1,69	8,23>1,69 Reject
Atsas-Akaki	0,86	32	9,66	1,69	9,66>1,69 Reject
Atsas-Pedios	0,74	22	5,11	1,72	5,11>1,72 Reject
Atsas-Yialias	0,75	27	5,82	1,70	8,38>1,70 Reject
Elea-Limnitis	0,80	31	7,32	1,70	7,32>1,70 Reject
Elea-Xeros	0,76	27	6,15	1,70	6,15>1,70 Reject
Elea-Marathasa	0,74	24	5,45	1,71	5,45>1,71 Reject
Elea-Karyotis	0,90	32	11,55	1,69	11,55>1,69 Reject
Elea-Atsas	0,84	32	8,83	1,69	8,83>1,69 Reject

Appendix 3.2 (Continuous) The significance of the relation of the rivers with Sperman correlation method.

LOCATION	**Sperman correlation coefficient**	***n-2***	***t* test statistics**	***t* values for 0.05 probability from *t* distribution table**	**ρ *=0* Hyp. decision 0.10 significance level**
Elea-Peristerona	0,94	32	15,73	1,69	15,73>1,69 Reject
Elea-Akaki	0,96	32	19,39	1,69	19,39>1,69 Reject
Elea-Pedios	0,94	22	13,29	1,72	13,29>1,72 Reject
Elea-Yialias	0,92	27	12,46	1,70	12,46 >1,70 Reject
Peristerona-Limnitis	0,83	31	8,19	1,70	8,19>1,70 Reject
Peristerona-Xeros	0,79	27	6,76	1,70	6,76>1,70 Reject
Peristerona-Marathasa	0,80	24	6,62	1,71	6,62>1,71 Reject
Peristerona-Karyotis	0,94	32	15,17	1,69	15,17>1,69 Reject
Peristerona-Atsas	0,82	32	8,23	1,69	8,23>1,69 Reject
Peristerona-Elea	0,94	32	15,73	1,69	15,73>1,69 Reject
Peristerona-Akaki	0,97	32	21,47	1,69	21,47>1,69 Reject
Peristerona-Pedios	0,91	22	10,17	1,72	10,17>1,72 Reject
Peristerona-Yialias	0,92	27	12,20	1,70	12,20>1,70 Reject
Akaki-Limnitis	0,80	31	7,53	1,70	7,53>1,70 Reject
Akaki-Xeros	0,77	27	6,25	1,70	6,25>1,70 Reject
Akaki-Marathasa	0,77	24	5,99	1,71	5,99>1,71 Reject
Akaki-Karyotis	0,92	32	13,19	1,69	13,19>1,69 Reject
Akaki-Atsas	0,86	32	9,66	1,69	9,66>1,69 Reject
Akaki-Elea	0,96	32	19,39	1,69	19,39>1,69 Reject
Akaki-Peristerona	0,97	32	21,47	1,69	21,47>1,69 Reject
Akaki-Pedios	0,95	22	13,83	1,72	13,83>1,72 Reject
Akaki-Yialias	0,94	27	14,45	1,70	14,45>1,70 Reject
Pedios-Limnitis	0,66	22	4,08	1,72	4,08>1,72 Reject
Pedios-Xeros	0,65	22	4,02	1,72	4,02>1,72 Reject
Pedios-Marathasa	0,69	22	4,46	1,72	4,46>1,72 Reject
Pedios-Karyotis	0,79	22	5,94	1,72	5,94>1,72 Reject
Pedios-Atsas	0,74	22	5,11	1,72	5,11>1,72 Reject
Pedios-Elea	0,94	22	13,29	1,72	13,29>1,72 Reject
Pedios-Peristerona	0,91	22	10,17	1,72	10,17>1,72 Reject
Pedios-Akaki	0,95	22	13,83	1,72	13,83>1,72 Reject
Pedios-Yialias	0,93	22	11,42	1,72	11,42>1,72 Reject
Yialias-Limnitis	0,69	27	4,89	1,70	4,89>1,70 Reject
Yialias-Xeros	0,72	27	5,31	1,70	5,31>1,70 Reject
Yialias-Marathasa	0,63	24	4,00	1,71	4,00>1,71 Reject
Yialias-Karyotis	0,80	27	6,93	1,70	6,93>1,70 Reject
Yialias-Atsas	0,75	27	5,82	1,70	5,82>1,70 Reject
Yialias-Elea	0,92	27	12,46	1,70	12,46>1,70 Reject
Yialias-Peristerona	0,92	27	12,20	1,70	12,20>1,70 Reject
Yialias-Akaki	0,94	27	14,45	1,70	14,45>1,70 Reject
Yialias-Pedios	0,93	22	11,42	1,72	11,42>1,72 Reject

Appendix.3.3 The significance of the relation of the rivers with Pearson correlation method.

