Economics of Seawater Desalination in Cyprus

by

Mark P. Batho

B.S.C.E. (Civil Engineering)
Seattle University, Cum Laude, 1996

SUBMITTED TO THE DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ENGINEERING IN CIVIL AND ENVIRONMENTAL ENGINEERING

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Abstract

The Republic of Cyprus is currently suffering from severe drought conditions. This is not uncommon to Cyprus, as they frequently experience three to four year droughts every decade. They are currently in the middle of their fourth year of drought. Some Cypriots believe that the main reason for water shortages is due only to low levels of rainfall (average rainfall in Cyprus is 500 mm per year, and less than 400 mm per year is considered a drought year). It is not disputed that this is part of the problem. However, my belief, along with many Cypriots is that the biggest part of the problem is one of water allocation.

Agriculture in Cyprus contributes approximately 5% to the GDP, yet consumes 75% of available water in Cyprus. The remainder of water is left for the sector of the economy that produces the remaining 95% of the GDP, of which municipal, industrial and tourist uses are of greatest importance. One may ask why this is so. According to some Cypriots, it is because Cypriot farmers are thought to be a politically influential group, and that they farm more as a way of life, rather than to earn a living directly. Others discount this "way of life" theory. What is important, however is that farming is using a lot of water and is contributing very little to the GDP of Cyprus. For example, Citrus crops grown within the Southern Conveyor System (a large network of water conveyance pipes stretching for over 100 km in the southern part of the island) (see Figure 3, page 16) uses approximately 21% of all available water available in Cyprus, and without Government subsidies would not show profitability.

Although there may be some aesthetic value in citrus groves one must ask if it is economically and environmentally justified to continue farming citrus. To do so means building seawater desalination plants that contribute 5.0 to 6.0 kg of CO_2, a greenhouse gas, to the atmosphere per m^3 of water produced by desalination, along with the cost of the water nearing one US dollar per m^3. Desalination is a painful solution to Cyprus' water shortage that could be otherwise be addressed with a proper water allocation scheme.

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<u>Title:</u>
Economics of Seawater Desalination in Cyprus

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To all who may read this, thank-you, and just as a note, I may be reached "forever" at the following alumni email address: *atomic@alum.mit.edu*
Atomic? Yes, Atomic – just ask "The Herminator."

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> David H. Marks,
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Introduction

Water is the most valuable natural resource on the island of Cyprus, and currently, demand far exceeds supply, as Cyprus enters into the 4^{th} year of a drought. With reservoirs at some of their lowest recorded levels, many in Cyprus are left wondering what will happen in the future of water resources.

Three-Quarters of our planet is covered with water, yet of all this, only 2.5% is fresh water, of which approximately two thirds is frozen, and lies in the polar icecaps. Rising along with the demands of freshwater supply, are the opportunity costs of converting fertile river valleys to water supply reservoirs. To combat this, many countries are turning to salt-water desalination to add to their current supply shortcomings. The republic of Cyprus is no exception.

Currently in Cyprus, one desalination plant is in operation: the Dhekelia Desalination Plant. It is near Famagusta, on the southern shore of the island, near to the Dhekelia Power Station, from which it draws its power. This plant provides 40,000 m^3 per day. Cyprus has just entered into a contract with an Israeli firm to construct another plant near Larnaca, also in the south part of the island. This plant will provide an additional 40,000 m^3 per day. There are future plans to build two more plants, one near Limassol, and one in Paphos, both of which will supply 15,000 m^3 per day. Both the Dhekelia plant and the new Larnaca plant are Build, Own, Operate, Transfer (BOOT) contracts with a 10 year transfer period. The process of desalination used is that of reverse osmosis, with energy recovery turbines operating on the outlet.

The Dhekelia Plant is contracted to supply water at a cost of CY£ 0.54 per m^3, and the new plant in Larnaca will supply water at a cost of CY£ 0.42 per m^3. The approximate conversion rate at this time is 2 US$ to CY£ 1, so the cost of water from the desalination plants is US$ 1.08 per m^3 and US$ 0.84 per m^3 respectively

Seawater desalination, comes at a high price – a price that is above the cost of simply supplying the water. Desalination consumes vast quantities of power that are produced by fossil fuel consuming power plants in the case of Cyprus. There are considerable negative environmental externalities imposed by these plants, and generally speaking these are not internalized in prices charged to the water user. This is the case in desalination in The Republic of Cyprus. There are no extra costs imposed to include these externalities which are mostly in the form of air pollution such as carbon dioxide gas – one of the major contributors to global warming.

Desalination is one of Cyprus' last resorts in terms of water resources, and creates, in theory, an unlimited supply. However there are also certainly risks other than just the environmental ones in this type of water supply. When all of the power on the island is generated by fossil fuels, it leaves the prices and availability of drinking water in the hands of the countries that produce the fuel necessary to power the plant that supplies the electricity for desalination purposes. This risk is also not included in the price of the desalinated water, and as mentioned, neither are the negative environmental externalities associated with the burning of extra fossil fuel. Considering that if relatively dry climates like Cyprus' become drier as a potential result of global warming, more reliance will be placed on desalination, which produces the very gasses (CO_2, and NO_X) that result in further global warming and drier climates.

Although Cyprus, and many other Mediterranean and Middle Eastern Countries are turning to desalination as a last resort to meet continuing rising demands on water, not all are in favour of this solution.

Dr. Socratous of the Water Development Department in Cyprus writes:

"The environmental organization are against this measure [a new desalination plant west of Larnaca and others] because of its high cost and the burden it exerts on the environment, i.e. on the atmosphere due to the energy requirements of the plants as well as to the sea due to the dumping of the effluents from the plants. They are instead in favour of small desalination plants using renewable sources of power and probably heat generation from large complexes like hotels" (Socratous, 1998, p. 4).

One is left to wonder what can be done in areas like Cyprus that have significant variability in their rainfall, and are near the end of further exploitation of surface and ground water resources. However, Cyprus is not without water, and if limits were placed on agricultural irrigation, there would certainly be plenty of water for domestic users on the island. It seems to be more of an allocation problem, where vast amounts of water are used by citrus farmers, for example, who consume approximately one-third of available fresh water, yet would not be profitable without Government subsidies. With proper water resources allocation, i.e. away from crops like citrus and towards domestic users Cyprus may realize that there is more than enough water to go around. Only by removing subsidies on agriculture can the truly valuable crops justify the water they use, and as demand rises in domestic sectors, even these higher value irrigated crops (berries and tropical fruits in the case of Cyprus) may no longer be justified. The temporary purchasing of water from the farmers, in the form of a water bank, by the Government is one way to alleviate current shortages in supply to domestic users. Although, this too is a subsidy of sorts, it is very useful in the short term, especially in the case of droughts. Water Banking should be considered as a long-term solution to solving short-term drought problems. A brief description of water banking is outlined in the section called *water banking*, and can be found in the table of contents. Additional, detailed information is available in Appendix A, in Chapter 6 and 7 of a report entitled "Solutions to Water Scarcity in Cyprus."

Thesis Objectives:

- Explore current water allocation scheme in Cyprus.
- Look into water banking as a solution.
- Consider the implementation of desalination.

Thesis Findings:

- Due to subsidies low value users consume valuable, scarce water resources.
- Subsidies should be removed to allow market to return to efficiency.
- Implementation of a water bank will solve short-term allocations in the absence of the removal of water subsidies.
- Seawater desalination is a last resort that is only economical once all water allocation problems have been sufficiently addressed.

Background

Location and Physical Description

The island of Cyprus is located in the northeastern part of the Mediterranean Sea, some 70 kilometers south of the coast of Asia Minor (Figure 2.1). The island lies between latitudes 34°33' and 35°41' North and between longitudes 32°30' and 34°35' East. The total area of the island is 9,251 square kilometers with a length of approximately 222 km and a maximum width of approximately 95 km. The coastline is irregular and is 782 km long. Cyprus is the third largest island in the Mediterranean Sea.

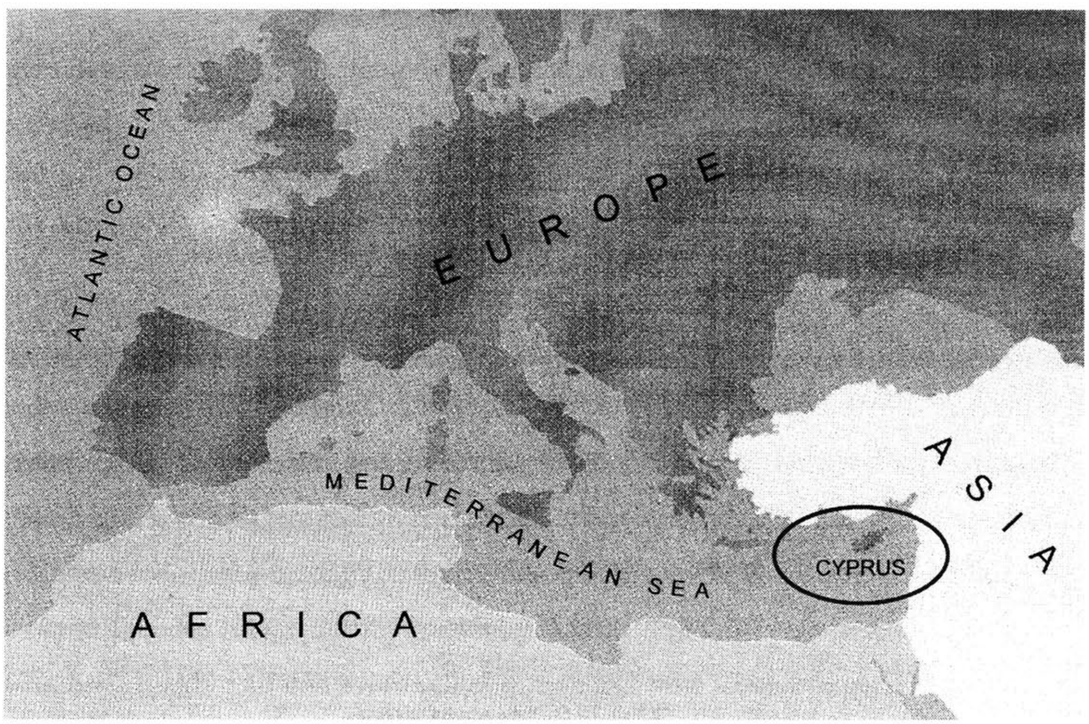

Figure 1: Map of the Mediterranean Sea Showing the Location of Cyprus

The altitude ranges from sea level to the peak of Mt. Olympus at elevation 1,957 m. The coasts are in general low and shelving. Sandy beaches bounded by dunes do exist, but for the most part the shores are rocky or stony. The principal physiographic features of Cyprus are two main mountain ranges separated by a wide sedimentary plain called the Mesaoria. The Kyrenia Mountain Range runs along the northern coast and extends towards the Karpas Peninsula – the "panhandle" of Cyprus. The Troodos Range is in the south-central part of the island and is visible from most of the island. Mt. Olympus is located in the Troodos Range (Solsten, 1991, xiv). A map of the island of Cyprus is shown in Figure 2.

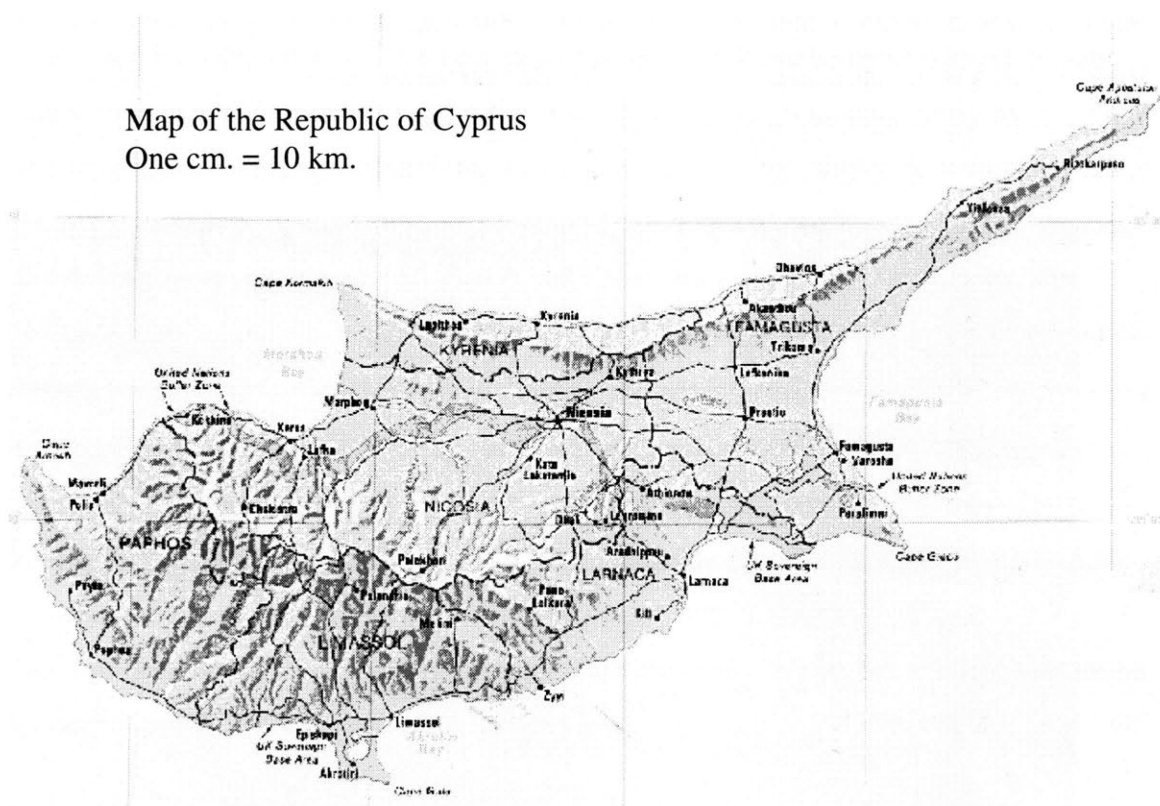

Figure 2: Map of Cyprus

Geology

In contrast to many of the neighboring karst islands of the Mediterranean, the geology of Cyprus is highly variable and complex. In general, approximately 80% of the island's surface geology is composed of calcareous sediments while the remaining 20% is formed from basic igneous rocks. The northern mountain range is mostly limestone and marbles with scattered basaltic sills and dykes. The southern Troodos Range is an igneous range with a variety of rock types. This range is bounded by white chalky marls and limestone. Some of the oldest known copper mines in the western world are located on the slope of the Troodos Range. The wide central plain was originally part of the ancient sea bed, but it is now overlain by recent alluvial deposits eroded from Pliocene and Pleistocene crusts and the nearby mountains. The sedimentary rocks of the central plain include calcareous sandstone, marls, and conglomerates.

The soils on Cyprus are likewise varied due to the numerous parent rocks. In general, the soils are thin and subject to heavy erosion during the sometimes intense winter rains. The central Mesaoria plain is the most fertile area and receives newly eroded silts each year during peak runoff period. The long history of human habitation on Cyprus has led to extensive modification of soils in many areas due to agriculture and forestry (Thirgood, 1987, 23-27).

Climate

The climate in Cyprus is typical of the Mediterranean area. The summers are hot and dry, and the winters are mild and can be relatively wet. The average maximum summer temperature is 35° C in August and the average minimum winter temperature is 9° C in December. The warmest temperatures are recorded at lower elevations while the cooler temperatures occur in the mountain ranges. Intermittent snow is not unusual on the slopes of the Troodos Range during the winter (Lytras, 1994).
Precipitation is highly variable over both elevation and time. The average annual rainfall over all of Cyprus is estimated between 470 mm to 515 mm. Average annual rainfall varies between 250 mm per year in the Mesaoria Plains to 1100 mm per year on the peaks of the Troodos Range. The isohyetal lines of equal rainfall roughly correspond with elevation contours producing higher average rainfall as elevation increases. Temporally, the majority of rainfall comes from late October to early May. On average, half of the average precipitation falls during December and January (Tsiourtis, p. 79). Estimates of the total average precipitation volume which falls on Cyprus each year range

from 4,500 million cubic meter (MCM) per year to 4,650 MCM per year (Ministry of Agriculture, 1998).

History

The history of Cyprus is long and distinguished. Neolithic cultures existed in Cyprus as early as 6000 BC. Remnants of these societies may now be found in the Museum of Antiquities in Nicosia. Almost 5,000 years ago, copper was first discovered on the island, in fact the Greek word for copper is *Kypros*. Copper and timber resources, along with Cyprus' strategic location along the maritime trade routes, drew the interest of many foreign powers. Indeed throughout history Cyprus has been subject to invasion and colonization by a host of civilizations and empires. A list of powers which have played a part in Cypriot history includes the Hittites, Egyptians, Greeks, Phoenicians, Romans, Byzantines, Arabs, Franks, Venetians, Turks, and British. It was not until a mere four decades ago that Cyprus was actually ruled by Cypriots.

Cyprus has been host to some of the most important personalities in the history of the Western World. Alexander the Great occupied the island in 333 BC. Cicero was sent as a Roman governor. St. Paul visited the island in 45 AD. Richard the Lionhearted stayed several years while returning from the Crusades. Of particular importance to the history of Cyprus was the establishment of the Orthodox Church in the 5th Century AD and conquest by the Turks in the late 16th Century. These last two events are among the keys to the current social and political situation on the island (Thurgood 1987, pp. 3-16).
The recent history of Cyprus might be said to begin when the British took control of Cyprus from the Ottomans in 1878. Many Cypriots fought alongside the Allies during the Second World War and expected independence after the war was won, but Britain was reluctant to leave Cyprus. In 1955, an armed liberation movement began and Cyprus became an independent Republic, although the British did retain several Sovereign Base Areas on the island. Development in Cyprus advanced rapidly after independence, but tensions between the ethnic Greek and Turkish communities were continually a concern. In 1974, a coup was staged by a military junta. During this period of crisis, Turkey

landed large numbers of troops on the northern part of the island and invaded. The resulting war left the island divided with Turkish occupation of the north and Government of the Republic of Cyprus control of the south. A UN peacekeeping force now patrols the cease-fire line (Solsten, 1991, pp.23-45).

This report and proposal deals only with water resources in the Government-controlled areas of the Republic of Cyprus. The water resources of the island should be inseparable, but the de facto division of the island has ultimately led to separate development of water infrastructure and usage.

Society

The current total population of the island of Cyprus is approximately 746,000. The population living in the government-controlled part of Cyprus is 650,000, while the other 90,000 reside in the occupied area. These figures do not include an estimated 90,000 people who have settled in the Turkish-occupied areas since 1974. The capitol of the Republic of Cyprus is Nicosia which is located in the lowland plains in the center of the island. Other large cities include Larnaca, Limassol, and Paphos. Famagusta and Kyrenia are in the occupied area. Approximately 70% of the southern population live in urban areas. For administrative purposes, Cyprus is divided into six districts. Nicosia, Larnaca, Limassol, and Paphos are in the government-controlled area while Famagusta and Kyrenia are not. (Planning Bureau, 1997)

Economy

The unit of currency in Cyprus is the Cypriot Pound (CY£). The exchange rate fluctuates around two US Dollars per Cypriot Pound. The Gross Domestic Product of the Republic of Cyprus in 1997 was CY£ 3.48 billion (US $ 6.96 billion). The primary sector of the economy, including agriculture and mining accounted for 4.7% of the economy. The secondary sector, including manufacturing and construction, accounted for a further 22.5%. The remaining 72.8% of economic production was produced in the tertiary sector, which includes tourism, transport, finance, and services. (www.kypros.org). Of all economic activities in Cyprus, the single largest industry is tourism. On average, over two million tourists visit Cyprus every year.

The standard of living in Cyprus is relatively high. The average per capita yearly income is CY£ 6,700 (US$ 13,400). Unemployment and inflation have both been relatively low recently with rates of 3.1% and 3.0% respectively. (www.kypros.org)

Water Resources

Cyprus is an island. This inescapable fact defines Cyprus' water resources situation. Ultimately, the only naturally available fresh water comes or came from precipitation which fell from the skies onto the island. Even groundwater is related to precipitation since at some point in the past rain waters infiltrated down from the surface, for aquifers can only be "recharged" from the surface. Desalination has recently become an option to enhance water supply, but it is expensive and currently production rates are small.

The total average quantity of precipitation which annually falls over Cyprus was calculated based on average annual precipitation and total surface area. This quantity does not however represent the actual annual total available volume of fresh water. The climate, vegetation, and soil all combine to produce a yearly evaporation rate of more than 80% of precipitation. Thus for every 100 cubic meters of rain which falls on Cyprus, more than 80 cubic meters of water returns directly to the atmosphere without the possibility of human usage. A commonly stated figure for *average* annual "usable" water is 900 MCM. Of this amount, approximately 600 MCM is in the form of surface water. Dams divert 190 MCM of surface water, another 150 MCM is diverted directly from rivers, and the remaining 260 MCM flow straight to the sea. Groundwater accounts for the other 300 MCM. Currently 270 MCM is estimated to be pumped or extracted from springs while 70 MCM flows to the sea. The total annual average amount of fresh water currently available for use throughout the entire island of Cyprus is thus 650 MCM. An estimated 40 MCM of this quantity is thought however to be overpumping which results in the unsustainable "mining" of groundwater (extracting more water than is recharged to the aquifers). Only 63% of the land area of Cyprus is controlled by the government of the Republic of Cyprus, so straight linear extrapolation would suggest average freshwater diversion and extraction of 385 MCM in the government controlled areas of the island. Government estimates state that overall agricultural water demand is 193 MCM per year while municipal, industrial, and tourist demands sum to another 55 MCM. The total demand is thus 248 MCM per year, or about 65% of that suggested by the water balance. Yet water is scarce in Cyprus, either due to periodic droughts, overestimation of supply, or both.

The Southern Conveyor Project

The Water Development Department (WDD) began planning the large-scale development of water infrastructure in the 1960's after the nation gained its independence. These plans included five major schemes to interconnect and form a complete loop around the island with the Troodos mountains in the center. This loop would allow any local excess of water to be distributed to areas with shortages, which are to be expected due to the large variability of rainfall across the island. The plans also proposed the construction of many dams to increase the surface water storage dramatically. The slogan to summarize this new policy was stated as "not a drop of water to reach the sea."

