MINISTRY OF AGRICULTURE, NATURAL RESOURCES AND
ENVIRONMENT OF THE REPUBLIC OF CYPRUS
Water Development Department

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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REASSESSMENT OF THE ISLAND'S WATER RESOURCES AND DEMAND

SYNTHESIS REPORT

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SUMMARY

The Water Development Department (WDD), in cooperation with the Food and Agriculture Organization of the United Nations (FAO), carried out a reassessment of the water resources of Cyprus. Its aim was to re-assess the country's water availability and water use. In addition, the project was to review water policy and management options.

Statistical analysis of the **precipitation** records available over the period of the hydrological years 1916/1917-1999/2000 shows a step change around 1970. The time series can be divided into two separate stationary periods. The mean precipitation of the recent period is lower than the mean precipitation of the older period a fact that had as a consequence the significant reduction in the water available on the island. The decrease in the mean annual **inflow to dams**, referred to as design estimates, varies between 24% and 58%, with an average of around 40%. It can be said that the island has roughly 40% less water than had been assumed based on pre-1970 records. Whether in the future the water resources will continue decreasing or will return to the pre-1970 level is an open question. Meanwhile, it is prudent to assume that the future annual water availability will continue oscillating around the 1970 – 2000 average.

Groundwater resources in Cyprus are overexploited by about 40% of sustainable extraction. The risk to agriculture has increased because of depleted aquifers. Unless groundwater is left to recover to a reasonable level, the resource will be of limited help to mitigate future water shortages. It is imperative for water sustainability that the adverse trend in groundwater is checked and reversed.

Water losses in **domestic water** distribution networks, mainly in rural areas, are quite high and additional effort should be made to detect and replace defective pipes and to establish a caring attitude towards precious water. The use of drinking quality water in garden irrigation should be discouraged. Seawater desalination has ensured a continued supply of good quality drinking water for domestic uses, including the economically important tourist industry. However, it represents a trend that leads the island's water security into dependence on oil imports for desalination.

The **agriculture** sector uses close to 70% of all water resources of Cyprus while contributing a minor part to national wealth. Agriculture also struggles with a shortage of labour. Water use efficiency, in terms of water used per ton of crop, is reasonably good. However, use of water in the services and light industries sector bears a potential to generate more and better remunerated employment. The schematic cost structure of most agricultural crops shows that the cost of water is only a minor factor when compared to the cost of investment and labour, suggesting that there may be leeway available towards achieving a higher level of water cost recovery. In this context, a review of water allocation criteria and tariffs should be in order.

Recycled domestic water is a growing resource in Cyprus. Policies may strengthen its role in enhancing the urban and rural environment (green areas, parks, forestation), in backing up agricultural water needs and in recharging groundwater reserves. Policies should discourage using the boon of recycled water for expanding an already subsidized agriculture.

Water management in Cyprus has met difficulties owing to the inherited **legal and institutional framework**. Most of these problems are on the way to rectification through the new legislation under consideration by Parliament. However, it is recognized that realizing a policy of uniform water rates over the island remains a difficult problem.

ACKNOWLEDGEMENT

This synthesis report was prepared on basis of the substantive reports produced for the WDD/FAO project, listed in Annex 2.

Thanks go to their authors and to the staff that collaborated in the work. The suggestions, ideas and inputs of Iacovos Iacovides, Panayiotis Skordis, Charis Omorphos, George Socratous, Loucas Savvides, Christos Ioannou, Gerald Dörflinger and Jean-Marc Faurès are acknowledged in particular.

LIST OF ACRONYMS

TCP	Technical Cooperation Programme
WDD	Water Development Department
FAO	Food and Agriculture Organization of the United Nations
EU	European Union
GIS	Geographical Information System
Cy£, CyP	Cyprus Pound
GH	Greenhouse
OF	Open field
MCM, mcm	Million cubic meters

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Introduction

The Water Development Department (WDD), in cooperation with the Food and Agriculture Organization of the United Nations (FAO), carried out a reassessment of the water resources of Cyprus. The project was undertaken in the light of water scarcity aggravated by drought threatening the base of the country's economy. The project had a focus on two immediate objectives:

(i) a re-assessment of the country's water availability and water use in the main water management regions. Main activities included an update of the hydrology of the island based on records now available on a longer time base, and a revision of current water demand; and

(ii) a review of policy and management options for presentation of a high-level seminar.

The project foresaw the production of intermediate outputs and collateral outputs, including the improvement of tools for data handling and analysis, assessment of the adequacy of the data collection networks, and a review of the existing legal and institutional framework. The various reports of the studies carried out under the project, and the underlying databases, are available in CD-ROM format. Hardcopies of the abovementioned reports comprise Volume I, Volume II and Volume III of the "Re-Assessment of the Water Resources and Demand of the Island of Cyprus". A list of all reports produced for the project is given in Annex 2.

The area under consideration in this report is the island of Cyprus. No data were collected in the northern part of the island under Turkish occupation since 1974.

Part A Water Supply

A.1 Trends in recorded rainfall[1]

Maximum precipitation in Cyprus reaches values of 1000 mm/year at the top of the Troodos mountains that feed most river basins and aquifers of the island. The area receiving more than 600 mm of rainfall per year is limited to elevations above 500 m on the south-western slope, and to elevations greater than 800 m on the north-eastern slope of the Troodos mountains. The distribution of rainfall through the year is similar over the entire island and shows a maximum in the December-January period.

Statistical analysis of the records available over the period of the hydrological years 1916/1917-1999/2000 shows that the precipitation time series displays a step change around 1970 and can be divided into two separate stationary periods. From 1916/1917 to 1969/70 the precipitation records do not show any trend. From 1970/1971 to 1999/2000 the data show a slight decrease in the precipitation but this trend is not significant compared to the variations from year to year. The mean precipitation of the recent period is lower than the mean precipitation of the older period (see Figure 1).

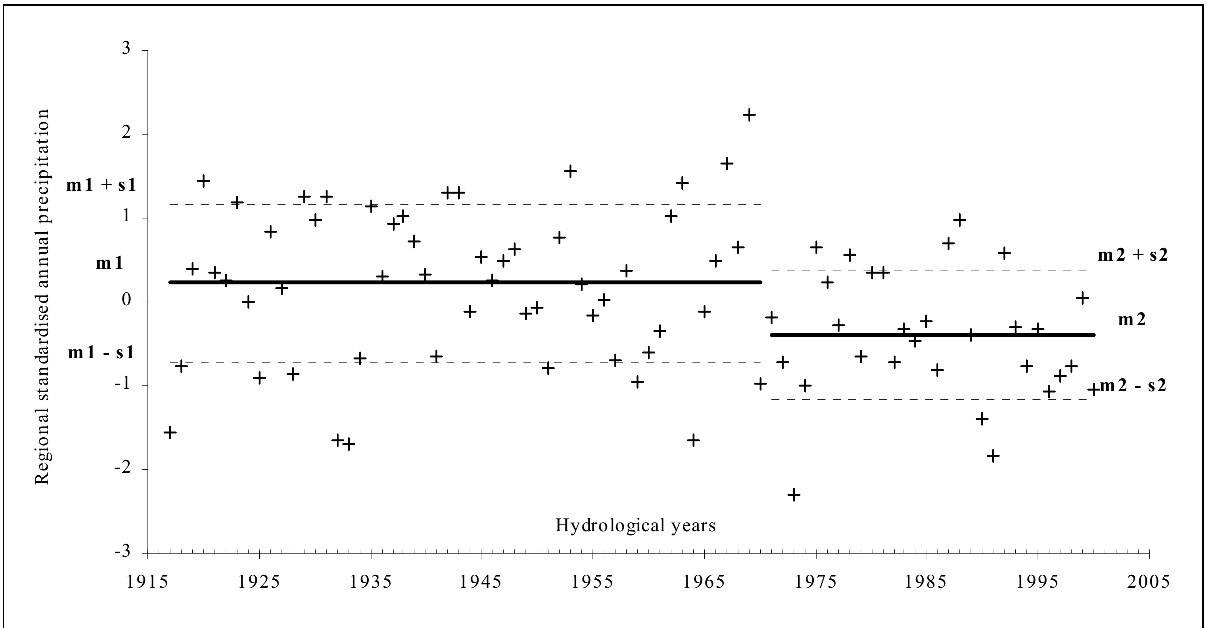

Figure 1: Troodos Mountain regional annual precipitation with indication of the mean and standard deviation for the 1917-1970 and 1971-2000 periods (Rossel, 2001).