LOCATION	**Pearson correlation coefficient**	***n-2***	***t* test statistics**	***t* values for 0.05 probability from t distribution table**	**$\rho=0$ Hyp. decision 0.10 significance level**
Limnitis-Xeros	0,83	27	7,61	1,70	7,61 >1,70 Reject
Limnitis-Marathasa	0,89	24	9,51	1,71	9,51>1,71 Reject
Limnitis-Karyotis	0,87	31	9,97	1,70	9,97>1,70 Reject
Limnitis-Atsas	0,62	31	4,39	1,70	4,39>1,70 Reject
Limnitis-Elea	0,77	31	6,61	1,70	6,61>1,70 Reject
Limnitis-Peristerona	0,82	31	7,98	1,70	7,98>1,70 Reject
Limnitis-Akaki	0,78	31	6,85	1,70	6,85>1,70 Reject
Limnitis-Pedios	0,67	22	4,23	1,72	4,23>1,72 Reject
Limnitis-Yialias	0,54	27	3,33	1,70	3,33>1,70 Reject
Xerox-Limnitis	0,83	27	7,61	1,70	7,61>1,70 Reject
Xerox-Marathasa	0,77	24	5,97	1,71	5,97>1,71 Reject
Xerox-Karyotis	0,87	27	9,26	1,70	9,26>1,70 Reject
Xerox-Atsas	0,54	27	3,33	1,70	3,33>1,70 Reject
Xerox-Elea	0,76	27	6,10	1,70	6,10>1,70 Reject
Xerox-Peristerona	0,83	27	7,67	1,70	7,67>1,70 Reject
Xerox-Akaki	0,78	27	6,52	1,70	6,52>1,70 Reject
Xerox-Pedios	0,64	22	3,92	1,72	3,92>1,72 Reject
Xerox-Yialias	0,71	27	5,19	1,70	5,19>1,70 Reject
Marathasa-Limnitis	0,89	24	9,51	1,71	9,51>1,71 Reject
Marathasa-Xeros	0,77	24	5,97	1,71	5,97>1,71 Reject
Marathasa-Karyotis	0,97	24	19,21	1,71	19,21>1,71 Reject
Marathasa-Atsas	0,77	24	5,91	1,71	5,91>1,71 Reject
Marathasa-Elea	0,85	24	7,97	1,71	7,97>1,71 Reject
Marathasa-Peristerona	0,88	24	9,22	1,71	9,22>1,71 Reject
Marathasa-Akaki	0,87	24	8,73	1,71	8,73>1,71 Reject
Marathasa-Pedios	0,78	22	5,85	1,72	5,85>1,72 Reject
Marathasa-Yialias	0,55	24	3,26	1,71	3,26>1,71 Reject
Karyotis-Limnitis	0,87	31	9,97	1,70	9,97>1,70 Reject
Karyotis-Xeros	0,87	27	9,26	1,70	9,26>1,70 Reject
Karyotis-Marathasa	0,97	24	19,21	1,71	19,21>1,71 Reject
Karyotis-Atsas	0,83	32	8,35	1,69	8,35>1,69 Reject
Karyotis-Elea	0,94	32	15,31	1,69	15,31>1,69 Reject
Karyotis-Peristerona	0,95	32	17,03	1,69	17,03>1,69 Reject
Karyotis-Akaki	0,95	32	17,03	1,69	17,03>1,69 Reject
Karyotis-Pedios	0,84	22	7,26	1,72	7,26>1,72 Reject
Karyotis-Yialias	0,74	27	5,77	1,70	5,77>1,70 Reject
Atsas-Limnitis	0,62	31	4,39	1,70	4,39>1,70 Reject
Atsas-Xeros	0,54	27	3,33	1,70	3,33>1,70 Reject
Atsas-Marathasa	0,77	24	5,91	1,71	5,91>1,71 Reject
Atsas-Karyotis	0,83	32	8,35	1,69	8,35>1,69 Reject
Atsas-Elea	0,89	32	10,98	1,69	10,98>1,69 Reject
Atsas-Peristerona	0,83	32	8,45	1,69	8,45>1,69 Reject
Atsas-Akaki	0,87	32	9,93	1,69	9,93>1,69 Reject
Atsas-Pedios	0,85	22	7,70	1,72	7,70>1,72 Reject
Atsas-Yialias	0,85	27	8,38	1,70	8,38>1,70 Reject
Elea-Limnitis	0,77	31	6,61	1,70	6,61>1,70 Reject
Elea-Xeros	0,76	27	6,10	1,70	6,10>1,70 Reject
Elea-Marathasa	0,85	24	7,97	1,71	7,97>1,71 Reject
Elea-Karyotis	0,94	32	15,31	1,69	15,31>1,69 Reject
Elea-Atsas	0,89	32	10,98	1,69	10,98>1,69 Reject
Elea-Peristerona	0,95	32	17,79	1,69	17,79>1,69 Reject

Appendix 3.3 (Continuous) The significance of the relation of the rivers with Pearson correlation method.