Table 1: Urban and Rural Centers of the Southern Conveyor Project

	Nicosia Area	Limassol Area	Larnaca Area	Famagusta Area
Urban Centres	Nicosia	Limassol	Larnaca	Famagusta
Rural Centres				
1	Lymbia	Episkopi	Aradhippou	Pyla
2	Pyrga	Kolossi	Klavdia	Xylotymbou
3	Kornos	Erimi	Trersephanou	Xylophaghou
4	Psevdas	Kandou	Kiti	Ormidhia
5	Sha	Phinikaria	Pervolia	Avgorou
6	Mosphiloti	Moutayiaka	Meneou	Liopetri
7	Alambra	Ayios Tykhonas	Dhromolaxia	Paralimni
8	Nisou	Parekklisha	Kalokhorio	Phrenaros
9	Perakhorio	Pyrgos	Livadhia	Dherinia
10	Dhali	Moni	Voroklini	Sotira
11	Yeri	Monagroulli	Mazotos	Ayia Napa
12	Laxia	Pendakomo	Alethriko	Akhna (Akhna Forest)
13	Xeri	Asomatos	Pano Lefkara	Vrysoules
14	Lythrodhontas	Trakhomi	Kato Lefkara	Ayia Thekli
15	Lakatamia	Amathus Dev.Area	Vavla	E.A.C. Area
16	Anthoupo1is	Episkopi	Zygi	Dhekelia
17	Mammari	Akrotiri	Kalavasos	Ayios Nicolaos
18	Dhenia	Berengaria	Maroni	Troulli
19		Kato Polemidhia	Psematismenos	
20		Ypsonas	Covernor's Beach	
21			Marj	
22			Menoyia	
23			Kofinou	
24			Anafotia	
25			Agglisides	
26			Kivisili	
27			Kelia	

Notes:

1. For convenience, the Larnaca villages of Pyla, Xylotymbou, Xylophagou and Ormidhia are included under Famagusta Area. Similarly, the Larnaca villages of Kornos, Pyrga, Mosphiloti and Psevdas are included under Nicosia Area.
2. The suburbs and adjacent villages included in the urban centers are given below
   Nicosia: Eylenja, Kaimakli, Ayios Dhometios, Engomi, Strovolos and Pallouriotissa. The Turkish occupied sector of Nicosia is also included as it receives water from the same sources.
   Limassol: Ypsonas, Polemidhia, Ayia Phyla. Ayios Athanasios, Mesa Yitonia, Yermasoyia, Potamos tis Yermasoyias and the SBA married quarters of Berengaria.
   Larnaca: Aradhippou

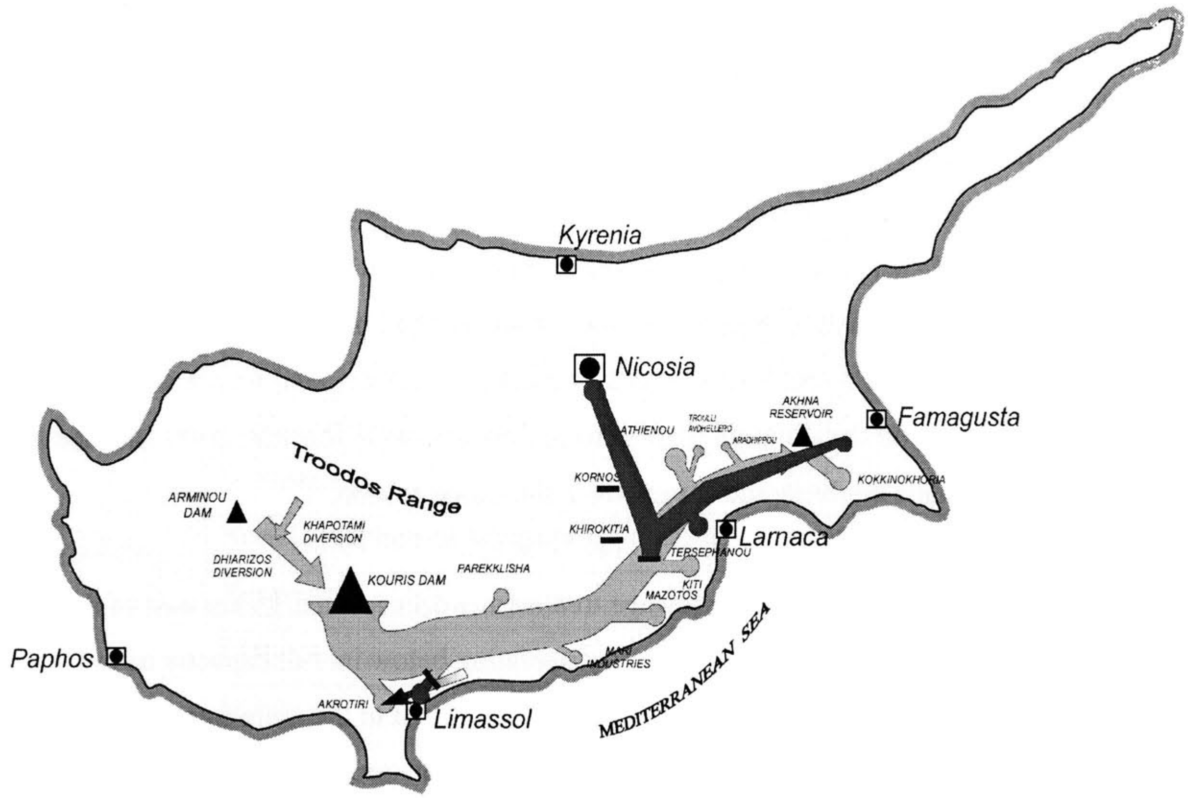

Figure 3: Map of the Southern Conveyor Project

The above map includes a schematic of the Southern Conveyor Project (SCP) with the general direction of flow from West to East. The Kouris Dam is shown as the principle source because it has the largest capacity at 115 MCM and a height at 110 m. This earthfill dam was constructed in 1988. The total surface water storage for the SCP is 176 MCM and the bulk of these dams were constructed in the 1980s. The Southern conveyor proper consists of a ductile iron pipeline of 1.8 m diameter and 100 km length. The Dhiarizos diversion tunnel is 14.5 km long, while the Tersephanou-Nicosia conveyor is 36.5 km in length. The dam structures are very impressive partly because they are newly constructed and partly because of their massive dimensions including the spillways designed for maximum probable flood (1 in 1000 year). The entire scheme is monitored and controlled by a modern System Control And Data Acquisition (SCADA) system from the Water Development Department WDD headquarters in Nicosia. The important parameters like reservoir levels, pipeline flows and pressures are recorded. Restrictions on supply are activated by the automatic closing of valves on reservoirs reaching "shut-off" levels.

The relatively new Dhekelia desalination plant is not shown, but is located to the east of Larnaca in the bay, and after expansion the plant now has the capacity to supply 40,000 m^3/day of potable water extracted from the Mediterranean Sea. It is connected to the Tersephanou –Nicosia conveyor just downstream of Khirokitia Treatment works. The desalination plant receives power from an adjacent oil-fired power plant for all but 3 hours a day. Between 5 and 8pm the peak domestic energy demand forces a short daily shutdown. A second desalination plant is to be constructed in the year 2000 with the same capacity, thus doubling the supply from the saline source.

Limassol has a newly constructed sewage treatment works located 15 km east of the city capable of tertiary treatment. It is currently operating below its full capacity as only a small percentage (10%) of the town's sewage is connected to the main interceptor rising main and only 3.5 MCM of tertiary treated sewage is now produced. Connection to the main sewer has been impeded by of the age of the city and its buildings and the narrowness of its streets. This water has gained acceptance for agriculture in the last several years and is used strictly for agricultural purposes. A new sewage treatment works at Nicosia is being planned and will increase the water available for reuse substantially (World Bank, 1996).

Previous to the construction of the SCP, land was irrigated to a lesser extent using groundwater pumps. These pumps are generally still in operation, but are costly to operate because of the relatively large drop in water table levels. The irrigation water supplied by the WDD is cheaper. The total available storage in the aquifers in the SCP regions greatly outweighs the surface water storage, but the introduction of higher lift pumps in the last few decades has facilitated extreme mining of the groundwater so that the SCP is practically a surface water supply system at this stage. There are currently no measures being taken for controlling the evaporation from the reservoirs and the total loss is calculated at 6 MCM/year.

The irrigation areas developed to date are listed in Table 2, on the following page.

Table 2: Irrigation Areas within the Southern Conveyor Project

Government Irrigation Scheme	**Area (ha)**
Akrotiri	2298
Larnaka	498
Kokkinokhoria-Famagusta	4169
Kokkinokhoria-Larnaca	1167
Vasilikos	614
Non-Government Irrigation Scheme	**Area (ha)**
Yermasoia	3496
Larnaca	1706
Other	1825

Other Projects

Apart from the SCP a number of other major water resource developments have taken place recently. The first to be mentioned is the Paphos Irrigation Project that receives most of its supply from the Troodos mountains as well. The irrigated area developed in the region around Paphos is only 5,000 ha, so that there has been an excess of water here during years when severe drought has been experienced on the East Coast. Naturally preliminary designs of a connection between the Paphos system and the SCP have been undertaken for costing purposes, but there are no proposals to begin this contract as yet. The town of Paphos is supplied from wells pumping an aquifer that is recharged adjacent to the Asprokremmos dam (capacity 51 MCM).

Also on the West Coast is the Khrysokhou Irrigation project which is smaller than the Paphos system with an irrigation area of 3,100 ha.

Drought

Based on the average values of rainfall and runoff described above, Cyprus should not have a water scarcity problem. The problem is that over time, about half of the measured values of rainfall and runoff will be below the averages. Moreover, historic data indicates that rainfall in Cyprus is extremely variable, so the actual amount of available water may be significantly below the norm in any given year or series of years. Several consecutive years of rainfall that are significantly below normal can lead to drought conditions. The construction of surface water reservoirs was meant to provide a certain amount of resilience to the water resources system during low rainfall years by creating multi-year storage; however, the total storage volume of all reservoirs in Cyprus is only 303 MCM. When compared to the estimate of a total demand of 248 MCM per year, it is apparent that water supplies could become scarce after only a few consecutive years of poor rainfall.

Most recently, low rainfall in the years 1996 to 1999 have produced drought conditions in Cyprus. In the last four years, annual rainfall has been less than 400 mm per year. At the end of March 1998, storage levels in Cypriot reservoirs were at historic lows. The total reservoir storage was only 38 MCM, or 14% of capacity (Socratous, 1998), and the situation became worse later in the year. The drought has caused a variety of problems for Cyprus. Water allocations have had to be severely curtailed to agriculture, municipal, industrial, and tourist users. Rationing to cities was instituted such that water was only delivered once every three days to cities and towns. Irrigation water to seasonal crops was almost completely restricted, and water allocated to permanent crops was reduced to close to the absolute minimum level needed for survival. There are many consequences of such reductions in water supply. Domestic users must contend with the inconvenience of intermittent and limited water. Hotels must restrict landscaping activities and ask tourists on holiday to be conscious of water usage. Business and industry may be required to reduce production. All of these users may also choose to supplement their own individual supplies at a significantly higher cost through purchases from private water vendors. Agriculture suffers even more during such times of severe shortage because crop yields are significantly or completely reduced. Potato exports in 1995, before the drought, totaled CY£ 44,300,000, but by 1997 exports had fallen to CY£ 8,400,000 – an over 80% reduction. It is interesting to note however that over the same period the value of citrus exports actually increased by CY£ 1,300,000, from CY£ 16,000,000 to CY£ 17,300,000 (Cyprus Planning Bureau, 1997). Water scarcity also constrains growth and new development in all sectors of the economy.

Water scarcity is very real in Cyprus. Droughts of three or more years must be expected. During these extended droughts it must be assumed that demand for water will certainly exceed supply. Extraordinary measures will be required of the Water Development Department, farmers, and all other citizens of Cyprus in order to properly manage water during these periods of drought. Innovative ideas will be needed to cope with such severe water scarcity.

Potential Solutions

Before I go into desalination and the concept of water banking in more detail, I would like to elaborate on a number of potential solutions exist for alleviating the water shortage problems in Cyprus. I will briefly expand on how these solutions have already been implemented, or why they are not feasible. As mentioned in the executive summary, in Cyprus, water banking has the ability to free up large amounts of water for domestic uses. However, one of the main focuses of long term future water supply enhancement is through the process of seawater desalination. Desalination may be able to theoretically supply an infinite amount of water, and although this may be true, one must first consider the economics and environmental impacts of this expensive solution.

Demand Reduction

In a situation of water shortage, one must look not only at supply enhancement, but also at demand management. Below, is a list that has been created to outline some of the ideas that demand management encompasses.

1. Control Leakage
2. Increase Water Prices
3. Improve Irrigation Efficiency
4. Reduce Demand Per Capita through Conservation Education
5. Reduce Total Area of Irrigated Crops
6. Change Crop Planting Patterns to More Water Efficient Crops
7. Install high-efficiency, low water use appliances and fixtures in homes and businesses
8. Limit Water Uses

1. Leakage Control

Leakage control is very often seen as an efficient way of reducing water losses in general. However, when leakage is reduced to approximately 15 percent or less of total flow, it is generally not seen as economical to further leakage control, due to diminishing marginal benefits. Cypriots have recently been very conscious of water supply pipe leakage, and Cyprus is known, therefore to have relatively low their supply network leakage rates

Total unaccounted for water in 1984 in Nicosia was in the order of 29% of the total water demand (2.75 MCM). Prior to 1985, the leakage control policy was merely a passive one: leaks were fixed when they were noticed. From 1985 to 1987, remedial actions were taken in the hope of reducing these water losses (Tsiourtis, 1995). Detailed monitoring was done on a regular basis, and this data was recorded on a computerized logging system, which was downloaded to a computer system. After much data collection, flow meters were installed at key location. Results were analyzed to determine areas in which an increase in consumption was noticed. If there was no explanation for the increase, an inspection team was dispatched to find the potential leak. Telemetry was introduced in 1991 and is the present system used today. Flow and pressure information is collected every five minutes, and statistical analysis is performed to find leaks. This statistical analysis will eliminate any apparent leaks due to meter leaks.

Active leakage control is justified when the marginal cost of water continues to rise. The total estimated quantity of water saved through leakage control has been nearly 7 MCM in total between 1985 and 1995 (Tsiourtis, 1995).

The comprehensive meter replacement program is ongoing; many older mechanical meters are being replaced with highly accurate electromagnetic meters.

Although water is becoming more valuable due to increasing demand, there are diminishing marginal returns on leakage control, and economics must always be considered when adapting a policy such as active leakage control. Currently, Cyprus has reached a point where, due to significantly lower leakage rates, the cost of further leak reduction is no longer cost effective.

2. Water Supply Pricing

Pricing largely controls typical household water consumption. The demand of most water users is fairly elastic, showing declines in demand upon price increases. Once prices are raised, and demand starts to fall, we can follow this trend until a point where large price changes will cause little or no change in demand. This would be at the point where only a bare minimum of water is available. At this point, an increase in price will not reflect a decrease in consumption. This is a reflection of a high shadow value of water. The term shadow value or scarcity rent refers to the forgone opportunity cost of using a scarce resource today instead of preserving it for future use. Chapter 5 of this report goes into more detail on shadow values of water on Cyprus. In terms of domestic versus agriculture users of water, it should be noted that agriculture users are far more elastic than domestic users. This means that for the same change in the price of water, farmers will lower their usage of far more than a domestic user will.

Experience suggests that for authorities to truly know how much people value a particular investment made by a public utility, users must pay full economic price for the service provided. While this may not always be possible in rural areas, because of the large infrastructure costs, this principle remains very important. An efficient policy is one in which the net benefit is maximized for the most users, without consideration to how those benefits are necessarily distributed. This stems from the idea that a service provided should be equated to the cost of providing an additional unit, or in other words, its marginal cost. The price charged for the good needs to incorporate the total cost of construction and maintenance of the supply utility. The danger of pricing less than the marginal cost is that if there is a demand for additional units of water, expansion of the system can not be justified. Only if price equals marginal cost, will market forces encourage an economic level of production. In the case of Cyprus that has very limited supply of water, an extreme case would be to perhaps price water at the cost of desalination as a way to ensure that there is always available supply.

Another consideration in pricing is to ensure that the price of water is at a level that would encourage wastewater treatment, as is done in Limassol. This water is currently used by farmers to irrigate citrus and by hotels to irrigate gardens. The treatment plant in Limassol is able to achieve economies of scale during their treatment process, due to the large volumes it processes (3.5 MCM/year). One should note, however that this volume of water is only approximately one third of the plant treatment capacity. This is due to the high costs of constructing the necessary pipes to convey sewage to the plant. There are plans in place to connect more users to the plant in the future.

In Cyprus, it is believed that household users are still fairly elastic in their demand for water, and that increases in water prices would result in a drop in usage. Cyprus is in a drought situation.. However, in Cyprus, water prices are set by the Parliament: the Water Development Department (WDD) has no control over pricing. The WDD has tried to raise prices eight times to levels closer to the real marginal cost, but has been unsuccessful (Socratous, 1999, personal communication). Water pricing, although possible in theory is not considered a policy instrument to reduce demand in Cyprus due to the Parliament's unwillingness to raise water prices.

3. Improve Irrigation Efficiency

Irrigation efficiency is a measure of the fraction of water applied to a plant or crop that is actually transpired by the plant or crop in question. If an irrigation efficiency of 80% is cited, that means that a plant uses 80% of the water applied to it, and 20 % is lost to either evaporation, or to groundwater infiltration.

In areas such as Cyprus that are suffering from water shortage issues, a policy of trying to yield the highest amount of "crop per drop [of water]" needs to be in place. This essentially means that as little water as possible should be used to grow crops. With high water costs, any lost water is essentially lost money to a farmer, and this is particularly important when the water that is lost is not replaceable due to limited amounts of water being available. As the scarcity of water increases, so does the marginal user cost of the resource. This "user cost" may eventually increase to a point where the value of the water applied to the crop exceeds the income of the specific crop. With this in mind, efficient irrigation systems are a way of continuing profitability in farming.

There are a number of factors that may contribute to water waste during irrigation in Cyprus. Those are inefficient irrigation methods such as flooding, long basin irrigation, furrows, and improper irrigation schedules, none of which are in use in currently in use in Cyprus today. Cyprus currently claims irrigation efficiencies in the range of 80% to 85%, which is considered very high (Tsiourtis, Editor, 1995, p.73). This is largely due to the wide spread use of drip irrigation and mini-sprinklers. With present irrigation technology, it is not anticipated that efficiencies higher than those already in place in Cyprus be reached.

4. Reduce Demand Per Capita through Conservation Education

As water resources dwindle and demand increases, there is a need for people to realize that water consumption must be reduced, and wasteful practices that were commonplace in past years are no longer socially acceptable. Washing cars and watering lawns during summertime are some examples of such practices. It seems difficult for the Water Development Department (WDD) to make people realize the severity of the situation at times. Overpumping of aquifers which leads to seawater intrusion is an example of a consequence of people's water consumption behavior. With this case in particular, as well as many others, people need to be educated with respect to the results of their water consumption habits.

One of the problems with water usage in general is the public's lack of understanding of water supply systems. Average citizens knows very little about water resources, and this can be reflected in their behavior at times.

Water Conservation Education is one of the many ways to manage this scarce and precious resource. Most people will agree that water is a precious resource, and that one can not live without it, however people sometimes still feel that it is free for the taking.

Only through education will people begin to realize the true value of water. They will begin to understand that groundwater is not an infinite resource, and that one may only take out that amount that will seep back into the ground over time. One very effective method of education is through children in schools. This may sound easy; however, first teachers must be educated in this field before the knowledge can be passed on. The Water Development Department (WDD) may want to consider taking part in a joint program with schools that involves field trips to certain reservoirs during the dry season, along with conservation education in general. Children are likely to point out ways in which their parents can use water more efficiently. The WDD has, however already been very effective in promoting awareness with its "Save Water, It's Precious" campaign, with both posters and stickers in hotel bathrooms that remind people to save water. From taking shorter showers to using water efficiently while cooking, if everyone treats water like a precious resource there will be more available in the future. Conservation education has a practical limit, but the WDD estimates that through further education, water demand can be further reduced by up to ten percent (WDD, 1998).

5. Reduce total area of irrigated crops

Reduction in total irrigated land area is one way to reduce water consumed by irrigation. Evaporation is always a problem during crop irrigation. Even with efficient irrigation methods currently in use by the Cypriots, there are still water losses due to evaporation, and water used on crops may be more valued more in other sectors. This will cause smaller crop yields, and will have an effect on income generated by crop sales. With higher water prices in Cyprus for farmers compared to countries like the United States, irrigation efficiency is of paramount importance. This is not only because water is in itself physically scarce, but also overuse of water will eventually drive farming costs up due to the increase in the scarcity value of water. The WDD, during times of drought has been known to restrict water usage to farmers, which forces the farmer to reduce the area of irrigated land, so this has already been done to a certain extent.

6. Change crop planting patterns to more water efficient crops

In the case here, "water efficient" crops mean crops that have a higher financial yield per unit of water than other crops grown on the island of Cyprus. Since Cyprus has been experiencing a drought situation for the last few years, water is becoming a more scarce resource. Water therefore comes at a higher premium than during non-drought times. Cities are demanding more water, and with limited supply, it is necessary to use more efficiently. Constraints within agricultural are shifting more to water and thus away from previous constraints such as land and labor.

There is a need in Cyprus to value crops on the basis of financial yield per unit of water, as opposed to unit of land or labor. This is because water is the scarce resource. An example of one crop that is known within Cyprus to use a significant amount of water is a high value potato like vegetable called Colocasia. Based upon its high water use, this is one of the crops that the WDD would prefer people did not grow. However, Colocasia is able to provide farmers with a very high financial yield per unit of land –higher than any other crop grown within The Republic of Cyprus. Many people still grow this crop however, even during times of drought. This is obviously a problematic situation when water is scarce. If one looks at the financial yield of Colocasia per unit of water, it falls in comparison to other crops grown on Cyprus, such as berries and tropical fruits (not including citrus fruits). Please see Figure 7.6. Berries are the highest value crop grown on Cyprus if value is calculated on a per unit water basis. The WDD is currently working on reallocating water to more "efficient" crops.

