Ministry of Agriculture, Natural Resources and Environment of the Republic of Cyprus
Water Development Department

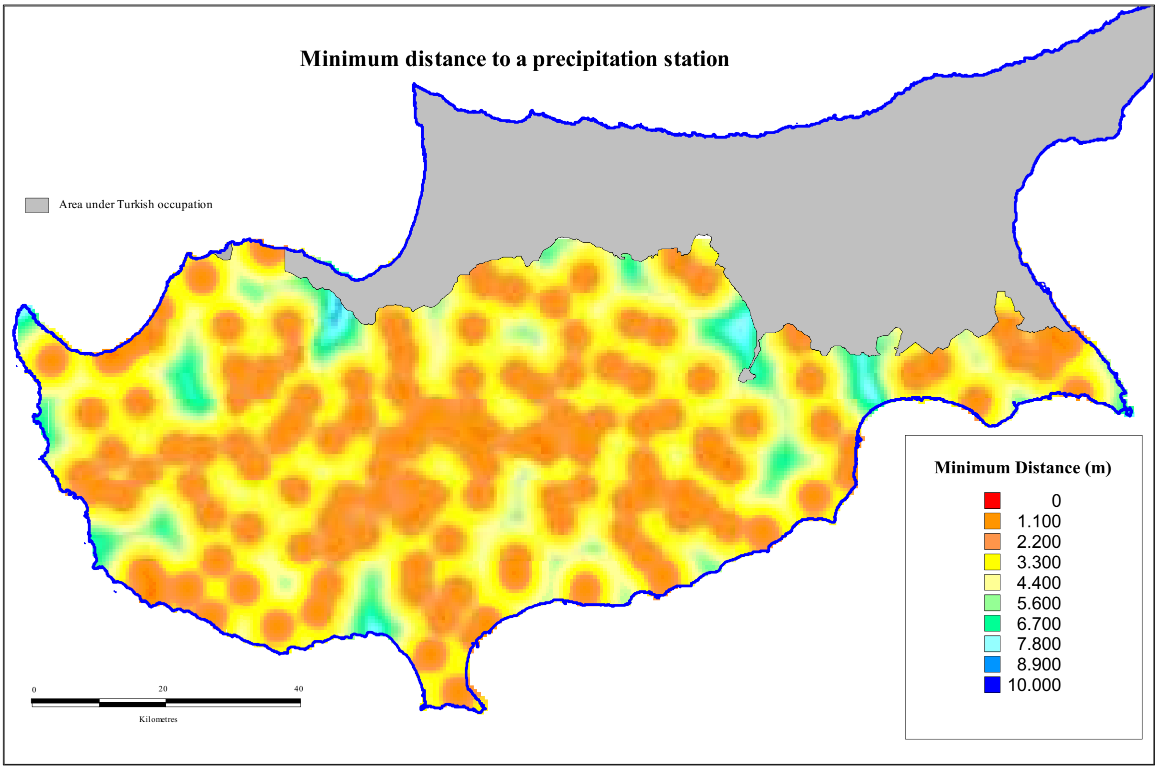
Food and Agriculture Organisation of the United Nations
Land and Water Development Division

TCP/CYP/8921

REASSESSMENT OF THE ISLAND'S WATER RESOURCES AND DEMAND

Objective 1 - Output 1.6

HYDROLOGICAL NETWORK ANALYSIS AND OPTIMISATION



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October 2001

MAIN RESULTS AND RECOMMENDATIONS

This analysis is part of the WDD-FAO project "Reassessment of the Island's Water Resources and Demand". Its main objectives were to examine and assess the effectiveness of the hydrological data collection network in Cyprus and review the quality control on the hydrological data collection and the data obtained.

I took the initiative to extend the assessment of the effectiveness of the data collection network to the precipitation stations network. At the light of the results of this study and with the help of the methodology and tools developed, it is recommended to extend the analysis to temperature and evaporation or evapotranspiration that are important parameters for water resources studies and management.

Our principal recommendation about the **precipitation stations network** concern the urban areas for which the network does not even meet the minimum WMO recommendation. There are only two stations in Nicosia, two in Limassol, one in Larnaca and none in Paphos. Densely populated urban areas need a very dense rain-gauge network for both temporal and spatial resolution of storms, for design, management, and real-time control of the drainage systems and for other engineering applications. For urban areas where the time resolution needed for rainfall measurements is of the order of one to two minutes, for reliable measurements, tipping-bucket rain gauges with an electronic memory are recommended. At least four to six of these stations should be installed in both Nicosia and Limassol, three in Larnaca and three in Paphos.

In the countryside, the precipitation stations network is dense enough and well distributed for water resources assessment. At any point of the area under government control it allows reliable estimation of the mean annual precipitation and the temporal variations of the annual precipitation over the 1970/71-1999/00 period. With the objective to have a homogeneous network our recommendation to the Meteorological Service is to move some stations from the areas with very high density to areas with lower density.

The Meteorological Service had install recently 16 automatic weather stations and is expecting to install additional 10 in the near future. The 16 already installed replace existing manual climatological stations. They are well distributed throughout the island answering partly the recommendations made here with the installation of two stations in Nicosia, one in Limassol and one in Paphos.

The descriptive analysis of the **stream-flow stations network** shows that no station should be removed from the actual network and we recommend the installation of a stream-flow station on the Pedhieos River at the level of Nicosia. Each of the existing stations has specific and important relevance for water resources assessment. In addition, the majority of the stations are powerful helps for the management of the dams that have been constructed throughout the island.

The statistical analysis realised here concludes that the temporal variations of the annual stream-flow can be estimated with significant level of confidence at any section of a river on which there are gauging stations. It can also be estimated for adjacent un-gauged rivers but with lower accuracy. This analysis also concludes that the estimation of mean annual flow for un-gauged watershed is doubtful with the actual stream-flow stations network. This analysis reveals the value of each station and the necessity to continue operating all the existing stream-flow stations.

Studies on flood propagation, rainfall-runoff modelling, erosion, influence of land-use on runoff, are relevant for water resource knowledge and planning. These specifics studies may require the installation of additional stations in experimental watershed.

The data that are generated by the field activities are of little or no value if they cannot be readily and confidently accessed by the potential data users. Numerous hydrological analyses relevant in Cyprus such as dam management, rainfall-runoff modelling, flood propagation, and erosion control require time-series of instantaneous flow. This information should therefore be available on computer and for some watersheds in real time.

The evolution of instrument technology and computer facilities imply improvement in the measuring instruments as well as in the data processing and storage, used at the Division of Water Resources.

For the measuring instruments, the main recommendation is to progressively replace graphical water level recorders with digital recorders. Some of the digital recorders should be provided with real time transfer of information. These will allow better management of the water supply projects implemented in Cyprus.

For the data processing, it is greatly recommended to process electronically the water level graphs. To this end hydrological data acquisition electronic equipment and software have to be acquired. The Division of Water Resources should be staffed with personnel trained in computer use. The costly and time-consuming employee recruitment and training can be a sound investment that results in greater productivity and effectiveness. A carefully structured training program is essential for all personnel engaged in data collection because they are in a strong position to influence the quality of the final data.

The acquisition of equipment for digital treatment of the water level graph will save a lot of time in the processing of the data. In addition, thanks to the digitalisation of the water level graph and the use of digital recorder, the information offered in electronic format will be easier and faster to access. This information will also be accessible at the short time-scale required for operational hydrology.

This kind of efforts is currently done by the Meteorological Service with the acquisition of 26 automatic weather stations reporting immediately through telephone line. Similar evolution and efforts have to be realised for the Division of Water Resources to give the hydrological data its real value, as the data will be effortlessly available for operational hydrology and research.

ACKNOWLEDGEMENTS

Iacovos Iacovides, Chief water engineer with the Water Development Department and National project coordinator, please find here my acknowledgements for your permanent support during my missions in Cyprus and valuable comments on the project expected results from this analysis. I would like also to thank Mr Panayiotis Skordis (Division of Hydrology, Deputy Project Coordinator) for his recurrent questions on the methodology and statistical techniques.

The author wants to address a special thanks to Mr Christos Ioanou (Division of Hydrology) and Mr Gerald Dörflinger (FAO, national consultant) for their participation in the identification of the methodology, for the elaboration of several Excel files and macros for the systematic application of the methodology to the entire database.

The author want to thanks the Meteorological Service and the Division of Water Resources of the Water Development Department for providing the data used for this study.

My best acknowledgements are also directed to Ms Marilena Panaretou (Division of Hydrology), Mr Stelios Pashiardis (Meteorological Service) and to Mr Gerald Dörflinger for their attentive review of this document

Thanks again to Mr Gerald Dörflinger for his help to realise the maps presented in this document. Without forgetting all the employees of the Division of Hydrology of the Water Development Department that made my stay in Cyprus more pleasant.

Frédéric Rossel

Nicosia, October 2001

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INTRODUCTION

This study is part of the WDD-FAO project “Reassessment of the Island’s Water Resources and Demand”. The preface of this document presents the context of this study and the overall objective of the project. One of the two immediate objectives of the project is to provide updated records about the water available in the island. The main objectives of this study are to examine and assess the effectiveness of the hydro-meteorological data collection network in Cyprus and review the quality control on the hydrological data collection and the data obtained.

The worth of the data derived from a network is a function of the uses that subsequently are made of them. Nevertheless, many of the uses of hydrological data are not apparent at this time and, therefore, cannot be used to justify the collection of specific data that ultimately may be of great value. In fact, few hydrological data would be collected if a priori economic justifications were required. However, modern societies have developed a sense that information is a commodity that, like insurance, should be purchased for protection against an uncertain future. Such an investment in the case of hydrological data is the basic network, which is established to provide hydrological information for unanticipated future water-resources decisions.

The basic network should provide a level of hydrological information at any location within its region of applicability that would preclude any gross mistakes in water-resources decision-making. The basic network of observing stations should be adjusted over time until regional hydrological relationships can be developed for un-gauged areas that provide the appropriate level of information.

Owing to the broad dependence on the stations in the basic network, it is very important that the records from all of these stations be of high quality. Even if the installation of a station is adequate, its records may be of little value if it is not operated correctly. Continuous operation may be difficult, especially over a period of 20 years or more. A minimum network, in which stations are abandoned or irregularly observed, will have its effective density reduced and is, therefore, no longer an adequate minimum network. For that reason, care should be taken not only in establishing, but also in providing for the continuing operation of these stations and for monitoring the reliability and accuracy of the collected records.

Numerous hydrological analyses such as dam management, rainfall-runoff modelling, flood propagation, and erosion control require time-series of instant flow. This information should therefore be available on computer format for historical data and this information should be also available in real time in some watershed. These requirements imply improvement in the measuring instruments as well as in the data processing and storage.

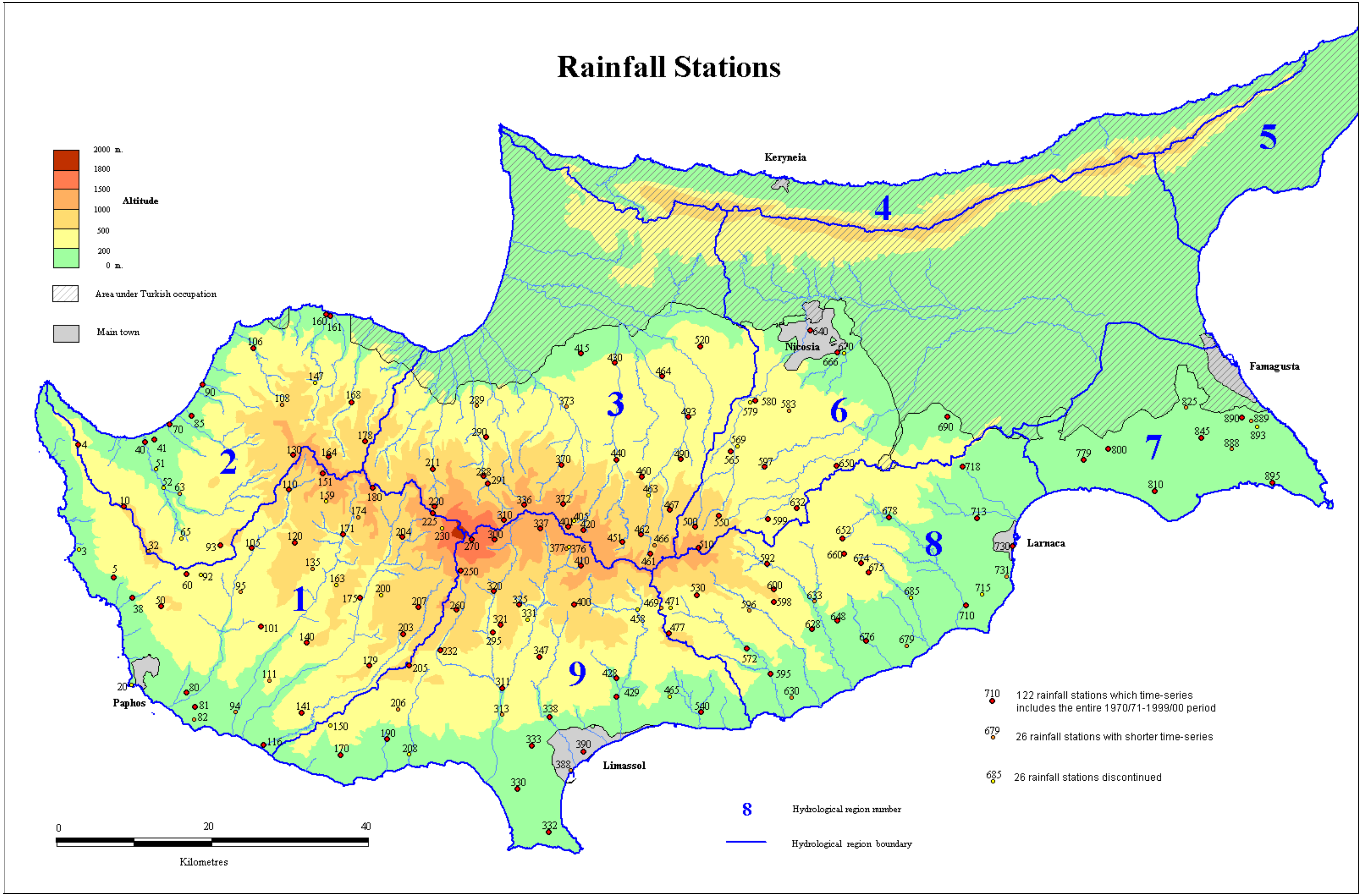

Figure 1: Location and reference number of the meteorological stations.