The shift in mean precipitation was found to be larger in the Troodos Mountains sector than in the coastal and inland plains area. At almost every location of elevation higher than 500 m, the mean annual precipitation in the recent period is lower by 100 mm or more than the mean of the older period. This decrease ranges between 15% and 25% of the mean annual precipitation of the older period. The decrease of the annual precipitation is noticeable for the months of December and January in the southeast of the island, and for December, January and February in all the other regions.

The multi-annual mean precipitation may increase or decrease in future, and it is prudent to assume that annual precipitation will continue oscillating around the 1971 – 2000 average. Thus, the pre-1970 rainfall data would belong to a past period with higher rainfall than at present. The study does not prove that the recorded decrease in annual precipitation was

[1] Rossel, F. (2001): Hydrometeorological Study examining Changes in recorded Precipitation

caused by global climate change, but this possibility is not necessarily excluded. For a better understanding of weather and climate changes in Cyprus, an analysis of changes in the tracks of depression systems in the eastern Mediterranean sector should be carried out. Such an analysis could bring to evidence a link between the climate of Cyprus, climate variations caused by factors such as marine currents, and global climate change owing to the greenhouse effect.

Evaporation in Cyprus is low during the winter with a minimum in January, and high during the summer with a maximum in July. Analysis of evaporation data series shows that the records are not reliable and therefore that it is necessary to carry out quality checks of the evaporation records before any use for water resources management.

A.2 Trends in river flow[2]

Eighty percent of surface runoff in Cyprus is generated in the Troodos Mountains. Because of the rainfall conditions, surface water flows in Cyprus are confined to a few months a year. A review of the recorded surface runoff time-series led to conclude that it was possible to generate continuous annual flow time series for 31 watersheds. These watersheds cover almost the entire area of elevation higher than 500 m, that is, the area that is the most productive in terms of surface runoff generation. It can thus reasonably be accepted that a large part of the surface water resources of Cyprus is quantitatively represented in this study. Surface runoff was totalized by hydrological region, by government water development project and for the entire area under government control.

The study showed that lower precipitation over the last 30 years than over the previous decades, was the cause of a very significant reduction in the water available on the island, with respect to what had been assumed to be available on basis of the pre-1970 records. In the reassessment of the island's water resources, only hydrometeorological records of the 1970/1971-1999/2000 period were used. Figure 2 shows, as an example, the regression curve between annual rainfall and annual runoff for the catchment of the Kouris Dam. A 13% decrease in annual rainfall for this catchment results in a 34% decrease in annual runoff. The exercise demonstrated in Figure 2 was repeated for other dams. Table 1 shows the mean annual inflow computed on basis of streamflow records and regression with rainfall. Decreases in runoff after 1970 with respect to the older time series vary between 20 and 60 percent.

[2] Rossel, F. (2002): Surface Water Resources

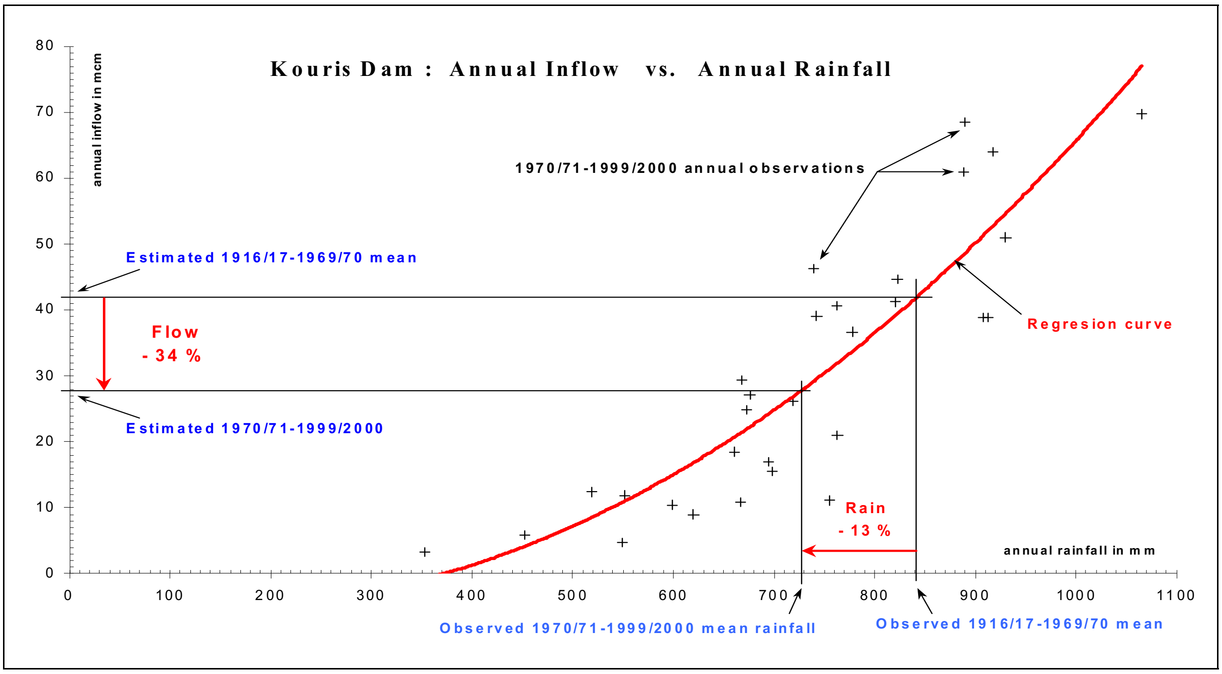

Figure 2: Relation between annual precipitation and annual inflow to the Kouris dam (Rossel, 2002).

Table 1: Mean annual inflow to a selection of dams (million cubic meter)

Dam name	Design Estimation	1971-2000 Observation	Difference (Obs-Est)/Est	Estimations with Rainfall 1917-1970	Estimations with Rainfall 1971-2000	Estimations with Rainfall Decrease	Rainfall Decrease
Pomos	5.0	3.4	- 32 %	5.1	3.1	- 40 %	- 16 %
Argaka	8.5	2.6	- 69 %	4.1	2.3	- 45 %	- 16 %
Evretou	12.0	6.4	- 47 %	9.7	5.7	- 42 %	- 17 %
Kannaviou	9.1	8.0	- 12 %	11.9	7.0	- 41 %	- 15 %
Asprokremmos	45.5	14.9	- 67 %	23.0	13.5	- 41 %	- 16 %
Arminou	22.7	18.0	- 21 %	26.2	16.2	- 38 %	- 15 %
Kouris	46.3	30.0	- 35 %	41.7	27.7	- 34 %	- 13 %
Polemidhia	No data	2.6	-	3.3	2.3	- 30 %	- 10 %
Yermasogeia*	*14.0*	*9.8*	- 30 %	16.6	12.5	- 25 %	- 10 %
Kalavasos	12.9	6.4	- 51 %	10.0	4.2	- 58 %	- 15 %
Dhypotamos	9.3	5.4	- 43 %	7.8	4.7	- 40 %	- 14 %
Kiti	No data	1.3	-	1.6	0.9	- 41 %	- 10 %
Tamassos	No data	5.2	-	8.1	4.7	- 42 %	- 18 %
Xyliatos	3.0	2.5	- 18 %	3.2	2.3	- 26 %	- 13 %
Kalopanayiotis	11.5	5.1	- 56 %	6.3	4.8	- 24 %	- 13 %

* For the Yermasogeia dam, the design estimation is the median annual inflow.

Source: Rossel, 2002

The mean annual surface runoff for the studied period and 31 watersheds is equal to 190 million m^3 of which 127 million m^3 (67 %) flow into government dams and irrigation systems. Further reduction in stream flows was caused by human intervention, such as exploitation of aquifers. The actually available surface water on the island is indeed substantially less than what had been assumed as a basis for the water development works.