7. Install high-efficiency, low water use appliances and fixtures in homes and businesses

Yet another form of water use reduction is the installation of water saving appliances, fixtures such as showerheads, and low flush toilets. Significant water loss reductions can be realized by such installations. Out of all the water used within a household, showering and flushing of toilets are responsible for most of the water used. In the Limassol area, where there is wastewater reuse, it may not be such a concern to use such devices, for whatever water is sent to the treatment plant will eventually be reused in agriculture.

People in Cyprus; however are very water conscious, and many households have water efficient appliances and toilets. Cypriots currently use approximately 137 litres of water per capita per day and this is already considered to be very low for a developed country (World Bank, 1996).

8. Limit Water Uses

Water uses such as car washing, swimming pools and hot tubs, and water parks are uses of water that need to be significantly limited in Cyprus, especially during times of drought. This is an issue, however that can be politically sensitive, for it is seen to somewhat infringe upon people's freedom.

Supply Enhancement

On the supply enhancement side, below is a list of possible alternatives, and their effectiveness on Cyprus.

1. Build More Dams
2. Reuse More Waste Water
3. Import Water
4. Pump More Groundwater
5. Reduce Evaporation
6. Examine Artificial Rainfall Enhancement
7. Connect Paphos Irrigation System to Southern Conveyor System (SCS)
8. Build more desalination plants

1. Build more Dams

As always, the building of more dams to further capture rainwater is a potential solution to increasing supply of water resources. By the year 2010, the demand of water on Cyprus is expected to rise to 415 MCM, of which 95MCM will be for domestic use, and 320 MCM for irrigation. This calls for construction of dams on the remaining possible rivers, Dhiarizos, Ezousas, Karyotis, Khapotami, Limnitis, Pedhieos, Akaki, and Peristerona.

The Dhiarizos-Ezousas Project will include two large dams, one on each river, as well as a water treatment plant on the existing Asprokremmos dam.

Two smaller recharge dams are to be built on the Dhiarizos River at Souskiou, and the Ezousas River at Episkopi.

Construction of the Arminou dam commenced in 1996, and is used to divert water towards the Kouris Dam, and into the Southern Conveyor System (SCS). This dam is estimated to add 4.6 MCM of water to the SCS

The Solea Major Water Works is to be the development of the Solea Valley water resources, to be used for irrigation of the Solea valley, as well as for additional supply to the city of Nicosia.

The Pedhieos river dam will be a recharge dam for the river valley groundwater aquifer up to Nicosia.

The storage dam on the Akaki river is expected to have a capacity of 2 MCM, to be used for irrigation purposes within the river valley.

The Peristerona river dam shall have a capacity of 6 MCM also to be used for irrigation purposes within the river valley.

The utilization of the Tylliria rivers (Marathasa, Xeros, Kambos, Limnitis, and Pyrgos rivers) is was under planning as well, however since these rivers flow into the Turkish occupied areas, there are political issues that prevent their development.

The implementation of the above projects is expected to add only marginally to the existing water resources in Cyprus. This is also assuming that rainfall will remain at normal levels of approximately 500mm per year. In drought years, the amount added be these dams could be fairly insignificant.

2. Re-use more wastewater

The re-use of wastewater is currently taking place in the Limassol area. A tertiary treatment wastewater plant is in operation, and all of the water that comes out of the plant is piped to the Limassol area where it is re-used in agricultural areas as well as in numerous hotel gardens. Since the beginning of the drought, approximately three years ago, farmers have become increasingly interested in purchasing such water for agricultural purposes, and demand has risen sharply since, to the point where all of the treated water is currently demanded. This is one area that Cyprus can realistically expand upon; however, there are very large infrastructure costs in piping more sewage to the plant, and this is presently putting a hold on treatment expansion.

3. Import Water

As an emergency supply, there is the possibility of importing water from Greece or Syria, however, it has been proven that in terms of maintaining an additional supply of water, desalination is more economically viable. Desalination is also a more stable supply, for during times of water scarcity, countries that export water will be forced to cut off water exportation to maximize their own welfare. Currently, prices of imported water are approximately CY£ 1.5 to CY£ 2.0, which is higher than the cost of desalination.

4. Pump more groundwater

During times of increased demand, it is always possible to pump more groundwater, however, in the case of Cyprus, where groundwater mining (pumping more than is replenished) is currently taking place, this is not a sustainable option. In numerous areas of Cyprus seawater has infiltrated into the ground, and has rendered many aquifers no longer useful. More groundwater pumping is not a recommended option of supply enhancement.

5. Reduce evaporation

Evaporation losses in Cyprus are estimated to be in the order of 80% of the total annual rainfall over the entire island. Reservoirs can lose up to 1.2 meters of depth on an annual basis. Evaporation reduction, if possible could add up to 3 MCM to the annual available water supply on Cyprus. This topic will be further discussed appendix D.

6. Examine Artificial Rainfall Enhancement

The process of cloud-seeding with a chemical that is meant to encourage precipitation has been looked at in Cyprus during the year of 1971, but has proved to be unsuccessful. The problem was that clouds needed to be very near to their dew point for this process to be at all successful, and in Cyprus, the main problem was that there were not enough clouds at all. The WDD is not currently looking to examine this process further.

7. Connect Paphos Irrigation System to Southern Conveyor System (SCS)

There has been talk within the WDD of future plans of connection the Paphos Irrigation System to the SCS, however this is not planned to occur in the near future, and is therefore not an option of supply enhancement for SCS irrigation or domestic users at this time.

8. Build more desalination plants

In February 1999, The Ministry for Natural Resources in Cyprus announced that two Israeli firms had been awarded a CY£ 20 million contract to build and operate a seawater desalination plant in Cyprus in a joint venture with a Cypriot company. This plant, expected to be completed by the middle of the year 2000, and is estimated to supply 40,000 m^3 of water per day at a price of CY£ 0.42. These figures lead to a yearly cost of CY£ 6,132,000. The net present value of the future costs of this sum of water over the next ten years is CY£ 37,678,000 given a discount rate of ten percent.

This will be a joint BOOT (Build, Own, Operate, and Transfer) venture, with the Cypriot Company, Epihaniou, IDE, and Oceana of Israel with a 10 year ownership period, upon which the plant is turned over to the Government of Cyprus to continue operating. The price of the water is to be CY£ 0.42 per m^3.

The site of the plant is to be on the western side of Larnaca, a southern coastal town, and will be one effective water supply enhancement supply tool into the 21st century.

Desalination is one of Cyprus' last resorts in terms of water resources, and creates, in theory, an unlimited supply. However there are certainly risks in this type of water supply. When all of the power on the island is generated by fossil fuels, it leaves the prices and availability of drinking water in the hands of the countries that produce the necessary fuel to power the plant that supplies the electricity for desalination purposes. This risk is not included in the price of the desalinated water, and neither are the negative environmental externalities associated with the burning of extra fossil fuel. One thought: if relatively dry climates like Cyprus' become drier as a potential result of global warming, more reliance will be placed on desalination, which produces the very gasses (CO_2, and NO_X) that result in further global warming and drier climates.

Rationing of Water

Rationing water is seen neither as a way of demand reduction nor supply enhancement, but rather the result failure to succeed at either. Rationing is simply a way to reduce consumption. Evidence from the Nicosia Supply Board indicates that rationing of water is somewhat limited in its effectiveness, and will only realistically slow economical growth. The problem with rationing is that while it is meant to reduce demand, what it really does is reduce consumption. The demand for water still remains where it was prior to the rationing. With a policy of rationing, there is a danger that people will race to maximize their share of supply

Users will typically set out to beat the system of rationing by some of the following methods:

1. Storage facilities investments.
2. Installing larger capacity water pipes to allow more flow during times of rationing.
3. Digging (usually illegally) of groundwater wells.
4. Purchase of water from water vendors.

Although rationing may reduce consumption, allowing the replenishment of groundwater aquifers and storage facilities, it does not provide any additional financial resources to further water resources development. It is important to realize that it is demand that needs to be reduced, which will lead to a reduction in consumption. As outlined previously, pricing is one way to reduce demand, and increase revenues [through higher prices] to increase the supply of water in the future through further dam building, desalination plant construction, etc. Water rationing also has the danger of interrupting economic activities and limiting tourism, as unreliable water supply is seen as unattractive to both industries. Water rationing is especially dangerous when one considers tourism, because the connotations surrounding intermittent water supply are those of developing countries.

Water Banking

The Republic of Cyprus is facing significant water scarcity problems. This is by no means startling to most Cypriots who have been forced to endure severe water rationing to their homes and businesses. Cypriot farmers are particularly aware of the water shortage problem because of recent extreme restrictions on the availability of irrigation water. There is no one cause of water scarcity on Cyprus. A number of geographic, climatic, economic, and political factors, and policy issues have all combined to produce the current situation. Innovative strategies are needed to enable the continued growth and prosperity of Cyprus in the face of limited water resources and frequent drought. Any potential solutions must deal fairly with farmers, domestic users, and the tourist industry while allowing each group to co-exist and contribute to the economy.

Water Banking is one such solution. Water banking is a proven water management strategy that facilitates the voluntary temporary reallocation of water from willing sellers to willing buyers. An emergency drought water bank will encourage farmers to become part of the solution to the water problems on Cyprus. In exchange for compensation, farmers (sellers) may choose to allow their irrigation water to be reallocated to cities, towns, industries, and tourist hotels (buyers) that are in need.

A water bank is an allocation and management policy, not a physical structure or device. The implementation of water banking in Cyprus will allow critical and high-value water demands to be met without the construction of additional, capital intensive infrastructure. The Cypriot government is currently turning to desalination of seawater to meet its water supply needs. This process offers a reliable but very expensive source of water. The water from the most recent desalination contract will cost the government more than *CY£ 61 million* in total over the next ten years, assuming that the price of oil does not rise. In order to minimize the cost of water resources development, forward-thinking policies such as water banking should be applied now in order to reduce the need for additional desalination plants.

Water banking is a new idea in Cyprus, but it has been applied and proven effective elsewhere. In California, whose climate and agricultural products are very similar to those of Cyprus, water banking was used during the severe drought of 1991 to reallocate over 1,012 million cubic meters of water with the voluntary cooperation of all participants.

Water banking in Cyprus will reallocate water in order to be used by municipal, industrial, and tourist consumers. Users in these sectors of the economy add significant value to the overall national welfare for every unit of water consumed. Reallocated water will come from irrigated farming, which by contrast makes a significantly smaller contribution to the economy. Agriculture consumes over 75% all of the nation's water resources, but only comprises of 5% of the GDP. Transferring water from agricultural to domestic users in times of drought is desirable in order to maximize national economic output.

Many Cypriots have invested heavily in farming however, and so even though the Government legally retains all water rights, it is not politically feasible to unilaterally reallocate water away from agriculture. A water bank in Cyprus will therefore seek the cooperation of farmers who are willing to take a cash payment in lieu of irrigation water during drought years. Farmers who choose to leave their fields, trees, or vines fallow, will be paid by the Government for the quantity of water to which they would have been entitled. The price to be paid to farmers is set based on the quantity of water required for reallocation and the profit that a farmer would normally have expected if he had chosen to irrigate his crops and then had sold them at market prices. Water that is reallocated from farmers is never physically conveyed to the farms, but is kept in storage in reservoirs or aquifers until such time as it is sold to a municipal water board or other user.

It is proposed that the Water Development Department administer the water bank. Activities should initially be limited to the area served by Southern Conveyor Project (SCP) because of its large storage capacity and extensive pipe network that serves both agricultural and domestic users. The water bank will only operate when water is scarce.

All farmers will be invited to participate in the water bank program, but the WDD will seek to minimize the price that it will pay for reallocated water. The results of this study indicate that citrus farmers, who use 57% of the irrigation water supplied by the SCP, are the most likely to participate in the water bank due to the high water requirements and low per-hectare profits of their crops. Farmers of citrus and other permanent crops who participate in the program will continue to receive a supply of irrigation water sufficient to insure the survival of their trees and vines. In years when reservoir storage is ample and irrigation water available, farmers may put their fields back into production. Water banking means Cyprus no longer needs to choose between its farms and its tourist hotels.

Application of an emergency drought water bank will result in a 13% increase in the reliability of the existing SCP water supply system when considering its capacity to meet 100% of current domestic demand. This increase in reliability will significantly reduce the need for rationing. By structuring water bank operations so as to appeal to citrus farmers, the price to be paid for reallocation of irrigation water will be less than CY£ 0.19/m^3. Due to the CY£ 0.13/m^3 subsidy provided by the Government on the price of irrigation water, water banking will often result in a *net savings* for the Government since during many drought situations the purchase price will be less than the subsidy. Based on the frequency of droughts in Cyprus and reservoir operation studies, it is expected that a water bank will be activated approximately once every five years. Unlike a desalination plant, there is no cost associated with water banking in those years when adequate water is available from conventional sources.

This report details the goals, structure, and operational strategy for a water bank in Cyprus. The MIT Water Resources Group recommends that the Government seriously consider the immediate application of water banking. A small-scale pilot project in a single irrigation district would allow the concept to be validated in the field. Water banking holds great promise as a means of helping to provide Cyprus with the water it needs for continued growth and prosperity.

Policy Considerations

In The Republic of Cyprus, the Government holds all water rights, both groundwater and surface water. One of the major concerns on behalf of the Government of Cyprus is that if it engages in a practice of water banking, farmers will have a potential legal position from which they can argue that since the Government has bought water from them, the Government is essentially recognizing water rights to the farmers. This could potentially lead to the Government having to relinquish water rights to farmers, and this would mean that the Government would lose control of these rights. This is a potentially dangerous situation, especially since water is scarce in Cyprus. Currently in Cyprus, during droughts, the Government is forced to cut back on water available to the farmers. Farmers, however, continue to grow their crops, and when these crops die due to unavailable water, farmers can show "damages." It is these damages that the Government pays the farmers for. This is essentially similar to water banking, but seen from a different point of view. In the first case, farmers are being paid for damages due to lack of water. In the case of water banking, farmers are paid for avoided damages. A policy of water banking is a policy that is typically to be used in times of emergency drought situations. It seems that there is a need to create some type of emergency drought legislation that will avoid the possibility of farmers taking advantage of the Government in terms of water rights.

With so much water being used on crops such as citrus, and such low profitability, Cyprus can not allow legal considerations to get in the way of proper resource allocation in terms of water resources. On the following graph, one can see the relative value of water to citrus farmers relative to other crops.

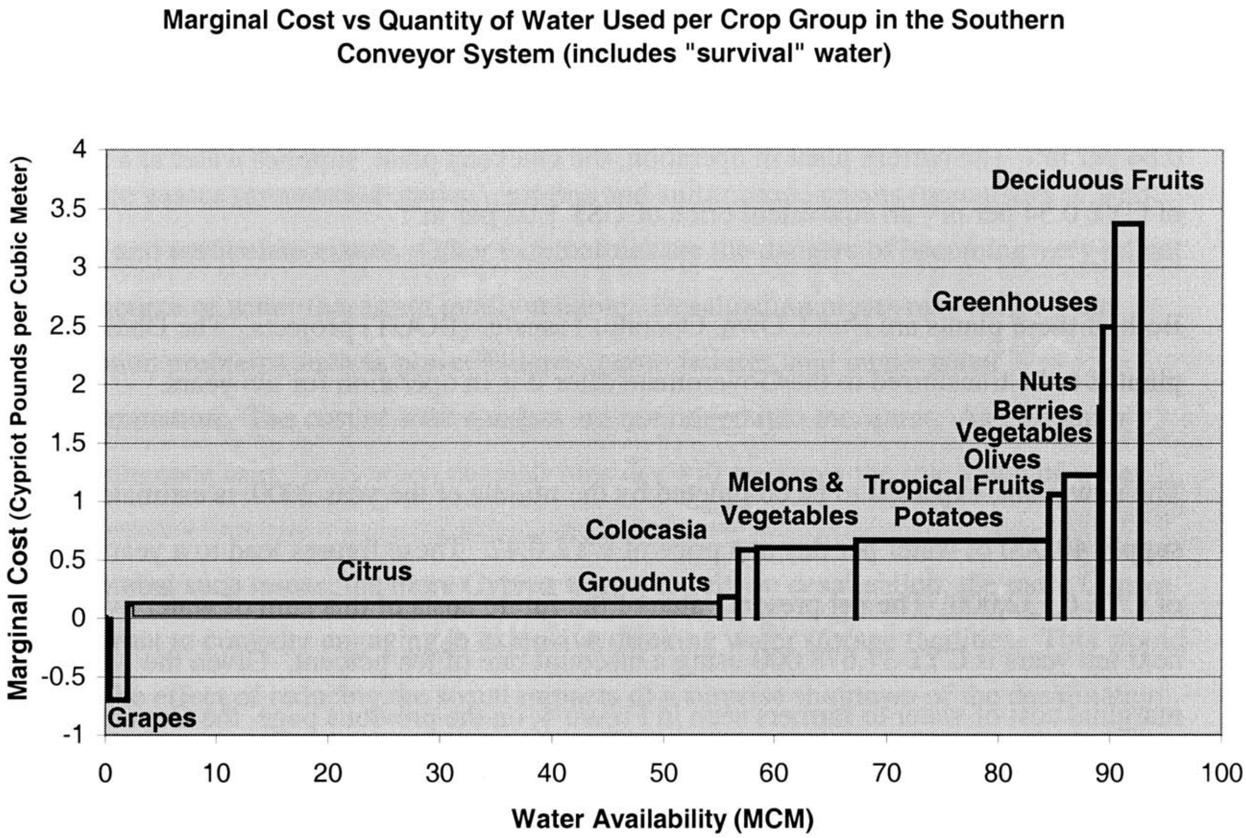

Figure 4: Relative value of water to different crop groups

Economics

As mentioned, seawater desalination is an expensive process, and results in very high water prices. The desalination plant currently awaiting construction west of Larnaca in Cyprus is anticipated to have a cost of CY£ 0.42 per m^3, which is approximately US$ 0.84 per m^3. The current plant in operation, the Dhekelia plant, supplies water at a price of CY£ 0.54 per m^3, an equivalent price of US$ 1.08 per m^3.

Both of these plants are Build, Own, Operate, Transfer (BOOT) projects. The Dhekelia plant is to be transferred to the Government after it is in operation for ten years.

The new plant, expected to be completed by the middle of the year 2000, is estimated to supply 40,000 of water per day at a price of CY£ 0.42. These figures lead to a yearly cost of CY£ 6,132,000. The net present value of the future costs of this sum of water over the next ten years is CY£ 37,678,000 using a discount rate of ten percent. Given the marginal cost of water to farmers seen in Figure 4, on the previous page, the Government could purchase 40,000 m^3 of water from citrus farmers for less than half of the cost of desalination, saving millions of pounds per year.

When the Government takes into account the subsidies that are included in the cost of the water to the famers, the amount of real money that they must spend to buy this water drops significantly. Farmers pay CY£ 0.07 per m^3 for their water, and the real cost is very near to CY£ 0.20 per m^3. As mentioned in the section titled potential solutions, for people to really have a true value of a resource, they must pay full price for it. This is clearly not the case with Cypriot farmers. Along with poor allocation, pricing of water in Cyprus is another reasons for water shortages. Since Government subsidies exist for farmers, water is being demanded for uses that are not economically justified. Benefits to the farmers may exceed costs to the farmers, but *overall* costs are higher that *overall* benefits. With water being a relatively scarce resource in Cyprus, there is a scarcity rent associated with using water today, and not conserving it for tomorrow. These scarcity rents are not incorporated into the cost of the water either, so there are really two issues here. The first is that farmers are not paying the full cost of the supply of water. The second is that farmers are not paying for the opportunity cost of the water to future users. In Cyprus, where water is so scarce that they have become reliant on desalination, all amounts of fresh water used, up to the supply demanded by the desalination plant essentially come at the cost of the desalination process, and the negative externalities imposed by the desalination process itself. Some externalities are the emission of carbon dioxide gasses (greenhouse gasses), nitrous and sulfur oxide gasses (precursors of acid rain), and particulate matter. Other externalities are the dangers of becoming very reliant on a source of water that is not totally reliable. Desalination plants may suffer from operation problems such as power failures, pump failures, and intake water contamination. The cost of such dangers are not priced into the water. As Benjamin Franklin once said, "only when the well runs dry will we know the true value of water."

To combat such issues, the more Cyprus begins to rely on desalination, the more Cyprus may want to consider engaging in extensive drinking water storage facilities. This would have the effect of reducing the social impacts of a surprise shutdown of the desalination plants.

Environmental and Safety Considerations

Although Seawater desalination may seem like the answer to Cyprus' water scarcity problems, there are some environmental concerns that should be addressed. The major concern of seawater desalination is the large amount of power that is needed for such a process. To supply one cubic meter of water through the reverse osmosis process, which is currently in use in Cyprus, electricity consumption can vary between 6.5 and 7.8 kilo-Watt-hours (kWh). One kWh of electricity generated from an oil-fired power plant (Cyprus' current power technology) generally produces in the area of 0.77 kg of CO_2, a greenhouse gas. This leads to figures of 5.0 to 6.0 kg of CO_2 emitted per m^3 of water produced by seawater desalination. When Cyprus finishes construction of the Larnaca desalination plant, production of water from both plants combined will be 80,000 m^3 per day. This will result in approximately 400 to 480 tonnes of CO_2 emitted to the atmosphere on a daily basis. On a yearly basis, these amounts may range from approximately 146,000 to 175,000 tonnes of CO_2 emitted. Average water consumption in Cyprus is currently 137 liters per day (0.137 m^3). As mentioned in the Introduction, if relatively dry climates like Cyprus' become drier as a potential result of global warming, more reliance will be placed on desalination, which produces the very gasses (CO_2, and NO_X) that result in further global warming and drier climates.

On the following page is a graph that shows some historical CO_2 emissions per capita in Cyprus. Given the Kyoto Protocol on Greenhouse Emissions, Cyprus will have a difficult time reducing CO_2 emissions if it continues to expand its reliance on desalination. The Third Conference of the Parties (COP3) met in Kyoto in December 1997 and reached agreement on the KYOTO PROTOCOL to the UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE. Once ratified, this Convention will impose defined targets for the permitted emission levels of climate change gases, including carbon dioxide (CO_2). The Convention sets these targets based on the emission levels in 1990. The overall, global, requirement by 2008 to 2012 is a reduction to 5 percent below the 1990 levels. With the increases in greenhouse gas emissions due to desalination, it will be harder for countries like Cyprus to meet standards like those set in Kyoto.