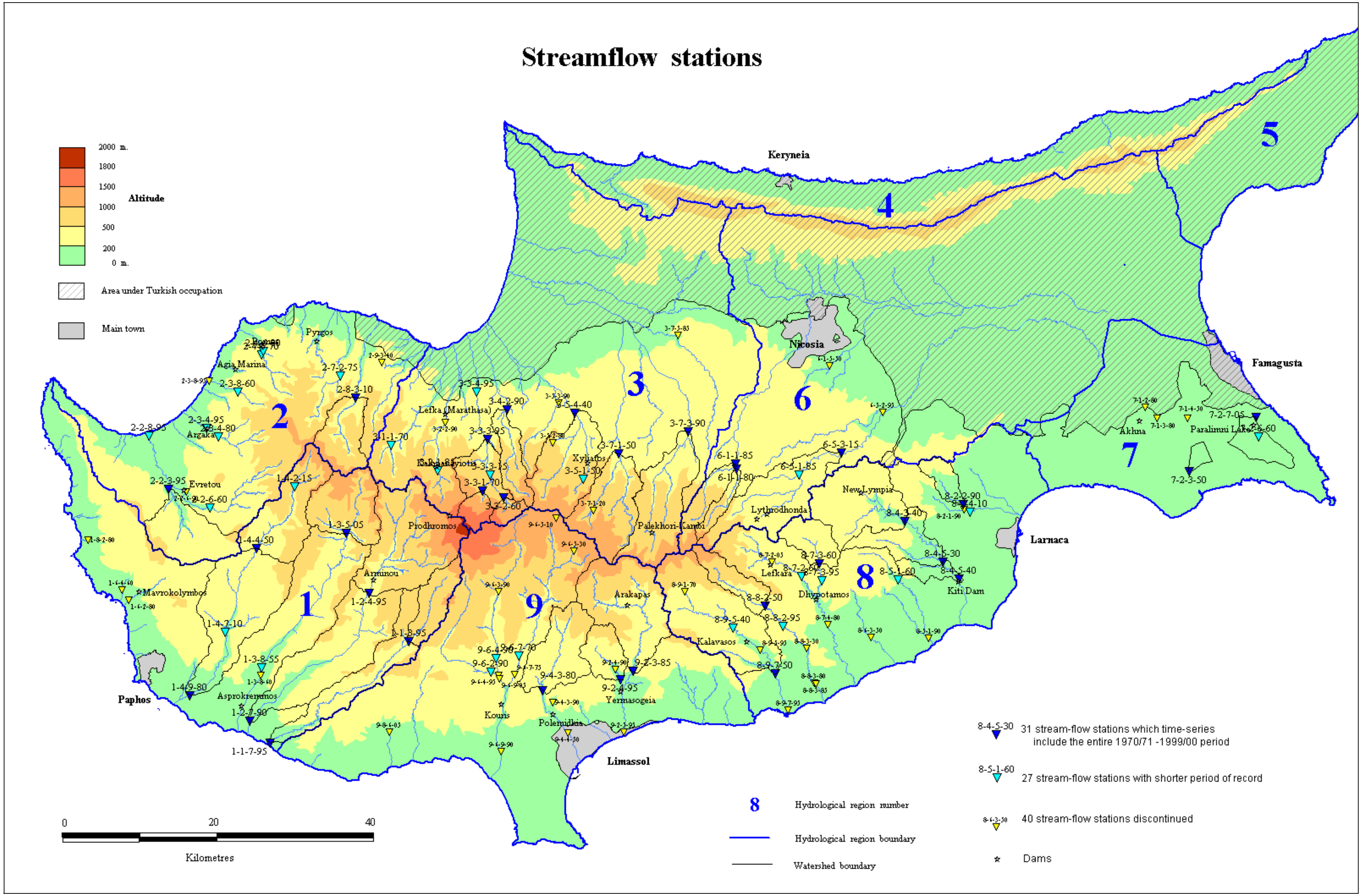

Figure 2: Location and reference numbers of the stream-flow gauging stations.

1 EXAMINATION AND ASSESSMENT OF THE EFFECTIVENESS OF THE HYDRO-METEOROLOGICAL DATA COLLECTION NETWORK

This chapter includes the description of the hydro-meteorological data collection network and information used (1.1), an examination of the geographical coverage of the precipitation stations network and an evaluation of the effectiveness of the network for estimation of mean annual precipitation (1.2), an examination of the geographical coverage of the stream-flow gauging stations network and an evaluation of the effectiveness of the network for estimation of mean annual flow (1.3), our conclusions on the effectiveness of the network and our recommendations (1.4).

1.1 Information used

The area under consideration is the island of Cyprus excluding the northern part of the island for which precipitation records available stopped in 1974 with the Turkish invasion and occupation of this part of the island (Figure 1).

The period of study is 1970/71 to 1999/00. It has been chosen according to the conclusion of the Objective 1.2 "Hydro-meteorological study examining changes in recorded precipitation" of the project. It is understood that the year used in this analysis is the standard hydrological year used in Cyprus. The hydrological year 1999/00 starts on the 1st of October 1999 and finishes on the 30th of September 2000.

Monthly precipitation time series are available for 122 meteorological stations over the entire 30 years period of study (Figure 1, and Annex 1). Twenty-six other stations have shorter time-series and 26 stations are discontinued. The Meteorological Service has realised a data quality check over the entire island. When possible, it has also estimated missing daily rainfall for stations with short periods of missing data. Before 1972, the missing data have been estimated using data from the three nearest stations. After 1972, daily isohyetal maps were used to this end.

Over the 30 years period of study, monthly mean flow time-series are available for only 19 hydrological stations, 12 additional time-series were used as the missing data is limited to two years (Figure 2 and Annex 2), most of them during the 1972-74 period. Twenty-seven other stations have shorter time-series and 40 stations are discontinued. The Division of Water Resources provided the time-series.

Thanks to this study, the monthly time-series for the 122 precipitation stations and 31 stream-flow stations are now available in Excel files at the Division of Hydrology. These files include only the 30-years period from 1970/71 to 1999/00. These files give precipitation time-series in millimetres and stream-flow time-series in either cubic metres or in millimetres. They also give standardised values for both. The standardisation of the data has been realised subtracting the 30-years mean from the observed data and dividing the result by the 30-years standard deviation. Several statistics values and graphs, useful for water resources assessment, are available in each station files, some of them are presented in Annex 3.

1.2 Precipitation station network

In section 1.2.1 we analyse the density and the spatial distribution of the stations throughout the island. In section 1.2.2 we determine if the actual precipitation network is dense enough to determine the relationship between mean annual precipitation and altitude. This relation is necessary to estimate the mean annual precipitation at any point of the island. Finally in section 1.2.3 we analyse the relation between the distance between two stations and the coefficient of determination between the annual precipitation time-series of the stations. The objective of this section is to determine if the temporal variations of the annual precipitation can be estimated at any point of the island.

1.2.1 Density of the network

The minimum densities recommended of precipitation stations by the WMO are 1 station for 250 km^2 for the mountainous area, 1 for 900 km^2 for the coastal area and 1 for 10 km^2 for urban areas (WMO 1994). Table 1 gives the numbers and densities of precipitation stations for the hydrological regions, urban areas and the entire area under government control. These values meet the minimum densities recommended by the WMO except for the urban areas of Nicosia, Limassol and Paphos. In average for the entire area under government control the density is six times higher than the minimum recommended.

Table 1: Average numbers and density of precipitation stations by hydrological regions.

Hydrological region			Precipitation stations			
			1971-2000		All stations	
Code	Name	Area km^2	#	*Dens*	#	*Dens*
1	Paphos	1174	26	45	33	36
2	Tylliria	718	15	48	18	40
3	Morphou	990	26	38	29	34
6	Mesaoria	552	13	42	14	39
7	South-East Mesaoria	366	6	61	9	41
8	Larnaca	1038	22	47	28	37
9	Limassol	1164	26	45	31	38
	Urban area of Nicosia	40	2	20	2	20
	Urban area of Limassol	40	1	40	2	20
	Urban area of Larnaca	10	1	10	1	10
	Urban area of Paphos	10	0	-	0	-
	Area under government control	6002	122	49	148	41

Note: # corresponds to the number of stations within the region. *Dens* corresponds to the density of stations by region in km^2/station (*Dens* = area of the region / number of stations within the region)

In general, precipitation stations should be as uniformly distributed as is consistent with practical needs for data and the location of volunteer observers. In mountainous regions, attention must be given to the vertical distribution of the stations. These two conditions are relatively well respected in Cyprus (Figure 1). It can be noted that several stations are very close together: 40 and 41, 81 and 82, 160 and 161, 889 and 890. Figure 3 provides the minimum distance to a precipitation station from any point of the island. This map shows the areas with the lower and higher density of precipitation stations. Seven areas of the lowlands present lower density than the rest of the island: Paphos, east of Polis, Akaki area, south of Nicosia, west and north of Larnaca, west of Limassol. At the other end, several areas come with many stations of less than two kilometres apart.

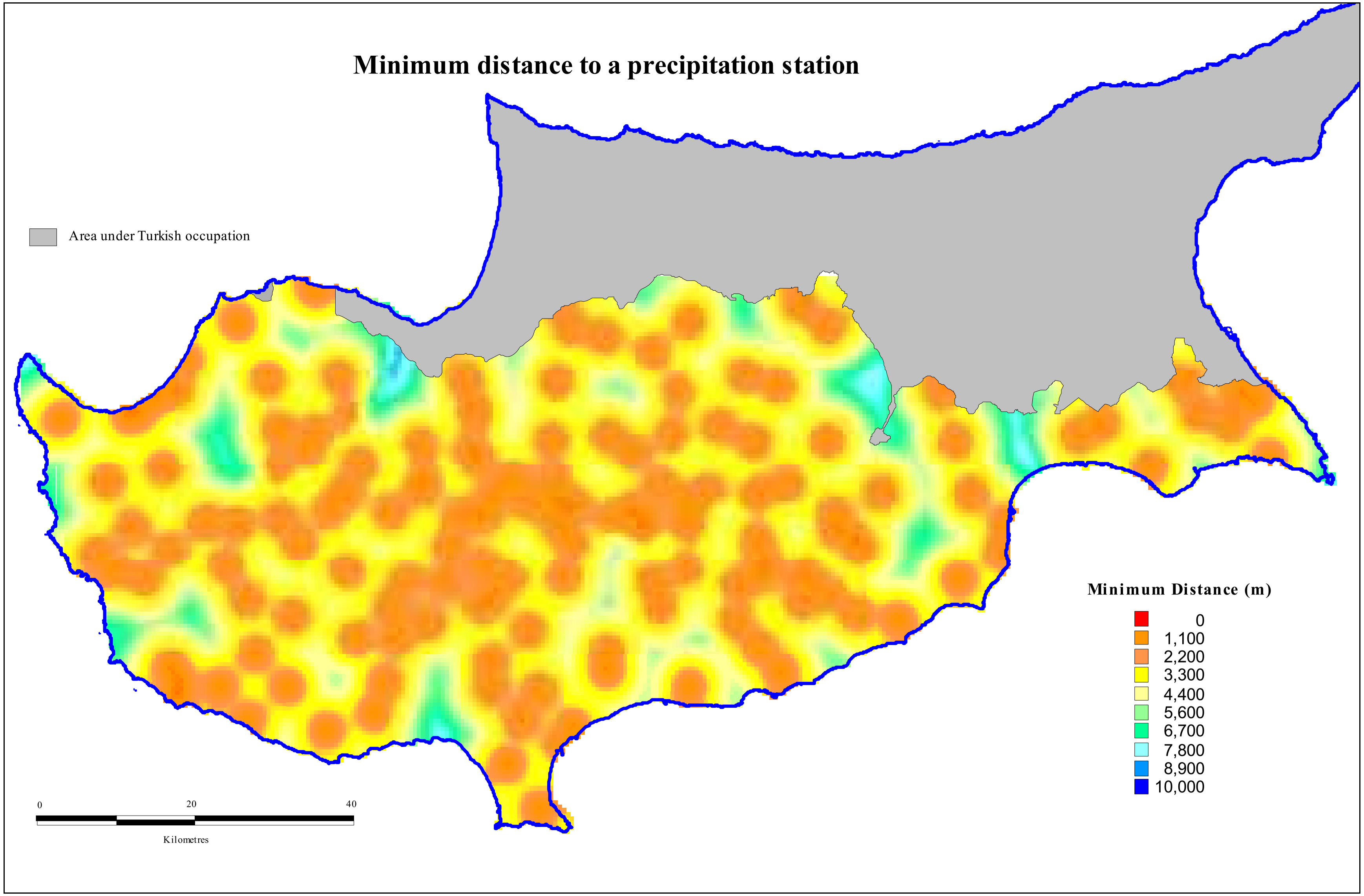

Figure 3: Minimum distance to a precipitation station from any point on the island.

1.2.2 Effectiveness of the network for estimation of mean annual precipitation at any location

The WMO recommends that the basic network of observation stations should be adjusted over time until hydrological information can be developed for un-gauged areas (WMO 1994). The existing time-series allow the determination of the relationship between mean annual precipitation and altitude for each hydrological region with satisfactory confidence (Figure 4, Figure 5 and Annex 4). Therefore it will be possible to estimate the mean annual precipitation at any point of the island with satisfactory confidence. The south-east Mesaoria region (Region 7) is not included here as this region does not present significant topography, the six stations have mean annual precipitation between 300 and 350 mm for elevation between 20 and 70 m.

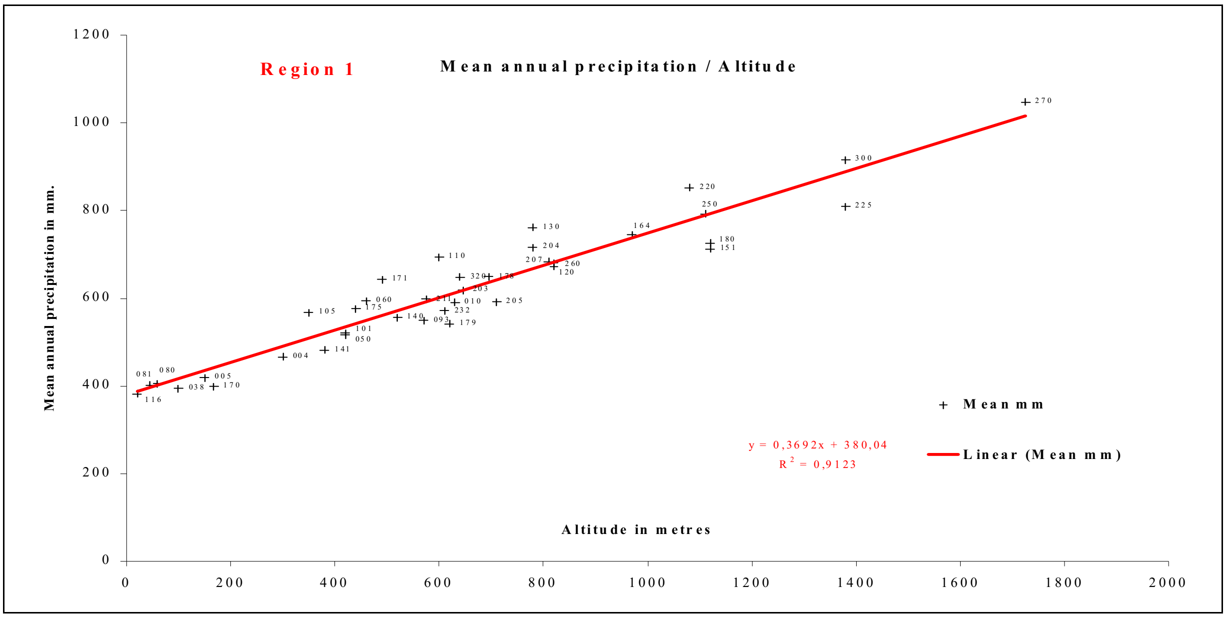

Figure 4: Variations of the mean annual precipitation at a station with the station elevation within Region 1.

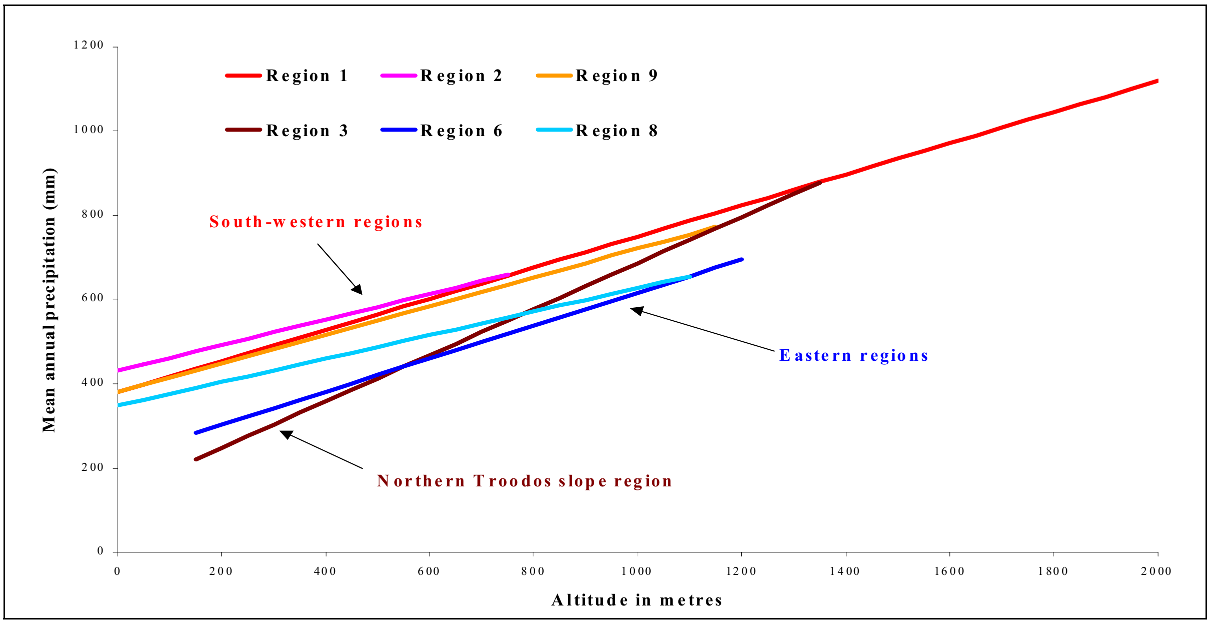

Figure 5: Linear regression line of mean annual precipitation against station elevation for the Troodos Mountain regions (Regions 1, 2, 3, 6, 8 and 9).