A.3 Groundwater trends[3]

Surface runoff in Cyprus is available for only a few months. Groundwater, available round the year, traditionally provided the resource needed for domestic use and irrigation. The construction of dams on the main rivers of the island, substantially carried out in the second half of the 20th century, secured an additional supply that would otherwise be lost to the sea. However, groundwater remains the main, most secure and low-cost source of water for both irrigation and domestic supply on the island. Nearly all the water for the non-governmental irrigation sector stems from underground.

The biggest and most dynamic aquifers are phreatic aquifers developed in river or coastal alluvial deposits. During the last decade, aquifers exhibited depleting trends, as can be seen on borehole hydrographs. Repeated and persistent drought episodes reduced direct and indirect groundwater recharge, while the construction of dams further reduced recharge of downstream aquifers. Farmers have continued extracting the same quantities of groundwater and in many cases have increased these quantities.

For reassessment of groundwater resources, sixty-six aquifers, all in the area under Government control, were taken into account. Some information on aquifers in the occupied northern part of Cyprus is also given. The water balance of the aquifers is based on the hydrometeorological, hydrological and hydrogeological conditions of the aquifers during the 1991 to 2000 decade. These are estimated average values that can be used for the development of long-term plans.

Table 2: Annual groundwater balance of Cyprus (averaged over period 1991-2000)

Replenishment of the aquifers ($x10^6$ m^3):

Natural Recharge from:			
	Rainfall	205.1	
	River flows	44.8	
	Return from irrigation/domestic	22.1	
	Groundwater inflow	8.8	
	Dam losses	1.7	
	Natural Recharge	282.5	282.5
Artificial recharge			9.8
Sea intrusion			12.8
REPLENISHMENT (TOTAL RECHARGE)			**305.1** mcm

Outflow from the aquifers ($x10^6$ m^3):

Extraction	129.1
Groundwater Outflow	166.7
Sea Outflow	24.6
TOTAL OUTFLOW	**320.4** mcm

Source: Georgiou, 2002

The water balance of the aquifers is summarized in Table 2. The present level of extraction is estimated close to 130 million m^3 per year. Ten million m^3 stem from artificial recharge. The

[3] Georgiou, A. (2002): Assessment of Groundwater Resources of Cyprus

amount of extracted groundwater originating from natural recharge is therefore of the order of 120 million m^3/year. The aquifers show an overall annual negative balance (net extraction) of 15.3 million m^3.

Aquifers are at present (2001) at a very low level and partially intruded by seawater. For sustainable aquifer management and protection of groundwater resources, it is estimated that extraction from all aquifers should not exceed 81.3 million m^3. This estimated figure is not in arithmetic balance with the other members of the water balance equation because, once the drought crisis is over, aquifers should be left to recover. Year-to-year water management must of course be based on the prevailing hydrogeological conditions of each aquifer at the time of study, but overall there is a major gap between actual and recommended water extraction from the aquifers: groundwater resources in Cyprus are overexploited by about 40% of sustainable extraction. The existing conditions have resulted in saline water intrusion and consequent quality deterioration in coastal aquifers and depletion of inland aquifers. Saline water intrusion in aquifers results also in spoiling valuable underground water storage room.

The average extraction for domestic water supply over the period 1991 - 2000 is estimated to be of the order of 25 million m^3/year; for irrigation it is estimated to be around 102 million m^3/year and for industrial use it is estimated to be around 2.5 to 3 million m^3. Owing to its gradual replacement by desalinated water, the use of groundwater for domestic water supply has been significantly reduced in recent years. Its present level is of 18 to 20 million m^3. Besides its growing scarcity, groundwater is also being abandoned for domestic supply because of quality problems. Intensive agriculture and excessive use of fertilizers have resulted in nitrate pollution of many aquifers. Similar nitrate pollution problems appear in aquifers developed in inhabited areas because of direct sewage disposal in adsorption pits.

According to European Union directives, aquifers in a country should be managed in ways that guaranty adequate quantities of good quality water. Intense pressure on the island's water resources, and the current state of quantitative and qualitative degradation of groundwater in the most important aquifers in Cyprus, point to the need for the establishment of an island-wide groundwater monitoring system.

A.4 Recycled water[4]

At present about 3 million m^3 of treated sewage effluent is used for agriculture and landscape irrigation. The crops irrigated with recycled water are citrus, olives, vines and fodders. It is estimated that by the year 2012 an amount of approximately 30 million m^3 of treated sewage effluent will be available for agriculture and landscape irrigation.

[4] Savvides, L. et al. (2001): The Assessment of Water Demand of Cyprus

Part B Water use and demand[5]

B.1 Overall water demand

The total annual water demand all over Cyprus for the year 2000 is estimated to be 265.9 million m^3. Its distribution over the sectors is shown in Figure 3 and Table 3. Agriculture is the main user with 69% of the total water use.

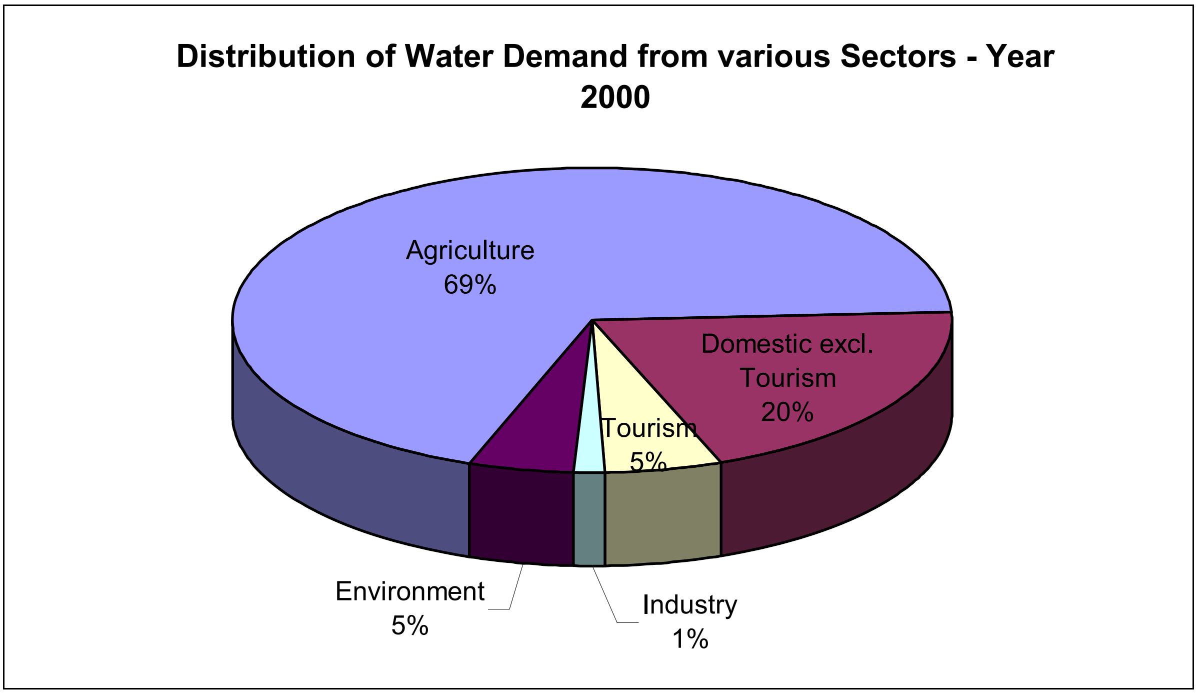

Figure 3: Distribution of Total Water Demand amongst various Sectors for year 2000 (Savvides et al., 2001)

Table 3: Annual Water Demand by Sector for the year 2000 (see also Figure 4)

AGRICULTURE			**182.4 million m^3**		**69%**
DOMESTIC			**67.5 million m^3**		**25%**
Residents	53.4 10^6 m^3	79% of Domestic		20%	
Tourism	14.1 10^6 m^3	21% of Domestic		5%	
Total domestic	67.5 10^6 m^3	100%		**25%**	
INDUSTRY			**3.5 million m^3**		**1%**
ENVIRONMENT			**12.5 million m^3**		**5%**
TOTAL WATER DEMAND			**265.9 million m^3**		**100%**

Source: Savvides et al., 2001

Water demand in the context of this study includes conveyance and distribution losses. The projected annual water demand in million m^3 for the years 2005, 2010 and 2020 is shown in

[5] Savvides, L. et al. (2001): The Assessment of Water Demand of Cyprus

Table 4. As can be seen from this table, a constant water allocation to agriculture is assumed. Water shortage in scarcity situations is settled through rationing and, where this possibility exists, increased groundwater extraction.