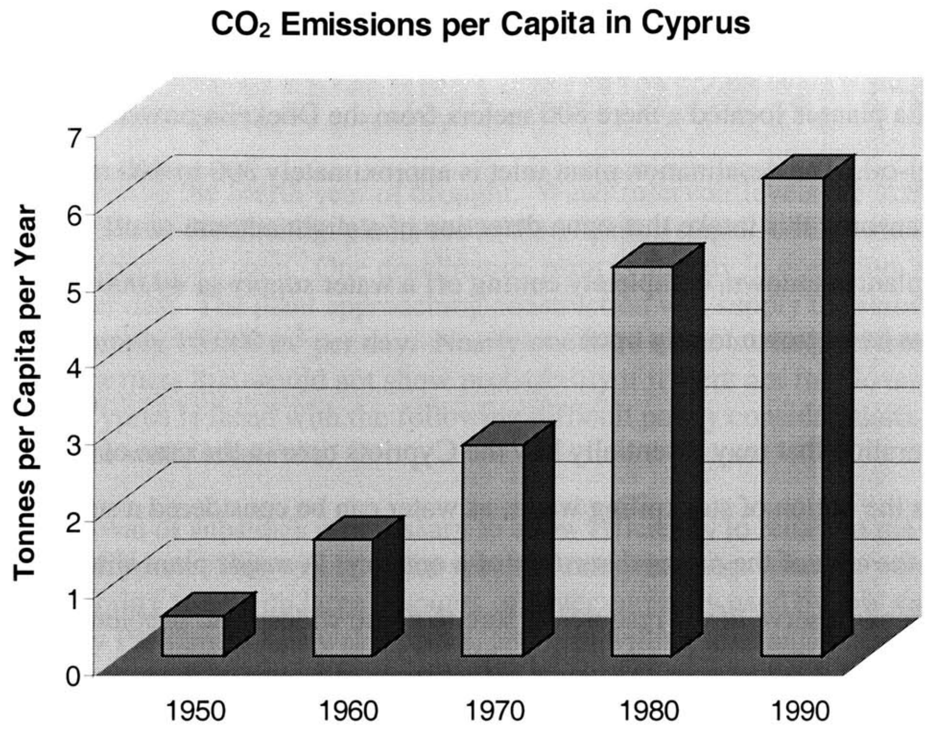

Figure 5: CO_2 Emissions per Capita in Cyprus

With approximately 146,000 to 175,000 tonnes of CO_2 emitted per year in Cyprus due to desalination, this will add from 0.22 to 0.27 to the tonnes per capita emissions. Keep in mind that these emissions are spread over the entire island population of 650,000. If we look at per capita per year emissions from only users of desalinated water based upon 137 liters per day usage, and a supply of 80,000,000 liters per day, we find that these numbers increase slightly to approximately 0.25 to 0.30 tonnes per capita per year.

Along with the environmental considerations of seawater desalination, are the safety concerns, of which there are many. As mentioned previously, one of the significant dangers of desalination is the event of a plant shutdown due to either a power plant shutdown, or a desalination plant shutdown due to the presence of contaminants near the desalination plant intake. The phrase "if you build it, they will come" comes to mind in regard to Cyprus' desalination plants, except in this case, the saying should be more like "if you supply it, they will consume it." Making more water available typically has an influence on people's demands on water, which essentially means that people will come to rely on that additional source. This poses great dangers in the event of an immediate, unavoidable plant shutdown due either to lack of power, or contaminants, as mentioned.

The Dhekelia plant is located a mere 800 meters from the Dhekelia power plant, which is fired by fuel-oil. The desalination plant inlet is approximately 300 to 400 m. out to sea. There is a sensor at this intake that upon detection of a slight amount of oil will result in immediate plant shutdown, completely cutting off a water supply of 40,000 m^3 per day that Cypriots have grown to rely upon.

One consideration that may essentially buy the Cypriots time in the case of plant shutdown is the notion of stockpiling water, as water can be considered a strategic resource in the case of the national security of a country. A major plant shutdown without a proper reserve of the resource is sure to cause widespread problems.

Conclusions

Cyprus is entering the fourth year of drought. Water reservoir levels are at their lowest levels ever. Three desalination plants are in the planning stages, one of which is due to start construction very soon. One desalination plant is already in operation, supplying 40,000 m^3 per day. The plant approaching construction will supply the same, and the two others will supply 15,000 m^3 per day. Nearly one third of the water consumed in Cyprus is by citrus farmers that would not show profitability if it were not for Government subsidies. Cyprus is faced with the following difficult policy considerations in the future with regard to water resources.

1. The removal of subsidies is necessary to allow efficiency to return to the "market" for water in Cyprus. This will have the result of removing non-valuable water users, and has the ability to free up large amounts of water currently used by low value users. Currently Parliament sets water prices, and is unwilling to change these prices. The Parliament needs to seriously consider the state of Cyprus in the long-run, and realize the importance of removing subsidies on water, and price water to achieve efficient usage of the scarce resource.

2. In the short run, if such price increases are not yet possible, it is strongly suggested that the Government implement a water bank. In this case, the Government would offer to purchase water from farmers in such a way that farmers are essentially being compensated for avoided damages to crops in the event that there would not have been enough water to produce the entire crop as a result of Cyprus' policy of water rationing during droughts.

3. Desalination is a very painful last resort to augment water supply. Due to environmental and social safety concerns, as well as high costs, desalination should not be implemented until all other methods such as water banking or subsidy removal have thoroughly been explored and implemented.

The shadow value of a resource is defined as the forgone opportunity of using a scarce resource today instead of saving it for use tomorrow. In Cyprus, the shadow value of water is not so simple to calculate because it includes more than just the forgone financial opportunity cost of the resource. This shadow value needs to include the forgone environmental benefits that using a resource today causes. This shadow value will certainly be higher than just the mere cost of desalinated water. The cost of the negative effects of pollution, risk costs, and other costs such as costs imposed by groundwater aquifers contaminated with seawater due to overpumping – an effect of overusing a resource today instead of preserving it. As a resource becomes more scarce, this shadow value increases. Shadow values of a few US dollars per cubic meter are not unreasonably high values, yet they are much higher than the cost of production of desalinated water, which is near to one US dollar.

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Appendix A

Water Banking in Cyprus:

Chapters 6 and 7 of a report titled:
Solutions to Water Scarcity in Cyprus

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The most relevant sections of this report have been included here. To view the entire report, contact the Department of Civil and Environmental Engineering at The Massachusetts Institute of Technology in Cambridge, MA.

Chapter 6 CONCEPT OF WATER BANKING

The previous Chapters have shown that many of the potential solutions to water scarcity in Cyprus have either been implemented to their fullest extent or are not feasible. There is however one new concept which has not yet been applied in Cyprus. This is Water Banking. *Water banking is a means of reallocating water via existing supply infrastructure so that it can be either used to satisfy high priority demands or stored for future use.*

The large-scale use of water banking is a relatively new water management tool. For example, in the United States the concept has only been widely applied in the last several years. The idea has gained interest as the opportunities for building additional water supply infrastructure have decreased. Water banking is a legal concept as much as an engineering idea because it involves the transfer, either temporarily or permanently, of water rights. It is therefore necessary to have a basic understanding of water rights law. In the United States, there are two types of water rights law. *Riparian* law gives water rights to individuals or entities who are physically adjacent to water sources. A water user who abuts a lake or river has rights to the use of a certain amount of water from that body. This form of law is generally applicable in the eastern United States. *Prior Appropriation* law gives priority rights to those water users who can establish a history of beneficial use of water from a particular source. The quantity of water a user is entitled to is connected to that user's prior level of extraction. This form of law is usually applicable in the western United States (Chow, 1964, sec. 27 p.4-19). In Cyprus, an individual's right to water is significantly more limited. There is a variety of actual legislation which deals with water and has its basis in the Constitution of the Republic of Cyprus. These laws state that "All surface water, groundwater, and wastewater is vested to the Government which has the power to construct waterworks and undertake their management" (World Bank, 1995, p. 10). While individuals and other entities may apply for permits to construct wells and extract groundwater, the government legally has the right to restrict either of these activities and maintains ownership of the water.

Presently there are four states in the U.S. which are actively involved in water banking: Arizona, California, Idaho, and Texas. There is also some interest in water banking in Europe and Australia (CDWR, Oct. 1995). The water banks in each of these places are structured in different ways, according to the particular needs and conditions of the area. In general, there are two different types of water bank which respond to different extremes of hydrologic conditions.

6.1 Savings Bank

One type of water bank might be referred to as a *savings bank.* This concept is applied when there is a temporary general surplus of water in an area. Arizona now operates a water "savings" bank in order to store surplus water which would otherwise be lost. The Arizona Water Banking Authority (AWBA) was created by the state government in order to take full advantage of all the water to which Arizona is legally entitled. The State of Arizona has rights to 3455 MCM of water from the Colorado River in any normal hydrological year as agreed to by the United States Bureau of Reclamation USBR; however, Arizona does not currently use its full allotment of water. In 1998, Arizona's level of demand for irrigation and municipal and industrial (M&I) uses was only 2764 MCM. The remaining 691 MCM of water remained in the Colorado River and flowed downstream towards California. At current levels of growth, it is projected that Arizona will not use its full allocation of Colorado River water until the year 2030. During the interim, a total of approximately 17275 MCM would flow out of Arizona without ever having been used (AWBA, 1999, p. 1).

The AWBA extracts water from the Colorado River during those years when demand is less than the total amount of water available to Arizona. The water is then transferred via existing water conveyance infrastructure to other areas of the state and pumped into the ground. Groundwater aquifers are used as underground storage facilities where water can be kept until needed during a drought. Excess water is also provided to farmers to be used in lieu of groundwater in order to reduce the pumping and encourage natural recharge. Arizona is thus saving otherwise unused water, which can be pumped out of the ground to augment supply in years when demand exceeds available surface water.

6.2 Lending Bank

The other type of water bank might be termed as a *lending bank*. This type of bank is generally used when water demand exceeds supply. Under this scheme, water users with access to some excess water (sellers) make short-term "loans" to users who do not have enough water (buyers). The water buyer pays the water seller for the use of the water. In this way, market forces are used to efficiently allocate a scarce resource. Those who are willing to pay an increased price for water can obtain additional supplies.

Texas and Idaho both have "lending" water banks operated by the state governments. These two water-banking agencies work to assist in the voluntary marketing of water rights among willing buyers and sellers. These banks do not generally actively seek to acquire water but rather function as a clearinghouse for information and a facilitator of water lending transactions. These banks help individuals or organizations with excess water find buyers to whom they can sell or lease their water rights. They do this by maintaining registries of willing buyers and sellers of water. The information in the registries includes the name of the interested party, the quantity of water, the location of supply or demand, and the terms of transfer. Water to be transferred can be in the form of water diverted from a river, extracted from groundwater aquifers, or released from reservoir storage. Both the Texas and Idaho water banks receive a percentage fee on each completed transaction to cover administrative costs (TWDB, 1998 and IWRB, 1998).

6.3 California Emergency Drought Water Bank

The State of California has the most experience with large-scale "lending"-type water banking. The State Water Project (SWP) is the largest state-built, multipurpose water project in the United States (CDWR, 1996, p. 1). As of 1990, during a year with average or above-average rainfall the SWP was capable of delivering 3455 MCM of water (California Water Plan 1994, Chapter 11). At the start of 1991, California had already endured four drought years and was facing another dry winter. The California State Department of Water Resources stated that the State Water Project (SWP) would deliver only 10% of requested domestic water demand and no water to agriculture (CDWR, ref #66). Other local, state, and federal water agencies, including the U.S. Bureau of Reclamation (USBR), were in a similar situation. In February of 1991, the Governor of California established a Drought Action Team to develop and implement emergency policies and plans to deal with the water shortage. Within two weeks the Team had recommended the creation of the California Emergency Drought Water Bank. The identified goals of the Water Bank were to provide supply for the following four critical needs (CDWR, ref #13, p.2):

1. Municipal and industrial uses
2. Agricultural uses (protection of permanent crops, etc.)
3. Minimum flows for the protection of fish and wildlife
4. Carryover storage for the following year (1992).

In order to achieve these objectives, the Water Bank was given the authority to purchase water from willing sellers and re-sell it to entities with critical needs. The California Emergency Drought Water Bank of 1991 differed from the water banks in Texas and Idaho in that it actively sought out water sellers and purchased water from them directly, using State funds. The water was then re-sold by the Water Board to buyers who paid the cost of the water plus a transaction fee and delivery costs. Sellers could make water available to the Water Bank in one of the following ways (CDWR, 1993, ref #16, p.4):

1. Fallowing farmland (i.e. not planting or not irrigating a crop) and transferring conserved water to the Bank
2. Shifting to crops that consume less water
3. Using groundwater instead of surface water and selling the surface water

4. Direct delivery of groundwater
5. Conserved water through demand reduction
6. Transferring water stored in local reservoirs to the Bank

The idea behind fallowing and crop shifting is that water formerly used to irrigate agricultural crops could be temporarily diverted to supplying M&I demand. Farmers could sell their water rather than the crops they would have grown using this water. This was possible because the cost of irrigation water to farmers was so low that they could irrigate low-value crops. Drought-stricken cities were willing to pay a very high price for water which would otherwise be unavailable. The average price for irrigation water in the State Water Project SWP and in USBR's Central Valley Project (CVP) is approximately $0.002/m^3 while cities in California pay up to $0.08/m^3 for untreated water. The products produced by agriculture have lower value-added to water consumed ratios than M&I uses do. Therefore cities could in effect afford to buy out a farmer's entire crop before it was even planted in order to gain the use of the water which would have been used to grow that crop. The fallowing option requires planting no crop at all on irrigated land. This allows a recovery of all of the water consumed by the crops. Problems may arise when a portion of the transferred irrigation water normally would have recharged the groundwater, as this may create a new deficit elsewhere. Crop shifting involves planting a crop that does not need irrigation or a crop which needs less irrigation water. This allows a full (in the former case) or partial (in the latter case) recovery of consumed water.

Groundwater substitution provided farmers with incentives to irrigate crops with groundwater from beneath their farms rather than with surface water from the SWP or the CVP. The surface water conserved in the system could then be transferred to cities or other buyers. Groundwater could also be pumped directly into the distribution system in order to augment supply.

Conserved water is produced by improving the efficiencies in water distribution and usage systems. If more efficient methods of irrigation, such as drip irrigation, are substituted for inefficient techniques, such as large diameter sprinklers, then less water is needed to produce the same crop yield. The difference in usage is counted as conserved water and may be transferred to other users.

Transfers of water from reservoirs involve the taking of water from reservoirs that normally do not input water into the SWP system. The reservoir owners or operators who have water remaining in their storage facilities could choose to sell their water to the State rather than use the water for its otherwise normal purpose (irrigation, power generation, etc.). If a water-rights holder had excess water in storage, he or she could sell that water for profit, but incur the risk that the reservoir might not re-fill in the next year.

The "type" of water transferred was categorized for all water transfers. This was important in ensuring that water sellers actually had the rights to the water they were intending to sell. This was also vital in the determination of prices offered by the Water Bank to the sellers. Water transfers were divided into the following categories (CDWR, 1993, ref #16, p.3):

1. New Water: Water not previously available to the system, created by reducing irrecoverable losses. Only "New" water actually increases the total amount of water available within the system. Lining of a canal in an area where there is no groundwater use is an example of the creation of "New" water.
2. Real Water: Water transferred within the system that does not impact on any lawful user other than the seller. Water produced by fallowing cropland is an example of "Real" water.
3. Paper Water: Water proposed for transfer that does not actually help to satisfy more demands. The transfer of "Paper" water to satisfy a demand in one area would create a deficit in another area. An example of "Paper" water would be the transfer of water which would have otherwise remained in a channel and used by a downstream appropriator. The Water

Bank did not buy paper water because it would cause negative externalities to be imposed on the downstream user or require the purchase of more water to compensate the downstream user.

One of the most important and difficult decisions to be made by the Water Bank was the purchase price for water. In 1991 the Water Bank concentrated on purchasing water from fallowed farmland; therefore the price was based on potential profits to be derived from farming of irrigated crops. "The intent was to offer a price that would yield a net income to the farmer similar to what the farmer would have earned from farming plus an additional amount to encourage the farmer to enter into a contract with a new and untried Water Bank." (CDWR, 1991, ref #13, p.3) Due to the emergency nature of the 1991 Water Bank, it was decided to offer a single price for all water purchased by the Bank regardless of source. A price of $\$0.10/m^3$ was arrived at somewhat arbitrarily after considering input from agricultural economists, farm extension agents, and others. Based on this price for water, a unit area contract price was then established for fallowing of various crop types. This was done by multiplying the average irrigation requirements per unit area of a particular crop by the unit price of water to be paid by the Water Bank.

$$\text{Unit Area Price for Fallowing (\$/ha)} = \text{Unit Purchase Price of Water } (\$/m^3) * \text{Water Use of Crop Per Unit Area } (m^3/ha) \qquad (6\text{-}1)$$

For example, farmers were paid $182/ha for fallowing alfalfa because each hectare left un-irrigated was assumed to make available 4319 m^3 of water (CDWR, 1991, ref #13, Table 3). Compliance with the terms of the fallowing contracts was closely monitored using aerial photographs and site visits. The contracts contained clauses covering liquidated damages in the case of violation of the terms of the agreement, i.e. unauthorized irrigation.

Payments on contracts for groundwater substitution or direct pumping were made based on actual quantities pumped. Meters were placed on the pumps at the boreholes and read by Water Bank personnel or others. Observation wells were also monitored to ensure that groundwater pumping did not adversely impact other parties. Water from reservoir storage withdrawals was paid for based on actual releases as gauged by standard methods.

Once the Water Bank acquires water rights from water sellers, the next step is to allocate the water to the interested buyers and then to deliver the water. Interested buyers filed requests for water detailing the amount of water needed and the purpose for which the water would be used. It was expected that the demand for water from the Bank would exceed supply; therefore a list of priority allocations was established:

1. Emergency needs such as health and public safety
2. Critical needs such as urban areas with less than 75% supply; permanent or high value agricultural crops, and fish and wildlife resources
3. Other critical needs such as carry-over storage for the first few months of the next year
4. Additional water for communities without critical needs but who require water to reduce significant economic impacts due to limited water supply
5. Carry-over storage for all of the following year

The selling price of water from the Bank was set at $0.14/m^3. The additional $0.04/m^3 was used to cover the transaction costs incurred by the Water Bank. These costs included administrative staff overhead, legal work in preparation of the contracts, monitoring effort, and other costs. The cost of actually physically conveying water from the seller to the buyer was added to the base cost of $0.14/m^3 (CDWR, 1991, ref #13, pp. 5-6).

6.4 California's Water Bank Experience

The 1991 Drought Water Bank was established rapidly and under duress, yet it was highly successful in meeting its stated goals. In approximately 45 days, the Water Bank was able to purchase the rights to over 1012 MCM of water under 351 separate contracts. The majority of this water, 518 MCM, was obtained from the fallowing of farmland. Groundwater substitution provided for 320 MCM of supply, and the additional 175 MCM of water came from releases of stored water. A relatively minuscule amount of water, less than 12 MCM, was taken from direct groundwater extraction. No other methods were used (CDWR, 1991, ref #13, Table 1). Contrary to initial expectations, significantly more water was purchased by the water bank than was required for critical needs; therefore hard choices about prioritization of supplies were unnecessary. Finally, about 493 MCM of water was distributed to buyers with critical needs, and 320 MCM carried over for supply of the SWP in early 1992. The remaining water was either used for environmental water quality improvement, was lost in transit, or was left in storage as insurance against continued drought. The initial buying price was $ 0.10/m^3, but by the later stages of the process, better-than-expected spring rains and the surprising response to the Water Bank allowed for a reduction in buying price to as low as $ 0.02/m^3) in several contracts. (USOTA, 1993, p.1)

The primary focus of the Water Bank was to provide water for critical M&I needs, but environmental concerns were also addressed both directly and indirectly. Impacts on the environment by the Water Bank were possible in several forms. Some water purchases could have reduced supplies to critical habitats and fisheries. Fallowing and plowing of fields potentially had detrimental effects on nesting birds. Pumping of water from some large rivers might have killed numbers of migrating juvenile fish. The Water Bank worked with state and federal wildlife and environmental agencies to mitigate these effects. Minimum flows were established for critical rivers, pumping periods were modified, and 300,000 fish (yearling striped bass) were purchased for release by the California Department of Water Resources. The Water Bank also provided positive environmental benefits. Water stored until later in the year helped to reduce river temperatures for salmon runs, and fallowing of farmlands decreased the fertilizer loading of drainage during periods of low river flow, when contaminants would have a greater effect on water quality (CDWR, 1991, ref #13, p.11).

Another concern about the implementation of the Water Bank was the possible effects on so-called third parties. These are individuals or groups who did not directly participate in the Water Bank but were affected nonetheless. The primary concern was for agribusiness in the rural areas where fallowing of farmland was the heaviest. It was found that there were some impacts on third parties, especially those engaged in the storing and hauling of harvested crops. However, the overall economic consequences of the Water Bank were positive due to the benefits to high value M&I and agricultural users, but it is clear that there were some localized negative impacts. Based on the experience of the 1991 Water Bank, water transfers made available by future fallowing will not exceed 20% of the water which would have been applied. This measure is intended to reduce third party impacts by more evenly distributing the reduction of crop production due to fallowing. (CDWR 1993, ref #16, p.4)

Due to the success of the 1991 Drought Water Bank program and the continuing shortage of water in California, the Water Bank was activated again in 1992. The operation of the 1992 Water Bank was similar to the previous year - with the advantage of applying lessons learned in 1991. The major differences were as follows:

1. No water was bought by the Water Bank until a contract was signed with a buyer. This was intended to insure that the Water Bank did not end up purchasing more water than was required.
2. No water was obtained by fallowing. In order to reduce environmental and third party impacts, all water was obtained by groundwater substitution and reservoir storage releases.
3. Direct purchase of water was made by the state wildlife agency from the Water Bank for habitat uses.
4. The buying and selling price for Water Bank water was much lower than in 1991.

The 1992 Water Bank purchased about 238 MCM of water from 19 sellers at $0.04/m^3. Approximately 196 MCM were allocated to 16 buyers at a price of around $0.06/m^3. The remainder of the water was either used for enhancing water quality in rivers and estuaries or lost in transit (CDWR 1992, ref #14, pp. 3-6).