1.2.3 *Effectiveness of the network for estimation of annual precipitation variations at any location*

This is an analysis of the variations with space of the temporal variations of annual precipitation in Cyprus. It is look for the relationship between the coefficient of determination between the time-series (temporal variability) and the distance between the stations (spatial variability). In other words, it is look for the relationship between the temporal variability and spatial variability.

The coefficients of determination, r^2 between the annual precipitation time series of any two stations were calculated. The coefficient of determination between two series of numbers is equal to the percentage of the variance of the first series that can be explained with the second series. Each hydrological region was considered separately. Stations in neighbouring regions were included in the analysis only on low land and only in cases where the stations lie 5 km or less outside the region under consideration. The coefficients of determination (r^2) were then plotted against the distances between each pair of stations (Figure 6).

The regression line through the plotted points defines the statistical relation between the distance between two stations and the percentage of the variance of the annual precipitation time-series of one station that can be explained with the time-series of the second station. Distances greater than 15 km were not included in this regression analysis because the greater majority of the stations lie within 15 km of any neighbouring stations. (Figure 6, Figure 7 and Annex 5)

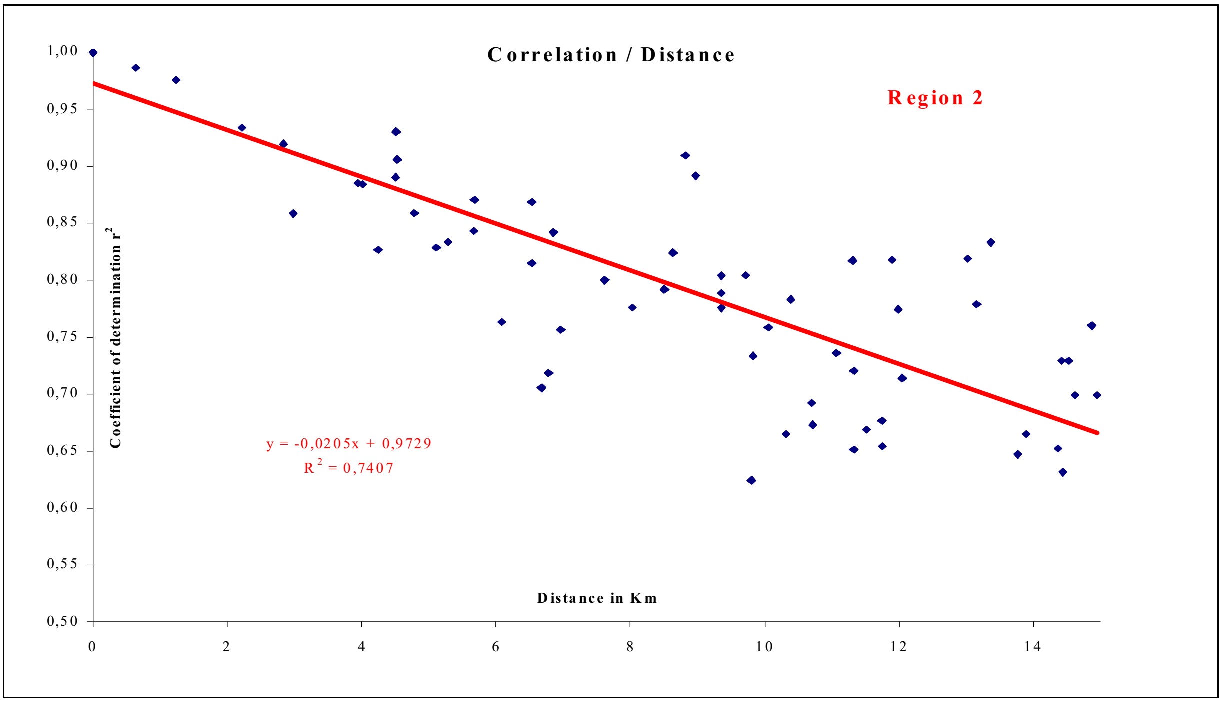

Figure 6: Variations of the coefficient of determination between the annual precipitation time-series of any two stations and the distance between the two stations.

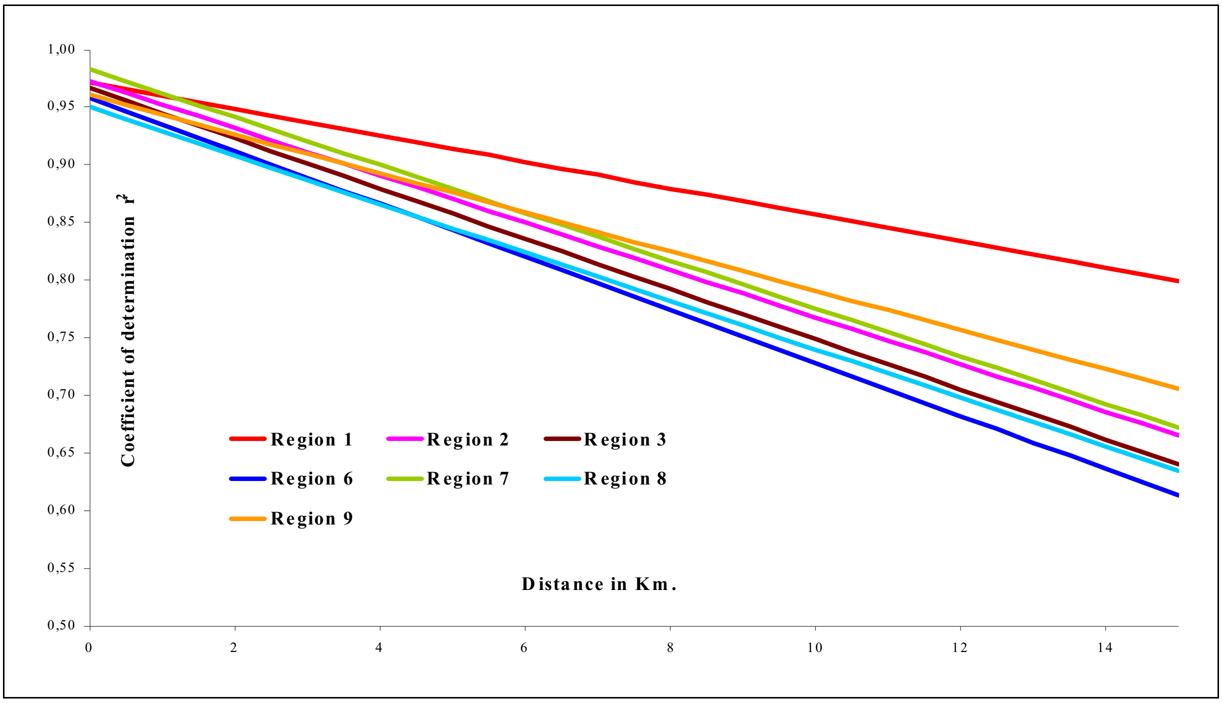

Figure 7: Regression Lines of coefficients of determination against distances between any two precipitation stations within each of the 7 regions.

This relation allows determine for any point of the island the percentage of the variance of the annual precipitation that can be explained with the actual network. A 1x1 km grid covering the whole island was established and for each grid node the distance to the nearest rain-station was determined (Figure 3). Applying the regression equations derived above (Figure 7) to the distance of each grid node to the nearest rain-station the coefficient of determination for each grid node was calculated. This resulted in Figure 8, which provides an illustration of spatial definition of the temporal variability of precipitation by the existing station network.

This map highlights the areas with very good definition of the precipitation temporal variations (red colours) and lower definition (green and blue colours) where stations could eventually be added. In the light of these results and considering values of the coefficient of determination of 0,90 satisfactory, we suggest to think about moving some stations from the western slope of the Troodos Mountain to the low lands shaded in green on the map.

All these imply that the temporal variations of the annual precipitation can be estimated with significant level of confidence at any point of the area under government control.

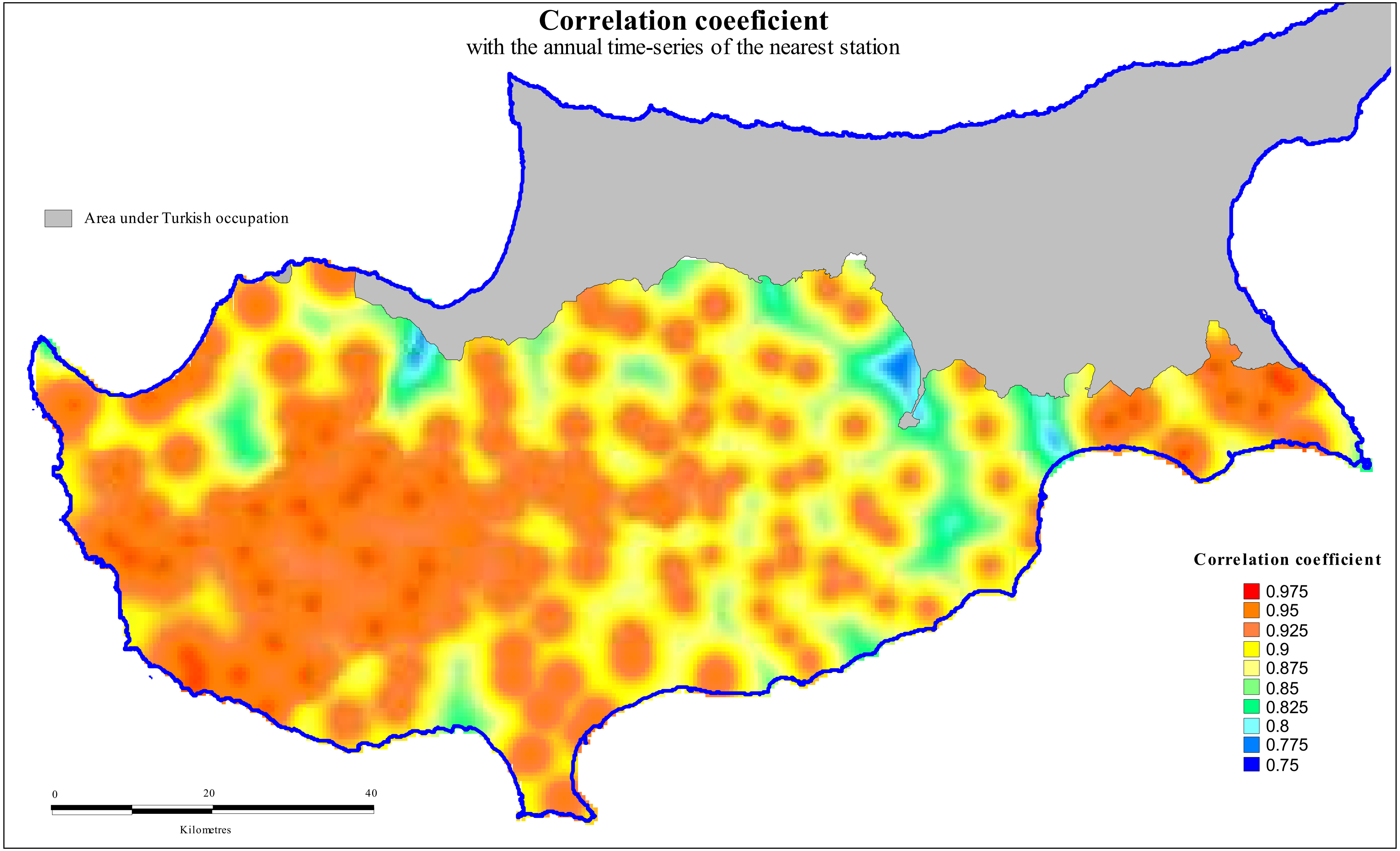

Figure 8: Percentage of the variance of the annual precipitation that can be explained at any point of the island.

1.3 Stream-flow station network

This analysis of the stream-flow station network is similar to the analysis realised for the precipitation station network (section 1.2).

1.3.1 Density of the network

Table 2 gives the numbers and densities of stream-flow stations for the hydrological regions and the entire area under government control. These values meet the minimum densities recommended by the WMO, that is 1 station for 1000 km^2 for the mountainous areas (WMO 1994). The WMO is also recommending that stations should be installed to gauge the runoff in different geologic, topographic and land-use environments. Because runoff varies also greatly with elevation in mountains, the basic network stations must be located in such a way that they can, more or less evenly, serve all parts of a mountainous area, from the foothills to the higher regions. Account should be taken of the varying exposure of slopes which is of great significance in rough terrain. Similarly, consideration should be given to stations in districts containing numerous lakes or dams, whose influence can be determined only through the installation of additional stations upstream and downstream the reservoirs.

Table 2: Average numbers and density of stream flow stations by hydrological regions.

Hydrological region			Stream-flow stations			
Code	Name	Area Km2	1971-2000 #	1971-2000 *Dens*	All stations #	All stations *Dens*
1	Paphos	1174	7	168	10	117
2	Tylliria	718	2	359	10	72
3	Morphou	990	7	141	12	83
6	Mesaoria	552	3	184	4	138
7	South-East Mesaoria	366	2	183	3	122
8	Larnaca	1038	7	148	13	80
9	Limassol	1164	3	388	6	194
Area under government control		6002	31	194	58	103

Note: All stations correspond to all the stations operated in 2000. # corresponds to the number of stations within the region. *Dens* corresponds to the density of stations by region in km^2/station (*Dens* = area of the region / number of stations within the region).

The topographic map on Figure 2 shows that a stream-flow station should be installed on the Pedhieos River at the level of the urban area of Nicosia. A good site for the station may be the Pedhieos Bridge on Griva Digheni. The stream-flow stations are well distributed throughout the Troodos Mountain. They are evenly distributed between higher and lower altitudes, between the larger and smaller watersheds and between the northern and southern slopes of the Troodos Mountain. Rational management of the regulation work at dams requires measurement of the inflow and outflow. Except for some small constructions, all the dams have these records.

The geological map (Figure 9), soil map (Figure 10) and land-use map (Figure 11) show that all the existing stations are necessary to be able to quantify water resources of the different geologic, soil and land-use environments. Each station has a watershed with different characteristics.