Table 4: Projected water demand per year for the main sectors (2000 – 2020)

Sector of Demand / Year	2000	2005	2010	2020
Agriculture	182.4	182.4	182.4	182.4
Domestic				
Inhabitants	53.4	58.4	63.2	73.5
Tourism	14.1	18.0	22.9	30.8
Industry	3.5	5.0	6.0	7.0
Environment	12.5	14.0	16.0	20.0
TOTAL (million m^3)	**265.9**	**277.8**	**290.5**	**313.7**

Source: Savvides et al., 2001

Figure 4 and Table 5 show water demand by sector and source of supply for the year 2000. Groundwater remains the main source of water supply, particularly for the agricultural sector and in areas outside the government-owned irrigation schemes.

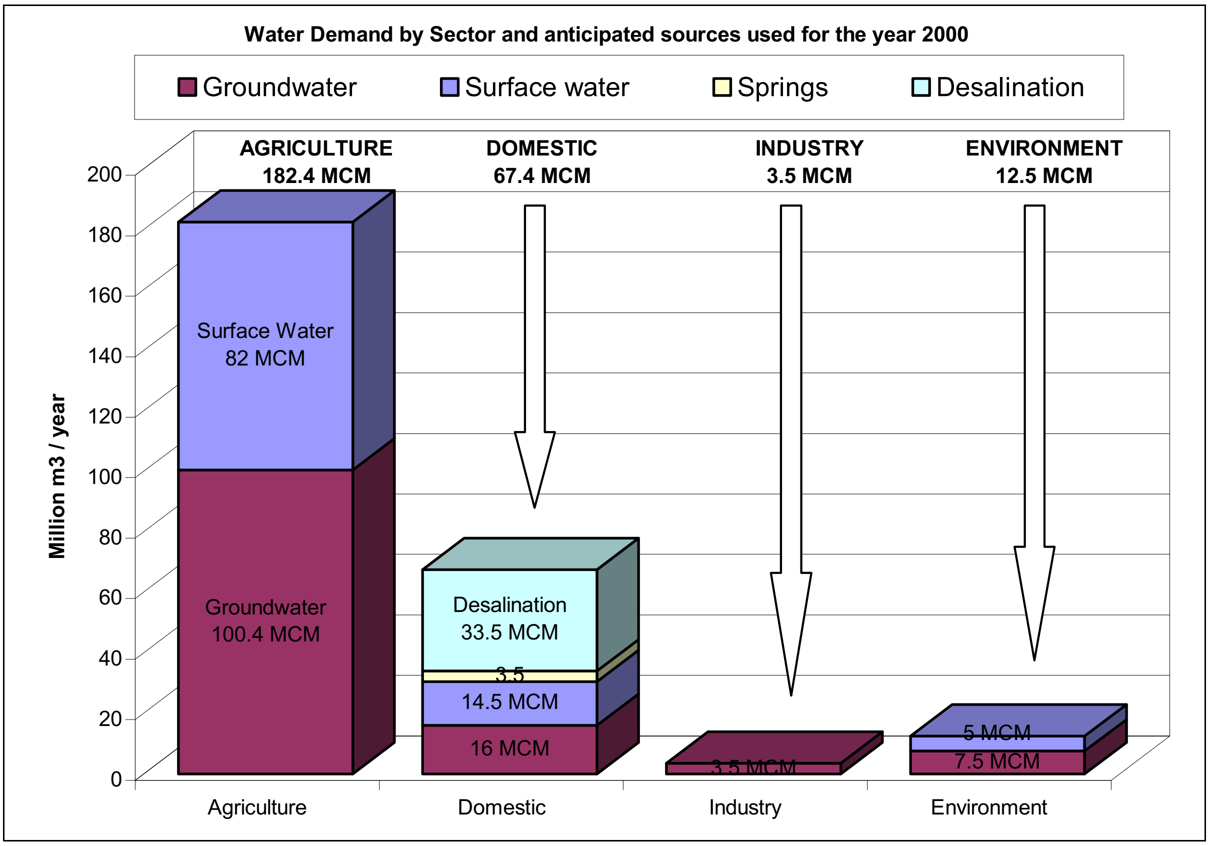

Figure 4: Water Demand by Sector and anticipated sources used for the year 2000 (Savvides et al., 2001)

Table 5: Water demand by sector and source of supply for the year 2000 (see also Figure 4)

WATER DEMAND BY SECTOR AND ANTICIPATED SOURCE OF SUPPLY FOR THE YEAR 2000										
	Surface water		Groundwater		Springs		Desalination		TOTAL	
	million m^3	%	million m^3	%	million m^3	%	million m^3	%	million m^3	%
Agriculture	82	43	100.4	57	-	-	-	-	182.4	68.6
Domestic	14.5	21.6	16	23.1	3.5	5.2	33.5	50	67.5	25.4
Industry	-	-	3.5	100	-	-	-	-	3.5	1.3
Environment	5	42	7.5	58	-	-	-	-	12.5	4.7
TOTAL	**101.5**		**127.4**		**3.5**		**33.5**		**265.9**	**100**
%	**38.2**		**47.9**		**1.3**		**12.6**		**100.0**	

Source: Savvides et al., 2001

B.2 Agricultural water demand

Agricultural water demand was assessed on basis of the irrigated areas per crop category in a “normal” (non-drought) year. The amount of water consumed was then calculated according to the water demand of the crop in the environment of Cyprus. Computed in this way, the total agricultural water demand is of 182.4 million m^3, distributed between irrigated agriculture and animal husbandry as follows (see also Figure 5):

- Irrigated agriculture 174.4 million m^3
  - Major government irrigation schemes 100.1 million m^3 (57%)
  - Outside government irrigation schemes 74.3 million m^3 (43%)
- Animal husbandry 8 million m^3

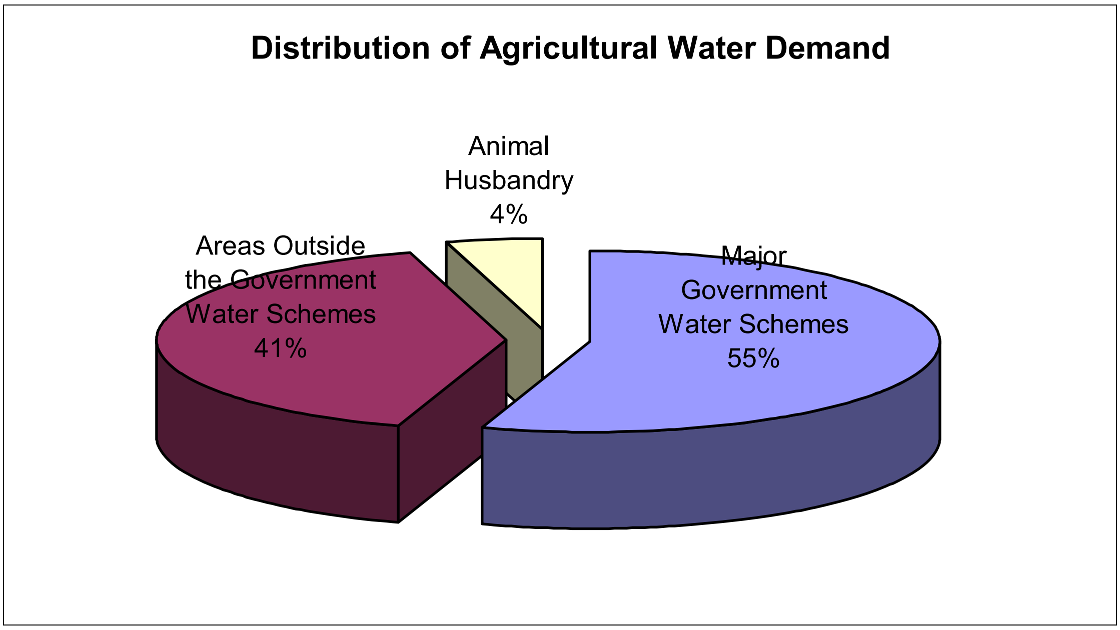

Figure 5: Distribution of Agricultural Water Demand (Savvides et al., 2001)

The major government irrigation schemes use 57% of the total (100 million m^3), including 15% estimated conveyance losses. The remaining 43 % (75 million m^3) is used in scattered irrigated areas developed by individuals and communities.