LOCATION	**Pearson correlation coefficient**	***n-2***	***t* test statistics**	***t* values for 0.05 probability from t distribution table**	ρ **=*0* Hyp. decision 0.10 significance level**
Elea-Akaki	0,98	32	27,17	1,69	27,17>1,69 Reject
Elea-Pedios	0,94	22	12,69	1,72	12,69>1,72 Reject
Elea-Yialias	0,91	27	11,12	1,70	11,12>1,70 Reject
Peristerona-Limnitis	0,82	31	7,98	1,70	7,98>1,70 Reject
Peristerona-Xeros	0,83	27	7,67	1,70	7,67>1,70 Reject
Peristerona-Marathasa	0,88	24	9,22	1,71	9,22>1,71 Reject
Peristerona-Karyotis	0,95	32	17,03	1,69	17,03>1,69 Reject
Peristerona-Atsas	0,83	32	8,45	1,69	8,45>1,69 Reject
Peristerona-Elea	0,95	32	17,79	1,69	17,79>1,69 Reject
Peristerona-Akaki	0,97	32	21,82	1,69	21,82>1,69 Reject
Peristerona-Pedios	0,93	22	11,42	1,72	11,42>1,72 Reject
Peristerona-Yialias	0,88	27	9,48	1,70	9,48>1,70 Reject
Akaki-Limnitis	0,78	31	6,85	1,70	6,85>1,70 Reject
Akaki-Xeros	0,78	27	6,52	1,70	6,52>1,70 Reject
Akaki-Marathasa	0,87	24	8,73	1,71	8,73>1,71 Reject
Akaki-Karyotis	0,95	32	17,03	1,69	17,03>1,69 Reject
Akaki-Atsas	0,87	32	9,93	1,69	9,93>1,69 Reject
Akaki-Elea	0,98	32	27,17	1,69	27,17>1,69 Reject
Akaki-Peristerona	0,97	32	21,82	1,69	21,82>1,69 Reject
Akaki-Pedios	0,93	22	11,87	1,72	11,87>1,72 Reject
Akaki-Yialias	0,91	27	11,40	1,70	11,40>1,70 Reject
Pedios-Limnitis	0,67	22	4,23	1,72	4,23>1,72 Reject
Pedios-Xeros	0,64	22	3,92	1,72	3,92>1,72 Reject
Pedios-Marathasa	0,78	22	5,85	1,72	5,85>1,72 Reject
Pedios-Karyotis	0,84	22	7,26	1,72	7,26>1,72 Reject
Pedios-Atsas	0,85	22	7,70	1,72	7,70>1,72 Reject
Pedios-Elea	0,94	22	12,69	1,72	12,69>1,72 Reject
Pedios-Peristerona	0,93	22	11,42	1,72	11,42>1,72 Reject
Pedios-Akaki	0,93	22	11,87	1,72	11,87>1,72 Reject
Pedios-Yialias	0,92	22	10,86	1,72	10,86>1,72 Reject
Yialias-Limnitis	0,54	27	3,33	1,70	3,33>1,70 Reject
Yialias-Xeros	0,71	27	5,19	1,70	5,19>1,70 Reject
Yialias-Marathasa	0,55	24	3,26	1,71	3,26>1,71 Reject
Yialias-Karyotis	0,74	27	5,77	1,70	5,77>1,70 Reject
Yialias-Atsas	0,85	27	8,38	1,70	8,38>1,70 Reject
Yialias-Elea	0,91	27	11,12	1,70	11,12>1,70 Reject
Yialias-Peristerona	0,88	27	9,48	1,70	9,48>1,70 Reject
Yialias-Akaki	0,91	27	11,40	1,70	11,40>1,70 Reject
Yialias-Pedios	0,92	22	10,86	1,72	10,86>1,72 Reject

APPENDIX 4

Appendix 4.1 Table of the annual surface runoff (mcm) of the 10 rivers originating from Troodos Mountains.