In 1995 the Water Bank was once again activated due to forecasts of possible water shortages. Working with a very limited staff, the Water Bank purchased "options" on water rights. Due to uncertainty about future supply levels, water users wanted to have in place the rights to additional water, but did not want to commit to an outright purchase. The Water Bank therefore negotiated these "options" contracts with water sellers. A seller was paid $0.003/m^3 in return for the right to purchase his or her water if the need arose. If the option was exercised, the contract price of water was set between $0.030-$0.034/m^3. If the water was not transferred, the seller was entitled to keep the option payment. A total of 36 MCM of water options was purchased before the available supply situation in California improved. In the end, no water options were exercised.

Chapter 7 APPLICATION OF WATER BANKING TO CYPRUS

It is proposed that a drought water bank similar to the California Emergency Drought Water Bank be used in Cyprus to mitigate some of the problems caused by temporary severe water shortages. The water resources situation in the Republic of Cyprus is very similar to the one in California. The climate of Cyprus is similar to that of Southern California, and also like California, Cyprus is subject to periodic, multi-year droughts that severely strain the capacity of the water storage facilities. In Cyprus, water is moved from a water-rich region to drier regions through the Southern Conveyor Project which is similar to the State Water Project in California, and in both Cyprus and California, large percentages of water supply are dedicated to agriculture. The similarities between Cyprus and California suggest that the lessons learned in the western United States could effectively be utilized in the eastern Mediterranean.

An emergency drought water bank in Cyprus could be used to provide immediate relief to the water resources supply system during the kind of severe multi-year drought that is currently being experienced (1996-1999). When reservoir storage is very low, a water bank could be used to provide for the full demands of municipal, industrial and tourist users by re-allocating water from agricultural users. At the same time, a water bank is fair to the farmers because it compensates them for the losses incurred due to a reallocation of irrigation water. In this way, water banking could be used as an equitable method of reallocating water temporarily (one-year period) to critical and high value uses, without imposing permanent consequences on the agricultural community. A drought water bank would also introduce added reliability into the current water infrastructure system without the need to invest in large, capital-intensive projects or commit to long-term contracts.

As in California, the proposed Cyprus Emergency Drought Water Bank would be a *lending* bank. In other words, one group of water users would lend water to another group of water users in exchange for compensation. The choice of who lends water to whom is based on the following criteria:

1. *National Economics:* In order to maximize the overall economy of the nation, most resources should be allocated to those uses which add the most value, thus water in Cyprus should be allocated first to those uses which contribute the most to the economy.
2. *Willingness to Pay:* A water user who's end product is very profitable is willing to pay a large premium for water, while a user who is producing a good of lower value may be willing to forego production if he or she is compensated for water not used.
3. *Fairness and Equity:* In Cyprus, water rights belong to the government, but fairness and equity suggest that users who have relied on water in the past should be entitled to some proportion of the available resources or compensation for not receiving those resources. In a situation where water is severely limited, all users must expect some reductions in supply, but priority should be given to allocating water to those sectors where the most users will receive benefits.
4. *National Priorities:* There are many uses for water which come into conflict with each other when supplies are limited. Decisions must be made as to which uses are to be given priority. Prioritization may be based on social, political, or economic justifications. In Cyprus, some priority uses may be minimum supply for personal domestic consumption, supply for tourist areas, conservation of permanent crops, recharge of threatened aquifers, etc.

Given the above criteria, it is clear that there is some justification for re-allocating water from agricultural uses to municipal, industrial, and tourist uses. Agriculture accounts for less than 5% of the GDP (Cyprus Planning Bureau, 1997) while it consumes almost 75% of the nation's water resources in a normal year (World Bank, 1996). Farming also accounts for a very low level of employment. Some estimates state that there are approximately 70,000 persons involved in farming in Cyprus. This is over 22% of the economically active population. However, many sources suggest that there are actually only approximately 6,000 full-time farmers whose primary source of income is derived from agriculture. Full-time farmers would then represent only 2% of the work force.

There is also a large difference in price paid for domestic and irrigation water. Domestic users pay full price for water while farmers pay only 34% of the full capital recovery and operation and maintenance cost of irrigation water due to government subsidies. The average price of irrigation water from surface water sources is CY£ 0.07/m^3 while the average price of domestic water is CY£ 0.43/m^3. The cost of domestic water supply, however, includes treatment and distribution costs. Raw water, before treatment, costs CY£ 0.20/m^3, so the actual disparity between domestic and irrigation water prices is only the subsidy amount of CY£ 0.13/m^3. Based on average annual national irrigation demand in the area of the Southern Conveyor Project SCP (91 MCM) and the current subsidy level, the government spends CY£ 12 million per year supplying water to agriculture. The price of domestic water represents the full cost of water including both capital recovery and O&M costs.

The shadow value analysis detailed in Chapter 5 along with examination of the GDP percentages clearly shows that domestic, industrial and tourist uses should be favored over agricultural uses in terms of resource allocation. Yet even though it is a relatively small sector of the economy, agriculture is an important industry in Cyprus. In 1995, a non-drought year, exports of potatoes and citrus accounted for CY£ 61.1 millions in export sales -- almost 12% of all exported goods (Cyprus Planning Bureau, 1997). Irrigated cropland covers over 6% of the area of government-controlled Cyprus and is one of the most scenic aspects of the landscape. Many families derive at least some income from farming or farming related activities, as evidenced by the number of part-time farmers. Clearly, there is a place for agriculture in Cyprus and therefore a need for irrigation water. But on an island such as Cyprus where water resources are scarce, every effort must be made to ensure that irrigation water is used as efficiently as possible. It is therefore necessary to have a thorough understanding of the types of crops grown in Cyprus, the extent of their area, the amount of water they use, and their profitability.

7.1 Examination of Irrigated Farming

Table 7.1 shows the total areas of land devoted to agriculture of all types in Cyprus. The table divides crops into permanent crops such as fruits, olives, citrus, and grape vines, seasonal crops such as potatoes and vegetables, and crops grown in greenhouses or tunnels. Further distinction is made between irrigated and non-irrigated land. It can be seen that irrigated crops are grown on fully 30% of the land devoted to farming in Cyprus. Farmland connected to the Southern Conveyor Project (SCP), the nation's largest water project, has been shown separately. The land within SCP comprises over 43% of the nation's irrigated cropland.

Table 7.1: Agricultural Areas in Cyprus

Type of Crop	All Government-controlled Cyprus (including SCP) (ha) **(% of total)**	Southern Conveyor Project		
		Government Irrigation Schemes (ha)	Non-Government Irrigation Schemes (ha)	SCP Total (ha) **(% of total)**
Permanent Crops				
Irrigated	21,886 **(18.3%)**	3,098	3,738	6,836 **(43.3%)**
Non-Irrigated	17,933 **(15.0%)**	0	0	0 **(0%)**
Total Permanent	39,819 **(33.3%)**	3,098	3,738	6,836 **(43.3%)**
Seasonal Crops				
Irrigated	13,584 **(11.4%)**	5,575	3,238	8,813 **(55.9%)**
Non-Irrigated	65,474 **(54.9%)**	0	0	0 **(0%)**
Total Seasonal	79,058 **(66.3%)**	5,575	3,238	8,813 **(55.9%)**
Greenhouse & Tunnel Crops	454 **(0.4%)**	75	50	125 **(0.8%)**
Cropped Area				
Irrigated	35,924 **(30%)**	8,748	7,026	15,774 **(100%)**
Non-Irrigated	83,407 **(70%)**	0	0	0 **(0%)**
Total Cropped Area	119,331 **(100%)**	8,748	7,026	15,774 **(100%)**

The concept of water banking involves the transfer of water from irrigated agriculture to other users. Rain-watered (i.e. non-irrigated) crops such as wine grapes and wheat are important agricultural products in Cyprus; however, rain water clearly cannot be reallocated from these crops to other uses. For the purpose of this study, non-irrigated agriculture will not be included or considered.

A large variety of irrigated crops are grown in Cyprus. A complete list of these crops may be found in Appendix A. For the purpose of this study, all irrigated crops were collected into 13 separate crop groups. The crop groups will be treated as a single crop in this study with land areas summed and characteristics such as water consumption and profitability averaged from all crops in the group. Appendix A shows the crops within each crop group. Table 7.2 lists all the crops groups and displays the important statistics for each.

Table 7.2: Irrigated Agriculture in Cyprus

Crop Group	National Breakdown (%)	Area Cropped [Nationally] (ha)	Annual Water Require-ment (m^3/ha)	Total Water Used Nationally (MCM)	Irrigation Cost **(1)** (CY£/ha)	Net Profit **(2)** (CY£/ha)
PERMANENT CROPS						
Citrus	19.94%	7163.25	10000	71.63	700.00	-95.64 **(3)**
Grapes	5.38%	1932.71	3060	5.91	214.00	-1284.00 **(3)**
Olives	16.24%	5834.06	5375	31.36	376.00	2465.00
Deciduous Fruit	7.43%	2669.15	5800	15.48	552.29	9359.21
Tropical Fruit	1.13%	405.94	13350	5.42	934.34	5847.79
Nuts	10.82%	3886.98	2830	10.99	197.94	2620.71
TOTAL	**60.94%**	**21892.09**		**140.80**		
SEASONAL CROPS						
Melons & Vegetables	6.57%	2360.21	5760	13.66	405.31	3047.34
Vegetables	5.78%	2076.41	2180	4.52	147.13	2497.56
Potatoes	23.64%	8492.43	3140	26.67	219.67	1860.67
Colocasia	0.30%	107.77	24000	2.59	1680.00	12160.00
Groundnuts	1.36%	488.57	5300	2.59	371.00	592.00
Berries	0.15%	53.89	5840	0.31	409.00	10091.00
TOTAL	**37.80%**	**13579.27**		**50.34**		
GR.HOUSE+TUNNELS						
Greenhouse & Tunnels	1.26%	452.64	4225	1.91	295.37	10229.50
TOTAL	**1.26%**	**452.64**		**1.91**		
OVERALL TOTAL	**100.00%**	**35924.00**		**193.05**		

Notes:

(1) Irrigation costs are based on a price of CY£ 0.07 / m^3 for raw water. Not all crops, however, are irrigated with water bought from the government. Many farmers pump water from their own wells.

(2) Net profit equals gross profit minus all costs (irrigation, all labor, etc.)

(3) Negative net profit means an overall loss on the production of these crops

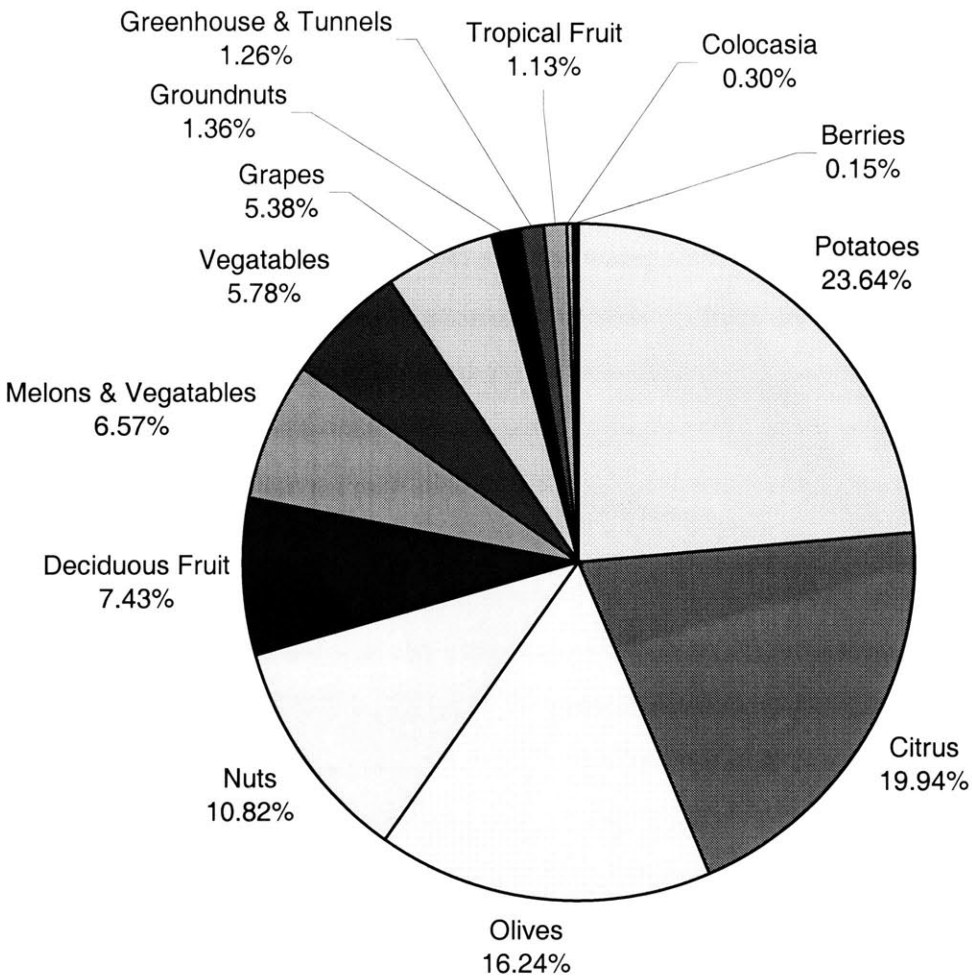

Figure 7.1: Total Crop Areas for all of Government-Controlled Cyprus

Figure 7.1 shows the portions of land devoted to each irrigated crop group as a percentage of the national total of irrigated cropland. The crop groups to which the most land is devoted are potatoes (23.6%) and citrus (19.9%).

In addition to the total area of each crop group, it is also necessary to know the water consumption per hectare for each group in order to evaluate total water resource utilization. The Agricultural Research Institute in Cyprus has done extensive investigation into the optimum level of irrigation water application per hectare for all crops grown in Cyprus. The water requirements stated in Table 7.2 are illustrated in order of decreasing requirement in Figure 7.2.

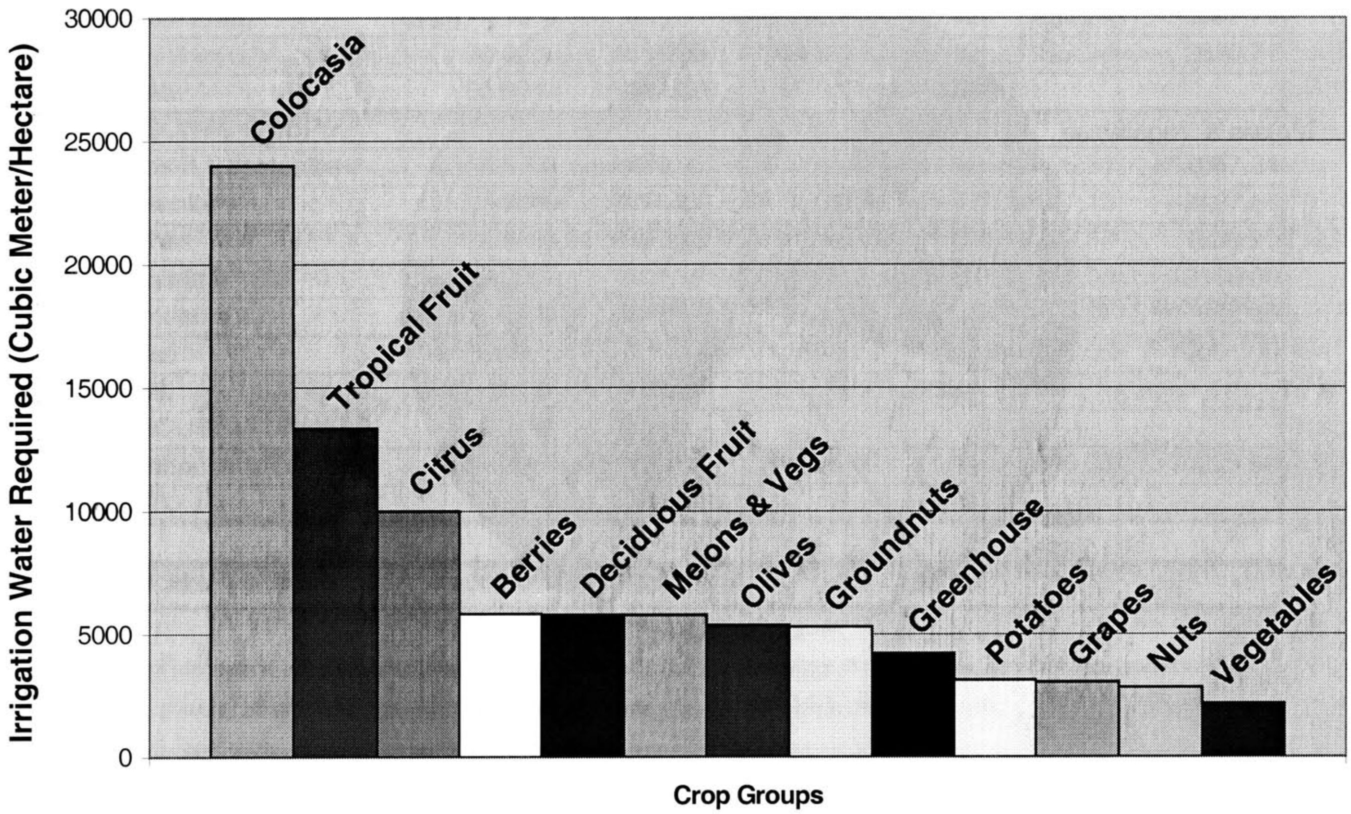

Figure 7.2: Irrigation Water Requirements per Hectare for each Crop Group

Clearly colocasia, a vegetable from the potato family, is the largest consumer of irrigation water per hectare of land at 24,000 m^3/ha. In fact, this crop is so water intensive that the Cypriot government has taken active steps to control its planting. What is more interesting is that citrus is also a relatively large consumer of water per unit area (10,000 m^3/ha). Potatoes, by contrast, consume far less (3,140 m^3/ha when all growing seasons are averaged.). Unit area water requirement for citrus is more than three times that for potatoes.

Having established the area of coverage for each crop group and per unit area water requirements, it is now a straightforward exercise to estimate the total amount of water devoted to the irrigation of each crop group. The total quantities of irrigation water used in Cyprus for each crop group are shown in Figure 7.3 and Figure 7.4. The source of the irrigation water may be either surface water reservoirs or groundwater. The present total average annual demand for irrigation water throughout Cyprus is 193.25 million cubic meters (MCM).

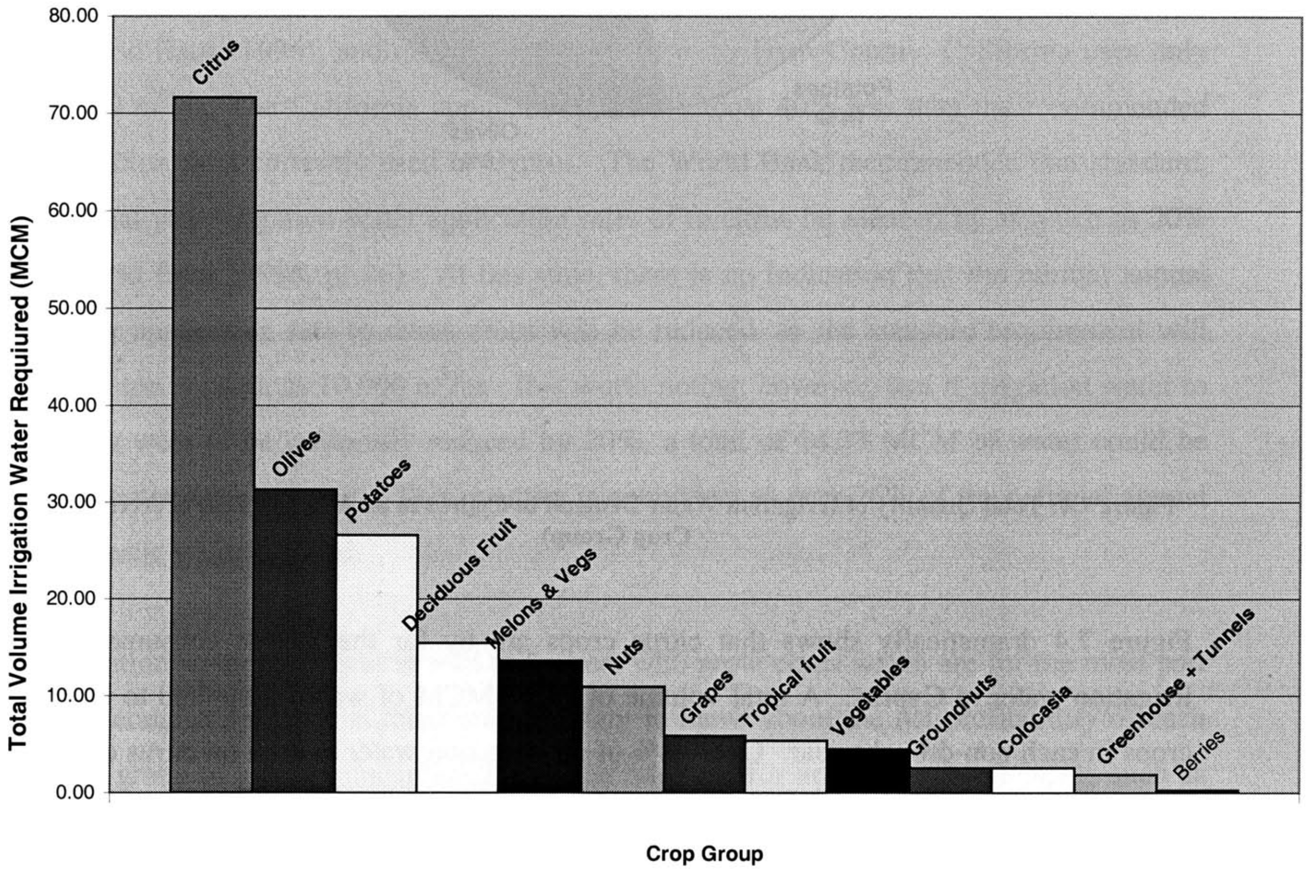

Figure 7.3: Total Quantity of Irrigation Water Demand in Cyprus in an Average Year

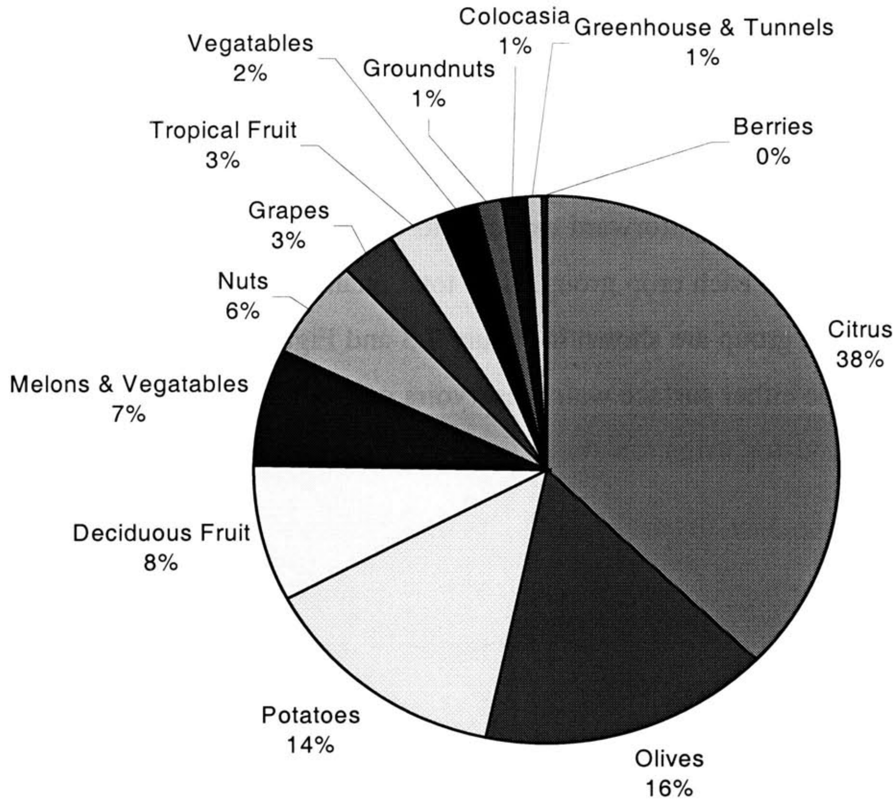

Figure 7.4: Total Quantity of Irrigation Water Demand in Cyprus in an Average Year (Percent by Crop Group)

Figure 7.4 dramatically shows that citrus crops are by far the largest consumers of irrigation water in Cyprus. A total volume of 71.63 MCM of water is applied to citrus crops in each non-drought year. Over 38% of all irrigation water is used on citrus crops. As the majority of water in Cyprus is used for irrigation, Citrus irrigation accounts for almost 30% of all water used in Cyprus. The average total quantity of water used for citrus irrigation exceeds total gross average annual domestic demand (62 MCM – World Bank, 1996, Annex 5.4) by over 15.5%.