Almost 96% of the water demand outside the government schemes is satisfied by groundwater.

The distribution of water demand by crops is shown in Table 6. It is worth noting the large share of permanent crops, in particular citrus, in water demand. This is partially explained by preferential quotas allocated to the sector during drought periods.

Table 6: Distribution of water demand by crop

Permanent Crops	Citrus	32%
	Deciduous*	11%
	Olives	5%
	Table Grapes	3%
	Bananas	2%
	Remaining areas	6%
	Total	**59%**
Annual Crops	Greenhouses	2%
	Open Field Vegetables	22.5%
	Potatoes	9.5%
	Fodders	7%
	Total	**41%**

* Deciduous: apples, pears, peaches, cherries, prunes and plums, kiwi, *diospiros kaki* or lotos, walnuts, pecan nuts, hazelnuts, figs, pomegranates and irrigated almonds.

Source: Savvides et al., 2001

B.3 Domestic water demand

The sources for domestic water supply are desalination (50%), groundwater (23%), surface water (22%) and springs (5%). Per capita daily water use (including network losses) in the year 2000 in the main towns and the aggregated villages is shown in Table 7.

Table 7: Actual per capita daily water consumption during the year 2000

Town	Litres/capita/day including losses
Lefkosia	150
Lemesos	215
Larnaka	162
Pafos	222
Villages	144

Note: Pafos has the higher losses in the distribution network, which are over 30%

Source: Savvides et al., 2001

The amount of water of drinking quality needed to satisfy domestic demand was calculated on basis of the following per capita figures:

- 215 Litres/capita/day for main towns
- 180 Litres /capita/day for villages
- 465 Litres /capita/day for tourist demand

The results of the calculation are presented in Table 8 and Figure 6.

Table 8: Domestic Water Demand for residents and tourists for the year 2000 (see also Figure 6)

	Water demand (million $m^{3)}$)			% of total
	Resident	Tourist	Total	
Lefkosia & Suburbs	16.6	0.7	17.3	26%
Lemesos & Suburbs	12.8	3.6	16.4	24%
Larnaka & Suburbs	5.8	2.0	7.8	12%
Pafos & Suburbs	3.0	3.5	6.5	10%
Ammochostos	1.2	3.5	4.7	7%
All villages	11.3	0.8	12.1	18%
British Bases	1.8	-	1.8	3%
Turkish Sector / Lefkosia*	1.0	-	1.0	1%
Total	**53.4**	**14.1**	**67.5**	**100%**

*) Note: The Water Board of Lefkosia provides about 1 million m^3 of water annually to the Turkish sector of Lefkosia.

Source: Savvides et al., 2001

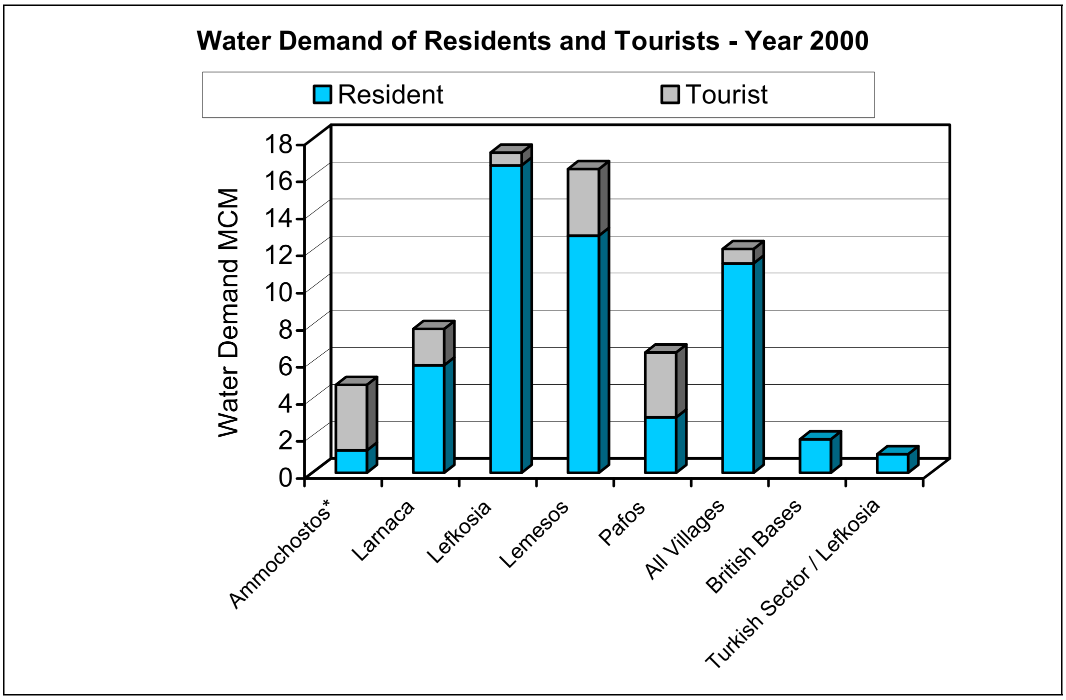

Figure 6: Water Demand of Residents and Tourists per Main Towns and Suburbs for the year 2000 (Savvides et al., 2001)

B.4 Water demand for amenities and the environment

Landscape irrigation exists all over Cyprus using municipal domestic water, groundwater and treated sewage effluent. The irrigated areas include house gardens, municipal landscape areas, hotels and playgrounds. Municipal potable water was extensively used for watering house gardens in the past, however this use has been considerably reduced due to the water shortages. Boreholes drilled within the main towns by individuals, subsidized by the Government, have led to groundwater becoming the main source for irrigating house gardens and hotels. Playgrounds and municipal landscape areas are also irrigated, mostly from groundwater. In addition, part of the municipal areas in Limassol and a number of hotels receive treated sewage effluent. Small treatment units exist also in many hotels, where the treated water is used for irrigating landscaped areas. In addition to the water demand of the natural environment that is covered by rainfall, some water is required for protection of special ecological areas and the flora and wild life of riverbeds, lakes and marshes. The total demand for natural ecological areas and landscaped irrigated areas is estimated at 19 million m^3.

Part C Legal and institutional framework[6]

At the foundation of the Republic, Cyprus inherited problematic institutional arrangements for water management. The 70s and 80s of the past century brought other priority goals and activities, such as securing water to people displaced by the 1974 invasion and developing the infrastructure of reservoirs and conveyance systems for water management. A study carried out in 1987 brought forward the need and options for institutional and legislative reform. The persistent drought that befell the island since the 70s brought the need for institutional reform into the forefront, but no decision was taken. Finally, a political decision: to seek accession to the European Union, made changes in the water legislation necessary in order to achieve harmonization with the EU Directives. New draft legislation was approved by the Council of Ministers in 2001 and submitted to Parliament for discussion and approval.

Existing legislation divides responsibility for water administration between several ministries exercising overlapping jurisdictions, often resulting in instances where there is duplication of efforts and other instances where no action is taken. In some cases, the public does not know, for example, where one should apply for a borehole permit. Follow up on permits, and the conditions set therein, is lax and as a result there are many illegal boreholes. Implementation, operation and maintenance of sewage projects for municipalities are carried out by different government services applying different standards. For irrigation water there are various ways of supply, where landowners owning boreholes obtain water individually. Groundwater may be state property but boreholes owners appear to consider the water pumped as private property. Certain urban water charges must be approved by Parliament, which may take years. There is, in practice, a variety of water charges to consumers, contradicting a policy of uniform water rates. In a drought situation, various organizations set different rules and degrees of supply. These and other weaknesses and deficiencies are known and targeted for correction through the new legislation.