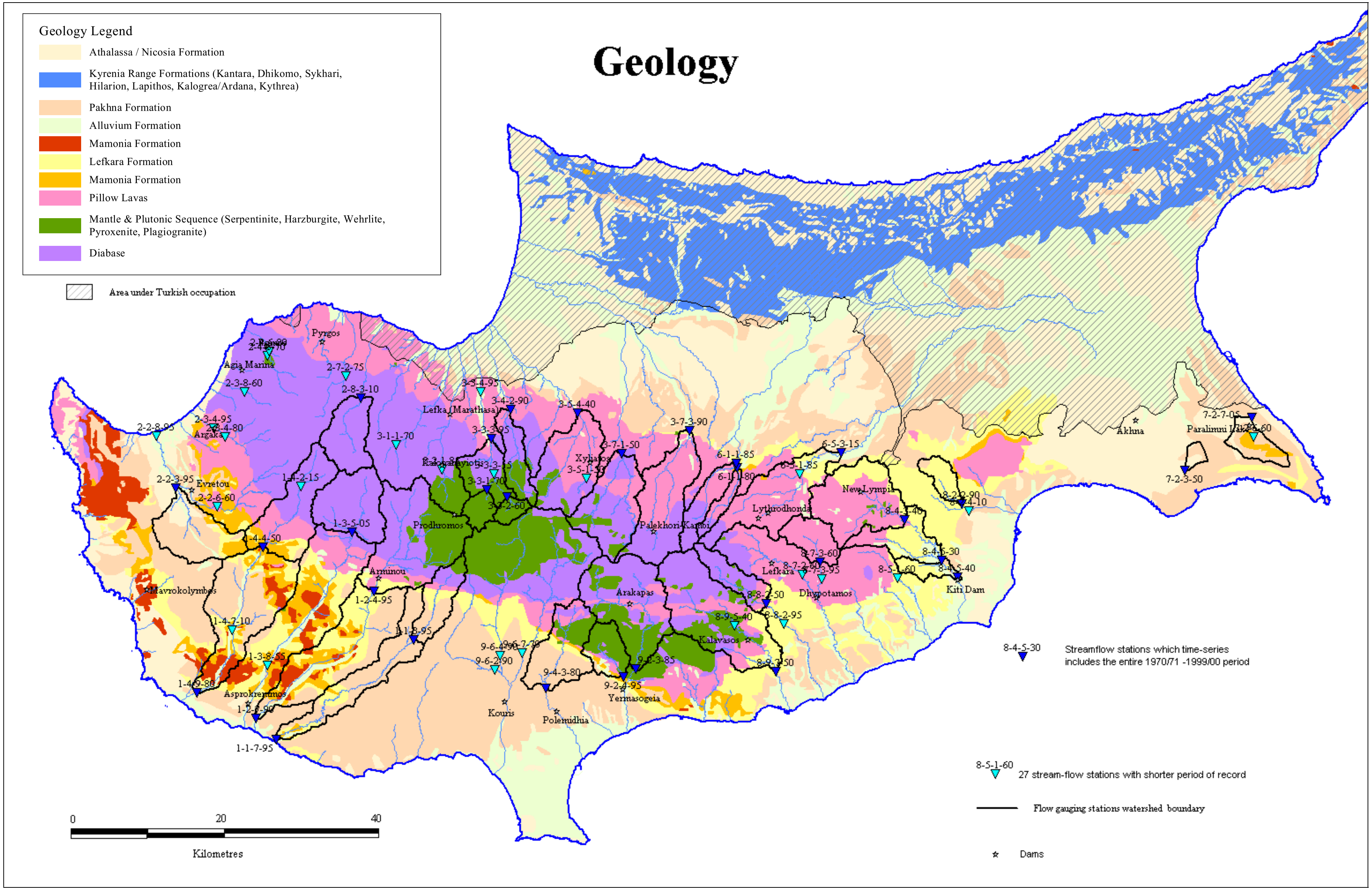

Figure 9: Geological map of Cyprus with boundaries of the main watershed and stream-flow gauging stations.

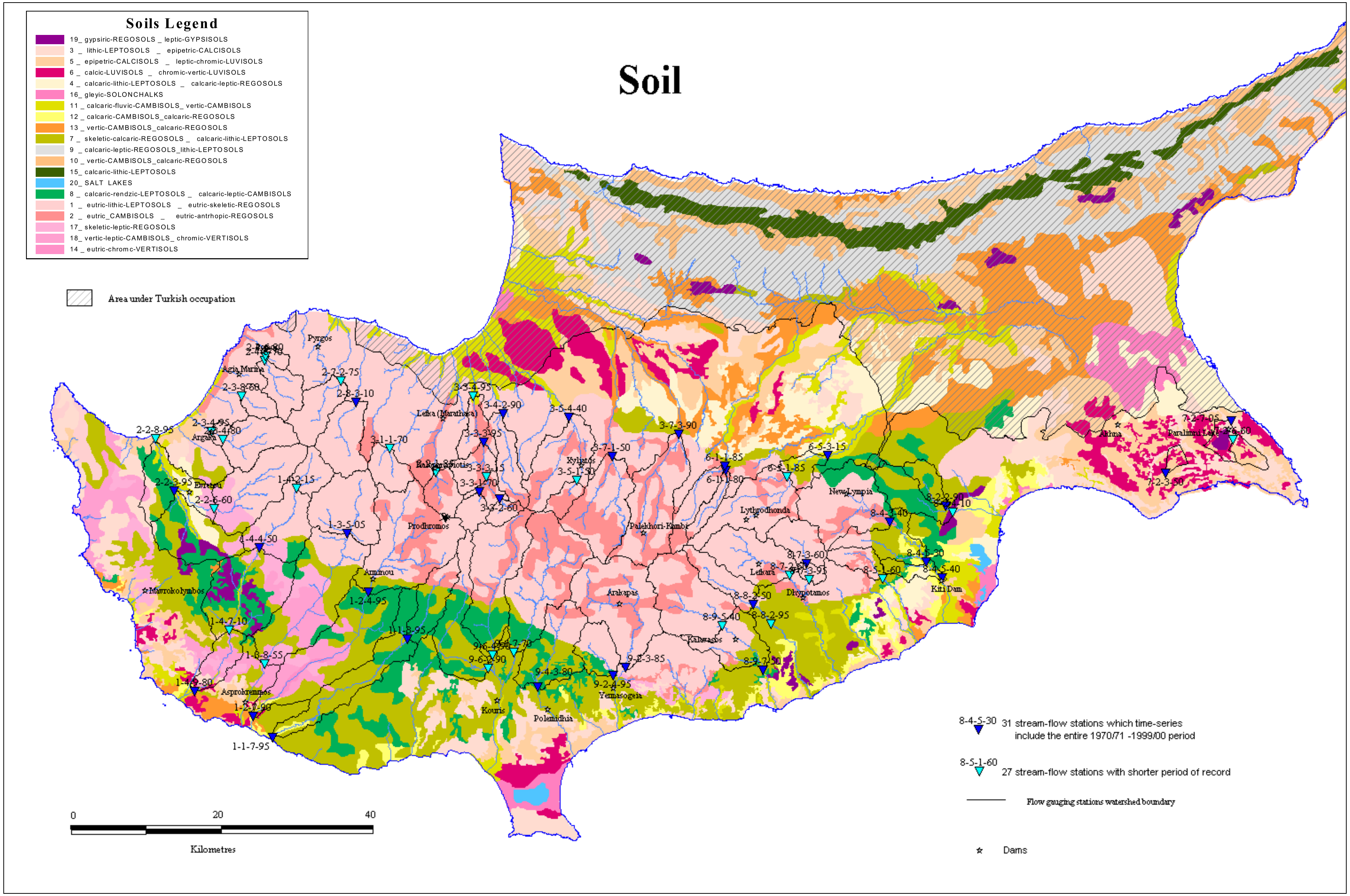

Figure 10:Soil map of Cyprus with boundaries of the main watershed and stream-flow gauging stations.

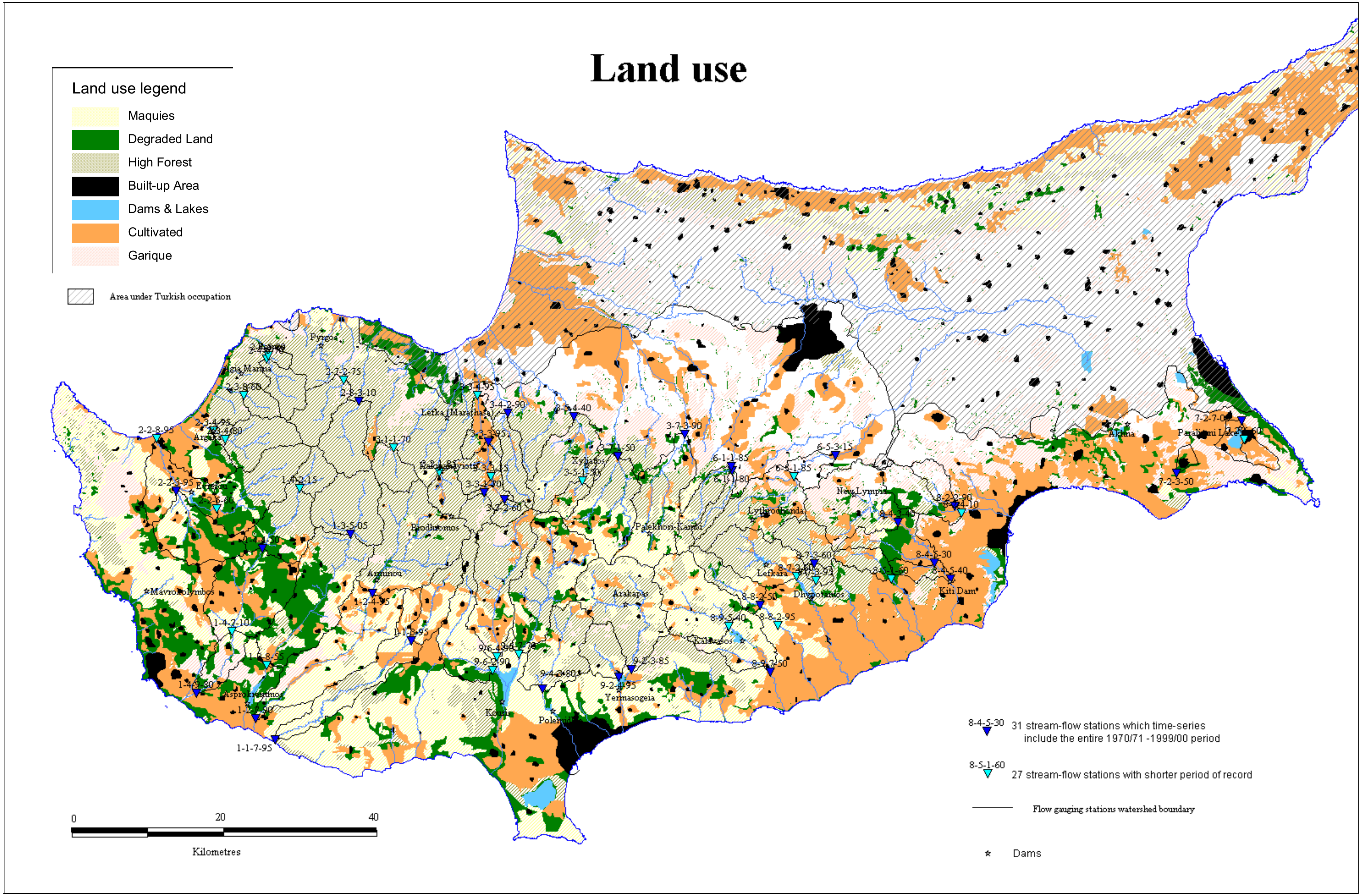

Figure 11: Land-use map of Cyprus with boundaries of the main watershed and stream-flow gauging stations.

1.3.2 Effectiveness of the network for estimation of mean annual flow at any location

The objective of this statistical analysis is to check if a relationship can be found between the mean annual flow at a station and either the elevation of the station or the area of the watershed drained by the station. The identification of such relationships is important for water resources assessment, as it will be useful for estimation of mean annual flow for un-gauged watersheds.

The 31 stations time-series of which cover the entire 1970/71-1999/00 period are too few to allow the identification of these relationships at a statistically acceptable level neither for the hydrological regions nor for the entire island (Figures 12 and 13). This is partly due to the number of dams that have been constructed over the last 30 years which resulted in the modification of the natural flows and the reduction in the number of the useful stations for this specific analysis. It is also due to the relatively low number of these stations in each hydrological region.

However, two observations can be made. These however require additional analysis to confirm their validity. Figure 12 indicates that the mean annual specific flow increases with the elevation of the station. This is certainly due to the higher precipitation and steeper slopes of watersheds in higher areas. Figure 13 shows that the relationship between the mean annual flow at a station and the watershed area is not clear at all. It can be remarked that the mean annual flow does not vary a lot for three pairs of stations located in the same watershed. This indicates that for these three rivers (Khapotami 1-1, Dhiarizos 1-2 and Ezousas 1-4) there is no net gain of flow from the lower part of their waterways. This is certainly due to the higher infiltration rates and lower precipitation in the lower areas. These 3 pairs of stations can be seen in Figure 13 joined by lines.

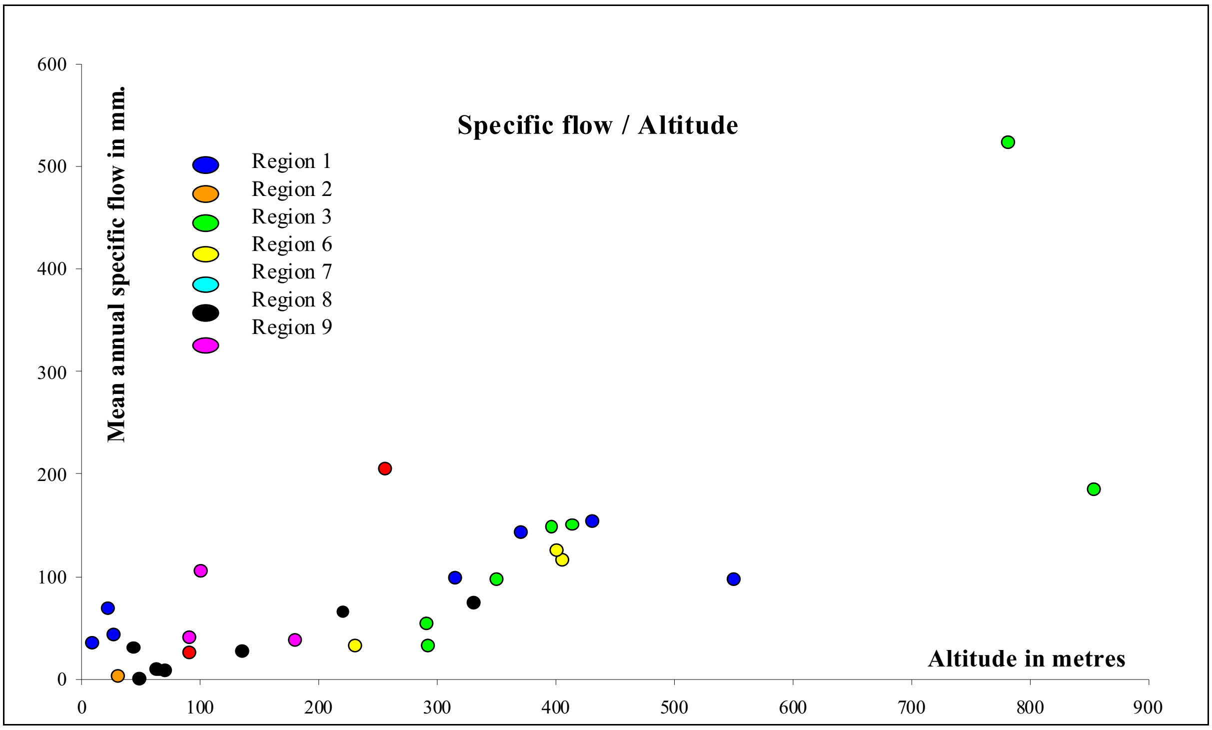

Figure 12: Variations of the mean annual specific flow with the elevation of the station.