Hydrologic year (1 Oct.-30 Sep.)	Limnitis	Xeros	Marathasa	Karyotis	Atsas	Elea	Peristerona	Akaki	Pedios	Yialias	TOTAL SUM (mcm)
1965-1966	-	-	-	11,51	1,32	4,7	11,3	10,11	-	-	38,94
1966-1967	20,34	-	-	22,72	9,54	15,22	26,29	25,07	-	-	119,18
1967-1968	15,91	-	9,78	19,17	2,63	6,71	16,39	13,92	3,55	-	88,06
1968-1969	25,55	-	17,48	35,93	8,67	27,23	38,97	45,02	12,88	-	211,73
1969-1970	4,19	-	3,7	7,38	0,57	2,91	5,91	3,82	1,11	-	29,59
1970-1971	7,33	6	5,4	11,94	1,6	7,6	14,78	12,28	5,02	5,25	77,2
1971-1972	3,45	3	3,44	8,63	1,3	5,45	11,88	10,51	4,44	2,5	54,6
1972-1973	4	2	1,14	3,23	0,12	0,54	1,67	0,76	-	1	14,46
1973-1974	9,8	5	2,41	6,18	0,36	5,08	11,03	6,92	-	4,5	51,28
1974-1975	15,62	7,8	8,8	13,8	1,23	8,13	16,86	11,59	7,08	7,5	98,41
1975-1976	16,82	6,2	6,35	12,69	1,18	7,19	13,12	12,58	6,01	4,5	86,64
1976-1977	12,79	6,25	5,87	8,81	0,4	4,41	8,79	8,13	2,83	2,82	61,1
1977-1978	23,37	6,4	9,97	14,89	1,42	6,27	13,03	10,55	3,9	2,75	92,55
1978-1979	7,81	6	3,83	7,5	0,41	2,4	8,61	6,74	2,61	3,27	49,18
1979-1980	16,07	8,7	6,85	12,99	1,29	6,81	18,42	17,34	5,09	8,64	102,2
1980-1981	18,14	7,4	8,11	16,2	2,69	10,2	20,3	16,84	5,2	6,99	112,07
1981-1982	6,01	5,8	4,94	9,04	0,52	3,01	7,98	4,75	1,59	1,52	45,16
1982-1983	11,7	5	6,38	10,81	0,46	1,65	10,43	6,06	2,42	1,41	56,32
1983-1984	8,51	4,6	5,57	7,48	0,27	1,81	8,56	4,6	1,81	1,89	45,1
1984-1985	8,67	3	4,8	9,57	0,74	4,91	14,85	9,78	3,6	4,59	64,51
1985-1986	3,59	4	2,41	3,38	0,01	0,19	5,52	3,5	1,71	1,05	25,36
1986-1987	17,46	9,2	7,74	14,5	0,68	4,27	17,3	9,72	3,27	2,12	86,26
1987-1988	18,36	9,5	8,76	16,99	1,55	8,22	21,41	15,8	5,48	6,03	112,1
1988-1989	11,95	5	7,85	14,36	3,32	9,81	19,99	17,78	7,25	9,25	106,56
1989-1990	4,24	1,3	2,86	4,08	0,21	0,97	5,56	4,73	2,29	1,6	27,84
1990-1991	1,5	0,74	1,76	2,04	1,6	0,11	2,8	1,53	0,93	0,48	13,49
1991-1992	15,65	10,75	7,38	15,79	3,47	10,86	22,39	19,58	8,84	13,14	127,85
1992-1993	12,53	8,52	7,35	15,16	5,11	12,73	22,23	17,81	7,3	11,95	120,69
1993-1994	6	4	27,54	9,2	1,2	4	13,75	11	0,83	6	83,52
1994-1995	5	3,2	41,12	7,2	0,8	3,2	10	8	1,65	3,5	83,67
1995-1996	3,3	1,8	2,59	4,1	0,08	0,5	5	1,9	3,07	0,55	22,89
1996-1997	3	1,7	0,31	3,6	0,04	0,3	3,75	0,9	2,39	0,7	16,69
1997-1998	5	3	15,82	4,8	0,08	0,4	5	2,4	0,47	0,9	37,87
1998-1999	6	3,45	38,87	5,6	0,08	0,4	5	3,7	0,25	0,8	64,15

Appendix 4.2 Table of the predicted annual surface runoff (mcm) of the 10 rivers originating from Troodos Mountains.

Hydrologic year (1 Oct.-30 Sep.)	Limnitis	Xeros	Marathasa	Karyotis	Atsas	Elea	Peristerona	Akaki	Pedios	Yialias	TOTAL SUM (mcm)
1999-2000	23,69	7,69	36,62	17,87	0,61	4,08	0,11	8,08	0,42	0,26	99,43
2000-2001	13,78	2,04	17,34	10,63	0,53	4	1,86	0,29	1,11	0,02	51,6
2001-2002	12,61	4,55	29,4	29,56	0,24	4,22	2,56	0,12	1,29	0,19	84,74
2002-2003	31,85	8,24	6,92	50,61	0,44	4,23	0,16	5,79	2,74	0,54	111,52
2003-2004	12,04	9,37	10,26	26,93	0,35	5,13	1,83	6,45	3,64	0,85	76,85
2004-2005	5,08	6,48	10,83	7,82	0,76	16,55	10,66	26,11	5,01	0,77	90,07
2005-2006	19,89	3,2	0,55	14,14	0,98	15,33	30,29	72,96	4,81	2,03	164,18
2006-2007	0,5	2,87	0,37	2,77	1,38	9,63	6,72	21,48	7,24	2,45	55,41
2007-2008	28,8	3,83	1,15	29,57	0,95	5,14	4,75	15,54	8,19	1,51	99,43
2008-2009	10,93	5,91	1,68	18,65	0,57	2,04	0,23	3,07	11,75	2,29	57,12
2009-2010	15,53	7,95	2,08	33,07	0,82	5,83	17,88	10,45	11,31	6,77	111,69
2010-2011	17,87	7,96	9,97	23,23	0,77	5,13	29,45	13,53	7,87	12,9	128,68
2011-2012	1,58	5,61	7,27	3,21	0,66	3,16	10,91	4,78	5,11	7,61	49,9
2012-2013	3,29	3,38	9,09	3,3	0,49	3,07	3,15	2,57	4,62	3,61	36,57
2013-2014	0,96	3,49	14,22	2,48	0,67	3,42	1,4	1,8	4,71	2,96	36,11
2014-2015	13,78	5,51	7,65	13,38	0,61	3,52	8,29	4,59	4,12	3,16	64,61
2015-2016	3,74	7,02	8,34	10,63	0,71	3,47	11,79	6,06	2,75	2,79	57,3
2016-2017	16,42	6,38	7,74	14,16	0,86	4,95	24,96	15,06	2,24	2,02	94,79
2017-2018	7,54	4,53	4,48	6,6	1,11	7,07	23,48	17,25	-	2,11	74,17
2018-2019	5,42	3,6	2,9	6,37	1,35	6,56	26,08	21,2	-	2,5	75,98
2019-2020	16,09	4,02	-	10,43	1,16	3,44	10,29	10,87	-	2,34	58,64
2020-2021	4,81	5,03	-	8,85	0,97	2,86	4,07	4,38	-	2,02	32,99