The new legislation proposes a unified water code and the establishment of a new Water Entity[7] while abolishing a number of dispersed bills of law, and to harmonise Cyprus legislation with the EU Directive 2000/60/EC. The new Water Entity is proposed to develop and manage water resources within the framework of the national water policy. It will, inter alia, deal with the difference between water demand and supply. The Water Entity will deal with water for domestic purposes, irrigation and other agricultural purposes, sewage networks and treatment plants, governmental water works, safety of dams and reservoirs, control of water abstraction and retaining works, and management of natural streams. No major changes in the institutional setup are envisaged insofar as the new Water Entity would be based on the existing Water Development Department under the Ministry of Agriculture, Natural Resources and Environment. The main goals achieved with the new water code, as pointed out in the Attorney-General's reports, are:

- Regulate certain authorities exercised without the existence of the required legal framework;

- Dispersed authorities related with water management are transferred to the new Water Entity;

- Reservoir safety is given a legal framework;

- An Advisory Committee on Water Management will ensure wide participation in the formulation of water policy;

[6] Marcoullis, C. and Vassiliadou, D. (2002): Water Legislation and Institutions in Cyprus

[7] Marcoulli, E. (2002): Translation of the Water Entity Bill from Greek to English

- Water withdrawals from surface and groundwater systems will be controlled through a single permit;

- Charges and levies for the supply of water will be unified and will be sufficient for cost recovery; and

- Penalties for breach of water management provisions provided in the new code will be serious and dissuasive.

The process of restructuring and modernizing the framework for water management will proceed through the regulations to the law.

Part D Outlook – Policy options

National policy, including water policy, is a political matter and, as such, one that is the privilege and duty of political leaders, their constituencies and citizens to sort out. Water policy does not stand alone but meshes in with other national and sectoral policies. Thus, water policy is influenced, and has an incidence, on policies concerning agriculture, public health, energy and tourism, to mention only the most obvious connections. In a democratic society, policy options and their implications should lie open and transparent to scrutiny, so that a meaningful national and sectoral policy discussion can take place. In Cyprus, the newly streamlined water resources law and institutions open perspectives for more effective policy formulation and implementation.

To alleviate water scarcity strangling the national economy, since the 1960's Cyprus embarked in a programme to increase water supply by constructing dams and conveyance infrastructure under the motto "No drop of water to the sea". Since 1960, the freshwater storage capacity was increased 50 times from 6 million m^3 to 300 million m^3. Nowadays Cyprus ranks as one of the countries with the highest degree of dam development in the world. Water storage capacity in Cyprus is about twice the average annual runoff and a good degree of national water security was achieved in the face of unreliable rainfall. Many of the dams have as yet not spilt water over their spillways owing to their large capacity with respect to annual runoff and a persistent dry spell. While most river catchments are small, the construction of the Southern Conveyor and controlled connections to rural and urban user communities enabled wide area water management. Of all possible dams that engineering can construct in Cyprus, a large list taken from the more attractive opportunities has already been implemented. More dams are possible but carry a high price tag: the cost of water from new sources is higher than the cost of water that as already been developed.

The WDD/FAO project produced evidence showing that towards 1970 there is a clear step down in average annual rainfall. The dams were designed on the basis of the rainfall and river flow data series collected since 1917 in which the after-1970 year had little or no weight. In terms of surface runoff, the reduction in rainfall results in a runoff that in average is about 45% smaller than had been foreseen in designing the works. The calculation underlying the economic benefits of the dams is thus significantly undermined: no water is lost to the sea, but the amount of water retained is less than had been expected and the cost per m^3 of water is consequently higher than previously calculated.

Some policy issues are briefly outlined below.

D.1 Domestic water supply

The domestic water tariff is Cy£ 0.335 per m^3, way below the cost of desalinated water (Cy£ 0.62 per m^3). The water bill is only a minor item in the budget of most Cypriots: less than Cy£ 5 per month or Cy£ 60 per year. Many consumers are willing to pay about Cy£ 200 per m^3 for bottled water, although tap water is of good drinking quality. The European Union Water Framework Directive recommends that by 2010 the price of water should reflect the costs involved in providing it, including capital costs, operation and maintenance, as well as environmental and resource costs. Besides recovering cost, water policy for this segment will have to consider disincentives to the use of drinking quality water in garden irrigation and to foster and encourage use of cheaper, lower quality water (groundwater, recycled water) for this purpose. Unaccounted water and losses in many domestic water distribution networks, mainly in rural areas, are quite high and considerable additional effort should be done to detect and replace defective pipes and to establish a caring attitude towards precious water.

D.2 Seawater desalination

Aggravated water scarcity in the 1990's and the deficient situation of water supply for domestic uses, including the tourist sector, caused state intervention to ensure a stable, continued supply of good quality drinking water through seawater desalination. The measure was successful in providing to the domestic sector, including the economically important tourist industry, a steady supply. However, considering that close to 70% of all water resources on Cyprus are used by agriculture, a sector that contributes only a minor part to national wealth and struggles with labour scarcity problems, a close scrutiny of water allocation policy appears to be in order. It is important, in setting policies, to consider the ways in which water can best contribute to national wealth. Water security, food security and energy security are all part of a national security equation that is carried by a strong and resilient economy.

D.3 Agricultural water use

The irrigation water tariff is Cy£ 0.0631 per m^3, about one tenth of the cost of desalinated water. The EU Water Framework Directive would call for this tariff to be increased to full cost recovery at about Cy£ 0.30 per m^3. However, this target can be overruled as a result of social, environmental and economic effects of full cost recovery. Water policy for the agricultural segment may consider a number of incentives and disincentives to conciliate water availability with demand and to ensure that adequate food security and rural targets are achieved in exchange for the substantial subsidy the segment is receiving. The matter is complicated by the traditional two-tiered nature of water rights: users of government owned water systems pay the established tariff, while owners of "old" water rights and wells do not pay. Under such circumstances, an increase in water tariffs in the public systems is bound to encourage further overexploitation and mismanagement of groundwater.

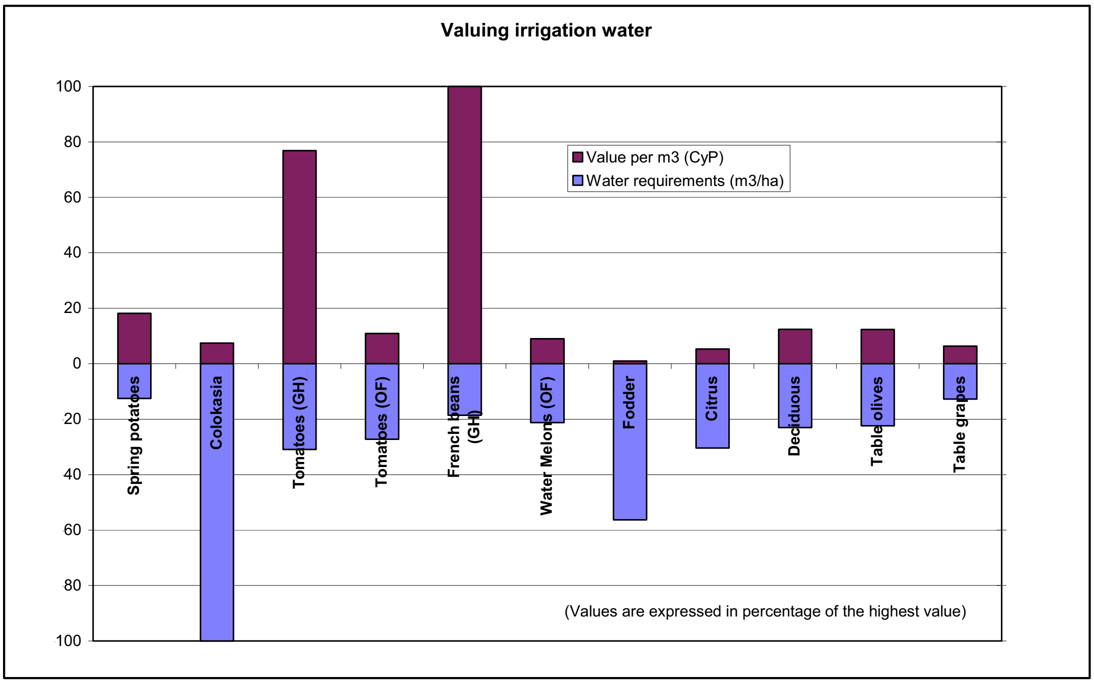

Figure 7: Water requirements in m^3 per hectare and the value obtained per m^3 of water

In a farmer's calculations, the cost of water represents only one parameter; other farming costs include infrastructure, labour and marketing risks. Rather than by the amount of water used for growing a crop, farmers are likely to be guided by the profit that can derive from the crop. Figure 7 shows, for a small selection of crops, an estimate of water requirements in m^3

per hectare and the value obtained per m^3 of water. It appears that crops with high water requirements, such as colokasia and fodder, yield a low value per m^3 of water. Figure 8 shows, for the same selection of crops as in Figure 7, the cost of water, other costs (labour, financial, etc.) and the benefit per hectare reaped by the farmer. None of the crops brought in example appears to be particularly sensitive to the cost of water. The water-greedy colokasia shows a good benefit for relatively small costs. Greenhouse tomatoes appear to be profitable and little affected by the cost of water but the high incidence of other costs suggests that the farmer may be running high risks and a shift in market prices could lead to a situation similar to that exemplified for french beans (large non-water cost and financial loss). Citrus, which takes 32 percent of all irrigation water, shows a low value-in-use of water and modest net benefits and invites to closer scrutiny in agricultural water policy.