The irrigation water requirement of each crop group is a function of the plant biology. Some crops are water-intensive while others are acclimated to dry climates and require little water to produce a suitable yield. The water requirements shown allow for the expected efficiencies of the irrigation systems used to apply the water. The amount of water allocated to a unit area of a crop is generally 15-20% more than the actual needs of the plant. This additional volume is lost to leakage or evaporation. The efficiencies of Cypriot irrigation systems are almost uniformly in the 80-85% range (Tsiourtis, p.73).

There is some question as to the magnitude of the per unit area water requirements for citrus. The Agricultural Research Institute is experimenting with reducing the water allocations to citrus plantations to determine the effects on yield. The irrigation application rate to grapefruit in Israel is 6900 m^3/ha assuming a 75% irrigation efficiency (World Bank, 1996), and drip irrigation of Citrus in Kern County, California uses only 6,100 m^3/ha. The California application rate is almost 40% less than the recommended irrigation rates currently used in Cyprus. The World Bank recommended that standard, normal-year irrigation water application rates of to citrus be reduced by as much as 20% (World Bank, 1996, p. 26). At this time, there is no indication that the normal annual water application rate to citrus crops will be reduced, so the standard requirement will continue to taken as 10,000 m^3/ha. It is worth noting, however, that if irrigation water to citrus were to be uniformly reduced by 20%, a total of 14.33 MCM of water could be conserved for other uses. This quantity is equivalent to over 26% of the national annual domestic water demand.

Irrigation water in Cyprus is sold to farmers who grow crops which are for the most part sold commercially. It is therefore important to know about the net profitability of each crop group to gain an understanding of the rationale for how agricultural inputs such as land and water are chosen by farmers. Table 7.2 shows the net profits generated by each crop group in Cypriot Pounds per hectare. Net profit is defined as the gross profit minus all production costs including irrigation water, fertilizer, family labor, hired labor, etc. Figure 7.5 displays net profit per hectare for each of the irrigated crop groups grown in Cyprus.

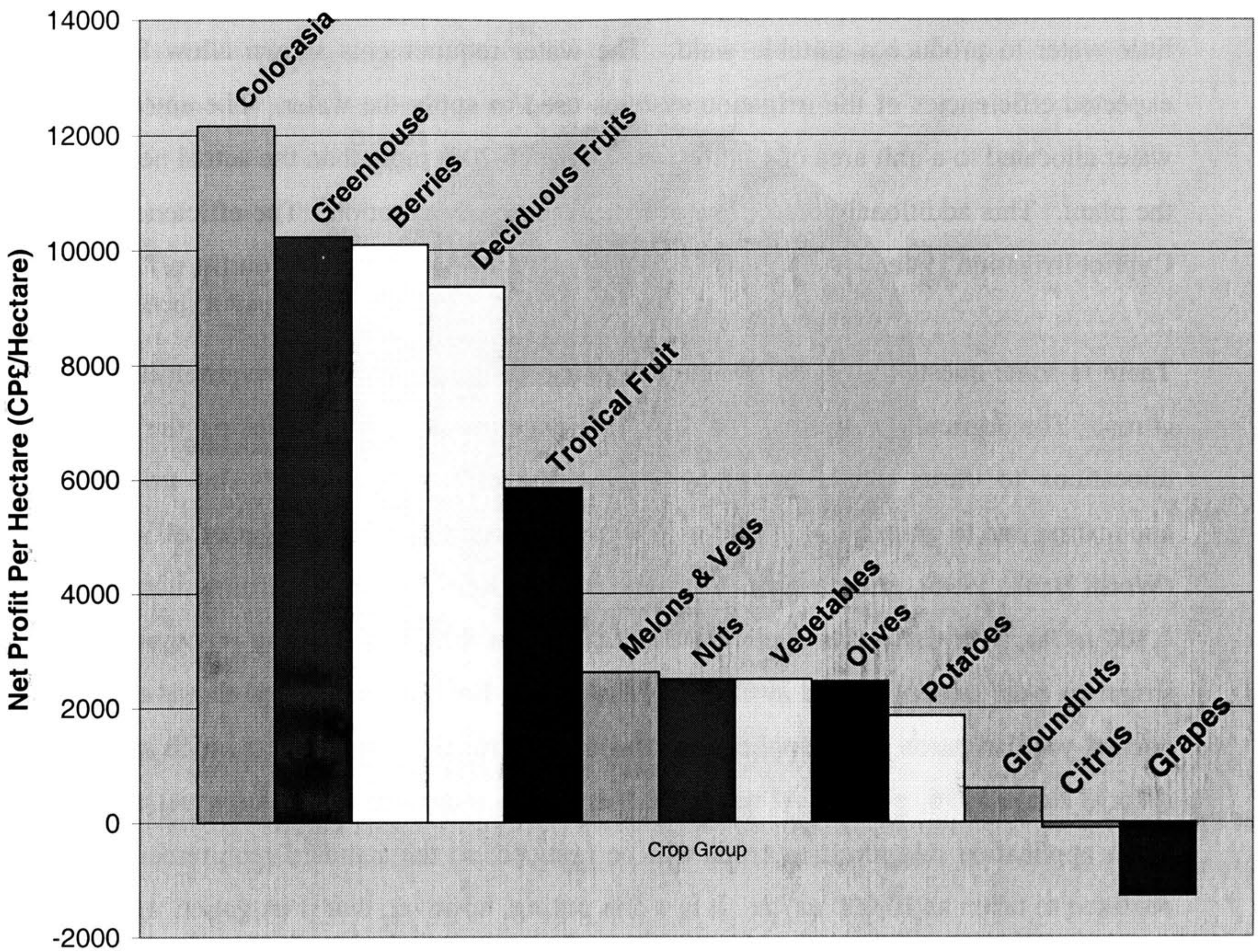

Figure 7.5: Net Profit per Hectare for Irrigated Crop Groups in Cyprus

In general, the crop groups can be separated into three clusters when examined in terms of profitability. The crop groups with a relatively high profitability are colocasia, greenhouse and tunnel crops, berries, deciduous fruits and tropical fruits. The profitability of colocasia, in spite of the very large irrigation costs, is a testament to the high market price of the crop. Moderately profitable crop groups are melons and vegetables, nuts, olives, vegetables, and potatoes. The final three crop groups, groundnuts, citrus, and grapes, have a low profitability. In fact, the data shows that citrus and table grapes are produced at a *net loss* to the farmer.

It is worthwhile to be explicit about the implications of the data which have been presented in Table 7.2 and Figures 7.1 – 7.5. Citrus is the crop group that occupies the *largest percentage of farmland* in Cyprus. It also requires large quantities of irrigation water per unit area; therefore citrus is the *largest consumer of water* in Cyprus. On an island where water is scarce, citrus crops require more water than all the cities, towns, and tourist hotels combined. Yet citrus is a crop which has an overall *negative net profit*, even with the CY£ 0.13/m^3 government subsidy for irrigation water. At a time when the citizens of Nicosia, Larnaca, and other cities and towns are required to endure severe rationing of domestic water, up to 30% of the entire nation's water resources are being used to irrigate this crop with an apparent negative value.

Why would a nation devote such a large portion of its natural resources to a crop which is unprofitable? There are perhaps several reasons. One reason may be that citrus crops were not always so unprofitable. In 1973, citrus accounted for 28.3% of all exports, whereas in 1997 citrus was only 2.9% of total exports. This may be explained by the growth of other sectors of the Cypriot economy and by the decrease in the price of citrus due to competition from Israel and North Africa. Since citrus is a permanent crop, there may be resistance by farmers to switching crop types in the face of declining profitability. There may well also be an aesthetic and sentimental value placed on citrus trees which makes both farmers and the government reluctant to uproot large orchards.

It is also possible that the negative net profits of citrus and table grapes are somewhat misleading. As previously stated, the net profit calculations are made by subtracting the value of all inputs and costs from the gross profit of each crop group. One of the inputs to the production of all of the crop groups is family labor. As has been stated, in Cyprus part-time farming is the norm; therefore, a significant portion of the labor required for farm production may be family labor. Because work on family farm plots is often done on weekends and in addition to other jobs, the cost of family labor is generally not a real, out-of-pocket expense to most farmers (World Bank, 1996, p. 5). Family labor does represent an opportunity cost, since time spent farming is time that cannot be spent in other profit-generating activities. Because farming is already a secondary occupation for most of the people who work in agriculture however, it is perhaps unlikely that other work would be substituted for farming. Table 7.3 lists the net profitability of crop groups grown in Cyprus when the costs of family labor are excluded from the production expenses.

Table 7.3: Crop Group Net Profitability when Family Labor Costs are Excluded

Crop Group	Family Labor (CY£/ha)	Net Profit w/o Family Labor (CY£/ha)
Grapes	665.00	-619.00 **(1)**
Citrus	473.03	377.39 **(2)**
Groundnuts	481.00	1073.00
Potatoes	553.67	2414.33
Vegetables	784.71	3282.26
Olives	1120.00	3585.00
Nuts	969.58	3590.30
Melons & Vegetables	2462.96	5510.30
Tropical Fruit	919.69	6767.48
Deciduous Fruit	2015.43	11374.65
Colocasia	2894.00	15054.00
Berries	5304.00	15395.00
Greenhouse & Tunnels	8083.79	18313.29

Notes:

(1) Table Grapes still apparently produced at an overall loss

(2) Citrus crops now show a positive net profit

The exclusion of the cost of family labor increases the net profitability of all crop groups. Citrus becomes minimally profitable, especially in light of the small average farm size in Cyprus (3.8 hectares [World Bank, 1996, p.5]). Irrigated table grapes become less of an unprofitable crop but continue to generate a net loss for the farmer. Therefore it is still puzzling why so much time, land, and water is devoted to citrus and to a lesser extent table grape production. Many of the government officials interviewed in Cyprus stated that farming continued to be a way of life for many newly urbanized Cypriots. People may continue to do part-time work on even unprofitable farms in order to retain a connection to ancestral lands and villages. While there may be some truth to this, it does seem slightly disingenuous. It is generally the case that most people who invest time and money in an arduous activity such as farming intend to gain a return on their investment. Most sources state that there are no direct subsidies to farmers other than the 66% discount on the price of water; however, Mr. George Constantiou, the retiring Director of the Cyprus Geological Survey stated in a personal interview that the government spends CY£ 80 million per year in direct subsidies to citrus wholesale companies and processing plants. This reportedly allows the wholesale companies and processing plants to pay Cypriot farmers a higher than market price for their crops. Under such a scheme, farming may be more profitable for Cypriot farmers than predicted by standard agronomic indicators. All of the government employees interviewed in Cyprus were in agreement that farmers were a particularly powerful constituency in the national political system.

The concepts of water supply and the agricultural economics may be linked by using data on water usage and net profitability to establish a marginal cost of water for each crop group in Cyprus. By examining each crop group individually, it is possible to determine the net profit per unit of water applied to each hectare of farmland (Eqn. 7-1). This is a measure of how much profit a farmer may expect to gain for each cubic meter of irrigation water he applies to his crops. This relationship is derived from normal application rates and standard yields. It should be noted that the relationship should not be linear since there is a minimum level of irrigation necessary for any crop yield at all. The marginal cost of water for each crop may also be computed (Eqn 7-2). This is the maximum price that a farmer of any particular type of crop would be willing to pay for water in order to avoid losing money. Table 7.4 lists the profits per unit of water and marginal cost of water for all Cypriot irrigated crop groups, assuming the current subsidized water price of CY£ 0.07 per cubic meter.

$$\text{Crop Profitability per Unit Volume of Water} = \frac{\text{Net Profit per Hectare (CY£/ha)}}{\text{Irrigation Water Requirement per Hectare (m}^3\text{/ha)}} \quad (7\text{-}1)$$

$$\text{Marginal Cost of Water} = \frac{\text{Net Profit per Hectare excluding cost of water (CY£/ha)}}{\text{Irrigation Water Requirement per Hectare (m}^3\text{/ha)}} \quad (7\text{-}2)$$

Table 7.4: Crop Group Profitability per Unit of Water and Marginal Cost of Water

Crop Group	Water Require-ment (m^3/ha)	Irrigation Cost (CY£/ha)	[Net Profit including all Costs] Crop Profitability per Unit Vol. Of Water (CY£/m^3)	[Net Profit including all Costs] Marginal Cost of Water (CY£/m^3)
Grapes	3,060	214.00	-0.42	-0.35
Citrus	10,000	700.00	-0.01	0.06
Groundnuts	5,300	371.00	0.11	0.18
Tropical Fruit	13,349	934.34	0.44	0.51
Olives	5,375	376.00	0.46	0.53
Colocasia	24,000	1680.00	0.51	0.58
Melons & Vegetables	5,790	405.31	0.53	0.60
Potatoes	3,140	219.67	0.81	0.66
Nuts	2,828	197.94	0.85	1.00
Vegetables	2,178	147.13	0.90	1.21
Deciduous Fruit	5,801	552.29	1.64	1.71
Berries	5,840	409.00	1.73	1.80
Greenhouse & Tunnels	4,224	295.37	2.05	2.49

When family labor is fully costed, the table shows that even with subsidized water prices, growers of both table grapes and citrus crops lose money for each cubic meter of water they apply to their fields, see Figure 7.6. The marginal cost of water for growers of grapes and citrus crops is lower than even the subsidized cost of water. The marginal cost of water for all of the rest of the crop groups is higher than the subsidized price of irrigation water. In fact, the marginal cost of irrigation water is higher than full cost (for O&M and capital recovery) for every other crop group except groundnuts. When the marginal cost of water for a crop is higher than the actual price paid for water, a farmer makes a profit on that crop. Thus for farmers of all crop groups except grapes, citrus, and groundnuts, farming would remain profitable even if the full O&M and capital recovery price of CY£ 0.20/m^3 were charged for water.

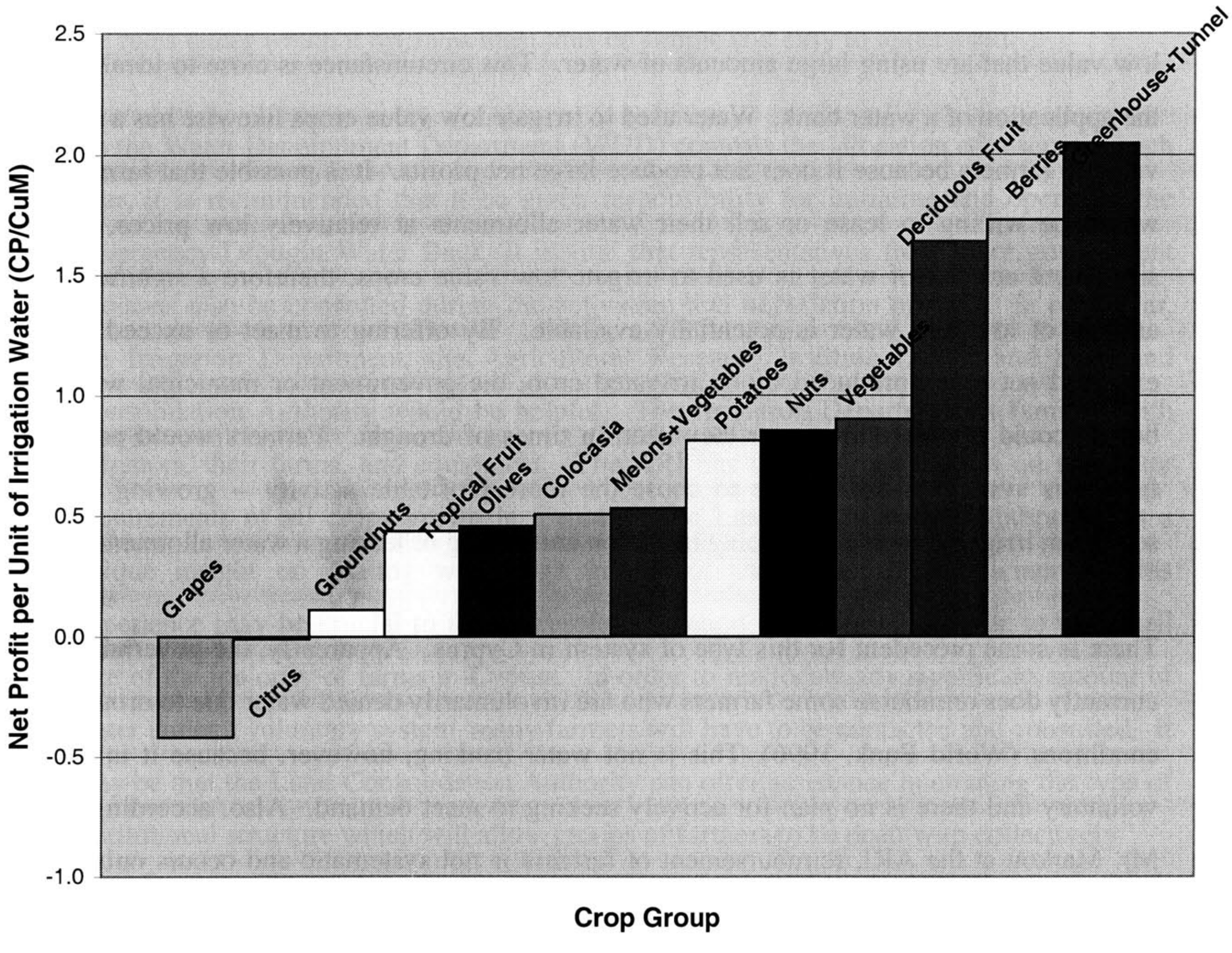

Figure 7.6: Net Profitability of Crop Groups per Unit of Water Applied

If family labor is not counted as a cash expense in the production of each crop, then the situation changes somewhat. Table grapes remain unprofitable, but the marginal cost of irrigation water for citrus becomes greater than the subsidized price of water. The marginal cost of water for citrus is still below the full price of water, but all other crops show a marginal cost well in excess of the full price.

This information is useful in evaluating the current pricing policy for irrigation water, but as discussed earlier, there is powerful political resistance to increasing the cost of water. What is more useful is the observation that there are crops, citrus in particular, of very low value that are using large amounts of water. This circumstance is close to ideal for the application of a water bank. Water used to irrigate low value crops likewise has a low value to farmers because it does not produce large net profits. It is possible that farmers would be willing to lease or sell their water allotments at relatively low prices. A significant amount of water is used to irrigate low value crops; therefore a significant amount of low cost water is potentially available. By offering to meet or exceed the expected net profit produced by an irrigated crop, the government or municipal water boards could purchase the water they need in times of drought. Farmers would profit from this system by being able to chose the more profitable activity -- growing and selling an irrigated crop or foregoing irrigation and selling or leasing a water allotment.

There is some precedent for this type of system in Cyprus. Apparently, the government currently does reimburse some farmers who are involuntarily denied water due to drought conditions (World Bank, 1996). This is not water banking, however, because it is not voluntary and there is no plan for actively seeking to meet demand. Also, according to Mr. Markou at the ARI, reimbursement of farmers is not systematic and occurs only in particular cases. An Emergency Drought Water Bank would seek to acquire water from agriculture for use in the cities, but if the arrangements for doing so are unfavorable to farmers, then the water bank will be politically infeasible. What is needed is a clearly articulated policy which encourages farmers to participate in order to serve their own best interests, while at the same time serves the interests of the society and nation as a whole by providing water to its citizens and productive industries.

7.2 Proposal for Cyprus Emergency Drought Water Bank

The first step in the creation of an emergency drought water bank is to define the goals and methods of the program. This is important both for policy and operational reasons. All stakeholders – municipalities, government agencies, farmers, politicians, etc. - must view the program as potentially beneficial. The reasons for creating the water bank and the rules under which it operates must thus be simple and easy to understand.