APPENDIX 5

Appendix 5.1 *t*-table for estimating *p* values (One tailed testing)

p	df																			
	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.450	0.132	0.131	0.130	0.130	0.129	0.129	0.129	0.128	0.128	0.128	0.128	0.128	0.128	0.127	0.127	0.127	0.127	0.127	0.127	0.127
0.400	0.267	0.265	0.263	0.262	0.261	0.260	0.260	0.259	0.259	0.258	0.258	0.258	0.257	0.257	0.257	0.257	0.257	0.256	0.256	0.256
0.350	0.408	0.404	0.402	0.399	0.398	0.397	0.396	0.395	0.394	0.393	0.393	0.392	0.392	0.392	0.391	0.391	0.391	0.390	0.390	0.390
0.300	0.559	0.553	0.549	0.546	0.543	0.542	0.540	0.539	0.538	0.537	0.536	0.535	0.534	0.534	0.533	0.533	0.532	0.532	0.532	0.531
0.250	0.727	0.718	0.711	0.706	0.703	0.700	0.697	0.695	0.694	0.692	0.691	0.690	0.689	0.688	0.688	0.687	0.686	0.686	0.685	0.685
0.200	0.920	0.906	0.896	0.889	0.883	0.879	0.876	0.873	0.870	0.868	0.866	0.865	0.863	0.862	0.861	0.860	0.859	0.858	0.858	0.857
0.150	1.156	1.134	1.119	1.108	1.100	1.093	1.088	1.083	1.079	1.076	1.074	1.071	1.069	1.067	1.066	1.064	1.063	1.061	1.060	1.059
0.100	1.476	1.440	1.415	1.397	1.383	1.372	1.363	1.356	1.350	1.345	1.341	1.337	1.333	1.330	1.328	1.325	1.323	1.321	1.319	1.318
0.095	1.516	1.478	1.451	1.432	1.418	1.406	1.397	1.389	1.383	1.377	1.373	1.369	1.365	1.362	1.359	1.357	1.354	1.352	1.350	1.349
0.090	1.558	1.517	1.489	1.469	1.454	1.442	1.432	1.424	1.417	1.411	1.406	1.402	1.398	1.395	1.392	1.389	1.387	1.385	1.383	1.381
0.085	1.602	1.559	1.529	1.508	1.492	1.479	1.468	1.460	1.453	1.447	1.441	1.437	1.433	1.429	1.426	1.424	1.421	1.419	1.417	1.415
0.080	1.649	1.603	1.572	1.549	1.532	1.518	1.507	1.498	1.490	1.484	1.478	1.474	1.469	1.466	1.462	1.459	1.457	1.454	1.452	1.450
0.075	1.699	1.650	1.617	1.592	1.574	1.559	1.548	1.538	1.530	1.523	1.517	1.512	1.508	1.504	1.500	1.497	1.494	1.492	1.489	1.487
0.070	1.753	1.700	1.664	1.638	1.619	1.603	1.591	1.580	1.572	1.565	1.558	1.553	1.548	1.544	1.540	1.537	1.534	1.531	1.529	1.526
0.065	1.810	1.754	1.715	1.687	1.666	1.650	1.636	1.626	1.616	1.609	1.602	1.596	1.591	1.587	1.583	1.579	1.576	1.573	1.570	1.568
0.060	1.873	1.812	1.770	1.740	1.718	1.700	1.686	1.674	1.664	1.656	1.649	1.642	1.637	1.632	1.628	1.624	1.621	1.618	1.615	1.612
0.055	1.941	1.874	1.830	1.797	1.773	1.754	1.738	1.726	1.715	1.706	1.699	1.692	1.686	1.681	1.677	1.672	1.669	1.665	1.662	1.660
0.050	2.015	1.943	1.895	1.860	1.833	1.812	1.796	1.782	1.771	1.761	1.753	1.746	1.740	1.734	1.729	1.725	1.721	1.717	1.714	1.711
0.045	2.098	2.019	1.966	1.928	1.899	1.877	1.859	1.844	1.832	1.821	1.812	1.805	1.798	1.792	1.786	1.782	1.777	1.773	1.770	1.767
0.040	2.191	2.104	2.046	2.004	1.973	1.948	1.928	1.912	1.899	1.887	1.878	1.869	1.862	1.855	1.850	1.844	1.840	1.835	1.832	1.828
0.035	2.297	2.201	2.136	2.090	2.055	2.028	2.007	1.989	1.974	1.962	1.951	1.942	1.934	1.926	1.920	1.914	1.909	1.905	1.900	1.896
0.030	2.422	2.313	2.241	2.189	2.150	2.120	2.096	2.076	2.060	2.046	2.034	2.024	2.015	2.007	2.000	1.994	1.988	1.983	1.978	1.974
0.025	2.571	2.447	2.365	2.306	2.262	2.228	2.201	2.179	2.160	2.145	2.131	2.120	2.110	2.101	2.093	2.086	2.080	2.074	2.069	2.064
0.020	2.757	2.612	2.517	2.449	2.398	2.359	2.328	2.303	2.282	2.264	2.249	2.235	2.224	2.214	2.205	2.197	2.189	2.183	2.177	2.172
0.015	3.003	2.829	2.715	2.634	2.574	2.527	2.491	2.461	2.436	2.415	2.397	2.382	2.368	2.356	2.346	2.336	2.328	2.320	2.313	2.307
0.010	3.365	3.143	2.998	2.896	2.821	2.764	2.718	2.681	2.650	2.624	2.602	2.583	2.567	2.552	2.539	2.528	2.518	2.508	2.500	2.492
0.005	4.032	3.707	3.499	3.355	3.250	3.169	3.106	3.055	3.012	2.977	2.947	2.921	2.898	2.878	2.861	2.845	2.831	2.819	2.807	2.797
0.001	5.893	5.208	4.785	4.501	4.297	4.144	4.025	3.930	3.852	3.787	3.733	3.686	3.646	3.610	3.579	3.552	3.527	3.505	3.485	3.467
0.0005	6.869	5.959	5.408	5.041	4.781	4.587	4.437	4.318	4.221	4.140	4.073	4.015	3.965	3.922	3.883	3.850	3.819	3.792	3.768	3.745
0.0001	9.678	8.025	7.063	6.442	6.010	5.694	5.453	5.263	5.111	4.985	4.880	4.791	4.714	4.648	4.590	4.539	4.493	4.452	4.415	4.382
0.00005	11.178	9.082	7.885	7.120	6.594	6.211	5.921	5.694	5.513	5.363	5.239	5.134	5.044	4.966	4.897	4.837	4.784	4.736	4.693	4.654
0.00001	15.547	12.032	10.103	8.907	8.102	7.527	7.097	6.765	6.501	6.287	6.109	5.959	5.832	5.722	5.627	5.543	5.469	5.402	5.343	5.290
0.000005	17.897	13.555	11.215	9.783	8.827	8.150	7.647	7.261	6.954	6.706	6.502	6.330	6.184	6.058	5.949	5.854	5.769	5.694	5.626	5.566
0.000001	24.771	17.830	14.241	12.110	10.720	9.752	9.043	8.504	8.082	7.743	7.464	7.233	7.036	6.869	6.723	6.597	6.485	6.386	6.297	6.218