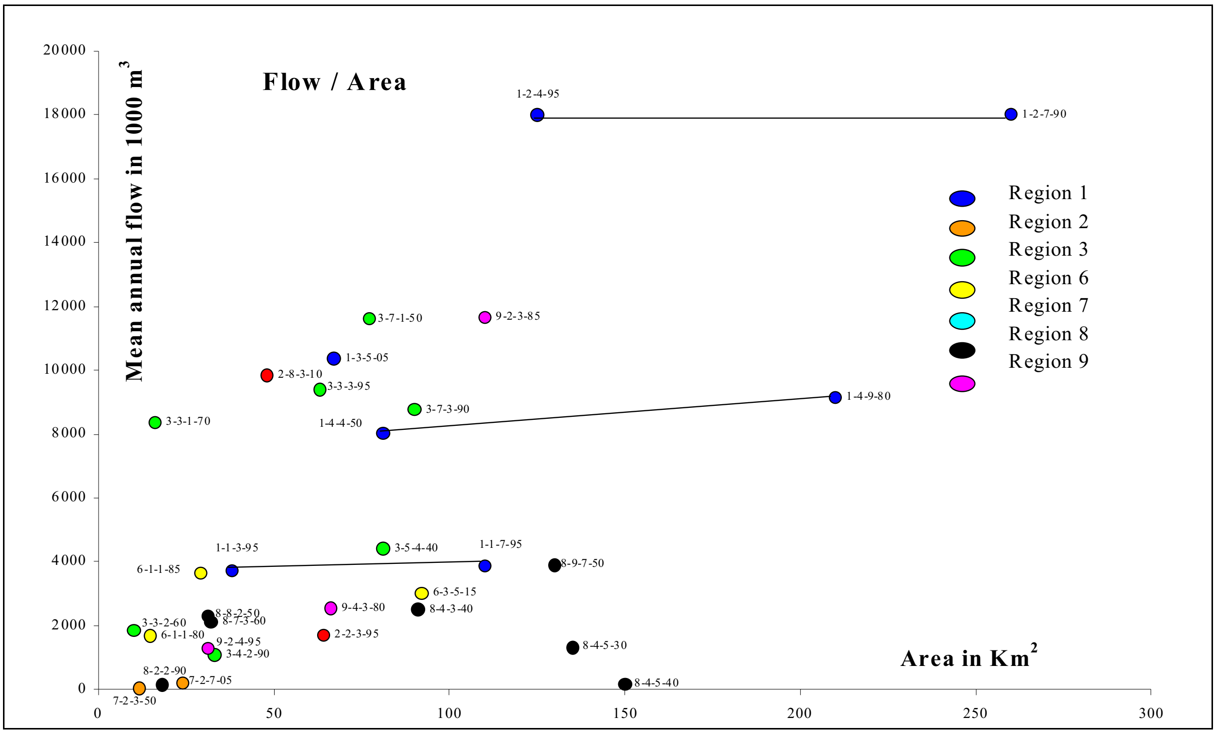

Figure 13: Variations of the mean annual stream-flow with the area of the watershed.

1.3.3 Effectiveness of the network for estimation of annual stream-flow variations at any location

Coefficient of determination between the annual time-series of any and all pairs of the 31 stream-flow stations have been determined (Annex 6). In the light of these values, it can be said that the Coefficient of determination is greater than 0,90 between time-series of stations located in the same watershed and greater than 0,80 for pairs of stations located in adjacent watersheds. This implies that the temporal variations of annual stream-flow can be estimated with significant level of confidence at any section of a river for which river there are measurements anywhere along its length. It can also be estimated for un-gauged rivers but with lower accuracy.

1.4 Conclusions on the effectiveness of the networks and recommendations

Our principal recommendation about the precipitation stations network concern the urban areas for which the network does not even meet the minimum WMO recommendation. Densely populated urban areas need a very dense rain-gauge network for both temporal and spatial resolution of storms, for design, management, and real-time control of the storm-drainage systems and for other engineering applications. There are only two stations in Nicosia, two in Limassol, one in Larnaca and none in Paphos. For urban areas where the time resolution needed for rainfall measurements is of the order of one to two minutes, special attention should be paid to the time synchronisation of the rain-gauges. For reliable measurements, tipping-bucket rain gauges with an electronic memory (or another computer readable medium) are recommended. At least four to six stations of this type should be installed both in Nicosia and in Limassol, three in Larnaca and three in Paphos.

The precipitation stations network is dense enough and well distributed to be able to properly estimate at any point of the area under government control the mean annual precipitation and the temporal variations of the annual precipitation over the 1970/71-1999/00 period. With the objective to have an homogeneous network our recommendation to the Meteorological Service is to add stations in the areas with lower density and if the network maintenance becomes too expensive remove some in the area with very high density.

The Meteorological Service had install recently 16 automatic weather stations and is expecting to install additional 10 in the near future. All of the stations are equipped with the following sensors: Temperature (max & min), Grass Min, Rel Hum., Wind speed & Direction at 10 m height, Wind Run at 2 and 10 m height and Rainfall. Some stations also have sunshine duration or Global radiation sensors. The time step of the measured values is 10 min. For Rainfall the time step is 5 min.

The 16 already installed replace existing manual climatological stations: 021 Kato Pafos, 041 Polis, 203 Mallia, 225 Prodromos, 270 Troodos, 377 Agros, 388 Limassol, 402 Kalo Chorio, 415 Astromeritis, 466 Pharmakas Mennogia, 592 Lefkara, 640 Nicosia, 666 Athalassa, 690 Athienou, 800 Akhna, 893 Paralimni. They are well distributed throughout the island answering partly the recommendations made here with the installation of two stations in Nicosia (640 and 666), one in Limassol (388) and one in Paphos (021).

The descriptive analysis of the stream-flow stations network according to WMO references shows that no station should be removed from the existing network. We recommend the installation of a stream-flow station on the Pedhieos River at the level of Nicosia. The island presents significant topography and various types of geological structure, soil and land use. This leads to a several major types of watershed environment. Each of the existing stations has specific and important relevance to water resources assessment. In addition, the majority of the stations are required for the management of the dams that have been constructed throughout the island.

In addition to this, the WMO recommends that the basic network of observation stations should be adjusted over time until hydrological information can be developed for un-gauged areas. The statistical analysis realised here concludes that the temporal variations of the annual stream-flows can be estimated with significant level of confidence at any section of a river on which there are gauging stations. It can also be estimated for adjacent un-gauged rivers but with lower accuracy. This analysis also concludes that no significant relation can be found between the mean annual flow at a station and either the elevation of the station or the area of the watershed drained by the station. The estimation of mean annual flow for un-gauged watersheds based on either the elevation of the point of interest or the size of the watershed area is then doubtful.

Both, the descriptive and statistical analyses reveal the value of each stream-flow station and the necessity to continue operating all the existing stream-flow stations. Studies on flood propagation, rainfall-runoff modelling, erosion, influence of land-use on runoff, are all relevant for water resource knowledge and planning. These specific studies may require the establishment of additional stations in experimental watersheds.

2 ASSESSMENT OF THE HYDROLOGICAL DATA COLLECTION

This chapter includes a brief description (2.1) and the suggested improvement (2.2) of the hydrological measurement equipment and data processing techniques used by the Division of Water Resources (DWR).

2.1 Brief description of the equipment and data processing techniques used

2.1.1 Equipment

The stream-flow gauging stations are well designed, built and operate. Most of the stations come with a weir that insures a permanent profile of the stream and stability of the control section. Stability of the section warrants the stability of the stage-discharge relationship. Stability of the stage-discharge relationship is a requirement for reliable record of river discharge. In addition, any changes and operations of maintenance realised at each station are properly report on history books. The river stage recorders are graphical recorders that register the water level on paper tape. The current-meters used by the DWR are in general propeller type with a horizontal shaft.

2.1.2 Data processing

The instant flow calculation is realised by hand following appropriated techniques to estimate instant flow through a river section with measured instant velocity at the river section. The rating curves are determined by fitting a regression line through the measured instantaneous flows. The measured instantaneous flows generally cover well the range of variation of the water level records. Extrapolation to the higher levels is therefore possible with good reliability. The changes with time of the rating curves are carefully reported. Each rating curves is adequately associated with dates for the beginning and end of its period of validity.

The calculation of the average daily flow with the use of the rating curves and records on the graph of instant water levels is realised by hand following appropriate techniques to estimate average daily flow manually using regular calculators. According to Christos Ioannou, formerly Hydrologist with the Division of Water Resources in charge of the data processing, an average of three weeks are required for the processing of one year of information of a single station.

Mean daily and daily maximum instantaneous flows are inputted on computers and are available in electronic format for all the stations.

2.2 Suggested improvement of the equipment and data processing techniques

2.2.1 Equipment

The stations are well designed and maintained in good operational condition and do not require major improvements. Most of the recorders and current-meters are 20 years old or more. High attention has then to be given to the frequency of the calibration of the current-meters and clock of the water level recorders.

Since the seventies and the construction of most of the weirs and the installation of the first graphical recorders of the river water level, technology has improved. Today equipment offer more accurate information and help accelerate the transfer of the information into a database.

As seen before, one of the most time consuming steps from flow-velocity measurement in the field to monthly mean flow available on computer is the process of the graph recording the water level. Digital recorders may be used instead of graphical recorders, and data can then be processed automatically. It is then recommended to progressively install digital recorders in place of the graphical recorders. We counsel to keep both equipment running together during several years. This period of double record will be use to determine if correction has to be made to assure constancy in the records.

The scarcity of water resource in Cyprus leads to the implementation of water supply projects involving construction of a series of dams and water abstraction from the main streams of the island. Operational hydrology is required for optimal management of these projects. It is therefore recommended to provide some of the new digital water level recorders with real time transfer of the information to the decision makers. Manufacturers offer several modes of data transfer such as phone, radio and satellite.

2.2.2 Data processing

Computers have taken an increasingly important role in all aspects of data collection and processing. With current technology, the primary data-processing function can be successfully performed on a computer in the DWR. The joint WMO/FAO Guidelines for Computerised Data Processing in Operational Hydrology and Land and Water Management (WMO/FAO, 1985) describe the concepts, terminology, and application of computerised data processing. In the Hydrological Operational Multipurpose System Reference Manual (WMO, 1988), there are a number of components that describe computer-based data-collection, processing, and storage systems.

Hydro-meteorological data acquisition and management software of today are very well designed and documented. They are capable of converting current meter measurements to instantaneous flows, determine rating curves and store them together with their periods of validity, import water levels from digital and graph recorders, compute instantaneous flows and export the information to a database.

The water level may be transferred from the graphs to digital form by means of electronic devices. Some of these are operated manually to produce x and y coordinates of the water level record on paper tapes. According to Marc Morell, from the MED-HYCOS Pilot Regional Centre, an average of one day is required for the process of one year of information at one station. This duration has to be compared to the three weeks actually spent by the Division of Water Resources employees.

Important improvement on the data quality that will come with the input to computer of the information is the possibility of computer quality check of the data. The advantages of computer validation techniques are that they are objective and uniform. Data from all sources are subjected to the same scrutiny. The computer also allows the use of complex checking algorithms impossible to implement by manual techniques. These algorithms may be complex in terms of the mathematical content or in the amount and type of control data that are used. A further advantage is the elimination of tedious manual checking of data. The computer permits the specialist to devise sets of validation rules that will report only those data considered in need of closer inspection. Meanwhile, data-validation techniques can never be made fully automatic. While some variables have strictly limited ranges of validity that the computer can check, most time-series variables have asymptotic probability distributions that only allow the computer to recognise a value as being suspect. The most extreme values may prove to be correct and, if so, are vitally important for all hydrological-data applications. For such variables, therefore, the computer should only be used to accept or to query data, but not to reject it. The computer must refer the suspect values to analysis by experienced human judgement.

2.3 Conclusions on the data collection and recommendations

The data that are generated by the field activities are of little or no value if they cannot be readily and confidently accessed by the potential data users. Numerous hydrological analyses relevant in Cyprus such as dam management, rainfall-runoff modelling, flood propagation, and erosion control require time-series of instantaneous flow. This information should therefore be available on computer and for some watersheds in real time.

The stream-flow stations are well designed and the instruments used are kept in good working condition. The data collection and processing techniques used at the Division of Water Resources are at the state of the art of the seventies. The evolution of instrument technology and computer facilities imply improvement in the measuring instruments as well as in the data processing and storage.

For the measuring instruments, the main recommendation is to progressively replace graphical water level recorders with digital recorders. Some of the digital recorders should be provided with real time transfer of information. These will allow better management of the water supply projects implemented in Cyprus.

For data processing, it is greatly recommended to process electronically the water level graphs. To this end hydrological data acquisition electronic equipment and software have to be acquired. The Division of Water Resources should be staffed with personnel trained in computer use. The costly and time-consuming employee training or recruitment can be a sound investment that results in greater productivity and effectiveness. A carefully structured training program is essential for all personnel engaged in data collection because they are in a strong position to influence the quality of the final data.

The acquisition of equipment for digital processing of the water level graph will save a lot of time in the processing of the data. In addition, thanks to the digitalisation of the water level graph and the use of digital recorder, the information offered in electronic format will be easier and faster to access. This information will also be accessible at the short time-scale required for operational hydrology. All these efforts will give the hydrological data its real value, as the data will be effortlessly available for research and operational hydrology.

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ANNEXES

Annex 1: Rainfall stations characteristics

Station #	Region	1917-00	1971-00	Records	Comments
3	1	-	-	77-94	
4	1 - 2	-	Yes	71-	Oct. 70 to Sep. 71 taken from station #10 (10 km)
5	1	-	Yes	64-	
10	1 - 2	Yes	Yes	10-	
20	1	-	-	70-84	
32	1 - 2	-	-	77-	
38	1	-	Yes		
40	2	Yes	Yes		
41	2	-	Yes		
50	1	Yes	Yes		
51	2	-	-	80-87	
52	2	-	-	70-90	
60	1	Yes	Yes		
63	2	-	-	86-	
65	2	-	-	70-81	
70	2	-	Yes		
80	1	Yes	Yes		
81	1	-	Yes		
82	1	-	-	83-	
85	2	-	Yes	72-	Oct. 70 to Nov. 72 taken from station # 90 (4 km)
90	2	Yes	Yes		
92	1	-	-	72-90	
93	2	-	Yes		
94	1	-	-	79-	
95	1	-	-	77-	
101	1	-	Yes	72-	Oct. 70 to Sep. 72 taken from station # 140 (6 km)
105	1	-	Yes		
106	2	-	Yes		
108	2	-	-	80-	
110	1	Yes	Yes		
111	1	-	-	79-	
116	1	-	Yes		
120	1	Yes	Yes		
130	2	Yes	Yes		
135	1	-	-	79-	
140	1	Yes	Yes		
141	1	-	Yes		
147	2	-	-	80-90	
150	9	-	-	70-81	
151	1	-	Yes		
159	1	-	-	79-90	
160	2	Yes	Yes		
161	2	-	Yes		Sep. 94 to Sep. 2000 taken from station # 160 (1 km)
163	1	-	-	79-94	
164	2	-	Yes	73-	Oct. 70 to Dec. 72 taken from station # 151 (2 km)
168	2	-	Yes		

Station #	Region	1917-00	1971-00	Records	Comments
170	9	Yes	Yes		
171	1	-	Yes		
174	1	-	-	79-	
175	1	-	Yes		
178	2	-	Yes		
179	1	-	Yes		
180	1 - 3	Yes	Yes		
190	9	Yes	Yes		
200	1	-	-	70-81	
203	1	-	Yes		
204	1	-	Yes		
205	1 - 9	-	Yes		
206	9	-	-	80-	
207	1	-	Yes		
208	9	-	-	81-92	
211	3	-	Yes		
220	3	Yes	Yes		
225	1 - 3	-	Yes		
230	1	-	-	17-90	
232	9	-	Yes		
250	1 - 9	Yes	Yes		
260	9	Yes	Yes		
270	9	-	Yes		
288	3	-	Yes		
289	3	-	-	81-	
290	3	Yes	Yes		
291	3	-	Yes		
295	9	-	Yes		Oct. 70 to Dec. 70 taken from station # 321 (1 km)
300	9	Yes	Yes		
310	3	Yes	Yes		
311	9	-	Yes		
313	9	-	-	85-	
320	9	Yes	Yes		
321	9	-	Yes		
325	9	-	Yes		Oct. 70 to Sep. 71 taken from station # 331 (2 km)
330	9	Yes	Yes		
331	9	-	-	70-90	
332	9	-	Yes		
333	9	-	Yes		Oct. 70 to Jan. 71 taken from station # 330 (6 km)
336	3	-	Yes		
337	9	-	Yes		
338	9	-	Yes		
347	9	-	Yes		Oct. 70 to Jan. 71 taken from station # 311 (5 km)
370	3	Yes	Yes		
372	3	-	Yes		
373	3	-	-	83-	
376	9	-	-	70-85	
377	9	-	-	76-	