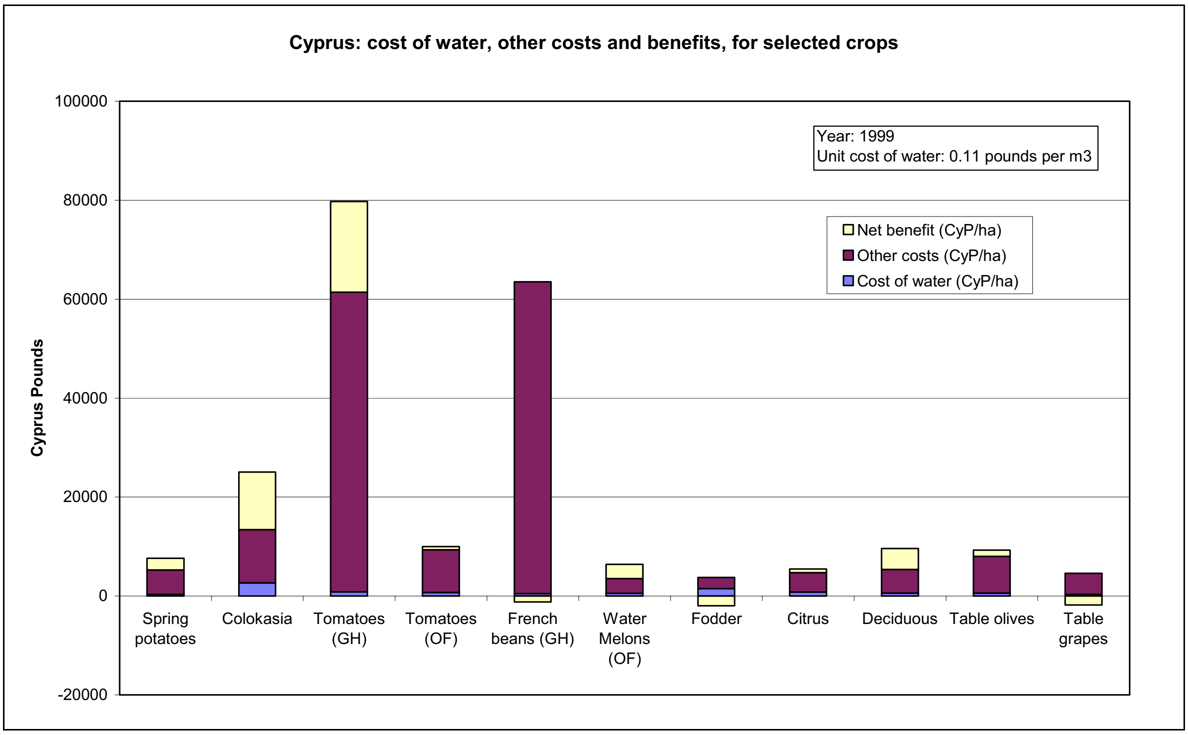

Figure 8: Cost of water, other costs (labour, financial, etc.) and benefits per hectare of selected crops

It would thus follow that, in a context of growing water scarcity and increasing water prices, a mix of policies should foster agronomical research and extension services covering a large diversity of suitable crops. For the majority of small-scale farmers, support to collective marketing arrangements can help to improve crop planning and reduce the risks to the farmer. With evolving EU policies, as subsidies for agriculture phase out, other subsidies compatible or even supported with European policies can phase in. These may be designed to support the farming sector to produce high added-value fresh products for an increasingly sophisticated services and tourism sector, and to enhance the role of farmers and rural people in protecting and enhancing natural and environmental resources.

D.4 Groundwater management

During 30 years of generally lowered rainfall and several dry spells, aquifers were over-exploited and depleted of the water contained in them. Groundwater extraction is larger than recharge. Because aquifers are depleted, agricultural risk has increased: unless groundwater is left to recover to a reasonable level, the resource will be of limited help to mitigate future water shortages. It is relevant for the island's water security that the adverse trend in groundwater is checked and reversed. It should not be taken for granted that all farmers necessarily subscribe to the principles of sustainability: it can well be, for example, that pumping groundwater for profitable crop production is seen by the farmer as a temporary activity that will allow earning enough money to get the children through college and out of farming. Policies should therefore reflect national and communal objectives as much as the legitimate objectives of individual farmers.

D.5 Water recycling

A substantial amount of water is recycled and has become available for agriculture and the urban and rural environment. Recycled domestic water is a growing resource in Cyprus. Policies may strengthen its role in enhancing the urban and rural environment (green areas, parks, forestation), in backing up agricultural water needs and in recharging groundwater reserves. Policies should probably discourage using the boon of recycled water for expanding an already subsidized agriculture.

Annex 1 Supporting services and facilities strengthened through the project

1. Databases[8]

The project database is a Web database application. It provides to clients a remote access through an Internet browser, without installing any kind of additional software on the client's computer. This approach provides the information system designer a wide set of possibilities. All the changes or software enhancements in the database are instantly available to the users. The result of user interaction is a data view in common formats like tables, graphs and statistics. Data export is also available, for ASCII and MS Excel file format in a form of data array and for MS Word file format as tabular report. The main application of the database is a map interface showing the geographical representation of the objects in the database (Figure 9).