Source: Gazi University Faculty of Art and Science Department of Statistics (http://www.fef.gazi.edu.tr/yeni/bolumDosyalari/statist/dokuman/T_Table.pdf)

Appendix 5.2 Area under the standard normal distribution curve ($z \geq 0$)

Z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986
3	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	0.9989	0.9989	0.9990	0.9990
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	0.9992	0.9992	0.9993	0.9993

Source: Gazi University Faculty of Art and Science Department of Statistics

Appendix 5.3 X^2 Distribution table

df	Area in the Upper Tail					
	0.99	0.95	0.9	0.1	**0.05**	**0.01**
1	0.000	0.004	0.016	2.706	3.841	6.635
2	0.020	0.103	0.211	4.605	5.991	9.210
3	0.115	0.352	0.584	6.251	7.815	11.345
4	0.297	0.711	1.064	7.779	9.488	13.277
5	0.554	1.145	1.610	9.236	11.070	15.086
6	0.872	1.635	2.204	10.645	12.592	16.812
7	1.239	2.167	2.833	12.017	14.067	18.475
8	1.646	2.733	3.490	13.362	15.507	20.090
9	2.088	3.325	4.168	14.684	16.919	21.666
10	2.558	3.940	4.865	15.987	18.307	23.209
11	3.053	4.575	5.578	17.275	19.675	24.725
12	3.571	5.226	6.304	18.549	21.026	26.217
13	4.107	5.892	7.042	19.812	22.362	27.688
14	4.660	6.571	7.790	21.064	23.685	29.141
15	5.229	7.261	8.547	22.307	24.996	30.578
16	5.812	7.962	9.312	23.542	26.296	32.000
17	6.408	8.672	10.085	24.769	27.587	33.409
18	7.015	9.390	10.865	25.989	28.869	34.805
19	7.633	10.117	11.651	27.204	30.144	36.191
20	8.260	10.851	12.443	28.412	31.410	37.566
21	8.897	11.591	13.240	29.615	32.671	38.932
22	9.542	12.338	14.041	30.813	33.924	40.289
23	10.196	13.091	14.848	32.007	35.172	41.638
24	10.856	13.848	15.659	33.196	36.415	42.980
25	11.524	14.611	16.473	34.382	37.652	44.314