Station #	Region	1917-00	1971-00	Records	Comments
388	9	-	-	75-	
390	9	Yes	Yes		
400	9	Yes	Yes		
401	3	-	Yes		
405	3	-	-	73-80	
410	9	-	Yes		
415	3	-	Yes		
420	3	-	Yes		
428	9	-	Yes		
429	9	-	Yes		
430	3	Yes	Yes		
440	3	Yes	Yes		
451	3	Yes	Yes		
458	9	-	-	70-89	
460	3	Yes	Yes		
461	3	-	Yes		Oct. 70 to Sep. 71 taken from station # 462 (3 km)
462	3	-	Yes		
463	3	-	-	79-84	
464	3	-	Yes		
465	9	-	-	85-93	
466	3	-	-	79-	
467	3	-	Yes		
469	8 - 9	-	-	89-	
471	8	-	-	83-89	
477	8 - 9	-	Yes		
490	3	Yes	Yes		
493	3	-	Yes		Oct. 70 to Jun. 73 taken from station # 464 (6 km)
500	6	Yes	Yes		
510	6 - 8	Yes	Yes		
520	3	Yes	Yes		
530	8	-	Yes		
540	9	Yes	Yes		
550	6	Yes	Yes		
565	6	-	Yes		Oct. 70 to Oct. 72 taken from station # 490 (6 km)
569	6	-	-	70-71	
572	8	-	Yes		
579	6	-	-	80-90	
580	6	Yes	Yes		
583	6	-	-	76-	
592	8	-	Yes		Oct. 70 to Dec. 71 taken from station # 600 (3 km)
595	8	-	Yes		
596	8	-	-	81-	
597	6	-	Yes		Oct. 70 to Dec. 73 taken from station # 632 (7 km)
598	8	-	Yes		
599	6	Yes	Yes		
600	8	Yes	Yes		
628	8	-	Yes		

Station #	Region	1917-00	1971-00	Records	Comments
630	8	-	-	83-	
632	6	-	Yes		
633	8	-	-	83-	
640	6	Yes	Yes		
648	8	Yes	Yes		
650	6	Yes	Yes		
652	8	-	Yes		
660	8	Yes	Yes		
666	6	-	Yes		Oct. 70 to Dec. 82 taken from station # 670 (1 km)
670	6	-	-	70-85	
674	8	-	Yes		
675	8	-	Yes		
676	8	-	Yes		
678	8	-	Yes		
679	8	-	-	83-	
685	8	-	-	70-81	
690	6	Yes	Yes		
710	8	-	Yes		
713	8	-	Yes		
715	8	-	-	70-90	
718	8	-	Yes		
730	8	-	Yes		
731	8	-	-	76-	
779	7	-	Yes		
800	7	Yes	Yes		
810	7	-	Yes		
825	7	-	-	78-	
845	7	-	Yes		
888	7	-	-	75-	
889	7	-	-	82-	
890	7	-	Yes		
893	7	-	-	76-90	
895	7	-	Yes		

Annex 2: Main stream-flow stations characteristics

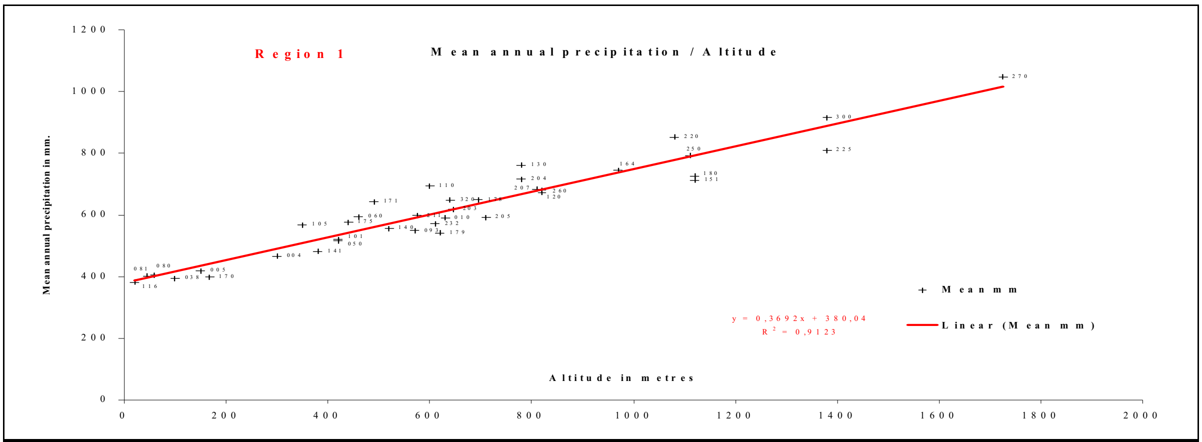
Station #	Stream	Location	Record	Comments
1-1-3-95	KHAPOTAMI	KISSOUSA	1964 TO DATE	
1-1-7-95	KHAPOTAMI	KOUKLIA	1962 TO DATE	Oct. 99 to Sep. 00 missing
1-2-4-95	DHIARIZOS	PHILOUSA	1965 TO DATE	
1-2-7-90	DHIARIZOS	KOUKLIA	1956 TO DATE	
1-3-5-05	XEROS	LAZARIDHES	1970 TO DATE	
1-3-8-55	XEROS	NATA		
1-4-2-15	AYIA	AYIA FOREST STATION	1979 TO DATE	
1-4-4-50	EZUSAS	KANNAVIOU	1964 TO DATE	
1-4-7-10	EZOUSAS	MORONERO	1981 TO DATE	
1-4-9-80	EZUSAS	AKHELIA	1962 TO DATE	
2-2-3-95	KHRYSOKHOU	SKOULLI	1956 TO DATE	
2-2-6-60	STAVROS TIS PSOKAS	SKARPHOS	1984 TO DATE	
2-2-8-95	KHRYSOKHOU	COAST	1979-TO DATE	
2-3-4-80	MAGOUNDA	U/S ARGAKA DAM	1980-TO DATE	
2-3-4-95	MAGOUNDA	ARGAKA DAM	1980-TODATE	
2-3-8-60	YIALIA	PANO YIALIA	1980 TO DATE	
2-4-6-70	LIVADHI	U/S POMOS DAM	1979 TO DATE	
2-4-6-80	MAVROKREMMOS	U/S POMOS DAM	1979-TO DATE	
2-7-2-75	PYRGOS	PHLEVAS	1955-64,1966-72,1978 TO DATE	
2-8-3-10	LIMNITIS	LIMNITIS SAW MILL	1967-1972, 1974 TO DATE	Oct. 72 to Sep. 74 missing
3-1-1-70	XEROS	KAMBOS	1990 TO DATE	
3-2-1-85	MARATHASA	U/S KALOPANAYIOTIS DAM	1967-72, 1979 TO DATE	
3-3-1-70	AYIOS NIKOLAOS	KAKOPETRIA	1965-1972, 1974 TO DATE	
3-3-2-60	PLATANIA	KAKOPETRIA	1965-1972,1974 TO DATE	
3-3-3-15	KARYOTIS	GALATA	1987 TO DATE	
3-3-3-95	KARYOTIS	EVRYKHOU	1963-1972, 1974 TO DATE	
3-3-4-95	KARYOTIS	SKOURIOTISSA	1987 TO DATE	
3-4-2-90	ATSAS	EVRYKHOU	1963-1972, 1974 TO DATE	Oct. 72 to Sep. 74 missing
3-5-1-50	LAGOUDHERA	LAGOUDHERA BRIDGE	1978 TO DATE	
3-5-4-40	ELEA	VIZAKIA	1964-1972, 1974 TO DATE	
3-7-1-50	PERISTERONA	PANAYIA BRIDGE	1955-1972, 1974 TO DATE	
3-7-3-90	AKAKI	MALOUNDA	1956-1972, 1974 TO DATE	
6-1-1-80	AYIOS ONOUFRIOS	KAMBIA	1967-1972, 1974 TO DATE	Oct. 72 to Sep. 74 missing
6-1-1-85	PEDHIEOS	KAMBIA	1967-72, 1974 TO DATE	Oct. 72 to Sep. 74 missing

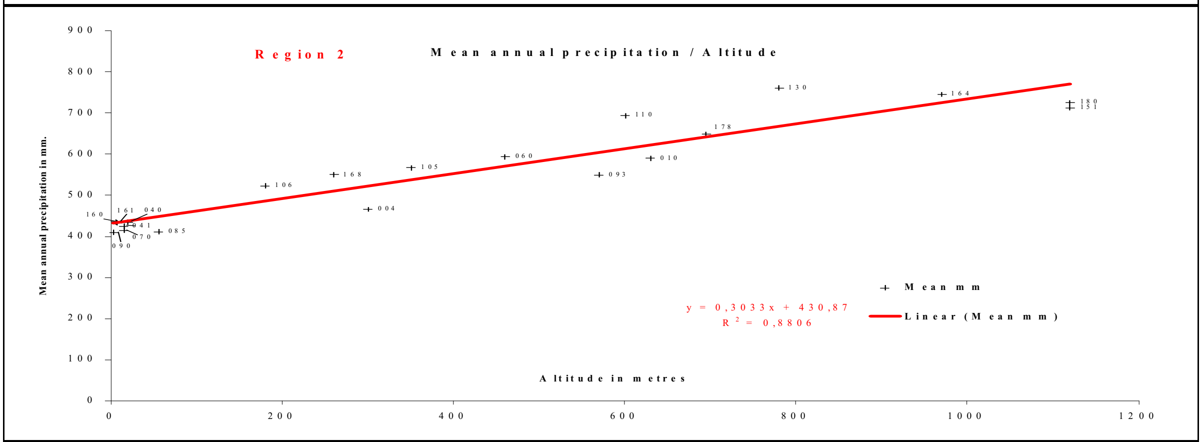
Station #	Stream	Location	Record	Comments
6-5-1-85	YIALIAS	KOTCHATI	1956-1963,1976 TO DATE	
6-5-3-15	YIALIAS	NISOU	1967-72,1974 TO DATE	Oct. 72 to Sep. 74 missing
7-2-3-50	LIOPETRI	LIOPETRI	1956-72,1976 TO DATE	Oct. 72 to Sep. 76 missing
7-2-6-60	VATHYS	PARALIMNI	1979 TO DATE	
7-2-7-05	PARALIMNI LAKE	OUTFLOW	1954-64,67-71,78 TO DATE	Oct. 72 to Sep. 78 missing
8-2-2-90	ARADHIPPOU	PANAYIA YEMATOUSA	1965-72,1974-TO DATE	Oct. 72 to Sep. 74 missing
8-2-4-10	ARADIPPOU	ARADIPPOU	1984 TO DATE	
8-4-3-40	TREMITHIOS	AYIA ANNA	1957-72,1974 TO DATE	Lympia dam built upstream in 1977
8-4-5-30	TREMITHIOS	KLAVDHIA	1970-72,1974 TO DATE	Inflow Kiti dam
8-4-5-40	TREMITHIOS	KITI DAM	1965 TO DATE	Outflow Kiti dam
8-5-1-60	POUZIS	ALETHRIKO	1984 TO DATE	
8-7-2-60	SYRKATIS	PANO LEFKARA	1980 TO DATE	
8-7-3-60	MYLOU	KORNOS	1964-72,1974 TO DATE	Inflow Dhypotamos dam, Oct 94 to Sep. 2000 missing
8-7-3-95	MYLOU	U/S DHYPOTAMOS DAM	1990 TO DATE	
8-8-2-50	MARONI	VAVLA	1968-72,1974 TO DATE	Oct 94 to Sep. 2000 missing
8-8-2-95	MARONI	U/S KHIROKITIA DIVERSION		
8-9-5-40	VASILIKOS	LAYIA	1984-TO DATE	
8-9-7-50	VASILIKOS	KALAVASOS	1963 TO DATE	Kalavasos dam built upstream in 1985, 10/ 94 to 09/00 missing
9-2-3-85	YERMASOYIA	PHINIKARIA	1968 TO DATE	Inflow Yernasogeia dam
9-2-4-95	YIALIADHES	U/S YERMASOYIA DAM	1970-1976,1983 TO DATE	
9-4-3-80	GARYLLIS	U/S POLEMIDHIA DAM	1970 TO DATE	
9-6-2-90	KRYOS	KHALASSA	1977-TO DATE	
9-6-4-90	KOURIS	U/S KOURIS DAM	1985-TO DATE	
9-6-7-70	LIMNATIS	U/S KOURIS DAM	1985 TO DATE	

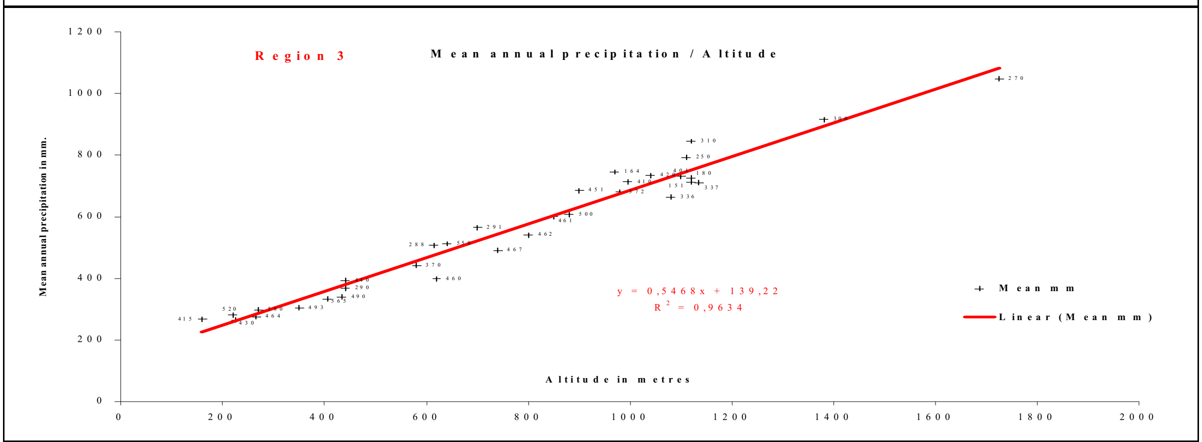
Annex 3: Stream-flow stations: annual and monthly means