As the Water Development Department (WDD) controls the allocation of resources each year, it is recommended that it be given responsibility for initiating and operating the Emergency Drought Water Bank. It is vital that representatives from other government agencies also be consulted during the activation and negotiation process. In particular, the Irrigation Department, the Agricultural Research Institute (ARI), and the Land Consolidation Authority would be helpful. The Irrigation Department is familiar with irrigators, their farms, and equipment. The ARI has detailed information on the water requirements of all crops grown in Cyprus. The Land Consolidation Authority has a unique insight on dealing with large groups of mainly small-plot farmers. This experience may be crucial to the successful operation of a water bank due to the small size of the majority of farms in Cyprus. In order to reallocate any significant amount of water under a voluntary system, many farmers will have to be contacted and consulted. It may be that the Land Consolidation Authority can offer assistance in creating the type of institutional structure which will allow groups of farmers to be dealt with collectively.

The Emergency Drought Water Bank should focus on operating in the areas served by the Southern Conveyor Project. The SCP is connected to the largest surface water reservoirs, serves the majority of the irrigated cropland (especially citrus crops), and delivers water to most of the major urban areas in Cyprus (Tables 7.5-7.6, Figure 7.7). The extensive water conveyance network already in place within the SCP will allow reallocated water to be sent directly from reservoirs to domestic users without additional costs and without the need for the construction of additional infrastructure. The capacity of the existing pipelines and intermediate reservoirs should be sufficient as they are only delivering the predicted domestic demand and no more.

Table 7.5: Domestic Demand in the Southern Conveyor Project

Municipal, Industrial and Tourism Demand served by the Southern Conveyor Project (MCM)	
District or Municipality Served	Projected Demand in Year 2000
Limassol	16.7
Nicosia	18.4
Larnaca/Famagusta	13.7
Total	**~49**

Table 7.6: Irrigated Areas and Agricultural Water Demand in the Southern Conveyor Project (Government and non-Government Systems)

Crop Group	Cropping Breakdown in the SCP (%)	Area Cropped [SCP] (ha)	Water Require-ment (m^3/ha)	Total Water Used in SCP (MCM)
PERMANENT CROPS				
Citrus	33.64%	5306.71	10000.00	53.07
Grapes	4.14%	653.07	3060.00	2.00
Olives	1.58%	249.23	5375.00	1.34
Deciduous Fruit	2.60%	410.00	5801.35	2.38
Tropical Fruit	0.03%	4.82	13348.67	0.06
Nuts	0.10%	15.30	2827.67	0.04
TOTAL	**42.09%**	**6639.13**		**58.89 (64%)**
SEASONAL CROPS				
Melons & Vegetables	9.67%	1525.38	5789.56	8.83
Vegetables	9.18%	1448.77	2177.58	3.15
Potatoes	34.80%	5488.60	3140.00	17.23
Colocasia	0.44%	69.65	24000.00	1.67
Groundnuts	2.00%	315.76	5300.00	1.67
Berries	0.22%	34.83	5840.00	0.20
TOTAL	**56.31%**	**8882.99**		**32.77 (35%)**
GR.HOUSE+TUNNELS				
Greenhouse & Tunnels	1.60%	251.89	4224.44	1.06
TOTAL	**1.60%**	**251.89**		**1.06 (1%)**
OVERALL TOTAL	**100%**	**15775**		**~93**

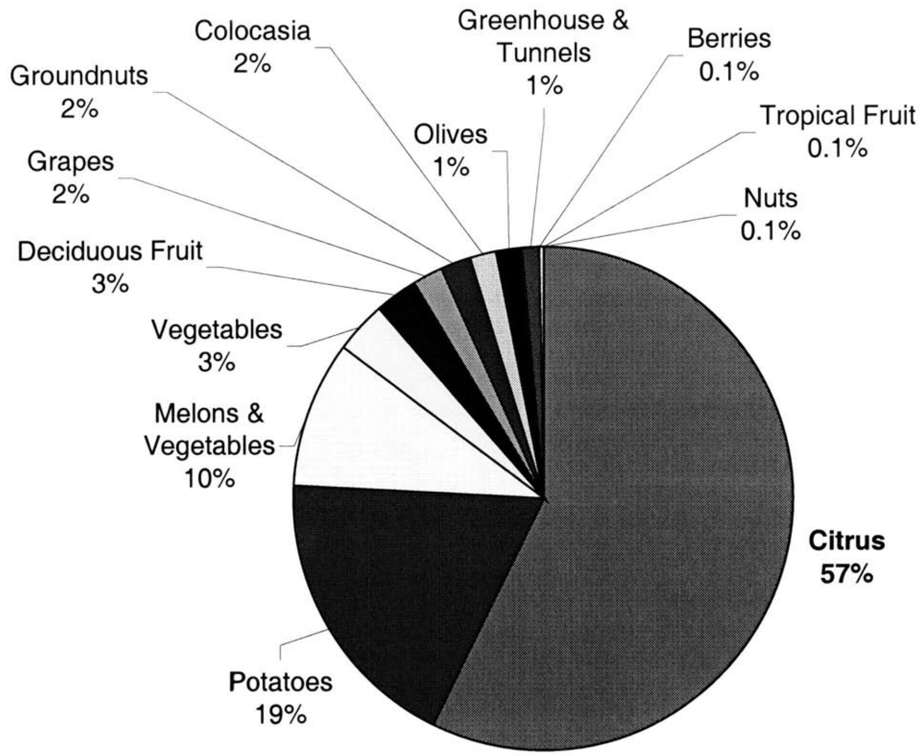

Figure 7.7: Irrigation Water Applied in the Southern Conveyor Project (Percent by Crop Group)

Figure 7.8 shows the marginal cost of each crop vs. the cumulative irrigation water requirement: this figure is very interesting in that it gives the user a rough unit water buying price (given by the y-coordinate) depending on the amount of water he needs (given by the x-coordinate).

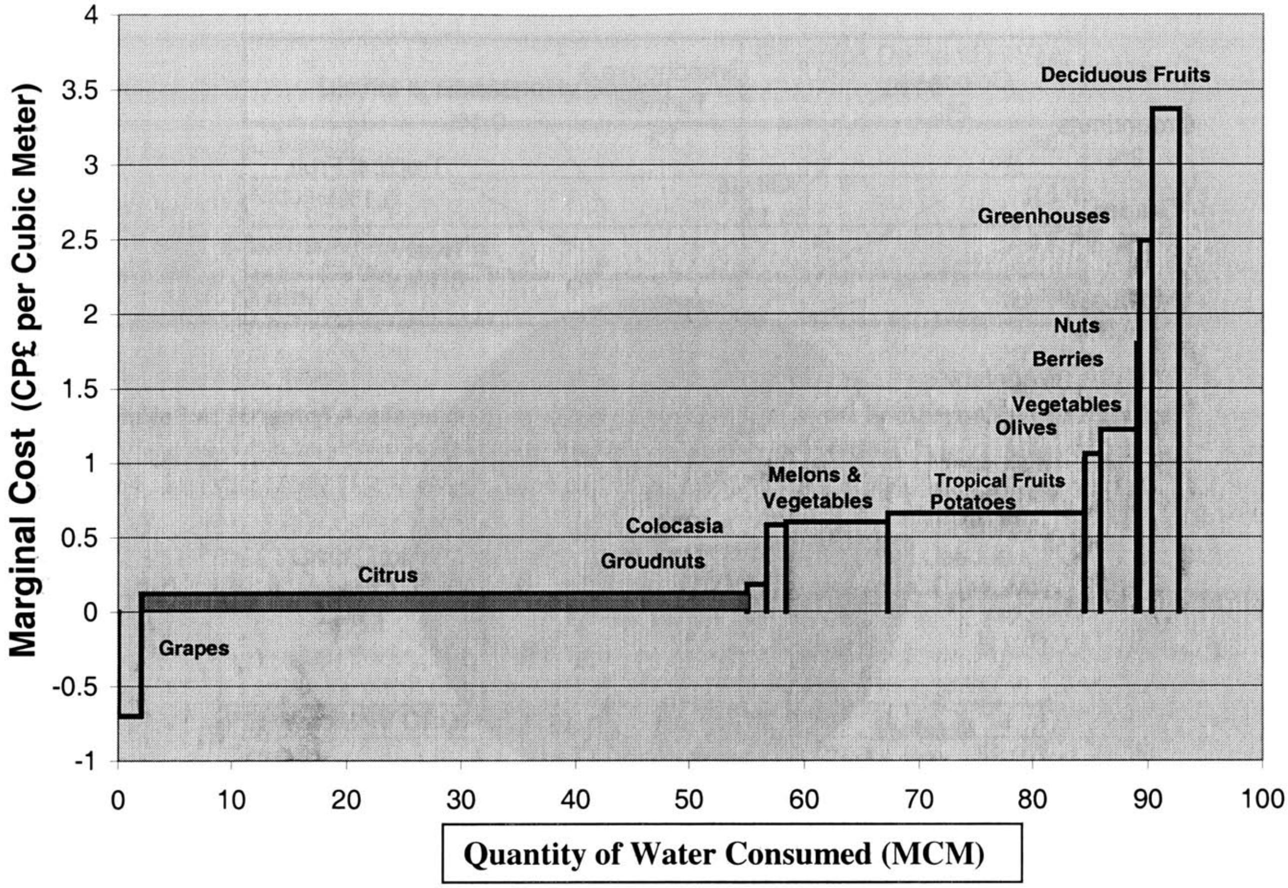

Figure 7.8: Marginal Cost of Water vs. Quantity of Water Consumed per Crop Group in the Southern Conveyor Project

The SCP is a highly suitable, ready-made scheme for the application of a water bank. There are high levels of domestic demand, a large proportion of water going to low-value crops, and a conveyance system tying together reservoirs, farms, and cities.

Now that the location of the water bank has been chosen, a structure is needed. A Cypriot water bank might be organized under the following model:

The Cyprus Emergency Drought Water Bank is an office of the Water Development Department. Its purpose is to assist in ensuring that all critical and high priority water demands are met during times of drought. The water bank works to facilitate the transfer of water allocations between willing sellers and buyers. Participation in the water bank is a voluntary action, which is meant to benefit both the water buyer and seller.

1) GOALS FOR CYPRUS EMERGENCY DROUGHT WATER BANK

A. "Provide water for…"

1. Municipal, Industrial & Tourist ('MIT') Uses
2. Agricultural Uses (Protect permanent crops and supply crops with high value and low water use)
3. Groundwater Protection (Usage Reduction)
4. Groundwater Recharge
5. Carryover Surface Storage
6. Environmental Uses

B. "Help to Promote…"

1. Efficient allocation of water between domestic and agricultural users in times of drought, and continued agricultural production when water is plentiful.
2. Conversion to crop groups with a high value to water use ratio (i.e. a reduction in the amount of citrus and table grape area cropped).
3. An overall gradual reduction in the total amount of water used in agriculture.

C. "Help to Reduce…"

1. Lack of reliability in the existing water supply system.
2. Need for expensive infrastructure investments necessary to obtain new supplies (i.e. desalination plants) by satisfying priority demands during drought periods.

2) METHODS OF OBTAINING WATER FOR THE CYPRUS BANK

1. Fallow farmland being used for growing seasonal crops.
2. Fallow permanent crops by reducing water down to "survival" levels.
3. Change existing seasonal crops to less water demanding ones
4. Shift from permanent crops to seasonal crops which can be fallowed during drought years.

The Cyprus emergency drought water bank will be activated whenever available supply of fresh water from all sources drops below the existing level of demand.

7.3 Discussion

7.3.1 Goals

There are several potential goals for an emergency drought water bank, each of which would serve the national interests of Cyprus in one way or another. The goals listed above are compatible with each other, but resources, i.e. water, committed to one goal will be unavailable to fulfill other goals. The goals of the water bank must therefore be prioritized, and the government must decide on the amount of money to be allocated towards non-reimbursable goals. Providing water for municipal, industrial and tourist should clearly be the highest priority of the water bank. This has already been established. When water is "bought" from farmers and "sold" to cities and water boards, there is little or no net cost to the government. In fact, since the price of irrigation water is subsidized, transfer of water from agricultural to domestic users could actually save the government money in terms of direct costs. Growers of high-value agricultural products might also be willing to pay extra money in order to acquire water from other farmers. The water bank should facilitate and encourage transfers that lead to more profitable utilization of agricultural water.

The remaining four goals create benefits which are somewhat harder to quantify. There are also generally no specific beneficiaries, so the government will probably have to bear the full cost of any water used to achieve these goals. Groundwater protection is important in Cyprus because of the over exploitation which has taken place and continues to occur at an alarming rate. Many aquifers have experienced or are in danger of salt-water intrusion, which is enhanced by a reduced based flow. The groundwater could be protected if pumping rates were reduced by substituting surface water for groundwater in critical areas. Surface water could also be used to directly recharge endangered aquifers through infiltration ponds or injection wells. The water bank could be used to make water available for these purposes. The water bank could also serve to conserve water rather than reallocate it. The multi-year nature of droughts in Cyprus makes year to year carry-over storage of water in surface reservoirs important. Based on WDD estimates of required carry-over storage, the water bank could reimburse farmers for the necessary quantity of water and then simply leave it in the reservoirs for use next year. Finally, the water bank might acquire water for environmental uses such as water quality preservation, habitat conservation and minimum discharge flow in the streams.

By allowing water to be reallocated between irrigators, the water bank will encourage the planting of crops with high profit-to-water use ratios. Farmers of these types of crops will be able to afford to purchase water through the water bank from farmers who are less profitable at reasonable prices. This will increase the overall productivity of the agriculture industry in drought years. The water bank might also be used to encourage conversion of cropland away from crops with high water requirements. Currently, the government has a program that pays farmers to uproot citrus trees and replant with other crops. This program could be combined with the water bank in various ways to produce long-term as well as short-term water supply reallocation (Markou, Feb.1999, personal communication). The water bank will allow for reallocation of water during droughts, but there are no continued effects during times when water is plentiful. Therefore, a water bank will have no permanent impact on farmers.

Currently, perhaps the biggest problem with the Cypriot water supply system is its reliability. The system is technically sound and is capable of supplying all demands during an average or better rainfall year, but the system is unreliable because supply drops below demand in years when rainfall is below average. The water bank can improve reliability of the system by helping to ensure that water is available to those who are willing to pay for it. The reliability of the system can also be improved by increasing the total available quantity of water through the construction of new infrastructure. The desalination plants which are currently being constructed or planned will serve this purpose. But these plants will also only serve those willing to pay an increased price since the cost of desalinated water is higher than the cost of treated surface water. The desalination plants will also run continuously, thus increasing the cost of water even in years when rainfall is adequate. The water bank will only be activated when needed and involves no capital costs.

7.3.2 Methods

The most obvious way to reduce the amount of irrigation water used is to reduce the area of land irrigated. This policy currently is being implemented by fallowing land used to grow seasonal crops. The rationale behind this policy is that denying irrigation water to a seasonal crop for one season does not adversely affect the viability of the farm in the following year. In other words, the farmer can simply replant his crop next season if water is available. Permanent crops, on the other hand, might very well die if no irrigation water is applied. New trees or vines might then take five to ten years to reach productive maturity. A farmer might also reduce the amount of irrigation water needed by simply planting a different crop. For example, switching from planting watermelons to planting peas could save 3,160 m^3 of water per hectare in one growing season. Since watermelons are more profitable than peas, the water bank might need to encourage such a switch by reimbursing the farmer for his lost potential profit.

In California, the seasonal crops which were fallowed by the water bank were generally less profitable than permanent crops and used far more water. The situation is somewhat different in Cyprus. It is the citrus crops (permanent) which use the majority of the water, and at the same time, citrus crops have a very low profitability. So from a resource allocation standpoint, exclusively fallowing seasonal crops makes less sense. The fairness of this policy is questionable because currently there is no consistent policy for reimbursing farmers who are denied water during drought. Why should a farmer who choose to grow a low-profit, high water-use crop like citrus be allocated water and allowed to produce at the same time that a farmer of a higher-profit, lower water use seasonal crop is being denied water without compensation? A more fair, and perhaps more efficient policy would be to also think of permanent crops as subject to "fallowing." Water supplied to permanent crops (specifically citrus and table grapes) could be reduced down to the minimum quantity required for the survival of the plant. Crop yield would be ignored and in fact discouraged in order to reduce water requirements as much as possible. The water bank could then reallocate all of the remaining water and reimburse farmers for the value of their lost potential net profit. A more radical extension of this policy might be to reallocate *all* irrigation water away from participating citrus groves and vineyards. The water bank would reimburse the farmers for their lost profits and "insure" the trees or vines. If the trees or vines die as a result of a lack of water, the water bank would then pay the farmer to replant with a more water efficient crop. This program would be administered in a manner similar to the current citrus uprooting incentive program, and would again serve to promote both short-term supply and long-term efficiency gains. Replacing permanent crops with seasonal crops could also help with future water bank operations by creating more easily fallowable farmland from which water could be reallocated during future droughts.

7.3.3 Activation

An emergency drought water bank is, by definition, an activity that only occurs during extreme conditions. The full-scale operation of the water bank is likely to be limited to serious multi-year droughts when surface water storage is low. It is likely that decisions about the activation of the water bank will be made sometime between January to March – after the rainy season but before the irrigation season.[1]

7.4 Water Buying Price

7.4.1 Water Banking Participation Approaches

Determining the method of compensating farmers for the reallocation of irrigation water – therefore determining the effective price of reallocated water – is perhaps the most important decision to be made by water bank managers. If the price is set too low, then farmers will not be willing to participate and no water will be available for reallocation. If the price is set too high then municipal water boards and domestic users will not be willing to pay for overly expensive reallocated water. Issues of fairness must also be

[1] More details on the frequency of water bank activation are provided in section 8.10

considered when choosing the method of compensation. Paying for water by the cubic meter is perhaps the most logical method of compensating farmers for the reallocation of irrigation water. However, this method allows farmers of water-intensive crops to benefit disproportionately and thereby rewards undesirable farming practices. A fixed price per hectare of irrigated land could be offered to those who are willing to forgo irrigation, but this method disconnects the price paid from the actual quantity of water reallocated. Finally, any farmer who agrees not to irrigate could be reimbursed for all profits lost. This perhaps seems the fairest method, since no farmer would gain or loose more income than if he had not participated. But again, this would lead to a variable price of water and some farmers would be paid much more than others.

Another important decision involving price, available water quantity, and overall policy, is the level of participation for each farmer. One potential implementation plan is to allow farmers to participate at a partial level. In other words, irrigation water might not be completely curtailed but merely reduced. The farmers might then be compensated on the basis of the final percentage of the water that they received. This type of approach may make the most sense for growers of permanent crops. Farmers may not agree to participate in the program if they do not receive enough water to keep their trees alive. In this case some irrigation water must be delivered, but yields will be decreased or perhaps even eliminated altogether. This approach would also allow the participation of seasonal crop farmers who are willing to switch to crops which are less water intensive. Another approach would be to require "all-or-nothing" participation in the water bank. A farmer would either receive all allocated irrigation water and no compensation or no irrigation water and full compensation. This approach would likely be easier to administer and monitor because fewer farmers would be involved. Many farmers of permanent crops might not be willing to participate in this type of program, though, because of the fear of losing their trees or vines. At minimum, an "insurance" program would be required in conjunction with this approach to compensate farmers who lose permanent crops. As has been stated, the loss of some citrus crops might actually correspond to current government policy of uprooting citrus trees to reduce total irrigation demand. A third approach would combine aspects of the first two and require "all-or-nothing" participation from farmers of seasonal crops, but allow for application of "survival-level" quantities of water to permanent crops. The permanent crop farmers would be entitled to full compensation for lost profits based on a complete loss of crop yield. In general, reducing water application to minimum survival levels for permanent crops completely prevents the development of any marketable fruit. Studies of some crops also indicate that water stress can also affect yields in the following year, so it is important to apply enough water to prevent long-term carry-over effects. In general, it is recommended that no participation be sought from greenhouse and tunnel growers, as this is a highly profitable industry and water brought from these growers would be highly priced.

In any case, no farmer will be entitled to compensation merely because his or her water allocation is reduced during a drought. A farmer is only eligible for compensation if he or she chooses to reallocate the water which he or she would have received after standard drought reductions.

In summary, there are three water bank participation approaches:

1) *Partial participation*: A farmer may choose to yield any portion of his irrigation allotment and receive compensation only for the water which he gives up;

2) *Full participation only*: A farmer must choose either to yield all of his irrigation allotment and receive full compensation or not to participate in the water bank and receive all allotted water and no compensation;

3) *Combined approach <recommended>:* Farmers of seasonal crops may only choose "all-or-nothing" participation in the water bank. Growers of permanent crops are entitled to participate in the water bank but still receive sufficient water to keep their trees or vines alive. The permanent crop farmers would be compensated for full crop loss. Table 7.7 shows the water quantities conserved for reallocation as a result of the combined approach. It should be noted that the

marginal cost of water varies with the amount of available water supply. Table 7.7 shows an example for an available supply of 140 MCM.

Table 7.7: Permanent Crop Group Profitability per Unit of Water and Marginal Cost of Water Based on Full Loss of Yield and Application of "Survival" Quantities of Irrigation Water (Available Supply of 140 MCM)

Crop Type	Minimum "Survival-Level" Water Require-ment (m^3/ha)	Water Conserved for Reallocation (m^3/ha)	"Survival-Level" Irrigation Cost (CY£/ha)	[Net Profit Only] Crop Profitability per Unit of Water (CY£/ m^3)	[Net Profit Only] Marginal Cost of Water (CY£/ m^3)
Grapes	1,530	1,530	107.10	-0.84	-0.70
Citrus	5,000	5,000	350.00	-0.02	0.07
Tropical Fruit	6,675	6,675	467.25	0.88	1.02
Olives	2,688	2,688	188.16	0.92	1.06
Nuts	1,414	1,414	98.98	1.70	1.98
Deciduous Fruit	2,901	2,901	203.07	3.28	3.39

7.4.2 Compensation Methods

Even though water is the commodity that is sought by the water bank, using the cubic meter of water as the basic unit of payment may or may not be the most effective way of compensating farmers. Paying farmers per cubic meter of reallocated water is perhaps the simplest and most equitable way of compensating farmers for reallocation of water, however, farmers may not be used to thinking in terms of volumes of water. This may cause confusion and result in farmers' unwillingness to participate. It may be useful to approach farmers with an offer to pay compensation per hectare of land that is left unirrigated or irrigated only at survival rates. The hectare is a unit that farmers are more familiar with and so may be more acceptable to farmers. In either case, the buying price per unit of water or per unit of land may be fixed at a specific level regardless of type of crop. By fixing the price, the government would be effectively targeting certain groups of farmers since farmers whose marginal costs of water are higher than the offered price would lose money by participating in the bank. The maximum amount of water available to the bank would depend on the price offered. A higher price would attract farmers of different types of crops, thus making more water available. The drawback is that if the price is fixed high enough to attract farmers of very profitable crops, then the farmers of less profitable crops such as citrus stand to collect a windfall profit, which may not seem fair to other farmers. In order to avoid such a situation, a variable price could be offered according to the type of crop. A farmer could be compensated for reallocated water according to the typical level of net profit generated by the type of crop normally grown. This method is fair because no farmer stands to make any more or less than usual, but it means that the actual water obtained from farmers of different crops has a variable cost even though there is no difference in the water itself.