Source: Gazi University Faculty of Art and Science Department of Statistics
(http://www.fef.gazi.edu.tr/yeni/bolumDosyalari/statist/dokuman/chisqr.pdf)

Appendix5.4 *p* values for Kendall's *S* statistic and Kendall's correlation coefficient

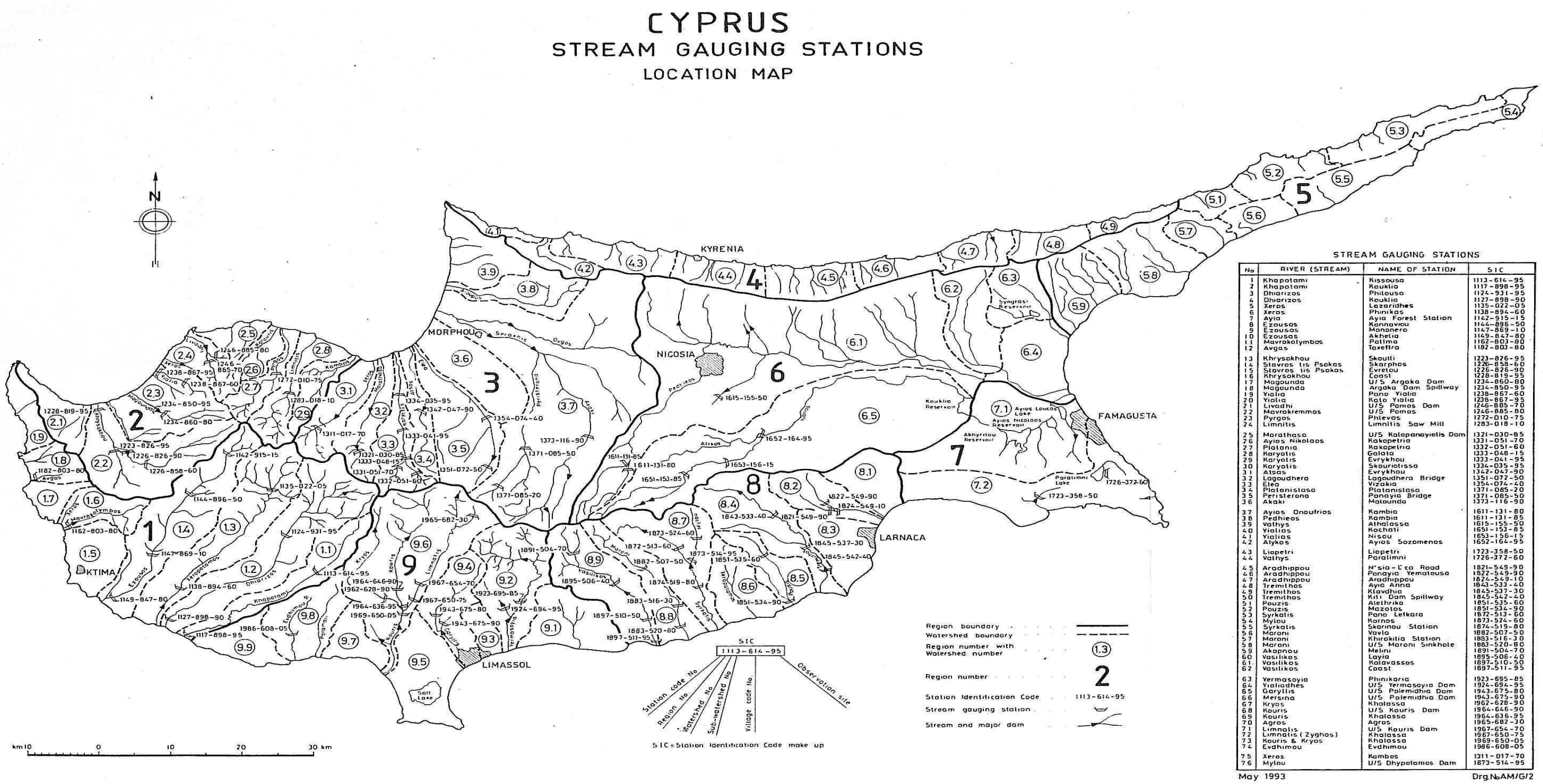
One-sided p = Prob [S ≥ x] = Prob [S ≤ −x]

	N = Number of data pairs					N = Number of data pairs			
	4	5	8	9		3	6	7	10
x					x				
0	0.625	0.592	0.548	0.540	1	0.500	0.500	0.500	0.500
2	0.375	0.408	0.452	0.460	3	0.167	0.360	0.386	0.431
4	0.167	0.242	0.360	0.381	5		0.235	0.281	0.364
6	0.042	0.117	0.274	0.306	7		0.136	0.191	0.300
8		0.042	0.199	0.238	9		0.068	0.119	0.242
10		0.0083	0.138	0.179	11		0.028	0.068	0.190
12			0.089	0.130	13		0.0083	0.035	0.146
14			0.054	0.090	15		0.0014	0.015	0.108
16			0.031	0.060	17			0.0054	0.078
18			0.0156	0.038	19			0.0014	0.054
20			0.0071	0.022	21			0.0002	0.036
22			0.0028	0.0124	23				0.023
24			0.0009	0.0063	25				0.0143
26			0.0002	0.0029	27				0.0083
28			<0.0001	0.0012	29				0.0046
30				0.0004	31				0.0023
32				0.0001	33				0.0011
34				<0.0001	35				0.0005
36				<0.0001	37				0.0002
					39				<0.0001
					41				<0.0001
					43				<0.0001
					45				<0.0001

Source: (Helsel & Hirsch, 1991).