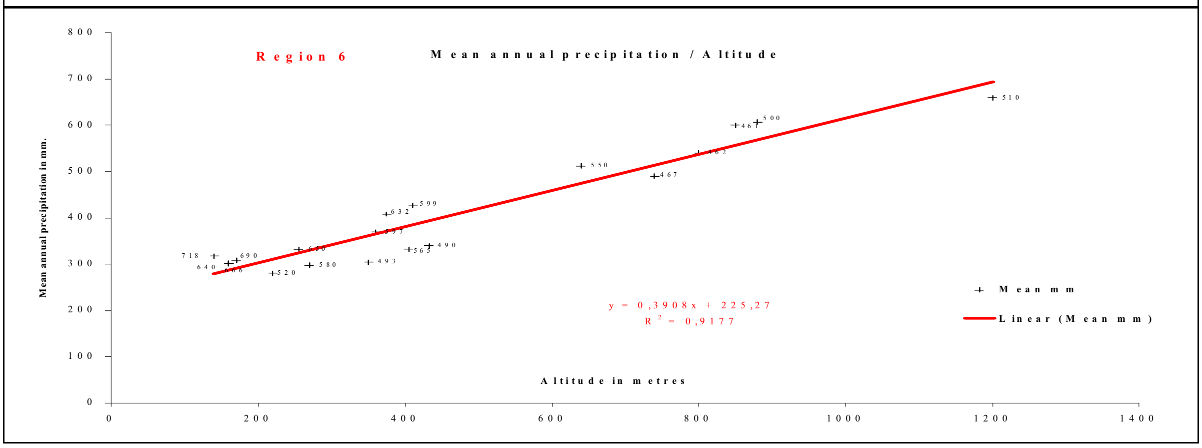
			Area	Annual flow in 1.000 m^3				Monthly mean in % of annual mean											
Station #	Stream	Location	Km^2	Median	Mean	St. Dev.	CV	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1-1-3-95	KHAPOTAMI	KISSOUSA	38	2.525	3.731	3.198	0,86	0	1	6	19	26	27	13	6	2	0	0	0
1-1-7-95	KHAPOTAMI	KOUKLIA	110	1.849	3.885	4.569	1,18	0	1	5	21	30	30	10	3	0	0	0	0
1-2-4-95	DHIARIZOS	PHILOUSA	125	17.263	18.001	12.108	0,67	1	4	10	19	21	23	12	6	2	1	1	0
1-2-7-90	DHIARIZOS	KOUKLIA	260	14.194	18.019	17.146	0,95	0	1	8	22	26	27	11	4	0	0	0	0
1-3-5-05	XEROS	LAZARIDHES	67	9.364	10.376	6.185	0,60	1	2	10	20	22	23	10	5	3	2	1	1
1-4-4-50	EZUSAS	KANNAVIOU	81	7.186	8.039	5.882	0,73	0	1	7	21	25	27	11	5	2	1	0	0
1-4-9-80	EZUSAS	AKHELIA	210	5.089	9.176	10.084	1,10	0	1	7	24	30	27	8	2	0	0	0	0
2-2-3-95	KHRYSOKHOU	SKOULLI	64	1.336	1.711	1.451	0,85	1	4	10	23	23	22	9	5	2	0	0	0
2-8-3-10	LIMNITIS	LIMNITIS SAW MILL	48	8.473	9.855	5.989	0,61	1	2	9	21	23	24	11	5	2	1	1	1
3-3-1-70	AYIOS NIKOLAOS	KAKOPETRIA	16	8.905	8.381	2.995	0,36	4	5	8	11	12	15	14	10	7	5	5	4
3-3-2-60	PLATANIA	KAKOPETRIA	10	1.843	1.849	993	0,54	2	4	8	13	16	20	14	10	5	3	2	2
3-3-3-95	KARYOTIS	EVRYKHOU	63	8.925	9.401	4.577	0,49	2	4	10	17	18	21	14	7	3	2	1	1
3-4-2-90	ATSAS	EVRYKHOU	33	601	1.092	1.250	1,15	0	3	8	21	27	25	9	5	2	1	0	0
3-5-4-40	ELEA	VIZAKIA	81	4.338	4.424	3.737	0,84	0	4	10	24	26	23	8	3	1	0	0	0
3-7-1-50	PERISTERONA	PANAYIA BRIDGE	77	11.189	11.627	6.337	0,55	0	4	12	23	24	22	9	4	1	0	0	0
3-7-3-90	AKAKI	MALOUNDA	90	8.506	8.775	5.785	0,66	0	4	12	23	27	22	8	3	1	0	0	0
6-1-1-80	AYIOS ONOUFRIOS	KAMBIA	15	1.588	1.695	1.046	0,62	0	4	14	23	27	21	6	3	1	0	0	0
6-1-1-85	PEDHIEOS	KAMBIA	29	3.432	3.664	2.278	0,62	0	4	14	23	28	20	7	3	1	0	0	0
6-5-3-15	YIALIAS	NISOU	92	1.510	3.015	3.299	1,09	0	6	12	21	31	21	6	2	1	0	0	0
7-2-3-50	LIOPETRI	LIOPETRI	12	3	42	109	2,59	0	22	40	11	25	1	0	2	0	0	0	0
7-2-7-05	PARALIMNI LAKE	OUTFLOW	24	13	200	463	2,32	0	2	9	17	23	24	11	9	4	0	0	0
8-2-2-90	ARADHIPPOU	PANAYIA YEMATOUSA	18	110	153	191	1,25	7	14	20	14	11	6	3	3	20	2	0	0
8-4-3-40	TREMITHIOS	AYIA ANNA	91	1.253	2.507	3.019	1,20	1	5	11	20	25	23	9	3	4	0	0	0
8-4-5-30	TREMITHIOS	KLAVDHIA	135	182	1.320	1.976	1,50	2	8	10	19	25	22	6	2	6	0	0	0
8-4-5-40	TREMITHIOS	KITI DAM	150	0	169	583	3,44	0	11	3	9	28	29	8	0	14	0	0	0
8-7-3-60	MYLOU	KORNOS	32	1.756	2.120	1.878	0,89	2	2	12	20	25	25	9	4	1	0	0	0
8-8-2-50	MARONI	VAVLA	31	1.671	2.309	1.687	0,73	0	0	10	18	28	26	10	5	1	0	0	0
8-9-7-50	VASILIKOS	KALAVASOS	130	2.217	3.907	4.820	1,23	0	1	6	18	34	24	11	4	1	0	0	0
9-2-3-85	YERMASOYIA	PHINIKARIA	110	9.009	11.672	7.686	0,66	0	4	11	20	24	22	11	6	2	0	0	0
9-2-4-95	YIALIADHES	U/S YERMASOYIA DAM	31	1.002	1.293	1.008	0,78	1	5	13	20	19	20	10	5	2	2	1	1
9-4-3-80	GARYLLIS	U/S POLEMIDHIA DAM	66	1.723	2.560	2.004	0,78	1	4	8	20	25	24	10	4	2	1	0	0

Annex 4: Variations of the mean annual precipitation with the elevation of the station within each hydrological region.

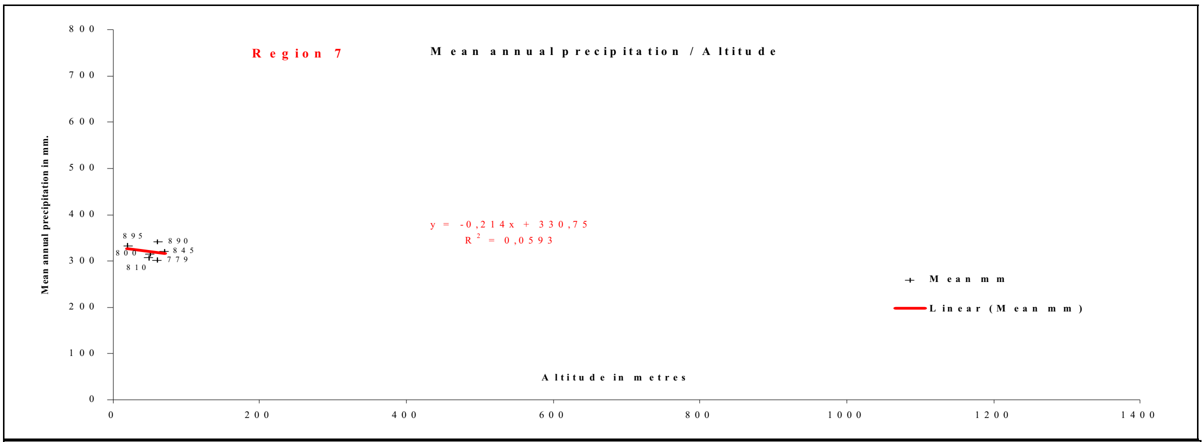


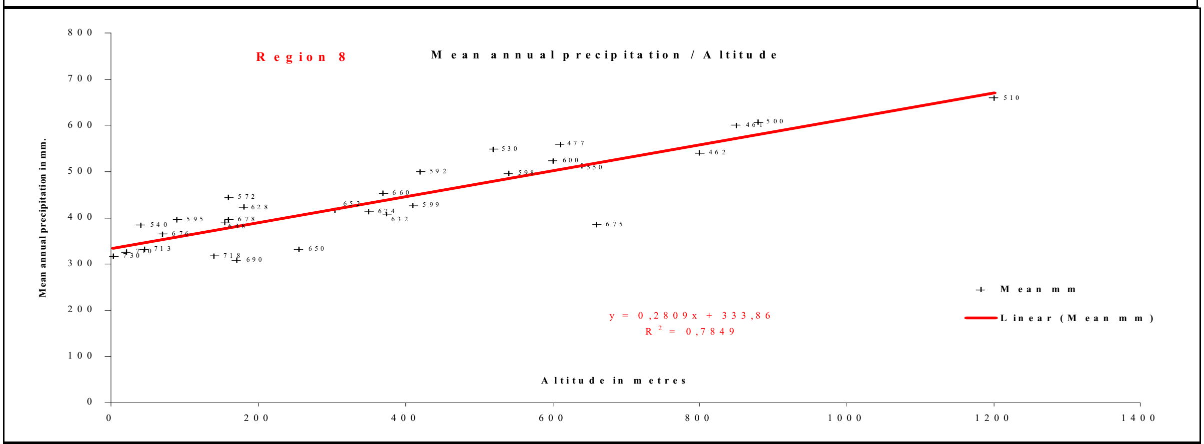


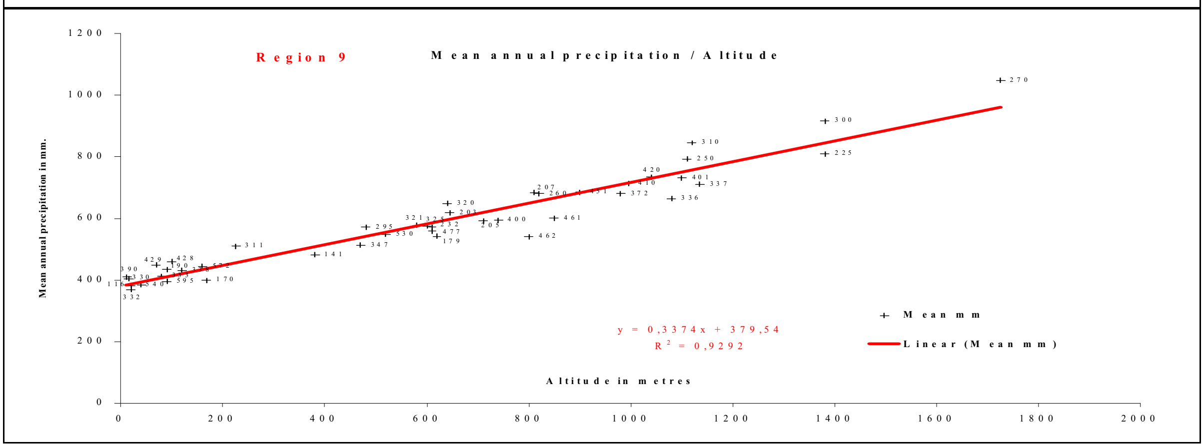




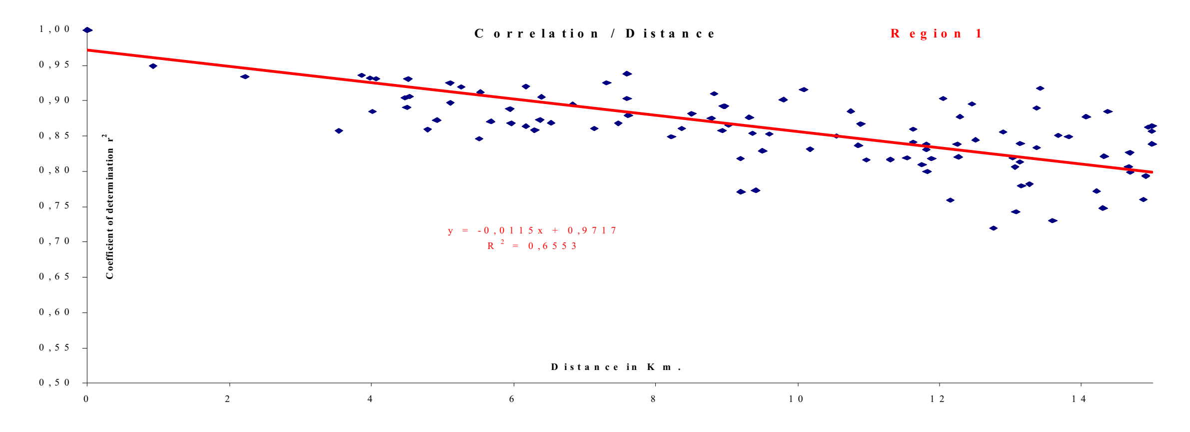
Annex 4 Continued

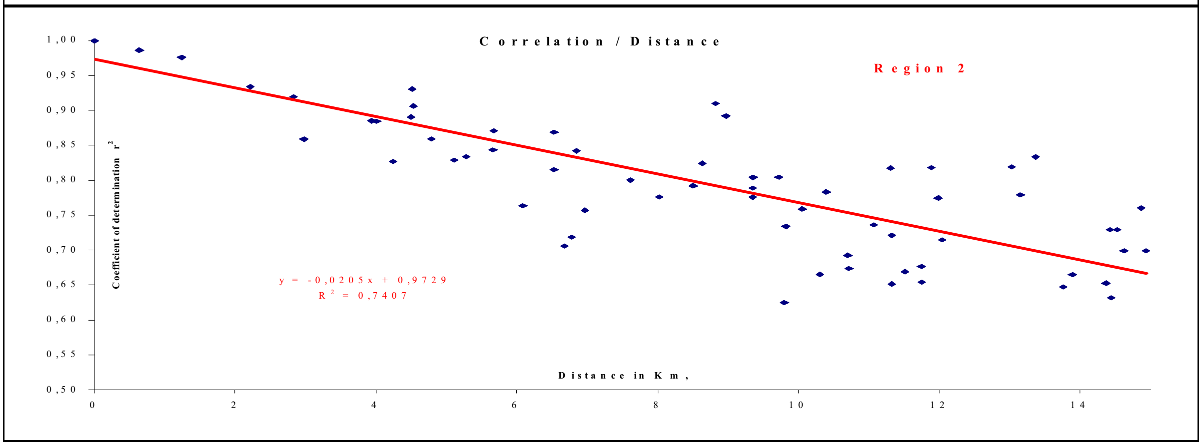


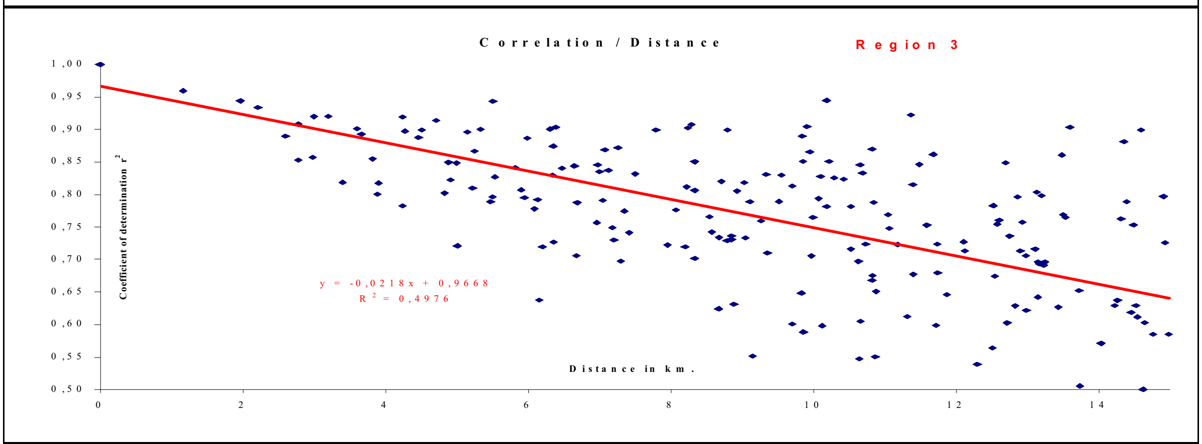


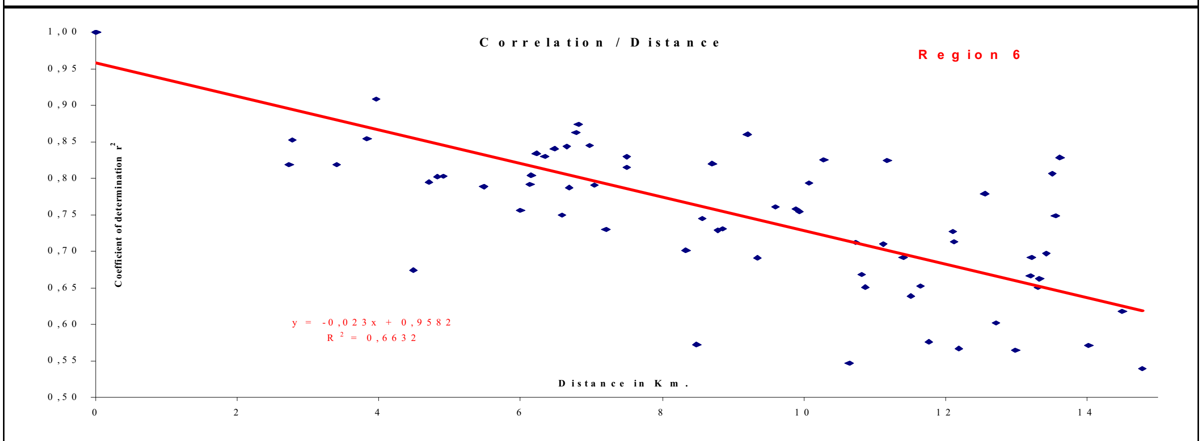


Annex 5: Variations of the coefficient of determination between any pair of annual precipitation time-series with the distance between the two precipitation stations.