As a summary, there are three possibilities for determining compensation to farmers (the buying price of water):

1. *A fixed price per cubic meter of water <recommended>:* A farmer would be paid based on the amount of water his or her crops would normally consume (according to the Agricultural Research Institute data) and the average profit per unit area. A single price would be offered by the Government per cubic meter of water transferred, thus a farmer growing a more water-intensive crop would receive more compensation than a farmer growing a less water intensive crop on an equal amount of land. The government would use the marginal costs of water (with or without family labor) to determine the initial buying price for water based on the amount of water required by the bank. This would actually lead to a fixed price per hectare for each separate crop group.

2. *A fixed price per hectare*: A farmer would be paid based on the area of farmland he or she would normally irrigate. A single price would be offered by the Government per hectare of irrigated farmland regardless of the type of crop grown on that land, the profitability of the crop, or the water consumption of the crop. The government would use the net profits per crop (with or without family labor) to determine the initial compensation rate per hectare based on the amount of water required by the bank.

3. *A variable price based on the profitability of the crop grown on the land*: A farmer would be compensated for all the potential net profits he or she will forego due to reallocation of irrigation water. Thus the price per cubic meter of water or the price per hectare of farmland would both be variable according to the type of crop. Offers would first be made to farmers growing the crop with the lowest value to water use ratio, then offers would be made to farmers of the crop with the second lowest ratio, and so on until the necessary quantity of water has been purchased.

7.4.3 The Effects of the Irrigation Subsidy

A very important factor to consider when setting the offering price for water to be reallocated by the water bank is the subsidy which is already paid by the government on irrigation water. The government, through the WDD, is responsible for the operation and maintenance of the dams, reservoirs, pump stations, and pipelines through which water is delivered to towns, cities, and farms. On average the operation and management costs 'O&M' and capital costs of delivering a cubic meter of raw water to any location in the SCP is approximately CY£ 0.20. This price includes operational costs of the WDD, and energy costs of pumping water from the reservoirs. The full cost of raw water is included in the final price paid by domestic users after treatment and delivery. Agricultural users, on the other hand, are not charged full price for water. The average price charged to farmers is CY£ 0.07/m^3. Therefore the government loses CY£ 0.13 on every cubic meter of water which is sold to agricultural users. This loss is seen as a subsidy to agriculture.

Government policy is to provide a subsidy to agriculture by charging less than the full O&M and capital cost of irrigation water. Subsidies at some level are, in general, allowed under the terms of the loan agreements that financed the construction of the water resources infrastructure. Subsidized agricultural water is also common throughout the world. A case could be made that a simple reduction in the subsidy would cause a reduction in agricultural water consumption and therefore would decrease water deficits.

The arguments in defense of this are beyond the scope of this report, but it is important to understand that there is a real cost to the government for each cubic meter of water delivered to agriculture. There is no similar cost associated with the delivery of water to domestic users. Therefore, if water normally allocated to agriculture is instead sold to domestic users, the government actually saves CY£ 0.13 per cubic meter. Operation of the water bank requires that farmers be compensated for reallocation of their normal allotment of irrigation water. Compensation of farmers is a direct cost to the government, but it is in lieu of the subsidy normally paid on irrigation water since all reallocated water will be sold to domestic users at full price. In other words, compensating farmers for the reallocation of irrigation water is similar to directly paying a cash subsidy to them rather than selling water at lower than full cost. Therefore, if the cash compensation is less than CY£ 0.13 per cubic meter, there is no net cost to the government. In fact, if the offering price for reallocated water is less than the equivalent of CY£ 0.13 per cubic meter, the government actually realizes a net savings, as demonstrated in Table 7.8.

7.8: Effect of Irrigation Subsidy on Water Bank Costs

Costs and Incomes on Raw Water Sales	**CY£/m^3.**
Irrigation Water Sold to Farmers	
Full O&M and Capital Recovery Cost of Raw Water	+ 0.20
Price to Agricultural Users	0.07
Net Loss to Government	- 0.13
Water Reallocated from Agriculture to Domestic Uses	
Offering Price for Reallocation of Irrigation Water (Example)	- 0.10
Full O&M Cost of Raw Water	- 0.20
Price to Raw Water to Domestic Users	0.20
Unpaid Subsidy on Irrigation Water	0.13
Net Savings to Government	0.03
Total Net Cost of Water Banking @ CY£ 0.10/m^3 and 100% Participation	
55 MCM (grapes & citrus) x CY£ 0.03 / m^3.	CY£ 1,650,000 (Savings)
Total Net cost of Water Banking @ CY£ 0.10/m^3 and 100% Participation with Minimum survival Level (50%)	
55/2 MCM (grapes & citrus) x CY£ 0.03 / m^3	CY£ 825,000 (Savings)

7.4.4 Transaction Costs

The operation of the water bank itself is not without costs. There are numerous administrative costs that are separate from the cost of compensating farmers for reallocated water. These costs include salaries for water bank staff, expenses involved in negotiation of water bank contracts, information management expenses, and the costs of the compliance-monitoring program. These transaction costs may have to be borne by the government and will thus increase the total cost of the water bank program. Alternatively, these transaction costs may be passed on to the municipal water boards which purchase the reallocated water.

7.4.5 Replanting Subsidy / Permanent Crop Insurance

The Government of Cyprus and the WDD recognize that citrus crops are extremely water-intensive and a major source of demand on the strained water resources of the island. The Government has therefore enforced a policy to encourage the uprooting of citrus orchards so as to reduce overall irrigation water demand. The Department of Agriculture provides a premium of CY£ 2,450 per hectare to farmers who uproot citrus trees. In mountainous and under-developed regions, the Department will provide an additional premium of CY£ 2,000 to farmers who re-plant with trees other than citrus (almonds, olives, carobs, etc.) (M. Markou, Feb 1999, personal communication)

Assuming an interest rate of 6%, the one-time cash payment for uprooting citrus trees is equivalent to an annual payment of CY£ 333 per year over 10 years. This is roughly the same as the net profit (CY£ 377) a citrus farmer might expect to make when the costs of family labor are excluded. If re-planting is done, new trees could be expected to be producing significant yields and providing replacement income within 10 years. The subsidy therefore seems to be a reasonable inducement to farmers to uproot their citrus orchards. Part-time farmers especially would seem to benefit from this policy since they would no longer incur the opportunity costs associated with occasional work in the orchards. Based on to date evidence, however, there does not seem to be a large movement on the part of farmers to take advantage of the replanting subsidy.

The goals of the water bank and the citrus uprooting premium program are compatible and perhaps complementary. The water bank will seek to reallocate irrigation water away from low value, high water-intensity crops – this clearly means that citrus will be the primary focus of the water bank. Reallocation of water away from a permanent crop like citrus will, either by chance or design, create the possibility that some of the trees may be lost due to water stress. The choice of how much "survival-level" irrigation will be the key to whether or not "fallowed" citrus areas will survive the summer and remain productive in following years. If "fallowed" trees are provided with reasonable quantities of irrigation water (50% of normal requirements), then problems with trees dying should be minimal. If no water is provided to "fallowed" permanent crops, however, it must be expected that some (perhaps significant) portion of the trees or vines will die due to water stress. In such a case it is essential that the water banking contracts contain a provision to reimburse farmers for the loss of permanent crops. This provision would in essence be an insurance policy against damage caused by the reallocation of irrigation water. Growers whose trees die should be entitled to compensation of a magnitude similar to the current premium paid for the uprooting of citrus orchards. It is unclear whether farmers would be willing to participate in the water bank knowing that there is a possibility that their trees may die, but if there are farmers who are willing to accept this risk then the water bank might be used to encourage citrus uprooting. This type of policy will increase the cost of water banking, but presumably certain funds have already been set aside by the Department of Agriculture for paying the premium for uprooting citrus.

It should be noted that even if a grower is provided with adequate "survival-level" irrigation water, some permanent crop losses might still result. Some farmers may decide to fully irrigate half of their crops in order to collect the reallocation payment and profits from the yield of half of their orchard. A policy should be developed for dealing with this potential situation before water bank contracts are signed. Farmers who engage in this practice are taking a risk in order to increase their profits and thus may be expected to accept the consequences of their actions. On the other hand though, if an overall reduction of the total area of citrus is a high priority goal, then it may be in the government's interest not to discourage such practices.

7.4.6 Initial Water Allocation Strategies

One of the most important factors in determining the feasibility and costs of a water bank in Cyprus is the initial allocation of water resources. The primary assumption of the type of water bank being proposed is that water can be reallocated from agriculture to domestic, industrial, and tourist uses. The water bank will compensate farmers in order to reallocate enough water to make up any deficit in municipal supply. It is therefore essential to know the following:

1. How large is the domestic supply deficit?
2. How much agricultural water is available for reallocation?

In the case of California, the answers to these questions were reasonably clear. Cities and farmers all had legal rights to certain amounts of water from certain sources. When water is scarce, quantities are reduced according to pre-defined legal criteria. Therefore, all users know precisely how much water to which they have a legal right.

By contrast, in Cyprus the legal rights of water users are less well defined. The law states that the government retains all water rights. Farmers technically do not have a right to any specific amount of water provided to them through the government conveyor systems. In addition, much of the water that goes to both agricultural and domestic users is stored and conveyed in the same government systems. The raw water itself is fungible so that there is no physical way of distinguishing between water for agriculture users or for domestic users. It is the function of the WDD to determine how much water is delivered to farms and how much goes to municipalities and industries.

In times of water surplus, this is not a difficult task because there is enough water to satisfy all demands. But when there is a water deficit then decisions must be made regarding who will receive water and how much. As the legal rights to water do not reside with individuals, the WDD has considerable discretion in this matter.

The way in which water is initially allocated is of the utmost importance to the operation of a water bank. The difference between the water allocated to domestic supply and the normal domestic demand is the deficit which the water bank will seek to address. Furthermore, the quantity of water that is available for reallocation is clearly related to how much water is allocated to agriculture. The cost of water banking will depend on which crops get irrigation water and how much water these crops are to receive. Paying to fallow a crop which has not been allocated any irrigation water is pointless because no water will be made available for transfer to other users.

The initial allocation system will determine both the viability and cost of water banking in Cyprus. If domestic demand is automatically met by reducing supply to agriculture, then there is no need for a water bank. It is unreasonable to pay for water which can be obtained for free. Legally, this seems to be possible in Cyprus since farmers have no codified rights to the water they normally receive. However, in practice this is not the case. While Cypriot farmers may have no legal rights to irrigation water, the WDD is clearly motivated to provide farmers with as much water as possible even to the point of restricting domestic supply in order to deliver irrigation water. This situation is complex and may be due to a number of different factors. Cyprus has made a significant investment in developing agriculture and specifically irrigated agriculture. The Government may be loath to see its investment go unused even during drought years. Individual farmers have also invested in agriculture. The nature of farming in Cyprus appears to make farmers a powerful political constituency. The small size of most farms and the part-time nature of the farm work means that there are a large number of people, i.e. voters, in Cyprus who have some personal stake in agriculture. These small, part-time farmers are supplementing their normal income through agriculture. As a result, this politically sophisticated group may exert a significant influence on WDD policy.

The exact algorithm by which water is allocated by the WDD during droughts is complex. The WDD has stated that domestic supply is its top priority. Nonetheless, significant rationing of domestic supplies has been common in the last several years during severe droughts. The WDD seems to have determined that 75% of normal demand is the absolute minimum level of supply to domestic users. After supplying the minimum domestic demand, the next priority is the irrigation of permanent crops. Only after much of the demand of permanent crops and greenhouses is met, does the remaining water get allocated to seasonal crops. In 1998, very little water was left over for seasonal crops. The WDD also attempts to keep some water in the surface reservoirs as carry-over storage (Socratous, 1998).

It is debatable whether or not the above is the optimal method for allocating water in times of scarcity. Based purely on contribution to GDP and shadow prices, all domestic demand would automatically be satisfied before any water was allocated to agriculture. Even simply seeking to maximize WDD revenues would lead to full supply of domestic demand since domestic users pay full price while farmers pay only a third of water costs. It may be argued, though, that fairness requires that both agricultural and domestic users be asked to conserve water in times of scarcity. If this is the case then water supply to agricultural and domestic users should be reduced simultaneously and proportionally until the minimum level of domestic supply is reached. Any additional reductions required would then have to come from irrigation demand.

If fairness dictates that both domestic and agricultural users share in the burden of limited water resources, then fairness should also dictate that scarcity constrains farmers of both seasonal and permanent crops. It is reasonable to establish the protection of permanent crops as a priority in water allocation, but profits for permanent crop farmers should not be either more or less important than profits for seasonal crop farmers. In fact, if optimizing total agricultural net profits is used as the criteria for allocating irrigation water, all seasonal crops would be given water before citrus or grapes. A possible compromise is to reduce the amount of water to both permanent and seasonal crops simultaneously and proportionally with "survival-level" allocations as the minimum allocation to permanent crops. Thus if the situation were such that seasonal crop farmers received no water and thus made no profits, permanent crop farmers would at the same time receive only "survival-level" quantities and thus make no profits either.

Fairness in the initial allocation scheme is important for the water bank because participation in the program is voluntary. Farmers must feel that the amount of compensation that they are being offered is fair, otherwise they will not chose to participate. Likewise, all farmers must have an equal opportunity to participate or they will claim that one group is being favored over another. It is clear that table grape farmers and citrus farmers will be most likely to participate in the program because these crops are the least profitable, and citrus crops are the single biggest total water consuming crop in Cyprus. If citrus farmers are given priority in initial water allocation and then are also given the opportunity to participate in the bank, other farmers will perceive (perhaps correctly) that citrus farmers are being given an advantage. In point of fact, citrus farmers should actually be discouraged because of the low profitability and high water use of their crops. All farmers should have the opportunity to make similar choices about the water bank – either use the limited amounts of water resources available and try to make a profit from farming or accept compensation from the water bank and forego the benefits of irrigation. Each farmer should act in his own best interest, and his choice should reflect the optimum uses of resources given his own specific situation.

There is actually a third possible choice. Depending on the severity of the drought and the staffing levels of the water bank, the government could allow farmers to use the water bank to reallocate water among themselves. Farmers of high value crops might offer to compensate farmers of lesser value crops in order to obtain supplemental irrigation water. This system would allow farmers to make decisions about allocation based on maximizing individual profit. If a farmer were unsatisfied with the quantity of water available to him under the standard government allocation procedures, he would be free to try to acquire additional supply so long as he can find a seller. Theoretically, this type of market system would optimize farming production, but there are several difficulties with such a plan. It is likely that the Government, through the WDD, would want to review all such contracts and to do so would require a very large staff. The bookkeeping would be difficult and additional work might be necessary in order to enforce the terms of all the agreements. Competition from farmers might also drive up the cost of water banking for municipal supplies. Simply raising the price of irrigation water might achieve the same goal with much less effort on the part of the government.

Thus it is important to understand the water allocation policies within which a water bank might function. The allocation strategy assumed for the purpose of modeling water bank operation is detailed in Section 8.2.

7.4.7 Non-Emergency Uses of the Water Bank

The emergency drought water bank that is being proposed is by definition a management tool which is meant to be utilized during times of water scarcity. However, there are potential uses for a water bank during times of water surplus as well. Significant surface water storage capacity has been built in Cyprus in the form of reservoirs. Yet many of these impoundments, Kouris in particular, have never filled or are rarely filled. If reservoirs are not filled during water surplus years, then the storage capacity serves no purpose in helping to mitigate the effects of drought during water-poor years. A non-emergency water bank could continue to function even in years when supply exceeds demand with the purpose of increasing the volume of water stored in the reservoirs. Limited volumes of water could be reallocated away from irrigation and left in storage in the reservoirs. This water would then be available for use in supplementing supply in years when rainfall is short. The cost of this type of program would be minimal due to the subsidy paid on irrigation water. Water not allocated to agriculture is water that does not need to be subsidized at a net cost to the government.

7.5 Third Party and Environmental Impacts

The water bank is an effective way of reallocating water without causing undue hardship to farmers. Farmers who do not produce crops due to the reallocation of their irrigation water are compensated for lost profits; however, there are other groups which may be affected by reduced farm output who will not be compensated. Those individuals who work as hired farm labor, who work in food processing businesses, farm product transportation industries, or who sell agricultural support equipment such as fertilizer, seed, or irrigation equipment may adversely be affected. The reduction in farm output may reduce profits to these types of businesses or even cause job losses due to decreased business activity.

After California implemented emergency water banking activities and other irrigation water reducing measures between 1986 and 1992, many parties became interested in possible third-party impacts. The U.S. Environmental Protection Agency commissioned a report to determine how agriculture was affected by such water reductions. The report (Rand, 1998) concluded that farmers adjusted to reduced water supply by improving irrigation efficiencies, switching crops, and fallowing land. However, the report also concluded, not surprisingly, that farmers, like those in all other sectors, suffered due to the drought, though the water bank did help. The long-term effects on third-party agricultural employment were more ambiguous. There may have been offsetting effects for a variety of reasons, including changes in cropping patterns towards more labor-intensive crops.

In Cyprus, the potential effects of water banking on third parties are likewise uncertain. Reduction of water to agriculture is certain to decrease yields, but water would be reduced during drought years with or without a water bank. A water bank would almost certainly reduce citrus output and thereby reduce the need for hired labor on citrus farms. Production of seasonal crops would likely decrease less in drought years due to a water bank since currently water is reallocated from seasonal crops first. Hired labor displaced from the citrus orchards might find work in seasonal crop fields. There is also some indication that a certain portion of farm laborers are foreign nationals, therefore, reductions in unskilled farm labor may not effect the Cypriot employment levels.

Certainly a sizable number of Cypriots must have a secondary connection to citrus production in light of the volume of citrus grown. A significant reduction in the yield of citrus due to water banking could effect many more individuals and businesses beyond just the farmers and farm laborers. In California, concerns about third-party impacts led to policy decisions restricting the amount of land which could be fallowed in any one area by actions of a water bank. It is thought that such a policy will spread the indirect effects of water banking widely enough to prevent large-scale unemployment or business failures. In California, no more than 20% of water from any one project may be transferred in any one-year (DWBP, ref #14). Such a policy might be applicable to Cyprus. Third-party impacts could be limited by restricting the amount of reductions in crop yields caused by a water bank. Such limitations would also limit the amount of water available to be reallocated. During severe drought, restricting the percentage of cropland to be fallowed might make the water bank incapable of producing sufficient water to satisfy all municipal demands.

In addition to unintended economic consequences, the water bank might also have unexpected environmental effects. Increased groundwater pumping is perhaps the most undesired consequence of water banking. It is possible that farmers who choose to participate in the water bank may choose to substitute groundwater for reallocated surface water. A farmer would have strong incentive to do so because he or she would stand to profit twice under such a scenario once from government compensation for surface water reallocation and again from profits realized on groundwater-irrigated crops. Clearly, increased groundwater pumping is an unacceptable side effect of water banking since most aquifers are already over-pumped. An important part of any water bank contract with individual farmers must be a provision forbidding additional pumping by farmers participating in the water bank. The stiffest penalties must be attached to this condition and enforcement must be vigorous. Verification of compliance with the terms of the agreement will need to be a priority of the government. Monitoring may take the form of site visits, spot checks, aerial photography, and groundwater observation well monitoring. Enforcement of rules against additional pumping will involve significant effort on the part of the water bank implementation agency, but staff currently employed to read water meters may be capable of doing the monitoring along with their current duties.

A more subtle type of environmental consequence of water banking might involve changes to the Cypriot landscape. It is possible that water banking might have the effect of encouraging farmers of unprofitable crops - particularly citrus- to either change crops or give up farming altogether. While citrus orchards may be unprofitable from an economic viewpoint, they do have an undeniable aesthetic appeal. Citrus tree orchards in Cyprus may have a existence value which exceeds the actual profitability of the fruit produced. It may be in the interests of the people of Cyprus to subsidize an unprofitable and water-intensive crop in order to maintain the aesthetic benefits of the citrus orchards. On the other hand, the citrus orchards are a recent addition to the Cypriot landscape, and are clearly an expensive luxury to maintain when they serve only as decoration. This is a policy issue which must be decided by the government and people of Cyprus. If it is decided that there is a high existence value to citrus orchards, the water bank program should account for this. Minimum levels of irrigation supply should be maintained in order to prevent trees from dying. It should be noted though that most of the citrus orchards in Cyprus are very dense in terms of trees per hectare. This is the best way of maximizing per hectare yield, but it may not be necessary to maintain such tree density for aesthetic considerations. Thinning of orchards might be a reasonable way of preserving the landscape benefits of citrus orchards while at the same time freeing water for reallocation to more profitable crops and domestic use.

Other environmental effects of water banking might include habitat impacts due to changes in crop patterns. The rate of groundwater recharge under irrigated fields might be slowed, but probably not substantially since high-efficiency irrigation systems are designed to prevent deep percolation. Likewise, stream flows should not be adversely affected. Some environmental effects may be beneficial. If banked water is set aside as carry-over storage, then higher reservoir levels will provide increased fish habitat and serve to improve the aesthetic appeal of the reservoir.

Some third party impacts and environmental consequences are predictable, so any water bank program should be designed to avoid or minimize these problems. Other effects are more difficult to predict and therefore must be dealt with as they occur.