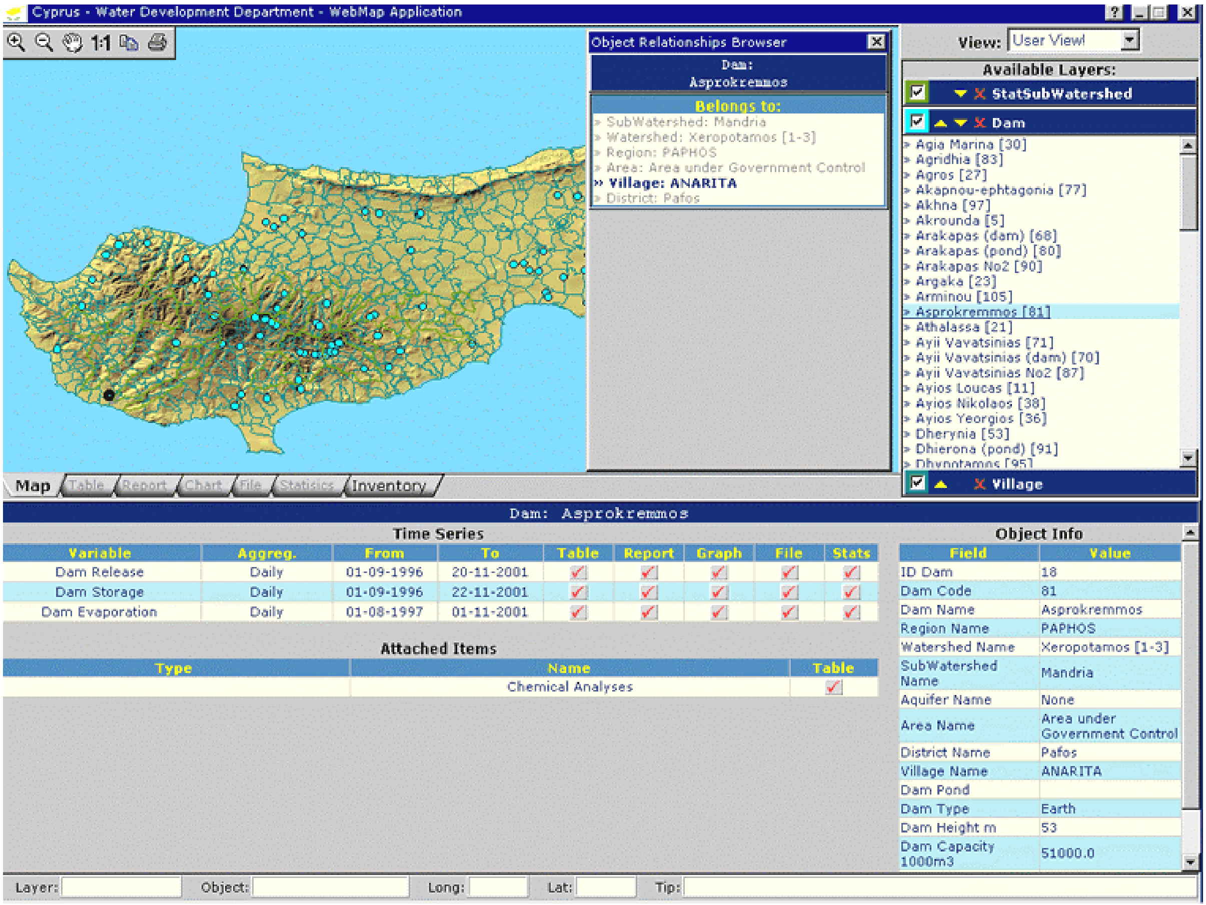

Figure 9: Map interface showing the geographical representation of the objects in the database (Lekić and Artinyan, 2001)

The reaction of the application to user interaction strongly depends on the speed of the user's computer. Recommended hardware configuration at present is Pentium 600 MHz with at least 128 MB RAM and screen resolution of 800x600 or higher. The application startup as well as regeneration of maps during runtime depends on the speed of the network. The recommenced LAN capacity is 100Mbs. The application was tested on Windows 98, Windows NT 4.0 and Windows 2000 Professional as OS and on Internet Explorer version 5.0, 5.5 and 6.0.

Organization and storing of aquifer data were found to be inadequate and deserve improvement. A database compatible with GIS applications should be developed for all aquifer data. This work was not foreseen under the project.

[8] Lekić, D. and Artinyan, E. (2001): Water Resources Data Management System

2. Models[9]

Rainfall data series are easier and less costly to obtain than river flow data. Rainfall/runoff models are used, among other purposes, to extend streamflow data necessary for water resource planning and management and hydraulic design. Such studies were made in Cyprus since 1967 using a model called, after its author, Mero. The project commissioned a study to review the Mero model, consider its possible upgrading, propose alternative models which could be applicable, recommend a course of action regarding rainfall/runoff modelling, and participate in training of staff. As an outcome of the activity, the Mero model continues to be used at WDD, updated and with modernized interfaces.

3. Monitoring network[10]

The objective of this activity was to examine and assess the effectiveness of the hydrological data collection network and to review the quality control in the hydrological data collection process. A statistical analysis led to conclude that the temporal variations of the annual streamflow are be estimated with a significant level of confidence at any section of a river on which there are gauging stations. Annual streamflow can also be estimated for adjacent un-gauged rivers, but with lower accuracy. The analysis also concluded that the estimation of mean annual flow for ungauged watershed with the actual stream-flow stations network is doubtful. Each of the existing stations has specific and important relevance for water resources assessment and the majority of the stations are valuable for reservoir management. Existing water level measuring instruments should be progressively replace with digital recorders. Some of the digital recorders should have a capacity for real time transfer of information.

The urban precipitation network has only two precipitation 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. 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 1970/1971-1999/2000 period.

The existing monitoring system of the aquifers covers only the main aquifers and in most cases is insufficient and inadequate. A great number of smaller aquifers of local importance are not monitored at all. The networks and the surveys for quality control of the aquifers have been neglected for many years.

4. Growers' database[11]

To assess water demand of Cyprus, accurate information on the cropping patterns was required. To this end, a crop/grower database was developed. The aim of the databank is to provide easily accessible and editable information about farmers and farming companies, their land properties and the plantations on these land properties. The database enables the user to view all the land properties and plantations of a specific grower in a compact form and edit them; collect cropping pattern information per district, village, per sheet or plan, etc.; collect all the grower's cultivating a specific crop; and collect information using other scenarios from

9 Wheater, H.S. et al. (2001): Review and Development of Rainfall-Runoff Modelling Tools for Water Resources Applications in Cyprus
10 Rossel, F. (2001): Hydrological Network Analysis and Optimization
11 Dörflinger, G. (2001): Development of a Databank for related Agricultural Crop/Grower Information

among the stored input data. The database is designed to be compatible with a future GIS application, which will give the opportunity to present the database outputs in the form of maps allowing quick overviews and easy visual analyses.

5. Remote sensing and GIS[12]

Remote sensing bears a potential for agricultural development planning, monitoring crops, estimating water use and demand and assessing the water resources situation. A pilot remote sensing survey was carried out within the Project in order to examine the possibility of applying remote sensing techniques. Results on land use interpretation indicate high accuracy for sea and dam water, built up areas and forest; however, there was low accuracy on crop classification. Only citrus and olive plantations were identified at significant levels. The results so far obtained, after applying the remote sensing technique are below level of acceptance. The team that carried out the study believes that many of the problems encountered can be overcome in the future and the accuracy of the results considerably improved.

[12] Savvides, L. et al. (2001): Pilot Survey Project: Use of Remote Sensing Techniques for Land Use Classification and Processing with GIS

Annex 2 List of reports produced for the WDD/FAO project

The "Re-Assessment of the Water Resources and Demand of the Island of Cyprus" comprises 3 Volumes: Volume I, II and III.

Volumes I, II and III are published as a set: ISBN set 9963-1-7003-X

In addition each volume is published separately:

Volume I: ISBN Vol.I 9963-1-7004-8

Volume II: ISBN Vol.II 9963-1-7005-6

Volume III: ISBN Vol.III 9963-1-7006-4

Volume I – Water Resources

Rossel, F. (2001): Hydrometeorological Study examining Changes in recorded Precipitation

Rossel, F. (2002): Surface Water Resources

Georgiou, A. (2002): Assessment of Groundwater Resources of Cyprus

Volume II – Water Demand and Use

Savvides, L., Dörflinger, G. and Alexandrou, K. (2001): The Assessment of Water Demand of Cyprus

Dörflinger, G. (2001): Development of a Databank for related agricultural Crop/Grower Information, Annex in: Savvides, L. et al. (2001): The Assessment of Water Demand of Cyprus

Savvides, L., Dörflinger, G., Iacovides, I. and Skordis, P. (2001): Pilot Survey Project: Use of Remote Sensing Techniques for Land Use Classification and Processing with GIS

IntelliGraph Consultants (2001): Preparation of Data for GIS Analysis, Annex in: Savvides, L. et al. (2001): Pilot Survey Project: Use of Remote Sensing Techniques for Land Use Classification and Processing with GIS

Agrio Remote Sensing Ltd. (2001): Multispectral Classification Pilot Study, Annex in: Savvides, L. et al. (2001): Pilot Survey Project: Use of Remote Sensing Techniques for Land Use Classification and Processing with GIS

Agrio Remote Sensing Ltd. (2001): Multispectral Classification Pilot Study – Using Landsat TM data, Annex in: Savvides, L. et al. (2001): Pilot Survey Project: Use of Remote Sensing Techniques for Land Use Classification and Processing with GIS

Alexandrou, K. (2002): Agricultural Parcel Identification System, Annex in: Savvides, L. et al. (2001): Pilot Survey Project: Use of Remote Sensing Techniques for Land Use Classification and Processing with GIS

Volume III – Water Management supporting Tools and Documents

Lekić, D. and Artinyan, E. (2001): Water Resources Data Management System

Wheater, H.S., Bird, R. and Jones, D. (2001): Review and Development of Rainfall-Runoff Modeling Tools for Water Resource Applications in Cyprus

Rossel, F. (2001): Hydrological Network Analysis and Optimization

Marcoullis, C. and Vassiliadou, D. (2002): Water Legislation and Institutions in Cyprus

Marcoulli, E. (2002): Translation of the Water Entity Bill from Greek to English, Annex in: Marcoullis, C. and Vassiliadou, D. (2002): Water Legislation and Institutions in Cyprus

Klohn, W. (2002): Synthesis Report