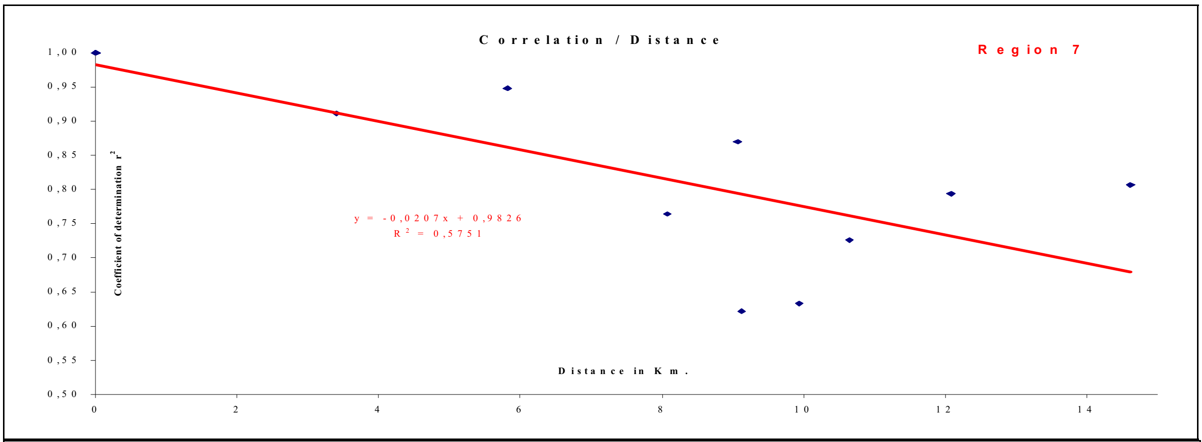


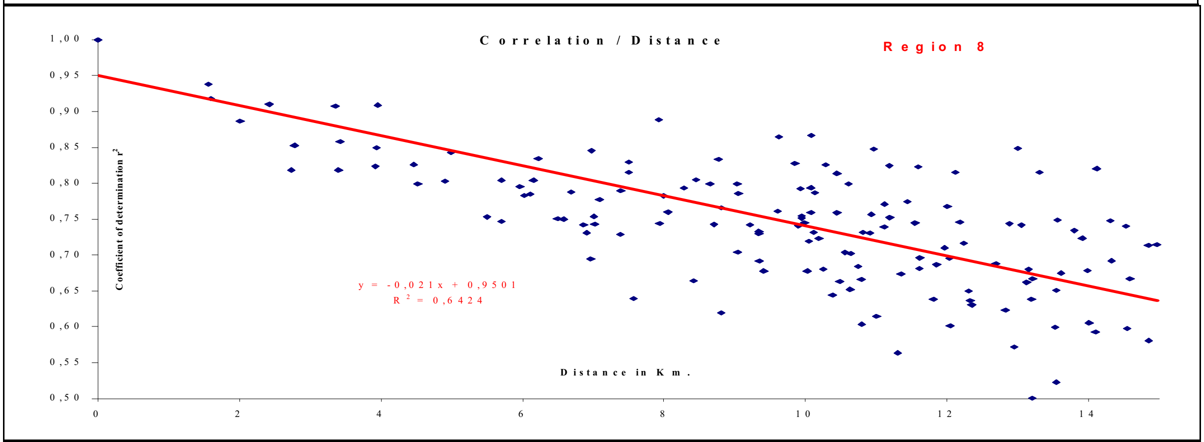


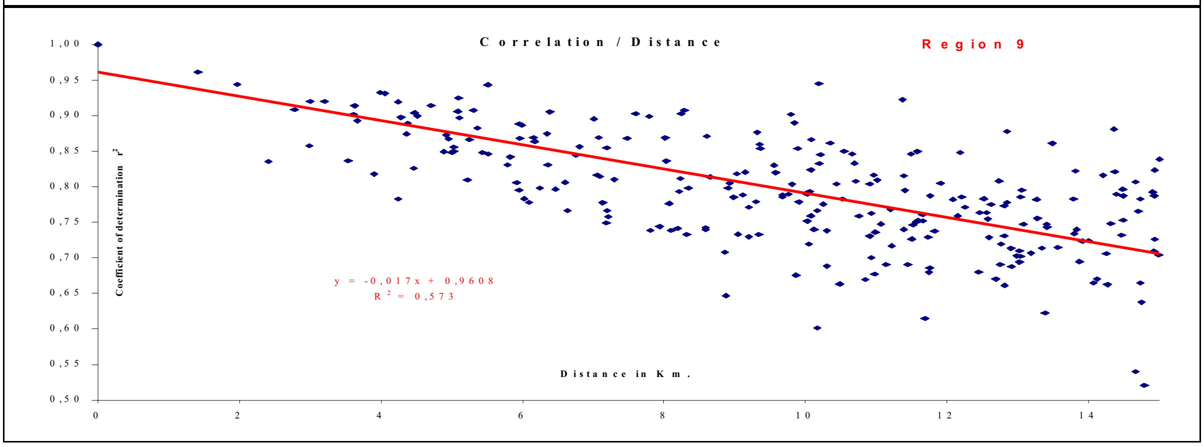




Annex 5 Continued







Annex 6: coefficient of determination between any pair of stream-flow annual time-series

	Station	11395	11795	12495	12790	13505	14450	14980	22395	28310	33170	33260	33395	34290	35440	37150	37390	61180	61185	65315	72350	72705	82290	84340	84530	84540	87360	88250	89750	92385	92495	94380	Station
		Region 1							Region 2		Region 3							Region 6			Region 7		Region 8							Region 9			
Region 1	11395	1,00	0,94	0,93	0,96	0,87	0,91	0,91	0,79	0,83	0,74	0,78	0,73	0,19	0,43	0,58	0,50	0,36	0,35	0,22	0,16	0,23	0,23	0,32	0,34	0,11	0,27	0,39	0,34	0,80	0,68	0,77	11395
	11795	0,94	1,00	0,85	0,93	0,75	0,82	0,87	0,81	0,81	0,64	0,67	0,60	0,10	0,34	0,42	0,38	0,26	0,25	0,13	0,09	0,14	0,26	0,26	0,30	0,09	0,19	0,29	0,49	0,70	0,53	0,64	11795
	12495	0,93	0,85	1,00	0,95	0,85	0,88	0,85	0,79	0,84	0,83	0,88	0,82	0,29	0,54	0,66	0,58	0,45	0,44	0,30	0,18	0,23	0,21	0,37	0,34	0,09	0,32	0,44	0,31	0,83	0,75	0,76	12495
	12790	0,96	0,93	0,95	1,00	0,87	0,92	0,91	0,79	0,86	0,76	0,79	0,74	0,20	0,44	0,57	0,50	0,35	0,34	0,21	0,17	0,22	0,23	0,32	0,31	0,10	0,26	0,38	0,32	0,80	0,69	0,77	12790
	13505	0,87	0,75	0,85	0,87	1,00	0,94	0,79	0,64	0,88	0,75	0,76	0,81	0,27	0,45	0,63	0,54	0,38	0,38	0,24	0,22	0,35	0,10	0,32	0,28	0,09	0,34	0,49	0,18	0,77	0,70	0,72	13505
	14450	0,91	0,82	0,88	0,92	0,94	1,00	0,89	0,79	0,87	0,74	0,73	0,74	0,18	0,40	0,57	0,48	0,34	0,34	0,20	0,16	0,29	0,14	0,30	0,26	0,07	0,29	0,37	0,23	0,73	0,67	0,71	14450
	14980	0,91	0,87	0,85	0,91	0,79	0,89	1,00	0,85	0,72	0,61	0,67	0,64	0,17	0,37	0,50	0,43	0,27	0,28	0,18	0,16	0,19	0,25	0,35	0,35	0,13	0,24	0,31	0,30	0,71	0,63	0,76	14980
Region 2	22395	0,79	0,81	0,79	0,79	0,64	0,79	0,85	1,00	0,70	0,64	0,65	0,60	0,13	0,36	0,42	0,37	0,32	0,29	0,16	0,03	0,04	0,30	0,27	0,28	0,07	0,15	0,18	0,43	0,61	0,49	0,56	22395
	28310	0,83	0,81	0,84	0,86	0,88	0,87	0,72	0,70	1,00	0,82	0,78	0,78	0,24	0,48	0,54	0,49	0,40	0,40	0,23	0,10	0,24	0,22	0,30	0,29	0,10	0,27	0,39	0,38	0,75	0,61	0,57	28310
Region 3	33170	0,74	0,64	0,83	0,76	0,75	0,74	0,61	0,64	0,82	1,00	0,90	0,85	0,30	0,55	0,65	0,61	0,50	0,49	0,30	0,11	0,18	0,23	0,31	0,26	0,07	0,29	0,40	0,34	0,72	0,58	0,52	33170
	33260	0,78	0,67	0,88	0,79	0,76	0,73	0,67	0,65	0,78	0,90	1,00	0,96	0,51	0,77	0,84	0,80	0,65	0,67	0,50	0,15	0,22	0,26	0,50	0,44	0,14	0,49	0,63	0,32	0,85	0,73	0,69	33260
	33395	0,73	0,60	0,82	0,74	0,81	0,74	0,64	0,60	0,78	0,85	0,96	1,00	0,56	0,78	0,88	0,81	0,71	0,70	0,54	0,17	0,24	0,21	0,53	0,46	0,16	0,53	0,67	0,25	0,84	0,76	0,70	33395
	34290	0,19	0,10	0,29	0,20	0,27	0,18	0,17	0,13	0,24	0,30	0,51	0,56	1,00	0,84	0,70	0,74	0,63	0,72	0,82	0,06	0,14	0,12	0,66	0,58	0,21	0,72	0,76	0,03	0,48	0,51	0,40	34290
	35440	0,43	0,34	0,54	0,44	0,45	0,40	0,37	0,36	0,48	0,55	0,77	0,78	0,84	1,00	0,86	0,89	0,81	0,86	0,84	0,12	0,22	0,26	0,70	0,61	0,20	0,76	0,82	0,21	0,69	0,65	0,54	35440
	37150	0,58	0,42	0,66	0,57	0,63	0,57	0,50	0,42	0,54	0,65	0,84	0,88	0,70	0,86	1,00	0,93	0,82	0,82	0,74	0,16	0,26	0,19	0,64	0,54	0,19	0,69	0,82	0,12	0,80	0,76	0,73	37150
	37390	0,50	0,38	0,58	0,50	0,54	0,48	0,43	0,37	0,49	0,61	0,80	0,81	0,74	0,89	0,93	1,00	0,81	0,88	0,82	0,12	0,22	0,23	0,77	0,64	0,21	0,77	0,85	0,19	0,79	0,73	0,68	37390
Region 6	61180	0,36	0,26	0,45	0,35	0,38	0,34	0,27	0,32	0,40	0,50	0,65	0,71	0,63	0,81	0,82	0,81	1,00	0,93	0,82	0,11	0,24	0,15	0,61	0,50	0,17	0,69	0,73	0,09	0,59	0,57	0,45	61180
	61185	0,35	0,25	0,44	0,34	0,38	0,34	0,28	0,29	0,40	0,49	0,67	0,70	0,72	0,86	0,82	0,88	0,93	1,00	0,90	0,13	0,28	0,15	0,69	0,54	0,16	0,80	0,79	0,11	0,60	0,58	0,45	61185
	65315	0,22	0,13	0,30	0,21	0,24	0,20	0,18	0,16	0,23	0,30	0,50	0,54	0,82	0,84	0,74	0,82	0,82	0,90	1,00	0,08	0,19	0,15	0,77	0,65	0,20	0,88	0,81	0,07	0,50	0,54	0,42	65315
Region 7	72350	0,16	0,09	0,18	0,17	0,22	0,16	0,16	0,03	0,10	0,11	0,15	0,17	0,06	0,12	0,16	0,12	0,11	0,13	0,08	1,00	0,77	0,01	0,07	0,03	0,04	0,12	0,15	0,04	0,13	0,25	0,17	72350
	72705	0,23	0,14	0,23	0,22	0,35	0,29	0,19	0,04	0,24	0,18	0,22	0,24	0,14	0,22	0,26	0,22	0,24	0,28	0,19	0,77	1,00	0,00	0,14	0,08	0,09	0,30	0,33	0,03	0,19	0,31	0,19	72350
Region 8	82290	0,23	0,26	0,21	0,23	0,10	0,14	0,25	0,30	0,22	0,23	0,26	0,21	0,12	0,26	0,19	0,23	0,15	0,15	0,15	0,01	0,00	1,00	0,43	0,55	0,51	0,12	0,12	0,49	0,33	0,20	0,22	82290
	84340	0,32	0,26	0,37	0,32	0,32	0,30	0,35	0,27	0,30	0,31	0,50	0,53	0,66	0,70	0,64	0,77	0,61	0,69	0,77	0,07	0,14	0,43	1,00	0,93	0,55	0,81	0,76	0,23	0,63	0,59	0,56	84340
	84530	0,34	0,30	0,34	0,31	0,28	0,26	0,35	0,28	0,29	0,26	0,44	0,46	0,58	0,61	0,54	0,64	0,50	0,54	0,65	0,03	0,08	0,55	0,93	1,00	0,65	0,73	0,69	0,33	0,59	0,53	0,52	84530
	84540	0,11	0,09	0,09	0,10	0,09	0,07	0,13	0,07	0,10	0,07	0,14	0,16	0,21	0,20	0,19	0,21	0,17	0,16	0,20	0,04	0,09	0,51	0,55	0,65	1,00	0,31	0,31	0,14	0,24	0,18	0,17	84540
	87360	0,27	0,19	0,32	0,26	0,34	0,29	0,24	0,15	0,27	0,29	0,49	0,53	0,72	0,76	0,69	0,77	0,69	0,80	0,88	0,12	0,30	0,12	0,81	0,73	0,31	1,00	0,89	0,12	0,53	0,60	0,43	87360
	88250	0,39	0,29	0,44	0,38	0,49	0,37	0,31	0,18	0,39	0,40	0,63	0,67	0,76	0,82	0,82	0,85	0,73	0,79	0,81	0,15	0,33	0,12	0,76	0,69	0,31	0,89	1,00	0,15	0,70	0,71	0,59	88250
	89750	0,34	0,49	0,31	0,32	0,18	0,23	0,30	0,43	0,38	0,34	0,32	0,25	0,03	0,21	0,12	0,19	0,09	0,11	0,07	0,04	0,03	0,49	0,23	0,33	0,14	0,12	0,15	1,00	0,35	0,15	0,17	89750
Region 9	92385	0,80	0,70	0,83	0,80	0,77	0,73	0,71	0,61	0,75	0,72	0,85	0,84	0,48	0,69	0,80	0,79	0,59	0,60	0,50	0,13	0,19	0,33	0,63	0,59	0,24	0,53	0,70	0,35	1,00	0,89	0,88	92385
	92495	0,68	0,53	0,75	0,69	0,70	0,67	0,63	0,49	0,61	0,58	0,73	0,76	0,51	0,65	0,76	0,73	0,57	0,58	0,54	0,25	0,31	0,20	0,59	0,53	0,18	0,60	0,71	0,15	0,89	1,00	0,88	92495
	94380	0,77	0,64	0,76	0,77	0,72	0,71	0,76	0,56	0,57	0,52	0,69	0,70	0,40	0,54	0,73	0,68	0,45	0,45	0,42	0,17	0,19	0,22	0,56	0,52	0,17	0,43	0,59	0,17	0,88	0,88	1,00	94380
	Station	11395	11795	12495	12790	13505	14450	14980	22395	28310	33170	33260	33395	34290	35440	37150	37390	61180	61185	65315	72350	72705	82290	84340	84530	84540	87360	88250	89750	92385	92495	94380	Station

Colour Key:

Correlation Coefficient between 0.7 and 0.8

Correlation Coefficient greater than 0.8