Appendix 5.5 Cyprus stream gauging stations location map

-XXIX-



STREAM GAUGING STATIONS

No	RIVER (STREAM)	NAME OF STATION	SIC
1	Khapotami	Kissousa	1113-614-95
2	Khapotami	Kouklia	1117-898-95
3	Dhiarizos	Philousa	1124-931-95
4	Dhiarizos	Kouklia	1127-898-90
5	Xeros	Lazaridhes	1135-022-05
6	Xeros	Phinikas	1138-894-60
7	Ayia	Ayia Forest Station	1142-915-15
8	Ezousas	Kannaviou	1144-896-50
9	Ezousas	Mononero	1147-869-10
10	Ezousas	Akhelia	1149-847-80
11	Mavrokolymbos	Potima	1162-803-80
12	Avgas	Toxeftra	1182-803-80
13	Khrysokhou	Skoutli	1223-826-95
14	Stavros tis Psokas	Skarphos	1226-858-60
15	Stavros tis Psokas	Evretou	1226-826-90
16	Khrysokhou	Coast	1228-819-95
17	Magounda	U/S Argaka Dam	1234-860-80
18	Magounda	Argaka Dam Spillway	1234-850-95
19	Yialia	Pano Yialia	1238-867-60
20	Yialia	Kato Yialia	1238-867-95
21	Livadhi	U/S Pomos Dam	1246-885-70
22	Mavrokremmos	U/S Pomos	1246-885-80
23	Pyrgos	Phlevas	1272-010-75
24	Limnitis	Limnitis Saw Mill	1283-018-10
25	Marathasa	U/S Kalopanayiotis Dam	1321-030-85
26	Ayios Nikolaos	Kakopetria	1331-051-70
27	Platania	Kakopetria	1332-051-60
28	Karyotis	Galata	1333-048-15
29	Karyotis	Evrykhou	1333-041-95
30	Karyotis	Skouriotissa	1334-035-95
31	Atsas	Evrykhou	1342-047-90
32	Lagoudhera	Lagoudhera Bridge	1351-072-50
33	Elea	Vizakia	1354-074-40
34	Platanistasa	Platanistasa	1371-085-20
35	Peristerona	Panayia Bridge	1371-085-50
36	Akaki	Malounda	1373-116-90
37	Ayios Onoufrios	Kambia	1611-131-80
38	Pedhieos	Kambia	1611-131-85
39	Vathys	Athalassa	1615-155-50
40	Yialias	Kochati	1651-153-85
41	Yialias	Nisou	1653-156-15
42	Alykos	Ayios Sozomenos	1652-164-95
43	Liopetri	Liopetri	1723-358-50
44	Vathys	Paralimni	1726-372-60
45	Aradhippou	N'sia-L'ca Road	1821-549-90
46	Aradhippou	Panayia Yematousa	1822-549-90
47	Aradhippou	Aradhippou	1824-549-10
48	Tremithos	Ayia Anna	1843-533-40
49	Tremithos	Klavdhia	1845-537-30
50	Tremithos	Kiti Dam Spillway	1845-542-40
51	Pouzis	Alethriko	1851-535-60
52	Pouzis	Mazotos	1851-534-90
53	Syrkatis	Pano Lefkara	1872-513-60
54	Mylou	Kornos	1873-524-60
55	Syrkatis	Skarinou Station	1874-519-80
56	Maroni	Vavla	1882-507-50
57	Maroni	Khirokitia Station	1883-516-30
58	Maroni	U/S Maroni Sinkhole	1883-520-80
59	Akapnou	Melini	1891-504-70
60	Vasilikos	Layia	1895-506-40
61	Vasilikos	Kalavassos	1897-510-50
62	Vasilikos	Coast	1897-511-95
63	Yermasoyia	Phinikaria	1923-695-85
64	Yialiadhes	U/S Yermasoyia Dam	1924-694-95
65	Garyllis	U/S Polemidhia Dam	1943-675-80
66	Mersina	U/S Polemidhia Dam	1943-675-90
67	Kryos	Khalassa	1962-628-90
68	Kouris	U/S Kouris Dam	1964-646-90
69	Kouris	Khalassa	1964-636-95
70	Agros	Agros	1965-682-30
71	Limnatis	U/S Kouris Dam	1967-654-70
72	Limnatis (Zyghos)	Khalassa	1967-650-75
73	Kouris & Kryos	Khalassa	1969-650-05
74	Evdhimou	Evdhimou	1986-608-05
75	Xeros	Kambos	1311-017-70
76	Mylou	U/S Dhypotamos Dam	1873-514-95

Source: (Helsel & Hirsch, 1991).